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# MEMOIR 139

# COQUIHALLA AREA, BRITISH COLUMBIA

BY

C. E. CAIRNES

GEOLOGICAL SURVEY DEPARTMENT OF MINES OTTAWA 1924





View of Coquihalla valley above Portia siding, Kettle Valley railway, overlooking an area composed chiefly of batholithic rocks. The smoothly rounded summits exhibited by all except the high peak of Needle mountain in the middle background indicate the effective height of regional glaciation in this area. The slight vegetation supported by these granitic rocks is also notable. (Page 22.)

# CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

# GEOLOGICAL SURVEY

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# MEMOIR 139

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# Coquihalla Area, British Columbia

ву С. Е. Cairnes



OTTAWA F. A. ACLAND PRINTER TO THE KING'S MOST EXCELLENT MAJESTY 1924

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# Coquihalla Area, British Columbia<sup>1</sup>

### CHAPTER I

## INTRODUCTION

The completion in 1916 of the Kettle Valley railway down Coquihalla valley gave a renewed impetus to exploration in a district whose development had previously been very backward. Although, comparatively, near points of civilization this district has an extremely rugged topography, a dense vegetation, and few serviceable pack trails, and was consequently less favoured by prospectors than other areas more remote but more easily explored. It was known to be situated in a mineral province of great variety and wealth and physical difficulties alone retarded its development. Important mining properties had been successfully operated on the borders of the area, and in the less accessible interior a few courageous individuals had made attractive discoveries.

In view of the consequent need for accurate information a phototopographic survey of Coquihalla map-area was made in 1918 by F. S. Falconer and a contoured map on a scale of 4,000 feet to 1 inch was prepared. With this as a base, Camsell began, in 1919, a more careful geological examination than had hitherto been attempted. The work begun by Camsell has been completed by the writer and forms the basis for the present report.

## FIELD METHODS

The field seasons of 1920 and 1921 were mostly devoted to a fairly detailed examination of the geology and mineral resources of Coquihalla area, but some time was occupied in examining mineral properties in adjoining areas, references to which are made in this report only as far as they bear on the problems of Coquihalla area.

Field work was handicapped by an abundant rainfall, usually accompanied in the high altitudes by prolonged fogs. July and August were the only months when fine weather could be anticipated for more than twenty-four hours in advance. Even a high or rising barometer was not to be relied on, and many a tiresome struggle to the mountain peaks or drainage divides was rendered useless by the encroachment of a thick blanket of fog which ended any adequate attempts at observation. Camp equipment was moved chiefly by means of Kettle Valley railway. The more permanent camps were located near the railway and explorations were conducted within a convenient radius. Where adequate trails exist a horse was employed to carry bedding and provisions. Usually, however, back packing was resorted to.

<sup>&</sup>lt;sup>1</sup> A résumé of this report is given in the last chapter.

The mountain slopes are, in general, heavily timbered and the rocks are buried under a heavy mantle of soil or drift. Exposures on these slopes were encountered only by chance, and geological contacts could rarely be located or followed for any distance. In part, too, the side hills are too precipitous to traverse. The creek beds present better natural sections, but travel in the valleys occupied by these streams was commonly very bad. Progress was hindered by a dense underbrush of willow, poplar, devil's club, and other moisture-loving shrubs and trees. The most extensive exposures were found on the summits of the various drainage divides, particularly where these project above timber-line. Here travel was usually fair and, in many parts, excellent, and outcrops were everywhere abundant.

Many ore and rock specimens were collected, and a number of fossil collections were made at various points both within and without the area. Laboratory work was conducted by the writer at Princeton University.

#### ACKNOWLEDGMENTS

The writer desires to express his appreciation for the many courtesies extended him in the field by various citizens, officials, mine owners, and prospectors, particularly Dr. Edwin T. Hodge, consulting engineer for the Liberator Mining Company, and Mr. T. Kerruich, manager of the Emancipation mine; Mr. A. S. Williamson, manager of the Eureka-Victoria and Lucky Four mines; Mr. W. H. Robinson of Twentythreemile Camp on Skagit river; and Mr. A. E. Raab, notary, at Hope, British Columbia. He is deeply indebted to the faculty of the Department of Geology of Princeton University, who not only provided every facility for laboratory work but were a constant source of valuable advice and assistance in the preparation of the report. Thanks are specially due to Professor C. H. Smyth, jun., and Dr. A. F. Buddington, under whose immediate direction the report was written. W. E. Chantler rendered most efficient assistance in the field.

## LOCATION AND SIZE OF MAP-AREA<sup>1</sup>

Coquihalla area includes almost the entire watershed of Coquihalla river, a stream that enters Fraser river at Hope, 91 miles by rail east of Vancouver (Figure 1). The area is nearly triangular, with the smallest angle, at the head of Coquihalla river, slightly truncated. It is 36 miles long in a northeast-southwest direction, has a maximum width of 17 miles, and an area of approximately 300 square miles.

<sup>&</sup>lt;sup>1</sup>The names of the following streams and mountains referred to in this report do not appear on the accompanying maps and, to avoid frequent explanation of their location, the following list is given. *Filtenmile creek* enters Coquinalls river from the west less than a mile above Jessica station. *Fossib All* is a conical peak situated half a mile west of Tulameen mountain.

Goat mountain is a flat-topped hill about 3 miles northwest of Tulameen mountain and west of the south fork of Dewdney creek. Jessica mountain is the long, flat-topped hill or ridge west of Jessica station overlooking Coquihalla valley and

its tributary, Fifteenmile creel

Silver peak is situated half a mile east of Isolillock (Holy Cross) mountain and contains the ore-bodies of the Eureka-Victoria mines. Tangent creek enters Coquihalla river from the west and crosses Kettle Valley railway a short distance above

the railway siding at the foot of the trail to Emancipation mine. Wardle creek enters Silver creek from the west and about 2 miles above its mouth. The workings of the Aufeas

gold mine are located in the valley of Wardle creek.

Physiographically, the map-area is part of the most westerly extension of the Cascade Mountain system which, after crossing the International Boundary, fingers its way into the Interior Plateaus as far north as Thompson river. On the southwest, the district is separated from the Coast range by Fraser valley. On the east, it merges into the great plateau region of British Columbia. To the north, west, and south it coincides with the western edge of the Cascade system represented here by Cheam, Hope, and Anderson River mountains.



Figure 1. Index map showing location of Coquihalla River area, Yale district, B.C. (Map 1988).

## HISTORY OF DEVELOPMENT

Attention was early drawn to Coquihalla area by the efforts of the Hudson's Bay Company to find a suitable route from lower Fraser river into the southern interior of British Columbia. The necessity for such a route arose when by agreement in 1846 the 49th parallel was established as the International Boundary, and the old route from the coast by way of Columbia river was abandoned as it lay across this border. Commencing in 1846, A. C. Anderson, an officer of the Company, spent a number of years in exploring Coquihalla and adjoining regions, and succeeded in opening several trails through Hope mountains. That which led up Nicolum and down Sumallo rivers, and thence by way of Skagit river to Vermilion Forks, was subsequently cleared for brigade transportation by Henry Peers. As an initial step in the adoption of this route the company erected in the winter of 1848-49 Fort Hope near the mouth of Coquihalla river. This served as the main trail until 1860, when the Government road from Princeton to Hope, following closely the brigade route, was constructed. Another main trail led up the Coquihalla and thence, via Coldwater river, to Nicola lake. Still another route followed up the Coquihalla and its tributary Peers<sup>1</sup> river to the head of the latter, and continued across Sowaqua<sup>2</sup> river over the Tulameen divide and down Tulameen river into the interior of the province via Campement des Femmes (Tulameen village).

The history of Coquihalla area in these early years is chiefly concerned with the fur trade. Officers of the Hudson's Bay Company annually conducted their long pack trains loaded with trade goods or furs over the trails from the interior of the province to the trading posts on Fraser river. During this period the Indian doubtless acquired a keener interest in the furry denizens of the forest whose pelts might be exchanged for the white man's comforts. In some 300 miles along Fraser river between Langley and Alexandria, the only points occupied by white men were, with the exception of a salmon fishery established at the mouth of Silver creek, Fort Hope, and Fort Yale.

The discovery of placer gold in the early fifties culminated in 1858 in one of the greatest stampedes in Canadian mining history. Years before, gold had been found at various points along the coast of British Columbia from the strait of Georgia to Skeena river. In the interior, natives had reported its discovery near Kamloops as early as 1852, and in 1855 gold was found on the banks of the Columbia, at Colville, and at the mouth of Pend-d'Oreille river, near the International Boundary. According to some authorities gold in paying quantities was first found at Nicomen on Thompson river near its junction with the Fraser, and it was probably the exaggerated reports of this discovery in 1857 reaching California that caused in the following year a rush of 20,000 gold diggers into Fraser valley. By October, 1858, a population of 10,000 was distributed between Langley and Yale, of which 400 lived at Hope and 1,300 at Yale. As the more productive bars became exhausted, the population in this section steadily declined, although as late as 1860 the Hope district was still occupied by over 200 miners. Operations were, however, more desultory and the white miner was displaced in a great measure by Chinese and Indians. In 1861, 2,000 Chinese were reported to be digging around Yale.

During this boom Hope and Yale became important places. In 1858 town sites were surveyed beside the Hudson's Bay Company's posts, and Hope became "the most important place in the mainland" and served "for present and practical purposes as the capital of the country. It is here the Queen's representative sets up his little government and publishes a plan for establishing order and administering justice on Fraser river."3

<sup>&</sup>lt;sup>1</sup> This river was also known as the Anderson, after the H.B.C. officer mentioned above. <sup>2</sup> According to a ruling made by the Geographic Board the name of the river should be Sowaqua. It is also known as Peers. <sup>3</sup> Bancroft, H.H., "History of the Pacific States", vol. xxvii, British Columbia 1792-1887, p. 393.

As an additional accommodation to miners entering British Columbia, a trail was constructed in 1860 by the British government across Hope range, mainly along the old route of the Hudson's Bay Company into Similkameen district via Nicolum, Sumallow, and Skagit rivers and Whipsaw creek. This trail is known as the Hope or Dewdney trail in honour of Sir Edgar Dewdney who, in partnership with Walter Moberly, constructed it. In 1861 a wagon road for 25 miles from Hope was built on the site of this trail.

In 1868 a new interest was lent to the mining industry by the discovery and subsequent operation of the Eureka and Van Bremer mines on Silver peak, 7 miles by trail south of Hope. This property was the first Crown-granted claim in the province.<sup>1</sup> It was successfully operated as a high-grade silver property until 1874, when unfortunate litigation as to ownership and management put an end to further developments, and not until 1920 did these interesting mines again attract the attention of the mining public.

In 1872 the Canadian Pacific Railway Company began a series of explorations for routes through the Cordillera, in the course of which one party under Edgar Dewdney traversed Coquihalla and Coldwater rivers, and another under J. Truch made, in 1874, an unsuccessful attempt to locate a suitable route through Hope range from Coquihalla to Tulameen rivers.

The search for the source of the gold and platinum of the placers in Tulameen district led to the discovery in 1895, and the year following, of the silver-lead ores at Summit Camp on the headwaters of Tulameen river and in the adjoining sections of Coquihalla area in the upper basins of Dewdney and Cedar creeks.<sup>2</sup>

In 1901 the copper ores of Independence Camp were located on the divide between Bear creek and Coldwater river near the extreme northern end of the map-area.

In the same year another attempt was made by the Canadian Pacific Railway surveyors to locate a suitable route through Hope mountains. H. E. Carry under the direction of Hon. E. Dewdney made a survey to Coquihalla river from Tulameen district via Railroad and Unknown (Carey) creeks. This line proved unsatisfactory and not until after 1905 was a practical survey completed.

The route finally adopted, over which the Kettle Valley railway now operates, follows directly up Coquihalla river to its head at Coquihalla station. Construction of this railway occupied six years from July, 1910, and operation commenced down Coquihalla valley on July 1, 1916. The section of 36.7 miles from Coquihalla station to Hope cost about \$136,000 a mile and the 2 miles from Hope to Petain \$220,000, exclusive of the bridge over Fraser river which cost about \$560,000. Between Coquihalla and Hope there are twelve tunnels with a total length of 3,117 feet, and sixteen snow-sheds totalling 8,812 feet.<sup>3</sup>

<sup>&</sup>lt;sup>1</sup>B.C. Minister of Mines, 1902, p. H 196.

<sup>&</sup>lt;sup>2</sup> Galloway, J. D., Rept. of Minister of Mines, B.C., 1013, pp. K 229-230.

<sup>&</sup>lt;sup>3</sup> McCulloch, A., Chief Engineer and Superintendent. Personal communication.

The years immediately preceding and following the construction of Kettle Valley railway have, as might be expected, witnessed great strides in the development of the mineral resources of Coquihalla area. Some placer work has been undertaken, but largely owing to physical difficulties has not proved commercially successful. A number of gold-quartz properties have been opened in the basin of Ladner creek and the territory adjoining. Of these, the most important, and the only one in which any considerable development work has been attempted, is the Emancipation mine. The silver-lead properties at the head of Dewdney and Cedar creeks, and at Summit Camp, beyond the eastern limits of the map-sheet, have attracted considerable attention, but almost no development has been attempted within Coquihalla area. The Eureka-Victoria silver mines have reopened and recent developments seem to augur a bright future for this property. Other important properties discovered prior to 1916 include the Aufeas gold mine on Wardle creek and the Dominion Mineral group, a molybdenite property located on the summits west of Iago.

#### PREVIOUS GEOLOGICAL WORK

During the regime of the Hudson's Bay Company some attention was paid to the underlying rocks of the district by officers who were engaged in constructing roads and trails. Following the gold rush of 1858 a general idea was gained by the miner and prospector of the formations exposed along that section of Fraser valley included in Coquihalla map-area and it was suspected that other formations exposed farther up the Fraser trended southeast across Coquihalla river.

In the construction of the Dewdney trail in 1860 and the wagon road over the site of this trail in 1861, some attention was paid to the geology of the country traversed, and a few observations are recorded by Lieutenant Palmer in a book written by Capt. R. C. Mayne on "British Columbia and Vancouver Island" published in 1862.<sup>1</sup> The investigation carried on by members of the British North America Boundary Commission during the survey of the International Boundary included some general observations on the physiography and geology of southern British Columbia.<sup>2</sup> During the exploration and surveys made by the Canadian Pacific Railway Company, a few more ideas of the geology were gained.<sup>3</sup>

The most important early geological work embracing Coquihalla area must be attributed to Dawson<sup>4</sup> who, in 1877, traversed Coquihalla river and the Dewdney trail. He gives as full a description of the rocks encountered as could be expected from a brief examination and also attempts certain geological correlation with neighbouring areas. He observes that "without doubt" the great width of argillites below the mouth of Carey<sup>5</sup> creek represents the same rocks that occur on Fraser

<sup>&</sup>lt;sup>1</sup> "The geological character of the several districts (Ft. Hope to Pt. Colville) is throughout very uniform, the rocks belonging principally to the igneous and metamorphic series. The bulk of Manson mountain appears to be granite tipped with slate, here and there presenting particles of white indurated clay, found on examination to contain fragments of white quartz," p. 374.
<sup>2</sup> Gibbs, G., Amer. Jour. Sci., 1869, vol. IV, 1874. "Physical Geog. of the N.W. boundary of the United States." Bauerman, H., Rept. of Prog., 1882-34, pt. B.
<sup>8</sup> Moberly, N., "Rocks and Rivers of British Columbia."
<sup>6</sup> Dawson, G. M., Rept. of Prog., 1877-78, pt. B.
<sup>6</sup> This stream is also known as Unknown creek.

river at Boston Bar where they are included with the Boston Bar series of the provisional classification.<sup>1</sup> These rocks, he also thought, resembled certain sediments on Whipsaw creek which held the fossil Monotis subcircularis and were regarded as probably of Triassic age. (It is rather confusing to note that, although Dawson correlates the slates of the Coquihalla with the Boston Bar group of the Fraser River section, and although he agrees with Dr. Selwyn in assigning this group to an horizon underlying the Cache Creek formation,<sup>2</sup> he, nevertheless, indicates by his structure section along Coquihalla river and, by his comparison with the Monotis shales from Whipsaw creek, that the slates of Ladner creek, if not younger than the Cache Creek rocks, at least occur at horizons above other members of this formation.)

The remainder of the sediments and volcanic rocks examined in the Coquihalla River section, as well as those observed along the Dewdney trail in Nicolum valley, were considered by Dawson as exhibiting points of resemblance to the Cache Creek rocks and, accordingly, provisionally grouped with this series, and regarded as probably Carboniferous in age.

After Dawson's investigations in 1877 no geological work was attempted in Coquihalla area until 1919, when Camsell began a more detailed study of the rocks of the lower Coquihalla valley.<sup>3</sup> As his time in the field was very limited, he confined his investigations chiefly within a radius of 4 miles of Hope, but also extended his work up Coquihalla valley to Boston Bar creek and included brief examinations of the gold properties in the Ladner slate belt.

The results of Camsell's geological investigations may be summarized as follows:

Glacial and Recent Deposits. Glacial and fluvioglacial deposits, remnants of which occur in Coquihalla valley, and, in the vicinity of Othello, have succeeded in diverting the river from its original course through the depression now occupied by Kawkawa lake to its present position below Othello.

Lower Cretaceous. The only representative examined was the small area of conglomerate exposed on the west bank of Fraser river near the Kettle Valley railway bridge. It was considered to be younger than the batholithic rocks in this neighbourhood and to owe its position in Fraser valley to "down faulting along a north-south line, a line which was afterwards followed by Fraser river in cutting out its valley."

Coast Range Batholithic Rocks. Mainly granodiorites, but including more acid as well as more basic types. The different members were, however, not considered to vary much in time of intrusion.

Pre-batholithic Rocks. Black, slaty rocks, grey quartzites, chert bands, schists, narrow limestone bands, and some serpentine, intruded by the large areas of batholithic rocks exposed in the district.

Camsell's brief study of the geology of this region, besides corroborating to a great extent many of Dawson's observations, has thrown additional light on the relations and relative ages of the geological formations and

 <sup>&</sup>lt;sup>1</sup> Selwyn, A. R. C., Rept. of Prog., 1871-72, p. 62.
 <sup>2</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept. 1894, vol. VII, p. 38 B.
 <sup>3</sup> Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, pt. B.

intrusive rocks. Those which Dawson included in the Cascade Crystalline series<sup>1</sup> and thought to be, in part at least, of sedimentary origin, have been shown by Camsell to be entirely plutonic and to form parts of a great batholithic complex of post Triassic and probably Jurassic age. Camsell believed them to intersect all preglacial formations examined except the conglomerate, of presumably Lower Cretaceous age, exposed near Haig station. He also infers that some members at least of the pre-batholithic rocks are of Mesozoic age, but makes no attempt to separate these from Palæozoic rocks.

In the present report it is shown that the batholithic rocks belong to at least two—and probably three—periods of intrusion ranging from Jurassic—or earlier—to Tertiary, and that the great bulk of them are Cretaceous in age. It is also shown that the pre-batholithic rocks, as exposed along the railway below Ladner creek, represent two geological periods separated by a great unconformity. The older of these rocks is correlated with the Cache Creek series of Dawson and regarded as of Pennsylvanian age. The younger formation includes the rocks of the Ladner series which is assigned tentatively to the Jurassic.

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<sup>1</sup> Dawson, G. M., 1877-78, p. 63 B.

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## CHAPTER II

#### GENERAL CHARACTER OF THE DISTRICT

### TOPOGRAPHY

#### REGIONAL RELATIONSHIPS OF COQUIHALLA AREA

Coquihalla area lies almost entirely within the northern end of the Cascade Mountain system, a physiographic province of which only a small area is in southwestern British Columbia. At the International Boundary it extends in width 120 miles from the edge of the coastal depression near Sumas, eastward to Similkameen river. To the south it stretches through Washington and Oregon into northeastern California. On the north it projects for a short distance into the belt of Interior Plateaus of British Columbia and is cut off from the Coast range to the northwest by the valley of Fraser river.

Cascade mountains in northern Washington are divided into three ranges by Pasayten and Skagit rivers. The easternmost, Okanagan range, lies between Similkameen and Pasayten rivers at the International Boundary. Hozameen range, in the middle, lies east of Skagit river; and Skagit mountains, forming the westerly unit, reach to the eastern border of Sumas prairie.

Where Okanagan range crosses the border it is 40 miles wide. In detail this range exhibits great irregularity, but possesses, in general, a northeastern trend and an average elevation of over 7,000 feet. The higher peaks reach a height of from 8,000 to 8,500 feet. North of the International Boundary this range crosses Similkameen river between the mouths of Ashnola river and Keremeos creek, and continuing north with a gradual decrease in elevations, finally dies out in the Interior Plateaus region of British Columbia about the headwaters of Twentymile creek.

Hozameen range is over 20 miles wide at the 49th parallel. It is named after mount Hozameen, a prominent peak that overlooks Skagit river, a short distance south of the border. This range is much less rugged in British Columbia than it is a few miles south of the Boundary where several peaks reach a height of nearly 9,000 feet. The general elevation of the higher ridges lies between 7,000 and 8,000 feet. The western section is characterized by sharper peaks of the Matterhorn type, whose shape has been occasioned by mountain glaciation and subaerial denudation. At the Boundary, Hozameen range is separated from Skagit range by the deep valley of Skagit river, but a few miles farther north this dividing line is absent and Hozameen range merges into the Interior Plateaus near the headwaters of Granite creek. The spur of the Cascades crossed by Skagit river below the mouths of Beaver and Ruby creeks extends to the northwest and forms the range to which the name Skagit is given. This range includes the wildest and most rugged area in the Cascade Mountain system. Small alpine glaciers are abundant and have greatly affected the topography. Skagit range is the most persistent of the three divisions of the Cascade system. North of the Boundary it continues under various local names to Thompson river, where it merges into the Interior Plateau. Its western boundary is Fraser valley, west of which occur the mountains of the Coast Range physiographic province.

North of Klesilkwa river, Skagit range is known as Hope mountains. These continue northward on the east side of Coquihalla river to the headwaters of this stream and there merge into the Interior Plateau region. North of Chilliwack river a very rugged part of Skagit range follows in a general northerly direction between Fraser river and Silver creek under the name of Cheam mountains. These are separated on the north and east from Hope mountains by the valley of Silver creek. West of Coquihalla and Coldwater rivers is Anderson River range, beyond which Stoyoma and Lytton mountains maintain the general characters of Skagit range to Thompson river.

In British Columbia the boundary between the Cascade province and the Interior Plateaus is difficult to define, for although the interior features of these two physiographic provinces are quite distinct the transition from one to the other is not always pronounced. They are distinguished casually by a difference in degree of uplift which has conditioned a difference in their subsequent dissection.

Hope, Anderson River, and Cheam mountains are essentially similar in their larger and in many of their minor features. Although separated by distinctive natural boundaries, they are genetically akin and are only units in that larger subdivision of the Cascades known as Skagit range. Anderson River mountains include, to the east of Boston Bar creek, a minor ridge only a few miles in length, but distinct enough to warrant separation. It is bounded to the west and north by Boston Bar creek and to the east by Coquihalla river. It may be called the Boston Bar ridge. Elsewhere in the area many of the spurs or ridges that extend from the main divides towards Coquihalla valley constitute minor ranges. Thev lie nearly at right angles to the principal axial divides and are in many cases only slightly inferior in elevation. Where, as in many cases, they are flattopped, they are consistently lower than the high peaks of the area and probably represent remnants of old valley floors of the Cascade peneplain. In the nomenclature of Willis these flat-topped spurs represent the mature topography of the Entiat stage<sup>1</sup> in the physiographic development of Cascade topography. Elsewhere they are more irregular in profile and as such may equal in height the principal drainage divides. An important ridge of this character lies between Nicolum river and Silver creek and culminates in Hope mountain, 6,030 feet high. These transverse spurs or ridges descend, in a remarkably abrupt manner, into the main drainage valleys.

<sup>&</sup>lt;sup>1</sup> Willis, B., Prof. Paper No. 19, U.S. Geol. Surv., p. 70.

#### Relief

Altitudes in Coquihalla map-area range from 140 feet at Hope, on Fraser river, to 7,490 feet, the elevation of Tulameen mountain. The greatest relief exhibited by any one slope is that obtaining between the summit of Isolillock (Holy Cross) mountain, 6,800 feet, and Silver creek whose elevation at the foot of the trail to the Eureka-Victoria mines is 500 feet; Silver peak is 5,930 feet above Silver creek at the same point. Ogilvie mountain is about 4,900 feet above Fraser river at Hope. Tulameen mountain, although the highest peak in the area, is only 4,500 feet above the valley of Sowaqua river immediately to the southwest, but is 6,200 feet above the mouth of Dewdney creek, from which point it is most easily approached.

The elevations of the higher peaks in the different ranges and of the nearest stations to them on the Kettle Valley railway are appended. The railway bed has an average grade of 1.8 per cent between Hope and Coquihalla station in which distance of 36.7 miles it climbs 3.514 feet.

Hope mountains	Anderson River mountains	Cheam mountains			
Elev. (Feet) Peak east of Manson mt7,284 (L) Manson mt7,115 (L) Tulameen mt6,700 (J) Goat mt6,700 (I) Coquihalla mt7,080 (I) Hope mt6,030 (H)	Elev. (Feet) Ogilvie mt5,545 (U) Ninemile hill5,400 (L) Tenmile hill6,000 (L) Ladner mt5,900 (J) Needle mt. (north of Romeo)6,700 (R) Needle mt. (west of Romeo)6,860 (R) Coldwater hill6,200 (R)	Elev. (Feet) Silver peak6,430 (H) Isolillock mt6,800 (H)			

	Stations				
	•				Feet
(H) Hope					14
(O) Othello.					55
(L) Lear					76
(I) Jessica					1 30
(P) Portio		•••••			1,00
(T) T		• • • • • • • • • • • •	• • • • • • • • • • • • • • • • • • • •	·····	1, 50
(1) lago					2,40
(R) Romeo,					3,00
C) Coquihalla					3.65

Hope mountains include the highest peaks of the district and Map 1988 shows that all hills over 7,000 feet fall nearly in line along the western edge and, with the exception of Manson mountain, along the rim of Coquihalla basin. They mark the position of the axis of uplift for the northern part of Hope range and the approximate elevation reached by the higher points in that section of the Cascade peneplain. The amount of uplift may be approximated from a study of the rock composition, structure, and glaciation exhibited by these peaks. Other things being equal, the more

resistant rocks should compose the higher peaks and, consequently, it might be assumed that Tulameen mountain, the highest peak in the area, would be composed of such material. This mountain, however, is formed of bedded rocks which stand at high angles. They are of varying composition and texture, are shattered by dynamic forces, and are intersected by intrusives. They are, in general, fairly susceptible to erosion, and it is, consequently, difficult to estimate the height at which this peak once stood. It seems probable, however, that it formed a residual monadnock of prominence above the general level of the Cascade plateau at the close of the period of uplift of the Cascade peneplain. It, therefore, affords an unsatisfactory basis for calculating the height of this uplift. The sharp peak about 1<sup>1</sup> miles east of Manson mountain affords a more reliable basis for estimation. This peak is composed of a metamorphosed cherty sediment capable of resisting erosion to a remarkable degree. Above an elevation of 6,500 feet it occupies a very small area and above 6,600 feet its flanks are unscored by regional glaciation. It represents probably more closely than any other peak in the area, an original position on the Cascade, or, in the nomenclature of Willis, the Methow plateau.<sup>1</sup> Manson mountain, less than  $1\frac{1}{2}$  miles to the west of this peak, is 169 feet lower. This difference may be in part due to the less resistant character of the greenstone composing the summit of Manson mountain, but it is probably due, in part, to the position of this mountain which lies slightly to the west of the main axis of elevation. The fact that this difference is so small in spite of differential erosion lends additional support to the theory that the top of the sharp peak represents very closely an original point on the Cascade or Methow plateau in Hope mountains.

North of Tulameen mountain the principal axis of elevation of the Hope range shows a decided decrease in elevation. The hills at the head of Dewdney and Cedar creeks do not reach 6,500 feet; on either side of Coquihalla peak they are approximately 6,300 feet; and, still farther north, the summits above Independence mine are less than 6,000 feet. The fact that these higher points have all been glaciated indicates that their summits probably never greatly exceeded their present height, for the upper limit of glaciation appears to be in the neighbourhood of 6,500 or 6,600feet. Their diminishing elevation in this direction is regarded as an heirloom of preglacial physiographic development, as the summits here pass without noticeable break northward into the province of the Interior Plateaus. Coquihalla peak and the nearby volcanic knobs present an interesting variation in the topography of this section of Hope mountains, and it is believed that they projected above the general surface of the Cascade peneplain before it was uplifted. The rocks composing these peaks were extruded or deposited as a thick series upon a surface of moderate relief in Miocene time, and protected the underlying rocks from erosion during the ensuing periods of deplanation. The areas so protected were not reduced so nearly to base-level as the surrounding territory and, on re-elevation, stood, and still stand, somewhat above the general plateau That they were, however, considerably eroded before elevation is level. evidenced by the exposure of the moderately coarse intrusive rock composing the neck or core of Coquihalla peak.

Willis, B., U.S. Geol. Surv., Prof. Paper No. 19, p. 70.

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The principal axis of elevation of Anderson River mountains follows somewhat closely the drainage divide between waters flowing into the Fraser and those draining into Coquihalla and Coldwater rivers. Most of the higher peaks occur along this divide which is broader than that in the northern section of Hope range and includes some of the minor ridges parallel to or running out from the principal divide. Within the limits of the map-area the elevation of this divide varies considerably. Except at the most southerly end of the range the higher peaks do not fall below 6,000 feet and in certain cases exceed 6,500 feet. Nowhere do they attain the height of the higher peaks of Hope range and as structure and rock composition are similar on either side of Coquihalla river, it seems possible that a slight differential elevation of the two ranges occurred. As in the case of Hope mountains, only those peaks standing above 6,500 feet have escaped regional glaciation, and only two such peaks occur in this range within the map-area. Both of these are located in the granite area to the north and west of Romeo and have been designated as "'needles" because of their sharply pointed peaks. They lie on either side of the headwaters The southern peak has an elevation of 6,860 feet of Boston Bar creek. and the other is about 6,700 feet high. These peaks may be regarded as approaching very closely the original maximum elevation of the Cascade plateau in this section of Anderson River mountains. They are composed of a massive granite which resists erosion much better than the sedimentary rocks composing the hill about 3,000 feet to the east of the more northerly needle peak. Consequently, if any great erosion of the granite hill had occurred, the difference in height between it and the sedimentary peak should also be great. This difference, however, is only 100 feet, and part of that may have existed prior to elevation to plateau level. It is consequently inferred that there has been very little reduction in elevation of either of these hills since the period of uplift. The objection to this theory that the sediments may have overlain the granite peak at the time of elevation is contradicted by the structural evidence in this part of the map-area. This argument in support of the view that there has been small reduction of summit levels since the elevation of the Cascade plateau has already been employed in discussing the relief features of Hope range in the vicinity of Manson mountain.

In that part of Cheam range which falls within the map-area are the two peaks, Isolillock mountain and Silver peak. The former is composed of a massive quartz diorite intrusive and the latter of a jointed Cretaceous conglomerate. Their notable difference in elevation, although only 3,000 feet apart, suggests that differential erosion effected a large part of the present difference in their heights at a period antedating their uplift. Farther to the south, and beyond the limits of the map, the peaks of this range rise considerably higher and at the time of uplift exceeded 7,000 feet in elevation. Near the International Boundary the Cascade plateau stood still higher, reaching a height of 8,000 feet or more. The decrease in elevation towards the north is noticeable across the entire width of the Cascades and is due, principally, to an accomodation to the still lower elevations of the Interior Plateau of British Columbia into which the northern Cascades merge. More locally, as exemplified in Coquihalla area, the axial ridges of each of the minor ranges tend to decrease in height towards the principal valleys, due to a retention in part of the original drainage system of the Cascade peneplain, whose minimum relief was still sufficient to control the courses of the principal streams. As a result, many of the spurs projecting from the main ridges toward the larger valleys have been reduced by erosion since their uplift to a more mature stage than the higher ridges farther back from the valley bottoms. The superior altitude of these axial ridges is also, in part, due to compound warping during the elevation of the Cascades.

#### Drainage

The greater part of Coquihalla map-area is tributary to Coquihalla river. This stream separates the mountains of Hope range on the east from Anderson River range to the west. In its entire length of about 37 miles from Coquihalla lakes, at an elevation of 3,600 feet, to Fraser river, 140 feet above the sea, it maintains such a uniform grade that the line of the railway, although following closely along its right bank, nowhere rises over 500 feet above the stream bed. The course of the river is direct and consequently the grade, although comparatively uniform, is steep, and the constant roar of the river can be distinctly heard, to a considerable height above the stream, at almost any point along its course.

Fluctuations in volume are characteristic of Coquihalla river as of all mountain streams in regions of irregular and heavy precipitation. In the spring and autumn, freshets due to melting snows and heavy rains are common, and in some cases prolonged. July and August are the driest months, following which the river is generally low and can be forded on foot at almost any point. Estimations based on eight years records show that the ordinary minimum flow at a point about 5 miles from the mouth is 143 second feet and its maximum flow at the same point 329 second feet.

The larger tributaries of Coquihalla river possess low, uniform grades over the greater part of their length. In their upper courses there is commonly an abrupt rise to the drainage divides. Illustrations of this change in grade include the following large streams:

Eightmile creek, tributary to Nicolum river—rises 3,000 feet in the first 6 miles and 2,500 feet in next  $1\frac{3}{4}$  miles.

Dewdney creek—rises 1,500 feet in lower 8 miles and 3,500 feet in the next  $2\frac{1}{2}$  miles.

Cedar creek—rises 2,500 feet in lower 5 miles and 1,500 feet in the next  $1\frac{1}{2}$  miles.

Peers river-rises 2,000 feet in lower 4 miles and 1,500 feet in the next mile.

This type of drainage, taken in conjunction with the comparatively narrow interstream divides, is characteristic of a topography which has reached a stage of early maturity or adolescence.

Nicolum river and Boston Bar creek are two rather exceptional tributaries. The grade of the former increases slightly in the upper third of its length, but the increase is not as notable as in the streams mentioned above. This is due to the exceptionally low altitude of the divide at Beaver lake, the head of the Nicolum, which stands less than 2,300 feet above sea-level. Boston Bar creek is also exceptional in that its more northerly branch rises within  $1\frac{1}{2}$  miles of Coquihalla river (at Romeo) and

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at an elevation of only 2,700 feet above its subsequent junction with this stream (near Portia). Its average grade over the  $10\frac{1}{2}$  miles of its length is 5 per cent, as compared with an average grade of 3 per cent, for Coquihalla river above their junction.

The present system of drainage in the district is concluded from the foregoing facts to be, in part, an heirloom from an earlier topography, and, in part, of subsequent origin. The remarkably uniform grade of Coquihalla river has been constructed across formations entirely dissimilar in character and suggests that it follows for the most part the same channel which it occupied in early or pre-Pliocene time. The abrupt change in course below Othello has, no doubt, been caused by accumulation of glacial debris along the original course of the stream through Kawkawa lake. The pronounced western bend below the mouth of Carey creek may also represent a subsequent valley, the original course of the stream having continued more nearly in line with the upper valley, across that narrow neck in the divide south of Portia into Dewdney Creek valley.

The valleys now occupied by Nicolum and Sumallo rivers on either side of Beaver lake are also relicts of an earlier topography. It is likely that the Sumallo now drains a considerable area in its upper basin which originally was tributary to Nicolum, the divergence having been occasioned in part by differential elevation on either side of Beaver lake during the late Pliocene uplift, and in part by the very recent accumulation of landslide debris at the head of Nicolum river. If the Interior Plateaus and Cascade mountains lay at the same general level at the time of Cascade peneplanation and, in their subsequent elevation, the Cascades were raised to a considerably higher altitude, it is reasonable to suppose that a part of the drainage which, prior to uplift, found its way to Fraser valley, would, by reason of this differential elevation, be diverted into more eastern water systems.

Other streams in Coquihalla area may also be antecedent in character, but they are less obviously so than Coquihalla river and those tributaries referred to. Most of the streams are doubtless of subsequent origin, their position having been determined in part by such warping as may have occurred in the elevation of the area; in part by the angle of slope of such residual hills as remained above base-level; in part by the angle of exposure of these hills to atmospheric agencies; and in part by differences in rock composition.

#### Glaciation

Glaciation has modified the topography of the district very greatly. It developed along two opposing lines in which the forces of regional glaciation tended to reduce the topographic relief, and those of alpine and valley glaciation to increase it.

The regional ice-cap ground off the more acute points on the upland surfaces and left in their place characteristic roches moutonnées and shallow surface depressions which are now occupied by many small lakes. In a lesser degree this ice-sheet polished the underlying rocks and furrowed the less resistant ones. The materials so eroded were carried by the moving ice and by later gravitative and stream activities to the lower valleys, or were swept beyond the district. Both in its erosive and depositional features regional glaciation tended to reduce the relief of the area, although it is not believed that any great reduction in general altitude actually resulted. The upward limit of glaciation seems to be at about 6,500 feet. Peaks from 200 to 500 feet higher are unscored and their flanks apparently unaffected, although the surrounding areas, are well polished and rounded off. From this it might appear that these modified surfaces never stood much higher than at present.

Further, only the softer or less resistant rocks show glacial grooving and the grooves vary from mere scratches to trough-like depressions at most 5 or 6 inches in diameter. None were noted on the granitic areas or where the more resistant of the sediments were encountered. Evidence of only one period of regional glaciation was obtained from the direction of glacial grooving and the position of transported materials. This icesheet appears to have crossed the area in a direction approximately south 55 degrees west. That this sheet was capable of transporting large rock fragments for considerable distances is indicated by an interesting occurrence of large erratics of Tertiary volcanics several tons in weight which were carried 8 miles from the vicinity of Coquihalla mountain to the top of the ridge south of Portia.

The topography of the district has been greatly modified by valley and alpine glaciation whose period of activity succeeded the withdrawal of the regional ice-cap and has, in the case of mountain glaciation, continued to the present. Large glaciers doubtless occupied major valleys for a considerable period, and to these must be attributed the remodelling of the sharply V-shaped valley troughs of the pre-Pleistocene topography into their present U-shaped form; the aligning and straightening of the valley sides by truncation of projecting and overlapping spurs; the formation of hanging valleys at the junction of tributary streams; the glacial grooves and striæ along the sides of the valley; the removal of pre-existing talus slopes; the steeper grade at the valley head; and the broad, flat valley To these valley glaciers must also be ascribed the deposition floors. of great volumes of eroded materials of which only a small part now remains in the valley bottoms. A large proportion of glacial debris would be carried beyond the limits of the area or would tend to concentrate near the mouths of the valleys. On the retreat of the valley glaciers considerable morainal deposits were left. These have been partly removed, but a large accumulation still remains in the lower Coquihalla valley and smaller deposits are found at the mouths of Dewdney and Boston Bar creeks.

While the valley glaciers were actively employed in remodelling the lowland topography, smaller mountain or alpine glaciers were changing the contours of the higher ridges and peaks. Their work has continued up to the present. At the valley heads or on the shadier northern and northwestern slopes of the mountain crests, these alpine glaciers have developed cirques with steep headwalls (Plate III B), the opposite sides of the mountains conforming to the more gentle average slope of the valleys. A series of such peaks when viewed on either side from a distance presents a striking picture which has been likened to a "series of breaking waves" (Plate III). Where the alpine glaciers have partly or entirely disappeared, small, beautifully clear lakes now occupy the cirque depressions. A few very small alpine glaciers, which might be more properly termed permanent snow fields, are still present in the map-area and represent the last trace of the glacial period. They are all small, but, depending on elimatic conditions, vary considerably in size within intervals of only a few years. The best example of glacial remnants in the district is afforded by the snow fields occupying the tandem circues on the northern slopes of Coquihalla mountain.

#### Terraces

Terraces occur at different elevations in Coquihalla basin. A stream terrace occurs near the summit of the Coldwater-Coquihalla divide and is best exposed along the railway about  $2\frac{1}{2}$  miles north of Coquihalla station and on the left bank of Coldwater river. It is composed of well-stratified sands and silts and has an elevation of about 3,400 feet. It lies 250 feet below Coquihalla station. This is probably the terrace to which Dawson assigned an elevation of 3,286 feet.<sup>1</sup>

A terrace, or series of terraces, appears at elevations of from 1,800 to 2,500 feet in the valley of Coquihalla river and its tributaries. The following approximate measurements were taken at various points in the valleys of these streams.

Coquihalla valley

	12	eet
(Above and to the northeast of the mouth of Carey creek	1	2,250
Above railway about a mile above Ladner creek	±	1,700
Above railway about a mile below Ladner creek	±	1,700
On trail to Emancipation mine	$\pm$	1,720
Above and to the east of the mouth of Dewdney creek	$\pm$	1,700
Valley of Dewdney creek about $5\frac{1}{2}$ miles from mouth	±	2,500
Valley of Sowaqua river about $4\frac{1}{2}$ miles from mouth	<u>.+-</u>	2,100

The continuity of these terraces is not well-defined, so that it is impossible to say whether one or more distinct levels are represented. The 1,700-foot terrace following down Coquihalla valley seems to be almost horizontal for at least 2 miles. Those in the tributary valleys are somewhat higher and it appears that they may slope gently down their valleys with a grade considerably less than that of the present stream bed. In this case the terrace along Coquihalla valley may join with them and also grade downstream, but so gently as to be imperceptible over a distance of a mile or so.

An important bench occurs between Othello station on the Kettle Valley railway and Kawkawa lake. It is about 500 feet above the lake and has resulted from the accumulation and subsequent partial reworking of morainal material heaped up during the retreat of the valley glacier up Coquihalla valley. This moraine was disposed over the original course of Coquihalla river and diverted this stream into the narrow box canyon it has cut for itself through sheared and jointed batholithic rocks.

The formation of the stream terraces followed the accumulation of a great body of glacial debris in Coquihalla valley during the period of regional and, in particular, valley glaciation. These deposits were reworked in the period succeeding the withdrawal of valley glacial ice. The tendency of the glacial debris to accumulate in greater abundance in the lower

<sup>&</sup>lt;sup>1</sup> Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877-78, p. 148 B.

course of Coquihalla valley and its main tributaries had the effect of decreasing the grade in the upper sections of these streams and consequently in increasing their breadth and weakening their powers of erosion. In cutting their way through the glacial debris an assortment of the material was effected. This assortment is distinct, but, on the whole, irregular. The irregularity was due in part to temporary damming of the streams, and the formation thereby of lake-like expansions of the river and its tributaries. In these expansions the reworked glacial material would be deposited over considerable stretches of the valley in almost horizontal beds of finely assorted and bedded materials. At irregular intervals, during flood seasons or under torrential conditions, these dams would be broken and the deposits previously formed would be partly destroyed and reassorted farther downstream. Much coarse, ill-assorted materiai would also be carried into the stream beds and incorporated with the more regularly bedded sand and mud (Plate IV A).

There is no convincing evidence at hand to show that there has been either post-glacial submergence or elevation in the district. The stream deposits nowhere contain shells or other fossil evidence indicative of a marine invasion. On the other hand the terrace deposits extend, in the lower course of Coquihalla river, almost to stream-level, suggesting that there has been little or no elevation since their deposition. Farther up the valley the river has cut into the solid rock below the terraces. This erosion has occurred since the period of fluvioglacial sedimentation and while it was taking place much of the terrace material was removed and has contributed to the building of the delta at the mouth of Coquihalla river.

#### Summary of Topographic Development

The principal stages in the history of the development of the present topography may be briefly summarized as follows:

The development in pre-Pleistocene time of a very mature topography eroded nearly to base-level but still retaining sufficient relief to maintain a definite drainage system. At the close of this period several monadnocks stood above the general surface of the peneplain. Tulameen and Coquihalla peaks are examples of these residuals.

A general uplift in the late Pliocene or early Pleistocene in which the entire area was raised from 4,000 to 6,000 feet. The upheaval was differential in character, so that certain parts of the district attained altitudes varying appreciably over others. The uplift was accompanied by crustal warping and was greater than in the adjoining region of the Interior Plateaus. Only near the borders of the two provinces was the uplift comparable. Elevation was accomplished slowly enough to permit the principal streams to incise themselves along their original courses, although some departure from the older stream beds doubtlessly occurred.

Development of preglacial topography by weathering and stream erosion. Modification of this topography by regional and local glaciation.

Formation of post-glacial terraces; subsequent erosion of the greater bulk of these terraced deposits and additional cutting in valley floors; delta deposition.

### CLIMATE

The climate of Coquihalla area is similar to that of the British Columbia coast. Precipitation is heavy for more than two-thirds of the year and in the winter months occurs chiefly as snow. The hills usually remain covered until well on in May, and even as late as July snow in considerable abundance is found on the summits and northern slopes (Plate II A). It is the melting of this snow in the late spring that swells the Coquihalla and its tributaries to abnormal volumes. From July until the middle or close of September there is comparatively little rain and periods of from ten to twenty or more days in succession may occur without any precipitation. Such intervals of drought are usually followed by torrential thunder storms and sometimes by heavy rains lasting from two to four days, during which time the main streams may rise several feet in a few hours, only to subside almost as rapidly when rain ceases. In late September and October the heavy autumnal rains begin, the streams once again become turbulent, murky torrents, and maintain a nearly maximum volume until the late autumn and winter months when precipitation turns to snow and the run-off from the hills diminishes. Hope enjoys a somewhat milder climate than the greater part of the district. Temperatures and precipitation are not very different here from those obtaining in Vancouver or at Chilliwack.

			Vancouver	Chilliwack	Норе
	1916	High Low	82·9 6·0	91.0 1.0	91·0 6·5
	1917	High Low	$82.6 \\ 10.3$	87.0 1.0	86·0 6·5
Temperature in degrees Fahrenheit	1918	High Low	$83 \cdot 4 \\ 17 \cdot 4$	$90-0 \\ 15 \cdot 0$	$91.0 \\ 8.5$
	1919	High Low	$81 \cdot 3 \\ 11 \cdot 2$		$92.0 \\ 1.5$
	1916	Rain Snow	$48.03 \\ 80.55$	$\begin{array}{r} 45.7\\100.0\end{array}$	
Precipitation in inches	1917	Rain Snow	$54 \cdot 00 \\ 72 \cdot 50$	$63 \cdot 30 \\ 72 \cdot 00$	$47.78 \\ 79.00$
	1918	Rain Snow	$58 \cdot 51 \\ 42 \cdot 00$	$62 \cdot 39 \\ 30 \cdot 50$	$60.86 \\ 33.00$
	1919	Rain Snow	$54 \cdot 01 \\ 32 \cdot 00$	$55 \cdot 64 \\ 6 \cdot 25$	$48 \cdot 26 \\ 66 \cdot 55$

Comparison of Temperature and Precipitation, 1916-1919<sup>1</sup>: Hope, Chilliwack, and Vancouver

Province of British Columbia, Dept. of Agriculture, Climate of British Columbia, Bull. 27, 4th ed.

			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature de- grees Fahrenheit	1916	Vancouver Chilliwack Hope	11 20 26	30 35 37 -	$38 \\ 41 \\ 42$	$\frac{47}{49}$	52 53 52	60 60 60	61 61 61	64 64 63	 57 57	$42 \\ 47 \\ 47 \\ 47$	36 39 40	$27 \\ 31 \\ 34$
	1917	Vancouver Chilliwack Hope	$30 \\ 32 \\ 34$	$30 \\ 32 \\ 35$	37 38 99	45 47 40	54 54 54	56 57 57	$\begin{array}{c} 64 \\ 63 \\ 63 \end{array}$	 84 64	57 58 58	49 51 50	$44 \\ 46 \\ 48$	31 35 39
	1918	Vancouver Chilliwack Hope	- 33 37 40	$31 \\ 36 \\ 37$	$37 \\ 40 \\ 41$	49 50 49	$52 \\ 53 \\ 54$	$\begin{array}{c} 61 \\ 61 \\ 61 \end{array}$	$\begin{array}{c} 65 \\ 64 \\ 64 \end{array}$	${}^{62}_{63}_{62}$	$\begin{array}{c} 65 \\ 62 \\ 60 \end{array}$	$50 \\ 53 \\ 51$	$39 \\ 42 \\ 43$	33 .37 33
	1919	Vancouver Chilliwack Hope	34 87 39	32 35 38	$38 \\ 41 \\ 42$	$49 \\ 49 \\ 48$	$52 \\ 53 \\ 53$	56 57 57	${}^{64}_{62}_{62}$		60 59 58	$\frac{44}{45}$	$36 \\ 40 \\ 41$	29 34 36

Average Temperature from	<b>Observations</b>	of Te	i or	More	Years
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	Vancouver	Jan.	Feb.	Mar.	Apr.	May 54	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Degrees Fahrenheit	Chilliwack Hope	33 27	37 32	42 40	49 48	55 54	$59 \\ 59$	64 64	63 64	57 58	50 49	40 38	37 32	· · · · · ·
				Preci	pitati	on in	Inch	ies						
1916	Vancouver Chilliwack Hope	$5.96 \\ 4.85 \\ 2.65$	$7 \cdot 40 \\ 7 \cdot 95 \\ 6 \cdot 71$	$14.55 \\ 11.35 \\ 8.26$	$4.07 \\ 4.35 \\ 4.35 \\ 4.35$	$1 \cdot 41 \\ 3 \cdot 78 \\ 3 \cdot 60$	$1 \cdot 34 \\ 1 \cdot 79 \\ 1 \cdot 98$	$5 \cdot 25 \\ 4 \cdot 43 \\ 2 \cdot 76$	0·58 0·58 0·31	$1 \cdot 28 \\ 1 \cdot 56 \\ \dots$	$2 \cdot 16$ $1 \cdot 76$ $2 \cdot 89$	$\begin{array}{c} 6\cdot 37 \\ 7\cdot 21 \\ 4\cdot 55 \end{array}$	$5.71 \\ 6.09 \\ 4.61$	56.08 55.70
1917	Vancouver Chilliwack Hope	$9.33 \\ 9.10 \\ 6.97$	$5.87 \\ 7.08 \\ 4.68$	$5 \cdot 61 \\ 5 \cdot 08 \\ 6 \cdot 26$	$8 \cdot 20 \\ 5 \cdot 51 \\ 3 \cdot 94$	$1.69 \\ 1.40 \\ 1.08$	$5 \cdot 40 \\ 5 \cdot 41 \\ 3 \cdot 42$	$0.48 \\ 0.80 \\ 1.10$	$0.93 \\ 1.14 \\ 1.18$	$3 \cdot 30 \\ 2 \cdot 51 \\ 1 \cdot 88$	$3.49 \\ 5.35 \\ 3.55$	$5 \cdot 23 \\ 7 \cdot 63 \\ 7 \cdot 42$	$11.72 \\ 19.49 \\ 14.20$	$ \begin{array}{r} 61 \cdot 25 \\ 70 \cdot 50 \\ 55 \cdot 68 \end{array} $
1918	Vancouver Chilliwack Hope	$11 \cdot 04 \\ 9 \cdot 61 \\ 7 \cdot 91$	$   \begin{array}{c}     10 \cdot 50 \\     8 \cdot 33 \\     8 \cdot 31   \end{array} $	$7 \cdot 47 \\ 7 \cdot 02 \\ 7 \cdot 12$	$1.70 \\ 1.17 \\ 1.31$	$1 \cdot 15 \\ 3 \cdot 09 \\ 3 \cdot 30$	$1 \cdot 00 \\ 0 \cdot 73 \\ 1 \cdot 07$	$2 \cdot 29 \\ 1 \cdot 99 \\ 1 \cdot 36$	$4 \cdot 59 \\ 3 \cdot 70 \\ 3 \cdot 14$	$0.30 \\ 0.33 \\ 0.67$	$7.56 \\ 10.18 \\ 9.42$	7.03 6.64 6.80	$8.07 \\ 12.05 \\ 13.75 $	$\begin{array}{c} 02 \cdot 71 \\ 05 \cdot 44 \\ 64 \cdot 16 \end{array}$
1919	Vancouver Chilliwack Hope	$7.57 \\ 8.63 \\ 9.19$	$7 \cdot 35 \\ 5 \cdot 75 \\ 5 \cdot 03$	$6 \cdot 61 \\ 6 \cdot 37 \\ 6 \cdot 57$	$4 \cdot 47 \\ 5 \cdot 45 \\ 4 \cdot 75$	$3.60 \\ 5.29 \\ 4.16$	$1 \cdot 02 \\ 1 \cdot 17 \\ 1 \cdot 32$	$0.15 \\ 0.40 \\ 0.29$	1 · 15 0 · 57 0 · 28	$1 \cdot 16 \\ 2 \cdot 43 \\ 1 \cdot 76$	$3 \cdot 14 \\ 3 \cdot 64 \\ 2 \cdot 80$	$11 \cdot 25 \\ 11 \cdot 60 \\ 11 \cdot 44$	$9.74 \\ 10.59 \\ 7.33$	$57 \cdot 21 \\ 61 \cdot 89 \\ 54 \cdot 92$
Average ten years or more	Vancouver Chilliwack Hope	$8.51 \\ 7.72 \\ 7.04$	$5.73 \\ 5.92 \\ 5.10$	$5.44 \\ 3.83 \\ 4.87$	$3 \cdot 36 \\ 3 \cdot 63 \\ 2 \cdot 86$	$3 \cdot 05 \\ 3 \cdot 75 \\ 2 \cdot 80$	$2 \cdot 64 \\ 2 \cdot 73 \\ 1 \cdot 69$	$1 \cdot 46 \\ 1 \cdot 68 \\ 1 \cdot 27$	$1 \cdot 61 \\ 1 \cdot 93 \\ 1 \cdot 62$	3.66 3.66 3.01	5.61 5.77 5.86	$   \begin{array}{r}     10 \cdot 19 \\     9 \cdot 31 \\     9 \cdot 35   \end{array} $	$7 \cdot 80 \\ 8 \cdot 67 \\ 7 \cdot 28$	89.06 63.78 52.75

## FLORA<sup>1</sup>

The vegetation of the district is typically that of the coast areas of British Columbia where the climate is mild and precipitation heavy. Forests range to an elevation of 6,000 feet or more and consequently extend over all except the higher peaks and ridges. Their luxuriance is, however, markedly dependent upon the character of the underlying rocks. In

<sup>1</sup> The writer is indebted to Prof. J. Davidson of the University of British Columbia for most of the Latin names of the trees and shrubs mentioned in this report, and for other valuable suggestions.

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general the larger granitic tracts are more scantily covered and can in many places be recognized easily from a distance by their barer slopes (Plate I). In the southern part of the district this distinction cannot be employed, for magnificent forests here thrive on intrusive as well as on sedimentary and volcanic rocks. That the difference in composition of the batholithic rocks is of some ecological importance in determining the abundance of vegetation is illustrated in the northern part of the district where the Eagle diorite and quartz diorite support a considerably heavier forest growth than either of the adjoining more acid batholithic bodies. In this northern part the upper tuffaceous beds of the Coquihalla series support a very scanty vegetation. Of all the rocks in the district those composing the Ladner slate belt support the most luxuriant forests, but they are closely followed in this respect by the slaty members of the Cache Creek series and, to a less extent, by other members of this series (Plate II B).

Towards the summits of the divides the forest growth diminishes, and at the higher elevation is entirely absent. Frequently, however, a tangled mat of shrubbery persists and occasional stunted and contorted conifers weather the severe gales and cold prevailing at these altitudes.

The more common trees at elevations of over 5,000 feet include the common juniper Juniperus communis var. montana, which is hardly more than a shrub on the higher summits; Alpine fir Abies lasiocarpa, variously called white balsam fir, Oregon balsam fir, downy cone fir, mountain balsam, and Pumpkin tree; Engelmann's spruce Picea Engelmanii, sometimes erroneously referred to as white spruce, mountain-spruce, Arizona spruce, balsam, and white pine; and mountain or western white pine Pinus monticola. Of these trees probably the most imposing and beautiful is Engelmann's spruce which grows to a height of over 100 feet and may attain a trunk diameter of 3 feet. In many places it forms groves of considerable size and although not forested within the district is used elsewhere in carpentry and takes a fine polish.

At somewhat lower elevations still larger conifers include the magnificent giant cedar *Thuja plicata*. This tree is known in commerce under a variety of other names, among which arbor-vitæ, gigantic cedar, and shinglewood are most common. It is also commonly referred to as red cedar and white cedar. The western yew, *Taxus brevifolia* (also called mountain mahogany and Pacific yew) is also fairly abundant at these altitudes.

In descending into the lower valley slopes, or roughly, at elevations between 4,000 and 3,000 feet, other important conifers occur, including the widely-known Douglas fir, *Pseudotsuga taxifolia*, variously referred to as Douglas spruce, red fir, yellow fir, and Oregon pine; yellow cedar *Chamaecyparis nootkatensis*, sometimes called yellow cypress; lovely fir, *Abies amabilis*, also called red fir and erroneously referred to by the lumberman as larch; and the western hemlock *Tsuga heterophylla*.

In the lower valleys and valley bottoms a great wealth of both evergreen and deciduous trees appears, and here the more majestic of the forests are found. The division between this group and the preceding ones, is adopted purely for convenience in defining the zones of altitude where the various trees are more abundantly and typically encountered within the Coquihalla area. In this lowest zone the more important evergreen trees include Giant cedar; western hemlock; Douglas fir; Grand fir *Abies grandis*, also called great silver fir, yellow fir, and Oregon fir; scrub pine *Pinus contorta*; and Sitka spruce *Picea sitchensis*, also called tideland spruce, Western spruce, and Menzie's spruce. This spruce is the important tree in the paper and pulp industry of the Pacific coast. Among the deciduous trees the cottonwood *Populus trichocarpa*; aspen *Populus tremuloides*; western birch *Betula occidentalis*; and red alder *Alnus rubra* are very common. Both vine and broad-leaved maples *Acer circinatum* and *A. macrophyllum* are occasionally observed and in the vicinity of Hope the western dogwood *Cornus Nuttallii*, cascara tree *Rhamnus Purshiana* and California hazelnut *Corylus rostrata* have been identified.<sup>1</sup> Willows are very abundant along the banks of some of the streams.

The underbrush, abundant over a great part of the area, is less noticeable on those hill-slopes supporting heavy forests. In the moist valley lands the devil's club Fatsia horrida; yellow arum Lysichiton Kamtschatcense, often locally known as skunk cabbage, and bracken Pteris aquilima are common and usually very abundant. Other shrubs including salal Gaultheria shallon; salmonberry Rubus spectabilis; and, less frequently, blackberry, form dense thickets which are very difficult to penetrate. The more open spaces on the sunny slopes of the hills are commonly clothed with a luxuriant growth of huckleberry bushes (red huckleberry Vaccinium parvifolium and blueberry Vaccinium ovalifolium) which, in fruiting season, form a favourite rendezvous for bears who satiate their healthy appetites on the tasty berries.

#### FAUNA

The larger game animals are not well represented in the district. Mule deer and at least one smaller variety have been observed in considerable numbers in Hope mountains east of Romeo, Coquihalla, and, less frequently, on the west side of the river in Anderson River mountains. Black or brown bears are rarely seen except during the late summer in the huckleberry patches which grow luxuriantly on the more open and sunny slopes of the hills. Grizzly bears have been reported but are very scarce. They probably stray over from the Skagit River country to the southeast, where they are comparatively numerous. Mountain goats were frequently observed on the more rugged peaks and ridges of Hope range and their trails are often of considerable assistance in crossing the summits of the less accessible divides. Coyotes are not uncommon, but wolves have rarely been reported from this district. Marten, fisher, lynx, and weasel are all caught by the trapper during the winter season and are occasionally observed at other times of the year. A few beaver are known to exist in Beaver lake at the head of Nicolum river, but have not been observed elsewhere in the district. The wolverine is not plentiful, but his reputation for thieving and cunning is as well sustained here as elsewhere. A few porcupines were seen. Groundhogs are numerous on the rocky summits and their shrill warning whistle is as aggravating to the hunter in pursuit of game as it must be acceptable to the quarry being stalked. Of other small animals skunk, wood rats, red and grey squirrels, chipmunks, wood-

<sup>&</sup>lt;sup>1</sup> Davidson, J., Third Annual Rept. of the Botanical Office, Prov. of B.C., 1915, vol. 1, pt. 3, pp. O 81 to O 150.

mice, and rabbits abound; flying-squirrels are more sparingly represented. Owls, crows, and hawks are plentiful and some eagles are seen, but there are few song birds. Different species of grouse are encountered, blue and willow grouse being most common. Ptarmigan are fairly abundant on the summits.

Coquihalla river and its tributaries are well stocked with fish and are much frequented by anglers during the summer months. Rainbow and Dolly Varden are the most common species of trout. Salmon are abundant in the lower Coquihalla, in Kawkawa lake, and in Fraser river during spawning season. As early as 1846 a salmon fishery was established near the mouth of Silver creek on Fraser river.

#### INDUSTRIES

Next to mining, lumbering is the chief industry. The larger and more luxuriant forests occur in the valleys and on the lower drainage slopes of the area, but from the bare glaciated summits composed of granitic rocks, which have so remarkably resisted the advance of vegetation, to the majestic forests of the lowlands, there is a wide gradation. Douglas fir, and giant red cedar are of present chief commercial importance.

The first sawmill was established in Hope in 1858 by John Coe, H. White, and Daniel C. Patterson, their licence being granted by Crown Commissioner Richard Hicks. From the autumn of 1917 until recently the Pacific Tie and Lumber Company have operated three mills in Hope, but only one is now running. A sawmill was started at Othello in 1919 by the Othello Lumber Company, but was closed in the autumn of 1921. The Kawkawa Lake Lumber Company, established in 1920, is still in operation cutting principally dimension timber (fir). At Jessica a shingle mill was erected in 1917 and is at present owned and operated by Campbell and Sons.

What little agriculture there is, the delta land, at the mouth of Coquihalla river and in the vicinity of Hope, supports. The soil is fertile and provides fine pasturage. Common vegetables are grown and there are a few natural hay meadows.

Waterpower—an important asset of the area—has as yet been little developed. About 5 miles above the mouth of Coquihalla river a waterpower site has been established and it has been estimated that with a head of 225 feet obtained by means of a 60-foot dam and a 2,600-foot tunnel, an ordinary minimum flow will give 2,925 horsepower, and a maximum development without storage of 6,730 horsepower may be obtained. The ordinary minimum flow is here 143 second feet; and the estimated flow for maximum development without storage 329 second feet. About 4 miles above the mouth of Nicolum river another site, with an available head of 2,000 feet, has been estimated, on a basis of six years' records, to have a possible power, at ordinary minimum flow of 22 second feet, of 4,000 horsepower and a maximum development without storage and with a flow of 546 second feet of 5,820 horsepower.<sup>1</sup>

<sup>1</sup> Water Resources Paper No. 14 and Rept. of Water Rights Branch, Dept. of Lands, Prov. of Brit. Col., 1913.

# INHABITANTS

Hope, with a normal population of about 200, is the only place of importance in the map-area, and includes the greater number of the inhabitants. The sawmill at Kawkawa lake, the shingle mill at Jessica, the Emancipation and Pipestem mines, and the Kettle Valley railway employ a few additional white men and several Chinese labourers.

# CHAPTER III

## GENERAL GEOLOGY

## OUTLINE OF REGIONAL GEOLOGY

Coquihalla area lies on the eastern flank of the Coast batholith. It forms a very small part of a large province referred to in the geological literature of the Canadian Cordillera as the western geosynclinal belt or prism. This belt has been greatly intruded to the west of Fraser river by the complex of batholithic rocks comprising the Coast mountains. To the east of Fraser river the belt occupies a broad terrain at the eastern margin of which it rests unconformably on a basement of Precambrian rocks (Shuswap series). The geological outline which follows deals chiefly with this western geosynclinal belt, particularly in the vicinity of the International Boundary and north of this line as far as Thompson river.

The oldest rocks in this section are presumably Carboniferous, but earlier Palæozoic formations may at one time have been present. The Carboniferous rocks were laid down during a general submergence by Pacific waters in Lower Pennsylvanian time. Sedimentation was accompanied by widespread vulcanism, and at least 10,000, and probably more nearly 20,000 feet of submarine deposits were accumulated. The stratified rocks are chiefly slates, cherts, and limestone with a small proportion of arenaceous rocks and a few conglomerate beds. These rocks and the lava flows and minor pyroclastic beds intercalated with them are included in southwestern British Columbia under the general name of Cache Creek series, but more local names are also applied in districts where correlation with the typical Cache Creek rocks has not been definitely established. The upper member of the Cache Creek rocks consists chiefly of limestone, and is referred to in its type exposure as the Marble Canyon formation. Distinctive Carboniferous fossils have been found in this, as well as in narrower beds of limestone at lower horizons in the series. Although at one time occupying the greater part of British Columbia and the Yukon, as well as large areas in Alaska and in Washington, the Cache Creek series is now exposed in relatively small, isolated, and greatly deformed patches. It doubtless underlies much of the later sediments and volcanic rocks, but has been entirely eroded from large areas now chiefly occupied by that vast complex of intrusive rocks related to the Coast batholith.

Following the Cache Creek (Pennsylvanian) period of submergence the western region was probably re-elevated to form an erosion surface. There is some inconclusive evidence that sedimentation continued to the close of the Triassic, but more probably an interval of uplift and erosion intervened until Upper Triassic time, when a second incursion of Pacific water spread over an even greater area than in the Pennsylvanian period. Sedimentation was, however, subordinate to vulcanism, and a great proportion of both extrusive and pyroclastic deposits was accumulated in the sea and intercalated with minor argillaceous and calcareous beds. These deposits were first described by Dawson, from the vicinity of Nicola lake, and have been called the Nicola series. In their type locality they have an estimated thickness of from 10,000 to 15,000 feet. The Cultus formation of argillite and subordinate sandstone at the boundary; the lower sections of the Vancouver series from Vancouver and Queen Charlotte islands (chiefly andesitic volcanic rocks containing many intercalated limestone beds); and the Tulameen series of unknown but great thickness (mainly submarine lava flows) are probably all contemporaneous with the Nicola series. Like the Palæozoic, these Triassic rocks now occur in relatively small areas and although, in many respects, their lithological characteristics are remarkably similar in different districts, their faunal content is scanty and not always sufficiently well known or preserved to base authoritative correlations upon.

The close of the Triassic was marked by a general withdrawal of epicontinental waters toward the west. This recession was accompanied by crustal warping and deformation along the Pacific border. Vulcanism was active until well on in the Jurassic.

Towards the close of the Middle Jurassic there occurred a broad marine incursion from the north Pacific southeastward across the greater breadth of British Columbia and far to the south of the boundary. The duration of this submergence is uncertain, but in southwestern British Columbia it may have remained until well on in Upper Jurassic time. It is uncertain whether Jurassic formations are definitely represented in this section, although within Coquihalla area both the Ladner and Dewdney Creek series are referred tentatively to this period.

The Ladner series is represented by at least 8,000 feet of sediments, mainly slates or other fine-grained argillaceous rocks. About 500 feet of fine conglomerate and grit occur near the top of this section and, in all, several hundred feet of greywackes are represented. This series represents a long period of denudation from a land of low relief into a comparatively shallow sea. The tuffaceous character of the sediments indicates that vulcanism, either directly or indirectly, furnished material for these beds and, as no corresponding lavas or definite pyroclastic deposits were identified in the series, it is likely that the tuffaceous beds were obtained chiefly by erosion of earlier pyroclastic deposits.

The Dewdney Creek series is apparently conformable on the Ladner rocks, but unlike those sediments is composed largely of undoubted pyroclastic materials. Many of the interbedded clastic rocks, however, much resemble members of the underlying Ladner series. No sediments coarser than sandstones were observed in the Dewdney Creek series, justifying the belief that until the close of its deposition the relief of the adjacent land areas was low, and the absence of limestone beds indicates that the waters were muddy and comparatively shallow.

The great thickness of these two series, aggregating over 15,000 feet, was accumulated on a sinking sea-floor. The general assemblage of fossils, including only a few belemnites in the Ladner series and a small representation of molluscs, ammonites, and belemnites in the Dewdney Creek rocks, suggests deposition in a large bay rather than in the open sea. It is, consequently, probable that the incursion of Pacific waters, mentioned above as occurring toward the close of the Middle Jurassic, formed the sea in which these rocks accumulated.

In Coquihalla area a rapidly sinking sea-floor; an increasingly conspicuous proportion of arenaceous or coarser sediments, indicative of crustal deformations; and local great abundance in the Dewdney Creek series of volcanic materials, seem to have heralded the opening phases of the great orogenic disturbance which was to close Jurassic sedimentation and usher in a succession of great batholithic irruptions. In subsequent Mesozoic and Tertiary time these intrusions take a prominent part in the geological history of the western Cordillera.

The proportion of Upper Jurassic or early Cretaceous intrusives in the great batholithic complex of the Coast mountains is not known, but is probably very great. Such as have been recognized consist chiefly of granodiorites and quartz diorites with subordinate proportions of more acid and basic types, and are very similar in composition, and probably also in age, to those plutonic members intruded at the close of the Sierra Nevada disturbance in the western United States.

Preceding, and probably to some extent accompanying, the intrusion of these batholithic rocks, the older formations were greatly deformed, and with this deformation the marine waters retreated towards the west, or remained behind in deep intermontane troughs in which great thicknesses of coarse sediments were rapidly accumulated from the rejuvenated land masses adjoining. These sediments consist of sandstone, conglomerate, and shale, and although not equally deformed with the older sediments, stand at high angles and strike in a direction not very different from the earlier formations. In the accumulation of these sodiments, much of the older formations was eroded, and erosion bit deeply into the underlying plutonic rocks, so that for the first time in the history of sedimentation in the western geosynclinal belt, batholithic detritus became an important constituent of the beds. This period has been referred to as the Lower Cretaceous or Comanchean and, along the Pacific border, also as the Shastan. The Cretaceous sediments of Coquihalla area belong to this period.

In Coquihalla area no Upper Cretaceous sediments were recognized, but the Lower Cretaceous seems to have been brought to a close by a second period of batholithic intrusion of rocks ranging from granite to diorite with a preponderance of granodiorite types. It is probable that in this section of British Columbia the break between the Lower Cretaceous and succeeding Upper Cretaceous formations is an important one. Bread folding of the Lower Cretaceous rocks probably preceded and may, in part, have accompanied these intrusions.

Still another unconformity separates the Cretaceous from the Tertiary. This interval is represented by the Laramide revolution, whose influence in eastern British Columbia, as well as in regions farther south, has been so phenomenal, but whose effects in the west are less pronounced. This orogeny still further deformed the Cretaceous rocks. Pre-Cretaceous formations were partly overturned to the northeast, the deformation being accompanied by considerable thrusting and faulting of the sedimentary and volcanic rocks, and mashing, shearing, and jointing of the plutonic intrusives. Other batholithic intrusions may have immediately followed this disturbance, and certain granodiorites on Similkameen and Ashnola rivers are referred to this period.

The Tertiary period is notable for the abundance of volcanic materials, chiefly lavas, which characterize nearly every part of it and vary markedly in composition. Their sequence has not been clearly determined. They are probably most prominently represented in the Miocene and Pliocene periods and cover immense areas in southwestern British Columbia and in the northwestern United States. No sediments are recorded from this section of British Columbia in Eocene time, except in the Puget Sound depression<sup>1</sup>. In succeeding Oligocene time sedimentation was more general but occurred usually in basins of limited extent, where, nevertheless, beds aggregating thousands of feet in thickness were accumulated. In southwestern British Columbia these sediments are referred to as the Coldwater group, and are usually associated with minor proportions of volcanic rocks belonging to the same period.

The Miocene period was predominantly one of vulcanism, orogenic activity, and batholithic intrusion. Locally some sediments, such as the Tranquille beds in southern British Columbia, were formed. Andesite flows characterize early Miocene vulcanism, but other types, chiefly basaltic, close this period. A number of batholithic intrusions are doubtfully referred to this period. They have been exposed over broad areas near the Canadian border in the Skagit range and for some distance on either side of the Boundary. The Otter granite of Tulameen area and certain batholithic rocks in Coquihalla area are assigned to this period. Considerable deformation of earlier sedimentary rocks was accomplished during the Miocene, particularly at its inception, or at the close of Oligocene sedimentation, but a second and less pronounced period of crustal warping occurred toward the close of the Miocene.

The Pliocene was a period of erosion accompanied by the extrusion of considerable, and locally great, flows, chiefly of basaltic character. Much of the lavas of the Cascades was erupted at this time and vulcanism was probably continuous there into the Pleistocene. Near the close of this period the Cascades and Interior Plateaus were reduced almost to a peneplain.

At the close of the Pliocene, or in early Pleistocene time, there was a general elevation of these peneplained lands followed by erosion, glaciation, and deposition of glacial, fluvioglacial, and fluvial deposits. A few basalt dykes, and some important basalt flows, are recorded from this time.

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<sup>&</sup>lt;sup>1</sup> Recently some Eccene sediments have been recorded from the valley of North Thompson river (Uglow, W. L., Geol. Surv., Can., Sum. Rept. 1922, pt. A, pp. 82-86). These were originally correlated by Dawson with the Coldwater group (Geol. Surv., Can., Ann. Rept., vol. vii, N.S., 1894, p. 229 B) and to throw some doubt on the age classification of this group and correlated formations in southern British Columbia.

### GEOLOGICAL OUTLINE OF COQUIHALLA AREA

The oldest rocks in the area belong to the Cache Creek group. They are partly volcanic and partly sedimentary and are believed to have all been laid down or extruded in sea water. No fossils have been found in these rocks, but they are lithologically identical with members of the Cache Creek group in which Carboniferous fossils have been discovered, and may be traced directly to Fraser river where they join with rocks that have been referred by Dawson to the Lower Cache Creek formation.

An unconformity extending from Carboniferous (probably Pennsylvanian) to Upper Triassic time separates the Cache Creek group from the oldest of the Mesozoic formations referred to in the Coquihalla and adjoining Tulameen map-areas as the Tulameen series. The bulk of this series is composed of submarine andesite flows. Within the Coquihalla area there is intercalated with these a considerable proportion of argillaceous and calcareous sediments and a number of sills of both acid and basic character. The intrusives, however, belong at least in part to later geological periods.

The Tulameen series does not come in contact with any later Mesozoic sediments. Within the map-area younger formations do, however, overlie the Cache Creek group and are regarded as including rocks of both Jurassic and Cretaceous age.

The oldest member of these later Mesozoic formations occupies a belt  $2\frac{1}{2}$  miles wide extending northwesterly across Coquihalla river above the mouth of Dewdney creek. This belt is composed dominantly of slaty rocks in which the writer discovered Mesozoic fossils of Jurassic or Lower Cretaceous age. This palæontological evidence, combined with the results of investigations on other lines, definitely separates them from the Cache Creek group and justifies the position here assigned to them in the geological time scale. Their typical exposure over the greater part of the basin of Ladner creek has suggested their designation as Ladner slates. Although consisting dominantly of fine-grained slaty rocks this belt includes some coarser feldspathic strata resembling tuffaceous greywackes. One narrow conglomerate belt also occurs near the base of the series.

The Ladner slates are overlain conformably by a series of slates, tuffaceous greywackes, and conglomerates, which, although of considerable thickness, occupies a relatively small area. It is most prominently exposed on the divide west of the North fork of Ladner creek. No determinable fossils have been obtained from these rocks, but their lithical similarity to members of the slate belt and their structural conformity with these Ladner slates leave little room for doubt as to their stratigraphic and geological position. They have, therefore, been grouped as the upper division of the Ladner series, of which the Ladner slates constitute the lower.

On their prolongation to the southeast of Coquihalla river the Ladner series underlies with apparent structural conformity a thick series of fossiliferous tuffaceous sediments which, from their occurrence on the headwaters of Dewdney creek, have been named the Dewdney Creek series. A number of fossil collections from these rocks have determined their age as probably Upper Jurassic. They are composed largely of pyroclastic materials that either settled directly or were transported into marine waters with a small proportion of clastic detritus. Overlying the Dewdney Creek series with apparent unconformity is a thick series of deformed Cretaceous sediments ranging from fine, shaly rocks to coarse conglomerates. They are distinguished from the earlier formations by an abundance of coarse, epiclastic materials and the presence of plutonic detritus. Their sandy components resemble arkoses rather than greywackes; the matrix of some of the conglomerates is in many cases difficult to distinguish in the hand specimen from an acid plutonic rock; and the pebbles have in varying proportions been obtained from granitic intrusives.

All the Cretaceous and earlier formations are intruded by bodies of batholithic rocks which occupy nearly 50 per cent of the map-area. They belong to at least two, and probably three, distinct periods of intrusion, ranging from Jurassic to Tertiary. The older types occupy a relatively small area in the southern section of the district. They are sheared and foliated rocks ranging from granites to diorites and are correlated with the Jurassic batholithic rocks of the Coast mountains. They were followed in Cretaceous time by intrusions, chiefly of granodiorite, but including important granite and diorite members. These intrusives occur to the exclusion of other batholithic rocks in the northern part of Coquihalla area and also predominate in the southern part. The granodiorite belt crossing Cedar and Dewdney creeks, and the batholithic rocks exposed in the vicinity of Manson mountain, are both regarded as belonging to this period. A still later phase of batholithic activity is believed to be represented by the quartz diorite exposed between Silver lake and Isolillock mountain. It has been correlated with the Chilliwack batholith of Skagit range<sup>1</sup> and referred tentatively to the Miocene. The smaller areas of quartz diorite exposed near the heads of Dewdney and Cedar creeks may also belong with the Tertiary irruptives.

Unconformably overlying or intruding both batholithic intrusives and Cretaceous sediments are broadly folded volcanic rocks which occupy a single area in the northeastern section. From their typical exposure in the vicinity of Coquihalla mountain they have been named the Coquihalla series. Their age, estimated on structural evidence, is probably Miocene.

Glacial and stream deposits occur in the valleys and have supplied material for the Coquihalla delta. Accumulations of these materials near Othello have diverted the river from its original course through Kawkawa lake, into the narrow gorge it now occupies.

Period	Name	Character -
Pleistocene and Recent		Stream and glacial deposits
	Unconformity	
Tertiary (probably Miocer	ne)	Quartz diorite batholithic intrusive
	Relation not shown	
	Coquihalla series	Pyroxene diorite intrusives basalt and rhyolite flows; acia tuffs and breccias

	Ί	'able	of	Formation	s
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<sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 534. 70994-3<sup>1</sup>/<sub>2</sub>
Period	Name	Character
	Unconformity	
Late or Post Lower-Cretaceous and pre-Tertiary	3	Granites and acid granodiorites in northern part of map-area. Chiefly granodiorites in south- ern part
	Relation not shown	
Probably Cretaceous, but may be Tertiary		Quartz diorite stocks
Intrusive in diorite and granodi relation	orites of northern section; relation ion to granodiorites in southern sect	to quartz diorite stocks uncertain; ion uncertain
Late or Post Lower-Cretaceous and pre-Tertiary	Eagle granodiorite	Chiefly granodiorite
	Probably intrusive	
	Eagle diorite	Chiefly diorite; some quartz- diorite
	Intrusive	
Probably Lower Cretaceous		Conglomerates, grits, arkcse, greywackes, shales, and meta- morphosed equivalents
	Probable unconformity	
Upper Jurassic (may be in part or entirely Lower Cretaceous)	Dewdney Creek series	Chiefly tuffs; tuffaceous shales and slates; some normal clastic sediments
	Relation not shown	
Upper Jurassic?		Granodiorite, quartz diorite, and diorite
	Relation not shown	
Probably Upper Jurassic	Ladner serics (1) Upper Ladner group	Conglomerates; tuffaceous grey- wackes; slates
	Conformity	
	(2) Lower Ladner group (Ladner slate belt)	Chiefly slates; tuffaceous grey- wackes; one narrow conglom- erate belt
	Unconformity	
Triassic (?)	Tulameen group	Volcanic rocks, slates, etc.
	Unconformity	
Carboniferous (probably Penn- sylvanian)	Cache Creek group	Andesite greenstones; chert; slates

# Table of Formations-Continued

# CACHE CREEK GROUP

### Distribution

Rocks referable to this group form a belt averaging over 6 miles wide crossing Coquihalla river in a general northwesterly direction below the mouth of Dewdney creek. Smaller patches also occur farther to the southwest and must at one time have been continuous with the main area. Their original volume has, however, been greatly reduced by intrusive and erosional processes and they are partly concealed by younger rocks. It is hardly likely that they are underlain by older formations, but everywhere within the district the basement rocks are probably younger batholithic intrusives.

### Petrography

The Cache Creek group is represented by three rock types which differ markedly in mode of origin, and in their typical exposures are easily distinguished. These types are volcanic greenstones, cherts, and fine-grained, argillaceous and calcareous sediments. The greenstones are sufficiently well exposed and differentiated to be mapped separately. They are composed chiefly of andesitic lava flows, but contain a small proportion of pyroclastic deposits. The cherts and other sediments, although in places easily separable, are commonly so intricately interbedded as to preclude division.

Greenstones. The greenstones of Coquihalla area were formed during two major periods of extrusion, between which there were doubtless many minor eruptions. They are separable by structural relations only, and are dominantly fine-grained aphanitic rocks, dark green to greyish-green, and possessing a dull decomposed appearance. Many powdered fragments commonly have a smooth talcose feel suggesting alteration to either sericitic or chloritic products. In the railway section they exhibit a notable tendency towards a schistose or slaty structure, due to the intense deformation to which they have been subjected.

Under the microscope these greenstones are seen to be fine-grained augite andesites, but they vary considerably in texture and composition. They are in part slightly, and to a very small degree, notably, porphyritic, either feldspar or pyroxene forming the phenocrysts. The principal constituent is a plagioclase feldspar with the composition of oligoclase or albite-oligoclase. In some members the feldspar is more basic. Plagioclase constitutes from 60 to 90 per cent of the rock, the larger proportions being characteristic of the upper and more acid horizons of the thicker flows. It occurs in part as small, idiomorphic, lath-shaped individuals and in part as less perfect crystal forms. In general the lath-shaped crystals are characteristic of the more acid members, but they are also present where the dark constituents are more plentiful, exhibiting, in this case, a micro-diabasic or even ophitic texture. The important dark mineral is a pyroxene showing an extinction angle like that of augite. It is frequently uralitized to fibrous amphibole and in the more altered varieties very little of the original pyroxene remains. Hornblende may also result from partial or complete solution and recrystallization of the original dark minerals, or may be present as a primary constituent. Orthoclase may be present in very small proportions. Other primary minerals include small grains of apatite, magnetite, ilmenite, and pyrrhotite. Secondary alteration products are always abundant and include uralite, hornblende, serpentine, chlorite, zoisite, epidote, calcite, talc, and hematite.

The greenstone underlying the Ladner series is an augite andesite containing a little primary hornblende and some secondary fibrous aggregates or needles of amphibole that penetrate the feldspar, or are disposed in veins surrounding fragments of a breccia near the slate contact.

The greenstone adjoining the granodiorite contact above Othello affords an interesting variation from the more normal type of augiteandesite. It is a massive, dark green hornblende andesite in which the hornblende appears to be primary and constitutes between 30 and 40 per cent of the rock. Under the microscope the hornblende forms radiating pleochroic green fibres between, or penetrating, the feldspar. The latter is a clear plagioclase of about the composition of andesine. It constitutes a somewhat larger percentage of the rock than the hornblende and occurs in part as phenocrysts in a fine-grained groundmass of smaller hornblende and plagioclase crystals. This greenstone is very similar to that encountered on the Dewdney trail near Beaver lake. It was also observed at other points farther east on this trail, and at Twentythreemile Camp on Skagit river contains some important ore deposits.

The following analysis, by M. F. Connor, was made of as fresh a specimen of the greenstone as could be received and represents as nearly as could be estimated the average composition of the greenstone underlying the Ladner slate belt.

SiO <sub>2</sub>	53.42
$Al_2\tilde{O}_3$	$14 \cdot 12$
$Fe_2O_3$	0.15
FeO	7.26
MgO	7.12
CaŌ	8.08
Na <sub>2</sub> O	4.47
K <sub>2</sub> O	0.63
$-H_2O$	0.42
$+H_2O$	2.53
CO <sub>2</sub>	0.39
$\mathrm{TiO}_2$	0.70
$P_2O_6$	0.03
$\mathrm{SO}_3$	traces
$\mathrm{FeS}_2$	0.36
MnO	0.13
NiO	0.03
$Cr_2O_3$	$0 \cdot 02$
-	00.86

According to the Quantitative Classification this rock is Auvergnose near Camptonose. Its composition, according to Daly's tables of rock analyses, is slightly basic for an average andesite, but is too acid to be included in the basalts.

Intimately associated with the greenstone underlying the Ladner series are a number of areas of serpentine. These are, in general, irregular in outline. They tend to occur along or near fracture or shear zones in the greenstone and thus suggest alteration or replacement of this rock. The source of solutions effecting such a metamorphosis may be the diorite which intrudes the greenstone parallel to the slate contact. The transition from greenstone, in which little or no serpentinization has occurred, into almost pure serpentine, is very abrupt, the zone of transition being sometimes less than an inch in width and usually not over a couple of feet. In this zone two steps in the process of alteration or replacement may be recognized. In the first the typical greenstone, which everywhere exhibits some degree of alteration to saussuritic, chloritic, and uralitic products, is replaced by a carbonate resembling calcite, which probably contains a considerable proportion of magnesium, and a colourless almost isotropic substance of uncertain composition which here and there exhibits a feeble birefringence and a bladed structure resembling a serpentine. A few scattered remnants of feldspar and uralite and some secondary quartz can be recognized. In the second stage, pure serpentine showing beautifully bladed structure and bluish birefringence is developed. Within a few feet of the transition zone the serpentine is commonly intersected by a meshwork of talc and calcite veinlets and contains scattered, irregular areas of these minerals. Farther from this contact practically pure serpentine may form. A few grains of magnetite are usually present, but no trace of other original minerals remains. Occasionally an outline in the serpentine suggests a pseudomorphed pyroxene crystal, but even these are rare. The serpentine presents a minutely fibrous or bladed texture, not unlike that of the adjoining greenstone, and seems to have resulted from the gradual but complete replacement of both feldspathic and mafic minerals by solutions rich in calcium and magnesium, obtained in part from the minerals of the greenstone and in part from solutions originating in the diorite intrusive.

From the frequent occurrence of the serpentine along fracture zones in the greenstone it might be considered that shearing or crushing of this rock had directly influenced its metamorphosis. It is more probable, however, that the shearing occurred at some time previous to this transformation, and thus furnished easy channels for the magmatic solutions effecting the alteration. An analyses by M. F. Connor of as nearly a pure specimen of the serpentine as could be secured, gave the following results:

SiO <sub>2</sub>	38.84
$Al_2O_3$	$0 \cdot 10$
$\mathrm{Fe}_2\mathrm{O}_3$	$6 \cdot 49$
FeO	$3 \cdot 60$
MgO	$36 \cdot 90$
CaO	traces
$Na_2O$	0.13
K <sub>2</sub> O /	0.13
$-\mathrm{H}_2\mathrm{O}$	0.27
$+\mathrm{H}_{2}\mathrm{O}_{2}$	13.03
$\mathrm{CO}_2$	0.23
TiO <sub>2</sub>	
$Cr_2O_3$	0.37
MnO	$0 \cdot 14$
NiO	0.16
	100.26

It is difficult to conceive of a process by which a rock with the composition of the greenstone could be metamorphosed into a serpentine as pure as that indicated in the above analysis. The presence of nickel and chromium in both rocks is of genetic significance, but the small percentage of alumina in the serpentine presents such an obstacle to the preceding hypothesis of the origin of the serpentine as to lead the writer to suggest either that those sections of the greenstone which have been serpentinized were originally more basic than that from which the analysis was made, or, in spite of the lack of either field or microscopic evidence, that the serpentine has resulted from the alteration of basic intrusives akin to the diorite which intersected the greenstone and whose serpentinization has furnished zones of weakness along which shearing subsequently occurred.

Cherts and Other Sedimentary Rocks. It was found impossible to map these rocks separately. Together they have an areal distribution about equal to that of the greenstones with which they are intimately associated.

The cherts are fine-grained, highly siliceous rocks occurring either as bands up to several inches in width alternating with thin partings of shaly or slaty material, or in massive beds commonly many feet in thickness separated by greenstones or sedimentary beds. They vary from dark blue or black to light grey, passing in other directions to yellowish-grey, pink, and nearly white.<sup>1</sup> Those exposures occurring on the bare, glaciated summits usually have a more bleached appearance on the surface than others overlain by vegetable matter. The more thinly-bedded varieties are often greatly crumpled and contorted (Plate V A), but exhibit no open fractures. The shaly material between these beds has, on the other hand, developed a thinly laminated cleavage and, when struck, breaks easily into thin plates or scales. Usually the chert layers are much thicker than the intervening argillaceous partings, but occasionally the latter equal or exceed the chert bands in thickness. In many places the two are so thinly interbedded as to practically lose their individualities, the whole presenting an irregularly laminated appearance. In thin section the cherts are exceedingly finegrained, almost colourless rocks which in polarized light show an intricate grey pattern of interlocking crystalline quartz. The groundmass is traversed by a network of white veinlets and threads of the same mineral, which, however, belongs to a second generation. Near the contacts of large intrusive masses these cherts are somewhat bleached and more coarsely crystallized and commonly contain small garnet crystals.

The argillaceous sediments or slates associated with the cherts are commonly dark grey or black, but also occur in lighter shades of grey with an occasional tinge of pink. The black varieties are mostly lustrous, owing to a considerable amount of black, carbonaceous or graphitic material being smeared over the lamination planes. The slates are not confined to narrow partings between broader chert bands, but also form beds from several inches to several hundred feet thick. These are black, slaty rocks, mostly greatly fractured and jointed, frequently minutely contorted, and, in general, characterized by lustrous cleavage and bedding surfaces. Where iron sulphides are present the rock weathers in shades of

<sup>&</sup>lt;sup>1</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, p. 40 B.

brown and red. In the vicinity of dykes or other intrusive bodies these slates are abundantly intersected by irregular quartz veins. An exposure typical of these rocks occurs in cuttings along the Canadian Pacific railway above Haig.

A few narrow limestone beds have been found associated with these Cache Creek rocks, and some of the slaty members are calcareous. A bed of limestone, 20 feet thick, is exposed on Kettle Valley railway a short distance above Tenmile creek. Other still wider limestone strata have been found in the area of Cache Creek rocks southwest of Nicolum river. These beds vary in colour from dark bluish grey to almost white. In thin section they appear as fine-grained rocks composed almost entirely of calcite, showing minute fracturing and crushing, but very little evidence of recrystallization.

# · Internal Structural Relations

The Cache Creek rocks have been involved in all geological events in the history of the area. Since, however, the principal periods of orogenic activity have occurred since early Mesozoic time and were most active at and after the close of the Jurassic, these Palæozoic rocks are not much more deformed than later pre-Cretaceous or even Cretaceous formations, all of which are closely folded.

The Cache Creek group conforms by its northwest strike to the general axis of deformation for the district, an axis determined by compressional forces acting chiefly from the southwest, preceding—and to a less extent during—the great irruptions of batholithic material in Mesozoic time. The strata composing the group have been intensely folded and, to a certain degree, overturned to the northeast, so that their inclinations are dominantly at high angles to the southwest. Numerous irregularities occur, due to thrusting, faulting, and, in part, to the relative competency of the deformed strata. The minute crumpling exhibited by the thinly banded cherts (Plate V A) was, however, for the greater part, induced during the accumulation and consolidation of these rocks prior to, or during, their early elevation above water to form land areas.

A study of the structure of the Cache Creek rocks exposed along the Kettle Valley railway has shown that there is probably one major synclinal fold in the vicinity of Tenmile creek and an accompanying anticline below Fifteenmile creek. These folds involve the entire section in this district and throw considerable light on the order of superposition and thickness of the series. Measurements across the strike of these rocks, as exposed in this section, indicate that between the granodiorite contact near Othello and the Ladner series near Jessica the Cache Creek rocks have a maximum thickness of 16,000 feet, of which 11,000 feet is composed of greenstones and the remainder of cherts and other sedimentary rocks. It is impossible to state definitely what deformation has occurred between the granodiorite contact and the scattered patches of Cache Creek rocks that occur farther to the southwest near Hope and south of Nicolum river. These small areas have a prevailing northeasterly dip suggesting that they represent lower horizons than the broader belt above Othello. In addition, the slaty rocks near Haig and the finely-banded cherty rocks of Hope mountain strongly resemble, and are nearly in line with, the lower section of Cache Creek rocks exposed on Siwash creek in the area adjoining and to the west of the Coquihalla map-area. The more thickly banded cherts and the limestone strata found in the Cache Creek rocks to the southwest of Nicolum river, may, on the other hand, represent a higher horizon in the series about equal to, or higher than, that section exposed on Tenmile creek where a single narrow limestone bed occurs.

# Tabular Description of Section of Cache Creek Rocks Exposed along the Kettle Valley Railway

(Commencing about one-half mile above Fifteenmile creek at the contact of the Cache Creek group with the Ladner series)

$\mathbf{Fe}$	et			Feet
Appro ate dis alc rail	oxim- stance ong way	Description	Average dip	Estimated true thick- ness
Total	Detail	·		Total
6,100	1,500	Chiefly slaty andesite greenstone showing alteration and mineralization induced by	75° S.W.	3,850
	2,200	Chieffy andesite but including a considerable proportion of serpentine at and on either side of Fifteennile creek. Some intrusive diorite		
	$1,000 \\ 1,400$	Chiefly greenstone including a considerable proportion of diorite intrusive.		
5,700	3,000	Chiefly massive cherty rocks extending on either side of Jessica station.	50° S.W.	2,600
	2,700	Interbedded cherty and slaty rocks intersected by a number of rhyolite and diorite porphyry dykes.		
3,300	1,500	Chiefly slaty andesitic greenstones.	±70° S.W.	2,800
1,000	1,800 600	Chiefly massive andesitic greenstones. Including overturned anticlinal structure. Interbedded slate and chert with small pro- portion of massive greenstone.	65° S.W.	900
2,800	200 200	Finely banded, light-coloured chert. Interbedded slate and massive chert. Chiefly massive greenstone.	±70° S.W.	2,400
2,300	700 1,600	Interbedded slate and chert. Chiefly massive chert—includes section cross- ing Elevenmile crock	±1	2,000
1,500		Chiefly massive greenstones—some porphyritic varieties—good vertical jointing with strike		1,200
300		Cherty and limy rocks forming synclinal struc- ture about 700 feet above Tenmile creek—a fault or thrust of importance may be repre- sented here—separating a limestone bed from		300 (?)
2,000		the following section of greenstones. Chiefly slaty greenstones.	80° N.E.	1,800

${\rm Fe}$	et			Feet
Appro ate dis alo raily	oxim- stance ng way	Description	Average dip	Estimated true thick- ness
<b>Fotal</b>	Detail			Total
1,400 350 6,200 11,000	600 800 2,500 200 200 3,200 2,200	Chiefly slaty greenstones. Chiefly slaty sediments containing a few cherty bands. Massive greenstone. Chiefly cherty and slaty sediments. Finely-banded, light-coloured chert. Chiefly massive chert reaching to Ninemile creek. Massive chert and interbedded slaty sedi- ments. Chiefly soft chloritic greenstone schists includ-	70° N.E.	1,100 300 4,700 6,880
	7,500 1,300	ing a few slaty sedimentary beds—extending to Lear station. Chiefly slaty and massive greenstone, but including some sedimentary beds—poorly exposed over a considerable part of this section. Chiefly massive hornblende andesite inter- sected by aplite dykes and extending to granodiorite contact.		

Tabular Description of Section of Cache Creek Rocks Exposed along the Kettle Valley Railway—Continued

#### External Structural Relations

The Cache Creek group is intruded by all batholithic rocks with which it comes in contact.

An unconformity extending from Carboniferous to Upper Jurassic time is believed to exist between the Cache Creek rocks and the Ladner series. The latter are, however, almost equally deformed and appear, therefore, to have participated in all the great orogenic disturbances that mark the history of this region.

With the exception of short contacts with Cretaceous conglomerates in the southwestern corner of the map-area, the Ladner slate belt is the only sedimentary formation with which the Cache Creek group is observably in contact. The unconformity with the Cretaceous exposures is unmistakable. Pebbles of the Cache Creek rocks are abundant in the Cretaceous conglomerates, and the Jurassic batholithic rocks definitely intrude the one, and as certainly unconformably underlie the other, and supply detritus for its strata.

### Metamorphism

Some references have already been made to the alterations produced in the members of the Cache Creek rocks by the intrusive bodies with which they are in contact. Near their contacts with the larger batholithic intrusives the cherts are bleached and mottled. Under the microscope they are seen to be considerably coarser than their unmetamorphosed equivalents. Some garnets of microscopic size are developed. The slaty sediments also have a baked appearance near the intrusive. Reddish-brown biotite is extensively developed and metacrystals of cordierite have been observed. Quartz veins are numerous both in these and in the cherty rocks which, together with the adjoining country rock, are in many places sparsely mineralized by sulphides and sulpharsenides of iron, copper, and arsenic.

Large pink crystals of axinite were discovered near the contact of a diorite intrusive with the greenstone at the head of the South fork of Ladner creek. Small tourmaline crystals are very abundant in other greenstone areas and may have formed under lower temperature conditions than the axinite. The greenstones are very commonly heavily impregnated with pyrrhotite. In some places other sulphides are abundant, but these as a rule occur in, or close to, the numerous quartz veins that intersect the greenstones. These sulphides were, probably, deposited from aqueous solutions at some distance from the intrusive rocks, or at a late stage in their consolidation. Gold, copper, and silver-lead ores occur in these greenstones, and owe their metallic content to intrusive rocks. In Coquihalla area the gold deposits are of economic value and are confined to the vicinity of the contact of the greenstone with the Ladner slates.

### Mode of Origin of Greenstones

Although the great body of the greenstones seems to be made up of lava flows, some of the dense, green, slaty members, as pointed out by Dawson, represent probably accumulations of fragmental pyroclastic material. These are, however, so greatly altered that little light is thrown on their origin by petrographic study. In some sections they are interbedded with normal slaty sediments from which, except for their green colour, they are almost indistinguishable. Such occurrences speak strongly in favour of a fragmental origin for these members.

The greenstones were, probably, extended under water, for they are intimately intercalated with argillaceous and calcareous sediments which, probably, accumulated at a considerable depta. Although the profile sections show great thicknesses of greenstone, these are commonly so finely crystalline as to suggest that they comprise a series of flows, a suggestion borne out by abrupt changes in composition from point to point, and by the common occurrence of thin beds of chert, or other sedimentary material. The latter indicate that there were many intervals of sedimentation during the accumulation of the lavas and that these flows probably never stood above the waters in which the sediments were being deposited. The absence in these lavas of pillow structure such as is supposed to be characteristic of subaqueous flows, is not considered to invalidate this theory, for such structure, if ever present, might have been obliterated by subsequent deformative processes. The absence of pillow structure in the lava flows of the Tulameen series has been suggested by Camsell as possibly due to such later deformation.

# Origin of the Cherts

The cherts of the Cache Creek group have frequently been referred to as "cherty quartzites" because of their highly siliceous character and their association with fragmental beds. It is conceivable that a wellcrystallized quartzite might be finely granulated by some dynamic disturbance so as to resemble the cherts of the Cache Creek series, but there is evidence of quite a different origin for these rocks. Examination under a microscope shows that typical specimens of these rocks are composed entirely of silica occurring as an exceedingly fine-grained aggregate of tiny crystals of nearly uniform size.

The occurrence of interbedded argillaceous and calcareous sediments also opposes the idea that the cherts were originally coarse-grained rocks. The low relief that is thought to have existed in the neighbouring land areas while these deposits were formed, would not, probably, give rise to thick, arenaceous beds. It seems, therefore, likely that these cherts were not deposited as arenaceous beds and consequently never were quartizes.

Dawson's suggestion that these rocks were "laid down as argillites or silts" because of their association with "black, glossy argillite schist" is offset by the comparative abundance of carbonaceous and other impurities in these argillaceous beds. It is difficult to conceive of sedimentation in which pure beds of clastic silica with impure slaty beds could occur so frequently as to produce the fine banding here exposed.

The absence of any foreign material such as might be expected to occur in any clastic sediment, however pure, points strongly to chemical precipitation rather than clastic deposition. This supposition calls for an explanation of the source of so much silica and of the manner of its precipitation and intimate association with clastic sedimentary strata.

The writer believes that the theory advanced by Davis<sup>1</sup> in explanation of the origin of the Franciscan cherts of California would nearly account for the cherts of Coquihalla area or the Cache Creek cherts in general. The silica is regarded as having been derived from silicate solutions coming in part from the greenstones while the latter were being extruded or were in process of consolidation beneath the sea, and in part from submarine siliceous springs which derived their content from magma reservoirs beneath the sea-bottom. The reactions of these silicate solutions, which were probably alkaline, with salts of sea water, would precipitate gelatinous silica acid contemporaneously with the normal deposition of argillaceous material obtained by erosion from the adjoining low-lying land areas. The rhythmic segregation of the colloidal silica from these mechanical impurities—a phenomenon that has been reproduced experimentally would account for that characteristic banding of cherts and slates which has already been referred to.

This theory is supported by the large proportion of volcanic material in these sections of the Cache Creek rocks; the occurrence of chert bands unaccompanied by clastic material in the volcanic flows; and the nodular character of the chert bands, testifying to the localization in the supply of silicate solutions and to irregularity in the precipitation of colloidal silica.

<sup>&</sup>lt;sup>1</sup> Davis, E. F., Pub. of Univ. of Cal., Dec. 23, 1918, "The Radiolarian Cherts of the Franciscan Group."

Features distinguishing these chert deposits from those of the Franciscan series are : (1) no radiolaria were observed by the writer in the Cache Creek cherts; (2) no red cherts such as are most common in the Franciscan varieties were observed in Coquihalla area, although some are slightly pink; nor are the interbedded sediments ever red although also occasionally slightly pink; (3) the volcanic flows of Coquihalla area are typically andesites, and show no pillow structure, whereas the Californian varieties are mainly basaltic, and pillow structure is pronounced. These distinctions are not, however, regarded as antagonistic to the similarity of the origin of the cherts and in all its essentials this origin is believed to be the same in the two series. The crumpling always exhibited by the narrow chert bands is identical with that shown in the Franciscan rocks. The minute veining characteristic of the Cache Creek cherts is due, probably, to facturing and compression subsequent to their consolidation, the fractures being filled with recrystallized quartz obtained from the cherts themselves, and not introduced after the manner of normal quartz veins.

### Origin of the Slates

The clastic rocks of the Cache Creek series are mainly argillaceous slates, exceedingly fine grained and containing a considerable proportion of carbonaceous matter. A very few limestone beds have been found intercalated with these slates, and some of the latter are slightly calcareous. No coarser clastic materials were observed. The character of these sediments suggests a land surface of low relief covered by a considerable vegetation.

The proportion of clastic to cherty beds in the Coquihalla River section varies from point to point and may be said to depend rather upon the irregularity in the supply of chemically precipitated silica than upon lack of uniformity in the deposition of sedimentary detritus. In the thinly bedded cherts the proportion of slate is almost everywhere less than that of the cherty material, but there are abundant variations in the other sections. Some sections of massive chert 100 feet or more in thickness occur, in which very little clastic material can be found. Again, equal thicknesses of slates are observed with almost no associated cherty beds, indicating a long period of normal sedimentation and volcanic quiescence.

#### Age and Correlation

The Cache Creek rocks of Coquihalla area have been traced to the southeast into rocks assigned by Daly to the Hozameen formation. The Hozameen rocks have so far produced no fossils and were assigned to the Carboniferous period largely on their lithological similarity to the Cache Creek rocks of southwestern British Columbia, in which Carboniferous fossils have been found. The Hozameen rocks also present many points in common with the Chilliwack series from the International Boundary farther to the west. The Chilliwack series is in part fossiliferous and from its faunal content has been assigned tentatively to the Upper Carboniferous.<sup>1</sup> To the northwest the Coquihalla section may be followed to Fraser river, where it forms part of a thick series regarded by Dawson as

<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 515.

in part identical with, and in part probably older than, the typical series of Cache Creek rocks from Thompson and Bonaparte rivers. Those rocks referred to as older than, but probably passing conformably upward into, the typical Cache Creek rocks were stated to be a thick series of grey argillites occurring near Boston Bar and were assigned to a special group known as the Boston Bar argillites. More recently Bowen<sup>1</sup> discovered a single Mesozoic fossil in these rocks on their continuation across Fraser river above North Bend, and from the structural conformity existing between them and the more typical cherts, argillaceous rocks, and greenstones of the Cache Creek series it was thought probable that the Carboniferous rocks might there pass continuously upward into sediments of Mesozoic age. It is, however, very doubtful whether such a continuity exists in the Fraser River section because of the absence of those heavy deposits of limestone which characterize the upper horizons of the Cache Creek rocks near Marble canyon, on Bonaparte river. Thick beds of limestone of similar character also occur in the upper horizons of the Hozameen rocks, which are continuous with both the Coquihalla and Fraser River sections. It seems, therefore, that at the latter localities the Cache Creek group suffered considerable erosion prior to the deposition of the Mesozoic formations.<sup>2</sup>

Mesozoic rocks also overlie the Coquihalla section of the Carboniferous rocks, but are regarded as representing only the younger members of the Boston Bar argillites. Accordingly, the unconformity between Palæozoic and Mesozoic in the Coquihalla area is considered to be greater than that in the Fraser River section.

# TULAMEEN GROUP

#### Distribution

The rocks of the Tulameen group occupy less than 5 square miles in the extreme northern end of the district. They are, however, exposed continuously to the southeast over the Tulameen map-area where they "cover a larger area than any other individual formation and almost as large an area as that covered by all the other formations together."<sup>3</sup> Only a very general description of these rocks will be given here, and the reader is referred to Camsell's report on the Tulameen area.

# Petrography

The members of this group are very similar to types encountered in the Tulameen area and include sediments as well as volcanic rocks. The former are principally grey or black slates, but include a few, thin, limy beds. Other sandy members, especially notable near Independence Camp, have been metamorphosed into hard, white, and finely banded quartzites, showing, in thin section, a secondary development of a green pleochroic amphibole resembling actinolite. Volcanic rocks here, as in the Tulameen area, form the bulk of the group, although their proportion is not as great as that prevailing in the larger exposures to the southeast. They are

Bowen, N. L., Geol. Surv., Can., Sum. Rept., 1912, p. 110.
 See Chapter on "Structural and Historical Geology."
 Camsell, C., Geol. Surv., Can., Mem. 26, p. 37.

commonly dark green, of medium basicity, and include schistose, as well as massive, varieties. The latter may represent, in part, later intrusive sheets or sills. The schistose varieties constitute the greater bulk of the volcanic rocks, and represent lava flows that have developed a slaty structure through later metamorphic processes. They are mostly porphyritic, the phenocrysts being hornblende, augite, or plagioclase feldspar. Alteration has progressed far in all the schistose volcanic rocks, and, to a less extent, in the more massive types. Chlorite, epidote, zoisite, green amphibole, calcite, and magnetite are common secondary minerals, and chlorite and talcose schists are abundantly represented. An interesting member of this group is a crushed granite porphyry occurring as belts or sills up to several yards in width. These represent intrusions subsequent to the formation of the Tulameen group, and are at least as old as any of the Jurassic batholithic rocks of the area and consequently older than the batholithic rocks intruding the Tulameen group in Coquihalla area.

### Structural Relations

As these rocks are the oldest in the northern part of Coquihalla area, and have been subjected to great erosion, neither top nor bottom is exposed and no attempt was made to ascertain their thickness. All members have been greatly deformed and stand, as a rule, at high angles and strike about northwest. These rocks may, at one time, have overlain the entire district, but they have been eroded from all except the small area they now occupy.

The Tulameen rocks are in contact with the Eagle granodiorite, and are also intersected by a number of dykes in the vicinity of this contact and at other points farther removed. The metamorphism effected by the batholithic and smaller intrusions has received attention in other sections of this report and is also discussed by Camsell in his report on the Tulameen area. A number of small areas of hornblende schists were observed to be apparently intruding the Tulameen rocks. They may represent metamorphosed equivalents of the pyroxenite which forms one large, and a number of smaller, bodies in the adjacent Tulameen map-area.

# Mode of Origin

Concerning the origin of the Tulameen group, the writer can do no better than quote in part from Camsell's report on these rocks.

"The Tulameen group comprises two distinct classes of rocks, the one sedimentary and the other volcanic in origin." The origin of the sedimentary rocks "is simply that of true sediments laid down in the usual way on the floor of the sea. The volcanic rocks . . . are lavas which rose presumably through fissures in the earth's crust, and flowed over the surface. No tuffs or rocks of explosive volcanic origin have yet been identified in this group, but they are represented in the Nicola series, with which this group is correlated. The fact that these volcanic rocks are distinctly bedded and interstratified with true sediments, indicates that they are subaqueous in origin, and were extruded over the floor of the sea in which the sedimentary rocks were being deposited." No fossils were found in the Tulameen rocks in Coquihalla area, but some obscure plant remains were discovered in Tulameen area near the mouth of Slate creek and were referred doubtfully by Knowlton to the Triassic. On other lines of evidence they have been correlated tentatively by Camsell with Dawson's Nicola series and with other rocks from Whipsaw creek presumably of Upper Triassic age. The Nicola series is generally referred to the Upper Triassic, but, as stated by Dawson, some Lower Jurassic members may be represented in it. It is less probable, however, for reasons elsewhere outlined in this report, that Jurassic rocks are represented in Coquihalla area where the members of the Tulameen group may be regarded as entirely of Triassic, and probably of Upper Triassic, age.

#### LADNER SERIES

The Ladner series overlies unconformably the Cache Creek rocks in Coquihalla area. It may be divided into two groups. The lower group occupies over 90 per cent of the area covered by the series, and is composed dominantly of slaty rocks. Because of its continuity across the Coquihalla area this group is frequently referred to in this report as the "Ladner slate belt" or more briefly the "slate belt." The upper group is conformable with the rocks of the slate belt and is composed of about 50 per cent conglomerates and tuffaceous greywackes and an equal proportion of more slaty rocks. The only one area of importance occupied by members of the upper group occurs on the divide west of the North fork of Ladner creek.

It is, however, probable that these rocks are equivalent in part to certain horizons of the Dewdney formation occurring on the eastern slope of Coquihalla valley, where fossils of Jurassic or Lower Cretaceous age have been found.

# Ladner Slate Belt

The slate belt occupies a long and roughly rectangular area that crosses Coquihalla river in a general northwesterly direction above the mouth of Dewdney creek and maintains an average width of about  $2\frac{1}{2}$  miles. To the southwest it is unconformably underlain along its entire length by the Cache Creek rocks. To the northeast it comes in contact with later Mesozoic sediments and with coarse-grained granite and granodiorite intrusives of Cretaceous age. Within these boundaries occur the relatively small areas of the upper group of the Ladner series. The entire area of the slate belt is almost exactly half that occupied by the Cache Creek rocks and about 13 per cent of the entire map-area.

Because of its important bearing on a number of gold quartz properties that have been discovered within Coquihalla area the slate belt has been studied in somewhat greater detail than the other formations of the area. Its lithological characteristics are discussed in the chapter dealing with the economic geology of these gold deposits, and some remarks on the structure of the Ladner series are also included there. More attention will, however, be given here to the lithology apart from its economic significance, and somewhat greater stress will be laid on the various members, other than slates, which comprise the so-called "slate belt."

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### Petrography

Slate. The principal member of the slate belt is, as its name implies, a slaty sedimentary rock usually dark grey to black in colour, but including light grey, greenish grey, and green varieties. It commonly weathers rusty brown owing to the presence of sulphides of iron. The slates are, in general, finely laminated, and for the most part the cleavage coincides with the lamination, which has an average strike of north 35 degrees west and dips at high angles to the southwest. Besides this well-defined cleavage the slates are usually intersected by one, and in some cases by two, sets of joints. The prevalent one cuts across the slates almost vertically and at an angle of about south 65 degrees west. The other jointing is less well developed and is more nearly horizontal.

The slates vary greatly in texture, structure, and composition. The more common type is comparatively soft, and gives a characteristic slategrey streak. It is a fine-grained rock, and the cleavage planes mostly have a dull, moderately rough, and somewhat scaly appearance. Many of them show an abundance of small, shiny flakes of colourless sericite, and are sufficiently carbonaceous to blacken the hands. The cleavage surfaces are in many places marked by numerous small, sub-ovoid cavities mostly about 2 millimetres long and pointed at the ends. These are, as a rule, perfectly oriented along the general strike of the rocks. Some thin cross septa are noted in these cavities and are composed, apparently, of argillaceous material. The entire cavity is in places filled with a whitish powder, which has a bitter taste. It is probably a soluble iron sulphate, a result of the decomposition of some original sulphide, either pyrrhotite, or pyrite, as these minerals are very abundant in the slates. The sulphide was almost certainly introduced after the consolidation of the slates, and probably through the influence of batholithic or smaller intrusions. The peculiar orientation and elongate forms of the cavities suggest adjustment to deformational stresses affecting the slates.

The typical slates are commonly very fissile, breaking up into thin plates terminated by joint-planes or more irregular fractures. Less fissile varieties commonly break into longer and nearly rectangular fragments from the size of a pencil to bars several feet long. Where the jointing is less perfect the bars have splintery ends and much resemble broken beams of wood.

The darker slates are carbonaceous and contain iron sulphides, of which pyrrhotite is the most common. Veins of calcite occur and calcareous matter is abundant in most of these slaty rocks, and in some localities forms narrow beds of almost pure limestone.

Variations from the more typical slates are numerous and interesting. Some are distinctly greenish and hand specimens are difficult to distinguish from some of the mashed greenstones of the Cache Creek series. The colour is doubtless due to the occurrence of iron in ferrous rather than ferric form. Colour, is however, only one of many variations notable in these slaty sediments. The fissility as a rule so pronounced in these slates is in places less noticeable, and the beds have a banded massive appearance more resembling argillites than slates. Massive beds are, however, more characteristic of the coarser-grained sediments interbedded with the slates than of the slates themselves.

Hardness is also a variable feature. In most places the slates are comparatively soft, but, in a number of localities, beds several feet thick were encountered which were nearly as hard as hornstone or chert. That this hardness has resulted, in general, from later impregnation of silica, is concluded from the microscopic study of coarser sediments of like hardness.

Under the microscope the finer-grained slaty rocks show well-defined bedding planes commonly minutely contorted. The constituent fragments are mostly associated with an abundance of dark carbonaceous matter, or have been so completely decomposed as to obscure their original character. As a rule a number of small quartz grains may be identified, and in many places small specks or crystals of iron sulphides or their coloured oxides are present. Calcite is common as a primary cementing material and is redistributed in veinlets through the rock. Quartz stringers occur in many places, but are very irregularly distributed. In the vicinity of batholithic intrusions the slates are greatly modified both in texture and composition. Their lithology in this connexion will be discussed later.

Conglomerate. There are a number of coarser types in the slate belt, as a study of the tabulation of the cross-section exposed along the Kettle Valley railway will show. These types have proved of value in determining the structure of the slate belt and the source of the material composing these rocks. They also afford a means of comparison with other formations in the area.

Probably the most interesting and important of these coarser sediments is a narrow conglomerate bed that extends along the base of the slate belt at, or within a few feet of, the contact with the Cache Creek rocks. This conglomerate is exposed at close intervals from the northwestern edge of the sheet to a point nearly 2 miles southwest of Coquihalla river. At its more westerly extension above the head of the Middle fork of Ladner creek it is nearly 50 feet wide, but elsewhere it seldom exceeds a width of 10 feet. It is a fine conglomerate in which the constituent pebbles rarely exceed an inch in diameter and are, in general, coarser where the width is greatest. The matrix is a dark, fissile slate similar to the adjacent slate rock. The pebbles very much resemble some of the underlying Cache Creek rocks, They are characterbut have not been positively identified with them. istically fine-grained cherty pebbles, dark blue, light green, or almost white in colour. Some are undoubtedly fragments of quartz porphyries. Besides these fine-grained varieties there are a few distinctly plutonic pebbles that resemble diorite or gabbro.

Although this conglomerate is a distinctive stratigraphic member in the slate belt, its minor width, and the abundance of slaty matrix, do not indicate any important break in the sedimentation of the slates, nor does its general position somewhat above the base of the slate belt give it importance as a basal formation. Its increased width above the Middle fork of

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Ladner creek indicates that locally there must have been considerable irregularity of sedimentation near the base of the slate belt, and it is possible that the stratigraphic importance of this conglomerate may become increasingly evident as it is traced farther northeast towards Fraser river. It may mark a break in the Mesozoic series. The plutonic pebbles suggest the possibility of early or pre-Jurassic batholithic intrusions somewhere in the vicinity of Coquihalla area.

Greywackes. In addition to this conglomerate there are a number of strata in the slate belt that are markedly coarser than the slates them-selves. These may be divided into two groups. In one, quartz is the predominant mineral; in the other, it forms only a small percentage of the rock. The first type is represented by a number of narrow strata and by two prominent belts, one several hundred feet thick crossing the railway above Tangent creek, and a second, about 100 feet wide, lying midway between Ladner and Boston Bar creeks. In the outcrops these are hard, massive, grey rocks containing conspicuous irregular fragments of black argillite, averaging less than one-quarter inch in diameter. Under the microscope a large proportion of the slide is occupied by a fine-grained, grey, siliceous groundmass through which occur fragments of feldspar and quartz crystals. The feldspar fragments predominate greatly and apparently include both plagioclase and potassic varieties. No rock fragments were identified, but certain areas appear to suggest replacement of such by quartz. Both sericite and calcite occur as alteration products.

The other type of coarse sediments is even more abundant. It forms, in part, the country rock at the Pipestem mine, and was observed at other points not far from the contact of the Cache Creek rocks. It has also been discovered on the east side of Coquihalla valley at widely distributed points. This type has about the hardness of the finer-grained slates, and near the surface has a very decomposed appearance and weathers in shades of brown. Freshly fractured surfaces are nearly black. Under the microscope these rocks show a fine, dark, argillaceous groundmass in which are scattered fragments of fresh-looking feldspars, a smaller proportion of quartz crystals, and grains of volcanic and felsitic rocks. Calcite is a common alteration product.

Although different in general appearance these two rock types are suspected of having been much the same at the time of their formation. The higher percentage of silica in the first type is believed to be due to induration by juvenile aqueous solutions rich in silica, derived from the same magmatic source as the igneous bodies intruding the slate belt.

These coarse sediments, as determined from parts which have escaped silicification, are distinctly unlike normal sedimentary rocks. This is evident from the abundance of fresh feldspar crystals; small proportion of quartz grains; numerous angular fragments of rocks, most of which are definitely lavas or cherty felsitic rocks of doubtful origin; and high percentage of fine, dark, almost isotropic groundmass. The sediments are, probably, of tuffaceous origin, but it is difficult to say to what extent they represent a subaqueous accumulation of volcanic ejectamenta or what proportion is due to the rapid erosion of older volcanic rocks. The uniformity of these sediments in texture, composition, and thickness, over wide areas, and the abundance of what appears to be carbonaceous matter, suggest that they are chiefly the product of erosion of a pre-existing land mass. That this erosion was rapid and that the distance transported was not great, is evidenced by the freshness of the feldspars and the angularity of the constituent fragments as a whole. From the abundance of these coarser rocks and their wide distribution throughout the slate belt it might appear that the intervening fine-grained slates were themselves formed from the same materials. Owing, however, to their more complete comminution and consequent more rapid alteration, it was found to be impossible to discover their true character by microscopic study alone.

In consequence of this difficulty a composite sample of these finegrained, slaty rocks was taken across the entire width of the slate belt in the vicinity of the Kettle Valley railway. An analysis of this sample was made by M. F. Connor of the Geological Survey with the following results:

SiO <sub>2</sub>	61.36
$Al_2 \tilde{O}_3$	$16 \cdot 20$
$\operatorname{Fe}_2O_3$	0.88
FeO	$5 \cdot 17$
MgO	2.00
CaO	$1 \cdot 40$
Na <sub>2</sub> O	2.57
$K_2O$	1.65
$-H_2O(at \ 110^{\circ} C.)$	0.33
$+H_2O(above 110^{\circ} C.)$	5.87
CO <sub>2</sub>	0.46
$\mathrm{TiO}_{2}$	0.70
$P_2O_6$	0.11
S O <sub>3</sub>	0.08
$\mathrm{Fe_7S_8}$	0.29
${ m FeS}_2$	0.62
MnO	0.04
NiO	
Organic matter	0.82
	100.55

### Remarks

The analysis of this sample is distinctly different from that of a normal argillaceous sediment in that the soda content is notably in excess of the potash. In this respect it resembles an analysis of an igneous rock rather than a sediment, and, consequently, lends considerable support to the view already expressed by the writer that the sediments of the Ladner series are of tuffaceous origin and that they have accumulated rapidly as compared with normal argillaceous sediments, and have, consequently, not been afforded that opportunity for decomposition which falls to the lot of such clastic rocks. The presence of organic matter suggests an indirect rather than a direct accumulation of the tuffaceous material, but does not exclude the possibility that part of the material composing the rocks was accumulated directly as contemporaneous volcanic ejectamenta. The high percentage of iron sulphides, frequently referred to in discussing the Ladner rocks, is very noticeable in this analysis. The presence of marine fossils, calcite, and intercalated limestone beds or calcareous strata in the rocks of the slate belt, are indicative of normal submarine sedimentation. The fact that these fossils occur in both coarse and fine-grained beds is additional evidence of similarity in origin. The wide distribution of scattered individuals of only one species of fauna is, however, an indication that conditions during sedimentation were unfavourable to animal life.

# Internal Structural Relations

The average strike of the Ladner slates is about north 35 degrees west. The dip varies on either side of the perpendicular, but is dominantly at high angles to the southwest. The general structure is a syncline whose axis crosses Coquihalla river about 3,000 feet above the mouth of Ladner creek. There are also indications of an anticlinal structure near the northern contact of these rocks with the Cretaceous sediments on the divide between Cedar creek and Coquihalla river. A minor anticlinal fold strikes up Ladner creek from its mouth, and is bounded on either side of this stream by well-defined thrust planes.

The northeast limb of the syncline is cut off by the granodiorite north of Coquihalla river. The southwest limb, however, is complete. Its thickness, as measured from the railway section, is approximately 6,000 feet, but the apparent thickness varies from point to point owing to the more intense deformation and thrusting in some sections than in others.

To the southeast the greater part of the slate belt is exposed to the south of Dewdney creek, but a narrow strip of slate, regarded as forming a part of the slate belt, follows in a general way up the left bank of Cedar creek, where it is faulted off from the Cretaceous sediments to the north. This strip dips about 40 degrees southwest and may be a part of the northeast arm of the syncline already mentioned. In this case the entire Dewdney Creek series accumulated within this synclinal basin or trough which apparently plunges slightly toward the southeast. The slate belt is, consequently, likely to be less well-exposed in this direction beyond the Coquihalla map-area than to the northwest in the direction of Fraser river.

To the south of Coquihalla river, and on the divide between this stream and Cedar creek, there is evidence of an anticlinal fold passing unconformably under the basal conglomerate of the Cretaceous sediments. The axis of this fold could not be located, but it would lie near the neck of granodiorite intrusive which forms a large apophysis from the main body of the batholith and has highly metamorphosed the slates in its vicinity. Farther to the southeast the major syncline of the slate belt broadens out, and in this direction is faulted against the Cretaceous rocks without the suggestion of anticlinal structure seen on the Cedar-Coquihalla divide.

# Section of Ladner Formation along Kettle Valley Railway, Beginning at Syncline between Portia and Ladner Creek

	T GGI
Contorted slates penetrated by a diorite dyke 20 feet wide containing many quartz stringers	150
Coarser beds of massive greywacke	100
Friable slates including small proportion of coarser greywackes-attitude	
irregular-perpendicular jointing running S. 40° W	300
Surface deposits obscure section for	400
Black fissile slate containing scattered crystals of andalusite—attitude N. 35° W., perpendicular	350
Greatly contorted section of black slates including two important thrusts and many minor faults and a minor anticlinal structure running up the bed of Ladner creek	900(?)
Contorted black and grey slates well mineralized chiefly by pyrrhotite. Some more massive beds of greywacke showing gradations into slates—one important "syenite" dyke near overthrust west of Ladner creek—other smaller dykes. Numerous irregular quartz veins and some limy strata and calcite veins, average attitude N. 35° W., 75-90 degrees southwest	2,500
Black slates and massive greywackes—N. 35° W., 80 degrees southwest,	850
"Syenite" dyke or sill 12 feet wide, carrying arsenopyrite, pyrrhotite, and pyrite with values in gold, crossing the railway 300 feet west of bridge over Tangent creek	
Chiefy dark fissile slates_attitude N 35° W 70.80 degrees southwest	700
Chieffy data home states autoude 11.00 W., 70-00 degrees southwest	
	6,150
Bottom of section. Contact with greenstone of Cache Creek series.	

#### External Structural Relations

To the southwest the Ladner slates overlie the Cache Creek rocks unconformably and, where they have not been cut away by batholithic rocks, also pass unconformably under, or are faulted against, the Cretaceous sediments to the northeast. They pass conformably upward into the Upper Ladner group and are apparently, but not certainly, conformable with the overlying Dewdney Creek series, some of whose members bear a strong petrological resemblance to the tuffaceous greywackes of the Upper Ladner group.

In general there is a marked concordance in the attitudes of the Ladner slate belt with those of the other bedded formations with which it comes in contact. This, combined with the universally high dips that vary in a most confusing manner on either side of the perpendicular, has often made it extremely difficult to recognize a major structural fold or to distinguish conformities from unconformities by structural evidence alone. There are, further, both older and younger rocks than those constituting the Ladner series which, in the hand specimen, are almost identical in appearance; and where, as frequently happens, these occur at or near the contact of the Ladner series, the line of division between the two cannot be located with accuracy without a microscopic study of the rock specimens.

Feet

#### *Metamorphism*

The Ladner slates have been subjected to dynamic and thermal metamorphism on both a regional and local scale. Orogenic activity has resulted in their intense deformation in the vicinity of thrusts or folds, in the high and overturned dips, and in much shearing, faulting, and thrusting of the beds. Thermal metamorphism is most pronounced near the contact of intrusive batholithic rocks, but is also noticeable where any of the numerous dykes or sills intersect these slates. The zone of contact metamorphism induced by batholithic intrusion has a width measurable in hundreds of yards. Close to the intrusive the slates are intersected by many dykes, some of which represent apophyses from the batholith and are frequently nearly as coarse in texture. In this zone of apophyses the slates commonly vary from purple to brick red. A reddish-brown biotite is the most conspicuous mineral developed in this contact zone. Welldeveloped acid plagioclase crystals have been observed in the slates within a few inches of the actual contact (Plate VII A). The constituent minerals of the slate are mostly recrystallized, and some igneous material has been injected, particularly along the cleavage planes. Farther from the contact, but still within the red biotite zone, small metacrystals of cordierite filled with minute inclusions are prominent, and still farther out in the slates and extending beyond the limits of the red biotite, and alusite (chiastolite) is in many places very conspicuous, but its crystals rarely exceed 2 or 3 millimetres in length. One instance of a contact metamorphosed limestone was observed along the granodiorite contact to the northwest of Portia where an outcrop, less than a yard wide, of a rock composed chiefly of red garnets and fibrous white tremolite, evidently marks the original position of a limestone bed in which very little calcite remains. The garnets average about one-quarter inch in diameter.

More information regarding the contact metamorphism of the slate belt, and its relation to the ore deposits occurring in these rocks, is given in the chapter on economic geology.

### Age and Correlation

The age of the Ladner slates cannot be definitely fixed until more is known of the fauna which they and the overlying formations contain. Fossils from these slates, obtained at the Pipestem mine, were fairly well preserved but were all of one kind, an unknown species of *Belemnites* which was reported by McLearn to be probably either Jurassic or Lower Cretaceous. Scattered *Belemnites* have been obtained from a number of other localities and appear to be the only fossil represented in these rocks. However, a better fauna was obtained from the overlying Dewdney Creek series and McLearn reported the probability of it being Jurassic rather than Cretaceous. There is, moreover, an apparent unconformity between the Dewdney Creek series and those sediments in this area which have been placed in the Lower Cretaceous. It is, therefore, highly probable that the underlying formations are pre-Cretaceous and, from their faunal content, Jurassic.

Beyond Coquihalla area the Ladner slates extend northwest across the upper valley of Siwash creek and thence to Fraser river, where they are included in the Boston Bar argillite series. On Siwash creek the slates were grouped by Bateman with the underlying Cache Creek rocks and to the whole was given the name Siwash Creek series.<sup>1</sup> It was correlated with the Lower Cache Creek formation. That there is a distinct unconformity in the Siwash Creek series now seems certain. The writer found Mesozoic fossils (Belemnites) in the slates of the upper section. These slates were traced directly from the Ladner slate belt and undoubtedly represent the same formation. The writer also examined a section of the Boston Bar argillites exposed along the Canadian Pacific railway above North Bend. It was in these rocks that Bowen found a single Mesozoic fossil<sup>2</sup> and by this discovery apparently confirmed the opinion formerly held by Dawson that post-Palæozoic rocks were probably included in the geological section exposed along Fraser river in this vicinity. Owing to their apparent structural conformity with rocks more typical of the Cache Creek series of Carboniferous age, these argillites might be regarded as Triassic in age and, because of some similarity to the Ladner slates and their apparent continuity from Coquihalla to Fraser river, it might, therefore, be assumed that the Ladner slates were also Triassic. Structural and palæontological evidence in the Coquihalla area points, however, to the age of these slates as belonging to a later period in Mesozoic history and, consequently, it is probable that the Boston Bar argillites also include post-Triassic horizons. On the other hand it is not improbable that this series of argillites from Fraser river contains strata which are older than any member of the Ladner series and belonging to an earlier geological period. There is a certain lithical resemblance between certain members of the Boston Bar series as exposed near North Bend and other argillaceous rocks of the Tulameen series from both Tulameen and Coquihalla mapareas. In the Coquihalla area the Tulameen rocks are regarded as of Triassic and probably Upper Triassic age. Consequently, should an identity between any member of the Boston Bar argillites and the Tulameen series be established, the former must be regarded as including an unconformity below that section whose continuity with the Ladner series has been proved. The base of such a conglomerate as that occurring near the base of the Ladner series might mark such a break in Mesozoic sedimentation.

# Upper Ladner Group

#### Distribution

The Upper Ladner group occupies less than 3 square miles and is typically exposed on the divide west of the North fork of Ladner creek. A smaller area, presumably of the same group, occurs south of Portia between Coquihalla river and Dewdney creek.

<sup>&</sup>lt;sup>1</sup> Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1911, p. 126. <sup>2</sup> Bowen, N. L., Geol. Surv., Can., Sum. Rept., 1912.

# Petrography

This group is distinguished from the rocks of the Ladner slate belt chiefly by its greater percentage of coarse sediments. A conglomerate member is situated at the base of the group and separates it from the underlying slate belt. This conglomerate is associated with a large proportion of grit and, in all, has a total maximum thickness of approximately 1,000 feet. The larger pebbles are rarely over 6 inches long and are mostly tabular fragments of slate or black shale which are arranged parallel to the bedding planes. The other pebbles are mostly much smaller, more rounded, and composed chiefly of fine-grained, hard, felsitic rocks of more doubtful origin. The matrix is a moderately coarse grit or greywacke which elsewhere forms beds of its own and altogether constitutes the greater part of the so-called conglomerate belt.

In the hand specimen these greywackes vary from coarse to finegrained, granular rocks. The finer varieties are commonly dark grey to black and the coarser members more nearly a greenish grey. In both varieties a few scattered, grey, felsitic pebbles up to an inch in diameter were observed. Under the microscope the greywackes are seen to be highly feldspathic rocks in which fresh, angular feldspar grains constitute the greater part of the slide. Fragments of cherty and volcanic rocks are also abundant, but quartz grains occur in a very minor proportion. In the fine-grained, dark coloured rocks an almost isotropic, ashy groundmass occupies a great part of the slide, but in the coarser grits it is less abundant. Calcite is a common secondary mineral and is found replacing all except the quartz fragments.

The upper section of the Upper Ladner group is composed of fine-grained, black or dark grey, platy slates very similar to members of the Lower Ladner group.

# Structural Relations

The rocks of the Upper Ladner group form a compressed syncline lying entirely within the Lower group. The underlying member is the conglomerate belt, composed of conglomerate, grits, and tuffaceous greywackes with a total thickness of not more than 1,000 feet. Above these coarser strata is a belt of platy slates 800 feet thick, forming the upper horizons of the syncline. All members strike about north 50 degrees west, and are almost vertical or dip at high angles to the northeast. The smaller area of these rocks on the divide south of Portia has no conglomerate member but is composed chiefly of coarse greywackes and platy slates. Neither its geological boundaries nor its thickness could be closely determined, because of the lack of adequate exposures, but its lithology and structure are sensibly the same here as on the Ladner Creek divide.

### Mode of Origin

The manner of accumulation of this group is regarded as essentially similar to that of the underlying Ladner slates. The abundance of fresh, angular feldspar fragments is evidence of rapid accumulation. The source of the material might be in part credited to the deposition of crystalline and lithic tuffaceous material as volcanic ejectamenta, and in part to erosion of nearby tuffaceous and extrusive volcanic rocks. The presence of many lava fragments, as well as others of uncertain origin, might have resulted from either of these methods of accumulation. On the other hand the well-rounded pebbles in the conglomerate, and the fine carbonaceous material in the finer sediments, suggest a more normal clastic origin The large fragments of slate in the conglomerate are for these sediments. believed to be of intraformational origin, and to have been derived from the underlying slates of the Ladner slate belt before these had been well consolidated. It would appear that vulcanism was active at the time these sediments were laid down; that accompanying this vulcanism there were certain minor structural disturbances sufficient to effect some deformation of the slate belt; that erosion was for a time accelerated and intraformational slate fragments torn from the partly consolidated slate floor and mixed in with more rounded pebbles that had been transported from a greater distance; and that, although some volcanic ejectamenta may have settled directly into the sea, the greater part of the material composing this group was obtained by the rapid erosion of adjacent volcanic detritus that had accumulated in part at least from contemporaneous volcanic eruptions.

The platy slates which form the upper 800 feet of this group mark a return to more quiescent conditions when erosion was less rapid, but the source of material essentially the same.

#### Age and Correlation

The Upper Ladner group has been regarded on both structural and lithological grounds as conformable with the underlying rocks of the slate belt. No recognizable fossils have been found in the upper group, but specimens showing imprints of what are undoubtedly organic remains were observed and a more careful search would probably result in the discovery of identifiable forms.

These rocks are possibly the same as the Hidden Creek series described by Bateman<sup>1</sup> from the Siwash Creek area. They were said to be composed of "a series of arkoses and greywackes occurring in the vicinity of Hidden creek, a tributary of Eightmile. The rocks are made up of quartz, feldspar, calcite, and small fragments of andesitic and trachytic tuff. Their relation to the Siwash series and granitic rocks has not been definitely established."

From their structural conformity with, and their lithical resemblance to, members of both the Lower Ladner group and the succeeding Dewdney Creek series, the rocks of this group are tentatively regarded as of Jurassic, and probably Upper Jurassic, age.

<sup>&</sup>lt;sup>1</sup> Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1911, p. 127.

# DEWDNEY CREEK SERIES

### Distribution

The name Dewdney Creek series has been applied to a group of tuffaceous sediments that occupy a single area of about 15 square miles in the basin of Dewdney creek above the mouth of Cedar creek. Occurring as it does at elevations over 3,000 feet this series is for the most part well exposed. It is not probable that these rocks underlie to any great extent the younger sedimentary formations of the district, but from their closely folded character and the vigorous erosion to which they have been subjected, it is certain that they once covered an area much greater than they now do.

# Petrography

The Dewdney Creek series is composed almost entirely of tuffaceous rocks which, as far as could be ascertained, have all been laid down in marine waters. These rocks are all hard and well compacted, differing markedly in this respect from the Tertiary volcanic tuffs of the Coquihalla series. They contain thinly bedded as well as very massive strata, and in practically all horizons a few scattered fossils have been obtained. They vary from exceedingly fine-grained, cherty hälleflintas to coarse, granular tuffs.

The series varies greatly in composition, texture, and colour, as well as in its manner of accumulation. Vitric, lithic, and crystal tuffs have been recognized, but the bulk of the rocks contain both crystal and rock fragments. Some horizons are composed almost entirely of equigranular lapilli, whereas others are made up of a heterogeneous aggregate of both fine and coarse materials. The predominating colours are green and black, but shades of grey, brown, and red also occur. In general the lower beds of the series are composed of the coarser materials and are dominantly green as contrasted with the upper sections where dark, finegrained rocks prevail. There are, however, many exceptions to this generalization. In the following petrographic descriptions the Dewdney Creek series is divided into: (1) a lower section of crystal-lithic and lithic andesite tuffs; (2) an intermediate section of crystal-lithic tuffs; and (3) an upper section of vitric and crystal tuffs.

Lower Section of Crystal-lithic and Lithic Andesite Tuffs. These tuffs are the oldest members of the Dewdney Creek series. They are extensively exposed on the divide between Cedar and Dewdney creeks and on the ridge following around the head of the East fork of Dewdney creek. They also occur on the northern slopes of Goat mountain, overlooking Dewdney creek, and have been recognized on the divide west of the head of the South fork of Dewdney creek, overlooking Peers river. The entire thickness of this section is somewhat over 4,000 feet.

These tuffs vary from dark green to greyish green and include the coarsest as well as some of the finest tuffs in the Dewdney Creek series. The coarser varieties are by far the most abundant. They vary in composition not only across the strike of their beds but along it. In part they are distinctly granular and fragments of black argillite or shale and of light grey felsitic cherty rocks are conspicuous. The latter are frequently so smoothly rounded as to resemble normal clastic grains or pebbles. Other fragments are undoubtedly volcanic. Some of the strata are more homogeneous in texture and so crystalline and massive as to be indistinguishable in the outcrop from lava flows. Under the microscope the two varieties vary markedly. The more granular specimens (Plate VII B) contain many rock fragments of varying composition and texture interspersed with numerous crystals of feldspar and a few of quartz. The more massive type is largely composed of fragments of porphyritic lavas with a subordinate proportion of small feldspar crystals. The composition of the lava is about that of an andesite. The matrix or groundmass is very similar in the two types, but is more abundant in the crystallithic than in the lithic andesite tuffs. It is light grey to dark grey, forms an almost amorphous aggregate showing numerous tiny microlites, and, in general, much resembles a volcanic ash. Other minerals prominent in these tuffs include brownish-red biotite, fibrous acicular green or almost colourless amphibole, sericite, epidote, zoisite, and calcite.

The two types included in this section are in part interbedded and may represent variations in the same stratum. It appeared, however, that the crystal-lithic tuff predominated along the edge of the series on the divide between the extreme headwaters of Dewdney and Cedar creeks and also extended for a short distance to the south of the head of the Dewdney Creek trail. The more homogeneous lithic tuff is common in all other areas occupied by this section of the Dewdney Creek series.

Although most of this section is composed of moderately coarse to coarse tuffs there are some very fine-grained members. These are of local occurrence and at the most only a few fect thick. Many show rapid gradations in a single hand specimen from the coarser and more typical types. These fine-grained tuffs are mostly massive, fairly hard, and in some cases cherty rocks varying in colour from green to dark purplish red. They appear to be composed of volcanic ash in which some secondary minerals such as biotite and epidote have developed. Their specific gravity is very nearly 2.73.

The tuffs comprising this lower section almost everywhere contain scattered *Belemnites* and these appear to be the only fossil represented. Their occurrence to the apparent exclusion of all other types both in these tuffs and in the underlying Ladner slates is rather remarkable and indicates, if not an equivalency in age, at least a similarity in existing conditions of sedimentation.

Intermediate Section of Crystal-lithic Tuffs. The rocks constituting this group are distinguished from the lower section by their dark colour, well-bedded structure, and finer texture. They also contain a greater variety of fossils. This section is about 3,500 feet thick. The lower 1,000 feet is interbedded with the rocks comprising the lower section of the Dewdney Creek series just described. The upper 2,500 feet forms a closely compressed synclinal belt standing nearly on edge and striking north 20 degrees west across Dewdney creek between the batholithic contact  $6\frac{1}{2}$  miles from the mouth of the creek and a point less than half a mile above the junction of the South and East forks of Dewdney creek. Farther to the southeast these rocks are intruded by a stock of quartz diorite and are partly obscured by later strata occupying the Tulameen Mountain ridge. Their areal extent is less than that of the lower section of tuffs, but their thickness is nearly as great.

These rocks are dominantly dark-coloured, varying from a bluishgrey to brown and black. They frequently show thin bedding and a banding in brownish and black colours. They are moderately hard and very compact rocks, and where the bedding is not recognizable have a black basaltic appearance due in part to their colour and hardness, and in part to reflection from the faces of crystal particles and abundant small scales of mica.

Under the microscope they show many irregular angular fragments of clear or partly altered feldspars, together with a smaller proportion of quartz and fine-grained lithic lapilli some of which are undoubtedly fragments of lava. A fine, ashy matrix constitutes a much greater percentage of these rocks than it does of the tuffs of the lower section. The average size of the larger fragments, too, is considerably smaller, but the proportion of feldspar crystals is greater than in the underlying tuffs.

Variations from the more normal type are of frequent occurrence, but in all they constitute only a small proportion of the entire section. Some exceedingly fine-grained specimens were obtained, which, except for their black colour, much resemble the green and red hälleflintas from the lower section of the series. These give a ringing metallic sound when struck with the hammer, break with a conchoidal or feathered fracture, and show no lamination planes. Their specific gravity is nearly 2.73. Other varieties very similar in other respects to these black hälleflintas are finely bedded in alternate black and brown laminæ, usually a fraction of a millimetre in width.

The lower 1,000 feet or so of these tuffs occurs in beds from less than five to several hundred feet in thickness, interbedded with the coarser and more massive green tuffs of the lower section of the Dewdney Creek series. This intimate intercalation has prevented the separate mapping of the two sections, but has assisted in other ways in interpreting the structure of the entire series.

In addition to their lithological characteristics the tuffs from this intermediate section are distinguished from those of the lower division by their more abundant and more varied fauna, the significance of which will receive some attention when discussing the mode of origin of the Dewdney Creek series.

Upper Section of Crystal Tuffs (Tulameen Mountain Section). The members of this section of the Dewdney Creek series are best exposed on the ridge which extends around the head of the South fork of Dewdney creek, from an elevation of 6,000 feet on the divide north of Tulameen mountain to about the same elevation on the southern shoulder of Goat mountain. These rocks within Coquihalla area are confined almost entirely to the upper 1,500 or 2,000 feet of this ridge and are consequently of less areal extent than either of the other sections of the Dewdney series.

The position of this section is not definitely established, for, although the rocks are well exposed, their structure has been complicated by thrusting and faulting, and there are many minor irregularities in the attitude of The lithology of these rocks does not help much, for they are the beds. distinctly different from the sections already described and do not include intercalated members which are similar to others in the series. The fossils obtained from these rocks have tended rather to confuse than to elucidate. The assignment of these rocks to a position overlying the other sections of the series accords with the greatest number of observations, but this section may include an unconformity above which rocks of later Mesozoic age are represented. The rocks of this section are mostly fine-grained, but contain some moderately coarse strata. They are mainly of pyroclastic origin, but include some more normal sedimentary material.

Fine-Grained Vitric and Crystal Tuffs. The ridge extending north from Tulameen mountain between elevations of 6,000 and 7,000 feet includes a section of massive, hard, fine-grained rocks, varying in one direction from grey to almost white and in another from grey to purple, brown, and dark red. A thin section of a white specimen afforded an excellent example of a partly devitrified tuff composed entirely of comminuted fragments of glass showing characteristic bogen structure (Plate VIII A). Other specimens more nearly resembled fine-grained crystal tuffs in which small, angular crystals of both quartz and feldspar abound in an ashy groundmass. Small granules of epidote and some calcite were noticed and are probably both of secondary origin. The calcite may originally have been precipitated from sea-water, as the presence of a few scattered belemnite fossils indicates that these tuffs in common with other members of the Dewdney series accumulated in marine waters.

Coarser Crystal Tuffs with Slaty Sediments. The entire peak of Tulameen mountain is composed chiefly of coarse, massive tuffs, interbedded with slaty rocks, and except in coarseness of texture, not essentially different in composition from the finer-grained tuffs just described. They vary through shades of grey to almost black, and possess a fairly well-defined strike of north 45 degrees west and a dip at high angles to the southwest. These coarser crystal tuffs form massive beds, averaging about 5 feet in width, alternating with narrower strata of black, platy slates. The latter probably represent returns to more normal sedimentary deposition. On their strike of north 45 degrees west they are carried across the valley of the South fork of Dewdney creek and along the summit of Goat mountain, where they may be recognized by this peculiar alternation of strata. Under the microscope these tuffs from Goat mountain are somewhat similar to members of the intermediate section of the Dewdney Creek series. They contain a large proportion of feldspar crystals and an assortment of lapilli which appear to be chiefly fragments of lava. The matrix has much the appearance of a volcanic ash. Epidote, zoisite, calcite, and brownish biotite are occasionally abundant as accessory minerals.

Some beds very similar to the Tulameen Mountain rocks were encountered about half-way along the divide which joins Goat mountain to Tulameen peak and, as these beds dip in the opposite direction, or to the northeast, they probably form the other arm of a syncline, and are consequently underlain to the north by the finer-grained tuffaceous rocks just described.

Fossil Hill Crystal Tuffs (?). To the west of Tulameen peak lies a conical mountain which is referred to in this report as Fossil hill because of its important faunal content. This peak, together with the ridge lying to the west of it, is composed of fine-grained rocks resembling crystal tuffs, varying from light grey to dark purplish red and very similar in composition to the fine-textured tuffs north of Tulameen mountain. They contain fossils which have been regarded as either Jurassic or Lower Cretaceous in age.

Under the microscope these rocks consist of small, well-defined, and very angular fragments of feldspar, lava, and quartz, the latter being more abundant than in most of the rocks of the Dewdney Creek series. The matrix has an ashy appearance and is irregularly stained by the decomposition of iron sulphides present in the rock. Accessory minerals include pleochroic grains of epidote, reddish-brown to colourless mica scales, and some green chloritic mineral. The coloured mica is particularly abundant near the quartz diorite intrusive which occupies the basin of the South fork of Dewdney creek. Near the contact the Dewdney Creek rocks have a purplish to dark red colour. To this intrusive is also due the heavy impregnation of iron sulphide in some members of these rocks.

### Internal Structural Relations

Some attention has already been given to the order of superposition and structure of the Dewdney Creek series in the descriptions of the different sections of these rocks. They appear to be underlain by slaty rocks of the Ladner series, with which they form a closely compressed syncline complicated by minor folds and flexures and much thrusting and faulting. It is also believed that the transition from the Ladner series, if not actually conformable, represents a disconformity of comparatively short time interval. The axis of the syncline is continuous to the southeast of the main synclinal axis of the Ladner series. In this direction it follows approximately the valley of Dewdney creek to a mile or so below the junction of the East and West forks of this stream, above which point it swings more to the south and crosses the summit of the Coquihalla divide about a mile north of Tulameen peak. The structure is particularly complicated along the Tulameen Mountain ridge by additional deformation and also by an original irregularity of deposition of the tuffaceous materials, so that the main synclinal axis of the Tulameen Mountain section does not coincide with the principal axis for the series but lies parallel to it over a mile to the southwest.

The most important thrust occurs on the northeast flank of Goat mountain about 300 feet below the summit. It strikes north 45 degrees west and has a dip of 70 degrees southwest. By this thrust the sediments to the southwest composing a part of the Tulameen Mountain section have been carried to the northeast over other members of the series, which

are here represented mainly by the green tuffaceous rocks of the lower section, dipping at high angles to the northeast. To the southeast this thrust may cross the South fork of Dewdney creek, but its position on the Tulameen Mountain ridge was not definitely located. To the northwest it may be continuous with that one observed on the Kettle Valley railway below the bridge over Ladner creek. In addition to this thrust many other structural breaks, mostly having the character of reverse faults, were observed and are particularly common along the Tulameen-Goat Mountain ridge. The intervening strata are usually much contorted and are locally thrown at various abrupt angles to their general course.

The total thickness of the Dewdney Creek series may be distributed among its three sections as follows:

 $\mathbf{Fcet}$ 4,000 Lower section (not including intercalated members of the Intermediate section). Intermediate section (including members intercalated with the lower section)... 3,500 Upper or Tulameen Mountain section<sup>1</sup>

### Top

1. Fossil Hill section of fine-grained, massive, light grey to dark-coloured	`
crystal and crystal-lithic tuffs—altitude variable—average dips	1 700
2 Tulameen Mountain real-massive coarse-grained ervetal lithig	1,700
and lithic tuffs with intercalated narrower strata of slaty and	
sandy material greatly faulted	800(?)
3. Tulameen Mountain section of vitric and crystal tuffs (chiefly)—much	
faulted and deformed $\pm$	1,000
Total thickness	.11,000

Partial Section of Dewdney Creek Series to the Northeast of Dewdney Creek Following Up Small Tributary 8 Miles Above the Mouth of Dewdney Creek

	Between Dewdney creek and trail crossing rocks obscured-	Feet
	Coarse to fine-grained, dark, detrital tuffs, well pyritized,	800
	attitude N. 15° W., dip vertical or high angle to south Black, fine-grained, detrital tuffs—intersected by a number of narrow diorite and lamprophyre dykes. Occasional	190 190
	fossil Belemnites observed. Attitude N. 15° W., dip vertical	310
	Coarse, dark tuff bed	20
Intermediate	Fine-grained, dark, detrital tuffs, well banded	100
section	Concealed.	175
Dewdney Creek	Coarse, green, massive tuff—attitude uncertain	30
series 3,025 feet	degrees northeast	280
	Diorite dyke or sill	-00
	Dark, fine-grained, detrital tuffs-N. 25° W., dip 85 degrees	
	northeast	220
	Fine-grained, dark blue or black detritul tuffs; massive,	50
	southwest.	600
	Dark, fine-grained, detrital tuffs, nearly perpendicular	350
		3,025
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<sup>1</sup> As the position of this Upper section corresponds, at least in part, with that of the Intermediate section, it is likely that the total thickness of the series is considerably less than indicated above.

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	Coarse, green, massive tuffs, attitude N. 30° W., dip 70 degrees southwest	1,320
	Containing narrow, interbedded, dark, fine-grained, detrital tuffs with fossil <i>Belemnites</i> .	,
	Green, massive tuffs	100
Lower section 4.370 feet	Dark, fine-grained, detrital, massive tuffs, fossiliferous Lamprophyre sill 30 feet wide	450
,	Coarse, green, massive tuffs	1,200
	Finer-grained, dark, banded, detrital tuffs	200
	interbedded, dark-coloured, fossiliferous, detrital tuffs	1,100
		4,370
E	Base seems to grade into or is difficultly separable from	

tuffaceous members of the Ladner series.

### External Structural Relations

Where its boundaries are exposed the Dewdney Creek series overlies, and is apparently structurally conformable with, the Ladner series, but this contact is in part obscured by batholithic rocks which have intruded both series. The extent or character of the Dewdney Creek series beyond the limits of the map-sheet to the east has not been investigated.

# Mode of Origin

The Dewdney Creek series is regarded as largely composed of pyroclastic deposits laid down in marine waters; in part directly as volcanic ejectamenta and in part as tuffaceous materials swept into the sea from contemporaneous pyroclastic deposits that had accumulated on the adjacent land areas. The massive green tuffs composing the lower section of the series are, probably, examples of direct volcanic accumulation, whereas the black, thinly-bedded rocks of the intermediate section, whose dark colour is due at least in part to carbonaceous matter, and whose varied faunal content indicates less rapid accumulation, probably represent tuffaceous deposits of indirect origin. The presence of obscure plant fragments, and a variety of marine fossils, in the rocks of Fossil hill, favours a similar origin for those rocks.

Associated with the tuffaceous materials is a small proportion of normal sediments whose rate of accumulation would be slow in comparison with that of the pyroclastic material. The thinly-bedded, narrow bands of slate or shales which are interbedded with the massive tuffs on Tulameen and Goat mountains, and to a smaller extent at a number of other horizons in the series, represent such normal sedimentary types.

The granular crystal-lithic tuff member of the lower section of the series contains a number of black rock fragments that have apparently been torn from the sedimentary strata through which the volcanic eruptions supplying the pyroclastic material have forced their way. They may be fragments from the Ladner rocks or may have come from older formations. The cherty felsite lapilli may also represent fragments from older rocks, but are more probably bits of rhyolitic or andesitic lavas that, in their course through the air or in their descent through the water, acquired, while still in a molten condition, a rounded, globular outline resembling well-worn pebbles. With the exception of the rock fragments mentioned above, most of the lithic lapilli found in these, as in other members of the Dewdney Creek series, are definitely volcanic and doubtless represent fragments of lava thrown out by the volcances. Many of these have an amygdaloidal structure in which the small, round vesicles have later been filled with secondary chlorite, calcite, and epidote. Many of the lava fragments show lath-shaped microlites of feldspar such as are common in the finergrained groundmass or matrix of the tuffs.

From the nature of its materials the Dewdney Creek series must have accumulated very rapidly as compared with the rate of normal sedimentary deposition, and, assuming that the material composing these rocks was obtained from nearby sources and in no case suffered transport for any great distance, the accumulation must have been very irregular, the deposits forming to great thicknesses within relatively small areas, and rapidly thinning near their borders. Nor would the area occupied by the successive tuff beds be identical. Instead there would be an irregular overlap of the borders of each deposit on the flanks of the earlier beds. Ocean currents would tend to equalize the distribution, and would be successful to an extent depending upon the rapidity and manner of accumulation and the coarseness of the detrital materials. The well-bedded tuffs may be regarded as having been much more equally distributed than the more massive varieties. The latter are regarded as of direct pyroclastic origin, whereas the bedded varieties, except in the case of the very fine, tuffaceous materials, were probably deposited on land, and later transported to the sea.

That the adjacent land areas were of low relief is evidenced by the absence of coarse beds among those strata regarded as the product of normal stream erosion. These beds are composed of fine-grained shales or slates, whereas if erosion had been more active a certain proportion of arenaceous or even conglomeratic beds might be expected. It would seem that those great periods of orogenic activity and batholithic intrusion of the late Mesozoic era had not yet commenced, a supposition which is strengthened by the observation that the rocks of the Dewdney Creek series have been deformed to a degree comparable with the underlying Ladner and Cache Creek series.

# Igneous Metamorphism

The Dewdney Creek series has been intruded by a number of igneous bodies varying both in mode of origin and in composition. To the northwest they are in part separated from the Ladner slates by a belt of coarse granodiorite which forms a large apophysis from the much greater area on the other side of Coquihalla river. Near the contact with the intruded rocks the borders of this apophysis are more basic, and the composition more nearly approaches that of a hornblende diorite. A small area of this diorite occurs near the summit of Goat mountain on the northern slope, and may be directly connected with the large granodiorite apophysis. Near the contacts with these intrusives the Dewdney Creek series is somewhat reddish, a colour coincident with the abundant development of brownish-red scales of biotite. Some recrystallization and induration have accompanied this metamorphosis and a slight mineralization by iron sulphides is locally noticeable.

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This metamorphism is more pronounced near the hornblende quartz diorite areas at the head of Dewdney and Cedar creeks. On the ridge between the South fork of Dewdney creek and Sowaqua river the intruded rocks have been very heavily and extensively impregnated with pyrite and, to a less extent, with magnetite in the vicinity of the granodiorite stock and the several more basic dykes which here intrude the series. The strata have been in part brecciated by the intrusives, the fractures filled with pyrite, and the rock heavily impregnated with the sulphide and with reddish biotite. Similar heavy mineralization was observed on the divide to the north of the East fork of Dewdney creek, where the rocks are intruded by a similar quartz diorite.

The Dewdney series is intersected by a great number of small dykes and sills. These are in places very basic, being composed largely of crystals of hornblende easily distinguished with the naked eye. At the contacts of these intrusives the darker tuffs are bleached and recrystallized, and show the development of innumerable sheaves of an acicular pleochroic amphibole resembling actinolite.

# Age and Correlation

The Dewdney Creek series is assigned tentatively on palæontological, structural, and lithological grounds to the Upper Jurassic. On palæontological evidence alone, however, this series might, together with the underlying Ladner series, be grouped with the Lower Cretaceous.

Fauna. Belemnites are the only fossils that have yet been discovered in what has been termed the lower section of the Dewdney Creek series. They occur chiefly as scattered individuals at different horizons in this section. The best-preserved specimens were obtained on the divide between the head of Cedar and Dewdney creeks and although they have not been specifically identified they are apparently similar to those Belemnites discovered near the Pipestem mine. They may be either Jurassic or Lower Cretaceous in age.

The intermediate section of the Dewdney Creek series has supplied a greater variety of fauna in which a species of *Belemnites* is still the most abundant and most widely distributed fossil. The best collections were made at elevations of over 5,000 feet on the left bank of a stream that enters Dewdney creek from the north about 8 miles from its mouth. A collection made in 1920 included the following<sup>1</sup>: *Goniomya* sp. (probably a new species); *Oleostephanus*? sp.; *Belemnites* sp.; and was reported on as "possibly Lower Cretaceous."

Another collection obtained in 1921 from nearly the same locality included the following forms: *Trigonia* sp. of the *Clavellatæ* group; *Belemnites* sp.; and was reported as "certainly either Jurassic or Lower Cretaceous and much more likely Jurassic."

Collections were also made from rocks of this intermediate section about 4,000 feet to the south of the East fork of Dewdney creek and at an elevation of approximately 6,000 feet. This is regarded as practically

<sup>&</sup>lt;sup>1</sup> McLearn, F. H., Geol. Surv., Can.

the same horizon as the one from which the preceding collections were taken, but over 2 miles to the southeast. Fossil specimens included: indeterminate *ammonites; Belemnites* sp.; Oxytoma sp.; and were regarded as of the same age as the preceding.

Although the rocks from which these fossils were obtained are grouped with the intermediate section of the Dewdney Creek series they occur also as strata interbedded with upper horizons of the lower section. The two sections are consequently of the same age, their difference in fauna being due to their mode of accumulation on the sea-bottom, a matter which has already received some discussion.

The fauna from the Tulameen Mountain section of the Dewdney Creek series affords some confusing chronological evidence. A single float specimen obtained from the very peak of the mountain, and much resembling some of the underlying strata, was reported by the Palæontological Division of the Geological Survey as "probably Arniotites or Arnioceras and probably either Triassic or Lower Jurassic." On the other hand a collection obtained from Fossil hill about one-half mile west of Tulameen peak contained fairly well-preserved specimens of a pelecypod identified as *Pleuromya* (?) sp. I = Pholadomya vancouverensis (?) and as such affords comparison with the Jackass Mountain group of Dawson which has been regarded as Lower Cretaceous.

Taken as a whole, and excepting the ammonite float from Tulameen peak, the fossils from the Dewdney Creek series were regarded as "evidently all of one fauna which is certainly either Jurassic or Lower Cretaceous and more likely Jurassic." The rocks from Tulameen peak containing the conflicting ammonite certainly dip to the southwest under the rocks of Fossil hill, but there is little or no structural evidence to prove that they constitute an anticline dipping also to the northeast under the other sections of the Dewdney Creek series to the north of Tulameen peak. Structural evidence is decidedly in favour of the occurrence of other members of the Dewdney Creek series underlying them, evidence which is considered much more convincing than that deduced from the tentative age designation of a single fossil from a float specimen. As other ammonites occur in other fossil localities in the Dewdney Creek series it is quite possible that this specimen belongs to the same fauna and would consequently be referred to the Jurassic or Lower Cretaceous.

Age as Revealed by the Structure. The structural disposition of the rocks of the Dewdney Creek series has already been discussed. In brief, these rocks are regarded as lying conformably, or at most with slight disconformity, upon the Ladner series and are, therefore, of the same age.

Age as Revealed by Lithology. In common with the underlying Ladner slates the rocks of the Dewdney Creek series are characterized by an abundance of feldspar crystals, a paucity of quartz fragments, a large proportion of lithic fragments chiefly of volcanic lavas, and a matrix which is commonly abundant and, particularly in the Dewdney series, much resembles volcanic ash.

This similarity in lithology suggests a similarity in origin. The origin of the Ladner slates has already been discussed, and the inference has been drawn that vulcanism has both directly and indirectly had much to do with the accumulation of its constituent beds. The similarity, both megascopically and microscopically, between the darker beds of tuffaceous greywackes in the Upper Ladner group and the dark-coloured crystal-like tuffs of the Dewdney Creek series, is very striking. The only noticeable difference in thin section is the comparative abundance of calcite in the Ladner rocks. In the hand specimen they are nearly identical.

Correlation. Within Coquihalla area the Dewdney Creek series is, therefore, regarded as of nearly the same age as the Ladner series. Beyond the district, however, fossils were found in a series of rocks exposed on the southern shoulder of Hopeless mountain, at the head of Sowaqua river. These rocks have been regarded as of Lower Cretaceous age and have been correlated with the Pasayten formation of the International Boundary.<sup>1</sup> Fossils found in these rocks included: Belemnites sp.; Pecten sp.; Pseudomonotis (?) sp.; and Pleuromya sp. I = Pholadomya vancouverensis. On the basis of the latter, these rocks might be correlated with the rocks of Fossil hill in Coquihalla area and with the Jackass group also regarded as Lower Cretaceous.

There is some evidence, too, favouring a correlation of the Dewdney Creek series with the presumably Cretaceous rocks of Thompson river. This evidence is, however, slight and is based purely on the petrographical resemblance of the coarse green tuffs from the lower section of the Dewdney Creek series to members of the Cretaceous rocks exposed along Bonaparte river on the trail from Ashcroft to Cache creek.

Conclusions. There is great doubt as to whether the Dewdney Creek series is in part, or all, Lower Cretaceous, or entirely Jurassic. If more specific identification of its fauna prove it to be entirely Cretaceous then the break between the Dewdney Creek and Ladner series must be of greater significance than the writer has, for reasons already stated, considered it to be, for there seems little doubt that the Ladner series is pre-Cretaceous. If, as seems still more probable, the entire Dewdney Creek series is of Jurassic age, there must have been great similarity of the fauna from the Upper Jurassic (Dewdney Creek series) and Cretaceous (Pasayten) rocks, or subsequent investigation may result in a partition of the Pasayten rocks into Jurassic as well as Cretaceous formations. For the present, however, the Dewdney Creek series is placed in the Upper Jurassic.

# LOWER CRETACEOUS ROCKS

#### Distribution

Cretaceous<sup>2</sup> rocks occur in a number of widely separated patches in Coquihalla area. The largest of these, 14 square miles in extent, is situated in the basins of Cedar and Carey creeks. Another forms a belt 4 miles long and less than half a mile wide to the northwest of Romeo. A still narrower strip, or series of strips, is exposed in the railway cuttings for about 3 miles below Romeo. Small areas of Cretaceous rocks also appear on Hope mountain, on Silver peak, and on each side of Fraser river near Hope.

<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 479. <sup>2</sup> In the following discussion the term Crotaceous, where applied alone to rocks of Coquihalla area, is equivalent to Lower Cretaceous. Some of the batholithic rocks in the map-area are older than the Lower Cretaceous stratified deposits, but they are not described until farther on in this report in order that all the batholithic intrusives may be discussed together.

#### Petrography

The Cretaceous rocks are markedly different lithologically from the older stratified rocks of Coquihalla area. Besides being composed on the average of much coarser material, this material has been largely derived from the erosion of batholithic rocks. The latter feature is especially noticeable in the conglomerates in which boulders or pebbles of granitic rocks are in places present to the practical exclusion of all other types. In the finer-grained sediments crystal fragments predominate over lithic grains. Quartz grains are always much in excess of the feldspar constituents. Fragments of ferromagnesian minerals and muscovite are usually present, but in variable proportions. Grains of magnetite, titanite, and apatite are occasionally seen. The feldspar in these clastic rocks is fresh looking, although not so well preserved as in the tuffaceous Dewdney Creek series. Inasmuch as the areas of Cretaceous rocks are comparatively small and are commonly bounded in part or entirely by later intrusive batholithic rocks, the phenomena of contact metamorphism are especially pronounced.

Granitic Conglomerate. The conglomerates vary in composition from those in which the cobbles or pebbles are mainly plutonic to others more conspicuous for other coarse detrital material. Granitic conglomerate is best represented in the narrow strip of Cretaceous rocks exposed along the railway. It occurs at different horizons, but is most widely exposed between 1 mile and  $1\frac{1}{2}$  miles below Romeo. Probably less than 50 per cent of this section is conglomerate and the total thickness may not exceed 500 feet. The cobbles are well rounded and range in diameter up to 6 or 8 inches. They are almost entirely plutonic and include very few distinctly gneissic varieties. A few basic pebbles were observed, but the greater number are distinctly from granite and granodiorite intrusives. With these granitic pebbles is included a small proportion of other types representing volcanic and sedimentary rocks.

This conglomerate has been so firmly cemented that fractures break indifferently across pebble and matrix. The latter is a moderately coarse and very hard grit composed of granitic detritus and itself much resembles a plutonic rock. It is referred to on a later page in discussing the peculiar processes of induration to which certain sections of the Cretaceous rocks have been subjected.

Chert Conglomerate. An interesting conglomerate, in which dark blue and light-coloured pebbles, identical with the cherts of the Cache Creek series, are particularly abundant, constitutes the great bulk of the Cretaceous rocks in the southwestern corner of the area. The cobbles rarely exceed 6 inches in diameter and there is every gradation to fine conglomerate and grit, the latter forming the matrix of the coarser beds or constituting distinct strata in itself.

In this conglomerate the proportion of plutonic to other pebbles varies greatly. In the small area below Haig the granitic pebbles are, for at least part of the section, in the majority, but appear to diminish in proportion as the exposure is followed towards Petain. In general the plutonic pebbles of this conglomerate appear to form less than half of the rock, and are similar in composition to those in the granitic conglomerate already discussed.
The matrix is composed of the same materials as the pebbles. Angular quartz and feldspar grains predominate. The feldspars are acid plagioclases and orthoclase and are not greatly altered. Fragments of slaty and cherty felsitic rocks form a smaller percentage than the quartz and feldspar grains, but are more abundant than the other constituents. Some fragments of plutonic rocks are recognized. Biotite is in places abundant and muscovite is as a rule present in smaller proportions. Chloritic alteration products have formed from the ferromagnesian minerals, of which biotite is the principal representative. Grains of epidote and zoisite are present in most places and calcite is a variable constituent. The quartz shows varying degrees of strain or fracture and in part resembles fragments of vein quartz. The matrix constitutes a small proportion of the rock. Its cementing power varies with the degree of silicification. Induration is particularly pronounced near intrusive batholithic rocks, as on Silver peak and certain sections on Hope mountain.

Similar chert conglomerates occur in several narrow belts between the head of Cedar creek and Carey creek. These are, however, much finer conglomerates than those described from the southern areas, the pebbles rarely exceeding an inch in diameter. In all other respects, and although occurring at widely separated points, they seem to be identical.

Volcanic Conglomerate. The fine chert conglomerates are in part interbedded with coarser volcanic conglomerates. The latter occur in a number of beds at the head of Cedar creek and on the divide between Cedar and Carey creeks. These beds have a total thickness of nearly 2,000 feet. Chert pebbles are uncommon in these conglomerates, their place being taken chiefly by varieties of volcanic rocks, some of which very much resemble the greenstones of the Cache Creek series, whereas others are petrologically similar to members of the Dewdney series of tuffaceous rocks. Granitic pebbles are, as a rule, abundant, but their proportion is variable and appears to change within a single bed. The matrix is in general gritty, composed of materials similar to the pebbles, and cemented by silica or calcite.

These conglomerates are commonly highly metamorphosed in the vicinity of batholithic intrusives and many of the less resistant pebbles have been elongated by pressure during deformation.

Arenaceous and Argillaceous Rocks. These rocks grade from fine conglomerates or grits, such as form the matrices, or are interbedded with, the coarser conglomerates, to very fine-grained, platy, argillaceous shales and slates.

The gradation from fine, shaly beds to coarse-grained sandstones is, in some sections of the Cretaceous rocks, very abrupt, and alternation of the two types is frequent. In such cases the coarser beds are as a rule the thicker, but broad belts of shaly rocks several hundred feet thick also occur. The most complete section of these rock types was obtained on the Carey-Coquihalla divide and is included among the structural sections of the Cretaceous rocks.

The arenaceous and shaly beds vary from black to dark grey or green, and a brownish or rusty weathering is common. Under the microscope the shales are mostly too fine-grained to permit determination of their mineral composition. Very small quartz grains are, as a rule, discernible in a dark argillaceous groundmass. Calcite is a common constituent, and it is probable that the greater part of it was precipitated during the accumulation of the beds in the sea.

These shales are characterized in certain sections by innumerable small cavities, mostly irregular in outline; some have a roughly honeycombed structure and others have long, somewhat cylindrical forms onequarter to one-half inch in diameter. These possibly represent the original site of organisms, but no definitely recognizable forms could be found. Near intrusive rocks these cavities are often lined with, or completely filled by, a green epidote, and afford an interesting criterion for the correlation of the strata from different sections.

The coarser-grained, arenaceous rocks much resemble the typical grits from the conglomerate belts. The constituent grains are usually of very uniform dimensions (Plate VIII B) and are closely packed together in a dark, argillaceous groundmass. Either lime or silica may, on occasion, be the principal cementing material. Angular grains of quartz form the most abundant constituent, and are commonly strained or much fractured. Feldspar crystals or grains are common, but are much less abundant than the quartz. They show both Carlsbad and albite twinning and are usually somewhat altered, but may be quite fresh. There are as a rule a number of rock fragments present, of which some are definitely volcanic; others are siliceous or cherty in appearance; and still others are decidedly argillaceous and accordingly represent sedimentary rocks. Muscovite foils are commonly present and in the vicinity of batholithic contacts brownish-red biotite scales are as a rule abundant, their size and number being more or less inversely proportional to the distance from the intrusive. Calcite is commonly observed and in some places forms the cementing material. Sericite is a common alteration product and occurs in fine, colourless scales or shreds replacing the various constituents or collecting around the borders of the grains. These sediments are commonly silicified in the vicinity of intrusive rocks.

## Internal Structural Relations

The most complete section of Cretaceous rocks in Coquihalla area has a total thickness of about 8,000 feet. Near the base of this section is a moderately coarse and highly metamorphosed conglomerate composed largely of volcanic pebbles, some at least of which appear to have been derived from the Dewdney series or from lava flows contemporaneous with this series. This conglomerate is regarded, from such structural evidence as could be obtained, as well as from its composition, as the basal member of the Cretaceous rocks in Coquihalla area. It is exposed on the Cedar-Carey divide at the contact with the slaty rocks of the Ladner series.

There is some doubtful structural evidence to indicate that the granite conglomerate below Romeo may underlie this volcanic conglomerate. There are better indications that it overlies the volcanic member, for, in the first place, it is very similar in composition to the conglomerate from the lower slopes of the Carey-Coquihalla divide which actually overlies this volcanic conglomerate, and in the second place these granite conglomerates must have been laid down after the erosion of the rocks overlying the batholithic intrusives, and it is consequently to be expected that other conglomerates composed largely of boulders from these overlying formations should be found beneath later granite conglomerates.

The chert conglomerate from the southwestern part of Coquihalla area might there appear to represent a basal member of the series but for the occurrence of a similar conglomerate in the Cedar-Carey Creek section at an horizon considerably higher than the volcanic conglomerate. Further, this chert conglomerate on Silver peak is underlain by a narrow belt of metamorphosed biotite-quartz schists which are believed to represent lower members of the Cretaceous rocks.

The Cretaceous rocks have been thrown into closely compressed folds in which the strata dip from 40 degrees to the perpendicular, the higher dips being often peculiarly characteristic of the more axial sections. No reverse folds or important thrusts were observed, but considerable crushing and slipping must have occurred along the axes of some of the folds to allow for the nearly vertical attitudes obtained there, instead of along the limbs of these folds where the dips are at more moderate angles.

The average strike, as obtained from the principal section on the Coquihalla-Carey Creek divide, is north 15 degrees west, or about 20 degrees farther to the north than the underlying Dewdney Creek and Ladner series. This section is evidently a compressed syncline, the dips varying from about 50 degrees on the flanks to almost vertical near the axis. Among the higher attitudes several contrary dips were observed, but these are probably of only local significance.

The attitude of the Cretaceous rocks on the hills northwest of Romeo is remarkably regular considering that these rocks overlie the contact of two intrusive bodies. They strike about north 35 degrees west and dip 40 to 60 degrees southwest.

The Cretaceous belt along Coquihalla river below Romeo appears to strike a little more to the north and to dip at high angles to the southwest, but attitudes were difficult to obtain in this section.

The chert conglomerate areas in the southwestern corner of the maparea appear to be aligned along a strike which is almost north and south. The dips of the conglomerate below Haig average about 70 degrees west, but to the southeast of Fraser river the dips are prevailingly to the east at high angles. The structure as a whole is, therefore, a syncline, but there has been much orogenic disturbance among these small areas and a great deal of deformation and faulting have resulted in many variations from these general attitudes. The position of the Cretaceous conglomerates in the bottom of Fraser valley, with older rocks forming the hills on either side, has been explained by Camsell "by downfaulting along a north and south line, a line which was afterwards followed by Fraser river in cutting out its valley." Faulting of somewhat similar character, possibly accompanied by thrusting, has occurred down Coquihalla valley on either side of Romeo and will be referred to repeatedly in succeeding sections of this report.

## Section of Cretaceous Rocks along Cedar-Carey Divide

### Bottom of Section

	Base not shown—faulted against Ladner slate belt	Feet
1.	Chiefly massive, sandy beds with some conglomerate—pebbles in latter, chiefly felsitic rocks of volcanic and sedimentary origin, deformed	+650
<b>2</b> .	Grit with shaly beds	800
3.	Black, slaty sediments, some varieties carrying small chiastolite crystals-	
	attitude N. 35° W., dip 80 degrees northeast	500
4.	Conglomerate and grit—more granitic pebbles—otherwise similar to lower	
~	conglomerate belt—all except plutonic pebbles may show deformation	450
Э. С	Massive beds of grit	600
0.	massive grit beds and line conglomerate-large proportion of chert and	650
	Jointing S 30° W dip 80 degrees southeast	050
	Mainly dark shaly and slaty rocks with occasional evaludrical holes	
	probably of <i>Belemnites</i> —light weathering, attitude N, 10°W, dip	
	45-60 degrees northeast—upper section more gritty	1,500
7.	Coarse conglomerate—round cobbles and pebbles of volcanic, sedimentary,	_,000
	and granitic rocks—latter in minor proportion	700(?)
8.	Grit and shale with some dark, slaty beds showing impressions resembling	.,
	plants	800
9.	Massive sandstone beds, grit, and small proportion of fine conglomerate-	
	chert and volcanic pebbles predominating—narrow strata of shale and	
	slate interbedded with coarser beds	1,200
	Total	7,850

## External Structural Relations

Relation to the Cache Creek Rocks. The great unconformity between these two series is exhibited at or near their contacts by a lack of accordance in their separate structures and lithology. Pebbles of the Cache Creek rocks, as well as from the Jurassic batholithic formations that intrude them, occur in the Cretaceous conglomerates. Contacts between these two formations were observed on Hope mountain and Silver peak.

Relation to the Ladner Series. The unconformity that separates these two formations was observed on the Cedar-Coquihalla divide at the contact of the basal volcanic conglomerate of the Cretaceous series with the underlying slates of the Ladner rocks. The conglomerate contains pebbles, some of which resemble fragments of the Ladner series, and the attitudes of the two formations are not strictly conformable. The two series are in faulted contact to the south of Cedar creek. They dip in opposite directions and their average strike differs by about 20 degrees.

Relation to the Jurassic Granite and Granodiorite on Hope Mountain. A contact between this intrusive and a chert conglomerate of the Cretaceous series was observed near the base of the northern slope of Hope mountain. No contact metamorphism was in evidence, and pebbles very similar to the granodiorite were seen in the conglomerate. The plutonic rock is, in addition, greatly sheared and, under the microscope, the direction of crush-schistosity could be plainly observed to run at an angle to the line of contact, where it was abruptly truncated. The conglomerate does not show this crush metamorphism. It contains, however, fragments of quartz which are highly fractured and in this respect similar to the quartz crystals of the Jurassic intrusives from which they were, in part, derived. Other exposures of the Cretaceous rocks close to the contact with the Jurassic intrusives were observed, but in no instance was there any sign of metamorphism. In addition, the matrix of the conglomerate near these contacts is frequently characterized by an abundance of biotite and much resembles a decomposed variety of the underlying batholithic formation. The pebbles near these contacts also much resemble the Jurassic rocks.

Relation to the Eagle Diorite. Distinct metamorphism and intrusion of the Cretaceous rocks by this diorite were observed to the southeast of Iago, as well as in the Cretaceous belt northwest of Romeo.

Relation to the Eagle Granodiorite. The contacts between this intrusive and the small areas of Cretaceous sediments near Coquihalla river below Romeo are not well exposed, and it is impossible to say to what extent the metamorphism displayed by the Cretaceous rocks is due to this intrusive or whether it has entirely resulted from the later intrusion of granite exposed principally on the west bank of Coquihalla river. It seems probable that the Eagle granodiorite has been faulted against the sedimentary rocks and that consequently no contact metamorphism between them may be observed directly, although the sediments are, for other reasons, regarded as older rocks.

Relation to the Other Cretaceous Batholithic Rocks. The Lower Cretaceous sediments are characteristically metamorphosed near their contacts with these batholithic rocks to the northwest of Romeo; along the railway cuttings below Romeo; on the divide between Cedar and Carey creeks; on the western flank of Hope mountain above Silver creek; and on the west slope of Silver peak. This metamorphism will be described in a later section dealing with the metamorphism of the Cretaceous rocks.

Relation to the Tertiary Quartz Diorite on Silver Peak. The chert conglomerate, together with the underlying belt of metamorphosed schists, have been intruded and metamorphosed by this batholithic formation near the summit of Silver peak. The conglomerate is indurated or silicified and recrystallized and other minerals are developed near the contacts. The ore deposits of the Eureka-Victoria mines situated within this conglomerate are regarded as due to this intrusion.

Relation to the Coquihalla Volcanic Series. The contact between these two formations is exposed on the divide north of the head of Carey creek and represents a distinct unconformity. The pyroclastic beds of the volcanic series overlie the highly deformed Cretaceous sediments at an entirely different angle and a number of Tertiary dykes, regarded as of the same age as the Tertiary formation, intersect the Cretaceous rocks.

### Dynamic Metamorphism

The Cretaceous sediments have all been, to some degree, modified by processes of deformation and intrusion. Orogenic forces have thrown these rocks into a series of highly pitching folds and, in the process, have effected characteristic changes in the different members of the series. The pebbles of the conglomerate have in part been crushed and deformed and the matrix moulded around them. Good examples of squeezed conglomerate were observed on the divide between Carey and Cedar creeks at an elevation of about 4,000 feet, and on the western end of the divide between Coquihalla river and Carey creek at about the same altitude. In these conglomerates the pebbles of volcanic and argillaceous rocks are greatly deformed, whereas the more resistant plutonic pebbles are either fractured outright or but slightly deformed, the pressure on them being relieved by the matrix that was crushed around them.

The grits or other arenaceous beds have, in certain sections, been greatly crushed and, where heat metamorphism has accompanied this deformation, some recrystallization and development of other minerals have produced siliceous, quartz-mica schists. The bulk of arenaceous rocks has, however, resisted deformation much better than the interbedded argillaceous sediments. These have almost everywhere developed a thin, irregular, platy cleavage and one or two sets of joint fractures. From the more thinly plated varieties it is often difficult to secure a good specimen, for, on the first stroke of the hammer, they break into innumerble, thin, scaly or pencil-shaped fragments.

## Contact Metamorphism

The phenomena of contact metamorphism are more prominently displayed in the Cretaceous rocks than in any other formation of Coquihalla area. This is in part because these sediments come in contact chiefly with later batholithic intrusives, and, in part, because they form comparatively small or elongate areas which fall entirely within the zone of heat metamorphism. Fractures caused by deformational stresses locally facilitated the invasion of magmatic solutions. The pressure during batholithic intrusion may also have aided the production of metacrystals with smaller molecular volumes than the original detritus of the sedimentary beds. Such minerals include andalusite, cordierite, garnet, enstatite, and sillimanite in about this order of decreasing abundance.

Complete recrystallization is notable only within the inner zone of the contact aureoles and for probably not over 100 feet from the actual contact. Within these limits the argillaceous beds are changed to moderately coarse quartz schists varying from dark purple to brick red. A reddishbrown biotite is the most conspicuous mineral in thin sections of these rocks. Small garnets are fairly abundant and may show secondary alteration to chloritic material. The carbonaceous matter present in the original rock forms small, black, microscopic specks of graphite which are in many places abundantly scattered between the constituent grains or crystals or form inclusions in them.

The arenaceous sediments are entirely recrystallized into hard, compact hornfels. Quartz predominates and forms a mosaic of equant interlocking grains filled with tiny inclusions. Feldspar is less plentiful, but where observed occurs in clear crystals also filled with many inclusions. Much biotite occurs in reddish-brown scales rarely exceeding a millimetre in diameter. Its pleochroic fibres show strong absorption from light brown to deep brownish-red. The biotite forms a border around or within the borders of the other minerals, and may also form a large percentage of the groundmass of the rock. Thin fibres and foils of colourless muscovite are commonly present in smaller proportions. Enstatite is in some cases intergrown with the quartz. Sillimanite, a still rarer constituent, occurs in minute acicular crystals penetrating the quartz. A few crystals of brown tourmaline are observed; pyrrhotite is present in some places in notable proportions.

The zone characterized by micaceous minerals and silicate metacrystals overlaps the zone of complete recrystallization and extends for many hundreds of feet from the actual contact. Quartz is still the most abundant constituent, but with increasing distance from the contact the recrystallized quartz gives place to that which has been strained and fractured by deformative processes. Biotite is still abundant, but the individual scales are smaller and tend less to form inclusions in the other minerals. Garnets



Figure 2. Camera-lucida drawing showing development of silicate metacrystals in Lower Cretaceous hornfels. Magnification: 16 diameters. A, andalusite; B, cordierite; G, garnet; Q, quartz; groundmass composed chiefly of quartz, biotite, and feldspar.

increase in size and abundance towards the contact. At their maximum development they rarely exceed 2 millimetres in diameter, and show no optical anomalies. Metacrystals of cordierite appear within a few yards of the contact and are abundantly developed over a distance of 150 feet or more. They occur as round, almost colourless crystals with light bluish birefringence and spherulitic extinction. They average about one-half millimetre in diameter and are abundantly filled with minute inclusions of other minerals. Small garnets occur in some places either entirely within, or cutting the borders of, the cordierite (Figure 2). Overlapping the cordierite zone is another characterized by metacrystals of andalusite occurring in long, prismatic or equilateral basal sections. Foils of biotite are commonly wrapped about their borders or appear in minor proportions within the crystals. The andalusite prisms in many places intersect the cordierite and probably developed at a later stage in the metamorphism. An extensive induration of the Cretaceous sediments is commonly observed at no great distance from the intrusive contact. It is best developed among the coarser gritty members of the series. The induration is accomplished by a partial recrystallization of the constituent minerals and by the replacement of others and of the groundmass by secondary silica from magmatic solutions. This silica has also filled irregularly distributed veins. This silicification is particularly well displayed in the granite conglomerate below Romeo.



Figure 3. Diagram showing approximate range of certain minerals in Lower Cretaceous hornfels within zone of contact metamorphism.

## Mode of Origin

The Cretaceous rocks of Coquihalla area include a large proportion of moderately coarse to coarse-grained sediments and are composed in great measure of detritus from plutonic rocks. Hence, the batholithic rocks must have been uncovered since the deposition of the earlier formations and the area supplying the sedimentary material must have been one of considerable relief. The angularity of the particles composing the gritty and arenaceous beds and the moderately well-preserved feldspar fragments indicate rapid erosion and short transport.

The spherical cobbles are characteristic of stream deposits rather than of beach accumulations. The abundance of the conglomerates, their occurrence in beds of great thickness, and their intermixture with much finer gritty material, suggest such an irregular accumulation as characterizes delta deposits at the mouths of large rivers in regions of high relief subject to both seasonal and torrential weather conditions. This irregularity is particularly in evidence in the case of the conglomerate beds which show great variations in thickness in comparatively short distances. Conglomerates several hundred feet thick may diminish within as many hundred yards to less than half their maximum thickness. This decrease is commonly accompanied by a corresponding diminution in the size of the pebbles. In other sections, as on the valley slope to the south of the headwaters of Carey creek, there appears to be an almost regular alternation of conglomerate with finer sediments, indicative of either rejuvenation of adjoining land areas or cyclic variations in the climate. Either of these conditions would profoundly affect the character of delta deposition.

The scarcity of anything resembling organic remains in these Cretaceous rocks suggests either that the waters in which the sediments were deposited were too fresh or the rate of accumulation was too rapid to favour the development of a marine fauna. Only in the more shaly members that were evidently deposited in deeper water and at a more moderate rate, have fossils been found. These were not sufficiently well preserved to afford even a generic identification. They included what were considered to be obscure plant remains, found on the Cedar-Carey divide, and curious irregular cavities in the sediments on the divide between Carey creek and Coquihalla river and near the head of Coldwater river. Some of the more cylindrical of these cavities suggest casts of *Belemnites*.

To summarize, it is thought that these Cretaceous rocks were rapidly accumulated near the mouths of rivers draining a region of high relief where erosion had unroofed considerable areas of batholithic rocks; that the sediments have the general character of large delta deposits, and that the waters in which they were laid down were comparatively shallow and only slightly brackish, due, in part, to the great volumes of fresh water draining from the adjoining land and, in part, to partial isolation of the marine water from the open sea.

## Age and Correlation

All the members of this sedimentary series are regarded tentatively as of Lower Cretaceous age. This position is supported by their structure, lithological characteristics, and correlation with Cretaceous rocks in neighbouring areas.

It has already been shown that the conglomerates in this series contain pebbles of the Cache Creek rocks, and probably, also, of the Ladner and Dewdney Creek series; that the series overlies the Ladner series; and that the lithology, and to a less extent the structure, at the contact indicates an unconformable relation. It has also been shown that these rocks have been intruded by several batholithic bodies believed to range from late Lower Cretaceous or early Upper Cretaceous to Tertiary in age, and that they overlie and contain pebbles from other batholithic intrusives assigned to the Upper Jurassic. In other words, these sediments were laid down during an interval between batholithic intrusions. Structural and lithological evidence thus seems to point strongly to a post-Jurassic age for these sediments.

These sediments have not been traced directly into formations of known Cretaceous age in neighbouring areas. They are, however, so similar lithologically and structurally to at least some of the members of the Pasayten formation<sup>1</sup> at the head of the South fork of Tulameen river,

<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 489.

that the writer has little hesitation in correlating them with that group, which on palæontological grounds includes both Lower and Upper Cretaceous and possibly also older members. The discovery of diagnostic fossils by Daly and Camsell in the Pasayten formation leaves little doubt as to its age being, at least in part, Lower Cretaceous.

The conglomerate from Fraser river below Haig was considered by Camsell as Lower Cretaceous in age<sup>1</sup> and was correlated with other Cretaceous rocks occurring farther north along Fraser river.

# COQUIHALLA SERIES

### Distribution

The Coquihalla series, named after Coquihalla mountain, occupies a single area of about 8 square miles east of Coquihalla river and southeast of Romeo. The series is exposed for some distance east of the map-area, though its areal extent in this direction has not been determined. Certain members of the series were observed by Camsell near the head of Eagle creek, but apparently do not occur much farther east, for they are not present in the Tulameen map-area.

Being the youngest consolidated formation in this section, it is, save for minor surface accumulations, fully exposed. It occurs at elevations exceeding 3,000 feet and supports a sparse vegetation, a peculiarity in part due to altitude, and in part to the porous character of the upper beds.

These rocks have been deeply eroded and at one time occupied an area much greater than at present.

# Lithology

The rocks of this series, excepting the core of Coquihalla peak and a number of dykes, are all volcanic and include both flows and pyroclastic deposits. No normal sediments were observed.

Intrusive Rocks of Coquihalla Peak. The core of this picturesque mountain is composed of medium fine to fine-grained rocks of moderately basic composition. The coarsest and probably the most basic type occupies the exact centre or core of the hill. It has the composition of a pyroxene diorite and appears to merge—at least on the western shoulder of the peak—into finer-grained and slightly more acid types which, however, are probably not less basic than diorite.

These rocks are grey, massive, and fresh in appearance and show in places large crystals or phenocrysts of plagioclase feldspar. Under the microscope a section from the coarser diorite was seen to be composed of about 70 per cent fresh plagioclase, strongly zoned and broadly twinned after the albite law. This plagioclase has the composition of andesine and contains small inclusions of a mineral resembling a pyroxene. An almost colourless pyroxene with an extinction angle of about 45 degrees also forms over 25 per cent of the section. This has been partly altered to chlorite. Magnetite and apatite are common accessory minerals.

<sup>&</sup>lt;sup>1</sup>Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, pt. B, p. 33. 70994-6

The finer intrusives are mostly lighter in colour and more porphyritic. The groundmass is fine grained and indeterminate in composition. Phenocrysts of plagioclase feldspar form the most conspicuous mineral and are not so conspicuously zoned as in the coarser varieties. The principal dark mineral is a brownish hornblende showing evidence of alteration to chlorite. Epidote is an important secondary mineral. Magnetite and apatite are less abundant accessory minerals.

Below these intrusive rocks the slopes of the mountain are enveloped by lavas, of which a dense cherty rhyolite is most conspicuous and probably was extruded from the crater now occupied by the intrusive rocks.

Basalt Flows. Basalt flows aggregating several hundred feet in thickness occur at the base of the volcanic series and are prominently exposed at the higher elevations, where erosion has removed the overlying members of the series. With the exception of Coquihalla peak, they compose all the higher points on the ridge above 6,000 feet and have been uncovered at elevations as low as 5,300 feet. In their outcrops on the divide they show excellent columnar jointing (Plate VI A) from which some idea of the structure and succession of flows was obtained.

These basalts are heavy and rather coarsely crystalline porphyritic melaphyres varying from dark grey to dark green or almost black, and weathering to various shades of greenish grey and brown. They commonly show phenocrysts of plagioclase feldspar and many effervesce quite strongly in acid. In thin section they are seen to be composed chiefly of calcic feldspar and altered pyroxene. The former occurs as large, euhedral phenocrysts in a fine groundmass of feldspar, pyroxene, and alteration products. The phenocrysts are frequently strongly zoned and the centres may be partly altered to sericite, leaving the outer zones still comparatively fresh. The pyroxene is almost entirely altered to chlorite, serpentine, and magnetite. Secondary calcite is usually abundant. Little or no quartz was observed.

*Rhyolite.* Rhyolite flows overlie the basalt and have a total thickness in the series of about 1,500 feet. They are best exposed around the base of Coquihalla peak at an elevation of about 6,500 feet, and in the lower 2,000 feet of the bluff which rises above the left bank of Coquihalla river less than 3 miles below Romeo.

These are massive, hard, fine-textured rocks dominantly creamy white, but many of them mottled, and showing shades of pink, yellow, and brown. Under the microscope they show a uniform finely crystalline texture. Quartz is the principal mineral. The feldspar is mostly too far altered to be determined. Sericite is an abundant secondary mineral. Brecciated varieties of this rhyolite were observed in which the angular fragments are separated by thin, yellowish films of limonite.

Tuffs and Breccias. These pyroclastic rocks are the most widely distributed members of the Coquihalla series. They have been observed at all elevations between 4,000 and 6,500 feet and their maximum thickness is not less than 2,000 feet.

They vary from fine, ashy tuffs to coarse breccias in which fragments an inch or more in diameter are common, and others many times as large are occasionally encountered. In the outcrops they have a bedded appearance, and near the surface are broken into thin, roughly fractured plates or chips. They are mostly light coloured, varying in shades of grey, white, and pink, and weathering in white, yellow, and brown tints. Hand specimens are very light in weight, have a porous texture, and a soft, ashy appearance. They form a heterogeneous aggregate of glass fragments showing a striated vesicular texture, crystals of quartz, and angular particles of acid plutonic rocks in a soft, ashy groundmass. Less frequently fragments of other rocks much resembling lavas were observed and are probably of the same age as this or earlier members of this series. Small black scales of biotite may be very abundant.

## Internal Structural Relations

The rocks of the Coquihalla series are only slightly deformed as compared with older stratified formations of the area. Their general strike is about north and south, and they dip at angles rarely exceeding 20 or 25 degrees. A section from east to west across the series would show two synclines with an intermediate anticline. The series has a maximum thickness of about 4,500 feet.

The deformation of the series bears no direct relation to the present topography, as is evident from the position of the anticlinal structure across the large tributary of Coquihalla river below Coquihalla peak, and the development of a broad synclinal fold on the spur west of this creek. The disposition of the folds may have been in part influenced by the older underlying topography, but their general symmetry is more suggestive of deformational stress or crustal warping since the deposition of the series.

The different members of the series are not equally distributed. The basalts show a maximum thickness at the eastern flank of the area on the main divide, whereas the heaviest sections of rhyolites, breccias, and tuffs occur above Coquihalla river on the western flank of the series.

The structure of the basalt is in part illustrated by its columnar jointing (Plate VI A), from which it is seen that there have been a number of successive flows. These overlap at slightly different angles, but the time interval between each was probably short. The rhyolite also appears to have been extruded at intervals, between some of which tuffaceous material has been deposited. The fragmental rocks are the most widely exposed member of the series and overlie the older extrusives at depths varying from 2,000 feet to a veneer only a few inches thick.

## External Structural Relations

The Coquihalla series is, except for a small area to the southeast where it overlaps earlier Cretaceous sediments, entirely underlain by older batholithic rocks. The contact between the two has been observed at a number of points and plainly shows that the batholithic areas had been almost entirely denuded of overlying formations prior to the deposition of the volcanic members of the Coquihalla series.

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# Mode of Origin

*Basalts.* The small peaks of basalt along the summit of the divide north and east of Coquihalla peak may mark points of eruption of the basaltic lavas. The lava in these different peaks differs slightly both in general appearance and mineral composition. There is also a considerable difference in the attitude of the basaltic flows near these peaks, a difference due in part to conformation with the general structure of the series, but in part of more local significance.

The coarser diorite intrusive of Coquihalla peak may perhaps mark the position of a crater that supplied the basalt, but would not explain the lack of uniformity in composition of the basalt at points close together and on the same horizon. It is more probable that the basalts were extruded from a number of vents or fissures almost simultaneously; and that the peaks on the divide composed of columnar basalt mark the site of some of these eruptions.

Rhyolite Flows and Acidic Pyroclastic Rocks. These, from their general similarity of composition, are believed to have been derived from the same vents, the positions of which have not been definitely located. The fact that the tuffs and breccias contain an abundance of plutonic fragments resembling the Eagle granodiorite and none that could be identified with the Eagle diorite indicates that the eruptions burst through the granodiorite to the northeast of the diorite body. The size and number of these fragments suggest, too, that the eruptions were rather violent. One possible source of the lavas was discovered in a belt of rhyolite about 50 feet wide cutting through the basalt in a southeasterly direction almost parallel to, and a few hundred feet to the northeast of, the Eagle diorite This belt was observed at various points between the summit contact. of the divide and an elevation 500 feet lower down, below which point its course was not investigated. Its borders are highly brecciated, but composed of the same material as the more massive interior. Although such a fissure or other similar fissures might have been the source of the rhyolite lavas, they do not appear to have furnished the later tuffaceous rocks, and since the greater bulk of these two volcanic types is believed, from structural relations and similar composition, to have been derived from a common vent or vents, such fissures are, consequently, not regarded as a satisfactory source for either type. It is more likely that Coquihalla peak is the original vent or crater and that its occupation by basic intrusives is due to later eruption of more basic lavas that have since been eroded, leaving only the core or neck of the volcano exposed. The predominance of rhyolitic lavas around this peak, and the increasing fineness in grain of the intrusive plug towards its contacts with the lavas, suggest that the latter had partly or entirely cooled prior to the later eruptions. The observation, too, of basaltic dykes cutting rhyolite flows to the east of Coquihalla peak and beyond the limits of the area, lends some strength to the theory that there were later more basic eruptions than those supplying the rhyolites and pyroclastic rocks.

## Age and Correlation

The age determination of the Coquihalla series is based almost entirely on structural evidence. The series overlies both the Cretaceous sediments and the later batholithic intrusives and is consequently younger than any The surface upon which the volcanic flows and pyroclastic of these rocks. formations were laid down, probably possessed a considerable relief and was one from which the older and more steeply folded Cretaceous sediments had been largely eroded, exposing broad areas of the batholithic rocks. The broad folding of the Coquihalla series may have been influenced in part by the character of this underlying topography, but the symmetry of the folds is so pronounced as to indicate deformation rather than conformation with an underlying topography. The present drainage has been developed across the series, irrespective of the underlying structure, and in itself strongly suggests that these volcanic rocks were laid down prior to the peneplanation of the area in Pliocene time.

It is, therefore, considered that the Coquihalla series was deposited upon a surface of moderate relief, prior to the peneplanation of the district, and that its present volume is but a part of what originally composed the series. After deposition the volcanic members were broadly folded, and during Pliocene time suffered profound erosion, but owing to their late and heavy accumulation they did not reach the mature stage of peneplanation characterizing the older terrains less protected by Tertiary rocks. As a consequence, on their re-elevation in late Pliocene time, they stood somewhat above the general plateau level, and their more resistant members, such as the core rock of Coquihalla peak, still maintain a superior elevation. From late Pliocene or early Pleistocene to the present, these rocks have, in common with all others in Coquihalla area, been subjected to constant erosion resulting in the present topography.

As no formations similar to the Coquihalla series have been described from any adjacent areas, and as the age of the series is itself in some doubt, no satisfactory correlations can be made. It appears, both structurally and lithically, to be quite different from the Cedar Creek volcanics in the Tulameen area<sup>1</sup> which are definitely of Oligocene age. Its deformation is in general less than that of the Cedar Creek series, suggesting that it was not subjected to all the deformation endured by that series. Two periods of orogenic activity are represented in the Tertiary period of southwestern British Columbia and the adjoining areas of the United The earlier one at the close of the Oligocene was the most pro-States. nounced, and was the only one recognized by Dawson in the Kamloops map-area.<sup>2</sup> Evidence for a second period of deformation has, however, been obtained near the International Boundary by Daly, and in the Snoqualmie and Mount Stuart quadrangles in the state of Washington by officers of the United States Geological Survey. This disturbance is regarded as having taken place near the close of the Miocene. Its effect may not have been sufficient to cause a general crumpling of the post-Oligocene formations in the Interior Plateau of British Columbia. It was

<sup>&</sup>lt;sup>1</sup> Camsell, C., Geol. Surv., Can., Mem. 26, p. 82. <sup>2</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept. 1894, vol. VII, p. 71 B.

probably more pronounced in the Cascade Mountain province and sufficiently great to have deformed the Coquihalla series. These two periods of deformation would account for the greater deformation of the Cedar Creek series, and would place the Coquihalla series in the Miocene period, which would correlate it with volcanic rocks that cover a great part of the western half of the Cordilleran belt. The bulk of the volcanic rocks in the Kamloops map-sheet (Kamloops volcanics) were assigned by Dawson to this period.<sup>1</sup> South of the International Boundary the great volcanoes of the Cascades and of Mexico; the immense eruptions of andesites and basalts in Yellowstone park; and the great Columbia River basaltic flows, are of Miocene age.<sup>2</sup>

## BATHOLITHIC ROCKS

### General Subdivision and Distribution

Batholithic rocks are exposed over about 45 per cent of the map-area. They constitute a complex of plutonic intrusives ranging in composition from granites to diorites, and in age from Jurassic to Tertiary. They occur principally in two large areas of nearly equal size at opposite ends of the map-area.

The northerly area is composed entirely of Cretaceous intrusives. These have been subdivided into three types which were probably intruded at brief intervals from the same magmatic reservoir. The rocks range from acid granites to diorites. The more basic types represented by the Eagle diorite and quartz diorite formations were the first to be intruded. They were followed by the Eagle granodiorite and still later by an intrusive complex in which true granites predominate. The southwestern area is much more complex, and boundaries of the several members are less accurately located. Besides including types which are lithically very similar to the Cretaceous intrusives of the northern area, they contain others of both acid and basic composition which are probably Upper Jurassic in age, and still others of basic composition which are believed to be Tertiary. Between these two principal areas of batholithic rocks are a number of smaller intrusive bodies. None of these is pre-Cretaceous, but those occurring near the head of Dewdney and Cedar creeks may be of Tertiary age.

## Jurassic Batholithic Rocks

### Distribution

Batholithic rocks referable to this period of intrusion are confined to relatively small areas east of Fraser river at Hope and on both sides of this river above Haig station. They are exposed on both sides of Coquihalla river above the mouth of the Nicolum and constitute a part of the batholithic complex lying between this tributary and the broad belt of Carbonif-

<sup>&</sup>lt;sup>1</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1894, vol. VII, p. 76 B. <sup>2</sup> Scott, W. B., "An Introduction to Geology," 2nd edit., p. 752.

erous (Cache Creek) rocks. They are the least well-exposed of the batholithic formations in the map-area. Although they include part of Hope mountain with an elevation of 5,700 feet, they are for the greater part low and covered by surface accumulations. The vegetation is also especially heavy in this section of the map-area almost to the higher summits. The shattered character of the rocks has rendered them an easy prey to surface alterations, so that it is in many places difficult to secure fresh specimens.

### Petrography

Although occupying a relatively small area these rocks include a variety of types which more detailed investigation might show to differ not only in mineral composition but in time of intrusion. They occur, however, in an area of great relief and dense vegetation, so that it is difficult either to find adequate exposures or to follow the contacts for any distance.

As a whole these Jurassic rocks are distinguished from later batholithic intrusions by an intensely sheared and fractured appearance and a somewhat gneissoid structure. The shearing and crushing are noticeable not only in the outcrop but in hand specimens. The directions of shearing did not appear entirely constant, but varied for different members or even within these members themselves. In general, shearing at steep angles in a northwest-southeast direction is most prevalent, but is usually accompanied by nearly vertical jointing in one or more other directions. An almost horizontal jointing was also observed in some outcrops. Fragments broken off with the hammer are commonly bounded by irregular fracture planes along which decomposition of the rock has begun.

The Jurassic intrusives may be subdivided into the following types without, however, any detailed attempt to outline their respective boundaries.

Hornblende Granite, and Granodiorite from Hope Mountain. This rock composes a large part of Hope mountain and is typically exposed along the Canadian National railway above Hope, and on the Canadian Pacific railway above Haig station. It outcrops as an extremely sheared and fractured rock of medium grain, varying from light to dark greenishgrey, according to the abundance of dark minerals present. It is as a rule somewhat gneissic. Where hornblende is the conspicuous mafic mineral it occurs as narrow, greenish streaks in which the original crystal outlines are rarely distinguished. All varieties of this rock are intersected by innumerable small quartz stringers and by white aplite veins or dykes. Some of the latter reach several feet in width and are abundantly exposed in the railway cuttings on each side of Fraser river.

Under the microscope this rock is remarkable for its pronounced cataclastic structure. The quartz grains, which constitute about 30 per cent of the rock, are excessively fractured and drawn out into long, parallel forms, or bent around the more resistant feldspar crystals which are hypidiomorphic and are arranged roughly parallel to the crushed quartz bands. They are altered to sericite and kaolinic products. These feldspars include both potassic and acid sodic varieties in varying proportions. The plagioclase is distinguished by narrow albite twinning and has a composition about that of albite or albite-oligoclase. Together the feldspars occupy from 40 to 60 per cent of the slide. The darker constituents are arranged between the bands of quartz and feldspar. They were probably chiefly hornblende, but have been entirely altered to chlorite and magnetite. Their proportion to the light minerals varies considerably in different specimens, but is rarely over 10 per cent of the whole. Magnetite and titanite are present in small proportions as accessory minerals. The former is partly altered to reddish oxides of iron.

Intersecting these intrusives are many aplite veins and dykes varying from narrow stringers to belts several feet wide. Their composition, aside from a smaller content of mafic minerals, is not very dissimilar to the rocks which they intersect. They are massive, white intrusives which occasionally show streaks of micaceous minerals, chiefly muscovite, but are usually composed almost entirely of quartz and feldspar. They are considerably fractured, but do not possess the pronounced cataclastic structure of the older rocks. In thin section they show a fine, siliceous groundmass through which are scattered many euhedral feldspar crystals. Some of these are acid plagioclase, but orthoclase is more abundant and shows good Carlsbad twinning. A few irregular and greatly strained quartz crystals were also observed, but most of the quartz is, apparently, contained in the groundmass.

Granodiorite West of Haig Station. In the hand specimen this rock has a fractured appearance, but crushing is less noticeable than in the preceding type. A specimen was obtained from a coarse, inequigranular granodiorite outcrop possessing a crude gneissic structure in which irregular bands of quartz and feldspar alternated with others of coarsely crystalline green hornblende and black biotite.

Under the microscope the dark minerals include about equal proportions of green hornblende and brown mica, both of which are remarkably fresh and together compose about 20 per cent of the slide. They occur principally as comparatively large crystals which have been partly resorbed and replaced by later feldspar and quartz. The mica is crumpled and in polarized light shows variegated interference colours. The most abundant mineral is a fresh-appearing albite-oligoclase feldspar showing very clear albite twinning. A much smaller proportion of orthoclase was observed. Quartz constitutes about 20 per cent of the slide, and occurs interstitially between hypidiomorphic tabular feldspars. It is greatly strained and partly comminuted.

Hornblende Quartz Diorite and Diorite from Wardle Creek. These more basic members of the Jurassic batholithic rocks are best exposed in the valley of Wardle creek, a tributary of Silver creek, at elevations ranging from 500 to 3,500 feet above sea-level. They vary from quartz diorites to basic diorites, in which hornblende and biotite and, in one case, enstatite, form the conspicuous dark minerals. They are, in common with other types of these batholithic rocks, much sheared and fractured and as a rule slightly foliated.

The most abundant mineral is a plagioclase feldspar, mostly fresh and showing albite twinning. Its composition varies from basic oligoclaseandesine to andesine-labradorite. It occurs in part as large, euhedral, tabular crystals and in part as smaller allotriomorphic individuals associated with the darker constituents. In one section it was observed graphically intergrown with hornblende within a corroded embayment in a large brotocrystal of hornblende. Hornblende is the most abundant of the mafic minerals in these rocks, but its proportion to biotite varies considerably and in certain specimens they are present in about equal amounts. The hornblende usually shows strong absorption and its larger crystals are often remarkably poikilitic, enclosing a variety of small, granular crystals of other minerals, among which apatite, magnetite, and pyroxene are most noticeable. The hornblende is in part altered to chlorite and probably some of the magnetite present is secondary after the amphibole and biotite.

Biotite occurs in large brown or almost black basal sections and in pleochroic shreds showing characteristic absorption colours. It is in many places partly or completely altered to chlorite and magnetite. In the more fractured rocks the biotite is greatly warped and distorted and some basal sections show a streaked brown and black appearance probably due to crumpling. The larger crystals show a marked protoclastic structure, the granulated particles of a single flake forming a mosaic with equant crystals of quartz and feldspar.

Quartz constitutes between 5 and 15 per cent of the quartz diorites, but is less in the more basic rocks. It is interstitial and usually fractured or strained. Apatite and magnetite are the more important accessory minerals, but small titanite and rutile crystals are also present.

The order of crystallization for the different rock types depends upon their basicity and mineral composition. Large euhedral crystals of hornblende and biotite appear to have been the first to form, but as crystallization proceeded these were in part resorbed and present characteristic corroded outlines. The hornblende is commonly poikilitic and both hornblende and biotite exhibit a somewhat protoclastic or granulated texture. In the case of the biotite this texture is specially pronounced. Following these larger crystals of mafic minerals a large proportion of the plagioclase crystallized out, usually in well-developed euhedral or subhedral crystals inferior in size only to the earlier mafic minerals. These feldspar crystals. in turn, may be partly resorbed. Small crystals of magnetite, apatite, and rutile appear to crystallize out most abundantly at about this stage. Following the more perfectly developed feldspars the order of crystallization is less well-defined and there is probably a more nearly simultaneous crystallization of the remaining constituents. The average size is here much smaller, the texture more allotriomorphic and to some extent intergrown, and there is some replacement through resorption of the earlier formed minerals.

Enstatite Quartz Diorite. An interesting variety of these basic rocks was observed at an elevation of about 3,000 feet, and at higher points on the ridge between Silver creek and Fraser river. In the hand specimen this rock is massive, moderately coarse-grained, and nearly equigranular. It is yellowish brown but weathers in darker shades, and has, in common with other members of this group, a fractured appearance. Under the microscope, however, this rock shows little sign of alteration. The dark constituents include large, irregular brotocrystals of biotite showing very strong absorption colours from light brown to deep reddish brown; almost equally large green and only slightly pleochroic hornblende crystals, the larger of which show markedly corroded outlines; and an abundance of almost colourless enstatite, occurring, for the most part, in euhedral prismatic and basal sections showing characteristic parallel extinction, high relief, and low birefringence. This pyroxene is partly replaced by the hornblende, and its crystals, associated with others of feldspar and quartz, commonly occur within large basal sections of biotite.

From 50 to 60 per cent of the slide is composed of beautifully clear aggregates of quartz and plagioclase, which, in ordinary light, are almost indistinguishable, but between crossed nichols are easily differentiated. The plagioclase has a composition of about and esine-labradorite and shows some tendency toward zonal growth. The crystals are somewhat tabular or hypidiomorphic. No orthoclase was identified. Quartz is associated both interstitially and in consertal aggregates with the feldspar and is about half as abundant. It is considerably fractured and strained but not comminuted and is, in part, graphically intergrown with the hornblende and enstatite. Magnetite is an abundant accessory mineral and is associated with the hornblende and biotite. Numerous small crystals of apatite were observed.

The entire slide shows in ordinary light a yellowish stain following the peripheries of the crystals and the fracture lines in them. This is a chloritic or limonitic alteration product.

### Internal Structural Relations

The gneissoid structure of the Jurassic rocks is regarded as due in a great measure to dynamic forces acting at a period subsequent to their consolidation. In this particular, it differs genetically from the gneissic structure exhibited in the later batholithic rocks and developed chiefly during consolidation.

As stated in a previous section, the composition of the Jurassic batholithic rocks varies widely, ranging from granites to diorite. The boundaries between the different members are poorly exposed and the members were not studied in sufficient detail to account for their manner of differentiation or their order of intrusion. It seems fairly certain that they were not all intruded simultaneously, but it is probable that the several types are not separated by important time intervals.

### External Structural Relations

The Jurassic batholithic rocks come in contact with later intrusives as well as with both older and younger sedimentary and volcanic formations. They are definitely intrusive in the Cache Creek series. Contacts are well exposed along the southern slope of Ogilvie mountain; southwest of Nicolum river; on Hope mountain; and along the railway cuttings above Haig. The older rocks are metamorphosed in a varying degree as described in discussing the Cache Creek series. Many dykes and apophyses from the batholithic intrusives are conspicuous near the contacts with these older rocks. A contact with the Cretaceous sediments was observed on the southwest flank of Hope mountain a short distance above the railway, and at other points farther up the hill. Although the conglomerate there participated to a marked degree in the orogeny of the underlying batholithic rocks, there are no indications of contact metamorphism between the two formations. The gritty matrix of the conglomerate is distinctly feldspathic and many of the plutonic cobbles and pebbles are identical in appearance with the batholithic rocks. The contact between the two is loosely cemented and it was difficult to secure a specimen showing parts of both formations. A thin section from such a specimen showed the gneissic structure of the granite running at an angle to, and abruptly truncated by, the line of contact. The calcite that forms a large part of the cementing material of the conglomerate matrix is also deposited in the fractures of the underlying batholithic rock.

To the west of Haig the actual contact between this Cretaceous conglomerate and the granodiorite was not observed, but a few feet on either side the same relations hold as on Hope mountain. No sign of metamorphism is apparent, and the matrix and pebbles of the conglomerate so much resemble detritus from the underlying igneous rock as to leave little doubt regarding the relative ages of the two formations.

The contacts between the Jurassic and the Cretaceous intrusives have furnished less satisfactory criteria as to their relative ages than is obtainable from their separate relations to the Cretaceous sediments. On the western slope of Silver peak and on the southern shoulder of Hope mountain the younger batholithic rocks have been found intruding these Cretaceous sediments, whereas the older intrusives definitely underlie them. The clearest relation between the two batholithic bodies was observed on the summit of the ridge to the southeast of Hope mountain and on the northern slope of this ridge above Nicolum river. Near the contacts with the Cretaceous intrusives, the Jurassic rocks are intersected by many dykes which, although not proved to be direct apophyses from the younger formation, are, from their attitudes and composition, judged to be of approximately the same age. The younger batholithic rocks too, are, in general, more massive and less sheared and fractured in appearance than the older intrusives. The actual line of contact along the summit of the Hope Mountain ridge proved difficult to follow, for there are a number of irregular areas on this divide too small to map, which more closely resemble the older than the younger rocks, although included with the latter. These areas are small near the summit of the ridge, but they may extend for some distance down the steep southwestern slope toward Silver creek. This side hill was, however, too precipitous to investigate, and, as the greater proportion of the rocks more distinctly resembled the Cretaceous intrusives, they have, for lack of more precise information, been included with them. Elsewhere the contact is believed to be more accurately located, but at every point investigated the dense vegetation so obscures the actual contact that its position was determined mainly from abrupt changes in the character of the rocks. The contacts, in some instances, coincide with breaks in the topography.

### Mode of Formation

The Jurassic intrusives exposed in Coquihalla area do not afford very reliable criteria regarding their manner of intrusion, as both intrusive and intruded rocks have been greatly deformed and metamorphosed by subsequent batholithic intrusions. The only rocks in the area which are cut by these Jurassic intrusives are those included with the Cache Creek series. The contact of the two formations is best exposed along the southern shoulder of Ogilvie mountain. Within the older rocks near this contact is an ill-defined zone of apophyses in which a number of acid and a few basic dykes were observed. These appear to have been intruded during and toward the close of the invasion and consolidation of the larger batholithic body. Within the latter no broad zone of inclusions, so characteristic of the contacts of later batholithic intrusions, has been observed, but this may, at least in part, be due to the character of the cherty rocks of the Cache Creek series exposed along this contact. The small area of slates exposed at Haig has been more completely invaded by batholithic material, chiefly in the form of acid sills, but even there evidence of magmatic stoping or absorption is not conclusive.

In more favoured areas the relation of these Jurassic intrusions to the older formations is better shown and it has been indicated by Daly, Camsell, Bancroft, Bowen, and others that the processes of invasion are very similar to those which the writer was able to recognize along the contacts of later batholithic intrusions in Coquihalla area. These processes in general involve a gradual rather than a violent incursion of magmatic material into overlying formations; the injection of a network of dykes, or in the case of well-bedded rocks, sills; the gradual rifting of overhanging blocks from their parent formation; the filling of the cavities so formed with igneous material and the partial or complete resorption of the loosened fragments at other levels in the magmatic chamber.

# Age and Correlation

The age of these batholithic rocks cannot be fixed with any great degree of accuracy from observations within the map-area. Certain of them definitely intrude the Cache Creek rocks and as definitely underlie the Cretaceous rocks of the area. They appear to form a small outlier from the great body of batholithic rocks of the Coast range, which is regarded, for the greater part, as Upper Jurassic. Cretaceous members have, however, been recognized and pre-Upper Jurassic intrusives may be represented.

North of Coquihalla area these presumably Jurassic intrusives are continuous with exposures of sheared granodiorite through which Fraser river has cut a narrow and difficult passage. The age, structure, composition, and mode of formation of these more northerly sections have been discussed by Camsell and Bowen in reports already referred to.

# **Cretaceous Batholithic Rocks**

Batholithic rocks of Cretaceous age occupy nearly 90 square miles in the northern section of Coquihalla map-area, where they have been subdivided into three formations on structural and lithological grounds. They also occupy a large part of the southern areas of batholithic rocks where both Jurassic and Tertiary intrusives are represented. In the southern section of the area no subdivision of the Cretaceous irruptives has been attempted. The large apophysis of batholithic rocks that extends across Cedar and Dewdney creeks, and the granodiorite bodies exposed in the vicinity of Manson mountain in the southeastern corner of the map-area, belong to this period of intrusion. The quartz diorite stocks exposed near the head of Dewdney and Cedar creeks have also been tentatively included with the Cretaceous intrusives, but may be of Tertiary age.

The three intrusives forming the northern area of Cretaceous batholithic rocks are genetically related and are believed to have been intruded separately as successive stages of the one period of batholithic invasion. The first stage is represented by the Eagle diorite which occupies two comparatively small and irregular areas, one on either side of Coquihalla river. At a somewhat later stage, or possibly even contemporaneously with the invasion of this diorite, the much larger body of Eagle granodiorite was intruded farther to the northeast. Still later a third and, locally, even larger complex of granite and acid granodiorite was intruded to the southwest and includes the large apophyses which extend to the south across Cedar and Dewdney creeks.

#### EAGLE DIORITE

### Distribution

This diorite occurs in two comparatively small areas lying on opposite sides of Coquihalla river. At their lowest exposures these two areas of intrusives approach closely to the stream bed, but were, in no instance, observed to cross it. At one time they may have formed a continuous body and have been subsequently separated partly by a fault which closely follows the present stream bed of Coquihalla river, and partly by erosion. The separation may also be in part due to the pressure exerted on the still viscous body of Eagle granodiorite and the diorite by the large batholithic complex of granite and granodiorite west of Coquihalla river and south of the diorite. The diorite is well exposed in a series of precipitous cliffs to the east of Iago. It also forms a prominent needle-shaped peak north of Romeo, the northern flank of this mountain dropping abruptly in a series of nearly vertical cliffs into the glaciated valley occupied by Falls Elsewhere this formation appears on the whole to weather more lake. readily and to furnish a soil more conducive to vegetable and forest growth than the adjoining more acid batholithic rocks.

## Petrography

It was found in mapping this formation that, although it is easily distinguished from the adjoining batholithic members, it varies considerably both in composition and texture, particularly near its contact with older formations. It is in general a dark green, moderately coarsegrained intrusive, some of it massive but mostly slightly gneissoid and in some sections distinctly foliated. Hand specimens are in many places very irregularly fractured and much decomposed. Near the older Cretaceous sediments the rock is finer-grained and sometimes porphyritic.

In thin section the rock was found to contain between 50 and 60 per cent of plagioclase which has the composition of sodic andesine. This feldspar is as a rule turbid with alteration to sericite. It is finely twinned, on the albite law, and occurs for the greater part in tabular euhedral crystals, forming with the interstitial amphibole a crude diabasic texture. Hornblende is the principal mafic mineral and occupies over 25 per cent of It is pleochroic in light and dark green shades and twinning is the slide. common. It occurs both in large crystals which are slightly poikilitic, and in numerous, smaller, irregular forms interstitial between the feldspars. From less than 5 to about 15 per cent of quartz occurs interstitially between the other minerals, and is strained and somewhat fractured. Where most abundant the rock has the composition rather of a quartz diorite. Magnetite is the most abundant accessory mineral. Apatite occurs in smaller proportions. Some titanite is prominently developed as euhedral crystals and grains intergrown with magnetite. Epidote is the most characteristic secondary mineral and in some places is very abundant. Chlorite is another common alteration product of the mafic minerals. A rapid calculation of the mode, by the Rosiwal method, from a thin section of a specimen obtained from the left bank of Coquihalla river below Romeo, gave the following approximate mineral composition: plagioclase 57 per cent; quartz 14 per cent; hornblende 24 per cent; magnetite, epidote, and other accessories 5 per cent. With the plagioclase is included an irregular but small proportion of orthoclase which does not appear to exceed 5 per cent and is probably less. The average specific gravity of these rocks is approximately  $2 \cdot 79$ .

## Internal Structural Relations

The diorite shows a gneissoid structure which, in places, is well developed and in others poorly defined. In the finer-grained or porphyritic varieties such as are encountered near the borders of the mass there is little or no foliation. The direction of foliation is approximately parallel to that of the adjoining area of the Eagle granodiorite and varies a few degrees west of north. Jointing is pronounced in some outcrops, particularly on the steep slopes east of Iago and overlooking Falls lake. One principal joint system follows nearly parallel to the course of Coquihalla river on either side of Romeo. Another strikes a few degrees north of west, and has formed a steep escarpment above Falls lake. Still another, and more poorly developed, jointing is nearly horizontal, but is not as pronounced as in the more massive granite farther south. Some shearing has occurred, and fracturing is pronounced in the outcrop or in hand specimens.

## External Structural Relations

The diorite is in contact to the northeast with the Eagle granodiorite and the Coquihalla series and to the southwest with Cretaceous granite and Cretaceous sediments.

The actual contact with the Eagle granodiorite has nowhere been observed, owing to its relatively low elevation and consequent covering by a heavy mantle of surface accumulations. It is doubtful whether any definite line of division exists, for, in those parts examined, there appeared to be a zone of gradual transition 100 feet or more in width between the two formations. The direction of foliation in the two rocks is almost the same and was probably effected by the same forces. There is reason to believe that the diorite is the earlier intrusion, but it may represent a basic segregation developed in place, and consequently intruded contemporaneously with the granodiorite. From considerations discussed later the first view seems the more probable.

The diorite had evidently been bared and suffered considerable erosion prior to the extrusion of the Tertiary Coquihalla series. The latter overlie at low angles the flanks of the batholith, and their contacts have been observed at different elevations above the left bank of Coquihalla river, where the lowest exposures of the volcanic rocks are now found. Although no fragments of Eagle diorite have been definitely identified from the volcanic tuffs and breccias there is a great abundance of material from the adjoining Eagle granodiorite in the pyroclastic beds of the Coquihalla series.

Contacts with the older Cretaceous sedimentary rocks are exposed on either side of Coquihalla river. To the northwest of Romeo a long, irregular area of Cretaceous rocks overlies the contact between the Eagle diorite and a Cretaceous granite. The metamorphism of the Cretaceous rocks is very pronounced across their entire width, but is most marked on the side nearest the granite intrusive, and it would be difficult to judge from this exposure alone whether the entire metamorphism was not due to this intrusion. However, a number of acid and basic dykes cut both Cretaceous sediments and the diorite near their contact, and these may have originated from the granite magma. This evidence, taken in conjunction with the greater intensity of metamorphism exhibited by the sediments nearest the granite contact, and the observed intrusion of these Cretaceous sediments by the diorite east of Iago, seems to show that, not only were the Cretaceous rocks intruded by the two batholithic bodies, but the granite intrusive was the later.

To the east of Iago the diorite definitely intrudes the Cretaceous rocks exposed on the divide between Coquihalla river and Carey creek. A number of apophyses in the nature of broad dykes were observed on this divide. These have effected local metamorphism of the sediments to a degree varying with the distance from the contact. Near the contact the composition of the diorite is variable and the structure changes from a moderately coarse and gneissoid rock to one of much finer grain and sometimes distinctly porphyritic. These variations can be traced into the more typical diorite and become, in general, less pronounced as the distance from the older sedimentary rocks increases.

It has already been observed that the contact with the Cretaceous granite is obscured to the northwest of Romeo by the long, narrow belt of Cretaceous rocks which is more intensely metamorphosed at the granite, than at the diorite, contact. This observation, taken in conjunction with the occurrence of dykes cutting both diorite and sediments, and the heavy sulphide mineralization of the diorite at some points near the granite contact, indicates that the granite intrusion is the later. Along the left bank of Coquihalla river observations may be made within a few feet of the granite and diorite contact at a number of points. The granite appears barely to cross the river and a few feet above its left bank the diorite is always encountered. Along this contact the change is always very abrupt. Both rocks retain their peculiar characters without change at the contact. There is no apparent decrease in coarseness or change in mineral composition. The diorite is in places somewhat more shattered than normally, but this is, probably, due to other than contact influences. The contact is, in short, so clear cut as to suggest the occurrence of a fault up Coquihalla valley in this vicinity, a suggestion which has already received some consideration and is based on other structural factors.

About a mile above Iago, and along the railway, a number of andesite porphyry dykes, from a few inches to several feet wide, cut the granite and are apparently continuous with other dykes on the east side of the river, which intersect the diorite. These dykes might, at first, be taken to represent a late phase of intrusion of either the granite or the diorite more probably the latter—but they are coarser where they intersect the granite than where they intrude the diorite. There is, accordingly, some suggestion favouring the origin of these dykes from the granite magma at a period before the latter had entirely cooled.

The normal order of batholithic intrusion is also such as to suggest the later irruption of the granite.

# Mode of Origin

The form in depth of the two bodies of Eagle diorite is outlined by the natural exposures along the contacts west of Coquihalla river. Here the intrusive is seen to differ from a typical batholithic body which widens with depth, in that it is apparently narrower at the lower altitudes than nearer the summits of the divides. This peculiarity, together with the gradual transition noticed between it and the granodiorite, suggests that these rocks had the same source; that the diorite was first intruded; and that while it was still in a semi-molten state the main body of the granodiorite was intruded and under pressure carried the greater part of the diorite ahead of it. Later, a certain amount of mixing of the two intrusions occurred under the influence of gravitation, and possibly convection currents, producing a gradational zone of hybrid rock between them.

That the diorite was not violently intruded is suggested by the present attitudes of the old sediments which it invaded. Although these stand at high angles they are not more disturbed or deformed near the contacts of the intrusive than at some distance away, and, in the case of the Cretaceous belt northwest of Romeo, they preserve a uniform attitude across their entire width, although lying above the contact of two separate intrusions.

## Age and Correlation

The diorite definitely intrudes those sediments regarded as Lower Cretaceous and is as definitely overlain, after a long period of erosion, by the Tertiary volcanic rocks of the Coquihalla series. It is of nearly, if not quite, the same age as the Eagle granodiorite.

#### EAGLE GRANODIORITE

### Distribution

The Eagle granodorite is the most northerly of the batholithic formations exposed in the map-area. It forms a belt between 4 and 5 miles wide extending northerly across the upper end of the area on either side of Coquihalla station. To the south it is continuous with the Eagle granodiorite of the Tulameen map-area, where it has approximately the same width. Beyond the limits of these two areas its course has not been followed. To the south it may extend beyond the summit of Whipsaw creek and to the north it is probably continuous with Cretaceous members of the Coast Range batholithic complex.

The Eagle granodiorite is the best exposed of the batholithic rocks in Coquihalla area. It occurs at elevations ranging from 3,000 feet to over 6,500 feet above sea-level and its upland topography is everywhere modified by glaciation. It does not weather readily and has consequently provided too scanty a soil to support a heavy vegetation or forest growth.

### Petrography

The petrographical characters of this formation have been described by Camsell in his report on the Tulameen area. The following discussion, however, refers primarily to its occurrence within the Coquihalla area.

Here the Eagle granodiorite is a moderately coarse to coarse-grained and nearly equigranular rock showing slightly gneissoid to well-developed, foliated structure across the entire width of the belt. Foliation is particularly pronounced to the northwest of Coquihalla river. It is roughly parallel to the axis of the body, but varies through several degrees to the east of north in the areas east of Coquihalla and Coldwater rivers and is more nearly north or slightly west of north in the sections west of these streams. The foliation is not uniformly well-defined. In part it assumes the character of alternating bands of fine-grained, dark material with others of coarser grain composed chiefly of felsic minerals. A slightly miarolitic structure has been observed in some of these lighter bands and in such cases their composition is more nearly that of a granite

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than of a typical granodiorite. Either kind of band may show welldeveloped gneissic structure, and as a rule the darker bands are the narrower. The origin of the banding is uncertain. The moderately fine-grained and miarolitic characters of this banded rock indicate that it solidified as a peripheral phase of the batholith comparatively near the surface where it would have come in contact with overlying formations. The great regularity of the banding and the miarolitic structure of the intrusive suggest that there may actually have been some replacement of an earlier stratified formation resulting in the development thereby of a relict gneiss. Other sections of the granodiorite are more uniformly gneissic. Still others are quite massive. Hand specimens as a rule show less evidence of foliation than the exposures from which they are obtained.

The colour of the rock varies according to the character and proportion of the constituent minerals, and their decomposition under weathering conditions. Either grey or pink feldspars may be present in excess, and intermediate shades are common. A pinkish weathering was observed in many places where the freshly fractured rock is grey. Greenish hornblende and black biotite lend their colours to the rock in proportion to their abundance and decomposition. Plagioclase feldspar, with the composition of oligoclase, is the principal mineral constituent and may be either grey or light pink. Orthoclase is subordinate in amount to plagioclase. With the feldspar is associated an abundance of smaller grains of glassy quartz. Biotite is the chief dark mineral and mostly occurs in small, lustrous, black flakes. Hornblende can generally be observed and locally is in excess of the biotite. A colourless mica resembling muscovite is in many cases abundant and is characteristically present in the pink varieties of the granodiorite where biotite is absent or present in very minor proportions. Epidote is in many cases a very conspicuous constituent and is commonly most noticeable where hornblende is plentiful.

A thin section taken from a pink-weathered, greenish-grey, hornblende type showing slight foliation contained about 20 per cent of green hornblende and brown biotite partly altered to epidote and chlorite, 50 per cent of oligoclase, 5 to 10 per cent of orthoclase, and 20 per cent or less of quartz.

Pegmatites are of common occurrence in the granodiorite and do not appear to characterize any particular part of it. They are abundantly exposed along the railway cuttings between Coquihalla and Romeo and have been observed at a number of points on either side of Coquihalla river. They occur as very irregular intrusions from a few inches to several yards wide. In part, they definitely intersect and, in part, they appear to show a gradation into the granodiorite. Their mineral composition is very simple, consisting entirely of pink orthoclase, milky white massive quartz, and muscovite. The average specific gravity is  $2 \cdot 59$ . The texture is extremely variable, but the coarser varieties rarely show crystals over  $1\frac{1}{2}$  or 2 inches long. Graphic intergrowths of quartz in orthoclase are very characteristic of both coarse and fine-grained types. Muscovite occurs either in well-crystallized, tabular books or in fern-like aggregates. These pegmatites were, probably, intruded at a late stage in the consolidation of the granodiorite.

## Internal Structural Relations

A gneissoid structure is apparent over the greater width of the granodiorite belt, but is not always equally well-defined. No generalization, however, can be expressed as to where foliation is best developed. Camsell found that in the Tulameen area this structure was prominent near the contacts with the older rocks of the Tulameen series and was generally lacking in the more central parts of the batholith. In Coquihalla area this rule does not hold, although the contacts are here chiefly with younger formations. The trend of foliation is not uniform throughout the belt, but varies through several degrees east of north to the east of Coquihalla and Coldwater rivers, and slightly west of north to the west of these streams. It would seem, consequently, that the pressure producing this foliation, whether exerted on the solid rock or on a viscous magma, had not been uniformly applied. Thin sections show that the rock has undergone some fracturing since its consolidation, but that the fracturing was accomplished after the development of the foliation. The latter is not a type such as would result from crush metamorphism of an originally massive rock, but from its regularity, the linear arrangement of the mineral con-stituents, and an absence of intense granulation, seems to be rather the result of pressure exerted on, or movement effected in, a viscous or semimolten magma. The fact that the foliation seems to be more continuously developed west of Coquihalla river and is less conspicuous to the east of this stream and farther south in Tulameen area, has led the writer to believe that the pressure producing the gneissic structure was set up by the intrusion of the complex of granite and acid granodiorite to the southwest of the Eagle granodiorite in Coquihalla area, and that this pressure was applied while the granodiorite was still viscous.

The granodiorite does not appear to have been sheared or crushed to a like degree with the Jurassic batholithic rocks. Jointing is well-defined and is transverse rather than parallel to the foliation. Some fracturing has occurred, but thin sections do not exhibit that pronounced cataclastic texture so characteristic of members of the Jurassic batholithic rocks.

## External Structural Relations

The Eagle granodiorite forms an intrusive contact with the Tulameen series to the northeast; is faulted against the Lower Cretaceous sediments along Coquihalla river; underlies the Coquihalla series to the south; and is more or less gradational into the Eagle diorite to the west. It is in turn intruded by the granite member of the batholithic complex exposed along the railway at and below Romeo.

The granodiorite is definitely intrusive in the Tulameen series. Metamorphism and intrusion are pronounced near the contact. The older rocks have been invaded by a number of porphyritic dykes and apophyses from the batholith, and inclusions of Tulameen rocks are occasionally found in the granodiorite near the contact. The intrusive relations in the Tulameen area, where much longer contacts are exposed, have been described by Camsell.

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A discussion of the relation with the Lower Cretaceous sediments has already been given in dealing with these sedimentary rocks.

The volcanic members of the Coquihalla series were laid down on the Eagle granodiorite after it had been uncovered and had suffered considerable erosion. The unconformity between the two rocks is, therefore, very great. Fragments of the granodiorite are very common in the pyroclastic beds of the Coquihalla series and seem to be the only fragments of older material present.

There appears to be, as already mentioned, a gradation from the Eagle diorite to the Eagle granodiorite, the zone of transition being 100 feet or more wide. The possibility has been suggested of the diorite being a basic segregation developed subsequent to the intrusion of the same magma from which the granodiorite was also derived, but, from field observations, it seems more probable that the diorite was intruded a little earlier than the other, and had partly solidified prior to the invasion of the granodiorite. The zone of transition may represent a hybrid zone, limited in its breadth by the partly consolidated or still viscous condition of the diorite body. Had the diorite been entirely consolidated at the time of this intrusion the transition would, probably, have been much more abrupt.

It has been pointed out that the direction of foliation in the diorite coincides with that of the granodiorite, but that it is, on the whole, more irregular. This supports the theory that the diorite represents a somewhat earlier intrusion; that it had partly consolidated before the development of the foliation; and that, consequently, it exhibits a more markedly cataclastic structure than the granodiorite.

The actual contact between the Eagle granodiorite and the Cretaceous granite was not observed, being everywhere obscured by surface accumulations. It follows down Coquihalla river, and the two batholiths are probably separated along the same fault, to which reference has already been made. Although exposures have been observed within a few feet of this fault no change in the character of either of the intrusives was noted. Such foliation as occurs in the granodiorite is abruptly truncated and the granite shows no gneissosity. This in itself lends support to the belief that the granite is the younger rock. It has further been shown that this granite is in all probability intrusive in the Eagle diorite and that the latter is of approximately the same age as the granodiorite. It, therefore, follows that the granite is almost certainly younger than either of these other intrusives, although from other structural and petrographical features it does not appear to be separated from either by any important time interval.

### Mode of Origin

In the Coquihalla and Tulameen areas the Tulameen group is intruded by the Eagle granodiorite and along the contact Camsell has distinguished a zone varying up to 1,000 feet in width which is capable of subdivision into a zone of inclusions nearest the granodiorite and a zone of apophyses farthest away. These zones have been recognized in Coquihalla area, but their width is not well defined. From their occurrence, however, as well as from the similarity of the attitude of the intruded sediments near, and at some distance from, the contact, it is believed that the intrusion of this granodiorite was not accompanied by sudden or violent deformation, although considerable pressure may have been set up within the body of the magma. The processes by which it worked its way into the overlying rocks are regarded as essentially those described by Camsell and involve magmatic stoping of the Tulameen rocks by the invading magma.<sup>1</sup> It is, however, believed that the general gneissoid structure of the granodiorite in Coquihalla area may have resulted before the consolidation of this batholith, from pressure set up by later granite and granodiorite irruptives or other deformational stresses.

## Age and Correlation

It has been shown that the Eagle diorite is of almost, if not quite, the same age as the granodiorite, although probably intruded first. It is also almost certain that the sediments intruded by the diorite are not pre-Cretaceous. The great unconformity between the granodiorite and the Coquihalla series of Tertiary, and probably Miocene, age, indicates, further, that the granodiorite was intruded in pre-Tertiary time. There are also other large pre-Tertiary batholithic bodies in Coquihalla area which intersect the Eagle granodiorite. The age of the latter is, accordingly, referred to early Upper or late Lower Cretaceous time.

This batholith is continuous with the intrusive of the same name in the Tulameen area. Camsell tentatively assigned it to the Upper Jurassic on the basis: (1) of the occurrence of a "sheared and gneissic granitic rock much resembling but not actually known to be connected with the Eagle granodiorite" which appeared to be unconformably overlain by a volcanic breccia, the latter in turn being conformable beneath a coarse Cretaceous conglomerate; and (2) by the occurrence of granitic pebbles in this conglomerate which appeared to be identical with the Eagle granodiorite. The "volcanic breccia" mentioned by Camsell is probably a member of the Dewdney Creek series of Coquihalla area. This series is regarded by the present writer as older than the Cretaceous sediments of the area and as probably of Upper Jurassic age. The Cretaceous sediments are intruded by the Eagle diorite in Coquihalla area and this diorite is considered to be at least as old as the Eagle granodiorite. The writer was able to examine a number of conglomerate beds from the Cretaceous sediments and although some of the detritus somewhat resembled the Eagle granodiorite it was not considered that this resemblance was of particular value in indicating age relationship, for many of the pebbles bore an even more marked resemblance to the granites and granodiorites actually intruding the conglomerate than they did to the Eagle granodiorite.

The Eagle granodiorite may be tentatively correlated with Coast batholithic rocks belonging to contemporaneous periods of intrusion.

<sup>&</sup>lt;sup>1</sup> It must be admitted, however, that the curious "banding" (See p. 94) observed at some points in the granodiorite bears a suggestion of actual replacement in situ of bedded rocks and the formation thereby of what Sederholm calls a "relict gneiss." As, however, field evidence in general points strongly to a "stoping" process, the latter has been accepted as the more important factor in batholithic invasion in this area.

### COMPLEX OF CRETACEOUS BATHOLITHIC ROCKS FROM BOTH NORTHERN AND SOUTHERN AREAS—GRANITES, GRANODIORITES, AND QUARTZ DIORITES

### Distribution

Rocks of this composition are the most widely exposed of the batholithic formations in the district. They occupy a large, rectangular area to the northwest of Coquihalla river, between Romeo and Portia, and include the large apophysis that stretches southward from this area across Cedar and Dewdney creeks. The smaller areas of acid granodiorite exposed near Manson mountain are regarded tentatively as belonging to the same period of intrusion. The batholithic rocks south of Coquihalla river, below its junction with Peers river, include large areas of Cretaceous intrusives which have here been grouped together. They include members more nearly corresponding in lithology, and also probably in relative age, with the Eagle granodiorite and more siliceous parts of the Eagle (quartz) diorite.

In the northern areas to the west of Coquihalla river, and also in the vicinity of Manson mountain, they are well exposed, and support a very scanty forest or vegetable growth. In their extension across Cedar and Dewdney creeks, and in their distribution south of lower Coquihalla river and north of Hope Mountain ridge, they are densely forested, and, in general, so poorly exposed that it was difficult to observe the contacts of different types with each other or with rocks belonging to other geological periods.

### Petrography

These batholithic rocks are massive, moderate to coarse-grained, as compared with other intrusives in Coquihalla area, and are characterized, in general, by an abundance of granular glassy quartz. Orthoclase is an important constituent, is mostly pink, and, according to its abundance and the size of its crystals, influences the colour of the rock as a whole. The plagioclase is also in some cases slightly pink. The weathered surfaces of many of these rocks show a light pink coloration which is absent in the freshly fractured surfaces. All the rocks are massive in appearance, except in the immediate vicinity of contacts with older formations, where a slight foliation may occur.

The composition varies from that of granites and acid granodiorites in the northern part of the map-area, to quartz diorites in the southern part. A type of hornblende diorite occurs in some places as a basic border phase of the granodiorite and is gradational into the more acid body of the batholith.

## Northern Area

Typical granites are exposed along the railway between Romeo and Portia and on the hills to the west. They are coarse-grained, massive rocks and are, in part, markedly pink and, in part, light grey in colour. Alkali feldspars and glassy, slightly smoky quartz are the most prominent constituents. Small proportions of green hornblende and black, lustrous biotite are nearly always present. Either one of the mafic minerals may be present in excess or almost to the exclusion of the other. Where biotite is least abundant, the orthoclase possesses the deepest pink colour. These rocks weather to a coarse feldspathic sand.

In thin section the pink granite shows typical granitic texture. The alkali feldspar is principally an orthoclase occurring in large crystals often twinned after the Carlsbad law. It is a sodic orthoclase and commonly exhibits well-developed microperthitic intergrowths of acid plagioclase showing albite twinning. Small crystals of microperthite are common. Microperthitic borders were observed on the alkali feldspar and show a higher refraction than the interior of the crystal. Borders of similar appearance also occur on some plagioclase crystals and may represent myrmekitic intergrowths of plagioclase and orthoclase feldspars. No microcline was identified. Acid plagioclase, albite or albite-oligoclase in composition, is as a rule more abundant than the orthoclase, but in some types may occur in about equal proportions with it. It shows narrow albite twinning and commonly both it and the orthoclase are strained. In the plagioclase crystals, a faint zoning is developed in some places and may be the result either of straining or of differences in chemical composition. Quartz occurs abundantly in large and small granular It is commonly somewhat fractured and possesses notable undulaareas. tory extinction. Green pleochroic crystals of hornblende, many of them twinned, and a brown biotite are the principal mafic minerals. They are, as a rule, partly altered to chlorite and magnetite. Sericite and kaolin are the common alteration products of the feldspars. The specific gravity of this pink granite ranged from 2.60 to 2.63 in the specimens examined. The grey granite and acid granodiorite might be roughly separated from the pink granite by a line drawn from the head of the North fork of Ladner creek to a point on the railway 2 miles above Iago. The actual line of division was not followed, but, where observed, was found to be very intricate. The transition does not involve separate intrusions, but a differentiation in place. The change from deep pink to slightly pink or grey is due, in part, to the increased proportion of plagioclase in the greyer type. Where the transition is also marked by a change in the proportion of the mafic minerals the change in colour is abrupt, being noticeable in a single hand-specimen.

This grey granite is a moderately coarse, massive rock, more inequigranular than the pink granite, due to the occurrence of large, irregular crystals or crystal aggregates of white plagioclase one-quarter of an inch or more in diameter which lend a rather spotty or porphyritic appearance to the rock. Quartz is abundant as glassy, granular aggregates, or individual crystals. Biotite is the principal mafic mineral. Some hornblende is always present. It occurs mostly as larger crystals than the biotite, but there are fewer of them. Brownish crystals of sphene are plentiful in many places, but rarely exceed a millimetre in diameter. Magnetite and apatite are less abundant accessory minerals.

The texture of the rock in thin section is granitic. Plagioclase was the first to commence to crystallize. It was followed in order by quartz, microperthite, orthoclase, hornblende, and biotite. The order of cessation of crystallization begins with the accessory minerals. The mafic minerals

follow these, and intergrowths of feldspar and quartz appear interstitially between all other minerals. Plagioclase feldspar is the most abundant constituent. Its indices of refraction varied from albite to oligoclase in the different specimens examined. Some crystals show a poorly-defined zonal structure. This may be due to strain phenomena as well as to differences in composition. A smaller proportion of orthoclase is present and can be distinguished by its lower refraction, absence of albite twinning, and more altered appearance, as well as by abundant microperthitic and micrographic intergrowths. No microcline was observed.

The composition of this intrusive is for the greater part that of a true granite, but ranges in basicity to a type more closely allied to a granodiorite. Such a type is represented by that body extending, in the nature of a large apophysis, across Cedar and Dewdney creeks. Except for a generally larger proportion of mafic minerals in the granodiorite this intrusive is almost indistinguishable in the hand specimen from the true granite, an analysis of which is given below. Only by such analyses and by careful microscopic study can the two types be satisfactorily separated. Both are regarded as forming part of the same intrusion, and no attempt has been made to map them separately.

A specimen regarded as typical of the grey granite was obtained near the Kettle Valley Railway siding at Portia, and was analysed by M. F. Connor of the Geological Survey. It had the following chemical composition.

SiO <sub>2</sub>	71.90
$Al_2O_3$	$14 \cdot 21$
$\mathrm{Fe}_{2}\mathrm{O}_{3}$	0.33
FeO	0.86
MgO	0.30
CaO	1.70
Na <sub>2</sub> O	4.07
K <sub>2</sub> O	$4 \cdot 24$
$-H_2O$	0.15
$+H_2O$	0.70
$\mathrm{CO}_2$	0.23
TiO <sub>2</sub>	0.30
$P_2O_5$	0.05
$\mathrm{FeS}_2$	0.15
MnO	0.02
F	trace
. –	$99 \cdot 21$

In connexion with this analysis Mr. Connor concludes that the low total is attributable to the acid radicle and not to the basic radicle and that the deficit may be due to inclusions of matter which was volatile under the conditions necessary for the decomposition of the rock in the analytical procedure.

The analysis shows this rock to be a fairly acid granite. Silica is high and the percentage of iron abnormally low. The alkalis, particularly the soda, are sufficiently above the average to bring the rock almost within the range of alkaline granites.<sup>1</sup> Of such analyses of Coast Range intrusives of British Columbia as the writer has observed, that of the Cathedral granite, older phase, most nearly approximates the one given above.<sup>2</sup>

<sup>1</sup> Daly, R. A., "Igneous Rocks and Their Origin," p. 20. <sup>2</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 460.

These two batholithic rocks also present many petrographical points in common. The Cathedral batholith is, however, placed by Daly in the Tertiary, whereas the granite from Coquihalla area is regarded as of Cretaceous age.

The intrusives from the southern areas of the district include types very similar to the granite and granodiorite types described above. In the vicinity of Manson mountain the rock is a moderately coarse, acid granodiorite, massive, slightly pink, and in the hand specimen identical with members from the granodiorite of the northern area. The hornblende and biotite occur as small, prismatic crystals and lustrous black scales, and in thin section are seen to be partly altered to chlorite. Albite twinning is not conspicuous, but Carlsbad twins are common. No microcline was observed. A feeble zonal structure characterized some of the plagioclase crystals. The quartz was partly fractured and had strong undulatory extinction. Sericite was the common alteration product of the feldspars. The specific gravity of a typical specimen was 2.64.

A rock very similar to the above occurs to the south of Nicolum river and east of Sevenmile creek. Elsewhere in the southern part of the district the batholithic rocks are more basic. They are either granodiorites or intermediate in composition between granodiorites and quartz diorites. No separation of the different types has been attempted. They are dominantly massive, grey, coarse-grained rocks in which biotite is the conspicuous dark mineral but is always accompanied by more or less dark green hornblende.

Near their contacts with the older Cache Creek and Cretaceous rocks some of these intrusives are foliated. In such cases biotite is the most conspicuous mafic mineral and occurs in comparatively large flakes from 2 to 4 millimetres in diameter. Along the railway cuttings and tunnels below Othello, and between this station and Kawkawa lake, these rocks are massive, moderately fine to fairly coarse grained, and are considerably jointed and fractured. Brownish yellow grains of titanite are in many cases conspicuous and are commonly a millimetre or more in diameter. Quartz is always a prominent megascopic constituent.

## Internal Structural Relations

These intrusives include the most coarsely grained batholithic rocks in the area. They are almost entirely massive, but show some shearing and are usually well jointed in large block patterns. A series of sheared zones, along which considerable movement had taken place, was observed west of Boston Bar creek and within a mile of its mouth. One general northeast-southwest direction of almost vertical jointing is characteristic not only of these batholithic rocks but of most of the formations in the district. As a rule another set occurs at angles of from 60 to 90 degrees to this and also dips at a steep angle. A third direction more nearly horizontal is very conspicuous and in some of the steeper slopes gives the appearance, from a distance, of bedding.<sup>1</sup> Jointing has combined with glaciation in producing some interesting topographic forms. On the northern or northeastern slopes of the mountains, where valley and mountain

<sup>&</sup>lt;sup>1</sup> Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877-78, p. 71 B.

glaciation has been active, steep head walls have been formed by the undermining effects of glacial ice in developing their cirque-like depressions, or in excavating their U-shaped valleys. Excellent examples of cirque head walls occur in the granite hills or "needles" west and north of Romeo (Plate III B) and the precipitous southern slope of Hope Mountain ridge is due both to original shearing and jointing and to glacial erosion along the valley of Silver creek.

### External Structural Relations

The batholithic rocks included in this group are in contact with every other formation in the Coquihalla district except the Tulameen series and the quartz diorite stocks at the head of Dewdney and Cedar creeks.

The older Cache Creek, Ladner, Dewdney Creek, and Cretaceous formations have all been notably metamorphosed near the contacts with these intrusives. A zone of apophyses extending into the older formations, and another zone of inclusions within the intrusive, can always be distinguished. The apophyses are predominantly acid, the commoner varieties including dykes of aplite, pegmatite, and granodiorite porphyry. The inclusions are mostly small ellipsoidal masses averaging a foot in length and have been found miles from any large area of pre-batholithic rocks. Such inclusions are especially abundant in the batholithic area west of Coquihalla river between Romeo and Portia.

These rocks are in contact with the Coquihalla series for less than a mile along Coquihalla river between Romeo and Iago. The actual contact was not observed, but there is no doubt, from structural and other lines of evidence, that the Coquihalla series is the younger, and that its volcanic members were deposited on the granite after the latter had suffered a long period of erosion.

Sufficient has been learned to show that these Cretaceous batholithic rocks are intrusive into at least some members of the batholithic rocks which have been assigned to the Jurassic period. They also intrude the Eagle diorite and granodiorite, but the difference in age is not as great as in the case of the Jurassic intrusives.

With the Tertiary quartz diorite a contact is well exposed about 500 feet above, and to the north of, the Silver Creek trail, and at the extreme southern limits of the area. There, a schistose structure was developed in the granodiorite either before or during the intrusion of the diorite. The difference in composition and structure of the Tertiary quartz diorite and these Cretaceous intrusives is marked wherever the two are observed near each other.

# Mode of Origin

In their more northerly exposures the granites and granodiorites comprising this complex of Cretaceous rocks represent the last of a series of three intrusions which, however, are not separated by any great time intervals. The first and smallest intrusion was that of the Eagle diorite, followed after a very short interval by the much larger Eagle granodiorite batholith which, in turn, was succeeded by the still larger intrusion of more acid granite and granodiorite at present under consideration. This is the normal order for batholithic intrusion and in itself lends some support to the theory that these separate intrusions represent differentiates from the same magma. The sulphide mineralization of the Eagle diorite already referred to; the abundant epidote in both this diorite and the Eagle granodiorite, especially near their contacts with the later granite intrusive; and the pegmatites in the Eagle granodiorite; may all, or in part, have been introduced during a late stage in the intrusion and consolidation of the great bulk of these later granite and acid granodiorite rocks.

In the southern areas, different types were also recognized, but time did not permit of their separate mapping. No members as basic as the Eagle diorite and sufficiently large to map were encountered. The granodiorites, however, are in many cases lithically similar to the more massive types of the Eagle granodiorite, whereas other types are distinctly more basic. Except in the immediate vicinity of their contacts with older rocks no foliation was observed in these intrusives and there was, in general, less evidence of successive intrusion and more of differentiation in place, than in the case of the Cretaceous intrusives of the northern area.

## Age and Correlation

The same general age is assigned to these rocks as to the Eagle diorite and granodiorite, although it is recognized that they were not irrupted at the same time, but as successive stages in one great period of batholithic activity. In the northern area the order of succession has been defined, but beyond stating that all these intrusions are Cretaceous and much older than the Tertiary Coquihalla series, their age can only be estimated. They are all sheared to some extent, but not as much as the Jurassic batholithic rocks. They all show some fracturing in the hand specimens and under the microscope show evidence of considerable dynamic metamorphism. In this respect they differ from the massive unsheared quartz diorite near Silver lake, tentatively referred to the Miocene. Their age must, therefore, lie somewhere between the late Lower Cretaceous and the beginning of Tertiary time.

These batholithic rocks are tentatively correlated with Cretaceous members of the Coast Range batholith, the age of the latter being generally regarded as ranging from Jurassic, or, possibly earlier, to Tertiary. In the Coquihalla area the evidence of intrusion in both pre- and post-Lower Cretaceous time seems quite conclusive. Not only are granitic boulders very abundant in the Cretaceous conglomerates, but these sediments overlie older batholithic rocks and are in turn intruded by others. Outside the district, Dawson recognized batholithic rocks intruding Cretaceous sediments in the Coast Range complex of west-central British Columbia. More recently, Brock mentions the occurrence of Cretaceous intrusives at the head of the Nechako or north branch of Fraser river, which are "probably connected with the Coast Range batholith." Mackenzie also observes that the batholithic rocks of the Coast mountains, occurring between Taseko lakes and Fraser river, may be of post-Lower Cretaceous age.
#### QUARTZ DIORITE STOCKS OF CRETACEOUS OR TERTIARY AGE

### Distribution

Intrusives belonging to this group occupy three small neighbouring areas near the head of Dewdney and Cedar creeks. Two of these areas extend beyond the eastern limits of the map-area where their boundaries have not been followed. One occurs entirely within the map-area and occupies the basin at the head of the South fork of Dewdney creek.

### Petrography

In all three areas these intrusives much resemble each other. They are moderately fine-grained, light coloured, massive rocks, usually characterized by comparatively large and nearly rectangular prismatic crystals of dark green hornblende, which lend a somewhat porphyritic appearance to the rock. Under the microscope the hornblende appears as poikilitic crystals containing many small inclusions of magnetite, feldspar, and quartz. Its indices of refraction as determined by the immersion method are:  $\alpha = 1.654$ ,  $\gamma = 1.672$ . Brown biotite is present in greater abundance than the hornblende, but occurs in small, black, less conspicuous flakes. Quartz is a prominent megascopic constituent and constitutes 20 per cent of the rock. Plagioclase, oligoclase-andesine in composition, occurs in larger proportions and is notably inequigranular. Orthoclase is present in very minor proportions and is distinguished from the plagioclase by a slightly greater turbidity, a lower index of refraction, and the absence of albite lamellation. Apatite and magnetite are the chief accessory minerals, and chlorite, magnetite, and kaolin the principal alteration products. There is little appearance of strain or fracturing in the minerals. This may be due in part to the stock-like character of the intrusives, or it may be that this quartz diorite belongs to a later period of intrusion than the batholithic rocks previously described, and has, consequently, escaped those disturbances to which they were subjected.

The specific gravity of this quartz diorite is about  $2 \cdot 69$ .

This rock contains a number of small, finer-grained and darker masses, rounded in outline and usually only an inch or two in diameter. These grade outward into the lighter-coloured body of the granodiorite and may represent basic segregations. It is possible, however, that they were originally inclusions from the intruded rocks, which have been completely absorbed by the intrusive magma. No trace of original minerals or structure remains, these basic bodies being composed of essentially the same minerals as the main mass of the granodiorite, but containing a larger proportion of the dark minerals.

### Structural Relations

The quartz diorite occurs in three stock-shaped bodies, separated at no great interval from each other and probably connected in depth. They are very massive rocks showing little evidence of orogenic disturbance and no tendency to foliation. Their borders are in places more basic in composition, but the main body of the intrusive is very uniform in texture and composition.

The only formation of the district contiguous to this quartz diorite is the older Dewdney Creek series, which has been metamorphosed and impregnated with pyrite and, to a smaller extent, magnetite, to a distance of several hundred feet from the contact. It is considered as highly probable that these intrusives have an important bearing on the origin of the silverlead ores of Summit Camp beyond the eastern limits of the map-area.

### Mode of Origin

It is believed that these three bodies of quartz diorite were contemporaneously intruded as separate stocks through the Dewdney series. They are more basic than the granodiorite belt crossing Cedar and Dewdney creeks, but their proximity to that intrusive suggests that they may be satellitic stocks injected at about the same time as, or somewhat earlier than, the larger batholithic intrusion, but from the same magmatic source. Their finer texture and zoned plagioclase would be factors dependent on their rate of cooling and crystallization, which was accelerated by reason of the comparatively small size and isolation of these stocks from the main batholithic body.

# Age and Correlation

In Coquihalla area this quartz diorite intrudes only members of the Dewdney Creek series, which is regarded as of Upper Jurassic age. In the adjacent areas to the east it also invades the Lower Cretaceous sediments and are, therefore, younger than these. A similar intrusive was observed on the north side of Sumallo river near its junction with Skagit river, and about 15 miles to the southeast of the head of Dewdney creek. There it cuts the Pasayten formation, which has been generally regarded as Cretaceous, but which, in the opinion of the present writer, is in part Jurassic and, near the quartz diorite intrusive, equivalent in age to the Dewdney Creek series. The writer has no hesitation in correlating this intrusive with the quartz diorite from Coquihalla area. The representative from Skagit river was tentatively referred by Camsell to the Tertiary on the basis of its fresh, unsheared character and its intrusion into the Pasayten formation which was regarded as Cretaceous. In Coquihalla area there is reason to believe that these intrusions are genetically related to the larger batholithic bodies farther to the west, and that they are, therefore, pre-Tertiary, their period of intrusion lying somewhere between the close of the Lower Cretaceous, and the beginning of Eocene time. The alternative theory, that this quartz diorite is Tertiary, is not, however, without support, and the present position allotted to it in the geological column must be regarded as tentative only.

# Tertiary Quartz Diorite Batholithic Rocks

### Distribution

This quartz diorite occupies two separate areas in the southwestern corner of the map-area. The more easterly body is exposed on the mountain slope southwest of Silver lake. It composes the peak of Isolillock mountain and is believed to be continuous with the large Chilliwack batholith of presumably Tertiary age, which occupies a broad area in the Skagit range farther to the south. According to Daly, it composes some of the wildest and most rugged mountains in the Skagit range, and forms the largest intrusive body along the Canadian boundary west of the Remmel batholith.<sup>1</sup> In its northern prolongation this batholith composes the bulk of the Cheam range which extends northward from Chilliwack river into the southwestern limits of Coquihalla district between the junction of Fraser river and Silver creek. The other body is exposed on the west bank of Fraser river below Haig and, in all, occupies about one square mile within the map-area. Its extension beyond the limits of the district has not been investigated.

## Petrography

The quartz diorite is quite distinctive in appearance from all other batholithic rocks in the area, and its two separate occurrences have been correlated, chiefly on lithological grounds.

It is a massive, moderately coarse-grained, grey rock containing a varying, but usually high, percentage of dark minerals, and is everywhere remarkably fresh. Nowhere was any notable evidence of surface decomposition seen, in spite of its maintaining a luxuriant forest growth below an elevation of 6,000 feet. Fresh specimens are, consequently, easy to obtain, and break from the parent rock in massive fragments uninfluenced by pre-existing fractures.

Hand specimens show a varying abundance of dark green, lustrous hornblende prisms, and scales of black biotite. Magnetite is usually an important constituent. The felsic minerals include a noticeable proportion of quartz and quantities of white, striated plagioclase. The proportion of dark minerals varies from less than 15 to nearly 50 per cent. The darker varieties contain hornblende in much larger proportions than biotite, and in crystals notably larger than the light-coloured minerals. The specific gravity in the specimens collected ranges from 2.75 to 2.80.

Under the microscope this rock shows very little alteration.

Dark green pleochroic hornblende and brown biotite occur in part as well-defined euhedral and subhedral crystals. They are as a rule closely associated, and the hornblende appears in part to replace earlier formed biotite. The larger crystals of these mafic minerals show some resorption and replacement by later felsic minerals. In some slides little or no alteration of these minerals was observed, but in others a little secondary green chlorite was observed. Magnetite is an important accessory mineral and in part may be secondary after the hornblende and biotite. The principal feldspar is a fresh basic andesine. In part, it occurs in coarse euhedral tabular crystals and, in part, forms a finer anhedral aggregate

<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, pp. 534-535.

with other mineral constituents. The plagioclase is commonly strongly zoned and shows both albite and Carlsbad twinning. Quartz constitutes, in those slides examined, from 8 to 15 per cent of the rock. It occurs interstitially and shows little sign of strain or fracturing.

A rough determination of the mode by the Rosiwal method, from a specimen obtained, 1,000 feet above Silver creek and half a mile south of Silver lake, gave the following mineral composition.

	Quartz diori	te
	Per cent	
Orthoclase	1.8	
Andesine	15.2	
Hornblende	9.8	
Biotite	6.3	
Quartz	14.9	
Magnetite (chiefly) and other accessories	2.0	
Sp. gr	$ \pm 2.75$	

### Structural Relations

The quartz diorite intrudes both the Cretaceous sediments in the vicinity of Silver peak and the Cretaceous intrusives to the north of Silver creek. It was observed in direct contact with a narrow belt of biotitequartz schists lying in the divide between Silver peak and Isolillock mountain. These schists are regarded as part of the Cretaceous series, but their original character is masked by metamorphism. Elsewhere in this locality the Cretaceous sediments are indurated, and reddish biotite is developed in some of their strata adjacent to the intrusive. The high-grade silver deposits of the Eureka-Victoria mines are credited to this quartz diorite. The actual contact between the intrusive and the Cretaceous conglomerate below Haig station on the west bank of Fraser river was not observed.

The difference between this and the Cretaceous intrusives was observed near the divide between Silver peak and Isolillock mountain. The older intrusives have there the composition of a quartz diorite or basic granodiorite, and are slightly foliated near their contact with the schists mentioned above. Under the microscope this older intrusive differs both in the character of its minerals and in its structure from the younger quartz diorite that composes the peak of Isolillock mountain and which is easily recognized by its fresh, massive appearance.

# Mode of Origin

The origin of the quartz diorite is involved with that of the Chilliwack batholith and is regarded as not essentially different from that assigned to the other batholithic rocks of the district. As exposed in Coquihalla area this intrusive is more basic than the average for the entire batholith, which is typically a granodiorite but includes both granite and quartzdiorite types.<sup>1</sup> The writer cannot say whether the quartz diorite represents a basic differentiate of the batholith or whether it has been intruded separately. The general uniformity in colour, grain, and massiveness of the batholith as a whole, together with the recognition of no sharp contacts between the different phases or types, suggests that they were all parts of one intrusion which differentiated in place, and, on the northern edge of the batholith in Coquihalla area, produced a more basic type than the average.

<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, pp. 534-540.

## Age and Correlation

The quartz diorite definitely intrudes sediments whose age has been regarded as Lower Cretaceous. It also cuts other batholithic rocks referred to late or post-Lower Cretaceous time which also intersect these sediments. The quartz diorite is, therefore, younger than either of these formations. It is massive and fresh in appearance and shows no sign of shearing in the outcrops or of strain or fracturing in thin section. It has apparently not been involved in the orogenic disturbance closing the Cretaceous era and may consequently be regarded as Tertiary in age.

It is correlated with the Chilliwack batholithic complex, which in turn has been tentatively referred by Daly to the Miocene, and correlated by him with the post-Cretaceous Castle Peak stock<sup>1</sup> and with the granodiorite at Snoqualmie pass in Washington which intrudes Miocene argillites.<sup>2</sup> The age of the Chilliwack batholith and, therefore, of the quartz diorite of the Coquihalla area may be tentatively regarded as Miocene. Although of mid-Tertiary age this intrusive probably represents a late stage in Coast batholithic intrusion, of which two other stages, one in pre-Cretaceous and another in Cretaceous time, have been recognized in Coquihalla area.

# SMALLER INTRUSIVE BODIES

In a region where batholithic activity was as pronounced as in Coquihalla area, it is not surprising to find that small intrusive bodies are very abundant. These commonly take the form of dykes or sills, but more irregular bodies also occur. In size they vary greatly. Their width is mostly under 50 feet, but many equal or exceed 500. They may be traced lengthwise for many hundreds or even thousands of feet, though only rarely are they continuously exposed over such distances. When penetrating bedded or slaty rocks they tend to follow the line of stratification or cleavage and, in many places, are more or less perfectly intercalated with the formations as sills. More frequently, however, the dip of the intrusive dyke is steeper than that of the bedded rocks, although on plane surface exposures the resemblance to sills is very striking.

These smaller intrusive bodies range from acid aplite and pegmatite types to others composed almost entirely of dark constituents and included among the lamprophyres. The acid types are more prominent near the batholithic contacts and, in some places, are directly traceable as apophyses from these larger intrusives. The basic types are more prominent at a distance from the batholiths.

The age of these intrusives is even more variable than that of the plutonic rocks of the district, but, like these larger irruptives, the great majority fall between Jurassic and late Tertiary time.

<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 535. <sup>2</sup> Bull. U.S.G.S., vol. II, 1900, p. 223. Snoqualmie Folio U.S.G.S., 1906, p. 9.

# Acid Types

The great bulk of the smaller intrusive bodies are acid rocks ranging in composition from acid aplites and pegmatites to leucocratic diorites. The different types, considered in their general order of increasing basicity, include: (1) aplites; (2) pegmatites; (3) granite porphyries; (4) quartz porphyries; (5) syenite porphyries; (6) porphyries<sup>1</sup>; and (7) granodiorite porphyries.

#### APLITES

Aplite dykes are very abundant in the southern section of the area, where they intrude Jurassic batholithic rocks on the western slopes of Hope mountain and on either side of Fraser river, above Hope. They are so numerous, and constitute such a large percentage of these batholithic irruptives, that no attempt was made to map them separately. They form an approximately parallel series of dykes, striking a few degrees west of north, and following somewhat closely the direction of maximum shearing in the batholith. These dykes vary from mere stringers to belts many yards wide. They are almost white rocks, massive in structure, and are much less fractured than the batholithic rocks they intrude. Their contacts are, in part, sharply defined, and, in part, very irregular and so transitional in character as to suggest replacement of the older rock. Their petrological characters have been given in discussing the Jurassic batholithic rocks and it need only be noted here that their composition may vary, particularly in the narrower stringers, from almost pure quartz to leucocratic microgranites in which quartz, orthoclase, plagioclase, and muscovite are all important constituents. This change may occur within a few yards along a single stringer. Excellent examples of it were observed in the railway cuttings above Othello, where a number of aplite dykes intersect a greenstone member of the Cache Creek series near the batholithic contact.

#### PEGMATITES

The pegmatites are confined chiefly to the northern section of the area and, like the aplite dykes, are most abundantly associated with batholithic rocks. They are typically exposed along the railway cuttings between Romeo and Coquihalla, where they intersect and, to some extent, replace the Eagle granodiorite. Their lithology has been discussed with that of the Eagle granodiorite. Where they intrude this granodiorite they are, apparently, of no economic value, but on the hills west of Iago an important molybdenite deposit is associated with pegmatitic quartz, occurring as irregular lenses in Cretaceous granite.

The aplites and pegmatites are referred to the same general period of intrusion as the Cretaceous batholithic rocks, although probably representing a relatively late stage of these irruptions.

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<sup>&</sup>lt;sup>1</sup>The term "porphyry" is here used in the restricted sense implying an hypabyssal rock containing phenocysts of alkali feldspar and having, therefore, the composition equivalent of a syenite.

### GRANITE PORPHYRIES

The oldest variety of granite prophyry is associated only with the Tulameen series, and occurs as belts or sills several yards wide intercalated with older volcanic and sedimentary beds. With the exception of some of the Jurassic batholithic rocks, no other intrusives in the district exhibit crush metamorphism to the extent of these porphyries. The phenocrysts of both orthoclase and plagioclase are drawn out into long, lerticular or augen shapes in a crushed holocrystalline groundmass of quartz and feldspar containing a few, long, twisted foils of muscovite and biotite. Epidote, chlorite, and calcite are the common alteration products. The age of these intrusives is at least pre-Cretaceous and probably pre-Jurassic.

An important granite porphyry near Independence Camp in the northern section of the area contains the copper ore-bodies of the Independence mine. This dyke was traced by Camsell for about 3 miles to the south in Tulameen map-area<sup>1</sup>, and in Coquihalla district it continues, in a northerly direction, nearly to Coldwater river. It is at least 5 miles long and its maximum width is nearly 1,500 feet.

This porphyry is intruded between the Tulameen series and the Eagle granodiorite, and was, probably, introduced not long after the intrusion of the granodiorite, and from the same source. It has been considerably fractured and is intersected by a number of smaller dykes of syenite porphyry and allied leucocratic types. It is pinkish and massive, and contains phenocrysts of orthoclase and plagioclase, as well as quartz and biotite. The groundmass is fine grained, contains a larger proportion of free quartz than the coarser constituents include, and is intersected by numerous veinlets of secondary quartz. Near the ore fissures the porphyry is greatly decomposed and constitutes the bulk of the gangue. Elsewhere it is much fresher. Pyrite is a common, and molybdenite a rare, constituent. Both may occur at a distance from the ore-bodies.

#### QUARTZ PORPHYRIES

Quartz porphyries were intruded in both pre-Tertiary and Tertiary periods, and in the majority of cases are readily distinguished in the field. The older types include white or cream-coloured felsitic dyke rocks and were most commonly observed intersecting the Cache Creek series. The groundmass is in all cases exceedingly fine grained, but small phenocrysts of clear quartz and others of feldspar are generally present. Under the microscope comparatively large euhedral quartz and feldspar phenocrysts and a few scattered smaller crystals of hornblende are observed in a cryptocrystalline groundmass composed, probably, of similar constituents. The feldspar phenocrysts include both orthoclase and soda plagioclase, and are rarely over a millimetre in diameter. The quartz phenocrysts are more abundant, show undulatory extinction, and some include idiomorphic feldspar crystals. The edges of the phenocrysts are commonly slightly corroded. Secondary calcite was observed in certain slides, and appears to replace the feldspar. Small crystals of magnetite and, in many cases of iron sulphides, are present.

<sup>&</sup>lt;sup>1</sup> Camsell, C., Geol. Surv., Can., Mem. 26, p. 166.

An interesting variety of quartz porphyry intersects the Lower Cretaceous conglomerate on Silver peak, and is referred to in the discussion  $\mathbf{of}$ the Eureka-Victoria silver mines.  $\mathbf{It}$ forms one large and several smaller dykes, varying in width from a few inches to about 20 In the outcrop it is a massive, pinkish-weathered, light grey rock, feet. containing many clear quartz crystals in a felsitic groundmass. Under the microscope the quartz appears as large, idiomorphic phenocrysts and also forms spherulitic aggregates with feldspar. The groundmass is microcrystalline and its mineral composition quite indeterminate. It is, in general, much decomposed and commonly stained with iron oxide. Where they are crossed by the ore-bodies, the dykes are sparingly mineralized, and elsewhere contain a few scattered grains of iron sulphide. Thev were intruded in post-Lower Cretaceous time and antedate the formation They are probably, therefore, of pre-Tertiary age. of the ore-bodies.

Tertiary quartz porphyry dykes intersect all pre-Tertiary rocks in the northern section of the area in the vicinity of the area occupied by the Coquihalla series. They are probably derived from the same source as this Tertiary series. They are either white or slightly pink, and commonly show small phenocrysts of both quartz and feldspar in a felsitic groundmass. In thin section quartz, orthoclase, and soda plagioclase are recognized, and some small flakes of biotite are present. They are very similar in appearance to other dyke rocks of the same age occurring in the same general locality, and which, from the absence of free quartz, have been classified as porphyries. Other nearly pure white varieties show practically no porphyritic constituents. They possess a groundmass of quartz and feldspar too finely crystalline to be specifically identified. All these types intersect the basalt flows of the Coquihalla series, but have not been observed intruding the later members. They are probably of Miocene age.

# SYENITE PORPHYRIES

The intrusives included in this group are among the most abundant in the area, and are, as a rule, readily distinguished by a prevailing leucocratic appearance and well-defined porphyritic texture. In composition, a considerable proportion of these intrusives are more nearly akin to diorite than syenite, and there appear to be many gradations between these extremes. In their general appearance they are, however, all very similar, and even the more basic varieties are distinct from those more melanocratic types of dioritic and andesitic intrusives elsewhere described. For convenience in classification, they are all included under the term "syenite" as referring in a general way to their highly feldspathic, rather than alkalic, composition. They are prevailingly intrusive in the Ladner series, but intersect older as well as younger formations.

In the Ladner series they strike approximately parallel with the slaty rocks and, in some instances, appear to be true sills. Usually, however, their trend only approximately coincides with the sediments and their dip is, in general, nearly vertical, irrespective of the dip or cleavage of the sedimentary strata. Elsewhere these intrusives occur at or near the Independence mine, where they intersect the ore-bearing granite porphyry

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as well as the older Tulameen rocks, and apparently possess no uniformity of trend. Dykes of this type intersect the pre-Tertiary batholithic rocks, as well as the Cretaceous sediments. Commonly these intrusives vary in width from 5 to 20 feet; but larger as well as smaller bodies occur, and in certain places are over 50 feet wide.

The more porphyritic varieties, commonly referred to by the prospector as "bird's-eye" porphyries, show comparatively large crystals of feldspar in a fine-grained, grey groundmass. Other types are more equigranular, but are otherwise very similar in composition.

Under the microscope the porphyritic constituent is predominantly a plagioclase feldspar, varying from albite-oligoclase to oligoclase-andesine. In the more typically syenitic varieties orthoclase also forms prominent The feldspar phenocrysts are commonly beautifully euhedphenocrysts. ral, although their edges may be slightly corroded. The groundmass consists chiefly of a holocrystalline aggregate of feldspar, but is usually too fine-grained to afford specific identification of this mineral. Quartz is rarely observed, and then occurs in veinlets or other secondary form. Crystals and grains of magnetite and iron sulphides are common. The great majority of these rocks contain no recognizable mafic minerals, but there is commonly present an almost colourless or slightly green and practically amorphous alteration product resembling serpentine, which, in part, forms pseudomorphs after an earlier mineral very similar in crystal form to hornblende. In other cases this secondary mineral seems to replace feldspar, so that it is impossible to estimate how much hornblende or other mafic mineral was originally present. Calcite is another abundant secondary mineral, and only in the more completely altered rocks is its percentage inferior to that of the serpentinous mineral. Still a third secondary mineral common in some specimens examined is sericite. A microscopic study of several slides from rock specimens showing little or no evidence of weathering, but in which an abundance of these secondary minerals occurs, suggested that the alterations were accomplished at comparatively high temperatures, and that the solutions effecting the change were not of meteoric origin. In general the more fractured of these intrusives have been subjected to the greatest alteration.

These "syenite porphyries" are of considerable economic importance. They occur at the Independence copper mine and near several gold prospects in the Ladner slate belt. In the slate belt it is believed that they may be of genetic significance in connexion with the gold values in certain quartz veins, as at the Pipestem mine; the Rush-of-the-Bull Fraction; the Broken Hill claim of the Morning group; and a number of other prospects. The gold-quartz veins occurring in the Ladner slates (of the Siwash Creek series) in the adjoining Siwash Creek area, have been regarded as directly connected with porphyry dykes that come under the present classification.<sup>1</sup> In general, the gold values occur in quartz veins in the adjoining slates, but in certain instances the dyke rock itself constitutes the ore-body. A dyke of this character crosses the railway just above Tangent creek. It is abundantly mineralized with pyrrhotite and coarsely crystalline auriferous arsenopyrite.

<sup>&</sup>lt;sup>1</sup> Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1911, p. 127.

The age of these syenitic intrusives is probably not greatly different from that of the Cretaceous batholithic intrusives in the district. They intersect the Cretaceous sediments, but do not appear to intrude any of the Tertiary rocks of the area.

#### PORPHYRIES

This group includes intrusives that are mostly slightly pink or brown and, because of their susceptibility to weathering, present a soft decomposed appearance. They contain numerous small, white feldspar phenocrysts that are quite lustreless. Biotite, when present, is commonly almost completely altered to brownish decomposition products. Some of these biotite flakes are black and lustrous, and in such cases stand out conspicuously against the light-coloured groundmass. A yellowish plastic clay is developed where surface water has come in contact for any length of time with these rocks.

These rocks are confined to the northern section of the district near the area occupied by the Coquihalla series. They much resemble the Tertiary quartz porphyries already described from this section, differing chiefly in the proportion of free quartz present. They are typically exposed along the railway on either side of, but chiefly below, Romeo, where they are intrusive in Cretaceous sediments as well as in later batholithic rocks. No general trend was recognized, although many strikes vary within a few degrees on either side of north. Their width varies from a few inches to several yards. Exceptionally well-defined flow structure and chilled border zones were observed along their contacts with older rocks. Α greatly contorted dyke occurs about one-half mile above Romeo on the west side of the track. Its irregularity is the result, not of deformation after intrusion, but of conformation to the existing structure of the granodiorite at the time of intrusion, during which the dyke evidently followed the direction of least resistance in the shattered plutonic rock.

These intrusives are remarkably uniform in appearance, and were readily recognized in the field. In thin section they show a fine microcrystalline groundmass composed of small feldspar microlites, some arranged in such a manner as to suggest flow structure. Within the groundmass are greatly altered phenocrysts of orthoclase and plagioclase in, as far as could be determined, about equal proportions. Biotite, where present, is usually dark brown to black and, owing to the presence of alteration products of which magnetite and limonite are most conspicuous, almost opaque. Calcite is also a common secondary mineral. A small proportion of quartz may be present.

The age of these porphyry dykes may be regarded as about that of the members of the Coquihalla series and, as in the case of the quartz porphyries from this section of the district, may be placed in the late Tertiary, and probably Miocene period.

#### GRANODIORITE PORPHYRIES

Intrusions of this composition are abundant in the more southerly sections of the area, where they commonly intersect the Cache Creek and, to a smaller extent, the Ladner series. They occur as a rule within a mile or so of the batholithic contacts with these older formations, and in some cases are apophyses from these plutonic bodies which they much resemble in composition. They possess no uniformity in trend and include several of the larger dykes in the district, their width being commonly measurable in hundreds of feet. Due to their size they are comparatively coarse grained, being, in some instances, only slightly finer than the batholithic rocks.

These porphyries are dominantly massive grey or slightly pink rocks, and less porphyritic than the majority of the smaller intrusive bodies in the district. Feldspar is the most prominent mineral, and Carlsbad twins are commonly recognized in the hand specimen. In addition, these rocks are mostly speckled with small, dark green, lustreless crystals of hornblende. Biotite is a rare constituent.

In thin section, euhedral crystals of both orthoclase and plagioclase are recognized. Orthoclase is less abundant than the plagioclase. The latter is fresh and about albite-oligoclase or oligoclase in composition. Hornblende is the chief dark mineral and as a rule is commonly almost entirely altered to green chlorite and magnetite. Primary magnetite is fairly abundant, and may be well crystallized. A few phenocrysts of quartz, somewhat smaller and less idiomorphic than those of the feldspars, are present in all cases. The groundmass is a microgranular aggregate of quartz and feldspar. The common alteration products are chlorite, epidote, zoisite, sericite, and probably kaolinite.

The age of these dyke rocks is regarded as about that of the Cretaceous batholithic intrusives with which they are associated. No significant ore mineralization was observed in any of the dykes and, as far as could be determined, they are of no economic importance.

# **Basic Types**

The basic intrusives are as widespread as the more acid types, but, with the exception of the diorite belt above Jessica, tend to form somewhat narrower bodies. They are more abundant at a greater distance from any large batholithic body than the acid intrusives, so that their relation to these large plutonic bodies is more often conjectural and their age, in consequence, less certain. The following types have been recognized and will be considered separately: (1) diorite, (2) diorite porphyries and lamprophyre, (3) augite and hornblende porphyrites.

### DIORITE

This type includes the largest of the dyke intrusions in the district. It occurs as a broad, irregular belt striking across Coquihalla river below Dewdney creek, and is intrusive for the most part in that greenstone member of the Cache Creek series which structurally underlies the Ladner slate belt. It is not continuously exposed across its entire width, but appears to have penetrated the greater part of the greenstone as well as parts of the adjoining formations. On the map its inferred presence is indicated by blue crosses, and some of its more prominent outcrops are roughly outlined. There are doubtless many others that are not included, as heavy vegetaion and surface accumulations in this section of the district have obscured the greater part of the underlying rocks.

This diorite is typically a massive, moderately coarse-grained, dark grey rock containing between 50 per cent and 60 per cent dark constituents. Fractured surfaces are lustreless and suggest advanced decomposition. Thin sections show broad prisms or more bladed forms of altered pyroxene, in part penetrating, and in part surrounding, feldspar crystals. Much of the mafic mineral has the fibrous matted appearance and irregular birefringence of uralite. Some is, however, quite massive and possesses an extinction angle of a pyroxene. Other prisms more closely resemble hornblende. It seems probable that the original mineral was a pyroxene which subsequent uralitization processes have largely changed to hornblende. The feldspar is plagioclase with a composition about that of oligoclase. A little orthoclase may be present, but the extreme alteration of all the feldspar renders it difficult to make determinations. A little quartz Ilmenite partly altered to leucoxene is a common is observed in most places. accessory mineral. The abundant alteration products of the rock include uralite, chlorite, calcite, zoisite, epidote, possibly kaolinite, and leucoxene.

Finer-grained equivalents of this diorite occur near the larger body and, in some cases, are probably apophyses from it. They somewhat resemble the older andesite greenstone they intrude, but may be distinguished by their slightly coarser texture, absence of flowage lines, darker green colour, more massive habit, and, in thin section, by difference in composition.

This diorite is of great economic importance. Near its northeastern contact with the older greenstone and, in particular, with the Ladner slates, these rocks are impregnated with sulphides, and carry auriferous quartz veins. The ore deposits at the Emancipation mine and several other properties in the vicinity of the slate-greenstone contact owe their mineral content to this intrusive.

The diorite cuts both Cache Creek and Ladner series and is, therefore, not older than Upper Jurassic. It shows very slight evidence of dynamic metamorphism and is, therefore, probably not as old as the Jurassic batholithic rocks of the district. On the other hand, it is quite dissimilar to any Tertiary intrusives in the area, and may be regarded as older than these. Its age is probably not greatly different from that of the larger Cretaceous batholithic intrusives of the area, and its size and basicity suggest that it may have been among the first of the Cretaceous intrusives.

#### DIORITE PORPHYRIES AND LAMPROPHYRES

There are a number of smaller intrusives in the district of somewhat similar composition to the diorite just described. In some of these the percentage of dark constituents and alteration products is abnormally high, and these types might be included under the term lamprophyre, although their mineral constituents are essentially similar to those of other more normal and more abundant types.

These rocks occur either as dykes or sills. They are predominantly dark, massive, fine to coarse grained, and some are nearly equigranular. Typical examples were found intersecting the Cache Creek rocks at various points in the railway section and at other localities. A couple of dykes of this character appear in the cuttings about three-fourths mile below Jessica. They are grey, massive rocks containing a considerable percentage of free quartz. The mafic mineral is a brownish hornblende showing good twinning. The feldspar is about oligoclase in composition, and is twinned on both Carlsbad and albite laws. Muscovite is present in very minor proportions. Magnetite and apatite are prominent accessory minerals, and some pyrrhotite is present. The feldspar is cloudy with decomposition, and the hornblende is partly altered to chloritic material. These dykes are cut by felsitic quartz porphyries previously described. They are pre-Tertiary and probably post-Jurassic.

A number of diorite sills and dykes intersect the Dewdney Creek series at different horizons. The dykes strike at various angles up to 90 degrees with the bedding planes of the series, but the sills, as their name implies, are perfectly intercalated with the strata. They are all dark, massive rocks in which green hornblende and light-coloured feldspar can be distinguished. In thin section the hornblende occurs in part as euhedral prismatic and basal sections, and is frequently twinned. It is pleochroic in light green shades, has an extinction angle of about 18 degrees, and is partly altered to chloritic products. The plagioclase has a composition about that of andesine or andesine-labradorite. It is turbid with alteration products, in part resembling sericite, and only occasionally shows welldefined twinning. The proportion of mafic to felsic constituents is variable, and with this variation there is also a slight difference in rock texture. The more basic types are commonly coarser, and in some instances hornblende forms over 80 per cent of the rock. Such types are included as lamprophyres in this classification.

These intrusives have effected local metamorphism of the rocks they intersect, and some pyritization is as a rule apparent in their vicinity or within the intrusives themselves. Their age is at least later than Jurassic and is probably pre-Tertiary.

#### PORPHYRITES

Porphyrites are widespread. They intersect all except the Tertiary rocks of the area, and range in age from Triassic to Tertiary. They vary in texture from rocks which might be included as fine-grained diorites to others dense and aphanitic. They fall into two classes, distinguished principally by the character of their mafic minerals. In the one, pyroxene, probably augite, predominates, and in the other hornblende is the most abundant and commonly the only mafic mineral.

Green pyroxene porphyrites were found intercalated with beds of the Tulameen series and may, in part, represent contemporaneous flows. Very similar types were observed intersecting the Eagle granodiorite approximately parallel to the direction of foliation of that body (Plate VI B). Still others cut the batholithic complex above Iago, and their significance here in regard to the age relationship of this complex and the older Eagle diorite has already been discussed.

Under the microscope, a section from the porphyrite occurring with the Tulameen rocks revealed a very fine-grained groundmass composed chiefly of feldspar and numerous, small, acicular crystals of green hornblende. Through this were scattered several comparatively large phenocrysts of augite which had been partly or completely altered to serpentinous products. Epidote was also a common secondary mineral, occurring in small grains disseminated through the slide.

Hornblende andesite porphyrites are more abundant and, although they commonly occur as comparatively narrow dykes, they also form wide belts of massive aphanitic andesite much resembling lavas in their structure, texture, and composition. Examples of this latter type outcrop in the bed of Cedar creek and on the Cedar-Coquihalla divide, and their position near the base of the Dewdney Creek series is of possible genetic significance in connexion with the andesite tuffs of this formation. In thin section, this fine-grained green porphyrite shows comparatively large feldspar phenocrysts in a microcrystalline groundmass composed of a radiating fibrous net of acicular green amphibole, resembling actinolite, and feldspar. To some extent this amphibole penetrates, and apparently replaces, the feldspar phenocrysts, and in certain places forms a dense mat-like aggregate resembling a pseudomorph after an earlier mineral, probably a pyroxene. Other dark green, massive, and, in some cases, distinctly porphyritic andesitic rocks, possibly representing contemporaneous flows, were observed associated with the Cretaceous rocks in the railway cuttings between Romeo and Iago and in part seemed to form the matrix for the Cretaceous conglomerate there. In part, however, they were undoubtedly intrusive in the Cretaceous sediments.

Hornblende porphyrite dykes intrude the Cache Creek, Tulameen, and Ladner series. They are rarely more than 10 feet wide, and in many places not over 2 feet. Phenocrysts of hornblende are as a rule conspicuous, but plagioclase feldspar may be equally, or even more, prominent.

### SURFACE DEPOSITS

# Glacial Material

Coquihalla area was subjected to glaciation, regional as well as local. The characteristic glaciated appearance of the upland topography has already been described, and it has been shown that during this period of glaciation a sheet of ice moved across the area in a direction averaging about south 55 degrees west, its passage being recorded by grooves and striæ, roches moutonnées, and glacial debris. The debris forms a thin mantle of ill-assorted material over a considerable area of the more protected mountain slopes, and extends to the highest ridges. Included in this debris are glacial erratics, already referred to, some of which weigh many tons, and have been transported for distances measurable in miles. The finer debris has become incorporated with the decayed vegetable material of the district, and its original character has been destroyed. No typical deposits of glacial till were recognized in the area.

Small morainic deposits at the mouths of Dewdney and Boston Bar creeks have an irregular thickness of about 100 and 200 feet respectively, and are formed of a partly reworked collection of fine and coarse materials, among which many almost spherical boulders of granitic rocks are conspicuous. A much larger morainic deposit fills the old valley of Coquihalla river between Kawkawa lake and Othello to a depth of about 500 feet above the level of the lake. The surface of this deposit is marked by many irregular depressions in which small bodies of water stand. The deposition of this material deflected Coquihalla river into the narrow gorge which it has cut in massive batholithic rocks. This, as well as the smaller deposits mentioned above, was deposited during the retreat of the valley glaciers. The irregularity displayed on the surfaces and in the composition of these deposits testifies to considerable disorder in this retreat.

### Stream Deposits

The stream deposits of the area include well-stratified terrace materials whose location and origin have already been discussed. They are also represented by the sands and gravels occupying the present stream beds, where a varying proportion of boulders reaching diameters of  $1\frac{1}{2}$  to 2 feet are encountered. The streams have, in addition, supplied the material for the delta land at the mouth of Coquihalla river.

The terraced materials are mere remnants of deposits that at one time extended across the principal valleys, filling them to a height of 500 feet or more above the present stream beds. They are composed chiefly of silts and sand beds that exhibit a remarkable uniformity in grain, and are sharply defined from each other. In detail the stratification is very irregular and, doubtless, depended upon the oscillation in stream level at different seasons of the year as well as upon more variable torrential and drought conditions. Temporary damming of the streams by accumulated glacial debris, and the development thereby of broad, lake-like expansions in the river, might well account for the greater horizontality of the terraces in some sections than in others. In the midst of well-assorted beds of sand and silt it is common to find irregular heaps of coarse debris showing little or no evidence of arrangement under water, and probably representing parts of landslides from the adjacent slopes, or abnormal flood conditions (Plate IV A). Frequently the rock fragments in these coarser beds can be identified with the underlying consolidated formations. The most common cobbles or boulders are, however, from plutonic rocks and are mostly well-rounded. No glacial striæ have been observed on any of these and their spherical shape in itself suggests prolonged stream erosion. It is probable, however, that these boulders were obtained from the Cretaceous conglomerate of this and adjoining districts and were, consequently, well rounded prior to their separation from the older formation (Plate IV B).

The finer silt beds are commonly compacted into stiff mud or clay banks. The coarser beds are as a rule quite uncemented. Locally, where many fragments from the underlying slaty or volcanic rocks are present, the gravels are moderately well indurated by a calcareous binding which was probably dissolved from these fragments and reprecipitated to form a cement.

The sands and gravels occupying the present stream beds are prominent only in the larger valley bottoms where the stream grade is such as to permit their accumulation. In Coquihalla valley, below Ladner creek, these gravels have been investigated for their placer content and are found to contain considerable detrital gold and a smaller proportion of platinum (See page 132). A fan-shaped delta at the mouth of Coquihalla river extends into Fraser river, constricting and, to some extent, changing the original course of this stream. The delta has here an area of about a square mile, but it may be regarded as extending up Coquihalla valley for a mile or more, in which direction it forms a flat averaging 3,000 feet in width. The material composing this delta was obtained in part through the partial destruction of the post-glacial terrace deposits formed in the valleys of Coquihalla river and its tributaries, and in part from subsequent erosion below the base of these terraces. Some of the earlier morainic material left by the retreat of the valley glaciers has, no doubt, also entered into its composition.

# CHAPTER IV

# STRUCTURAL AND HISTORICAL GEOLOGY

It is here proposed to recapitulate in a more general fashion what has already been stated as to the structural and historical features of the formations and to draw such conclusions as seem warrantable.

In Coquihalla area the present topography is the result of dissection of a plateau surface developed in late Tertiary or early Pleistocene time by the gradual uplift of a land area which had been reduced in earlier Tertiary time almost to base-level or to the condition of a peneplain. Its present elevation may be considered, consequently, as the result of epeirogenic movements during which little deformation of the constituent rock members occurred. It is found, however, that all the formations that are older than the Tertiary are greatly deformed, hence movements of a more violent character must have exerted a predominating influence on their structure in earlier geological periods.

The structure of the rocks is shown on the cross-sections accompanying the map-sheet (No. 1988). The oldest rocks are the Cache Creek series, referred to Carboniferous and probably Pennsylvanian time. The sedimentary members of this series, consisting of slaty and cherty rocks, were laid down in a nearly horizontal position, the land areas supplying the detrital materials lying far to the east and south of the district. At least the bulk of the chert was derived by chemical precipitation of colloidal silica from juvenile silicate solutions accompanying submarine extrusions The silica was segregated from the argillaceous clastic sediof lavas. mentary material, and the amount of it precipitated from time to time no doubt varied with the contemporaneous volcanic activity, whereas clastic sedimentation was more uniform. The alternating bands of slate or argillite and chert, so prominent over large sections of these Cache Creek rocks, everywhere show the most minute crumpling or plication, a feature which is probably not so much due to deformation of these rocks after their consolidation, as to some diagenetic phenomena operating prior to or during their emergence from the marine water in which they were deposited. Some of this deformation may, however, be due to later disturbances facilitated by the relative incompetence of the cherty and slaty layers to resist lateral compression. The lavas poured out from time to time over the sea-floor would tend to form more irregular deposits than the sedimentary materials, but it is improbable that the original angle or dip of these flows ever exceeded more than a few degrees from the horizontal. The great thickness of the Cache Creek rocks, and the uniformity in the character of the materials composing them, indicate that conditions of accumulation remained very constant over a long period. Such conditions involve no great difference either in the height of adjacent land areas or in the depth of the sea-water in which the sedimentary and volcanic materials were accumulated. The sea-floor may have sunk gradually, but in this process little permanent deformation of the yet unconsolidated beds would be expected.

Because of the uniform character of the several members of this series over the entire district, as well as in neighbouring areas, it is difficult to judge the position of the old shore-line at the time of their deposition. The marine incursion in Lower Pennsylvanian time covered the greater part of British Columbia and, probably, extended for some distance south of the International Boundary, and it is accordingly probable that the bulk of the sedimentary material was obtained from areas farther to the east and south. Coarser sediments, including a considerable abundance of metamorphosed sandstone and fine conglomerate, are reported from Washington<sup>1</sup>, and seem to indicate an approach in this direction to a part of the old shore-line. The volcanic material was, probably, derived chiefly from submarine fissure eruptions, but isolated cones may have projected above sea-level and supplied part of the small proportion of pyroclastic material associated with the extrusive flows.

Following the accumulation of the Cache Creek rocks, the area experienced the first structural disturbance of which there is any record. This movement consisted in the gradual emergence of the area above sea-level. It was of far-reaching extent and represents an epeirogenic rather than an orogenic disturbance. Broad crustal warping may have resulted, and much of the minute crumpling exhibited by the finely-banded chert and slate may have occurred. The areas in south and southeastern British Columbia were among the first to experience rejuvenation, and as a consequence the Pacific waters were tilted from the continental platforms towards the northwest, where, in southeastern Alaska, they may have remained into Triassic time. In Coquihalla area and neighbouring areas of southwestern British Columbia the Cache Creek rocks appear to have been subjected to a very considerable erosion during a period extending well up into Triassic and probably to Upper Triassic time, although Dawson was of the opinion that in this region sedimentation might have been continuous from the Palæozoic to the close of the Triassic. There is, however, strong evidence to conflict with this possibility. In the table of western Triassic formations compiled by Smith<sup>2</sup> in 1907, no representatives of Lower Triassic, and few or none of Middle Triassic, are given for British Columbia. The amount of Cache Creek rocks eroded from these areas during this interval cannot be safely estimated. It seems probable, however, that a considerable thickness of limestone has been removed, or other members corresponding to the Marble Canyon limestones from the upper horizons of the typical Cache Creek section described by Dawson from Bonaparte river.<sup>3</sup> This limestone member has a thickness there of at least 3,000 feet, and even as far south as the International Boundary and in northern Washington limestone beds varying in thickness up to 100 feet or more are encountered. In Skagit valley, near the mouth of Sumallo river, the upper section of the Hozameen (Cache Creek) rocks contains between 700 and 1,700 feet of limestone.<sup>4</sup> On the assumption that these limestone beds increase in thickness in the direction of Bonaparte river, and that their absence at intermediate points is chiefly due to erosion, it seems probable that at least 2,000 feet of Cache Creek rocks have been eroded from the sections exposed on Coquihalla and Fraser rivers, where only an occasional thin limestone pod appears.

 <sup>&</sup>lt;sup>1</sup> Smith, G. O., and Calkins, F. C., Bull. U.S.G.S. 235, 1904, p. 22.
<sup>2</sup> Smith, J. P., Festschrift v. Koemen, 1907.
<sup>3</sup> Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1894, vol. VII.
<sup>4</sup> Camsell, C., Geol. Surv., Can., Sum. Rept., 1911, p. 118.

Following this interval of emergence and denudation, which continued to at least the close of Lower Triassic time, there occurred a second great inundation by Pacific waters, commencing in Middle Triassic, and in Upper Triassic time extending southward over British Columbia, eastern Washington, and Idaho, to connect with the older Lower Triassic sea of northern California and Nevada. This incursion persisted over the remaining Triassic time. Sedimentation during this period was accompanied by an even greater proportion of volcanic material than in the late Palæozoic.

In Coquihalla area rocks related to this period of submergence were all laid down under marine water in a position more nearly horizontal than otherwise, the greatest irregularities arising, as in the case of the Cache Creek rocks, through the disposition of the lava beds. It is problematical what thickness of these rocks was developed over Coquihalla area, but they have been entirely eroded from the greater part of it. They are still represented by a thick section in the adjoining Tulameen area where they have been correlated with Dawson's Nicola series in which Upper Triassic fossils have been found. Some of the upper members may be of Lower Jurassic age.<sup>1</sup> The local accumulation of great volumes of lavas, which compose a great proportion of the Tulameen rocks, may have been accompanied by local warping of the earth's crust, in part due to the weight of the overlying rocks and in part to weakness induced in the crust by the extravasation of igneous matter from beneath the surface. In these sunken areas the Tulameen rocks would be protected from erosion which removed representatives of the group from other areas where their accumulation was, in the first place, less, and where downwarping had not occurred.

It is uncertain to what extent the Lower Jurassic is represented in western British Columbia. Authorities on the historical geology of this section are apparently agreed that, during the closing stages of the Triassic, disturbances chiefly affecting the eastern Cordillera resulted in the general withdrawal of the late Triassic sea towards the extreme western fringe of the continent, remaining throughout the Jurassic in sections of Cook inlet and Alaska peninsula.<sup>2</sup> It may also have remained over parts of northwestern British Columbia<sup>3</sup> until late Upper Jurassic time. Pacific water also persisted in early and Middle Jurassic time over a large part of California, as well as in Oregon and western Nevada. The greater part of British Columbia is, however, regarded as having no representative of the Lower Jurassic, but on the islands off the west coast of British Columbia this period is represented by the Maude argillites of Graham island<sup>4</sup> and less certainly by the Sutton limestone of Vancouver island.<sup>5</sup> It seems probable, too, that the Upper Triassic sea may have remained over a considerable part of the southwestern mainland of the province during the early part of the Lower Jurassic period.

Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1894, vol. VII, p. 112 B.
Stanton and Martin, Bull. G.S.A., vol. 16, 1905.
Leach, W. W., Geol. Surv., Can., Sum. Rept., 1910, p. 93.
MacKenzie, J. D., Geol. Surv., Can., Mem. 88, p. 46.
Clapp, C., Geol. Surv., Can., Mem. 13, p. 68.

The period of formation of the Tulameen group may, therefore, have extended into the Lower Jurassic, but at some time in the early Jurassic a second epeirogenic disturbance occurred during which the Tulameen rocks were raised above sea-level and subjected to erosion until some time in Middle or possibly until early Upper Jurassic time. This uplift was probably not as high as that which occurred in late Pennsylvanian time. but it was sufficient to ensure in the succeeding interval of erosion the removal of the Tulameen rocks from the greater part of Coquihalla area. Some additional erosion of the underlying Cache Creek rocks may also have occurred, but if so it was probably not great. As in the case of the earlier uplift, very little deformation of the Tulameen and Cache Creek rocks resulted beyond slight crustal warping. The Cache Creek rocks, however, having been now subjected to two periods of uplift, would be likely to show a certain degree of deformation, although it is doubtful whether the average angle of dip of their strata would exceed 15 degrees or 20 degrees and might be considerably less.

In Middle or early Upper Jurassic time the district was again submerged, and during the remainder of Jurassic time two heavy series of sedimentary rocks, referred to as the Ladner and Dewdney Creek series, were deposited. The Ladner series was laid down on the eroded surface of the Cache Creek rocks. It consists chiefly of slates and tuffaceous greywackes with a small percentage of fine conglomerate. The character of the sediments still suggests adjacent land areas of low relief, a feature that persists through the period of deposition of the succeeding Dewdney Creek series in which the percentage of clastic sediments is much smaller and volcanic tuffs constitute the great proportion of the beds. The total thickness of these two series is in the neighbourhood of 20,000 feet. To accommodate such a heavy deposit the sea-floor must have gradually sunk, although from the absence of limestone beds it is doubtful whether the depth in which the strata were formed was at any time very great. The paucity of limestone may, however, be due rather to the meagre assemblage of fossils, chief of which are belemnites, trigonias, and ammonites. The character of this assemblage suggests that these waters were rather brackish in character and were consequently those of a large arm of the sea rather than a part of the main coastal waters. These mainland deposits are contrasted in this respect with those of Vancouver island where limestones were more abundant and where typically marine conditions prevailed. In Coquihalla area vulcanism was more apparent in the abundance of pyroclastic rather than extrusive rocks, and in this respect also differed from the rocks of the coast islands where lavas and flow breccias were more common.

The Jurassic period was closed by the first, and probably the greatest, orogenic disturbance in the history of the region, and this was accompanied, or immediately followed, by the first of the series of batholithic intrusions which were to characterize late Mesozoic as well as Tertiary time. The main forces producing this disturbance acted laterally from the southwest, and threw the Jurassic and older formations into great folds with axes extending in a northwest-southeast direction. This folding was on a scale great enough to develop mountain ridges with corresponding intermontane depressions, some of which extended well below sea-level, and from which the late Jurassic seas may never have been entirely excluded. It is probable that deformation was more intense in regions to the west of Coquihalla area where the great body of late Jurassic or early Cretaceous batholithic rocks were intruded, and that towards the east the force of this orogeny gradually diminished. Folding was doubtlessly very pronounced in Coquihalla area, but it is hardly probable that any great compression of these folds occurred, and still less likely that reverse folding or overthrusting was developed on anything except a minor scale. In this area only a relatively small body of intrusives belonging to this period is represented and it may be considered as an outlier from the greater batholithic bodies farther to the west. Folding on a large scale, in which the rock structure accorded fairly closely with the topography, may be considered to represent the characteristic expression of this late Jurassic orogeny. No important faults belonging to this period have been differentiated from those occurring at later periods in the Mesozoic. The overthrusts involving the Jurassic and older formations are regarded as having resulted from a To what extent the batholithic intrusions effected deformalater orogeny. tion of the overlying rocks is uncertain, but, within Coquihalla area, deformation due to such intrusion would not, in any case, be great, for these intrusions were comparatively small. Fracturing is in evidence near the batholithic contacts with older rocks, but some of this preceded the intrusion, and the direction of the numerous apophyses cutting these older rocks may have been determined by pre-existing fractures instead of the fractures themselves being caused by the intrusion.

Following this period of diastrophism, there began a long period of sedimentation during which the Lower Cretaceous rocks of the Coquihalla and neighbouring areas were deposited. These were laid down in long, geosynclinal downwarps induced during the late Jurassic orogeny. During this period great thicknesses of comparatively coarse sediments were deposited. The adjoining lands were deeply eroded, and denudation cut deeply through the older formations into the underlying batholithic rocks, which in turn furnished much detritus for the Cretaceous beds. At least 7,000 feet of sediments belonging to this period are represented in Coquihalla area. Here, however, the upper sections have been removed by subsequent erosion, so that the original thickness must have been considerably greater. At the International Boundary a much thicker series of Cretaceous rocks (Pasayten formation) has been described by Daly, and is regarded as including both Lower and Upper Cretaceous members between which no division has been made. The Cretaceous rocks from Fraser River sections are probably of Lower Cretaceous age and have been estimated by Dawson to be not less than 7,000 feet and probably 10,000 feet or more in thickness. In many cases these Cretaceous rocks are sparingly fossiliferous, but within the Coquihalla area no palæontological discoveries of any specific value were made. In western British Columbia these Lower Cretaceous rocks occupied a broad geosynclinal downwarp along the west coast between the Coast range and an older land area that lay west of the present coast islands. This belt does not appear to have extended far south of the International Boundary except along the extreme west coast, where it is much narrower than north of the boundary line. It was shown that these sediments accumulated very rapidly from the nearby mountain ranges, and that consequently the arenaceous beds are composed of fresh-looking, angular grains; that the larger pebbles, cobbles, and boulders of granitic detritus show an increasing tendency towards spherical shapes in proportion to their size, and indicate a modification of their original outlines by the action of river water; that a great bulk of these sediments accumulated near the mouths of large rivers after the fashion of huge delta deposits; and that the water in which they were deposited was often brackish in character, due both to abundant local discharge of fresh water and to the partial isolation of the marine water in an intermontane sea. These Lower Cretaceous rocks are correlated with the Shasta series of California, and the word Shastan is often used synonymously for Lower Cretaceous or Comanchean along the Pacific border.

Following the deposition of these Lower Cretaceous sediments, the region was subjected to a second orogenic disturbance of whose intensity there are few local data available. There are, as far as is known, no Upper Cretaceous beds present in the Coquihalla area whose deformation might be compared with that of the Lower Cretaceous, but a comparison can be made between the deformation exhibited by the late Jurassic or early Cretaceous intrusives and those of late Cretaceous age. Assuming that these two periods of batholithic intrusion accompanied, or, possibly to an even greater extent, followed the orogenic disturbances at the close of Upper Jurassic and Lower Cretaceous time, the older intrusions would have experienced cataclastic deformation only in the last orogeny and the younger intrusives would not be included in either. Consequently the difference in fracturing exhibited by the intrusives of these two periods may be regarded as some measure of the intensity of the later revolution. The older intrusives show more pronounced cataclastic texture than the others; and, although shearing is common to both, it is more strongly developed in the earlier batholithic rocks. Along these shear zones in certain members of these intrusives a great number of aplite dykes were These dykes are, with few exceptions, quite massive in contrast intruded. with the rock they intrude and are probably about the age of the later batholithic intrusives in their vicinity. In this case these dykes themselves indicate that the second orogeny was pronounced, and also that the forces producing it acted from about the same direction as in the preceding revolution. It is uncertain how much additional folding was induced in the pre-Cretaceous formations by this last revolution, or to what extent the Cretaceous sediments themselves were deformed. Neither is it certain to what extent the faulting occurring in the Cretaceous rocks must be ascribed to this orogeny or to the succeeding Laramide revolution. The apparent conformity reported between Lower and Upper Cretaceous rocks in the Pasayten series at the International Boundary<sup>1</sup> at no great distance from Coquihalla area would indicate that no great degree of folding had been instituted by this late Lower Cretaceous orogeny, whereas the evidence already cited with regard to the batholithic rocks of the area favours the view that considerable deformation must have occurred. In face of this conflicting evidence it is impossible to arrive at a satisfactory

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<sup>&</sup>lt;sup>1</sup> Daly, R. A., Geol. Surv., Can., Mem. 38, p. 480.

conclusion as to the importance of this revolution until the age of the Cretaceous formations exposed over southwestern British Columbia is more certainly determined, and comparison can then be made between the deformation exhibited by members of known Lower and Upper Cretaceous age.

Batholithic intrusions accompanying or following the late Lower Cretaceous revolution were very prominent, but no convincing evidence that they effected much deformation in the older rocks was obtained, except perhaps in the case of the Eagle granodiorite whose gneissic structure has been attributed to pressure by the slightly later intrusion of the complex to the south. Evidence points to a gradual rather than violent irruption of the batholithic material. The foliation indicates that the general trend of deformation induced by this orogeny was more nearly north and south than in the preceding late Jurassic or early Cretaceous revolution, although the angle between the two was probably not over 20 or 25 degrees. The batholithic rocks of this period mostly represent a progressive easterly phase of those late Jurassic or early Cretaceous intrusions that constitute the great mass of the Coast Range batholithic complex west of Fraser river. The proportion of true granites is greater in these more easterly and later representatives, but granodiorites still predominate. The order of succession is well defined in the northern section of Coquihalla district and is the one normally developed in the Coast Range intrusives. A small body of diorite and quartz diorite (Eagle diorite) was first irrupted, but was followed closely by the greater bulk of the Eagle granodiorite. Succeeding this intrusion there appeared a still more acid complex of granodiorite and granite, also of large areal dimensions. The bulk of this complex is a true granite in composition.

The period following the late Comanchean disturbance was, apparently, one of erosion, but submergence and deposition during part of Upper Cretaceous time may have occurred, and it is doubtful whether the volume of rocks eroded was nearly as great as that removed during the period of Lower Cretaceous sedimentation. The top of the Lower Cretaceous is removed in Coquihalla area, but the thickness remaining is still very great and is composed for the most part of beds containing an abundance of granitic detritus probably from late Jurassic or early Cretaceous intrusives. This material could have been supplied only after a great thickness of strata had been removed. The beds containing this detritus would consequently be among the first to be removed, and their present abundance suggests that no great thickness was removed in Upper Cretaceous time, and in this respect lends some support to the belief that during part of Cretaceous time these areas of Lower Cretaceous rocks may have been covered unconformably by Upper Cretaceous beds. Such a relation is probably still preserved in the case of the Pasayten series at the International Boundary, where both Lower and Upper Cretaceous strata are present.

Following the late Lower Cretaceous disturbance, the next great revolution affecting the rocks of Coquihalla area may be correlated with the Laramide revolution of the eastern Cordillera. The age of this revolution has not been definitely determined. Its effect extended probably well into Eocene time, but the maximum deformation—at least within the Canadian Rockies—seems to have been accomplished at the close of the Cretaceous period, and in the present report it is assigned to that position. This revolution was not as pronounced in the western as in the eastern Cordillera, but even in the west its effects were probably second only in importance to the late Jurassic orogeny. In Coquihalla area the deformation accomplished by the Laramide revolution is in many places difficult to distinguish from that referable to the late Comanchean orogeny. It is best shown by the deformation of the Cretaceous batholithic rocks of the area. All the larger intrusive bodies referable to this period are somewhat sheared, and exhibit a fractured or cataclastic texture. From such deformation it is evident that this orogeny was an important one.

The compression producing the deformation of this period acted from the southwest, or from some angle intermediate between this and the west. It produced a great deal of overturning and thrusting in the pre-Cretaceous formations. In the Cache Creek and Ladner series the crushing, overturning, contortion, and thrusting were most prominently developed in the less competent slaty beds. Deformation was almost equally pronounced in the Dewdney Creek series, and some of the most complex faulting in the area was observed in the Tulameen Mountain section of this series. Probably the more important overthrusts, such as those on either side of Ladner creek, and that occurring on Goat mountain, are products of the Laramide revolutions. Another important break related to this period separates the Cretaceous rocks from the Ladner series near Cedar creek, and appears to represent an overthrust of the latter toward the northeast. The fault-probably resulting from this orogenic disturbance-between Romeo and Iago probably extends for some distance on either side of these stations. Besides these larger breaks there are numerous smaller faults, commonly of reverse, but including normal, types.

During this period, too, the Lower Cretaceous sediments, which had been moderately folded during the late Comanchean revolution, were more tightly compressed. Considerable slipping and faulting occurred during the compression of these rocks as is evidenced by the curious arrangement of the strata near the axes of the folds, where they are frequently more nearly perpendicular than farther out on the flanks. This is most noticeable where the folds occur in shaly or slaty rocks that yield readily to compressive forces. On the whole, however, the Cretaceous rocks are less deformed than the Dewdney Creek or still earlier formations. The axis of folding in this period seems to be similar to that induced in the late Lower Cretaceous revolution, or about north 20 degrees west, but the strike of some of the more important overthrusts is more nearly northwest-southeast.

Following the Laramide revolution, there is no record of structural disturbance in Coquihalla area until Miocene time. The land areas in southwestern British Columbia appear to have been reduced in Eocene time to low relief and, except along the coast, neither sedimentary nor volcanic rocks are recognized as belonging to this period. In Oligocene time local freshwater sedimentation occurred in isolated basins and in the deposits of this period correlated with the Coldwater formation, and these sediments are regarded as having been broadly folded in late Oligocene

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It is improbable, however, that any of the Tertiary rocks from time. Coquihalla area date as far back as Oligocene. Their deformation would consequently be referred to late Tertiary time. The disturbance at the close of the Oligocene was in the nature of an orogeny, but not nearly as intense or widespread in effect as the revolution closing Mesozoic sedimentation. Its effect in Coquihalla area is unknown. Some uplift accompanied the deformation, and the Oligocene beds were thrown into broad folds which in the Tulameen area rarely exceed 45 degrees. In certain sections vulcanism accompanied Oligocene sedimentation, and volcanic materials are associated with the freshwater deposits. An important association of this character occurs in the Tulameen area where members of the Cedar Creek volcanics are intercalated with Oligocene beds of the Coldwater series. The Coldwater sediments are composed chiefly of conglomerates and sandstones, and contain coal seams.

The Miocene period was notable for an orogeny that affected the entire Pacific coastal regions from California north into the Aleutian chain, and occurred probably in the interval between Middle and Upper Miocene time.<sup>1</sup> The deformation of the Coquihalla series, whose beds dip at angles that rarely exceed 25 degrees, has been attributed to this disturbance. Crustal warping was probably nearly continuous during the Miocene and attendant upon the great volcanic activity of the period. A considerable regional uplift may have occurred during this time.

The Coquihalla series is probably of Miocene age and its structure indicates that considerable crustal warping either attended or succeeded the period of its accumulation. The succession of events during this period may be summarized as follows:

Extrusion of basaltic lavas to a depth of 1,000 feet into a local basin, which may have been gradually sinking under the weight of accumulating deposits.

Extrusion of rhyolitic lavas to a maximum depth of 1,500 feet, accompanied by short intervals of deposition of acid tuffs and breccias.

Deposition of acid pyroclastic rocks to a maximum depth of at least 2,000 feet.

Possible extrusion of basaltic lavas or pyroclastic materials of about the same composition as the intrusive now forming the core rock of Coquihalla peak. These later volcanic materials have since been eroded, but their original occurrence is inferred from the character of the core rock of Coquihalla peak and from the occurrence of a few basaltic porphyry dykes that intersect all earlier members of the series.

The Miocene is also notable for the number and bulk of its batholithic rocks. In the southern part of Coquihalla area are two areas of quartz diorite which are regarded as probably of late Miocene age. One of these composes the peak of Isolillock mountain, and is continuous to the south with the Chilliwack granodiorite batholith which "forms the largest intrusive area in the Boundary belt west of the Remmel batholith."<sup>2</sup> It has been correlated with the Castle Peak stock, also in the Boundary belt. and with the Snoqualmie granodiorite and diorite batholith from central

<sup>&</sup>lt;sup>1</sup> Blackwelder, Elliot, Jour. Geol., vol. 22, p. 633. <sup>2</sup> Daly. R, A., Geol. Surv., Can., Mem. 38, p. 534.

Washington which has been referred to the Miocene. The Otter granite from Tulameen area is probably, also, of Miocene age. These Tertiary intrusives are notable for their massive, unsheared appearance which indicates that they have not been involved in any of the major periods of deformation affecting the pre-Tertiary rocks of the region.

In Pliocene time, only small structural disturbances apparently occurred until toward the close of the period. Vulcanism was very pronounced in some sections of the western Cordillera, but in Coquihalla area erosion seems to have been continuous over the greater length of the period and the area was reduced in late Middle or Upper Pliocene time to almost a peneplain. A great uplift began in late Pliocene time, increased in intensity, and extended into the early Pleistocene. This epeirogenic uplift was somewhat differential in character, so that the physiographic province referred to as the Cascade Mountain system, within whose northern limits Coquihalla map-area is situated, was elevated 2,000 feet or more above the average attained by the more eastern Interior Plateau region. In Coquihalla area this elevation seems to have been in the neighbourhood of 4,500 feet, whereas in Hedley district, less than 50 miles to the east in the plateau province, it is estimated to have been about 2,500 feet. Uplift proceeded so gradually as to permit many of the principal streams draining the older topography to incise themselves along old channels which they continue to occupy to the present time. Such antecedent streams include Fraser river, and some of its principal tributaries, including the Coquihalla.

With the exception of a few dykes which intersect the Coquihalla series no rocks of possible Pliocene age have been recognized in Coquihalla area. Even these dykes are regarded as of late Miocene age.

Following the latest uplift, a new cycle of erosion was instituted, and in the Coast mountains progressed to a stage of early maturity before the period of glaciation began.

There is evidence in Coquihalla area of only one period of regional glaciation. It was preceded, probably, by valley glaciation and it is possible that an ice cap covered the northern Cascades at more than one period, to be succeeded by conditions of valley glaciation alone, or the entire absence of glacial ice. In Puget Sound region two deposits of glacial till, the Admiralty and Vashon, are respectively older and more recent than the important interglacial period known as the Puyallup.

Valley and mountain glaciation have greatly modified the topography of Coquihalla and adjoining areas.

One important morainic deposit still remains near the lower course of Coquihalla river, and smaller deposits occur at the mouths of Dewdney and Boston Bar creeks. Glacial erratics and fine debris are thinly distributed over a great part of the district, but have lost much of their identity in their incorporation with the heavy soils covering these areas.

Subsequent to the retreat of the valley glaciers, fluvioglacial terrace deposits were formed in the valley bottoms and remnants of these are still preserved in the larger valleys. The streams have in very recent time cut through these deposits and formed narrow V-shaped troughs in the underlying rock. The materials carried down Coquihalla river have built up the delta at its junction with Fraser river.

# SUMMARY OF GEOLOGICAL EVENTS IN COQUIHALLA DISTRICT

### PALÆOZOIC

Submergence in Upper Carboniferous time; clastic and chemical sedimentation accompanied by subaqueous extrusion and deposition of volcanic materials. (Cache Creek series.) Emergence near close of Palæozoic; erosion of Cache Creek rocks

amounting to at least 2,000 feet.

### MESOZOIC

Submergence in Upper Triassic time; sedimentation accompanied by subaqueous extrusion of volcanic materials. (Tulameen series.)

Emergence at close of Triassic (?) followed by erosion of most of the Triassic (Tulameen) rocks.

Submergence beginning probably in Middle Jurassic, but more general in early Upper Jurassic time; normal sedimentation accompanied by an increasingly important percentage of pyroclastic materials. (Ladner and Dewdney Creek series.)

Upper Jurassic revolution; uplift and deformation of older formations.

Intrusions of late Jurassic or early Cretaceous batholithic rocks, chiefly granodiorite, but including quartz diorite and diorite. (Jurassic batholithic rocks.)

Submergence and deposition of Lower Cretaceous rocks.

Late Lower Cretaceous revolution; uplift and moderate deformation of Lower Cretaceous sediments and earlier batholithic rocks.

Batholithic intrusions including the Eagle diorite, Eagle granodiorite, and a complex of granite and acid granodiorite in the northern sections of the area and chiefly granodiorites in the southern sections. An important stage in the development of ore deposits in the area.

Probable submergence and deposition of Upper Cretaceous rocks.

Laramide revolution; uplift and deformation of Cretaceous and earlier formations; deformation of pre-Cretaceous rocks accompanied by much faulting, thrusting, and overturning of the beds toward the northeast.

## TERTIARY-QUATERNARY

Erosion probably continuous throughout Eocene and Oligocene time. Miocene extrusion and deposition of volcanic rocks (Coquihalla series) accompanied, and probably followed, by a period of crustal warping near close of Miocene. Intrusion of quartz diorite batholithic rocks (Tertiary quartz diorite) tentatively referred to the late Miocene or early Pliocene period.

Period of erosion and uplift culminating in late Pliocene but probably extending into early Pleistocene time; total uplift of about 4,500 feet.

Erosion in late Pliccene and Pleistocene reaching a stage of early maturity.

Glaciation both regional and local-remnants of morainal deposits.

Post-glacial terrace deposits.

Recent deepening of valleys and construction of delta at the mouth of Coquihalla river.

# CHAPTER V

# ECONOMIC GEOLOGY

# HISTORY OF MINING DEVELOPMENTS

# EARLY PLACER MINING ON FRASER RIVER

Attention was first drawn to the economic possibilities of Coquihalla area in the years following the great stampede to Fraser River placers in 1858. During this period Hope became a place of leading importance. Its population increased from a mere handful of white men to about 400. In October of 1858 it was estimated that 4,000 miners were distributed between Cornish Bar, a couple of miles below Hope, and Yale, 13 miles "In the Hope district," Bancroft states<sup>1</sup> "an ounce or more a day above. was common wages, while some miners earned two or more ounces for weeks together. Between Cornish Bar and Hope alone there were in November of this year thirteen ditches in operation and more in process of construction." As the bars in this vicinity showed signs of depletion in values the majority of the miners withdrew to more profitable diggings, although as late as 1860 Hope district was still occupied by over 200 miners who were making an average of \$6 a day on old ground. This rate was maintained for several years, during which, however, the white man was largely replaced by the Chinese and to a less extent by Indians.

These operations were confined entirely to Fraser river whose length within Coquihalla map-area is less than 6 miles. It is quite probable that during this period some investigations may have been made of the stream beds of Coquihalla river and its tributaries.

### LATER PLACER MINING IN COQUIHALLA BASIN

The first recorded attempts to work the gravels of Coquihalla river and its tributaries began about 1911 and have continued in a desultory fashion up to the present time. The sections chosen included Ladner creek, below the junction of the South and North forks, and scattered sites along Coquihalla river from Ladner creek to Peers river. The more important work on the main stream was done near the mouths of Fifteenmile creek and Sowaqua river. Owing to physical difficulties the results proved disappointing. Like all mountain streams the Coquihalla and its tributaries are subject to great fluctuations, and the boulders in the stream beds are a serious handicap to the placer miner. Where the precious metals have been segregated, the great depth to bedrock discourages private operations.

<sup>&</sup>lt;sup>1</sup> Bancroft, H. H., "History of the Pacific States," vol. XXVII.

That gold, and to a similar extent platinum, occur in these stream deposits has been proved. Good colours may be obtained at almost any point along the Coquihalla below Ladner creek simply by overturning any of the larger boulders and panning the underlying sands. Nearer bedrock comparatively coarse gold, and platinum nuggets, have been recovered, but profitable extraction has failed because of the difficulties enumerated. These can be surmounted only by the installation of efficient pumping machinery and the construction of permanent flumes and dams.

The most promising section of the river lies between the mouths of Boston Bar creek and Peers river. Above Ladner creek, however, the Coquihalla is rapid, and very little of the stream deposits remain. Below Ladner creek the river bed widens, the grade is lower, and deposits have accordingly accumulated, although they are not equally distributed. Ladner creek itself provides likely sections for small placer accumulations.

In Coquihalla area the lode values are chiefly confined to the slate belt, and it is accordingly from this formation that most of the placer gold has been derived. A great deal of this gold must have been carried down Coquihalla valley well below the lower limits of the slate belt. The source of the platinum is less certain, but this metal is probably derived from the younger basic intrusive rocks.

#### LODE MINING

Lode mining began in 1868, with the discovery of the Eureka-Victoria silver deposits on Silver peak. In the ensuing six years a considerable tonnage of high-grade ore was shipped from this property, but in 1874 the property was closed down. Within the last two years, however, it has been reopened.

For over twenty years following the closing of this property no further discoveries were recorded.

In the years succeeding the discovery of silver-lead ores in 1895 at Summit Camp east of Coquihalla area, some claims were staked and some ore discovered in the upper basins of Dewdney and Cedar creeks, but little development work has yet been done on these properties.

In 1901 the copper ores of the Independence mine were discovered. These are situated at the northern end of the area and during the seven years following their discovery were extensively developed. No work has been done on this property since 1908.

The succeeding years mark another but shorter break in the history of lode mining in this area. In 1911, and the years following, active prospecting began in the interior of the district, stimulated largely by the construction of the Kettle Valley railway, which began operations between Midway and Petain via Coquihalla valley on July 1, 1916. In this period a number of gold properties were discovered in the Ladner slate belt west of Coquihalla river and chiefly in the basin of Ladner creek. Several of these contain high-grade ore and at one, the Emancipation, a mill has been erected. Recent prospecting has resulted in the discovery of a great number of prospects, and a few have developed into properties of importance. Among these are the Aufeas gold-arsenopyrite property on Wardle creek, a tributary of Silver creek, about 4 miles south of Hope; the Pipestem gold mine at the head of the Middle fork of Ladner creek; and the Dominion Molybdenite claims on the granite summits west of Iago.

The principal metals, in the order of decreasing importance, are gold, silver, copper, and molybdenum. Gold is the most widespread of the ore minerals and occurs in a variety of mineral and geological associations. Silver, as a rule, occurs in minor values with the gold, but at the Eureka-Victoria mines is of chief importance. Copper ores of commercial value occur only at the Independence mine, and there is but one molybdenum property, the Dominion Mineral group.

### Gold

The future of mining in the district is largely dependent upon the economic extraction of the gold. Except at the Aufeas mine (See page 148) the principal gold deposits occur in, or are intimately associated with, the Ladner slate belt which has an average width of  $2\frac{1}{2}$  miles and occupies a somewhat irregular synclinal depression between coarsely crystalline batholithic and Cretaceous sedimentary rocks to the northeast and a complex of volcanic rocks and basic intrusives to the southwest. On the summit of the divide west of the North fork of Ladner creek the Upper group of the Ladner series overlies these slates conformably, and a much smaller and ill-defined area of the same group appears on the divide south of Portia between Coquihalla river and Dewdney creek.

Although the members of the Ladner series have a prevailing southwesterly dip, variations in attitude are common, as a result partly of overthrusting and faulting, partly of differential warping of competent with less competent strata, and partly of intrusions of dykes, sills, and more irregular porphyritic bodies. Two prominent thrusts occur in the railway section, one on either side of Ladner creek. The more southwesterly one has a strike of north 35 degrees west, dips at about 70 degrees to the southwest, and represents an overthrust from the southwest. It may be the continuation of that thrust which can be traced along the northern flank of Goat mountain over 6 miles to the southeast. In the railway section its position is marked by a seam of gouge breccia over 2 feet wide (Plate V B). It is impossible to say to what extent this thrust has duplicated the slate section, but from the high angle of the thrust and the high dip of the slates themselves, as well as from an examination of the beds on either side of the thrust, it is believed that, although the displacement may have reached several hundred feet, the duplication of strata was not nearly as great. The thrust on the northeast side of Ladner creek is also a prominent one, but appears to be of more local extent and the duplication of the strata even less and from the opposite direction. Between the two thrusts the slates have been intensely warped to form a subsidiary anticlinal fold.

Estimating the general strike of the slates as north 35 degrees west, and the average dip to the southwest as 70 degrees, the thickness of the slates as exposed in the railway section would be approximately 8,000 feet. The eastern limb of the syncline has been in part cut away by batholithic intrusions, but the western limb is complete and affords a fair basis for calculation.

On the whole, the members of the slate<sup>1</sup> belt are fissile, dark grey to black, fine-grained rocks and commonly exhibit a well-defined slaty cleavage. Except in the more intensely crumpled sections the cleavage follows closely the original bedding planes and strikes approximately parallel to the course of the slate belt. These rocks are almost everywhere sparingly mineralized by pyrite and pyrrhotite. In the vicinity of local intrusives these sulphides are as a rule more plentiful. Pyrrhotite is the more abundant. As a result of this mineralization the weathered surfaces, as well as the cleavage and joint-planes, are commonly stained with iron oxide and large areas of such outcrops are decidedly reddish when viewed from a distance. Fractured surfaces of these slates in many places present numerous small cavities, some oval or irregular and some quite angular, which were at one time occupied by the iron sulphides and in which some white powdery sulphate of iron commonly remains.

### Northeast Contact

In the vicinity of the large batholithic intrusions these slates exhibit varying degrees of contact metamorphism. Close to the contact they are frequently heavily impregnated with igneous material and largely recrystallized (Plate VII A) although usually retaining a laminated structure. They are commonly stained a purplish to brick red colour and are characterized under the microscope by the development of innumerable tiny shreds of red biotite. Their texture and composition are those of biotite quartz schists. Farther from the contact these schists are replaced by slaty phyllites containing metacrystals of cordierite and andalusite. The latter, as the variety chiastolite, is particularly abundant and has been observed in the railway section several hundred feet from the batholithic contact.

In spite of the intense metamorphism to which these slates have been subjected, no mineral deposition of economic importance has yet been discovered in the vicinity of this contact. The slates are themselves commonly heavily impregnated with iron and, to a smaller extent, copper sulphides. An assay obtained from a heavily mineralized composite sample contained: copper, 0.14 per cent; iron, 8.26; no arsenic, gold, or silver. A few prospects have been opened along certain quartz veins near the contact where such mineralization seemed most abundant, but they have invariably proved disappointing and are soon abandoned. A few of the many dykes intersecting the slates near the contact have proved more seductive to the prospector. Usually these dykes are themselves sparingly mineralized and quartz veins in their vicinity mostly give low assay values in gold.

<sup>&</sup>lt;sup>1</sup> For fuller description see section in preceding chapter dealing with the Ladner slates.

## Southwest Contact

Along the contact of the Ladner slate belt with the rock complex to the southwest entirely different conditions prevail. Here the slates have been bedded unconformably upon an older greenstone or lava flow of the Cache Creek series whose average composition is that of an andesite. The upper section of this greenstone is, however, less basic in character, being composed mainly of plagioclase with a composition of oligoclase or oligoclase-andesine. Under the microscope this andesite in places shows a primary flow structure, and near the contact with the slates exhibits a slaty structure due to the intense deformation to which it has been subjected.

This greenstone has been intruded by a large dyke-shaped body of diorite which has sent out large apophyses along the slate contact. Some of these intersect the slates. This diorite<sup>1</sup> is a moderately coarse-grained, massive rock, which, in the hand specimen, appears to be composed of from 30 to 60 per cent of pyroxene and dark green hornblende. Under the microscope the rock shows a crude diabasic texture. The feldspar is probably oligoclase, but is so turbid with alteration that it is difficult to obtain satisfactory determinations. It shows carlsbad, albite, and pericline twinning. The hornblende is in part a massive, dark green variety and in part shows a matted fibrous texture and high birefringence, suggesting its derivation from a pyroxene. Accessory minerals include ilmenite, magnetite, and apatite. Among the secondary alteration products are uralite, hornblende, zoisite, calcite, and leucoxene.

The greenstone has been intensely altered by the intrusion of this diorite. The more acid and, in general, the upper parts of the flow have been heavily impregnated with sulphides and are frequently altered to a complex of chloritic and saussuritic products, with calcite and secondary hornblende replacing the feldspars. A number of areas of serpentine are closely associated with this greenstone. Their origin has been discussed on pages 35, 36.

It is in the vicinity of the greenstone-slate contact, and principally within the slates themselves, that the chief gold properties of the district occur. That most of these, at least, are genetically related to the diorite intrusive rather than to the main body of batholithic rocks might be concluded merely from their singular arrangement along the southwestern contact in the vicinity of this intrusive. A detailed study of the various properties more firmly establishes this relationship.

It is not to be inferred, however, that all of the gold in the slate belt is attributable to this basic intrusion. There is definite proof that some of the minor dykes intersecting these slates are also auriferous and to these may be due the gold deposits occurring either in themselves or in the adjoining slates. The rich showings in the slates at the Pipestem mine are in the immediate vicinity of such a dyke, and the auriferous quartz veins on the Rush-of-the Bull Fraction occur in slates close to an intrusive porphyry. In the adjoining Siwash Creek area, Bateman<sup>2</sup> states that the

A more complete description of this diorite is given in the chapter dealing with smaller intrusive bodies in 2 Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1911, p. 125.

gold in the properties located in that district was "genetically dependent" on the numerous porphyry dykes cutting the slates. These dykes are very similar to those occurring on the Coquihalla side of the divide.<sup>1</sup>

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# **Emancipation** Mine

Emancipation mine is the most important of a series of properties located along or near the southwestern slate contact. It is operated by the Liberator Mining Company of Vancouver whose holdings in this locality include thirteen claims and a fraction, all of which have been surveyed.

The history of development work on this property has been recorded from time to time in the Annual Reports of the Minister of Mines for British Columbia. In the 1920 issue Robertson gives a more complete description of the property than theretofore and briefly discusses its future possibilities. The mine was visited by Camsell in 1919 and reported on in the Summary Report for that year. In the following two years the writer spent some time in an examination of the mine workings and the geology in their vicinity. A report on investigations made in 1920 has already been published<sup>2</sup>.

Between May, 1916, and November, 1919, shipments totalling 118.29 tons of high-grade, hand-sorted ore netted a gross return of \$35,683.83 or \$302.22 per ton. Arrangements are now being made to treat the ore on the property. For this purpose an aerial tram has been constructed from the mine to a mill near the railway. A compressor driven by a gas engine has been installed alongside the railway, and a pipe-line extended from it to the mine. A railway siding has been constructed at the foot of the mine trail.

General Description of Property. The principal workings are situated near the centre of the group and chiefly on the Emancipation claim (Figure 4). The ore occurs in certain quartz veins which lie on either side or dip across the slate-greenstone contact. This contact follows approximately the attitude of the slates which here strike north 30 degrees west and dip from 60 to 80 degrees to the southwest. At an elevation of 1,200 feet above the railway an adit has been driven about 380 feet along a quartz vein whose width varies from point to point and averages less than 18 inches. At this level the vein is entirely confined to the greenstone member of the Cache Creek series which underlies the Ladner slate belt. This vein may for convenience be referred to in future as the "Dyke vein."<sup>3</sup> Until recently, it has supplied most of the ore at the mine and some of this ore has proved to be very high grade.

Sixty-two feet north of the portal of this adit is a much larger and more persistent quartz vein that strikes nearly parallel to the dyke vein, but dips at a higher angle and lies entirely within the slates. It has an average width of 8 feet and is designated at the mine as the Boulder vein. Between the Dyke and Boulder veins occur a network of quartz stringers averaging only a few inches in width. These, as crosscut from the 1,200-foot adit, converge within 275 feet of the portal of the adit to form a single vein several feet wide referred to at the mine as the Intermediate lens.

<sup>&</sup>lt;sup>1</sup>Although the writer believes that the gold values occurring in the porphyry dykes intersecting the Ladner slates, as well as the mineralization induced in the slates immediately adjoining or within a few yards of these auriferous dykes, have originated from the dykes themselves, it is quite possible that both dykes and ore minerals were introduced separately from a common magmatic source. This latter view would be supported by the character of the alteration of these dykes which, in a previous chapter of this report, has been referred to permeation of thermal solutions of magmatic origin. Such thermal solutions might have introduced the ore minerals as well as effected the alteration of the dyke rock. <sup>2</sup> Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1920, pp. 31-32 A. <sup>3</sup> Robertson, W. F., B.C. Min. of Mines, Ann. Rept. 1920, p. N 170.



Figure 4. Plan of the Emancipation and Packard groups of claims, Coquihalla River area, Yale district, B.C. (Plan of claims reproduced by permission of Liberator Mining Company.)

In the interval between the Dyke and Boulder veins the country rock on either side of the greenstone-slate contact has been greatly crushed, heavily impregnated with vein quartz and to a less extent with calcite, and sparingly mineralized by pyrite, pyrrhotite, arsenopyrite, and some chalcopyrite. The two veins might, in short, be regarded as forming the bounding walls of a crushed and mineralized zone, on either side of which little vein quartz or mineralization might be expected. Investigation, however, shows that neither deformation nor mineralization is confined to this "zone," but is more or less noticeable on either side of it, and that on the hillside 250 feet above the mouth of the 1,200-foot adit the Intermediate lens crosses the Boulder vein and follows an irregular and as yet untraced course up the hill to the northeast. The Boulder vein maintains its course above this intersection. It is quite possible that further surface strippings may reveal other quartz veins still farther out in the slates and that the ore and gangue minerals of such veins would be derived from the same source as that furnishing the minerals of the veins already discovered.

Dyke Vein. The Dyke vein has an average strike of north 16 degrees west and dips 50 degrees to the southwest. From the portal of the 1,200foot adit it has been followed underground for about 380 feet. Near the face the vein has been faulted upward in a series of steps and its strike has been diverted farther and farther towards the north and northeast. The difficulty of following the vein was further aggravated by the ill-defined character of the hanging-wall which had so far served as an excellent guide.

The values along this Dyke vein vary greatly and are sufficiently concentrated in certain sections to provide rich shoots from which selected specimens assay high. A sample of 1,198 pounds of ore from near the portal is reported to have run \$1,595 per ton. At 100 feet from the portal a shoot provided over 115 tons of sorted ore that netted over \$34,000 or nearly \$300 to the ton. A polished section of a particularly rich specimen of this ore was examined. In it both arsenopyrite and free gold were observed in a gangue of calcite and quartz. The arsenide and gold both replace the gangue minerals, but give no indication of replacing each other and, apparently, were deposited contemporaneously.

The rich shoots, with some lower grade ore, have been partly extracted by stoping and winze work.

The rock forming both walls of the Dyke vein in the 1,200-foot adit is a fine-grained, slaty felsite, dark green to almost black in colour, and so mashed as easily to be mistaken for the slates themselves. Under the microscope it is seen to consist almost entirely of minute laths of plagioclase with a varying proportion of secondary minerals. Locally it has been largely altered to calcite, zoisite, epidote, chlorite, and serpentine. To the west, or below, the portal of the 1,200-foot adit a belt of serpentine follows the bed of Tangent creek for several hundred feet. At the contact of this serpentine with the slates, and 170 feet below the main adit, another adit has been driven north 37 degrees west for 230 feet. This adit was originally planned to cut the Dyke vein, but the discovery of a fault running up Tangent creek has rendered the position of this vein so problematical at this depth that work on the lower adit has been temporarily discontinued. Two shorter drifts, the lower 17 feet and the upper 80 feet above the 1200-foot level, have been run along the vein. The lower is connected by stopes and a raise with the 1,200-foot level. The upper is above a section of the vein from which a great deal of ore was stoped.

Overhead stoping from the 1,200-foot level to a height of 50 feet has been confined to two valuable shoots. Below the first of these stopes and at an interval of between 80 and 120 feet from the portal of the main adit, a winze has been sunk over 40 feet. Two crosscuts have been driven towards the east from the 1,200-foot adit, at distances of 70 and 275 feet respectively from the portal. The first is approximately 80 feet long and intersects the Boulder vein at 65 feet from the main adit. The second has been driven for 75 feet and, at 20 feet, a couple of short drifts have been run in either direction along the quartz vein previously referred to as the Intermediate lens.

Boulder Vein: Intermediate Lens and Blue Vein. Attention is also being paid to those larger quartz veins that lie nearer the slate contact and chiefly within the slates themselves. Owing to heavy surface accumulations their courses farther up the hill have been only approximately determined by a series of open-cuts.

In this manner the Boulder vein has been traced up the hillside to a point 250 feet above the portal of the 1,200-foot tunnel, where it is intersected by the Intermediate lens. The latter is an irregular quartz body lying between the Dyke and Boulder veins. Near its junction with the Boulder vein this quartz lens swings widely to the northeast and changes its dip from a comparatively steep angle to the southwest to a low angle to the northwest. It also widens considerably and has consequently provided a large body of milling ore. It is sparingly mineralized with arsenopyrite and chalcopyrite. These ore minerals have concentrated in separate parts of the vein. Their presence is found to indicate the best gold values in the Intermediate lens and some remarkably rich specimens have been obtained. The bulk of the Intermediate quartz lens is, however, almost barren of sulphides and a couple of assays obtained by the writer from such quartz gave no values in either gold or silver.

About 60 feet beyond the intersection of the Boulder vein and Intermediate lens the latter turns abruptly to the north again and within a few feet pinches out between greatly contorted slate walls. It has, however, been picked up farther northwest, but appears to be very irregular in character and uncertain in its strike.

There is another quartz vein known because of its dark colour as the This intersects the Boulder vein about 35 feet above the Blue vein. intersection of the latter with the Intermediate lens. From its position to the southwest of the hanging-wall of the Boulder vein the Blue vein may represent the upward continuation of the Dyke vein. If so its general character and mineralization have changed markedly. Microscopic study shows the quartz from this vein to be almost identical with that of the Both are composed of nearly pure silica, excessively strained Boulder vein. The suggestion of crush metamorphism or other and comminuted. dynamic disturbance is in part borne out by the occurrence of a number of small faults cutting across the veins. At each fault the more northerly segment, including both quartz vein and adjoining wall-rock, appears to be carried upward and towards the northeast. These faults occurred, appar-
ently, towards the close of the period of quartz deposition, for in some cases the veins have been completely sheared off, and in others the interval between the dislocated ends has been filled with later quartz gangue. In certain cases, as in the main 1,200-foot adit, this second generation of quartz carries the higher values, and is, no doubt, connected with the closing phases of that period of igneous intrusion of diorite and allied porphyritic rocks to which the ore-bodies owe their origin.

*Mineralization*. The mineralization of the Dyke vein is, on the whole, distinctly different from that of the quartz veins occurring in the slates farther to the east. The gangue is chiefly a turbid quartz, streaked with inclusions of country rock and with concentrations of sulphide particles. The latter are particularly prominent in the high-grade ore-shoots. A small proportion of calcite gangue is commonly encountered, and a few nodules of slightly pink albite occur with the other gangue minerals. The most prominent ore mineral is arsenopyrite, and with this the gold is closely associated, mostly in fine particles indistinguishable to the naked eye, but some large enough to be readily detected. A polished section of rich ore was examined in which the gold occurred as distinct particles associated with the arsenopyrite, but not, as far as could be observed, replacing it. Other ore-minerals commonly present and locally abundant include the sulphides pyrite, pyrrhotite, and chalcopyrite. This association of admixed sulphides and the occurrence of albite in the gangue suggests a mineral deposition at moderately high temperature.

The large quartz veins, on the other hand, are composed of massive milky quartz sparingly mineralized by individual sulphide particles, and low in gold values. Streaked or turbid quartz is rarely noted and then this appearance is due only to inclusions of fragments of the wallrocks. No calcite was observed among the gangue minerals. Values seemed highest where sulphide mineralization is greatest and as a rule where the quartz has a decomposed and drusy appearance. The pure, massive quartz contains little or no gold.

The rock of both walls is, as a rule, mineralized in proportion to the gangue. Pyrrhotite is, probably, the most abundant sulphide. It is particularly prominent in the wall-rock of the Dyke vein, and less noticeable in the slates where arsenopyrite and pyrite are more abundant, and occur as small individual crystals that rarely exceed a millimetre in length. Chalcopyrite was observed only locally and is confined chiefly to the quartz gangue where it carries values in gold.

The order of deposition of the sulphide minerals is not altogether clear, but it can be definitely stated that gold was one of the last minerals to be deposited, and may have come down in part with the arsenopyrite.

Genesis of Deposits. The ultimate source of the ore minerals is referred to the diorite intrusive. There are, however, a number of dykes intersecting the slates in the vicinity of the mine which may have effected some localization of values. The most common type is a fine-grained, dark green, massive andesite which is petrographically similar to the diorite intrusive and has not been mapped separately. Dykes of this character were probably intruded at about the same time as the diorite. Some are almost certainly apophyses of this plutonic rock and all gradations in grain have been observed. Others may have been intruded later, but from the same source as the diorite.

Another type of intrusive is more acid in composition, lighter in colour, and moderately fine to felsitic in texture. Under the microscope it is seen to be composed chiefly of acid plagioclase with a small proportion of orthoclase and quartz. Calcite is, as a rule, abundant and replaces all the principal mineral constituents. Some chloritic aggregates in the slide suggest that mafic minerals may originally have been present, but no remnants were observed. Veins of calcite and quartz occur in dykes of this description and are in some places associated with an abundance of coarsely crystalline auriferous arsenopyrite. A dyke of this character crosses the railway just below the bridge over Tangent creek. Another darker, but very similar in composition, crosses the trail to Emancipation mine. Similar dykes occur in the railway section less than a mile below Ladner creek. They were also observed on the opposite side of Coquihalla river on the Morning group, where they are associated with the ore showings on the Broken Hill claim. These dykes have been referred to in an earlier chapter of this report under the general term of "Syenite porphyry" (See page 111).

*Conclusions.* Development work at the Emancipation mine has proved an important ore reserve in the Dyke vein from which samples have yielded very satisfactory returns, and in which some high-grade shoots occur. The values in the larger quartz veins are very irregularly distributed and the average assay is low. Large bodies of these quartz veins may be expected to be almost barren. Profitable ore can be expected only where sulphide mineralization is in evidence. Many such pockets or shoots can be detected in the process of surface stripping, and in their exploitation others should be discovered.

The great bulk of low-grade ore could be milled, locally, very economically.

The progress of this mine will be eagerly followed not only by those financially interested, but by others who hold properties in this slate belt. The belt has been the source of much placer gold, particularly in adjoining areas, but lode mining in it has not yet met with great success.

### Snowstorm Group

The Snowstorm group includes seven claims, comprising the original Pittsburg group together with the more recently added Snowstorm claim. These claims adjoin the property of the Liberator Mining Company and follow the greenstone slate contact across, and for some distance to the west of, the South fork of Ladner creek. The claims have not yet been surveyed.

Most of the work on this property has been done on the Pittsburg claim, which lies on the western slope of the South fork of Ladner creek. Here, at an elevation of 3,000 feet, or 300 feet above the bed of the creek, an adit has been driven 40 feet along a fractured and mineralized zone in a fine-grained andesite or greenstone adjoining the slates, which lie about 200 feet to the northeast. This zone holds a direct course up the hill, striking north 55 degrees west and dipping at 80 degrees to the northeast. It has been traced by a series of open-cuts over the entire length of the claim and into the adjoining Idaho property. This fracture zone may for

convenience be named the Contact vein, as it follows very closely the contact between the volcanic rock and the slate and in the upper half of its length, or for about 500 feet, occurs in the slates themselves. Its width varies considerably, as does the amount of vein quartz associated with it. A few feet above the portal of the adit a second mineralized belt intersects the Contact vein from the west and it was towards this intersection that the adit was directed. The course of this second vein, which may be called the West vein, is more difficult to follow because of the lack of definite walls. It is represented by a shattered belt in the volcanic rock where heavy mineralization occurred and a certain amount of vein quartz was deposited. The course of this ore-body near the adit has been determined rather by the abundance of sulphide mineralization than by any definite structure. Farther up the hill the West vein is more easily followed, because of the increased percentage of quartz which, in certain exposures, forms a vein several feet in width. The course of this West vein resembles the curve of a bow to which the Contact vein furnishes the string. The two veins meet farther up the hill in the adjoining Idaho claim. They are farthest apart at an elevation of about 3,450 feet or half-way between the two intersections.

In addition to these two veins, another, which may be called the North vein, occurs near the boundary between the Pittsburg and Idaho claims and, in the latter, intersects the Contact vein a few yards below the intersection of the West and Contact veins. It is exposed for about 100 feet in the bed of the creek flowing from the Idaho workings, but has not been traced far beyond the creek bed. This vein lies entirely in the slates and contains a large percentage of vein quartz. The adjoining slates have been silicified and both slate and quartz are impregnated with sulphides and sulpharsenides of iron. Values are likely to be similar to those obtained on the Idaho property, where average assays of about \$8 a ton in gold were obtained. No systematic sampling of the North vein has yet been attempted.

The work has been done, principally, on the adit driven along the Contact vein: on the West vein below or to the east of its lower intersection with the Contact vein, and on the West vein above this intersection and about 80 feet above the portal of the adit. These workings will be considered in detail.

The adit on the Contact vein has been driven through a highly shattered volcanic rock which is intersected by many quartz stringers and is very similar in mineral composition to that encountered at the Emancipation mine and at various other points near the slate contact. It is characteristic of the greenstone andesite member of the Cache Creek series which immediately underlies the Ladner slate belt. It is a massive, fine-grained, greyish-green, and somewhat mottled rock which, near the surface, weathers rapidly. Under the microscope it is seen to be composed almost entirely of plagioclase, about oligoclase in composition. In some sections the rock has a microporphyritic texture. No mafic minerals were observed, but the rock is liberally sprinkled with sulphide particles, of which pyrrhotite is the most abundant.

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The amount of vein quartz occurring in this shattered zone varies greatly. To the right of the portal of the tunnel and extending about halfway up to the level of the roof is a solid body of quartz between 10 and 11 feet wide. At the level of the roof only a few narrow stringers of quartz remain, demonstrating how rapidly the vein pinches and swells in a zone of this character. The quartz carries very little or no sulphide minerals; a sample taken across the widest part of the vein and assayed by the Mines Branch, gave no values in either gold or silver.

The total width of the shattered zone of the Contact vein probably averages between 15 and 20 feet. Good pannings may be obtained near the adit, and the presence of a little arsenopyrite is indicative of gold.

Below its intersection with the Contact vein the West vein reveals a mineralized belt 60 feet in width, composed largely of weathered and decomposed volcanic rock and a few scattered veins and lenses of quartz. The mineralization is much more abundant at some points than at others and is more noticeable in the volcanic rock itself than in the veins. The chief sulphide is pyrrhotite, but some pyrite is present. Little or no arsenopyrite was observed and a sample of the more heavily mineralized rock in this zone gave no silver or gold values. No definite walls to the West vein were observed at this point, but the mineralization is most noticeable where the fracturing is greatest and becomes gradually less prominent when passing into the adjoining greenstone.

On the West vein above the intersection another large open-cut has been made. The mineralized part is here considerably narrower than at the last locality, averaging 25 feet in width, but in other particulars it is very similar. Good pannings have been obtained along the outcrops at this point.

Genesis of Deposits. Fractured zones in the volcanic greenstone and adjoining slates, which were developed during a period of dynamic disturbance preceding igneous intrusion, furnished comparatively easy channels for ensuing silica-rich and sulphide-bearing solutions. These, in the process of cooling, and aided by chemical reactions set up by the wall-rocks, deposited their load of vein quartz and sulphide minerals and effected a considerable replacement of the rock traversed. With the ore minerals and, in particular, the arsenopyrite, the gold values were also precipitated. Arsenopyrite is scarce in the greenstone, but fairly abundant in the slates where it occurs as distinct crystals averaging about a millimetre in length. This habit is very noticeable in all properties where this mineral occurs, either in the quartz veins or in the slates adjoining them.

The origin of the mineralization and the vein quartz in this property must be sought in connexion with the diorite intrusive which is exposed at a varying distance from the greenstone-slate contact. Serpentine is commonly found near this intrusive and serpentine outcrops are usually a good indication of the propinquity of the diorite. That the greenstone is as a rule more highly mineralized with pyrrhotite than the adjoining slates is possibly due to its proximity to the intrusive, where pyrrhotite may have been precipitated at a higher temperature than the other sulphides.

# Idaho Group

This property was examined by Camsell in 1919 and by the writer in the following year. Little additional work has been done in the past year.

The Idaho group comprises four claims, but development work has been confined almost exclusively to the principal showing on the Idaho claim. A series of trails, some passable for pack horses, connects this property with the Kettle Valley railway  $2\frac{1}{2}$  miles to the southeast.

The principal showing is located at an elevation of 3,400 feet in the bed of a small gulch 800 feet above the South fork of Ladner creek. Here two quartz veins occur in the slates a few hundred feet to the east of the greenstone contact. One of these follows, in general, the attitude of the slates, which here strike north 80 degrees west and dip to the north at an average angle of 45 degrees. This vein has an average width of 5 feet and an investigated length of about 100 yards. It resulted from the deposition of vein quartz in a fractured or crushed zone in the slates. Numerous fragments of the country rock are included in the vein and are highly silicified. They give to the quartz gangue a streaked appearance which



Figure 5. Diagram showing development and intergrowth of arsenopyrite and pyrite in slaty rock on Idaho mineral claim. Magnification: 24 diameters. A, arsenopyrite; P, pyrite; groundmass composed of slaty rock.

might be mistaken for finely disseminated sulphides. The latter are, however, usually coarsely crystalline and, consequently, easily distinguishable. Both the quartz and the adjoining country rock have been impregnated with pyrite and arsenopyrite. Pyrite is the more abundant. In polished sections the two sulphides are seen to be intergrown with each other, but may also occur separately (Figure 5). These sulphides carry values in gold, in some places visible. A sample of typical but not necessarily average vein material was assayed by the Geological Survey, Ottawa,

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and gave 0.055 ounce in gold and no silver. The total width of the mineralized zone, including vein quartz and mineralized wall-rock, averages nearly 9 feet, but varies considerably in the distance exposed. Gold has been concentrated on the weathered surfaces of the vein, and some of the material removed in surface stripping and run over a series of sluice boxes and riffles gave a fair amount of fine but little worn gold.

The other vein crosses the slates at an angle of about 60 degrees and is thought to represent the continuation of the West vein of the Snowstorm group, as the first vein represents the northwesterly continuation of the Contact vein from that group. This West vein is here 6 feet wide and is composed mainly of massive milky quartz, containing a few fragments of the wall-rock. Both the quartz and the wall-rock are sparingly mineralized.

The origin of these veins and their mineral content may be referred to the diorite intrusive occurring near the contact of the slates and greenstone volcanic rocks.

### Montana Claim

In this claim, which adjoins the Idaho to the northwest, the goldbearing quartz veins occur in the greenstone volcanic rock about 20 yards southwest of the slate contact. The greenstone is here an andesite, which. under the microscope, is seen to be composed chiefly of small, lath-shaped feldspars and alteration products. A number of larger phenocrysts of plagioclase occur, giving it a microporphyritic texture. Small crystals of pyrite are fairly abundant. No mafic minerals are preserved, but their decomposition products may have afforded the greenish coloration of the rock. A number of quartz veins averaging 2 inches in width have been exposed in an open-cut, and show occasional rich specimens of free gold. The veins appear to converge and widen as they go down so that a more important ore-body may occur at greater depth. The volcanic rock adjoining the veins is mineralized with pyrite.

### Rush-of-the-Bull Fraction

Little additional work has been done on this property since last reported upon.<sup>1</sup> At an elevation of 4,500 feet on the trail leading from the Idaho showings to the Pipestem mine, there occur two small quartz veins averaging 4 inches in width. These cut across the slates and, together with the adjoining wall-rock, are heavily mineralized with coarse arsenopyrite crystals and some free gold. Many rich specimens have been obtained from these veins, but more development work is necessary to prove whether they constitute the main ore-body or are off-shoots from some larger vein. Other larger quartz veins of bedded character have been discovered in the slates below the trail, but no free gold has been noticed in them and they are in general scantily mineralized.

The mineralization on this fraction may be due to one of a number of acid feldspar porphyry dykes or sills which intersect the slates in this These intrusives are very similar in composition to the dyke vicinity. rock at the Pipestem mine and to others intersecting the Ladner slates both in Coquihalla area and in the adjoining Siwash Creek area.<sup>2</sup>

<sup>&</sup>lt;sup>1</sup> Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1919, p. 33 A. <sup>2</sup> Bateman, A. M., Geol. Surv., Can., Sum.Rept., 1911, p. 127.

# Gem Group

The Gem group of three claims was visited by the writer in 1920<sup>1</sup>. Little work has been done on this property.

The claims are situated north of and adjoining the Rush-of-the-Bull Fraction and follow somewhat closely the contact between the slate belt and the underlying greenstone member of the Cache Creek series.

On the southernmost claim, known as the Golden Cache No. 1, six quartz veins have been discovered, striking about north 70 degrees west and dipping at high angles to the north and south. They are all sparingly mineralized with pyrite and arsenopyrite. The assay values in gold are, as far as known, low. No average can be given, for no systematic sampling has been attempted. Adjoining this claim is the Golden Cache No. 2, where little of interest has yet been discovered. The third claim, known as the Gem, has been prospected by three open-cuts approximately in line with each other and exposing either the same or closely parallel veins. The ore-body is represented by a decomposed quartz vein about 6 feet wide which is filled with silicified fragments of the slate wall-rock. Both the vein matter and the wall-rock show sparing mineralization by pyrite and arsenopyrite, the presence of the latter being easily recognized by the garlic odour emitted when struck by the hammer. In a few places the mineralization is quite heavy, and in such cases appears to favour the slate wall-rock, particularly the hanging-wall, which is heavily impregnated with, and partly replaced by, silica. The average strike of the vein is north 70 degrees west and it dips at 70 degrees to the north. A red, decomposed earth, overlying the most northerly of the three surface showings, gives good colours when panned.

### Pipestem Mine

The Pipestem group, referred to in an earlier report, <sup>2</sup> is situated on the divide between the Middle fork of Ladner creek and the headwaters of a branch of Siwash creek at approximately 4,500 feet above sea-level. It consists of six claims.

Surface work has been confined chiefly to a richly mineralized vein on the Pipestem No. 1. There, two open-cuts have been made where the quartz vein varies in width from 6 inches to 2 feet. Along the course of this vein the slate walls are so heavily mineralized as to increase the actual width of the paystreak from 50 to 100 per cent. A specimen of this country rock showing exceptionally heavy sulphide mineralization was assayed by the Mines Branch, and ran 3.76 ounces in gold. The vein occurs within the slates which here have a more massive habit than farther down the valley and contain fossil belemnites. They strike approximately north 80 degrees west and dip at high angles to the north and south. The course of this principal quartz vein is nearly that of the slates themselves which, near the mine, have been much disturbed and dip from 30 to 80 degrees to the southwest. In line with the two open-cuts, which are about 150 feet apart, a shaft 30 feet deep has been sunk at a point 130 feet farther

<sup>&</sup>lt;sup>1</sup>Cairnes, C. E., Geol. Surv., Can., Surn. Rept., 1920, p. 34 A. <sup>2</sup>Cairnes, C. E., Geol. Surv., Can., Surn. Rept., 1920, p. 34 A.

to the northwest. This intersected a couple of quartz stringers about 4 inches wide which are heavily mineralized. From the character of the quartz stringers and wall-rock in this shaft it is probable that these veins are subsidiary to the main quartz lead in the open-cuts to the southeast. An adit has been projected with the intention of intersecting the main quartz vein below the present position of the shaft. The mouth of this adit lies 100 feet below, and 180 feet to the northeast of, the head of this shaft.

The principal ore vein has been traced by a series of open-cuts and natural exposures for several hundred feet, both to the northwest and southeast of the rich shoots. To the northwest it forms a series of long, narrow lenses of quartz at most only a few inches wide, but towards the southeast it widens considerably and at two different exposures observed averages 3 feet in width. In neither of these directions, however, is that heavy mineralization noted which is so characteristic of the chief surface showings.

The principal sulphide is pyrite, occurring as well-defined cubes, many several millimetres in diameter, in the quartz gangue, and also impregnating the adjoining slates. Some arsenopyrite is also present and in polished sections was observed, at least in part, to replace the pyrite (Plate IX A). The quartz gangue carries the chief values. In it, gold occurs both in visible and in microscopic particles. Some silver is also present, but apparently in no fixed ratio to the gold.

The mineralization may be genetically dependent on a feldspar or "birds-eye" porphyry dyke about 15 feet wide which is exposed a few feet to the north of the cabin. The attitude of this dyke is uncertain, but is probably not very different in strike from the slates themselves and stands nearly vertical. This dyke was the only intrusive rock observed near the mine, but, as far as could be ascertained, is very sparingly mineralized, so that, not improbably, its position near the ore-bodies at the mine is incidental, in which case both it and the ore minerals in the slates may be considered as having originated independently from another magmatic source. In view, however, of the common association of porphyry dykes of similar character to this, with gold ores in the slates both of this district and of the adjoining Siwash Creek area, the origin of the Pipestem ore is referred tentatively to this dyke. The dyke is slightly more acid than a diorite and because of its leucocratic appearance it has been included with the "syenite porphyries" of the district.

#### Morning Group<sup>1</sup>

This group consists of four claims on the east side of Coquihalla river above the mouth of Dewdney creek. Work on this property has been confined to surface strippings, in which a number of quartz veins from a few inches to several feet wide have been uncovered. These occur chiefly in the slates and near the contact with the underlying greenstone of the Cache Creek series. The veins are mostly sparingly mineralized with pyrite and to a less degree with arsenopyrite. A small proportion of calcite is commonly associated with the quartz gangue and to some extent replaces it. A few of the veins are abundantly mineralized.

<sup>&</sup>lt;sup>1</sup> Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1920, p. 35 A.

The largest showing in this group is found on the Broken Hill claim at an elevation of 2,500 feet on the precipitous slope of the hill overlooking Dewdney creek. There a quartz vein, varying in width from a few inches to nearly 10 feet and traceable for at least 200 feet, is exposed. It is irregularly mineralized with arsenopyrite. Pyrite appears in smaller proportions and a trace of galena has been found. A small percentage of calcite is associated with the quartz gangue. A sample taken across this vein at a point where it is 6 feet wide, but where mineralization is less abundant than in some narrower sections, was assayed by the Mines Branch, and gave no values in either gold or silver.

The country rock is slate striking about north 27 degrees west and dipping 45 degrees to the southwest. Intrusive into this are a couple of moderately coarse-grained grey dykes which have undergone considerable alteration and are in part replaced by calcite. Their composition is about that of an andesite in which the dark constituents have been completely altered to chlorite or serpentine and to calcite. These dykes are 15 and 8 feet wide, respectively, and 50 feet apart. They may have some genetic bearing on the ore mineralization. The upper and larger dyke is in intimate contact with the quartz vein and itself contains a considerable proportion of vein quartz. Gypsum was noted on the hanging-wall of the lower dyke.

The origin of the veins and their mineral content in the Morning group is, in part, similar to that of those encountered in the larger gold properties on the opposite or west side of Coquihalla river. The large diorite belt or dyke, together with its finer-grained apophyses, which intersects the greenstone member of the Cache Creek series underlying the slate belt, is probably responsible for such mineralization as occurs near the slate contact. Elsewhere, and more locally, dykes such as those passing through the Broken Hill claim may have contributed somewhat to the mineralization.

### General Review of Gold Properties Associated with the Ladner Slate Belt

The gold-quartz veins in the preceding properties are vein deposits formed at intermediate depths and temperatures, both of which variants may have a considerable range.

The slate belt, the underlying greenstone, and the later intrusives have all been subjected to deep erosion since the formation of the mineral deposits, this depth varying from at least 5,000 feet at the higher points to over 8,000 feet at the lower exposures. The date of the intrusions, including both the large diorite belt or dyke southwest of the slate belt and various smaller sills and dykes of both basic and acidic composition intruding different horizons of the slates, is almost certainly pre-Tertiary and probably late or post-Lower Cretaceous. Great deformation of the slates and underlying formations preceded these intrusions and the subsequent mineralization, but the numerous faults crossing the quartz veins and the mashed appearance of the vein quartz indicate that orogenic forces have been active since its deposition.

There are various structural types of quartz veins represented. They all conform in their general strike with the northwest-southeast axis of deformation for the slate belt and older rocks, but in detail they are in many cases very irregular. A prominent type has resulted from the filling of long fractures in the slates, the fractures running more or less in line with the bedding or cleavage and also coinciding closely with the trend of areal compression. Some replacement of the wall-rock has occurred and the width of the vein is in many places materially increased by this process. These veins have been referred to as bedded veins and are represented by the Boulder vein at the Emancipation mine; the principal quartz vein on the Idaho claim; and by several veins on the Gem group. Another type occurring both in the slate and older and esite or greenstone occupics shatter or fracture zones in these rocks. In these zones the quartz veins occur as a network of irregular, linked veins commonly only a few inches wide, but in some places uniting to form a solid vein several feet in width. In this type silicification of the fractured rocks has played a more important role than in the bedded veins. The Intermediate and Dyke veins of the Emancipation mine; the West and Contact veins on the Snowstorm group; and the principal vein on the Idaho property are illustrations of this type.

Practically the only gangue mineral is a milky white quartz. This is in places slightly drusy and often possesses a dark, streaked appearance due chiefly to included and almost completely silicified fragments of the wall-rock. A banding may also result either from the linear distribution of such fragments or the arrangement of sulphide particles and may have resulted from crushing and shearing of the vein quartz.

In thin section the quartz rarely shows idiomorphic forms, but is commonly massive and greatly fractured and strained in appearance. Some of it is well mineralized. A small proportion of calcite is present in some places. Small albite nodules have also been observed in the Dyke vein at the Emancipation mine.

These quartz veins are as a rule sparingly mineralized. The wallrock is always included and may show mineralization when the vein quartz does not. Pyrrhotite and pyrite are both common in the wall-rock, but arsenopyrite and chalcopyrite occur in both wall-rock and the quartz gangue. Other sulphides occasionally encountered in very small proportions include sphalerite, galena, and stibnite. The gold is commonly associated with the arsenopyrite, but may also occur with pyrite or chalcopyrite. It does not, however, seem to favour pyrrhotite even where this mineral is most abundant.

The principal intrusive genetically related to these auriferous quartz veins is the large dyke or belt of diorite southwest of the greenstone-slate contact. Feldspar porphyry dykes such as that on the Pipestem mine, and many others crossing the Middle and South forks of Ladner creek, may also be responsible for gold quartz deposits in their vicinity. Others cutting the slates below the mouth of Ladner creek are themselves auriferous where mineralized with arsenopyrite. Such a dyke crosses the railway below Tangent creek.

#### Aufeas Mine

The Aufeas mine is located on the Jumbo group of five claims, which lie on either side of Wardle creek. This stream enters Silver creek at a distance of 3,500 feet from, and 1,200 feet below, the mine workings. An excellent wagon road leads down Silver creek and thence to Hope, a distance of 3 miles from the mouth of Wardle creek. The property was visited by Camsell in 1911 when it was still in an early stage of development. A careful description of the underground workings was later given by Brewer.<sup>1</sup> In 1914 a light aerial tramway was constructed from the portal of the lower tunnel to the wagon road on Silver creek, a distance of about 3,000 feet. Shipment of ore has, however, been postponed until cheaper freight rates can be secured.

The principal workings are located on the Jumbo claim, on the right bank of Wardle creek, at elevations ranging up to 300 feet above the stream bed. They include, besides a considerable amount of surface work, 575 feet of crosscutting and 516 feet of drifting. The writer was, however, unable to examine part of the underground workings because of recent caving in the tunnels.

The country rock around the mine may be generally described as a quartz diorite. Its petrographic description has been given in an earlier part of this report. Though locally massive this rock is, in general, somewhat gneissoid. It has been sheared and mashed, and in the process fissures have been developed in which ore deposits occur. In part, and particularly where zones of shearing are pronounced, there is marked alteration to a finer-grained, and comparatively soft, greenish rock. Such a type is noticeable on either side of and above the portal of the lower tunnel. A thin section of this rock was seen under the microscope to be composed almost entirely of calcite. This altered rock is thought to represent part of the main intrusive mass in which the original minerals have been largely replaced by calcite.

The ore deposits occur in concentrated form in well-defined fissure veins. They are also distributed as a network of smaller veins or veinlets through the belts of altered rock referred to above. Ore minerals may also be sparingly disseminated through the rock on either side of these veins.

The principal fissure vein outcrops about 250 feet above the bed of Wardle creek. It follows the direction of a zone of shearing running north 85 degrees east and dips to the southeast into the hillside at an angle of about 50 degrees. It is somewhat lens-shaped on the surface with a maximum width of about 12 inches. To the southwest of this thickest section it narrows to the width of an inch in a distance of 30 feet and beyond this point disappears. To the northeast of the maximum section, and at a distance of 40 feet, the position of the vein is marked by from 2 to 3 inches of reddish gouge in which a few fragments of ore mineral may be recognized. The ore consists mainly of massive arsenopyrite with some chalcopyrite and pyrite. A small proportion of quartz gangue is present. A sample of the solid arsenopyrite was taken by Brewer for assay and gave 1.05 ounces in gold, 0.63 ounce in silver, and no copper. A second vein outcrops about 45 feet lower down and although only a few inches wide is well-defined. It contains arsenopyrite as the chief ore mineral, and a greater abundance of quartz gangue than in the upper vein.

An adit, driven in to meet these veins, intersects the lower vein 6 feet from the portal; at 50 feet another vein was intersected which according to Brewer was regarded as intermediate between the other two. Short drifts 6 feet to the east and 10 feet to the west were driven on this vein. At the face of the shorter drift Brewer obtained a sample across 8 inches of arsenopyrite and pyrite which assayed 0.24 ounce in gold, 0.2 ounce of silver, and no copper.

<sup>&</sup>lt;sup>1</sup> Brewer, Wm., B. C. Min. of Mines, Ann. Rept., 1915, p. K. 255-256.

A lower adit was driven for 470 feet from a point about 80 feet below the upper adit and cuts what is regarded as the lower vein at 190 feet and intersects the upper vein at 386 feet from the portal. At the intersection of the lower vein a drift of 60 feet was run towards the west along the vein. The latter is very irregular in width and composition. Pyrite and arsenopyrite are the chief ore minerals. At the intersection of the upper vein a 200-foot drift was run towards the southwest and another,48 feet long, in the opposite direction.

At this depth the ore has been exposed over a greater length than at the surface. Good ore occurs along the entire length of the shorter drift and along the greater part of the longer drift. A persistent vein of ore composed chiefly of arsenopyrite and pyrite adheres closely to the hangingwall which dips at an average angle of 50 degrees to the southeast. Thisvein varies in width from 2 or 3 inches to about 2 feet. Quartz, and, in certain sections of the ore-body, calcite, form the chief gangue minerals and their proportion to the ore minerals is, in general, greatest in the wider sections of the vein. In addition to this hanging-wall vein another vein of ore has been exposed near the intersection of the adit with the main drift. This vein follows the direction of the drift and dips 33 degrees to the southeast. It is well exposed along the northwest side of the shorter drift to the northeast of the adit where it has an average width of about 4 inches, and is similar in character to the hanging-wall vein. It is probably this vein, too, which is exposed in a stope above the longer drift and a few feet below the hanging-wall vein.

About 50 feet west of the main adit a crosscut 58 feet long was driven from the longer drift into a belt of altered country rock in which several narrow veins filled with quartz and containing arsenopyrite and pyrite occur. This entire width of 58 feet is regarded by the owners as a possible concentrating ore.

The principal ore minerals are arsenopyrite, pyrite, and chalcopyrite. Arsenopyrite is the dominant mineral and occurs in both massive and crystalline form. The more massive varieties frequently occupy the entire width of the fissure veins. Chalcopyrite is locally plentiful and in a study of polished sections of the ore (Plate IX B) was clearly seen to be later than either the arsenopyrite or pyrite. It replaces these sulphides as well as the quartz. Both the arsenopyrite and chalcopyrite carry gold values. The gold occurs either in solid solution with the sulphides or in mixtures too fine to be distinguished through a microscope. No free gold was observed. Pyrite and arsenopyrite appear to have been precipitated at about the same time as the quartz gangue. In the principal ore fissures quartz and, more locally, calcite, constitute the gangue. In the larger bodies or belts of more sparingly mineralized rock calcite is also very abundant.

The mineral associations characterize the ore-bodies as vein deposits of intermediate depth and temperature. How far they originally extended above their present outcrops is conjectural, but it is clear that several thousand feet of rock lay above the present workings at the time of ore deposition. The extensive fissuring and shearing to which the batholithic rocks in this vicinity were subjected probably preceded the intrusion of the later batholithic rocks exposed farther to the southeast. These later intrusions also provide a competent source for the mineralizing solutions which, in traversing the fissures of the older rocks, deposited their valuable load of auriferous sulphides and largely replaced the wallrock of the fissures. They may likewise have furnished the solutions which so extensively replaced the country rock along fracture zones with calcite. The resultant calcareous belts follow roughly parallel to wellrecognized fissures and shear zones, and probably represent an alteration of the batholithic intrusive. A belt of this character forms the bed of Wardle creek for some distance above the workings, and may have had some influence in determining the present course of this stream.

From such observations as the writer was able to make, chiefly on the surface geology, combined with information received from other sources, it might appear that the Aufeas mine could be successfully worked either by developing the larger veins alone or, possibly, by including larger bodies of sparsely mineralized rock intersected by numerous small ore veins. The property is primarily a gold proposition, but the percentage of arsenic is large enough to afford a valuable by-product. The mine has the advantage of easy accessibility and convenience to transportation. Further prospecting and development may reveal ore deposits in this or adjoining property. The areas to the south of Wardle creek, occurring in these older batholithic rocks, are considered more especially worthy of exploration.

### Silver

Silver is, following gold, the most important metal in the district. It occurs in both high-grade polysulphide minerals and lower grade silverlead deposits, and is associated in varying proportions with the gold properties of the district. Only one silver property is at present receiving attention in the area, namely, the Eureka-Victoria mines on Silver peak at the extreme southern edge of the sheet. The ores here occur in highgrade vein deposits in which argentiferous tetrahedrite is the chief ore mineral. Secondary concentration has produced some very valuable ore pockets or shoots in which values up to \$700 a ton have been obtained.

Silver-lead ores in the district have not received that attention from the prospector which in the writer's opinion they deserve. Important deposits have been discovered at Summit Camp, on the headwaters of Tulameen river near the divide overlooking the head of Dewdney creek. The ores in this camp occur as vein deposits of intermediate temperature type in fracture zones and fissures cutting Cretaceous and what are probably earlier sedimentary rocks. The chief ore minerals are zinc blende, galena, chalcopyrite, and pyrrhotite. The silver values occur in the galena and are usually high. Extensive development has been done on some of the properties of this camp, but shipping awaits cheaper transportation. Formations identical with those of Summit Camp occur on the headwaters of Dewdney and Cedar creeks, but prospecting on this side of the Coquihalla divide has proceeded in a very desultory fashion. Sufficient has, however, been done to reveal mineral deposits similar to those in Summit Camp, but the difficulty of access has handicapped development. The trail up Dewdney creek has fallen into disuse and is at present passable for horses for 8 miles only.

The writer strongly advises the extension and improvement of this trail over the summit. Such a trail, properly constructed, would not only encourage prospecting in this region but would also serve as a more direct route to the Kettle Valley railway from Summit Camp.

Other silver lead deposits have been discovered on the west slope of Coquihalla valley, below Ladner creek, in the Ladner slate belt, and in the Eagle granodiorite about 4 miles south of Coquihalla station. At the former locality the Galena group of four claims is situated to the northeast of the Liberator Mining Company's property. Little work has been done on these claims. The galena occurs with some blende and chalcopyrite in quartz veins in the slates and may be genetically related to some of the syenite and porphyrite dykes that intersect the slates in this neighbourhood. The other property, known as the Galena Mineral claims, was not visited by the writer, but is reported to contain steel galena associated with chalcopyrite

#### Eureka-Victoria Mines

The history of this property is unique among the ore deposits of the district. It is much the oldest mine in the area and has, in fact, the distinction of being the first Crown-granted property in British Columbia. "It was first discovered by an Indian, Peter Emery, while hunting goat in 1868. He showed samples of the ore to George Schooley of Yalc who located the ground for himself and friends and later sold the Eureka to some Victoria business men for several thousand dollars. In 1869 a company was formed by local and Victoria capital, called the Eureka Mining Company. About 1871 they sold out to the New Eureka Mining Company, Limited, for \$80,000. That company had a capital of \$150,000. The Victoria claim was also disposed of by the original locators. The purchasers afterwards formed a company called the Victoria Silver Mining Company, Limited, with R. P. Rithet, secretary, and a nominal capital of \$600,000 in \$20 shares. Among the original subscribers were the wellknown pioneers of British Columbia, S. P. Moody, who built the first sawmill on Burrard inlet, H. Nelson, George Dietz, and George Dunbar. Cariboo pioneers were Francis Garesche, T. C. Hughes, and others prominent in the early history of British Columbia.

The amount of ore shipped apparently amounted to a considerable tonnage containing high values. The ore was packed part way down on Indian backs, and the rest of the way to Hope on pack horses. It was then floated on barges down Fraser river, towed to Victoria, and loaded on sailing vessels for San Francisco. Some shipments went round cape Horn to Swansea, Wales.<sup>1</sup> This ore netted \$420 per ton."

The mines were closed in 1874, due, in part, to the expensive methods of transportation and, in part, to unfortunate litigation as to their ownership and management.

The mines were reopened in 1920 for the present owners Sperry and White, of Seattle, under the management of A. S. Williamson.

In the summer of 1920 the writer made a very hurried examination of the principal workings<sup>2</sup> and in the following year was able to spend some time in the vicinity of the mines.

Williamson, A. S., Daily Province, Vancouver, Dec. 16, 1921, p. 16.
Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1920, p. 36 A.

The upper 2,000 feet of Silver peak is Geology (Figures 6 and 7). composed chiefly of a massive conglomerate of Lower Cretaceous age. Other remnants of this formation occur on the southern flank of Hope mountain and in Fraser valley on either side of the river near Hope. The conglomerate varies greatly in the size of its constituent pebbles. A large proportion might be regarded as a coarse-grained grit, but in other sections it contains cobbles varying up to 6 or 8 inches in diameter. The general attitude on Silver peak is nearly north and south, with an average high dip to the east. The attitude is, however, subject to local variation and the structure as a whole may represent a remnant of a steeply folded syncline. This conglomerate has been invaded by a large batholithic body of quartz diorite, locally known as "granite", that comes in contact with the conglomerate on all except the southern flank of Silver peak, where a narrow band of highly metamorphosed sediments, probably also of Cretaceous age, intervene. These sediments on the divide between Silver peak and Isolillock mountain form a belt less than 200 feet wide, but their width at lower elevations could not be determined. They comprise both shaly and sandy materials, but their original character has been largely masked by the metamorphism to which they have been subjected by the quartz diorite, as well as by an earlier intrusive lying farther to the northwest.

Cutting the conglomerate at an angle to both bedding and jointplanes are a number of quartz porphyry dykes. The largest of these has an average width of 20 feet and follows in an irregular fashion the line of the Glory Hole gulch which cuts through the middle of the property in an east-west direction (Figures 6 and 7).

Mineral Deposits. The mineral deposits at the Eureka-Victoria mines occur in well-defined fracture zones in the conglomerate. These coincide with a prominent set of joint-planes which intersect the conglomerate in a general northeast-southwest direction. Along these joint fissures more or less movement and brecciation of the conglomerate has occurred, so that fracture zones, many of them several feet wide, have been developed. These zones furnished relatively easy passage to the mineralizing solutions forming the present ore deposits.

The principal deposits occur in veins within the fracture zones. They rarely occupy the entire width of the zone, often form only a minor part of it, and in general, favour the hanging-wall side. Together with the intervening and in some cases sparingly mineralized conglomerate gangue they constitute the ore-bodies or lodes. Only in rare instances can the high-grade vein material be mined separately.

The chief gangue minerals are siderite, limonite, and quartz. The first occurs either as a brownish, coarsely crystalline mineral with large, lustrous cleavage surfaces, or as a cream-coloured aggregate intergrown with clear crystalline quartz. The limonite occurs in two generations. That of the first is, in part, pseudomorphous after siderite and forms characteristic wedge-shaped crystals that project into open fissures in the veins. That of the second generation has been deposited over the older gangue minerals, is quite soft, and shows a botryoidal structure. The quartz also formed in two generations, the first intergrown with the siderite as well as with tetrahedrite and iron sulphides, and the second forming minute crystals on the surfaces of the other minerals.









The principal ore mineral is the sulphantimonide of copper, tetrahedrite. This mineral carries a varying proportion of lead as well as the primary silver values in the ore deposits. It occurs intergrown or deposited at different stages with siderite, quartz, and pyrite and may replace the earlier formed minerals. It is disseminated irregularly through the orebodies in small specks or irregular masses that rarely exceed a cubic centimetre in size.

A concentration of silver values occurs in certain of the upper sections of the ore-bodies. There, surficial processes involving oxidation, carbonatization, and solution have resulted in the substantial reduction of gangue minerals and a differential enrichment of the mineral content of the veins. The tetrahedrite has there suffered decomposition. The copper has largely disappeared and the little left converted to carbonates with their characteristic blue and green colours. The lead has been largely retained, probably as an amorphous carbonate, and holds the silver values. The oxidation products of the silver and lead have lent a characteristic yellowish appearance to the decomposed ore. The result is a rich concentrate, running into hundreds of dollars per ton, from which shipments were made in the early years of mining.

Description of Ore-bodies. The principal mineral deposits occur in the Eureka, Victoria, and Victoria West ore-bodies. A couple of minor bodies cross the Glory Hole gulch below the Eureka lode outcrops (Figures 6 and 7).

The Eureka lode, at present the most important ore-body, has been traced across the summit of Silver peak for about 1,400 feet, its course for the greater part of the way being well defined by solid conglomerate walls. Its width varies, according to surveys made by the management, from 5 to 20 feet, and is greatest east of the Glory Hole gulch where for about 600 feet it is between 12 and 20 feet. The western section of 800 feet has been neither closely followed nor measured, but may average 5 feet in width. The actual proportion of vein and mineral deposition within this fracture zone is extremely variable. In part the entire zone is occupied by gangue minerals, but these are mostly confined to narrow veins or stringers within the fractured belt and their combined width is measurable in inches rather than feet.

An adit was driven, in the early days, from the eastern side of Silver peak, and at 5,190 feet above sea-level, for a distance of 240 feet along the principal ore-body. At the face a sample taken across 2 feet of ore was assayed by the Mines Branch, and ran 4.42 ounces in silver per ton and 0.17 per cent copper. Near the mouth of the adit some gangue richly impregnated with tetrahedrite is said to have assayed high in silver. Farther up the hill the values have been concentrated by processes already described and an adit disclosing copper-stained ore was driven for 20 feet along a narrow vein of this oxidized ore.

Where the Eureka ore-body crosses the Glory Hole gulch it encounters the wide rhyolite dyke previously mentioned. This dyke does not cross the ore-body, but forms the northwest wall for a distance corresponding to its width. The opposite wall is conglomerate, but the dyke may reappear again farther up the gulch. This, however, could not be determined at the time the mine was visited because of the precarious footing at this point. The Victoria lode originally constituted the old Van Bremer mine. It has been traced for approximately 1,200 feet on the southwestern slope of Silver peak, its course, like that of the Eureka ore-body, being obscured at lower elevations by snow. The general character of this lode is essentially similar to the other.

At an elevation of 5,510 feet, or 90 feet above the snowbank (Figure 6), a drift 8 feet long, known as the lower Victoria tunnel, has been driven on the ore-body, the mineralized part of which has a width of 14 inches. A sample across this was assayed by the Mines Branch, and showed: silver, 11.65 ounces per ton; no gold; no lead; and 0.30 per cent copper.

Two hundred and twenty feet above this short drift another adit has been driven for 50 feet along a vein of richly oxidized ore. The vein, which strikes nearly east and west and dips at about 70 degrees south, has an average width of a foot. A sample taken at the portal of this tunnel across 14 inches of ore was assayed by the Mines Branch, and yielded 168.75 ounces silver per ton, a trace of gold, 1.12 per cent copper, and 11.96 per cent lead. A sample taken the previous year from the richest part of this vein gave an assay return of 658.42 ounces silver, and 26.72per cent lead.

At 50 feet below the portal of the upper adit this enrichment is not noticeable. A sample was taken across a vein 12 inches wide in which the gangue minerals were siderite and limonite. This sample, assayed by the Mines Branch, yielded 38.65 ounces of silver, trace of gold, 1.04 per cent lead, and 44.37 per cent iron.

The Victoria South ore-body, and the smaller veins crossing the Glory Hole gulch below the Eureka lode, are composed of much the same materials, and their relative size and continuity are indicated on Figure 6. No samples were taken from these ore-bodies.

The Cretaceous sediments on Silver peak were Genesis of the Ores. subjected to two periods of batholithic intrusion. In the first a great batholithic complex, composed chiefly of granodiorite, was intruded to the west of Silver peak, and strongly metamorphosed the lower part of the belt of schists underlying the Cretaceous conglomerate beyond the limits of These schists are probably of the same age as the Cretaceous Figure 4. conglomerate. Preceding or accompanying this period of intrusion, the Cretaceous sediments were moderately deformed, and an extensive system of jointing was developed, afterwards important in determining the position of the ore-bodies. Very little mineralization, however, accompanied this first intrusion. In Tertiary, probably Miocene, time a second batholithic intrusive invaded the Cretaceous rocks, and is in intimate contact with the conglomerate on all sides except where the narrow schist belt intervenes between Silver peak and Isolillock mountain. This intrusive has the composition of a quartz diorite and has been described in another section of this report. Still further deformation of the conglomerate occurred at this time, but was probably even more pronounced during the great revolution at the close of the Cretaceous period. Movement along the older joint-planes produced considerable brecciation, involving not only the Cretaceous sediments but also certain quartz porphyry dykes that were

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intruded probably after the earlier irruptions, but before the Tertiary quartz diorite. This conclusion is based on the facts that the shearing or fracturing along the joint-planes of the conglomerate included the quartz porphyry and that, at the intersection of the ore-bodies with these dykes, a sparse mineralization has been induced in the latter and vein materials were deposited in the fractures developed in these dykes in somewhat the same manner as, but to a less degree than, in the case of the conglomerate. Elsewhere the porphyry is almost barren of ore mineral, save for an occasional grain of pyrite. As these dykes are, on the whole, less fractured than the Cretaceous sediments, the earlier period of deformation probably occurred prior to the intrusion of the dykes, which, consequently, were intruded subsequent to the invasion of the Cretaceous batholithic rocks.

In the early stages of consolidation of the quartz diorite there appears to have been scarcely any ore deposition. The belt of schists (Figure 6) was still further metamorphosed, and the conglomerate bears evidence of the high temperatures to which it was subjected. As the intrusive cooled, an abundance of magmatic solutions rich in iron, carbon dioxide, and silica, and, to a less extent in sulphides of copper, antimony, and lead, were set free and in their passage through the overlying Cretaceous rocks found their readiest egress along the fracture zones following the nearly vertical joint-planes of the conglomerate. Here a current deposition of siderite and quartz occurred and with them a small proportion of pyrite and tetrahedrite (freibergite). Some replacement of the conglomerate in the crushed zones has occurred, but is not regarded as having been a very important factor in determining the bulk of the ore deposits. The siderite varies from light cream to dark brown, the brown variety commonly showing large, lustrous cleavage surfaces or forming wedge-shaped crystal edges which project into the open fissures or numerous small vugs in the ore veins. Quartz occurs in minor proportions to the siderite and is commonly well crystallized. It is most abundant when associated with the lighter-coloured variety of the siderite. The tetrahedrite occurs in irregular particles or lumps; polished surfaces show, under the microscope, intergrowths of this polysulphide with the gangue minerals. It may be associated with varying proportions of pyrite which, as far as could be determined, was deposited contemporaneously. The ore and gangue minerals were deposited at different stages. Small fractures in the ore veins are, occasionally, filled with a second generation of tetrahedrite and pyrite which also replace both earlier gangue and ore minerals adjacent to these fractures. Siderite is most susceptible to this attack, and its replacement by tetrahedrite was in many places very beautifully shown (Plate X A). The contemporaneous deposition of the ore and gangue minerals is often well exhibited in the numerous small vugs in the vein deposits. In these, perfect crystals of pyrite, quartz, siderite, and more amorphous lumps of tetrahedrite have formed contemporaneously. The silver values occur with the tetrahedrite, and the low gold assays reported from some samples are probably associated with the pyrite.

The processes so far described are those which took place during deposition from ascending thermal waters and are not to be confused with subsequent secondary changes which markedly affected the character of the deposits. These changes, as observed in the present ore deposits, occurred long after the primary deposition and resulted solely through the agency of groundwaters. At least two stages are recognized during this later period. In the first, the siderite was attacked, and a considerable proportion replaced, by limonite. Pseudomorphs of those wedge-shaped crystals of brown siderite, previously referred to, have such a resemblance in form, colour, hardness, and lustre to the original mineral as in many cases to require verification by chemical tests. Elsewhere the limonite has a more characteristic dull, amorphous, brownish-red appearance. This replacement is pronounced at all sections of the ore-bodies examined, and may be expected over the greater depth of the ore-bodies in future development work. Where tetrahedrite has been caught up in this secondary limonite, partial, to complete, decomposition has taken place and is usually marked, even in the more unaltered stages, by a greenish copper stain in its vicinity. Some secondary quartz usually appears in this stage, as small clear crystals over the surfaces of the siderite and limonite, and doubtless represents a deposition from surface waters. An interesting occurrence of marcasite was observed in the ore-body near the portal of the Upper Victoria tunnel. It occurs in a single vein about an inch wide, and was not recognized at any other section of this or any of the other ore-bodies. Polished sections of this sulphide showed it replacing both gangue and ore minerals (Figure 8). It is probable that this marcasite is entirely a secondary sulphide deposited from groundwater solutions.



Figure 8. Diagrams showing replacement of ore and gangue minerals by marcasite at the Eureka-Victoria mines. Magnification: about 30 diameters.

The final stage of surface alteration has proved of great importance from an economic point of view. This alteration appears only near the present surface of the ore-bodies. It is a very recent development and is due to the continual seepage of surface water through certain sections of the ore-body. Surface decomposition has here attacked both gangue and ore minerals and formed a residual concentrate of silver-rich carbonates, oxides, and possibly chlorides, from which high assay returns are obtained.

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The origin of the original ore-bearing solutions has been referred to the quartz diorite intrusive intersecting the conglomerate. There seems little doubt that the ore and gangue minerals, as first deposited in these fracture zones in the conglomerate, were derived from ascending thermal solutions.

It must be remembered that several thousand feet of rock have been eroded from above the present site of the ore-bodies since their formation, and that much ore has probably been removed with it. The remaining deposits all show evidence of modification by meteoric solutions; and from the strong evidence of shattering in the conglomerate, it is probable that this modification may be apparent over at least the greater part of the entire vertical range of the ore-bodies below the summit of Silver peak. Under the continued influence of meteoric solutions the tetrahedrite breaks down and there results a progressive impoverishment of its copper content and a proportional increase in lead and silver. In all specimens of the unaltered tetrahedrite studied, it appeared to form a primary intergrowth with either siderite, quartz, or pyrite, and commonly with all three of these minerals. Its occurrence in part replacing other minerals, and especially siderite, is taken to represent a later phase in its primary deposition from thermal solutions, and there is apparently a progressive overlap from one stage to another, in each of which this same group of ore and gangue minerals is deposited and during its deposition partly replaces the earlier formed minerals.

### Copper

Chalcopyrite is the only copper mineral of economic importance in Coquihalla area, but in only one property, the Independence mine, is it the chief ore mineral. It commonly occurs in small percentages, locally concentrated into unimportant deposits associated with other ore minerals of greater value; or it may be minutely disseminated through the country rock. It is always found associated with one or more other sulphides such as pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, bornite, and chalcocite. It occurs most commonly with the iron sulphides in the gold deposits of the area, and, at the Emancipation and Aufeas mines, carries gold values, although in respect to its abundance it is less important than the arsenopyrite. Chalcopyrite is also found with galena and blende in the silver-lead prospects at the head of Dewdney creek, and with the same minerals in the Ladner Creek basin and near the head of Coquihalla river. Owing to erosional processes there has been very little opportunity for the development of copper carbonate deposits. The characteristic green and blue copper stain is, however, a familiar sight where copper minerals occur, and has guided the prospector to the discovery of orebodies that might otherwise have escaped observation.

### Independence Mine

The Independence mine is situated over  $1\frac{1}{2}$  miles due east of, and 1,800 feet above, Coquihalla lakes, on the divide separating the waters of Bear creek, which flows into Tulameen river, from a small tributary draining westward into the head of Coquihalla river. The principal workings are approximately 5,400 feet above sea-level, but the summits to the north and south reach elevations several hundred feet higher.

The property communicates on the west by a trail 2 miles long with Kettle Valley railway at Coquihalla station. To the east the same railway is reached, partly by trail and partly by wagon road, at Tulameen village 15 miles distant.

The Independence mine falls within the northwest corner of the Tulameen map-sheet, which at this locality overlaps Coquihalla area. The mine has consequently been reported on by Camsell.<sup>1</sup> Brief reports on development have been published from time to time.<sup>2</sup> As no work has been done at the mine since 1908 the following is largely a repetition of earlier observations.

The copper deposits of Independence Camp were discovered in 1901. The early prospecting and development work was largely done by a New York syndicate. Later, the Granby Company of Phoenix, British Columbia, operated the mine under bond from the original owners.

Geology. The Independence group of seven claims lies near the contact of rocks of the Tulameen group with later batholithic and dyke intrusives. Representatives of the bedded rocks occur to the northeast of the camp and, within the district, include slates, quartiztes, and siliceous schists, together with interbedded volcanic greenstones, mashed granite porphyries, and mica schists of igneous origin. Small bodies of later intrusives, including massive pyroxenite and its sheared and altered hornblende schist equivalents, together with patches of massive granodiorite, penetrate the Tulameen rocks.

To the south and southwest of the camp lies a great area of gneissoid batholithic rocks, dominantly granodiorite, but including granite and more basic types. These represent the direct continuation of the Eagle granodiorite from the northwestern section of the Tulameen maparea, and in their general northerly course can be traced entirely across Coquihalla area. These rocks have been intersected by a number of porphyritic dyke rocks representing at least two periods of intrusion. In the earlier period a large, dyke-like body of granite porphyry was introduced between the Tulameen rocks to the northeast and the Eagle granodiorite to the southwest. Its resistance to erosion has been less than the adjoining rocks and accordingly a saddle has been developed in the divide at this point. This dyke has been traced for 3 miles to the south, where its width decreases from 1,000 to 50 feet. To the north it appears to underlie the depression occupied by the stream draining towards the head of the pass traversed by the Kettle Valley railway near Coquihalla station. Its course in this direction was not accurately outlined by reason of the poor exposures in this neighbourhood. It does not, however, appear to extend across the railway and its width also decreases in this direction. This dyke is of economic importance in that it contains the ore-bodies at the Independence mine. The following petrographic description of this dyke rock has been given by Camsell. "It contains phenocrysts of quartz, feldspar, and biotite in a fine-grained groundmass. The thin section shows the feldspars to be both orthoclase and plagioclase and the quartz exhibits a corroded outline. Much pyrite is also present. The composition of the rock is by no means uniform, being more siliceous in some parts than

<sup>&</sup>lt;sup>1</sup> Cunsell, C., Geol. Surv., Can., Mem. 26, p. 166. <sup>2</sup> Minister of Mines, B.C., Ann. Repts., 1906, p. H 180; 1907, p. L 144; 1908, p. J 132; 1913, p. K 237.

others. It is traversed by little veins of quartz which are barren and appear to have been formed previous to formation of the ore-bodies. The structure of the rock is massive, and when not affected by mineralizing solutions is quite fresh. It is only slightly sheared, and shows fracturing in two directions, the most pronounced of which is about north 25 degrees west."

Cutting this granite porphyry are a number of smaller intrusive dykes of varying composition. At the mine workings they include syenite porphyries from which quartz is absent, and in which orthoclase is an essential mineral. Farther to the northwest these dykes contain a larger proportion of plagioclase, which occurs in part as conspicuous phenocrysts in a fine-grained, grey groundmass. Some of these dykes are coarser grained and in such the porphyritic texture is less apparent. These dykes range in composition from syenite to monzonite, quartz-monzonite, granodiorite, and diorites. The more intermediate types predominate.

Mineral Deposits. The ore deposits occur in fracture zones in the granite porphyry. The principal direction of fracturing is a few degrees west of north and is consequently at an angle to the foliation of the Eagle granodiorite body which, on this side of Coquihalla river, varies from 10 to 20 degrees east of north. Some cross-fracturing has occurred, in which ore is also found. The principal gangue is altered granite porphyry and the chief gangue minerals include calcite, quartz, and sericite. These secondary gangue minerals are most abundant where the fracturing is most pronounced.

The chief ore mineral is chalcopyrite, but pyrrhotite and pyrite are also abundant and molybdenite has been observed in small flakes disseminated through the country rock. The chalcopyrite almost everywhere shows slight enrichment to chalcocite, although masses of solid chalcocite are rare. It is consequently difficult to secure fresh specimens of chalcopyrite for analysis, and assays run high in copper. A sample analysed by the writer gave 32.85 per cent copper. According to Camsell "the surface ore is said to have given assays of 20 per cent copper, but the ore on which the value of the deposits depend will only yield about 3 per cent. Gold to the value of about \$1 to the ton is associated with these ores."

Cuprite occurs as a very minor enrichment product of the chalcopyrite. Sphalerite and tetrahedrite have also been observed in very small proportions and are of no economic importance.

Microphotographs of polished sections of the ore (Plate X B) show chalcopyrite replacing pyrite and being in turn replaced by chalcocite.

The ore-bodies are regarded as replacement deposits of the Butte type.<sup>1</sup> Solutions rising from some deeper seated magmatic source, in their ascent through the fissures and fracture zones of the granite porphyry, deposited part of their load of gangue and ore minerals, and attacked and partly replaced the porphyry, with similar materials. Camsell concludes

Camsell, C., Geol. Surv., Can., Mem. 26, p. 166.

that there were two periods of fracturing and mineral deposition. "During the first period chalcopyrite, pyrrhotite, and blende were introduced along with calcite, so that we find all these minerals in the fissures. Pyrite was also introduced, and often migrated farther into the wall-rock where it formed crystalline individuals by metasomatically replacing the country rock. In the second period of fracturing there was a very limited introduction of sulphides, but a greater influx of gangue minerals, so that we find veinlets of calcite cutting the previously formed ore minerals, and geodes filled with quartz, calcite, and sericite."

Development. Work on the property has included a great number of open-cuts, shallow pits, and surface stripping chiefly within the granite porphyry belt. Work underground includes over 1,000 feet of tunnelling and drifting, and 265 feet of shafts. The main adit has been driven 500 feet along the strike of one of the productive ore-bearing fissures. At 360 feet from the portal are crosscuts on either side, of 145 and 342 feet respectively. At 390 feet from the portal a raise of 126 feet was made to the surface.

#### Molybdenite

Molybdenite is a common accessory mineral in some of the batholithic rocks of the district. It has been observed near the Independence mine and also along the railway near Portia in the Cretaceous granite exposed there. At the former locality it is, Camsell says, "sparingly disseminated in minute particles throughout a granite porphyry and is of little significance." At Portia it occurs in small, lustrous, bluish-grey scales scattered through the coarse granite within a few hundred feet of the contact of this intrusive with the Ladner slate belt. It is intimately associated with the rock minerals and was probably introduced during the consolidation of this intrusive. Its occurrence here is of no economic importance.

### Dominion Mineral Group

The Dominion Mineral group is located at an elevation of approximately 5,500 feet on the summit west of Iago.

The only showing of importance seen by the writer was located in the face of a steep granite bluff where a quartz lens  $1\frac{1}{2}$  feet wide was heavily impregnated with molybdenite. This mineral occurs in flakes or lumps filling small cavities in the quartz or more finely distributed in the adjoining granite. Solid masses of molybdenite equivalent in volume to a cubic inch were observed, but as a rule the lumps were smaller and were confined to the quartz. In the granite the sulphide occurs in finer particles.

Only a few feet of this mineralized quartz lens could be seen because of a heavy blanket of snow, and it is possible that other ore-bodies may be likewise concealed.

The granite composing the wall and country rock is typical of the coarse pink granite member of the Cretaceous batholithic rock in this section of the district, except that near the quartz lens it is slightly miarolitic and the small cavities are commonly occupied by flakes of the molybdenite. The quartz lens is so intimately and irregularly intergrown with the granite as to suggest its origin as a pegmatitic phase of the intrusive. It has a very vitreous lustre, is greatly fractured, and contains small cavities occupied by the ore mineral.

The molybdenite was probably introduced together with the quartz gangue during the later periods of the intrusion of the batholithic country rock. Subsequently it has been partly oxidized near the surface to yellowish molybdite ( $MnO_3$ ). No other molybdenum minerals were observed.

The percentage of molybdenite in this deposit seems to be well above that necessary for economic extraction, but no estimate could be made as to the actual amount of ore present.

### CHAPTER VI

# SUMMARY AND CONCLUSIONS

#### TOPOGRAPHY

Coquihalla map-area is 300 square miles in extent and includes the greater part of the basin of Coquihalla river. The town of Hope, situated at the southwestern end of the area, is 91 miles by rail east of Vancouver (Figure 1). The relief, ranging from less than 150 to over 7,500 feet above the sea, decreases towards the head of Coquihalla river. This stream flows southwesterly through the map-area and in its length of about 37 miles descends over 3,500 feet.

The map-area falls within the northern prolongation of Skagit range, the most westerly of the component ranges of the Cascade Mountain system which cross the International Boundary. Within Coquihalla area Skagit range is subdivided into three units or sub-ranges including Hope mountains east of Coquihalla river. Anderson River mountains west of this river, and Cheam mountains south of Silver creek. These ranges have a general uniformity of summit level, a feature peculiar to the entire Cascade physiographic province, of which a small part only extends north of the Canadian boundary. This concordance of summit level is interpreted as having resulted from the uplift in late Tertiary time of the Cascade peneplain to an elevation not greatly different from that still retained by the upland topography.

East of the map-area the rugged Hope mountains give place to the gently rolling expanse of the Interior Plateaus. The transition is imperceptible in the northern section of the area, but, farther south, a more abrupt escarpment, from a few hundred to 1,000 feet or more, marks the break from the mountainous Cascade province to the lower region of the plateaus. The increase in stream grade west of the plateau belt is most marked and has caused great difficulty in locating a suitable railway route from the interior to the coast of British Columbia. The greater elevation to which the Cascade province has been raised over the Interior plateaus has, doubtless, rearranged considerably the older drainage system, so that much of the water that originally drained westward into the old channel now occupied by Fraser river, has been deflected into eastern watercourses.

The district has reached a stage of early topographic maturity. The drainage systems are well-defined. The main streams have, for the greater part of their length, a remarkably uniform grade, but the grade, as a rule, rises rapidly towards the summits of the divides in their upper courses. Coquihalla river and some of its tributaries occupy antecedent valleys, but most of the stream courses have been developed since the uplift in late Pliocene or early Pleistocene time.

The upland slopes have been modified by a regional ice-sheet which moved over the area in a southwesterly direction and has left the characteristic rounded outlines, polished and striated surfaces, lee and stoss gradients, and glacial erratics up to an elevation of 6,500 feet. Later valley and mountain glaciation has in addition played a notable part in the development of the present topography.

## GENERAL GEOLOGY

The oldest rocks in the map-area are those included in the Cache Creek series. They comprise volcanic and sedimentary formations in nearly equal proportions. The volcanic rocks are chiefly altered augite andesites, to which the general name of greenstone has been applied. They include some hornblende andesite flows and a few pyroclastic beds. The sedimentary beds include chert and slaty rocks. The latter are normal clastic rocks, whereas the chert is regarded as a chemical precipitate genetically related to the volcanism of this period. No fossils have been found in the Cache Creek rocks within the district, but the series is continuous, to the northwest, with Cache Creek rocks exposed along Fraser river near North Bend and, to the southeast, with the Hozameen series at the International Boundary.

The series has been differentiated in Coquihalla area from post-Palæozoic rocks and is regarded as Carboniferous and probably Pennsylvanian in age.

The Cache Creek series occupies a greater area than any other formation in the district. It occurs, principally, in a broad belt crossing Coquihalla river in a northwesterly direction between the mouths of Dewdney creek and Peers river. This trend is roughly parallel to the major axis of deformation of the entire area. The strata stand at high angles and have been, in part, overturned to the northeast. Along their contacts with later batholithic rocks they have been metamorphosed to a degree largely dependent upon the character of the particular member of the series adjoining the contact.

The general character of the Cache Creek rocks testifies to a period of great volcanic activity, and to a region of low relief untroubled by any severe orogenic disturbance. The entire series is regarded as having accumulated beneath marine waters whose reaction with the magmatic silicate solutions that accompanied the erupted lavas has been the chief factor in the precipitation of the cherty members of the series.

The Cache Creek rocks are in contact unconformably to the northeast with the Ladner series which has been assigned tentatively to the Upper Jurassic. The time interval between these two formations is consequently a long one, but is represented in part by the Tulameen group, of which a small area occurs in the extreme northern section of the district.

The Tulameen rocks include volcanic and sedimentary members. They are widely exposed in Tulameen area and have been tentatively referred to the Triassic, and correlated with Dawson's Nicola series. With their exception no other rocks of Triassic age are believed to occur in the district.

The oldest Jurassic rocks are the Ladner series, which overlies the Cache Creek group unconformably and occupies a somewhat narrower belt having the same general trend as the Palæozoic rocks. The Ladner series has been subdivided on lithological grounds into two conformable groups. The older group occupies over 90 per cent of the areal distribution of the entire series, and has been termed the Ladner slate belt. It consists mainly of dark, fissile slates, but includes an abundance of somewhat coarser, more massive, and highly feldspathic strata. One narrow conglomerate belt also occurs near the base of the series. The coarser beds have the petrologic characteristics of tuffaceous greywackes. They were probably formed from clastic material eroded from pyroclastic and extrusive volcanic rocks. It is probable that both contemporaneous and earlier volcanic activity contributed material towards the accumulation of the Ladner series. The widespread distribution of the beds suggests that the finer-grained slates, which compose the great bulk of the slate belt, have had a similar origin, a suggestion borne out by the analysis of a composite sample of these slates given on a preceding page.

The Upper Ladner group is composed of a greater proportion of coarser beds. Conglomerates and greywackes constitute about half of the entire thickness of the group. The conglomerates contain many large intraformational fragments from the underlying slates. The greywackes and slates of this group are, however, lithically identical with members of the underlying slate belt and there is little doubt but that the two groups are conformable. The Upper group has been mapped separately in two small areas, one on either side of Coquihalla river. Its thickness decreases towards the southeast, but it is probably represented immediately beneath the succeeding Dewdney Creek formation at the head of Dewdney creek, where, however, its lithology is so similar to that of the underlying members of the Ladner slate belt that no separation from the latter was attempted.

The entire series is almost equally deformed with the Cache Creek Carboniferous rocks. The strata not only stand at high angles, but are largely overturned towards the northeast, so that the prevailing dip is a southwesterly one.

The only fossils obtained from this series were unidentified species of *Belemnites* which have been referred to either the Jurassic or Lower Cretaceous. The structural relations of the series indicate that the age of these rocks is more probably Upper Jurassic.

The Dewdney Creek series is structurally conformable above the Ladner formation, and occupies a single area in the upper basin of Dewdney creek from which it has received its name. The series is composed largely of tuffs and tuffaceous rocks which owe their origin, at least in part, to contemporaneous volcanic eruptions. They have been subdivided into three sections characterized by certain rock types. All these appear to have accumulated under marine waters and are associated with a small proportion of clastic sediments. Nearly all the members contain fossils which indicate either a Jurassic or, less probably, a Lower Cretaceous age. Some beds are very similar to certain types represented in the underlying Ladner series and it is quite possible that they represent a separate facies of the Ladner series, although, on the whole, evidence favours the view that they form part of a separate series.

The Dewdney Creek series is deformed to about the same extent as the Ladner series. Their clastic sediments are fine to moderately finegrained, indicating that the land areas of the time were still of low relief.

Great orogenic disturbances, accompanied or followed by batholithic intrusions, closed the period of volcanism during which the Dewdney Creek series was formed. The intrusives are referred to the Upper Jurassic period and include rocks ranging from granite to diorite. No attempt has been made to map these types separately. These Jurassic intrusives are exposed only in the southwestern part of the area. They are, in general, distinguished from later batholithic rocks by their more fractured character and by their structural and intrusive relations with other formations.

Following this period of mountain building and intrusion a great thickness of sediments was rapidly accumulated. The cover of the Jurassic batholithic intrusives was in part removed, and the plutonic rocks themselves were deeply eroded. During this period the Cretaceous sediments of the area were laid down. These have been tentatively correlated on structural and lithological grounds with the Pasayten formation near the International Boundary and, more doubtfully, with the Jackass Mountain formation on Fraser river, both of which are regarded as, at least in part, of Lower Cretaceous age. No recognizable fossils have been obtained from these rocks in Coquihalla area.

Lithologically these rocks are distinctly different from the older formations in the area. They include much coarser beds and are composed, to a great degree, of detritus from plutonic rocks.

Structurally they have been interpreted to overlie unconformably the earlier Ladner and Dewdney Creek formations and, although standing at angles varying from about 45 degrees to vertical, they exhibit less intense deformation than the earlier formations, and their general axis of folding lies at a smaller angle to the west of north. They are, however, more severely metamorphosed by later batholithic rocks than any other formation in the district because they occur in comparatively small, and in many places narrow, elongated areas surrounded in part or entirely by intrusive rocks.

The bulk of the intrusives in Coquihalla area are of Cretaceous age and were probably irrupted near the close of Lower Cretaceous time. They occur in two broad areas, one in the northern and one in the southern part of the map-area, and are also represented near Manson mountain and probably at the head of Dewdney and Cedar creeks. In the northern area these batholithic rocks have been subdivided in order of time into three intrusions: Eagle diorite, Eagle granodiorite, and granite and acid granodiorite complex. The first two are closely related and show a grada-tional contact zone. There is, however, some structural evidence to show that the diorite was intruded first and closely followed by the Eagle granodiorite. Both rocks commonly show foliation, which is parallel in the two intrusives but more regularly developed in the granodiorite. The granodiorite continues south into Tulameen area, where it first received its name.<sup>1</sup> The complex of granite and acid granodiorite was intruded as one body and cuts the other two intrusives. The granite is difficultly distinguishable in the field from the granodiorite and constitutes the bulk of the complex. It is, in part, distinctly pink and in part grey, in colour; frequently coarsely textured; and dominantly massive in appearance. The granodiorite much resembles the grey varieties of the granite, but is commonly finer in texture. Its chief exposures occur in a large, irregular body which extends, in the nature of an apophysis, across Cedar and Dewdney creeks.

<sup>&</sup>lt;sup>1</sup> Camsell, C., Geol. Surv., Can., Mem. 26, p. 76.

In the southern area no subdivision of these Cretaceous intrusives has been attempted. No true granites were observed, the rocks varying from acid and basic granodiorite to quartz diorite. The acid granodiorite is very similar lithically to that of the northern area. It is also identical in appearance with those intrusives near Manson mountain.

The massive quartz diorite stocks at the head of Dewdney and Cedar creeks probably belong to about the same period of intrusion as the larger Cretaceous batholithic bodies, but may be of Tertiary age. From their disposition near larger areas of Cretaceous batholithic rocks, and from their slightly more basic composition, they have been considered to be of the nature of satellitic stocks.

Following the Cretaceous period of batholithic intrusion there ensued a long interval during part or all of which older formations were eroded from large areas of Cretaceous batholithic rocks and these themselves deeply eroded. The sediments accumulated during this interval are not represented within the district.

In Tertiary time, probably in the Miocene, igneous activity was again pronounced and is represented by intrusive and extrusive rocks. In the northern part of the area a heavy series of volcanic materials was laid down on the eroded surfaces of the Cretaceous batholithic rocks, and one small stock or neck of basic intrusives penetrated the Eagle granodiorite and forms the core of Coquihalla peak. It has been included together with the volcanic rocks under the local name of the Coquihalla series. The volcanic rocks include in their order of superposition basalt flows, rhyolite flows, and pyroclastic tuffs and breccias. The basic intrusives are pyroxene gabbros and occupy the site of what is regarded as having been a crater in Coquihalla mountain, from which the rhyolite flows and pyroclastic rocks may have been in part or entirely erupted. The bedded members of the Coquihalla series are gently folded, lying at angles rarely exceeding 20 or 25 degrees. They are regarded as belonging to the Miocene period of volcanic activity which was so pronounced in the western section of the Cordillera.

In the southern part of the district the Tertiary is represented by two areas of quartz diorite, one south of Silver creek and the other below Haig station on the west bank of Fraser river. This rock has been correlated with the Chilliwack batholith which has been referred tentatively to the Miocene. It is a massive, fresh, dark grey rock showing no shearing and, in thin section, little sign of strain or fracturing. It intersects the Cretaceous sediments and the Cretaceous intrusives and is consequently younger than either of these.

Fluvioglacial and stream deposits occupy only a small part of the area. They are most abundant near the lower course of Coquihalla river and its chief tributaries. This river has furnished the delta land upon which the town of Hope is built. Morainal material has also accumulated in sufficient amount west of Othello to have deflected Coquihalla river from its original course through Kawkawa lake into its present narrow channel through a jointed and sheared member of the Cretaceous batholithic intrusives.

# ECONOMIC GEOLOGY

The economic minerals and metals in their present decreasing order of importance include: gold, silver, copper, molybdenite, arsenic, platinum, lead, manganese, and iron. They occur in both detrital and lode deposits. In the former, gold and platinum are the only minerals of importance.

The lode deposits of commercial value include gold, silver, copper, and molybdenum.

Gold ores are the most important and characteristic of the district. They occur in two distinctly separate sections of the area and in quite different geological associations. Their most important development is confined to gold-quartz veins in the Ladner slate belt and the underlying andesite greenstone member of the Cache Creek series. Their origin in the vicinity of the slate contact is attributed to a large diorite intrusive which closely follows this contact. Other gold quartz veins seem, however, to be genetically related to smaller and more acid porphyritic dykes and sills, intruding the slates. The quartz veins occur as combinations of filled and replacement vein type. They are commonly bedded with the slates or occupy irregular fissures in either slates or greenstones. They also occur in shatter zones in either of these rocks and appear as a network of linked veinlets forming a zone many yards wide and persistent over many hundred, and possibly thousand, feet. In all these types, gold values are very irregularly distributed, but are commonly highest where arsenopyrite, and to a less extent pyrite or chalcopyrite, are most abundant.

The gangue consists of milky white quartz, with in some cases a little calcite and a still smaller proportion of albite. Sulphide minerals are disseminated either in aggregates of fine grains or in larger individual crystals, but never in solid masses. They include pyrrhotite, pyrite, arsenopyrite, and chalcopyrite, named in order of abundance, and deposition. Pyrrhotite is, however, not as common in the quartz veins themselves as in the adjoining wall-rock. Very locally small proportions of galena, blende, and stibnite are encountered. Gold is chiefly associated with the arsenopyrite and occurs either in the free state or so finely mixed or intergrown with this or other sulphides as to be even microscopically invisible. The most important property in this section is the Emancipation mine, from which nearly 120 tons of hand-sorted ore has been shipped, yielding a gross return of \$300 a ton.

Gold ores also occur at the Aufeas mine where the ore minerals are massive auriferous arsenopyrite. Chalcopyrite and pyrite are associated in varying amounts in a quartz gangue. The minerals occur in welldefined veins occupying shear zones in a moderately coarse-grained, basic plutonic rock that varies from quartz diorite to diorite and is regarded as of Upper Jurassic age. The veins are of intermediate character as regards both temperature and depth of formation. Arsenopyrite is sufficiently abundant and massive in character to justify its separate treatment for arsenic. The origin of these ore deposits is referred to batholithic intrusions which intersect the older plutonic rocks.

Silver ores are of present commercial importance only at the Eureka-Victoria mines on Silver peak. They occur as vein deposits of intermediate and low temperatures in fracture zones following joint fissures in a massive Cretaceous conglomerate. The gangue includes siderite, limonite, and quartz in this order of decreasing abundance. The principal ore mineral is an argentiferous tetrahedrite carrying a varying proportion of lead. Secondary concentration of the vein material by surface waters has resulted in the differential enrichment of the silver and lead at the expense of the other metallic and gangue minerals. Values up to \$700 a ton have been obtained from these enriched shoots or ore-pockets. Average values in the primary vein deposits vary up to about \$60, but are as a rule less.

The only copper ores of economic value occur at the Independence mine. They form veins and replacement deposits in fractures or fissures in a large granite porphyry dyke cutting the Eagle granodiorite and rocks of the Tulameen group. This property was examined by Camsell who regarded the ore deposits as strongly resembling the Butte type. The gangue includes altered granite porphyry and secondary quartz, calcite, and sericite. The principal ore mineral is chalcopyrite, but pyrrhotite and pyrite are abundant and some chalcocite, cuprite, blende, and molybdenite were observed. Tetrahedrite is also reported to occur here.

One important molybdenite deposit has been discovered on the Dominion Mineral group in the Cretaceous granite on the summit west of Iago. The sulphide occurs in a high temperature quartz lens of pezmatitic origin and is also impregnated through the adjoining granite. The molybdenite occurs in large flakes and lumps in the quartz and in disseminated smaller flakes in the country rock. Some secondary oxidation to yellow molybdite has occurred. No other ore minerals were observed.

## FUTURE OF THE DISTRICT FROM A MINING STANDPOINT AND FAVOURABLE AREAS FOR PROSPECTING

The construction of the Kettle Valley railway has proved a great boon to the district. It passes directly through the middle of the area, no part of which is more than a few miles from transportation. The area is, however, rugged and, on the whole, heavily forested and densely overgrown with underbrush, so that it is impassable for pack horses except along a few trails. The only ones over which a pack train can be taken with safety lead up Nicolum river and Silver creek, and from Hope to Othello via Kawkawa lake. Prospecting is consequently an extremely arduous task, but with certain improvements in trail construction can be immensely facilitated. The trail leading up Nicolum river and thence down Sumallo to Skagit river is in excellent condition and sufficiently wide for 12 miles from Hope to justify its status as a wagon road. This is the route which the provincial government has under consideration for a trans-provincial highway through the southern interior of British Columbia. This highway will open up the southern section of Coquihalla district for more careful prospecting. It will also tap the mining properties at Twentythreemile camp and promote further investigation at more southern points on Skagit river where recently some interesting prospects have been discovered. The southern section of Coquihalla district is particularly difficult to prospect because of its great topographic relief and heavy vegetation. A likely area for prospecting lies in the vicinity of Wardle creek in those basic intrusives which have in this report been included with the Jurassic batholithic rocks.

In the more central parts of the area gold is at present the most important economic mineral and is confined principally to the Ladner slate belt. More prospects have been located in these slates than in any other formation in the area, but as the slate belt is, on the whole, deeply covered by surface accumulations, only a small proportion of the auriferous quartz veins have been uncovered or explored for any considerable distance. The success with which these quartz veins can be mined is still largely a matter for speculation and, at present, attention is centred on work at the Emancipation mine, where the showings are somewhat typical of those occurring on other properties in the slate belt. More development work has been done on this than on the other deposits and provision is being made to treat the ore on the property. The success of this mine would stimulate prospecting of the slate belt. For this purpose it is most desirable that the government trail leading from the railway to the South fork of Ladner creek be improved and extended at least to the head of the Middle fork near the Pipestem mine. Should the latter property fulfil present expectations it may be desirable to continue this trail across the divide and down Siwash creek to connect with the present trail from Fraser river to the Emigrant mine, where development work is now in progress. A trunk road of this character would assure thorough prospecting of this slate belt, upon whose economic possibilities so much depends.

To the east of Coquihalla river it is equally desirable that the trail up Dewdney creek be improved. The writer had this trail cleared for pack horse transportation for 8 miles from the Coquihalla, but even in this distance it is still poor, and in part even dangerous. The grade over this first 8 miles is uniform and averages 4 per cent. Beyond, to the summit, a distance of over  $2\frac{1}{2}$  miles, the trail rises rapidly and averages nearly 20 per cent. It could be cleared, however, at comparatively small cost and its continuation over the divide would not only afford a more convenient route from the silver-lead properties of Summit Camp on the eastern or Tulameen side of the divide, but would encourage prospecting around the head of Dewdney and Cedar creeks where, in the writer's opinion, a favourable area is still comparatively unexplored. It was observed that the formations in this section are commonly heavily impregnated with sulphides, chiefly pyrite, near the quartz diorite intrusive at the head of Dewdney and Cedar creeks. The formations are also intersected by numerous acid and basic dykes near which mineralization is in many places unusually heavy. Several silver-lead prospects were staked in this section in the late nineties. Some of these were Crown-granted and practically no work has been done on any of them for years. It might repay the prospector to give this section his special attention and for this purpose a good pack trail up Dewdney creek would be of great assistance.

Other favourable sections for prospecting include:

The contact of Eagle diorite and other intrusives with the Cretaceous sediments west of Romeo, where some heavy sulphide mineralization has been observed.

The contact of Eagle granodiorite with the Tulameen rocks in the extreme northern part of the district.

The contact of batholithic intrusives with limestone members of the Cache Creek series south of Beaver lake and Nicolum river.

The Ladner slate belt near the granodiorite intrusive crossing Cedar and Dewdney creeks.



A. View looking south over northern part of Hope mountains, with Coquihalla peak in left middle background. Shows abundance of snow remaining on these summits on July 5, 1922. (Page 20.)



B. Looking down Coquihalla valley towards Jessica station on the Kettle Valley railway. Illustrating the density of vegetation in this section of the area and also the cliffy topography so prominently developed by the cherty rocks of the Cache Creek series. (Page 22.)

70994 - 12



A. "Wave" topography, Anderson River mountains, west of Romeo, B.C. Illustrating the effects of mountain glaciation in an area composed almost entirely of granitic rocks. (Page 17.)



B. Showing cirque head-wall in granite peak west of Romeo. (Page 17.)


A. Showing irregularities in bedding of post-glacial terrace material in the valley of Coquihalla river along railway cuttings near Elevenmile creek. (Pages 19, 118.)



B. Boulders from post-glacial terrace deposits along Kettle Valley railway below Iago. (Page 118.) 70994—12<sup>1</sup>/<sub>2</sub>



A. Illustrating crumpling of chert bands, Cache Creek rocks—Coquihalla area west of Jessica. (Page 37.)



B. Overthrust in Ladner slate belt along Kettle Valley railway below Ladner creek. (Page 133.)



A. Illustrating columnar jointing in basalt of the Coquihalla series. (Page 79.)



B. Andesite dykes (dark) cutting Eagle granodiorite, south of Independence camp. (Page 116.)



A. Microphotograph of contact between slate and granite near Portia on Kettle Valley railway, showing development of acid plagioclase feldspar in older slate rock near contact. Magnification: X 20. (Page 52.)



B. Microphotograph of crystal-lithic tuff from the lower section of the Dewdney Creek series. Magnification : X 20. (Page 57.)



A. Microphotograph of vitric tuff from the upper section of the Dewdney Creek series. Magnification: X 20. Plain light. (Page 59.)



B. Microphotograph of Lower Cretaceous greywacke showing uniformity in size of the constituent grains; their angularity; and the large proportion of quartz grains in these rocks as compared with members of the Ladner and Dewdney Creek series. Magnification: X 20. (Page 69.)





A. Microphotograph of polished specimen of ore from the Pipestein mine showing replacement of pyrite by arsenopyrite. Magnification: X 23. (Page 146.)



B. Microphotograph of polished ore specimen from Aufeas mine, showing replacement of pyrite and arsenopyrite by chalcopyrite. Magnification: X 24. (Page\_150.)



A. Microphotograph of a polished section of ore from the Eureka-Victoria mines showing replacement of siderite gangue by tetrahedrite. T = tetrahedrite; TG = gangue partly replaced by tetrahedrite; G = gangue chiefly siderite. Magnification: X 49. (Page 158.)



B. Microphotograph of polished ore specimen from Independence mine, showing replacement of pyrite by chalcopyrite and enrichment of chalcopyrite to chalcocite. Magnification : X 24. ch = chalcocite; cp = chalcopyrite, py = pyrite. (Page 162.)

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