GEOLOGY OF THE THOMPSON RIVER VALLEY BELOW KAMLOOPS LAKE, B.C.

(*Chas. W. Drysdale.*)

Introduction.

GENERAL STATEMENT.

During the field season of 1912, a 10-mile strip of territory along the Thompson valley between Sixmile point on Kamloops lake, and Lytton was geologically mapped and studied. The work was carried on for the purpose of extending the work of Professors R. A. Daly and J. A. Allan along the line of the Canadian Pacific railway in the eastern Cordillera westward to include the whole Cordillera from the plains to the Pacific coast.

A topographic base map was used upon which the geology was mapped by means of plane-table, and telemeter and compass traverses run along the main formational contacts. Three months were spent in field work. Mr. M. F. Bancroft rendered efficient service as field assistant.

The district included in the report is situated about 200 miles east of Vancouver along the main line of the Canadian Pacific and Canadian Northern Pacific railways, both of which follow the Thompson valley. The length of the region mapped in a northeast-southwest direction is about 74 miles and its average width is about 10 miles. The area included, therefore, is about 740 square miles.

The writer wishes to thank the residents of the region traversed, for their kind courtesy and interest, which aided considerably in the progress of the work.

HISTORY[1].

In the spring of 1808, Mr. Simon Fraser with Messrs. John Stuart, Jules Maurice Quesnel and a crew of 19 men and two Indians, started out in four canoes from Fort George, now on the line of the Grand Trunk Pacific, to explore the unknown waters to the south which were regarded then as the main tributary of the Columbia river. In June, 1808, they reached a large and rapid river flowing from the east. This was named Thompson river after David Thompson, astronomer to the North-West Company, who shortly afterwards founded Fort Kamloops. The Thompson river in later years became known the world over through a series of great gold rushes. The first gold discovery in British Columbia is said to have been made by an Indian in this district at the junction of the Nicoamen river with the Thompson, about 10 miles above its mouth. The Indian, while stooping to drink, saw a large nugget glittering in the water. He picked it up and brought it in to Mr. McLean, the officer in charge at that time of Fort Kamloops. The Nicoamen locality was noted for its coarse gold, but the supply was soon exhausted.

In 1857, it is said that the Hudson's Bay Company had received from October 6 to the end of the year, 300 ounces of gold, through their agent at the Thompson and Fraser rivers.

---

[1] The reader is referred to the following works for more detailed accounts:—
The works of Hubert Howe Bancroft, vol. XXXII, History of British Columbia, 1792-1887.
Begg, Alexander, History of British Columbia, 1894.
Mayne, R. C., Four Years in British Columbia and Vancouver Island, 1862.

About this time, the region was becoming known abroad through its placer gold discoveries, and prospecting parties travelled north from Oregon and Washington territories in quest of the precious metal. Some of the gold seekers entered British Columbia by way of Colville and made their way to the junction of the Thompson and Fraser rivers where they found several rich bars, which were worked successfully.

The great rush, however, did not take place until 1858. In the spring of that year the whole country was a scene of great excitement. Hundreds from the northern counties of California 'trecked' northward with their pack trains and cattle trains by the interior route via Okanagan and Kamloops. They found it necessary to travel in large companies for protection against Indians. When the cattle trains reached their destination, the oxen were sold for beef. In May, June, and July, of 1858, over 30,000 people migrated northward into British Columbia, but before January 1859, they had all returned to the United States, with the exception of about 3,000.

The aggregate yield through placer mining along the Thompson and Fraser rivers for the years 1857, 1858, and 1859 alone, amounted to not less than $1,700,000[1]. This mining was conducted on river bars and benches with the aid of rocker and sluice box. The gravel and boulder deposits generally capping the river terraces and the recent river gravels were found most productive of gold. Since 1859, little mining on a large scale has been done in this district. In September 1860, 200 Chinese were digging near the mouth of the river, and in the autumn of 1861, 150 miners were reported at work making $16 per day near Tranquille river on the north shore of Kamloops lake. The famous 'Cariboo rush' began in 1860 and lasted until 1862. This resulted in 1862 in the building of trails and a wagon road to make the rich Cariboo region between the head-waters of the main Fraser and Thompson rivers, accessible to prospectors and miners.

The old trails and wagon roads were built at great expense through the Thompson valley and are still used considerably as highways. The first sod was turned on the Canadian Pacific railway early in 1880 and the road was open for traffic in 1885. The Canadian Northern Pacific commenced construction work in the spring of 1911 and will shortly be open for traffic.

CLIMATE AND AGRICULTURE.

The climate of this region, which is commonly known as the Dry Belt of British Columbia, is most delightful. The scanty precipitation of the district is largely due to the intermontane position it occupies between the Coast range on the west and the Gold ranges on the east. The westerly moisture-bearing winds are partly arrested by the western barrier and become desiccated before they reach the district. The higher air currents touch upon the green grassy upland tracts, with scattered trees, which receive more moisture than the deeply entrenched valleys which are largely devoid of timber but support much bunch grass and small sage. Where irrigated, however, the valley flats support good crops of vegetables and fruits. The upland country is good for grazing purposes and the production of timber.

The following statistics have been kindly supplied by the Dominion Meteorological Bureau:—

[1] Dawson, G. M., Report on Kamloops Map Sheet, vol. VII, 1894, p. 326B.

	Mean annual rainfall inches.	Mean annual snowfall inches.	Total mean annual precipitation inches.	Highest temperature		Lowest temperature		Mean annual temp.
				Deg.	Year.	Deg.	Year.	
Kamloops.....	7·56	27·34	10·30	102·4	1906	–26·9	1899	47·34
Kamloops in 1910........	5·61	20·75	7·69	96·5		–8·6		48·50
Douglas lake..	....	....	9·34	......		......		......
Câche creek...	....	....	11·20	......		......		......
Spence bridge.	....	....	7·68	......		......		47·4

WATER POWER.

The Thompson river, which drains an area of 21,800 square miles, has an average gradient between Kamloops lake and its mouth at Lytton of approximately 0·18 per cent, or a drop of about 9½ feet per mile. The grade, however, is not uniform and certain stretches have quite a gentle gradient. Between Thompson Siding and Lytton, the river falls 200 feet.

In the autumn, the river carries from 15,000 cubic feet to 20,000 cubic feet of water per second. The water is highest during the month of July. The range between high and low water is great, amounting in places to as much as 40 feet.

The minimum figure, estimated for the available water-power between Thompson and Lytton, has been placed at 100,000 horse-power[1].

FLORA AND FAUNA.

The main species of trees are: Douglas fir (*Pseudotsuga douglasii*), yellow pine (*Pinus ponderosa*) and in the dry Alpine country the white-barked pine (*Pinus albicaulis*). The valleys are comparatively clear of wood, except along the banks of streams which traverse them, and on which there is ordinarily a growth of willow and alder. The trees in many places follow the draws or dry gullies where the ground water level is close to the surface.

A number of interesting animals inhabit the district; among these are black-tailed deer (*Cariacus mecrotis*) and, not so commonly, the white-tailed deer (*cariacus virginianis*); black bear (*ursus Americanus*) occasionally occur and at the western edge of the district in the vicinity of Lytton mountian, grizzlies (*ursus horribilis*) have been seen. Coyotes (*canis latrans*) are fairly common in the valleys. Rattlesnakes mainly inhabit the lower and dry valleys, and are common.

PREVIOUS WORK.

The first important geological work was done in this district in 1871 by Dr. R. C. Selwyn, Director of the Geological Survey, and Mr. James Richardson who made a reconnaissance trip from Yale, on the Fraser river, to Kamloops. The following classification of the rocks in the Province was based upon this exploratory work:—

I. Superficial deposits.
II. Volcanic series and coal and lignite group of the mainland and the coal rocks of Vancouver island.
III. Jackass Mountain conglomerate group.
IV. Upper Câche Creek group (Marble Canyon limestone).
V. Lower Câche Creek group.

[1] Water-powers of Canada, 1911. Report of Commission of Conservation, pp. 321, 326.

VI. Anderson River and Boston Bar group, and upper rocks of Leather pass and Moose lake.

VII. Cascade Mountain and Vancouver Island crystalline series.

VIII. Granite, gneiss, and mica-schist series of North Thompson, Albreda lake, and Tête Jaune Câche, including the micaceous schists of the Cariboo district.

During the field season of 1877, Dr. G. M. Dawson made a reconnaissance survey along the main routes of travel through the southern portion of the interior of the Province. As a result of this work a preliminary report and map were published in the Report of Progress of the Canadian Geological Survey for 1877-78.

In 1899 and 1890 Dawson's work was confined to the northwestern quarter of the old map, of which the scale was doubled, making a map of the same size as the first but covering only one-fourth of the original area. The topography was revised by Mr. James McEvoy. The result of this more detailed examination of the district appeared in Dawson's 'Report on the Area of the Kamloops Map-Sheet'[1].

BIBLIOGRAPHY.

The following list of publications contains the mort important papers and reports bearing on the geology and physiography of the district:—

Atwood, W. W.—Working hypothesis on the physiography of Alaska: Science, New Series, vol. XXVII, 1908, p. 730.
Jour. of Geol, vol. XIX, pp. 449-453, 1911.

Arnold, W. W.—Environment of the Tertiary faunas of the Pacific coast of the United States: Jour. of Geol., vol. XVII, 1909, pp. 509-533.

Ball, S. H.—Economic Geology of the Georgetown Quadrangle, Colo.: U. S. Geol. Surv., Prof. Paper 63, 1908.

Bancroft, Hubert Howe.—History of British Columbia, vol. XXXII, 1792-1887.

Beag, Alexander.—History of British Columbia, 1894.

Blackwelder, Eliot.—Cenozoic History of the Laramie Region, Wyoming: Jour. Geol., vol. XVII, 1909, pp. 429-444.

Bowman, I.—Physiography of the United States, Forest Physiography (1911): pp. 342-368.

Brooks, A. H.—Geology and Geography of Alaska, U. S. Geol. Surv., Prof. Paper 1906, pp. 286-293.
The Mount McKinley Region, Alaska: U. S. Geol. Surv., Prof. Paper 70, pp. 113-136.

Cairnes, D. D.—The Wheaton River District, Yukon: Geol. Surv., Can., Memoir 31, 1912.

Calhoun, F. H. H.—The Montana Lobe of the Keewatin Ice Sheet. U. S. Geol. Surv., Prof. Paper 50, 1906.

Clapp, C. H.—Southern Vancouver Island: Geol. Surv., Can., Memoir No. 13, 1912.

Dall, W. H. and Harris, G. W.—Correlation Papers, Neocene, Bull. 84, U.S. Geol. Surv., 1892.

Daly, R. A.—The Nomenclature of the North American Cordillera: Geog. Jour., vol. XXVII, 1906, p. 588.
The Geology of the North American Cordillera at the 49th parallel: Memoir No. 38, Geol. Surv., Can. 1913.

Davis, W. M.—Continental Deposits of the Rocky Mountain Region: Geol. Soc. Am., Bull. XI, pp. 596-60; 603-604, 1900.
An excursion to the Grand Canyon of the Colorado: Harv. Coll. Mus. Comp. Zool. Bull. 38, pp. 108-201, 1901.

[1] Annual Report of Progress, Geol. Surv. of Can., New Series, vol. VII, 1894.

Dawson, G. M.—On the superficial geology of British Columbia: Quart. Journ. Geol. Soc., vol. xxxiv, 1878, pp. 89-123.

Additional Observations on the Superficial Geology of British Columbia and adjacent regions; Quart. Journ., Geol. Soc., vol. xxxvii, 1881, pp. 72-285.

On the later physiographical geology of the Rocky Mountain region in Canada: Trans. Royal Soc. of Canada, vol. viii, 1890, sec. 4, pp. 3-74.

Geological Record of the Rocky Mountain Region in Canada: Bull. Geol. Soc. of Am., vol. xii, 1901, pp. 57-92.

Report of Progress, Geol. Surv. of Can., 1877-78, pp. 23-36 B.

Geol. Surv. of Can., Ann. Report, vol. vii., 1894, pp. 1-447 **B.**

Drysdale, C. W.—The Geology of the Franklin Mining Camp, B.C.: Geol. Surv., Can., Memoir. In preparation.

Leach, W. W.—Summary Report, Geol. Surv., Can., 1910, pp. 93-95.

Le Roy, O. E.—The Geology and Ore Deposits of Phoenix, B. C.: Geol. Surv., Can., Memoir 21, 1912.

Rich, J. L.—Jour. of Geol., vol. xviii, pp. 601-632, 1910.

Salisbury, R. D.—Three new physiographic terms: Jour. Geol. vol. xii, pp. 707-715, 1904.

Schuchert, C.—Paleogeography of North America, Geol. Soc. America, Geol. Soc. America Bull., vol. xx, 1910, pp. 427-606.

Smith, H. I.—Archaeology of Lytton, B. C., Mem. Am. Nat. Hist., vol. ii, part iii. May 25, 1899.

Smith, G. O.—Mount Stuart Folio, U. S. Geol. Surv. No. 106 (1904).

Spencer, A. C.—Pacific Mountain System: Bull. Geol. Soc. Amer., vol. xiv, 1903, pp. 117-132.

Stanton, R. B.—The Great Land Slides on the Canadian Pacific railway in British Columbia: Minutes of the Proceedings of Quat. of Civil Eng., England, vol. cxxxii, session 1897-98, part ii.

Tarr, R. S.—The Yakutat Bay region, Alaska: Prof. Paper, U. S. Geol. Surv., No. 64, 1909, pp. 28-29.

Willis, B. and Smith, G. O.—Contributions to the Geology of Washington: U. S. Geol. Surv., Prof. Paper 19, 1903.

Veatch, J. A.—The Cinnabar Mining Co., Ltd., of British Columbia: Report of Minister of Mines, B. C., 1896, pp. 568-571; 1897, p. 614.

Summary and Conclusions.

PHYSIOGRAPHY AND PHYSIOGRAPHIC HISTORY.

The district along the Thompson river between Sixmile point on Kamloops lake and Lytton, falls within the physiographic province known as the Interior Plateau. This belt is characterized by many flat-topped or gently undulating upland surfaces separated by deeply entrenched valleys (from 3,000 to 5,000 feet deep).

The main Thompson valley is, as a rule, partially filled by several hundred feet of fluvio-glacial materials which have been carved by the meandering river into broad fertile river terraces. The present river channel is in a gorge deeply incised in the valley-fill material and even deep into bed-rock itself as is the case at the Thompson and Black canyons.

The main tentative conclusions derived from a study of the physiography of this and neighbouring regions are as follows:—

(1.) The Thompson and Fraser rivers are antecedent streams whose courses transverse to the regional structure have persisted from courses developed during a Cretaceous erosion cycle.

(2.) In the Coast range the advanced stage of dissection which has left only accordant summit levels and a few possible plateau remnants suggests that the former land surface was an uplifted erosion surface of an earlier age rather than of Tertiary age.

(3.) Tertiary erosion did not bring the Coast range down to a peneplain as it did many portions of the then low-lying Interior Plateau. The Tertiary erosion surface in the Coast range had only reached a mature and post-mature stage of topographic development prior to uplift.

(4.) The upland surfaces of the Interior Plateau represent glaciated remnants of a late Tertiary peneplain.

(5.) During a pre-Miocene erosion cycle the way was prepared for the more complete late Tertiary cycle and the former was responsible for the removal of much of the early Tertiary rock record.

(6.) The deep youthful valleys entrenched beneath the upland with broad terrace-steps represent the work of erosion and sedimentation due to both water and ice, since the late Pliocene uplift.

(7.) Post-Glacial erosion, invigorated in part by recent elevation, is responsible for the canyons, gorges, and land slides so prevalent throughout the district.

(8.) The present topography may be said to have been dominantly developed during Pliocene and later erosion cycles.

GENERAL GEOLOGY.

The district under consideration includes an unusually good record of sedimentary, metamorphic, and igneous rocks ranging in age from Carboniferous to Recent. Among the bed-rock formations the Mesozoic and Tertiary have by far the widest distribution.

The Carboniferous formations (Câche Creek group) consist of very highly metamorphosed, marine sedimentary and eruptive materials. They outcrop in the central portion of the district, as cherty quartzites, argillites, greenstones, and crystalline limestones (Marble Canyon limestone)—the latter apparently the youngest, although in many places the marble is intimately interfolded or interbedded with the older members of the group.

There are four distinct Mesozoic formational groups, namely: Jura-Triassic (Nicola group), upper Jurassic (granitic intrusives), Jura-Cretaceous (Spence Bridge Volcanic group), and Lower Cretaceous (Queen Charlotte Islands formation.)

The Jura-Triassic rocks are chiefly altered eruptives (diabasic in composition) of both flow and fragmental type, with included argillaceous, arenaceous and calcareous beds. The upper Jurassic rocks which occur as batholiths, stocks, and tongues are made up of granular intrusive rocks varying from granite to granodiorite and diorite, and are all subalkalic in composition. The Jura-Cretaceous rocks consist of over 5,000 feet of liparitic and andesitic lavas with interbedded tuff, agglomerate, and conglomerate beds. The Lower Cretaceous rocks are carbonaceous shales, sandstones, and conglomerates.

There are two distinct Tertiary formational groups in the district which are of Oligocene (?) or possibly Eocene (Coldwater group, and Ashcroft rhyolite porphyry) and of Miocene (Kamloops Volcanic group) age.

The Oligocene (?) rocks consist of indurated continental sediments, which include remnants of coarse, river and lake conglomerates, sandstones, and shales. Under the Oligocene (?) is also included a rhyolite porphyry formation capping a hill in the vicinity of Ashcroft. The Miocene (lowest) consists of basalts (both amygdaloidal and vesicular types), agglomerates, breccias, and tuff beds with smaller quantities of younger mica andesites and various porphyrites, the whole group approximating 3000 feet in thickness.

Deposits of Pleistocene and Recent age are very plentiful and consist of Glacial till, gravels, sands, clays, and silts.

During the past field season fossil plants were found near Spence Bridge in the tuff beds belonging to the Lower Volcanic group as previously mapped (Miocene of Dawson's Kamloops map sheet), which on identification place the group in the Jura-Cretaceous instead of the Miocene. On this account and because the town of Spence Bridge is situated near the centre of this broad belt of chiefly volcanic rocks the writer feels justified in changing the name from that of Lower Volcanic group to *Spence Bridge Volcanic group*.

More detailed field work is needed to extend and delimit the Spence Bridge Volcanic group to the north and south. As a result of such work it may prove necessary to include in the Mesozoic over 400 square miles of territory at present mapped as Tertiary. The structural relations of this group with both older and younger formations require examination. No contacts between the Spence Bridge group and the Queen Charlotte Islands formation were observable within the limits of the railway belt examined last season.

It has further been deemed advisable in the Kamloops Lake vicinity to include both the Lower Volcanic group (which bears no resemblance to the Spence Bridge Volcanic group), and the Tranquille beds, with the conformably overlying Upper Volcanic group of Dawson and to call the whole series by the new term *Kamloops Volcanic group*.

Collections of invertebrate fossils from some hitherto undescribed localities within the Nicola group (Jura-Triassic) area were made. Dr. T. W. Stanton reports:.... 'that the general character of the fossils, with possibly one or two exceptions, indicates that the rocks are Jurassic and it is possible that some, or all, of them may be Lower Jurassic.

ECONOMIC GEOLOGY.

The main economic mineral resources of the district include low grade gold placers, mercury ore, copper ore in small quantities; much clay suitable for brick making; limestone suitable for the manufacture of lime; and agates and chalcedony of fair quality for ornamental purposes.

Physiography and Glacialogy.

GENERAL ACCOUNT.

The western British Columbia Cordillera is broadly divided into the Coast range fringing the Pacific ocean and an eastern belt known as the Interior Plateau. The Coast range, whose summits rise to altitudes of from 8,000 to 9,000 feet, is bounded on the south by the Cascade range which ends at the Fraser river and Lytton and on the east by the Fraser river. East of the Fraser river above Lytton and east of Chilco lake to the north, extends the Interior Plateau Belt[1] characterized by many broad flat-topped hills whose elevations range from 3500 to 5000 feet, with deep intervening valleys.

[1] Daly, R. A., The Nomenclature of the North American Cordillera: Geog. Jour., vol. xxvii, 1906, p. 588

The map-area includes that portion of the broad and deep valley of the Thompson river which traverses the Interior Plateau from the centre of Kamloops lake where it is over 6 miles wide and 3500 feet deep, to its terminus at Lytton, where the valley narrows to about 3 miles and is more than 5,000 feet deep.

The lower stretches of the valley are characterized by the presence of wide fertile terrace steps, composed of fluvio-glacial materials, rising from 30 feet to 1000 feet above the level of the river. Upon such bench lands, fruit and vegetables are grown extensively by the aid of irrigation. Where the land is not under cultivation, sage brush and cactus abound. The terraces and steep valley slopes are cut by innumerable small gullies and ravines which are generally dry.

There is comparatively little bottom land near the river which flows, as a rule, in a narrow winding gorge incised deeply in the alluvial bench lands and in places even deeply into bed-rock itself. The Upper and Lower Black canyons and the Thompson canyon furnish good examples of down-cutting in bed-rock.

Above the terraces, the valley slopes rise rather abruptly in rocky ledges and escarpments up to an elevation of approximately 3500 feet in the eastern portion of the district and 5000 feet in the western. At this elevation a pronounced change of slope is reached, and instead of bare rocky slopes and rock knobs, there prevails a more gently undulating type of topography. The woods are open and park-like and on the green grassy hills are many different types of wild flowers. Here and there are depressions occupied by lakes and stagnant pools, leading down to which are many cattle paths. The upland tracts afford good grazing ground for cattle and stand in strong contrast to the semi-arid lands of the deep youthful valleys with their steep rocky upper slopes, and flat, fertile, fluvio-glacial terraces beneath.

DETAILED ACCOUNT.

Physiography deals not only with the configuration or shape of the landscape as we see it to-day, but also with the manner of its development and origin. In this detailed section, it will be attempted to systematically assemble and discuss the data bearing on the genesis of the land forms and the conclusions derived from their study. Such discussion, which will include a genetic classification of the land forms in the district, must necessarily be based on a comprehensive knowledge of the facts of the geological history. Sedimentation, vulcanism, and diastrophism of the past have all left their impress to a greater or less degree upon the present topography. For facts bearing on the geological history the reader is referred to a later section of this report and for the geological details upon which the conclusions regarding the geological history are based, he may refer to the section on General and Structural Geology.

The field data will be classified under the main headings of:—

(*a*) Data bearing on erosion cycles and glaciation.

(*b*) Data bearing on drainage combined with outline of drainage history.

It will be noted that the topography of the district has been greatly influenced by topographic forms developed during previous erosion cycles, mainly by those of late Tertiary age which have been modified by differential uplift and glaciation. The influence of bed-rock structure is of minor importance. Where bed-rock structure does dominate the topography, as for instance in the vicinity of Spatsum, it is interesting to note that it does this in the youthful valleys below the old upland surface.

(*a*) *Data Bearing on Erosion Cycles and Glaciation.*

Owing to the dry climate in this portion of British Columbia, the sets of physiographic forms resulting from the late Tertiary and Quaternary erosion cycles can be clearly seen and are separated by sharp topographic breaks or unconformities.[1] Three main sets have been distinguished and they will be discussed in the following order commencing with the oldest:—

(1) Old upland erosion surface.
(2) Youthful valleys.
(3) Post-Glacial erosional forms.

(1) *Old Upland Erosion Surface.*—From the summits above 3500 feet in elevation in the eastern and 5000 feet in the western portion of the district, may be seen broad remnants of a gently undulating upland which embraces many square miles and extends for about 100 miles in width between the Columbia mountains on the east and the Coast range on the west. Northward the upland is probably continuous with that of the Yukon plateau. The upland surface merges both to east and west into the more mountainous topography of the bordering ranges. Rising above the general level of the upland are residual hills (monadnocks) and highland masses which have withstood erosive agencies and have been left standing above the old surface. The most prominent residual ridges are composed of crystalline limestone (Marble Canyon limestone) and on account of their whiteness are conspicuous as, for instance, the ridge west of the Thompson valley between Ashcroft and Spatsum, and those of the Pavilion and Marble mountains farther north.

Generally the upland summit level grades down toward the axis of the major streams, whose valleys, as will be indicated later on, probably occupy positions inherited from the previous erosion cycle. This upland erosion surface bears no relation to underlying structural features and truncates or bevels tilted volcanics of lower Miocene age (Kamloops Volcanic group). This is well shown on Savona mountain, Hardy mountain, and elsewhere.

The upland slopes are thickly mantled with morainic drift and glacial erratics. Bare surfaces of rock show evidence of continental glaciation in the presence of glacial striæ with average strike of S. 35° E. The valleys of the upland, however, in contrast to the younger deeply entrenched valleys within it, do not show evidence of having been powerfully glaciated, as, for example, by the presence of deep scoring and glacial plucking.

From the above facts concerning the upland erosion surface, it may be inferred that they are in the main glaciated remnants of an uplifted gently undulating surface developed during a later Tertiary erosion cycle because lower Miocene volcanics are truncated. Later than the uplift which possibly occurred in late Pliocene time[2] the erosion surface has been dissected by the youthful valleys.

Previous erosion cycles have no doubt influenced to some extent the degree of perfection of this late Tertiary erosion surface. The surface as viewed from the upland grades gradually into the high bordering mountains where it gives place to the more mountainous topography of the ranges which, prior to Pliocene uplift, had reached only a mature or late mature stage of development. Since uplift, it has been further carved by deep V-shaped valleys and well sculptured by alpine glaciers. It appears as if this uplifted mature or late mature upland surface was the result of the dissection of a still older erosion surface, probably of Cretaceous age. The deep glaciated valleys cut below the Tertiary upland, represent erosion since the late Pliocene uplift.

An alternative hypothesis favoured by many[3], is that the Coast range represents an upwarped and dissected late Tertiary peneplain. The axis of the Coast range, which had been a locus of previous disturbances, was uplifted higher than the

---

[1] Salisbury, R. D., 'Three New Physiographic terms,' Jour. Geol., vol. XII, pp. 707-715 (1904).
[2] G. M. Dawson: Bull. Geol. Soc. Am., vol. XII, 1901, p. 90.
[3] Spencer, A. C.: Pacific Mountain System in British Columbia and Alaska, Bull. Geol. Soc. Am., vol. 14, 1903, pp. 117-132.

interior region, so that while the latter preserved to a large extent its plateau character the Coast range, by reason of the greater relief, was extensively dissected and thus became the present rugged, irregular mountain mass, which has preserved its plateau features only in the even crest lines.[1]

From the facts bearing on the glaciation of the Interior Plateau it may be inferred that during the Pleistocene it was overridden by the Cordilleran ice sheet moving in a general direction of about S. 35° E., which considerably modified the upland topography, and on its retreat left much morainic material. No evidence as to the probable depth of the Cordilleran ice cap over this section of the country could be obtained.

(2) *Youthful Valleys.*—Beneath the old upland are entrenched deep valleys with steep sides. The main one is the Thompson valley which narrows and steepens on approaching the Coast range to form the Thompson canyon. From the main Thompson valley many steep-sided tributary valleys extend back for many miles and gradually grade headwards into the upland itself.

The valley slopes show evidence of more intense scouring and plucking action by glaciers than do the upland slopes.

The bottom lands are flat and consist of a series of broad step-like river terraces cut out of fluvio-glacial materials. The terraces display sharp points between concaved reaches, the result of former meandering of the stream. The lower meanders have in many cases cut out older terraces at higher levels and a high terrace ends abruptly at a single escarpment at whose base the river is busy undercutting. This is well illustrated at Walhachin a town located on a high terrace overlooking the river.

For convenience in describing the various valley features of the district, this strip of territory along the Thompson valley may he divided into three general sections which grade into one another. The eastern section is characterized by a deep broad valley with an uneven rocky floor at present occupied by Kamloops lake, whose average depth is 300 feet. Along the valley sides may be seen truncated spurs, small tributary hanging valleys or rock niches with alluvial fans and deltas built out into the lake. The main valley itself is comparatively free from broad flats. There is, however, south of Savona near the west end of Kamloops lake at an elevation of about 2000 feet, a conspicuous flat underlain by resistant Triassic rocks which protrude in places above the general level forming rocky knolls. In the depressions upon this flat there are numerous alkali lakelets and stagnant pools. Lying upon this rock floor and in an early Tertiary valley eroded within it, are slightly deformed chiefly coarse-grained sediments with a general east and west trend capped and protected from erosion by lower Miocene volcanics. The early Tertiary sediments form prominent strike ridges. The volcanic rock cliffs have been considerably retrograded and as a result, high precipices with outstanding pinnacles or 'hoodoos' and talus accumulations skirting their base are common features to be seen on the high rocky slopes of the valleys. In some localities, where the country which is semi-arid is underlain by fine-grained flat-lying tuff beds of varying resistance (Tranquille formation), 'bad land' topography results with the development of innumerable drainage lines upon the valley slopes.

The central section extends from the west end of Kamloops lake to Thompson siding, a distance of 59 miles. It is characterized by a great depth of fluvio-glacial material, beautifully terraced by the meandering Thompson river. The deeply incised river, however, has only in a few places reached bed-rock. The terraces rise from 30 to 400 feet above the river, and the terrace steps slope gently toward the river and have as a rule near their surface a coarse bouldery layer of river origin, the boulders overlapping one another with their longer diameters in the direction of flow.

[1] Brooks, A. H., Geography and Geology of Alaska, U.S. Geol. Surv., P.P. No. 45: p. 271.

A till sheet underlies in places cross-bedded gravels and sands which in turn are covered by a still younger till sheet. The tills, gravels, sands, and silts interfinger and are in places difficult to separate from one another. A clay silt, well bedded, and of considerable thickness is very persistent throughout the valley at about the same general elevation. Where the river has cut into the white silt banks and boulder clay to form cliffs, 'hoodoos' or pinnacles of this material stand out in prominence.

The deltas at the mouths of tributary streams consist largely of coarsely cross-bedded gravels and sands. The delta of Barnes creek near Ashcroft appears to have forced the Thompson river to cut into its north bank composed of silts, sands, and gravels. As a result the silt cliffs are becoming rapidly retrograded and only a narrow stretch of terrace land now fringes Rattlesnake hill.

Esker-like ridges occur on the higher valley slopes east of Spatsum in the central portion of this section. In the same vicinity bordering the North and South Thompson valley may be seen a prominent limestone mountain, the limestone having a north-northeast and south-southwest trend and dipping steeply toward the centre of the valley and controlling the topographic form.

The western section from Thompson Siding to Lytton—the Thompson canyon proper—displays a very mountainous appearance in bold contrast to the eastern section. Here the mighty Thompson river has deeply incised itself through the fluvio-glacial materials well into bed-rock, forming a deep canyon. The canyon contains many huge blocks of rock that have tumbled from above, and are now in process of being broken up and carried down stream by the turbulent river.

The south slope of the valley is well wooded and very steep. The north slope is more open and park-like but is sharply scarped in places where the river has undercut it. The tributary creeks have incised deep ravines near their mouths which contain much coarse talus material tumbled down from the cliffs above. A few miles above Lytton, there is a prominent scarp known as the 'Crag', which would appear to have been formed by comparatively recent faulting along the trend of Botanie Creek valley.

From the above facts regarding the valley features it may be inferred that the present valleys are youthful and the product of an erosion cycle following the late Pliocene (or early Pleistocene) uplift, and including at least two advances of valley ice. The second advance of the valley ice may have taken place at the time of the maximum extension of the Keewatin ice sheet to the east.[1]

In the eastern section glaciation was mainly erosional resulting in glacial deepening and widening of valleys. This combined with the impounding effects of the Deadman Creek delta brought about the formation of Kamloops lake. On the north side of Kamloops lake, glaciation has produced truncated spurs, hanging valleys or rock niches, whereas on the south side, the tributary streams have built out large alluvial fans and deltas, since dissected and terraced.

The central and western sections were dominantly belts of aggradation in contrast to the eastern section of degradation. The valley glaciers acted here in a constructive manner, and heaped up great thicknesses of valley train materials since excavated by the meandering river into broad terrace flats. The river terraces

[1] The eastward succession of the continental ice sheet has been pointed out by J. B. Tyrrell and G. M. Dawson, who found that the Cordilleran glacier reached its greatest extent and retired before the boulder-clay that generally underlies the western plains was deposited. This boulder-clay, Mr. Tyrrell takes to be the true till or ground moraine of the Keewatin glacier when the glacier had reached its greatest southwesterly extent.

Tyrrell, J. B., The Genesis of Lake Agassiz, Jour. of Geol., vol. IV, 1896, pp. 811-815.

Dawson, G. M.: Glacial Deposits of Southwestern Alberta in the vicinity of the Rocky Mountains: Bull. Geol. Soc. Am., vol. VII, pp. 31-66, Nov., 1895.

Calhoun, F. H. H. : The Montana Lobe of the Keewatin Ice Sheet: U.S. Geol. Surv., P.P. 50 (1906), p. 56.

have been influenced a great deal in their development by protective rock shoulders or spurs. As the river, swinging from side to side, slowly degraded its valley floor it encountered rock ledges projecting from the sloping valley wall. The deeper the valley floor was excavated the less breadth of free swing the river had. Westward where the Thompson valley narrows and steepens the river does not have as many meanders. With this straightening of the river course the terraces become narrower and the river cuts through them to form a canyon in bed-rock.

(3) *Post-Glacial Erosional Forms.*—Beneath the youthful valleys are cut secondary small valleys or canyons and gorges varying from 60 feet to 400 feet in depth and 300 to 400 feet wide. In the gorges and canyons there is comparatively little bottom land, and the river occupies nearly the whole width of its valley. In places, as at the Black canyon and Thompson canyon, the river has cut deep into bed-rock and the tributary creeks have in many places cut deep V-shaped ravines. These younger gorges and ravines show no evidence of glaciation.

A prominent rock slide may be seen on the east side of the Thompson valley opposite 89-mile stable a few miles north of Toketic. The structural relations there were favourable for a rock slide in that an outlying mass of altered sedimentary and eruptive rocks (Mesozoic), striking parallel to the valley and dipping towards it, rest unconformably upon highly inclined metamorphic rocks (Palæozoic)—the plane of unconformity dipping toward the valley bottom. The younger rocks have been cut into a series of strike ridges and ravines parallel to the cliff face and are also crevassed along joint planes at nearly right angles to their bedding.

In several places throughout the valley, the alluvium is slowly creeping riverwards and in the past few decades notable land slides of this material and several small slips have taken place. Gaping crevasses are formed on the upper surfaces of those areas which are slowly creeping towards the river. The landslides of the years 1881 and 1905 were the most destructive to life and property. In October, 1881, a few miles below Ashcroft on the east side of the valley about 150 acres of bench land (probably weighing about 100 million tons) suddenly sank vertically in one movement to a depth at the back edge of over 400 feet and the lower portion of the slide about 2000 feet wide was forced entirely across the river, a distance of 800 feet to 1000 feet; and abutting against the steep bluff on the opposite side, it filled the whole inner gorge of the valley and formed a dam fully 160 feet high, completely stopping the flow of the river for several days, so that men walked dry-shod across the river bed below the dam.[1] As soon as the water rose and formed an outlet it swept away the slide material, and caused a terrific flood in the valley below.

At Spence Bridge a short distance below the town on the west side of the valley, three slides have occurred in almost the same place within recent years, but the most disastrous slide happened the afternoon of August 13, 1905. A large bluff of alluvium at the base of Arthur's Seat broke away suddenly and descended to the river with great velocity, filling the valley bottom from bank to bank. The slide material, as at Ashcroft, formed a dam causing a mighty wave 10 to 15 feet high to sweep up the river against the current, carrying all before it. The river was completely dammed for four or five hours and rose 20 feet in that time before it found an outlet and rapidly cut through the dam. The wave overwhelmed the Rancherie[2] on the flat below the town of Spence Bridge, killing ten Indians and injuring thirteen. Five Indians were buried alive in the slide.[3]

---

[1] Stanton, R. B., Minutes of Proceedings of Inst. of Civil Eng., England, CXXXII, 1897-98, part II, pp. 7 and 8.

[2] Indian ranch.

[3] To show the force the wave exerted, it was stated on good authority that a granite and marble headstone was carried fully 200 yards from its original location without throwing it from its upright position. A horse tied to a hitching post at the rancherie had its tie rope broken, and was carried upstream 300 yards. It was finally thrown ashore on the northern bank of the river, where it managed to get its forefeet in the gravel bank and hold on until the waters receded.

A much older landslide composed of older volcanic and sedimentary materials of a reddish brown colour is traversed by the railway a few miles north of Dry-rock. A deep cirque-like scar on the upland, with steep bounding walls, may be seen a couple of miles back from the railway and marks the source of the material. The slide material forms exceedingly rough ground containing stagnant pools and simulates in many places a glacial moraine with the thickening of earth flow material down valley. It differs, however, from a moraine in the nature of the materials and the abundant open crevasses on its upper surface.

From the above it is evident that since the retreat of the valley glaciers the rivers have been busy cutting down to grade and excavating the valley fill material. The denuded regions of former vigorous glaciation supplied but little waste to the streams. With the reduction in waste supply and only a moderate reduction in volume the streams degraded their earlier aggraded valley and through normal swinging of the river within the valley developed broad terrace lands. A recent post-Glacial uplift[1] has probably invigorated the river and caused it to incise itself more deeply in its present channel.

It is natural in such youthful valleys, where wasting of land goes on rapidly and the corrasive power of streams is great, that land and rock slides should be of common occurrence. The semi-arid nature of the climate further favours their presence. The agent through whose influence the forces of gravity can produce such results is water. The precipitation in the district is of a semi-torrential type as shown by the character of the valley hillsides which are carved into innumerable gullies and ravines which terminate below in many cases at the terrace flats in alluvial fans or aprons. The ground water table is low in the valleys, both on account of the dry climate and the nature of the steep, rocky slopes bordering the alluvial bench lands, which rapidly shed and drain the surface water into the loose and porous fluvio-glacial materials. At the contact of the alluvium and bed-rock, springs may be noted in some places as is well shown in the Thompson canyon at the mouth of Botanie creek. The surface water oozes through the alluvium by means of drought cracks and creep crevasses and in time reaches a boulder clay or clay-silt layer. This layer, when saturated, forms a plastic medium upon which the heavy overlying mass may flow riverwards. The movement takes places as if on lubricated slipping planes. The earth flow forms a glacier-like mass with open crevasses in its lower extension. A small slip may result in great masses suddenly subsiding at the head and forcing the lower alluvium and toe of the slide forward into the river. As a result, the stream is dammed and a lake formed in which the water rises until it reaches an outlet in the dam when the great volume of water may break loose and flood the valley below.

(*b*) *Data Bearing on Drainage Combined with Outline of Drainage History.*

The Thompson river drains practically the whole district and is a rapid stream with an average gradient of 0·18 per cent, or a drop of about 9½ feet per mile. It and its main tributaries are considered to be antecedent streams with courses inherited from previous erosion cycles. The facts upon which this conclusion is based are recorded in the rock records of Mesozoic, Tertiary, and Quaternary time. A brief discussion of the field data, combined with an outline of the drainage history commencing with the more remote, will here be considered. For the full evidence upon which the following history is based the reader is referred to later sections of this report.

The Palæozoic rock record, dimmed by antiquity, shows no direct evidence of continental sedimentation so that it is impossible to locate the site of any old Pa-

[1] Summary Report, Geol. Surv., Can., 1911, p. 109.

læozoic drainage lines. Owing to the lack of pre-Devonian sediments it is thought, however, that this district formed a part of that ancient land area known as 'Cascadia' on palæogeographic maps[1]. During the early Palæozoic 'Cascadia' underwent continued marine and continental erosion and was brought down to a base level before Carboniferous time. The ancient rivers of this continent probably washed out materials into the bordering epicontinental seas. The western portion of 'Cascadia' was submerged in late Palæozoic time by the 'Vancouver sea'[2] and a great thickness of marine sediments and volcanics was heaped up on the downwarped mid-Palæozoic peneplain.

The Mesozoic record of drainage, although very fragmentary, indicates that this district had more relief, then, than during the Palæozoic era. Through Triassic and lower Jurassic time marine conditions of sedimentation with deposition of muds, sands, and calcareous sediments, continued, interrupted often, however, by igneous activity. During the Jurassic revolution which probably culminated in the late Jurassic, the older formations were uplifted high and deformed. The Coast range and Sierra Nevadas were outlined at this time. A coarse conglomerate near the base of the Spence Bridge Volcanic group (Jura-Cretaceous) near Thompson Siding is composed of much granitic material with boulders arranged overlapping one another eastward. The old fluviatile deposit appears from this to have been laid down in a river probably flowing from the Coast range into an interior basin to the east where the sediments were soon entrapped and protected from erosion by younger volcanics. The drainage following Jurassic mountain building was probably very haphazard and disorganized, with many local lake basins and estuaries in which volcanic, dust, arkoses, and conglomerates accumulated. Youthful conditions of erosion and sedimentation in time gave place to quieter conditions. Volcanism had largely ceased, vegetation flourished, and the dominantly argillaceous sediments of the Lower Cretaceous were laid down in probably brackish water arms of the sea. Diastrophic movements took place about the close of the Lower Cretaceous; the whole region was uplifted and subjected to a long continued period of erosion. The drainage became well organized and by the end of the Cretaceous, it is possible that the land was brought down to a peneplain. The present transverse courses of the Thompson and Fraser rivers were probably outlined at this time.

The Cretaceous erosion surface or possibly peneplain was slowly upwarped about the time of the Laramide revolution and the broader orographic features of the Cordillera outlined. The major Cretaceous rivers maintained approximately their courses throughout the slow uplift. The early Tertiary Fraser and Thompson rivers flowed much as they do now and drained the Interior Plateau country. An Eocene delta (Puget group) was built up at the mouth of the Fraser river. Owing to protective lava cappings in the Kamloops district, a fragmentary record of the Oligocene (?) or more probable Eocene Thompson River valley and some of its tributaries has been handed down to the present. South of Savona, a coarse, chiefly river deposit of boulders, coarse gravels, and sands with some lake material (Coldwater group) lying almost horizontal, outcrops beneath the lava hills and appears to occupy a valley eroded in a well-preserved remnant of the Cretaceous erosion surface. What was probably a tributary of the Eocene Thompson flowed west of Copper creek from the north and represented the ancestral Copper creek. The Coldwater group sediments there, chiefly fluviatile, have been severely deformed however, and dip steeply to the northeast-east. Local rhyolitic eruptions took place during the early Tertiary which effected the drainage, and supplied material for the acidic tuff beds of this period.

[1] Schuchert, Charles: Palæogeography of North America, Bull. Geol. Soc. Amer., vol. xx, pp. 464, 469.

[2] Op. cit., p. 447, 463.

Sedimentation of Coldwater time was closed by a crustal disturbance, whose intensity differed greatly in different parts of the district. This probably Oligocene orogeny inaugurated a new cycle of erosion which removed much of the loose, early Tertiary sediments and prepared the way for the more complete erosional work of the late Tertiary. The topographic relief was probably much reduced and lacustrine sedimentation predominated over the fluviatile of the preceding periods.

Many of the old valleys were filled and the drainage changed considerably in some localities owing to the widespread volcanic activity of the Miocene. Crustal warping in later Miocene time which affected mostly the eastern portion of the district inaugurated the late Tertiary erosion cycle during which the planating work of the mid-Tertiary was continued. Before the end of the Pliocene the deformed Miocene volcanics were bevelled and the interior country reduced to late maturity and local peneplanation. At this time some of the more resistant Palæozoic rock formations, chiefly crystalline limestone, remained surmounting the general level of the peneplain. On this erosion plain of Tertiary age, with few exceptions, the drainage was entirely independent of underlying rock structure. The main Thompson and Fraser rivers had then virtually their present courses which, as described, were first defined in the late Mesozoic.

The Pliocene topography in the interior country was coarse-featured or textured with broad low interstream areas; that in the Coast range was finer textured with smaller interstream areas, and with a greater relief.

The Tertiary closed and the Pleistocene period began with a great regional uplift of a differential character. The Pliocene drainage became deeply entrenched below the Tertiary erosion surface and the present valleys were carved out by the streams, leaving, as in the case of Savona mountain, the more resistant synclinal basins of the deformed Miocene volcanics in relief.

Pleistocene glaciation and river work modified the valleys, leaving in many places throughout the district great thicknesses of fluvio-glacial materials. The rivers since the Glacial period have been busy excavating the valley fill into broad terrace steps, indicating different meander periods at different levels in the downcutting process. The course of the river has been diverted slightly in some localities where land slides have temporarily dammed the stream.

In conclusion it may be noted that although the origin of the landscape in the Interior Plateau and Coast range has been traced far back into geological time and its physiographic development briefly outlined as above, the present topographic surface is dominantly post-Pliocene and younger in age. It may further be noted that here in this section of British Columbia the same conditions of long denudation prevailed in the late Tertiary as have already been identified in many regions outside the British Columbia Cordillera where similar upland surfaces were in course of development.[1]

General and Structural Geology.

GENERAL STATEMENT.

The character, structure, origin, and age of the various igneous, sedimentary,

[1] Atwood, W. W.: Jour. Geol., vol. XIX, pp. 449-453, 1911.
Smith, G. O.: U.S. Geol. Surv., Geol. Atlas, U.S., folio 106, 1904.
Cross, W.: Ibid, Mon. XXVII, p. 202, 1896.
Spencer, A. C.: Ibid, Prof. Paper No. 26, p. 12, 1904.
Ball, S. H.: (Spurr, J. E. and Garrey, G. H.) Ibid, No. 63, p. 52, 1908.
Rich, J. L.: Jour. of Geol., vol. XVIII, pp. 601-632, 1910.
For an analytical summary, see:—
Bowman, I.: Physiography of the United States, in Forest Physiography, pp. 342-368, 1911.

and metamorphic rock formations encountered in the survey of this portion of the Kamloops district will here be discussed.

The former classification and correlation of the formations by Dr. G. M. Dawson[1] have been followed in general, with, however, the two following notable exceptions: it has been found necessary to replace the name Lower Volcanic group used for the extensive development of Jura-Cretaceous rock (mapped as Tertiary on the Kamloops map) in the western portion of the section, by the new term *Spence Bridge Volcanic group.* Again it has been thought advisable to include the Lower Volcanic group and Tranquille beds in the vicinity of Kamloops lake, which are undoubtedly post-Eocene in age, with the conformably overlying Upper Volcanic group and call the whole by the new term *Kamloops Volcanic group.*

Table of Formations.

			Approx. thickness in feet.
Quaternary	Recent	Soil and subsoil	
	Pleistocene	Fluvio-glacial deposits	
Tertiary	Lower Miocene	Kamloops Volcanic group basalt, andesite, agglomerate, breccia, and tuff (Tranquille beds).	3,000∓
	Oligocene (?)	Ashcroft rhyolite porphyry	1,000∓
		Coldwater group conglomerate, sandstone, and shale	5,000∓
Mesozoic	Lower Cretaceous	Queen Charlotte Islands formation (?) chiefly shale, conglomerate and sandstone	5,000±
	Jura-Cretaceous	Spence Bridge Volcanic group liparitic and andesitic lava, tuff, arkose, and conglomerate.	5,000±
	Upper Jurassic (?)	Granitic intrusives.	
	Jura-Triassic	Nicola Group greenstone (porphyrites), impure quartzite, argillite, limestone, agglomerate, and tuff.	10,000∓
Palæozoic	Carboniferous	Câche Creek group cherty quartzite, argillite, greenstone, and limestone (Marble Canyon limestone).	9,500 ±

DESCRIPTION OF FORMATIONS.

Câche Creek Group.

The Palæozoic rocks in the district are very much metamorphosed and form a complex known as the Câche Creek group[2] composed of cherty quartzites, crystalline limestones, argillites, and greenstones. The major portion of this complex is definitely referable through fossil evidence to the Carboniferous period although the basal portions are possibly Devonian.

Distribution and Thickness.—The Câche Creek group is confined in its distribution to a belt between the Thompson and Bonaparte rivers on the east and the Fraser river on the west. In the district under consideration the Câche Creek rocks are met with first about 3 miles up Bonaparte river where they are in contact with the younger Queen Charlotte Islands formation. The contact runs south through the broad dry Cornwall valley and reaches the Thompson river at Basque. The Thompson river follows the contact for several miles (6·2 miles), until Spatsum is reached where the Palæozoic rocks extend across the river as a narrow belt fringing the river and cut off to the east by a broad underlying granite batholith. The

[1] Report on Area of Kamloops Map-sheet; Geol. Surv., Can., Ann. Rept., vol. VII (1894).
[2] Report on Kamloops Map-sheet, Geol. Surv., Can., Ann. Rept. vol. VII, 1894, p. 37B.

Câche Creek formation is overlain at Toketic by the Spence Bridge Volcanic group which extends in a northwestwardly and southeastwardly direction for many miles.

On account of the unfavourable character of the outcrops in the railway section it has proved impossible to ascertain the full thickness. The estimate of Dawson and order of succession (descending order) is as follows:—

	Feet
"(1.) Massive limestones (Marble Canyon limestone) with minor intercalations of volcanic rocks, argillites, and cherty quartzites. At least 1000 feet seen in some single exposures. Total thickness probably at least..........	3000
(2.) Volcanic materials and limestones, with some argillites, cherty quartzites, etc. Minimum thickness, about..........	2000
(3.) Cherty quartzites, argillites, volcanic materials, and serpentines, with some limestone. The thickness of these beds, or of a part of them, was roughly estimated in two places as between 4000 and 5000 feet. Minimum total thickness say..........	4500
Total..........	9500

Thus the entire volume of the rocks of the Câche Creek formation, as this is now defined, may be assumed to be about 10,000 feet as a minimum while I am inclined to believe that it really exceeds 15,000 feet."

Lithology.—The rocks belonging to the Câche Creek group form a complex made up of both sedimentary and eruptive types all much metamorphosed. The commonest rock members are cherty quartzites and altered tuffs traversed by veinlets of quartz. They are very fine grained and of a dark grey to yellowish grey and greenish grey colour. Associated with the above and of more local occurrence are dark massive meta-argillites and greenstones. The latter represent contemporaneous eruptive materials since metamorphosed. The argillites have been subject to static metamorphism (silica metasomatism) to such an extent that the planes of breakage never coincide with the bedding planes nor have they a slaty cleavage. In many places grey and white largely crystalline limestones or marbles are intimately interfolded with the above rocks.

The pyritic cherts and sheared rhyolites belonging to this group as exposed on Red hill near Basque have been badly oxidized and form prominent red outcrops. Such oxidized outcrops, owing to the semi-arid nature of the climate, are quite common throughout the region. Near Spatsum, gypsum and china-clay may be seen in crumbling outcrops of red, yellow, and white. The highly coloured decomposed materials are almost devoid of vegetation. The metamorphism, both contact and regional, of the rocks has been so intense that microscopic study throws very little light upon their original character. Under the microscope the cherty quartzites appear to be fine-grained dense rocks, made up of quartz, epidote, and iron ore. Pyrite and magnetite are very common. Some of the slides show obscurely angular forms which suggest a pyroclastic origin for the material, thus pointing toward an original tuff.

The greenstones or altered eruptives are massive, dense rocks of a general dark green colour, sometimes porphyritic with small feldspar phenocrysts scattered throughout a very largely chloritized groundmass. Under the microscope the limestone appears wholly crystalline, and shows larger individuals of calcite in a generally finer crystalline aggregate of the same mineral. Lattice structure is quite pronounced. All the crystals are polysynthetically twinned. Some of the larger crystals have been strained and contorted, producing in places an imbricated structure. One thin section from a railway cut near 89-mile stable on the Cariboo road, where the rock underlay limestone, proved to be of a calcareous arkose.

Structure.—The original structure of the rocks comprising the group has been greatly obscured owing to their massive character and the fact that they have been chloritized and silicified in the zone of cementation to such a degree that their bedding is seldom discernible or cannot be distinguished from the planes of jointing and shearing.

The observed strikes and dips varied a great deal from place to place, the average strike being in a north-northwest and south-southeast direction with dips chiefly to the west. This is the normal Cordilleran trend for formations in the Main Pacific geosynclinal.

Conditions of Deposition.—The rocks belonging to the Câche Creek formation were probably laid down in a Carboniferous sea ('Vancouver Continental sea')[1] slowly transgressing from the northwest upon a low-lying land area ('Cascadia' positive element[2])which probably supported abundant vegetation. In this continental sea, argillaceous, arenaceous, and calcareous sediments were deposited. The limestones represent the off-shore deposits whereas the carbonaceous argillites and sandstones represent the inshore phases.

Marine sedimentation was interrupted at intervals by volcanic activity, which resulted in the accumulation of much volcanic dust and the outpouring of lavas.

Age and Correlation.—Fossils were collected in 1871 by Mr. James Richardson from a locality on the Cariboo wagon road 2½ miles above the 89-mile stable. The following genera were recognized: *Cyrtina*, *Spirifera*, *Rhynchonella*, a small *Myolina* and a *Euomphalus*. Mr. Billings reported them as follows: 'Although none of the above have been determined specifically, they indicate almost certainly a horizon between the base of the Devonian and the summit of the Permian.'[3]

In 1877 the diagnostic Carboniferous fossil *Fusulina* was found in a few localities outside the limits of this district. The Fusulina were found in limestone of the Câche Creek group at Stuart lake (lat. 54° 30′), Dease river (lat. 59° 15′), Frances river (lat. 60° 30′), and on Tagish lake (lat. 60°). A large foraminifera *Loftusia columbiana* has been found and described by Dawson in the Marble Canyon limestone[4]—the upper member of the Câche Creek group. Associated with the above fossils are remnants of crinoids and corals. The lower portion of the Câche Creek group may be older than Carboniferous but as yet no characteristic Devonian fossils have been found.

The Câche Creek group may be correlated with Daly's Attwood series[5] of the 49th parallel belt to the south. The lower portion of the group would correspond to the Knobhill group[6] of Phoenix, and the Franklin group[7] of the Franklin camp; the upper portion to the Brooklyn limestone formation of Phoenix and the Gloucester limestone formation of Franklin, the latter containing *Crinoid* columnals and an obscure *Fusulina* (?).

Nicola Group.

The Nicola group includes a vast thickness of volcanic rocks which are inter-

---

[1] Schuchert, Charles, Paleogeography of North America, Geol. Soc. Amer. Bull. vol. xx, pp. 447, 463.

[2] Op. cit., p. 464, 469.

[3] Report of Progress, Geol. Surv., Can., 1871–72, pp. 61–62.

[4] Dawson, Dr. G. M., Quart. Jour. Geol. Soc. 1879, p. 69.

[5] Daly (R. A.): The Geology of the North American Cordillera at the 49th Parallel, Memoir No. 38., Geol. Surv., Can. 1913.

[6] Le Roy (O. E.): The Geology and Ore Deposits of Phoenix, B.C., Memoir No. 21, Geol. Surv. Can., 1912, p. 30.

[7] Drysdale (C. W.): The Geology of the Franklin Mining Camp, B.C. Geol. Surv., Can. In preparation.

stratified with marine sediments. They lie within the same general geosynclinal belt as do the underlying Câche Creek rocks, although separated from them by an unconformity.

Distribution and Thickness.—The Nicola formation has a wide distribution in the railway belt examined and extends with few interruptions from the eastern border of the sheet to Spatsum, a distance of about 40 miles. The thickness of the formation is roughly estimated at between 10,000 and 15,000 feet.

Lithology.—The rocks in the Nicola group are chiefly altered eruptives of both flow and fragmental type with included argillaceous, calcareous, and arenaceous beds. The altered eruptive rocks (porphyrites) have a general greenish colour and are included under the convenient field term of greenstones. They are largely diabasic and basaltic in composition. The argillites are dark grey in colour and massive; the limestones found most extensively near the summit of the series, are light to dark grey and contain many impurities.

A greenish grey rock of the Nicola series collected from the north shore of Kamloops lake proved, under the microscope, to be an amygdaloidal augite porphyrite containing augite, plagioclase, and iron ore in a groundmass of the same minerals. Some orthoclase and quartz are also present. The amygdules are of calcite and prehnite. A dark green, medium-grained rock showing reddish weathered-out olivines outcrops on the Canadian Northern Pacific railway west of Copper creek and elsewhere in this vicinity. It is an augite picrite porphyrite, a rock somewhat similar to the augite porphyrite just described, but containing olivine and more basic in composition. The chief minerals are augite, olivine, iron ore, titanic oxide, serpentine, chlorite, and epidote. The commonest lavas proved to be andesites and the pyroclastics are altered andesitic tuffs and coarse agglomerates.

Structure.—The lavas are very massive and it is difficult to determine the structure of the group. In places, the series appears to have been broadly folded into anticlines and synclines with general Cordilleran trend. There is no general uniformity of structure, however, and local faults are of common occurrence. The upset structure of portions of the group is probably largely due to the deformative movements accompanying the intrusion of the late Jurassic granitic batholith. The Nicola group sediments (chiefly calcareous) in contact with the batholith in the vicinity of Spatsum have been metamorphosed at the contact into cherts or hornstones. The topography in this vicinity closely conforms to geological structure.

The strikes and dips of the master joint planes in the group were observed but no definite system could be recognized. Calcite seams frequently fill the joint planes in the greenstones.

The series is cut in many places by younger aplite dykes which are probably complementary to the underlying granitic batholith. The Nicola group lies unconformably upon the Câche Creek group and is cut off at the top by the Cretaceous surface of erosion. Many cappings of Tertiary rocks are found upon this ancient erosion surface.

A dyke of the rare rock alnöite[1] was found intrusive into the rocks of the Nicola group about 2 miles east of Semlin. The age of the intrusion whether Mesozoic or Tertiary is uncertain, but on account of its intimate association with Nicola rocks, the occurrence will be here described.

This interesting rock type outcrops on a rocky knoll scarped and undercut on its southern flank by the Thompson river. At this point in the valley bottom the meandering river, on encountering the projecting rock shoulder of the Nicola

---

[1] Adams, F. D.; Am. Jour. Sci., vol. XLIII, 1892, pp. 269–279.
Rosenbusch, H.; 'Mikroskopische Physiographie": 1907, vol. II, p. 705.
Harvie, Robert; Trans. Royal Soc. of Canada, Third Series, 1909–1910: vol. III, sect. IV, pp. 249–299.

group, reached its limit of free swing and was forced to make a sharp bend southward where it continued to deeply incise itself within the loose fluvio-glacial materials that form the valley fill.

The alnöite dyke averages 4 feet in width, strikes northeast and southwest and dips 70° to the southeast. Blocks of alnoite containing large plates of biotite (first generation biotite) up to one inch in diameter in a dark fine-grained groundmass have been taken from the talus and cliffs to help form retaining walls for the wagon road between Walhachin and Ashcroft. It was from this locality that the alnöite-like rock described by Dr. F. D. Adams in Dawson's Kamloops report[1] was very likely obtained. Dawson reported that the rock was probably a dyke of Tertiary age, but that the rocks at the locality were much broken and confused.

Under the microscope, the rock consists of large phenocrysts of biotite, olivine, and augite in a fine-grained groundmass of the same minerals. The augite shows zonal structure and the olivine has largely broken down to serpentine. Perovskite is present in small dusty square outlines and melilite occurs in lath-shaped forms which show obscurely the pegged-in structure. The melilite is partly decomposed to calcite. Magnetite is disseminated in small grains through the groundmass. Feldspar is entirely wanting in the rock.

Origin.—The Nicola rocks are chiefly of volcanic origin, having been thrown out from vents and deposited in the Jura-Triassic sea bottom along with clays, sands, and calcareous sediments.

Age and Correlation.—The age of the Nicola group has been determined to be of Triassic age grading up into lower Jurassic. The scattered joints of a crinoid columnal closely allied to *Pentacrinites asteriscus* were found by Dr. G. M. Dawson in the limestone of McDonald river and Nicola lake. *Pentacrinites asteriscus* has been obtained from Triassic beds in the Pah-Ute range of Nevada[2] and in California localities it is associated with undoubted Triassic fossils.[3]

In 1890, the following fossils were obtained by Dawson from limestones near the mouth of Deadman creek: *Myacites* like *M. humboldtensis*, Gabb., a *Daonella* like *D. lomaneli*, a *Trigonodus*, a *Cardita* and other fragments. In 1894, Dawson made a detailed examination of the rocks on the east side of the Thompson, south of Ashcroft, and found fossils at two different horizons, separated by about 12,000 feet of strata. The lower horizon yielded a *Daonella*, a *Panopea* like *P. remondi*, Gabb. The upper horizon contained two species of *Rhynchonella*, one of *R. gnathophora*, a *Pecten* like *P. acutiplicatus*, Gabb, and *Entolium* like *E. equabilis* Hyatt M.S. and *Lima parva*, Hyatt, M.S. Professor Hyatt believed the upper horizon to be of lower Jurassic age, equivalent to the Hardgrove sandstone, and possibly to the Mormon sandstone of Taylorville, California.[4]

A large number of small lots of fossils were collected during the past field season from several localities in the calcareous members of the Nicola group. The fossils were sent to Dr. T. W. Stanton, of Washington, D. C., for determination, who reports: 'I have not been able to make any satisfactory determination and can only say that the general character of the fossils, with possibly one or two exceptions, indicates that the rocks are Jurassic and it is possible that some, or all of them may be lower Jurassic. I can see no evidence for referring any of them to any of the known American Cretaceous faunas and they show no relationship with the upper Jurassic of the Rocky Mountain region'.

Very large, coarsely-ribbed *Pectens* sp., *Lima* ? sp., and an obscure fragment of an *ammonite* were collected in the vicinity of Rattlesnake hill, northeast of Ash-

---

[1] Annual Report, Geol. Surv., Can., vol. VII, 1894, p. 388.
[2] U.S. Geol. Exploration of the 40th parallel, vol. IV. p. 280.
[3] Smith, J. P., Bull. Geol. Soc. Am., vol. v, p. 250.
[4] Ann. Rept. Geol. Surv., Can., 1894, p. 112B.

croft. A *Terebratula* sp., large *Pecten* sp. and a fragment of a fibrous shell, possibly *Inoceramus* or a large *Lima* were found in the Nicola group east of Basque. A fragmentary imprint of an *ammonite* came from the Nicola group, on the east lower slope of the Thompson valley, a couple of miles north of Spatsum.

Many fossils were collected from localities in the vicinity of the old 89-mile stable at the mouth of Venables creek where Dawson made collections which were sent to Hyatt for examination.[1] The following fossils were collected: abundant large *Terebratula*, *Ammonite*? section, *Phynchonella*? sp. Undetermined *pelecypod* and *gastropod* casts, *Pecten* sp. *Pecten* sp. (Entolium?), fragments of *Gervillia* sp. Dr. Stanton reports: 'It is probably Jurassic and may be lower Jurassic as Hyatt thought, but the evidence is not sufficiently definite to be positive about exact correlation.'

The Nicola group may possibly be correlated with the Vancouver volcanics and Sutton formation in Southern Vancouver island[2] and the Cultus formation of the 49th parallel section.[3]

Granitic Intrusives.

Distribution.—The rocks of the Câche Creek and Nicola groups are frequently cut by aplitic dykes and small granitic bosses which are in all probability connected with the Coast Range batholith of late Jurassic or early Cretaceous age.

The granite rocks as indicated on the map are well distributed throughout the area but reach their greatest development in the vicinity of Lytton. They are capped in many places by the younger Tertiary volcanics.

Lithology.—The rocks of upper Jurassic(?) age are light grey to greenish grey, granitoid rocks which vary in composition from true granite to granodiorite and quartz diorite. Hornblende or biotite or both occur as chief ferromagnesian constituents. They are medium-grained rocks consisting of both plagioclase (chiefly andesine) and orthoclase feldspar and quartz with essential hornblende and with accessory biotite, magnetite, pyrite, and titanite. Micrographic intergrowths of the quartz and potash feldspar are present in some of the sections and in these biotite is the chief ferromagnesian constituent. The secondary minerals are biotite, chlorite, epidote, sericite, muscovite, limonite, and kaolin.

A border facies of the granitic batholith east of Spatsum is a granite porphyry containing corroded quartz and phenocrysts of orthoclase and hornblende in a holocrystalline groundmass of the same minerals.

Structure.—The deep-seated rocks have all been subjected to considerable regional metamorphism but in only a few places do they display gneissoid texture. They are greatly jointed and fractured and have also in places pronounced shear zones developed through them.

The granitic rocks, where intrusive into the limestone of the Nicola group, have produced wide contact zones, as is the case in the vicinity of Spatsum, where a wide chert zone fringes the batholith. The uplifting and deformation of the Nicola group at its eastern borders, where in contact with the granodiorite batholith, is probably connected with the intrusion of the latter in late Jurassic time.

Origin.—The formation of the batholith was probably in the nature of a passive invasion preceded by dyke intrusions and possibly volcanic activity, and followed by minor complementary dykes.

Age and Correlation.—The batholith is intrusive into lower Jurassic rocks,

---

[1] Ann. Rept., Geol. Surv., Can., vol. VII, 1894, p. 115B.

[2] Clapp, C. H.—Southern Vancouver Island: Geol. Surv., Can., Memoir No. 13, 1912, pp. 61–71.

[3] Daly, R. A.—Geology of the North American Cordillera at the 49th parallel. Memoir No. 38, Geol. Surv., Can. 1913.

and is capped by volcanics and sedimentaries of upper Jurassic to Lower Cretaceous age. It may be referred, therefore, to the late Jurassic and correlated with similar batholiths from other parts of the British Columbia Cordillera, as, for example, with a portion of the Coast Range batholith of western British Columbia and Yukon; the Nelson granitic batholith of West Kootenay, Remnel, and Osoyoos batholiths of the Okanagan range and Kruger Mountain plateaus, and the Sumas granite stocks of the Skagit range.[1] In central Washington, it correlates with the Mount Stuart batholith.[2]

Spence Bridge Volcanic Group.

Distribution and Thickness.—The Spence Bridge Volcanic group includes a vast thickness (over 5000 feet) of volcanic materials of both flow and fragmental type. The group is distributed particularly along the eastern front of the Coast range and occupies a synclinorium about 14 miles wide in the railway belt, extending in a northwest and southeast direction. The rocks of the group commence at Toketic and end at Thompson Siding. The Thompson river has in no place cut through to the base of the synclinorium.

Lithology.—The rocks are chiefly andesitic and liparitic lavas with amygdaloidal and vesicular types. The amygdaloids consist of quartz, chalcedony, and zeolites. Interbedded with the lavas are agglomerates, breccias, and tuffs, the latter containing plant remains of Jura-Cretaceous age.

The lower part of the formation is made up of massive breccias, tuffs, and lava flows with one layer of coarse conglomerate outcropping on the Canadian Northern railway opposite Thompson Siding. The conglomerate contains many granitic boulders and pebbles with cherty quartzites, greenstones, and porphyrites. The lavas are andesitic and have augite as the chief ferromagnesian constituent. The augite has broken down to uralite in many of the types. The plagioclase approaches in composition that of labradorite.

Comformably overlying the above rocks are white to pale grey liparitic tuff and lava, the latter in many places showing marked spheroidal structure. The former is in places marked by peculiar fine twisted lamination surfaces. The liparite is in turn intruded and capped by andesitic lavas which are interbedded toward the summit of the series with argillaceous sediments. A conglomerate made up chiefly of subangular pebbles of quartz, quarzite and granitic rocks and an occasional fragment of argillite (the whole embedded in an arkosic matrix) outcrops on a summit between Twaal and Murray creeks. The conglomerate member is associated with greyish tuffs and andesitic lavas belonging to the upper horizons of the group. The lavas have porphyritic varieties containing phenocrysts of plagioclase and augite. The basaltic lavas near the top of the series on the Scarped mountains, weather out spheroidally in onion-like forms. Reddish lavas containing cavity fillings of the hydrous silicate stilbite occur near the summit of the series in the vicinity of Drynock, 6½ miles below Spence Bridge.

Structure.—The members of the group are broadly folded into anticlines and synclines, and in some localities they are much deformed. The rocks have been subjected to more regional metamorphism than those of the Tertiary Volcanic formations and can thus be readily distinguished from them. Calcite seams, which are not common in the Tertiary Volcanics, are abundant in the Mesozoic rocks.

No contact between the Spence Bridge Volcanic group and the Queen Charlotte Islands formation was observed so that their probable conformable relations could not be definitely determined.

---

[1] Daly, R. A.—The geology of the North American Cordillera at the 49th parallel. Memoir No. 38. Geol. Surv. Can. 1913.

[2] Smith, G. O.—Mount Stuart Folio U.S. Geol. Surv. No. 106 (1904).

Origin.—The members of the Spence Bridge Volcanic group, as the name would imply, are chiefly of volcanic origin although conglomerate beds are found interstratified with the tuffs and breccias. The andesitic eruptions were probably from numerous fissures from which the lava spread out over a broad, comparatively level basin. The main axis of eruption was along the line of the present Arthur's Seat, Mount Murray, and Cairn mountain. The liparitic eruptions were probably explosive in their nature as indicated by the acidic tuffs and breccias. The earlier lavas as they poured westward became intermixed with delta and river deposits from the Coast range. Some of the rivers then flowed through to lake basins nearer the centres of eruption. Around such lakes vegetation was abundant. In this belt, volcanic activity was very pronounced and the outpouring of lavas prevented the accumulation of great thicknesses of coal-bearing sediments as was in progress farther north in the Groundhog district and elsewhere along the eastern front of the Coast range.

Age and Correlation.—Plant remains were found in the tuff beds of the Spence Bridge Volcanic group in the Thompson valley, at an elevation of 2500 feet above sea-level. The beds outcropped on the western slope of the Pimainus hills about half way between the Nicola river and Pimainus creek. The plants were examined by Mr. W. J. Wilson, who reports as follows: 'This small collection, though fragmentary and poorly preserved, seems to indicate that the rocks in which it was found are of Lower Cretaceous age, probably about the equivalent of the Kootenay, Potomac or Wealden. Some of the plants, however, have a decidedly Jurassic aspect.'

This collection was then forwarded to Dr. F. H. Knowlton, of Washington, who confirmed most of Mr. Wilson's determinations. The corrected list is as follows: *Nilssonia* cf *Schaumburgensis* (Dunker), *Taeniopteris* cf *T. orovillensis* (Font), *Sequoia reichenbachii* Heer, *Podozamites lanceolatus* (L. and H.), *Podozamites* cf. *P. gramniæfolia*, *Podozamites fragments*, *Sagenopteris* cf. *S. paucifolia* (Phili) Ward, *Cladophlebis* cf. *C. falcata montanensis* Font, *Cladophlebis* cf. *browniana* (Dunker) *Oleandra*, *Equisetum?*, *Sphenolepidium* sp., fragments of bark and stems. Referring to this collection, Dr. F. H. Knowlton writes[1]. 'They are certainly lowest Cretaceous, if not indeed upper Jurassic. So far as I recall *Sagenopteris* has not been noted in the Kootenay, and the several species of *Nilssonia*, *Tæniopteris*, etc., which seem to compare most closely with them are Jurassic species. . . On the whole, I expect it is best to regard them as Kootenay—with decided Jurassic affinities. They have, of course, absolutely no relation to the Miocene'.

This new plant evidence favours Dawson's early views regarding the age of the volcanic rocks of this group which he thought, in 1877, were connected with the contiguous Cretaceous strata underlying the Fraser River Lower Cretaceous.[2] He correlated them on lithological grounds with certain 'porphyrites' which had been found to contain earlier Cretaceous fossils in the more northern parts of British Columbia in 1875 and 1876.[3] Dawson later preferred to consider them as of Tertiary age on account of their intimate association with distinctly Tertiary volcanic rocks and classed them in his Lower Volcanic group of Miocene age.[4]

The Spence Bridge Volcanic group very probably correlates with the Hazelton group (at least 5000 feet thick) farther north in the Skeena River region. Concerning the Hazelton group Mr. W. W. Leach writes: 'Generally speaking, it may be said that to the south, this formation is built up almost entirely of flow rocks, chiefly andesites, massive, with characteristic dark red and green colours. At the top of the series, a few thin beds of fossiliferous sandstones and shales appear, a

[1] Personal communication.
[2] Ann. Report, Geol. Surv., Can., 1894, vol. VII, p. 151B.
[3] Report of Progress, Geol. Surv., Can., 1877–78, p. 111B.
[4] Dawson, G. M.—Geol. Surv., Can., Annual Report, 1894, vol. VII. p. 199B.

number of fossils from which have been determined to be of Jurassic or early Cretaceous age. These are overlain directly by the coal-bearing Skeena series, so that in the Telkwa River district little difficulty was encountered in separating these two formations in the field. On travelling northwards, however, it was found that these flows gradually thinned out, and were replaced by a considerable thickness of tuffs and tufaceous sandstone, although a few of the andesite beds extended as far north as Hazelton. Locally these tufaceous beds are known as sandstone, and where altered near the contact with intrusive masses, as quartzite.[1]

The Spence Bridge Volcanic group may be further correlated on lithological grounds with Daly's Skagit Volcanic formation (5200 feet thick) and Pasayten Volcanic formation of the Western Geosynclinal Belt at the 49th Parallel[2] both of which contain augite andesites. The Skagit formation contains both liparitic and andesitic lava flows having similar relationships to conglomerate beds, as have the Spence Bridge Volcanics. The Naknek formation[3] of Cooke inlet, Alaska peninsula, which also consists of conglomerate, arkose, sandstone, and shale with (interstratified) andesitic flows (with a total thickness of about 5000 feet), may also be correlated with the above.

Queen Charlotte Islands Formation(?).

Distribution and Thickness.—The shales, sandstones, and conglomerates included under this formation, occur in two isolated areas, the main one in the vicinity of Ashcroft occupying an area of about 48 square miles, and the other at the mouth of Botanie creek of about 2 square miles in area. This formation has been referred by Dawson on lithological grounds to the Lower Cretaceous and correlated with the Queen Charlotte Islands formation of the Pacific coast.

The approximate thickness of the Ashcroft Queen Charlotte formation is about 5000 feet. The Botanie Creek Queen Charlotte formation is too severely metamorphosed and drift covered to give any idea of its thickness.

Lithology.—The rocks belonging to this sedimentary series vary from coarse conglomerates to fine-grained argillites and shales. Much of the material is of an arkosic character and the sandstones are feldspathic rather than siliceous. The shales and argillites which occur in the upper part of the section are dark and in many places carbonaceous. The sandstones are, as a rule, highly indurated and of a greenish or greenish grey to grey colour.

The conglomerates are never in great thickness and are made up of fragments of greenstones, cherty quartzites, and granitic rocks generally in an arkosic matrix. The fragments are often well rounded, but in some beds are angular and subangular and, in the latter case, the beds are found near the borders of the area and probably represent subaerial cone or fan deposition at the borders of the basin. In the Botanie Creek area the blackish and brownish shales have been badly metamorphosed and slickensided.

Structure.—The rocks belonging to the Queen Charlotte formation of Ashcroft and Botanie Creek localities, have all been considerably deformed and their original structure is very obscure. The least deformation is shown at the eastern border of the Ashcroft area where the dips are comparatively low, ranging from 10° to 45° west. The formational dips steepen westward to 60° and up to vertical. Broadly speaking, the formations strike in a northerly and southerly direction, forming a syncline with its western limb overturned, faulted, and, in places, crushed. Within the main synclinal and particularly in the western portion of it, are

[1] Summary Rept. Geol. Surv., Can., 1910, p. 93.
[2] Daly, R. A.—The Geology of the North American Cordillera at the 49th parallel, Geol. Surv. Can. Memoir No. 38. 1913. pp. 475–529.
[3] Stanton and Martin, Bull. Geol. Soc. of Am., vol. xvi (1905), p. 410.

numerous minor folds and local faults. The formational strikes in the southern portion of the inlier are approximately east and west, and the deformed beds form a local syncline within the main one, but with an east and west trend.

Origin.—The rocks are all of sedimentary origin and were probably deposited after the late Jurassic mountain-making revolution, by streams draining into marine estuaries or brackish water lakes in which Selachian[1] fish and such organisms as Pectens and Goniobasis lived. At the borders of the basin or estuary, subaerial deposition was in progress, and coarse conglomerates with, here and there, quite angular fragments accumulated. Arkosic materials were swept down by the rivers; vegetation flourished and carbonaceous muds accumulated in the central parts of the basins.

Age and Correlation.—Fossils are scarce in this formation and were found last field season for the first time in the Ashcroft area. Very large coarsely ribbed pectens and undeterminable forms were found on the west flank of Rattlesnake hill, a few miles north of Ashcroft. Concerning the pecten, Dr. T. W. Stanton writes:[2] 'So far as the characters are preserved this specimen might be Jurassic, Cretaceous or Tertiary, but it is probably from the Jurassic.'

Dr. G. M. Dawson, in 1893, found some small fragmentary fish bones in the Botanie Creek shales associated with what were apparently the crushed tests of minute Ostracoda.[3]

The Ashcroft and Botanic Creek areas of the Queen Charlotte formation Dawson correlated lithologically with the Fraser River Cretaceous. Plant remains were collected by him in the Fraser River Cretaceous on the east side of the Fraser, about a mile above the mouth of Stein creek. Sir J. W. Dawson has described the collection made in 1877 as containing two indeterminable dicotyledonous leaves and one flabellate leaf resembling that of a Salisburya.[4] Concerning the collection made in 1890, he supplies the following note:—

> '1.—*Platanus obtusiloba*, Lesq., or closely allied. This is a species found in the Dakota group in Nebraska.
>
> '2.—Probably *Magnolia tenuifolia*, Lesq., which is found in the Dakota of Nebraska and also in the Dunvegan group of Peace river.
>
> '3.—*Menispermites*, allied to *M. grandis* of the Dakota group, but probably specifically different.
>
> '4.—*Laurophyllum*. Several leaves referable to this genus, and near the Dakota species.
>
> '5.—*Sequoia*, a fragment which may be S. Rechenbachii.
>
> '6.—Grass-like stem or *Phragmites*, *Carpolites*, etc.,—scarcely determinable. The whole probably belongs approximately to the age of the Dakota group or near to this.'[5]

No contact between the Queen Charlotte formation and the Spence Bridge Volcanic group was present in the area mapped, so their exact relations could not be ascertained. It is thought, however, that Dawson's first views were correct with regard to the relations of the two, and that the Spence Bridge Volcanic group (Jura-Cretaceous) is older and underlies conformably the Queen Charlotte formation. If this be the case the Queen Charlotte formation of this district would probably correlate with the Skeena series (coal-bearing) farther north which also consists of carbonaceous shales and sandstones.

---

[1] Ann. Report, Geol. Surv. Can., vol. VII, 1894, p. 148 B.
[2] Personal communication.
[3] Annual Report, vol. VII, Geol. Surv., Can., 1894, p. 154B.
[4] Report of Progress, Geol. Surv., Can., 1877–78, p. 110B.
[5] Annual Report, 1894, Geol. Surv., Can., vol. VII, p. 148B.

Coldwater Group.

Distribution and Thickness.—The sediments of early Tertiary age are known as the Coldwater group and have a relatively small distribution within the limits of the map. They extend in two detached areas, one on the north side of Kamloops lake elongated in a northerly direction and capped by the younger volcanics to the east and west, and the other belt on the south side of the lake fringing the lower Miocene volcanics of Savona mountain. They represent the remnants of former much more extensive beds of continental origin preserved through time by protective lava cappings.

Lithology.—The Coldwater group is made up of coarse conglomerates, shales, and sandstones all of continental type. The conglomerates are dark brown or greenish grey in colour and are composed of well rounded to subangular boulders chiefly of metamorphic (including cherty quartzites, greenstones, etc.), sedimentary, and igneous rocks varying in size from a few inches to 2 feet and more in diameter, the whole embedded in a firm compact cement. They include fragments of practically all the older formations and none of the Miocene volcanics were found contained in them. The conglomerate shows a rude stratification in places and the flatter boulders parallel one another and overlap in the direction of the flow of the early Tertiary stream that deposited them. Interbedded with the conglomerates are greyish feldspathic sandstones and tufaceous shales.

The Tertiary clastics are not so well indurated as the Cretaceous and joint planes do not traverse indiscriminately boulders and matrix alike as they do in the case of the Mesozoic conglomerates.

Structure.—The Coldwater group rocks of the southern area underlying the volcanics (lower Miocene) of Savona mountain, lie with very low dips to the south and although uplifted they have apparently not taken part in the deformative movements that elsewhere effected beds of this age prior to Miocene volcanism. The rocks appear to fill erosion channels in a Mesozoic (Cretaceous) erosion surface.

The conglomerates and sandstones of the group belonging to the northern area west of Copper creek, have been badly deformed along a north-northwest and south-southeast line and dip steeply to the northeast-east. In places, the beds even stand vertical. The sediments are made up chiefly of well water-worn cherty quartzites from the Câche Creek group and of greenstones and altered granitic rocks.

Conditions of Deposition.—The sediments appear to have been laid down by swift-flowing rivers in valleys and local lake basins. The topographic relief as indicated by the coarseness and unconcentrated character of some of the sediments must have been considerable. The coarse heterogeneous sediments which show slight stratification and contain subangular to angular boulders probably represent alluvial cone or fan deposition. The well-stratified and water-worn boulder conglomerate represents river deposition. The fine-grained sandstones and shales were laid down in quiet waters and are chiefly of lake origin. Considerable tufaceous material of acidic nature is found in the fine-grained sandstones and shales, which indicates that volcanic activity was in progress at the time.

It is thought that the climate then was probably humid and cool, as indicated by the light coloured leached sediments and grey and greenish grey colours with the presence of carbonaceous shales containing plant remains.[1] Under such conditions of climate and relief continental erosion must have proceeded rapidly, and great thicknesses of loose unconsolidated sediments were laid down in local lake basins and river valleys.

---

[1] Barrell, J.—Climate and Terrestrial Deposits: Studies for Students, Jour. of Geol., vol. XVI, pp. 293, 294 (1908).

The deformative movements, however, in the Oligocene (possibly the post-Kenai revolution of Alaska) inaugurated a new erosion interval which removed most of this early Tertiary material before the widespread outpouring of Miocene lavas and pyroclastics. What remnants of Coldwater group sediments and correlated formations that do exist to-day owe their preservation largely to protective lava cappings of Miocene age.

Age and Correlation.—No new plant evidence was obtained in this area from the sediments of the Coldwater group. They are correlated lithologically and structurally with the Similkameen beds[1] (Oligocene?) and the Kettle River formation[2] (Oligocene?) of other portions of the British Columbia Cordillera which are considered to belong to a period between the late Cretaceous and the early Miocene.

The Coldwater group in this district may possibly be correlated with the Kenai series in southeastern Alaska, which consists of friable sandstone, conglomerate, shale, and coal seams similarly deformed and separated from the younger volcanics by an erosion surface. The writer follows Dawson in placing the Coldwater group of this district in the Oligocene(?) but favours an Eocene age for the same and he would refer the post-Coldwater elevation, deformation, and erosion to the Oligocene.

Ashcroft Rhyolite-Porphyry Formation.

Distribution and Thickness.—The Ashcroft rhyolite porphyry formation has only a small development in the district. It occupies a couple of square miles on a prominent hill in the Thompson valley, southeast of the town of Ashcroft and to the west of Barnes lake. It has a maximum thickness approaching 1000 feet and caps unconformably shales and sandstones belonging to the Queen Charlotte formation.

Lithology.—The rock is a rhyolite porphyry varying from coarse to fine in texture and showing in places a fluidal structure. It is a light greenish grey holocrystalline rock of porphyritic habit with mica as the chief ferromagnesian constituent and small limpid quartzes and feldspars as phenocrysts. Under the microscope it was found to consist of: apatite, zircon, iron ore (pyrite, magnetite), titanite, biotite, plagioclase, orthoclase, quartz, chlorite, and kaolin. The structure is porphyritic with phenocrysts of corroded quartz zoned plagioclase, partly kaolinized orthoclase and biotite in a micro-granitic groundmass of the same minerals. The magnetite is included chiefly in the biotite. Apatite is present in small needles and prismoids.

Structure.—The Ashcroft rhyolite porphyry has a massive jointing in planes parallel to the general slope of the hill, which resemble planes of bedding. The formation lies unconformably upon deformed shales and sandstones of the Queen Charlotte formation and is capped unconformably by basalts of lower Miocene age. The rhyolite porphyry was subjected no doubt to the same deformative movements that disturbed the Coldwater group as well as to the erosion cycle prior to Miocene volcanism.

Origin.—It is thought that the rhyolite-porphyry remnant represents the basal portion of an early Tertiary acidic flow of lava which poured out from a local vent. The massive flow being viscous did not extend far from its orifice which is repre-

---

[1] Camsell, Chas.—Prelim. Report, on a part of the Similkameen District, B.C., Geol. Surv. Can., 1907, p. 27.

Dawson, J. W.—Proc. and Trans. Royal Soc., Canada, vol. 8, sec. 4, 1890, pp. 75–91.

[2] Daly, R. A.—The Geology of the North American Cordillera at the 49th parallel, Geol. Surv., Can. Memoir 38. 1913.

LeRoy, O. E.—The Geology and Ore Deposits of Phœnix, B.C., Geol. Surv., Can. Memoir No. 21, p. 42.

sented possibly by the hill itself. The tufaceous material in the Coldwater group probably represents the products of the same rhyolitic eruptivity only in its earlier stages before the lava itself was poured out. The outpouring of rhyolitic lavas at this time appears to have been confined mainly to local basins or their margins, and not along the axes of the main mountain ranges.

Age and Correlation.—The rhyolite porphyry is thought to have been poured out toward the close of the Coldwater period, and is possibly connected with the pre-Miocene deformative movements. The formation may be correlated with the rhyolite porphyry of the Franklin mining camp[1] which is of early Tertiary age.

Rhyolite flows are also found in the John Day basin, Oregon, intercalated with upper Oligocene tuff and conglomerate beds which bear unconformable relations to the underlying Chico Cretaceous and the capping lower Miocene basalts.[2]

Kamloops Volcanic Group.

Distribution and Thickness.—The rocks belonging to the Kamloops Volcanic group have a widespread distribution throughout the district. They occupy the present hill tops and cap unconformably nearly all the older formations.

The following section in descending order is taken from Savona mountain and gives an approximate thickness of the group.—

Coarse agglomerate (andesitic matrix)	200 feet.
Reddish, black and greenish black lavas, chiefly vesicular and amygdaloidal (contain agate, serpentine, and a little asbestos)	900 feet.
Agglomerates, and ropy lavas	800 feet.
Grey, black, and red basaltic lavas, some vesicular, in places slightly agglomeratic	600 feet.
Total	2500 feet.

Lithology.—The extrusives of the Kamloops Volcanic group are fresh and unaltered in appearance and on this account can readily be distinguished from the Mesozoic volcanic groups. They are mainly basaltic lavas and pyroclastics with younger mica andesites cutting them and forming coarse agglomerates in an andesitic matrix. The latter are the uppermost beds in the series and are well exposed on the summit of Savona mountain.

The basalt in some localities is very basic, and one slide taken from a flat-topped lava hill or mesa near the mouth of Bonaparte creek had over 50 per cent of magnetite in it. This basalt shows pronounced ball and socket jointing. The compact basalt, generally displaying columnar jointing, passes transitionally into vesicular and amygdaloidal types. The amygdules are in many places agates well banded but pale-coloured. Zeolites, green chloritic material, rose quartz, and calcite (the latter intergrown with chalcedony) also fill vesicles. The amygdules are generally oval shaped, due probably to flowage at the time of extrusion, which drew out and extended the gas pores in which the chalcedony and calcite were subsequently deposited.

In some sections of the basalt, the lath-shaped crystals of plagioclase appear under the microscope to have a fluidal arrangement around larger augite individuals. The andesite of Savona mountain and elsewhere is a mica andesite of a pale greyish colour. It is fine-grained rock in which occur numerous porphyritic crystals of quartz, plagioclase, biotite, and augite in a groundmass composed of

[1] Geology of the Franklin Mining Camp, B.C., Geol. Surv., Can. Memoir. In preparation.
[2] Bull. Geol. Soc. of Am., vol. XXIII, No. 2, 1912, p. 246.

a felted mass of the same minerals, with trachytoid structure. Andesitic tuffs and breccias of the same period of eruptivity outcrop on the summits west of Savona mountain.

Structure.—The volcanic rocks of the group east of Ashcroft were broadly folded into synclinal basins and anticlinal domes. Rarely, however, do the formational dips exceed 15°, and west of Ashcroft the members of the group lie almost horizontal. In this respect the Kamloops Volcanic group stands in bold contrast to the unconformably underlying Coldwater group which is in many places much deformed. The group caps the early Tertiary and older formations, and is cut off at the top by the late Tertiary erosion surface, which truncates the folded volcanics. The anticlinal portions have been eroded away leaving the synclinals now exposed on the hill tops.

Origin.—The Kamloops Volcanic group consists mainly of surface lava flows, tuff beds, and agglomeratic accumulations. Many of the dykes in the region probably represent the fissures through which the basaltic and andesitic lavas reached the surface.

The youngest flows of andesite were of more local occurrence and not so widespread in distribution as the basalt flows. Erosion has removed much of this younger material particularly the agglomerate, breccia, and tuff members. The latter represent the volcanic ash and dust accumulated in local lake basins during quiescent intervals.

Age and Correlation.—The rocks of the Kamloops Volcanic group are the most recently consolidated in the district. Plant and fish remains have been found near the base of the series in the Tranquille beds. The plant remains were determined by Dr. D. P. Penhallow who identified the following: *Alnus carpinoides, Audromeda delicatula, Betula* sp., *B. heterodonta, B. macrophylla, Carpinus grandis, Carpolithes* sp., *C. dentatus, Carya antiquorum, Cinnamomum affine, Corylus americana, Cratægus tranquillensis, Cyperites* sp., *Ficus asiminaefolia, Gingko adiantoides, Glyptostrobus europœus, Juglans rhamnoides, Picea tranquillensis, Pinus* sp., *P. trunculus, Planera longifolia, Populus acerifolia, Populus cuneata, P. mutabilis oblonga, P. zaddachi, Rhamnus eridani, Salix varians, Sequoia* sp., *S. angustifolia, S. brevifolia, S. heerii, S. langsdorfii, Taxodium distichum miocenium, T. orcidentale, Typha latissima, Ulmus tenuinervis, Viburnum dentoni.* Dr. Penhallow concludes that: 'An inspection of the distribution shown in the above table[1] conveys the information that there are

Eocene, chiefly lignite Tertiary	14
Oligocene,—	
Upper Eocene	14
Lower Miocene	4
Miocene	15

thus giving a preponderance of the Eocene over the Miocene, in the proportion of 28 to 19; but inasmuch as the Eocene and the Miocene are practically equal, while there are 18 Oligocene, the conclusion appears justified, to the effect that these beds [Tranquille beds near base of series] are of Oligocene age, and possibly not higher than upper Eocene, though the presence of such strong Miocene types as *Ficus asiminæfolia, Pinus trunculus,* and *Sequoia brevifolia* would seem to give them a stronger Miocene tendency. I therefore assign them to the Lower Miocene provisionally.' The flora of the lower portion of the Kamloops Volcanic group was apparently transitional with stronger affinities toward the Miocene. Fossil fish were collected the past season by B. Rose from Red point on Kamloops lake and await determination.

---

[1] Report on Tertiary Plants of British Columbia: Geol. Surv., Can. (1908), No. 1013, pp. 115–116.

The Kamloops Volcanic group, including the Tranquille tuff beds at their base, are certainly younger than the deformative and erosional periods which followed the deposition of the Coldwater group rocks (Oligocene?) The post-Coldwater deformative movements may be correlated with those general crustal movements throughout the Cordillera known as the post-Kenai revolution in Alaska. Brooks[1] in Alaska has considerable evidence to show that this dynamic revolution occurred there during late Eocene or early Miocene time.

It seems safe to refer the Kamloops Volcanic group to the lower Miocene and correlate it with other extensive basaltic and andesitic flows bearing similar structural relations to early Tertiary and older formations in the Boundary district, and elsewhere throughout the Cordillera.

The placing of this group in the Miocene following Oligocene elevation and deformation would be in accord with Ralph Arnold's conclusions regarding the Tertiary on the Pacific coast[2]. He concludes that, 'the periods of marked elevation were the Oligocene, late Pliocene, and Quaternary; the periods of maximum subsidence were the middle Eocene and upper Miocene; the periods of greatest volcanic activity were the middle Eocene and the middle Miocene.'

Superficial Deposits.

Fluvio-Glacial Deposits.—Boulder clay or glacial till blankets many portions of the upland surfaces. It consists of a hard sandy clay, with stones and boulders scattered abundantly and irregularly through it. Glacial erratics are also commonly found on the upland tracts. The valley-fill material flooring the deeply entrenched valleys is largely composed of unmodified and modified morainic debris. The modified glacial materials predominate over the true till sheets and were probably laid down by heavily burdened streams as outwash valley-trains contemporaneous with the retreat of the valley glaciers. Such deposits are well stratified and consist of cross-bedded sands, silts, and gravels. A stratified clay silt occurs at a uniform level throughout the region, and was probably deposited under quiet lake conditions following the first period of valley glaciation.

The structure, mode of origin, and correlation of the Pleistocene deposits are discussed under the physiography and glacialogy section of this report and will not be repeated here.

Stream Deposits.—The recent deposits consist of the present stream deposits such as sands, gravels, silts, and soils.

Economic Geology.

The chief minerals of economic value in the district both metallic and non-metallic may be enumerated as follows: placer gold, mercury, copper, coal, clay, lime, agate, and chalcedony.

PLACER GOLD.

Dr. G. M. Dawson, who made a detailed study of the placer deposits, gives the following list of conglomerates and gravels in the Kamloops district either known to be auriferous or that may be regarded as possible sources of gold:—

'1. Cretaceous Conglomerates.—No gold yet found.

'2. Oligocene Tertiary Conglomerates.—Traces of gold found.

'3. Miocene Conglomerates or buried river gravels.—Not yet discov-

---

[1] Brooks, A. H.—Prof. Paper No. 45, U. S. Geol. Surv., 1906, pp. 292–293.

[2] Arnold, Ralph.—Environment of the Tertiary Faunas of the Pacific coast of the United States; Jour. of Geol., vol. XVII, 1909, pp. 509–533.

ered in this district, though sandstones and water-bedded tufaceous rocks are known in some places.

'4. Early Pliocene gravels—

'(*a*) In high-level valleys.—Buried under drift deposits wherever remaining; not prospected.

'(*b*) Along main river valleys.—Excavated and redistributed in succeeding period.

'5. Later Pliocene gravels.—Possibly in part still remaining along Fraser, Thompson, and other deep valleys, and if so, probably in some places above, in others below the present river-level. These would undoubtedly be richly auriferous, but no such deposits appear yet to have been discovered or worked by miners.

'6. Boulder clay.—In this the gold is probably everywhere too much disseminated for profitable working.

'7. Interglacial gravels, silts, etc.—These have constituted most of the drift-filling of the Fraser and Thompson at one period, and still form the mass of the river terrace—probably containing payable gold in places.

'8. Gravels and bouldery deposits capping river-terraces.—These, with the gravels of the next class, have been those chiefly worked on the Fraser and Thompson. Nearly everywhere auriferous along these rivers, and often elsewhere.

'9. Modern river gravels.—Nearly everywhere auriferous along the Fraser, frequently so on the Thompson, and often elsewhere.'[1]

In discussing favourable places for prospecting, Dawson states: ' . . . . wherever the early Pliocene valleys have been excavated on or near to areas of the older rocks, and particularly those of the Câche Creek formation, placer deposits of gold referable to the time of erosion of these valleys may be looked for. It must be borne in mind, however, that these valleys lay open to the work of the ice of the glacial period, and that it is probably in the main, if not alone, in such of them as lie transverse to the general direction of motion of this ice, that placer deposits may be expected still to remain intact. Where the direction of the old and wide valley nearly coincided with that of the motion of the Cordilleran glacier, it is probable that in most cases the original deposits may have been swept out to the bottom by this agent.'[2]

MERCURY.[3]

In the vicinity of Copper creek, Kamloops lake, occur deposits of cinnabar which have not been worked since 1897. The cinnabar occurs in irregular veins traversing a grey feldspathic and dolomitic rock which readily weathers to a yellowish colour. The country rock is an altered greenstone containing pyroxene and olivine. The cinnabar is associated with small quantities of stibnite and has a calcite and quartz gangue. The mines have produced over 7,000 pounds of mercury. It is said that 150 tons of ore produced 114 flasks of mercury valued at £900.

---

[1] Report on Kamloops Map sheet, Annual Report, vol. VII (1894), pp. 328–329B.

[2] *et. seq.* p. 319B.

[3] Report on Kamloops Map Sheet, Annual Report, vol. VII, Geol. Surv., Can., 1894, pp. 340–341B.

Report of Minister of Mines, B.C., 1896, pp. 568–571; 1897, p. 614.

Mining Districts near Kamloops Lake, B.C., by G. F. Monckton., Trans. Inst. Mining Engineers, Sheffield, England, 1899.

COPPER.

Copper ore (chalcopyrite and bornite) also occurs in the vicinity of Copper creek in small quantities and appears to be associated with dykes of augite porphyrite.

COAL.

Lignite has been described from many localities in the Tertiary sedimentaries but no workable seams have as yet been discovered within the limits of the district examined. A small bed of lignite outcrops at Red point, Kamloops lake, and was first found during the progress of the Government railway surveys in 1878.

No workable coal seams have as yet been found in the Jura-Cretaceous (Spence Bridge group) or Lower Cretaceous(?) (Queen Charlotte Islands formation) of this district, although coal seams do occur in formations of the same age farther north in the Skeena and Groundhog districts.

CLAY.

The clay silt formation ('White silts') partially filling the youthful valleys affords an unlimited supply of material from which ordinary bricks of fair quality might be made.

The clay deposits here resemble those now being worked 2½ miles west of the town of Kamloops where 'dry wood is used for fuel, at a cost of $3.50 per cord, and a half cord of wood is consumed in burning 1,000 bricks.'

'The bricks are burned hard and to a deep red colour, the price obtained is $14 per thousand at the yard, or $16 delivered at Kamloops, where the output is mostly used.'[1]

LIME.

Limestones (Marble Canyon formation) suitable for burning and the production of lime are very abundant and are indicated on the map.

AGATES AND CHALCEDONY.

Agates and chalcedony occur in considerable abundance as cavity fillings (amygdules) particularly in the younger Tertiary lavas. The colours are usually pale but many prettily banded and striped specimens may be obtained from the amygdaloidal lavas of the Kamloops Volcanic group.

Geological History.

A brief outline of the succession of the ascertained geological events in this portion of Canada, including the most important facts and suggestions concerning the structure, stratigraphy, and correlation of the formations examined will here be given. The facts must necessarily be interwoven with theory in such a section in order to give the reader as connected and realistic a version as possible of the life history of the region.

The Palæozoic period, so far as it may be inferred from rock records of that age, was a time of ever-changing epicontinental seas with intervening land barriers of a general low topographic relief.

---

[1] Preliminary Report on the Clay and Shale deposits of the Western Provinces, Geol. Surv. Can., Memoir No. 24-E (1912), pp. 122, 123.

There is no record in the Kamloops district of pre-Carboniferous history and it is thought that the district then formed a part of an ancient land barrier known as 'Cascadia' in paleogeography.[1] This probably almost featureless land area underwent long continued erosion and supplied sediments to the bordering early Palæozoic seas including the Rocky Mountain basin to the east and the Yukon and Alaska basins to the north. Erosion progressed until the land surface was at length brought down to a plain of very low relief.

This mid-Palæozoic peneplain slowly subsided beneath a transgressing embayment of the Pacific ocean from the north (Vancouver continental sea[2]) in which over 9,000 feet of marine sediments and intercalated volcanics became deposited before the close of the Palæozoic period represented by the Câche Creek group. The oceanic waters then were probably warm, as suggested by the presence of fossil crinoids, corals, and foraminifera. Although the sea no doubt engulfed low-lying swamps containing much vegetable material, conditions were not favourable for the accumulation of coal seams. Sedimentation proceeded on a sinking sea floor, consisting first of argillaceous material followed by cherty and calcareous material (Marble Canyon limestone), the latter indicative of an expanding sea, which may have covered the whole region. Sedimentation was interrupted at times by the intrusion and extrusion of lava and the accumulation of tuff beds partly on the land and partly in the sea.

The Palæozoic period closed with an uplift of the sea bottom and bordering Carboniferous coastal plain. Although this was accompanied by deformation in the interior of British Columbia (marked by an angular unconformity between the Carboniferous formations and those of the overlying Triassic) some coastal regions, as evinced by conformities, underwent continued sedimentation into the Mesozoic period. Diastrophism in the west at this time was not so pronounced as that going on—the Appalachian revolution—in the east. It was sufficient, however, to raise the continent as high as it probably was at the beginning of the Palæozoic era.

The Mesozoic and later history is characterized by a higher relief of the continent with a stronger tendency towards emergencies rather than submergencies as was so typical of Palæozoic history.

The Mesozoic period opened with vigorous erosion of the newly uplifted land surface which probably had a moderate relief. Erosion was followed by another marine transgression by an embayment of the Pacific ocean and over 10,000 feet of sediments and predominantly volcanics (Nicola group) were laid down in this Jura-Triassic sea bottom. As sedimentation proceeded the proportion of clastic materials gradually decreased and the deposits became more calcareous (lower Jurassic) indicative of continued subsidence and retrogression of shore-lines. Vulcanism almost ceased and a through connexion eastward with the Jurassic Logan sea may have existed. The climate as suggested by the animal life (corals, etc.) may have been subtropical.

In the late Jurassic, a great mountain-making uplift took place accompanied by large intrusions of igneous rock (granitic intrusives). The Nicola group limestones in the vicinity of Spatsum were probably then uptilted. This orogenic movement is known as the 'Jurassic revolution' and it gave birth to the Coast ranges, Sierra Nevadas, and other rugged ranges in the western Cordillera.

About this time (Jura-Cretaceous) volcanic eruptions on a large scale broke forth from fissures and central craters, and resulted in the accumulation of over 5000 feet of andesitic and liparitic lavas with corresponding pyroclastics as well as contemporaneous conglomerates and arkoses (Spence Bridge Volcanic group).

[1] Schuchert, Charles, Palæogeography of North America, Bull. Geol. Soc. Am., vol. xx, pp. 427–606.

[2] *et. seq.*, pp. 447, 448, 463.

The conglomerates and arkoses were laid down subaerially by the disorganized river systems then existing.

When volcanic activity had ceased and erosion had proceeded for some time, a series of carbonaceous muds, sands, and gravels (Queen Charlotte Islands formation) was deposited in chiefly brackish water estuaries and local shallow lake basins, in which fish lived. A temperate climate is indicated by the plant remains found in the formation and the topographic development of the land surface had probably reached at least a stage of maturity.

Following sedimentation, epeirogenic uplift, local deformation, and batholithic intrusion ensued, which resulted in the close folding and faulting particularly of the Lower Cretaceous(?) deposits. The broad emergence of the land commenced a new cycle of erosion and this portion of the Cordillera underwent continued denudation and supplied much material for the bordering Upper Cretaceous geosynclinal seas to the east and west.

The Cretaceous erosion cycle removed most of the cover of the late Jurassic granitic batholiths in the Coast range and elsewhere, for the early Tertiary sediments are found resting directly upon them in many places. By the close of the Mesozoic, erosion is thought to have brought the land area down to a state of old age and peneplanation. The ancestral Thompson and Fraser rivers flowed then as now into the Pacific and their present courses transverse to the regional structure are thought to have persisted from courses developed during this Cretaceous erosion cycle (antecedent rivers).

Following the deposition of great thicknesses of sediments in the Cretaceous geosynclinal seas, crustal unrest commenced which culminated later in the 'Laramide revolution.' This was in the nature of regional upwarping and the broader orograpic features of the Cordillera were probably outlined about this time. In some coastal regions, however, both to the east and west there was continuous sedimentation as borne out by conformable relationships between Upper Cretaceous and early Tertiary sediments. The climate in the mountains, then, was probably cool and humid and in possibly the eastern portion of the Coast range and in the Columbia mountains which happened to be loci of maximum uplift, conditions may have been favourable for the support of alpine glaciers. The presence of boulders and pebbles similar to those of glacial origin found in the early Tertiary sediments of the Columbia mountains suggests such an inference. The major Cretaceous rivers emptying into the Pacific ocean maintained approximately their western courses throughout this epeirogenic uplift of the Cordillera. The 'Laramide revolution' as the name would imply, resulted in some overthrusting and faulting in the eastern portion of the Cordillera and commenced the growth of the physiographically youthful Rocky mountains.

The Laramide revolution began a new cycle of erosion; the drainage became invigorated and the rivers were deeply entrenched within the older Cretaceous erosion surface. Denudation proceeded rapidly with continental sedimentation in local lake basins where vegetation flourished (later to be formed into coal) under moist, possibly warm, climatic conditions. With later subsidence aggradation of the valleys set in and early Tertiary sediments were laid down both as delta and river deposits as, for instance, at the mouth of the Eocene ancestor of the Fraser river (Puget group) and in portions of the ancestral Thompson river as recorded south of Savona and Walhachin (Coldwater group). Local volcanic vents supplied rhyolitic lavas (Ashcroft rhyolite porphyry) and acidic tuffs which are frequently associated with the early Tertiary formations. They were largely responsible for the disorganized nature of the drainage in many localities as evidenced by the intimate association of rhyolitic flows, arkosic grits, conglomerates, and acidic tuffs.

During the Oligocene which continued the erosive work of the Eocene, elevation and local deformation of the early Tertiary formations took place. This post-Coldwater orogeny (probably the post-Kenai revolution of Alaska) further affected the eastern front of the Rockies causing renewed overthrusts and faults[1]. It inaugurated a new cycle of erosion which removed vast records of the early Tertiary.

Volcanic activity broke forth on a grand scale in the early Miocene, and great volumes of basaltic and andesitic lavas, agglomerates, breccias, and tuffs (Kamloops Volcanic group) were poured out into depressions upon the Oligocene and older erosion surfaces. This extravasation of lavas was widespread and affected large tracts of country.

Crustal warping with local buckling and faulting took place probably in the Middle Miocene which threw the eastern portion of the generally flat-lying Kamloops Volcanic group into broad anticlinal domes with intervening synclinal basins, the latter at present preserved on the hill tops. The alkalic intrusions and extrusions of the Boundary and West Kootenay districts may be referred to this period of crustal unrest.

Mid-Miocene diastrophism brought about a most important erosion cycle from the standpoint of the present topography. It lasted during a long period of crustal stability from the middle of the Miocene to near the close of the Pliocene and resulted in the production of an erosion surface of mature and late mature relief in the Coast range and Columbia mountains and a peneplain (present upland surface) in the intervening tracts of Interior Plateau. It probably did not, however, reach the perfection and extent of the previous Cretaceous erosion surface.

The climate was gradually becoming cooler. The Tertiary closed and the Quaternary period began with a great regional upwarping of the Pliocene erosion surface. The uplift, which was of a differential character, varied in degree from place to place perhaps averaging about 4000 feet. The drainage was rejuvenated and the master streams on the Pliocene erosion surface became deeply entrenched, resulting in the present youthful valleys.

During the Pleistocene refrigeration of climate, the Cordilleran ice sheet advanced and retreated leaving much drift. At least two distinct periods of valley glaciation and alluviation succeeded the disappearance of the ice cap.

The retreat of valley ice increased the eroding activity of the streams which began the dissection of the alluvial gravels, sands, and silts. This process of dissection, still active, was probably further aided by regional uplift.

Summarized Geological History of the Region.

The geological history of this region may be presented for the sake of conciseness in the following tabular scheme:—

(1.) Downwarp of a mid-Palæozoic peneplain with the transgression of a Devono-Carboniferous epicontinental sea. Probably warm tropical climate. General marine sedimentation with local vulcanism (Câche Creek group).

(2.) Uplift and local deformation of coastal plain deposits toward the close of the Palæozoic; followed by cycle of erosion. Humid cool climate(?). Moderate relief. Organized drainage. Continuous sedimentation in some coastal regions.

(3.) Transgression of Jura-Triassic sea. Probably semi-arid climate. Marine sedimentation in shallow seas accompanied by pronounced igneous activity (Nicola group).

4. Orogenic uplift—'Jurassic revolution.' Birth of Sierra Nevadas and Coast range and batholithic intrusions of the Pacific coast (granitic intrusives). Youthful topography. Rapid subaerial erosion. Chiefly consequent drainage followed by subsequent, etc.

[1] Summary Report, Geol. Surv., Can., 1910, p. 157.

(5.) Jura-Cretaceous continental sedimentation and widespread volcanic activity. (Spence Bridge Volcanic group.) Semi-arid climate. Rugged probably fine textured topography with many volcanic peaks. Disorganized drainage.

(6.) Lower Cretaceous sedimentation in brackish waters and in part marine. (Queen Charlotte formation). Cool humid climate.(?) Mature topography.

(7.) Epeirogenic uplift and local deformation with possibly granitic intrusions. Followed by Cretaceous cycle of erosion during long period of crustal stability in which the land surface was brought down to a peneplain. Coarse textured topography. Transverse courses of Thompson and Fraser rivers inherited from this Cretaceous peneplain.

(8.) Laramide revolution. Epeirogenic upwarp of Cretaceous peneplain with maximum uplift along the axes of present mountain ranges. Probably humid, cool climate. Continuous sedimentation into the Tertiary in some coastal regions.

(9.) Early Tertiary continental erosion and sedimentation (Coldwater group) with local rhyolitic eruptions (Ashcroft rhyolite porphyry). Moist semi-tropical climate(?). Major streams antecedent with slightly different courses than at present. Drainage rejuvenated and much of it disorganized with many local lake basins. Development of topography from state of youth through adolescence to post maturity.

(10.) Oligocene diastrophism. Widespread elevation with intense local deformation (possibly birth of Rocky Mountain system proper). Followed by Oligocene erosion cycle which removed much of the early Tertiary rock record and paved the way for later planation. Semi-tropical climate.

(11.) Lower Miocene volcanic activity. (Kamloops Volcanic group.) Slight topographic relief. Drainage locally disorganized by lava flows.

(12.) Mid-Miocene crustal warping with local buckling and faulting of lower Miocene volcanics. Probably intrusion and extrusion of alkalic rocks to the south and east in the Boundary and West Kootenay districts.

(13.) Late Miocene and Pliocene cycle of erosion during long period of crustal stability. Production of peneplain in the Interior Plateau and mature to post-mature erosion surface in bordering mountain ranges (old upland erosion surface). Coarse textured topography in Interior Plateau and finer textured in Coast range. Climate becoming cooler. Drainage well organized.

(14.) Differential uplift of epeirogenic character in late Pliocene or early Pleistocene. Uplift slow enough for antecedent streams some of whose courses were inherited from a Cretaceous peneplain, to maintain their general courses. Pre-glacial erosion with deep incision of Pliocene drainage within the upland surface (youthful valleys). Drainage, therefore, antecedent from Pliocene and rejuvenated.

(15.) Pleistocene glaciation. Arctic climate with milder interglacial period. Cordilleran ice cap softened the contours of the old upland topography; steepened the slopes of the youthful valleys and left on its retreat much morainic and outwash material. (Admiralty period of Pacific coast). Followed by slight subsidence with deposition of clay silts in lakes.

A recent advance of valley glaciers (Vashon period of Pacific coast) is recorded which further modified the youthful valleys and supplied considerable till and outwash material. Followed by alluviation and deposition of much gravel, sand, and silt.

(16.) Post-glacial erosion cycle. Uplift. Excavation of valley fill by meandering river into river terraces. Incision of canyons, gorges, and ravines.

(17.) Recent river deposits, land slides, and mud creeps. In the Interior Plateau climate is dry with extremes in temperature; while in the Coast range it is humid and temperate.