MEMOIR NO. 26

GEOLOGY, AND MINERAL DEPOSITS

TULAMEEN DISTRICT, B. C.

BY

CHARLES CAMSELL

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

OTTAWA

1913

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY

Hon. Robert Rogers, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

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No. 1206

LETTER OF TRANSMITTAL.

To R. W. Brock, Esq.,
Director Geological Survey,
Department of Mines.

Sir,—I beg to submit the following memoir on the geology and mineral deposits of the Tulameen district.

I have the honour to be, sir,
Your obedient servant,
Charles Camsell.

June, 1911.

CONTENTS.

ILLUSTRATIONS.

Photographs.

Drawings.

Maps.

TULAMEEN DISTRICT

BRITISH COLUMBIA

BY

Charles Camsell.

CHAPTER I.

INTRODUCTION.

General Statement.

Previous to the commencement of the present geological work in the Tulameen area, the district was little known to geologists or the mining public except in so far as its gold placer deposits were concerned, and from the fact that these placer deposits contained platinum in relatively greater quantity than those of any other part of North America. From preliminary examinations made in 1906 and 1908 and from its brief literature it was ascertained that the field offered a number of interesting problems in purely geological subjects, and contained a great variety of mineral deposits which might prove to be of some economic importance in the future.

Geological work in this field was, therefore, undertaken by the Survey, for the purpose of studying these geological problems and examining the nature and occurrence of the mineral deposits, so that some assistance might be rendered to prospectors and owners of mineral claims, who had been working in the district without much knowledge of the geological conditions under which these mineral deposits occurred. Also, the district lay in the path of a projected railway line which, when built, would connect the mining centres in the interior of British Columbia with the cities on the coast, and it was important on that account that the geology should be worked out and a report made on the variety, distribution, and probable importance of its mineral deposits.

For these reasons, a geological map of the district covering about 160 square miles has been completed and the present report prepared.

The purely geological results that have been obtained are very satisfactory, but the study of the mineral deposits has not been as complete as it might have been if there had been more development work done on them. From an economic point of view the district is still in the prospect stage, and its future in this respect depends altogether on the fulfilment of the promise given by the outcrop of the mineral deposits. In certain cases that future is assured, but in others it is still problematical.

The most important geological results obtained bear on the age of certain rocks, and the origin and relations of other igneous rocks to each other. For example, proof has been obtained that a certain batholithic igneous body, herein called the Otter granite, is post-Oligocene in age, and, so far as known, younger than any other igneous rock of like origin in British Columbia. It is true that batholithic igneous rocks of Tertiary age have been described by a number of other geologists in British Columbia, but no proof has been offered that these igneous bodies are not of pre-Oligocene age. A batholithic body of Miocene or later age has, however, been described, in the adjacent State of Washington, by Smith and Calkins, and with that intrusion the Otter granite is correlated.

Dr. G. M. Dawson, whose general knowledge of the geology of the southern interior of British Columbia was greater than that of any other geologist, states, in his report on the Kamloops district, that, in that district at least, the first rocks to be formed in the Tertiary were the coal-bearing rocks of the Coldwater series, and that vulcanism, in this period, did not commence until after the deposition of the Coldwater series. In the Tulameen district, however, positive proof has been obtained that vulcanism commenced before the deposition of the Coldwater series, and even continued for a short time concurrently with it. We find, therefore, in this field that the coal-bearing rocks rest partly, at least, on Tertiary volcanic rocks and not wholly on Triassic or older rocks as in other parts of British Columbia.

Another point of geological interest upon which some light has been thrown by this examination, is the relation of peridotite to pyroxenite, and to diorite and augite syenite. The excellent section of nearly 3,000 feet in vertical height, cut by the Tulameen river through these rocks, shows that the different varieties pass gradually one into the other by a change in composition, peridotite in the centre of the stock to pyroxenite on the outer side, and the latter again in many cases into diorite or syenite on the extreme edge of the body. The transition indicates a common source for all these rocks and a differentiation of the magma to form the different varieties.

The results obtained along economic lines have also been of considerable interest and value. Prof. Kemp's work on the geology of the platinum of this district has been supplemented by additional investigation and his results confirmed. These results show that the original source of the platinum of the placers is to be sought for in the peridotite and perhaps, to a lesser degree, in the pyroxenite. Some light has also been thrown on the original source of the gold of the placers.

Another result, and one which emphasizes the importance of detailed mineralogical examination of even common mineral occurrences, was the discovery of diamonds in chromite segregations in the peridotite. This result is of far reaching scientific importance, proving as it does the magmatic origin of the carbon which crystallizes as diamond, and refuting the old idea of the organic origin of this mineral. It is also of considerable commercial significance since, though the diamonds actually found were very small, it indicates to the prospector the kind of rock in which diamonds occur, and should induce placer miners to watch carefully the placers that have been derived from basic rocks of this character.

Other results have been the delimitation of the area of coal-bearing rocks in the district, and the estimation of the probable quantity of coal contained in them; consideration has also been given to the nature and occurrence of other mineral deposits.

Field Work and Acknowledgments.

The present report is based on field work carried out in the Tulameen district during parts of the summers of 1909 and 1910. Portions of the district had been visited with J. A. Allan during the field seasons of 1906 and 1908, but this was merely for the purpose of making special examinations and collecting rock specimens.

The topographic work in this district was begun by L. Reinecke in August, 1908, and was carried to completion in the summer of 1909. The methods employed were partly photographic, and partly plane-table and sketching from traverses run between fixed points.

The geological work was begun by the author in July, 1909, and continued until the end of September of the same year, the assistants being W. J. Wright and W. G. S. Agassiz. In the following year the months of June and July were spent in this field, and the work was carried on with the assistance of J. D. Galloway and W. S. McCann. Altogether five months were required to complete the geological mapping and to collect the necessary information for the report.

In the study and mapping of the various geological formations considerable care was exercised, and as the rocks are as a rule well exposed, the results obtained are believed to be as accurate as the conditions and the scale of the published map demand. In the case of the mineral deposits, however, there is in most instances much that can only be learned after mining development shall have been carried out more extensively. As far as these deposits are concerned the present report is merely a preliminary statement of the conditions, as they occur practically at the surface, and is not meant to be a complete study of those deposits. Greater space is devoted to those deposits that appear to be economically most important, or have the greatest scientific interest.

The author desires to express his appreciation of the work done by his field assistants. Owners of mineral properties and other residents in the Tulameen district were always willing to render any assistance in their power to further the work of the party, and for such courtesy the acknowledgments of the author are due.

Location and Area.

The Tulameen area lies in the southwestern portion of British Columbia, and forms a part of the Similkameen Mining Division of that Province. The southern border of the area is 31 miles north of the International Boundary line, and its northern border is 20 miles east of the Fraser river at the town of Yale.

General view of the Tulameen district, looking southeast from Spearing mountain.

Physiographically the Tulameen district is situated on the eastern flank of the Cascade mountains, the component of which is here called the Hope range. To the north and east lies the Interior Plateau region of southern and central British Columbia. The typical mountain features of the Hope range are not well developed within the limits of the sheet, and virtually the whole of it lies within the Interior Plateau region.

The sheet covers a rectangular area, each of whose sides is approximately 13 miles in length. The total area, therefore, is about 169 square miles. Within these limits are embraced the villages of Tulameen and Granite Creek, the placer mining district of the Tulameen river and its tributaries, the coal basin on Granite creek and Collins gulch, and the gold, silver, and copper localities on Bear and Boulder creeks and at other points.

History.

GENERAL HISTORY.

Little is definitely known of the history of the Tulameen before 1883. The first explorers in the district were undoubtedly the fur traders and voyageurs of the Hudson's Bay Company, who traversed it about the middle of last century, entering the country by the Okanagan and Columbia River route, which was then the main outlet for the southern interior. When, by agreement in 1846, the 49th parallel was fixed upon as the International Boundary, and Oregon became part of the United States, this route was no longer suitable for explorers and traders, since it lay largely beyond the border. It was desirable, then, to find a route through Canadian territory, and, the Fraser river being navigable only as far as Yale, an overland route was decided on.

A. C. Anderson, an officer of the Hudson's Bay Company, who was probably the first white man to enter the region, spent several years in exploring a route of this kind to the Pacific coast, from Kamloops, which was one of the main distributing points in the interior. His explorations covered a large part of the region about the headwaters of the Similkameen, Coldwater, and Coquihalla rivers, and in the course of them he opened several trails through the Hope mountains.

One of the main trails followed by the parties of voyageurs or brigades in their annual trips for furs or for trading goods, led from Hope on the Fraser to Nicola lake via Coquihalla and Coldwater rivers. This route passed a short distance to the northwest of the Tulameen. Another trail followed by the brigades led through the area mapped by way of Lodestone mountain, Tulameen village, then called 'Campement des femmes,' and Otter valley to Nicola lake. This trail, though now very little used, is still known as the Brigade trail.

This period in the history of the Tulameen is obscure, and the only record of it known to have been published is contained in Bancroft's History of British Columbia.

Reference to the Tulameen is made in a book called 'British Columbia and Vancouver Island,' written by Captain R. C. Mayne, and published in 1862, which contains a few brief notes on the geology of the region between Hope and Princeton, by Lieutenant Palmer, who in 1859 traversed the whole length of the Tulameen river from its source down to its junction with the Similkameen.

In the years 1859-60 and 1861 the International Boundary Commission was occupied in defining the boundary line between Canada and the United States, but apparently none of the geologists or surveyors connected with this work were as far north as the Tulameen district.

The discovery of placer gold in the interior of British Columbia is stated to have been made in 1852, and in 1858 white miners began to come in from the California gold fields to the south. The rush then instituted continued, in greater or less volume, until about 1864. The majority of the miners went directly to the diggings on the Fraser river or, later, to the Cariboo district, though a few found their way into other portions of British Columbia. One of the main trails followed by these miners was up the Columbia and Okanagan rivers to Okanagan lake, and thence, overland, to the upper Fraser or the Cariboo. Some of those following this route diverged up Similkameen river, and for many years worked bars on the lower part of that stream.

In 1860 placer gold was found higher up Similkameen river, near the mouth of the Tulameen. The discovery of Williams and Lightning creeks, in the Cariboo district, in the following year, however, caused the withdrawal of nearly all the miners from the Similkameen valley, and only a few whites and some Chinese remained. These continued to work the bars and benches of the Similkameen, and no doubt extended their operations to that portion of the Tulameen river lying within the limits of the Tulameen map-sheet. No startling discoveries were made in the region at this time, and a record of the mining operations of that time is preserved only in some abandoned workings near the mouth of Slate creek, found later, during what is known as the Granite Creek rush of 1885 and the years following.

To accommodate the large numbers of miners entering British Columbia, the British government in 1860 built a trail across the Hope range into the Similkameen district, following one of the routes originally explored by Anderson. This trail crosses the mountains through the valleys of Nicolume and Skagit rivers and Whipsaw creek a short distance to the south of the Tulameen area, and has been in constant use up to the present time. This trail is known as the Hope or Dewdney trail.

There is a blank in the history of the district from 1860 up to 1872, at which time the Canadian Pacific Railway Company began to explore British Columbia for railway routes through its mountain ranges. The surveyors of this Company explored many of the main passes through the mountains, and one of their parties, under the charge of Edgar Dewdney, traversed the Coquihalla and Coldwater rivers, which rise together near the northwest corner of the district.

In 1874, J. Trutch and H. J. Cambie, surveying for the same Company, endeavoured to find a suitable pass through the Hope range from the Coquihalla to the Tulameen river. In this they were unsuccessful and since then no other attempts were made, to find a feasible route for a railway through these mountains.

The Tulameen district, and more particularly the adjacent country to the north and east, was looked upon from the earliest period of its history as one of the most favoured portions of British Columbia for cattle and horse ranching, and to this fact is due in large measure the later discovery of placer gold which attracted so much attention.

In August, 1885, some cowboys, who were driving a band of horses down the Tulameen valley, camped at the mouth of Granite creek. One of the horses strayed from the rest, and in searching for it, John Chance, one of the cowboys, rode up the bed of Granite creek. This stream flows on solid bed-rock, through a steep-walled gorge; and in stooping down to drink, Chance saw a nugget of coarse gold glistening on the bed-rock. The discovery was soon advertised throughout the country, and the rush to Granite creek began; but the season was then too far advanced for many miners to get in or for much work to be done. In the following spring, however, there was a large influx of miners to the district, and the greater part of the productive area on the Tulameen river and its tributaries was staked out in mineral claims. The village of Granite Creek, which now has only a score of inhabitants, then boasted a population of several hundreds, while Tulameen, 6 miles higher up the river, had quite as many. The high tide of production was reached in the year 1886, when gold and platinum to the value of $193,000 were washed out of the gravels, principally of Granite creek.

Since 1888 the district has gradually been on the wane as far as placer mining is concerned. Some work has been done every year, however, up to the present time. Apart from the simpler methods of placer mining used by the individual miner, several attempts have been made at hydraulicking, but it cannot be said that any of these were highly successful.

In 1898 and 1899 prospectors began to enter and overrun the district in the search for the original source of the gold and platinum of the placers. Some high grade gold quartz veins were discovered on the Granite Creek basin, and in 1899 the gold-copper ores of Boulder creek were staked out. In 1900 the mineral claims on Bear creek, known as Laws camp, were located; and in 1901 the copper ores of Independence camp at the head of Bear creek were discovered.

Since then every year has seen the location of new mineral claims in various parts of the district, while a few of the prospectors have continued to devote their energies to the search for the original source of the platinum in the solid rocks.

Some time after the Granite Creek excitement of 1885 coal seams were discovered by placer miners, but it was not until 1905 that further work on this coal basin disclosed, on Granite creek, the seams which have since been further explored.

The railway development which has taken place throughout southern British Columbia in recent years is responsible for a great deal of exploratory work in the Tulameen district, and especially in the Hope range directly west of it. After the discouragements experienced by the Canadian Pacific Railway surveyors in 1874, no surveys were made through the Hope range until 1901. Under the direction of Hon. E. Dewdney, a survey was then made by H. E. Carry, of a line running directly through the district, along the valley of the Tulameen river and via Railroad and Unknown creeks, to Coquihalla river.

A charter having been granted to the Victoria, Vancouver, and Eastern Railway Company, for the construction of a railway through the Tulameen district, the surveyors of that Company, since 1905, have been engaged in exploring the various passes through the Hope range. Having finally decided on a practicable route, construction of the road through the district is now under way. The route follows the Tulameen river from its mouth up to Tulameen village, whence it strikes northward, up the valleys of Otter creek and its west branch, to the summit of the divide. Thence, passing down into the valley of the Coldwater, it traverses that valley to its head and crossing the divide to Coquihalla river follows that stream down to the Fraser river at Hope. The route is by no means an easy one, but the only alternative appears to be through the Hope range by means of a tunnel over 7 miles in length, which would have one portal at the mouth of Eagle creek on the Tulameen river and the other directly west on the Coquihalla.

PREVIOUS WORK.

Almost all of the early geological work in southern British Columbia must be credited to Dr. G. M. Dawson. The report and map published by Dawson as a part of the Report of Progress for 1877-78 covers all of the southern portion of British Columbia lying between Okanagan lake and the Fraser river and includes the area of the Tulameen sheet. In obtaining the information for this report and map he travelled over all of the area that was then accessible by trails, but does not seem to have entered the Tulameen district.

The information for the Tulameen portion of his map must have been obtained from prospectors or explorers, or possibly the geological boundaries were merely sketched in from contacts found in the adjacent country.

In 1888, however, three years after the discovery of gold on Granite creek, Dr. Dawson made a hurried visit to the region, and, without making any geological map, recorded a few notes on the economic geology of the placer deposits.[1]

The most important contribution to the geology of the Tulameen was that by Professor J. F. Kemp in 1900. Professor Kemp spent three months in investigating the geology of the platinum found there, and published his observations, together with a small geological sketch map, as a bulletin of the United States Geological Survey.

In 1901 the Tulameen was visited by Mr. W. F. Robertson, provincial mineralogist for British Columbia. Mr. Robertson's visit was necessarily short, and his observations were confined to the ore deposits and the progress of placer mining at that time.

In 1906, and again in 1908, the district was visited by the author for the purpose of looking at some of the more important ore deposits, but no attempt was then made to begin any general geological work in the district. In 1909 the present investigation began, and was continued through a part of the season of 1910.

BIBLIOGRAPHY.

Mayne, R. C.—'British Columbia and Vancouver Island,' 1862, pp. 374, 375.

Fleming, Sanford—Report on the Canadian Pacific Railway, 1877. Part R.

Dawson, G. M.—Geological Survey, Canada, Report of Progress, 1877-78, pp. 50 B, 156 B.

Bancroft, Hubert Howe—History of British Columbia, Vol. XXXII, p. 161.

Hoffmann, G. C.—Geological Survey, Canada, Annual Report, Vol. II, 1886, p. 5 T.

Dawson, G. M.—Geological Survey, Canada, Annual Report, Vol. III, Part I, 1887-88 p. 62 A.

[1] G.S.C. Annual Report, 1887-8, Vol. III.

Dawson, G. M.—Mineral Wealth of British Columbia, Geological Survey, Canada, Vol. III, Part II, pp. 38 R, 104 R.

Donald, J. F.—Engineering and Mining Journal March 19, 1892, page 327.

Hoffmann, G. C.—Geological Survey, Canada, Vol. XII, 1899, Part R, page 29.

Dawson, G. M.—Geological Society of America, Vol. XII, 1901.

Waterman, W. J.—Economic Geology of the Similkameen District, B.C. Min. Record, Nov., 1900, p. 411.

Robertson, W. F.—Annual Report, Minister of Mines, B.C., 1901, pp. 1176-77.

Ingall, E. D.—Mineral Resources of Canada. Bulletin No. 1, 1903.

Camsell, Charles—Geological Survey, Canada, Summary Report, 1906, p. 43.

Camsell, Charles—Geological Survey, Canada, Preliminary Report on part of the Similkameen District. No. 986, 1907.

Camsell, Charles—Geological Survey, Canada, Summary Report, 1908, p. 61.

Penhallow, D. P.—Tertiary Plants of British Columbia. Geological Survey, Canada, 1908.

Camsell, Charles—Geological Survey, Canada, Summary Report, 1909, p. 104.

Camsell, Charles—Platinum Mining in the Tulameen District. Canadian Mining Institute, Vol. XIII, 1910.

Handlirsch, Anton—Contributions to Canadian Palæontology. Memoir No. 12 P, Geological Survey, Canada, 1910.

Camsell, Charles—Mineral Resources of Part of Yale District. Canadian Mining Institute, Vol. XIV, 1911.

Camsell, Charles—Geological Survey, Canada, Summary Report, 1910.

CHAPTER II.

SUMMARY AND CONCLUSIONS

General Geology.

The Tulameen district is underlaid by a variety of rocks of both igneous and sedimentary origin, ranging in age from Triassic up to Recent.

The oldest rocks in the district have been classified under the name Tulameen group and are tentatively referred to Triassic age, being correlated with Dawson's Nicola series. The rocks are distinctly bedded and are made up of volcanic flows, interstratified with some argillites and limestones. The volcanic portion makes up perhaps 90 per cent of the whole group as exposed within the limits of this district, and is prevailingly andesitic in composition. The sedimentary portion contains a few fossil plants, but the specimens found are too fragmentary to be of much use in determining the age of the rocks.

The beds dip at angles varying from 25 to 90 degrees, and the general trend of the strike is slightly west of north, corresponding to the main orogenic axis of the region. A schistose structure is frequently evident, and the rocks have been greatly altered both by regional and contact metamorphism. They cover a larger area than any other single formation in the district, even though their extent has been greatly reduced by igneous intrusions and partly covered by later rocks.

Mountain building, accompanied by batholithic intrusions, closed the period of deposition of the Tulameen rocks. The intrusions are all referred to the Jurassic period, and may be designated, enumerating them in order of time: (1) Boulder granite; (2) peridotite and pyroxenite; (3) augite syenite; (4) Eagle granodiorite.

These igneous rocks are found in various parts of the district in large and small bodies, all having an elongation in a general north and south direction. The Boulder granite is an average granite, somewhat sheared and fractured, particularly where it has been intruded by later rocks. The peridotite and pyroxenite are closely related to each other, and, in their structural and genetic relations, grade into each other, the peridotite forming the core of the body while the pyroxenite is merely a shell around and over it. The augite syenite is related to the peridotite and pyroxenite, but is, as a rule, somewhat later in time of intrusion. Its composition varies, and the formation mapped as augite syenite ranges from a true syenite to a gabbro. The Eagle granodiorite is a normal rock developing in places a gneissic structure.

No rocks referable to Cretaceous or Eocene age are found within the limits of the district mapped, and these periods appear to have been marked by some orogenic disturbance, followed by long continued erosion, during which the district was very maturely eroded and reduced almost to a peneplain.

The oldest rocks of Tertiary age in this district are volcanic flows belonging to the Oligocene period, and are known as the Cedar volcanic series. They underlie, and are conformable with sedimentary rocks of the Coldwater series, and consequently represent the earliest period of Tertiary vulcanism that we know of in this part of British Columbia. They are prevailingly andesitic in composition. The Coldwater series is made up of sandstones, shales, conglomerates, and coal seams, deposited in a lake basin of very limited extent. The two series cover the greater part of the eastern half of the district. They lie at angles that rarely exceed 45 degrees, and have not been very greatly disturbed since their deposition.

Following the Oligocene sedimentation some disturbance took place presumably in Miocene times in which the Cedar volcanic series and the Coldwater series were tilted and deformed. This was accompanied by batholithic intrusion of the Otter granite, a pink, alkaline rock, which cuts the rocks of the Cedar volcanic series. The granite is exposed over an area having a length of over 9 miles and a width varying from 1 to 2 miles, lying on the eastern side of Otter valley.

The youngest consolidated formation in the district is a volcanic flow of olivine basalt. This is a sheet-like body of circular outline, lying unconformably on top of the Coldwater series, on the water and between Granite creek and Collins gulch. It still preserves its horizontal attitude, and, from this fact, is considered to be of late Miocene or perhaps Pliocene age.

Through the older of the above-mentioned rocks, dykes of granite porphyry, syenite porphyry, lamprophyre, and diabase have been intruded in a sequence too intricate to be clearly worked out.

Stream and glacial deposits of unconsolidated material cover the floors of all the valleys and much of the higher country.

Mineral Deposits.

The exploitation of the mineral deposits of the Tulameen district may be said to have been begun about the year 1860, when its placer deposits were first discovered by prospectors who had been attracted to the country by the discovery of gold in the Cariboo district. It was not until 1885, however, when gold was discovered on Granite creek, that much interest was taken in these deposits, and from that time to the present more or less placer mining has been continuously carried on.

The number of miners working the placers has gradually decreased, and the value of the production has diminished proportionally—to a few hundred dollars annually. In the summer of 1910, however, renewed activity was manifested by the taking up of a great deal of placer ground in the valley of the Tulameen river, and this activity has, more recently, been increased by the discovery of diamonds in the district and the prospect of this mineral being found in the placers.

The production from placer mining represents, to date, the total mineral production of the district. This production amounts to almost $800,000, of which 94 per cent must be credited to gold and the remainder to platinum.

Lode mining is still in the prospect stage, and though the number of mineral claims staked out within the last twelve years amounts to some hundreds, no production has yet been recorded from them.

The economic minerals found in the district include diamonds, gold, platinum, copper, magnetite, chromite, molybdenite, asbestos, coal, and clay. These are found in two classes of deposits, namely, primary and secondary.

The secondary deposits are the placers, which are known to contain gold and platinum as well as diamonds. They are found in the valleys of Tulameen river and many of its tributaries, and have been worked to a considerable extent in all these places. Much placer ground yet remains, which is probably rich enough to repay the cost of mining.

The primary mineral deposits contain not only the minerals which have been mentioned as being found in the placers, but they include deposits of copper, iron ore, chromite, molybdenite, asbestos, coal, and clay. Not all of these have an economic value at the present time, and some of them have little more than scientific interest, but they are all described at some length on account of the possibility that they may some time prove to have some value.

The primary deposits which show the strongest indications of commercial importance are gold, copper, and coal.

Gold ores occurring in quartz veins have been worked to a limited extent at Granite creek, and, as it is believed that these veins are the principal source of the gold of the placers, they deserve considerably more attention than has been directed to them in the past.

The copper deposits are probably the most important metallic deposits of the district and certainly the most wide-spread; and on them most of the prospecting and development work has been done. The deposits are of three classes, namely: (1) disseminated ores; (2) contact metamorphic deposits; and (3) veins and replacement deposits. Of these the veins and replacement deposits give the greatest promise of becoming producers of copper. In all cases the copper occurs in the form of chalcopyrite, and is generally associated with galena, zinc blende, magnetic, tetrahedrite, or molybdenite in a gangue which is either siliceous or calcareous.

The coal seams of the district are of Oligocene age and occur in a small basin covering about 3,700 acres in the region about the head of Collins gulch. The coal field contains in the best exposed portions four workable seams of coal aggregating 20 feet in thickness. The grade of the coal is bituminous, and the tests to which it has been subjected show that in most of the seams it is of a fair coking quality.

The most interesting scientific result that has been arrived at from the study of the mineral deposits of this region is the discovery of diamonds in the original matrix. The diamonds were discovered in chromite segregations in the peridotite of Olivine mountain, and were extracted from the matrix by R. A. A. Johnston in the laboratory of the Geological Survey. They have been identified also in thin sections cut from the chromite. The occurrence is such that no doubt can be entertained of the primary nature of the diamonds in the chromite, and of their existence in the original peridotite magma.

Some further light has also been thrown on the geology of platinum, and the existence of this metal as a primary constituent of the peridotite has been definitely proved. It has not, however, been demonstrated that either diamond or platinum occurs in such form or in sufficient quantity in the peridotite to make that rock a commercial ore of these minerals.

With the exception of clay, the other mineral deposits have at present merely an academic interest, and under the present conditions of treatment and market value it is not likely that any attempt will be made to work them.

Although the whole of the Tulameen district is yet in the prospect stage, as far as its mineral resources are concerned, there are in it a number of deposits of different kinds that are undoubtedly very promising, but they have been hindered in their development by the lack of a cheap and easy means of transportation. This handicap is at present being overcome by the building of the Victoria, Vancouver, and Eastern railway through the district, and it is believed that, with the completion of this road through the mountains to the Pacific coast, mining will be stimulated and some of the prospects will develop into producing mines. The improvement is to be looked for first, perhaps, in the case of the coal field, the development of which is now being vigorously pushed. Some of the gold and copper deposits, also, are promising enough to warrant more extended development work, while in placer mining there is a field which offers fair opportunities for the investment of capital.

CHAPTER III.

GENERAL CHARACTER OF THE DISTRICT.

Topography.

REGIONAL.

One of the main topographical features of central British Columbia is the Interior Plateau region, or as it has been called by Daly, 'the belt of Interior Plateaus.'[1] This region has its southern limit approximately at the 49th parallel of latitude, in longitude 119° 30′, from which point it extends northward, in a gradually widening belt, through central British Columbia, for many hundreds of miles. On the 50th parallel, which is the latitude of the Tulameen area, it has a width from east to west of almost 100 miles, and is bordered on the south and west by different units of the Cascade Mountain system, and on the east by the Columbia mountains.

In this latitude the highest points of the plateau maintain an average elevation of from 5,000 to nearly 6,000 feet above sea-level. To the north these elevations decrease somewhat, and everywhere the various streams, which traverse the belt, cut trough-like valleys into it, some of which are as much as 4,000 feet deep.

The boundaries of the Interior Plateau region are difficult to define. The transition from plateau to mountain is nowhere sharp or well defined; on all sides the plateau fades gradually into the loftier and more rugged mountain ranges encircling it.

The Cascade Mountain system, which rises in northern California, extends northward through Oregon and Washington, and at the 49th parallel, where it first touches the Interior Plateau region, has a width of over 100 miles. Immediately north of this parallel the Cascade mountains divide into two branches, and the branches continue northward into British Columbia, enclosing

[1] The nomenclature of the North American Cordillera between the 47th and 53rd parallels of latitude. Geog. Journal, June, 1906.

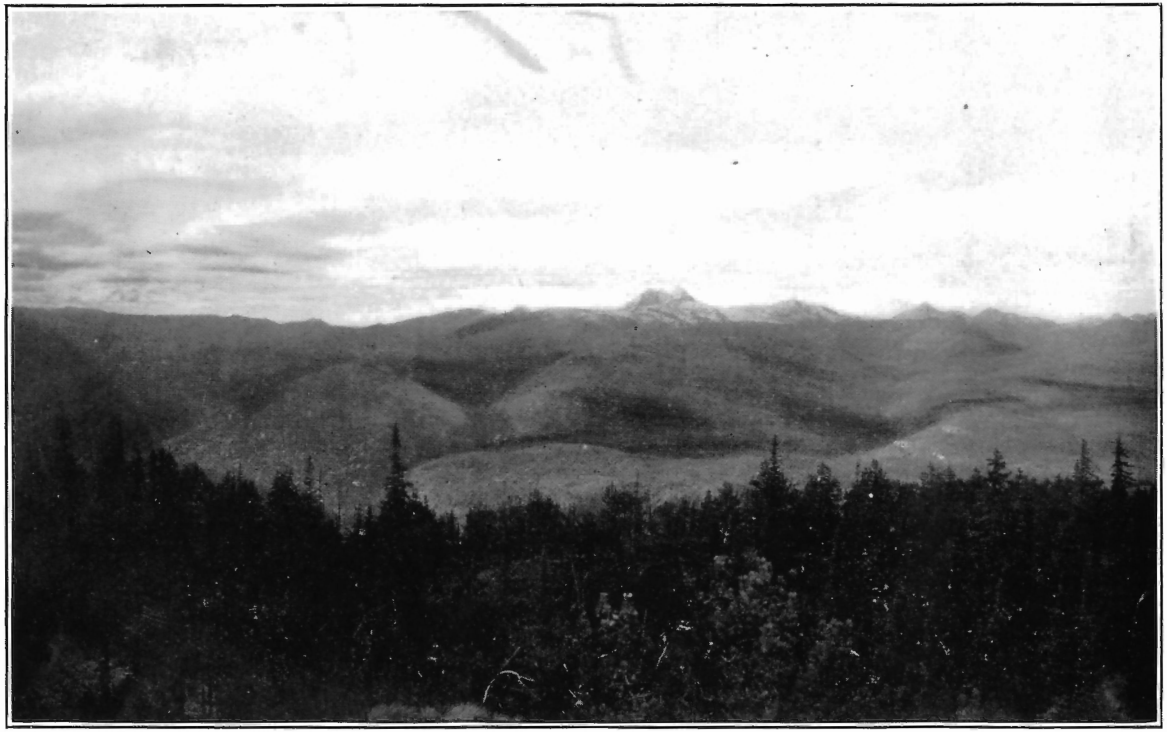
between them a bay of the Interior Plateau region. This bay is the basin of that part of the Similkameen river above the mouth of the Tulameen.

The eastern mountain branch, which is called the Okanagan range, crosses the Similkameen river between the mouths of Ashnola river and Keremeos creek, and, continuing northward with gradually decreasing elevations, finally dies out in the Interior Plateau region, about the headwaters of Twentymile creek.

The western branch is made up, at the Boundary line, of two distinct units, the Skagit and Hozameen ranges, which are separated by the deep valley of the Skagit river. A few miles to the northward of the 49th parallel this dividing line is absent and the Hozameen range appears to die out, like the Okanagan range, in the Interior Plateau region about the headwaters of Granite creek. The Skagit unit, however, being the stronger and more rugged portion of the Cascade mountains, persists, under various names, as far northward as the Thompson river, where like the other it dies out in the Interior Plateau region. Immediately west of the Tulameen area the mountains, which are a continuation of the Skagit range, are called the Hope mountains. These mountains may be said to begin at the Klesilkwa river and to extend northward on the east side of Coquihalla river as far as the headwaters of the Coldwater river, where their summits diminish so much in elevation as to merge into the Interior Plateau region. West of the Coquihalla and Coldwater rivers are the Anderson River mountains, Stoyoma mountains, and Lytton mountains, the last named forming the northern extremity of the Cascade Mountain system.

Physiographically, each of these mountain groups is quite distinct from the other, and is separated from its neighbour by some well marked topographic feature; yet, genetically, they can be referred to the same time and mode of origin, and all are, therefore, parts of the Cascade system.

Peaks in the Cascade mountains at the 49th parallel attain an elevation of 9,000 feet above sea-level. To the west of the Tulameen area, 35 miles north of the 49th parallel, the highest points in the Hope mountains are not more than 7,600 feet above sea-level; and in the ranges to the north of this, while many peaks are about this level, few appear to exceed it.



Coquihalla peak, Hope mountains.

From the crest of the various ranges, which together make up the eastern branch of the Cascade mountains, north of the International Boundary line, the drainage is either towards the east or towards the west. On the eastern side the Similkameen river, with its tributaries, takes virtually all the water which, after flowing eastward as far as the valley of the Okanagan river, is carried southward by that stream to the Columbia river and thence westward to the sea. On this side the gradient is long and easy, without any abrupt change in slope at any one point.

On the west, the ranges are drained by the Coquihalla river and various smaller streams, which empty, within a few miles, into the Fraser river. On this side the gradients are very steep, and the streams are usually nothing more than mountain torrents flowing in rock walled canyons.

The difference in slope of the two sides of this portion of the Cascade mountains is most marked, for while on the east the streams flow many hundreds of miles before reaching sea-level, on the west they descend almost to sea-level in distances of 10, 20, or 30 miles. In profile the surface shows a long, easy slope from the east up to the crest of the mountains, followed by a sharp, steep drop on the west almost to sea-level. This feature presents an obstacle, which has proved almost insuperable, to the building of any railway lines through these mountains.

LOCAL.

While the Tulameen district may properly be described as being a part of the great Interior Plateau region, it is situated so near to the border, where this plateau region begins to pass into the loftier mountain range to the west, that the more typical plateau features are not everywhere highly developed in it, and there is a tendency to the formation of a more rugged type of topography. The change begins to appear at the extreme western border of the area, though it is about 5 miles farther westward before the plateau features are entirely lost and the mountain features fully developed.

The mountains directly west of the Tulameen district are locally called the Hope mountains. The crest of these mountains is about 5 miles distant from the western border of the area, and the highest points in this portion of them are about 7,600 feet above sea-level.

In the northeast part of the district the plateau features are more pronounced than elsewhere, and the summit levels are not more than 5,000 feet above sea-level. In the southwest the highest points are slightly over 6,000 feet high, so that we have a difference of 1,000 feet in elevation between the ends of a line drawn diagonally from southwest to northeast through the area. This line also lies in the direction of greatest general slope of the summit levels.

As elsewhere throughout British Columbia, the Interior Plateau region is characterized by broadly rounded summits, with, in the higher levels, gently sloping sides. Looking over the region towards the east or north from one of the higher points, the summits are seen to be of such uniform height and appear to so run into each other, that the impression is conveyed of a rolling country, having an almost level sky line; the valleys are almost or quite obliterated from view, and one would hardly suspect the presence of any of those deep valleys with which the country is traversed. These valleys, however, become very prominent when a nearer view is obtained.

The main valleys are those of the Tulameen river and Otter creek. Both of these are broadly U-shaped, and show a distinct contrast to the shape of valleys tributary to them. The latter tributary valleys, in their lower parts at least, are usually strongly V-shaped, though in their upper parts they flare out more broadly.

Relief.—The character of the relief in the Tulameen sheet is fairly uniform throughout, and is that which is found as a rule throughout the whole of the Interior Plateau region. As previously stated, there is a uniform slope of the upper levels of the whole area from southwest to northeast, and a difference between the highest points in the southwest from those in the northeast of about 1,000 feet. The drainage, however, does not in every case necessarily follow this slope. The highest point in the district is Lodestone mountain, with an elevation of 6,150 feet above sea-level, while the lowest point is the bed of the Tulameen river where it passes out of the area of the map-sheet on the east. The latter point has an elevation of about 2,350 feet above sea-level, giving a total vertical relief of about 3,800 feet.

If the whole area were covered with water up to about the 4,500 contour, so that all the deep valleys were submerged, we should have exposed an undulating surface with rounded summits and dome-shaped hills rising to heights of 500 to 1,500 feet above the water. All the slopes from these summits would appear easy and gentle, and no sharp crags nor precipitous bluffs would be seen. The whole exposed topography would be that of mature erosion.

Below the 4,500 foot contour the angle of slope of many of the hills steepens, so that cliffs flanked by talus slopes are of common occurrence. While this is not true of every hill, it is true of so many that it becomes a noticeable feature.

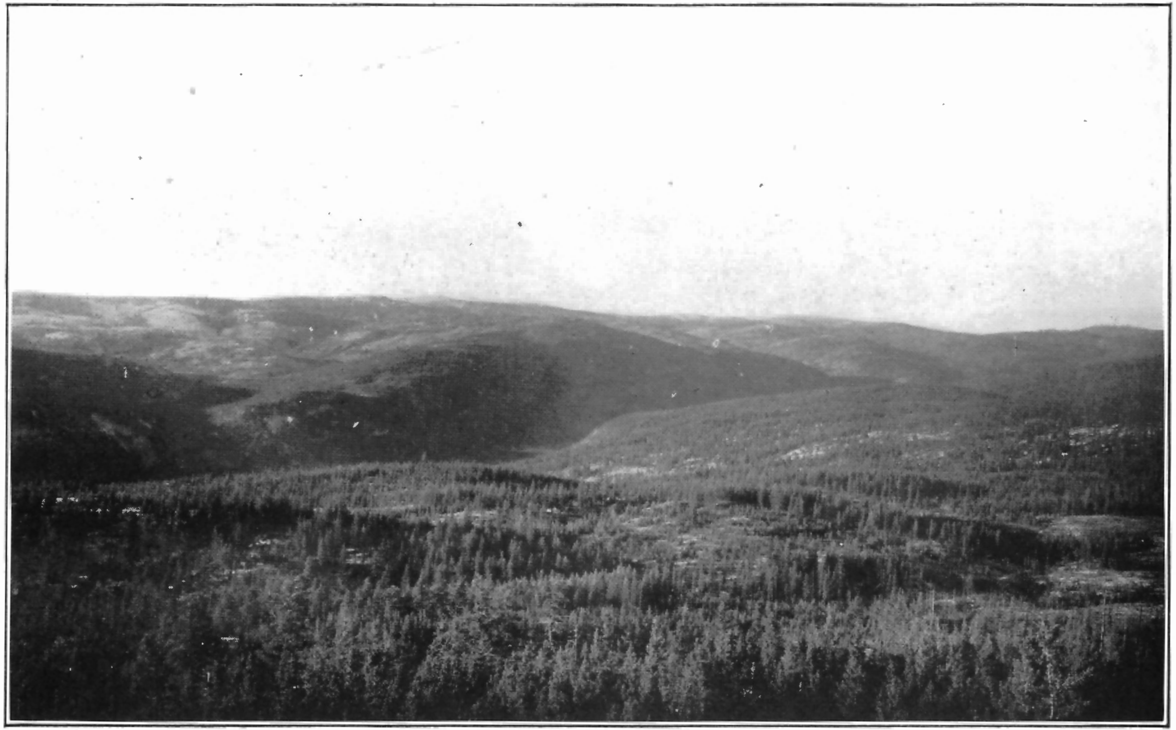
The contrast between the two kinds of topographical forms at the two levels described is not so marked in the Tulameen district as it is in other portions of the Interior Plateau region, as for example in the Hedley district; and unless one examined the region from the summits as well as from the valley bottoms the impression would be conveyed of the presence of only one kind of topography. From the summits one sees only features of topographical maturity, developed on the upper levels, while from the valleys these features are not evident, and one only sees the more youthful topography of the lower levels.

The primary causes for this diversity of topographic form are long continued erosion and subsequent uplift. Other factors have entered, but they are relatively less important. These factors with others of less importance may be classified under the four following headings: (1) long continued erosion under stable conditions; (2) uplift and revival of drainage; (3) glaciation, both regional and local; (4) difference in hardness of the various kinds of rocks.

Largely because no sediments of Eocene age are found in the Interior Plateau region, Dr. Dawson came to the conclusion that, after the Laramide revolution at the close of the Cretaceous, there succeeded a long period of erosion, during which the region was worn down almost to a peneplain. While there is no direct evidence in the southern portion of the plateau region of actual peneplanation in the Eocene, it seems probable that this region during that time suffered long continued erosion, and was reduced to comparatively low relief. The relief at the close of this period could not have been great, and was certainly so low that lake basins of approximately circular outline dotted the surface of the region throughout the whole of succeeding Oligocene times. The region then must have exhibited over all its parts features such as exist at the present time only above the 4,500 foot contour line—that is to say, mature relief, and a well developed drainage, flowing in valleys, broadly flaring.

Local batholithic intrusion, accompanied by more or less general uplift of the plateau region and its bounding mountain ranges, closed the Oligocene period of erosion and local sedimentation. Whether this uplift was continuous or whether it was interrupted at intervals is immaterial in this discussion, but it appears to have culminated in the Pliocene when the Cascade mountains were uplifted with adjacent parts of the Interior Plateau region. A revival of drainage resulted. This revival deepened the existing valleys, and instituted the development of the topographic forms now found in the lower levels. The total vertical relief in the Tulameen district must have been increased approximately 2,000 feet by this uplift. The resulting topography must have shown, in the higher levels, features of slope and summit not greatly different from those which now obtain at the same levels, and at the same time there would have appeared in the lower levels a new topography. The streams must have cut deeper and deeper into their beds, and if the gradients of these streams were not vastly different, the depth of the resulting valley would have been dependent largely on the size of the stream. All valleys would have become sharply V-shaped, with the greatest depth in the master streams, namely, Tulameen river and Otter creek.

Glaciation during Pleistocene times is responsible for a modification of pre-existing topographic forms rather than for the development of new ones. The action of glaciation on the upper levels no doubt contributed something to a general reduction of relief by smoothing off projecting points, or by filling up some of the irregularities of the surface; but this action was effective for only a part of the glacial period when the whole region was covered by ice moving slowly southward. At the beginning and towards the close of the glacial period, when the ice had not yet reached, or had passed, its maximum development, valley glaciers alone can have existed, and it is to these rather than to the continental ice-



Interior Plateau, and the deep trough-like valley of Otter creek.

sheet that we must attribute any increase in vertical relief that may have resulted. The action of regional glaciation produces results that are in direct contrast with those produced by local or valley glaciation, for while the former tends towards a reduction of relief, the latter increases it.

Valley glaciers occupied both the Tulameen and Otter valleys for a considerable period of time. Each of these valleys must have had at the beginning of the glacial period a sharply V-shaped valley, resulting from uplift and revival of drainage in Pliocene times. After occupation, however, by valley glaciers, the shape of these valleys would become U-shaped. Some deepening probably also took place, but this effect may have been later counteracted in some parts by a filling of the beds of the valleys with debris carried down by the streams.

Glaciers are not now found anywhere within the limits covered by the Tulameen map-sheet, but a small well formed cirque at the headwaters of Bear creek, in the northwest corner of the area, indicates the position at which a mountain glacier once lay. This is probably the last point in the region from which the ice retreated.

Since the modification of the Tulameen valley by a valley glacier, and the development of a broadly U-shape, there has been a later uplift or tilting of a part of the region, localized in the country west of the mouth of Slate creek. This uplift has caused the stream to cut down into the bed-rock below the bottom of the old glacial valley, and to form there a narrow, steep sided canyon. This local uplift has further increased the vertical relief by about 300 feet.

The last factor to contribute to a diversity of relief is the relative ability of the various rocks to resist erosion. The rocks within the Tulameen district most resistant to erosive agencies are the peridotite and pyroxenite formations. These stand up above all the others, and the hills occupied by them dominate all the rest of the hills in the region. At the other extreme are the soft sandstones and shales of the Coldwater series, the outcrop of which is frequently marked by depressions in the surface. Tertiary lava flows cover a great part of the region, and though they still occupy some of the higher points this is not due to superior resisting qualities. On the contrary they are, as a rule, soft rocks, easily worn down, and it is more likely that their presence on the higher points is due to the fact that they are the youngest rocks in the district and have not been subjected to erosive agencies as long as the other rocks. They were extruded only after the long period of Eocene erosion. It is quite probable that they at one time covered a much greater extent of country and have since been eroded away, particularly from the valleys where erosion has been strong.

Drainage.—The whole area mapped lies within the drainage basin of Tulameen river. This stream rises on the eastern flank of the Hope range some 15 miles to the southwest of this district. It enters the area of the map-sheet near the southwest corner, and, flowing easterly through the middle of it, passes out at Granite creek on the east. After flowing in this direction for 12 miles farther it joins the Similkameen river at the town of Princeton.

Tulameen river, like all mountain streams, carries a volume of water that varies with the seasons. In June and July the volume is so great that it is almost impossible to cross the stream where there are no bridges. Later in the summer, however, there is no difficulty in fording it on foot or horseback at almost any point at which the stream bed can be reached.

The principal tributary of the Tulameen is Otter creek, which flows in from the north in a broad, deep valley and drains a portion of the Interior plateau. Several lakes lie in the valley, and these regulate the volume of water in the creek, so that its flow is fairly uniform throughout the year. The principal tributary entering from the south is Granite creek, which is important on account of the gold and platinum placers found in its bed. This stream occupies a deep and narrow valley, and drains a portion of the plateau region more elevated than that to the north. Other streams tributary to Tulameen river are Champion, Slate, and Cedar creeks on the south, and Siwash, Eagle, Bear, Cook, and China creeks on the north.

It has not been found possible to determine with any degree of certainty whether or not the present drainage lines coincide in every respect with those of more ancient time. The grade of Otter valley is so low that a very small degree of tilting of the region to the south would reverse the drainage and force the water to flow

General view of Interior Plateau, looking east from Rabbitt mountain.

PLATE V.

Otter valley, looking north towards Thynne lake.

northward to Nicola river. Also the general average slope of the whole district is now towards the north, so that it is quite possible that in former times Otter creek may have flowed north, instead of south as it does now. Under these conditions it would have certainly taken the water of that part of Tulameen river above Tulameen village, and probably also of the part below the village.

The width of Otter valley is out of all proportion to the size of the stream now flowing in it, and it appears as if it might once have been occupied by a stream with considerably greater volume. However, as Otter valley lies almost parallel with the direction of movement of the continental ice-sheet, and was itself also occupied, probably for a great length of time, by a valley glacier, the width of the valley may be partly due to glacial erosion.

A well defined valley, which may have been a former channel of the Tulameen river, starts from near Siwash creek on the north side of Tulameen river and runs across Eagle creek to Murphy lakes, and thence eastward to Bear creek and back again to Tulameen river near Slate creek. This old valley passes around and to the north of the body of peridotite through which the river cuts. It is covered largely with glacial debris, and even if it did not once carry the water of the Tulameen river it was certainly occupied and modified by a branch of the Tulameen Valley glacier.

Another, and a much more clearly defined, old valley leaves the main Otter valley about the middle of Otter lake, and, running southeast from here behind Otter mountain, joins the Tulameen valley at the mouth of Cook creek. This valley is broad and U-shaped, and has evidently been occupied by the Otter Valley glacier and modified thereby. It is now filled with a thick deposit of gravel and debris, which has been carved into benches and terraces by post-glacial stream action.

Grades.—Of the two main valleys which traverse the district, Otter valley has almost a true north and south trend, while the Tulameen is approximately east and west. Both are much alike in form because each has been operated on by the same causes.

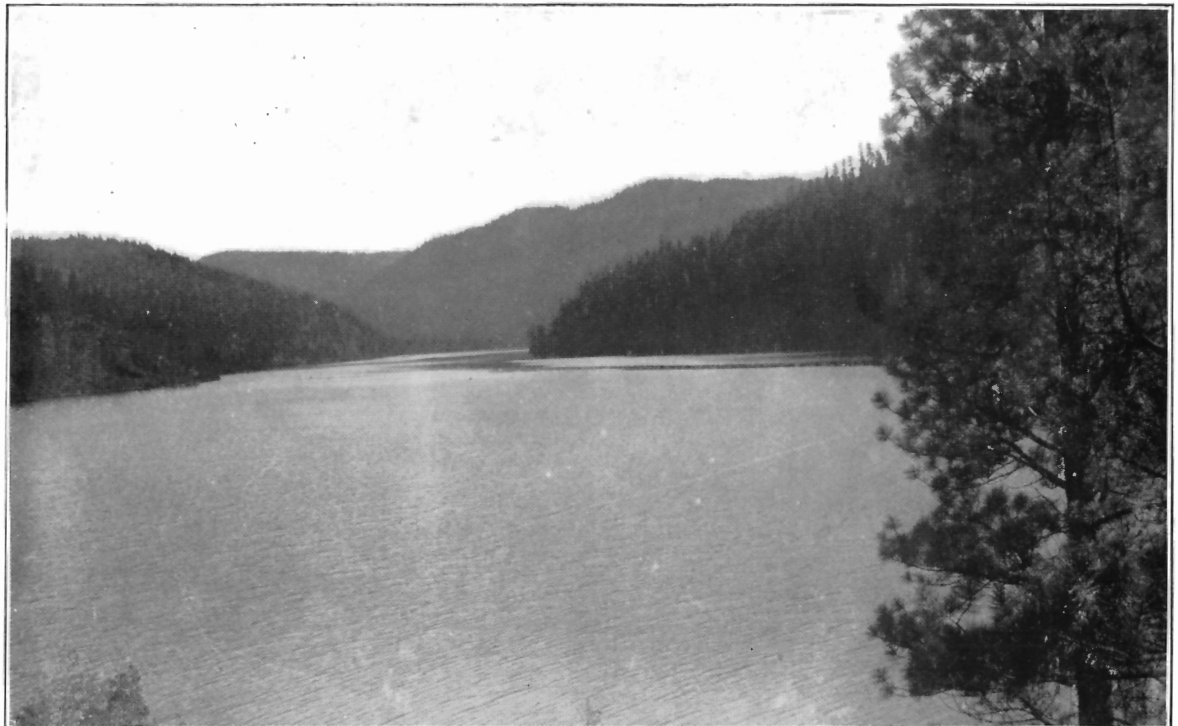
Otter valley is broadly U-shaped and trough-like, with rather steep sides and a broad, flat bottom. Its grade is exceptionally low for a mountain stream. For a distance of 8 miles north from its junction with the Tulameen it has an average grade of 12 feet to the mile. Nearly 4 miles of this distance, however, is occupied by lakes. For another 10 miles beyond the limits of the map the grade is not perceptibly greater.

The Tulameen valley from Slate creek down to the mouth of Granite creek is of the same character as Otter valley, though the bottom through which the stream meanders from side to side is perhaps a little wider and the sides higher. The grade of this portion of the valley is reckoned as 29 feet to the mile.

Above Slate creek the grade and shape of the valley change suddenly. From this point upward, virtually to its head, the grade is steeper—about 100 feet to the mile—and the stream is correspondingly rapid. The stream here occupies a narrow, steep-sided canyon cut down 200 to 300 feet into the bed of a broader open valley above. The upper valley has certainly been modified by glacial action, but the lower one has not. The upper, broad valley still shows benches of gravel clinging to its sides, while the lower canyon is too steep for the formation of any terraces.

All the tributary streams flowing into the Tulameen and Otter valleys enter through narrow V-shaped canyons in which there are often well marked falls. Falls occur on Elliot and Boulder creeks, which flow into Otter valley, and on Slate, Champion, and Siwash creeks, flowing into the Tulameen. Above the falls on the tributary streams there is generally a lessening of the gradient, and the streams occupy more broadly flaring valleys. The ultimate effect is that of hanging valleys on the above-mentioned streams. On other streams adjacent to these valleys hanging valleys are not so well developed, but virtually all of them have this feature in more or less obscure form. The scale on which the topographic map is drawn does not allow of the representation of these features very clearly.

The steepening in the grade of Tulameen river above Slate creek was undoubtedly caused by a recent post-glacial tilting which increased the erosive power of the stream. The effect of this tilting was also to produce hanging valleys in the smaller streams tributary to the Tulameen, which had not the erosive power to cut down their beds to a more uniform grade. In the case of Otter valley, however, the hanging valleys of the streams tributary to it cannot be attributed to recent uplift and differential erosion following that



Otter lake.

uplift; for, since the modification of Otter valley by glacial action there has been no uplift to cause the stream to cut down below its glacial bed; so that the hanging valleys which are tributary to it can only have been formed in the usual way, namely, by a deepening of the main valley by the scouring action of a valley glacier.

Lakes.—Occupying the bed of Otter valley are three lakes. Two of these are within the limits of the area mapped and a third—Thynne lake—lies about a mile to the north. Otter lake is the largest of these, being 3¼ miles in length and about one-third of a mile wide. Its lower end lies almost in the valley of the Tulameen river. It appears to owe its formation to damming of Otter valley by debris brought down the Tulameen valley. The grade of Tulameen river changes a short distance above the mouth of Otter valley, and, in this part, it is cutting down its bed. The material eroded out by the river in its upper part is carried down and deposited again where the gradient is not so steep—that is to say, about the mouth of Otter valley.

The same process is illustrated in the case of Boulder creek, which flows into Otter valley near the north end of Otter lake. At the mouth of this stream a fan, formed of gravel and boulders carried down by the water, has pushed out into Otter lake, so that the lake has been narrowed by nearly three-fourths of its average width. The northern end of the lake is now joined to the main body by a narrow channel, and if the Boulder Creek fan continues to build up the result will eventually be the formation of two lakes where only one now exists.

The same kind of action has produced Frembd lake. This lake lies immediately above the mouth of Elliot creek, and the material brought down by that stream has built up an alluvial fan which has dammed back the water of Otter creek to form the lake.

Thynne lake also is the result of damming, by material brought down by Thynne creek.

Two lakes known as Murphy lakes lie at the head of one of the branches of Eagle creek and in the old valley of the Tulameen, which has been before described as extending to the north of the present valley from the mouth of Siwash creek to Slate creek. These lakes are held in by morainal material, accumulated at their outlet by glacial ice.

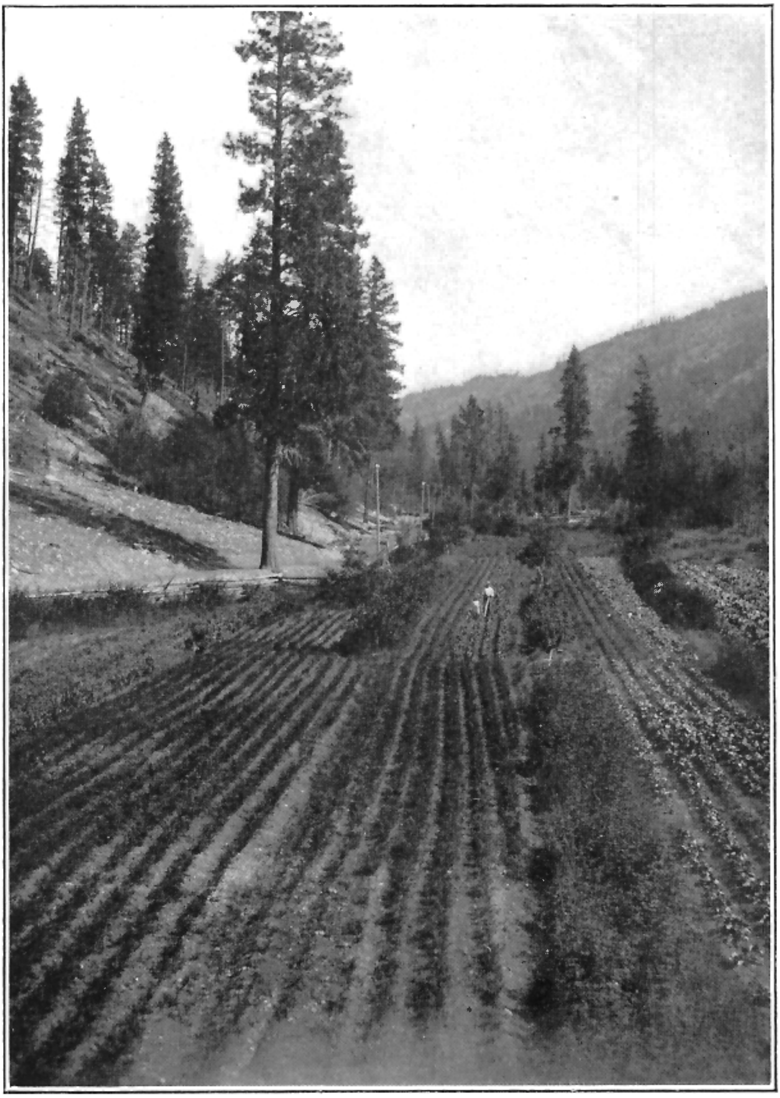
Lodestone lake on the summit of Lodestone mountain occupies a rock basin formed probably by the scouring action of the continental ice-sheet which overrode the mountain, leaving its traces in numerous striæ.

Some small ponds at the head of Bear creek near Independence camp occupy glacial cirques and mark the position once occupied by small mountain glaciers. To these glaciers the ponds owe their origin.

Stratified clays, which are presumably of lake origin, have been found in the bed of Bear creek. Their thickness is less than 20 feet, but they show that lake conditions existed in a part of the Bear Creek valley for a short time at least. The lake in which the clays have been deposited may have been formed either by landslides from the banks of Bear creek itself, or by a damming of its outlet by the Tulameen Valley glacier.

Climate and Agriculture.

The whole of the southern portion of British Columbia, lying along the eastern base of the Coast ranges of mountains, has a drier climate than most of the rest of the Province. Going westward into the Coast ranges from the Interior Plateau region the precipitation becomes progressively greater and greater until the actual coast line is reached, where the annual rainfall is as much as 100 inches and frequently more. In the belt immediately north of the International Boundary line, the region of minimum precipitation, where only about 10 inches of water fall annually, lies about 20 or 30 miles east of the Tulameen district. Going westward into the Cascade mountains the annual precipitation increases until a maximum of about 70 inches is reached on the western slope of the range. On the eastern slope of these mountains and in the plateau region immediately adjoining, where the Tulameen district is situated, the annual precipitation varies, in different years, from 20 to 40 inches. Most of this falls in the winter months, as snow, and in the spring months, as rain. In the winter months snow often accumulates in portions of the western half of the area to a depth of 10 or 15 feet, while in the summer July and August frequently pass without a single shower of rain.



10015—p. 28. Garden in Otter valley.

Temperatures in the Tulameen district are, on the average, lower than in the Similkameen and Okanagan valleys, to the east, or in the Fraser River valley to the west; the summer temperatures do not rise as high as they do in these valleys and the winter temperatures are somewhat lower. Neither summer nor winter temperatures, however, are extreme, and the climate is rather to be characterized as moderate, with an average temperature for the year of about 45° F.

Agricultural land in the district is limited to the bottoms of the main valleys. The rest of the district is not adapted for agriculture, since on account of its elevation frosts are liable to occur in it in every month in the year. The whole of Otter valley as well as the lower part of Tulameen valley is taken up in homesteads, on which vegetables and various kinds of garden produce are raised to a limited extent. The average elevation of these valleys above sea-level is about 2,500 feet, and even at this height summer frosts are so frequent that farming cannot be said to be a distinct success.

The upper limit of agriculture is not constant throughout the whole of the Interior Plateau region, but is dependent largely on local conditions. Experience has shown that in the Princeton district to the west and the Kamloops district to the north of the Tulameen area the upper limit for the cultivation of wheat lies at about 3,300 feet above sea-level. Both the Tulameen and Otter valleys, within the limits of the map-sheet, are well below this level, yet wheat cannot be grown successfully in them. At the same time the lower portions of the plateau region are often exempt from frosts, which kill everything in the valleys below.

Fauna and Flora.

The district cannot be said to contain a great variety of the larger game animals. The mule deer is fairly abundant in the region about the headwaters of Granite creek, and this region was formerly a favourite resort for Indians from the lower Similkameen valley and Nicola lake during the hunting season. These animals now appear to be decreasing somewhat in numbers. The black bear is not uncommon, and the grizzly is found in the mountains to the west. Neither mountain sheep nor goat are found within the area covered by the map-sheet, though goats have been seen in the mountains a few miles to the west and sheep in the neighbourhood of the International Boundary line to the southeast. Work done by beavers is frequently met with in Otter valley, and it is noticeable that these animals have been increasing in numbers throughout southern British Columbia ever since the killing of them was prohibited by law. Coyotes are quite common, and wolves are infrequent. A few marten and lynx are caught by trappers during the winter. Blue grouse, ptarmigan, willow grouse, and Franklin grouse are common in certain localities.

Yellow pine, Douglas fir, jackpine, and white spruce are the commonest trees throughout the district, while poplar, birch, and cedar are less abundant and are found only in the lower levels.

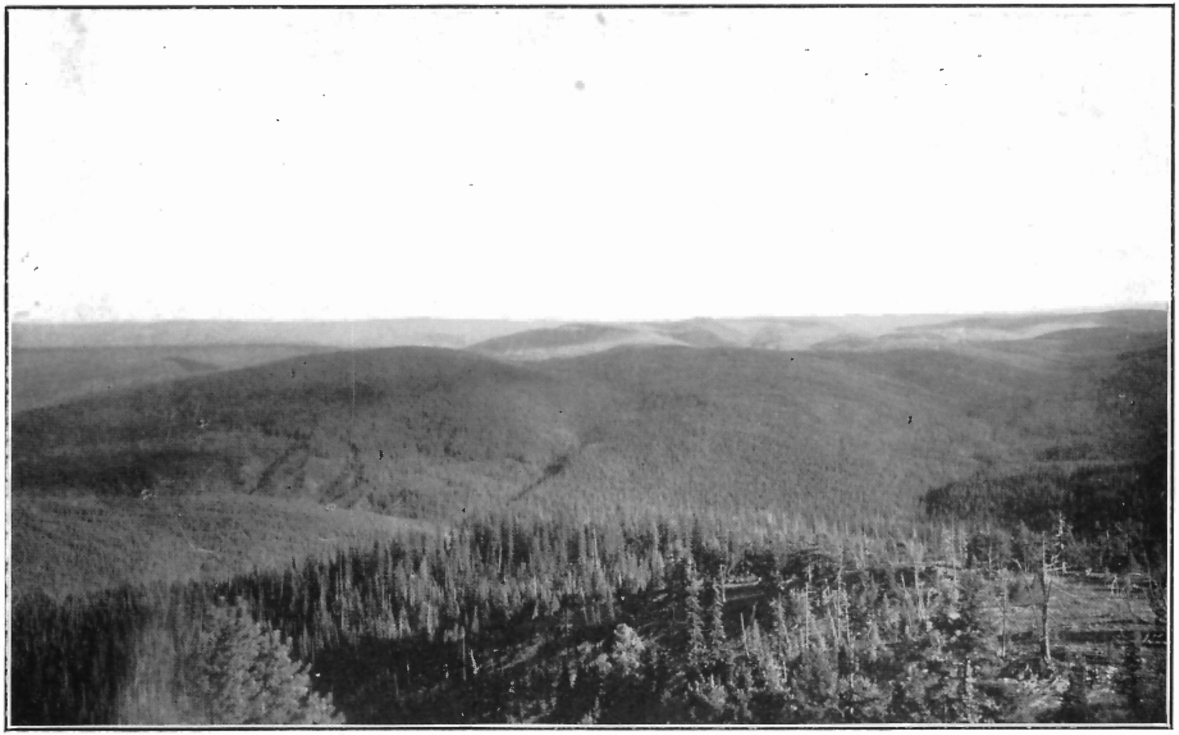
Bunch grass which is so wide-spread over a great part of the Interior plateau is only found in the Tulameen district in a few places. Pine grass, however, is plentiful, and there are a few natural meadows where hay is annually cut and stacked for winter use. Horses as a rule do not winter out in the district, but are usually sent down the valley to Princeton, or northward to the Nicola ranges.

Inhabitants.

No Indians now reside permanently within the limits of the area mapped, though, during the season a few hunters from the Okanagan tribe to the eastward and the Nicola tribe to the north visit in pursuit of deer. Probably not more than a dozen white men within the district are engaged in agricultural pursuits and live permanently on their ranches. The rest of the population is interested, either directly or indirectly, in the mining industry, and many of them only remain in the district during the summer season.

Transportation and Communication.

Previous to the construction of the Vancouver, Victoria, and Eastern railway the Tulameen district could only be reached by means of wagon, either from Nicola lake to the north or from Princeton to the east. A trunk wagon road was built about 10 years ago between these two points, and a stage carrying mail and passengers travels through once a week in each direction. When



Forest in Bear Creek valley.

10015—p. 30.

the railway reached Princeton a daily stage was put on from Princeton to Tulameen, but connexion with Nicola is still only made once a week.

Two pack trails, that were at one time much used and kept in good repair, connect Tulameen with the village of Hope on the main line of the Canadian Pacific railway. One of these follows the Tulameen river almost to its source and then turns westward across the Hope range to the Coquihalla river and continues down that stream to its mouth. The other strikes southward from Tulameen village across Lodestone mountain and joins the old Dewdney or Hope trail on the Skagit river. Both of these trails are now quite impassable for horses, and they are rarely used even by travellers on foot.

The easiest way to enter the district at the present time is by the Vancouver, Victoria, and Eastern railway, which follows the Similkameen valley as far as Princeton, and which connects with branches of the Canadian Pacific railway at Midway in the Boundary district. This railway when finished will run through Tulameen, Otter, Coldwater, and Coquihalla valleys to the Fraser valley at Hope.

An alternate means of entry to the district is to take a branch of the Canadian Pacific railway to Nicola lake, from which point the Tulameen can be reached in a drive of one day.

Within the Tulameen district itself roads are not numerous. Besides the main wagon road which follows the Tulameen and Otter valleys, there are shorter wagon roads up Granite creek to Holmes ranch, and from Tulameen village to Laws camp on Bear creek. Other roads are merely pack trails, radiating in all directions from Tulameen village to the different mineral prospects, and these are maintained generally by a government grant, or in some cases by the prospectors themselves.

CHAPTER IV.

GENERAL GEOLOGY.

General Statement.

REGIONAL.

The Tulameen district forms a small part of a larger geological province which is bounded on the east by the Okanagan valley and on the west by the Fraser river. These two topographical features correspond closely to two of the strongest geological units that are found in the southern and western parts of British Columbia, on the one hand the old Pre-Cambrian series of rocks and on the other the great Coast Range batholith. The other boundaries of this geological province are not sharply defined; they stretch far to the south of the International Boundary line and northward into central British Columbia. These limits are very wide, and in the north enter into little known territory, therefore the description of the geology of the region of which the Tulameen forms a part, will be restricted to the portion north of the 49th parallel of latitude and south of the Thompson river.

This district thus outlined lies to the west of the British Columbia Pre-Cambrian axis which is represented by the old Shuswap series found on the eastern shores of Okanagan lake and north and east of that lake. The Shuswap series consists of gneisses and crystalline schists, which form the basement on which all the sedimentary rocks of the region were laid down.

The middle Cambrian transgression of the sea was so general over a great part of the North American continent, that it is quite possible all of this region may have been at one time covered by Cambrian sediments. None, however, are now found, except in the extreme northeast portion of the region, in the neighbourhood of Shuswap lake.

Following the Cambrian sedimentation the region west of the Pre-Cambrian axis was elevated above the sea, and from that time to the close of the Devonian period the whole of the region was undergoing erosion. No igneous action is recorded in this length of time.

During Carboniferous times the region was again depressed and the sea came in from the west. Sedimentation was accompanied by vulcanism, and at least 10,000 feet of stratified rocks consisting of limestones, argilites, some quartzites, and much volcanic material were laid down. These constitute the Cache Creek group, and though once of great areal extent, they have been so intruded and covered by later igneous and sedimentary rocks that they now outcrop only in small patches.

The unconformity which exists in most parts of the continent between Palæozoic and Mesozoic rocks probably holds for this region also, though Dawson obtained some evidence which led him to suspect a complete transition from one to the other. Whether such an unconformity exists or not we have no direct evidence in this region, and it is quite possible that sedimentation continued, without a break, from Carboniferous through to the end of Triassic.

Like the Carboniferous, and for a similar reason, the Triassic rocks now occur only in small patches, though they once had a wide distribution. Areas of these rocks, however, are found here and there, notably in the Tulameen district itself and in the vicinity of Nicola lake, the locality at which they were first described and from which they obtain the name Nicola series. They consist mostly of volcanic materials with which are interbedded some true sediments.

The period between Triassic and Cretaceous is remarkable all over western British Columbia not only for great orogenic disturbance, but also for the number and size of the batholithic intrusions that are known to have taken place in it. Plutonic rocks of this age have a wide distribution in this region, and if the whole were geologically mapped their area would probably prove to be much greater than that now credited to them. They consist of granites, granodiorites, syenites, monzonites, and even some peridotites and pyroxenites.

Since the Jurassic revolution, which closed the period of Triassic sedimentation and vulcanism, this region has never been completely covered by the sea, but more or less of it has been continuously exposed to erosive agencies.

Cretaceous rocks of sedimentary origin, containing material derived by erosion from the older sediments and plutonic rocks, were laid down in an intra-montane geosyncline, and now form a band extending from the head of the Pasayton river northwestward to the sources of the Tulameen river. Patches of these rocks are also found in the valley of the Fraser river, northward on the same strike as the first mentioned band. They consist of sandstones, conglomerates, and shales dipping at moderately high angles.

Another great unconformity intervenes at the close of the Cretaceous—between it and the Tertiary period following. The revolution, however, which produced the unconformity was not as strong in this part of British Columbia as it was in the eastern half of the Province.

Some batholithic intrusion probably followed the disturbance at the close of the Cretaceous, and certain granodiorites on the Similkameen and Ashnola rivers are referred to this period.

The sequence of events in the Tertiary history of this region has not yet been clearly worked out. It is known, however, that sedimentation during that period played a minor part, while vast outpourings of lava characterize nearly every portion of it.

The Tertiary sedimentary rocks are all of Oligocene age, and occur in isolated basins of limited extent. Such basins are found at Princeton, Granite Creek, Nicola, and a few other places. They contain conglomerates, sandstones, shales, and coal seams, and are referred to as the Coldwater series. At Granite Creek some volcanic rocks are interstratified with the basal members of this group.

A minor, but quite distinct, unconformity separates the Oligocene rocks from those above them. The erosion period responsible for this unconformity was probably accompanied by the eruption of at least one plutonic igneous body, which has strongly marked, alkaline affinities.

Volcanic rocks of a prevailingly andesitic composition were extruded in great quantity during early Miocene times, and they now cover an enormous area. In the later Miocene other volcanic rocks were extruded and laid down under water, and with these some true sediments are associated. These sediments are referred to as the Tranquille group, and are best developed in the northern part of the region.

Volcanic rocks of basaltic character are the youngest of the consolidated formations. They rest unconformably on Oligocene sediments and still preserve an almost horizontal position. They have a wide distribution in the northern parts of the region, but are not so wide-spread to the south.

Dykes, ranging in character from acid granite porphyries to basic lamprophyres and diabases, are numerous throughout the whole region; and over these and all of the above-mentioned rocks lies the glacial drift.

LOCAL.

The oldest rocks in the Tulameen district are those of the Tulameen group. They are tentatively correlated with Dawson's Nicola series which is of Triassic age. These rocks are mostly of volcanic origin, and because they are interstratified with some argillites and thin beds of limestone are thought to have been laid down under water. Some plant remains have been found in the argillites, but they are too fragmentary to be identified. These rocks have been greatly altered both by regional and contact metamorphism, and now stand at fairly high angles. They cover the largest area of any rock formation in the district.

In the period between the deposition of the rocks of the Tulameen group and the Cretaceous, a number of igneous intrusions took place, which are probably contemporaneous with large batholithic intrusions throughout the whole western Cordillera. These igneous rocks are referred to the Jurassic period, and have been thrust through the rocks of the Tulameen group in the following sequence: (1) Boulder granite; (2) peridotite and pyroxenite; (3) augite syenite; (4) Eagle granodiorite.

These igneous rocks are now found in various parts of the district in large and small bodies all having a general north and south trend. Their combined area, within the limits of the sheet, is somewhat less than that of the Tulameen group.

Resting unconformably on top of the above-mentioned rocks are two groups of conformable rocks, which are referred to Oligocene age from the plant remains found in them. The lower of these two groups, consisting almost entirely of volcanic flows of a prevailingly andesitic composition, is called the Cedar volcanic series;

while the upper containing nothing but sediments and made up of sandstones, shales, conglomerates, and coal seams, is called the Coldwater series and is correlated with similar rocks in the Kamloops district. The rocks of these two groups cover the greater part of the east half of the area, with the volcanic portion preponderating. They now lie at angles which rarely exceed 45 degrees, and have, therefore, not been greatly disturbed since deposition.

Intrusive into the Oligocene rocks, and presumably of Miocene age, is a body of pink alkaline granite, called the Otter granite, which is found on the eastern side of Otter valley from China creek to the northern limit of the sheet. It has a length of about 9 miles and a width varying from a mile to 2 miles.

The youngest consolidated formation in the district is a volcanic flow of olivine basalt. This occurs as a circular body, in the region between Granite creek and Collins gulch, where it is seen to rest unconformably on the Oligocene sediments. It still preserves its horizontal position, and from this fact is considered to be late Miocene or perhaps Pliocene in age.

Dykes of a composition ranging from granite porphyry to olivine diabase are very common in the district, and cut principally the pre-Oligocene rocks.

Stream deposits cover the floor of Otter valley and the lower part of the Tulameen valley. Above the mouth of Slate creek, however, in the Tulameen valley, and in the tributary valleys, stream gravels are not very abundant, and are found merely in patches here and there.

Glacial material is irregularly distributed over the whole of the district, having been accumulated to considerable extent in some parts, while in others it appears only as a thin veneer.

Table of Formations.

Period.	Special Name of Formation of Group.	Character of Rocks.
Quaternary	....	Stream deposits Glacial material.
Post-Oligocene probably Miocene	.... Otter formation..........	Olivine basalt. Granite.
Oligocene	Coldwater series......... Cedar volcanic series.....	Sandstone, shale, conglomerate. Andesites, breccias, etc......
Jurassic	Eagle formation.......... .... Boulder formation........	Granodiorite. Augite syenite. Pyroxenite. Perodotite. Granite.
Triassic ?	Tulameen group..........	Volcanic rocks, limestones, and argillites.

Tulameen Group.

DISTRIBUTION.

The rocks of the Tulameen group cover a larger area in the Tulameen district than any other individual formation, and almost as large an area as that covered by all the other formations together. They are the oldest rocks in the region, and at the time of deposition probably covered the whole area included in the map-sheet. Their volume, however, has since been decreased by the intrusion into them of several igneous bodies, and their outcropping area diminished by having younger stratified rocks superposed on them. By these means their surface distribution has been reduced, so that they now appear on the map in three main bodies, completely separated from each other by other formations.

The largest of the three bodies occupies the central and northern part of the area, and extends from Slate Creek basin northward in a gradually widening band to the northern limit of the map-sheet.

This body fills the greater part of Bear Creek basin and has a length of 10 miles and a greatest width along the northern border of the area of 8½ miles.

A second body, about 6 miles in length, lies near the southwest corner of the area mapped in the basin of Champion creek, and appears as a narrow band lying between Eagle granodiorite on the west and pyroxenite on the east.

The third body occupies the southeast corner of the area, lying in the valley of the Tulameen river below China creek, and on either slope of Granite Creek valley.

In all three bodies the rocks are as a rule well exposed, so that the limits assigned to them on the map are fairly correct.

LITHOLOGY.

The name Tulameen group, which is used to describe the oldest stratified rocks of this district, is employed here for convenience in default of conclusive evidence whereby these rocks could be correlated with other rocks whose position has been definitely fixed in the time scale. They do not constitute a well individualized group of rocks the top and bottom of which have been clearly defined, but they embrace a variety of rocks all apparently conformable with each other and laid down in one great period of geological time. They are, for the present, correlated with Dawson's Nicola series, but they may represent only a part of that great series.

The rocks of the group are so cut up by igneous intrusions, and in their broader area so covered by drift, that no good sections of them could be obtained. They are very well exposed on Bear creek, but the direction of the stream coincides so closely with the general strike of the rocks that the section does not give much information. The Tulameen river, from Hine creek down to Slate creek, gives the best natural section, but at the same time this is far from being complete.

In general the rocks of the Tulameen group consist of an enormous development of volcanic rocks, with which are interbedded one or two thin strata of limestone and some argillite.

The section exposed on the Tulameen river from Hine creek down gives the following succession of strata in descending order:—

(1) Siliceous and argillaceous schists.
(2) Andesites and porphyrites.
(3) Andesitic breccias.
(4) Chloritic and talcose schists.
(5) Banded argillites and limestone.
(6) Andesites and porphyrites.

This list embraces virtually all the known species of rocks that were found in the Tulameen group within the limits of the map.

The volcanic rocks, which form the great bulk of the group, are prevailingly dark green in colour, and the majority of them have a well developed schistose structure. In composition they are medium basic, and include andesites, porphyrites, diabases, and andesitic breccias. In these a porphyritic structure is common, the phenocrystic minerals being hornblende or feldspar. The groundmass is made up of feldspar, hornblende, and some devitrified glass and iron ores. Metamorphic processes have gone so far that much chlorite, epidote, and calcite have been developed, and the rock itself is often altered to a chlorite schist.

The sedimentary rocks include limestones and argillites. The limestones are dark grey or white and crystalline. The latter variety is found in the neighbourhood of igneous intrusives, and has been marbleized thereby. It contains crystals of calcite, with a small amount of quartz, and such secondary minerals as mica and epidote.

The argillites are dense black or greyish in colour, and when metamorphosed develop into mica or hornblende sillimanite schists. In places they contain some indeterminate fossil plants.

Narrow bands of quartz schist are also found interbedded in places with the sediments. Thin sections of these show rounded and irregular grains of quartz, some feldspar and flakes of mica arranged in parallel alignment. They probably originally represented clayey or impure sandstones that have been metamorphosed by dynamic action.

On account of the lack of both a top and bottom to this group of rocks, no attempt has been made to determine its thickness or the relative proportions of the different varieties found in it. Dawson's estimate of the minimum thickness of the Nicola series[1]

[1] G.S.C. Annual Report, Vol. VII, page 54 B.

in the type locality at Nicola lake is 7,500 feet, and on the Thompson river south of Ashcroft over 13,000 feet. The volume of the sediments in this series is not more than two per cent of the whole, and in the Tulameen group the percentage of sediments is probably about the same.

STRUCTURAL RELATIONS.

Internal.—The age of the Tulameen group is believed to be Triassic, or possibly even earlier, and its present structural features are a record of events that took place in the geological history of the region since the deposition of its rocks. Since the close of Cambrian times the events which have had the greatest influence on the rock structure of the western Cordilleran region happened during the close of Triassic and succeeding times, so that at the present time we find Palæozoic rocks not much more greatly deformed than those of early Mesozoic. The rocks of the Tulameen group show strong evidence, in their attitude and structure, of those disturbing influences.

The rocks are well bedded, and their dips vary from 25° up to 90°, with a great many more instances of the latter than of the former.

The main strike of the rocks is slightly west of north, coinciding with the elongation of the eruptive rocks and with the mountain axes of the adjacent region. Many discordant dips are recorded, including a strong one almost at right angles to the main one; indicating that compression was not always exerted from the same direction, but that there were two strong movements at right angles to each other. These two conflicting directions of compression have produced a complication of structure which is very difficult to work out, though generally the rocks are found folded into anticlines and synclines whose axes run normal to the two main directions of compression.

Some faulting has also occurred either as a result of compressive forces or as an accompaniment to the intrusion of the various batholithic bodies that have been thrust into these rocks.

Besides folding and faulting, schistosity is a well developed structural feature of the rocks of the Tulameen group. This appears to be more a result of contact than regional metamorphism, for it is clearly more pronounced in the vicinity of the large igneous bodies than it is outside the sphere of influence of these bodies. Regional metamorphism, however, must have produced some schistose structure at the time the rocks were folded and before the intrusion of the Eagle granodiorite, for the large blocks of rocks of the Tulameen group, included in the granodiorite in the contact zone, show that schistosity had already been induced in them before the intrusion of the granodiorite. And because the Eagle granodiorite is pre-Cretaceous in age, the date of the deformation of the Tulameen group is fixed as about early Jurassic or late Triassic—coinciding in time with the great Jurassic revolution of the western Cordillera. Some deformation of these rocks probably took place later, but it was comparatively weak in its action.

Along its contacts with the Eagle granodiorite, Boulder granite, and pyroxenite, the Tulameen group has been fractured and broken into fragments, which have been cemented together again in a matrix composed of the materials of these various igneous rocks, to form a breccia. On the contact with the Eagle granodiorite this brecciation is particularly well marked and covers a zone in places 1,000 feet wide. Another effect of these various intrusives was to send off many apophyses into the rocks of the Tulameen group, especially along bedding planes.

Contact metamorphism of the Tulameen group has accompanied igneous intrusion to an extent which varies with the composition of the intruded bed. In the limestone such typical contact metamorphic minerals as garnet, epidote, biotite, and hornblende have been developed. In places the limestones have been silicified and often mineralized with sulphides. Quartz veins in the rocks of the Tulameen group are common, on the borders, particularly, of the more acid rocks, and the majority of the ore deposits of the region are intimately associated with these intrusions. Virtually all the veins and replacement deposits of ore in the Tulameen district lie in the rocks of the Tulameen group, and have been formed as a result of intrusion into them of the large igneous bodies of the region such as granodiorite, Boulder granite, and pyroxenite.

External.—The relations existing between the rocks of the Tulameen group and those of the other formations are perfectly clear. They are intruded by all the batholithic igneous bodies of the region, and well exposed contacts can be found to prove this.

Between this group and the Cedar volcanic and Coldwater series there exists a strong unconformity, which is proved by a marked discordance of dips and strikes wherever the two come into contact. The Tulameen group must have been uplifted, compressed, and its upturned edges eroded, long before the deposition of either of the formations mentioned.

MODE OF ORIGIN.

The Tulameen group comprises two distinct classes of rocks, the one sedimentary and the other volcanic in origin.

The sedimentary rocks represent a very small fraction, in bulk, of the whole group, though the time required for their formation was probably greater foot for foot than that for an equal thickness of volcanic rock. Their origin is simply that of true sediments laid down in the usual way on the floor of the sea.

The volcanic rocks, which compose the great bulk of the group, are effusive in origin; that is to say, they 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. The texture of these rocks throughout is not so fine as to suggest very rapid cooling, such as might be developed under subaerial conditions, though some devitrified glass appears in many of them. Though there are no examples in them of that pillow structure which is considered to be characteristic of subaqueous volcanic flows, this structure may have been present and afterwards obliterated in the process of deformation of the rocks.

AGE AND CORRELATION.

The actual age of the Tulameen group has not yet been definitely fixed, because of the absence of good palæontological evidence. Its relative position, however, in the table of formations of this district is perfectly clear, for it is intruded by all the igneous rocks, and overlaid unconformably by all the stratified formations. It is, therefore, the oldest group of rocks within the limits of the map.

Although the great bulk of the rocks of the group are volcanic in origin, there are also included with them a small proportion of true sediments. These were carefully examined for fossils, but only in one place—namely, near the mouth of Slate creek—were any obtained. In the argillites of this place some long, bladed, plant-like remains were found, but were too incomplete to be of much use as evidence in the determination of the age of the rocks.

This material was submitted to Dr. F. H. Knowlton, of the United States Geological Survey, for determination, who states that it 'is very obscure and embraces not more than two types of vegetation. These are: (1) a thick, structureless stem of unknown character, and (2) a flat-leaved plant that has the appearance of being dichotomously branched and consequently to belong to the genus Baiera, but it is very obscure. It seems altogether probable that this collection should be referred to the Triassic, but the evidence for such reference is neither complete nor adequate. It does not suggest the Cretaceous, and as the choice appears to lie between these horizons it is most probably the former—namely, Triassic.'

Lithological characters, and the relative position of these rocks in the region were the main available criteria on which to base an estimate of age. The enormous preponderance of volcanic materials, together with the small proportion of interbedded sediments, suggested their correlation with Dawson's Nicola series. Again, not more than 8 miles south of the southeast corner of the area, on Whipsaw creek, Dawson,[1] in 1877, found Triassic fossils in rocks which are lithologically similar to the Tulameen group, and have the same general strike and attitude.

The only other group of rocks in the adjacent country, with which the Tulameen group might be correlated, is the Cache Creek group, but their lithological dissimilarity to this group made this correlation unsatisfactory. It was, therefore, concluded, though the

[1] G.S.C. Report of Progress, 1877-78, page 66 B.

evidence at hand was slight, to correlate the Tulameen group with the Nicola series.

The evidence of the age of the Nicola series is mainly palæontological and is fairly strong, and in summing up this evidence Dawson states [1]"that while the great bulk of the Nicola formation is undoubtedly equivalent to the Triassic, it passes up in a few places into rocks of lower Jurassic date.'

Boulder Granite.

DISTRIBUTION.

While the texture of the Boulder granite formation is such as to suggest that it was originally a body of considerable magnitude, its present area is scarcely 6 square miles, and part of this is covered by the stream deposits of the Tulameen and Otter valleys. Its present form is that of a large dyke roughly 6 miles in length and averaging about a mile in width. It extends from the mouth of Elliott creek southward along the west side of Otter valley to the Tulameen valley, where it is largely covered by recent stream deposits; but a number of outcrops appearing through these stream deposits, as far down the Tulameen valley as the mouth of China creek, suggests that it may be found to extend continuously under the drift to this point.

It is not likely that the Boulder granite formation ever extended much farther to the west than the limits ascribed to it on the geological map, and certainly not where it is in contact with the rocks of the Tulameen group. Along the greater part of its eastern boundary, however, it is in contact with the Otter granite formation, and it is quite possible that that granite has reduced the area of the Boulder granite by intrusion into it. Volcanic flows of later age, occurring to the southwest and east of the Boulder granite, may also cover part of its area.

The Boulder granite nowhere abuts against the Eagle granodiorite, but is separated from it by a width of about 6 miles, all of which distance is occupied by older rocks of the Tulameen group.

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[1] G.S.C. Annual Report, Vol. VII, p. 51 B.

LITHOLOGY.

As seen in hand specimens the typical rock of the Boulder granite formation is rather coarse grained and granitic in texture. It shows much glassy quartz in large crystals, pink feldspar, and a little black hornblende. There is a strong greenish tinge to the rock due to the alteration of the feldspar and the development of epidote. Crystals of pyrite can frequently be seen in the hand specimen. The rock is often traversed by small quartz veinlets, and along fracture planes—of which the rock is full—there is a strong development of chlorite, epidote, and other secondary minerals. Biotite is very rarely seeen in the hand specimen, and in this respect the Boulder granite differs from the Eagle granodiorite in the field in that the latter has biotite as the principal ferro-magnesian mineral, while the former has hornblende or its alteration products.

Thin sections of the Boulder granite show a rock of fairly coarse but even grain. The predominant constituents are quartz and orthoclase. These two minerals often show a micrographic intergrowth, but more commonly the feldspar is idiomorphic towards the quartz. The quartz is clear and glassy, and occurs in large individuals or in aggregates of small grains. It is frequently fractured, and the fractures are filled with secondary calcite or quartz. The orthoclase is in large crystals, which are always cloudy and show decomposition to flakes of mica and grains of epidote. A little plagioclase is usually present in small individual crystals. The principal dark mineral is hornblende, which, however, is never fresh, but shows alteration to a green pleochroic chlorite. Epidote is generally present with the chlorite as an alteration product of the hornblende. When biotite is present, which is rare, it is generally altered to chlorite and magnetite.

The accessory constituents are apatite, titanite, magnetite, and pyrite. Calcite is a common secondary constituent, which with quartz occurs as a later infiltration of fracture planes. The alteration products are epidote, chlorite, and mica.

As a rule the normal order of crystallization prevails in the Boulder granite rock, but in some cases the quartz and orthoclase have crystallized together with the development of a micrographic structure.

In the development of chlorite, epidote, and mica, the rock shows considerable metamorphism. Dynamic stresses are also shown in the broken crystals and in the formation of many small fractures. Gneissic structure, however, is never apparent.

A sample taken from Collins gulch and analysed in the laboratory of the Mines Branch by M. F. Connor gives the following chemical composition:—

SiO_2	73·16
Al_2O_3	12·78
Fe_2O_3	1·43
FeO	1·20
MgO	0·55
CaO	2·00
Na_2O	3·84
K_2O	3·08
H_2O+	0·87
H_2O-	0·06
TiO_2	0·30
P_2O_5	0·15
Mn.O	trace.
	99·42

The analysis shows the rock to be a fairly normal granite without any striking peculiarity. In comparison with an average granite its silica is a little high and its alumina and iron a little low, but in other respects it is quite normal. In composition it resembles closely many granites from various parts of the continent, but perhaps its closest parallel is a rock called micrograuite from Mariposa, California, described by H. W. Turner.[1] The analysis also is strikingly like the rhyolites and obsidian described by Iddings[2] from the Yellowstone National Park.

According to the Quantitative Classification of igneous rocks, this rock is a lassenose.

STRUCTURAL RELATIONS.

Internal.—For the reason that the Boulder granite is one of the oldest rock bodies in the district and has suffered erosion for a great length of time, it does not form prominent topographic features and, except where cut into and exposed by the streams, it is generally covered with drift.

Wherever exposed, it shows evidence of having suffered deformation and metamorphism either from dynamic forces or as a result

[1] U.S.G.S. 17th Annual Report, Part I, page 721.
[2] Bull. Phil. Soc. of Wash.: Vol. 12, page 204.

of intrusion by later igneous bodies. Even where it is not in direct contact with later igneous rocks, the granite is fractured and sheared and in thin section it shows strained and broken crystals. These fracture planes run in all directions, but mainly in a general north and south direction.

Where the Boulder granite is in contact with younger igneous rocks, such as augite syenite at the mouth of Otter creek, it is still more fractured and deformed. Slickensided faces are common, and in these there is a strong development of epidote. Quartz veins and small calcite stringers are also quite common, but these are generally barren or are only slightly mineralized by pyrite.

As a result of the metamorphic agencies to which the rock has been subjected, fresh, unaltered samples are almost impossible to obtain, but in all there is a strong development of epidote, chlorite, and other secondary minerals.

Except on some of its contacts, the Boulder granite is remarkably uniform throughout, in composition and texture. On its contacts, however, with the rocks of the Tulameen group, it generally contains many inclusions of those rocks.

External.—The only rock formations with which the Boulder granite is in contact are the Tulameen group, the augite syenite, and the Cedar volcanic series. Its relations to these formations, however, furnish sufficient evidence to fix its relative position in the geological column of this district.

At Elliott creek, Smith creek, Boulder creek, the head of Riddell creek, and at Collins gulch the contact of Boulder granite with the Tulameen group is well exposed. At all of these points the granite is clearly shown to be intrusive into the rocks of the Tulameen group. All the contacts show it to contain inclusions of the rocks of the Tulameen group, while on Riddell creek apophyses of the granite penetrate the same rocks. Quartz veins are quite frequently formed at these contacts in the rocks of the Tulameen group. Contact metamorphism and replacement by silica is also often apparent in the intruded rocks. Only occasionally are the quartz veins mineralized sufficiently to form ore bodies, but more often the phenomena of replacement have been accompanied by a mineralization by iron and copper sulphides, forming ore bodies with fairly high gold and silver contents.

The relation of the Boulder granite to the augite syenite is not so well shown. At the mouth of Otter creek the two formations approach very near to each other though the actual contact is not exposed. The relation can only be determined by the effect which the one rock has on the other. While the augite syenite is apparently quite unaffected, the Boulder granite is fractured, slickensided, and cut by a number of small quartz stringers. A slight mineralization by pyrite and chalcopyrite is also evident. This evidence seems to show that the augite syenite is intrusive into the Boulder granite.

The only other rock formation with which the Boulder granite is in contact is the Cedar volcanic series. The actual contact is not exposed, but outcrops of the two rocks occur within a few feet of each other on the benches west of Tulameen village. Here it appears as if the lowest bed of the Cedar volcanic series had flowed over the eroded surface of the Boulder granite, inducing a slight contact metamorphism and giving it the oxidized and burnt appearance that it now has all along this contact.

MODE OF ORIGIN.

Although the size of the Boulder granite formation is not now such that it is worthy of the name of batholith, its contacts with the older rocks of the Tulameen group give evidence that its origin was not unlike that of a batholithic body. Its area may, however, have been considerably greater at one time than it is now. These contacts show angular blocks of the intruded rocks incorporated in the body of the granite, suggesting that the granite worked its way upwards in a molten state from the depths of the earth, stoping off fragments of the intruded rock and replacing it gradually and quietly, until it attained its present size and position, where it solidified. While this process was in operation apophyses were being sent off into the intruded rocks, which also solidified and now appear as granite porphyry dykes. The intrusion was accompanied by highly heated siliceous emanations from the molten rock, which went to form the quartz veins or were instrumental in forming the replacement ore bodies which occasionally—as at Boulder creek—border the Boulder granite formation.

AGE AND CORRELATION.

As the age of an igneous body is determined almost entirely by its contacts with rocks of known age, the evidence for fixing the age of the Boulder granite intrusion is very slight. We know it is intrusive into the rocks of the Tulameen group, but the age of the Tulameen group has only been provisionally placed in the Triassic from its lithological resemblance to the Nicola series of Dawson, which contains Triassic fossils. On this evidence and because it is older than the augite syenite and the Eagle granodiorite, which are pre-Cretaceous, the age is determined as early Jurassic.

The Boulder granite, then, if the age ascribed to it be the correct one, represents in the Tulameen district the beginnings of batholithic intrusion in the Jurassic period, a period that is remarkable throughout the whole of the western part of the continent for the magnitude of its igneous activity and the variety of the rocks resulting therefrom.

Peridotite.

DISTRIBUTION.

Two separate bodies of peridotite have been outlined on the Tulameen map. Both lie in the southwestern portion of the area and are closely associated with pyroxenite. The smaller one of these two bodies lying on the northeast slope of Lodestone mountain is dyke-like in form, being only about 500 feet in width but having a length of a mile and a half within the limits of the map-sheet. It is quite probable that this body extends some distance beyond the southern border of the map-sheet, and is cut through by the upper branches of Newton creek. It strikes northwest and southeast and is bordered on both sides by pyroxenite. The north end of this body is well exposed, but towards the south it is covered by drift and thick forest, so that its outlines could not be accurately delimited.

The larger body of peridotite has an area of 2·8 square miles and extends from Olivine mountain northwest across Tulameen valley to Grasshopper mountain. The total length of this body is almost 2½ miles, while its width varies from half to a little more than a mile. The strike of the body is directly across that of Tulameen valley, and this stream divides it into two almost equal parts.

The rocks are well exposed and, except that the contact line with the pyroxenite is never sharp or clean cut, the boundary line is fairly closely defined. The northwest end of this body is heavily covered by drift, and it is only on this contact that the boundary line might be pushed farther out.

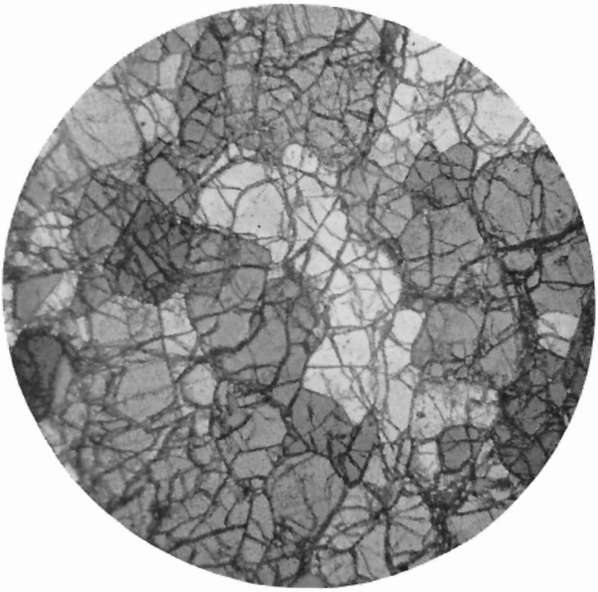
LITHOLOGY.

Throughout the main body of the peridotite area there is remarkable uniformity of mineralogical characteristics, which simplifies the description of this formation. On the outer edges of the body, however, variations are noted in the mineral constituents which mark a transition through intermediate stages into true pyroxenite. There is no sharp line of demarcation between the peridotite and pyroxenite formations, and the transitory stage between the two, while generally about 100 feet in width, is often much more than this. The boundary line between the two formations is placed on the peridotite side of this transition belt, or where the peridotite begins to show enough pyroxene that this mineral becomes more than an accessory constituent and is an essential. Beyond that the rock becomes an olivine bearing pyroxenite, until, losing its olivine entirely, it passes into a true pyroxenite.

Over a great part of its area the peridotite has been altered to serpentine, and this on a fresh fracture shows a black or dark greenish colour. No crystalline structure is here apparent, but the rock is massive and dense. In a few places the peridotite is quite unaltered, and shows a compacted mass of olivine grains and a few scattered crystals of chromite.

On the surface the peridotite exhibits a dun or a bluish-grey colour, but this colour only penetrates the rock for one inch or less. It weathers to spherical shapes and breaks down to a talus of small shaly fragments.

Besides olivine the only other visible constituent is chromite, which occurs either in distinct individual grains or in short irregular veins and bunches. These veins vary from one-eighth to one inch in width and rarely run more than a few feet. Both the veins and bunches are found only in restricted areas, while the



Microphotograph of fresh peridotite, composed entirely of olivine grains; crossed nicols.

individual grains are more widely disseminated through the mass of the rock.

Mineralogical study of the chromite by Mr. R. A. A. Johnston has revealed the fact that diamonds, platinum, and some gold are associated with it in the veins and bunches.

In its serpentinized parts the peridotite formation is frequently traversed by small veins of asbestos, which are, however, never more than one-half an inch in width. In these veins the fibre runs perpendicularly to the walls, as is the common habit in serpentine bodies. They are not found everywhere throughout the formation or even throughout the serpentinized portions, but appear to be restricted to certain areas, presumably where some weakness occurs in the rock. These veins weather reddish-brown, doubtless from the decomposition of the associated chromite. Along lines of jointing or fracture it is often noted that a scale of green hornblende forms to a depth of about one-fourth of an inch. This hornblende is probably tremolite, and occurs in radiating bundles of thin fibres of a light greenish colour. The variety of serpentine known as picrolite is also frequently observed along lines of dislocation in the rock. This mineral is also light green in colour, has a smooth feel and a fibrous structure. The fibres, however, are brittle, and in distinction to the soft flexible fibres of asbestos, run parallel to the cracks in which they are found.

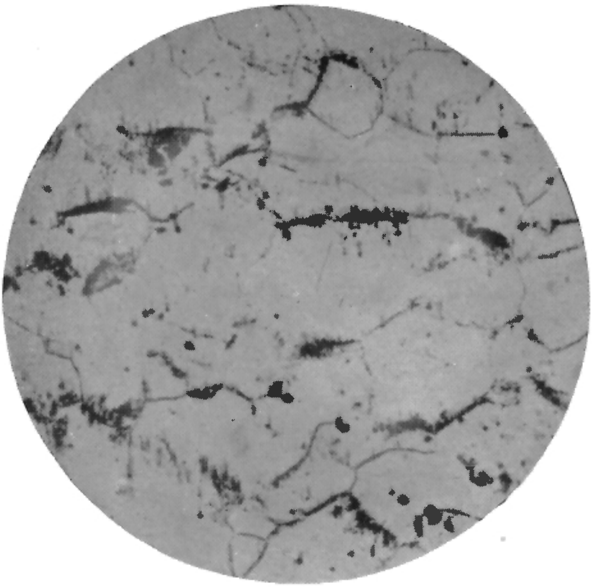
In certain places—notably in the bed of the Tulameen river immediately below the mouth of Eagle creek—the peridotite appears to show a brecciated structure; but on closer examination this is merely a pseudo-brecciation, and the structure has been induced solely by the alteration of the rock to serpentine along irregular lines, which leaves blocks of unaltered peridotite, corresponding to the fragments in a breccia, in the areas between the lines.

The extreme stage of metamorphism of the peridotite is reached along certain lines of dislocation where the rocks have been altered to a soft friable mass of yellowish magnesite and scales of glistening mica.

In the thin section every sample taken shows some degree of alteration to serpentine and none show entirely fresh olivine. In all the sections examined only two minerals are present—olivine and chromite. Where the rock has not been completely serpentinized, the olivine appears in rounded grains, separated from each other by irregular lines of serpentine. Where alteration has been extreme nothing remains but a dense mat of serpentine fibres. Chromite is an abundant accessory mineral, and occurs in large crystals scattered through the sections, or else in rounded grains which are strung out in lines following the veins of serpentine. When complete alteration of olivine has taken place to serpentine these strings of chromite grains remain to mark the original lines aiong which serpentinization first began.

The above petrographic description covers the major part of the peridotite formation, and according to it, the rock is classified in the Rosenbusch system as a dunite. On the borders of the formation, however, the peridotite passes by a gradual transition into pyroxenite, and the first indication of this change is marked by the presence of augite. In passing towards the pyroxenite the augite gradually increases in proportion as olivine decreases, until the olivine is eliminated altogether. This zone is characterized generally by a development of abnormally large augite crystals. Crystal faces of augite, which are 4 inches in length and half that width, can often be seen glistening in the sun. These are embedded in a ground of greenish olivine in small crystals. There is also abundant iron ore—either chromite or magnetite. The thin section of this phase of the formation also shows occasional crystals of brown biotite. The large augite crystals are here very fresh and show no inclination to alter to hornblende, as they so frequently do in the main body of the pyroxenite. These crystals contain many inclusions of ilmenite in long narrow blades symmetrically arranged with their longer axes at angles of 60° with each other.

Dyke forms of the peridotite formation, which appear to be aplitic phases of the same magma, are found in many places. They are generally only a few inches wide and appear to fill cooling cracks in the peridotite. In hand specimens they resemble pyroxenite more than the peridotite, but thin sections show them to contain much olivine, and to be similar in composition to the outer contact phase of the peridotite. They contain both augite and olivine in varying proportion, sometimes the one and sometimes the other being in excess. Biotite is always present, but in very limited amount; and the iron ores, magnetic and chromite, are either inter-



Microphotograph of serpentinized peridotite; areas of original olivine outlined by grains of chromite.

stitial or along lines of alteration or dislocation. Serpentine and magnesite are the alteration products. From their constituents these dykes would be classed as picrites.

Chemical analyses of two samples of rock from this formation are given below. No. 1 was collected by the author and analysed by M. F. Connor in the laboratory of the Mines Branch. No. 2 was collected by Prof. J. F. Kemp, and the analysis is by W. F. Hillebrand, made in the laboratory of the United States Geological Survey. No. 2 is published in Bulletin 193 of the United States Geological Survey.

Sample No. 1 was taken from a point near the summit of Olivine mountain, while No. 2 was taken from Eagle creek at a distance of about 2,500 feet vertically below No. 1. Each of these analyses is recalculated water free. The third analysis is that of an average dunite, the figures being taken from Daly's paper on 'Average Chemical Composition of Igneous Rock Types.'[1]

	No. 1.		No. 2.		No. 3.
	Natural rock.	As water free.	Natural rock.	As water free.	Natural. rock.
SiO_2	33·48	38·95	38·40	39·99	40·06
Al_2O_3	1·50	1·74	0·29	0·30	0·57
Fe_2O_3	7·27	8·45	3·42	3·56	2·29
FeO	1·36	1·58	6·69	6·97	7·32
MgO	42·02	48·85	45·23	47·10	46·62
CaO	0·02	0·02	0·35	0·36	0·35
MnO	0·06	0·07	0·24	0·25	0·24
K_2O Na_2O	0·29	0·34	0·08	0·08	0·01
H_2O-	0·60	....	0·24	....	
H_2O+	13·26	....	4·11	....	2·53
CO_2	....	....	1·10	1·15	
P_2O_5	....	....	trace.	....	0·01
S	....	....	0·06	0·06	....
NiO	....	....	0·10	0·10	....
Cr_2O_3	....	....	0·07	0·07	....
	99·86	100·00	100·38	99·99	100·00

According to the Quantitative Classification of igneous rocks, each of the Tulameen samples would be classed as dunose.

[1] Proc. Am. Academy of Arts and Sciences. Vol. XLV, No. 7, page 226.

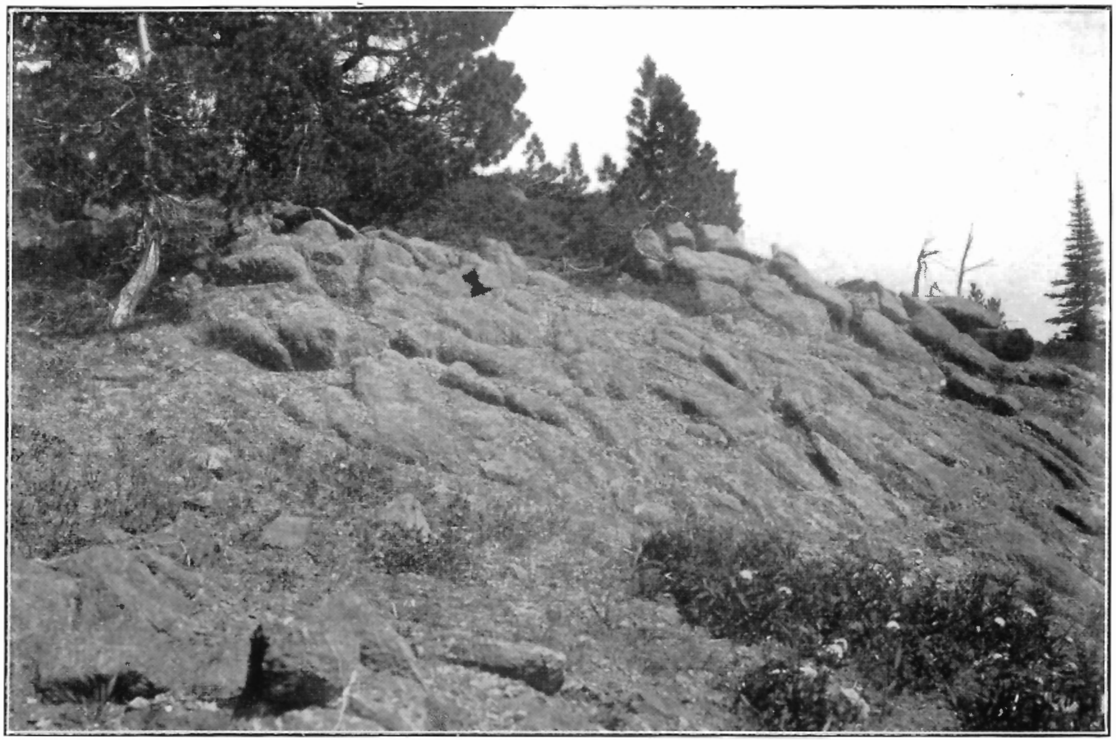
Sample No. 2 is described by Kemp as a rock containing olivine, serpentine, and iron ore; the olivine having only partly gone to serpentine and occurring as rounded grains or kernels separated by narrow bands of serpentine. The thin section of No. 1, however, shows nothing but serpentine and iron ore, the olivine having been completely altered by the addition of water. If, however, we eliminate the water and recalculate both the analyses to 100 per cent, the resulting figures are almost identical except for a difference of about one per cent in the silica and magnesia content. Allowing for a probable loss of iron and loss of magnesia in the change from peridotite to serpentine, these figures give an approximation to the composition of the original peridotite and show it to have been composed of almost pure olivine, comparable to certain olivines from Vesuvius that have been analysed and tabulated in Dana's System of Mineralogy.[1]

The uniformity of the two analyses when recalculated water free is very striking, even though the two samples were taken at a distance of over a mile apart and with a difference in elevation of about 2,500 feet between them. They suggest a remarkable homogeneity in the chemical composition of the main body of the peridotite formation.

METAMORPHISM.

There is a tendency inherent to all peridotite bodies to become metamorphosed to serpentine, and the Tulameen peridotite is no exception to this general rule. Virtually the whole formation shows this metamorphism to a greater or less extent. It is rare to find peridotite in this body, that is composed of entirely fresh olivine, though it does occasionally happen. In the early stages of the progress of metamorphism from olivine to serpentine the alteracion begins along a number of irregular lines which traverse the mass of olivine in all directions. The metamorphism advances inward from these lines into the olivine, and in a more advanced stage the olivine appears as small rounded kernels separated from each other by bands of serpentine. The final stage in the serpentinization of peridotite is the complete disappearance of the olivine, leaving only a drusy mat of small serpentine fibres.

[1] Dana's System of Mineralogy, page 453, Nos. 6 and 12.



Spheroidal weathering of peridotite.

The principal result produced in serpentinization is an increase in the percentage of water in the rock until it reaches a maximum of about 15 per cent. Accompanying this is a slight decrease in the proportion of iron and magnesia. The volume of the rock also increases.

The cause of the metamorphism of peridotite by serpentinization is not clearly understood, and has been attributed by various writers either to the contact effect of igneous intrusions or to the action of circulating surface waters. Whatever the primary cause, serpentinization appears to be a result of the passage of time, for the older the peridotite the more likely it is to have become altered to serpentine.

After serpentinization has taken place the formation of asbestos veins often follows in the serpentinized areas; in fact asbestos is considered to be merely a crystalline form of serpentine. The asbestos occurs in small narrow veins, less than half an inch wide, and has a silky, silvery lustre. The fibre in the veins is delicate and flexible, and runs always at right angles to the length of the vein.

Atmospheric weathering takes place on the outer edge of the serpentine to a depth of one inch or less. The colour of this outer shell is either dun or bluish-grey, and the thin section shows it to consist of serpentine, carbonate of magnesia, and grains of iron ore. In certain places along zones of shearing the alteration goes deeper and is more extreme, so that the result is a soft friable mass of magnesite and scales of mica which break down readily to a fine dust.

STRUCTURAL RELATIONS.

Internal.—A glance at the geological map of the district will show that the peridotite formation occupies one of the highest points in the whole area. This is due wholly to the resistance of the peridotite to atmospheric weathering, for it can be noted that the surrounding summits, which are all occupied by rocks of other formations, are considerably lower in elevation.

In outline, however, the peridotite rarely forms cliffs of sharp, jutting points of rock, though its slopes are all fairly steep. Atmospheric agencies appear to attack, equally, all exposed surfaces of the rock, producing rounded outlines to all outcrops. An example of the resultant forms is figured on Plate XI. Weathering only extends a limited distance into the rock, and this weathered surface acts as a blanket to the fresh rock underneath, protecting it from further erosion. The weathered surface often shells off on steep slopes and forms a talus of small, shaly fragments. Large detached blocks of this formation are not common.

The peridotite is very resistant also to dynamic forces, and although the formation must have passed through periods of disturbance, great enough to produce shearing and schistosity in rocks of other formations, it bears little evidence of these disturbances. No schistose structure is ever apparent in it, and lines of fracture or shearing are not frequent. Such lines of fracture as were noted have a general east and west trend. Some picrolite and radiating bundles of amphibole are found in the fracture planes. Asbestos veins of small size appear to favour zones of shearing or places where there have been minor dislocations.

In several places the peridotite has the appearance of having been brecciated. Closer examination shows, however, that this structure is not exactly that of brecciation, but that the effect is produced by alteration of the rock to serpentine along irregular cracks, the alteration having proceeded only so far as to leave kernels of peridotite, like inclusions, in a matrix of serpentine. The effect on a large scale is similar to that seen in detail in a thin section of partly serpentinized peridotite.

Differentiation, as a structural element of the peridotite, is not a very pronounced feature of the main central portion of the formation. Omitting for the present the border facies, where differentiation is undoubtedly a strong factor in producing the change from peridotite to pyroxenite, and considering only the central portion of the formation, the only evidences of differentiation we find are the segregated veins and masses of chromite. These segregations of chromite occur in the peridotite along certain east and west zones, where the rock is more or less altered to serpentine. The veins are short and irregular, and vary in width from a fraction of an inch up to an inch, while the masses of chromite are rarely as large as 6 inches in diameter. Chromite also appears in small disseminated crystals in the massive peridotite and not connected with any system of fracturing. Its origin is doubtless similar to that of the magnetite in the pyroxenite, that is to say it is a differentiation product of the molten rock in the process of cooling.

It appears to be generally true of chromite bearing districts, that in a body of peridotite the chromite segregations are larger and more abundant towards the outer edge of the body than they are in the central part. Sufficient evidence was not obtained to determine whether or not this is also true in the case of the Tulameen chromitè, but segregations of this mineral were found in all parts of the peridotite body.

It is a statement worth making, and it is borne out by the experience of all those who have been engaged in the search for platinum in the solid rock of this district, that veins and masses of chromite generally contain a higher percentage of platinum than the massive peridotite which does not show any chromite. This seems to show that, although platinum may frequently migrate in solution like other metals it may also be a product of magmatic differentiation and be found as segregations in peridotite like the chromite.

This formation is undoubtedly the original home of the platinum which is now found in the placers of streams which traverse it. Chemical tests have proved that it exists in varying quantity in the peridotite, and besides being actually found in the bunches of chromite, it also occurs in the small picrite dykes which cut this formation and have probably originated from the same magma.

On the outer border of the peridotite formation variations in the mineral constituents enter which are considered to be the result of differentiation during cooling. In passing outward from the typical peridotite towards the pyroxenite, which always borders the peridotite, the first indication of the change is the presence of augite in large glistening crystals in a ground of olivine. Going farther outward the augite increases in quantity while the olivine decreases, until the latter is absent altogether and the rock contains nothing but augite and becomes the typical pyroxenite. This change is clearly the result of differentiation during cooling, and the process will be referred to again in discussion of the origin of the two formations involved.

External.—The peridotite formation is not found in contact with any formation other than the pyroxenite. Its relations to the pyroxenite are clearly shown in a number of good exposures. On the contacts of the main bodies of the two formations with each other, there is always a gradual transition from one rock to the other, showing that they are virtually contemporaneous in time of intrusion. On the slopes of Olivine mountain, dykes and small stringers of olivine-bearing pyroxenite were found traversing the peridotite. On the other hand, at two other points in the pyroxenite not far from the peridotite, dykes of peridotite were found cutting the pyroxenite, and in these dykes there were small inclusions of pyroxenite. This again indicates a contemporaneity in time of intrusion, so that any data bearing on the relations of the pyroxenite to formations other than the peridotite would apply to the peridotite formation also. The date of the intrusion of the pyroxenite is placed between that of the Boulder granite and the augite syenite.

Both on Eagle creek and on Tulameen river narrow dykes of picrite containing both olivine and augite, were found intrusive into the schists of the Tulameen group. These dykes are presumably apophyses from the main body of the peridotite-pyroxenite body.

On the east of Eagle creek about half a mile above its mouth, a dyke of hornblende lamprophyre cuts the peridotite. Near the same point the peridotite is cut by a narrow quartz vein which runs westward towards the creek and gradually changes to a granite porphyry showing phenocrysts of biotite in the quartz. Its further extension towards the border of the peridotite was covered by drift, at a distance of about half a mile from the Eagle granodiorite contact. If this quartz vein and granite porphyry are connected with the Eagle granodiorite—as seems likely—it fixes the relative ages of these two formations as well as that of the pyroxenite, and makes the Eagle granodiorite later in time of intrusion.

ORIGIN AND AGE.

The origin and age of the peridotite are so closely associated with those of the pyroxenite that the discussion of these features is deferred to a later section of the report dealing with that formation.

Pyroxenite.

DISTRIBUTION.

The pyroxenite occurs in one fairly large mass and in a number of smaller bodies. The main body lies in the southwest portion of the area, and extends from Grasshopper mountain southeast to Lodestone mountain and beyond that, in the same direction, for an unknown distance outside the limits of the area mapped. It is an irregular stock-like body having a length of at least 7 miles and a very variable width. It completely encloses the two bodies of peridotite, and, exclusive of these, has an area within the map sheet of nearly 12 square miles. It forms some of the highest land in the whole district, and its surface is consequently generally well exposed.

Smaller bodies of pyroxenite outcrop on Henning mountain at the head of Bear creek, at the forks of Bear creek, and on the trail running from Slate creek to Olivine mountain and on that running from Cedar creek to Lodestone. The two bodies on Bear creek are simply large dykes, and their outline has been closely defined. The two bodies on the south side of the Tulameen river are of unknown extent, and their boundaries on the geological map have been roughly sketched in from the three or four outcrops that are exposed through the drift.

LITHOLOGY.

The pyroxenite formation is not always uniform in character throughout, but shows some variations both in composition and in texture. The variations in texture are due to the varying size of the pyroxene constituent; while in composition the two main factors which enter and tend to produce variations are the magmatic segregations and the presence of some feldspar on the outer edges of the formation. On the peridotite contacts some olivine enters, but as soon as this mineral becomes an essential constituent the rock is mapped as belonging to the peridotite formation.

In the hand specimen the normal variety of pyroxenite is a black or dark green rock containing only two visible constituents—augite and magnetite. The augite is generally large and often shows crystal faces 2 inches by 4 inches in size. The colour of the augite controls the colour of the rock, and is either a very dark green or a glistening black. Magnetite is generally in small crystals but often occurs in more massive lenses or bunches. No olivine is visible except on the contact of the peridotite formation.

Quartz was noticed in one place in the pyroxenite in the bed of the Tulameen river, where it appears as large, coarse crystals filling or partly filling cavities in the rock.

Biotite is occasionally present, and the accessory constituents visible to the unaided eye are pyrite, chalcopyrite, and some pyrolusite. The last mineral appears in shear zones and quartz veins in the pyroxenite, while the copper and iron sulphides are either disseminated through the rock or appear in minute fracture planes and in the larger shear zones.

The augite alters readily to hornblende, and where squeezed develops into a hornblende schist. A further alteration along lines of dislocation produces a coarse brittle asbestos.

The pyroxenite is cut by coarse pegmatite dykes of hornblende, and by quartz and calcite veins. The veins are occasionally mineralized, but have not been proved to contain any of the precious metals in paying quantity.

When viewed in the thin section the most abundant and often the only essential constituent of the pyroxenite is augite. This mineral is light coloured and occurs in large crystals which generally show a well developed rectangular cleavage. Its extinction angle is high, and it often contains many inclusions. There is always a strong tendency in the augite to alter to hornblende and later to chlorite or serpentine. In the process of alteration the rectangular cleavage becomes obscured, and there is a development throughout the mineral of small tablets of biotite and crystals of magnetite symmetrically arranged with relation to the cleavage.

Hornblende is occasionally an original mineral, but is in the majority of cases secondary from augite. Some sections show large crystals of enstatite or hypersthene which give a parallel extinction between crossed nicols. Olivine as an accessory constituent is present only in those samples taken from near the border of the peridotite. Some feldspars are found in the pyroxenite near its outer border, marking a transition to augite syenite.

Besides augite, magnetite is the most persistent and prevailing constituent of the pyroxenite. Its typical form is as massive segregations through the pyroxenite. It often fills interstices between the augite crystals. It appears also in small crystals symmetrically arranged throughout the augite, when that mineral is altering to hornblende, or again as irregular grains following definite lines of alteration in the rock. In its massive form it holds inclusions of a highly refracting greenish mineral which is probably one of the spinels.

Small veinlets of calcite or of serpentine often traverse the sections. The accessory minerals besides those already mentioned are titanite and some sulphides.

A pegmatite phase of the pyroxenite which is classed as a hornblendite dyke, cuts the pyroxenite on the ridge south of Olivine mountain. The dyke is about 2 feet wide and in the hand specimen shows only very large hornblendes, with cleavage running across the strike of the dyke, and containing small inclusions of magnetite. The thin section of this shows dark green primary hornblende, with an extinction angle of about 20°, calcite, magnetite, and some titanite and olivine. The calcite appears to be secondary. The magnetite is both interstitial and in crystalline individuals, and is usually bordered by grains of titanite.

A sample of pyroxenite taken from the summit of the ridge south of Olivine mountain was analysed by M. F. Connor in the laboratory of the Mines Branch. The thin section of this shows much light coloured augite, a little original green hornblende, and interstitial magnetite. The augites contain many inclusions of magnetite, and brown magnetite, symmetrically arranged, marking an alteration of the augite to secondary hornblende.

The following is the chemical analysis:—

	Per cent.
SiO_2	37·33
TiO_2	1·66
Al_2O_3	7·27
Fe_2O_3	13·41
FeO	9·24
MnO	0·07
MgO	12·27
CaO	16·50
K_2O	0·30
Na_2O	0·45
H_2O-	0·10
H_2O+	1·03
	99·63

Calculating this analysis according to the Quantitative Classification, the rock is found to fall into a space in the tables to which no name has been assigned. According to this classification the rock belongs to the Rang texase, of the Order Scotare of the Class Dofemane. It is also calcimiric and domagnesic. After consulting with Prof. L. V. Pirsson, one of the authors of this classification, the name tulamose is proposed for this rock, taking the root 'tulam' from the district in which the rock is found.

METAMORPHISM.

When examined broadly the pyroxenite does not exhibit any strongly marked features that are attributable to metamorphosing agencies. Even on the outcrop it generally has a fresh appearance, and only when examined under the microscope do we find evidences of metamorphism in the alteration of the pyroxene to hornblende. In advanced stages of this metamorphism the hornblende alters to chlorite and also to serpentine. The development of biotite and small grains of iron ore usually accompanies this change. Along lines of dislocation a coarse, brittle variety of asbestos also frequently results. Bunches of radiating green epidote associated with calcite are other evidences of local metamorphism.

Small, sheet-like apophyses, which have emanated from the main mass of pyroxenite and been thrust into the bedding planes of the rocks of the Tulameen group, have been involved in the same disturbances which those rocks have gone through, and metamorphosed to hornblende and chlorite schists.

STRUCTURAL RELATIONS.

Internal.—Like the peridotite, the pyroxenite formation gives little indication of having been subjected to dynamic forces, such as produce faulting, shearing, schistosity, or brecciation. Along certain north and south lines, however, where shearing has been somewhat effective, we frequently find a hornblende schist developed for a few feet. Large biotites and chlorite sheets also often occur in these shear zones. An analogous structure is developed in small apophyses from the pyroxenite, which have been thrust as sheets into the planes of bedding of the rocks of the Tulameen series.

Slightly mineralized quartz veins occupy these shear zones in one or two places, and these are associated with a number of small calcite stringers, forming a network of branching veins. In such cases the quartz veins belong to a later period of formation than the calcite veins and always cut them.

In the streams, where the pyroxenite is water worn, it forms a smooth, slippery surface which is not favourable as a bed-rock for gold and platinum placers. In such places large, deep, water-worn pot-holes are of common occurrence.

One of the principal features which mark a change in the internal structure of the pyroxenite, is due to differentiation in the magma before complete solidification. The effect of such differentiation is noticeable in segregations, here and there, of magnetite through the mass of the rock, and in the formation of an acid zone at many places along its outer border.

While it would be almost impossible to obtain a sample of pyroxenite that did not show some magnetite, it frequently happens that over considerable areas the magnetite is quite as abundant a constituent as the augite. Again, in the case of short, irregular veins and in bunches 6 or 8 inches in diameter the magnetite is sometimes almost pure. The occurrence in this case is analogous to that of chromite in the peridotite.

In discussing the internal structural relations of the peridotite it was stated that this formation passed by a gradual transition into pyroxenite, and it is believed that the transition must be attributed solely to differentiation. In the same way it was noted in the field that in one or two places the pyroxenite passed gradually into a rock which was classed as augite syenite. This change is brought about by the introduction of feldspar into the pyroxenite along its outer borders, and here also differentiation in the magma during cooling is believed to be the primary cause of such a change.

To a very limited extent brecciation has taken place in the pyroxenite on its contact with the rocks of the Tulameen group. An example of this appears in the bed of the Tulameen river above Eagle creek, where angular fragments of pyroxenite are recemented together by a rock of the same composition. This result was brought about, doubtless, at the time of intrusion, when, the outer border of the pyroxenite having cooled and solidified, it was broken into fragments and these fragments were recemented by liquid rock from the central portion of the pyroxenite body.

External.—The relative position occupied by the pyroxenite formation in the geological column of the district is very well fixed except in its relation to the Boulder granite formation. Well exposed contacts have been obtained between this formation and the Tulameen group, the peridotite, and the augite syenite. Sufficient evidence, also, of its relation to the Eagle granite has been obtained to fix the relative position of these two formations.

In Bear Creek basin two well exposed, dyke-like bodies of pyroxenite have been found intrusive into the rocks of the Tulameen group. For several miles, also, on either side of its main body the pyroxenite is in direct contact with the same rocks. This contact very often shows a zone of brecciation with fragments of the rocks of the Tulameen group lying in a matrix of pyroxenite. In the outer portion of this zone of brecciation the fragments are numerous and angular, but in the main part of the zone they are less abundant and rounded in appearance, as if they had been partly fused by the heat of the intrusive. Some mineralization by copper and iron sulphides has taken place in this zone; and the usual contact phenomena are also present, garnet, epidote, hornblende, and calcite and some quartz being developed in the intruded rock. Apophyses of pyroxenite, or what was originally pyroxenite, project out into the rocks of the Tulameen group. The conclusion, therefore, concerning the age of the pyroxenite is that it is later than the rocks of the Tulameen group which are believed to be Triassic.

The pyroxenite-peridotite contact is well exposed in a number of places and particularly on the south side of Olivine mountain. As described in a previous section, the contact is a transitional one, so that the date of intrusion of the one rock is virtually that of the other. Their contemporaneous age is shown also in the fact that small dykes of olivine bearing pyroxenite cut the peridotite, and vice versa.

The great body of the augite syenite is intrusive into the pyroxenite, as shown in Plate XII, and, on the contact, blocks of pyroxenite are set in a matrix of augite syenite. Dykes of augite syenite are also commonly found intrusive into the pyroxenite. In a few instances, as in the contacts exposed on the slope

Contact of pyroxenite and augite syenite, Olivine Mountain.

10015—p. 64.

of Britton mountain, and on the long ridge south of Olivine mountain, there is no sharp contact of pyroxenite with the rock which is mapped as augite syenite, but which is in places more correctly called an augite diorite or even a gabbro. Such a rock in the places mentioned is a differentiation product of the pyroxenite, and passes gradually into it by a loss of its feldspar constituent. At these points also the pyroxenite appears as narrow lenses or basic inclusions in the augite syenite, suggesting that the two varieties of rocks were not far apart in time of solidification from a molten state. In such cases the augite syenite would be contemporaneous in origin with the pyroxenite.

No well exposed contact of pyroxenite with Eagle granodiorite was found. Evidence bearing on the relative position of these two formations in the time scale is furnished by the fact that on Eagle creek just above the forks, an outcrop of pyroxenite in close proximity to the Eagle granodiorite is bleached and highly metamorphosed as if by contact with the Eagle granodiorite. Also, the pyroxenite in several places is found to be cut by dykes of granite porphyry which are thought to be genetically connected with the Eagle granodiorite.

Upon the relation of the pyroxenite to the Eagle granodiorite depends the actual age of the former. In the upper part of the Tulameen river, Cretaceous rocks are found to rest directly on the eroded surface of the Eagle granodiorite, so that the granodiorite is pre-Cretaceous. The pyroxenite, therefore, is also pre-Cretaceous in age.

The relation of the pyroxenite to the Boulder granite is not shown by any contacts, nor is the pyroxenite in contact with any other formations than those described.

MODE OF ORIGIN.

The origin and history of the pyroxenite is so intimately bound up with that of the peridotite that it is impossible to discuss the genesis of each of them separately, without a great deal of repetition. For convenience, therefore, both formations are included under this heading.

Some geologists at one time regarded the pyroxenites and peridotites as doubtfully of igneous origin, and placed them with the metamorphic rocks. At present, however, this view has been abandoned, and no one now doubts their true igneous nature.

In the Tulameen district their intrusive origin is clearly apparent, for where Tulameen river cuts through the central part of the two formations exposing a vertical section several hundred feet in height, the contact with the Tulameen group shows the pyroxenite to cut through and across the beds of the Tulameen group, going upwards through them, irrespective of their dip and strike.

The general relation of these two formations as now exposed is that of a core or central mass of peridotite surrounded on all sides and in places capped by a shell of pyroxenite.

The contact between the peridotite and pyroxenite, as already described, is transitional and shows a gradation from an almost pure olivine rock, or dunite, in the centre, through a zone of peridotite containing pyroxene, into pure pyroxenite on the outside which contains no olivine whatever. In this passage from the peridotite interior towards the pyroxenite border there is a gradual replacement of olivine by pyroxene until the olivine is eliminated altogether. There is no sharp contact between the two rocks to suggest that one of them was intruded into the other some time after the latter was crystallized; but all the evidence indicates that the two rocks originated from one common magma, and that by some process of differentiation, taking place presumably during consolidation, they separated out into two kinds, the more basic in the centre and a comparatively acid rim on the outside.

Both the pyroxenite and peridotite are cut by dykes of small size which fill what appear to be cooling cracks in them. These dykes to the eye resemble the pyroxenite, but the thin section shows them to contain both olivine and pyroxene, and to be similar to the transition phase between the two types of rocks.

The form of the peridotite-pyroxenite body is that of an elongated stock, having a length of over 7 miles and a width varying from one-half to 2½ miles. It is significant that the two bodies of peridotite occur in the broader parts of the stock. The Tulameen river makes a vertical exposure of nearly 3,000 feet of the stock, showing the downward contact to be vertical or plunging outward.

The conditions governing the intrusion of the stock are purely matters of theory, and the history of the event as outlined below is merely as it appears to the author after a study of the effects produced.

The peridotite-pyroxenite stock is believed to have been a simple one, that is to say, it was composed of homogeneous material and intruded in one period of eruption. Differentiation later rendered the material heterogeneous, as we now find it.

The material of this stock is thought to have risen upward from the magma chamber in the heated interior of the earth to its present position at the surface. The intrusion was not simply that of forcible injection into an open space above it, but the method was probably analogous to that of a batholithic intrusion, in which an igneous body gradually forces its way upward into overlying rocks by stoping off blocks of these rocks and filling the spaces occupied previously by them. By this process the molten igneous material in its upward progress, continues to replace the solid rocks until the molten material loses its heat and begins to solidify.

In the final stages of the intrusion and probably during the process of cooling, the molten, igneous material of the stock began to lose its homogeneous character, and to separate out into two distinct fractions, a peridotite core and a pyroxenite shell. That the separation did take place is clear from the results now seen, but the causes or method of separation are not clearly understood.

The process does not appear to be simply a case of fractional crystallization and gravitative adjustment, because the stock should then show a separation along horizontal lines instead of, as it actually does, an acid shell around a basic core; but it appears rather to the author as if thermal convection currents had been set up in the magma chamber, and that, in the migration of the material around the chamber, certain minerals of the magma froze and separated out along the cooler walls. Such a process of separation is frequently made use of in chemistry and has been suggested by Becker as applicable also to igneous rocks.[1] This process would involve fractional crystallization to some extent, but the final effect would be that which now obtains in this stock, namely, a core of peridotite surrounded on the top and on all sides by a shell of pyroxenite. In the broader parts of the stock the top part of the

[1] American Journal of Science. Vol. IV, 1897.

shell has been eroded away, exposing the peridotite core, while in the narrow parts the pyroxenite cover still protects the peridotite core of the interior. To use a simple illustration the stock resembles a hard boiled egg, the peridotite being equivalent to the yolk, and the pyroxenite to the white of the egg.

The composition of the original magma was probably intermediate between that of the two principal types of rocks, and the small dykes which cut these rocks, and have such a composition, may represent portions of the undifferentiated magma injected into the cooling cracks of these rocks.

AGE AND CORRELATION.

Since the pyroxenite-peridotite stock is intruded by the Eagle granodiorite, and the latter rests unconformably below Cretaceous rocks, the pyroxenite-peridotite body is, therefore, earlier than Cretaceous. On the other hand it is intrusive into the rocks of the Tulameen group, which are tentatively referred to the Triassic, so that it is at least post-Triassic. This places it, provisionally, in the Jurassic, and in the early part of that period, and correlates it with the beginning of the batholithic intrusions, which so strongly characterize the whole of the Jurassic period.

Augite Syenite.

DISTRIBUTION.

The augite syenite is found, in this district, in the form of several detached areas, none of them large and some of them so small that they are mere dykes only a few feet wide. The largest area is in the southern part of the sheet. This is an elongate body striking approximately northwest and southeast, and having a length of about 6 miles and an average width of slightly over a mile. This body extends from the head of Hine creek, on the eastern slope of Olivine mountain, southeasterly across the heads of Slate creek and the North Fork of Granite creek, where it passes outside the limits of the area mapped. Smaller bodies of augite syenite, having the same general shape and strike, occur on the southern end of the main ridge separating Slate from Champion creeks, on the western slope of Otter mountain, and at two points on the northeastern slope of Bear Creek valley. A number of dykes of augite syenite of small size are found in various parts of the district in which the larger bodies occur. Some of these have been mapped, but there are many others that are not indicated on the geological map.

LITHOLOGY.

As seen in the field there is nothing typical or characteristic about the habit, appearance, or composition of the rocks grouped under the name of augite syenite. The texture of the rock varies from place to place, and the colour changes with variations in the relative proportion of the constituent minerals. In composition, also, there is a wide range, so that under the formational name of augite syenite are grouped rocks which range from gabbro to granite. There is, however, no line of contact between the various kinds of rocks, which appear to have been derived from the same magma, and are transitional into each other. The prevailing type, however, is an augite syenite.

In hand specimens the augite syenite is a fine to medium grained rock of granitic texture. It is always dark in colour and shows two main constituents, a white or slightly yellowish feldspar, and a black augite or hornblende. Neither of these constituents has well defined, clean cut outlines, and the microscope shows that the feldspar contains many small inclusions of augite grains. The rock is, as a rule, massive in structure, but along lines of shearing develops a schistose structure. A similar structure has been induced in the rock along some of its contacts with other rocks of earlier age. It holds some basic segregations of fine grained, dark material in oval or lenticular shape.

Thin sections show the augite syenite to be much altered and to have suffered much decomposition. The texture of the typical rock is granitic, but generally not equigranular. The dominant feldspar is orthoclase, which is generally turbid from alteration or inclusions, and has no well defined outline. A subordinate amount of acid plagioclase is present, and in the twinning some strain and bending of the crystals is evident. The principal dark mineral is augite, which is often altered to hornblende. The augite appears either in large idiomorphic crystals or in small grains which are scattered abundantly through the larger constituents. The hornblende is in large bluish-green crystals, generally secondary from augite or less often original. The hornblende again alters to chlorite. A few shreds of brown biotite are also present. In some sections, particularly in those taken from some of the smaller bodies of augite syenite, some quartz appears. This is either interstitial between the feldspar individuals, or else it is intergrown with the orthoclase in a typical micrographic structure. Generally the quartz is not so abundant as to rise above the position of a mere accessory constituent, but one section contains quartz enough for the rock to be classed as a granite. The secondary minerals developed are chlorite, epidote, mica, and some calcite. The accessories are magnetite, titanite, and some apatite.

The analysis given below is that of a rock taken from the southern end of Olivine ridge between Slate and Champion creeks. Unfortunately the sample is not typical of the average rock of the whole augite syenite formation, but is undoubtedly much more basic in composition. The thin section of this rock shows the usual dark coloured constituents abundantly developed, but the feldspars are so cloudy and full of inclusions that it is difficult to separate the orthoclase from the plagioclase. The percentage of K_2O in the analysis indicates that the proportion of orthoclase cannot be very great, and the calculation of the norm of the rock shows that it might be about 6·12 per cent. Most of the cloudy indeterminate feldspar, therefore, must be plagioclase.

In the specimens collected from the main body of the augite syenite formation, the dominant feldspar is orthoclase. Often, also, a variable proportion of quartz appears, so that the average rock of this formation is much more acid than that represented by the analysis. The location from which the sample analysed was collected may account for its more basic composition.

In working out the relation of the augite syenite to the pyroxenite it was found that while the main body of the augite syenite was, without doubt, later in date of intrusion than the pyroxenite, there were certain small areas that appeared to show a transition, by decrease of feldspar, into the mass of the pyroxenite. In other words the pyroxenite, presumably by a process of differentiation in the magma during cooling, in places showed a tendency on its outer borders to grade into a rock which in the field was classed as augite syenite. The sample analysed was taken from such a place, on the western border of the pyroxenite, and although probably not typical of the whole augite syenite formation, it serves to show the progress of differentiation in a basic magma from peridotite, through pyroxenite and gabbro to augite syenite and even to granite—a series that becomes progressively more acid as it advances from the centre to the border of the mass.

The following analysis of this rock was made in the laboratory of the Mines Branch by M. F. Connor:—

SiO_2	49·41
TiO_2	0·95
Al_2O_3	18·08
Fe_2O_3	5·93
FeO	4·08
MnO	0·09
MgO	4·61
CaO	10·10
K_2O	1·01
Na_2O	3·48
H_2O-	0·04
H_2O+	1·59
	99·37

Calculation of the norm according to the Quantitative Classification gives the following percentages of the different constituents:—

Quartz	= 0·42
Orthoclase	= 6·12
Albite	=29·34
Anorthite	=30·58
Diopside	=15·28
Hypersthene	= 5·53
Magnetite	= 8·58
Ilmenite	= 1·82

This rock is, therefore, a hessose, and comes in the same class as the Hedley gabbro, of which an analysis is given in a previous report on that region.[1]

The chemical analysis given above is almost identical with that of the average gabbro as calculated by R. A. Daly from twenty-four typical analyses.[2] This phase, then, of the augite syenite formation would be more correctly called a gabbro rather than an augite syenite even of the most basic kind.

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[1] G.S.C. Memoir 2. "The geology and ore deposits of Hedley Mining District" page 83.

[2] Proc. Am. Academy of Arts and Sciences. Vol. XLV, No. 7, Jan., 1910, page 225.

STRUCTURAL RELATIONS.

Internal.—The augite syenite formation is, as a rule, not very well exposed except on the tops of prominent ridges or in the beds of creeks flowing through it. It appears to suffer decomposition very easily, so that fresh samples are difficult to obtain. Either on account of this lack of resistance to weathering or because it has already passed through long periods of erosion, it does not form prominent features in the landscape, but is characterized by more mature topographic forms.

As stated in a previous section, both the physical and chemical characters of the augite syenite vary widely. In composition the range extends from a gabbro at one end to a granite at the other, though all varieties are believed to have the same magmatic source.

On account of the lack of good exposures the differentiation in the magma, which gave rise to the varieties of rocks in the augite syenite formation, has not been well studied. The most basic variety included under this heading is an ordinary gabbro. This, while appearing often as segregated masses in the augite syenite, is often found to be a border phase of the peridotite-pyroxenite series. Augite diorite is found in the main body of this formation, and augite syenite, of course, forms the major part of it. In some of the smaller bodies, mapped under this colour, such as those lying to the northeast of Bear creek, a small percentage of quartz comes into the rock, while towards the southern limit of the area the rock takes on the character and composition of a granite. It is not absolutely certain whether all these varieties can be referred to the same or simultaneous intrusions, but the general habit and structure of the different varieties, with the presence in all of them of the augite constituent, has impelled the author to correlate them together, and to refer them all to the same magmatic source. As will be discussed later, this magma is thought to have given rise to the pyroxenite and peridotite, but at a more remote period in its history.

The augite syenite magma appears to have been a somewhat unstable one which split easily to form different kinds of rocks. Besides forming large areas of widely differentiated species, the augite syenite contains many small segregations. These are in every case more basic—at least in appearance—than the matrix, and consist of fine grained dark material, arranged in oval or lenticular shapes 1 or 2 inches in greatest length.

As a rule all phases of this formation have well developed granitic structures. In parts of the contact zone, however, a gneissic structure is apparent. This gneissic structure is thought to be due to squeezing at the time of intrusion rather than to later dynamic movement.

External.—A study of the relations of any igneous body to the rocks with which it is in contact is the only means of arriving at the relative age of that body, and only when contacts with fossiliferous rocks are obtained can the absolute age be fixed with any degree of accuracy. In the case of the augite syenite formation, contacts were obtained with the Otter granite, Cedar volcanic formation, the pyroxenite, the peridotite, and the Tulameen group. These contacts were sufficient to fix the intrusion of the augite syenite as having taken place after that of the pyroxenite but prior to that of the Eagle granodiorite.

At the southern end of Spearing mountain, and just north of the summit of Bear Creek wagon road, there is a well exposed contact of augite syenite with the Otter granite. The contact is not a sharp line of division, but, on the contrary, there is a wide contact zone of brecciation which shows fragments of augite syenite of angular shape, enclosed in a matrix of Otter granite. Towards the augite syenite border of this contact zone the fragments of syenite are so large that the granite matrix becomes merely a network of branching apophyses, traversing the planes of fracture between large blocks of syenite. This contact clearly proves the intrusive nature of the Otter granite in the augite syenite.

Contacts of augite syenite with the Cedar volcanic series are well shown on two of the branches of the North Fork of Granite creek, where the Cedar volcanics clearly rest on the augite syenite, and there is no contact metamorphism or other evidence of intrusion of the syenite into the Cedar volcanics.

The contacts of the augite syenite with the pyroxenite, peridotite, and Tulameen group leave no doubt as to the relative ages of these formations. In many instances dykes of augite syenite were found cutting all three formations. The contact of the main body of the augite syenite with the Tulameen group, as seen on

Slate creek and elsewhere, is fairly clean cut and rarely shows any zone of brecciation such as appears on contacts of the latter with other igneous bodies. With the pyroxenite the augite syenite formation has not always the same kind of contact, for in some cases the syenite is later and in others contemporaneous in age with the pyroxenite. Plate XII illustrates a contact of pyroxenite with augite syenite, as seen on the ridge about a mile south of the top of Olivine mountain. The pyroxenite is here a glistening, black rock, while the augite syenite is light coloured. At the contact the syenite contains angular blocks, rounded fragments, and elongated lenses of pyroxenite, showing that the syenite is intrusive into the pyroxenite, but suggesting that the pyroxenite had not yet thoroughly solidified when the intrusion took place or else that it was re-fused by the heat of the syenite. At another point on the same ridge the contact is still less sharply defined, and long streaks of black pyroxenite from 1 to 4 inches in width appear in the lighter coloured rock, which is here a gabbro, but passes, apparently without any break, into true augite syenite. At this point the change from pyroxenite to augite syenite is transitional rather than abruptly intrusive.

No contacts of augite syenite with the main body of Eagle granodiorite are known, though a careful search was made for them. An apophysis of Eagle granodiorite, however, was found cutting both the pyroxenite and the peridotite, while on Eagle creek included blocks of pyroxenite were found in the granodiorite. The close magmatic relationship of the augite syenite to the pyroxenite and peridotite as well as the nature of its contacts would lead one to infer that the augite syenite followed the pyroxenite and peridotite very closely in time of intrusion. The Eagle granodiorite, however, appears to have been somewhat later, and to have been intruded after the pyroxenite had completely solidified. In the sequence of intrusion, therefore, the augite syenite is placed between the pyroxenite and the Eagle granodiorite.

MODE OF ORIGIN.

The form of the main body of augite syenite is that of an elongated stock, intrusive on the one hand into pyroxenite and on the other into the rocks of the Tulameen group. Its contacts show included blocks of both these formations in the augite syenite, a fact which indicates that its mode of origin is analogous to that of the other large igneous bodies of the district, that is to say, it rose in the form of a column of molten rock, from the heated interior of the earth up to the surface, where it solidified. The method of its uprising is a matter of theory, but it probably rose by stoping off fragments of the overlying rocks, and filling the spaces formerly occupied by them. Having this mode of origin the walls of the stock will, therefore, be either vertical or highly inclined.

Some of the smaller bodies of this formation presumably reached their present position from the same source, but by being thrust upward into existing fissures by pressure from below. These bodies would, therefore, be properly classed as dykes.

In discussing the internal structure of this formation it was stated that its chemical characters vary greatly. In some parts of the mass it approaches a gabbro in composition, while in others it is almost acid enough to be called a granite. Between these different phases no well defined contact could be found. Again, augite syenite was occasionally found as a border phase of the pyroxenite formation, into which it passed by a loss of the feldspar constituent. These observations suggest the conclusion that the augite syenite magma was an unstable one, and that, before conditions of equilibrium could have been set up in it, its viscosity increased until it finally solidified. Its position, adjacent to the pyroxenite in which it sometimes occurs as a border phase, also suggests a genetic relationship to the magma which previously gave rise to the pyroxenite-peridotite group of rocks.

AGE AND CORRELATION.

All the evidence whereby the age of the augite syenite can be fixed has been already given in a previous section. It was there stated that the formation is intrusive into the Tulameen group and the pyroxenite formation, while on the other hand it has been intruded by the Otter granite and very probably also by the Eagle granodiorite. This places the relative age of the formation between that of the pyroxenite and the Eagle granodiorite. As both of these rocks are referred to the Jurassic period, when many igneous bodies were irrupted in the Cordilleran belt of North America, the augite syenite must also be referred to the same period of eruptive activity.

Eagle Granodiorite.

DISTRIBUTION.

The Eagle granodiorite occupies the whole of the western border of the area mapped, and extends outside the limits of this area to the north, west, and south. It occurs in the form of a long narrow band, with its longer axis lying in a north and south direction. The width of this band is from 4 to 5 miles, and the length is unknown, being somewhat longer than the length of the area, which is about 12 miles. It may be 30 miles in length, for a granite of somewhat similar character has been described by Dr. Dawson as occurring on the Hope trail at the summit of Whipsaw creek, this locality being in the same strike as that of the Eagle granodiorite of the Tulameen.

To the west the Eagle granodiorite may be connected with and form a part of the great Coast Range batholith, but this is not definitely known to be so.

LITHOLOGY.

The Eagle granodiorite is generally coarse grained in texture, and, from constituents that can be identified in the field, appears to be of fairly uniform composition. In hand specimens it shows crystals of white feldspar, glassy quartz, and much biotite. The biotite is often, though not always, arranged in well defined lines, parallel to longer axis of the granodiorite body, giving a gneissic structure to the rock.

Thin sections do not as a rule exhibit any gneissic structure. They show an even grained rock consisting of orthoclase, quartz, considerable plagioclase, and much biotite. The feldspars are generally altered; and the plagioclase, which is about oligoclase, shows no zonary banding. The quartz is in smaller grains of irregular outline, interstitial between the feldspar crystals. Brown biotite and a few shreds of muscovite give evidence of pressure in the bending of the crystals. Augite is a variable constituent, being lacking in most specimens, but present in considerable amount in samples taken from the neighbourhood of Siwash creek. Of the accessory constituents epidote is the most abundant. Magnetite in well crystallized individuals is fairly abundant, apatite and zoisite much less so.

As a rule the rock is fresh, and, except for the epidote, shows little evidence of decomposition.

A sample taken from Siwash creek and analysed in the laboratory of the Mines Branch by M. F. Connor, gives the following chemical composition:—

SiO_2	64·44
Al_2O_3	17·05
Fe_2O_3	1·53
FeO	2·40
MgO	1·28
CaO	4·28
Na_2O	5·16
K_2O	1·48
H_2O+	0·78
H_2O-	0·02
TiO_2	0·45
P_2O_5	0·31
MnO	0·03
	99·21

The analysis shows the rock to be a typical granodiorite, and running very close to the average granodiorite as given by Daly.[1]

Chemically it is very close to the typical granodiorite as defined by Lindgren[2] in the Ophir district of California, and does not vary from the analyses of that rock in any marked degree. It resembles, also, though not so closely, a granodiorite described by G. O. Smith[3] from Mount Stuart in Washington.

The most evident characteristics of this rock as exhibited by the chemical analysis are its high content of lime, and the excess of soda over potash.

According to the Quantitative Classification the rock is yellow stonose.

STRUCTURAL RELATIONS.

Internal.—The Eagle granodiorite is probably the best exposed formation in the whole sheet. It everywhere exhibits a broken, uneven surface, and has generally only a slight covering of soil;

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[1] Average Chemical Composition of Igneous Rock types: Proc. Am. Acad. of Art and Science, Vol. 45, No. 7.
[2] U.S.G.S. 14th Annual Report, Part II, page 255.
[3] U.S.G.S. Mount Stuart Folio, No. 106, page 5.

consequently it does not support a luxuriant forest growth. Where exposed it frequently weathers down to a coarse feldspathic sand.

Decomposition as a rule does not go deeply into the rock, and there is no difficulty in obtaining fresh specimens.

A well developed foliated structure is often apparent, particularly on its contacts with older rocks. This structure is generally lacking, however, in central parts of the body, and consequently may be due not to later squeezing of the rock, but more probably to some movement along the contacts at the time of intrusion, when the rock was solidifying from a state of fusion.

The granodiorite is traversed by numerous small quartz veins, and by a few coarse pegmatite dykes. Jointing is well developed in two main directions which are transverse to the plane of foliation. These joint planes strike N. 8° E. and S. 3° W. Inclusions of the intruded rocks are very common near contacts.

External.—The only older rocks with which the Eagle granodiorite is known to be in direct contact, are the interbedded limestones, argillites, and volcanic rocks of the Tulameen group, which have been provisionally correlated with the Nicola series and classified as Triassic in age. These rocks border the Eagle granodiorite on its east side from one end of the map to the other. They also lie on the western border in most places where this border has been examined.

Contacts in the bed of Tulameen river and on Eagle creek show a zone of brecciation several hundred feet in width, where the Eagle granodiorite holds angular inclusions of the Tulameen rocks. Apophyses of the granodiorite also traverse these rocks, lying frequently in the bedding planes of the stratified rocks.

A well exposed contact of Eagle granodiorite with interbedded limestones and schists appears on a branch of Bear creek about a mile northwest of Laws camp. For about 1,000 feet along a line at right angles to the general strike of the contact there is a zone of mixed rock, made up of angular fragments of limestone and schist in a matrix of granodiorite. Going from the granodiorite towards the stratified rocks, inclusions become more and more abundant until they form the greater part of the rock, after which one passes into a zone where the granodiorite appears merely as apophyses in the limestones and schists, and the latter are not broken into fragments.

In the inner contact zone, or the zone of inclusions, the granodiorite is of the normal kind, coarse grained and somewhat foliated. In the outer contact zone, or zone of apophyses, it becomes finer grained though containing the same constituents. It is not much metamorphosed by the intrusion, and from the foliation induced in it, appears to have been somewhat viscous at the time of intrusion.

The contacts of the Eagle granodiorite with the rocks of the Tulameen group on Eagle creek and Tulameen river show the same relations. Wherever the granodiorite appears in direct contact with the beds of limestone, bands of dark red granite, associated with green epidote, are often formed in the limestone. Where the contact metamorphism has not been so extreme the limestone simply becomes crystalline. The development of crystals of biotite scattered through the crystalline limestone suggests that in this manner, with more intense or long continued contact action, a true mica schist might be formed.

The development of abundant sillimanite in some of the schists indicates that these rocks were originally argillaceous, and have been metamorphosed by the heat of the granodiorite. The limestones, as a rule, have been simply crystallized near the contact, though occasionally lime silicates have been developed in them. They are also occasionally cut by small quartz stringers, emanating from the granodiorite magma. As an accompaniment of the granodiorite intrusion, mineralization and replacement of the limestone by sulphides has often been important enough to form ore bodies of commercial value.

Both the granodiorite and the intruded rocks are sheared and slickensided, and show some faulting along lines at right angles to the plane of the contact.

The relation of the Eagle granodiorite to the pyroxenite and peridotite formations has not been definitely settled, but certain facts observed in the rocks near the mouth of Eagle creek seem to throw some light on the subject. On the east side of Eagle creek and about half a mile above its mouth some small veins of quartz were found cutting the peridotite. Followed westward towards the granodiorite these veins change in character, and large phenocrysts of biotite and feldspar appear in the quartz. Farther on they change to typical granite porphyry and appear as if they might pass, under the drift, into the Eagle granodiorite. Although not continuously exposed, outcrops of these veins are so close together that there appears to be little doubt of their continuity and of their origin in the granodiorite. If they have this origin, they afford another instance of apophyses from a granite body passing, in distance, through granite porphyries into true quartz veins; also they afford proof that the Eagle granodiorite belongs to a later period of intrusion than the peridotite and pyroxenite.

Another fact, observed at a point just above the forks of Eagle creek, is significant of the relative age of the Eagle granodiorite. A small outcrop of pyroxenite, probably an offshoot from the main body, appears in close proximity to an outcrop of granodiorite. The pyroxenite is bleached and altered to a light coloured shaly rock, as if by contact with the granodiorite. This also would suggest that the Eagle granodiorite was intrusive into the pyroxenite.

Little evidence bearing on the relation of the Eagle granodiorite to younger formations can be obtained inside the limits of the Tulameen sheet. On the western edge of the mass, at the head of Eagle creek, the granodiorite is overlaid by volcanic rocks, which from their attitude and structure appear to belong to a late Tertiary date. The relation of these two formations to each other indicates that the volcanic rocks were extruded over the surface of the granodiorite some time after its irruption and after it had suffered considerable erosion.

On the headwaters of the Tulameen river is a series of Cretaceous sediments consisting of shales, sandstones, and conglomerates. The basal bed of this series is a volcanic breccia lying beneath a coarse conglomerate. On the eastern edge of the Cretaceous belt the breccia is in direct contact with a sheared and gneissic granitic rock, which, though not actually known to be connected with the Eagle granodiorite, is so close to it and at the same time so like it in general character, that it was considered to be the same. This contact shows the breccia to have been laid down as a surface deposit on the top of the granodiorite, and there is no evidence that the granodiorite is intrusive into the breccia. The conglomerate, also, which lies conformably above the breccia, contains pebbles of a rock which appears to be identical with the Eagle granodiorite. Altogether the evidence suggests that the Eagle granodiorite was intruded prior to the deposition of the Cretaceous sediments, and may be, therefore, of late Jurassic age.

MODE OF ORIGIN.

The nature of the origin of the Eagle granodiorite is determined from a study of its contacts with rocks through which it has been thrust. Its size is batholithic, and its mode of origin is identical with that of other batholithic rocks of this or any other region. Its contact zone with the rocks of the Tulameen group, as already described, covers a belt sometimes 1,000 feet in width. This belt can be divided into two zones: namely, a zone of included fragments nearest the granodiorite itself, and a zone of apophyses farther away from the granodiorite. As described by Daly, Barrell, and others in the case of similar intrusions, the granodiorite batholith is believed to have slowly worked its way upward from the heated interior of the earth through the overlying rocks of the solid crust, by stoping off fragments of them and by filling the space formerly occupied by them. These fragments settled downward in the molten mass of the granodiorite magma and were absorbed and perhaps assimilated by it. As it ascended higher and higher into the cooler rocks of the outer crust the granodiorite magma slowly lost its heat until it cooled sufficiently to solidify. The cooling would commence on the outer edge of the uprising mass while the central portions yet remained fluid. Probably by some movement in the central fluid parts of the mass a schistose structure was induced in the outer viscous shell, giving the effect we now see in the outer zone of the granodiorite formation.

While the granodiorite magma was slowly rising in the chamber, offshoots would presumably be sent from it into the adjacent rocks to form the granite porphyries that we now find. Offshoots of this kind are usually more acid in composition than the main body, the greater acidity being accounted for by the rise of the acid lighter parts of the magma towards the upper parts of the chamber, while the heavier more basic portions remained below it.

AGE AND CORRELATION.

All the available evidence that has been obtained on which to fix the age of the Eagle granodiorite intrusion has been given in preceding sections of this report. The evidence may be enumerated thus: on the headwaters of the Tulameen river fossiliferous lower Cretaceous rocks rest unconformably on the Eagle granodiorite; the Eagle granodiorite is intrusive into the stratified rocks of the Tulameen group which, though they have yielded no fossils up to date, are lithologically similar to Triassic rocks. This places the Eagle granodiorite in the Jurassic period, and it is placed in the upper part of that period, because the Boulder granite, peridotite, pyroxenite, and augite syenite, all referred to the same period, are older than it.

Placing the Eagle granodiorite in the Jurassic period is equivalent to correlating it with the Coast Range batholith and the numerous other batholithic bodies that are referred to this period of igneous activity.

Cedar Volcanic Series.

DISTRIBUTION.

The rocks of the Cedar volcanic series cover a great part of the eastern half of the Tulameen district. Being one of the youngest formations they partly cover some of the older rocks and are themselves covered, in the southern part of the district, by the rocks of the Coldwater series, while on the north they are intruded by the Otter granite and have probably been reduced in areal extent by it.

Four separate areas of this series have been outlined on the geological map. All of these areas, however, were probably at one time connected with each other and formed one large sheet, which stretches far to the north of the present map.

The largest of the four areas lies to the east of Otter valley, on the headwaters of Manning and Cook creeks. This area covers a length of about 10 miles and a greatest width of 4 miles inside the limits of the sheet. A small area caps the summit of Otter mountain. A third lies to the west of Otter lake, covering the top of Riddell mountain, and a fourth lies to the south of the Tulameen valley in the basins of Cedar creek and the North Fork of Granite creek. The last mentioned area extends southward beyond the limits of the map, and its original outcropping extent has been somewhat reduced by being covered by later sedimentary rocks. The total area of this series as mapped is about 30 square miles.

LITHOLOGY.

The Cedar volcanic series is made up essentially of volcanic materials that have been extruded, in a number of consecutive flows, over the surface. The effusion of these lavas, however, was accompanied by a local downwarping of the surface in the district now covered by the sedimentary rocks of the Coldwater series. Some of the lavas of the Cedar volcanic series flowed out into this downwarped area after sedimentation had begun in it, so that a few feet of the lower part of the Coldwater sediments are now found interbedded with the Cedar volcanics. These few feet of the Coldwater rocks are not of great enough thickness that they could be shown on the geological map, but they have been found in half a dozen places to the west, northwest, and southwest of the area mapped as Coldwater, and have there been included in the Cedar volcanic series and mapped as such. With that exception the Cedar volcanic series is wholly volcanic in origin.

In general the rocks of the Cedar volcanic series are dark in colour and of basic or medium basic composition. They range from dacites to basalts with a strong preponderance of andesitic beds.

The series, being made up of successive flows of volcanic material, emanating perhaps from a number of sources, naturally does not show the same sequence of beds throughout the whole series. This generalization, however, holds, that the more basic material emanated first, and lies in the bottom beds, while towards the top the beds become slightly more acid.

On the north and west slopes of Jackson mountain, where this series was best studied, the lowest beds were found to be basalts and some breccia.

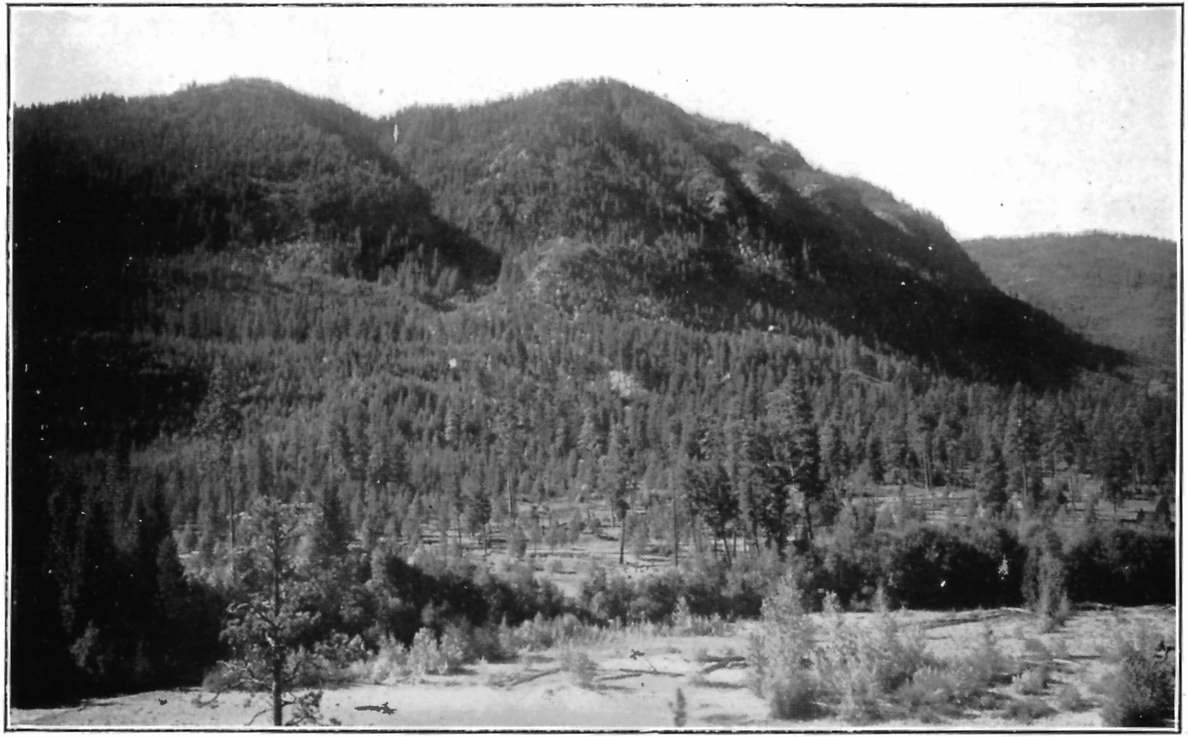
A good exposure of breccia is seen on the Bear Creek wagon road, in the angle between the Tulameen and Otter valleys. This bed is distinctly stratified and weathers to a dull red colour. It is soft and friable, and is made up of angular fragments of volcanic rocks of red, green, and black colours in a matrix of andesitic material. A breccia of somewhat similar character and in the same stratigraphic position outcrops in the North Fork of Granite creek. This is traversed by many small veins of calcite, which cement the fragments together.

The basalts of the lower part of the series are dark, fine grained rocks which show a vesicular texture, especially on weathered surfaces, and are often traversed by small veins of chalcedonic quartz. In structure they are massive, and frequently show a well developed columnar jointing. They are soft and weather down very easily. The thin section shows small acicular needles of plagioclase, small rhombs of pyroxene and an occasional large feldspar. It is full of amygdules, and shows much magnetite and some glassy base.

Rocks on Otter mountain and in the basins of Cook and Manning creeks, belonging stratigraphically to the same horizon as the basalts, that is near the bottom of the series, are as dark in colour but more acid in composition. They have a well developed porphyritic structure with phenocrysts of plagioclase, a little orthoclase and occasional quartz, in a dark coloured groundmass composed largely of small feldspar laths and glass. A little augite enters into the groundmass of some of the specimens.

The upper part of the Cedar volcanic series is prevailingly andesitic in character. They are lighter in colour and often have an ashy look and a harsh feel. They have a shaly structure on the outcrop and break easily into small fragments, so that a fresh fracture is hard to obtain. In the thin section the rock exhibits a tendency to porphyritic structure, with a few phenocrysts of hornblende, generally much altered, embedded in a holocrystalline groundmass of small plagioclase laths. The shape of the hornblende suggests that it is an alteration from augite. Flow structure is generally well developed in the groundmass.

The topmost bed of the Cedar volcanic series, as seen in the section exposed in Collins gulch, is a breccia. This breccia is very much decomposed and weathers to a reddish colour. The fragments consist entirely of volcanic materials through which run small seams of chalcedonic quartz.



Jackson mountain.

STRUCTURAL RELATIONS.

Internal.—The Cedar volcanic series consists essentially of bedded volcanic rocks which have been extruded over the surface in a succession of flows emanating for one or several foci. The bedded character of the rocks is not always apparent on a small, isolated outcrop, but is very evident when the series is viewed on a large scale from a distance. The northern face of Jackson mountain exhibits this feature very well, and when looking at the face of the mountain from Tulameen village several massive beds can be identified outcropping in an almost horizontal line from east to west. Where the dip is obtainable the beds are found to lie at angles which rarely exceed 40 degrees. As this succession of flows appears to have been extruded into a downwarped basin, the strike is not constant but forms a curve which conforms to a certain extent to the strike of the Coldwater sediments on the western and southern sides of those rocks.

The majority of the beds which make up this series are massive in structure, but some of the uppermost ones have a laminated structure, and break down to a talus of small flat plates.

Brecciation is present in beds which form the base and the top of the series. This structure is not the result of subsequent fracturing, but was probably induced in the rock at the time of extrusion. A brecciated structure which has a different origin is noticed on the contact of the Otter granite at the headwaters of the western branch of Cook creek. The brecciation in this case is due to the intrusion of the Otter granite into the volcanic rock, for the matrix is of Otter granite material, while the fragments belong to the Cedar volcanic series.

Over much of its area the Cedar volcanic series forms a bold, irregular topography, with many outcropping ledges. The rocks do not break down very easily and are very often covered only with a very thin mantle of soil.

External.—The various rock formations with which the Cedar volcanic series comes in contact are the Tulameen group, Boulder granite, augite syenite, Otter granite, and the Coldwater series.

The unconformity which exists between the formation under discussion and the Tulameen group is shown on the North Fork of

Granite creek about a mile above its mouth, and also on the west slope of Cedar creek. At each of these places the dip of the rocks of the Tulameen group is high and often vertical, while the beds of the Cedar volcanic series dip at very low angles. These contacts show that the rocks of the Tulameen group were folded and eroded before the Cedar volcanic series was laid down on top of them.

Contacts with Boulder granite are exposed on the west side of Riddell creek, and with augite syenite on the main branches of the North Fork of Granite creek. In each of these cases the rocks of the Cedar volcanic group show no such indication of contact metamorphism as might be expected if the Boulder granite and the augite syenite were intrusive into them. On the other hand the Boulder granite which outcrops directly west of Tulameen village has been slightly altered by the heat of the breccia bed which forms the base of the Cedar volcanic series. This breccia was apparently a volcanic flow which was extruded over the surface of the Boulder granite, and it contained sufficient heat to slightly metamorphose the surface of the Boulder granite, so that its appearance is now somewhat abnormal.

Contacts with Otter granite are seen at several points on the east side of Otter valley, and the intrusive nature of the Otter granite into the Cedar volcanic series is clearly apparent. At the headwaters of the westernmost branches of Cook creek, a breccia has been formed on the contact which shows fragments of the volcanic rocks in a matrix of Otter granite. Again on the ridge which separates China creek from Cook creek the contact is well exposed, and apophyses of Otter granite cut into the rocks of the Cedar volcanic series.

The relation of the Cedar volcanic series to the Coldwater series has been carefully studied on account of the bearing it has on the occurrence of coal. The contact between these two formations is well exposed in the bed of Collins gulch. The succession of strata up to the sandstone which here forms the base of the Coldwater series is as follows: volcanic agglomerate and beds of andesite overlaid by a stratum of conglomerate which grades into sandstone. Above this are more andesites and breccia, in which is intercalated a thin bed of sandstone and another of red clay. Conformably above the breccia is the arkose sandstone of the Coldwater series.

The conglomerate and sandstone which are intercalated with the andesites of the Cedar volcanic series outcrop on Blair creek on the north side of the Tulameen river, on Cedar creek, and in several places in the basin of the North Fork of Granite creek. Some coal markings appear in the sandstone of Blair creek, and a narrow seam of coal is visible at the same place and on Cedar creek; but it is hardly probable, on account of the limited thickness of these true sediments, that a workable seam of coal will be found in them.

From the fact that some true sediments are intercalated with the volcanics of this series the inference is drawn that the volcanics were extruded into a basin in which—when vulcanism had ceased temporarily—thin sedimentary beds were deposited, and when vulcanism had finally terminated the sediments of the Coldwater series were laid down.

MODE OF ORIGIN.

Both the structural features and the lithological characters of the Cedar volcanic series indicate that its various members, exclusive of the small thickness of true sediments mentioned above, were extrusive in origin and poured out over the surface in the form of lava flows. The details given in foregoing parts of this section give us a fairly clear conception of its origin.

Over the great part of the area covered by the Cedar volcanic series the basal bed of the series is a volcanic breccia, containing fragments of various kinds of rocks embedded in an andesitic matrix. This bed is presumably a lava flow which has caught up and incorporated in its own mass fragments of the rocks with which it came in contact, as well as those fragments of its own material which consolidated on its surface and were broken up by the movement of the flow. Other lava flows succeeded this, pouring over the surface of the breccia. Probably as an effect of the extrusion of the lavas a downwarp of the surface took place to form a basin, and during a cessation of vulcanism some true sediments represented by sandstones and conglomerates were laid down in the downwarped surface. After a short period of rest volcanic activity was resumed, and a great thickness of volcanic rocks was extruded, some of them perhaps being laid down under the water of the basin, as we find them near the top interbedded with thin beds of clay and sandstone. When vulcanism finally ceased altogether the sedimentary beds of the Coldwater series were deposited conformably above these rocks.

No tuffs or rocks of explosive origin are found in the whole series, so that it is not likely that these rocks originated from open volcanic craters. It is far more probable that they emanated from fissures which tapped magma chambers in the interior of the earth. It is inferred also from their wide distribution and from the great thickness of these rocks in certain places and their thinness or total absence in others, that they arose not from one fissure alone, but from several, which may not have had any connexion with each other.

AGE AND CORRELATION.

The age of the Cedar volcanic series has been definitely settled from the relation which this series bears to the Coldwater series. The great mass of the Coldwater series lies conformably above it, but some of the lower members are interbedded with the beds of the Cedar volcanic series. These intercalated members of the Coldwater series contain many plant remains, which have been identified as Oligocene in age. The Cedar volcanic series, therefore, is also of that age.

No volcanic rocks, with which the Cedar volcanic group can be correlated, have been previously described in British Columbia. The Tertiary volcanic rocks described by Dawson in the Kamloops district are all said to lie unconformably above the Coldwater series.

Certain rocks described by G. O. Smith[1] in the Columbia lava field of Washington may be contemporaneous with this formation. The Teenaway basalt is referred by Smith to the top of the Eocene, and from its stratigraphical position with relation to certain coal bearing formation in that region, might be correlated with the Cedar volcanic series.

With our present knowledge of the geology of southern British Columbia, we may say that the Cedar volcanic series represents the beginning of volcanic activity in the Tertiary in that region.

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[1] U.S.G.S. Prof. Paper, No. 19.

Coldwater Series.

DISTRIBUTION.

The name 'Coldwater series' is applied to a series of rocks of Oligocene age lying in the drainage basin of Collins gulch and extending over the divide to the Granite Creek slope. Rocks of similar age have been referred to by Dawson as the 'Coldwater group'; but since the term *group* was given to it, this series of rocks has been studied palæontologically by Lambe and Penhallow,[1] with the result that it was found to be confined to a definite period of time in the Tertiary. This conclusion has convinced the writer that the more limiting term *series* is better than *group*, and will be used throughout this report, with the understanding, however, that it replaces Dawson's term group only when applied to this series of rocks.

On account of the economic importance of these rocks, their distribution has been very carefully outlined on the geological map. The area covered by them is slightly oval-shaped, with its longer axis running northwest and southeast. In this direction it has a length of almost 3½ miles, while the greatest width is 2⅓ miles. The total area as measured on the geological map is 5·78 square miles, or 3,700 acres. Of this amount 1,070 acres are covered by a flow of olivine basalt, so that only 2,630 acres of the Coldwater series are mapped as being exposed.

LITHOLOGY.

The rocks which make up the Coldwater series are all soft, and weather down so easily that good exposures of them are not numerous. The best natural section of them is exposed in Collins gulch, a ravine which cuts directly across the strike of the beds. This section was carefully measured with compass and chain, and a thickness of 2,270 feet of strata was obtained from the top of the Cedar volcanic series up to a point where the rocks are entirely covered by drift. This point was probably within 100 or 200 feet of the top of the series, so that the total thickness of these rocks would be less than 2,500 feet along this line.

[1] Tertiary Plants of British Columbia, Geol. Surv., Can., 1908.

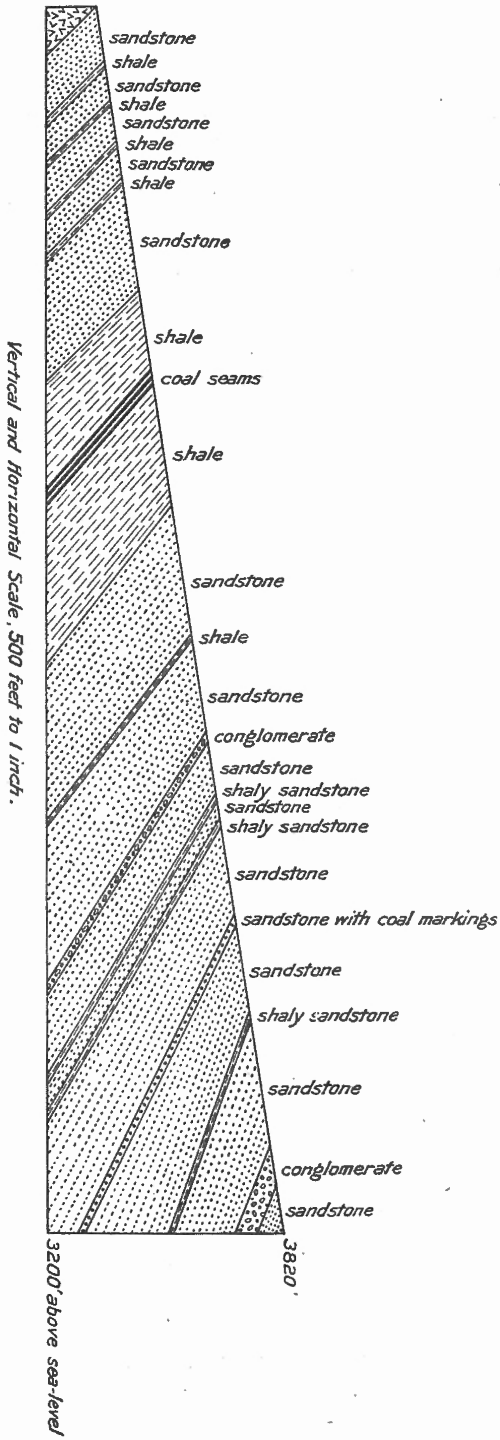

Fig. 1. Profile of Collins gulch.

The basal bed of the series is a conglomerate, which on the western half of the basin is separated from the main body of the series by a considerable thickness of Cedar volcanic rocks, but in the eastern half is probably united with the rest of the series. This conglomerate is exposed on the north face of Jackson mountain, on Blair creek, and at points on Cedar creek and the North Fork of Granite creek. A thickness of about 25 feet of this conglomerate is exposed on Blair creek below some sandstone, and is seen to consist of some waterworn pebbles of siliceous and argillaceous rocks cemented together with a matrix of sand grains which contain some plant remains. Some sandstone carrying fossil plants and associated with very thin seams of coal rests directly on top of the conglomerate.

A columnar section of the rocks exposed on Collins gulch is shown in Fig. 2. This section may be divided roughly into three groups of rocks. The lowest group measuring 600 feet in thickness and resting conformably on the Cedar volcanic rocks is composed of sandstones with which are interbedded a few thin seams of shale. Above this is 460 feet of very fissile shale containing at least two coal horizons. The upper part of the section has a great preponderance of sandstone, but contains also some thin shale bands and beds of conglomerate.

The sandstone at the base of the Collins Gulch section rests directly and conformably on a flow of andesite, and is a soft, friable arkose, reddish-brown in colour, massive in structure, and containing many plant remains. From the lack of a continuous exposure it is not possible to state the relative proportion of shale to sandstone in this division of the series, but the figure shows four bands of shale each one of which is 10 feet or more in thickness.

The sandstones of the lower division of the series pass gradually into the shales of the middle division by becoming more thin bedded in structure and argillaceous in composition. The middle division contains at least two coal horizons, but is otherwise made up entirely of shales to a thickness of 460 feet. The shales are very fissile and split easily into thin plates. They are dark coloured but often weather whitish on the outcrop. On most of their exposures no fossils could be found in them, but at certain locali-

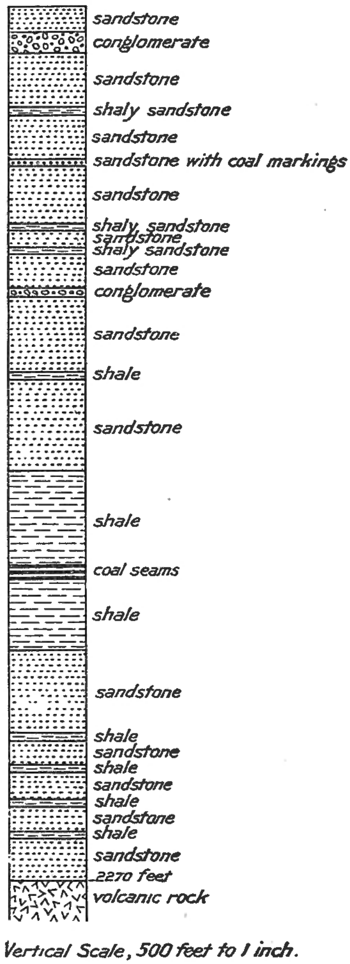

Fig. 2. Columnar section of Coldwater series on Collins gulch.

ties such as at the northwest edge of the basin and on the little North Fork of Granite creek they contain many plant remains. These plant remains have served to identify their age and to correlate the whole series with other series of rocks in the adjacent country. These fossils are referred to under a subsequent heading.

The upper division of the series, like the lower, consists mainly of sandstones, but holds also thin beds of shales and some conglomerate. The sandstones are generally rather coarse in texture and massive in structure. They are light coloured and are composed of quartz grains embedded in a white, fine grained, sandy matrix. The shale and conglomerate bands intercalated with the sandstones are comparatively thin and few in number. The shales are more or less sandy and often contain coal markings. There is a probability that a coal seam may be found in this division of the series, for on the southern side of the basin a small seam outcrops, which belongs apparently to this horizon.

METAMORPHISM.

In the sandstones and shales of the Coldwater series no metamorphism is apparent either of regional or contact origin. There is, however, some evidence of metamorphism in the coal seams which are found associated with the shales. This metamorphism is not apparent on a cursory examination of the coals, but is revealed in the chemical analysis of coal samples taken from different parts of the basin. For example, samples taken from the workings on the Granite Creek slope a short distance from the olivine basalt give a firmer and higher percentage of coke than those taken from Collins gulch at a greater distance from the basalt. The fuel ratio of the former is also higher. This difference can only be accounted for by metamorphic action due to the heat of the basalt, and it is reasonable to expect that when the coals come into close contact with the basalt a stronger metamorphosing action will have produced a still higher grade of coal. This, however, can only be proved by further examination.

STRUCTURAL RELATIONS.

Internal.—The Coldwater series is essentially sedimentary in origin, and consists of a succession of strata deposited in a horizontal, or approximately horizontal attitude. Subsequent events, however, have so affected the whole series that at the present time it does not preserve the original position in which its members were laid down. Its structure is now that of a synclinal basin having its longer axis running approximately northwest and southeast. On the southwest side of this basin the dips of the beds are in general towards the northeast; and in the northeast side of the basin they are towards the southwest. These dips vary—where they have been measured—from 20 degrees up to 70, and are greatest on the outer borders of the syncline. The average dip along the outer edges of the basin is about 40 degrees, and this decreases gradually towards the centre, where the strata presumably become horizontal before rising in the opposite direction.

Although it can be accepted as a general rule that the dips of this series are regular on both sides of the basin, it is sometimes apparent, where sections have been exposed either by natural agencies or in the course of mining development, that there are other dips which do not conform to the general direction obtaining throughout the basin. In these cases pressure has been exerted in a different direction to the main one, which resulted in the formation of the syncline, and minor folds have been produced. Examples of such folds are seen on Collins gulch at the old mine workings, and again at the main workings on the Granite reek slope. In the latter case at No. 1 and 2 tunnels the dip of the strata is towards the east, but it is impossible that it can continue far in that direction before the strata rise and the dip changes to the opposite direction.

Although there are these small folds, no instance has yet been observed where the folding has gone so far as to produce faulting except to a very minor degree. It is not to be expected, however, that faults will not be encountered in the whole basin. It is certain from the age of these rocks and their present attitude that they have passed through periods of orogenic disturbance which in themselves might have resulted in faulting; and it is the experience obtained in mining the coal in most of the basins of this age in this part of British Columbia and the adjacent regions of Washington, that faults have been encountered. It is probable, therefore, that faults do occur.

For another reason faulting might be expected to have taken place. In the structure sections which are drawn through the coal basin, olivine basalt is shown as a sheet covering part of the basin. It is probable that, because dykes of olivine basalt are found in the immediate vicinity of the coal basin, the fissure or fissures through which the olivine basalt reached the surface traverse the rocks of the coal basin, and that, therefore, the source of the olivine basalt was directly beneath the coal basin itself. The withdrawal of the olivine basalt magma from the region beneath, and its deposition on top of the coal basin would cause a readjustment by sinking of the strata between, and in this readjustment faulting might have occurred.

The Coldwater series of the Tulameen district is made up of rocks that are so easily weathered down that natural exposures of them are comparatively rare. To this fact it is due that, although coal was long known to outcrop in Collins gulch, it was years before it was discovered anywhere else. The shale beds of the series are the softest, and can often be identified and followed by a depression on the surface of the ground. The sandstones are the most resistant members, and where they are interbedded with shales they form hard outstanding ribs with depressions between them.

The whole formation is characterized in the topography by rounded outlines and gentle slopes.

External.—The oldest formation with which the Coldwater series is in contact is the Tulameen group, and the nature of this contact leaves no doubt of the relation existing between these two groups of rocks. On Fraser gulch the lower sandstones of the Coldwater series outcrop within a few feet of the black and bluish slates of the Tulameen group. The sandstones dip towards the southwest, and strike about S. 60° E., while the slates strike about N. 65° E. and dip 65 degrees to the north. A discordance of dips with a much higher angle in the Tulameen rocks than in the Coldwater can also be noted on the trail to the Granite Creek mines where that trail crosses the contact between these two groups of rocks. These facts, coupled with the strong difference in structural and physical features between the two groups of rocks, proves that a long period of time must have elapsed between the deposition of each group. The evidence suggests that the rocks of the Tulameen group were upturned and compressed, and their edges truncated before the deposition of the Coldwater series. In other words there is a strong unconformity between the two groups of rocks.

Around two-thirds of its outer border the Coldwater series is in direct contact with the Cedar volcanic series. This contact is described in detail on a preceding page. The two series are there stated to be conformable with each other, because the lower strata of the Coldwater series are interbedded with the upper members of the Cedar volcanic series. The lower beds of the Coldwater series, consisting of conglomerate passing upward into sandstone, become separated from the main body of the series by a wedge of the Cedar volcanic series at Fraser gulch. Passing around the western side of the basin from north to south, the conglomerate and sandstone do not again unite with the main body of the Coldwater series until the wedge of Cedar volcanic rocks pinches out on the North Fork of Granite creek at the southern end of the basin. In this distance the sandstone and conglomerate can be found outcropping in a number of places, and in others their position can be identified by the topographic expression. The evidence shows that deposition of the lower beds of the Coldwater series began in this region before the extrusion and deposition of the uppermost beds of the Cedar volcanic series, and hence the two periods overlap to a certain extent and there is no time break between them. The dips of the two series also coincide in degree and direction, and their strata are, therefore, conformable.

The only younger formation with which the Coldwater series is in contact is the olivine basalt. This lies as an almost horizontal sheet over the top of the Coldwater series covering about one-third of its total area. The actual contact between the two was nowhere found exposed. The relation between the two formations is best seen near the head of Fraser gulch. At this point the sandstones and interbedded shales of the Coldwater series dip at an angle of 25 degrees towards the south and strike directly underneath the covering of flat-lying olivine basalt. That the strike and dip of the sandstones persist underneath the basalt is indicated by the topography of the surface, which shows parallel ridges, presumably of sandstone, separated by hollows, probably marking shale beds, continuing up to the contact of the basalt. These features indicate that there is an unconformity between the two formations, for the Coldwater series must have first of all been tilted and then the upturned edges truncated by erosion before the olivine basalt flowed over its surface.

MODE OF ORIGIN.

The structure of these rocks and their association with beds of coal indicate that they were laid down in a horizontal or nearly horizontal attitude by the action of water. They have been correlated by their fossils with Dawson's Coldwater group described in his report on the Kamloops Map-sheet.[1] In the course of the present examination of them no further information was obtained of their mode of origin than that outlined in the report above cited. Dawson states that 'these beds were laid down in lakes or river estuaries, in hollows then existing in the old denuded surface of the Palæozoic and Triassic rocks,' and that 'they may well represent the work of some river systems of the early Tertiary time of denudation.' It might be argued from the present shape of the Coldwater series of this district, a shape which is now oval but before compression might very well have been almost circular, that the evidence in favour of it having been a lake basin is stronger than that for an estuary. Indeed, Penhallow,[2] in speaking of rocks of similar age outcropping on the Tulameen river near its junction with the Similkameen, distinctly states that 'the beds were evidently laid down in the bottom of a lake.'

AGE AND CORRELATION.

The determination of the age of the Coldwater series of the Tulameen district depends entirely on its fossil plants. Plant remains were collected from three different localities within the area covered by this series. The most productive locality was one near the head of the little North Fork about the middle of lot 295. Another was at the head of a small creek flowing into Collins gulch and directly south of Jackson mountain. The third was in Collins gulch immediately below the point at which coal mining was formerly done. The two first mentioned localities were in the shales which form the middle of the three groups into which the whole series was lithologically divided. The last was in the sandstones which form the lowest of the three groups. Besides these three localities a few plants of the same varieties were observed in sandstones near the head of Collins gulch and in the sandstones inter-

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[1] G.S.C. Annual Report. Vol. VII, Part B.
[2] Tertiary Plants of British Columbia, G.S.C. 1908, page 20.

calated with beds of the Cedar volcanic series which form the base of this series and which outcrop in Blair creek on the north side of the Tulameen river.

A collection was made of over forty specimens, many of which were well preserved. These were studied by Dr. F. H. Knowlton, of the United States Geological Survey, who has been able to identify two different species of plants. These plants are:—

Comptonia cuspidata Lesquereux.
Sequoia langsdorfii (Brongniart), Heer.

Dr. Knowlton says that 'this material—thirty-nine specimens of the conifer and a single dicotyledonous leaf—is not sufficient to definitely fix the age, though it is presumably Oligocene or lower Miocene.'

Accepting Dr. Knowlton's determination of the age of these rocks, they can, therefore, be correlated with certain coal bearing rocks called by Dawson the Coldwater group, which are found at the following places in the adjacent region of British Columbia: Hat creek, Copper creek, Nicola valley at the junction with the Coldwater, and the Similkameen valley at Princeton. These various localities had already been correlated with each other by Penhallow in the report cited above and their age determined from plant remains as Oligocene. The same conclusion is arrived at by Handlirsch from a study of the insects found in the beds.[1]

In the adjacent region south of the International Boundary line, coal-bearing beds having a strong lithological resemblance to those of the Tulameen have been described under the name of the Roslyn formation.[2] This formation is classified by the United States Geological Survey as upper Eocene, but it may probably be of similar age to the Tulameen beds.

The occurrence of Amyzon in the beds of the Similkameen area at Princeton led Cope and Lambe to correlate that area with the Amyzon beds of Oregon, Nevada, and Colorado. The correlation of the beds in the Tulameen district with those at Princeton would, therefore, include correlation with the areas in the United States mentioned above.

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[1] G.S.C. Memoir No. 12-P. Contr. to Can. Palæontology.
[2] U.S.G.S. Folio No. 139. 1906.

Otter Granite.

DISTRIBUTION.

The Otter granite formation is limited in distribution to the north side of the valley of the Tulameen river, and the main part of it lies on the eastern side of Otter valley. This body is elongated in a north and south direction and has a length within the limits of the map of 9½ miles. Its width varies from one-half mile up to 2½ miles. From China creek on the south it extends northward, following the eastern slope of Otter valley and passing out beyond the limits of the map at Manning creek as a dyke-like body a little more than half a mile wide. To the north of the map it crosses to the west side of Otter valley and continues on in that direction for an unknown distance.

A smaller boss-like body outcrops on the ridge between Boulder and Bear creeks south of Spearing mountain. This body is mapped as being about half a mile in diameter, but as the country on the slope of Bear creek is heavily timbered and drift covered, the areal extent of this body in that direction is merely conjectural.

Over the greater part of its area the Otter granite is fairly well exposed, and as it is one of the youngest formations in the district the area mapped as such represents the total exposed area that this formation ever had, not including, however, that part which might be covered by the recent deposits.

LITHOLOGY.

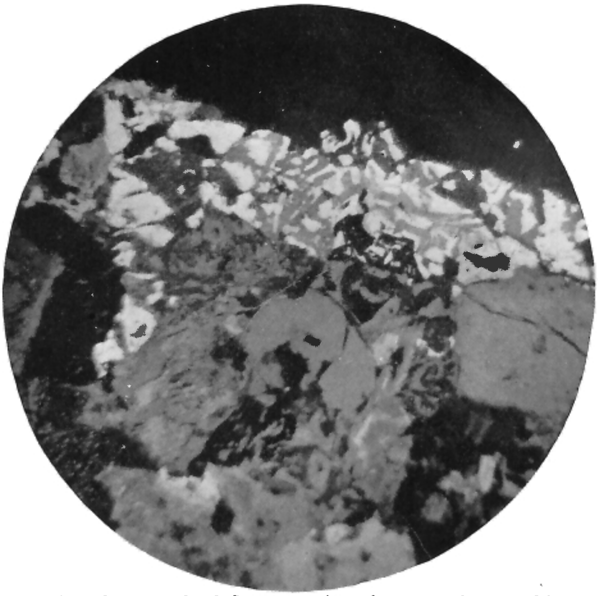
It has been found in the course of the mapping of this formation that while the type rock of the main central portion has a well marked uniformity of physical and mineralogical characteristics, it was bordered on a few of its contacts by a rock of more basic composition. It was at first thought that this bordering rock represented a totally different type, and for a time it was mapped as such. On examination, however, no sharp contacts could be found between the two types, and the field evidence suggested a transition between them. The microscopic study of samples taken from the border type tended to confirm that suggestion. The structure also of the two types of rocks showed that they were not widely separated in time of intrusion, and that they were both comparatively recent rocks. The combined weight of this evidence led to the conclusion that the one type was merely a basic border phase of the other. Consequently the two types were grouped together and have been mapped under the name of Otter granite.

The typical rock of this formation is pink in colour and medium grained in texture. In general the texture is granitic, but there is occasionally a tendency in it to develop a porphyritic structure in which the phenocrysts are large white feldspars in a pink groundmass. The constituents that can be identified in the field are pink and white feldspars, quartz, a little biotite, and some hornblende. In this type the acid minerals greatly preponderate over the basic minerals.

The extreme basic phase of the Otter granite formation is a dark coloured granitic rock showing white feldspar, some quartz, and much black hornblende and less biotite. In this type the dark coloured minerals are much more abundant than in the main type mentioned above. Intermediate types of rocks have some of the characteristics of the two extremes.

In the thin section the whole Otter granite formation from the most acid to the extreme basic type is characterized by containing quartz and orthoclase intergrown together in a micrographic structure. More instances of this structure are seen in the acid type of this formation, because in these the quartz is more abundant; but even in the most basic type, which is a quartz mica diorite, any quartz present is generally intergrown with feldspar, or else it is interstitial. Biotite also is an essential constituent of all phases of this formation.

A sample taken from the east side of the north end of Otter lake, and typical of the main body of the formation, has been analysed by M. F. Connor, of the Mines Branch, and its chemical composition is given below. Under the microscope this rock is seen to contain clear glassy quartz intergrown with turbid feldspar in a micrographic structure. The feldspars are always altered, and are both orthoclase and plagioclase, the latter being fresher in appearance. They show no albite twinning, though Carlsbad twins are common and there is some zonary banding. Biotite is sparing in small pleochroic shreds. There is a little accessory magnetite and apatite. The chemical composition of this rock is as follows:—



Microphotograph of Otter granite, showing micrographic intergrowth of quartz and feldspar.

SiO_2	72·32
Al_2O_3	14·53
Fe_2O_3	0·67
FeO	1·37
MgO	0·58
CaO	1·52
Na_2O	4·46
K_2O	3·51
H_2O+	0·67
H_2O-	0·06
TiO_2	0·30
P_2O_5	0·17
MnO	0·02
	100·18

The analysis indicates that the rock is a fairly acid granite, with the peculiarity that the soda is slightly higher than the potash, and, therefore, much of the untwinned cloudy feldspar seen in the thin section must be albite rather than orthoclase. According to the Quantitative Classification of Igneous Rocks this rock is lassenose.

In the porphyritic variety of the acid type the white phenocrysts prove to be plagioclase, while the pink groundmass is composed of smaller individuals of orthoclase and quartz. In all types the plagioclase is more idiomorphic than the orthoclase and appears to have crystallized out before either of the orthoclase or the quartz which remained to crystallize together as the final product.

Intermediate types of this formation contain an approximately equal proportion of orthoclase and plagioclase, and much hornblende. Quartz is less abundant and is intergrown as usual with the feldspar. Titanite is present as an accessory constituent. This type is probably a granodiorite.

The extreme basic types are diorites, all of which contain quartz and mica, besides the feldspars and hornblende, and in one section some augite grains are present. Examples of these types are found at the northern limit of the map, on the east side of Frembd lake, and to the north of the Princeton wagon road between Cook and China creeks.

The Otter granite formation is always fresh looking, and shows on its outcrop little evidence of metamorphism. In the thin sections the only evidence of alteration is seen in the turbid character of the feldspar, and in this alteration the orthoclase goes more rapidly than the plagioclase.

STRUCTURAL RELATIONS.

Internal.—Because it is one of the youngest formations in the district, and has been subjected only to those dynamic disturbances which have followed the Oligocene period, the Otter granite formation is still massive in structure and fresh in appearance. It is not traversed by fracture planes and does not break along a number of definite lines. The only apparent lines of dislocation in the rock are due to jointing, and joint planes were noted running in two directions, namely, S. 80° E. and S. 25° E.

As described in a preceding section, the Otter granite formation is not homogeneous in composition throughout; but while the main body of the rock is a granite, often on its outer borders it passes by a change in the relative proportion of the two kinds of feldspar into a rock which is properly called a quartz diorite. The quartz diorite does not appear everywhere on the borders of the granite, but is present more especially on the two ends of the body and only in patches on the sides. The cause of the variation in composition is not readily apparent, but is thought to be due rather to differentiation in the magma than to assimilation of rocks through which the rock has been thrust.

External.—On the divide between Boulder and Bear creeks south of Spearing mountain are exposed contacts of Otter granite with the Tulameen group, and with augite syenite. With the former the Otter granite forms a clean cut but ragged contact, with little evidence of contact metamorphism in the rocks of the Tulameen group. With the augite syenite, the Otter granite makes a brecciated contact, showing the granite acting as a matrix for angular fragments of syenite. Farther into the syenite are small apophyses of the granite striking at various angles. In each case the Otter granite is intrusive into the other rocks.

Although Otter granite is represented on the geological map as cutting the Boulder granite, the actual contact between these rocks is not exposed, because of the covering of drift. The relations existing between these two formations, however, are clearly inferred from the fact that the Otter granite is intrusive into rocks which are younger than the Boulder granite.

Directly east of the north end of Otter lake, as well as on the ridge to the west of China creek, are well exposed contacts of Otter granite with the Cedar volcanic series. These contacts are critical, as they determine the relative position of the Otter granite in the table of formations. At the first mentioned place the contact is a brecciated one, rounded and partly fused fragments of the Cedar volcanic series being embedded in a matrix of Otter granite. At the latter place the contact is sharper, and the Otter granite sends off apophyses into the volcanic rocks. Some metamorphism also has taken place, and the volcanic rocks have been shattered so that they break easily into small cubical fragments.

The Otter granite is not intruded by any large igneous bodies, but is cut by a number of small dykes, of which dark lamprophyres and light coloured syenite porphyries are the most common.

MODE OF ORIGIN.

The mode of origin of the Otter granite is not different from that of the other large igneous bodies of the district, already described. It is believed to have worked its way upward through the overlying rocks from a magma chamber below not so much by forcible injection into an open fissure, as by gradual replacement of the space occupied by overlying rocks. In its present outlines it is elongated in a general north and south direction, and that shape is the result of the magma entering along lines that were already predisposed to weakness in those directions by dynamic forces. It shows no evidence of having developed that shape since final consolidation.

AGE AND CORRELATION.

The age assigned to the Otter granite is based entirely on the nature of its contact with the Cedar volcanic series, and on the relations of the Cedar volcanic series to the fossiliferous rocks of the Coldwater series. The evidence on each of these points has already been given in preceding sections of this report. The contact of the Otter granite with the Cedar volcanic series is well exposed, and there can be no doubt that the Otter granite is intrusive into, and, therefore, later in age than, the Cedar volcanic series. On the other hand the Cedar volcanic series is conformable, and in its upper part contemporaneous with the lower part of the Coldwater series, so that the two series are virtually of the same age. Fossil evidence places the Coldwater series in the Oligocene period of the Tertiary; consequently the Otter granite is post-Oligocene in time of intrusion.

In the course of his work in the Kamloops district, Dr. Dawson[1] recognized two periods of vulcanism in the Tertiary separated by a considerable lapse of time. The older of these two periods produced a series of rocks which he placed in the lower Miocene, and the younger in the upper Miocene, with a probable unconformity between them.

The olivine basalt of the Tulameen district is correlated on lithological and structural grounds with Dawson's upper Miocene rocks. This formation lies as an almost horizontal sheet, and does not appear to have been disturbed since its intrusion over the surface. It appears to be younger than the Otter granite, because it is not reasonable to suppose that it would have remained undisturbed throughout the period when the Otter granite was being irrupted. The conclusion is drawn, therefore, that the Otter granite preceded the extrusion of the olivine basalt, and if the latter is late Miocene, then the Otter granite must be at least middle Miocene in age.

By another course of reasoning the same conclusion is arrived at. The Oligocene period of disturbance was closed by a period of disturbance and mountain building, when the sediments then laid down were upturned and deformed. This period of disturbance is recorded in the Tulameen district itself. Dawson in the report cited above recognizes the same period of disturbance, as also do the officers of the United States Geological Survey in their work in the adjacent region south of the International Boundary line.[2] It has come to be recognized as something more than a mere coincidence that batholithic intrusion is so often preceded by mountain building. So many instances of this sequence have been recorded that it is now almost an established rule of dynamical geology that before batholithic intrusion there must be mountain building. If this sequence of events holds true in the case under discussion, we should expect the Otter granite body to have been

[1] G.S.C. Vol. VII, 1894, Part B.
[2] U.S.G.S. Smith and Willis, Prof. paper No. 19
U.S.G.S. Folio No. 106. G. O. Smith.
U.S.G.S. Folio No. 139. Smith and Calkins.

intruded directly after the mountain building period which closed the Oligocene, and, therefore, in the early part of the Miocene.

Until more conclusive evidence is obtained it seems advisable, therefore, to place the date of the intrusion of the Otter granite in the lower or middle Miocene.

Tertiary granitic intrusions are by no means rare in the western part of the continent, and several instances of such can be cited. In British Columbia itself, in the Hedley district not far to the east of the Tulameen, a granodiorite intrusion is referred to the Tertiary, but the evidence for placing it there is by no means as strong as in the case of the Otter granite. Again, on the International Boundary line between the Okanagan valley and the Pasayton river, granite batholiths of three distinct periods of intrusion are placed by Daly[1] in the Tertiary period, but the evidence does not permit of them being further limited to any particular period in the Tertiary.

One of the clearest cases of granitic intrusion in the Tertiary is that recorded by Smith and Calkins[2] in the Snoqualmie quadrangle of Washington, where the Snoqualmie granodiorite is placed on convincing evidence in the Miocene or later.

Although there is not much lithological resemblance in these various rocks to the Otter granite, it seems perfectly legitimate that we should correlate them broadly with each other. There is perhaps not sufficient grounds for close correlation with the Hedley granodiorite and the granitic intrusions on the International Boundary line, but in the case of the Snoqualmie granodiorite the evidence is certainly good enough for closer correlation in time of intrusion.

Olivine Basalt.

DISTRIBUTION.

The olivine basalt has a very limited distribution, and is only found on the divide between Collins gulch and Granite creek. Its area has been carefully estimated on account of the bearing it has on the development of the coal field on which it lies, and this estimate can be considered as reasonably accurate because of the

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[1] Bull. G.S.A. Vol. 17, page 329.
[2] U.S.G.S. Folio No. 139.

ease with which the outlines of the basalt can be marked. Exposures are very numerous, and the topographic expression of its contact is also distinct. The area covered is about 1,070 acres, and the outline of this area is almost circular in shape.

The basalt is simply a sheet lying on the surface, and its thickness varies from 500 feet at the south edge to about 200 feet along the northwest border.

Besides this sheet of basalt, dykes of the same material up to 20 feet in width were found in two or three places rising through the older rocks not far from the outer edge of the sheet. The most distinct of these dykes appears in the canyon of the North Fork south of the basalt area, and it is probable that this and other dykes represent the original fissures through which the basalt was extruded.

LITHOLOGY.

As seen in the field the olivine basalt is a dark, almost black, rock of rather fine grain. The upper portion of the sheet is a typical basalt, open in texture and full of amygdules which are filled with a white zeolitic mineral. The lower part of the sheet is more compact and is not vesicular.

The thin sections of the rocks of this formation show it to be made up of two distinct types of rock, though without much apparent change in mineral composition. Sections of the upper part of the sheet show a rock of fine grain and slightly porphyritic structure, containing phenocrysts of plagioclase, augite, olivine, and some mica in a holocrystalline feldspathic groundmass. The groundmass shows a strong flow structure and contains much iron ore. The lower part of the sheet is an olivine diabase. It exhibits a well marked ophitic structure, with long laths of plagioclase feldspar embedded in large crystals of augite. Olivine is present in large rounded grains, which are generally fresh, but show some alteration to serpentine along cracks. Magnetite is very abundant as an accessory constituent. The rock is quite fresh, and shows no evidence of strain or movement subsequent to crystallization. The relative order of crystallization appears to be: (1) magnetite, (2) plagioclase, (3) augite and olivine.

STRUCTURAL RELATIONS.

Internal.—The olivine basalt formation is everywhere well exposed, and the topography formed by it is rugged and broken. All around its edges it forms steep cliffs flanked by talus slopes of large blocks of rock, while the surface of the formation itself is very irregular and holds many small ponds and deep ravines.

The formation has the form of a horizontal sheet lying on the surface, and having a thickness varying from 500 to 200 feet. The upper part of the sheet is porous and amygdalodail in structure, while the lower part is more compact. The rock is always fresh and only weathers on the surface to a dull rusty colour. Spheroidal forms are common on the outcrop as a result of weathering. It fractures easily into large blocks that are cubic or irregular in shape. In places it shows well marked hexagonal jointing.

External.—For a short distance along its southeastern border the olivine basalt is in contact with Triassic rocks. The contact is an unconformable one, for the basalt lies horizontally on the upturned edges of the Triassic strata, which dip at high angles and strike east and west.

On all other sides the basalt is in direct contact with the Oligocene sediments. The actual plane of contact is nowhere exposed, but the two formations outcrop so near to each other that no doubt remains in the author's mind as to the relation of the one to the other. At a point directly east of the head of Fraser gulch the sandstones of the Oligocene formation dip about 20 degrees to the southwest. These sandstones form successive ridges with hollows between them represented probably by shale bands. These ridges pass with the same dip and strike underneath the basalt, which here, as elsewhere, lies horizontally on the surface. Again at the coal mines on Granite creek, the shales and coal seams of the Oligocene formation have a dip of about 35 degrees to the northeast, while a very short distance to the north the basalt is exposed above them, again as a horizontal sheet. At the southeast edge of the basalt the same relation exists, so that there is no doubt about the unconformity between these two formations. The Oligocene sediments appear to have been first tilted at angles varying from 20 to 40 degrees, then after a considerable erosion period had elapsed, the basalt was extruded as a lava flow over the upturned edges of the sandstone and shale beds.

The effect of the basalt on the rocks over which it spread was not so great as to be now easily apparent. It is true that the basalt must have been extruded probably through a fissure as a molten mass of highly heated rock; but being exposed to the cooling influence of the atmosphere it quickly lost that heat, and with the loss of heat it lost also its power to metamorphose the rocks with which it came in contact. Its effect on the Triassic rocks or the sandstones and shales of the Oligocene formation would be inconsiderable, but on the coal seams with which it came in contact the effect would be much greater. This, however, could not be studied by actual observation of a contact between basalt and coal. Coals of Oligocene age are normally lignitic, and many basins of this age occurring in other parts of the Cordilleran region contain only lignites, because they are not greatly disturbed and are not closely associated with igneous rocks. In this basin the average grade of the coal is bituminous, but coal seams which outcrop in the northwestern part of the basin some distance away from the basalt are almost lignitic. The heat of the basalt would tend to raise the grade of the coal from lignite to bituminous, and even to anthracite, when the heat would be still greater. On the direct contact of the basalt with a coal seam and where there was no access of air, coke might be expected to form.

MODE OF ORIGIN.

The mode of origin of the basalt has an important economic bearing, and various opinions have been expressed by engineers who had been engaged to report on the coal basin associated with it. One of two views prevailed. Either the basalt was intrusive, cutting up through the rocks of the coal basin in the form of a stock or boss, and carrying its contact down vertically from the outcrop to an indefinite depth; or else it was a surface flow rising up through a comparatively narrow fissure and spreading out over the surface, forming a horizontal contact line with the rocks of the coal basin. To a geologist the latter view is the only tenable one. Both the vesicular structure of the surface of the basalt and the hexagonal jointing are typical of a surface flow, while the absence of any marked contact metamorphism or the lack of well developed crystalline structure in the basalt destroy all probability of it being a stock or boss.

Dykes of olivine diabase up to 20 feet in width were found cutting the Triassic rocks in the bed of the North Fork about half a mile above the mouth of this stream. It is very probable that these were at one time open fissures through which the basalt—then in a fluid state—rose and spread over the surface. From the fact that the basalt lies almost wholly within the limits of the area covered by the Oligocene sediments, it is likely that the fissures through which the basalt welled up to the surface cut the Oligocene sediments; and that these fissures would now be represented by dykes of olivine-diabase, which would probably be discovered in the course of mining and development of the coal basin.

AGE AND CORRELATION.

The olivine basalt is the youngest solid rock formation in the district. It rests unconformably on rocks which have been definitely fixed by their fossils as Oligocene in age, and this unconformity is great enough to indicate that a long period of time separates the two formations. A period of orogenic disturbance followed or terminated the Oligocene sedimentation, and this was in time followed by a long period of erosion before the extrusion of the basalt. Since the extrusion and deposition of the basalt little disturbance has taken place in this region—that is to say there has been no crumpling of strata, though there was probably regional uplift or warping of the surface on a large scale.

From the information obtained in this district alone no definite age—other than that it is post-Oligocene—can be assigned to the olivine basalt. Rocks having the same structural features and similar composition have been described by Dawson[1] in the Kamloops district to the north. In his table of Tertiary formations (page 76 B) he calls these rocks later Miocene, because they are presumably conformable with the Tranquille group which contains Miocene fossils. Dawson was able to find evidence for only one strongly marked period of orogenic disturbance in the Tertiary, and that at the close of the Oligocene period. This period of oro-

[1] G.S.C. Vol. VII, Part B.

genic movement appears to have been fairly general in this part of the Cordillera, for it is recorded by officers of the United States Survey both in the Snoqualmie and Mount Stuart quadrangles in the State of Washington. A second period, however, of orogenic movement is recorded in this region as having taken place towards the close of the Miocene. Both of these periods are recognized by Daly in his work on the International Boundary line, but whether the later period of disturbance was general enough to have affected the strata in the Tulameen sheet so as to produce crumpling we have no evidence. We do know that there was regional uplift at the beginning of Pliocene times in this region, and this period may correspond to the second period of disturbance in the region to the south. In any case we have not here sufficient data to fix definitely the age of the basalt. Its position now is that of a horizontal sheet. If there was disturbance here at the close of the Miocene period corresponding to that in the Snoqualmie sheet, then we would be justified in placing this formation in the Pliocene period. If there was only regional uplift without crumpling, as seems probable, then the basalt may be as old as Miocene.

In this portion of British Columbia and in the adjacent parts of the United States local vulcanism accompanied by the extrusion of lavas was characteristic of every one of the four periods of Tertiary time. In the Miocene period, however, the vulcanism was much more wide-spread and general, and we find volcanic rocks of this age covering a great part of the western half of the Cordilleran belt. Among these volcanic flows of the Miocene period are many rocks having a composition similar to that of the basalt, while in the other Tertiary periods the volcanic rocks described are generally more acid in composition. Lithological character, however, is an unsafe criterion on which to correlate volcanic formations over wide areas, but taking this evidence for what it is worth in connexion with Dawson's conclusion as to the age of the basalt in the Kamloops sheet, it would appear to be safer to refer this formation tentatively at least to later Miocene.

Granite Porphyries.

GENERAL CHARACTER AND DISTRIBUTION.

Among the smaller intrusive igneous bodies of the district the granite porphyries form a distinct class of rocks which are differentiated by well marked qualities from the other dyke rocks. They are essentially acid feldspathic rocks of a light reddish colour, and generally of a marked porphyritic habit. The phenocrystic constituents as seen in the hand specimens are feldspar, quartz, and either biotite or hornblende. The feldspar and quartz are present in all of the varieties, but biotite and hornblende are often absent. The groundmass is feldspathic, and generally contains specks of iron sulphides or some of the metallic oxides.

The area covered by granite porphyry is small compared to the other igneous bodies already described, but is considerably larger than that of the syenite porphyries or lamprophyres. The granite porphyries occur solely as dykes. They are generally situated in close proximity to the larger granite bodies, and are doubtless in some cases genetically associated with those bodies. It is infrequently that they are found more than a mile away from either the Eagle granodiorite, Boulder or Otter granite formations. The principal localities where they are found are at Champion creek, Laws camp, and Independence camp, or the eastern border of the Eagle granodiorite, on Otter mountain and Otter lake, or the western border of the Otter granite, and on Rabbit mountain and Elliott creek or the edge of the Boulder granite formations.

As a rule the trend of the granite porphyry bodies does not depart much from a true north and south direction, and in this respect they conform to the main orogenic axis of the region. The width of the majority of those dykes seen varies from 5 to 20 feet, but in one notable case a width of 1,000 feet is attained. The latter case is that of a dyke intrusive between the Eagle granodiorite and the rocks of the Tulameen group at Independence camp on the headwaters of one of the branches of Bear creek. This dyke has been traced in a southerly direction from Independence camp for a distance of 3 miles, in which distance it decreases in width from 1,000 feet to about 50, and then disappears entirely under the drift of the creek bed.

The granite porphyries do not form conspicuous topographic features, and are neither hard enough to be strongly resistant to erosion, nor soft enough to be easily weathered down. The large dyke at the head of Bear creek is not so resistant to erosion as either the Eagle granodiorite on the one hand, or the bedded volcanic rocks on the other, and consequently makes a saddle in the long ridge separating Bear creek from the Coldwater river on the west.

An economic feature of the granite porphyries is that they either contain ore bodies in themselves or else are closely associated with ore bodies that have been formed in the rocks through which they have been intruded.

PETROGRAPHY.

The granite porphyries show a gradation in lithological characters from well marked porphyritic rocks in which the constituents of the groundmass are well developed and easily identified in the thin section, to those in which the groundmass is very fine grained and almost indeterminate. The first mentioned rocks are those which occur in the larger dykes. In these the phenocrysts are orthoclase, quartz, some plagioclase, and either biotite or hornblende or both. The feldspars are always cloudy from decomposition. The quartz is large and rounded in outline and often shows corroded borders, and the hornblende is frequently completely altered to chlorite. Plagioclase is often present as phenocrysts, and indicates a tendency to dioritic affinities in the rock. The groundmass of these dykes is holocrystalline, and contains the same constituents that appear as phenocrysts.

In the smaller dykes, feldspar is frequently the only mineral appearing as phenocrysts. Quartz when present as phenocrysts is always clear and glassy and shows corroded borders. Biotite rarely appears either as phenocrysts or in the groundmass. Hornblende in long lath-shaped crystals is more common, though it is frequently altered to chlorite. The groundmass is always very fine grained, and contains small feldspars, interstitial or idiomorphic quartz, and generally much accessory magnetite and iron sulphides.

The most frequent secondary minerals in all the forms are sericite and chlorite. These are abundantly developed in the large dyke at Independence camp, and in the ore body which occurs at this point in the granite porphyry, calcite is very common either in vuggs in the porphyry or replacing the groundmass of it. Small veinlets of quartz are also present.

AGE.

No definite age for the granite porphyry intrusions has been worked out, and it is very probable that they have recurred at different stages in the geological history of the region. Some of the dykes are cut by syenite porphyry intrusives. Granting that they are genetically connected with those larger granite bodies with which they are really associated, intrusions of the various kinds of granite porphyries might range from about Jurassic to post-Oligocene. The majority of them are found cutting the bedded volcanic rocks of the Tulameen group, which are at least Triassic in age. Some of them also cut the Cedar volcanic rocks which lie conformably below fossiliferous Oligocene sediments.

Syenite Porphyries.

GENERAL CHARACTER AND DISTRIBUTION.

In general characters the syenite porphyries are not easily confused with any of the other class of dykes, and are readily recognized in the field. The rocks classed under this head are of a prevailingly light colour, and have a strongly marked porphyritic habit. Many of them have much plagioclase in addition to the orthoclase, and show thereby a tendency to pass over to diorite porphyries. The predominant type, however, is identified in the field by phenocrysts of white feldspar and smaller black hornblende in a fine grained grey groundmass. Quartz is absent in all varieties of this group.

In distribution the syenite porphyries are among the commonest forms of dyke rock, and are found in nearly all parts of the area examined. Typical examples are found at Independence camp on the head of Bear creek, in various parts of Champion Creek basin, and many other places. They cut most of the main rock formations.

As a rule the width of the syenite porphyries is considerable, and often reaches 25 feet. No uniformity of trend is apparent in these dykes, and strikes were obtained which varied from northeast to southeast.

PETROGRAPHY.

The thin sections of the syenite porphyries all show a holocrystalline texture in the rock. The majority show a well marked porphyritic structure, with a strong difference in size between the phenocrystic constituents and the constituents of the groundmass. A few show a suggestion of gradation in size between these two constituents. Both orthoclase and plagioclase occur as phenocrysts in all the specimens. Hornblende also forms phenocrysts in many specimens, but is usually of smaller size and less abundant. The orthoclase is in large tabular crystals often twinned after the Carlsbad law. The plagioclase is in longer, more lath-shaped crystals which frequently show albite twinning. Both feldspars are generally turbid through alteration. The hornblende of the phenocrysts is dark green in colour and appears in long blades which often show a tendency to alter to chlorite on the outer edges.

The groundmass of the syenite porphyries is fine or rarely medium grained, and contains the same constituents that form the phenocrysts. Some quartz is occasionally present, and where seen is micrographically intergrown with the feldspar. Magnetite is the most common accessory constituent.

The secondary minerals developed are sericite and chlorite in the phenocrystic constituents, and calcite in the groundmass.

AGE.

Syenite porphyries have been found cutting augite syenite, Eagle granodiorite, the rocks of the Tulameen group, and the large granite porphyry dyke at the head of Bear creek. Outside the limits of the sheet and in the upper waters of the Tulameen river, large typical syenite porphyry dykes were noted intrusive into Cretaceous rocks. They may cut the Oligocene rocks, but no instance of such has been found. With what evidence we have, therefore, it is not possible to fix their age more definitely than to say that they are of Tertiary age.

Lamprophyre.

GENERAL CHARACTER AND DISTRIBUTION.

Certain small dykes of a general basic composition, but showing considerable range in their constituent minerals, have been classed together and will be described under the general name of lamprophyre. They are all dark coloured rocks, and the chief constituents that can be identified in the field are feldspar, hornblende, and sometimes biotite or augite. These appear usually as small phenocrysts in a dark, fine grained groundmass.

These dykes are always of small size, and are not limited to any particular area or formation, but are found in all parts of the district cutting rocks of varying ages. A great many of these dykes cut the oldest stratified rocks, some cut the Eagle granodiorite formation, and others were found intrusive in the Otter granite formation.

The trend of these dykes varies more widely than any of the other groups of dykes, though as might be expected the greater number of them conform to the main orogenic axis of the region which is slightly west of north.

The lamprophyres are, as a rule, very soft and weather down easily, consequently they are not conspicuous features in the topography.

PETROGRAPHY.

The lamprophyres of the Tulameen district are dark grey to black, holocrystalline rocks of fine to medium grained texture. The majority of them show a slight tendency to porphyritic structure by the development of short needles of black hornblende, but in a few the constituents show a uniformity of size, which marks a transition to rocks of syenitic affinities.

Microscopically, the essential constituents of these rocks are plagioclase, orthoclase, and hornblende, and in some specimens augite, biotite, and quartz. Where porphyritic, the phenocrysts are always the ferromagnesian minerals, and less often the feldspars. The feldspars are always cloudy from decomposition. The plagioclase is in long, lath-shaped crystals not frequently showing albite twinning. The orthoclase is in tabular crystals. Both feldspars are generally of later formation than the ferromagnesian mineral that is associated with them. Hornblende is the most common dark mineral, and appears in long dark green crystals. Biotite is not abundant. It always appears in the same rock with hornblende and is much less in quantity. Augite is often an essential constituent, and generally occurs to the exclusion of the other ferro-magnesian minerals. When hornblende is present with the augite, the former is always an alteration product of the latter. Quartz is rarely so abundant as to become an essential constituent, and never forms phenocrysts in the porphyritic varieties. Its position is always in the groundmass of the porphyritic forms, and in the others it occupies a position interstitial between the accompanying minerals.

The groundmass of the porphyritic varieties is fine grained, though holocrystalline, and consists of the same minerals that make up the phenocrysts and of the accessories. The accessory minerals are magnetite and some sulphides, with a great deal of non-metallic isotropic mineral which appears as small rounded particles.

The alteration of these rocks is generally much greater than would be expected from their megascopic appearance. The commonest secondary constituents are chlorite, calcite, and kaolin. The feldspars are rarely unclouded. Both the hornblende and augite alter readily to chlorite, but the biotite is more resistant. Calcite in certain specimens is so abundant that the rock effervesces freely with cold hydrochloric acid. Small veinlets of calcite are also occasionally seen in some sections.

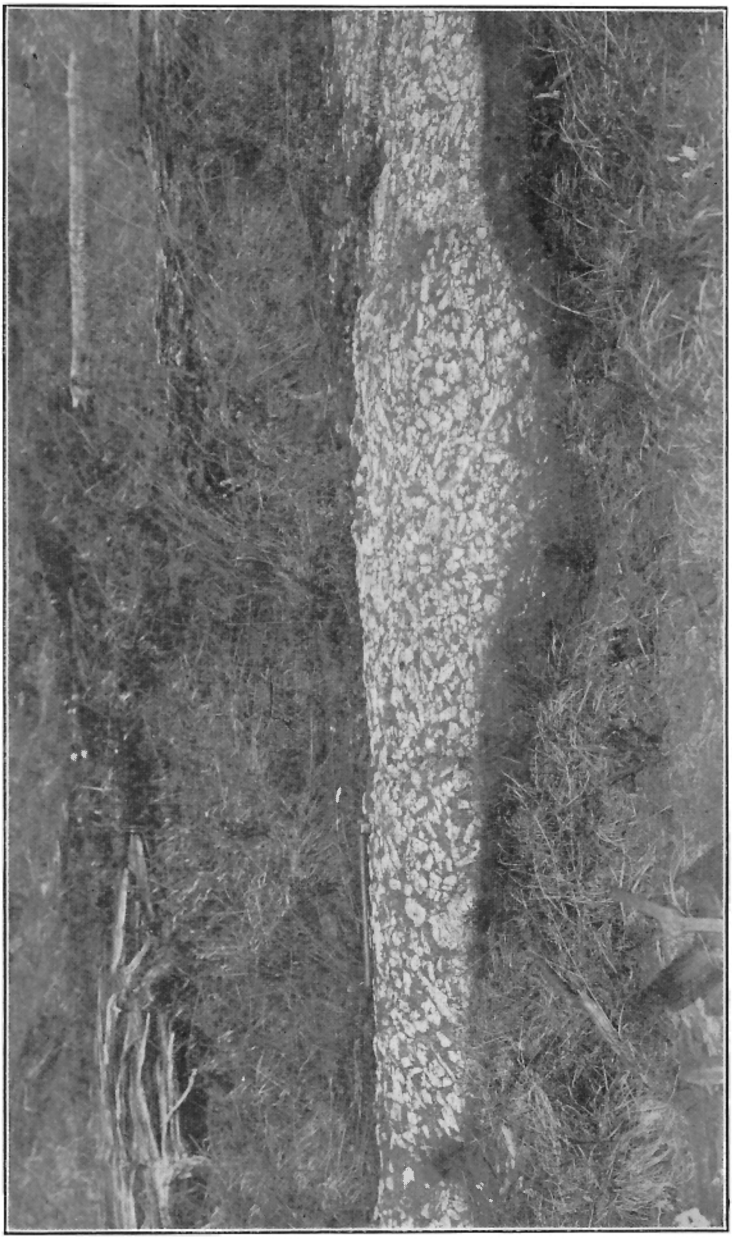
AGE.

As in the case of the granite porphyries no definite age can be assigned to the lamprophyres. Because of the variation in their physical and chemical character it is not possible to correlate the various kinds with each other, and it is probable that their intrusion covers a wide range of time. The lamprophyres cut almost every one of the main geological formations of the district. Many of them are found in the oldest stratified rocks others cut the Eagle granodiorite and Boulder granite. Some were found in augite syenite and pyroxenite. One was noted as intrusive into the Otter granite formation, so that this one at least must be of very late date. None, however, have yet been found cutting the olivine basalt. The youngest of them, however, must be at least Miocene in age.

Diabase.

Dykes that can be positively classed as diabases are not abundant in the district, but the few that occur are worthy of note. A

PLATE XV.



Coarse grained diabase dyke.

unique variety of this kind of dyke was noted at the south end of the long ridge lying between Slate and Champion creeks. This dyke (see Plate XV) is 5 feet wide and cuts both pyroxenite and augite syenite and strikes northeast. The diabase structure is well developed in it, and shows phenocrysts of white feldspar from 1 to 4 inches in length, embedded in a fine grained crystalline groundmass of basic material.

Dykes of olivine diabase were noted in the bed of the North Fork of Granite creek, where they cut the rocks of the Tulameen group. They were not seen to be intrusive into the Oligocene sediments, but from their physical and mineralogical characters they appear to be related to the olivine basalt formation. It is probable that these dykes are directly connected with the olivine basalt, and that they fill the fissures through which the olivine basalt reached the surface.

Surface Deposits.

GLACIAL MATERIAL.

The evidence of a large ice-sheet covering the whole of the Tulameen region even up to the highest points is preserved to us by many records such as striæ, roches moutonnées, and glacial deris. Besides this large ice-cap, there is much evidence to show that, after the melting away or retreat of the ice-cap from the highlands, and probably also before its maximum development, the valleys alone were occupied by ice which moved slowly down the present grade of the streams. Evidence of this occupation is recorded in the shape of these valleys, the striæ in them, the hanging valleys of tributary streams, and other criteria of valley glaciation. The evidence, however, with which we are directly concerned here is the material deposited, such as morainal material, unassorted debris, boulder-clay, and glacial lake deposits.

Unassorted glacial debris lies as a thin mantle over a great part of the district up to highest points. This contains boulder erratics, which show the direction of the Cordilleran ice movements, and now lie to the south or southwestward of the solid rocks from which they were originally derived.

Material of valley glacier origin consisting apparently of unmodified material covers the floors of the two old glacial valleys, one of which lies east of Otter mountain and the other west and north of Grasshopper mountain.

The boulder clay of the Tulameen sheet is the typical boulder clay described in such detail by Dawson in the Kamloops district.[1] It is stiff, hard, and compact, light in colour and consists of a paste of sandy clay holding pebbles and boulders of all sizes. It is irregularly distributed throughout this region generally in the lower and intermediate levels, but rarely if ever on the higher parts. It is found clinging to the sides of many of the valleys tributary to the main streams, especially in the valley of Bear creek where it is exposed by landslides.

There is in this district some evidence of two boulder clays separated by stream deposits, possibly denoting an interglacial period. This evidence has been derived from a section exposed on the south side of Tulameen valley immediately below the mouth of Slate creek. The section, from top to bottom, is as follows:—

(1) Stiff, light coloured boulder-clay, containing small angular pebbles..	100 feet+
(2) Coarse sands and gravel, stratified and water-worn..	10 feet
(3) Fine sands separated by stream gravels.. ..	16 feet
(4) Boulder clay holding huge boulders..	20 feet+

The middle portion of this section contains stream gravels deposited either between periods of glaciation when the boulder clay was laid down, or else by glacial streams flowing on or under the ice.

Typical morainal deposits have only been identified here in the valley beds, and are, therefore, to be referred to later stages of glaciation, when glaciers lay in the valleys and were slowly retreating up them. At several points glacial debris has been heaped up to form a collection of irregular hills and hollows, and each of these collections represents a halt for a considerable period made by the retreating glacier.

The greatest accumulation of morainal material is found at the Tulameen end of the old glacial valley which runs from the centre of Otter lake southeast towards the mouth of China creek.

[1] G.S.C Part B. Vol. VIII. Report on the Kamloops Map Sheet.

Near the mouth of China creek, glacial material has been indiscriminately dumped, so that there now appears a great number of kettle holes separated from each other by winding ridges and irregular mounds.

On a smaller scale similar accumulations of glacial debris can be found on the west side of Otter lake near the mouth of Riddell creek, or again on the south side of the Tulameen valley at the mouths of Slate and Cedar creeks, and above the mouth of Collins gulch. Other morainal accumulations are found at points in the course of the old glacial channel which lies northwest of Grasshopper mountain.

Certain stratified deposits of clay found at a point in the bed of Bear creek have been doubtfully referred to a glacial lake formed in this valley when the Tulameen Valley glacier blocked the outlet of Bear creek. These deposits lie on the east branch of Bear creek, about three-fourths of a mile above the wagon bridge. The section, exposed in a cut bank, shows thin bedded clays, overlaid by more massive clays, over which are stratified sands and gravels of fluviatile origin. Lake clays whether of glacial or post-glacial origin cover the floor of Otter valley above Frembd lake. These are exposed in the banks of Otter creek, and are seen to extend for over 2 miles up the valley, but what their thickness is could not be ascertained.

STREAM DEPOSITS.

The stream deposits of this district have been and are still highly important from an economic point of view, because from them a considerable quantity of gold and platinum has been obtained.

The principal deposits of this origin are those found in the main valley, namely, in that of the Tulameen river. These deposits are found in the valley bottom and on the slopes up to a height of 300 feet. They have been carved into a series of terraces by stream action and in some places, such as the mouth of Granite creek, as many as a dozen different terraces can be recognized at different levels. Above the mouth of Slate creek the Tulameen valley narrows, and there is little room on its steep sides for the reception of stream gravels. Below that point, however, the valley grows wider, and gravel deposits have accumulated in considerable quantity.

Otter valley, though broad and deep, has comparatively few accumulations of stream deposits, except at its immediate junction with the Tulameen river. The grade of the valley is so low that the stream can not now transport any but the finest kind of material; and even much of the material that is now found in its bottom has apparently been deposited in the quiet waters of a lake and not by running water.

In the smaller streams of the district gravel deposits are found in much greater abundance at some distance above the mouths of the streams than in the immediate vicinity of their junction with the master valleys of the Tulameen and Otter. This is due entirely to events which happened in the later stages of the history of these streams whereby their grade was altered to form hanging valleys, and sufficient time has not yet elapsed to enable all these tributary streams to cut down their beds and enter at grade. The effect is as we now find it, namely, a rock-walled canyon in the lower part with a more open flaring valley above this. The result is that we now find in nearly every case in these tributary streams shallow deposits of gravel or no gravel at all for a short distance above the junction with the Tulameen and Otter valleys, and above that more extensive deposits, constituting in the case of the larger tributaries what the placer miners call 'deep ground.' Such deep ground exists in Granite creek above the mouth of the North Fork, and in Slate, Champion, and Eagle creeks about the canyons at their mouths. Similar deep gravels are found in the upper parts of Boulder and Elliot creeks, but their economic importance is negative. The deep ground, however, of Granite and Slate creeks is important, and wherever bed-rock has been successfully reached in placer mining operations the gold and platinum obtained has well repaid the extra outlay necessary to mine them.

Structural Geology.

A discussion of the structural geology of a region involves, first of all, a clear conception of the original conditions under which the rocks in it were formed, and a knowledge of the causes which are likely to produce changes in structure, and secondly, a description of the present position, attitude, and condition of the various rock bodies. The structural sections drawn through the geological map from east to west illustrate, diagrammatically, to a certain extent, the structural conditions now existing and the relations between the various formations.

It is perhaps needless to state that all the stratified formations, namely, the Tulameen group, Cedar volcanic series, Coldwater series, and the olivine basalt, were laid down on the surface of the older rocks in an attitude which was originally nearer horizontal than otherwise. The dip of the true sediments would certainly not have been greater than 10 degrees, while the volcanic beds may have been slightly greater. The eruptive igneous rocks, however, found their way upward from the interior of the earth, so that their contacts would be as a rule more vertically inclined than otherwise.

Through disturbances in the earth's crust the attitude of the stratified rocks has been changed so that they do not now always lie in the same position in which they were first laid down, and the older the formation the more greatly will it have been deformed.

The principal causes of structural changes in the rocks are orogenic disturbance and batholithic intrusion.

The strongest orogenic disturbance recorded in the western part of the Cordilleran region since the formation of the Tulameen group took place in the Jurassic period. At the beginning of this disturbance the only rocks present in the Tulameen district, that we now know of, were those of the Tulameen group. In this disturbance the attitude of the Tulameen group was changed and its strata were compressed and folded into a series of anticlines and synclines with high dips. The main compressive forces acted in an east and west direction, so that the axes of the folds now trend north and south. Compression, however, was also exerted in a north and south direction, so that folds are also found with axes running normal in this direction. Although it has not been possible to identify many faults in the beds of the Tulameen group, some faulting undoubtedly took place as an accompaniment to the folding. And as the effect of this disturbance on the strata has been on the whole a shortening horizontally, the resulting faults would be other than normal faults.

Immediately following this disturbance eruptive igneous action began, resulting in the intrusion of a number of igneous bodies, each of which had some effect on the structural conditions of the region. Around the borders of these igneous bodies the rocks of the Tulameen group are fractured, fissured, and faulted, and to some extent a schistose structure is induced in them. The folding and faulting resulting from these intrusions is probably less than that produced on the strata by mountain building forces. Apophyses of the igneous rocks were at the same time thrust into the fissures so produced, and many small quartz veins were formed.

The igneous bodies themselves are as a rule elongated in a direction which conforms to the main orogenic axis of the region, that is to say they have a greater length in their north and south axes than in their east and west. This shape is due not so much to later compression along east and west lines, but rather to the fact that the intruded rocks had been predisposed to weakness in those directions, so that when the intrusion took place the igneous magma followed those lines of weakness in preference to cutting across the strike of the rocks.

For the same reason the majority of the smaller igneous intrusions trend north and south instead of east and west.

Neither the Cedar volcanic series nor the Coldwater series are as greatly deformed as the Tulameen group, for their dips are now rarely more than 45 degrees. These rocks lie in a downwarped basin and their dips are roughly inward from all sides towards the centre of the basin. The cause of this downwarp is not known, but it may possibly be due to withdrawal of the material which constitutes the Cedar volcanic series from a chamber underneath, and its extrusion on the surface, causing a sinking of that surface. In this process normal faulting might be expected to have taken place, though no instances of such have yet been noted.

The youngest stratified formation in the district is the olivine basalt. This lies as an approximately horizontal sheet on the surface and does not appear to have been seriously disturbed since its extrusion.

Historical Geology.

GENERAL ACCOUNT.

The earliest geological events in the Tulameen district of which any record has been preserved to the present are contained in the rocks of the Tulameen group. The major portion of this group is volcanic in origin, but some true sediments are also interstratified with the volcanic materials. From this and other evidence it is inferred that all the beds of the Tulameen group were laid down under water. If the idea is accepted that the Tulameen group is Triassic in age, then the Triassic of this region was a period of submergence beneath the waters of the sea.

Because neither a top nor a bottom has been found to the Tulameen group there is nothing in this region to indicate what was the relative position of sea and land during the Triassic, but it is probable that the land from which the clastic members of this group were derived lay far to the eastward.

During this submergence sedimentary beds were deposited on the floor of the sea, but the progress of sedimentation was frequently interrupted by vulcanism before more than a few feet of sediments were formed. The effect of such vulcanism was the extrusion of great thicknesses of lavas over the floor of the sea. There is no evidence in the rocks that open craters existed, but all of the volcanic material appears to have risen to the surface through fissures in the earth's crust.

Following the period of Triassic sedimentation and vulcanism came the Jurassic revolution, during which the Triassic rocks were uplifted from the sea, folded and crumpled to a remarkable degree, and in many cases rendered schistose by regional metamorphism. This revolution elevated the whole region from the sea, and it has never since been completely submerged, so that from that time to the present the greater part of it has been undergoing erosion.

Immediately following and probably genetically connected with the Jurassic revolution, batholithic intrusion on a grand scale began. The results of this period of intrusion are seen all the way along the Pacific coast from Puget sound to Alaska in what is known as the Coast Range batholith. In the Tulameen district this period is represented by intrusions of various rock bodies in the following sequence:—

(1) Boulder granite.
(2) Peridotite and pyroxenite.
(3) Augite syenite.
(4) Eagle granodiorite.

These rocks worked their way upward from the interior of the earth into the crumpled and deformed rocks of the Tulameen group, reducing the area of these rocks by a considerable amount. At the same time the Tulameen group was metamorphosed by contact action, fractured and fissured along the borders of these intrusions, and many veins and replacement deposits carrying the valuable metals were formed in them.

The erosion period which then began continued throughout the whole of Cretaceous times. Much of the material eroded away at this time from the Tulameen district was probably carried westward to be deposited in a geosynclinal basin which lay only a few miles to the west of the western border of the region covered by the map, and in this basin some 30,000 feet of sediments are estimated to have been laid down.

The Larimide revolution which was so effective in the eastern half of British Columbia was not as pronounced in its action in this region. It was, however, effective to the extent of putting a stop to sedimentation in the Cretaceous basin by elevating it out of the water. It probably also raised the level of the region inside the Tulameen district, thereby instituting a new cycle of erosion.

Throughout the whole of the succeeding period of the Eocene no sedimentation nor vulcanism is recorded either in the Tulameen district itself or anywhere in the adjacent parts of British Columbia. It appears to have been entirely a period of erosion, and for this reason Dawson[1] concluded that erosion went so far as almost to peneplain the whole country known as the Interior Plateau region. Whatever evidence we have in the Tulameen district supports this idea, and it is reasonable to suppose that if erosion continued from the Jurassic revolution to the close of the Eocene, with only one uplift of unknown strength at the close of the Cretaceous, the result would be that of a very mature topography or conditions approaching peneplanation. The evidence of the next recorded event, however weak, also supports this idea.

[1] Bull. G.S.A. Vol. XII, 1901.

Nearly everywhere else in the southern interior of British Columbia the first event recorded in the Tertiary period was sedimentation in lake basins in the Oligocene. The shape of these basins suggests that the country was certainly not as mountainous as it is now, but that the surface was fairly well worn down, as it was presumed to be after the period of Eocene erosion. In the Tulameen region, however, a period of volcanic activity immediately preceded Oligocene sedimentation and even continued simultaneously with it. The sequence of events as recorded here at this time is as follows:—

(1) Extrusion of lavas into a synclinal basin which was gradually sinking.
(2) A short period of sedimentation in this downwarped basin.
(3) Renewal of volcanic activity and an enormous outflow of lava.
(4) Cessation of vulcanism and an uninterrupted deposition of sediments and coal seams throughout the remainder of the Oligocene period.

In the adjacent parts of British Columbia and Washington the greatest disturbance of Tertiary times is recorded in the Miocene, and in the Tulameen district there is no exception to this rule. The evidence of the rocks shows that the period of quiet sedimentation in the Oligocene was closed by a movement in the earth's crust, which disturbed the Oligocene sedimentary and volcanic rocks and tilted them at angles which reach a maximum of 45 degrees. This was accompanied or followed closely after by batholithic intrusion of the Otter granite, which probably somewhat reduced the area covered by Oligocene rocks.

A break in the geological record then follows, during which erosion of the uplifted Oligocene rocks went on, and the upturned edges of these rocks were bevelled off. This erosion period must have continued for a considerable length of time, for when the next event occurred we find an extrusion of olivine basalt rising through fissures to the surface and flowing over the truncated edges of the Oligocene sediments and covering them as a sheet. This is the final event recorded in the solid geology of the region.

From the history of adjacent regions we know that towards the close of the Pliocene a regional uplift of the southern interior of

British Columbia took place, which included the Tulameen region. At this uplift the Cascade mountains were elevated as well as the Interior Plateau, and again a new cycle of erosion was instituted. It has been estimated in the adjacent Hedley district that the amount of uplift which took place in Pliocene times was about 2,500 feet,[1] and there was probably as much in the Tulameen district. This uplift was responsible for a revival of the drainage, and resulted in the cutting down of the stream beds so that they flowed in sharply V-shaped valleys instead of in the broadly flaring ones which probably characterized the topography before the Pliocene uplift.

The glacial period then followed, the records of which are left rather in the topography than in the solid geology of the region. The effects produced in the glacial period have been preserved to the present, and from those effects we have to reason back to the causes in order to arrive at a history of events which produced them.

Glacial conditions were probably begun in the higher levels of the adjacent region, namely, in the mountains to the west of the Tulameen district. Here snow and ice would tend to accumulate first. Small mountain glaciers would be the first indications of glacial conditions, and as these conditions increased in strength the glaciers would grow larger, pushing their lobes farther out from the central gathering grounds by following the course of the valleys. The first glacial ice then to enter the Tulameen district would be one of these valley glaciers following the course of the Tulameen valley, and that while the country between the valleys was still free of ice.

As glacial conditions increased the interstream parts of the Tulameen district would themselves become gathering grounds of ice, and these would gradually unite with each other until the whole country was covered with ice in the form of a large continental ice-sheet. The movement of the ice would then change from flowing down the grade of the valleys to a direction which is indicated by the striæ on the summit levels, namely, somewhat west of south. This would represent the maximum of glaciation.

Whether there was more than one period of maximum glacia-

[1] G.S.C. Memoir No. 2, page 35.

tion or not we have no positive proof in this region, but there is some evidence that there might have been at least two such periods of maximum glaciation, with a return between them either to conditions of valley glaciation alone or even to a total absence of glacial ice.

The final retreat of glacial ice would be in reverse order to the advance, namely, that after the period of maximum glaciation there would follow conditions of valley glaciation and the final retreat of the ice up the valleys to the higher mountainous tracts.

The effects of valley glaciation before the maximum development of the ice would probably all be obliterated by glaciation at later stages. But we can infer that one of the effects of this period would be the modification of the shape of the valleys occupied by ice.

During maximum glaciation the effects on the topography would be more pronounced on the higher levels, where it would all work towards a reduction of the relief, both by wearing down projecting points and by filling up hollows.

When the ice was finally retreating the valleys would again be the scene of the most active glaciation, with the result that these valleys might be deepened, and certainly widened, and made more U-shaped. Morainal deposits here and there are evidence that the valley glaciers halted for a certain length of time at different points in their retreat. The streams flowing out from the ends of these glaciers would no doubt be heavily laden with glacial detritus, which was deposited again below on the sides and bottom of the valley forming our present stream deposits.

The last recorded event worthy of note was the local tilting of the southwestern part of the Tulameen area, as a consequence of which the Tulameen river above Slate creek cut down its bed below the old glacial bed to a depth of about 300 feet, so that we now find in that portion of its course a narrow rock-walled canyon incised into the broader glacial valley above it.

Summary of Geological Events.

MESOZOIC.

(1) Submergence in Triassic times; sedimentation accompanied by subaqueous effusion of volcanic materials.

(2) Jurassic revolution; uplift and deformation of Triassic rocks; effect very pronounced.

(3) Batholithic intrusion of igneous rocks in the following order: Boulder granite, peridotite and pyroxenite, augite syenite, and Eagle granodiorite. Resulting contact metamorphism and formation of many ore deposits.

(4) Erosion period extending in parts of this region up to the present time.

(5) Larimide revolution.

TERTIARY.

(6) Eocene erosion period.

(7) Effusion of lavas of the Cedar volcanic series on the old denuded surface.

(8) Local downwarping, and formation of Oligocene lake basin in which sediments and coal were laid down.

(9) Miocene orogenic disturbance; tilting of Oligocene sediments and batholithic intrusion of Otter granite.

(10) Erosion period.

(11) Vulcanism and effusion of olivine basalt.

(12) Pliocene uplift of Interior Plateau and Cascade mountains.

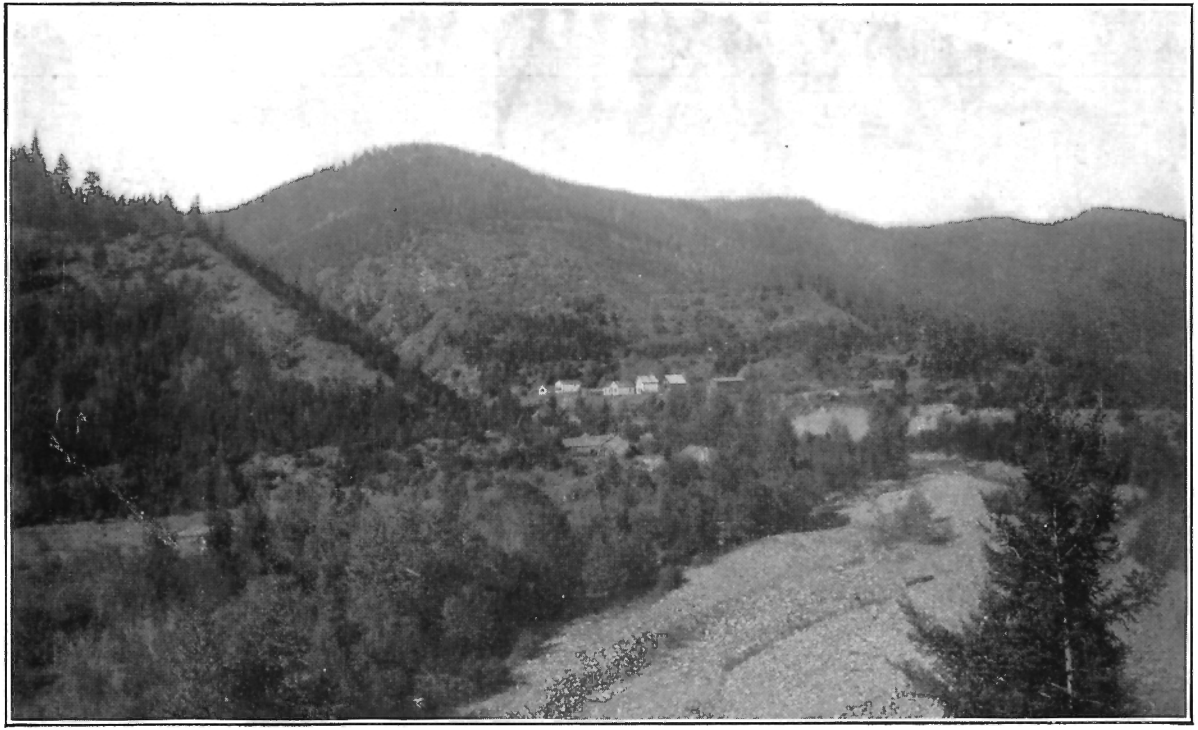
(13) Revival of drainage in erosion period following; cutting down of valley bottoms.

QUATERNARY.

(14) Pleistocene glaciation, modification of land forms and broadening of valleys.

(15) Retreat of glacial ice and local tilting of land surface following.

(16) Local deepening of some valleys.



Village of Granite Creek, August, 1910.

CHAPTER V.

ECONOMIC GEOLOGY.

General Statement.

The Tulameen district first attracted the attention of the mining public through its placers, and although these are believed to have been worked as long as the early sixties, it was not until 1885 that they attracted much attention. In that year considerable excitement was caused by the discovery of rich placers in Granite creek, and ever since that date some placer mining has been carried on in the district. About 1899 the search for the metals in primary deposits began and discoveries were soon made. The prospecting and development of some of the lode deposits has continued up to the present, although as yet without any extraction having been made from them.

The various classes of mineral deposits occurring within the limits of the Tulameen sheet are arranged below in tabular form, and this list includes all the ores of the district that are known to have any present or prospective value. The variety is great though the area of the district is small. It is quite certain that some of the deposits to be hereafter described have little or no present value, but a description of them is given here because of the possibility that they may at some future time become valuable.

Up to the time of writing the only deposits that have been profitably worked are the placers, and the production of gold and platinum from them represents the total value of the mineral production of the district. There are no data of the amount produced previous to 1885, but since that date the total value of gold and platinum produced amounts to nearly $800,000.

The platinum recovered from the gravels of this district has been variously estimated at 10,000 to 20,000 ounces, and at one time this district was the principal producer of platinum on the North American continent.

The more easily worked of the placers have been gradually exhausted, and at the present time mining of these deposits is only being carried on by a few individuals, in the summer season. The gravel deposits of the district are not very large, but there is still a considerable area of what is known as deep ground and some bench deposits, that might be worked at a profit.

Virtually all the other mineral deposits are still in the prospect stage of development, but, with the advent of the railway lines now being built, some of them, especially the coal beds, should soon enter the producing stage.

After the excitement caused by the discovery of placer gold died out, interest in the district gradually waned. At the present time this interest is being revived owing to the building of the Victoria, Vancouver, and Eastern railway through the district, to the discovery of diamonds in the rock of Olivine mountain, and because of the increased value of platinum which has made the working of some of the Tulameen placers an attractive venture.

Classification of the Mineral Deposits.

A. Placers, containing gold and platinum.

B. Primary deposits.

(1.) Diamond.
(2.) Platinum.
(3.) Gold.
(4.) Copper, usually associated with gold and silver.
(5.) Magnetite.
(6.) Chromite.
(7.) Molybdenite.
(8.) Asbestos.
(9.) Coal.
(10.) Clay.

In classifying these deposits according to genesis it is found that a variety of causes have been instrumental in producing them and that ore formation has taken place at different periods in the geological history of the region. In a genetic classification the mineral deposits of the Tulameen district fall into one of the five following groups:—

(1) Placers.
(2) Magmatic segregations.
(3) Veins or replacement deposits.
(4) Contact metamorphic deposits.
(5) Bedded deposits of coal and clay.

Placer Deposits.

GENERAL FEATURES AND DISTRIBUTION.

The placers of the Tulameen district are valuable for their gold as well as their platinum content, and these deposits have up to date proved to be the most important of its ore deposits.

There is some evidence that the placer deposits were worked to a limited extent many years before 1885, but at that date they came into considerable prominence through the discovery of coarse gold on Granite creek. For the few years following, the district produced remarkably well for such a small area, and about 1891 it came to be recognized as the most productive platinum region on the North American continent. Since then the production has steadily declined year by year until, in 1910, it was so small that placer mining might almost have been said to be extinct.

Taking into consideration the length of time during which placer mining has been carried on in this district, it seems remarkable, in view of the recent discovery of diamonds in the rock of Olivine mountain, that up to 1911 none of these gems have been recovered from the placers. It is reasonable to suppose that they do occur in the gravels, and this coupled with the advancing price of platinum may cause a revival of the placer mining industry in the district.[1]

The streams in the district which carry an appreciable amount of gold or platinum or both are: Tulameen river, Granite creek and its tributary Newton creek, Collins gulch, Cedar creek, Bear creek, Hine creek, Eagle creek, Champion creek, and Boulder creek.

Tulameen River.—The Tulameen river has not been proved to be everywhere productive in gold or platinum. The reason for this is not apparent, but it is probably because bed-rock is not easily reached on some parts of it. Mining has been carried on in three

[1] Since the completion of this report many small diamonds have actually been recovered by the writer from the gravels of Tulameen river.

separate sections of the river, namely, near the mouth of the river; about 2 miles below the mouth of Granite creek; and between Slate creek and the mouth of Champion creek. The last mentioned portion of the stream is the only one that comes within the limit of the area under discussion.

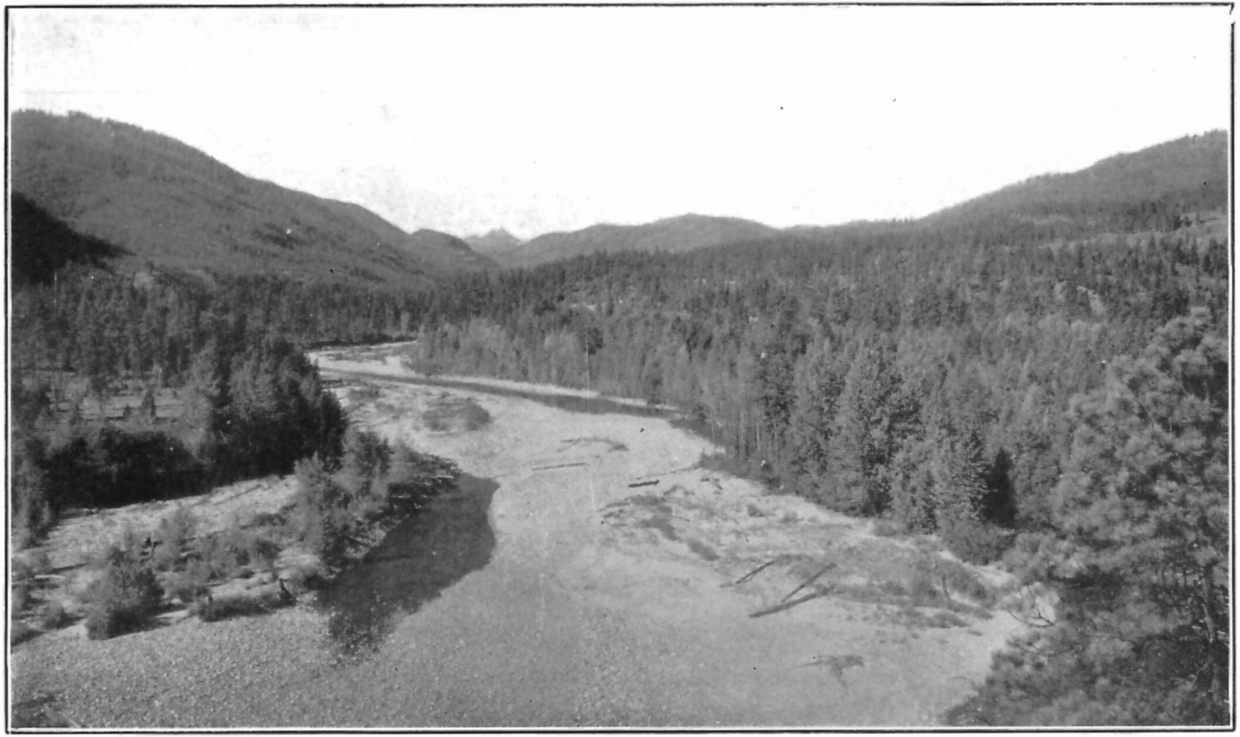
From Granite creek up to Slate creek the Tulameen valley is wide and its gravel deposits deep, and no attempts have been made to prospect it, so that it is impossible to say what it may contain. Above Slate creek, however, the valley contracts, and the stream flows in a narrow, rock-walled canyon, about 300 feet deep. This canyon is of comparatively recent formation and has been cut down, since glacial time, into the bottom of the old, glacial valley.

In this part of its course the stream has cut out its valley in peridotite, pyroxenite, and in the stratified rocks of the Tulameen group.

The productive placers of this part of Tulameen river are of two kinds, namely, those lying in the stream bed, and the bench deposits which rest on the sides of the valley either in, or above the level of, the canyon. Owing to the narrowness of this part of the valley these gravel deposits are not of great extent, but they constitute some of the best paying ground in the whole district. They rest directly on bed-rock, which is never more than a few feet below the surface.

The placers of this part of the Tulameen carry both gold and platinum, and contain also small quantities of native copper and rich gold bearing pellets of silver glance. The proportion of platinum to gold is greater here than in any of the other localities, and in mining it was found to increase up stream as far as the mouth of Eagle creek, where the greatest quantity was obtained. At hydraulic workings a short distance below the mouth of Eagle creek the proportion of platinum recovered was greater than of gold, and nuggets of platinum were often obtained which weighed from one-fourth to one-half an ounce each.

Different portions of this part of the river have been worked over many times, and at present it is, with the exception of Granite creek, the only part of the whole district in which placer mining is carried on year by year.



Tulameen river above Otter creek.

Granite Creek.—Granite creek, one of the principal tributaries of Tulameen river, enters it from the south and drains a part of the Interior Plateau region. From Tulameen river up to the mouth of Newton creek, or virtually for the whole of that part of its course which lies within the limits of the map, it flows in a narrow, rock walled canyon, cut about 300 feet deep into the bottom of a broader and more open valley. In this part the stream flows in many places directly on the bed-rock, and the gravels are nowhere deep or very wide-spread. In the more open part of the valley, above Newton creek where the grade is easier, the gravel deposits are deeper and of greater volume.

The rocks cut through by Granite creek are the stratified rocks of the Tulameen group, which in places contain gold bearing quartz veins.

Granite creek has been mined from the Tulameen river up to Newton creek, above which the gravels were so deep that bed-rock could not be easily reached. In this part there was little bench gravel, the workable deposits being found in the bed of the present stream, and occasionally in old, abandoned channels, which cut across points in the present valley. The shallowness of these gravels made them easily mined and they were soon worked out. The pay gravels were found resting directly on bed-rock, and proved to be compact and cemented together with a stiff clay.

Both gold and platinum occur in the creek, the ratio varying from 4 parts of gold to 1 of platinum, to equal parts of each metal. The proportion of platinum increased higher up the stream and was greatest in the Newton Creek branch.

The gold is coarse and rough, denoting a local origin, and nuggets have been obtained worth from $100 to $150. Some of the nuggets examined appeared to be aggregates of smaller nuggets grown or welded together.

The platinum is in smaller nuggets, generally rounded and pitted with holes. No nuggets have been obtained, to the writer's knowledge, weighing more than half an ounce.

Collins Gulch.—Collins gulch is a small stream not more than 2½ miles in length entering the Tulameen river from the south, about 1½ miles below Tulameen village. It contains only a limited quantity of gravel, and was mined years ago for about half a mile up from the Tulameen river. Its gravel carried some coarse gold, but it is not known whether or not there was any platinum present.

The portion of this stream mined lies virtually in the Tulameen valley, so that these gravels may have been formed by the Tulameen river itself at an earlier stage in its history.

For the greater part of its length Collins gulch traverses the coal bearing rock of the Coldwater series, and unless the conglomerates and sandstones at the base of that series carry gold, it is difficult to say from what source the gold of Collins gulch may have been derived. Conglomerates of this age in other parts of British Columbia do carry some gold,[1] and it is quite possible that these may also; although, since a favourable spot at which to test them was not found, proof that they do so was not obtained.

Cedar Creek.—Cedar creek is a small stream flowing into the Tulameen river about 2 miles above Otter creek. No work is now being done on it, but when mined some years ago it yielded both gold and platinum. The stream is about 2½ miles long, and its valley has been cut into the rocks of the Tulameen group, and the Cedar volcanic series. The conglomerate and sandstone at the base of the Coldwater series are also exposed in several places in the valley of the stream.

Slate Creek.—Slate creek enters the Tulameen river from the south, about 3 miles above Tulameen village. It is a stream about 7 miles in length, occupying, in its upper part, a fairly deep but flaring valley. Lower down it passes through short canyons and empties into the Tulameen in a series of waterfalls. It drains a considerable area, the greater part of which is occupied by the stratified rocks of the Tulameen group.

The placers of Slate creek lie in the bed of the stream, the most extensive deposits being in the broader parts of the valley, above the falls at its mouth. A thick deposit of boulder-clay, associated with some stream gravel, lies at the mouth of the creek and some attempt had been made to mine this by hydraulic methods, but apparently without success.

Slate creek yielded well in former years, and still contains some gravels that might be mined profitably, though nothing is

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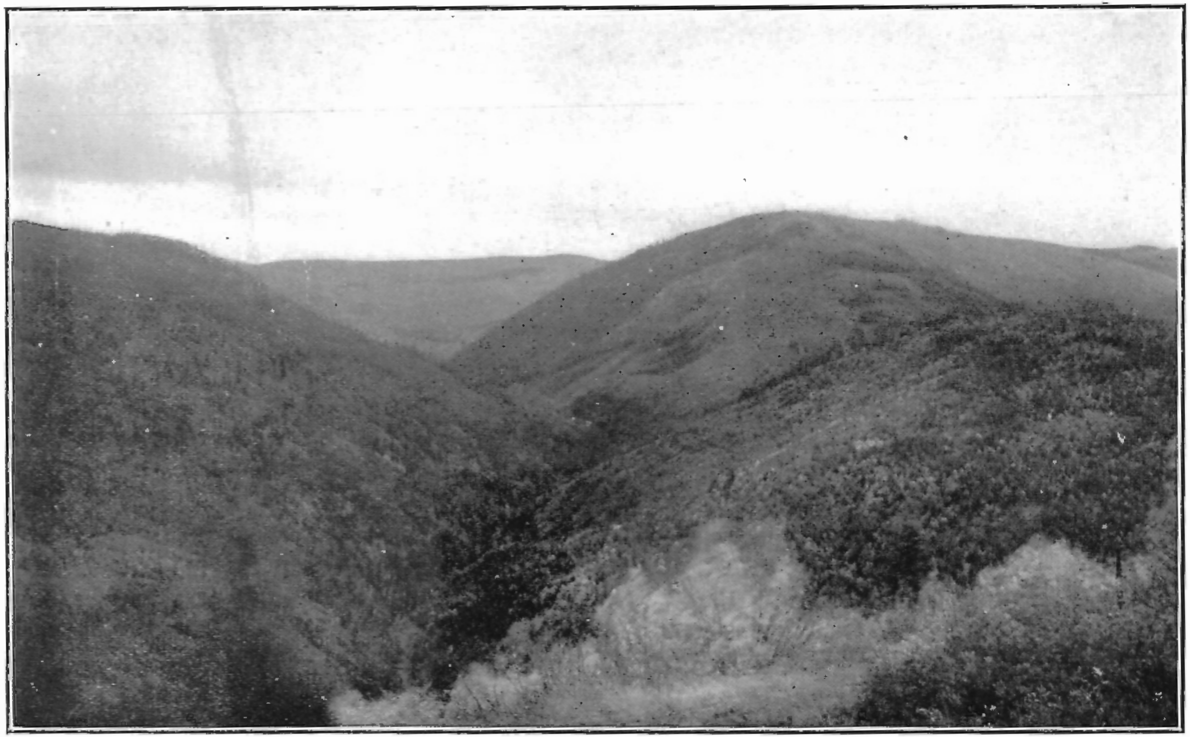
[1] G.S.C. Vol. VII page 314 B.

Cedar Creek valley.

PLATE XIX.



Valley ot Bear creek.

now being done. Coarse gold was found associated with coarse platinum in all its gravels.

Bear Creek.—Bear creek empties into Tulameen river from the north about a mile above the mouth of Slate creek. It occupies a deep and narrow valley cut into the stratified rocks of the Tulameen group. On account of the narrowness of the valley there is not much room for gravel deposits to rest, and they are mostly confined to the bed of the stream. Bed-rock is never deep, and is exposed in many places throughout the length of the creek.

The largest nugget of gold obtained in the whole Tulameen district was recovered from Bear creek. It is said to have been worth $320. Platinum is not found in as great quantity on this stream as in many of the others.

Hine Creek.—Hine creek is an inconsiderable stream emptying into the Tulameen from the south, nearly a mile above Bear creek. Some work was done on it years ago, a short distance above the Tulameen river, but the quantity of gravel in it is very small indeed. Both platinum and gold were obtained.

Eagle Creek.—Eagle creek is one of the larger tributaries of the Tulameen, flowing in from the north about 3 miles above Bear creek. In its lower part it occupies a narrow V-shaped canyon, and its upper branches flow in broadly flaring valleys. It cuts through granodiorite, a small band of the Tulameen rocks, and at its mouth through pyroxenite and peridotite.

Very little mining has been done on the stream, and its gravel deposits are of small extent, especially in the lower parts. Above the canyon they are deeper and more wide-spread, but it was not ascertained whether or not they had ever been prospected. Near the mouth coarse gold and platinum were obtained.

Champion Creek.—Champion creek joins the Tulameen from the south, nearly 2 miles above Eagle creek. Its valley is similar to those of many other tributaries of the Tulameen, having a narrow rock-walled canyon near its mouth and a broader flaring valley above.

Good prospects have been obtained in gold and platinum from the gravels above the canyon, but the ground is deep and has not been bottomed. There are virtually no gravels in the canyon portion, at the mouth of the stream.

Boulder Creek.—Boulder creek is a tributary of Otter creek, and flows into the north end of Otter lake from the west. It is a small stream, flowing for the greater part of its length through rocks of the Tulameen group. These rocks are well mineralized, and have probably yielded the gold now obtained in the placers.

The stream was mined for a mile and a half above its mouth, and gave good returns in gold, though it yielded no platinum. The last work done there was in 1909, when a few Chinamen worked over some of the old gravel dumps.

CHARACTER AND COMPOSITION OF THE METALS.

Most of the gold obtained from the placers of this district is coarse, and has the rough unworn appearance which is characteristic of gold that has not travelled far from its source. There is comparatively little flour gold to be found, and fairly large nuggets were cmmon. The largest nugget found in the district was obtained in Bear creek, and is said to have been worth $320. Most of the gold examined looked quite clean, but in several cases it was associated with white quartz. A peculiar form of nugget, obtained from workings on Granite creek near the junction of the North Fork, looked as if it were made up of a number of smaller nuggets grown together.

The value of the gold from the various creeks in the Tulameen district is fairly constant, the banks paying $17.80 for it. Boulder Creek gold is slightly better.

Platinum rarely occurs in large nuggets, and never in nuggets comparable in size with those recorded in the case of gold. The largest nugget ever found in the world is reported to have come from the Ural mountains in Russia, and weighed 21 pounds troy or 252 ounces. In the Tulameen district the nuggets are invariably small, and the writer has not heard of any from this area whose weight exceeded half an ounce, although he has seen one which approximated that weight.

Again, the platinum of the Tulameen district is in small grains or pellets, varying in size from one to four millimetres in diameter; the weight of each grain is measured in milligrams. The grains are generally rounded in shape, and not flattened or angular like the gold that occurs with them. The surface is usually pitted with

[1] Bull. U.S.G.S. No. 193.

rounded cavities, and these cavities are often filled with foreign rock matter. In the majority of the platinum grains examined this foreign matter proved to be chromite, but Prof. Kemp states that he also found both olivine and pyroxene associated with the platinum.[1]

All the platinum can be separated into two parts, namely, magnetic and non-magnetic. The non-magnetic part forms the greater proportion of the total bulk. The magnetic part was found to consist of grains of platinum loosely covered with small particles of a black metallic mineral, probably magnetite.

The heavy minerals associated with the platinum in the concentrates were found to be magnetite, chromite, and native copper. Dawson reports finding some silver glance also in certain of the concentrates.[2]

A sample of platinum obtained from Granite creek was analysed by G. C. Hoffmann, of the Geological Survey, in 1886.[3] The sample contained 17·894 grams of platinum with a specific gravity of 16·686. The platinum was separated into a magnetic and a non-magnetic part, the former weighing 6·779 grams and the latter 11·115 grams. Each of these parts was analysed separately and the composition of the whole calculated from them, with the following results:—

—	Magnetic.	Non-magnetic.	Total.
Platinum	78·43	68·19	72·07
Palladium	0·09	0·26	0·19
Rhodium	1·70	3·10	2·57
Tridium	1·04	1·21	1·14
Copper	3·89	3·09	3·39
Iron	9·78	7·87	8·59
Osmiridium	3·77	14·62	10·51
Gangue (embedded chromite)	1·27	1·95	1·69
	99·97	100·29	100·15

In default of other analyses, whereby an average could be obtained of the relative proportion of the various metals associated

[1] Bull. U.S. Geol. Surv. No. 193.
[2] G.S.C. Vol. III, p. 62 A.
[3] G.S.C. Vol. II, p. 5 T.

with the Tulameen platinum, the above may be taken as representing the average. The only important constituent, besides the metallic platinum, is the osmiridium, the percentage of which is seen to be 10·51. Previous to 1907 no return was given by platinum merchants for the osmiridium content, but in that year a distinction was made for the first time between 'ordinary' and 'hard' platinum. The hard platinum brings a higher price and is that which is rich in osmiridium, which is allowed to remain in the platinum of the ingots. The Tulameen platinum contains sufficient osmiridium to allow it to be classed as the hard metal, and it, therefore, brings the higher price.

The price of platinum has increased rapidly within the last four or five years, and as the world's visible supply is limited there is no likelihood of the price falling, especially as jewellers have recently decided to use platinum more largely as a setting for gems.

ORIGIN AND FORMATION OF THE PLACER DEPOSITS.

Much of the gold and platinum found in the Tulameen district is coarse, and has that rough, unworn surface characteristic of nuggets which have not travelled far from their original source. Even in the beds of rapid streams the distance to which coarse gold travels is as a rule not considerable, and the same rule applies to platinum, which has a specific gravity not greatly different from that of gold. Much of the gold of the district is still found embedded in quartz, while the platinum is often associated with pyroxene, olivine, or chromite. It is to be concluded, therefore, that the present placers are not very old; that they have been derived from the breaking down of rocks not very far distant, and are not entirely the result of the working over of more ancient placer deposits formed by earlier streams.

Some of the gold and platinum of the district may have had its source in certain old beds of sandstone and conglomerate in the Coldwater series, which have been determined as Oligocene in age and which outcrop on Cedar creek, Collins gulch, Blair creek, and the northern face of Jackson mountain. Dawson cites three localities in the Kamloops district to the north in which he found Oligocene conglomerates to contain traces of gold[1]; hence, by analogy,

[1] Geol. Survey, Canada, Vol. VII, p. 314 B.

there is some reason to suspect that both gold and platinum may be found in the Oligocene conglomerates of the Tulameen. It is not known, however, that any tests have ever been made of these beds. At the same time, because these conglomerates are among the youngest rocks in the district, they have been undoubtedly derived from the same rocks which have formed the present stream deposits; and because these stream deposits are productive in both gold and platinum, it is to be expected that the Oligocene conglomerates also carry a certain quantity of these metals. Whether or not that quantity is sufficiently concentrated to form payable deposits is not known, but a test to ascertain this point might well be worth while.

The ultimate source of the gold and platinum, in both the older and the younger placers, must of necessity have been the solid rocks which underlie and are adjacent to them. The constituents of placers have been produced by long processes of erosion, and the concentration of the metals therein is the result of the transportation and working over of the constituents by the streams. As placers are usually thin and unconsolidated deposits, easily removed by erosive action, only those most recently formed usually now remain, and these are found in the beds of the present streams.

The shape and size of the mineral in the placers are important factors in the process of concentration. The finer the mineral the more easily it is transported, so that the larger nuggets are found near the original source. The shape of the nuggets is also an indication of the distance they have travelled; thus, angular and unworn nuggets imply proximity to the original source.

The fact that the gold of this district is of local origin simplifies the determination of its source. Its frequent association with quartz in the nuggets suggests that these nuggets at least were derived from quartz veins. Such quartz veins are known to exist in the rocks of the Tulameen group and to be, locally, very rich in gold. The same group of rocks carries gold under different conditions of deposition to that in quartz veins, namely, in contact metamorphic and replacement deposits along the contact of igneous intrusives. Virtually every stream carrying gold traverses these rocks, and it is believed that they have furnished the major part of the gold of the placers. Gold has also been obtained by analysis from parts of the peridotite of Olivine mountain under conditions which preclude the possibility of it having been secondarily deposited in it. This gold appears to be a primary constituent of the peridotite magma, and as such probably occurs sparingly throughout the rock. Erosion of this rock causes the release of the gold, which would then go into the placers.

It was ascertained by the miners that no platinum was contained in the gravels of Tulameen river above the mouth of Champion creek; but thence to the mouth of Slate creek and in Slate creek itself were found the richest diggings. As the distance increased downstream from Slate creek the platinum gradually decreased in quantity, the grains became finer and had a much more water-worn appearance. The platinum bearing tributaries of Tulameen river besides Slate creek were Cedar, Eagle, and Bear creeks, with Granite creek and its western branches. The Granite Creek gravel, however, contained a diminished quantity of platinum, while, too, the grains of the metal were finer. All these streams, with the exception of Cedar creek, have their origin in, or else cut through the belt of very basic rocks, which runs from the head of Newton creek at Lodestone mountain northward across the Tulameen river to the first west branch of Bear creek. This belt of basic rocks is peridotite, having a flanking border of pyroxenite. From a careful study of the geology of the platinum, made in 1900, Prof. J. F. Kemp[1] concluded that the original source of the platinum was in both the peridotite and the pyroxenite, and that the placers were derived from these by the ordinary processes of decomposition, erosion, and stream concentration. His conclusions were based on both the distribution of the placers, and the occurence of olivine, chromite, and pyroxene—all constituents of either the peridotite or pyroxenite—with the platinum in the nuggets. From knowledge, moreover, of the relation of platinum to rocks of this character, in Russia and other parts of the world, no other source than that ascribed would seem possible. Prof. Kemp's observations in this respect have been corroborated by the author, who concurs also in his conclusions.

In testing for platinum in these rocks, Prof. Kemp's best results were obtained from the peridotite, or from pyroxenite dykes

[1] Bull. U.S. Geol. Survey, No. 193, p. 38.

in peridotite; and particularly where alteration had taken place to serpentine or where the rock was rich in chromite. No uniformity in the results, however, could be obtained, and in many cases where it was most expected no platinum could be got.

With a view to getting additional information, samples were collected by the author and were assayed for platinum by Mr. M. F. Connor, of the Mines Branch. One sample of peridotite, rich in chromite, gave 0·02 of an ounce of platinum to the ton of rock. Two samples of magnetite, from the pyroxenite of Olivine mountain, gave nothing. A sheared zone in pyroxenite containing some chalcopyrite, and a coarse pagmatitic dyke of hornblendite cutting pyroxenite, also gave nothing.

In the course of an analysis of the chromite of Olivine mountain, in which the discovery of diamonds was made, Mr. R. A. A. Johnston also demonstrated the presence of platinum in an amount approximating 2 ounces to the ton. These combined results seem to show that, of the two rocks, the peridotite is the more frequent host of the platinum, while the pyroxenite when distant from any body of peridotite contains none.

In this connexion it is worthy of note that Prof. Kemp[1] also obtained platinum by assay, from the Eagle granodiorite at Siwash creek, at a point where the rock had been greatly sheared.

PRODUCTION.

The production of placer gold for the Tulameen district since 1885 is given in the reports of the Minister of Mines for British Columbia, and is reproduced in condensed form in the table given below.

The figures bearing on the total production of platinum are incomplete and details are difficult to obtain. The reports of the Minister of Mines for British Columbia contain statistics of the value of the platinum produced from the years 1887 up to 1905, but for the years prior and subsequent to these dates no data are given. It is known that during the first two years of mining in the Tulameen, after the discovery of Granite creek, much platinum was saved with the gold, but no record of the yield is obtainable, and although the statistics for the years following 1905 contain no

[1] Bull. U.S.G.S. No. 193, p. 48.

mention of platinum, the writer has since seen platinum, to the amount of about 100 ounces, in the possession of Chinamen working on Tulameen river.

Much of the placer mining in the Tulameen district has been done by Chinese, and only those who have tried to secure information from these miners can realize how difficult it is to obtain reliable data. Necessarily, therefore, the statistics of production here given are incomplete; and doubtless err on the side of underestimation of the output.

Some compilers, in order to make proper allowance for the platinum production for which Chinese miners are responsible, actually go so far as to double in their estimates the returns as published in the government reports. Thus, Mr. C. F. Law, who has had a wide mining experience in the Tulameen country, and in recent years has purchased almost all the platinum produced in this district, estimates the total output at about 20,000 ounces, having obtained vouchers from platinum purchasers, accounting for over half of this estimated yield, while the balance is attributed to the production of Chinese miners.

In the following table the gold production includes that mined from the whole of Tulameen river both inside and outside the area of the map-sheet. This increases the total production of the district by a small amount, because there were two localities on the river, outside the limits of the map, at which placer mining was carried on. Both the value and the quantity of the platinum produced are given; the former is taken from the British Columbia reports, while the latter has been arrived at mostly by calculation based on the average prices paid for the metal in the respective years[1]:—

[1] Mineral Resources of the U.S., 1906, p. 551.

Year.	Gold.	Platinum.	
		Value	Ounces.
	$	$	
1885	114,000	....	....
1886	193,000	....	....
1887	118,000	5,600	2,000
1888	89,000	6,000	1,500
1889	31,800	3,500	1,000
1890	17,700	4,500	1,100
1891	17,800	10,000	2,000
1892	16,750	3,500	500
1893	9,550	1,800	257
1894	5,630	950	160
1895	41,650	3,800	633
1896	9,000	750	125
1897	23,500	1,600	266
1898	7,560	1,500	100
1899	6,600	825	137
1900	4,800	....	....
1901	4,680	457	22
1902	2,700	190	10
1903	2,000	....	....
1904	2,500	420	20
1905	1,140	500	30
1906	2,500	....	....
1907	1,000	....	....
1908	1,000	....	....
1909	1,000	....	....
Total	724,860	45,892	9,860

MINING.

The methods employed in placer mining in this district are those commonly practised by the individual miner everywhere.

Previous to 1891 mining in the Tulameen was not backed by much capital, and miners worked singly, or in small groups, on ground which might be developed without large capital outlay and which promised quick returns. The shallow bars and the beds of the streams naturally received first attention, and later the benches and some of the deeper gravels. By wing-damming, the beds of the streams were made accessible, while in the deeper workings drifting on the bed-rock was the common method employed to reach the pay gravels. The pay gravels in Granite creek rested directly on the solid rock, and were in a hard layer, compactly cemented together, but which disintegrated readily on washing. The washing operation was done either in a rocker or in a string of sluice boxes, by which means the platinum was concentrated with the gold in the black sands.

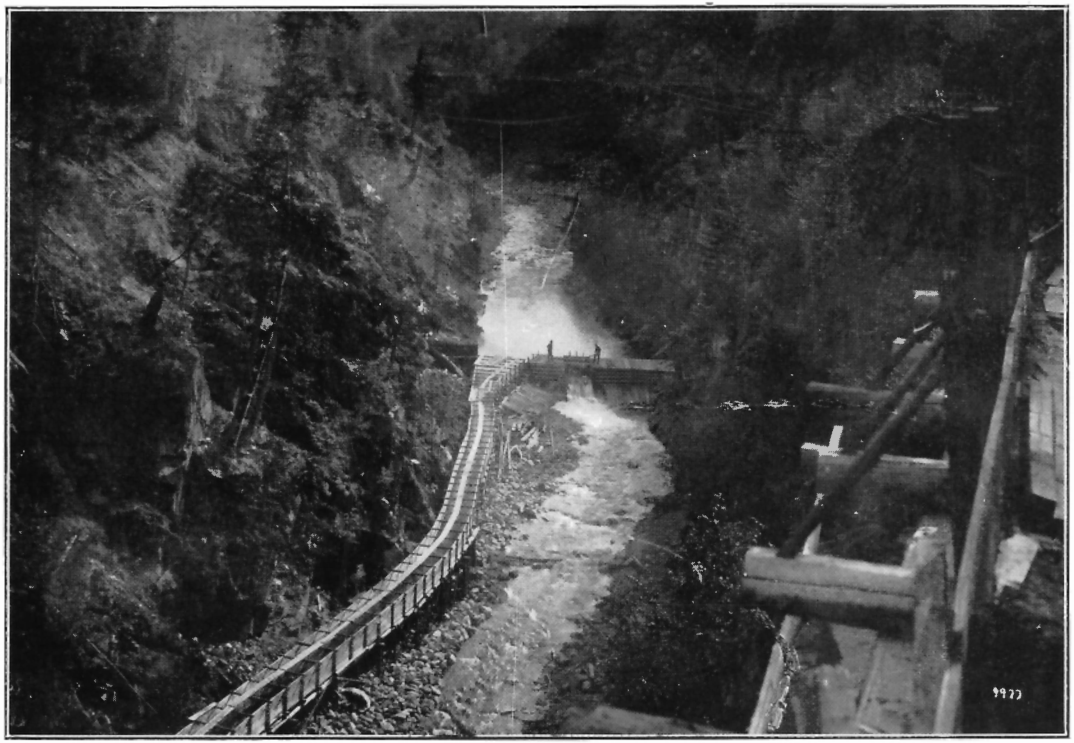
The earliest attempt at hydraulicing on Granite creek was that made by R. Stevenson and W. E. Hogg in 1891. A flume 4 miles in length was installed on the west bank of Granite creek, and work started on claims lying about three-fourths of a mile above the mouth of the creek. The promoters of this Company became involved in litigation with the owners of ground below them, and were forced into liquidation. It is stated that the court, acting as receivers, secured from the sluice boxes about $900, principally gold.

Mr. Hogg afterwards worked a small pit 4 miles below the mouth of Granite creek, and washed the gravels from an old high channel of Tulameen river. This venture was continued for one season, but in the following spring the pit filled with wash from the mountain side and was not reopened.

In 1892 the Tulameen Improvement Company began operations on a bench on the Tulameen river below the mouth of Eagle creek. A saw-mill was imported, at a time when the only means of transport was pack horses, and set up at the mouth of Eagle creek. A flume was built to convey water from Eagle creek, and hydraulicking operations were carried on for two seasons, under the direction of Judge Murphy. The proportion of gold to platinum at this point was about one to two, and the recovery of platinum was high; but the available ground was limited, and the results obtained did not pay for the cost of plant and management.

At the mouth of Slate creek, hydraulic operations were conducted for a short time by Alexander Swan, on a high bench above Tulameen river. A flume about a mile in length was laid up Slate creek and the water turned on to the bench. The bench was then found to consist largely of boulder-clay, and the only payable portion of this was a bed of stream gravels approximately 20 feet thick, nearly half-way down, between two deposits of boulder-clay. The boulder-clay was so stiff and compact that water had little effect on it, and the pay gravels were not easily reached; consequently the undertaking was not a success.

Within the last four or five years placer mining operations have been actively carried on by a few individuals only. Chinese have worked over the bed of the Tulameen river in the portions



Placer mining operations on Granite creek, August, 1909.

about the mouth of Slate creek and between the mouths of Eagle and Champion creeks. The heavier constituents of the gravels were recovered during the season of low water, by diverting the course of the water, by wing-dams, from the middle of the stream to the sides, thus leaving a portion of the bottom free for working. Other miners have been simply extracting pay from cracks in the bed-rock and from under and around large boulders which were left undisturbed by the earlier operations.

A short distance above the mouth of the North Fork, on the main Granite creek, Messrs. R. A. Lambert and Stewart have been doing the most serious placer mining in the whole district. The work of preliminary development has required the time of five men for three seasons, and the point of actual sluicing of the gravels has not yet been reached. Lambert and Stewart have a lease of 1½ miles of the creek above the North Fork, a very small part of which had been worked previously. The gold recovered from these portions was very coarse, though the bed-rock was only reached in one spot. In this particular portion, which was only 200 feet in length, the yield is said to have been $1,200 to the length of a sluice box, where the gravels in the stream bed had a width of 40 or 50 feet. The yield included nuggets, the gold value of which was from $100 to $150; the platinum, however, was fine. The remainder of the creek bed covered by the lease is deep ground and could not be bottomed. Lambert and Stewart endeavoured to cut down the bed of the stream in the lower part of their lease, in order to reach bed-rock and recover the gold and platinum lying on it. Commencing at the lower end of their ground, a dam was constructed across the stream bed, while 600 feet of a board flume carried the water over the portion of the channel which it was proposed to work first. The large boulders and rock in the lower part were blasted away, thus enabling the removal, by ground-sluicing, of about 25 feet of gravel, which before formed the bed of the stream. Before actual washing of the gravel had begun the dam and flume were partly washed away by a freshet and have not yet been replaced.

A company recently organized in Vancouver—the British Columbia Platinum Company—has obtained from the British Columbia Government three leases in what was formerly the most productive platinum district. One of these leases covers an area on Slate creek, and the others cover areas on Tulameen river above Slate creek. The Company proposes first to prospect the ground with a Keystone drill, and then to mine it by ground-sluicing or by drifting on the bed-rock.

Diamonds.

GENERAL FEATURES AND DISTRIBUTION.

Although placer mining in many of the streams of the Tulameen district has been carried on for a number of years, the presence of diamonds in the gravels had never been demonstrated, and consequently it was not suspected that they would be discovered in any of the rocks from which these gravels have been derived. For many years, however, officers of the Geological Survey, working in British Columbia, have been on the lookout for diamonds, and have warned prospectors of the possibility of finding them in the placers. Several years ago the present Director of the Survey drew the attention of miners to the necessity of observing carefully those placers which were derived from the erosion of such basic rocks as peridotite and expressed the belief that diamonds might occasionally be found in them. The results obtained have fully justified that belief.

In the course of the mapping and examination of the body of peridotite which extends from Olivine mountain across the Tulameen valley to Grasshopper mountain, masses of chromite were observed in several places in the peridotite. Hand specimens of the chromite embedded in serpentinized peridotite were brought in and handed to Mr. R. A. Johnston, mineralogist to the Survey, to determine the nature of the chromite. In the course of his analysis Mr. Johnston obtained a residual product from fusion which proved on examination to be diamonds. Further tests were made in New York by Dr. G. F. Kunz, who confirmed the discovery. This is the first recorded discovery of diamonds in Canada, that the Survey can vouch for.

So far as our knowledge of the occurrence yet goes, the diamonds are associated with the chromite, and are not found in other parts of the rock mass, so that their distribution depends upon that of the chromite. The chromite itself does not occur here in large bodies, and its distribution is very erratic.

The diamonds obtained from the samples analysed are small, though their quality is excellent. They have proved very difficult to extract from the rock without shattering, and even after extraction they often break up in the course of a few hours or days into much smaller fragments. For these reasons their value is not as great as it might appear to be, though the occurrence is of great scientific interest.

It is very probable that, in the course of placer mining of the gravels of this district diamonds may have been overlooked and discarded, and it is likely that with a more careful examination in the future of the concentrates obtained in washing for gold and p'atinum, some may be obtained. The materials founds in the gravels are derived from the solid rocks by the slow process of natural erosion, and the slowness of this action would tend to preserve the diamonds in their original size and form, so that diamonds of a larger size than have so far been extracted from the rock may possibly be found in the gravels.

These placers are valuable for their gold and platinum content, and it is likely will continue to be worked for these products alone; so that while placer mining for diamonds alone might not be a profitable undertaking, if any do occur in the gravels the value of the gold and platinum placers will be correspondingly increased.

MATRIX.

The matrix of the diamond is a peridotite of the variety dunite. It occurs as an intrusive igneous stock about 3 miles long and a mile wide, bordered on all sides by pyroxenite, into which the peridotite passes by a gradual change in composition. The two rocks are of the same age, and have been thrust through rocks of presumably Triassic age consisting of volcanic materials and a few thin beds of argillite and limestone.

Over a great part of its area the peridotite consists only of olivine. Chromite enters in isolated places, but rarely occupies a more prominent position than that of an accessory constituent in the rock. It then appears either sparingly disseminated through the peridotite or as segregations in short veins or bunches. These segregations are rarely more than an inch in width and a few inches in length. It is not evident that they are confined to any particular part of the peridotite mass, though in many other peridotite bodies such segregations of chromite have been found to be situated nearer the borders of the body than in its central parts. Magnetite occurs more sparingly than chromite.

Virtually all the samples of peridotite collected from this body show signs of alteration to serpentine. The freshest samples when seen under the microscope show cores of olivine separated by small veins of serpentine. In the extreme cases no olivine remains, and there is left only a dense mat of serpentine fibres.

The peridotite has the form of a stock elongated in a general north and south direction, and is cut through almost in the middle by Tulameen river, which exposes a section of it about 3,000 feet in height. In structure it is massive and shows little evidence of having been disturbed by dynamic movement. It is not brecciated and only to a limited extent sheared. It does not break down easily, and when it does it forms a talus of small flat chips. Surface decomposition generally only extends for about an inch in depth, and in weathering, rounded or spherical shapes are developed.

Two chemical analyses of the Tulameen rock are given below, showing different stages of alteration to serpentine. For the purpose of comparison the analyses of three other diamond bearing rocks are also given:—

—	Tulameen peridotite. (1) No. 1.	Tulameen peridotite. (1) No. 2.	Arkansas (2) peridotite.	Kimberley (3) blue ground.	New South Wales (4) hornblende diabase.
SiO_2	33·48	38·40	38·78	39·732	50·43
Al_2O_3	1·50	0·29	6·85	2·309	14·72
Fe_2O_3	7·27	3·42	8·83	....	2·90
FeO	1·36	6·69	1·99	9·69	4·59
MgO	42·02	45·23	26·34	24·419	6·67
CaO	0·02	0·35	3·88	10·162	7·13
MnO	0·06	0·24	....	....	0·03
$K_2O + Na_2O$	0·29	0·08	3·34	....	3·70
H_2O+	0·60	0·24	1·95	....	3·49
H_2O-	13·26	4·11	7·85	7.547	3·82
CO_2	....	1·10	0·14	6.556	1·67
TiO_2	trace	....	0·89	....	0·82
P_2O_5	....	trace	....	....	0·22
S	....	0·06	....	....	0·01
Cr_2O_3	....	0·07	....	....	0·02
NiO	....	0·10	....	....	....
V_2O_5	....	....	....	....	0·03
	99·86	100·38	100·84	100·415	100·25

(1) U.S.G.S. Bull. No. 193.
(2) Geol. Surv. of Arkansas, 1890, Vol. II, p. 377.
(3) Precious Stones by Bauer and Spencer, p. 190.
(4) British Assoc. for Adv. of Sci., 1906, p. 562.

The matrix of the Tulameen diamonds is similar to that in which diamonds have been found in Pike county, Arkansas, and from which up to July, 1909, over 700 commercial diamonds had been recovered. This rock is described as a peridotite occurring in a stock covering about 60 acres and thrust through Carboniferous sandstones and quartzites.[1]

The kimberlite of South Africa is also a related rock, and its occurrence in pipes indicates a similar origin to that of the Tulameen peridotite. The main difference between the Tulameen rock and both the Arkansas and the South African matrices is in the degree of alteration and decomposition that has taken place, a decomposition which in the Tulameen rock extends only to the degree of an inch or two, but in the other rocks to many feet.

The most common matrix of the diamond appears then to be a rock of extreme basic composition. There is, however, an instance, recorded by Prof. T. W. E. David,[2] of diamonds occurring in a

1 Economic Geology, Vol. III, p. 525, 1908.
2 British Association for the Adv. of Sci.: 1906, p. 562.

slightly more acid rock. This rock is described as a hornblende diabase, occurring as a dyke cutting granite, at Oakey creek, New South Wales, the diamonds having been found embedded in the rock.

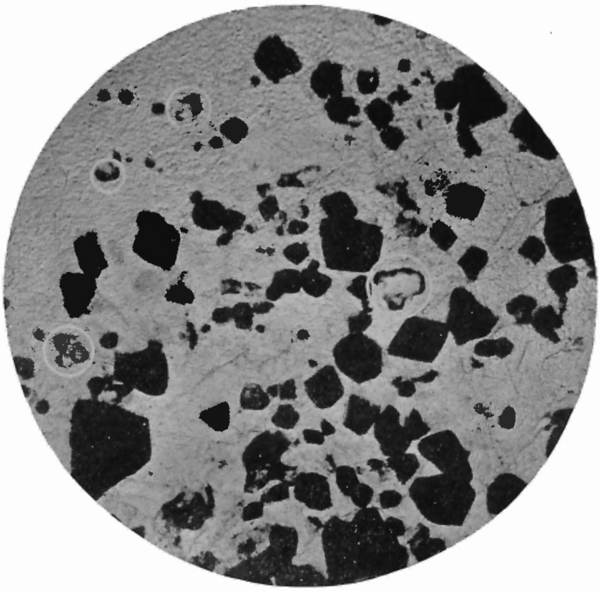
The Tulameen occurrence is one of only two instances in which diamonds have been found in the original matrix on the North American continent, the Arkansas occurrence being the other.

ASSOCIATION AND MODE OF OCCURRENCE.

In the course of chemical analysis of the sample submitted to him, Mr. Johnston found that the diamonds were associated with the chromite rather than with the serpentine. A small piece of chromite was taken and ground in a mortar and then separated into two parts—a magnetic and a non-magnetic part. The magnetic portion was found to contain about 6 per cent of diamonds, while the non-magnetic part carried about 3 per cent. Platinum and a smaller quantity of gold were also found to be associated with the chromite.

If it is true that the diamonds only occur with the chromite, the quantity of diamond in the rock will depend on the amount of chromite present. As the discovery of diamonds was only made after the completion of field work in the Tulameen district, it has not been determined, except in a general way, what proportion of chromite there is to olivine in the peridotite. From a general survey of the peridotite in the field and a more precise examination of the thin sections, the conclusion was drawn that the chromite forms a very small proportion of the rock, and except where segregations occur, is almost a negligible quantity. The segregations are either bunches or short irregular veins formed at the time of intrusion of the rock. The veins vary in width from mere threads up to thicknesses of one inch, they are not continuous in length for more than a few inches, and branch out into a number of smaller interlocking veinlets. The walls are irregular and are not always clean cut. Both the veins and the rock are traversed by small lines of dislocation.

The presence of platinum in the chromite segregations had previously been determined by assay, when 0·02 ounces of platinum to the ton were obtained. It was also identified under the micro-



Microphotograph showing aggregates of diamond crystals in rounded areas within the white circles, associated with chromite in a base of serpentine. Magnified 25 diameters.

Microphotograph illustrating the occurrence of diamond in veinlets traversing chromite. Magnified 25 diameters.

scope in the product derived by fusion from the chromite. In the latter case a quantity amounting to almost 2 ounces to the ton was obtained. A smaller quantity of gold was also found to be present.

MINERALOGY.

A careful examination of the peridotite with a hand lens has not yet resulted in the identification of any diamonds in it. The first results were obtained by Mr. Johnston by fusion in a crucible. Since then a sample of chromite from the same hand specimen which yielded the diamonds was taken and thin sections cut from it. In at least four of the thin sections diamonds could be identified under the microscope.

These thin sections show massive opaque chromite, traversed by narrow veinlets of serpentine associated with short fibres of hornblende. The diamonds occur as a rule in the narrow veinlets.

In general appearance the diamonds are brownish to yellowish in colour, partly or wholly opaque, and have a spherical or quite irregular outline. They frequently, though not always, abut against the chromite. They have a high relief and are generally isotropic. Some show optical anomalies. In reflected light they give a brilliant display of colours, which come from a number of small points in the material. Examined under the high power the brownish areas of diamonds are seen to be not single individuals, but to be small dust-like particles grouped together in aggregates. It is the grouping of these small particles together in aggregates that gives the great variety of colours in reflected light. These aggregates are more properly called bort.

Besides these aggregates small octahedra are occasionally seen associated with the chromite. These are clear and bright in transmitted light, have a high relief and are idiomorphic towards the chromite. Their outline is sharp, and they have undoubtedly crystallized before the chromite with which they are associated. They are translucent, and in reflected light give a strong play of colours. Between crossed nicols they are quite opaque, and, therefore, isotropic.

The product obtained by Mr. Johnston from fusion shows the two varieties already described, one being a yellowish massive substance, and the other small, well crystallized individuals of apparently great purity. Octahedral forms are very common, with sharp outlines and clean cut faces. Many of them show striations on the octahedral faces, and twins are common. Under a very high power the small individuals are seen to hold inclusions, either liquid or gaseous.

The largest individuals so far obtained by Mr. Johnston are about the size of an ordinary pin's head, but in a great many cases these individuals break up on being released from the rock into smaller particles which are rarely more than three-tenths of a millimetre in the long diameter. This shattering happens often within an hour or two, and is quite noticeable inside of a week. It is probable that the breaking up may be due to inclusions.

GENESIS.

Much of the evidence on which to base conclusions on the genesis of these diamonds has already been stated. For the sake of clearness a recapitulation of this is given here, together with certain other points which have not heretofore been mentioned.

In the first place there can be no doubt of the igneous origin of the rock which forms the matrix of the diamonds. In this rock the diamonds are associated with the chromite in such a way that they are evidently both primary constituents of it. The thin sections show these two minerals to be very often in contact with each other, and where crystalline individuals of diamond were identified, they were seen to have distinct crystallographic outlines and to be idiomorphic towards the chromite, showing that in crystallizing the diamond formed first, and the chromite has to adjust itself to the shape of the diamond. There is no evidence to show that the diamonds were introduced later than the chromite; and the chromite in such cases is generally considered by all geologists to be of magmatic origin. A few investigators believe that under certain circumstances and to a limited extent, chromite migrates in solution, but in such cases the conditions of occurrence are different. If then the chromite is an original constituent and a segregation from a cooling magma, the diamonds must have originated in the same way.

The matrix of the diamonds is intrusive through a series of rocks which contain little or no carbonaceous matter and are in fact largely volcanic in origin, so that the carbon could not have been derived from them. In fact the only carbonaceous rocks in the district are of Tertiary age, and were not formed at the time of the intrusion of the diamond bearing rock. The present occurrence of diamonds, therefore, in no way supports the theory of an organic origin for the carbon necessary to form the diamonds. It is more probable that the carbon existed in some form or other as an original constituent of the peridotite magma, and on solidifying crystallized out as diamond.

Platinum.

For the last ten years a few prospectors in the Tulameen district have been devoting their energies to the search for the original source in the solid rock of the platinum of the placers, on the chance that when found it might prove profitable to mine the rock as an ore of platinum. Although it is now definitely known what the original source of the platinum is, it still remains to be demonstrated whether or not the platinum occurs in such quantity in the rock as to make its extraction commercially possible. From our present knowledge of the conditions of occurence it does not seem likely that the mining of platinum from the solid rock of this region will ever be undertaken.

A careful and detailed examination of this field was made by Prof. J. F. Kemp in the season of 1900, with the special object of studying the geology of the platinum. His results are contained in a bulletin of the United States Geological Survey,[1] which is yet the most complete work on the subject. Prof. Kemp's conclusion as to the source of the platinum of the placers is that it was derived from the belt of peridotite and pyroxenite which stretches across the country from Lodestone mountain to Grasshopper mountain. This conclusion was based on the distribution of the placers, the association of minerals in the platinum nuggets, and on chemical analyses of many samples of these two rocks.

In testing for platinum Prof. Kemp's best results were obtained from the peridotite, or from pyroxenite dykes in the peridotite; and particularly where alteration had taken place to serpentine or where the rock was rich in chromite. Assays of serpentine veins

[1] Bull. U.S. Geo. Survey, No. 193.

in peridotite yielded platinum varying in amounts from a trace up to nearly 2 ounces to the ton, but it was found that the distribution of the platinum in these veins was not sufficiently even to justify exploitation. Masses of chromite also gave good results, which varied up to half an ounce to the ton. But here again the distribution was very uneven. No platinum could be detected in the rock itself or in concentrates of it obtained by panning, so that Kemp concluded that the platinum was in very fine scales and that large nuggets were rare.

The author's own work along this line corroborated Prof. Kemp's. Several samples of selected parts of both the pyroxenite and the peridotite were taken and assayed, as well as a number from localities in which platinum was stated by prospectors to have been obtained by assay. The best results and in fact the only results were obtained from masses of chromite in the peridotite. Other localities in the pyroxenite at which some development work was being done yielded no platinum whatever, though it was stated to be present and to have been obtained by certain assayers.

A sample of chromite from a mineral claim owned by T. Lee, on the northwest slope of Olivine mountain, was examined by Mr. R. A. A. Johnston, of the Survey, and found to contain diamonds. Associated with the diamonds was platinum in an amount approximating 2 ounces to the ton of rock. When examined under the microscope the platinum was seen to be in thin roughened scales or small sponge-like masses of silver-white colour. No crystalline form was apparent, but on the other hand the edges of the grains were very irregular and their projecting points rounded. The general appearance and form were often similar to the native silver of the Cobalt region. In this case again the distribution of the platinum was uneven, for no results were obtained from analyses of other parts of the same hand specimen.

The conclusion drawn, therefore, with regard to the finding of platinum in these rocks in sufficient quantity to mine is that the chances of doing so are small. Combined with the features already enumerated, these chances are further limited by the expense of thoroughly testing the rock, and the difficulty of getting reliable platinum assays made.

There are very few instances in which platinum is obtained in commercial quantity from the solid rock, and these are usually cases in which platinum is not the primary mineral sought. In Canada it is obtained as a secondary product in the reduction of the nickel-copper ores of the Sudbury district, and it has been described by R. W. Brock as occurring in an unknown form in a gold bearing quartz vein at Burnt basin, near Coryell, B.C.[1]

The most notable occurrence of platinum in the solid rock in America is that at the Rambler mine[2] in Wyoming, where it occurs as the arsenide sperrylite in association with a variety of copper compounds notably covellite. The recovery of the platinum from these ores has been the subject of study for a long time, and though many details of treatment are still to be settled, the results so far obtained have been highly satisfactory.

Some lode mining of platinum has been done at the Key West mine in Clark county, Nevada, where the platinum occurs in peridotite dykes which cut gneisses. The dykes vary in width from 10 to 50 feet, and carry platinum in an amount of 0·55 of an ounce to the ton. Some ore has been shipped from this mine, but the results of treatment are not known.

The instances cited of platinum in the solid rock justify the search that has been and is being made for platinum in workable quantity in the solid rocks of the Tulameen district, and suggest that there is yet a possibility that such an occurrence may be found. The advancing price of platinum, too, increases the chances, for the higher the price the lower the grade of the rock that can be mined.

Gold Deposits.

Probably the most important primary gold bearing deposits of the district are those which carry copper and other minerals in association. These will be described under a subsequent heading. There are, however, some deposits which contain gold as the only valuable metal. These occur as quartz veins carrying gold in a free milling state, and have been mined to a limited extent for that metal alone.

The most important gold bearing quartz veins are situated on the eastern side of Granite creek, about half a mile below the North

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[1] Eng. and Min. Jour. Feb. 18, 1904.
[2] Metallurgical and Chemical Engineering, Feb. 1911.

Fork. Similar veins are reported to have been found higher up Granite creek, on the divide between this stream and Ninemile creek. At both localities the quartz veins cut the green schistose volcanic rocks of the Tulameen group.

The width of the veins varies from a few inches up to 5 feet. This width, however, is not uniform, and the bodies of quartz would be more properly termed lenses. The quartz is white or glassy and is only slightly mineralized with pyrite. The gold in it is free, and can easily be detected in small specks scattered through the quartz gangue.

Estimates of the value of these veins vary because the gold is not evenly distributed throughout them. It is stated that one small vein on Granite creek averaged about $12 to the ton for a considerable distance.

A small 2-stamp mill was operated for a time on Granite creek and ore extracted from one of these veins, but the undertaking was not profitable on account of the uneven distribution of the gold in the vein.

Copper Deposits.

GENERAL STATEMENT.

The copper deposits of the Tulameen district are at present the most important of its primary metallic deposits. They are here described under one heading, but they do not all belong to the same class of deposits, nor do they all contain copper as the mineral of primary importance. All of them contain some gold in association with the copper, the quantity varying in different localities. The deposits are important not only for their wide distribution in the district, but for their economic value as probable producers of metal in the near future. On this account most of the prospecting and development work done by miners on metallic deposits has been carried out on deposits of this nature.

Although many of the deposits have been known for the last ten years and have been prospected more or less for that length of time, they have not yet produced a pound of metal. This is not due so much to the character of the deposits themselves as to their isolation and to the lack of good transportation facilities. Many of them are only connected with Tulameen, the principal distributing point of the district, by pack trails, and Tulameen itself has yet no railway connexion with outside points, though a connexion should now be effected within a short time.

In all cases the ores will have to undergo treatment by smelting, either directly or after concentration, and the fact that there is within the same district coal which yields a fair quality of coke increases the value of the deposits, and the probability of their being worked.

DISTRIBUTION.

The principal localities in which copper deposits are found and have been prospected are: at Independence camp on the headwaters of Bear creek, at Law's camp, Britton mountain, Champion creek, Olivine mountain, Slate creek, Rabbitt mountain, and at the head of Smith creek.

The majority of these deposits are situated in the rocks of the Tulameen group, and in nearly every case are located either on the immediate contact of some igneous rocks or within the sphere of influence of such rocks. The contact with the Eagle granodiorite is a favourite position for these deposits, particularly where the Tulameen rocks are represented by limestones, in which case the conditions are most favourable for ore deposition. Other deposits are situated on the Boulder granite contact and on the contact of the pyroxenite. No deposits have yet been found on the contact of the Otter granite.

In certain cases copper deposits have been formed within the igneous rocks themselves, as in the case of the pyroxenite or in dykes of granite porphyry. No copper nor other metallic deposits are known to occur, in this region, in any stratified formation other than the Tulameen group.

GENERAL CHARACTER OF THE DEPOSITS.

The copper deposits of the district have one characteristic common to all of them, and that is the presence of the copper in the form of the sulphide chalcopyrite. In one or two instances the higher form, chalcocite, has been developed, no doubt by secondary enrichment of chalcopyrite, and in other localities tetrahedrite occurs. The minerals usually associated with the copper minerals are pyrite, and pyrrhotite. Galena, zinc blende, magnetite, and molybdenite are present in some of the deposits.

The gangue of the ore minerals depends on the nature of the deposits. In some the gangue is the unaltered country rock, in others it is the country rock altered by contact metamorphic action, in others it is partly replaced limestone, and in others quartz.

The various kinds of copper deposits can all be classified under one of the three following heads:—

(1) Disseminated ores.

(2) Contact metamorphic deposits.

(3) Veins or replacement deposits.

Copper deposits of the first class occur on Olivine mountain and elsewhere in pyroxenite. The copper mineral is chalcopyrite, which is associated with pyrite and magnetite, and occurs either disseminated throughout the massive pyroxenite or in zones of shearing which run east and west and rarely north and south.

Deposits of the second class are found on Britton mountain on the contact of pyroxenite with the rock of the Tulameen group, and at Champion creek and elsewhere on the contact of Eagle granodiorite with the same group of rocks. In these instances chalcopyrite, associated with some pyrite, pyrrhotite, galena or blende, occurs in a gangue of calcite and such lime silicate minerals as garnet, epidote, and pyroxene.

Deposits of the third class are economically the most important in this field, and on them the greatest amount of work has been done. They are all closely associated with igneous intrusives, and the ore bodies have been formed either in the igneous rocks themselves along fracture zones, or they have been developed in the intruded rocks by a replacement of certain strata in these rocks. The first of these strongly resembles the Butte type and is exemplified at Independence camp, where a large dyke of granite porphyry has been fractured, and chalcopyrite, pyrite, and pyrrhotite have been deposited in the fracture planes and also penetrate the wall rock on either side.

The second type of these replacement deposits is illustrated at Law's camp, Boulder creek, and Rabbitt mountain. In these instances the copper and iron sulphides, frequently associated with galena and blende, have replaced calcareous or other strata to a greater or less extent, the ore bodies being confined to particular strata and bounded by the adjacent strata.

DETAILED DESCRIPTION OF THE DEPOSITS.

Olivine Mountain.—The copper deposits of Olivine mountain are situated to the south of the highest point of the mountain and on the ridge which separates Champion creek from Slate creek.

The first mineral locations were made there about nine years ago, when some local excitement was caused by the supposed discovery of very rich gold ores. The whole mountain was staked at that time, further prospecting was not encouraging, hence the claims were allowed to lapse.

In 1906 locations were again made, but this time for platinum and copper. About 25 claims were being held in 1910, and in the following spring all the vacant ground was taken up as diamond prospects.

The country rock of the copper deposits of Olivine mountain is pyroxenite, which consists essentially of pyroxene, sometimes altered to hornblende, and magnetite. The pyroxenite is sometimes sheared and rendered schistose along north and south lines, and in these shear zones quartz veins have been formed. The quartz veins are sparingly mineralized with pyrite, chalcopyrite, and pyrolusite, but they do not contain any of the metals in sufficient quantity to mine.

The copper deposits lie in the pyroxenite itself, and appear to be confined to certain east and west zones of shearing. In these zones chalcopyrite occurs in minute fracture planes, or is disseminated throughout the mass of the rock adjacent to the lines of fracture. In the latter case the chalcopyrite is apparently a primary mineral in the pyroxenite, for it appears embedded in the pyroxene crystals. In the former case it is secondarily deposited by percolating solutions.

Assays of samples of this ore yielded 3 per cent of metallic copper, and it is unlikely that the average grade of the ore will exceed that figure. The amount of work done is not great, consisting of open-cuts, prospect pits, and short tunnels, and is insufficient to demonstrate the value of the deposits.

Britton Mountain.—Britton mountain occupies a position on the north side of Tulameen river between Eagle and Siwash creeks. It is dome shaped and rises about 1,300 feet above the level of the river directly below it.

A group of mineral claims has been staked on this mountain, the oldest of them having been held for the last 11 years. They lie in a belt of rocks of the Tulameen group, about half a mile wide and bordered on one side by pyroxenite and on the other by Eagle granodiorite, both of which are intrusive into them. The rocks of the Tulameen group here consist of narrow bands of limestone interbedded with mica, hornblende, chlorite, and quartz schists, all of which dip at high angles and strike approximately north and south.

The copper deposits are of contact metamorphic origin and are situated in a zone of brecciation lying on the contact of pyroxenite with the schists. This zone of brecciation is mineralized with pyrite, chalcopyrite, and magnetite, which are associated with pyroxene, garnet, hornblende, and epidote. Adjacent to this zone is a bed of white quartz schist about 40 feet in width, mineralized with pyrite, which occurs in well crystallized individuals forming lines parallel to the plane of schistosity. Most of the development work has been done on this bed of quartz schist, but samples of it taken for assay have yielded no gold and only a trace of silver. The work on the copper ores in the zone of brecciation consists of open-cuts and prospect pits.

On the contact of Eagle granodiorite some mineralization has also been effected by copper and iron sulphides; but little work has been done to prove the extent of this mineralization or its importance.

Champion Creek.—A group of about 12 mineral claims is situated on Champion creek near its mouth, and in the neighbourhood of the contact of Eagle granodiorite with the limestones and schists of the Tulameen group.

The limestones and schists are penetrated along their bedding planes by many apophyses from the granodiorite, which has effected much contact metamorphism. They dip towards the granodiorite and strike approximately north and south, parallel to the contact. They are also traversed by many small quartz stringers all of which are more or less mineralized by sulphides.

The limestone bands have suffered the greatest amount of alteration from the intrusion of the granodiorite, and have been either marbleized or altered to a lime silicate rock consisting of reddish garnet, radiating green epidote, hornblende, and pyroxene. This altered rock is the gangue of the ore, which consists of pyrite, chalcopyrite, blende, tetrahedrite, and molybdenite. Besides copper, the ores yield gold and silver on assay; and in some cases the value is reported to be high.

A little development work has been done, consisting of opencuts, short tunnels, and prospect pits.

Rabbitt Mountain.—Rabbitt mountain lies in the angle between the Tulameen and Otter valleys to the south of Boulder creek. It is a broad, flat topped ridge, rising about 2,300 feet above Otter lake and extending northwestward to form the divide between Boulder and Bear creeks. Some years ago the whole mountain was staked out in mineral claims, but the majority of these have now lapsed and the only ones on which any work is being done are those situated at the eastern brow of the mountain and owned by Messrs. Conley, Speck, and MacGonigal.

The mountain is made up of stratified volcanic rocks belonging to the Tulameen group, which strike northwest and dip at various angles to the southwest. They are penetrated by sheets and dykes of granite porphyry and are intruded on the northeast by Boulder granite. The mineral claims are situated not far from the contact of the Boulder granite.

The mineral deposits are replacements closely associated with the granite porphyries, which are themselves mineralized with iron sulphides. They lie in the stratified rocks, which are here chlorite schists, andesites, and volcanic breccias. The ore minerals are pyrite and chalcopyrite disseminated through the country rock which has in some cases become silicified. Small veins of quartz, traversing the stratified rocks, also contain the above-mentioned sulphides.

Besides copper the deposits also carry gold. The development work consists of shallow pits and opencuts and three tunnels, the longest of which is over 300 feet in length.

Boulder Creek.—The mineral deposits of this locality are situated on the north side of Boulder creek and extend over the divide northward to Elliot creek. They were first staked in 1899, and though some of the mineral claims have lapsed, many of them still have the annual assessment work done on them.

The country rock of this field consists of soft green schists dipping at low angles to the west, and intruded on the east by the Boulder granite. Granite porphyry dykes penetrate the schists in many places. The mineral deposits lie in the schists in the neighbourhood of the Boulder granite and are closely associated with the granite porphyry dykes.

The country rock of the mineral deposits is a soft green schist, which is traversed by small veins filled with quartz or calcite. Mineralization occurs both in the veins themselves and in the wall rock of these veins. In the latter case the ore minerals are disseminated grains which have been introduced by a process of replacement. The ore minerals are pyrite, chalcopyrite, and some galena. The deposits carry gold in association with the copper, and are said to vary in value from $8 to $20 to the ton.

Considerable development work has been done on these deposits, which like those on Rabbitt mountain, are promising enough to deserve further work.

Law's Camp.—The group of mineral claims knawn as Law's camp is situated on the western side of Bear creek and about three-fourths of a mile west of the forks of the stream. It comprises eight Crown granted mineral claims and a number of others on which the annual assessment work is still being done. It is connected with Tulameen by a good wagon road 12 miles in length.

The original discovery of ore in this camp was made by a party of Swedes in 1900 on the old Indian trail which runs from Murphy lakes northward to the Coldwater river.

The rocks in which the mineral deposits lie are limestones interbedded with mica, chlorite, and talcose schists belonging to the Tulameen group. These are intruded on the west by Eagle granodiorite, into which they dip at various angles varying from 30 to 70 degrees. They are also cut by many apophyses from the Eagle granodiorite, and by dykes of granite porphyry and lamprophyre the former of which are highly mineralized with pyrite. The mineral deposits are situated in the stratified rocks on the eastern edge of the granodiorite and within the metamorphic zone affected by it and its apophyses.

The granodiorite forms either a clean cut or a brecciated contact with the stratified rocks and has effected some contact metamorphism. This action is most apparent in the limestone bands, which have been either rendered crystalline or been altered to a lime silicate rock containing garnets, epidote, hornblende, and other minerals. More or less mineralization by copper, iron, zinc and lead sulphides has accompanied the alteration.

The ore deposits are replacement deposits characterized by minerals formed at a moderate depth, and are undoubtedly genetically connected with the granodiorite intrusion. They lie almost exclusively in the limestone bands, which they frequently have replaced from wall to wall. The maximum width of the ore bodies is determined by the thickness of the limestone beds, the adjacent beds being mica or hornblende schists. The actual width of the ore bodies varies from 3 feet up to 12 feet. They occur as lenses in the limestone, pinching and swelling both horizontally and vertically. As the strata dip towards the west the ore bodies often seek the hanging-wall and are never on the foot-wall except when they fill the whole bed from wall to wall.

The ore minerals visible in the rock are pyrrhotite, pyrite, chalcopyrite, galena, zinc blende, and sometimes magnetite. The pyrite, galena, and blende are usually well crystallized and are disseminated through the gangue in individual grains or in bunches. The pyrrhotite and chalcopyrite are massive and often appear in well defined lines running through the gangue or through the other ore minerals. Gold and silver are associated with these sulphides, but are not visible in the ore and are only determined by assay.

The gangue of the ore is as a rule calcite. Secondary silica is also present in all the ore bodies but in relatively small amounts. In certain localities garnet, epidote, and hornblende are associated with the calcite as gangue minerals, and indicate a change in the origin of the deposits from simple replacement to contact metamorphic conditions.

These ores are valuable for their gold, silver, and copper content, and selected samples have yielded as much as $100 to the ton in these metals.

The mineral claims on which the greatest amount of development work has been done are the St. Lawrence, St. George, Liverpool, Chicago, Morning Glory, Frisco, and London.

St. Lawrence.—The St. Lawrence is the oldest claim in the camp, and is the one on which the mine buildings have been erected. It is developed by two incline shafts, No. 1 and No. 2, respectively 16 and 55 feet in depth, and by an adit tunnel which in July, 1910, was 620 feet in length and had two short drifts running from it.

No. 1 shaft has a dip of 45 degrees to the west, and shows 6 feet of ore lying between walls of schists. The ore consists largely of pyrrhotite with lesser amounts of pyrite, chalcopyrite, and blende.

No. 2 shaft lies 100 feet northwest of No. 1, and dips 52 degrees to the west. It shows 6 feet of ore containing pyrrhotite, pyrite, and chalcopyrite in a gangue of calcite lying between walls of schist.

The adit tunnel enters near the bunk house and was run to strike at some depth the ore body exposed in No. 1 and No. 2 shafts. It enters on a bed of mica schist and follows the strike of the rocks for 476 feet, and then cross-cuts them at a slight angle for 144 feet. No ore appears in the main tunnel, but a thin band about 12 inches in width was encountered in the drift which runs to the north.

St. George.—The St. George adjoins the St. Lawrence on the north, and belongs to the same company owning the St. Lawrence, namely, the Similkameen Mining and Smelting Company. On this claim are a number of open-cuts and two shafts, No. 3 which is about 50 feet in depth, and No. 4 which is 182 feet in depth.

No. 3 shaft was full of water at the time the examination was being made; but the ore on the dump was seen to consist of pyrrhotite, chalcopyrite, and pyrite in a gangue of calcite.

No. 4, the main shaft, is well timbered and equipped with a steam hoist and pump, and covered by a good log building. It dips 60 degrees to the west and is 182 feet in depth. At the 100 foot level drifts run 50 feet in either direction along the strike of the vein, and at the bottom are two cross-cuts each about 35 feet in length. The walls of the ore body are schists, while the ore itself lies in a stratum of white limestone, which it has replaced either wholly or in part. The width of the ore body varies up to 14 feet and in places pinches to a narrow seam. As a rule the ore favours the hanging-wall rather than the foot-wall. The ore minerals, which have replaced the limestone, are pyrite, pyrrhotite, chalcopyrite, and some blende; and the gangue is calcite and some quartz.

Frisco.—The Frisco adjoins the St. George on the north, and is not surveyed and Crown granted. The only development work seen on it consists of an open-cut about 10 feet deep. The cut shows 6 feet of ore in limestone lying on the upper side of a dyke of granite porphyry. The gangue of the ore is dark crystalline limestone, and the ore minerals are well crystallized pyrite and magnetite, and massive pyrrhotite and chalcopyrite, which follow definite lines parallel to the bedding of the rock. The association of sulphides with oxides in this case indicates crystallization or formation of ore under conditions of considerable pressure.

London.—The London mineral claims adjoin the Frisco on the north. The whole claim is drift covered, and the work consists of a number of surface cuts to expose the rock. One cut shows a small body of ore on the upper side of a sheet of granite porphyry which is intrusive into mica schist. The schist may have originally been a bed of limestone, for it now contains besides the mica some garnet and epidote. The deposit contains pyrite disseminated through a gangue of the above minerals and is about 10 feet wide. It is clearly contact metamorphic in origin. Other cuts show somewhat similar conditions, with the presence of chalcopyrite and massive magnetite with the pyrite.

Liverpool.—The Liverpool, lying directly south of the St. Lawrence, is surveyed and Crown granted. The development work on this claim is an open-cut running into a short tunnel. The country rocks are bands of blue and white limestone interbedded with mica schists dipping 35 degrees to the west. The outcrop of the ore body, which is a bedded deposit, consists of iron oxides and copper carbonates. Below this is the unaltered ore body, which consists of pyrite, pyrrhotite, chalcopyrite, and some galena and blende in a calcareous gangue.

Chicago.—The Chicago adjoins the Liverpool on the south and is also surveyed and Crown granted. It has been prospected by two long open-cuts, which show the country rocks to be banded limestone and lime schist dipping 25 to 30 degrees to the west. The ore body is a replacement of the limestone by pyrite, chalcopyrite, and blende, which follow well defined lines running parallel to the bedding planes.

Morning Glory.—The Morning Glory lies south of the Chicago, and is developed by a tunnel which follows the strike of the rocks. The rock is limestone, which contains disseminated crystals of pyrite and thin veins of pyrrhotite. It is cut by small quartz stringers, but these are barren of any sulphides.

Independence Camp.—Independence camp comprises a group of mineral claims situated in the northwest corner of the Tulameen map-sheet on the divide between Bear creek and the Coldwater river, and extending southward into the Bear Creek basin. The main workings of this camp are situated at an elevation of 2,900 feet above Tulameen and about 5,400 feet above sea-level. They are distant from Tulameen about 15 miles, and are connected therewith partly by wagon road and partly by pack trail.

To the east of the camp lies the main body of the rocks of the Tulameen group, which here consists of chlorite, sericite, and hornblende schists dipping at high angles towards the west. To the west lies the Eagle granodiorite, which is intrusive into the rocks of the Tulameen group; and between these two formations is a large dyke of granite porphyry which cuts both formations. In this dyke lie the principal ore bodies.

The granite porphyry has a maximum width of about 1,200 feet and extends southward in a gradually narrowing band for about 3 miles. It is cut by syenite porphyry dykes and traversed by zones of fracturing. 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 in 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 N. 25° W.

The deposits of this camp are replacement deposits of the Butte type. They lie in fissures in the granite porphyry in main direction of fracture, and the formation of ore has progressed along these fissures, passing outward from them into the country rock. Deposition of ore has been accomplished by ascending alkaline solutions carrying the various metals present in the ore bodies.

The ore minerals are chalcopyrite, pyrrhotite, pyrite, and lesser quantities of blende, chalcocite, tetrahedrite, molybdenite, and cuprite. The gangue of the ore is the granite porphyry which, however, has been so altered by ascending solutions that both the feldspar and the biotite have often disappeared entirely and only the quartz remains. The secondary gangue minerals introduced into the fractures and the bounding wall rocks are quartz, calcite, and sericite, and these are most abundant where the fracturing has been greatest.

From a study of the ores it appears 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 the gangue mineral, so that we find veinlets of calcite cutting the previously formed ore minerals, and geodes filled with quartz, calcite, and sericite.

Some secondary enrichment has taken place, forming cuprite and chalcocite, but this enrichment is very limited.

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 found associated with these ores.

The main workings in this camp are situated directly on the summit of the divide between Bear creek and the Coldwater river, and consist of over 1,000 feet of tunnels and drifts and 265 feet of shafts, with a number of open-cuts and prospect pits. The main tunnel is 500 feet in length, driven in on the strike of the ore. At a distance of 390 feet from the portal is a raise of 126 feet to the surface. At 360 feet from the portal are drifts to either side, one being 145 feet in length and the other 342 feet. In the latter drift is a winze 53 feet deep. Most of this work was done by the Granby Company.

Much work has also been carried out on claims lying south of Independence camp, in or adjacent to the same dyke of granite porphyry.

Magnetite.

The presence of magnetite in the rocks of Lodestone mountain has long been known to prospectors in the Tulameen district, and it is due to the fact that the quantity of this mineral was sufficiently great to affect the compass that the mountain was given this name. Several mining claims were at one time staked on this ground for iron ore, but they have long since been abandoned without any work having been done on them.

The rock in which the magnetite occurs is pyroxenite, which occupies a belt from 1 to 2 miles wide extending from Olivine mountain southward to Lodestone mountain, and beyond that for an unknown distance in the same direction.

Everywhere throughout its length the pyroxenite carries some magnetite as an original constituent, in which case it occurs in crystallized individuals scattered through the rock. In certain places, however, the quantity of magnetite increases to such an extent that the rock might be classed as an ore of iron. Such places are at Coutney's cabin on Olivine mountain, and at Lodestone mountain. At these places it occurs in short, irregular veins or in large bunches in the pyroxenite, the whole having a general east and west trend. These bodies are not connected with any system of fractures and are not secondarily deposited, but are primary constituents of the rock itself. Like the chromite in the peridotite, they are basic segregations, formed during the cooling of the pyroxenite magma.

No attempt has yet been made to demonstrate the extent of these deposits or to prove their value as a commercial ore of iron. Judging merely by what is naturally exposed, and the irregularity of the distribution of the bodies in these exposures, they have little present commercial value.

Chromite.

Chromite is an oxide of iron and chromium, and is valuable for its chromium content. When pure it contains 68 per cent of chromium sesquioxide (Cr_2O_3). To be marketable in its crude state chromite ore should contain about 50 per cent of chromium sesquioxide. If it falls much below that figure, concentrating methods must be employed to bring it up to the required grade.

Chromite is found, in all parts of the world, almost exclusively in one class of rocks, namely, peridotite; and in the Tulameen district it is confined to the same formation. It has been stated, and appears to be generally accepted, that in a peridotite body the greatest amount of chromite is found near the outer borders, while there is a relatively small amount in the central parts. This statement is not borne out in the case of the Tulameen chromite, for it appears to be scattered indiscriminately throughout the mass of the rock, being present in varying quantity in certain spots and totally absent over wide areas.

In general the chromite occurs, in the Tulameen peridotite, as an accessory constituent, and is often visible only in the thin section. In such cases it appears as individual grains scattered through the peridotite, having a crystalline or slightly rounded outline. In other places it appears as short irregular veins or irregular masses up to 4 or 5 inches in diameter. The veins vary in width from a fraction up to one inch in width and are not continuous for many inches. The boundaries of these veins are not clearly defined nor are they regular. They are not connected with any system of fracturing and have no marked uniformity of strike.

The chromite is iron black in colour and has a bright, metallic lustre. In the thin section it is quite opaque. It is slightly magnetic, and is very resistant to decomposition.

It is interesting to note that platinum is closely associated with the chromite, and some of the best assays for platinum have been obtained from bunches of chromite in the peridotite. It was from such bunches also that the diamonds of this district were obtained.

From its mode of occurrence the chromite is clearly a primary mineral in the peridotite, and has not been introduced at a later period than the consolidation of the rock. It is a basic segregation in the peridotite magma, and was formed at the time of the cooling of the rock from fusion.

A few mineral claims have been staked to cover the outcrop of the chromite bodies. These claims are still being held, but not a great deal of development work has been done on them.

Molybdenite.

Molybdenite is a sulphide of molybdenum and is one of the two minerals used commercially as a source of the metal molybdenum, the other being the lead molybdate, wulfenite. It is found in the Tulameen district in two separate localities, one situated at Independence camp on the headwaters of Bear creek, and the other near the mouth of Champion creek. At the former locality it occurs sparingly disseminated in minute particles throughout a granite porphyry and is of little significance. At Champion creek it occurs more abundantly, and some development work has been done on the deposits.

The deposits on Champion creek are situated near the mouth of the stream, and are found here and there for a distance of nearly a mile up the course of the stream. In this region Eagle granodiorite is intrusive into the rocks of the Tulameen group, which here consists of chlorite and mica schists and some limestone. These rocks dip towards the Eagle granodiorite lying on the west, and are penetrated along their planes of stratification or schistosity by many apophyses from the granodiorite. Much contact metamorphism has been effected by the granodiorite intrusion and with an abundant development of the usual contact metamorphic minerals in the intruded rocks. Some quartz veins, generally of small size, also traverse the schists and limestones.

The molybdenite occurs in small flakes and scales, having a bright metallic lustre and a lead-grey or slightly bluish colour. It is scattered plentifully in small particles throughout a gangue consisting of quartz, garnet, epidote, hornblende, and pyroxene. It is seen, in thin section, to be intergrown with these minerals in such a way as to indicate a contemporaneous origin.

The deposits are clearly of contact metamorphic origin, and were formed by and at the time of the intrusion of the Eagle granodiorite. The associated minerals indicate that the rock in which the molybdenite occurs was originally a limestone which, on the intrusion of the granodiorite, had its constituents altered from carbonates to silicates by a process of metasomatic replacement, the molybdenite being introduced into the limestone along with the silica which went to form the lime silicates.

The value of a molybdenite deposit depends upon the ease with which the mineral can be concentrated. Unless the molybdenite occurs in large lumps which can be hand picked it seems difficult to find a satisfactory method of separating it from its gangue, though both oil flotation and static electric methods are claimed to be effective. The occurrence in the Tulameen district is not such that the mineral can be hand picked, therefore, if the deposits are to be utilized at present one or other of the above methods must be adopted.

Asbestos.

Commercial asbestos deposits are confined to the olivine bearing rocks of the peridotite family, and the best quality of asbestos fibre is found in the rocks of this family, which consist wholly of olivine. The Tulameen peridotite consists essentially of olivine with a varying though always limited amount of chromite. Over a great part of its area no chromite can be detected in the peridotite, and olivine is the only constituent. Such a rock forms the most favourable matrix of high grade asbestos, or chrysotile.

In the process of the formation of asbestos the peridotite first alters to serpentine, in which process the rock takes up about 14 per cent of water and increases correspondingly in volume. Later, asbestos forms in the serpentinized rock as narrow veins, and it is believed to be merely a crystallized form of the serpentine. The quality of the asbestos fibre depends upon its fineness, flexibility, and tensile strength, and to a lesser extent on its length. The commercial importance of an asbestos deposit is governed by the size of the serpentine body and the proportion borne by the veins to the mass of the rock.

The Tulameen peridotite is not uniformly altered throughout to serpentine, and indeed in parts of the mass it still consists of the fresh unaltered olivine. In places, however, it has become completely altered to a dark green serpentine, and in such places asbestos veins have been formed.

No attempt has yet been made to prospect this region for asbestos, so that the asbestos veins noted were merely those which outcropped naturally on the surface. The veins run in no uniform direction, but appear to prefer certain east and west lines. Those outcropping on the surface are small and not numerous. The width varies from one-fourth of an inch down to a mere thread. The fibre, as in all veins of good asbestos, runs across the vein from wall to wall. The colour of the vein is glistening light green, and the fibre is fine and appears to have considerable tensile strength.

Another variety of asbestos is found in the pyroxenite and in certain impure portions of the peridotite. This has been formed by the alteration of pyroxene, and contains a fibre which is coarse and brittle. This variety has no commercial value whatever.

Coal.

INTRODUCTORY STATEMENT.

Coal occurs in the Tulameen district in a small basin which has been referred to by engineers and others as the Tulameen coal basin, the Granite Creek coal basin, or Collins Gulch coal basin. The last two names were originally applied to outcrops of coal seams in two separate localities, and since, during the present investigations, the two localities were found to be parts of the same basin, it seems advisable to discard both names, retaining the first name—the Tulameen coal basin—for the whole field.

Although this part of the Tulameen district has been well known to prospectors since the time of the gold discovery in Granite creek in 1885, and though the outcrop of coal in Collins gulch must have been quite evident to anyone travelling the bed of that stream, no attempt seems to have been made until quite recently to prospect the basin or to determine its area. Some coal has annually been extracted from the Collins Gulch outcrop for a number of years, but up to the present there has been no demand for it, and what was taken was merely sufficient to supply the needs of the owner, Thomas Rabbitt. Seven or eight years ago coal was discovered on the Granite Creek side of the basin, and shortly after the whole field was taken up in coal claims. These claims were then bonded to the Erl Syndicate, and some development work was done, but the option expired without the syndicate buying up the claims. Almost the whole basin is now owned by the Columbia Coal and Coke Company, which is prospecting it vigorously.

The first mention of the field is made by W. F. Robertson in 1901.[1] Brief mention is made of it by the author in the Summary Report of the Geological Survey in 1908, and a more extended account is given in the Summary Report for 1909.

LOCATION AND AREA.

The coal field lies in the southeast corner of the area covered by the Tulameen map, partly in the drainage basins of Collins and Fraser gulches and partly on the other side of the divide, in the basin of Granite creek.

The basin is roughly oval in shape, having its longer axis running northwest and southeast. In this direction it has a length of nearly 3½ miles, while its greatest width is about 2¼ miles. The area covered by the coal bearing rocks is 3,700 acres, and that covered by the coal itself has been calculated at 3,254 acres. Of the coal area, however, 1,070 acres are covered by a flow of volcanic lava.

Almost all of the coal is included in eight coal claims, each one of which is a mile square. Six other coal claims have been staked, but they lie mostly outside the limits of the productive field.

Small stringers of coal, associated with sandstone, are known to outcrop in Cedar creek and in Blair creek on the north side of the Tulameen river, and really form part of the main basin. Their thickness is so small, however, and the probable quantity of coal so limited that they have not been included on the geological map within the area coloured as coal bearing. The connexion of these rocks with the coal basin has already been described on pages 87 and 91, and need not be referred to again.

TOPOGRAPHY.

The situation of the coal field on the divide between Granite creek and streams flowing in the Tulameen river makes it difficult of access for mining, and the topography of the field adds somewhat to that difficulty. The field has a topography characteristic of the upper levels of the Interior Plateau region. The summits of the hills are rounded and the slopes from them gentle. The highest point in the basin has an elevation of 2,100 feet above Tulameen

[1] Annual Report, Minister of Mines, B.C., 1901.

river at Granite creek, and the lowest point at which coal outcrops is in Collins gulch, where there is a difference of 850 feet in height between that point and Tulameen river.

It is impossible to obtain access to the coal basin by any valley with an easy grade, because it lies at the headwaters of the streams and all of them have steep gradients down to the master stream which is Tulameen river. Collins gulch rises near the centre of the basin and flows northward through it, across the strike of the rocks. Fraser gulch also cuts the basin for about a mile and flows out of it towards the north. The North Fork of Granite creek cuts through the southwest border of the basin and flows in it for about a mile. These creeks, and some of their tributaries, are the only streams which flow through the coal basin, and all of them have relatively small valleys, so that they do not expose very good sections of the rocks.

Owing partly to the softness of the members of the coal bearing series, outcrops of solid rock are very rare, and except in a few places in the stream beds, the whole basin is covered with drift. It is also almost all covered with a forest growth, which assists in disguising the character and structure of the rocks.

GEOLOGY.

Stratigraphy.—The coal bearing rocks of this field are of Oligocene age, and have been correlated by their fossils with the Coldwater series of Princeton, Nicola, and Kamloops. They part in rest unconformably on volcanic rocks of Triassic age, and in part conformably on volcanic rocks of Oligocene age which have been called the Cedar volcanic series. Some of the lower members of the coal bearing rocks are intercalated, on the western side of the basin, with the upper part of the Cedar volcanic series, but these same members are on the eastern part of the basin, joined with the main body of the coal bearing series. About one-third of the whole basin is covered unconformably by a volcanic flow of olivine basalt.

The total thickness of the coal bearing rocks, as measured in a section along Collins gulch, is less than 2,500 feet. This section is shown in an accompanying figure (Fig. 2). In this section the whole series can be divided roughly into three groups. The lowest group, measuring 600 feet in thickness, is composed of sandstones, with which are interbedded a few thin bands of shale. The middle group is made up of 460 feet of very fissile shale, and in this group lie the principal coal seams. The upper part of the section contains a preponderance of sandstones, with which are associated some thin shale bands and beds of conglomerate.

From an economic point of view the most important of the three groups is the middle one, for in it lie the principal coal seams. The shales which compose this group are very fissile and split easily into thin plates. They are dark coloured on fresh surfaces, but often weather whitish where they outcrop. They contain many plant remains which have served to identify their age as Oligocene.

Two coal seams in this group, exposed in the bed of Collins gulch, show a floor and roof composed of shale. In what is believed to be the same horizons on the south side of the basin, the roof and floor are also shale, but the shale is somewhat more sandy.

In the lower of the two coal horizons on the south side of the basin the section exposed in the workings shows 5½ feet of clean coal resting on shale. Above that is 4 feet of impure coal, and above that again for 50 feet are thin seams of coal interbedded with clay or sand.

The upper of the two coal horizons at the same place shows the following section from top to bottom of a raise in No. 2 tunnel:—

SECTION IN NO. 2 TUNNEL, GRANITE CREEK.	Feet.	Inches.
Mostly sandstone with thin seams of coal	23	
Clay	4	0
Impure coal	2	1
Coal with clay partings	3	9
Clay	....	4
Coal	....	4
Clay	....	3
Impure coal	1	1
Coal	1	7
Clay	....	2
Clean coal	6	6
Coal with clay partings	4	6
Clay	1	0
Coal	3	0
Clay	1	8
Coal with 2 sandy partings	1	9
Clean coal	5	0
Total	60	0

On the same side of the basin a third coal horizon, containing a good seam of workable coal, is said to underlie the lower of the above-mentioned horizons, but its outcrop could not be found.

In the upper group of the three into which the whole series has been divided the prevailing rock is sandstone. On Collins gulch a certain shale band in this group contains many coal markings, and on the south side of the basin a small coal seam is exposed, which is probably in the same horizon.

The most complete section showing the coal has been exposed by prospecting operations on the south side of the basin. This, as already indicated, shows four seams of workable coal, 6½, 3, 5, and 5½ feet, respectively, in width, making an aggregate thickness of 20 feet. The reported coal horizon below and the uppermost seam of all, which may possibly develop into a workable seam, might be added to the estimate of the total thickness of coal in the basin, but for the present the estimate of quantity of coal in this field should be based merely on the known 20 feet of thickness.

The total area covered by the coal bearing rocks is about 3,700 acres. By following out the outcrop of the coal seams it has been estimated that 3,254 acres in the coal basin are covered by coal. Presuming that the 20 feet of workable coal exposed on the south side extends over the whole basin, and estimating 1,000 tons of mineable coal to the acre, there are in this field over 65,000,000 tons that can be extracted. The total quantity of coal in the basin, however, may greatly exceed this figure.

Structure.—The coal bearing rocks are essentially sedimentary in origin, and must, therefore, have been deposited in a horizontal or approximately horizontal attitude. Their structure now, however, is that of a synclinal basin having its longer axis running almost northwest and southeast. On the southwest side of the basin the dips of the beds are in general towards the northeast; and on the northeast side they are towards the southwest. These dips vary from 20 degrees up to 70, and are apparently greatest on the outer edges of the basin. The average dip, however, is about 40 degrees.

The structure of the beds does not always conform to the general structure of the syncline, and many discordant dips are noticed. In such cases pressure has been exerted in a different direction to produce dips and minor folds which strike in directions other than northwest and southeast. Such folds appear at the work-

PLATE XXIII.

Outcrop of coal seam at No. 2 tunnel, Granite Creek mines.

ings on Granite creek and in Collins gulch, but they are of very little importance.

Faulting is not apparent, except to a very minor degree, in the development work so far undertaken. Small faults, however, with a throw of 6 or 8 inches, appear in No. 2 tunnel on the south side of the basin. Larger faults will probably be encountered as development of the field proceeds. It is quite certain from other geological evidence that rocks of this age have passed through periods of considerable orogenic disturbance which might result in faulting, and it is the experience in most of the coal fields of this age in British Columbia and Washington that faults of some magnitude do occur, so that it is reasonable to expect that they are present here also.

In the accompanying map and structure section of this coal field, a sheet of olivine basalt is shown, overlying the coal bearing rocks. The basalt is an igneous rock which rose from the interior of the earth through fissures and flowed over the surface Dykes of the same rock appear in the bed of Granite creek, cutting the rocks which underlie the coal bearing rocks, and it is quite probable that they traverse the coal bearing rocks also. The source of the olivine basalt is probably, therefore, to be found beneath the coal basin itself. The withdrawal of the olivine basalt from the region beneath, and its deposition on the top of the coal basin, would cause a readjustment of the strata between, and in this readjustment, it is only to be expected that faulting should have taken place.

CHARACTER OF THE COAL.

The coal varies both in physical and chemical properties from one part of the field to another. On fresh faces it has a banded appearance, due to alternating layers of bright and dull lustre, with the latter predominating. The dull bands, however, show many small lenses of bright coal in them. Sulphur, in the form of films of pyrite, is present but is apparently not abundant. The powdered coal has a very dark brown colour.

Some of the coal is fractured into small cubical blocks, and in other seams it is more massive. On exposure to the atmosphere it breaks down in time to a fine dust, but as a rule resists weathering for a considerable period.

Chemical analyses of the coal show that it is to be classed as bituminous, though certain analyses from particular parts of the field indicate a somewhat lower grade. The coals resemble those of the Nicola coal field, and are somewhat better than those of the Princeton field. Most of the coals of this age in British Columbia are lignites, but the higher grade of this coal is accounted for either by the greater compression to which it has been subjected, or else by the presence of volcanic rocks in the immediate neighbourhood, which by their heat have driven off a certain percentage of the water.

The ash of the coals in some analyses is high, but this is characteristic of other coals of the same age in adjacent districts, and is due to the fact that the samples which included thin partings of clay were taken by cutting a channel across the seam from roof to floor.

The coke of the samples from the south side of the basin is strong and coherent and has a bright silvery lustre. A test of a larger sample than that used, however, would be necessary to ultimately determine the coking qualities of the coal.

The coke from the Collins Gulch seams is tender and less coherent and would not stand much pressure. The general quality of the coal from this part of the basin is inferior to that from the south side. The difference may be accounted for by the fact that the Collins Gulch seams lie at a greater distance from the overlying volcanic rocks.

The following analyses of coals from this field have been made in the laboratory of the Department of Mines, the first four from samples taken by the author, and the last two from samples taken by Geo. de Wolf in 1899 and published in the Annual Report of the Geological Survey for 1899, page 29 R:—

ANALYSES OF COAL SAMPLES.

No. of Sample.	1	2	3	4	5	6
Locality.	Granite Creek mines.	Granite Creek mines.	Granite Creek mines.	Collins gulch.	Collins gulch.	Collins gulch.
Width of seam......	6½ feet.	5 feet.	5 feet.	?	?	?
Moisture..........	3·04	4·34	2·97	3·26	4·62	4·87
Vol. combustible matter..........	31·88	31·08	31·28	43·33	41·16	36·86
Fixed carbon.......	51·11	48·89	52·49	49·70	49·04	50·99
Ash..............	13·97	15·69	13·26	3·71	5·18	7·28
Coke per cent......	65·08	64·58	65·75	53·41	54·22	58·27
Character of coke.	strong, coherent	strong, compact	strong, compact	tender, coherent	firm, coherent	tender, coherent
Fuel ratio.........	1:1·60	1:1·57	1:1·68	1:1·15	1:1·19	1:1·38
Colour of ash......	light grey	ash grey	light grey	....	light grey	light grey

DEVELOPMENT.

The earliest work done in this field was that on Collins gulch where three tunnels of unknown length were run in on the strike of the coal. Two of these tunnels enter on the west side of the creek, and both have now caved in. The third is on the east side of the creek and is the longest of the three.

Up to the spring of 1910 the principal work in this field was carried out on the south side of the basin, and consisted of six tunnels of various lengths aggregating over 1,300 feet, and a great number of open-cuts all in coal. The main tunnel is that known as No. 2, which runs in on the strike for a distance of more than 800 feet. In this tunnel a raise goes up on the dip for 40 feet and another across the dip for 60 feet. The problem of transporting the coal mined on this side of the basin to the railway which will run in the valley of Tulameen river was one of considerable difficulty and caused the abandonment of the work.

On Fraser gulch the coal outcrop approached nearer the Tulameen river, and work was consequently concentrated at this point. Here the coal seams outcrop at an elevation of about 1,000 feet above the river and dip away from it towards the southwest. A large number of open-cuts have been made on this side of the basin to trace the outcrop of the seams from Collins gulch eastward, and a prospecting tunnel was run in across the strike at the first bend in Fraser gulch. Some diamond drilling was begun at the head of Fraser gulch to ascertain the depth at which the coal seams lie at this point. A tunnel which it is proposed to make the main entry to the mine, is now being driven from a point about 400 feet above Tulameen river. From a consideration of the average dip of the coal seams and the slope of the valley, it has been estimated that this tunnel will have to be driven about 2,000 feet before it intersects the lower coal seam.

Clay.

Deposits of clay that may be of use for commercial purposes are found in the Tulameen district in two different geological formations. The older clay deposits are of Oligocene age and are found in the Coldwater series. The younger are associated with the recent deposits.

The Coldwater series of this region is divided roughly into three groups of rocks, the middle one of which consists of 460 feet of very fissile shales and some coal seams. No tests have been made of the shales as a whole to determine their value for use in the manufacture of clay products; but, associated with the coal seams, is a thin bed of massive clay from 6 to 20 inches in thickness which has proven to be very refractory. It is light coloured, smooth, and sticky, but cracks badly on drying. It has been tested by Mr. J.

Keele and found to stand a temperature of 1300° C., but it is doubtful whether it can be used, as it will not air dry after moulding.

An underclay which is said to have been obtained from Granite creek, and probably comes from the Coldwater series in the same horizon as that described above, was examined by G. C. Hoffmann, former chemist of the Geological Survey,[1] and found to burn perfectly white and to be almost infusible. Hoffmann states that 'it could be used for the manufacture of pottery—including the finer varieties of stoneware, is well suited for the manufacture of stove linings, and would make a fairly refractory brick.'

Another clay deposit in this region is of recent origin, and is found covering the floor of Otter valley at the northern border of the map-sheet. This clay is a lake deposit of unknown depth but probably considerable areal extent, for it is exposed at a number of points in Otter valley over a distance of about 3 miles. After testing it Mr. Keele finds that it would be suitable for the manufacture of ordinary red bricks.

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[1]G.S.C. Vol. XII, page 61 R.

INDEX.

A

B

C

F

G

H

I

J

K

L

M

O

P

R

S

T

V

W

Z

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

HON. ROBERT ROGERS, MINISTER; A. P. LOW, DEPUTY MINISTER;
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SELECTED LIST OF REPORTS AND MAPS

(SINCE 1885)

OF SPECIAL ECONOMIC INTEREST

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Report of the Mines Section:—

No. 245.	Report of Mines Section, 1886.	No. 662.	Report of Mines Section, 1897
272	" " 1887.	698	" " 1898
*300	" " 1888.	718	" " 1899
301	" " 1889.	744	" " 1900
334	" " 1890.	800	" " 1901
335	" " 1891.	835	" " 1902
360	" " 1892.	893	" " 1903
572	" " 1893-4.	*928	" " 1904
602	" " 1895.	971	" " 1905
625	" " 1896.		

Mineral Production of Canada:—

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*416	" 1888.	*577	" 1895.	813	" 1902.
*417	" 1889.	*612	" 1896.	861	" 1903.
*418	" 1890.	*623	" 1886-96.	896	" 1904.
*419	" 1891.	*640	" 1897.	924	" 1905.
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Mineral Resources Bulletin:—

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851.	Coal.	869.	Mica.	882.	Copper.
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857.	Infusorial Earth.	*877.	Graphite.	953.	Barytes.
858.	Manganese.	880.	Peat.	984.	Mineral Pigments (French).
859.	Salt.				

Report of the Section of Chemistry and Mineralogy:—

No. *102.	Year 1874-5.	No. *169.	Year 1882-3-4.	No. 580.	Year 1894.
*110	" 1875-6.	222	" 1885.	616	" 1895
*119	" 1876-7.	246	" 1886.	651	" 1896.
*126	" 1877-8.	273	" 1887-8.	695	" 1898.
*138	" 1878-9.	299	" 1888-9.	724	" 1899.
*148	" 1879-80.	333	" 1890-1.	821	" 1900.
*156	" 1880-1-2.	359	" 1892-3.	*958	" 1906.

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REPORTS.

GENERAL.

745. Altitudes of Canada, by J. White. 1899.
*972. Descriptive Catalogue of Minerals and Rocks, by R. A. A. Johnston and G. A. Young.
1073. Catalogue of Publications: Reports and Maps (1843-1909).
1085. Descriptive Sketch of the Geology and Economic Minerals of Canada, by G. A. Young, and Introductory by R. W. Brock. Maps No. 1084; No. 1042 (second edition), scale 100 m. = 1 in.
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ALBERTA.

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SASKATCHEWAN.

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1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201–51 A, scale 35 m. = 1 in.
1220. Memoir No. 29-E: Oil and Gas Prospects of the Northwest Provinces of Canada, by W. Malcolm. Map No. 1221 (55 A), scale 35 m. = 1 in.

NORTH WEST TERRITORIES.

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713. North Shore Hudson strait and Ungava bay, by R. Bell. Map No. 699, scale 25 m. = 1 in. } Bound together.
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ONTARIO.

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(1114 and 1119) Bound together.
1160. Memoir No. 17-E: Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., by M. E. Wilson. Maps No. 1177—31 A, scale 1 m. = 1 in.; No. 1178—32 A, scale 2 m. = 1 in.
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1032. Report on a Recent Discovery of Gold near Lake Megantic, Que., by J. A. Dresser. (French). Map No. 1029, scale 2 m. = 1 in.

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J. M.