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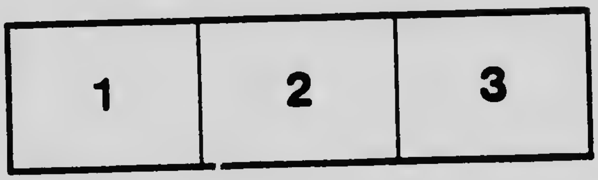

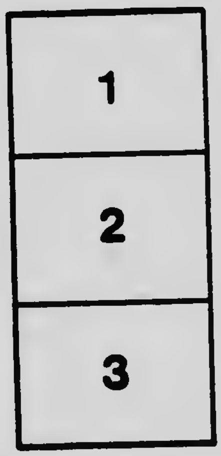

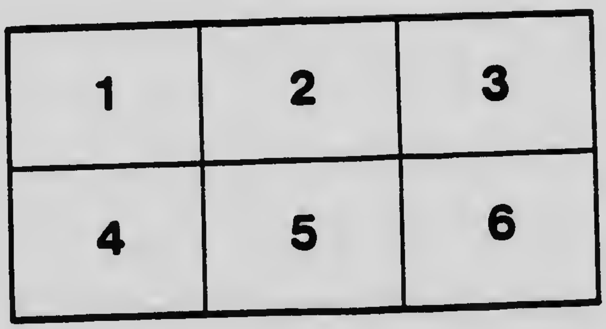

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GEOLOGICAL SURVEY

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Geology of Franklin Mining Camp, British Columbia

BY

Charles W. Drysdale

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

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PLATE I.

EXPLANATION OF PLATE I.

Looking down Franklin valley from northwest corner of map-area: Franklin mountain on left; McKinley mountain on right; Kettle River valley in distance; granite range in background. Shows V-shaped valley entrenched beneath older upland surfaces; trachyte lava cliffs to left. (See page 21.)

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Geology of Franklin Mining Camp, British Columbia.

CHAPTER I.

INTRODUCTION.

SITUATION AND MEANS OF COMMUNICATION.

The Franklin Mining camp forms a part of the Similkameen division of the Yale district in south-central British Columbia. It is situated on the east branch of the North Fork of Kettle river, due north of Grand Forks, British Columbia, and Danville, Washington, 37 miles from the International Boundary (Figure 1).

The district is accessible from Grand Forks on the Canadian Pacific railway, by the Kettle Valley railway as far as its terminal point at Lynch creek. From here a wagon road 25 miles in length leads to Franklin. This road is an extension of the one between Grand Forks and Lynch creek—points 18 miles apart—and was put in excellent condition last summer. The extension from Lynch creek to Franklin, however, is in very poor repair where it crosses numerous and extensive rock slides.[1]

FIELD WORK AND ACKNOWLEDGMENTS.

The field work upon which this report is based was carried on during the summer of 1911.

The topographic control for the 16 square miles of country mapped, was obtained by a series of transit and stadia traverses

[1] This portion of the road was put in good condition during the summer of 1912.

run in closed circuits. The latitudes and departures of these circuits were calculated, balanced, and the stations plotted by total latitudes and departures from a common origin.

Figure 1. Index showing location of Franklin map-area.

All details were mapped by means of plane-table and stadia traverses run between the control circuits. Elevations are referred to mean sea-level, and were taken from a bench-mark of the Kettle Valley Railway survey at Gloucester city.

Messrs. C. A. Fox and F. J. Alcock rendered efficient service as field assistants. Field work was facilitated through the kindly courtesies of Mr. Frederic Keffer of the British Columbia Copper Company, Mr. Forbes M. Kerby, Sheriff H. C. Kerman, Mr. H. B. Cannon, and many others.

The writer feels greatly indebted to Mr. O. E. LeRoy, of the Geological Survey, under whose supervision the field work was conducted. He particularly wishes to express his sincere gratitude to Professors L. V. Pirsson, Joseph Barrell, Isaiah Bowman, J. D. Irving, and Charles Schuchert, members of the Yale Geological Faculty, for their kind assistance, guidance, and advice during the preparation of the manuscript.

PREVIOUS WORK AND LITERATURE.

Previous work of a less detailed nature was done in Franklin by R. W. Brock, Deputy Minister of the Department of Mines, who examined the area in 1900[1] and again in 1906[2]. The results of this work were published in the annual reports of the Geological Survey. The geology and topography of the region are shown on the West Kootenay sheet, mapped on the scale of 4 miles to 1 inch.[3]

The annual reports of the British Columbia Minister of Mines for the years 1900, 1901, 1904, and 1906 make mention of the camp and a few of the leading properties. They contain simply a statement of the progress of development work on the several mining claims, and do not discuss the geology or mode of occurrence of the ore bodies. Outside the above-mentioned publications there is no other literature on the Franklin camp.

CLIMATE.

Meteorological data for Franklin camp itself, are lacking, but the accompanying tables from the nearest stations have been kindly furnished by Mr. R. F. Stupart, Director of the Dominion Meteorological Service, and Cooper Bros. of Grand Forks.

The first table is given for Needles, B.C., a small town about 25 miles northeast from Franklin, on the west shore of the Lower Arrow lake; and the other table is for Grand Forks, which is in the "Dry Belt."

---

[1]Brock (R. W.): Geol. Surv. Canada, Ann. Rept., XIII, 1900, p. 70 A.
[2]Ibid., Summary Rept., 1906, pp. 62-65.
[3]Ibid., Map sheet No. 792.

Needles, B.C.

Month.	Temperature.					
	Mean highest	Mean lowest	Mean	Daily range	Absolute highest	Absolute lowest
January	28·6	17·8	23·2	10·8	43·0	−6·0
February	30·6	14·7	22·7	15·0	40·0	−8·0
March	49·1	26·1	37·6	23·0	64·0	4·0
April	57·7	34·0	45·9	23·7	70·0	25·0
May	65·1	40·0	52·6	25·1	83·0	32·0
June	72·7	44·2	58·5	28·5	83·0	38·0
July	77·7	46·2	62·0	31·5	93·0	37·0
August	74·4	46·2	60·3	28·2	85·0	35·0
September	68·4	40·5	54·5	27·9	79·0	30·0
October	56·6	35·4	46·0	21·2	63·0	23·0
November	41·2	30·1	35·7	11·1	53·0	7·0
December	34·5	27·0	30·8	7·5	44·0	0·9

Month	Precipitation.			
	Number of days of rain or snow	Average rainfall	Averge snowfall	Total precipitation
January	9	0·04	21·2	2·16
February	7	0·00	24·9	2·49
March	4	0·60	....	0·60
April	3	1·85	....	1·85
May	11	3·40	....	3·40
June	6	2·70	....	2·70
July	4	1·48	....	1·48
August	6	1·40	....	1·40
September	5	1·48	....	1·48
October	4	2·16	....	2·16
November	9	2·90	9·8	3·88
December	5	0·43	13·9	1·82

Grand Forks.

Month.	Temperature.		Precipitation per month.	
	Highest	Lowest	1910 in.	1911 in.
January........	38	−13	0·82	1·49
February.......	35	− 5	1·11	0·89
March	69	0	1·03	0·54
April	72	22	0·29	0·83
May...........	87	30	1·21	3·43
June...........	93	37	1·45	2·78
July	100	43	0·08	0·45
August	94	42	0·64	0·52
September	92	28	0·82	0·85
October	78	15	0·75	0·08
November......	53	− 7	1·45	2·51
December	....	....	2·15	2·84
			11·80	17·21

The rainfall in Franklin would probably average 30 inches per annum, a large part of which falls as snow in the winter months. The summers are moderately warm and dry with cool nights, while the winters are severe with heavy snowfall, particularly on the western slopes of the mountains.

TIMBER.

This region was once heavily wooded with the following main species of trees: Douglas fir (*Pseudotsuga Douglasii*) and other varieties, tamarack (*Larix americana?*), spruce (*Picea canadensis*), hemlock (*Tsuga canadensis*), white cedar (*Thuya plicata*), white birch (*Betula papyrifera*), poplar (*Populus*), and cottonwood. The three last mentioned are found generally in marshy ground. Red cedar (*Juniperus scopularum*) is not found in Franklin, but does occur 25 miles farther to the south, in the vicinity of Christina lake. Large areas of timbered land have been recently destroyed by forest fires and second growth brush is rapidly springing up. There is, however, considerable timber left and available for mining purposes. The southern hill slopes are as a rule open and park-like. They support in season innumerable species of wild flowers, black raspberries, and huckleberries.

GAME.

Black-tailed deer (*Cariacus macrotis*) are numerous, and beaver (*Castor fiber*), owing to protective game laws, have become very plentiful. Black and cinnamon bear (*Ursus americanus*), mountain lion or "cougars" (*Felis concolor*), and coyotes (*Canis latrans*) are less frequently seen. Porcupine (*Erethizon dorsatus*,) mink (*Putorius vison*), red squirrel or chickaree (*Sciurus hudsonicus*), chipmunk (*Tamias striatus*), gopher (*Geomys bursarius*), and wood rat (*Neostoma*) are also included among the fauna. The birds include blue grouse (*Dendragapus obscurus*), ruffed grouse (*Bonasa umbellus*), partridge, prairie chicken (*Pediæcetes phasianellus columbianus*), in the valleys, ducks, geese (*Brant*), loon (*Gavia imber*), pied-billed grebe or "hell-diver" (*Podilymbus podicaps*), and "mud hen" or American coot (?).

CHAPTER II.

SUMMARY AND CONCLUSIONS.

GENERAL GEOLOGY.

The Franklin mining camp embraces an area of 16 square miles situated in the centre of the Columbia Mountain system—a system composed in large part of deep-seated igneous rocks.

The district, which occupies a structural or tectonic depression enclosed by granitic mountain ranges, presents to the geologist an unusually complete record of Mesozoic, Tertiary, and Quaternary events, particularly the latter two. All phases of igneous activity are represented, from deep-seated batholithic invasion on a large scale to the more surficial intrusions of dykes and irregular masses which have reached close to the surface and even formed volcanic vents from which ejectamenta and lavas have been derived.

A close geological examination of the Franklin district, combined with detailed field work in other nearby and surrounding regions, leads to the following summary and conclusions. Some of the conclusions stated here must be regarded as only tentative, owing to lack of extensive detailed work in this section of the Cordillera. They are largely suggestions, made in order to promote further investigation, correlation, and the obtaining of field facts which may throw further light on the problems in question and aid in their solution. For the details upon which the conclusions are based, the reader is referred to the succeeding chapters of the report.

Palæozoic Era.

The *Franklin group* of metamorphic tuffs, quartzites, and argillites, the latter containing plant impressions, are the oldest rocks in the district. They are correlated with the Knobhill group of Phoenix[1] and possibly represent the Lower Câche Creek group of the Kamloops[2] district. These formations may represent early marine coastal conditions of sedimentation and igneous activity prior to submergence and eastward transgression of a Carboniferous sea.

The *Gloucester* formation is correlated with the Brooklyn crystalline limestone of Phoenix and Deadwood in the Boundary district, and with the Upper Câche Creek group in the Kamloops district, which Dr. Dawson proved to be of Carboniferous age on palæontological evidence. The Gloucester formation in Franklin was found to contain crinoidal remains and an obscure Fusulina-like organism. These formations probably represent the off-shore calcareous phase of an eastwardly transgressing Carboniferous sea in whose waters crinoids and Fusulina flourished. The in-shore phase is represented by the carbonaceous limestones and argillites of the Slocan series in the Selkirk mountains, which contain obscure plant remains.

Mountain Making at the Close of the Palæozoic.

The main folding and regional metamorphism of the Palæozoic rocks took place at the close of the Palæozoic previous to the intrusion of the Jurassic granodiorite batholith. The Palæozoic rocks in the Columbia Mountain system were more highly folded and compressed than those to the west in the Interior Plateau country. The most intense folding took place in the mountainous regions to the east, as is well illustrated by the steeply inclined and compressed folds of the Slocan series in the Selkirk mountains.

The Franklin district, since its emergence at the close of the Palæozoic, has remained above the sea, although in upper Jurassic time the Logan sea may not have been far to the north.[3] The district has since undergone continued continental erosion and sedimentation.

---

[1] LeRoy (O. E.): Geol. Surv. Can., Map 16A, Phoenix, B.C., 1912.
[2] Dawson (G. M.): Ibid., Kamloops map sheet.
[3] Chamberlin and Salisbury: Geology, Vol. III, p. 66.

Mesozoic Era.

Triassic Period.

During this period, Franklin formed a part of the highlands which were supplying sediments for the Nicola series to the west in the Interior Plateau.

Jurassic Batholithic Invasion and Formation of Contact Metamorphic Ore Deposits.

The granodiorite batholith of the Franklin district is correlated with the Nelson granodiorite and the Remmel and Osoyoos granodiorite batholiths in the Okanagan[1] district. The batholith was intruded under a considerable cover of superincumbent material and did not have access to the surface.

The ores of contact metamorphic origin at Franklin and probably throughout the Boundary district were formed at this time, as well as some of the silver-lead ores of the fissure vein type in Franklin and possibly the Slocan district.

Cretaceous Cycle of Erosion (First Cycle).

The Cretaceous period in Franklin was one of long continued denudation, which laid bare great thicknesses of Palæozoic rocks. In some favourable places, erosion even exposed the underlying Jurassic granodiorite, as, for instance, on McKinley mountain, where the Eocene sediments lie directly upon it. To the west of the Columbia mountains, in the Interior Plateau of British Columbia, local peneplanation was developed. This surface, which was recognized by Dr. G. M. Dawson and assumed to be Eocene, has dominated the topography in many places.

During the Cretaceous period of erosion, no doubt many contact metamorphic ore-shoots associated with the Palæozoic calcareous beds and fissure veins were eroded off. Further study of this problem of Cretaceous erosion should lead to some interesting and important economic results with regard to the distribution and extent of certain types of ore deposits and their age.

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[1] See p. 62, General and Structural Geology, Ch. IV.

The Laramide Uplift and Mountain Making Period.

The Mesozoic era closed with the Laramide revolution, which uplifted the whole Cordillera and further folded and compressed the eastern mountainous belt. The Valhalla quartzose granite was probably intruded at this time.

The Cretaceous surface of erosion in the Interior Plateau was uplifted fully 3,000 feet along the region of maximum uplift to the north of the International Boundary, and decreased southward towards the Columbia lava plains. Vigorous dissection by rivers was commenced, with much consequent drainage away from the area of maximum uplift.

TERTIARY ERA.

Early Tertiary Conditions—as Shown by the Kettle River Formation (Coldwater Group of Dawson).

The Franklin district in early Tertiary time, was in the region of maximum uplift and formed part of a tectonic basin enclosed between lofty sedimentary mountain ranges. Great quantities of coarse alluvial gravels and some glacial origin were deposited, chiefly in alluvial cones at the base of the ranges. The main drainage was southward, and the coarse heterogeneous conglomerate member of the Kettle River formation in Franklin corresponds to the river gravels of the same formation farther south at the International Boundary.

With the regional sinking, or subsidence, following the maximum uplift, aggradation set in and the deep valleys and irregularities of the surface became filled with, chiefly, fluvial material, which includes water-laid acidic tuffs and rhyolitic arkoses. Sedimentation, with contemporaneous volcanic activity, progressed until near the close of the Oligocene.

Oligocene Deformative Period—Monzonite Stocks Intruded and Erosion Cycle (Second Cycle).

The early Tertiary closed with crustal disturbances which tilted the Kettle River formation in Franklin, to the north-northeast and inaugurated a new cycle of erosion.

Monzonite, a dark-grey, mottled, fresh-looking rock, comagmatically[1] related to the younger alkalic intrusives, was intruded at this time in the form of stocks.

A new cycle of erosion was commenced, which stripped off extensive records of loose Kettle River conglomerate and arkose, particularly the sediments along the main drainage courses.

Miocene Igneous Activity.

Porphyritic Syenite Intrusions. The first manifestation of Miocene igneous activity was the intrusion of small porphyritic syenite chonoliths[2] which reached the surface at least in one place to form the oldest trachyte flow on McKinley mountain. The syenite and trachyte of this period are less alkalic than those which followed later from the same parent stock. No important mineralization accompanied these intrusions.

Intrusion of Shonkinite-Pyroxenite Augite and Syenites. Extrusion of Corresponding Alkalic Basalt and Trachytes, and Formation of Tertiary Ores. A short erosion interval elapsed before the main alkalic intrusions and extrusions, which were of two immiscible magmas, feldspathic pyroxenite and augite syenite, the products of a deep-seated separation of the original magma into unlike portions. The basic pyroxenite portion was intruded slightly in advance of the augite syenite, and formed at the surface basal lava flows. The augite syenite followed, almost simultaneously, and favoured the lower contact of the pyroxenite. Portions of the pyroxenite were included and drawn out as "schlieren" in the syenite. The magmas were extruded from a vent on Tenderloin mountain and solidified as basaltic tuffs,

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[1] Means that both monzonite and the younger alkalic intrusives were all derived from a common parent magma, which separated into different types through a process of differentiation.

[2] A term defined by R. A. Daly as "an igneous body (a) injected into dislocated rock of any kind, stratified or not; (b) of shape and relations irregular in the sense that they are not those of a true dyke, vein, sheet, laccolith, bysmalith, or neck; and (c) composed of magma either passively squeezed into a subterranean orogenic chamber, or actively forcing apart the country rocks. Word derived from χωνος, a mould used in the casting of metal, and λίθος, a stone."

ejectamenta, alkalic basalts, and trachytes. The syenite, which has a characteristic trachytic or flow structure of its feldspar laths, was found in contact with the Kettle River formation on the east side of the Kettle river, and there the conglomerate and grit show intense contact metamorphism produced by a granular intrusive into an unconsolidated sedimentary formation.

The magmatic segregation type of sulphide ore, chalcopyrite, and bornite was formed at this time, as well as those deposited in contact zones adjacent to the syenite.

Period of Younger Pulaskite Dyke Intrusions and Local Faulting. In the last period of Miocene volcanic activity, tongues and dykes from the Rossland alkalic syenite and granite of the Granite range, penetrated the rocks of the district along certain definite systems. The rocks of this period are pinkish alkalic syenites and porphyries of the pulaskite type, and there is no evidence in Franklin to indicate that they reached the surface to form mica trachyte flows, as they did in the Boundary district. The youngest lamprophyre dykes, which are of the minette type, are genetically related to the pulaskites. The faulting of the post-Oligocene erosion surface on Tenderloin mountain is referred to this period of igneous activity.

Disorganization of Pre-Miocene Drainage and Inauguration of the Present System.

The extrusion of trachyte flows brought about a change of drainage, and instead of a single main stream, two streams were formed, one on each side of the trachyte flow. The easterly one went to form the new east branch of the North Fork of the Kettle river.

Pliocene Cycle of Erosion (Third Cycle).

Following igneous activity, a new cycle—the third cycle—of long continued erosion was commenced, which lasted through the most of Pliocene time and was of sufficient duration to transform former divides into valleys, and produce a coarse-textured, post-mature topography. The Franklin upland, which is present above 4,000 feet in elevation, is referred to this cycle of erosion.

Regional Uplift at Close of Tertiary and Incision of Antecedent Pliocene Drainage.

Regional uplift, amounting in this case to about 2,500 feet, closed the Tertiary, as it did the Mesozoic and Palæozoic eras. The Pliocene drainage was entrenched deeply below the upland surface by the invigorated rivers which formed V-shaped valleys very nearly as deep as those following the Laramide revolution.

CORDILLERAN ICE SHEET—PLEISTOCENE.

The course of the Cordilleran ice sheet, which covered all except a few of the highest peaks in the Cariboo range, was S. 30° E.

First Period of Valley Glaciation. With the waning of the continental ice sheet, the first period of valley glaciation was inaugurated and considerable till and erratic boulders were left on the upper slopes above the new level of the ice surface.

Second Period of Valley Glaciation. The intense glaciation of the valleys is referred to a period of valley glaciation at the time of the maximum extension of the Keewatin ice sheet. With the advance of the ice during this period, while the main valley heads were the scenes of vigorous denudation, extensive moraines were deposited. The streams draining the ice front carried down and deposited large quantities of land waste in the form of outwash gravels. In the waning stages of the Glacial period, glacial conditions gave place to high water conditions. The streams continued to be burdened with land waste and alluviation was prolonged into the high water stage.

Formation of Terrace-steps. Upon the complete withdrawal of the ice or its restriction to headwater cirques, those regions which had already been the scene of vigorous glaciation did not supply much waste to the streams. With the consequent reduction, then, in waste supply and but a slight reduction in volume, the streams degraded their earlier accumulations.

Periodic changes of climate in post-Glacial time brought about minor stages of alluviation and degradation with the production of the present terrace-steps, gorges, and ravines.

ORE DEPOSITS.

Up to the present, no ore has been shipped from Franklin and the camp may still be said to be in the prospect stage.[1] Owing to lack of extensive development work on the various properties, very little underground data could be obtained, so that any conclusions regarding the ore deposits must necessarily be based upon the areal and structural geology of the camp.

The Tertiary sulphide ores of the magmatic segregation type ("Black Lead" ores) should have great persistence in depth. They are, however, of no present economic value because of their low grade character and the fact that they cannot be treated by any known process of ore dressing. Until some suitable method of treatment is found, and the camp made more accessible to a smelter through railway connexion, such ores are of little value.

The most important ores in the district are those of the contact metamorphic and fissure vein types of Mesozoic age, although the former are of too low grade a character and limited an extent to be of much value at present. The fissure vein type yields the highest values.

The ore shoots developed at the McKinley mine are very small and low grade. The quantity and distribution of such ore depends (1) on the depth to which the calcareous rocks extend, and (2) upon the extent of the Cretaceous and subsequent cycles of erosion which have removed favourable ground for ore deposition. The fact that the Franklin valley exposes lenses of Gloucester marble as wide at its bottom as where they outcrop in its lower slopes, would point towards a depth of at least 1,000 feet of favourable ground for the formation of contact metamorphic ores similar to those developed at the McKinley. There is no reason why the ores, if present, should not extend to the parent granodiorite itself, provided the calcareous beds persist to that depth.

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[1]During the summers of 1913 and 1914, 1,767 tons of ore were shipped from the Union group of claims.

CHAPTER III.

PHYSIOGRAPHY.

GENERAL ACCOUNT.

REGIONAL.

The Columbia Mountain system of the North American Cordillera, in which the Franklin district lies, extends northward from the Columbia lava plain in Washington, to the great bend in the Columbia river about 80 miles north of Revelstoke, B.C. At the great bend, according to Daly's[1] delineation of the orographic boundaries (which is followed in this report), the Rocky Mountain trench truncates on the northeast both the Selkirk and the Columbia systems.

The Columbia system is bounded, in British Columbia, on the west by the rolling country of the Interior Plateau, into which it grades imperceptibly, dropping from elevations of 7,000 feet and more in the system itself, to elevations seldom reaching 6,000 feet above sea-level in the plateau country. The boundary line is placed by Daly along the Thompson river, Adams lake, and the west fork of Kettle river in British Columbia, while in Washington it is determined by the lower Okanagan valley. On the east the Columbia Mountain system is bounded by the Selkirk mountains and separated from them by the great Selkirk valley, within which lie the Arrow lakes.

The Columbia system comprises many ranges which trend in a general north and south direction. They are in many places separated by deep longitudinal valleys, here and there occupied by lakes.

Suess in the last edition of his "Das Antlitz der Erde"[2]

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[1] Daly (R. A.): The Nomenclature of the North American Cordillera, Geog. Jour., Vol. XXVII, 1906, p. 588.

[2] Suess (E.): Das Antlitz der Erde, III, Pt. 2, 1909.

Joerg (W.): Bull. Amer. Geog. Soc., XLII, No. 3, Mch. 1910. Combines translation and review.

follows structural and geologic principles for delineating the different ranges of the northern Cordillera, though in his text the mountain boundaries, owing to lack of sufficiently detailed information, are delimited only in a tentative way. His guiding principles are embodied in the two terms, syntaxis (or coalescence) and linking, which describe the manner in which mountain ranges or arcs encounter each other.[1] The term syntaxis or *coalescence* designates the union of convergent arcs at a terminal point, while *linking* is applied to cases where one arc cuts across the trend of the other and terminates it. He points out that as the coalescence or syntaxis of two mountain ranges shows the result of two opposing dynamic influences, it should be considered a boundary and that the name of a mountain range should never be extended beyond it.

He includes in his "Zwishchengebirge" or Inter-Mountains, corresponding broadly to Dawson's "Interior Plateau," the western half of Daly's Columbia system. This shifts the boundary line eastward to the western base of Dawson's Gold range, a unit of the Columbia system, and places it, possibly, along the North Fork of the Kettle river and Christina lake (118 ⅓° W.). He states that this important tectonic boundary between the Rocky Mountain system (using this term to include the Selkirk, Purcell, and Rocky Mountain systems of Daly) and the Inter-Mountains, is marked by no structural feature of note; no fault line separates the two divisions.

Which is the more advisable to adopt, a genetic classification or nomenclature based on underlying principles of geologic structure and origin following Suess, or one based on purely geographic principles as suggested by Daly? The genetic classification, which would take into consideration both deformational and erosional processes, however impracticable it may be at present, would certainly be the more logical. It would remove to a large extent those wrong impressions of sharp and well-defined boundaries between the different units, which

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[1] For example: the arcs formed in the case of a consolidating asphalt pavement, an analogy which Suess uses, present concave surfaces towards the areas of subsidence. The tension produced by the subsidence is resolved nto arcs, not of identical, but often of equivalent magnitude.

the geographic classification is likely to give. One would picture, instead, natural transitions between the various tectonic lines and their significantly curved and causally related trends. Furthermore, one would be forced to discontinue the bad practice of extending range names past important points of coalescence: such a classification would materially aid in the solution of certain problems in geologic history and in finding what relations there are, if any, between orogenic movement and igneous activity, a broad problem not only of scienti . but also of great economic interest, bearing as it does on the distribution of ore deposits and their exploitation.

The need of such a comprehensive classification, in which every local range and subrange can be tied up definitely to its broader system and that in turn to the Cordillera as a whole, is felt now in certain mining districts of British Columbia and will be felt more and more as the very extensive British Columbia Cordillera becomes better known and more thickly settled. However, such a genetic classification for mountain ranges and systems must necessarily evolve with the progress of detailed geologic and physiographic work.

For the present, then, it seems most advisable to adopt Daly's clear and concise geographic nomenclature, which is adequate for all immediate practical purposes, and to determine as far as possible the plan of the trend lines for this section of the Cordillera.

Local.

The Franklin district lies within 8 miles of the eastern boundary of the Columbia Mountain system and about 40 miles due north of the International Boundary (Figure 1).

It embraces three lava-capped mountains separated by deeply entrenched valleys. The valleys unite to the southeast with the main East Branch of the North Fork of Kettle valley, which extends through the eastern half of the district. The broad open valley of the North Fork has a gentle grade and affords easy access to Grand Forks, 45 miles southward by wagon road.

In a summit view the mountains appear to occupy a broad, gentle depression between the Cariboo range (local terminology) on the west and northwest, and the Granite range to the east and northeast. The Cariboo range exhibits alpine crest lines; the Granite range has a broad, dome-shaped summit with occasional rugged, outstanding peaks and ridges, and forms a great barrier between Franklin and the Lower Arrow lake, only 8 miles distant, upon whose waters there is considerable through traffic.

The Cariboo and Granite ranges coalesce 16 miles due north of Franklin, enclosing between them a broad longitudinal depression within which an older drainage system appears to have been deeply incised (Figure 2). The steep slopes, resulting from vigorous erosion and subsequent glaciation, give the whole district a decidedly mountainous aspect.

The intermont depression has been a tectonic trough or basin ever since it was formed, very probably in the great Laramide Revolution. Within it there is sealed, by protective lava cappings, a fairly complete record of Tertiary continental sedimentation, interrupted at intervals by epeirogenic movements, great erosion cycles, and igneous activity on a grand scale.

DETAILED ACCOUNT.

In order to give the reader a clear view of the many and diversified physiographic features of the Franklin district, the subject will be discussed under two main divisions: (1) Regional—erosion cycles and related forms; (2) Local—forms related primarily to rock structure.

REGIONAL—EROSION CYCLES AND RELATED FORMS.

Post-mature Upland Topography.

From the summits above 4,000 feet, may be observed the presence of a post-mature upland topography with gently rounded outlines except near the borders of the dissected lava remnants.

The upland can be traced in every direction. To the west it may be followed to the base of the residual granite ridge of

Geological Survey, Canada

Fig. 2 Franklin Intermontane Trough and coalescence of bounding mountain ranges

Miles

1 0 1 2 3 4 5 6

To accompany Memoir by C.W. Drysdale

the Cariboo mountains, which show a somewhat alpine topography, modified by post-Glacial erosion, with gently curved cols[1] and peaks on the crest line. It exhibits glacial cirques with post-Glacial talus accumulations along the bases of the bounding walls and arêtes or ridges between the glacial amphitheatres. The ridge due west of Franklin mountain clearly shows the effects of insolation upon cirque recession as seen on alpine summits.[2] The southern slopes, which receive the more direct rays of the sun and were, therefore, unable in Glacial times to support névé accumulations as large as the northern slopes, present gentle declivities in strong contrast to the steep northern exposures. Basal sapping has naturally taken place more vigorously on the latter slopes, causing the cirques to retreat in a southward direction, producing steeper bounding walls on their southern sides.

Northward along the Cariboo range these alpine features are not so pronounced, but the range as a unit becomes more massive and resembles the Granite range to the east, though it exceeds it in altitude. Looking southward on both sides of the broad North Fork valley, one still sees the typical undulating upland topography.

In the vicinity of Newby camp, north end of Franklin mountain, the upland or old erosion surface is seen to decline eastward towards the wide Gloucester Creek drainage course. This is shown by the flat-topped, gently sloping spurs, leading out from the main ridges, which are cut off sharply to the east by steep valley slopes. It is interesting to note that the best preserved remnants of the old erosion surface occur where the underlying formation is the resistant granodiorite. The spurs elsewhere underlain by the less resistant conglomerate and Palæozoic rocks have been greatly eroded and modified. In many other places the summit slopes on the old upland were found

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[1] A term used to designate a common form of crest line seen on alpine summits. It is a concave curve (theoretically a hyperbola) formed by adjacent cirque glaciers cutting down a crest line from opposite sides and lowering it at their points of tangency.

[2] Gilbert (G. K.): Systematic Asymmetry of Crest Lines in the High Sierra of Cal., Jour. of Geol., XII, 1904, pp. 579-588.

to decline gently towards the axis of the larger entrenched valleys. This fact signifies that the present drainage occupies antecedent valleys (discussed later under drainage).

The restoration of the old upland in the Franklin district has been attempted by filling in the deeply entrenched and glaciated valleys between the remnants. The result is shown in

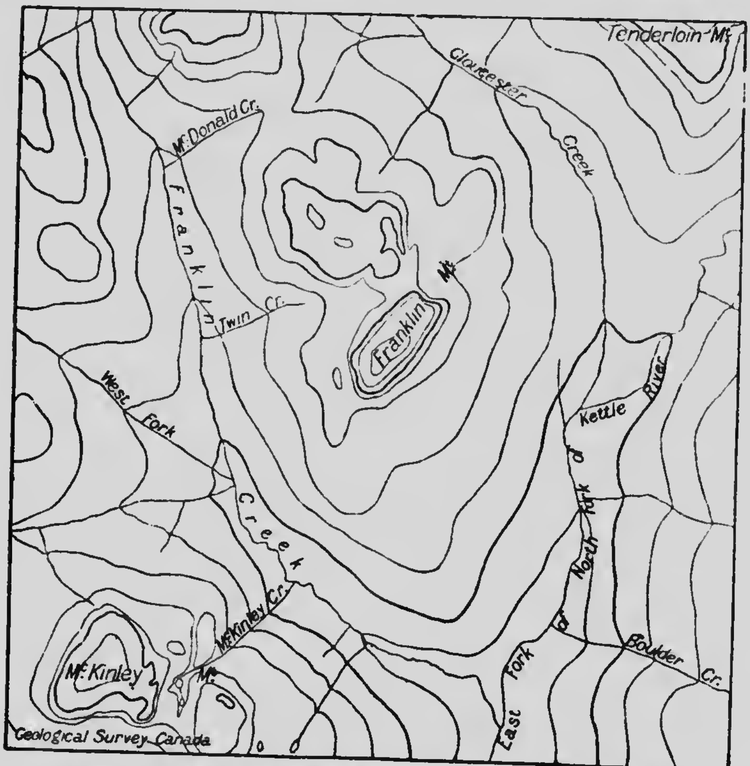

Figure 3. Diagram showing post-mature Pliocene upland restored.

Figure 3. This gives an approximate idea of the character of the old upland topography before it was uplifted and dissected, except that continental glaciation has slightly modified it. No doubt a much thicker mantle of soil existed on it before glacia-

tion, and rock exposures would be comparatively rare except on the steepest slopes.

It was found in Franklin that the mature upland bevelled both lavas and intrusive rocks of Miocene age. Thus the main erosion was accomplished during a long period of denudation in the Pliocene. The local irregularities of the upland indicate that this denudation stopped far short of a base level, for there are variations in relief amounting to hundreds of feet. The question of age and correlation will be discussed at the end of the chapter.

Younger Valley Topography.

On descending the upland slopes, younger valleys may be noted deeply entrenched below the upland surface (1,000 feet or more). The incised valleys with steep walls afford splendid rock exposures; on them conditions in certain localities are favourable for rock slides.

The present shape of the valleys may be attributed to the work of rejuvenated rivers following the late Tertiary differential uplift. The pre-Glacial valleys were characterized by having V-shaped sides with slopes of about 30 degrees, in strong contrast with the 10 degrees upland ones. The two slopes at their junction made rock shoulders about 1,000 feet above the valley floor which is now partially filled in many places by outwash material of glacial origin (to be discussed in a later section). The pre-Glacial valley slopes had relatively little soil compared with those of the u[illegible] The pre-Glacial V-shaped courses, however, were modifi[illegible] [illegible]unded to their present configuration by Pleistocene glacier[illegible] [illegible]e least modification of pre-Glacial valley-form is to be seen in the case of the present Franklin creek, and to a less extent in that of Gloucester creek, where the antecedent streams cut across an early Tertiary course before joining the main Kettle River valley (Plate I). Here the valleys are decidedly V-shaped and narrow, but towards their sources become typically U-shaped, leading up to broad glacial amphitheatres. The significance of this feature will be discussed in the section on glaciation.

Glaciation and Glacial Forms.

After this brief examination of the upland and younger valley topography, some of the more detailed features, due chiefly to glacial erosion, will now be considered.

Evidences of the Cordilleran ice cap were found on remnants of the upland within the Franklin map area. They consist chiefly of glacial striæ with an average strike about S. 30° E.

Further evidence of past continental glaciation may be seen, on the upland slopes, in the presence of scattered glacial erratics, till, glacially scoured and smoothed rock surfaces, and rounded hillocks with intervening depressions, in many places, occupied by stagnant pools of water locally known as "sloughs." The scouring effects of glaciation and ice motion, however, are not so pronounced on the summits as they are in the valleys, and it is probable that some of the highest peaks of the Cariboo range (those over 7,500 feet present altitude) stood as nunataks above the ice surface. It is known[1] from glacial striæ on the Cariboo range that the ice cap reached as high as 7,400 feet above sea-level. Evidence obtained by Daly in regions to the south and west, fixes the upper limit of the ice cap at about 7,500 feet, and this coincides with the results of investigations on the south side of the boundary line.[2]

Turning now to the valley features, it is to be noted that the Gloucester Creek valley unites with that of the main North Fork just below Tenderloin mountain, forming a broad U-shaped basin whose sides are well scoured and steepened (Plate II).

Glaciation has only slightly modified the upland as compared with the valleys, which show signs of intense ice motion. Fresh, sharp glacial striæ on valley floors and sides strike with the valleys, as do also the well scoured rock ridges (Plate III). Glacial still extends along the lower slopes of the valley walls and consists of a heterogeneous mixture of boulders, pebbles, and angular fragments of different kinds of rock.

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[1] West Kootenay Map Sheet. Topographic Sheet No. 791, G.S.C.

[2] Camsell (Charles): Hedley Mining District, G.S.C., Memoir 2, 1910, p. 126.

Smith (G. O.) and Calkins: U.S.G.S. Bull. 325, 1904.

The Franklin valley joins that of the main river at almost a right angle and does not show the broadening feature, as in the case of Gloucester valley, but, on the other hand, it does show the best preserved terrace-remnants composed of fluvio-glacial material, which, as will be shown later, has been laid down as valley trains contemporaneous with the retreat of the valley glaciers.

Both valleys have their heads in the Cariboo range; the Gloucester, with a larger drainage basin, rises at the base of one of the highest peaks (altitude, 7,325 feet); and the Franklin, about 2 miles farther south.

The Cariboo mountains, as already noted, exhibit alpine topographic features modified by post-Glacial erosion. Glacial cirques, some of which are occupied by lakes, arêtes, cols, and rugged crest lines, were developed.

From the preceding facts it may be inferred that during the Pleistocene period the whole region, with the possible exception of a few peaks on the Cariboo range, was buried beneath an ice sheet—the Cordilleran glacier. Farther south, however, in the State of Washington, the ice sheet was not general, but gave place to valley glaciers forced southwest from the main ice sheet to the north.[1]

The progressively younger age of the maximum extensions of the continental ice sheets as they occur in order eastward has been pointed out by Mr. J. B. Tyrrell[2] and Dr. G. M. Dawson,[3] who found that the Cordilleran glacier reached its greatest extent and retired before the boulder-clay that generally underlies the western plains was deposited. This boulder-clay Mr. Tyrrell takes to be the true till or ground moraine of the Keewatin glacier, when the glacier had reached its greatest southwesterly extent.[4]

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[1] Willis (Bailey): U.S.G.S., Bull. 40, 1887.

[2] Tyrrell (J. B.): The Genesis of Lake Agassiz. Jour. of Geol. Vol. IV, 1896, pp. 811-815.

[3] Glacial Deposits of Southwestern Alberta, in the Vicinity of the Rocky Mountains, by George M. Dawson, Bull. Geol. Soc. Am., Vol. VII, pp. 31-66, Nov. 1895.

[4] Calhoun (F.H.H.): The Montana Lobe of the Keewatin Ice Sheet. P. P. No. 50, U.S.G.S., 1906, p. 56.

It might be inferred, then, that if there was a second period of valley glaciation in the Franklin district the first period was associated with the retreat of the Cordilleran ice cap and this second period at the time of the maximum extension of the Keewatin ice sheet. There is evidence to support the idea of more than one period of glaciation throughout the Canadian Cordillera, but, in the Franklin district, the amount of direct evidence supporting this view is quite meagre. The field evidence present in the Franklin district to support the inference of a second period of valley glaciation is as follows:—

(1) The glacial striæ in the valley bottoms were found to be much sharper and fresher than those on the upland, and both were cut in the same rock formation (granodiorite).

(2) A divergence of 50 degrees was found between the strike of the main continental ice sheet striæ and that of the valley glacier (See geological map sheet 97 A).

(3) Fresh striæ were found 500 feet up on the valley side below the Little property.

The younger valleys below the upland surface were, no doubt, lines of maximum movement of the ice during Cordilleran glaciation, but the glaciation of the valleys appears to be much more intense than any single ice sheet would be capable of accomplishing. Furthermore, the valley glaciers associated with the retreat of the Cordilleran ice cap would be loaded with waste, enfeebled, and less capable of accomplishing vigorous valley erosion than the advancing valley glaciers of the second period. The work done in the valleys is fully as great as any accomplished by alpine glaciation.

With the retreat of the Cordilleran ice cap, glaciers became confined to the higher depressions of the ridges and in the intermont valleys where they were fed by extensive névé fields. At this time considerable superglacial and englacial material must have been left from the waning ice sheet on the upper slopes above the new level of the ice surface, as indicated by the present distribution of erratics and till. Then, with the advance of the ice during the second period of valley glaciation, while the main valley heads were the scenes of vigorous denudation, extensive moraines both lateral and terminal were deposited. In addition, the streams draining the ice-front carried down and deposited large quantities of land waste in the form of a deep alluvial fill. In Twin Creek gully, with its small fan-shaped drainage basin, there are preserved remnants, in a series of terraced spurs, of what was, possibly, a lateral moraine laid down subsequent to the maximum advance of this youngest valley glacier. The moraine may have been formed in a similar way to certain lateral moraines described by Penck[1], where the main ice sheet has forced tongues of ice up tributary valleys. No evidence of ice-shove, however, was noted in the case of these terraced spurs.

It is of interest to note here that valley glaciers, like rivers, erode more readily when flowing in longitudinal courses with the grain of the country than in transverse courses across the grain. This is well illustrated in the case of Franklin Creek valley, with its V-shaped transverse course below its West Fork and U-shaped longitudinal course above it (Plate I). In its longitudinal course the valley follows not only the regional strike of the master joint and bedding planes of the rock formations, but also a contact for some distance. In the valley's transverse course, on the other hand, it cuts through the more resistant greenstones and across the strike of many porphyry dykes (page 28) as well as the regional strike of the Gloucester formation. In the case of Gloucester Creek valley, this feature is not so marked because (1) the transverse course of the valley joins that of the main North Fork at a smaller angle, and (2) the Gloucester Valley glacier must have been larger than that in Franklin creek on account of its greater catchment basin and more strongly glaciated valley characters.

In the waning stages of the Glacial period, glacial conditions gave place to high-water conditions, for to the normal precipitation of the time was added the accumulated precipitation liberated from its previous condition as snow and ice. With the melting and recession of the ice, vast amounts of englacial land waste would be set free. The streams would continue to be burdened and the period of alluviation would be prolonged into the high water stage. Upon the complete withdrawal of the ice or its restriction to headwater cirques, the de-

[1] Penck (A.): Die Alpen im Eiszeitalter.

nuded region of former vigorous glaciation would supply but little waste to the streams. Thus with great reduction in waste supply and only a moderate reduction in volume, the streams would either cease cutting and accept the established gradients or they would actually degrade the earlier accumulations, as they did in the case of Franklin creek and the main Kettle river.

Without further climatic variations there would be a single cycle of degradation and no terraces except those due to the normal sidewise swinging of the streams. This is not the case in the Franklin district, for periodic changes of climate in post-Glacial time have brought about minor stages of alluviation and degradation. Such climatic oscillations are inferred on account of the presence on both sides of the Franklin valley, near its junction with the main Kettle valley, of a series of terrace steps with treads diminishing in width, but becoming more frequent and more closely spaced on descent to the river below (Plate IV). Nearest the bed of the stream the terraces usually show the coarsest gravels.

The origin of the river terraces in this district are explained, then, by ascribing them (1) to a major stage of alluviation and degradation contemporaneous with and dependent upon alpine valley glaciation; and (2) to later minor stages of alluviation and degradation dependent upon climatic oscillation.

These terrace features are most strikingly illustrated near the mouth of the Franklin Creek valley. This narrow and steep-walled portion of the valley trench, with its transverse course, was a favourable place for the accumulation of outwash materials, which reached a thickness of some 100 feet. The strong development of well-preserved terraces at the mouth of Franklin valley might be further explained by the possible impounding of drainag in that valley by the Kettle Valley glacier which blocked its mouth.

The extent of a valley glacier is necessarily dependent upon the size of its catchment basin, as well as upon precipitation and cold. A small tributary glacier may flow into a main trunk glacier during the climax of the glacial period, but with an amelioration of climate its small catchment basin may not supply enough snow to enable it to reach the main glacier. The result is the separation of the two and their gradual up-valley retreat.

Thus it is conceivable that the small Franklin glacier, fed by a relatively small catchment basin, may have shrunk back from a main Kettle Valley glacier. The latter would have then acted as a dam against which the stream from the former could have readily heaped up gravel deposits.

Post-Glacial Gorge Cutting.

The youngest set of topographic forms are the post-Glacial gorges, deep ravines, and hanging tributary draws, still in a very youthful stage of development. These forms are most markedly developed along the course of Franklin creek, whose present channel is a steep-sided tortuous gorge cut in the bottom of a wider valley. Its tributary creeks are left high above the water level of the main stream and join it in a series of water falls (about 35 feet high). The hanging relationships of some of the smaller tributary streams to the main Franklin creek is due to the excess of cutting of the latter with respect to the former, and must be distinguished from somewhat similar relationships due to glaciation. The Franklin gorge is cut not only in the readily eroded alluvium, but also well into the resistant bed-rock in places.

The accompanying photograph (Plate V) was taken on Franklin creek below the main valley to show the amount (approximately 100 feet) of post-Glacial gorge cutting. The rock formation seen is the Kettle River conglomerate.

Local—Forms Related Primarily to Rock Structure.

Under the second main division, namely, the discussion of those land forms which are dependent or consequent upon rock structure, may be included:—

(1). Those forms assumed by the early Tertiary conglomerate and grit formation through ordinary erosional processes.

(2). The strike ridges and structural troughs occupied often by "sloughs," chiefly along fault or contact zones.

(3). The mid-Tertiary lava cliffs skirted by coarse talus slopes showing progress in cliff recession as observed on all three mountains (Plate VI).

(4). Caves formed in lava cliffs along prominent systems of parting in the rock, which correspond as a rule to their lower contacts with the underlying grits (Plate VII).

(5). Recent rock slides causing prominent scars on the mountain slopes (Plate VIII).

(6). Mounds of monzonite, on both sides of Tenderloin volcanic vent which occupies the intervening depression.

(7). Crystalline limestone rock-shoulders best developed on the west slope of Franklin mountain, but also on the Dane property opposite Gloucester City.

The most singular topographic forms are possibly those developed upon the Tertiary conglomerate and grit. The unique forms of the conglomerate hillocks and mounds with prominent pinnacles or "hoodoos" are typical of those tracts which were in early Tertiary time areas of maximum deposition (Plate IX). The conglomerate ridges so conspicuous in places are a consequence of underlying structure and differential glacial erosion. Their strikes dominantly coincide with that of the valley, having steep escarpments on one side and relatively gentle slopes on the other.

An interesting case of stream deflection was noted about half a mile south of the junction of the West Fork with the main Franklin creek. A syenite-aplite dyke here strikes diagonally across the stream and has deflected it to the west, causing it to make a sharp bend in its course (See geological map 97 A).

All three mountains in the district have protective cappings of lava lying upon a porous conglomerate and grit formation. The conglomerate formation in its turn lies upon impervious basal rocks. It is quite to be expected, then, that when such a section is well exposed on the steep eastern slopes of the mountains, in a humid climate subject to great temperature changes, rock slides will take place from time to time. The breaking away of large blocks might be assisted greatly by seepage developed through breaks in the lava cap as well as by frost action.

Rock slides are caused chiefly by the undermining effects of seepage water issuing along the contact of pervious and impervious layers. Their development is hastened where the contact of the formations corresponds in gradient with the slope of the hill. Below the Maple Leaf property on Franklin mountain an alkalic syenite intrusion has bowed up its conglomerate-grit cover and makes the contact approximate in gradient that of the hill, thus facilitating rock slides in this vicinity.

It is of interest to note here that with few exceptions all the striking topographic forms dependent upon structure are to be found below the old upland.

Drainage.

The relations of the prominent drainage characteristics will be made clear by a few words concerning the geologic history of the region. The full evidence upon which the Tertiary history of this district is based is discussed in later chapters.

One persistent trait of the drainage ever since its beginning in the Laramide Revolution is its southward discharge.

Drainage conditions in early Tertiary time were naturally quite different in Franklin from what they are to-day. The district was then probably lower than it is now, but it still occupied the same intermont depression. The surrounding mountains were then composed chiefly of sedimentary rocks highly folded and broken during the great Laramide Revolution. No doubt the topographic relief was then much greater than it is now, and alpine conditions probably prevailed. It was found that the course of the early drainage was directed southwestwardly, as shown by current-markings in the grit formation on Franklin mountain. In this broad basin-like valley both streams and lakes were subject to great variations in size and position, due (1) to crustal disturbances and (2) chiefly to the ponding effect of contemporaneous lavas (rhyolites). Marshes and lakes were formed and about them vegetation flourished at intervals. Volcanic tuff was washed down into the shallow lakes and flood-plains. Much volcanic ash became mixed up and deposited with coarser arkosic (rhyolitic) grits in the rivers. Coarse gravels were swept down from the highlands to form subaëria cones, and alpine glaciers probably supplied a part of the material

Drainage in the early stages of the Tertiary must neces sarily have been in a decidedly disorganized state. In cours of geologic time, epeirogenic and igneous unrest gave place t quiet conditions; mature slopes were produced and the drainag became well organized with respect to one main river—the ancestral Kettle river—flowing about 25 degrees west of south or the site of the present mountain summits. The old valley was probably broader and flatter towards its head and narrowed somewhat to the south on the east end of the present site of McKinley mountain.

Upon the outbreak of Miocene igneous activity, great volumes of pyroclastic material, bombs, ejectamenta, and trachytic and basaltic tuffs were hurled forth from a vent on Tenderloin mountain. This was followed up by trachyte and phonolite lava flows which poured forth into this broad valley.

As a result of the lava flows, the drainage was once more disturbed; new courses had to be taken which naturally differed considerably from the older ones. Instead of a single main stream, two streams were formed, one on each side of the flow. The easterly one went to form the new Kettle river.[1]

A great period of denudation then took place, similar to that in progress throughout many sections of the Cordillera in late Tertiary time, and the whole district was reduced to a surface of low relief with residual ridges and peaks along the igneous cores of the once lofty mountain ranges enclosing the district.

The drainage was well organized, and with progress towards late maturity it became simplified; the topography was coarse-textured[2] as a result of (1) the fact that the land form had passed through a previous (pre-trachyte) cycle of erosion; (2) the character of the country rock, which was resistant to the

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[1] Lindgren (W.): The Gold Belt of the Blue Mountains, Ore.; 22nd Ann. Rept. U.S. Geol. Surv., pt. 2, pp. 574, 582, 597, 598. Mentions similar instances of drainage changes produced by lava flows.

[2] Johnson (D. W.): Relations of Geology to Topography; Principles and Practice of Surveying, Vol. II, Ch. 7, p. 246.

formation of numerous small drainage channels by smaller branch streams; (3) the character of the climate, which cannot be inferred for this district on account of the absence of Pliocene sediments; (4) age of land form, which had reached a post-mature development.

The courses of the present streams correspond closely to those of the preceding cycle of erosion. For instance, the course of McKinley creek at that time must have been about 500 feet above its present course, or, to state it more concisely, the McKinley mine was then buried beneath 500 feet of rock as well as a thick surface mantle of soil.

At the end of this cycle of erosion in late Pliocene or early Pleistocene time, a great regional uplift of a differential character occurred, which inaugurated a new erosion cycle with invigorated drainage which incised itself below the older surface of erosion. Certain rock benches high up on the mountain slopes, especially in the Franklin valley, may represent stream erosion during stable periods in the course of the uplift. The results of this uplift have already been considered.

There is no evidence of any crustal warping at this time, although it may possibly have been a minor factor controlling the position of the drainage courses.

Thus the composite character of the present drainage has been briefly traced through all stages of its physiographic development from its beginning in the Laramide Revolution to the present.

The drainage is typically antecedent in character, although there are a few places where underlying rock structure has dominated the course ' the streams, resulting in subsequent drainage. For example, the dome-shaped granodiorite batholith east of the East Branch of the North Fork of Kettle river has forced the stream to follow closely its western border, where it is in contact with the less resistant conglomerate formation. The river follows this contact for some miles south of a bend 800 feet downstream from the mouth of Boulder creek.

All of the main streams are perennial, while many of the draws or gullies with small catchment basins are intermittent, flowing only in wet weather or in time of melting snow. Boulder

creek is a typical torrential stream. The spring freshets car
down much coarse material to its delta, and at such flood seaso
it, along with many other swollen tributaries, helps to raise t
water in the turbulent Kettle river.

Some of the smaller tributaries of Franklin creek, as f
example Twin creek, on crossing the Carboniferous limesto
disappear in subterranean courses, leaving their stream channe
bare and dry. Lower down they may reappear at the surfa
for a distance until they reach the alluvial terraces below, whe
they disappear entirely. To this type the phrase "interrupte
streams" has been applied.

In a few places, where structure and erosion have brough
to the surface the underlying impervious basal rocks, capped b
porous conglomerate and grit, cool refreshing springs are found
such as the Deloro springs near McLaren's cabin on the wes
slope of Franklin mountain.

GRADIENT.

The gradient of the North Fork of Kettle river between Gloucester City in Franklin and Grand Forks, is about half of one per cent or 25 feet per mile. The tributary creeks, Franklin and Gloucester, have much steeper gradients, reaching as much as 150 feet per mile within the Franklin map-area itself.

The streams steepen their gradients before entering the main valley, as is the case with Franklin creek, but this is true to a lesser extent with Gloucester creek on account of the valley's more highly glaciated character.

There is sufficient water power available for ordinary mining purposes in Franklin and Gloucester creeks, as well as in the main Kettle river.

GENERAL CONSIDERATIONS.

A few topics of broad general interest, bearing on certain Cordilleran problems, upon which the Franklin district may be able to throw some light or at least contribute its share of data for correlation purposes, will here be discussed.

Age of Franklin Post-Mature Topography.

In order to refer the Franklin upland topography to any definite erosional period in the geologic history of the region, it will be necessary to attack the problem in a quantitative way. The relative amounts of erosion accomplished both before and after uplift will first be considered.

To determine the amount of erosion accomplished before uplift, the pre-trachyte topography must necessarily be restored. This is a difficult task on account of the erratic nature of the conglomerate and grit structure in so many localities, for following deposition, the early Tertiary sediments had been subjected to local orogenic movement, which uplifted them and gave them a regional dip in a direction slightly north of east. The grit was found, however, to dip under the trachyte in every case—a condition which points to the following facts: (1) an erosion interval intervened between the two formations; (2) hills and valleys existed on this surface of erosion; and (3) the valleys were subsequently filled by lava flows (Figure 4). As the present lava cappings represent basal portions of former extensive flows which filled at least one depression in the old pre-trachyte land surface, it is certain that the bounding, or possibly intervening, areas and valley sides occupied higher ground at the time the flows took place. The higher ground between the lava flows was worn down into valleys, leaving the former valley flows on the present divides.

The production of such broad valleys and mature slopes as we see to-day on the upland surface is necessarily the result of a long period of denudation—a period which began after the trachyte extrusions and which culminated with regional uplift. The trachyte extrusions can safely be referred to the Miocene, for the following reasons: (1) the Franklin early Tertiary grits and tuffs resemble closely in their lithological characters those of the Coldwater group in the Interior Plateau of British Columbia, which have been proved through palæobotanical evidence to be of Oligocene age; (2) the crustal disturbance and erosion interval between the sedimentaries and the volcanics in Franklin correlate[1] with a similar movement and erosion cycle in the Interior Plateau country which closed the Oligocene period; (3) trachyte lavas somewhat similar to those of Franklin were described by Dr. G. M. Dawson in the Kamloops district in the Interior Plateau, where they have been proved, palæontologically, to be of Miocene age.

A great period of time, then, has to be added to the Miocene in order to reach the end of a cycle of erosion of sufficient duration to be capable of eroding valleys where formerly there were divides, and of producing such mature slopes as those of the upland.

Having considered the amount of erosion accomplished during the cycle which extended from Miocene to the time of uplift, the amount of erosion accomplished since the uplift will be now dealt with, since it, too, has a bearing on the age of the older surface. The steep-walled entrenched valleys below the upland surface represent the amount of erosion accomplished since the uplift. This amount was practically all completed before the Glacial period, as glaciation has modified but slightly the pre-Glacial valley forms. The time limit, then, in this case for the younger period of erosion falls between time of uplift and the Glacial period (Pleistocene).

The accompanying figure (Figure 4) shows in a diagrammatic way the different stages in the development of the present land surface and the comparative amounts of erosion accomplished during each stage. In the figure two early Tertiary valleys are indicated. There is no conclusive evidence within the map-area to support this view, although the character of the upland topography to the west of the Franklin valley suggests it. It is evident from the figure that much more time has to be added to the Miocene than is subtracted from the Pleistocene to arrive at the date of the erosion cycle in which the post-mature topography was produced.

It seems safe, then, to infer that the Franklin erosion cycle extended through the most of Pliocene time and that the great uplift probably took place towards the close of the Pliocene or beginning of the Pleistocene.

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[1] Dawson (G. M.): Bull. Geol. Soc. of Am., Vol. XII, 1901, pp. 89, 90.

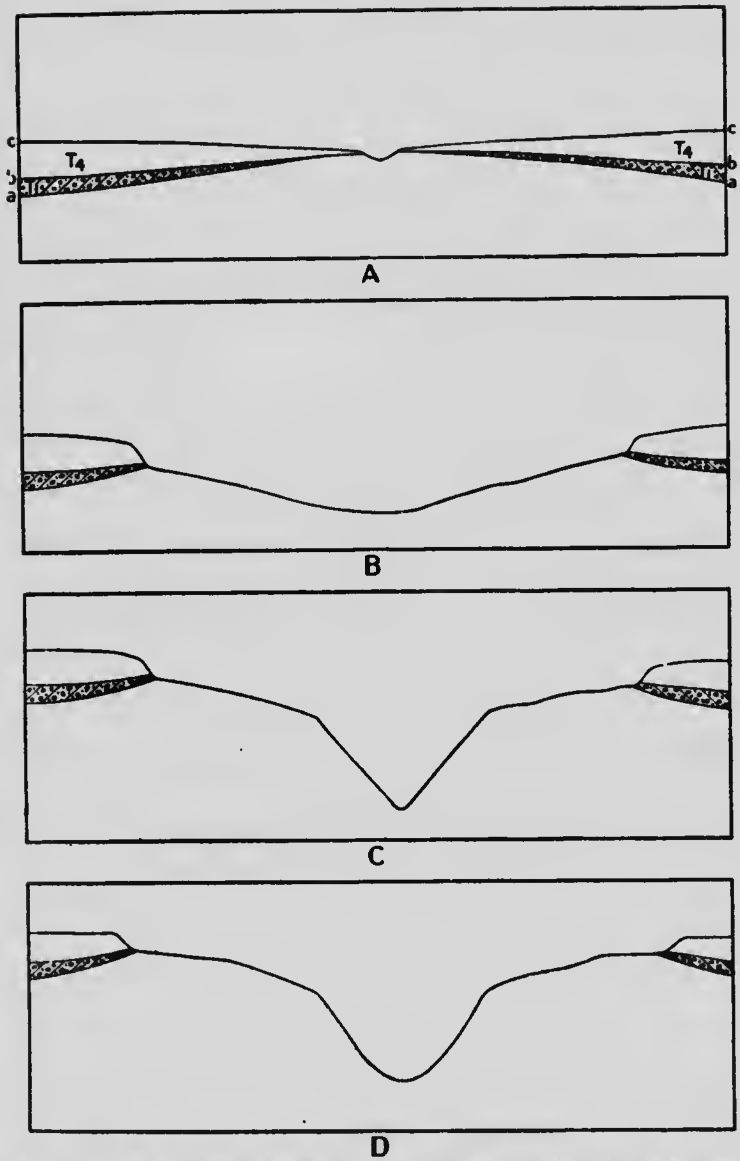

Figure 4. Diagrams showing relative amounts of erosion before and after uplift.

A—Drainage at beginning of Pliocene time; *a-a*, Cretaceous erosion surface; *b-b*, Post-Oligocene erosion surface; *c-c*, Pliocene erosion surface; T_1, early Tertiary river deposit; T_4, Miocene trachyte flows.
B—Drainage prior to late Pliocene uplift.
C—Drainage after Pliocene uplift and prior to glaciation.
D—Drainage after glaciation.

Dates of Principal Periods of Erosion in Franklin Map Area.

Introductory Statement.

The determination of correct ages for Tertiary erosion surfaces is of vital importance, owing to the bearing upon palæontological studies of the Tertiary faunas and floras of western America, as well as their use as a convenient datum plane to correlate the igneous history and the periods of ore deposition of the western Cordillera. Illustrations of such applications of physiography to igneous intrusion and ore deposition will be seen in Chapters IV and VII, on General Geology and Economic Geology.

The Franklin district, with its fairly complete Tertiary rock record, is an exceptionally favourable field for the study of Tertiary physiography and geology. In Franklin there is evidence of three well-defined periods of erosion. The first was in the Cretaceous; the second during an interval between the post-Oligocene deformative period and the outflow of Miocene lavas; and the third in Pliocene time. It was in the last-named period of denudation that the present upland topography was formed, although the preceding two have influenced to some degree its development.

The field facts to support these conclusions will here be discussed, and the reader is referred to Chapter IV, on General Geology, for age determination and correlation of the various formations mentioned.

Cretaceous Erosion Cycle.

Eocene conglomerate was found to lie directly upon the Jurassic granodiorite batholith on McKinley mountain—a fact indicating that sufficient erosion was accomplished to remove the entire cover from off the batholith. That the batholith consolidated under a great thickness of cover rock is shown by the character of mineralization that has been produced by it in the overlying Palæozoic formations. Contact metamorphic ore deposits of oxides of iron and sulphides in lime silicate gangues have been formed, which indicate deep-seated conditions with probable pneumatolytic action at time of intrusion. A great thickness of cover rock must, then, have been removed during the Cretaceous period.

Post-Oligocene Erosion Cycle.

As bearing on this period of erosion, the following facts are cited: (1) Miocene trachyte flows were found to lie unconformably upon a gentle undulating surface of erosion produced upon deformed early Tertiary deposits (Plate XVIII). The early Tertiary deposits (Eocene-Oligocene) have a prevailing dip to the northeast. Wherever the grits, however, were found in contact with the trachyte, they dipped under it. The geological map shows the flat attitude of the Miocene lavas where they lie upon the uptilted early Tertiary sediments, the latter even extending below the level of the present Kettle valley-bottom; (2) the rhyolite porphyry found on McKinley mountain is of a coarse texture, indicating that it is either the basal portion of a once extensive lava flow or that it is the vent itself. In either case it is apparent that a considerable thickness of the flow has been removed by erosion.

From the above facts it is evident that an erosion interval elapsed between the time of deformation of the early Tertiary sediments and the outflow of Miocene lavas. It is to be noted, however, that the erosion in no place within the district reached the base of the early Tertiary sediments and was in no way comparable to erosion following the Laramide revolution. The Miocene lavas in Franklin always lie upon early Tertiary sediments.

It will be seen later that this erosion period is believed to have played an important part in the Tertiary history of this section of the Cordillera, in that it is largely responsible for the stripping-off of vast sedimentary records of the early Tertiary.

Pliocene Erosion Cycle.

The recognition and results of the Pliocene period of erosion have already been discussed fully in a preceding section. It is sufficient, then, to merely state here that the present upla topography is largely the work of this last cycle of erosion whi under the special conditions of the district, eroded the valle where formerly there were divides.

Regional Application of Franklin Details.

Having thus considered the Franklin records of past erosi cycles, the conclusions arrived at from their detailed stu will now be compared with those supported by facts from t whole of south-central British Columbia and northern Washin ton. Very little detailed physiographic work has been done this section of British Columbia since Dr. G. M. Dawson death in 1901. Dr. Dawson recognized an ancient penepla surface upon which remnants of Oligocene and Miocene deposi lay. He assumed it, however, to be of Eocene age,[1] "chief because no deposits referable to the Eocene or earliest Tertia have been found in this part of the Cordillera." This erosi surface has since that date been generally referred to in geolog literature as the Eocene peneplain of British Columbia, and h been extended and correlated to only a slight extent both in Washington[2] and Alaska.[3] Recently an erosion surface h been recognized in northern Washington and from field eviden there (to be discussed in following paragraphs) it has been co cluded to be of Eocene age, correlating it with Dawson's Eoce peneplain to the north in the Interior Plateau of British Co umbia.[4]

Some theoretical considerations will now be introduce in order that further bearing of these facts may be apprehende Granting that a peneplain exists in a given geological perio such a peneplain (1) may remain at approximately the same lev throughout the succeeding period, or (2) may be depressed d rectly after its formation, or (3) may be elevated. Therefor

[1]Dawson (G. M.): Bull. Geol. Soc. of Am., Vol. XII, 1901, p. 89.

[2]Umpleby (J. B.): Washington State Survey Bull. No. 1, 1910, p. 11.

[3]Brooks (A. H.): Geography and Geology of Alaska. Prof. Paper, 4 1906, p. 279.

[4]Umpleby (J. B.): Jour. of Geology, Vol. XXII, 1912, pp. 139-147.

even if a peneplain existed in the Eocene, it *may* have been formed in a preceding geological period. The fact that Eocene lake sediments exist on a peneplain means (1) that the peneplain was formed in the preceding geological period and persisted into the Eocene, or (2) that it was completed in the very early part of the Eocene period. It can hardly be conceived that a peneplain, the product of such a long cycle of erosion, could be made in a small fraction of a geological period. Furthermore, the idea of Eocene peneplanation complicates matters in that the advocates of such a hypothesis, in order to account for the deep valleys in the Eocene peneplain down which Miocene lavas flowed, have to involve a great regional uplift following Eocene peneplanation which does not correlate with the physical history of the Cordillera elsewhere. It is true, as has been shown, that there was a minor period of crustal disturbance and erosion before the Miocene lava flows, a period in which there was in progress a stripping-off of loose continental sediments throughout the whole country. There is no evidence, however, of a great uplift at that time, such as it is necessary to assume in order to account for the deep valleys in the Interior Plateau of British Columbia, Republic district[1] in Washington, and Bitterroot range[2] in Montana and Idaho. Such deep valley cutting as is certainly the case in the Interior Plateau, shown by lava fillings, could be more readily and simply explained by the great regional uplift of the Laramide Revolution, which resulted in the formation of the Cordillera to the east of the Interior Plateau country.

This line of reasoning brings one to a conclusion possibly very little more secure than Dawson's, but certainly just as secure. In comparing the geological events of the Interior Plateau with those in the mountainous Cordillera to the east, as illustrated at Franklin, the hypothesis of a Cretaceous period of peneplanation is much more tenable. Furthermore, it ex-

[1] Umpleby (J. B.) : Republic Mining District, Wash. Geol. Surv. Bull. No. 1, p. 11.

[2] Lindgren (W.): A Geological Reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho; U.S. Geol. Surv. Prof. Paper, No. 27, 1904.

plains many field facts which could not be interpreted under t
hypothesis of an Eocene period of peneplanation.

For example, it was noted at the contact of the Eoce
Interior Plateau and the Miocene Basalt Plateau, that "tv
areas joining along a definite line and the one at least 2,000 fe
higher than the other, with the lower surface possessing co
siderable relief."[1] Thus the Columbia river south of Kell
may have been along a hinge line during the time of regional u
lift in the post-Cretaceous, the Interior Plateau region to th
north being uplifted relatively higher than the region at prese
known as the Columbia Basalt Plateau. The drainage he
was probably southward, as in Franklin. Such a hypothes
would further explain the finding in the Tertiary beds of th
Republic District fish remains which have not as yet been foun
to the north in the Interior Plateau country.

It would further explain the fact that the Kettle Riv
formation (Eocene) towards the heads of the old north and sout
drainage in the highlands contains coarse heterogeneous con
glomerates with admixed tillite as at Franklin, while farther sout
at the International Boundary the formation includes only wel
water-worn gravels. Well water-worn and well assorted pebbles
some of which were granodiorite, were found in the basal membe
of the Tertiary enclosed within the deep, broad erosion valley
near Granite mountain of the Republic district. The geographic
distribution of the older Tertiary formations containing the
products of long fluvial transportation indicates that the drainage was north and south.[2] The north and south alignment of
Tertiary beds at Phoenix, B. C., which may represent the same
river valley, extends about 30 miles south into the Republic
district.[3] At Phoenix, however, no very coarse conglomerate
member exists, although it is possible that one may have existed
and have been removed in the post-Oligocene cycle of erosion.
No direct evidence has been stated with regard to the direction

[1] Umpleby (J. B.): Wash. Geol. Surv. Bull. No. 1, 1910, p. 13. A footnote to the above states: "The observations were made from a stage near Kellar and are thought to be greatly minimized."

[2] See Phoenix Map, No. 16A, G.S.C., 1911.

[3] Umpleby (J. B.): Wash. State Surv. Bull. No. 1, 1910, p. 19.

of transport of early Tertiary stream gravels for this region. It is impossible, therefore, to make conclusive inferences as to the direction of flow for the Tertiary drainage. However, as no observations of a Cretaceous erosion surface south of the Interior Plateau have been recorded,[1] the present site of the Columbia lava plains was probably in early Tertiary time a region of subsidence, with delta deposition from the rivers flowing from the north, where the regional uplift was greatest. Slow subsidence with aggradation following such a period of maximum uplift would soon fill up all the irregularities of surface caused by the incision of the Cretaceous drainage. The lakes and rivers of the lower drainage areas and delta country of the Oligocene would naturally support fish life, fossils of which have been found and described.[2]

The main reasons for doubting the validity of an Eocene period of peneplanation are as follows:—

(1) The valleys in the old erosion surface filled with Miocene lavas and lake beds which lie unconformably[3] upon pre-Oligocene formations (dacite conglomerate in case of the Republic district) are too deep to be accounted for by any known Tertiary uplift between the Laramide revolution and the Pliocene uplift.

(2) The fact that there is in the Republic district in Washington evidence similar to that in Franklin, of an erosion cycle between early Tertiary and lower Miocene, which there, too, has not cut down to the bottom of the old erosion valley, would indicate a period of time between the lower Miocene and deformation of dacite conglomerate sufficient to remove great records of early Tertiary sediments and lava flows. It is thought that this erosion interval was not responsible for the deep, broad

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[1]Smith (G. O.) and Calkins (F. C.): U.S. Geol. Surv. Bull. 235, p. 90. Smith and Calkins, in discussing the differentiation of the Cascade mountains, state: "An example of this is found in the occurrence of an Eocene peneplain in the Interior Plateau region, while in the Cascades peneplanation of Eocene age has not been recognized, and indeed in central Washington the Miocene lavas are known to rest upon a surface *possessing considerable relief*."

[2]Wash. Geol. Surv., Bull. No. 1, 1910, p. 24.

[3]Umpleby (J. B.): Republic Mining Dist. Wash., Wash. State Surv. Bull. No. 1, 1910, p. 24 top.

valley, but rather was the cause of the erosional unconfor between the early Tertiary and the Miocene beds. The d broad valley is, on the other hand, to be ascribed to the Larar uplift, and in this way the unconformity between the e Tertiary beds and the basal rocks would be explained.

(3) An erosion surface such as the one in question co hardly be developed from as youthful a topography as which followed the Laramide revolution in the short fract of the Eocene period (before pre-Oligocene deposition and formation), as discussed in detail on page 33. The Laram revolution must have ended one erosion cycle and inaugura another, so that if the erosion surface is to be referred to Eocene, it must have been produced in an incredibly short ti

The Miocene lake beds[1] lie in the Republic district unc formably upon the dacite (rhyolite in Franklin) conglomera This fact points towards a minor erosion cycle intervening tween the early Tertiary and Miocene deposits similar to th found in Franklin. It seems necessary, however, in order account for the unconformity between the dacite conglomera and the underlying Palæozoic formations, to refer the orig of the broad deep valley to a still older period of uplift, befo the dacite conglomerate was deposited, and not to the Oligocen

The writer suggests that the upper surface of erosion re resents a Cretaceous rather than an Eocene peneplain, and th the deep valley is due to invigorated erosion following the Lar mide uplift; that the dacite conglomerate is of early Tert age (chiefly Eocene); that the unconformity represents a n erosion cycle following crustal disturbance, which was respo for the stripping-off of considerable early Tertiary m eri prior to the deposition of the Miocene lake beds.

Such a hypothesis would not only account for the deep valle in the Republic district, but also others so common throughou the Interior Plateau country, as, for example, at Phoenix an Franklin.

(4) The early Tertiary sediments contain practically n

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[1] Dr. C. R. Eastman has referred the lake beds to the early Miocene. (Op cit. pp. 24-25.)

vein quartz, indicating lack of thorough decomposition of an ancient soil naturally associated with a peneplain.

If there had been an extensive period of peneplanation, in the Eocene, such evidence would be expected of it similar to that found in the Pliocene sediments, which in many places contain auriferous quartz drift (Klondike beds), and the Cretaceous sandstones.

(5) The early Tertiary sediments in Franklin are characterized by extensive alluvial cone deposition and tillite (for further details see page 63), which point towards rugged alpine conditions in the surrounding sedimentary mountains, such as would naturally be expected following the Laramide revolution. There is no evidence there of any Eocene period of erosion such as would produce an erosion surface comparable to the one recognized by Dawson and Umpleby.

Future work in other areas may yield critical evidence on this problem of Cretaceous peneplanation in the western Cordillera; it would appear to consist chiefly of the following relations: (1) Finding that the Upper Cretaceous sediments are entirely different in lithological character (colour, texture, etc.) from those of the Eocene-Oligocene formations; the former being such as to indicate peneplain conditions before uplift, the latter sediments characteristic of regions undergoing rapid erosion in a generally cooler, more humid climate, with coarse basal members of conglomerates, arkosic grits, and tuffs, grading into finer sediments towards the top of the section. (2) The finding in other portions of British Columbia and northern Washington of Eocene sediments within the entrenched valleys, capped by Miocene lava flows or lake beds, as is the case in the Franklin and Republic districts. (3) By determination of the relative areal extent of the upland surface with its shallow water sediments, to that of the deep valleys filled with Miocene lavas. In so doing, one would be able to draw inferences as to the degree of peneplanation in the Cretaceous cycle of erosion and compare it with that of the Pliocene. From the data so far available, the Cretaceous surface of erosion appears to have reached a higher degree of peneplain development, with a much coarser topography than that of the Pliocene. As the old Cretaceous peneplain is frequently capped by extensive lava through the Interior Plateau country, one would be guid obtaining such information by the occurrence of tongu extensions of lava up-valley, where the Cretaceous u inter-flues have been swept bare of a part or all of their f lava cover.

The Age of the Upland Topography of the Inter Plateau of British Columbia.

Dr. Dawson ascribed the subequality of the present mou summits as an inheritance from the ancient Eocene erosion face developed in the region. The presence of this an erosion surface has been questioned among some geolog especially by Daly.[1] That there was such an erosion sur the evidence advanced in the foregoing discussion undoubt substantiates. However, there is ground for the conclusion it was not developed in the Eocene, but rather in the Cretace The extent to which the subequality of the present moun summits may be due to the Cretaceous erosion surface is an c question. The presence at Phoenix, in the Boundary C district of British Columbia, of a gently undulating upland to raphy bevelling Miocene lavas, would indicate that the trict to the west and southwest of Franklin had been subje to some degree of erosion in the Pliocene. The Pliocene ero cycle may not have reached the stage of development the Cr ceous one did before uplift, and, therefore, did not show as crest lines. The two preceding erosion cycles—the Cretace and the post-Oligocene—would to some extent influence perfection of the last one (Pliocene).

In conclusion, it is of interest to note that whatever c ditions may have prevailed throughout other sections of

[1]Daly (R. A.): Geol. Surv. Canada, Ann. Rept., 1904. Professor D saw no evidence of a period of peneplanation in the Interior Plateau, and sta "Mountains have not the broad, flat tops expected, but are generally of con or ridge-shaped form, such as belongs to a range worn down in one cycl denudation. Accordance in altitude of summits is far from perfect, and s accordance as does exist can be explained by other conditions of mount sculpture."

British Columbia Cordillera during late Mesozoic and early and late Tertiary times, in the Franklin district, at least, there are three well-defined periods of erosion, the first in Cretaceous, the second (a minor one) in post-Oligocene, and the third in Pliocene time; and it was in the last-named period of denudation that the present upland topography was formed.

Here in Franklin, then, situated well within the British Columbia Cordillera, the same conditions of long denudation prevailed in the Pliocene as have already been identified south of the International Boundary, where similar upland surfaces were in course of development. Recent studies[1] have shown that there exist upland surfaces in many widely separated districts in the Cordillera south of British Columbia which are likewise the result of a long cycle of erosion in *late* Tertiary time, and which imply widespread degradation and the development of the topography to a state of late maturity and local peneplanation.

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

CHAPTER IV.

GENERAL AND STRUCTURAL GEOLOGY.

GENERAL STATEMENT.

In this chapter an account will be given of the mode of
currence of the igneous, sedimentary, and metamorphic ro
of the Franklin district, and their structural relations to
another. The leading geologic features are those mainly c
nected with the widespread batholithic invasion and fold
of older rock formations intervening with great periods of eros
and continental deposition, the latter interrupted at times
minor igneous intrusions and lava flows.

The Franklin district lies in a basin-like depression
tween the Granite range on the east and the Cariboo on the we
which coalesce 16 miles due north. Both ranges are compos
of granitic rocks which are the igneous cores of early Tertia
mountains. The mountains at that time were composed
sedimentary and eruptive rocks and this is indicated by the cha
acter of the early Tertiary sediments within the basin, whi
are composed in large part of alluvial cone material and till
derived from sedimentary and eruptive, but not from the granit
rocks. This intermont basin or trough exists independently
erosion, and was apparently formed during the Laramide mou
tain-making period. In order to convey the structural origi
of the intermont depression the term tectonic basin or troug
has been employed.

The outline map (Figure 2) shows by its larger features tha
the Franklin district lies in a tectonic basin underlaid and sur
rounded by a composite batholith. Long continued erosio
has almost completely stripped the batholith's sedimentar
cover, leaving only here and there scattered down-hanging por
tions or remnants of an ancient roof, termed by R. A. Daly

"roof-pendants."[1] The roof-pendants occur chiefly in the tectonic depression between the two mountain ranges, and it is with the largest one of these remnants of a former roof that this report has to deal. Fortune has indeed favoured the preservation of this particular one, in that upon it lava cappings have protected in some perfection a record of early Tertiary sedimentation and igneous activity. Records of former continental and valley glaciation are present within the district and are fully discussed in Chapter III, on Physiography.

TABLE OF FORMATIONS.

Quaternary	Recent	Soil, subsoil.
	Pleistocene	Fluvio-glacial material, (gravel, sand, silt); morainic material.
Tertiary	Miocene	Midway Volcanic group. Minette and augite microdiorite dykes. Pulaskite porphyry dykes and plugs. Alkalic basalt and trachyte flows; ejectamenta. Trachyte flow.
		Shonkinite - pyroxenite and augite syenite volcanic core. Porphyritic syenite chonoliths.
	Oligocene	Monzonite and micromonzonite stock.
	Oligocene or Eocene.	Kettle River formation; —conglomerate, arkosic grit, acidic tuff, and rhyolite flows.

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[1]Daly, (R. A.): The Mechanics of Igneous Intrusion. Amer. Jour. Sci. (4), Vol. XV, pp. 269-298.

Mesozoic ...... Jurassic	....	Nelson granodi varies from g to diorite; gneiss
Palæozoic ...... Carboniferous	....	Gloucester cryst limestone.
		Franklin group; g stone, altered and silicified argi

DETAILED DESCRIPTION OF FORMATIONS.

PALÆOZOIC.

Franklin Group.

General Characters.

The oldest rocks of the district are those embraced in Franklin group. They include a complex of metamorphic ro of both sedimentary and igneous origin. These have been s jected to such intense contact and regional metamorphism t their record of sedimentation and vulcanism has been grea obscured. The group consists of silicified argillites, cherty qua zites, altered tuffs, and greenstones, whose detailed charact are given in the next chapter, on "Petrology." The lowest me ber of the group appears to be a dark, silicified argillite which co tains very obscure plant impressions. It forms outcrops Franklin Creek bottom and near the west border of the map-ar

Distribution.

The Franklin group rocks are widely distributed on three mountains, and represent the basal formation of the di trict. They are underlain and cut off below by a broad, dom shaped batholith of granodiorite, while above they are cappe in many places by the younger Tertiary formations.

Original Structures.

The original structure of the rocks comprising the group has been greatly obscured, owing to: (1) their massive character; (2) their large content of eruptive material, and (3) the fact that they have been chloritized and silicified in the zone of cementation to such a degree that their bedding is seldom discernible or cannot be distinguished from the planes of jointing and shearing. For these reasons the structural data of the complex are meagre and unsatisfactory, as is also any attempt to estimate the probable thickness of its sedimentary members. The argillites and quartzites, which occasionally display traces of original structure, have a general strike from a few degrees east of north to 45 degrees west of north, and dip from 35 degrees to 60 degrees to the west and southwest.

Secondary Structures.

Jointing is the most prominent secondary structure present, and although well developed in the rocks the directions are not constant over considerable areas, a fact due probably in part to the complexity of the stress to which they have been subjected and in part to the heterogeneous character of the rock complex. The master joint planes in many places correspond in a broad way to the regional strike of the bedding planes, where the latter are observable and may represent them. Brecciated and sheared zones were noted in places throughout the rocks of this group, but in no place was schistosity found to be developed, nor has the compression which these rocks have undergone developed any well marked slaty cleavage.

Conditions of Deposition.

From the obscure nature of the structure in the rocks of this group, inferences as to mode of deposition and subsequent deformation must necessarily be of a speculative nature. It is known, however, that the lowest member of the group is a silicified argillite containing obscure plant remains, while other members are of an eruptive origin. Some of the latter were no doubt laid down as tuffs and lava flows or intruded as por-

phyry dykes and stocks. The whole metamorphic sedim
series was originally composed of fine-grained sediments, i
ing deposition in quiet waters, presumably at a depth g
than that of wave action.

It seems, then, that the Franklin district, in so far a
be inferred from the oldest rocks preserved, was near an
Palæozoic shore-line on which vegetation flourished.
district gradually subsided beneath the sea, and depositio
sisted of argillaceous and siliceous mud, which during
subsequent ages consolidated to argillites more or les
in silica. Igneous activity supplied tuffs, lavas, dykes, a
regular masses of eruptive material.

Correlation.

The rocks of the group resemble in their lithological ch
ters, the argillites, tuffs, and greenstones of the Phoenix (K
hill group)[1] and Deadwood districts to the southwest, i
Interior Plateau of British Columbia. There they have
referred tentatively to the upper Palæozoic. In the Fra
district, however, these rocks are not so well developed
the Boundary country, where erosion has laid bare very
underlying granodiorite compared to what it has done in the
mountainous Franklin district. The Franklin group
further resemble, in some respects, the Boston Bar serie
described by Dr. G. M. Dawson,[2] which occur south of
Kamloops map sheet, and which Dawson provisionally u
with the Câche Creek series, although he states that they
belong to horizons much lower than that of the Carbonife
The Boston Bar series contains schistose and slaty rocks, h
ever, which are entirely wanting in the Franklin group. O
to the intimate relations, as will be seen presently, between
Franklin group and the Gloucester formation, which,
probably, is of Carboniferous age, the group will be tentati
referred to the upper Palæozoic.

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[1]LeRoy, (O. E.): The Geology and Ore Deposits of Phoenix, Bound
district, B.C., G.S.C., Memoir 21, 1912, p. 30.

[2]Report on Kamloops Map Sheet: Ann. Rept. G.S.C., VII, Pt.
1896, p. 44 b.

Gloucester Formation.

Distribution.

This crystalline limestone or marble formation (for detailed description of rocks, refer to page 97, Chapter V) occurs as irregular, detached masses and elongated ovals or lenses in three distinct and separate belts, which trend in a general north and south direction with steep dips to the west. The most easterly belt is exposed on the west slope of and near the base of the Granite range on the Dane property, opposite Gloucester city; and the most westerly one is on the IXL property on McKinley mountain. The most extensive and thickest belt, however, is the central one, which extends from Twin creek southward, along the west slope of Franklin mountain and across Franklin creek, up to the McKinley mine. Where this belt occurs on the west slope of Franklin mountain, it is locally known as the "Lime Dyke." It forms a very prominent, bare, white, rock shoulder. Here the marble attains a width of about 300 feet, which is a maximum for the district. On the eastern borders of the lenticular shaped masses exist, generally, zones of calcareous conglomerate, made up of well rounded quartz pebbles with occasional stray fragments of other rocks. Such zones in places, as in the case of the Banner occurrence, have been subjected to brecciation and shattering, with subsequent infiltration and cementation by calcareous and siliceous solutions.

From an economic standpoint, this Gloucester formation is important in that the ores of contact metamorphic origin with lime silicate gangues are closely associated with it, and are found either at its borders, as in the McKinley mine, or in mineralized zones within it (page 167). The mineralized lime silicate zones often show pore spaces and cavities, due to shrinkage, consequent upon metasomatism and expulsion of CO_2 (see Plate XXIII).

Method of Deposition and Correlation.

The Gloucester crystalline limestone resembles, very closely, the Brooklyn formation of Phoenix and Deadwood in the Boundary district, and occurs in similar, generally lenticular shaped masses within the altered tuffs and breccias. No fossils have ever been found in these formations.

It is possibly of the same age as the crystalline limestone occurring farther south, which Daly includes in his Atwood series of Carboniferous age, correlating it with the limestone in the Rossland mountains.

About 100 miles northwest of the Franklin district, between Kamloops and Little Shuswap lake, there is a grey, coarsely crystalline limestone of the Câche Creek series (Carboniferous), which Dr. G. M. Dawson[1] mentions as containing obscure fossils. He examined it under the microscope and found it "to be a coarsely granular aggregate of fragments of calcareous organisms about half of which are crinoidal, and have a pale-brown colour, which distinguished them from the rest of the mass. This minute structure is well preserved. The remaining moiety of the rock is principally composed of fragments of small corals. Fusilina are also abundant, well preserved and characteristic and differ from the crinoids and corals in the milky opacity of their shells. Several brachiopods in poor preservation were also found, among which is a *rhynchonella* and a shell which may be *Hemipronites crinistria*." A large foraminifer *columbiana* was found in the Marble Canyon limestone[2]—the upper member of the Câche Creek series farther to the west in the same district. In 1901 Dr. Dawson[3] stated that "rocks of the Carboniferous period are probably present in several parts of the system of Gold Ranges [Franklin is well within them] but practically no palæontological evidence of their existence has yet been obtained."

Some of the spotted crystalline limestones collected from opposite the mouth of McKinley creek, in the Franklin district, were examined under the microscope, and found to contain crinoidal columnals showing internal canals as well as an organism that resembles, in its outlines but not internal structure, a fusulina. The latter was too obscure for definite determination.

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[1]Dawson (Dr. G. M.): Report of Progress, G.S.C., 1877-78, P. 808.
[2]Dawson (Dr. G. M.): Quart. Jour. Geol. Soc., 1879, p. 69.
[3]Ibid. : Bull. Geol. Soc. of Am., XII, 1901, p. 70.

It seems highly probable, then, that the Gloucester crystalline limestone, as well as other similarly related crystalline limestones from districts to the south and west throughout the Boundary country and in Republic district in Washington,[1] were originally deposited in the same Carboniferous sea as the limestones of the Câche Creek series. The limestones throughout this section of the British Columbia Cordillera may correlate with the Madison limestone to the south in Montana. The conglomerate at the base of the Gloucester formation, composed of well water-worn quartz and quartzite pebbles, is, presumably, following the evidence of the limestone lenses, of marine origin, and probably represents the early period of its deposition.

Relations of Franklin Group to Gloucester Formation.

The question of relationship between the Gloucester formation and the Franklin group is a difficult one, on account of the meagre structural data obtainable, due to later metamorphism from below, and erosion from above.

The occurrences of the Gloucester marble are chiefly confined to a single north and south belt near the middle of the district, and only a few small and scattered lenses are found elsewhere within the Franklin group. These remnants are small and insignificant compared to the Franklin group, and whether they are intercalated lenses or remnants of a different formation is difficult to ascertain in Franklin.

As bearing on the problem, however, the following facts may be stated, which indicate that a positive conclusion cannot be derived from this district. (1) The narrow lenticular masses of marble lie within the altered tuffs and eruptives of the Franklin group. (2) The walls of the lenses are essentially parallel, and the lenses have a vertical elongation comparable to their horizontal elongation, since the deep valleys cut by erosion have not revealed fewer exposures than the upland. (3) The exposures are independent of topography. (4) The lenses tend to exist

[1] Umpleby (J. B.): Geol. and Ore Deposits of Republic Mining Dist., Wash. Geol. Surv. Bull. No. 1, 1910, p. 17.

in line, and the smaller ones have a greater thickness in comparison to their length. (5) There is a synclinal structure to the lens on McKinley mountain. (6) The contacts between the Franklin group and the Gloucester formation are always sharp and well defined. (7) The intrusive rocks associated with and cutting the Franklin group were not observed to cut the Gloucester formation (At the McKinley mine tongues from the Jurassic granodiorite batholith do cut the marble). (8) While the strike of the bedding planes in the marble corresponds in some places to that of the elongation of the lenses, in other places it corresponds to the regional strike of the Franklin Group sedimentaries. (9) Boulders and pebbles of the Gloucester formation and associated conglomerate, as well as of the Franklin group rocks, are found commonly within the Eocene conglomerate.

In favour of a hypothesis of intercalated marbles is the occurrence of a single dominant belt of discontinuous lenses just as abundant in the valley bottoms as on the hill tops.

In favour of the hypothesis that they are remnants of a different formation is the fact that the Gloucester formation has not been seen to be cut by the intrusives which are found in the Franklin group and are related to the latter. Furthermore, palæontological evidence points towards a correlation between the Gloucester formation and the upper member of the Câche Creek group.[1] This upper member or Marble Canyon limestone lies conformably upon the argillites and cherty quartzites of the lower Câche Creek group.

If the Gloucester marble be regarded, then, as the erosion remnants of a once extensive formation, this implies that mashing has proceeded to an extent sufficient to pinch a synclinal axis into elongated lenses and to compress the folds to such a vertical height that the limbs are now practically parallel.

The dominant lenticular shape and less prominent offset character of the outcrops may be due to pinching out and shearing off of formerly more extensive and continuous beds, as a result of the complex dynamic metamorphism to which the Palæozoic formations of this district have been subjected. That

[1]Dawson (Dr. G. M.): Geol. Surv. Canada, Report on Kamloops Map Sheet Rept., 1896, p. 468.

intense distortion and shearing action has taken place is shown by the presence of generally brecciated and mashed conglomerates and tuffs about the borders of the limestone lenses. It is further indicated by mineralogic distortion in the marble itself, where there has been slipping along twin planes in the larger calcite individuals of the rock, with production of an imbricated structure.

JURASSIC.

Granodiorite Batholith.

General Characters.

The rocks grouped under this heading embrace granular intrusives varying in composition from syenite and granite to diorite, and including some hornblendite. For detailed description refer to Chapter V, page 100. They are all more or less altered by dynamic metamorphism, and many of them are mashed to gneisses. There is a gradual transition from the average type, which is a grey granodiorite, to other less common varieties. This is true with one exception, and that is in the case of a hornblendite which occurs sparingly in two localities, one on the west side of Franklin creek as a border basification adjoining a main contact, and the other as "schlieren" in the granodiorite west of the Beaver meadows. In the former case the hornblendite appears to have segregated and consolidated at the batholithic border. Then it apparently was shattered and injected by acidic magma (Plate X). In the southeast corner of the district angular inclusions of older rocks occur within the batholith.

Distribution.

The rocks of this group, as shown on the accompanying map, are well distributed throughout the area, but have by far their best development at the borders of the quadrangle. Here they show by their contact relations with the older formations that they are all parts of a single broadly dome-shaped batholith underlying the whole district. Erosion is rapidly stripping the batholithic cover rocks and laying bare more of the intruded granodiorite.

In some places, notably on McKinley mountain, apophyses appear to have been given off from the batholith into the overlying rocks, producing intense metamorphism. Aplite dykes are quite common cutting the granodiorite in the contact zones. The rocks composing this batholith are readily distinguished from the younger monzonites and syenites belonging to an alkalic group of Tertiary age which occur within the district. The latter are comparatively fresh, and do not show the broad metamorphic effects from having been subjected to great mountain making movements, as do the rocks of the batholith. Furthermore, the batholithic rocks are prevailingly light grey in colour and contrast sharply with the darker coloured Tertiary intrusives. The granodiorite rocks have been profoundly affected by younger invading intrusives, as shown by pneumatolytic action along fracture planes in the granodiorite, which has been the means of producing veins of green secondary epidote. The Tertiary intrusives, on the other hand, are rarely epidotized. The epidotized surfaces in the granodiorite preserve the freshest glacial striæ.

Structural Relations.

INTERNAL. The rocks composing the batholith have commonly yielded to differential pressures during mountain building periods by mashing and flowage producing gneissic structures. This is well illustrated in the northwest and southeast corners of the quadrangle, where the foliation strikes N. 30° W. This is the average trend for the folded and tilted rocks in the district. Where the granodiorite is embayed or surrounded by the more resistant greenstones and cherty quartzites of the Palæozoic series it has yielded to dynamic stresses, chiefly by brecciation and shearing without the production of gneissic structure.

It may be inferred from these facts that the batholith at the time of the main orogenic movement was in the zone of combined flowage and fracture. Those portions of the mass well within the batholith appear to have yielded most readily to the regional stresses by rock flowage producing gneiss, while those portions, isolated from the main mass and well within the resistant Palæozoic cover which was in the zone of fracture, appear to have yielded by brecciation and shearing. All parts now exposed were essentially at the same depth, so that the above effects are to be ascribed to differences in the character of the rock masses surrounding the granodiorite. The shearing of the granodiorite has been an important factor in its mineralization (page 172 Chapter VII, Economic Geology).

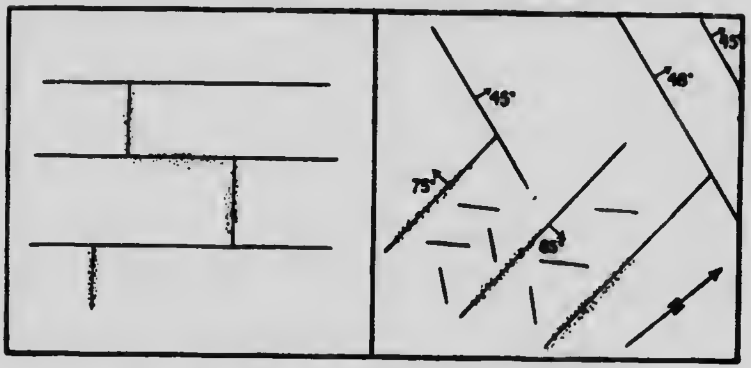

Figure 5. Jointing in Jurassic granodiorite.

Secondary structure within the batholith is present in the form of joint planes in two or three directions, the main set striking in a northwest and southeast direction with steep dips generally to the northeast or southwest. Older sets of jointing have been subsequently completely recemented, the cementation being accomplished by pneumatolytic action attending possibly the Tertiary igneous intrusions. The pneumatolytic action followed certain joint plane systems in the granodiorite, producing veins of pale green epidote 3 inches wide in some places. This feature is best seen in the granodiorite cover rocks on the concave side of the syenite chonolith (Figure 5).

EXTERNAL. *Relation to Older Formations.* Apophyses from the batholith have been intruded into the Palæozoic cover rocks, and both have subsequently undergone regional movement, resulting in local faulting of dykes, and metamorphism.

The rocks of the Franklin group, however, had already received their main folding before the invasion of the batholith and intrusion of apophyses. This is shown by the regular character of the contacts which dominantly plunge away from the main mass of granodiorite, towards the older cover rocks. The granodiorite contacts cut the older Palæozoic rocks irrespective of their structure, and display sharp well-defined boundaries, with nothing to indicate that they have been subjected to the mountain making movements that have folded and metamorphosed the older rocks.

The intrusion of tongues from the batholith and intense contact metamorphism of cover rocks probably took place at great depths, under considerable pressure or hydrostatic head afforded by the weight of a great thickness of superincumbent material.

The most intense contact metamorphism has taken place in the Gloucester marble formation, where by the expulsion of CO_2 and the substitution of SiO_2, the carbonates have altered to silicates, with formation of such minerals as garnet, epidote, tremolite, diopside, etc. This deep-seated contact metamorphism with wide aureole is in strong contrast to the contact metamorphism produced by granular rocks intruded close to the surface, which show intense action at the immediate contact, but do not affect rocks beyond a zone a few yards in width (page 80, syenite-shonkinite formation).

On the ridge west of Franklin creek occur small outliers of the Franklin group lying upon the batholith. They consist of altered eruptives whose contacts with the granodiorite are not always sharp and well defined, but when they are the contact surface appears as in Figure 14D.

Relation to Younger Formations. On McKinley mountain the early Tertiary rhyolite porphyries and conglomerate-grit formation are both found capping the granodiorite batholith. Such a relation shows that the ancient roof of the batholith must have been subjected to a period of pre-Tertiary denudation long enough to completely remove it and expose the underlying rocks.

The contact of the overlying Tertiary formation with the batholith is characterized by the presence of many pulaskite porphyry dykes. The pulaskite porphyry dykes are younger than both formations, and are found elsewhere in the district to cut all the formations with the exception of the lamprophyre dykes. They form in places irregular pinkish patches or veneer upon the upper surfaces of the batholith.

The contact of the granodiorite with the Tertiary monzonite lies beneath a drift-covered depression running north from the Royal Tinto property, but south of the Royal Tinto it could be observed, and the monzonite then appeared as a stock intrusive into the older granodiorite.

On the Mountain Lion claim, which adjoins the Gloucester on the west, a splendid exposure was studied of the contact between the Tertiary alkalic syenite and the Jurassic granodiorite. Contact metasomatism, with transfer of feldspar and development of secondary hornblende, extended for at least 10 feet from the actual contact, and was most intense next the syenite.

Below Little's property, on the east side of the east branch of North Fork of Kettle River valley, the granodiorite is cut by a lamprophyre dyke (augite microdiorite) as well as by many syenite porphyries.

On the Crystal Copper claim, a narrow short tongue from the underlying alkalic syenite intrusion has penetrated the granodiorite cover rock.

Mode of Origin.

The relations of the granodiorite body are such as to lead to the conclusion that it is a batholith which has reached the upper crust chiefly by means of the process of magmatic stoping, in which fragments of the roof have been broken away and the magma has passively risen to fill the places made vacant.

The significant features bearing on the above mode of origin of this batholith are itemized below.

(1) Wide areal distribution. The granodiorite mass has not only an extensive development within the district itself, but extends for miles in the surrounding country.

(2) The plunging character of its contacts with the older formations. Wherever exposed on steep valley slopes, the contacts of the granodiorite with the older formations always plunge away from the main granitic mass and towards the older invaded formations, indicating the downward enlargement of the igneous body.

(3) The entire lack of sympathy between structural planes in the invaded formation and the form of the intrusive body as exhibited in both Franklin and Kettle valleys.

(4) The presence of isolated roof remnants of the Palæozoic rocks within the granodiorite west of Franklin creek.

(5) The general high degree of homogeneity in composition and texture of the rocks composing the intrusions.

(6) The occurrence on McKinley mountain of long and narrow apophyses from the mass, indicating, as Daly[1] points out, high liquidity at time of intrusion.

(7) The abundance of angular inclusions near the contacts, and freedom from them in the interior. The fact that the batholith was liquid enough and had sufficient hydrostatic head to inject apophyses into the overlying cover rocks, as it did at McKinley mine, with production of intense contact metamorphism, would seem to indicate that the intrusion took place against a heavy load of superincumbent strata, and that connexion with the surface was not readily established. No lavas have yet been found referable to the Nelson granodiorite. The cover, however, was above the zone of deep-seated metamorphism or rock flowage, as indicated by the structure of the rocks and the entire lack of injection phenomena near the main contacts.

The objections to a laccolithic origin for this batholith are: (1) the contact surfaces of the batholith cut across the bedding planes of the invaded formation, and do not conform to them as in the case of the simple laccolithic intrusion; (2) there is no

[1]Daly (R. A.): The Mechanics of Igneous Intrusion. Amer. Jour. of Sci. (4), Vol. XV, pp. 269-298, Vol. XVI, pp. 107-126 (1903).

evidence of a bottom surface to the granodiorite mass, nor of splitting of invaded formation, as would be expected if it had been intruded with production of parting of cover from the bottom and a lifting of the cover.

The marginal assimilation hypothesis is further debarred because the contacts are in all cases sharp and distinct and cut at all angles across both sedimentary and eruptive formations, which would not be the case if assimilation at margins had taken place.

If the granitic intrusion were due to mere active intrusion on the part of the batholith, it would be expected to conform to the structure of the overlying formations, which it does not.

Age and Correlation.

The relative age of the batholith is known, in that it is younger than the mountain making movements which closely folded the Franklin and Gloucester formations, and which probably took place at the close of the Palæozoic period. On the other hand, it is older than the early Tertiary conglomerate. This limits the age of this formation to the Mesozoic. It is known from its contact relations with the younger conglomerate and grit formations—which, as has been noted, lie directly upon the granodiorite on McKinley mountain and elsewhere—that a long period of erosion took place after its intrusion and before the beginning of Tertiary time. Although the former thickness of the batholithic cover is not definitely known, the broad exposure of the granodiorite by erosion during this interval suggests that its invasion is to be correlated with the Jurassic intrusions rather than later.

On the West Kootenay map sheet[1] the Franklin granodiorite is mapped as part of the Nelson granite, which is there referred to the post-Jurassic. The same batholith extends southward to between Christina lake and Grank Forks, where it is more gneissic in structure; and it has been described by R. A. Daly,[2] who states that it is structurally and genetically a

[1]Geol. Surv. Canada, Map Sheet No. 792.

[2]Daly (R. A.): Rept. of Chief Astronomer, Dept. of Interior, 1906.

parallel to the Remnell and Osoyoos granodiorite batholiths of the Okanagan country,[1] which he refers to the Jurassic. It seems safe, then, to refer the Franklin granodiorite batholith to the Jurassic, which correlates it with many other similar batholithic bodies throughout the Cordillera.

EOCENE-OLIGOCENE.

Kettle River Formation.

General Statement.

The Kettle River formation of Franklin has preserved, through the character of its sediments and contemporaneous lavas, so widely distributed throughout the district, a rather complete record of early Tertiary conditions in this section of the Columbia mountains.

Distribution.

Protective lava cappings are largely the cause of the splendid preservation of the remnants of a once more extensive formation, which, as will be shown later, is of continental origin. It extends in a broad belt running northeast and southwest from Tenderloin mountain to McKinley mountain, and reaches from the mountain summits down to the valley bottom, where it fills old valley bottoms even deeper than those of the present day. The formation has been stripped for at least 2 miles to the west, leaving bare the Miocene syenite and shonkinite-pyroxenite, whose cover rock it was at the time of alkalic intrusions.

Thickness.

The Kettle River formation is much thinner in some parts of the district than in others. The maximum development appears to be in the vicinity of the junction of Franklin creek

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[1] Daly (R. A.): The Okanagan Batholith of the Cascade Mountain System: Bull. Geol. Soc. of Am., Vol. XVII, July 1906, pp. 329-376.

with the East Branch, where the creek has exposed to view about 100 feet of conglomerate. This represents only the basal portion, however, of a once more extensive and thick formation. On Franklin mountain the lava caps about 500 feet of grit and conglomerate. The differences in thicknesses are due in part to irregularity of original deposition, but chiefly to subsequent erosional effects and the positions of old Tertiary drainage courses.

Structure.

The formation has been affected by more pronounced folding and tilting than that affecting the volcanic rocks capping them. The causal stresses appear to have been in some cases local, for in one exposure the strata are found horizontal while in others they are steeply inclined. The prevailing dip of the formation, however, averages about 45 degrees to the northeast. The original dips probably varied from 30 degrees in the coarsest material to inappreciable dips for finer sediments. The sediments have apparently undergone considerable tilting and deformation followed by a period of erosion before the trachytic lavas were poured out. This is indicated by a well pronounced unconformity between the two formations. Faulted pebbles from the Kettle River formation, composed of Franklin group greenstones, are seen in the accompanying photograph (Plate XI A). Many pebbles over a large area in the conglomerate are thus broken, showing that the effect of the force was distributed throughout the mass of the rock.[1] Local faults of small throw, both normal and reverse, are present (Figure 6) in the grits and silts of the Kettle River formation, especially in the vicinity of the younger alkalic intrusions.

Condition of Deposition.

In order to arrive at a conclusion as to the origin and mode of deposition of the early Tertiary sediments, the field facts will be first considered briefly.

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[1]Diller (J. S.): Educational Series of Rock Specimens: U.S. Geol. Surv. 1893, p. 316. (Describes faulted pebbles from Siskiyou mountain in northern California.)

The arkosic grits and finer conglomerates of the formation are of white and grey colours, and are composed in large part of limpid quartz and fresh feldspar that shows very little attrition or signs of sifting water action. They are essentially rhyolitic grits in many places and occur intercalated with rhyolite

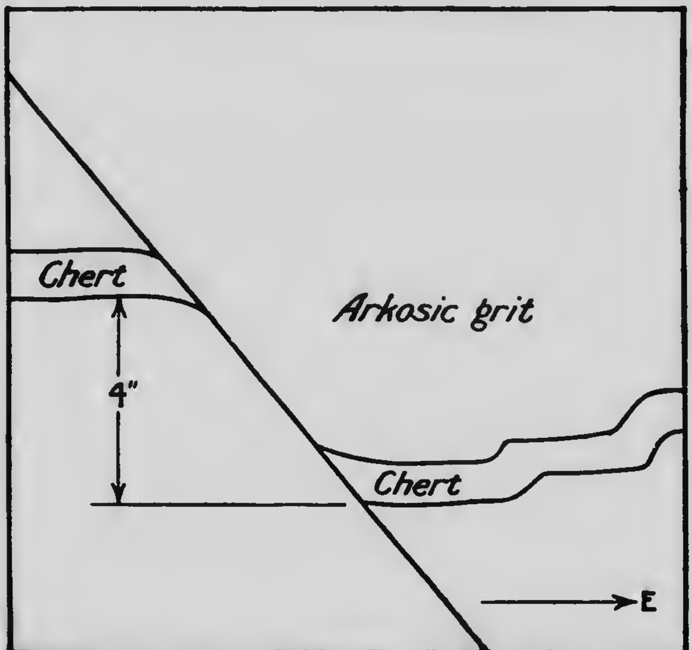

Figure 6. Normal fault with small throw, below post-Oligocene erosion surface on Tenderloin mountain and to west of main fault (Vertical section).

flows (Plate XI B). Cross-bedding, current markings, and rarely, ripple marks are to be seen in many exposures. The finer grained arenaceous and tufaceous portions contain obscure plant remains in one locality. The coarser phase contains well water-worn fragments of the more resistant older rocks, and passes in places into a very coarse heterogeneous conglomerate, made up of well-rounded to subangular boulders up to 2 feet and more in diameter, embedded in a firm compact cement.

The exposure shows traces of rude stratification in places. It contains imperfectly decomposed and incompletely leached sediments, such as light to dark impure limestones, argillites, and conglomerates. The boulders are chiefly of sedimentary and metamorphic rocks, with a very small proportion of grey granite. No Valhalla granite nor alkalic rocks, so common now in the district, were found in it. Very few pebbles of vein quartz are present, indicating no thorough decomposition of an ancient soil, but some well-rounded boulders, with thick weathered rims and oxidized surface skins, may represent boulders from older conglomerate formations. A subangular boulder 2 feet in diameter, within the conglomerate near the bridge over Franklin creek, showed striations and scourings that very closely resemble glacial work. Pebbles and boulders, some of which are soled from other parts of the same formation, also show similar effects. The photograph (Plate XI A) shows the facetted and striated character of some of these subangular pebbles. In comparing some of the larger glacial-like pebbles from the Kettle River formation in Franklin with local tillite in the vicinity of New Haven, Connecticut, a great similarity was noted. The pebbles from the local tillite, however, did not have as great a proportion of well developed concave surfaces as did those from the Kettle River formation. Comparative studies of tillite of Alpine glacial origin and that of continental ice sheet origin would aid considerably in the solution of such problems in sedimentation. The Franklin district lies well within the Gold Range of Dawson[1] (a unit of the Columbia Mountain system), which is considered by him to have been one of the main axes of elevation in the Canadian Cordillera.

From the field facts here stated it is inferred that the topography of the period following the great Laramide Revolution was of a decidedly rugged and Alpine character; that Franklin then as now occupied a tectonic trough or depression between the Cariboo and Granite ranges; and that the latter ranges were composed in large part of highly folded and broken sedimentary and metamorphic rocks.

The climate was probably humid and cool, as indicated by

[1]Dawson (G. M.): Bull. Geol. Soc. of Am., XII, p. 61.

the white leached sediments and grey colours with presence of carbonaceous shales containing plant remains.[1]

The coarse conglomerates were mainly deposited in alluvial cones about the margins of the basin. The material was swept down on steep slopes from the rugged summits, where rock breaking and disintegration through frost and water action progressed with great rapidity and dominated over rock decay. The mountain slopes were probably too steep to support vegetation and thus unfavourable to the accumulation of humus in the soil to accomplish rock decay. On steep mountain slopes rapidity of mechanical work obscures rock decay, even if it does go on. The rocks on the summits possibly in the vicinity of snow and ice, would be chilled below the freezing point at night and raised above the melting point during the day. Such rapid alterations form a most efficient means of breaking up solid rock. Under such climatic and physiographic conditions as have been inferred it would not be surprising to find that Alpine glaciers existed and supplied their quota of material to the basin below, which would thus explain the glaciated character of some of the boulders and pebbles in the coarse heterogeneous phase of the conglomerate.

In the basin itself a drainage system was in course of development, but owing to contemporaneous flows of rhyolite and deposition of acidic tuffs from the nearby McKinley volcanic vent, the drainage, as shown by the erratic nature of the sediments, was in a decidedly disorganized condition. For considerable intervals some areas were marshes and lakes in which acidic tuffs were deposited in evenly stratified beds. In the vicinity of these marshes or flood-plains vegetation flourished. The rhyolite flows contributed very largely to the early Tertiary sediments.

On the west slope of Tenderloin mountain is exposed a bed, 4 feet thick between bedding planes, of even-grained arkose with a few large scattered pebbles of argillite and quartzite mixed in, which would seem to indicate very rapid sedimentation by turbulent waters, or possibly stones dropped by floating

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

ice or trees. The variable texture of the formation in many places would indicate restricted or rapidly changing conditions of sedimentation. Current markings and stream bedding on the east slope of Franklin mountain, and also at the base of Tenderloin mountain, indicate that the course of the early Tertiary drainage was west of south.

Correlation.

The Kettle River formation of the Franklin district may possibly be correlated with the Coldwater group (Oligocene?) of Dr. G. M. Dawson[1] lying farther to the west and south, and many scattered localities throughout the Boundary district.[2]

Lithologically the Phoenix arkosic grits and tuffs are the same as those from Franklin, but the formation there lacks the very coarse heterogeneous conglomerate phase of the latter more mountainous region. There, too, they antedate the period of main volcanic eruptions, and appear to have been locally upturned and denuded before the Miocene period. It is with some doubt that they have been referred to the Oligocene.

The age assignment and correlation of the early Tertiary formations of southern British Columbia have been based chiefly on palæobotanical evidence, and physiographic evidence such as is present in the Franklin district has been entirely neglected. There is a great paucity of organic remains in this formation, possibly because of the volcanic nature of the materials composing it, and this is true in many other districts. This fact, along with the isolated positions of the known fossiliferous localities, makes it a difficult matter to construct a satisfactory and connected section of the Tertiary formations of British Columbia.

Dr. D. P. Penhallow has recently (1908)[3] made a detailed study of the plants from the various localities, collected by G.

[1]Dawson (G. M.): Rept. on Kamloops Map Sheet, Ann. Rept. G.S.C., Pt. B, Vol. VII, pp. 68-71 B.

[2]LeRoy (O. E.): Summary Rept. Phoenix Camp G.S.C., 1906, p. 67. Boundary Creek Map Sheet No. 828.

[3]Penhallow (D. P.): Rept. on Tertiary Plants of British Columbia. Geol. Surv. Canada, 1908.

M. Dawson and Daly (1903-1905) and by Lambe (1906). In this report the localities are spoken of as being a series of lakes, many of them small and often widely separated from the main formation, which is very irregular in outline. Penhallow concludes from rather unsatisfactory and limited plant evidence that the Kamloops beds (Coldwater group), which resemble lithologically the Kettle River formation of Franklin, belong probably to the Oligocene, certainly not higher, *possibly lower*. For the Quesnel beds, from his analysis of the plant specimens present, he concludes Eocene, with a strong tendency to Laramie. The Tranquille beds, which are distinct from the Coldwater group as shown by Dawson in the Kamloops district, he "assigns to the lower Miocene provisionally."

The Kettle River formation in Franklin will be tentatively referred to the Eocene-Oligocene period between the Laramide revolution and the time of crustal disturbances followed by the erosion cycle which preceded the great Miocene volcanic period, as shown by the unconformity in the Franklin district between the two Tertiary formations.

Early Tertiary Rhyolite Flows and Tuffs.

General Statement.

Rhyolite flows preceded by acidic tuffs, took place contemporaneously with and subsequently to the deposition of the Kettle River formation. The remnants of once extensive flows now occupy small areas following, chiefly, old Tertiary river courses. The glassy quartz and fresh feldspar so common in the arkosic grits of the Kettle River formation were probably derived from them, and in some places it is difficult to draw the exact line between the arkose and the rhyolite itself, on account of the blending of the one into the other. Where the rhyolite has poured out on the sticky silty bed of a lake or flood-plain the contacts are clear (Plate XI B). In the case shown in the photograph, gravity has been overcome in part by the viscosity of the magma, and the silt is in the process of being taken up by the lava. Throughout the rhyolite, cherty inclusions are frequently found.

Somewhat analagous conditions have been reported from beds of the same age in the Republic district, Washington,[1] where dacite flows have taken up conglomerate boulders and enclosed them. The formation is known as the dacite conglomerate.

Distribution.

The greatest thickness of rhyolite and rhyolite porphyry occurs as a capping on McKinley mountain, where it forms bluffs and almost perpendicular escarpments, as above the McKinley mine. Isolated erosion remnants of the youngest rhyolite flows in the district occur scattered on the summit to the west of the main capping. A continuation of probably the same flow was found on Franklin mountain, where it is capped by the younger trachyte. These represent the basal portions of once extensive rhyolite flows which filled up an old valley with a comparatively thin deposit of conglomerate and grit in it. At a period immediately preceding the volcanic eruptions of rhyolite, the accumulations of gravel were not deep on McKinley mountain west of the main drainage channel, and the rhyolite is even found resting directly upon the Jurassic granodiorite.

Structural Relations.

The rhyolite displays flow (or fluxion) and banded structures in places, due probably to the different proportions of water contained in the different parts of the molten lava which were drawn out in the direction of the flow. Inclusions of chert are found in the rhyolite and rhyolite porphyries, and were probably taken up in the lava in the manner shown in the photograph (Plate XI B) of a specimen from near the base of the formation near Franklin creek. The viscosity of the lava has apparently partly overcome gravitational influence and has forced up the probably moist sticky skin of silt along certain lines, attenuating it between ridges, and is in the process of drawing it up and

[1]Umpleby (J. B.): Wash. State Surv. Bull. No. 1, p. 20.

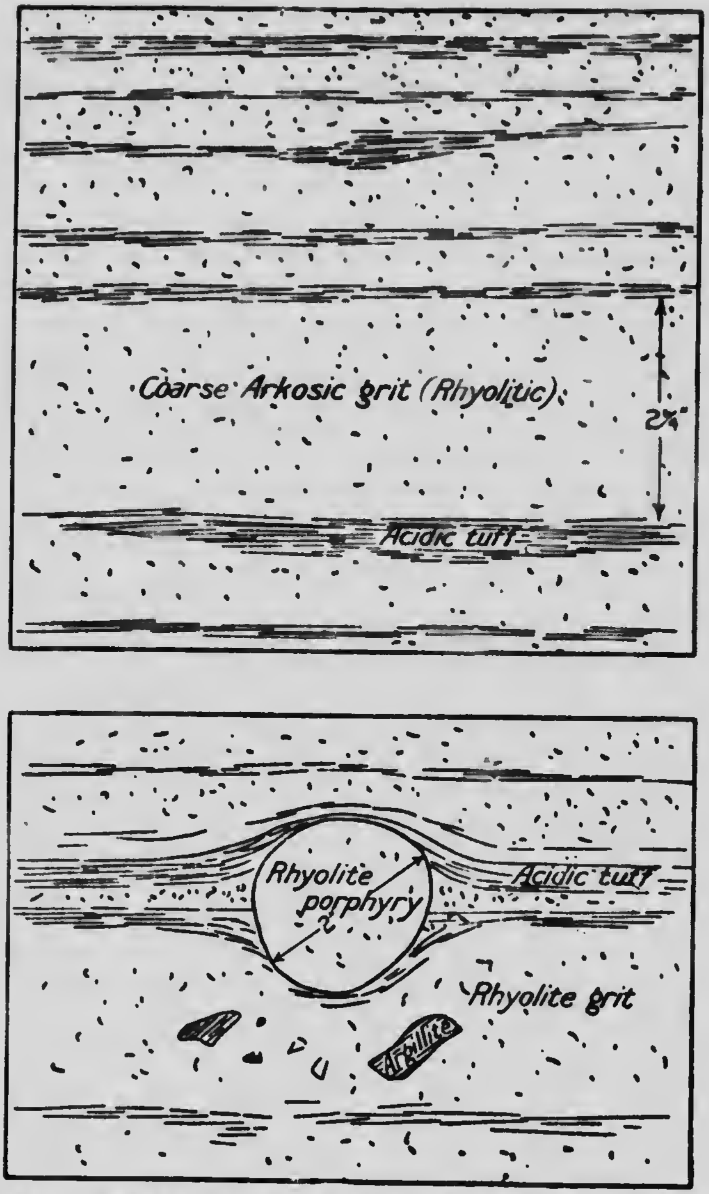


Figure 7. Illustrative of character of sedimentation in a portion of Kettle River formation (Eocene-Oligocene); northeast of Maple Leaf claim.

including it. Emerson[1] mentions trap sheets in New Jersey being poured out over muddy bottoms with somewhat similar results. He writes that "the heat produced strong upward convection currents and correspondingly strong indraught from the sides which carried muddy waters out over the surface of the trap while it was still flowing and covered it with a quantity of calcareous mud." However, in this case the rhyolite lava was probably too viscous for convection currents to operate.

The rhyolites are vesicular in places, having elongated gas cavities 1½ inches in length, as observed near the underlying grit contact. Variations in texture from rhyolite to quartz porphyry (rhyolite porphyry) take place transitionally on McKinley mountain. The curved character of the jointing in the rhyolite porphyry may be well seen, exposed in the McKinley Creek gap above the McKinley mine. The border of a rhyolite remnant on McKinley mountain displayed also curved jointing as well as a unique type of joint structure (Figure 8) not observed elsewhere.

The exothermal effects of the rhyolite upon the conglomerate and grit are obscured on McKinley mountain, owing to subsequent intrusions of pulaskite and pulaskite porphyry dykes near the contact. At the eastern border of the main rhyolite porphyry remnant, volcanic agglomerate composed of rhyolite porphyry was found below the flow itself, in the conglomerate-grit formation. The fragments vary in character and size from place to place, and show no stratification nor definite arrangement of the ejectamenta. They have evidently worked their way down into the unconsolidated conglomerate.

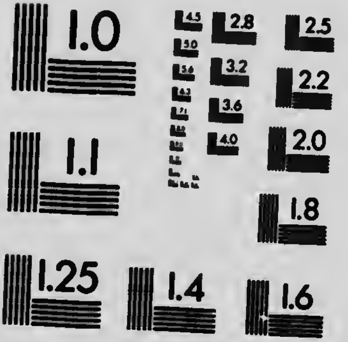
Mode of Origin.

The presence of considerable evenly bedded, water-laid acidic tuff near the base of the Kettle River formation, with occasional large pieces of rhyolite lava scattered at random in the arkosic grits and conglomerate (Figure 7), indicate that the rhyolite flows were preceded by explosive outbursts of coarser

[1] Emerson (B. K.): Bull. Geol. Soc. Am., Vol. VIII, pp. 59-86, Plates 3-9, 1899.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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fragments and volcanic dust that settled down in the basin marshes and flood-plains. Here it became worked over by the erratic drainage system, as has been shown to have existed in the basin at this time, due to the constant shifting of river courses by contemporaneous volcanic activity.

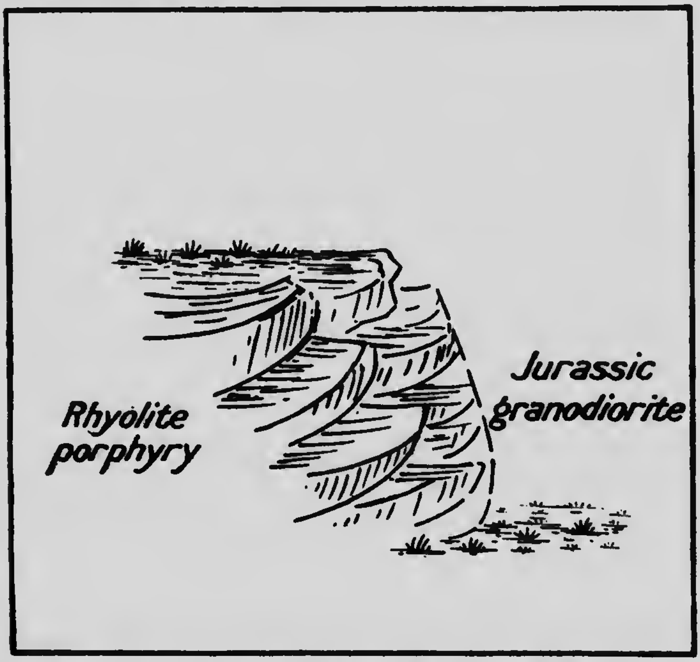

Figure 8. Character of jointing at border of early Tertiary rhyolite porphyry remnant lying flat upon Jurassic granodiorite, west of main flow on McKinley mountain.

The location of the vent or vents from which these eruptions took place is rather difficult to conjecture. Certainly from the lack of attrition and fresh appearance of the mineral constituents of the grit, it would appear that the source of supply was not far distant. The vents were in all probability confined to the valley or basin and not to the enclosing sedimentary mountain ranges, for no rhyolite boulders or pebbles were found in the conglomerate of the alluvial cones, as one would expect if the vents had been on the summits or outer slopes. On the other hand, the fluviatile material confined to the intermont basin is made up in large part of rhyolitic arkose. The eruption of lavas in the early Tertiary, as will be seen also in the case of the trachytic lavas of the Miocene, appears to have followed intermont troughs and not the high mountain ranges (page 140, Petrology).

The great thickness, coarse texture, topographic relief, agglomerate base, thinning out of flow northward on Franklin mountain, have all been noted in the case of the McKinley rhyolite porphyry capping, and point towards the likelihood of its having been the original volcanic vent and source of volcanic products in early Tertiary time. The rigidity it has shown also to the pre-Miocene orogenic disturbances, as well as the finding of no other likely vents elsewhere, either within or without the district, points strongly towards such an inference.

The massive flows, being viscous, did not extend far from their vents. Some of the tuffs may have been carried down in part by the streams as mud flows, deriving their contents from masses of volcanic ash accumulated near the vent, but the light grey ashes so common near the base of the formation were probably rapidly deposited as dust showers from the volcano, and may have been worked over by the streams during quiescent periods.

Subsequent to the eruption of rhyolite flows and contemporaneous deposition of sediments, crustal movement affecting certain north-northwest and south-southeast lines, disturbed and tilted all the sediments and flows to the northeast-east, but the McKinley Mountain mass preserved to a great extent its original attitude. This disturbance was followed by a long period of erosion represented in the unconformity exposed on all three mountains.

Age and Correlation.

The proof of the contemporaneity of the rhyolite with the conglomerate and grit lies: (1) in the manner in which they were interkalated one with the other, never cutting across the bedding planes of the formation; (2) in the similar mineralogic composition of the arkosic grit and the rhyolite, both of which contain the same limpid quartz and fresh feldspar; (3) in the finding of rhyolite agglomerate well within the conglomerate-grit formation on McKinley mountain below the main and younger rhyolite flow; and (4) the finding of acidic tuffs in the basal members of the Kettle River formation, which represent chiefly the light dust or ash into which the molten lava was blown by the violent volcanic explosions preceding the outflow of lavas. These showers of ashes were probably accompanied by torrents of rain, due to the condensing vapours (example, Pompeii eruption), but such rain falling on volcanic ashes, tuffs, and lavas, would quickly be lost or absorbed.

The presence of a marked unconformity between the early Tertiary formation and the Miocene volcanic series represents an erosion period in which much of the early Tertiary record was stripped off.

It is probable that the rhyolite eruptions may be connected with the intrusion of the Valhalla quartzose granite (page 103, Chapter V), of post-Cretaceous age, which forms the Cariboo range to the west and whose mineral composition resembles closely that of the rhyolite.

OLIGOCENE.

Monzonite Stocks.

General Statement.

This is a medium to coarse granular rock of a greyish black colour, with dark pyroxenes scattered through the light coloured feldspathic constituents, the contrast between the two giving the rock a mottled appearance. It occurs in two stock-like masses, one in the northwest and the other in the northeast corner of the district, and is always closely related structurally and mineralogically to the alkalic rocks which it preceded.

Structural Relation.

Internal. The texture and composition of the formation remain very constant throughout the mass, and what little variation there is tends to produce a rock more ferric, but never more salic than the type. This is in marked contrast to the younger intrusion, which reached to the surface and shows striking differentiation.

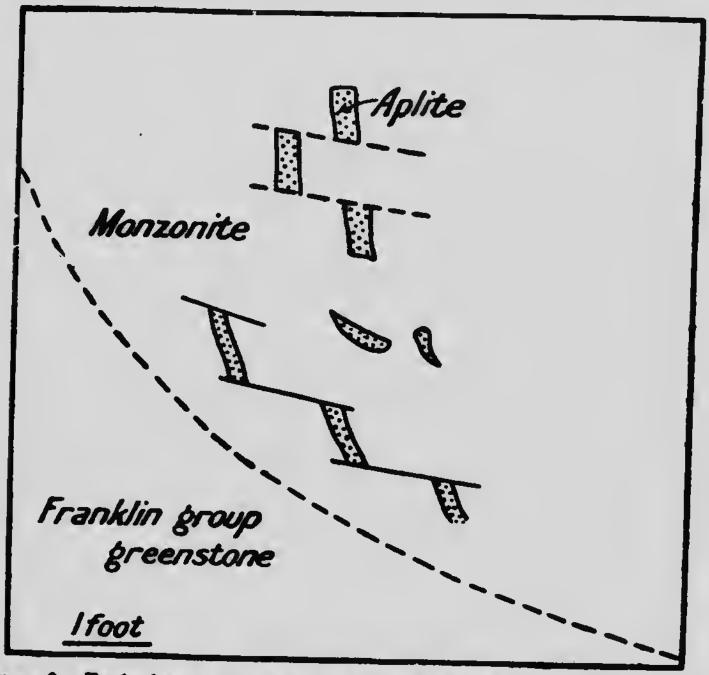

Figure 9. Faulted aplite dykes in monzonite at base of Tenderloin mountain. (In plan).

The monzonite is cut by aplite dykes which are faulted in places (Figure 9). More frequently, however, it is cut by systems of pulaskite porpyhry dykes, as in the northwest corner of the map-area. The Tenderloin monzonite stock is cut at its western extremity by an irregular intrusion of micromonzonite (page 105, Petrology). In two localities near the Royal Tinto claim, which is situated on the concave side of the syenite intrusion, the monzonite is cut by [illegible]w tongues (page 117, Petrology) from the syenite which underlies it.

In some places the monzonite is sheared and slightly brecciated, and in such zones mineralization by sulphides and magnetite has ensued (page 175, Royal Tinto claim). The production of the shearing and intrusion of syenite apophyses was in all probability connected with the chonolithic intrusion. The monzonite as a whole is much fresher and does not show the effects of regional dynamic metamorphism as does the Jurassic granodiorite.

EXTERNAL. *Relations to Older Formations.* The contact between the granodiorite and the monzonite, although in the majority of cases in drift covered depressions, was found near the Royal Tinto property to be sharp, with little variation in the monzonite, but the granodiorite had developed a strongly micaceous phase. The Palæozoics, where exposed in contact with the monzonite, showed practically no variation from their normal metamorphic condition.

Relations to Younger Formations. The Tenderloin monzonite stock was found to be capped by conglomerate and grit in places, the former lying loosely as erosion remnants, often too small to map, while the grit was indurated. This induration could hardly be due to the syenite intrusion, for the occurrence is over a quarter of a mile from the syenite chonolith. The syenite of Tenderloin mountain, as shown by its contact relations to the topography, is almost vertical, and the contact aureole it has produced is limited to within 50 feet of the main contact with the Kettle River formation. It is thought, then, that the monzonite reached the Kettle River formation at a time prior to the post-Oligocene erosion cycle, which carried away great thicknesses of superincumbent Kettle River formation. The contacts between the younger alkalic intrusives and the monzonite are always sharp, with no evidence of welding, indicating a hiatus between the two intrusions long enough for the latter to become thoroughly consolidated.

Mode of Origin.

Contact relations of the monzonite with the older formations, which point towards downward enlargement of the mass, indicate its intrusive nature, and, considering the size and shape of the body, homogeneity in texture, and mineral composition, it in all probability solidified under a thick cover of Tertiary formations. No evidence of a laccolithic origin or of an outlet to the surface is present, and it is assumed that the intrusions are in the form of irregular stocks or small bosses which may unite below to form a larger intrusive mass.

Age and Correlation.

The monzonite is younger than both the Jurassic granodiorite and the Kettle River formations. It is much older than the Miocene alkalic intrusives, as shown by sharp, non-welded contacts. This limits its age to an interval between the Eocene and the Miocene. Igneous intrusion in this section of the Cordillera has been frequently associated with deformative movements of the crust. Assuming this generalization, which may be true only to a limited extent and not of world wide application, the monzonite will here be referred to the period of crustal disturbances which inaugurated the post-Oligocene erosion cycle. The monzonite consolidated under a much greater superincumbent load of Tertiary continental deposits than did the younger alkalic intrusives, and there is no evidence to show that it had access to the surface. Monzonites of a somewhat similar lithologic and geologic character occur at Rossland, B.C., where they have been tentatively referred to the post-Jurassic.[1]

The Franklin monzonite is hypabyssal in the sense that it has reached nearer the surface than the deep seated Jurassic granodiorite. It is always intimately associated with and intruded by the younger alkalic intrusives. The pale green diopside, so characteristic of the younger augite syenite and pyroxenite, and entirely absent from the granodiorite, is present in the monzonite as an essential constituent. The accompanying photograph (Plate XII) shows the megascopic resemblance between the monzonite and the much younger augite syenite. The latter can always be readily distinguished, however, by the

[1]Brock (R. W.): Prel. Rept. on Rossland, B. C., Can. Geol. Surv., 1906. West Kootenay Map Sheet No. 792, 1904.

trachytic structure of its feldspars. Both on account of its geologic and mineralogic relations to the younger alkalic series, the monzonite is considered to be co-magmatically related to them, but naturally not so highly differentiated as they are, on account of the monzonite's less alkalic nature and because it did not reach the surface to form lava flows and thus promote differentiation—a process discussed in Chapter V, Petrology.

MIOCENE.

Alkalic Intrusives.

General Statement.

The alkalic intrusives will be considered as three distinct units, in order of age: (1) porphyritic syenite, (2) shonkinite pyroxenite, (3) augite syenite. The last two were intruded almost simultaneously.

Porphyritic Syenite Chonoliths. [1]

The porphyritic syenite forms comparatively small, irregular shaped intrusions on both sides of Franklin creek, and is less alkalic than the younger types. The three main occurrences are: (1) on the west flank of Franklin mountain intrusive into the "Lime dyke;" (2) on Syenite hill near the west border of the district; and (3) a small crescentic shaped outcrop on the ridge west of Franklin creek, whose concave side points towards Syenite hill.

It is characterized by the long elongated feldspar laths, showing often fluidal arrangement parallel, in a broad way, to the main contacts. On Syenite hill the unstriated feldspar laths are 2 inches and more in length, and have borders of a lighter coloured feldspar which is a plagioclase. The crystals in places radiate from one centre, as seen in the photograph (Plate XIII). This feature may possibly indicate stagnant conditions in the magma at the time of crystallization.

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[1] Daly (R. A.): Classification of Igneous Intrusive Bodies; Jour. of Geol. (1905), Vol. XIII, p. 485.

Microscopic study has shown that this rock is very probably the intrusive equivalent of the oldest trachytic flow on McKinley mountain. Both intrusive and extrusive show the tendency towards radial or starry grouping of the feldspars. The crescentic shaped outcrop farther north, as well as the long narrow outcrop crossed by the Banner trail, is probably an offshoot from the same intratelluric parent magma which supplied Syenite hill and the effusive trachytes. The porphyritic syenite is less alkalic than the younger syenite, and shonkinite-pyroxenite intrusives, in that it contains some accessory quartz and considerable microperthite.

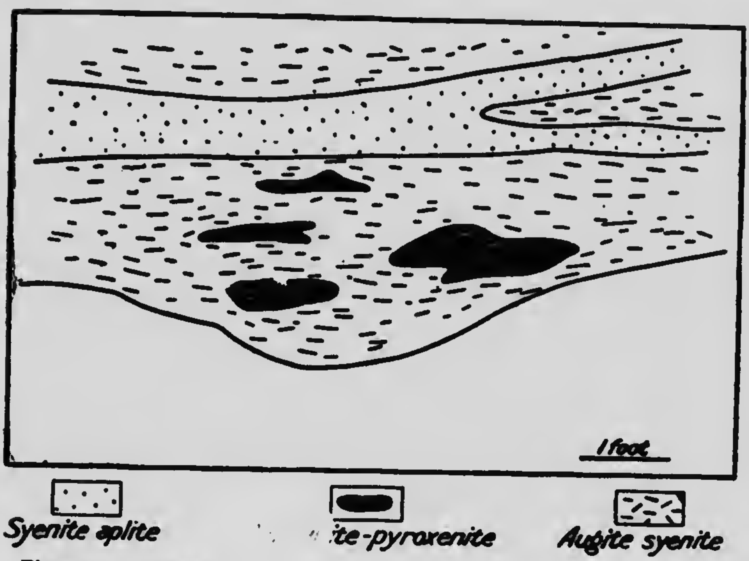

Figure 10. Endog... ns of shonkinite-pyroxenite within augite ...r Royal Tinto property.

Shonkinite-Pyroxenite.

This is a marginal phase of the augite syenite chonolith. This black differentiate from the augite syenite which has, in places, large augite phenocrysts up to 1 inch in length scattered through a general groundmass of pyroxene with interstitial fillings of alkalic feldspar, is locally known as the "Black Lead." It occurs chiefly at the margins of the syenite intrusion, although this is not always the case. On the Averill property in the northwest corner of the quadrangle, as well as on the Maple Leaf property above Gloucester City, the "Black Lead" or shonkinite-pyroxenite is surrounded by syenite (Figure 10). In many places the augite syenite was seen to pass rapidly into the shonkinite-pyroxenite (page 137, Petrology, Chapter V). At a contact, however, exposed in a shaft on the Averill property, the shonkinite-pyroxenite appears to have been shattered and injected with syenite aplite material. The accompanying photograph (Plate XIV) shows the sharp contact and contrast between the two extremes of differentiation.

The distribution of the "Black Lead" is indicated on the geological map. It has been opened up by numerous prospect pits and tunnels.

Augite Syenite Chonolith.

The augite syenite can always be readily distinguished by the characteristic trachytoid structure of its feldspar laths (Petrology, page 105, for details). This irregular shaped intrusion is distributed over the north half of the map-area, and extends from the northwest corner southward and eastward to the base of Tenderloin mountain, forming a broad arc concave to the northeast, with a general dip in that direction.

STRUCTURAL RELATIONS. *Internal.* The main endothermal features in connexion with this formation are: (1) the presence of endogenous inclusions and "schlieren" of shonkinite-pyroxenite within it; (2) the local variation in texture and composition of the mass from place to place, as, for instance, from nephelinitic syenite to melanite syenite; and (3) the injection by syenite aplites, of the contacts between the pyroxenite and syenite. Inclusions of monzonite were found in the syenite.

External. The syenite shows intense contact metamorphic effects upon all the older formations, but this is confined to the immediate contact. The width of contact zone or contact aureole depends directly upon the character of the country rock which is intruded by the syenite.

In the case of the Franklin group tuff and greenstone, the metamorphic effect was found to extend only a few feet. The accompanying field sketch (Figure 11) illustrates the character of the contact. For at least 15 feet in places, the country rock is saturated with secondary hornblende, but certain portions of the wall rock were less affected, as shown in the sketch.

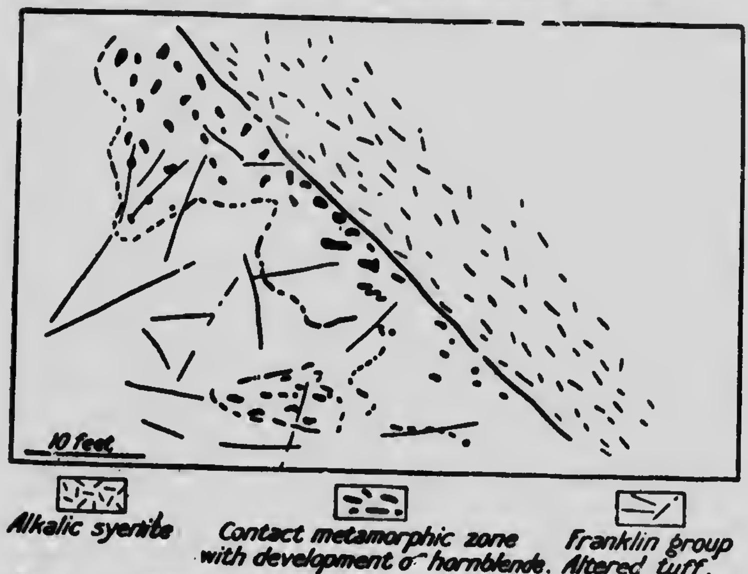

Figure 11. Contact between alkalic syenite and Franklin group altered tuff, near Maple Leaf claim. Shows irregular contact metamorphic zone.

Where the Jurassic granodiorite is in contact with the syenite, the metamorphic aureole extends for at least 10 feet from the actual contact, as shown by the transfer of feldspathic material to that distance, enriching the granodiorite in alkalies. The most intense action, as usual, at the immediate contact.

The monzonite in places has a slightly more biotitic aspect in contact with the syenite, but otherwise it varies little from the normal type.

The most intense contact metamorphic effects with widest metamorphic aureole, are to be seen on the east side of the

Kettle river, where the syenite is in contact with and intrusive into conglomerate and fine grit which was unconsolidated at the time of the intrusion. Figure 12 shows crenulation in the Kettle River banded chert near the augite syenite contact. Microscopic studies of the Kettle River formation in contact with the capping trachytic extrusives (effusive equivalent of the same syenite) showed that the pyroclastic trachyte penetrated for

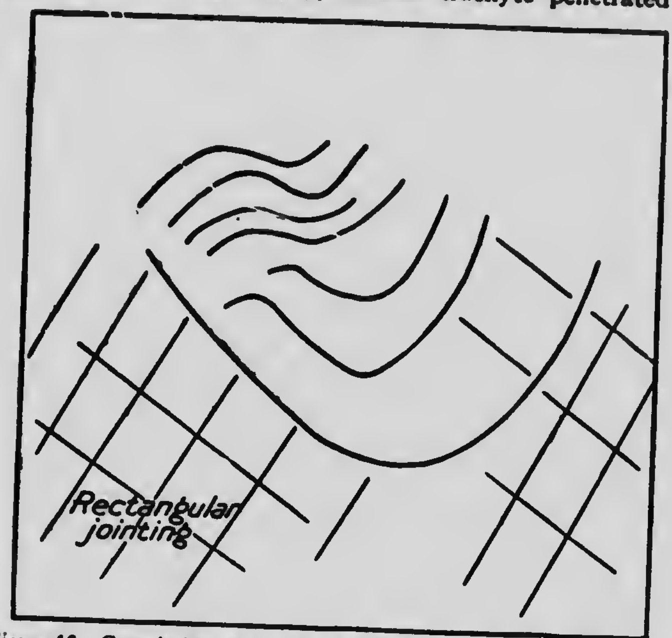

Figure 12. Crenulation in Kettle River banded chert nea · augite syenite contact; east side of Kettle river.

at least 5 feet down into the grit. No trachytes occur in the Kettle River formation except in this locality. There the syenite has permeated and saturated the conglomerate and fine grit for at least 50 feet from the main contact. Metasomatic replacement is indicated by the preservation of original structure of both conglomerate and silt. Pseudomorphs of syenite after the more permeable pebbles and matrix occur The fine silt, a little farther from the contact, has been i... ...ted to a dense brittle chert. The indurating effect of metasomatic replacement upon the Kettle River conglomerate is well illustrated by the accompanying photograph (Plate XV, cf. Plate IX, of the same formation in unaltered condition). The matrix, instead of the boulders, stands out in relief on weathered surfaces. The rounded boulders and pebbles that have been replaced present rough surfaces (Plate XI A). In some of the replaced boulders, titanite and a little chalcopyrite were found.

The quartzites and quartz pebbles show the least alteration, but the former, on close examination with a pocket lens, shows the presence of minute alkalic feldspars with characteristic trachytic structure. As already noted, the alkalic rocks are conspicuous by their absence in the Kettle River formation.

The silty and fine-grained grits, some 30 feet from the syenite contact, are metamorphosed to dense cherts, whose original bedding planes are well preserved and show minute faulting in places. The chert breaks with a sharp conchoidal fracture which never follows the original bedding planes.

This is the first case, to the writer's knowledge, of an intrusive granular rock having been found in contact with what was an unconsolidated gravel and sandstone formation at the time of intrusion.

Similar metasomatic contact metamorphism was noted on Franklin mountain between the same formations (Plate XVI). Below the Maple Leaf property on Franklin mountain, the alkalic syenite has bowed up its cover of conglomerate and grit, which has been subsequently largely stripped off. The evidence of bowing-up is present in the disturbed structure of the grit formation. Here local normal and reverse faults of slight throw are present, as shown in field sketch (Figure 6). The faulting is probably due to a slight subsidence of cover following the bowing up and consolidation of the syenite.

On Franklin mountain, above the Maple Leaf property, the trachyte is found very nearly in contact with the underlying syenite. The actual contact is in a depression and drift covered. Both pulaskite porphyry and quartz porphyry are found intrusive into the syenite and shonkinite pyroxenite.

Mode of Origin. Thermal variations, as well as those of gas content in a molten magma, are more pronounced in proximity to the earth's surface than at great depths, and should affect small bodies of magma more readily than large bodies. It is natural, then, that the alkalic intrusives of Franklin, which reached so near the earth's surface, both on this account and because of their alkalic nature, should show more marked differentiation than the more deep seated monzonite and Jurassic granodiorite.

Injection phenomena are absent at the main contacts of the syenite into the older formations. Aschistic (undifferentiated) dykes of syenite, however, occur on the concave side of the chonolith intrusion. They are short and narrow, and all lie well below the upper limit of the intrusion. The absence of injection at the main contacts may be due to the fact that the intrusion did not take place under a very great cover of superincumbent material, and, therefore, lacked the necessary hydrostatic head to produce such effects. The narrow syenite dykes cutting the cover formations may have their origin in tension cracks produced by shrinkage in the cover subsequent to the intrusion and consolidation of the magma.

In contrast to the limited contact metamorphism produced by the syenite chonolith, stands that accomplished by the deep seated granodiorite batholith which affected the adjoining formations hundreds of feet distant from the immediate contact.

The theoretical discussion of the rocks in the group belonging to the southern British Columbia petrographic province, with their mode of intrusion and differentiation, will be dealt with at the end of Chapter V, on "Petrology."

Age and Correlation. The syenite, as has been shown in the preceding discussion, is younger than the monzonite and the Kettle River formation. This is indicated by the manner in which narrow syenite tongues have been intruded into the cover rocks, which include monzonite, on the concave side of the intrusion. Furthermore, it is the intrusive equivalent of the trachyte, which will be shown later to be of Miocene age. This refers the intrusion without doubt to that great Miocene epoch of igneous activity so general throughout the Cordillera.

Midway Volcanic Group.

Trachyte Period.

General Statement. The lavas of this group are the extrusive equivalents of the intrusive alkalic rocks which have been already considered. They vary in composition from alkalic basalts to phonolitic trachytes. The alkalic basalt is the extrusive equivalent of the shonkinite-pyroxenite; the phonolitic trachyte, of the nephelinitic syenite. They occur as remnantal lava cappings on all three mountains, and represent parts of a former flow which poured out into an old river valley, as shown by the synclinal structure of the contacts.

An unconformity exists between the Kettle River formation and the trachyte lava flows, indicating a period of crustal movement along north-northwest and south-southeast lines, with tilting of sediments and intercalated and capping rhyolite flows to the northeast-east. This was followed by a period of erosion which produced the surface of unconformity.

Structural Relations. *Internal.* Pyroclastic agglomerates, bombs, and well banded basaltic tuffs intercalated with trachyte flows occur on the east slope of McKinley mountain, in the basal portions of the Tenderloin lava capping, and sparingly on the Franklin Mountain lava remnant.

The accompanying photograph (Plate XVII), taken of the cliff-exposure on the east side on Tenderloin mountain, shows the intercalated character of the basaltic tuffs, vesicular and amygdaloidal trachytes and alkalic basalts, all of slightly different structure and appearance, which accounts for the striking stratigraphic appearance of the whole series.

Towards the summit of Tenderloin mountain the flows become more massive, with less intercalated tuff. Vesicular and scoriaceous structure so prominent in places is due to the expansion of imprisoned vapours and gases in the molten lava. The gas pores or vesicles are filled in places by calcite, quartz, or chalcedony, and are almond shaped (amygdaloidal) owing to their elongation by movement of the lava before consolidation; and hence the common parallel arrangement along the direction of flow.

The alkalic basalts show columnar jointing in many places, caused by contraction during the cooling and shrinking of the lava.

External. The grit immediately below the trachyte capping on the precipitous west front of Tenderloin mountain (Plate XVIII) was found to contain pyroclastic fragments of trachytic tuff for at least 5 feet from the contact. This indicates that the lava and tuffs were extruded on an unconsolidated sedimentary formation, for nowhere else in the Kettle River formation were found products of Miocene volcanism. The grits are slightly indurated in placcs along the contacts.

The surface upon which the Miocene volcanics were deposited appears to have been of a gently undulating character. This surface was faulted on Tenderloin mountain (Plate XVIII) probably during the late Pliocene uplift.

Mode of Origin. The lavas and pyroclastics of this period of igneous activity are thought to have been extruded from a vent towards the south end of Tenderloin mountain, for the following reasons: There are two prominent monzonite mounds at the south end of Tenderloin mountain, between which lies a depression formed in syenite. The syenite shows pronounced trachytic structure, with feldspar laths oriented in a general way parallel to the contact. The contacts are nearly vertical, as shown by their relation to the topography. This syenite is the intrusive equivalent of the trachytes intercalated with the pyroclastics occurring on the same mountain higher up. The well stratified pyroclastic tuffs and intercalated lavas were found to dip away from the syenite. There is present at the south end of the remnantal capping much coarse pyroclastic material consisting of bombs and smaller angular fragments of vesicular and scoriaceous nature (Plate XIX), such as would be expected near a centre of eruption. As this is the only known occurrence of the intrusive equivalent of the lavas and tuffs on Tenderloin mountain, and considering its position, topographic expression, and the offshoots that have been given off from the main mass, which here is in an almost vertical position, it seems safe to infer that this syenite depression represents the eroded crater of an ancient Tertiary volcano. A hypothetical restora-

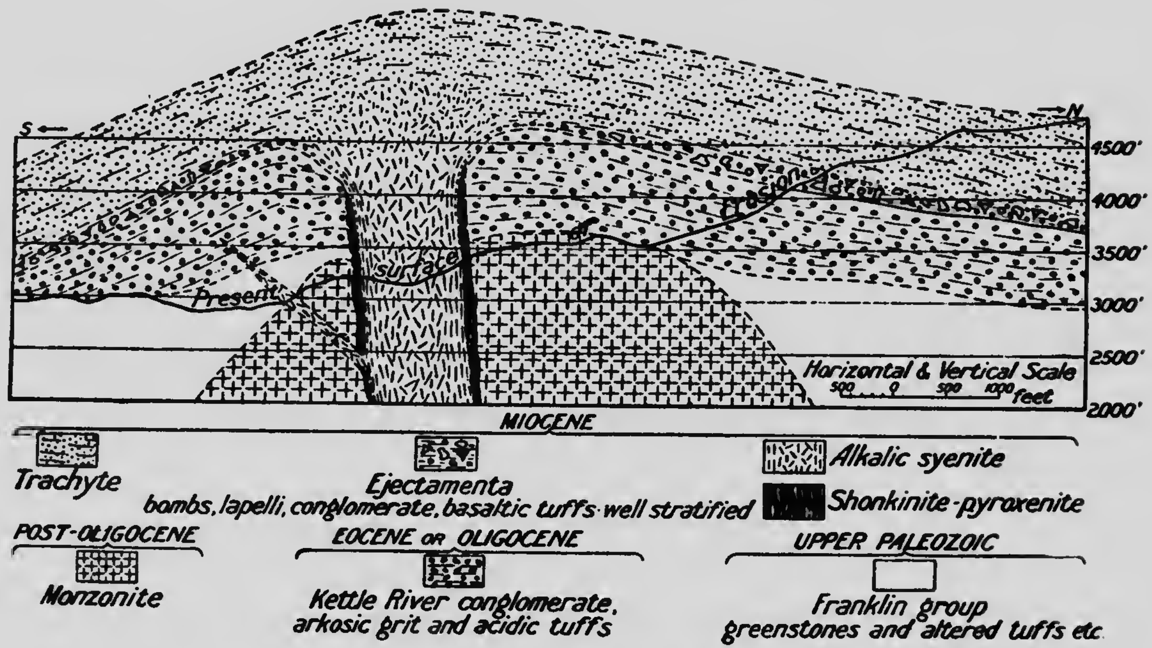

Figure 13. Restoration of Tenderloin volcanic vent.

tion of the volcano is shown in Figure 13, which appears as one of the Vesuvian (Strombolian) type. The fact that the upper portion of the vent must have been in the readily eroded Kettle River formation would account for the present low altitude of the old volcanic core. Some of the large rounded fragments in the capping, as exposed on the west slope of the mountain, may represent some of the boulders ripped off from the Kettle River formation at the time of eruption.

AGE AND CORRELATION. It is known that the trachyte period followed the erosion cycle subsequent to the crustal disturbances and monzonite intrusions, with the consequent upturning and tilting of the Kettle River formation to the north-east-east. This would correlate it with Dr. G. M. Dawson's period of Miocene volcanism as developed about 100 miles north-west in the Kamloops district,[1] in the Interior Plateau of British Columbia.

Dawson[2] draws attention to the fact that the Tertiary rocks in the southern part of the Interior Plateau do not form such extensive unbroken sheets as they do farther north and west, a fact due, he states, to the probably more mountainous and rugged character of the country at the time of their deposition, and also to extensive and severe disturbances and denudation subsequent to that time.

His provisional scheme[3] for the Tertiary rocks met with in the Kamloops sheet is as follows:—

	Feet
Early Pliocene.	
Beds of upper Hat creek and north part of Pavillion mountain. (Elsewhere: Horsefly gravels [yellowish cement], and quartz drift of Klondike).......................................	
Later Miocene.	
Upper part of great volcanic series, widely spread over the region. Composed of basalts and	

[1]Dawson (G. M.): Rept. on Kamloops Map Sheet, Ann. Rept. G.S.C., VII, 1896, p. 71 B.

[2]Dawson (G. M.): Geol. Mag., Dec. 11, VIII, p. 158, 1881.

[3]Op. Cit., p. 176 B.

basalt breccias with smaller quantities of melaphyre, mica trachyte, mica andesite, and various porphyries. Greatest thickness between Nicoamen and Nicola, about.........	3,100
Tranquille group, chiefly volcanic material arranged in water. Tranquille, Nicola valley, etc. Composed of fine-grained tuffs and other volcanic material well bedded. Greatest thickness, about	1,000
Earlier Miocene.	
Lower part of the great volcanic series, Nicola valley, Clear mountains, Kamloops lake, etc. Mainly augite porphyries and agglomerates, tuffs, mica porphyries, picrite porphyries. Greatest thickness apart from centre of eruption, about	5,300
Oligocene.	
Coldwater group. Near confluence of Coldwater and Nicola, Copper creek, Hat creek, etc. Composed of conglomerates of arkosic grit and acidic tuff. Greatest thickness on Hat creek, about.	5,000
	14,400

Younger Period of Dyke Intrusions.

General Statement. All the preceding formations are cut by younger dykes and plugs of alkalic syenite (pulaskite type) and pinkish pulaskite porphyries, the latter predominating throughout the district.

The youngest dykes of all are dark lamprophyres, including minettes and augite microdiorite, the former bearing a genetic relationship to the pulaskite.

Pulaskite Porphyries. The pulaskite shows great variation in texture from centre to border of dyke, a variation which is dependent upon the width of the intrusive and the rapidity of consolidation. West of the McKinley mine, on the north slope of the mountain, a pulaksite dyke has the typical spotted pulaskite porphyry texture (Bird's eye porphyry of the prospector) at its borders. The centre of the dyke is a granular facies and was found in one place to contain inclusions (Plate XX) of older formations. Many of the dykes show evidence of contact chilling in the dense character of the rock, with feldspar phenocrysts larger and farther spaced from each other (page 136, Petrology, for explanation).

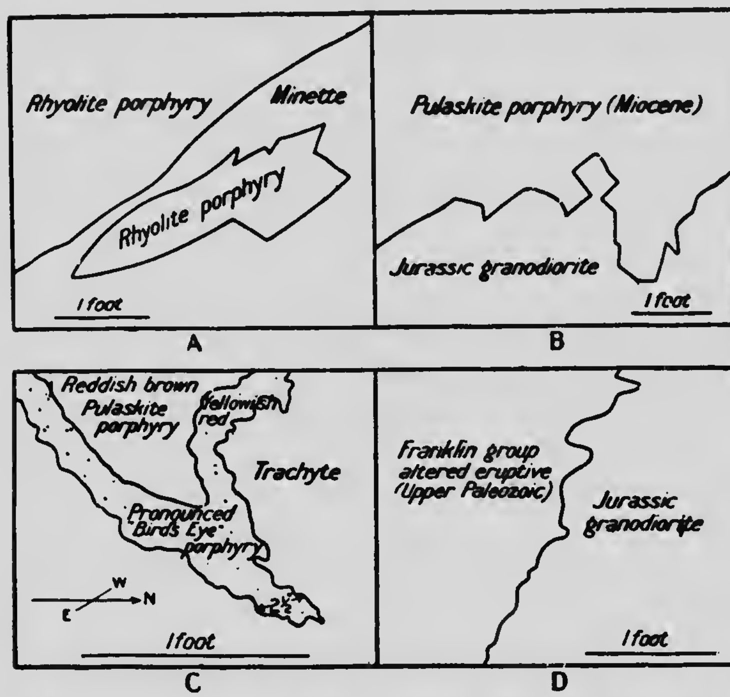

Figure 14 A—Contact of late Miocene minette dyke with early Tertiary rhyolite porphyry; exposed on cliff above McKinley mine.
B—Contact between late Miocene pulaskite porphyry and Jurassic granodiorite in southeast corner of map-area.
C—Contact between late Miocene pulaskite porphyry and early Miocene trachyte, on east slope of McKinley mountain.
D—Contact between Franklin group altered eruptive and granodiorite on west side of Franklin creek.

The accompanying field sketch (Figure 14C), taken on the east slope of McKinley mountain, shows the character of the pulaskite porphyry in contact with the Miocene lava at the lowest exposure of the latter in the district. Here it appears as if the pulaskite porphyry had intruded into a semi-viscous lava. The character of the granodiorite-pulaskite porphyry contact is shown in Figure 14B. Its contacts with the syenite and monzonite are sharp and straight, as are also those with the conglomerate and grit, a fact which indicates that the latter was in a consolidated condition at the time of the intrusion.

Mode of Origin. The pulaskite porphyry dykes so common in the district, follow certain definite systems of intrusion in different portions of the district. For instance, in the northwest corner a dominant northeast and southwest system may be noted, dipping vertically in most places. In the southeast corner they strike north and south. Where they are intrusive into the Jurassic granodiorite they dip to the west, a fact which explains in part the peculiar shaped outcrops on the steep western slopes of the Granite range. In the igneous rocks many of the dykes occupy joints and faults, and like such structures are variable in direction over small areas. A prominent curved pulaskite porphyry dyke outcrops on the Averill property, as shown on the map. Where the pulaskite porphyry cuts the conglomerate and grit formation on the west side of the Kettle river, the dykes dip steeply, as a rule, to the east.

A common and evidently favourable location for these dykes is along the upper border of the granodiorite batholith, as mapped in detail on McKinley mountain. In many places it forms a pinkish veneer or irregular shaped coating to the granodiorite surfaces. Such patches were as a rule too small and unimportant to map. In one locality near the centre of the west border of the map area, a hillock of pulaskite porphyry occurs in the form of a rudely circular plug or neck. It is intrusive into the granodiorite here, with contacts dipping steeply towards the centre of the mass.

The pulaskite intrusives on the east side of the Kettle river and towards the border of the quadrangle are more plentiful, and assume more granitic facies, forming larger irregular areas. The Granite range, a few miles farther east, is composed entirely of this granitic facies, which is known as the Rossland alkali syenite and granite.

LAMPROPHYRES. A very interesting lamprophyre-minette dyke is exposed on McKinley mountain for over a mile in length, pinching in width to 10 feet and swelling up to 150 feet in places. It persistently cuts through a whole series of formations. Figure 14A shows the minette dyke in contact with early Tertiary rhyolite porphyry above the McKinley mine. Where the rhyolite porphyry is most massive it does not outcrop. The accompanying photograph (Plate XXI) of this dyke cutting a brecciated grit near Last Chance ravine on the McKinley Mountain summit, shows the character of the contact as well as a striking differentially weathered surface. The outcrops of this rock decompose readily, and specimens for microscopic study had to be collected from the No. 1 tunnel of the McKinley mine, where a 4½-foot minette dyke follows a Palæozoic limestone-tuff contact. A small inclusion of the pulaskite syenite was found in this minette dyke.

AGE AND CORRELATION. It is known from the contact relations of these youngest dykes in the district, with the Kettle River formation, which was in a consolidated condition at the time of their intrusion, that they are referable to a period later than the Miocene lava flows. Field relations point towards their close connexion geologically and petrologically with the great Rossland alkali syenite and granite batholith to the east in the Granite range, which in all probability underlies at least the eastern portion of the Franklin district.

The pulaskite rocks of Franklin resemble very closely those occurring so commonly throughout the Boundary district and examined in detail at Phoenix[1] and Deadwood.[2]

QUATERNARY.

BOULDER CLAY OR TILL.

This is found on the upland surfaces along with glacial erratics. It consists of hard, sandy clay, with stones and boulders scattered abundantly and irregularly through it. It is generally of a light brown colour. The erratic boulders are chiefly of granite transported from the northwest.

[1]LeRoy (O. E.): G.S.C., Summary Rept., 1908, p. 66.
[2]Ibid., 1910, p. 128.

Fluvio-glacial Alluvium.

This consists of well rounded pebbles, cobbles, and boulders, with lenses of coarse sand. The boulders are predominantly granite and are comparatively fresh. The deposits form a valley fill in Franklin creek over 100 feet thick, and remnants of such alluvial deposits occur also in the main Kettle River valley.

These deposits represent the work of alluviation during the supposed second period of valley glaciation, when the streams were burdened with glacial debris. Later, with further retreat of the glaciers, the streams flowed from areas free from waste and began to cut down their previously built up material. Climatic oscillations have brought about different periods of aggradation and degradation, with the production of river terraces, as well illustrated in Franklin Creek valley, and which are further discussed in the chapter on Physiography. Coarse gravels, sands, and silts of the more resistant rocks occur along the present river courses. The syenite formation on Franklin mountain readily disintegrates into a coarse, feldspathic subsoil. The valley slopes and cliff bottoms are more or less skirted by talus accumulations.

CHAPTER V.

PETROLOGY.

GENERAL STATEMENT.

The Franklin district has proved an unusually interesting and favourable field for petrographic study. Forest fires have removed the once extensive covering of vegetation, leaving bare very finely glaciated rock exposures, which afford ideal conditions for detailed examination of the rocks within this mountainous section of southern British Columbia. Numerous prospect pits and mine workings have further lent considerable aid to the study of the rocks and their structure.

The rocks of the district will be described as geologic units under the three following groups: (1) Sedimentary; (2) Metamorphic; (3) Igneous.

SEDIMENTARY ROCKS.

The sedimentary rocks of the Franklin district are confined to continental deposits of conglomerates, arkosic grits, and water-laid acidic tuffs. The formation which includes these rocks (Kettle River formation) extends in a broad belt from Tenderloin mountain southwestward to McKinley mountain.

CONGLOMERATE.

This rock is made up of subangular to well-rounded boulders of metamorphic, sedimentary, and igneous rocks, varying in size from a few inches to 2 feet and more in diameter, embedded in a firm compact cement. This cement, composed in large part of sand and clay, was probably hardened and compacted chiefly as a result of pressure, and, to a minor degree, siliceous and calcareous binding materials.

Although the conglomerate, as a rule, is of a heterogeneous character, the presence, in some localities, of a rude parallelism in the case of some of the flatter boulders, indicates that a certain amount of sorting by water has taken place during its deposition.

The conglomerate, as typically developed throughout the area, contains boulders and fragments of practically all the older formations. It includes even such imperfectly decomposed and incompletely leached sediments as banded light to dark impure limestones with differentially weathered surfaces, argillites, and conglomerates. The more resistant rocks, such as pure and impure quartzites, cherts, sandstones, greenstones, feldspar porphyries, and porphyrites, predominate, and stand out in bold relief upon weathered surfaces of the conglomerate (Plate IX). Some of the contained pebbles are faulted (Plate XI A). Grey granite and quartz pebbles are present in relatively small amounts. No alkalic intrusive nor extrusive rocks, so common elsewhere throughout the district, were found in the conglomerate.

A subangular boulder 2 feet in diameter, within the conglomerate near the bridge over Franklin creek, exhibits striations and scourings that very closely resemble glacial work. Pebbles and boulders from other parts of the same formation also show similar effects. The accompanying photograph (Plate XI A) was taken to show the facetted and striated character of some of these subangular pebbles. The inferences to be drawn from these facts will be discussed in Chapter IV, on General and Structural Geology.

Arkosic Grit.

The next sedimentary member of this formation is an arkosic grit—a term here used to designate a coarse, feldspathic sandstone, whose grains are dominantly sharp and angular. The grit is a detrital rock of the same general mineral composition as that of a rhyolite porphyry—a rock with which it is frequently intercalated. It is difficult in places to delimit sharply the contact between the two, on account of its transitional character.

A typical arkosic grit from McKinley mountain was selected for petrographic investigation, with the following results:—

Megascopic. This coarse-grained rock is of a white to light grey colour, composed of about equal proportions of orthoclase feldspar and limpid quartz with occasional included stray fragments of other rocks. It breaks with an uneven crumbly fracture.

Microscopic. The microscope shows the presence of the following minerals: quartz, orthoclase, plagioclase, chlorite, kaolin, and secondary quartz.

The quartz is generally present in rounded globules or angular to subangular fragments. The small fragments are dominantly angular. The feldspars are largely kaolinized. Both orthoclase and a plagioclase between oligoclase and andesine (Ab_3An_1) are present in about equal amounts. The crystal outlines in places show only slight attrition. The cement is made up in large part of silica in the form of secondary quartz. Kaolin and chlorite are present as alteration products.

A grit from near McQuarrie's cabin, beside the Grand Forks road, is cemented by lime. A few grains of brown pleochroic tourmaline were found in this micro-slide, indicating pneumatolytic action by the underlying syenite.

Acidic Tuff.

The third and last sedimentary member to be described is an acidic tuff, which occurs intercalated in many places with the grits and rhyolite flows. This evenly bedded, water-laid tuff is to be distinguished from the pyroclastic, basic tuff of the district to be described later under the extrusive igneous rocks.

The fine textured tuff near the base of the formation alternates with the coarser grit many times in the course of a few yards, indicating a rapid change of conditions during their deposition. A specimen from Franklin Creek bottom has the following characteristics:—

Megascopic. It is a light grey rock, with a decidedly clayey odour when breathed upon, due probably to the alteration of its feldspathic constituents. The texture varies from fine granular to dense. The rock breaks with an uneven conchoidal fracture.

Microscopic. Under the microscope the rock appears to be composed of a fine-grained aggregate of angular quartz grains and fragments of feldspar, with isotropic glass and a few small zircon grains. Kaolin and chlorite are present as alteration products. Both microscopic characters and geologic field relations point towards an undoubted tufaceous origin for this evenly bedded rock.

A partial analysis of a tuff from McKinley mountain made by the Mines Branch gave the following results:—

SiO_2	51·72
CaO	5·32
Na_2O	4·22
K_2O	0·89

METAMORPHIC ROCKS.

The metamorphic rocks of the Franklin district are of both sedimentary and igneous origin. The former include light to dark bluish grey marbles, metamorphosed calcareous conglomerates, siliceous argillites, cherty quartzites, and altered tuffs; those of igneous origin include greenstones, many of which are porphyritic, and volcanic rocks of a general andesitic nature. These rocks have a wide distribution throughout the whole district, and are cut off at their base by the granodiorite batholith, and capped in many places by younger Tertiary rocks.

The metamorphic rocks will be described in the order given above.

Marble.

The purest variety of metamorphic limestone has a finely crystalline texture, and consists of a fine mosaic of calcite grains with little or no foreign matter. In other less pure types there are developed anastomosing and branching veinlets of lime silicate materials. When such types are exposed they present surfaces which are differentially weathered, showing the insoluble lime silicate matter standing out in bold relief.

Broad exposures of the marble on the west slope of Franklin mountain show sharp irregular boundaries between the light and dark bluish grey varieties.

This limestone formation (Gloucester formation) is distributed in three distinct belts trending north and south, with general steep dip to the west. The most easterly exposure is at the base of the Granite range on the Dane property, while the most westerly one, of about the same magnitude, is on the IXL property at the west end of McKinley mountain. Between these two belts, and extending in the north from Twin creek southward to the McKinley mine, is exposed the third and largest area of crystalline limestone. The ores of contact metamorphic origin in the district occur closely associated with the three belts, generally at their immediate borders or in lime silicate zones surrounded by crystalline limestone.

A specimen of marble taken from McKinley creek may be described as follows:—

Megascopic. It is a light grey rock, differing from the ordinary type in that it is spotted with dark, oval and round glistening crystals of calcite from 1 to 5 mm. in diameter. Siliceous impurities are present in small amounts.

Microscopic. Under the microscope it appears wholly crystalline, and shows larger individuals of calcite in a generally finer crystalline aggregate of the same mineral. Lattice structure is quite pronounced. All the crystals are polysynthetically twinned. Some of the larger ones have been strained and contorted, producing in places an imbricated structure. Another specimen taken from opposite the mouth of McKinley creek shows distinct crinoidal structures within the larger individuals, as well as an obscure fossil organism 2 mm. in length resembling somewhat a Fusulina.

Metamorphosed Calcareous Conglomerate.

West of each of the marble belts occur zones composed of metamorphosed calcareous conglomerates, which are frequently brecciated and re-cemented by lime and silica. The soil upon such zones has a characteristic reddish colour due to the oxidation of the iron sulphides in the underlying rock. Weathered surfaces show the quartz pebbles standing out in bold relief.

A specimen from the dump of the Banner tunnel is here described:—

Megascopic. This is a light to dark grey rock made up of well rounded quartz pebbles of different colours, the whole being cemented by lime. It has an uneven fracture.

Microscopic. Under the microscope many of the quartz fragments appear to be shattered, with the cracks filled in by calcite, which forms the main cementing material. A few rounded fragments of foreign eruptive material, highly altered, are contained in the rock.

Siliceous Argillites.

These rocks are found best developed in Franklin Creek bottom opposite the mouth of the West Fork. They are dark, carbonaceous looking mud rocks, very dense and cherty in character. Static metamorphism (silica metasomatism) has affected them to such an extent that the planes of breakage never coincide with the bedding planes.

Cherty Quartzites and Altered Tuffs.

These rocks are massive, dense, greenish to dark grey, resembling somewhat the siliceous argillites, but distinguishable from them by their general lighter colour and by the fact that they do not show any signs of stratification. They are traversed by minute joint planes and as a result readily break up into small angular fragments, which pass rapidly into the soil.

Thin sections show them to be a very fine-grained, dense rock, made up of quartz, epidote, and iron ore. Pyrite and magnetite are very common. Some of the slides show, obscurely, forms which suggest a pyroclastic origin of the material, thus pointing towards a tufaceous origin.

Greenstones.

These are massive, dense rocks of a general dark green colour, sometimes porphyritic with small feldspar or augite phenocrysts scattered throughout a very largely chloritized groundmass.

The metamorphism, both contact and regional, of these originally eruptive rocks, has been so intense that microscopic study throws but very little light upon their original character.

One thin section from the Eganville property proved to be a brecciated and altered syenite-porphyry with lath-shaped feldspars of both orthoclase and plagioclase, the former showing Carlsbad twins. There is much disseminated magnetite in the rock.

IGNEOUS ROCKS.

The Franklin district presents a great variety of igneous rocks, some of which are of unusual interest to petrographers.

In order to give the reader as systematic a treatment of the subject as possible, the following scheme and order of presentation have been adopted:—

- A. Intrusives
  - 1. Granular rocks of the batholiths, stocks, etc.
  - 2. Dyke Rocks
    - Aschistic
    - Diaschistic
      - Aplites
      - Lamprophyres
- B. Extrusives
  - 1. Flow rocks
  - 2. Pyroclastic rocks

INTRUSIVES.

Granular Rocks of the Batholiths, Stocks, etc.

These will be described in the order of their age as follows: Nelson granodiorite, Valhalla granite, monzonite, augite syenite, shonkinite-pyroxenite, and the Rossland alkalic granite and syenite.

Nelson Granodiorite.

This rock takes the form of a broad batholith underlying the whole Franklin district. It appears in many places, as indicated on the map, but is most widely exposed at the borders of the district. A comparison of specimens and sections from different parts of this batholith shows a marked uniformity in composition and texture, although there is a considerable variation in the degree of metamorphism to which different portions have been subjected. A representative type of the least altered granodiorite from the Crystal Copper property on Gloucester creek will be described:—

Megascopic. The rock is phanerocrystalline, medium grained, has a granitic texture, and is of a general light to greenish grey colour on fresh fractures. Weathered surfaces appear white to light brownish grey.

Microscopic. The microscope shows the following minerals present: orthoclase, andesine, and hornblende, as essential constituents; quartz, microcline, titanite, magnetite, apatite, zircon, and biotite, as accessory constituents; with chlorite, epidote, kaolin, and limonite as alteration products.

The feldspars show a considerable range of composition: they include both alkalic feldspar and plagioclase, the former being generally more turbid and decomposed than the latter. The plagioclase has a general tabular habit giving elongated sections which commonly show both Carlsbad and albite twinning, the latter with very thin lamellæ. A fresh section of plagioclase, showing both twinnings and cut perpendicular to (010), was determined by the Michel Levy method and found to be andesine, Ab_5An_3. Many andesine sections cut nearly parallel to 010 are zoned, indicating variation in composition, the inner zones being more calcic than the border zones, as is usual. The andesine forms about 20 per cent of the rock. Orthoclase is as a rule allotriomorphic with respect to the other constituents, and forms irregular masses filling the interspaces. It is considerably altered to kaolin. Microcline is present sparingly and exhibits characteristic "cross-hatching." The alkalic feldspars form about 50 per cent of the rock.

The hornblende is the common brownish green variety, idiomorphic with respect to the feldspars, but not forming very well defined prisms. It was the first essential constituent to crystallize from the magma, and is now altered in places to chlorite and grains of epidote, with some limonite. It forms about 12 per cent of the rock.

Iron ore is present chiefly in the form of pyrite in small irregular grains. Apatite is fairly common in short stout prismoids. Zircon occurs in small prisms with pyramidal terminations. Biotite is seen to a minor extent in most sections, but in places dominates over the hornblende. It is the common brown variety, becoming green on alteration to chlorite. Quartz was evidently the last mineral to crystallize, and appears in many places associated with the alkalic feldspar as interstitial fillings. Epidote, along with chlorite, occurs as an alteration product.

Although the above description holds good for the average type of rock composing this batholith, variations in composition occur, from syenitic and granitic to dioritic facies, and even to hornblendite in two isolated cases. The latter rock, on account of its rarity in this region, deserves here some consideration.

HORNBLENDITE. This rock occurs sparingly in two localities: one on the west side of Franklin creek, evidently as a border basic differentiate adjoining a main contact; and the other as 'schlieren' in the granodiorite west of the Beaver meadows. In the former case the hornblendite appears to have differentiated towards the batholithic border, where it consolidated and subsequently became shattered and injected by acidic magma (Plate X).

A specimen from the west side of Franklin creek is as follows:—

Megascopic. This rock is very coarsely crystalline, black and composed almost entirely of hornblende in grains up to one-half inch in length, showing good cleavage.

Microscopic. Under the microscope the following minerals are found: hornblende, apatite, titanite, epidote, and chlorite. The hornblende is strongly pleochroic, and blue green parallel to **c**, green parallel to **b**, and yellowish green parallel to **a**; absorption = **c**>**b**>**a**; angle of **c** $\wedge$c is 17 degrees.

Apatite is not very common, but when present occurs in stout prisms. Titanite is abundantly developed in wedge-shaped crystals. Epidote is present in large grains up to 1 mm in length. The pleochroism varies from colourless to deep rich green. Titanite is crowded around the borders of some of the grains of epidote. Chlorite and limonite are alteration products.

This black granular rock is of a very coarse grain, and on account of being made up almost entirely of hornblende has been called hornblendite.

Valhalla Granite.

The Valhalla granite does not outcrop within the limits of the Franklin map-area, but forms an extensive batholith to the west and north of the district.

It has been examined by R. W. Brock, and described by him in the explanatory notes accompanying the West Kootenay Map Sheet[1] as follows:—

"This is a medium-grained, light-coloured, very quartzose granite. The feldspars are orthoclase, microcline and plagioclase (albite to andesine). Micrograniti¢ intergrowths of quartz and feldspar are common. Green biotite and hornblende are the coloured constituents. Apatite, titanite, orthite, zircon, and iron ore are common . . . . Aplite, pegmatite and odenite dykes accompany its intrusion. It is older than the Rossland alkali-granitic rocks, but newer than the other plutonics. It has largely escaped mineralization."

Monzonite.

The monzonite of Franklin district varies in granularity from medium grained to coarse grained; in composition it is a monzonite of a somewhat dioritic type, which in places passes into dioritic facies. Considering its mineralogical composition as a whole, and its affinities with alkalic rocks, it seems better described as a monzonite than as a diorite. It has a characteristic mottled appearance due to its large content of ferromagnesian constituents. It occurs in stock-like masses in the northwest and northeast corners of the district.

A good average type, taken from below Averill's shaft, was selected for petrographic examination, with the following results:

Megascopic. Phanerocrystalline; medium grain; feldspar slightly dominant over ferromagnesian constituents; medium grey colour; equigranular fabric.

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[1]Map Sheet No. 792, Geol. Surv. Canada.

Microscopic. Under the microscope the following minerals are disclosed: andesine, orthoclase, microcline, and augite as essential constituents; iron ore, apatite, biotite, hornblende, and quartz as accessory constituents; with chlorite, epidote, kaolin, and limonite as alteration products.

Biotite is allotriomorphic with respect to the other minerals. It has a strong pleochroism between very pale yellow and deep olive brown. Its period of formation overlaps the pyroxene but commenced later, as some of the pyroxenes have interior zones filled with biotite shreds. The pyroxene is a clear, pale green diopside of wide extinction angle. Rutile needles are developed through the biotite in places, the latter being in spots surrounded by grains of iron ore.

The plagioclase feldspar occurs in short, thick laths, which are generally quite idiomorphic. They have elongated sections in places which show both Carlsbad and albite twinning, the latter with very thin lamellæ. Determination by the Michel Levy method proved it to be andesine of composition Ab_5An_5. It shows zonal structure in many places.

Orthoclase is allotriomorphic and fills up the interspaces. It is altered in part to kaolin. The hornblende is the common green variety and of rare occurrence. Zircon is present in short, thick crystals up to 5 mm. in length. Apatite is present in stout crystals, as well as titanite and iron ore, the latter occurring in large grains. Quartz appears here and there, associated with orthoclase. Kaolin and chlorite are alteration products.

The structure of the rock is hypidiomorphic granular, and it has about equal amounts of alkalic and plagioclase feldspar, which combined only slightly dominate over the pyroxene and biotite present.

A chemical analysis of the monzonite made by the Mines Branch yielded the following results:—

SiO_2	51·76
Al_2O_3	16·71
Fe_2O_3	2·58
FeO	5·37
MgO	5·09
CaO	7·30

Na_2O	4·09
K_2O	4·04
Tota! H_2O	1·66
TiO_2	0·27
MnO	0·10
CO_2	1·76
	100·73

MICROMONZONITE. A border facies of the monzonite occurs on the west side of the White Bear monzonite stock, close to Gloucester creek. It was found to include in places small fragments of the coarser normal type of monzonite showing welded contacts. It represents probably a slightly later intrusion, which, judging from its finer texture, solidified more quickly than the main stock rock.

A specimen from this locality appeared as follows:—

Megascopic. It is a fine-grained crystalline rock of a reddish grey colour, composed in large part of feldspar with ferromagnesian minerals well disseminated through the mass. It breaks with an uneven, hackly fracture, displaying films of lime, coating many surfaces.

Microscopic. The microscope shows it to be composed of the following minerals: apatite, magnetite, titanite, hornblende, plagioclase, augite, quartz, calcite, kaolin, and chlorite. The apatite is in needles and small prismoids. The augite occurs as a few large scattered phenocrysts of dark green diopside.

The green hornblende is present in long slender needles, while the plagioclase displays a trachytoid arrangement of its laths, including within it considerable magnetite. The quartz appears to be secondarily infiltrated.

Calcite, kaolin, and chlorite are present as alteration products.

Augite Syenite.

This, the youngest granular rock in the district, forms an irregular shaped intrusion, extending from the northwest corner of the quadrangle southward and eastward to the eastern boundary, forming a broad arc concave to the northeast, with a general dip in that direction. The intrusive assumes an almost vertical attitude at the base of Tenderloin mountain, the probable site of an old volcanic vent.

Other smaller, isolated areas of less alkalic and slightly older syenite occur: (1) on the west flank of Franklin mountain, (2) on Syenite hill near west border of the district, and (3) a small crescentic shaped outcrop on the ridge west of Franklin creek.

An average specimen of the augite syenite from the Maple Leaf property was found to have the following characteristics:—

Megascopic. On a freshly fractured surface the rock has a medium grey colour; is phanerocrystalline; medium grained; dominantly feldspathic, with the tabular orthoclases arranged in trachytoid texture; granular fabric; uneven hackly fracture.

Microscopic. Under the microscope the following minerals are seen: alkalic feldspar, pyroxene, hornblende, as essential constituents; iron ore, titanite, apatite, biotite, and melanite, as accessory constituents; chlorite and kaolin, secondary.

The feldspars are all alkalic, developed tabular on b (010) with cleavage parallel to c (001). They are frequently twinned after the Carlsbad law, and form about 56 per cent of the rock. The presence of a trace of nephelite was indicated by a chemical test which gave gelatinous silicate, but it must be very small in amount as it could not be determined optically.

The pyroxene is a very pale green diopside, the same as that in the shonkinite-pyroxenite ("Black Lead"), and is much cracked and broken. It forms about 24 per cent of the rock.

A dark green hornblende occurs with the pyroxene. The two minerals are very frequently found together in stout, well shaped crystals from 1 to 2 mm. long, the pyroxenes forming a core surrounded by the hornblende. The hornblende appears to be paramorphic after the pyroxene.[1] Such uralitized pyroxenes are readily recognized in cross sections.

The hornblende and feldspar in places have crystallized simultaneously. Some of the hornblende is primary, as shown by crystal outline. Hornblende forms about 14 per cent of the rock.

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[1]Iddings (J. P.): The Eruptive Rocks of Electric Peak. 12th Ann. Rept. U.S. Geol. Surv., 1890-91, p. 606.

Iron ore is rather abundant (about 2 per cent) in small and large grains, surrounded as a rule by narrow mantles of biotite. Titanite exhibits the usual diamond and wedge shaped crystals with a leucoxene-like alteration product. It forms about 1·8 per cent of the rock. Biotite is seen in scattered shreds without definite crystal outline, and is the common brown pleochroic variety.

Melanite garnet is present in dodecahedral outlines or rounded and irregular forms. It shows zonal structure in places, and has titanite frequently developed in it. The melanite is of a brownish to brownish yellow colour, and forms about a half of one per cent of the rock. The presence of melanite in a syenite will be discussed in a later paragraph. Chlorite and kaolin are secondary products.

The order of crystallization for the various minerals was probably as follows: iron ore, apatite, titanite, hornblende, pyroxene, biotite, melanite, orthoclase.

Mineral Composition or Mode. The relative quantities of the component materials, as determined by the Rosiwal method, is as follows:—

	per cent
Alkalic feldspar	56·0
Pyroxene	24·0
Hornblende	14·0
Iron ore	2·0
Titanite	1·8
Apatite	1·0
Melanite garnet	0·5
Remainder	0·7
	100·0

This rock has a trachytoid texture, which is conditioned by the lath shaped feldspars, and in places they assume a fluidal arrangement. Ferromagnesian minerals are interspersed throughout the constituents.

A chemical analysis of the syenite made by the Mines Branch resulted as follows:—

	per cent
SiO_2	55·16
Al_2O_3	17·30
Fe_2O_3	3·58
FeO	2·81
MgO	1·88
CaO	4·80
Na_2O	3·03
K_2O	8·73
Total H_2O	1·40
TiO_2	0·36
MnO	0·08
CO_2	1·40
	100·53

Melanite Syenite. One variety is a melanite syenite from the Maple Leaf property, whose characteristics are as follows:—

Megascopic. Phanerocrystalline, holocrystalline texture; medium grained; equigranular; light grey colour, mottled with small black ferromagnesian minerals; dominantly feldspathic, with elongated lath shaped crystals which exhibit fluidal arrangement, giving a tabular or trachytic fabric.

Microscopic. In thin section, the materials are apatite, magnetite, zircon, titanite, garnet (melanite), alkalic hornblende, biotite, muscovite, orthoclase, fluorite, chlorite, and kaolin, which are given in their probable order of crystallization.

Apatite is present in, usually, small prismoids; is always perfectly fresh, and may occur as inclusions in any of the other constituents. Iron ore is scattered irregularly throughout the rock in cubes and grains. Zircon is in short thick prisms. Titanite or sphene is in typical wedge-shaped crystals or small spindle-shaped granules, reddish brown in colour. Melanite is extremely well developed in octahedral forms, measuring 0·5 to 1 mm. in diameter. It includes in places, magnetite, titanite, and apatite. It is of a greenish to dark brown colour, but is bleached in places to a yellowish tone.

A hornblende with an extinction angle of 18 degrees is present; it varies from green to brown in colour; has strong pleochroism, and considering its colour and associations is judged to be of an alkalic nature, probably near arfvedsonite in composition.

The biotite is the green variety common in certain alkalic rocks, and occurs in shreds and irregular masses associated with other ferromagnesian minerals. It forms in place scattered inclusions in the feldspar.

Fluorite appears in small bluish masses filling cavities or cracks in the vicinity of the garnet. It is probably of pneumatolytic origin, deposited during the period when gases of magmatic origin rose through the mass of recently consolidated rock.

Orthoclase is the prominent feldspar and shows Carlsbad twinning. Microperthite is also present. Orthoclase was found included in the melanite garnet, as in the accompanying sketch micrograph (Figure 15).

The presence of melanite garnet in a syenite is rare. Its occurrence as a not uncommon constituent of alkalic igneous rocks, such as nephelite-syenite, phonolite, leucitic and nephelitic lavas, is mentioned in many places in the literature.

This melanite syenite could be classed with ledmorite, named and described by S. J. Shand,[1] from Assynt, Scotland, provided that not too much stress be laid upon the presence of ægerite augite and pinitic mica. which replaces original nephelite in ledmorite.

Porphyritic Syenite.

Another variety of slightly older syenite most peculiar in character, occurs on Syenite hill west of Franklin creek. It displays unusually long crystals, up to 2 inches in length, of unstriated feldspar, with thin borders or rims of a lighter coloured variety which is a plagioclase. The crystals in places radiate from one centre, as is well illustrated in the accompanying photograph (Plate XIII).

[1]Shand (S. J.): On Borolanite and its Associates in Assynt. Trans. Edinburgh Geol. Soc., Vol. IX, Part V, 1910, p. 384.

A

B

Figure 15. A—Micro-sketch to show skeletal crystal of melanite (black) enclosing orthoclase; melanite syenite from Franklin mountain; magnification, X40.

B—Micro-sketch to show skeletal crystal of melanite (black) enclosing orthoclase; augite syenite (ledmorite); after S. J. Shand; magnification, X24.

It has similar microscopic characteristics to that of the normal type, but is more acidic in that it has accessory quartz. It has a much greater proportion of microperthite than had the other feldspar of the foregoing type. The ferromagnesian mineral is hornblende altered largely to chlorite [illegible].

Shonkinite-Pyroxenite.

This rock occurs as a basic differentiate mainly at the borders of the augite syenite intrusion, and is locally known as the "Black Lead." Its geologic relation to the syenite and monzonite has already been discussed in the preceding chapter.

The shonkinite-pyroxenite maintains a fairly uniform character throughout the district. A type specimen which came from the prospect shaft on the Averill property is as follows:—

Megascopic. Phanerocrystalline; coarse grained; black to dark green colour; dominantly composed of pyroxene. In the coarsest grained forms the augite crystals are so large and abundant as to give the rock a strongly porphyritic appearance.

Microscopic. The following minerals are present, and are given in their probable order of crystallization: apatite, titanite, magnetite, pyrite, chalcopyrite, hornblende, biotite, augite, orthoclase, and microcline, quartz, chlorite, and calcite. The apatite is present in small prisms of euhedral as well as anhedral forms, and is enclosed in magnetite, augite, and feldspar crystals.

Magnetite and pyrite are rather abundant in occasional euhedral but chiefly irregular forms. The iron ore forms about 6 per cent of the rock. Titanite is present in characteristic wedge-like crystals. Common green hornblendes occur as irregular small masses within the augite. Magnetite is always abundant in the vicinity of the hornblende.

The augite present is of a green to greenish brown colour; is idiomorphic with respect to the orthoclase and microcline. Extinction angles measured in plane 010 vary from 31 degrees to 41 degrees. Some crystals are twinned on orthopinacoid a (100). The augite shows excellent prismatic cleavage and forms about 73·13 per cent of the rock.

Biotite is very sparingly developed, and occurs in small well formed tablets of the ordinary pleochroic brown variety, usually in the augite.

Orthoclase occurs allotriomorphic with respect to the augite and fills in all the interspaces. It is in places partly altered to kaolin. Microcline appears in a similar manner to the orthoclase but shows less alteration. It is characterized by the "gridiron" structure between crossed nicols. The alkalic feldspars make up about 17 per cent of the rock. Quartz is present only in small grains in the feldspar. Chlorite to a minor extent is present as an alteration product of the ferromagnesian minerals. Calcite occurs in narrow branching veinlets traversing the rock constituents.

Mineral Composition or Mode. The determination on mineral percentages by the Rosiwal method gave:—

	per cent
Augite	73·13
Feldspar	17·06
Apatite	1·06
Iron ore	6·06
Hornblende	1·47
Biotite	0·77
Titanite	0·41
Remainder	0·04
	100·00

It is seen from these figures that augite forms by far the greatest bulk of the rock (nearly three-quarters), with alkalic feldspar next, and iron ore third in importance.

A chemical analysis of this rock made by the Mines Branch resulted as follows:—

SiO_2	45·90
Al_2O_3	6·59
Fe_2O_3	7·58
FeO	8·19
MgO	7·70
CaO	18·00

Na_2O	2·16
K_2O	1·46
Total H_2O	1·20
TiO_2	1·10
MnO	0·20
CO_2	....
	100·08

The texture of the rock is very coarsely granular, with large phenocrysts up to 1 inch, scattered throughout a general groundmass of pyroxene of all sizes from 1 to 2 mm., with interstices between the crystals filled with alkalic feldspar.

The original type of shonkinite, which is a marginal facies of a sodalite-syenite at Square Butte, Montana, is a rather coarse granular rock, consisting of predominant augite, with orthoclase, albite, and anorthoclase, apatite, biotite, iron ore, sodalite, traces of nephelite, cancrinite, and zeolites.[1]

Besides the Square Butte occurrence, this rock is also found at Yogo peak in the Little Belt range, where the augite crystals are not so large and idiomorphic as at the former locality and the rock has a greater proportion of biotite.[2] In the Bearpaw mountains shonkinite is again found in the peripheral part of an alkalic syenite stock.[3] Brögger[4] in his work on the Monzoni rocks cites an occurrence of a "pyroxenite" with large crystals of orthoclase as a portion of a differentiated mass, and points out its resemblance to shonkinite.

In comparing microscopically the Franklin type with those from Montana it was seen that they closely resembled each other, both having the characteristic pale green diopside with considerable alkalic feldspar, but the Franklin shonkinite contains,

[1] Weed (W. H.) and Pirsson (L. V.): Highwood Mountains of Montana: Bull. Geol. Soc. of Am., Vol. VI (1895), p. 415.

[2] Ibid.: Igneous Rocks of Yogo Peak, Mont., Am. Jour. of Sci., 3rd Ser., Vol. I (1895), pp. 467-479.

[3] Ibid.: The Bearpaw Mountains, Mont., Am. Jour. of Sci., 4th Ser., Vol. I (1896), pp. 283-301, 351-362, Vol. II, pp. 136-148.

[4] Eruptionsfolge eruptivgestaine Predazzo, 1895, p. 66. Triad. Erup. Predazzo, 1896, p. 67.

on the whole, a much larger proportion of pyroxene, and hence the name shonkinite-pyroxenite seems best fitted for its description and classification.

Rossland Alkali-Granitic Rocks.

The batholith situated about 2 miles to the east of the district was mapped by R. W. Brock,[1] and the rocks described as follows:—

"The commonest rock included under the Rossland alkali-granitic group is a reddish to pink granitic rock, in which glassy pink and some greyish feldspar are the most conspicuous constituents. The dark constituents, while very noticeable on account of contrast in colour, are present in subordinate amounts. Its principal constituents are orthoclase, microperthite, albite, perhaps anorthoclase, sometimes quartz, sodalite, and probably other feldspathoid minerals, biotite, hornblende, diopside, magnetite, apatite, zircon, titanite, and orthite. The alkalis form 12 per cent of the rock. The rock shows a number of facies from granitic to probably essexetic types, but an alkaline syenite or pulaskite type is the commonest. . . . . . Their relationship to the Tertiary volcanics has not been satisfactorily proven but it appears as if they might be closely connected. A genetic relationship exists between them and the Tertiary volcanics of the Boundary Creek district. The dykes from these rocks include granite and syenite-porphyries, granophyres, quartz-porphyries, etc. Younger than these 'light' dykes are dark lamprophyric ones including fourchites, camptonites, monchiquites, and mica lamprophyres.

"These are probably the complementary basic dykes connected with this eruption. . . . ."

DYKE ROCKS.

The dyke rocks of the Franklin district present a great variety of rock types, and may most conveniently be described

[1] West Kootenay Map Sheet, No. 792, G.S.C.

under the general terms aschistic[1] (undifferentiated) and diaschistic (differentiated), with their subdivisions. The terms are limited here to the dyke intrusions, alone, and not to such complementary masses as the pyroxenite and syenite. The aschistic dykes occur as tongues or apophyses from igneous bodies; they have the same mineral composition as the main mass, and differ from it only in their texture. The diaschistic dykes, on the other hand, represent extreme divergences from the main parent stock and differ in their composition; the lamprophyres are the basic extreme, and the aplites the acidic extreme.

- Aschistic
  - Granodiorite porphyry
  - Quartz porphyry
  - Syenite porphyries
    - Augite syenite porphyry
    - Syenite porphyry of Tenderloin mountain
    - Pulaskite porphyry

- Diaschistic
  - Aplites
    - Granodiorite aplite
    - Monzonite aplite
    - Syenite aplites
      - Coarse phase of syenite aplite
      - Syenite-aplite porphyry
  - Lamprophyres
    - Minette
    - Augite microdiorite

Asc[illegible]

Granodiorite porphyry.

The granodiorite porphyries are found in tongues or apophyses, extending out from the main granodiorite batholith, and can best be seen at the McKinley mine. They are so highly metamorphosed in places that they are difficult to distinguish megascopically from some of the Franklin group altered eruptives.

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[1] Brögger (W. C.): Die Eruptivgestein[illegible] Kristianiagebietes, Vol. I, Die Gesteine der Grorudit-Tinguait-Serie (1894), pp. 125-153.

A specimen from the Franklin mine open-cut (locally known as the "Glory Hole") was found to have the following characteristics:—

Megascopic. It is a greenish grey rock, dotted throughout with dull white feldspar and black, generally altered, hornblende phenocrysts, which give the whole rock a decidedly porphyritic structure with an aphanitic groundmass. It has an uneven hackly fracture.

Microscopic. Under the microscope the rock appears to be a fine-grained, holocrystalline rock with a porphyritic fabric. The phenocrysts consist of idiomorphic green hornblende and plagioclase feldspar with subordinate quartz. The groundmass is made up of a fine aggregate of orthoclase, plagioclase, and quartz. The orthoclase is largely kaolinized.

On account of the similar mineralogic characteristics, as well as geologic relations between the granodiorite batholith and this dyke rock, it has been classified as granodiorite porphyry.

Quartz Porphyry.

This rock forms irregularly shaped dykes, generally near the contacts of the monzonite and syenite, and is younger than either of them. A typical specimen from the White Bear property was chosen for description:—

Megascopic. It is of a light grey colour; is porphyritic, aphanitic; has clear rounded quartzes and dull feldspar phenocrysts in a fine-grained groundmass; has hiatal (sempatic) fabric; breaks with conchoidal or splintery fracture.

Microscopic. Under the microscope the following minerals are present: apatite, biotite, andesine, orthoclase, quartz, epidote, and chlorite. The quartz phenocrysts (average 2 mm. in diameter) are partly corroded, and contain embayments of the groundmass. The groundmass is cryptocrystalline. The rock is a typical quartz feldspar porphyry, and on account of the andesine feldspar present in it, it may be related to the monzonite, which also had andesine well developed in it.

Augite Syenite Porphyry.

This rock occurs as small dykes penetrating the cover of the augite syenite intrusion on its concave side. A specimen from the Crystal Copper property appeared as follows:—

Megascopic. Holocrystalline; porphyritic, aphanitic with elongated orthoclase phenocrysts averaging 2·5 mm. in length, oriented often parallel to each other; light greyish colour; uneven fracture; feldsophyric groundmass.

Microscopic. The following minerals are present: apatite, titanite, melanite, orthoclase, chlorite, and kaolin. The orthoclase shows Carlsbad twinning, and is elongated on clinopinacoid (010) face with cleavage parallel to base (001). The augite has broken down into chlorite, calcite, and kaolin. The melanite occurs as brownish to brownish yellow octahedral forms up to 1·6 mm. in diameter.

The rock differs from the main syenite in its structure, which indicates a hiatus between time of crystallization of feldspar laths forming the phenocrysts and those of the groundmass. On account of the close similarity between the minerals of this rock and the parent alkalic syenite, and the finding of melanite garnet in these dykes, they are considered apophyses from the syenite intrusion which underlies the district in which they are found.

Syenite Porphyry of Tenderloin Mountain.

A different phase of syenite porphyry was found only in one locality, on the south end of Tenderloin mountain, where it cuts the trachytic and basaltic tuffs near their contact with the underlying grits. It has the following characteristics:—

Megascopic. Holocrystalline; porphyritic aphanitic; purplish grey, with large pink feldspar phenocrysts up to 10 mm. in length; breaks with an uneven conchoidal fracture.

Microscopic. Under the microscope the following minerals were determined: apatite, in large and prominent euhedral crystals; large and small magnetite grains; titanite, zircon, oligoclase, orthoclase, showing Carlsbad twinning; epidote and chlorite as alteration products. The phenocrysts of orthoclase, oligoclase, and apatite are in a microgranitic groundmass of the same minerals. A chemical test for nephelite gave slight gelatinization, but it must be present in very small amounts, as microscopic examination did not reveal it. The texture of the groundmass is trachytoid.

Pulaskite Porphyry.

Pulaskite porphyry is a very common rock in the Franklin district, and forms several definite systems of dyke intrusions, cutting all the other rocks with the exception of the lamprophyres. It is locally known as "Bird's eye porphyry." A typical specimen from the junction of McKinley trail with the Grand Forks road has the following characteristics:—

Megascopic. Holocrystalline; has a few scattered large pink feldspar phenocrysts (up to 3 mm. in length) in apharitic groundmass, with a few small biotite flakes in places; pinkish colour; uneven fracture: dull lustre.

Microscopic. Under the microscope were distinguished the following minerals: apatite in needles and prismoids; magnetite, biotite, hornblende, augite (pale diopside), orthoclase in starry grouping in places, oligoclase, albite, and chlorite.

This rock has a trachytoid structure and has considerable biotite. It resembles closely in mineralogical composition the pulaskite[1] type of alkali-syenite, and this term has been used in classifying it. It can always be readily distinguished from any other syenite porphyries by its pinkish colour and the spotted effect which the scattered feldspar phenocrysts give to the rock on weathered surfaces.

Pulaskite may be defined as a type of alkali-syenite, between a normal syenite and a nephelite syenite, with biotite as chief ferromagnesian constituent. Nordmarkite is a quartz-bearing pulaskite.

DIASCHISTIC.

Granodiorite Aplite.

Aplite occurs in the form of narrow dykes and dykelets traversing the granodiorite as a rule near its contacts with the

[1]Rosenbusch (H.): Intrusive-Gesteine, II, 1, 1907, p. 146.

other formations. Hand specimens show a light greyish rock of a very fine, even grain, in which are seen occasional black specks of biotite. It breaks with a slightly crumbly fracture, and has the sugar-granular texture of typical aplites.

A specimen behind Chisholm's cabin, when examined under the microscope, was found to be a fine-grained, allotriomorphic mixture of quartz and, mainly, unstriated feldspar. Some plagioclase is present in idiomorphic crystals. The biotite is in shreds and flakes.

Monzonite Aplite.

This rock is found sparingly in dykes cutting the monzonite. It resembles the granodiorite aplite very closely, but is not flecked with minute biotite flakes, and on weathered surfaces the unstriated feldspar appears as small, dull white spots. It can further be distinguished from the granodiorite aplite in that the feldspars tend towards trachytic structure.

Syenite Aplite.

No typical syenite aplites of the normal texture are found in the district, but under this heading will be described a coarse textured variety of syenite dyke rock found cutting both monzonite and syenite in places, as well as a porphyritic variety cutting the Franklin group rocks on the west side of Franklin mountain.

Coarse Phase of Syenite Aplite. This rock is found cutting the monzonite in several places. It is a coarsely crystalline rock, composed of elongated tabular feldspars of both pinkish and greyish colour with interspersed greenish chloritic areas. The rock breaks along the planes of cleavage of the feldspars, presenting very angular surfaces.

Syenite-Aplite Porphyry. This rock occurs in two parallel dykes dipping flatly to the northwest on the north side of Twin Creek ravine, and forms white outcrops. It is a prominent dyke in Franklin Creek bottom, below the Yellow Jacket property where it has forced the creek to take a sharp bend in its course. The specimen to be described was taken from this last mentioned occurrence:—

Megascopic. Holocrystalline; porphyritic aphanitic; ligh grey in colour; fine grained; hiatal (dopatic); uneven fracture dull earthy appearance.

Microscopic. Under the microscope the following mineral were observed: apatite in needles and prismoids; biotite shreds small amounts of accessory pale diopside; orthoclase laths con siderably kaolinized; some ferromagnesian mineral altered t chlorite; secondary calcite replacing mineral which formerl filled angular interstitial spaces and may have been nephelite Calcite appears to have replaced some of the diopside.

The rock displays trachytoid structure, with the feldspa phenocrysts not very well defined. There is too much ferro magnesian mineral in the rock to call it a bostonite, so the tern syenite aplite has been adopted.

Minette.

The main lamprophyric rock is a minette, which outcrop for over a mile in length on McKinley mountain and varies i width from 10 to 150 feet. The specimen whose characteristic are here given, was taken from the No. 1 tunnel of the McKinle mine, where fresh samples could be obtained of this readil weathered rock.

Megascopic. Holocrystalline; fine grained, average muc less than 1 mm.; compact; dark greenish grey colour; biotit appears as flakes scattered through the rock; phenocrysts of a greenish pyroxene seen in places; dull; hackly fracture.

Microscopic. The following minerals were found present iron ore, apatite, biotite, augite, orthoclase, plagioclase, and a trace of olivine, as well as calcite, chlorite, and kaolin.

Iron ore grains frequently clustered around the augite suggest a pushing of the already formed magnetite grains by the growing augite.

The interior of the biotite is a brownish ochre yellow, becoming deep brown at borders. This zonal structure, so common in the biotite of minettes, is seen best in basal plates. In sections perpendicular to the cleavage, the pleochroism varies between pale yellow and deep brown. It is bent in places and altered to chlorite. The augite is a pale greenish diopside and occurs chiefly in irregular masses, although in places it presents good crystal outlines. The feldspar is chiefly an unstriated alkalic one clouded by incipient kaolinization. The plagioclase is generally much fresher than the orthoclase, and is present in much less amounts. Chlorite, calcite, limonite, and kaolin are present as alteration products.

The lath-like feldspars give the rock a trachytoid structure in places. The geologic and mineralogic relations of the minettes to the pulaskite porphyries indicate that they are closely related genetically.

The Franklin minette has a greater proportion of augite and less hornblende than the minettes from the Little Belt mountains, Montana.[1]

A chemical analysis of the minette made by the Mines Branch resulted as follows:—

SiO_2	49·44
Al_2O_3	13·85
Fe_2O_3	3·43
FeO	5·24
MgO	8·48
CaO	7·80
Na_2O	3·34
K_2O	3·95
Total H_2O	3·30
TiO_2	0·62
MnO	0·15
CO_2	1·00
	100·60

Augite Microdiorite.

This rock occurs as a dyke cutting the granodiorite and a syenite dyke rock below Little's property. It had the following characteristics:—

[1] Pirsson (L. V.): Petrography of the Igneous Rocks of the Little-Belt mountains, Montana, 20th Ann. Rept. U.S. Geol. Surv., Pt. III, 1899, p. 526.

Megascopic. Holocrystalline; fine grained; dark greenish grey colour; seriate, inequigranular fabric; uneven fracture.

Microscopic. Under the microscope green diopside appeared in irregular and rounded phenocrysts; andesine feldspar, showing zonal structure, is in idiomorphic lath shaped forms, with allotriomorphic orthoclase in places; biotite is largely altered to chlorite, but shows deep brown pleochroism at borders; magnetite dust and apatite needles are present.

The structure of the rock is panidiomorphic, and somewhat resembles kersantite, except that it has augite as a dominant ferromagnesian constituent. On account of the dioritic composition of this fine-grained rock and the abundance of augite, it has been classified as an augite microdiorite.

EXTRUSIVES.

The extrusive rocks will be described under the following headings:—

1. Flows	Rhyolite and rhyolite porphyry Trachyte Phonolitic trachyte Alkalic basalt
2. Pyroclastics	Agglomerate and bombs Trachytic tuffs Basaltic tuffs

FLOWS.

Rhyolite and Rhyolite Porphyry.

The oldest Tertiary lava flows present in the Franklin district are certain rhyolites which were in part contemporaneous and in part subsequent to the deposition of the Kettle River formation. (For full details with regard to structure and areal extent see former chapter on General and Structural Geology). These rocks vary from holocrystalline types, practically quartz porphyries in structure, texture, and mineralogic composition, to semicrystalline types having flow and vesicular structure.

A specimen taken from the west side of Last Chance ravine on McKinley mountain was examined with the following results:—

Megascopic. Holocrystalline; porphyritic (aphanitic) texture with small limpid quartzes and feldspars as phenocrysts; white to light grey colour; hiatal (dopatic); fracture crumbly; slightly earthy, dull appearance, showing incipient alteration.

Microscopic. Under the microscope it was found to consist of: apatite, zircon, iron ore (pyrite, magnetite), titanite, biotite, plagioclase, orthoclase, quartz, chlorite, and kaolin. The apatite is in small needles and prismoids. Iron ore and zircon are rare, the latter occurring in places as inclusions in quartz. Titanite and a leucoxene-like alteration product are present generally in the vicinity of the biotite. Biotite is much broken and altered to chlorite. The plagioclase feldspar present is an acid andesine or basic oligoclase (Ab_3An_1) determined by the Michel Levy method of measuring extinction angles on crystals twinned according to both the Carlsbad and Albite laws. Albite is in small idiomorphic phenocrysts. Orthoclase shows incipient kaolinization. Quartz occurs usually in rounded grains or angular fragments which are poor in inclusions. The groundmass is felsophyric, composed of a mixture of quartz and feldspar, showing in places flow structure about the phenocrysts.

The McKinley rhyolite passes transitionally into a coarser textured rhyolite porphyry type which may be characterized as follows:—

Megascopic. Holocrystalline; porphyritic aphanitic; purplish grey colour; hiatal (dosemic); dull lustre; uneven fracture.

Microscopic. Under the microscope it was found to be composed of: apatite, zircon, titanite, leucoxene, magnetite, pyrite, biotite, plagioclase, orthoclase, and quartz.

The structure is porphyritic, with prominent phenocrysts of corroded quartz and partly kaolinized orthoclase in a microgranitic groundmass of the same minerals.

A partial analysis of a rhyolite from Franklin mountain, made by the Mines Branch, yielded the following results:—

SiO_2	69·60
CaO	0·68
Na_2O	3·97
K_2O	5·84

Trachyte.

This is the commonest as well as the youngest flow rock i the district. It forms protective lava cappings to all three moun tains, and varies slightly in composition from a phase approach ing phonolite in some places, to one approaching basalt in othe places. In structure it varies from porphyritic to dense an vesicular.

A normal type from the east slope of McKinley mountai was chosen for description:—

Megascopic. Holocrystalline; porphyritic aphanitic; light t dark grey, with purplish tinge; dull lustre; dense, subconchoida to uneven fracture.

Microscopic. Under the microscope the following mineral were observed: apatite in prominent prismoids; magnetite ir small disseminated and octahedral grains; biotite showin through alteration. sagenite webs; labradorite; orthoclase ir small prisms. The chemical test for nephelite gave slight gela tinization, but the mineral could not be definitely determinec in the slide, and if present must be as minute interstitial fillings. The feldspar and biotite phenocrysts are enclosed in a ground mass composed of a felted mass of the same minerals, with trachy toid structure and fluxional arrangement.

Another type, from an older flow, occurring on the east side of Last Chance ravine on McKinley mountain, is described, as it is of interest in showing the similarity between the large, fresh, unstriated feldspar and brown hornblende of the flow rock and that of its hypabyssal syenitic equivalent on Syenite hill not far distant.

Megascopic. Holocrystalline; porphyritic aphanitic; greenish grey colour with slight purplish tinge; hiatal (dopatic) fabric; uneven fracture.

Microscopic. Under the microscope the following minerals were noted: magnetite, hornblende, augite, plagioclase, unstriated feldspar, apatite, chalcedony, chlorite, and kaolin. The augite was a pale green diopside but is now largely chloritized. The brown hornblende is partly resorbed, and has magnetite dust at its borders. The feldspars are plagioclase, and an unstriated variety, the latter in long crystals with, in places, radial growth, and zoned like those characteristic of the porphyritic syenite type already described. The apatite occurs abundantly in prismoids. Corroded quartz grains are rarely present. Chalcedony fills some of the pore spaces. The rock is typically porphyritic, with a groundmass of trachytoid texture.

This lava, from its close mineralogic resemblance to that of the porphyritic syenite, is taken to be its effusive equivalent, and its geologic relations prove it to be slightly older than the more alkalic types of trachytic lavas.

A type from the south end of Franklin Mountain summit, where the trachyte is found capping the rhyolite, showed the presence of a pale green diopside; biotite is largely resorbed and displays sagenite network of rutile needles. This trachyte passed downward at the base of the flow into vesicular and slaggy, scoriaceous phases, still retaining pale green augites.

A specimen from the south bump of Tenderloin Mountain summit resembles very much the Franklin and McKinley Mountain trachytes. Under the microscope, orthoclase phenocrysts, largely kaolinized, are present, and the rock on being tested chemically was found to give a very slight gelatinous silicate, indicating the possible presence of nephelite. An altered ferromagnesian mineral shows sagenite structure, and was evidently biotite. Chlorite and calcite are alteration products. The groundmass is composed of alkalic and plagioclase feldspars showing trachytic structures.

A trachyte type from the east side of Tenderloin mountain may be described as follows:—

Megascopic. Holocrystalline; porphyritic aphanitic; olive grey colour; uneven fracture; hiatal (dopatic) fabric.

Microscopic. Under the microscope the following minerals were observed: apatite quite abundant; magnetite; biotite with sagenite structure and largely resorbed; pale green diopside in irregular masses; labradorite, and quite large orthoclase phenocrysts (up to 5 mm. in length), in a felted groundmass of alkalic feldspar showing trachytoid structure.

A trachyte from the west side of Tenderloin mountain which presents reddish weathered outcrops was found on microscopic examination to have augite strongly developed through it, some of the crystals showing zonal structure. The groundmass contained orthoclase phenocrysts which included a nondescript isotropic substance. Plagioclase phenocrysts were highly altered, while calcite and chlorite formed alteration products. The presence of a very small amount of nephelite was shown by a chemical test which gave a slight gelatinization.

This facies of trachyte appears to be an intermediate type between the normal trachyte and an alkalic basalt phase.

A chemical analysis made by the Mines Branch, of the average trachyte, resulted as follows:—

SiO_2	60·34
Al_2O3	18·10
Fe_2O_3	2·71
FeO	1·28
MgO	1·36
CaO	1·82
Na_2O	5·25
K_2O	7·35
Total H_2O	1·25
TiO_2	1·00
MnO	0·05
CO_2	....
	100·51

Phonolitic Trachyte.

A phonolitic phase from the escarpment above the Maple Leaf property appears as follows:—

Megascopic. Holocrystalline; porphyritic aphanitic; reddish grey colour; dense, subconchoidal uneven fracture; dull lustre.

Microscopic. Under the microscope are noted the following minerals: apatite, magnetite, titanite, leucoxene, alkalic feldspar, augite, chlorite, and kaolin. Titanite and apatite are common accessory constituents. The augite is a pale green diopside, and forms phenocrysts in a very fine microcrystalline base which the high power objective shows to consist of mostly short, irregular tablets of feldspar mixed with a relatively large amount of granules of pyroxene and magnetite, enveloped and cemented by a cloudy, faintly polarizing substance of which no nearer characters can be given. The whole is dusted through with the alteration products, limonite, chlorite, calcite, kaolin, and probably zeolites.

The general character of the rock, with its entire lack of quartz or silica in the groundmass, indicates that it is a trachyte inclining towards the phonolite side, and this is further indicated by gelatinization obtained by chemical testing, although it is not, of course, absolutely certain that the gelatinous silica may not come in part or wholly from zeolite products.

This rock as seen in outcrops on Franklin mountain tends to break with a platy parting, like many phonolites.

Alkalic Basalt.

A dark, basic looking lava occurring on the west flank of Franklin mountain is composed dominantly of a pale green augite in a felsophyric groundmass consisting of alkalic feldspar with much disseminated magnetite dust. On account of its high content of augite, lack of trachytic texture in groundmass, and megascopic characters, it has been classified as an alkalic basalt. Between the trachytes previously described and this alkalic basalt type all transitions occur.

The alkalic basalt bears the same relation to the trachytes that the shonkinite-pyroxenite does to the syenite, and it may represent the effusive equivalent of the former hypabyssal rock.

Some of the lavas, especially the basalts, are vesicular and amygdaloidal, and show chalcedony, intergrown with calcite, filling the gas pores, the whole surrounded by shells of epidote grains. The amygdules are generally oval shaped, due probably to flowage at the time of extrusion, which drew out and extended the steam pores in which the chalcedony and calcite were subsequently deposited.

A chemical analysis made by the Mines Branch of the basalt, resulted as follows:—

SiO_2	49·60
Al_2O_3	14·84
Fe_2O_3	4·14
FeO	3·45
MgO	7·58
CaO	7·72
Na_2O	2·68
K_2O	3·72
Total H_2O	3·30
TiO_2	1·10
MnO	0·10
CO_2	1·80
	100·03

Pyroclastics.

This division comprises all those rocks which consist of fragmentary materials varying in coarseness from volcanic blocks and bombs to true ashes and tuffs, and which were ejected from volcanic foci.

On the east slope of McKinley mountain considerable agglomeratic material is present, as is well shown in the accompanying photograph (Plate XXII). Here the large lava blocks are chiefly angular, and the agglomerate as a whole is altogether devoid of stratification.

The basal portion of the Tenderloin lava cap on the west side of the mountain has considerable coarse ejectamenta, with round volcanic bombs up to 1 foot and more in diameter. Along with the larger rounded fragments there are smaller angular ones, as shown in the accompanying photograph (Plate XIX). The ejectamenta are of a vesicular nature and dark in colour, resembling the alkalic basalt.

The trachytic and basaltic tuffs in the district are well stratified, and alternate between fine and coarse beds intercalated with trachytic and basaltic lava flows.

A typical specimen from the east side of Tenderloin mountain, where the bed was intercalated with vesicular and amygdaloidal types, appears as a dense black, hornstone-like rock, banded and breaking with a sharp conchoidal fracture. Weathered surfaces are often lime coated.

Under the microscope it showed sharp angular fragments of basaltic lava of pilotaxitic texture, in a glassy groundmass with calcite cement. Similar basaltic tuffs were also found on Franklin mountain.

THEORETICAL CONSIDERATIONS.

Introductory Statement.

The bearing of the foregoing petrographic details upon a few of the broader problems in petrology will be here briefly stated. The igneous rocks of the Franklin district may be conveniently grouped under two main divisions: (1) Regional—batholiths and related intrusives. (2) Local—alkalic series of intrusions. The regional group includes the three batholiths (Nelson, Valhalla, and Rossland) and their related dyke equivalents. The rocks of this group are discussed in detail in the General and Structural Geology, Chapter IV (pages 55, 103, 114). It is with the rarer and more interesting rocks of the local group that this section has to do.

Petrographic Provinces.

The discovery of alkalic rocks in the Franklin district, on the western side of the Rocky Mountain Cordillera, has a distinct bearing upon the question of petrographic provinces, their extent and orographic relations. The term 'petrographic province' was first introduced by Judd,[1] who conceived the idea of genetic relationship of igneous rocks which show a certain

[1]Judd (J. W.): Quart. Jour. Geol. Soc., Vol. XLII, (1886), p. 54.

'consanguinity,' to use Iddings' classic term. The principle has since been greatly enlarged upon and applied to many widely scattered regions, by Iddings,[1] Brögger,[2] Lacroix,[3] Pirsson,[4] Harker,[5] Adams,[6] and others. A petrographic province may be defined[7] as any definite area of the earth's crust where the igneous rocks have common petrographic characteristics or clan relationship, which serve to ally them together and delimit them from the rocks of other areas. The cause of this clan relationship between all the different rocks in the series has been thought to be due to the differentiation of one common magma, originally homogeneous. It has been urged by some[8] that there is a relationship between igneous activity, including differentiation, and crustal movements, but to what extent this can be universally applied is still a question of much dispute.

The Franklin series of alkalic rocks belongs to a petrographic province in south central British Columbia which includes Rossland and other isolated areas whose petrography has not yet been studied in detail. The rocks comprising the series resemble in many respects those of the central Montana petrographic province,[9] on the eastern side of the Cordillera. Future geologic work in the intervening area may demonstrate that the two provinces are continuous.

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[1] The Origin of Igneous Rocks: Bull. Phil. Soc., Washington, Vol. XII, (1892), p. 194.

[2] Brögger (W. C.): Eruptivgesteine des Kristianiagebietes, I (1894), II, (1895).

[3] Roches alcaline de Prov. Petrograph d'Ampasinlava, Nouv. Arch. d'Museum, 4me. Ser., Vols. I et V, 1902, 1903.

[4] The Petrographic Province of Central Montana: Am. Jour. Sci. (4), XX, July 1905, pp. 35-49.

[5] Natural History of Igneous Rocks, Chap. IV, 1909, pp. 89-109.

[6] Adams (F. D.): The Monteregian Hills, Jour. Geol. XI, pp. 239, 253, 1903.

[7] See Judd: Petrographic provinces or districts "within which the rocks erupted during any particular geological period present certain well-marked peculiarities in mineralogical composition and microscopical structure, serving at once to distinguish them from the rocks belonging to the same general group, which were simultaneously erupted in other petrographical provinces."

[8] Natural History of Igneous Rocks, 1909, pp. 12,330.

[9] Pirsson (L. V.): The Petrographic Province of Central Montana: Am. Jour. of Sci. (4), Vol. XX (1905), pp. 35-49.

Harker[1] contrasts the great diversity of types east of the Rocky mountains in his Atlantic Province, characterized by alkalic rocks, with those on the west side of the Continental axis in his Pacific Province, characterized by subalkalic types. The finding of such diverse alkalic types in Franklin, west of the Continental axis, shows that such broad specific delineations of the boundaries of petrographic provinces, based largely on assumptions of orographic control, cannot be made.[2] Furthermore, the remarkable similarity between the two provinces, one on either side of the Continental axis, renders very doubtful whether horizontally directed compressional forces influence at all the distribution and localization of petrographic provinces.[3]

The rocks included in the series are as follows: monzonite, porphyritic syenite; augite syenite melanite syenite, nephelinitic syenite, shonkinite-pyroxenite; augite syenite porphyry, syenite aplite; trachyte, phonolitic trachyte, alkalic basalt, and pyroclastics from agglomerates to basaltic tuffs. All the diverse rock types of the series are considered to be co-magmatically related. The oldest intrusives represent the least alkalic and contain accessory quartz, while the youngest are the most alkalic and show the greatest degree of differentiation.

The evidence upon which their common intratelluric origin is based consists of their chemical, mineralogical and textural peculiarities.

From a study of the micro-slides belonging to the series it was found that the general law formulated by Professor Pirsson for the central Montana province holds good for Franklin, namely:—

"The petrographic province of central Montana is characterized by the fact that in the most siliceous magmas the percentage of potash and soda are about equal; with decreasing silica and increasing lime, iron, and magnesia, the potash relatively increased over the soda, until in the least siliceous magmas it strongly dominates."

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[1] Harker (A): The Natural History of Igneous Rocks, 1909, p. 103.
[2] The Natural History of Igneous Rocks, 1909, p. 102.
[3] Op. cit., p. 330.

The mineralogic characteristics are dependent upon the chemical as well as physical conditions attendant upon crystallization.

Augite. One of the most characteristic minerals, and an essential constituent of nearly all the types, is a pale green to colourless augite. No brown or purplish augites were found, not even when the titanic oxide reached about 1·8 per cent (Rosiwal method), as it did in the case of the augite syenite.

Orthoclase. Another most diagnostic mineral characteristic of all the rocks in the series, from the oldest to the youngest, is the alkalic feldspar. Albite was not found. This shows the dominance of potash over soda throughout the whole series. Monzonite, the oldest type in the series, has considerable andesine present, as well as orthoclase, while the porphyritic syenite has microperthitic intergrowths of plagioclase, with orthoclase and narrow plagioclase rims about the larger phenocrysts of orthoclase (Plate XIII). All the others are entirely lacking in plagioclase. Microcline is present to a minor extent.

Biotite. Biotite occurs as an accessory constituent, and is generally the brown, strongly pleochroic variety. It is a diagnostic mineral of the youngest dyke and plug intrusions in the district, which are pulaskite porphyries and minettes.

Hornblende. Hornblende is present in the monzonite and the porphyritic syenite, but is entirely absent in the younger types. Zircon is uncommon. Titanite and apatite are both common accessory constituents in all the types.

Of the granular types all, with the exception of monzonite and shonkinite-pyroxenite, show megascopically the typical trachytic structure of the feldspar laths. The volcanic equivalents show the same structure when examined under the microscope. The photograph (Plate XII) illustrates what a close similarity exists in hand specimens between the monzonite and syenite, even though the former lacks entirely the trachytoid structure of the feldspar laths so marked in the latter.

The mode of occurrence and structural relations of the different intrusions have already been discussed in the previous chapter. The sequence was concluded to be as follows, commencing with the oldest:—

1. Monzonite stocks.
2. Porphyritic syenite intrusions with their corresponding trachyte equivalents.
3. Main alkalic chonolith, with great diversity of types from shonkinite-pyroxenite to nephelinitic syenite; apophyses of syenite porphyry; extrusive equivalents of granular types, varying from alkalic basalts to phonolitic trachytes.

All these diverse types of igneous rocks have been derived, without doubt, from a common magma reservoir, and present an excellent example of magmatic differentiation within a local area belonging to the south central British Columbia petrographic province. This differentiation has taken place prior to intrusion[1] intratellurically, and there is no evidence of differentiation in place. This is shown by the variations in mineralogic and chemical compositions of the different granular types intruded at different times, and the finding of their effusive equivalents. Future detailed petrographic work, however, may somewhat modify this conclusion. Such work should be chiefly confined to the close examination of both lavas and granular types, with their field and chemical relations to one another, in order to determine to what extent the chemical variations of the extrusives correspond with those of the intrusives.

Magmatic Differentiation.

Having briefly considered the sequence and variety of rock types developed in the Franklin member of the south central British Columbia petrographic province, it is now in place to discuss the fundamental process of magmatic differentiation that causes them and under what conditions they are produced. The subject is still largely in the realms of speculation, although the physico-chemical side of the problem has been built up on a firm foundation and is making rapid advances.

[1] Brögger terms the differentiation prior to intrusion primary, or 'deep magmatic,' and the one in place, secondary, or 'laccolithic' differentiation: Eruptivgesteine des Kristiana. gebestes, I (1894), pp. 178, 179.

There are two distinct controlling agencies that bear upon this broad problem: (1) mechanical, (2) chemical. The chemical side has received the most attention and will first be discussed, and the mechanical will be dealt with later.

The Franklin series of alkalic rocks owe their chemical differences to intratelluric differentiation prior to intrusion, which has given rise to the different varieties of intrusive and extrusive rock types. The following chemical processes will be applied, which have a bearing upon this difficult theoretical problem. Magmas may be considered as complex solutions, the solvents being the silica, alumina, and alkalies, the rest the solutes. Under the possible causes of differentiation from the chemical standpoint, a fundamental process may be crystallization. If the solvent is in excess it will tend to crystallize first at the outer margins. However, the more closely the composition of a magma approaches eutectic ratios, the less capable of fractionation it becomes.[1] The minerals in excess of ratios will be the first to crystallize and segregate to the outer margins of the intrusive. Why should the minerals in excess of ratios crystallize first at the *outer margins*? This leads to the question of the conditions under which differentiation is produced. Many hypotheses have been advanced, and for historical reviews and summary analyses the reader is referred to Iddings,[2] Harker,[3] Clarke,[4] Pirsson,[5] and Daly.[6]

The hypothesis advanced by Michel Levy,[7] in which he emphasizes the importance of the "fluides mineralisateurs," or water and other fluxes circulating in the magma under high

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[1] Clarke (F. W.) : Data of Geochemistry, U.S. Geol. Surv. Bull. 491 (1911), p. 298.

[2] Origin of Igneous Rocks.

[3] Natural History of Igneous Rocks.

[4] Data of Geochemistry.

[5] Pirsson (L. V.): Petrology of the Highwood Mountains, Mont., U.S. Geol. Surv. Bull. 237 (1905), pp. 181-201.

Pirsson (L. V.), and Rice (W. N.) : Geology of Tripyramid Mountains: Am. Jour. of Sci., (4) XXXI, 1911, p. 287.

[6] Daly (R. A.): Origin of the Alkaline Rocks: Bull. Geol. Soc. of Am., Vol. XXI (1910), pp. 87-118.

[7] Bull. Soc. Geol. France, 3d series, Vol. XXV, 1897, p. 367.

temperature and great pressure, deserves some consideration. Magmatic water and gases increase fusibility, diminish viscosity, and thus facilitate crystallization. A complete segregation, however, is not assumed; only a differential concentration of the magmatic components.

Gases and vapours may have played an important part in the case of the syenite chonolith, as is indicated by (1) the granular texture of a magma that consolidated relatively near the surface, (2) the presence of fluorite in the melanite syenite, and (3) the intense permeation of the wall-rock, particularly the porous types, such as the Kettle River conglomerate and grit. Brögger has demonstrated from his work in the Christiana region that great depth is not necessary for the development of granular rocks and contact metamorphism.

A later hypothesis of probably great importance in certain cases was put forward by G. F. Becker,[1] who showed that fractional crystallization may have been an important factor in differentiation. In this case magmatic differentiation is a sequence of the general cooling process. The walls to the intrusion being cooler than the molten mass itself would facilitate the crystallization of the less fusible or less soluble minerals towards them. The process would be aided by circulation and convection currents. The resulting mother liquor (portion of maximum fusibility) would approach to that of a eutectic mixture. If the original magma were a eutectic mixture, fractional crystallization would not influence differentiation at all; but the farther removed the solution is from the eutectic point the greater its power to promote differentiation.

It has been determined by physical chemists, through synthetic work in the laboratory, that the order of crystallization of salts or minerals depends on (1) their relative abundance, (2) their solubility in eutectic, (3) possibly their points of fusion. In the case of their relative abundance, the law of mass action[2]

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[1]Becker (G. F.): Am. Jour. Sci., 4th Ser., Vol. IV (1897), p. 257.

[2]"The reaction-velocity (the amount in gram molecules which is transformed from each system into the others in the unit of time) at any moment is proportional to the masses of the substances then present." Text book of Inorganic Chemistry Holleman-Cooper, p. 78.

will determine what silicates can form. It is found that the less soluble and fusible minerals are formed the earliest. There is a tendency also to set up as few centres of crystallization as possible. This is shown in the usual coarseness of phenocrysts found even in rapidly chilled rocks; for instance, the pulaskite porphyry ("Bird's eye porphyry") at the chilled borders of the large pulaskite dyke west of the McKinley mine has quite large feldspar phenocrysts dotted sparingly through a dense groundmass, giving the whole rock a spotted or "bird's-eye" effect. This is further shown in the case of a granular rock, the porphyritic syenite on Syenite hill, where the material in the central portion has apparently tended to migrate towards the sides and solidify upon the centres already established there, rather than set up new ones. This has resulted in the growth of quite large feldspar phenocrysts, up to 2 inches in length, some of which radiate from one centre (Plate XIII). The latter effect may be due possibly to local stagnant conditions in the magma during consolidation. The large pyroxene phenocrysts in the shonkinite-pyroxenite ("Black Lead"), which give the rock in many places a decided porphyritic aspect, are probably phenocrysts of the first generation which had commenced to crystallize previous to intrusion.

FACTORS PROMOTING CIRCULATION AND DIFFERENTIATION. The three most applicable hypotheses that have been advanced to explain how differentiation proceeds will be considered here. They are: (1) diffusion, (2) convection currents, (3) liquation.

Diffusion. This is controlled by the nature of the magma with regard to its degree of fluidity or viscosity, and is accelerated by pressure.[1] It is not a likely process in silicate magmas, unless there is much magmatic water or other fluxes present. So long, however, as crystallization is able to proceed, the viscosity of a magma is never too great to prevent molecular flow or diffusion, since it is through this that the molecules are able to arrange themselves in crystal form.

Diffusion, assuming perfect miscibility of the magmatic solution, may have been a major factor in the differentiation of

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[1]Rontgen, Wiedem, Ann., Vol. XLV (1892), pp. 98-107.

the syenite chonolith prior to intrusion and may have produced the diverse types from melanite syenite to nephelinitic syenite. The criteria for distinguishing differentiation controlled by this factor are the very gradual transitions from one type to another and their irregular distribution.

Convection Currents. This factor, controlling certain phases of differentiation, would in turn be controlled to a large extent by mechanical conditions promoting bodily movement. In the case of the syenite chonolith, with its marginal phase of shonkinite-pyroxenite which is usually present, it is thought that the shonkinite-pyroxenite was intruded first, and before it had time to entirely solidify and become jointed the fissure was opened and the syenite intruded. The younger syenite found the lower contact of the pyroxenite the most favourable place for intrusion, except where the chonolithic mass steepened to form the Tenderloin volcanic vent. There the pyroxenite is found at both borders of the syenite. In places the syenite contains 'endogenous inclusions' and 'schlieren,' as, for example, at the Averill and Maple Leaf properties.

The contacts between the shonkinite-pyroxenite and syenite are always well welded and pass rapidly from one to the other. This would seem to indicate that either the basic differentiate owes its origin to a liquation process, which implies immiscibility of the magma solutions, as discussed under the next heading, or to separate intrusions. The liquation hypothesis is here untenable, because in it gravitative adjustment is a controlling factor. In the case of the Franklin chonolith there is no evidence of gravitative adjustment, so that the simplest explanation appears to be that of separate intrusions.

In the case of the shonkinite-pyroxenite area on the Averill property, movement in the consolidating magma about the basic mass has possibly produced the shattering and brecciation along which the aplitic magma extract of maximum fusibility and liquidity would penetrate and crystallize. The force of crystallization would further accentuate the shattered appearance of the mass.

Both magmas, however, came from the same magma reservoir below, where they have been influenced to some extent in their differentiation by this factor of convection currents. Such influence would cease once the viscosity of the magma rendered bodily movement impossible, while diffusion, on the other hand, might continue for a long time subsequent to that period, and account in part for the variations in the syenite itself from melanite syenite to nephelinitic syenite.

The chemical composition and proximity to surface of the magma may be other conditions that influence differentiation.

Liquation. This factor in differentiation, as advanced by Durocher and Bächstrom, involves limited miscibility[1] of the magma solution, with gravitative adjustment and separation of the heavier basic extract below that of the lighter acid one. This factor, then, is not applicable to any possible differentiation in place of the Franklin chonolith, for there is no evidence of gravitative adjustment. In fact, the basic differentiate lies generally on top of the syenite. However, it may have played an important part in intratelluric differentiation prior to intrusion, as shown by the two sharply differentiated magmas, augite syenite and shonkinite-pyroxenite. It is possible that it was responsible for the splitting of the parent homogeneous magma into a basic heavier and an acid lighter portion. Where this factor has dominated in the case of differentiation in place, the basic margins should be regularly disposed at the borders with reference to the acid portions. Where differentiation has taken place intratellurically, and two distinct magmas are intruded, the one slightly in advance of the other, the older magma is found generally at the outer borders of the intrusive mass, irrespective of the chemical composition.

For example: At Mount Johnson, near Montreal, a volcanic vent, one of the members of the Monteregian petrographic province, has been described by Professor Adams,[2] who found the basic essexite towards the centre of the neck surrounded by pulaskite. There, however, the pulaskite is older than the

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[1]Fluids insoluble in each other.

[2]The Monteregian Hills—A Canadian Petrographic Province. Jour. of Geol., Vol. II (1908), p. 253. Also see G. A. Young: Geology and Petrography of Yamaska, G.S.C. Ann. Rept., XVI, Pt. H, pp. 8-43.

essexite. At Franklin, on the other hand, the basic pyroxenite is older than the augite syenite, and is naturally found chiefly at the outside borders of the intrusive mass.

Igneous Activity and Mechanical Considerations.

Having discussed in a summary manner, differentiation controlled by such physico-chemical agencies as "Fluides mineralisateurs," fractional crystallization, diffusion, convection currents, and liquation, the mechanical side of the problem, as well as that of igneous activity, will now be dealt with.

Here the nature of vulcanism in the Franklin district may be most safely inferred from both inductive and deductive reasoning. Dynamic movements of the earth's crust are of two kinds: continental building and mountain building. The former implies broad continental uplift, dependent on vertical forces, and the latter depends upon compressional forces. Pressure raises the melting points and tends to prevent the escape of dissolved vapour, and so to increase fluidity. Gases in the molten mass, however, lower the melting points, and probably more than offset the effect of pressure.

In order to correlate the different periods of igneous activity, erosion, and dynamic crustal movements in the Franklin district, the following sequence of events is tabulated:—

Eocene-Oligocene	1. Regional subsidence following the Laramide revolution, with deposition of great thicknesses of conglomerate, grit, and contemporaneous rhyolites. 2. Deformation and monzonite intrusions(?) 3. Erosion cycle.

Miocene	4. Porphyritic syenite intruded, and early trachyte flow. 5. Erosion interval. 6. Shonkinite-pyroxenite and augite syenite intruded and poured out surficially as alkalic basalt and tra chyte. 7. Period of youngest dyke intrusions, pulaskite porphyries, and lamprophyres.
Pliocene	8. Long erosion cycle.

It is noted that the epochs of igneous activity followed periods of erosion, which were in turn inaugurated by crustal movements. It is possible that following such movements dynamic strains of an acute kind, in this mountainous district, may have promoted more rapid progress in differentiation. There is no evidence, however, to show that mechanical forces of the nature of lateral thrusts have been an essential factor in differentiation.[1] On the other hand, the batholiths that appear to be closely related to mountain folding and lateral thrust show no marked differentiation, and are, in a general way, homogeneous throughout. Igneous activity, which has given rise to the local group of rocks in Franklin, does not appear to have been closely related to orogenic movement; but the regional group, on the other hand, does appear to have been closely related to mountain making movements.

It is to be noted that the Tertiary magmas found access to the surface only through the bottom of the Franklin Tertiary valley, which to the writer appears to have been developed in a synclinal basin, and that the main intrusion took the form of a concave arc conformable in a broad way to the early Tertiary formations. Where the intrusion had its outlet to the surface,

[1]Natural History of Igneous Rocks, p. 330.

however, the general northeast-east dip became vertical, as shown by contact relations on Tenderloin mountain.

Similar instances of confinement of vulcanism to synclinal basins is present in the Neapolitan area, Italy,[1] where "volcanic eruptions . . . . . began somewhere between the end of the Pliocene and the beginning of the Pleistocene period, upon the bottom of a great synclinal basin, resembling those to be seen elsewhere in the Appenines, but in part drowned by the sea." In the Tertiary districts of central and southern Europe in general the eruptions have found vent, not along the mountain range lines themselves, but within the depressions between the various orographic lines. All through the long volcanic history of ancient volcanoes of Great Britain, Sir Archibald Geikie found that the orifices of discharge for the erupted materials have been opened along low grounds and valleys rather than on ridges and hills.[2] Geikie also found that the volcanoes in Great Britain have been active on areas of the earth's surface that were sinking and not rising. This generalization would apply also to the Franklin district.

It is of general interest to note that the relatively close proximity between the granular intrusives and their extrusive lava equivalents in Franklin agrees well with Sir Archibald Geikie's generalization that "volcanic action is not deep seated but has its source not many hundred feet below ground."[3]

It further emphasizes the great importance of "fluides mineralisateurs" in the consolidation of molten magma, and indicates how a comparatively slight depth of erosion might remove all traces of lava extrusives, and expose simply their granular and intrusive types.

The chemical generation of heat by radioactivity may have been a potent factor in causing igneous activity, but too little is known concerning it to consider it here.

It is known that in Franklin, at certain definite periods in its Tertiary history, local increase of temperature within the subterranean horizon took place. Relief of pressure may have

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[1] De Lorenzo (Guiseppe): Quart. Jour. Geol. Soc., LX, Pt. 3, p. 296, 1904.
[2] Geikie (A.): Ancient Volcanoes of Great Britain, Vol. I, p. 470.
[3] Geikie (A): Text book of Geology, Vol. I (1903), p. 280.

resulted in volumetric expansion of the magma and eruption. Volcanic eruption broke forth from a vent on Tenderloin mountain, probably brought about both through terrestrial contraction and its effects and the tension of absorbed gases and vapours. The shonkinite-pyroxenite and syenite (the 'live rocks,' according to Brun) before eruption were heavily charged with aqueous vapour and other gases under great pressure, and high temperature. The temperature would vary considerably through: (1) heat lost by cooling, as the sudden expansion of gases released at the beginning of volcanic eruption would exert cooling effects on the residual magma; and (2) heat evolved by chemical changes. The pressure, too, was a variant during eruption, and must have fluctuated widely. When the pressure was released the gases escaped with explosive force and carried the liquid matter with them, which accounts for the bombs and other vesicular ejectamenta on Tenderloin mountain. The process also produced a great quantity of fiery spray, which solidified in the form of volcanic ash and formed the basaltic and trachytic tuff beds of both Tenderloin and Franklin mountains.

When the lava streams themselves appeared their effervescence had largely ceased, and the fluid or viscous lava cooled and consolidated quickly to a dense rock (the 'dead rocks' of Brun), very different in texture but not in composition from their original granular equivalents.

By further pressure contemporaneous with consolidation, the temperature needed to produce complete fluidity is raised, and this fact is emphasized by the phenomena of resorption displayed in the lavas of the district.

In conclusion, it is of general interest to petrologists to know that the Franklin district presents another example of magmatic differentiation among alkalic rocks of a new petrographic province in south central British Columbia.

CHAPTER VI.

GEOLOGIC HISTORY.

Introductory Statement.

The geologic history of the Franklin district has as its major features: sedimentation and igneous activity in the upper Palæozoic; erosion and batholithic invasion in the Mesozoic; continental sedimentation, igneous activity, and erosion in the Tertiary; and continental and valley glaciation in the Quaternary.

The records of ancient geologic history before the late Palæozoic era are entirely wanting in this district, and crustal disturbances, batholithic invasions, and erosion cycles, all on a large scale, have in their respective turn closely folded and broken, undermined, and removed full details of former events, leaving bare now only scattered fragments of a once complete record. Such a fragmental record of the late Palæozoic, much obscured by antiquity, has been left exposed in Franklin.

From that date until the end of the Mesozoic it will be possible to trace clearly only the major events, and the minor features must necessarily remain unknown or at best be only conjectured. With the approach of modern geologic time, however, the records become more numerous and their meaning is more evident.

In the Franklin region a part of the early Tertiary record is preserved by protective lava cappings, while the more recent events in its geologic history have been disclosed through physiographic study of the present significant land forms.

Upper Palæozoic Time.

The Franklin geologic history, in so far as its rock records permit, must necessarily commence with the upper Palæozoic and very probably with the Carboniferous. To get a broad view of prevailing conditions at this time it seems advisable to utilize rock records of the same age from the Selkirk mountains to the east, as well as the Interior Plateau to the west, and in doing so to try and arrive at some broad suggestive generalizations.

One may picture at this time a sea slowly transgressing from the east and subject to minor oscillations of level upon a relatively low lying land surface, with general off-shore marine conditions to the west and inshore conditions on nearing the broad continental area which supplied the thicknesses of upper Palæozoic sediments. This area probably extended from Alberta to Labrador. The oldest sediments in Franklin are of an argillaceous character with plant impressions, and probably represent old shore conditions about an upper Palæozoic island or along the main continental coast. From such islands or shores or from volcanic vents rising above the sea-level, volcanic activity burst forth at intervals and deposited vast amounts of pyroclastic tuffs having angular fragments along with the normal argillites and sandstones. The sedimentary materials are all fine grained and indicate deposition in waters without strong currents (Lower Câche Creek series of Dawson, Knobhill group at Phoenix of LeRoy, and Franklin group). Subsidence continued and in the course of time volcanic activity ceased. The inshore argillaceous conditions of Franklin may have migrated eastward to the present site of the Selkirk mountains, substituting, instead, open sea conditions with scarcity of land-derived sediments in which probably the Gloucester limestones were deposited with their crinoidal fauna (Upper Câche creek[1] and Brooklyn limestone at Phoenix).[2] The greatest and best preserved sections of this limestone are found farther to the west in the Kamloops district where orogenic movement has not been so intense as in Franklin. This marine transgression extended not far east of the Purcell range where the thin records of it have been entirely removed. With the maximum extension of marine conditions, minor oscillations of sea-level or of climate evidently prevailed, on account of the more minutely interstrati-

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[1]Dawson (G. M.): Report of Progress G.S.C., 1877-78, p. 80 B.

[2]LeRoy (O. E.): Report on Phoenix Mining Camp G.S.C., Memoir 21.

fied condition of the inshore calcareous and argillaceous sediments (Slocan series calcareous argillite and argillaceous limestone.)

Close of the Palæozoic.

This long period of quiet with only uniform and widespread crustal movements, was brought to a close by a series of great disturbances which lasted for a long while. The region was uplifted above the sea and the areas of greatest thickness of interstratified argillites and limestones, such as dominated the inshore areas, were subject to close folding as well as regional uplift, while those rigid areas of massive limestones, although elevated en masse, were, however, more competent to resist orogenic strains and yielded by open folding and tilting. This resulted in a more highly mountainous district to the east, composed of the more readily folded and broken sedimentaries, while the limestone and more massive sediments of the west were relatively low lying.

The great crustal disturbances which closed the Palæozoic period inaugurated conditions of continental erosion and sedimentation which have lasted to the present time.

Mesozoic Time.

Triassic Period.

There is no evidence in the vicinity of Franklin or neighbouring districts to the east, to indicate that any marine transgressions since that of the Carboniferous have taken place. However, there is evidence in the Kamloops district[1] that the Triassic marine waters extended over the Câche Creek series (equivalent of Franklin and Gloucester formation). There the Nicola series lies unconformably upon the latter formation and consists of thin irregular beds of limestone, some argillites, and eruptive materials, while the sedimentaries show evidence of subaqueous deposition and bedding,[2] but no proof, Dawson

[1] Dawson (G. M.): Kamloops Map Sheet, p. 50 B.
[2] " " " " Report, p. 55 B.

states, so far has been found of subaërial deposition. During the Triassic period, then, the Franklin district probably formed a part of the highlands which supplied waste for the deposition of the Triassic Nicola series farther west in the Interior Plateau country. As rock decomposition, from sedimentary evidence, at that time dominated over mechanical disintegration, the region was probably one of moderate relief.

Jurassic Period.

Epeirogenic elevation and batholithic invasion took place probably during the Jurassic. It was at this time that the Nelson granodiorite was intruded and the contact metamorphic ores deposited in the overlying calcareous cover rocks.

Cretaceous Period.

The crustal movements and uplift of the time invigorated the drainage and brought about a new cycle of erosion which lasted all through the Cretaceous period and removed the entire cover overlying the Jurassic batholith, so that early Tertiary conglomerate, grit, and rhyolite lie directly upon the Jurassic granodiorites on McKinley mountain in the Franklin district. The whole western region between the Pacific Cretaceous and that of the Albertan plains, at this time was brought down to a surface of low relief with local peneplanation in the Interior Plateau country. This surface stood 2,000 or 3,000 feet lower in relation to the sea than it does now.

Laramide Revolution.

At the end of the Cretaceous the Cordillera received one of the greatest orogenic disturbances in its history. The whole Cordillera was uplifted and folded in places and a new cycle of erosion inaugurated. The Interior Plateau country was uplifted and subsequent erosion produced deep valleys and the formation of a topography somewhat similar to that of the present. The highly folded Cordillera to the east was probably produced at the same time.

The larger topographic features such as the intermont trough within which the Franklin district lies, and the Cariboo and Granite Mountain ranges, were outlined during this mountain making epoch. Some parts of the Jurassic granodiorite batholith yielded to the crustal stresses by mashing with the production of gneissic structure, while elsewhere, particularly in the neighbourhood of its roof rocks, it yielded by brecciation and shearing with local mineralization along the shear zones. Connected with these crustal disturbances and relief of stress was possibly the intrusion of the Valhalla granite along the axis of the Cariboo range. Extrusive equivalents of this granite appear to have penetrated the synclinal basin and poured out in the form of rhyolitic lavas contemporaneous with the deposition of rhyolitic grits and conglomerates of the Kettle River formation (Eocene). Here in Franklin, as in the European Alps, the volcanic eruptions may have avoided the closely compressed folds along the mountain axis and found easier access to the surface through the basins and plateau stretches of the Interior Plateau country. This feature is also striking in the case of the Miocene igneous activity as will be seen later.

Tertiary Time.

Eocene-Oligocene Period.

Such were the conditions of mountain growth that left the Cordillera with a very rugged and youthful relief which at once inaugurated a new cycle of vigorous erosion and subaërial deposition. The axes of the sedimentary mountain ranges then were the same as the present granite ones, but their topographic relief was much greater.

The uplift and deformation brought about a change in climate for this section of the Cordillera, from the subtropical of the Cretaceous to one of coolness and humidity in the Eocene, as evidenced by the thoroughly leached light coloured sediments with carbonaceous shales and sandstones bearing plant remains in one locality. The coarse heterogeneous conglomerates containing scratched and facetted boulders and pebbles point towards rugged alpine conditions in the surrounding highlands, with even local glaciers supplying their quota of material to the conglomerates which were being deposited in alluvial cones at the base of the ranges.

The drainage of the Eocene-Oligocene period, although broadly the same as the modern, was in a decidedly disorganized condition due to (1) damming effects of contemporaneous lava flows and (2) the migration of the conglomerates of the subaërial cones from the borders of the basin. Local lakes and flood-plains existed where volcanic dust accumulated and vegetation flourished from time to time. Minor oscillatory crustal movements following the Laramide revolution and preceding the deformative period at its close, may have also affected the drainage and sedimentation. Fluviatile deposition went on rapidly as shown by (1) the coarseness of much of the material deposited; (2) the presence of abundant cross bedding; and (3) the distance between the bedding planes of the grit in places. The streams with strong gradients were loaded with coarse waste and rapidly aggraded their courses. The drainage of the time was cut deeper than that of the present day, a fact that might indicate that the region stood higher then than it does now and probably about the same height as it did after the Pliocene uplift.

Volcanic activity in the early stages of the period was of an explosive nature and beds of fine acidic tuff, as well as large and small blocks of rhyolite, were laid down in the basin and worked over by the streams. This was followed by minor rhyolite flows which are seen at present intercalated and tilted with the arkosic grits and tuffs. Sedimentation continued until the valleys were all filled up. Towards the end of the period, volcanic activity reached its culmination with the outpouring of a great rhyolite porphyry and rhyolite flow preceded by ejectamenta from McKinley mountain. This flow, as shown on Franklin and McKinley mountains, filled up an old valley which had been cut down almost to bed-rock. The bed-rock here was a portion of the Cretaceous surface of erosion on Jurassic granodiorite.

Oligocene Period.

Following this long period of continental sedimentation, epeirogenic movement took place probably contemporaneous with the intrusion of the monzonite stocks.[1] The movements affected north-northwest and south-southeast lines resulting in uptilting of the beds to the north-northeast. The McKinley Mountain rhyolite, however, preserved its rigidity to a great extent compared to the more readily disturbed grits, tuffs, conglomerates, and minor rhyolite flows.

The crustal disturbances inaugurated the new cycle of erosion which was so largely responsible for the stripping off through southern British Columbia, of vast thicknesses of early Tertiary sedimentary and volcanic records. It is impossible to estimate to what extent the Kettle River formation has been removed from localities where it once existed. This erosion interval is indicated in the Franklin district by an unconformity, which shows that the disturbed sediments had been eroded to an undulating mature stage of development with a broad and shallow river valley. The pre-rhyolite porphyry river was forced to take a new course and followed the east border of the resistant flow rock. By the close of the long erosion cycle, however, which preceded the Miocene lava flows, it had regained in part its former course, as shown by the manner in which the Miocene trachyte caps it on Franklin mountain.

Miocene Period.

Following long erosion, igneous activity broke forth explosively from a vent on Tenderloin mountain and deposited basaltic and trachytic tuffs and ejectamenta, followed by extensive trachyte flows which filled the low depressions and main alluvial filled valley of the later mature land surface. The intrusive shonkinite-pyroxenite ("Black Lead") and augite syenite, which supplied the surface flows, even reached the unconsolidated coarse gravels and silt of the Kettle River formation, producing intense contact metamorphic action which affected the formation

[1]The forerunners of younger alkalic intrusions in the Miocene.

for nearly 50 feet from the immediate contact. The "Black Lead" ores are referred in part to this period.

Tongues or apophyses of syenite porphyry penetrated the cover rocks of the chonolith on its concave side. The trachyte flows altered the course of the previous river and thus two rivers were developed at the borders of the flow, the eastern one going to form the main Kettle river.

Later, in Miocene time, when there was still a deep mantle of superincumbent lavas and sedimentaries, the pulaskite magmas penetrated the district in dykes and pipes, fed probably from the great Rossland batholith to the east, which comprises a large part of the Granite range. Batholithic invasion and igneous activity were in all probability connected with mountain making movements as shown by the definite dyke systems maintained in certain localities.

The faulting of the post-Oligocene erosion surface on Tenderloin mountain probably took place at this time, as syenite dykes of the same age were found cutting the same contact in a similar manner to the fault.

There is no evidence in Franklin that the pulaskite magmas ever reached the surface to form flows as they were found to do in the Boundary district.

The last intrusions of this epoch were the lamprophyre dykes which probably took place in late Miocene time and may be connected with the younger lava flows of basalt, remnants of which are found in the Interior Plateau country.[1]

Pliocene Period.

Following the great epoch of igneous activity and crustal movements of the Miocene, came peaceful stable conditions with a long period of erosion, which lasted through most of Pliocene time. To this long erosion cycle the present upland topography of Franklin at least, owes its origin, and it is probably continuous throughout the rest of southern British Columbia. The present drainage system was outlined and a coarse textured topography[2]

[1]Dawson (G. M.): Kamloops map sheet.

[2]"Where interstream areas are large, the contours have few reentrants, and the topography as a whole appears large featured, or *coarse textured.*"

produced. The land at this time was some 2,000 feet lower than it is at present. The early Pliocene auriferous quartz drift would imply long subaërial decay and stability of level somewhat analogous to conditions during the Cretaceous peneplanation at the end of the Mesozoic era, when sandstones, lignites, clays, and such products were deposited in contrast to the coarse mechanical sediments of the early Tertiary after uplift and mountain making.

Thus both the Mesozoic and Tertiary eras in this region ended with the land reduced to post-maturity and local peneplanation.

Quaternary Time.

Pleistocene Period.

The diastrophism which closed the Tertiary was in the nature of a broad differential uplift which permitted the invigorated drainage to incise itself deeply into the land surface with the production of steep-walled, V-shaped valleys. Since the drainage courses in the early Quaternary were not filled and shifted by lava flows, as they were in the early Tertiary, the present river courses are antecedent with respect to the Pliocene surface of erosion. The present Cariboo and Granite ranges may have been axes of maximum uplift as they were in other periods of diastrophism. The district was probably much higher than at present as Dawson[1] has presented evidence to show that the Pacific coast stood then 900 feet higher than at present, which means that there may have been a land barrier between the Arctic waters and those of the north Pacific, permitting the migration of Japanese faunas.[2]

Some auriferous gravels have been assigned to this pre-Glacial period in the Pleistocene.

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[1] Dawson (G. M.): On the later Physiographical Geology of the Rocky Mountain Region in Canada. Trans. Royal Soc. Canada, Section IV, 1890, p. 17.

[2] Smith (J. P.): Amer. Jour. Sci. (4), Vol. XVII, p. 226.

Glacial Period.

The most modern geologic events recorded in the history of the Franklin district are those connected with glaciation. The Cordilleran ice sheet covered the whole region with the possible exception of a few high peaks on the Cariboo range, which stood as nunataks above the ice surface. It but slightly modified the upland topography, leaving striæ and scourings in places, but on retreating left morainic drift and erratics stranded high on the upland.

The ice cap gave place to alpine valley and cirque glaciers[1] which slowly retreated until the time of the Keewatin ice sheet extension to the east, when the second main period of valley glaciation took place. It is to this period that the strongly glaciated valley forms (such as U-shaped valleys, lateral moraines, striæ, etc.) owe their origin, and the valley trains of outwash material were deposited.

Recent.

With the retreat of the valley glaciers the streams, unburdened of their morainic load, began to degrade their valley fills. A series of terrace-steps mark successive periods of aggradation and degradation dependent upon climatic oscillations.

The last events are connected with the slow normal weathering agencies of frost, ice, snow, rain, and humus, which are facilitating the disintegration and decomposition of the rock formations, with formation of subsoil and soil.

SUMMARY OF GEOLOGIC HISTORY.

Palæozoic.

Carboniferous. Deposition of Franklin group sediments (argillites, quartzites, and tuffs) followed by that of the Gloucester limestone formation in an eastward transgressing Carboniferous sea. Great uplift and orogenic movements brought the Palæozoic to a close and inaugurated new and lasting conditions of continental erosion and sedimentation.

[1] First period of valley glaciation.

Mesozoic.

Triassic. Franklin district undergoing rapid erosion and supplying material for Nicola group rocks to the west.

Jurassic. Regional uplift associated with the intrusion of granodiorite batholith with apophyses injected into cover rock and formation of contact metamorphic ore bodies.

Cretaceous. Long period of denudation in which the batholithic cover of sedimentary and metamorphic rocks was almost entirely removed.

The Mesozoic closed with the post-Cretaceous uplift and Laramide mountain building. Franklin intermont trough formed. The Valhalla acid granite batholith is referred to this period.

Tertiary.

Eocene-Oligocene. Continental sedimentation with great deposition of tectonic conglomerates and tillites and with contemporaneous and subsequent rhyolite flows in the basin itself. The rhyolites are very probably the extrusive equivalents of the Valhalla granite batholith.

Interval of crustal disturbances; intrusion of monzonite stocks, the forerunners of Miocene alkalic intrusions; long erosion cycle.

Miocene. Intrusion and extrusion of alkalic magmas (shonkinite-pyroxenite and augite syenite) with all associated dykes and ores.

Pliocene. Formation of present post-mature upland in Franklin during long extended erosion cycle.

The Tertiary closed with a great differential uplift.

Quaternary.

Pleistocene. Entrenchment of deep valleys; Cordilleran ice sheet followed by first period of valley glaciation; second period of valley glaciation—Keewatin stage—with alluviation.

Recent. Formation of terrace-steps; subsoils and stream gravels formed.

CHAPTER VII.

ECONOMIC GEOLOGY.

HISTORICAL INTRODUCTION.

The first mining claims to be located in the Franklin camp were the Banner and the McKinley, which were both staked in the summer of 1896. The locator of the Banner claim was Frank McFarlane, after whom the camp was named, while Jos. Wilcher located the McKinley claim. The Gloucester and adjoining claims were located by Thos. Newby in the summer of 1898. These were followed by the White Bear in 1899, the Maple Leaf in 1902, the Evening Star in 1903, the Buffalo in 1904, the IXL in 1904, and many others.

In 1900 a government trail was cut to the camp from Grand Forks, and the same year a 200-foot cross-cut tunnel was driven on the Banner claim to tap a vein encountered in a shaft. This was the main development work up to that time, as only open-cuts and small prospect pits had been attempted on the other properties. The year 1906 saw the greatest activity in Franklin, when considerable development was carried on and practically all the ground in the mineral belt was staked out. Town sites were surveyed, and the lots put on sale. Cabins were rapidly erected, and the camp was boomed extensively by mine promoters who freely made use of the newspapers in advertising this as a new and promising copper camp. That same year witnessed a gold placer rush of prospectors to Franklin on the news that gold nuggets had been found at Dinsmore's, about a mile below Gloucester City. This turned out to be a case of salting by a prospector, who was detected before he could dispose of his property and had to decamp in haste.

The McKinley was the premier property at this time, so far as exploitation was concerned, showing some hundreds of feet of tunnelling and considerable surface stripping and trenching. It had been bonded for two years to a company on behalf of eastern capital, for $200,000. The year 1906 saw some diamond drilling done on the Banner claim, as well as development work on the Gloucester group, bonded by the Dominion Copper Company, while in the same year the Fee Brothers did some work on the Maple Leaf property.

Following this boom period, a reaction set in and there was a period of depression up to 1908, when the completion of a wagon road from Grand Forks to Gloucester City made the camp more accessible, and mining activities were continued for a short period. The years 1909 and 1910 saw comparatively little prospecting and mining done, as the majority of the claims by this time had been crown granted and allowed to lie dormant.

Development work was carried on in the summer of 1911 on the McKinley property, under bond by the British Columbia Copper Company. Besides the work done on the McKinley assessment, development work was carried on on the Dane and Averill groups, the Union, Buffalo, and Royal Tinto claims.

The list of mining claims arranged in alphabetical order is as follows: Ajax, Aldie, Alert, Alpha, Alto Fr., Antelope, Athelston, A. X., Banner, Banner Fr., Big Cub, Black Bear, Blue Jay, Bryan, Buffalo, Bullion, Buttercup, Bystander, Columbia, Cottage, Crystal Copper, Doris Fr., Eclipse, Eganville, Evening Star, Florence, Franklin, Gloucester, Gloucester Fr., G. H., Golden Age, Grande, Hanna, Henneken, Hit-or-Miss, Homestake, Ida, Iron Cap, Iron Hill, IXL, Jumbo, Last Chance, Little Cub, Lucky Jack, Maple Leaf, May, McKinley, Montana, Montezuma, Mountain Lion, Munstar, M. S., Nakusp, Nellie, Newby Fr., Old Dominion, Omar, Opher, Ottawa, Ouray, Pinto, Rio, San Francisco, Shelby, Standard, Thnot, Tiger, Tiger Fr., Union, Verde, Violet Fr., Wallace, Waverly, White Bear, Yellow Jacket; all together, seventy-five claims. All of these are crown granted, with the exception of the Blue Jay claim.

TYPES OF ORE DEPOSITS.

The ores of the Franklin district present a diversity of types of considerable interest to economic geologists. The metalliferous ores of the district, as will be later shown, are the result of four distinct periods of mineralization—two in the Mesozoic and two in the Tertiary. As a basis for dividing the ores formed during these several periods of mineralization, the genetic types, which are very distinct, have been employed. In this way the following classification of the ores of the district has been compiled and will be used in the report for purposes of description:—

I. Mesozoic deposits.
   1. Contact metamorphic type
      Sub-types:
      a. Pyrite-chalcopyrite
      b. Galena-blende
      c. Magnetite-pyrite

   } Dependent upon intrusion of Jurassic granodiorite batholith.

   2. Fissure veins.
   3. (a) Contact zones
      (b) Shear zones in granodiorite

   } Dependent upon both intrusion of Jurassic granodiorite batholith and crustal movements during the Laramide revolution.

II. Tertiary deposits (Miocene).
   1. Segregation type—"Black Lead."
   2. Contact metamorphic type.
   3. Replacement along shear zones.

From the above, it may be noted that there are contact metamorphic deposits of two ages, the one in the Mesozoic and the other in the Tertiary.

Summary Description of Types.

The *Mesozoic type* is characterized by the presence of such lime-silicate gangue minerals as garnet, epidote, diopside, tremolite, and the ore minerals, including sulphides and oxides of iron, with some chalcopyrite. The mineralized zone extends in widths varying from 0 to 100 feet, about rudely lenticular shaped masses of marble. The marble which belongs to the Gloucester formation of Carboniferous age, has a closely compressed synclinal structure, with a general steep dip to the west. The basal formation is an altered tuff and greenstone of the Franklin group, which is heavily pyritized in the vicinity of the mineralized zone. The ore lies within the mineralized zone and forms rudely tabular shaped masses or shoots, chiefly at the immediate border of the barren marble. The contact between the marble and the mineralized zone is usually very sharp. The contact, on the other hand, between the altered tuff and the mineralized zone is very gradual, and it is difficult to tell where the ore ends and the country rock begins. The ores are divided into three sub-types, one characterized by predominant pyrite-chalcopyrite, a second by galena-blende, and the third by magnetite-pyrite. The galena-blende type follows the limy portions of the mineralized zone, where contact metamorphism has not been so powerful, while the pyrite-chalcopyrite and magnetite types, on the other hand, follow dominantly the siliceous portions. The deep-seated parent igneous rock which has produced the metamorphism is granodiorite, which cuts the ore and marble in several places.

For further details, see description of the McKinley mine, on page 159.

The *Tertiary contact metamorphic ores* stand in strong contrast to the Mesozoic type in their exceedingly small development and different mineralogic characters. The ore is chalcopyrite, pyrite, sphalerite, galena, malachite, and azurite, in a gangue of impure quartzite and greenstone, with considerable secondary hornblende, alkalic feldspar, and epidote. The sulphides are intimately intergrown, indicating deposition simultaneous with rock alteration. The igneous rock in this case is an augite syenite and shonkinite-pyroxenite. For further details, see description of Maple Leaf property, page 174.

The *fissure veins* are very few in number. They vary in width from a few inches to a couple of feet, and are traceable on the surface for only short distances. They are the simple filling type and show crustification. No definite fissure system was noted. They are considered to be of the same age as the Mesozoic contact metamorphic deposits.

Contact Zones. Another type of ore occurrence is confined to the contact of the Jurassic granodiorite and the Franklin group metamorphics, and is present in both, although chiefly in the latter. No marble is present, and the lime-silicate gangue minerals are not as abundant as in the typical contact metamorphic deposits. The mineralization is referred to both the time of intrusion of the granodiorite batholith and to crustal movements during the Laramide revolution.

Shear Zones in Granodiorite. Certain zones in the Jurassic granodiorite have yielded to crustal stresses of mountain making periods through shearing or slipping movements along definite planes (planes of scission or simple shear), which are inclined to the greatest pressure. Mashing, on the other hand, takes place in planes normal to the greatest pressure.

The shear zones have been favourable places for mineralization. The ore is disseminated chalcopyrite and pyrite, with some molybdenite in a quartz and calcite gangue. The molybdenite is in small flakes; the chalcopyrite generally with calcite in cleavage planes. The country rock is sheared, calcified, and silicified granodiorite. The shearing and mineralization are referred to that accompanying the mountain making at the close of the Mesozoic.

Segregation Type. The ores belonging to this type are locally known as the "Black Lead" ores. The ore minerals are chalcopyrite, pyrite, and some bornite in a gangue of shonkinite-pyroxenite. This formation is a basic marginal phase of the augite syenite. It is thought that they have both been derived from a common parent magma through a process of differentiation prior to intrusion. The chalcopyrite and bornite are often found surrounded by orthoclase feldspar, or in small masses closely associated with it. The pyrite, on the other hand, is generally disseminated in small grains through the ferromagnesian constituents. For details, see page 172.

Replacement Along Shear Zones. Magnetite and pyrite occur sparingly along certain shear zones in the Tertiary monzonite as replacements. The hydrothermal metasomatism is correlated with the intrusion of the younger alkalic rocks.

DETAILED DESCRIPTION OF PROPERTIES.

MESOZOIC DEPOSITS.

CONTACT METAMORPHIC TYPE: McKINLEY MINE.

The ores belonging to the contact metamorphic type of epigenetic ore deposits have received the most attention. Of this class of deposit, the most typical example is the McKinley mine. It was located by Jas. Wilcher on August 1, 1896, and recorded just three days before the Banner claim on Franklin mountain.

It is situated on the north slope of McKinley mountain (altitude, 3,500 feet), about 1¼ miles west by pack trail from the crossing of Franklin creek by the road to Gloucester City. The accompanying block diagram (Figure 16) shows the amount of development work done, which, besides open-cut work and trenching, includes over 400 feet of tunnelling.

There are other small occurrences of this type of deposit throughout the district, but the McKinley property, on account of the greater amount of development work done on it, furnishes the only opportunity for extensive observation, and is, therefore, described in detail. The less important occurrences are discussed at the end of the section.

The ores are closely associated with the Gloucester marble formation, and as a rule near its borders. See block diagram (Figure 16). The nearest outcrop of the granodiorite batholith is some 1,500 feet distant, although apophyses from it are found in the vicinity of the ore and a considerable mass of granodiorite porphyry outcrops about 150 feet above the No. 1 tunnel. McKinley mountain is here capped by a thick mantle of rhyolite porphyry of early Tertiary age. The rudely lenticular masses of marble have a closely compressed synclinal structure striking northeast and southwest with steep dips to northwest. There are two distinct lenses of marble, with different types of ore at their borders.

Between the marble on the one side and the altered tuff on the other, an intervening mineralized zone generally occurs, which varies in width from 0 to 100 feet. Its exact extent could not be determined at any one locality. The ore lies within this zone and has usually the form of rudely tabular masses or shoots, often with intricate boundaries, and which conform in both dip and strike with the transition zone. The contact with the marble is usually extremely sharp, but the ore minerals occasionally pass more gradually into the barren marble. The contact, on the other hand, with the altered tuff on the opposite side of the zone, is so extremely gradual that in many places it is impossible to tell where the ore ceases and the country rock begins. The walls, as shown in the workings, simply represent the limit of profitable work.

The altered tuff shows heavy pyrite mineralization, but the ore is confined to zones in the vicinity of the barren marble. The ore passes gradually into a garnet rock at its borders, and from garnet into pyritized altered tuffs and eruptives. The mineralization is here correlated with the intrusion of the Jurassic granodiorite batholith and was accomplished before the period of extensive erosion in Cretaceous time. The reasons for this correlation are the inferences to be drawn from (1) the presence of lime-silicate gangue minerals such as garnet, epidote, tremolite, and diopside; (2) the association of oxides of iron with sulphides; and (3) the extensive metasomatic effects of the eruptive rock. All these facts imply deep-seated conditions of mineralization, with possible pneumatolytic action by water above the critical temperature (+365°C., and with pressure over 200 atmospheres) given off from a large igneous body.

The only deep-seated igneous rock in the vicinity of the mine and intimately associated with the ores and country rock, are granodiorite porphyry dykes, which are believed to be offshoots or tongues given off from the underlying granodiorite batholith which outcrops 1,500 feet to the west. The granodiorite porphyry dykes have been faulted and altered by subsequent epeirogenic movements.

The Jurassic batholith is believed to be younger than the regional metamorphism of the Palæozoics. Its contacts are always found, where exposed on steep slopes, to plunge in a regular manner away from the main batholithic mass towards the main cover formation. This implies (1) downward enlargement of the igneous mass; and (2) an independent relationship between batholith and the structure of the cover rock. Furthermore, the granodiorite does not show the intense regional metamorphism that the cover rocks exhibit. From these facts, it is inferred that the cover rock had received its major folding and regional metamorphism prior to the batholithic intrusion. This inference is important in that it may account for the localization of the mineralized zones and included ore shoots in the vicinity of the barren marble contacts. Regional compression and folding would result in zones of mashing and shearing, particularly along the contacts of two different Palæozoic formations. Such zones have afforded favourable places for ore deposition by the mineralizing solutions which were given off under great pressure and temperature from the parent granodiorite magma. The ore shoots do not appear to be connected with any definite system of fissures. On the other hand, on account of their irregular form, lack of structural walls as the ore passes transitionally into barren rock, and the intimate relationship the ores bear to the calcareous rocks, they are considered to be metasomatic replacements of sheared and mashed calcareous rocks by mineralizing solutions under conditions of high pressure and temperature contemporaneous with batholithic intrusion. The marble itself proved an impervious formation and may possibly have borne a precipitating relation to the ore solutions, although there is no direct evidence to support such an hypothesis.

The ores may be divided into the three following distinct types:—

(1) Pyrite-chalcopyrite
(2) Galena-blende
(3) Magnetite-pyrite

The galena-blende type follows predominantly the limy portions of the mineralized zone, where contact metamorphism has not been so powerful, while the pyrite-chalcopyrite and magnetite types, on the other hand, follow dominantly the siliceous portions.

The mineralized zone in which the ore shoots occur is irregularly distributed, and, as has already been indicated, lies always close to the Gloucester barren marble.

The ore minerals are chalcopyrite, pyrite, magnetite, zinc blende, and galena; and gangue minerals are garnet, epidote, tremolite, diopside, quartz, chlorite, and calcite.

The following is a brief description of the ore and gangue minerals associated with the contact metamorphic deposits:—

Pyrite (*FeS_2*). This is the most abundant sulphide in the district and occurs as large masses intimately associated with the lime-silicates. It also is in the form of small crystalline grains, disseminated through the altered tuffs and eruptives. Some of it is copper-bearing, and on weathered surfaces appears brass yellow, with, in places, purple tarnish.

Chalcopyrite (*$CuFeS_2$*) generally accompanies the pyrite and was not found disseminated through the less altered rocks, as was the case with the latter mineral. It is always in the massive form and never in distinct crystals.

Sphalerite (*ZnS*). Sphalerite, or zinc blende, occurs in specks and small masses, with galena and pyrite in the more limy portions of the mineralized zone, as, for instance, near the face of the main west cross-cut in No. 1 tunnel, McKinley mine.

Galena (*PbS*). Galena is present, closely associated and contemporaneous with the sphalerite in the less highly metamorphosed part of the mineralized zones.

Magnetite (*Fe_3O_4*). Magnetite is present in massive form along with pyrite, replacing calcareous rock at the east border of the lower marble lens on the McKinley property. It is also disseminated in small grains through the garnet sulphide rock and appears as inclusions in the garnet, but more frequently along with calcite fillings. The latter has a slightly reddish tone, and, considering its association with calcite, may be goethite ($Fe_2O_3H_2O$).

Limonite (*$2Fe_2O_3+3H_2O$*). Limonite is found in the shallow oxidation zone of the ore shoots where they outcrop at the surface on the McKinley property.

Quartz (*SiO_2*). Quartz, where present, is usually in the form of fine-grained aggregates that have replaced the calcium carbonate of the marble. Small amounts of it are found associated with tremolite, diopside, garnet, and pyrite in the altered calcareous rocks.

Calcite ($CaCo_3$). Calcite in coarse and fine granular form composes the Gloucester formation and is one of the most abundant gangue minerals. It seldom, however, forms as large a part of the altered marble close to the ore as it does of the less altered rock in which contact metamorphism has not been so active. It has been largely replaced by the sulphides and lime-silicate minerals and is now found in veinlets in some places, cutting through the grossularite garnet.

Azurite ($2CuCo_3(OH)_2$) and *Malachite* ($CuCo_3Cu(OH)_2$). Some splendid specimens of blue and green basic carbonates of copper were found in the oxidized portions of the ore bodies.

Garnet. The calcium-aluminium garnet, grossularite ($Ca_3Al_2(SiO_4)_3$) occurs commonly associated with diopside in large dodecahedrons. It is present usually in reddish massive forms at the borders of the ore shoots, and is traversed in places by minute cracks filled with calcite and quartz. It exhibits a slight irregular birefringence not uncommonly seen in grossularite.

Epidote is present in abundance, intimately intergrown with pyrite. It is of a yellowish green (pistachio) colour, and occurs in considerable masses in some portions of the mineralized zone.

Tremolite ($CaMg_3(SiO_3)_4$) occurs in veins up to three-quarters of an inch wide, traversing irregularly the sulphide ore. It is in radiating aggregations.

Diopside ($Ca(MgFe)(SiO_3)_2$) is found associated with epidote and garnet and some of the sulphides. It resembles epidote somewhat under the microscope, but is slightly different in colour and shows distinct prismatic cleavage.

Chlorite. This greenish alteration product is of common occurrence throughout the metamorphic rocks, and was found in greatest abundance at the contact of the eruptives with the altered calcareous rocks, where it is quite massive and intimately associated with calcite and chalcopyrite.

Paragenesis of the Ore and Gangue Minerals.

Concerning the association of the various ore and gangue minerals with reference to the order and mode of their formation, there is not much to be said. The lime-silicate gangues were found intimately intergrown with the sulphides, as is characteristic of a true contact metamorphic ore deposit.[1] Both have practically formed simultaneously at the time of extensive contact metamorphism resulting from batholithic intrusion of granodiorites.

Values.

The highest values at present come from ore taken from the open-cut or "Glory Hole" in McKinley Creek bottom; where assayed, it carries 0·01 ounce gold, $1.10 in silver, and 2·70 per cent copper. The ore from the open-cut above the mouth of No. 1 tunnel ran 0·01 ounce gold, $1.42 in silver, and 2·50 per cent copper.

The small ore shoot in No. 2 tunnel, on the east side of the marble lens, is said to have assayed 0·01 ounce gold, $5.60 silver, and 5 per cent copper. Carbonate ore from farther up-hill, on the same contact with barren marble, ran 0·01 ounce gold, $2.70 in silver, and 2·60 per cent copper. The above figures represent the best ore on the property, and the average values would run very much lower than those given.

Genesis and Correlation.

The accompanying table gives a summary outline of other occurrences of contact metamorphic ore deposits:—

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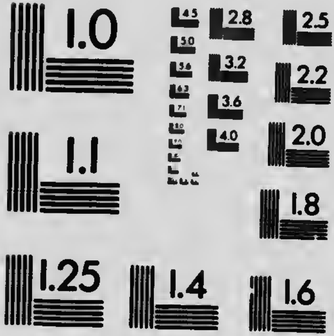
[1]Lindgren (W.): Character and genesis of certain contact deposits. Trans. Am. Inst. Min. Eng., Vol. XXXI, 1902, p. 227.

Name of dist.	Franklin dist.	Phoenix dist., B.C.	Texada island, B.C.	Hedley dist., B.C.	Clifton-Morenci, Ariz.	Bisbee, Ariz.	Seven Devils, Idaho.	White Knob, Idaho.	Elkhorn, Mont.	Maryville, Mont.	New Mexico.
Age	Jurassic	Jurassic	Upper Jurassic Coast Range batholith	Early Mesozoic	Cretaceous (?)	Triassic (?)			Tertiary		Latest Cretaceous or Early Tertiary
Gangue minerals	Calcite Garnet Epidote Tremolite Diopside Chlorite Quartz	Calcite Garnet Epidote (actinolite at Mother Lode mine) Chlorite	Calcite Garnet Epidote actinolite Quartz	Calcite Garnet Epidote Pyroxene Quartz Amphibole	Garnet Epidote Diopside	Calcite Garnet Tremolite Diopside Chlorite Quartz Amphibole	Calcite Garnet Epidote Quartz	Calcite Garnet	Calcite Garnet Diopside		Calcite Garnet Epidote Tremolite Diopside Quartz
Intrusive	Granodiorite	Granodiorite	Granitoid rocks	Diorite-gabbro	Granite-porphyry Quartz-monzonite	Granite porphyry	Diorite	Granite	Granite	Quartz-diorite	Monzonite Quartz-monzonite
Ore minerals	Pyrite Chalcopyrite Sphalerite Galena Magnetite Malachite Azurite limonite	Chalcopyrite Magnetite Specularite Pyrite	Coarsely crystalline Magnetite with pyrite and chalcopyrite (~3%)	Arsenopyrite Pyrrhotite Chalcopyrite Sphalerite and pyrite less abundant	Specularite Magnetite intergrown Chalcopyrite Pyrite and zinc blende	Malachite Azurite Cuprite with copper Chalcopyrite Pyrite Chalcocite	Bornite Chalcocite Chalcopyrite Native Specularite	Hematite Magnetite Chalcopyrite Pyrite and a little galena	Auriferous Tetradymite Bismuthite Magnetite Pyrite Zinc blende		Chalcopyrite Zinc blende Magnetite Pyrite Pyrrhotite Specularite
Intruded rock	Carboniferous marble	Upper Palæozoic crystalline limestone	Palæozoic limestone	Palæozoic limestones of banded and impure varieties	Modoc limestone (96% $CaCO_3$)	Carboniferous limestone	Triassic limestone		Crushed dolomite		Carboniferous limestone

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



From this table may be noted the pronounced similarity between the Franklin ore and gangue minerals, and those of many widely scattered districts throughout the western Cordillera. It is to be noted, too, that the parent intrusive rocks are dominantly granodiorite types and of very nearly the same age. The intruded rocks are chiefly limestones of upper Palæozoic age.

The Franklin contact metamorphic ores resemble those of Phoenix most closely in their mineralogic characters and belong to the same chalcopyrite-magnetite class. They differ from them, however, in not having, in so far as has been observed, specularite, and in having a greater percentage of pyrite. At Phoenix, however, erosion has not exposed so much underlying granodiorite as it has in Franklin. Furthermore, the Palæozoic rocks at Phoenix had not undergone so much regional metamorphism prior to Jurassic granodiorite intrusion as they had at Franklin. The Franklin occurrence has somewhat similar structural relations to that of the Elkhorn mine, Montana, described by W. H. Weed.[1] The auriferous and argentiferous ores there occur in irregular shapes beneath an arch of altered shale, either along its contact with the crystallized dolomite or as great stocks of ore enclosed in the dolomite. The ore bodies are situated in the crushed dolomite, forming the saddle of anticlinal folds which have in part been broken up into a breccia. The breccia lies beneath a rather impervious cover of altered shale (hornfels), which is also folded. The crushed rock served as a channel for solutions rising from the depth.

In the case of Franklin, however, the folds are compressed synclines, but the mashed and sheared contact zones have in a similar manner, as at Elkhorn, afforded channels of ingress for the solutions rising from the depths. Thus the McKinley mine, like the Elkhorn mine, is a good example of the influence of folding upon the localization of ore solutions and development of metasomatic ore deposits.

Tremolite is a frequent component of marbles produced by regional metamorphism. Regional metamorphism in Franklin was accomplished before mineralization, and nowhere out-

[1]Weed (W. H.): Elkhorn Mining District. 22nd Ann. Rept. U.S. Geol. Survey, Washington, 1902.

side of the heavily mineralized zone was tremolite found. The fact that it does occur in veins up to three-quarters of an inch wide, traversing the sulphide ores, would point towards the transfer of magnesia from the parent magma.

The question here arises as to whether the lime-silicate minerals simply represent a recrystallization, or whether they have received additional substances from the cooling magma. In the case of the McKinley mine, the mineralized zone in which these minerals are so well developed is of irregular form and closely associated with intrusive granodiorite porphyries. The ores appear to be metasomatic replacements (pneumatolytic metasomatism) along mashed and sheared border zones of the barren marble formation. Recrystallization of impure calcareous rocks may account for some of the diopside and tremolite, but the main mass of such minerals, with their associated lime-silicates, sulphides, and oxides, is considered to be due to emanations from the parent granodiorite magma during the cooling process. There has been introduction of silica, iron, various sulphides, and probably magnesia from the magma.

On the Yellow Jacket claim, small mineralized pockets of ore occur in garnetiferous zones within the barren marble and show the effects of shrinkage consequent upon expulsion of CO_2 (Plate XXIII).

On the Dane group, some of the mineralized rock is present adjacent to a marble lens, but most of the prospecting has been done along major shear zones in the Franklin group altered tuff and younger porphyry dykes.

Fissure Veins.

The fissure veins are very similar to those of other regions and are of the simple filling type. The three main fissure veins that have been opened up are on the Banner, Union, and Little properties.

Banner Claim.

The Banner claim is situated on the west flank of Franklin mountain and is one of the pioneer properties in the camp.[1]

[1]Staked by Frank McFarlane, August 9, 1898. Recorded 17th of August, at Grand Forks, B.C.

The fissure, which has been opened up by a shaft about 25 feet deep, strikes N. 34° W. and dips steeply to the southwest.

The ore is zinc blende, galena, chalcopyrite, and pyrite in a quartz gangue. It occurs in irregular shoots and shows in places crustification about angular and curved fragments of a friction breccia. The ore is reported to have assayed $18 per ton.

The country rock is altered tuff, quartzite, and brecciated calcareous conglomerate belonging to the Franklin group.

A cross-cut tunnel was driven farther down the hill in a direction S. 87° E., to intersect the vein in the bottom of the shaft. It was driven 175 feet, but did not reach the ore shoot exposed in the shaft. The first 95 feet is in a cherty altered tuff which ends at a strong slip striking N. 40° W. and dipping 45° S.W. From there, a dark grey quartzite extends for almost 50 feet and then a silicified and brecciated calcareous conglomerate is encountered. This latter formation is slightly mineralized and continues to the face of the tunnel. Some diamond drilling was done in 1906, but gave negative results.

Union Claim.

The Union claim was one of the first locations in the Franklin camp, although it was recorded under a different name and allowed to lapse. In 1906, P. McGinnis and L. Johnson staked it and the adjacent Idaho and Paper Dollar claims.

The fissure which has been stripped for several yards, strikes S. 80° W., and is vertical. The ore is galena and sphalerite, with a little copper carbonate in a quartz gangue, and very much resembles that of the Banner. The vein is crustified and contains drusy cavities in places lined with quartz crystals.

A picked sample of ore is reported to have assayed 24 per cent lead, 35 ounces in silver, $8.25 in gold. The country rock is greenstone (altered augite porphyrite) and a silicified calcareous sedimentary of the Franklin group.[1]

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[1]Twenty-three tons of ore shipped in 1913 from a newly discovered extension of this vein on the Union group, averaged $80 per ton. Transportation charges were $16.50 and smelting charges $6. The group of claims include the Union,

Little Claim.

The fissure vein on the Little property is located on the west slope of the Granite range, at an altitude of 3,700 feet. It strikes east and west, and has a vertical attitude.

Some splendid specimens of vein crustification came from this locality. Mineralization by sulphides is slight; calcite, quartz, and siderite are well developed. The siderite appears in botryoidal and globular forms; the calcite as nail-head spar, and the quartz in small perfect crystals.

The country rock is pyritic tuff and calcareous conglomerate of the Franklin group.

Age and Origin.

The fissure veins are referred to the intrusion of the Jurassic granodiorite batholith at the time when the contact metamorphic ores were being deposited in the contact zone of the batholith. It is thought that fissure veins were formed in the cover rocks following batholithic invasion and consolidation, through crustal tension, thus permitting the mineralizing solutions to circulate and deposit sphalerite and galena in the deep vein zone.

The sulphides were no doubt deposited at a considerable depth below the surface. The ores must have been formed before the close of the Cretaceous erosion cycle, for at that time they were as near the surface as at present. This is shown by the manner in which the Eocene deposits lie upon the basal rock formations, and even upon the granodiorite itself on McKinley mountain.

Union Fraction, Idaho, and Paper Dollar. The total amount of ore shipped from the commencement of shipping in August, 1913, until December, 1914, was 1767 tons; 443 tons of which was shipped to the Trail smelter, the remaining 1324 tons to the Granby smelter at Grand Forks, B.C. A typical analysis of the Union ore is as follows: gold 0·92 oz. per ton, silver 26·5 ozs. per ton, iron 5·0%, silica 71·5%, alumina 10·0%, lime 3·8%, and a trace of sulphur. The ore shoot containing pyrargyrite (ruby silver) and the high silver values (glory hole shoot) was found to occur in the vein at its acute angled intersection with a rhyolite porphyry dyke. The shoot which is being stoped in the [illegible]el below contains chiefly gold values. The ore shoots are replaceme[illegible]ots with commercial boundaries.

The Cretaceous is considered to have been a period of relative quiet and long continued erosion, so that it seems justifiable to correlate this mineralization with the Jurassic crustal and igneous disturbances.

CONTACT ZONES.

This type is similar in many respects to the contact metamorphic type already described. It differs from it in the following respects: (1) the ores are confined to the immediate contact of the granodiorite batholith and the Franklin group metamorphics; (2) the ores have a much smaller proportion of lime-silicate gangue than have the contact metamorphic type; (3) no marble is present and associated with the ore, as it is in the case of the typical contact metamorphic type; (4) both granodiorite and Franklin group cover rocks are mineralized along the contact zone, although the chief mineralization is in the Franklin group rocks.

The claims located on this contact are from west to east: the Mountain Lion, Gloucester, G.H., G.H. Fraction, Iron Cap, M.S., and Crystal Copper, all in the north half of the quadrangle.

Development.

The first claim to be located on this contact was the Gloucester, which was staked on August 14, 1898, by H. Garnett and Thomas Newby. The G.H. and other adjoining claims were staked shortly afterwards. The Gloucester, G.H., Opher, G.H. Fraction, and Tiger Fraction comprise the Gloucester group, which was bonded by the Dominion Copper Company in 1906, and the British Columbia Copper Company a few years before that.

Gloucester Claim.

As more development work has been done on the Gloucester claim than any other, it has been chosen for the type description.

The Gloucester claim is located on the Gloucester Creek slope of Franklin mountain, at an altitude of 4,200 feet A.T. The development work consists of a 40-foot shaft whose collar is in the Franklin group greenstone. A cross-cut tunnel was driven at a level 100 feet below the shaft head, with a view to making connexions and determining the extent of the ore shoot encountered in the shaft. The tunnel was driven 180 feet through sheared and calcified granodiorite, and then a raise was run for 71 feet, all in the same altered granodiorite which is a part of the main Jurassic batholith.

Besides this work, there are innumerable small prospect pits and open-cuts on the property. No work has been done on the Gloucester claim since 1906.

The ore occurs along the main contact of the Jurassic batholith with the overlying Franklin group rocks, but chiefly in the cover rock. The upper contact of the batholith was found to pitch to the south, as shown by its contact relations exposed in the steep ravines to the east of the Gloucester. Much useless expenditure of money and labour could have been saved if the relationship of ores to batholithic contact and dip of that contact had been noted before attempting cross-cut tunnel methods.

The ore minerals are chalcopyrite, pyrite, magnetite, molybdenite; the gangue minerals, calcite, quartz, epidote, chlorite. The ore and gangue minerals are intimately intergrown in some places; in other places, the sulphides appear to have been secondarily concentrated. At a depth of 15 feet in the main shaft, several feet of chalcopyrite-pyrite ore with some molybdenite were encountered. This ore is said to have run $5.60 in gold per ton and from 8 to 20 per cent in copper. The best ore is in the Franklin group side of the contact, although it does occur to a limited extent in the altered grey granodiorite.

Geologic Age of Mineralization and Origin.

In the case of these ores, the Laramide crustal movement was probably more responsible for the localization of the ore than was the intrusion of the Jurassic batholith. The reverse is true for the contact metamorphic type. The primary sulphides and oxides were deposited at the same time as those on the McKinley property, but have since been concentrated along the immediate contact where shearing and mashing during the Laramide revolution promoted further circulation of mineralizing solutions. The absence of the Gloucester marble formation may account for the restricted nature of contact metamorphic deposits here with the more pronounced secondary mineralization.

On the G.H. claim, adjoining the Gloucester to the east, there is a body of magnetite and pyrite ore up to 40 feet in width. The ore, however, has only traces of gold, silver, and copper. The other claims staked on this contact—the Iron Cap, M.S., and Crystal Copper—have had very little work done on them. Many of them have similar associations of oxides and sulphides of iron in the Palæozoic cover rocks overlying the batholith.

Shear Zones in Granodiorite.

Copper and Riverside Claims.

The best example of this type of deposit occurs on the Copper and Riverside claims, owned by A. Gelinas and J. Senter. These two claims are situated south of the quadrangle about 1 mile, and across the east fork of the North Fork of Kettle river from the lower Franklin townsite. The property was under bond to the British Columbia Copper Company in 1911.

The ore is disseminated chalcopyrite and pyrite, with some molybdenite, in a quartz and calcite gangue. The molybdenite is in small flakes; the chalcopyrite usually with calcite in the cleavage planes. The country rock is sheared, calcified, and silicified granodiorite. The strike of the shear zone along which the mineralization has taken place is N. 55° W., and can be traced for some hundreds of feet.

Age and Origin.

The shearing and mineralization is here referred to that accompanying the mountain making at the close of the Mesozoic.

TERTIARY DEPOSITS.

Segregation Type, "Black Lead."

The segregation type is locally known as the "Black Lead" ores. The claims located on this type of deposit are: Columbia, Ottawa, Evening Star, Iron Hill, Buffalo, Blue Jay, Averill group, Mountain Lion, Maple Leaf, and Lucky Jack, all of which are in the north half of the quadrangle.

The Maple Leaf was located by H. W. Young on October 14, 1902; the Evening Star by Capt. A. L. Rogers on June 26, 1903; the Lucky Jack by Henry Wotlin in 1909; and the Averill group by B. J. Averill in 1910 and 1911.

The development work that has been done on the various properties is not extensive and consists of numerous prospect pits and short tunnels.

The general discussion will apply to all the "Black Lead" properties and any variations from the normal type will be noted.

The ore is chalcopyrite, pyrite, and a little bornite, in a gangue of shonkinite-pyroxenite or "Black Lead." This formation is a basic marginal differentiate from the same parent magma that gave rise to the augite syenite.

The chalcopyrite and bornite are often found surrounded by orthoclase feldspar or in small masses closely associated with it. The pyrite, on the other hand, is generally disseminated in small grains through the ferromagnesian constituents.

The ore is usually near the outer margins of the shonkinite-pyroxenite and is very irregularly distributed. On the Buffalo claim, the ore is near a monzonite contact, and both the shonkinite-pyroxenite and monzonite are cut by a northeast and southwest system of pulaskite porphyry dykes.

A sample taken from the shaft dump on the "Blue Stem" claim, one of the Averill group, was analysed at the British Columbia Copper Company's smelter at Greenwood, B.C., with the f[illegible]ults:—

[illegible]..........	0·05 oz. per ton.
[illegible]..........	0·69 " " "
[illegible]per.........	1·90% (this was a selected sample).
Silica..........	48·20% as SiO_2.
Iron............	6·80 as Fe.
Lime..........	23·00 as CaO.
Sulphur........	1·40 as S.

The ore from the Averill group is higher grade than that from the Buffalo, and some bornite, as well as chalcopyrite, has been segregated. The chalcopyrite on the Buffalo, though much less in amount, is more evenly distributed through the whole mass.

The reasons for considering this ore a magmatic segregation are as follows: (1) the simplicity of the mineralogy, which does not go with ordinary ore development; (2) the gradation of ore into a basic igneous rock, which is an undoubted segregation from the same parent magma which gave rise to the syenite;[1] (3) the absence of pneumatolytic minerals in the shonkinite-pyroxenite, such as fluorite, sericite, tourmaline, chalcedony, etc.; (4) the fact that the igneous mass has not undergone regional metamorphism; (5) the distinctly igneous component minerals; (6) the peripheral arrangement of the ore, chiefly at the outer margins; (7) the rareness of minerals produced by thermal alterations, such as sericite, quartz, carbonates; (8) the relation of the component grains, which shows it to be an early crystallization.

Contact Metamorphic Type.

The only property where this type of ore is prominent is the Maple Leaf, situated on the east flank of Franklin mountain.

The ore is in the altered Franklin tuff and greenstone at its immediate contact with the syenite and shonkinite-pyroxenite. The shonkinite-pyroxenite is here in isolated areas surrounded by the syenite, the one passing rapidly into the other.

The ore is chalcopyrite, pyrite, sphalerite, galena, and the copper carbonates, malachite and azurite.[2] The sulphides are intimately intergrown, pointing towards deposition simultaneous with rock alteration. The gangue is impure quartzite and greenstone, with considerable secondary hornblende, alkalic feldspar, and epidote largely derived from the syenite. Small amounts

[1]Similar marginal basic differentiates from syenitic magmas occur in Montana and are described by Professor Pirsson in Amer. Jour. Sci. (4), Vol. XII, pp. 1-17, 1901.

[2]A sample of the ore ran as follows: gold a trace, silver 4·3 ozs. per ton, copper 16·0%, iron 16·6%, silica 31·4%, alumina 9·3%, lime 2·6%, and sulphur 13·8%.

of chalcopyrite were found in the Kettle River conglomerate where the latter was in contact with the syenite on the east side of the Kettle river. Here the conglomerate, for at least 30 feet from the contact, is saturated with the syenite magma, and pseudomorphs of syenite after the more permeable boulders are present (Plate XV).

The contact metamorphic effects of the hypabyssal syenite chonolith, with its narrow contact aureole, stand in contrast to the broad contact zone produced by the abyssal granodiorite batholith.

Replacements Along Shear Zones.

On the Royal Tinto claim, owned by John Holmes, at the north end of Franklin mountain, some magnetite and pyrite are present as replacements along a sheared zone in the monzonite. The strike of this zone is northwest and southeast corresponding to the strike of the syenite chonolith contact, which is distant 500 feet to the southwest.

The shearing and mineralization, which was in the nature of hydrothermal metasomatism, in this case may be correlated with the intrusion of the nearby alkalic syenite and pyroxenite.

Origin of the Tertiary Ores.

The field facts, upon which the following tentative conclusions are based, are discussed in previous chapters.

The Tertiary ores are considered to have primarily segregated along with the shonkinite-pyroxenite from a parent magma prior to intrusion and consolidation. This may have taken place by means of liquation and gravitative adjustment in a deep seated magma reservoir. With intrusion and extrusion, both the shonkinite-pyroxenite and syenite, which were immiscible solutions, became subject to the action of convection currents and diffusion, chiefly the former. Convection currents segregated the basic portions containing the ferromagnesian and sulphide minerals towards the cool walls. Both the shonkinite-pyroxenite and the syenite reached the surface at the base of

Tenderloin mountain and formed alkalic basalt and trachyte flows. When volcanic activity ceased, so did bodily movement in the magmas. Diffusion became dominant over convection as a factor in segregation, and produced the different types of syenite, with their gradual gradations from one facies to another. In the shonkinite-pyroxenite it further segregated the chalcopyrite. The chalcopyrite associated with the orthoclase may be largely due to this youngest segregation through diffusion.

CHAPTER VIII.

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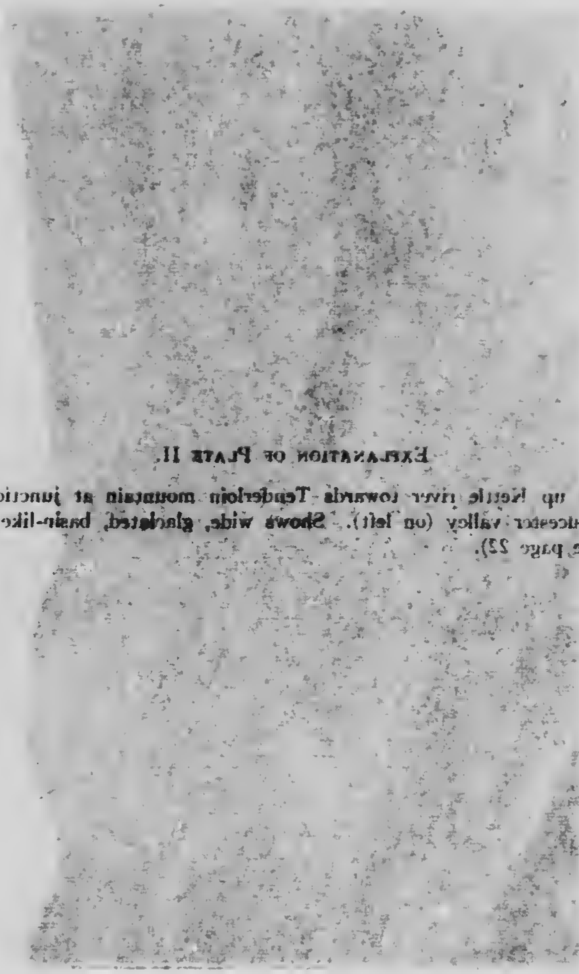


EXPLANATION OF PLATE II.

Looking up Kettle river towards Tenderloin mountain at junction with Gloucester valley (on left). Shows wide, glaciated, basin-like valley. (See page 22).

PLATE II.

Explanation of Plate III.

East side of Kettle valley; Boulder creek to right. Shows glaciated rock ridges and plunging character of the granodiorite contact (indicated by white line). (See page 22).

EXPLANATION OF PLATE III.

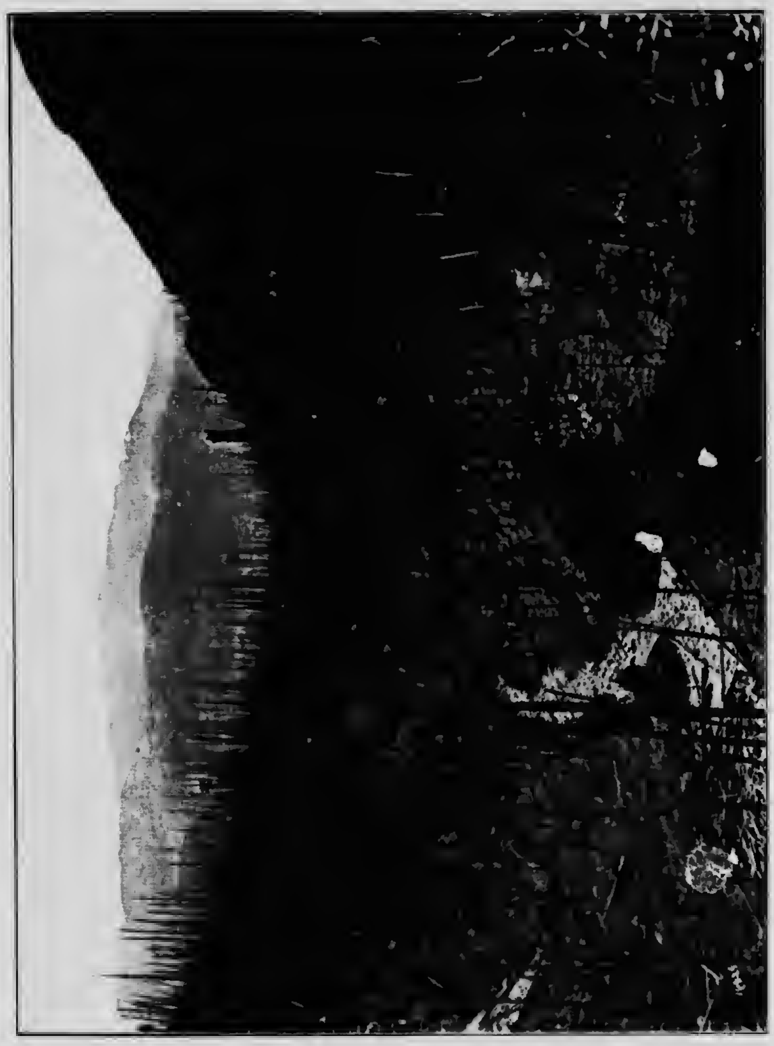
East side of Kettle valley; Boulder creek to right. Shows glaciated rock ridges and plunging character of the granodiorite contact (indicated by white line). (See page 22).

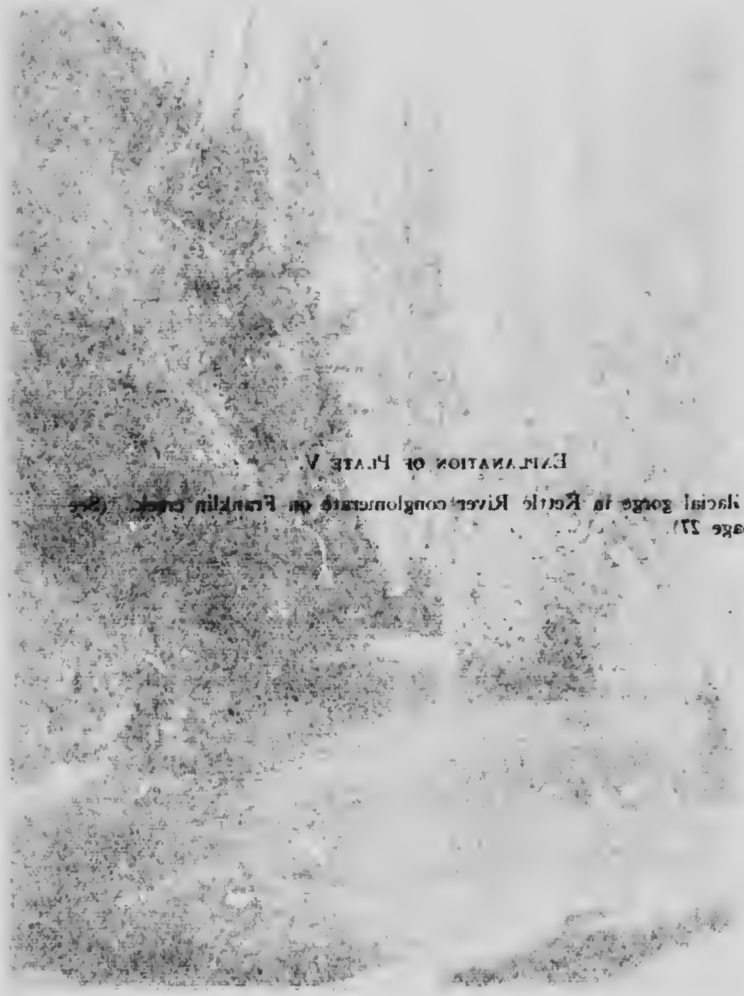
PLATE III.

EXPLANATION OF PLATE IV.

Looking down Franklin valley towards Kettle river. Shows terraced outwash gravels and deep incision of Franklin creek. (See page 26).

PLATE IV.





EXPLANATION OF PLATE V.

Post-Glacial gorge in Kettle River conglomerate on Franklin creek. (See page 27).

Explanation of Plate V.

Post-Glacial gorge in Kettle River conglomerate on Franklin creek. (See page 27).

PLATE V.

Explanation of Plate VI.

Tenderloin mountain from Newby cabin. Shows a typical lava capped mountain. (See page 28).

PLATE VI.

EXPLANATION OF PLATE VII.

Caves in trachyte lava cliffs, east slope of McKinley mountain. (See page 28).

Plate VII.

Explanation of Plate VIII.

Franklin mountain; Gloucester City in centre foreground. Shows scars on mountain slopes due to rock slides. (See page 28).

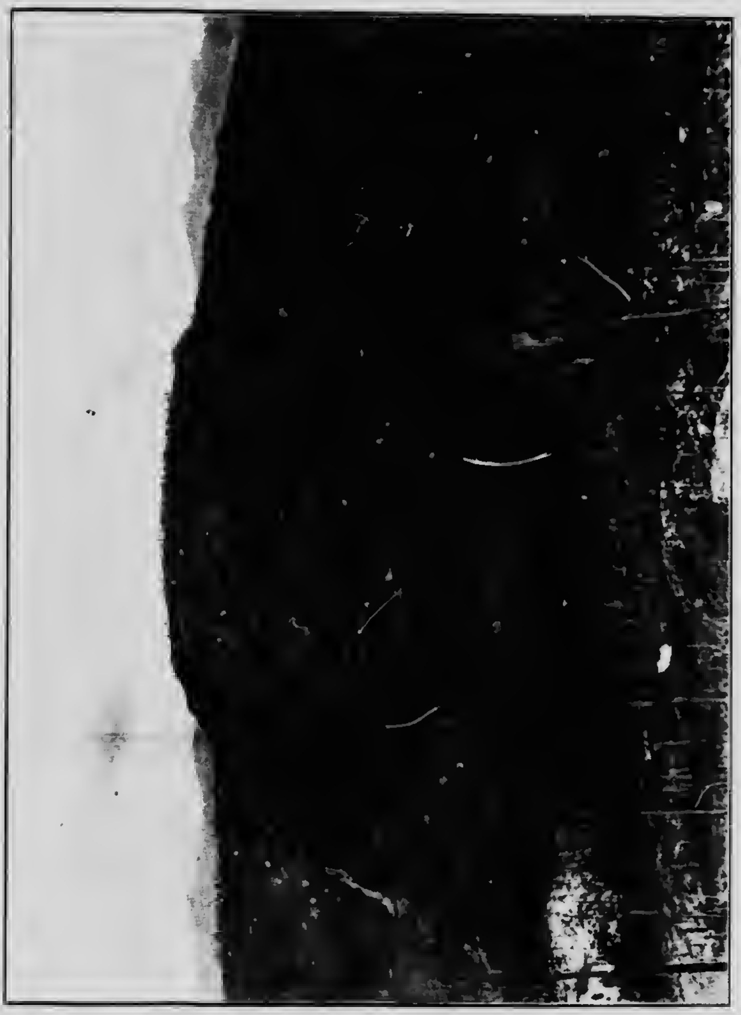
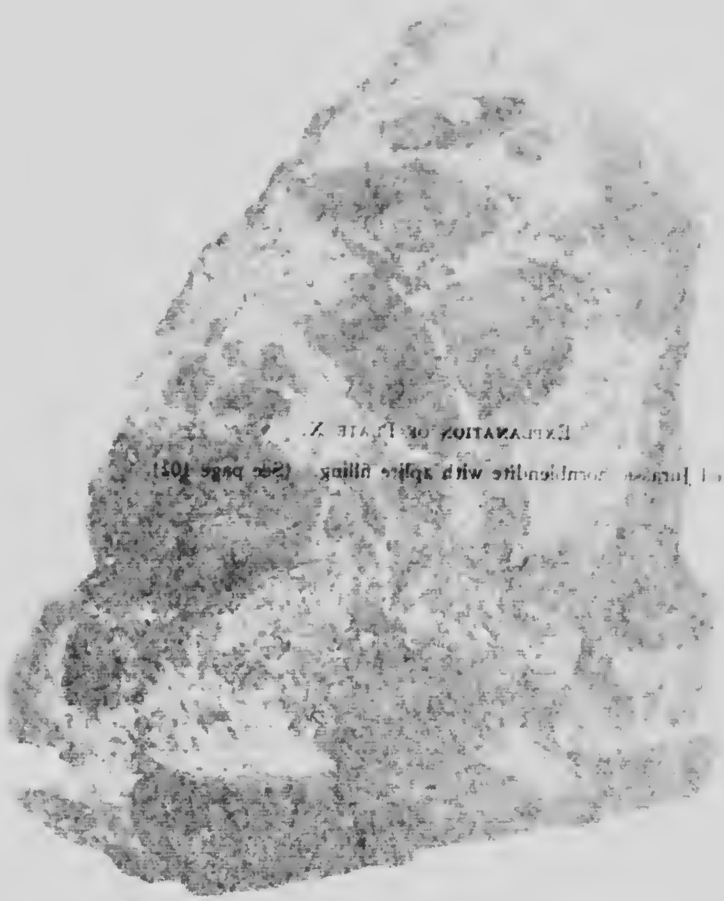


PLATE VIII.

Explanation of Plate IX.

Kettle River conglomerate "hoodoos." (See page 28).

PLATE IX.



EXPLANATION OF PLATE X.

Brecciated Jurassic hornblendite with aplite filling. (See page 102).

PLATE X.

EXPLANATION OF PLATE XI.

A. Pebbles from Kettle River formation.
Pebbles on right and upper pebble on left are composed of augite syenite, which has replaced the original material of pebbles. In the centre are two faulted pebbles; the three remaining pebbles show scratched and facetted surfaces and resemble pebbles from a tillite. (See pages 83, 95).

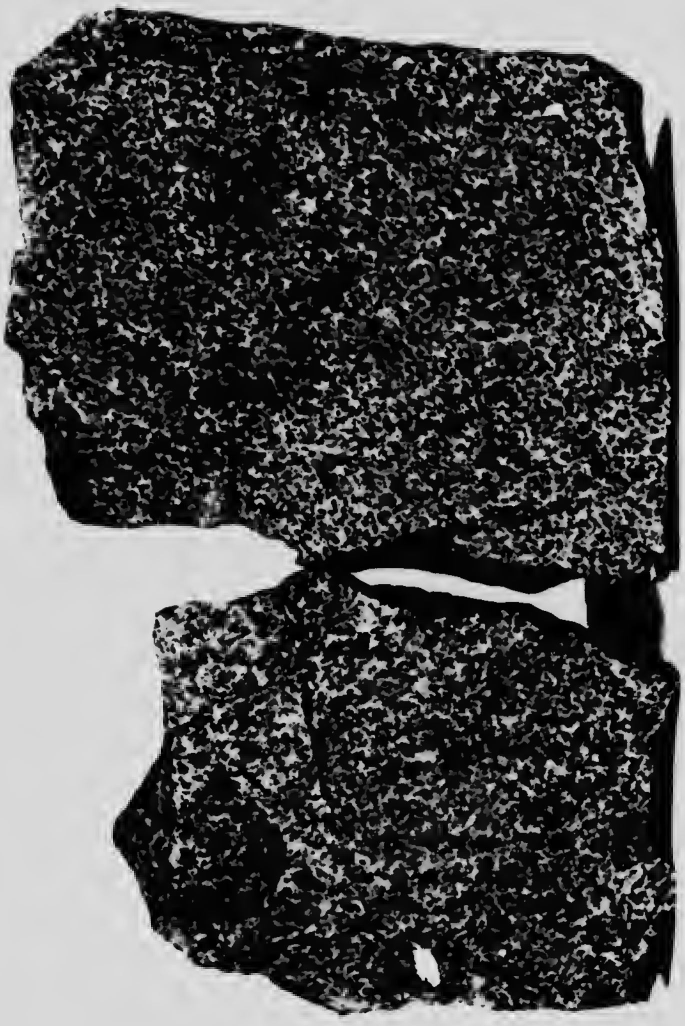
B. Vesicular rhyolite in contact with Kettle River silt. Shows thin bed in process of being drawn up and included by the rhyolite. (See pages 69, 71).

PLATE XI.

EXPLANATION OF PLATE XII.

Specimen of post-Oligocene monzonite on the left; specimen of Miocene augite syenite on the right. (See page 77).

Plate XII.

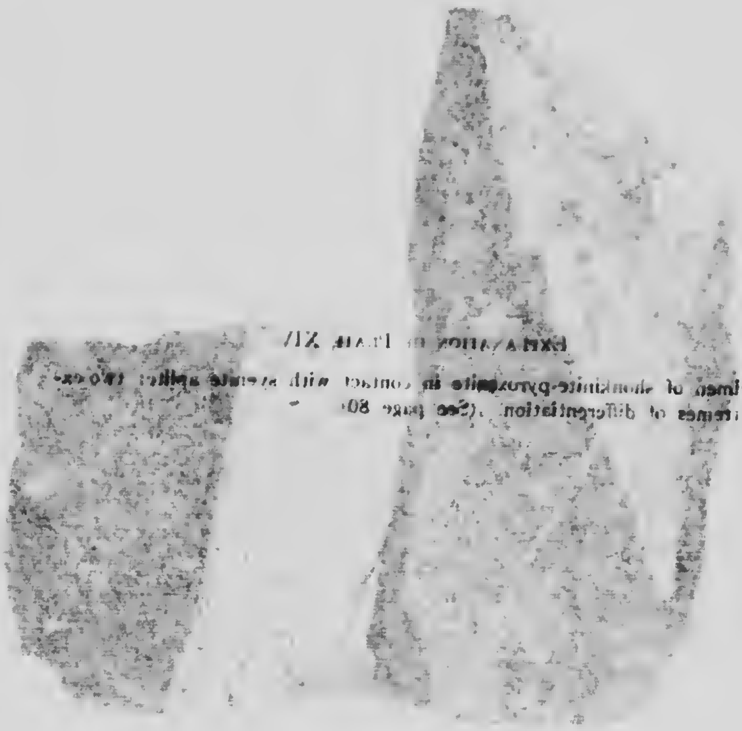


augite

EXPLANATION OF PLATE XIII.

Specimen of porphyritic syenite with elongated orthoclase feldspar phenocrysts with borders of plagioclase. Radiate structure. (See pages 109, 136).

PLATE XIII.



Explanation of Plate XIV.

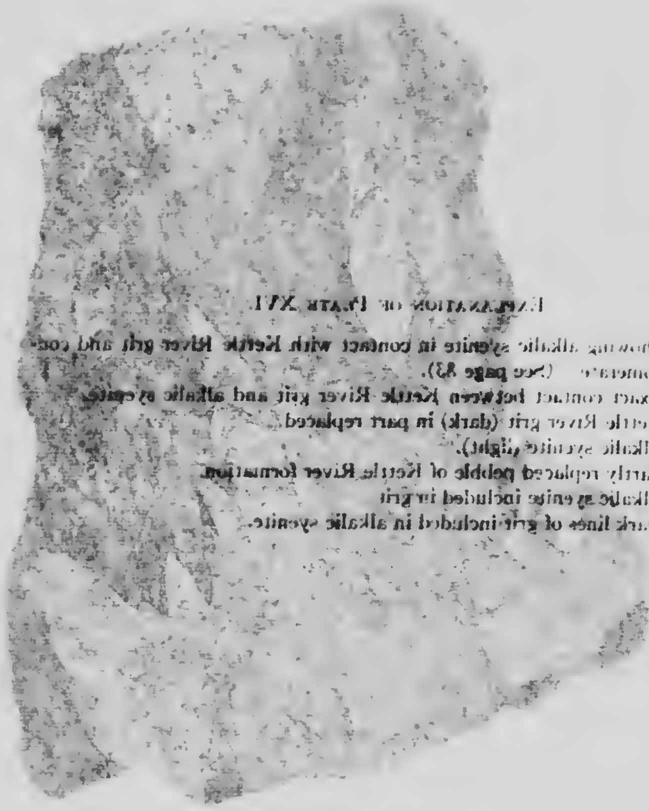
Specimen of shonkinite-pyroxenite in contact with syenite aplite: two extremes of differentiation. (See page 80).

PLATE XIV.

EXPLANATION OF PLATE XV.

Kettle River conglomerate at contact with alkalic syenite. Shows intense metasomatism accomplished by a granular alkalic magma intrusive into an unconsolidated formation. Compare weathered surface here with that of same formation shown in plate IX. (See page 83).

PLATE XV.

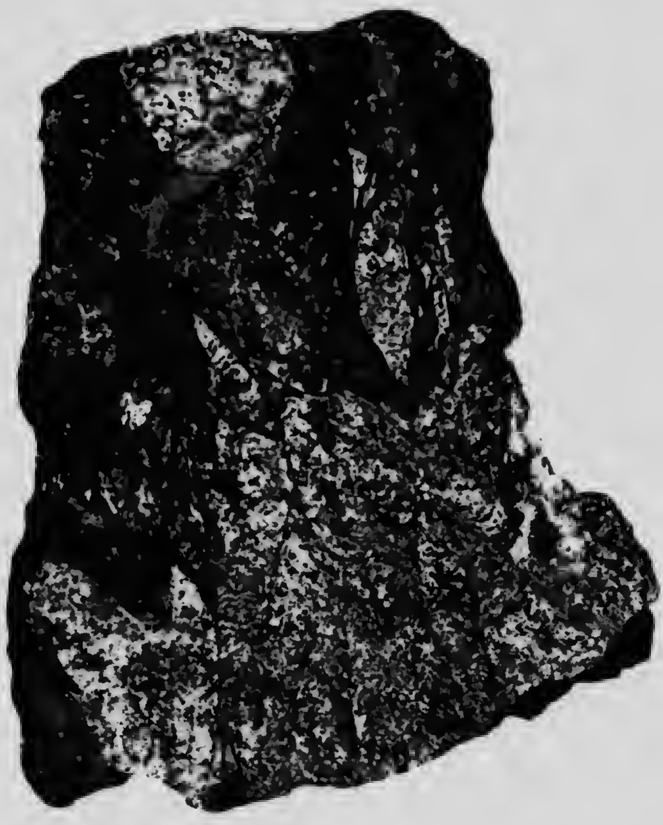


Explanation of Plate XVI.

Specimen showing alkalic syenite in contact with Kettle River grit and conglomerate. (See page 83).

(1) Exact contact between Kettle River grit and alkalic syenite.
(2) Kettle River grit (dark) in part replaced.
(3) Alkalic syenite (light).
(4) Partly replaced pebble of Kettle River formation.
(5) Alkalic syenite included in grit.
(6) Dark lines of grit included in alkalic syenite.

Plate XVI.



Explanation of Plate XVII.

[illegible] basaltic and trachytic tuffs intercalated with flows, on east slope of Tenderfoot mountain. (See page 85.)

Explanation of Plate XVII.

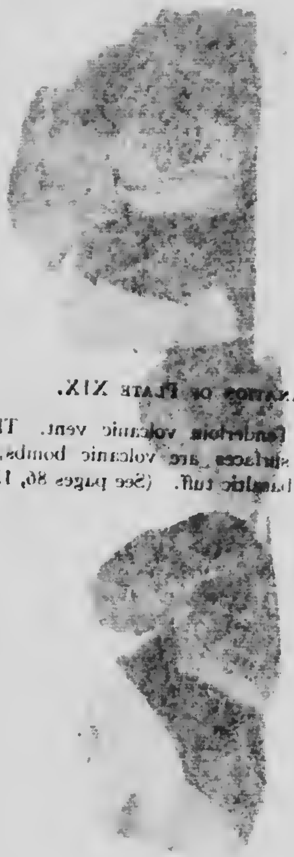
Stratified basaltic and trachytic tuffs intercalated with flows, on east slope of Tenderloin mountain. (See page 85).

Plate XVII.

EXPLANATION OF PLATE XVIII.

Faulted contact of Kettle River formation and overlying Midway volcanic group. (See pages 86).

PLATE XVIII.



EXPLANATION OF PLATE XIX.

Miocene ejectamenta from Sanderson volcanic vent. The three central specimens with pitted surfaces are volcanic bombs, the remaining specimens are of alkalic basaltic tuff. (See pages 86, 128).

Explanation of Plate XIX.

Miocene ejectamenta from Tenderloin volcanic vent. The three central specimens with pitted surfaces are volcanic bombs; the remaining specimens are of alkalic basaltic tuff. (See pages 86, 128).

Plate XIX.

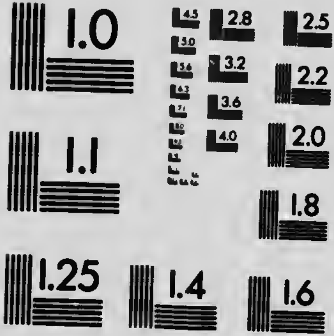
Explanation of Plate XX.

Specimen showing inclusions of quartzite (dark) and eruptive rock in pulaskite syenite dyke above McKinley mine. (See page 90).

PLATE XX.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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EXPLANATION OF PLATE XXI.

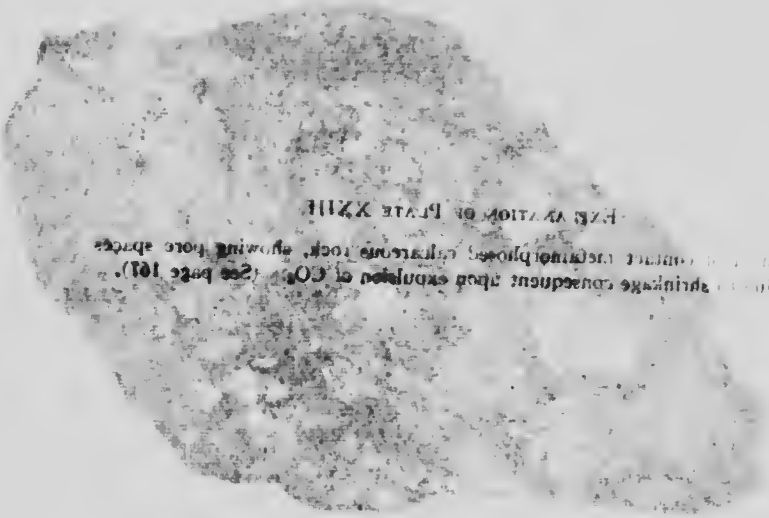
Minette dyke in contact with brecciated Kettle River grit. Shows differentially eroded surface. McKinley mountain. (See page 92).

Plate XXI.

EXPLANATION OF PLATE XXII.

Volcanic agglomerate (trachyte) on east slope of McKinley mountain. (See page 128).

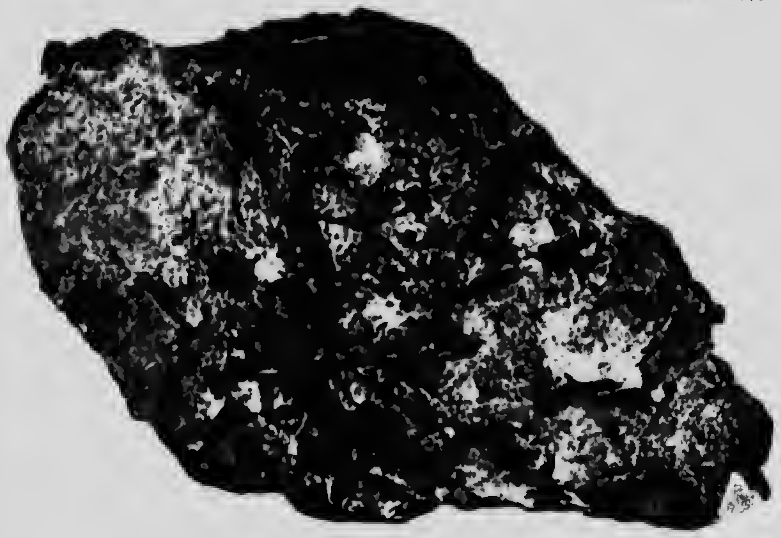
PLATE XXII.



EXPLANATION OF PLATE XXIII.

Specimen of contact metamorphosed calcareous rock, showing pore spaces due to shrinkage consequent upon expulsion of CO_2. (See page 167).

Plate XXIII



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LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Sin 1910, reports issued by the Geological Survey ha e been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario —by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries, assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B. C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletins Nos. 2, 3, 4, 5, 7, and 8 contain articles Nos. 13 to 22 of the Geological Series of Museum Bulletins, article No. 2 of the Anthropological Series, and article No. 4 of the Biological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 23. *No. 23, Geological Series.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 25. *No. 21, Geological Series.* Report on the clay and shale deposits of the western provinces (Part III)—by Heinrich Ries and Joseph Keele.

MEMOIR 30. *No. 40, Geological Series.* The basins of Nelson and Churchill rivers—by William McInnes.

MEMOIR 20. *No. 41, Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C.—by C. H. Clapp.

MEMOIR 52. *No. 42, Geological Series.* Geological notes to accompany map of Sheep River gas and oil field, Alberta—by D. B. Dowling.

MEMOIR 43. *No. 36, Geological Series.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec—by J. J. O'Neill.

MEMOIR 44. *No. 37, Geological Series.* Clay and shale deposits of New Brunswick—by J. Keele.

MEMOIR 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks, in southern Quebec—by J. A. Dresser.

MEMOIR 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G McConnell.

MEMOIR 47. *No. 39, Geological Series.* Clay and shale deposits of the western provinces, Part III—by Heinrich Ries.

MEMOIR 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake —by Andrew C. Lawson.

MEMOIR 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. LeRoy.

MEMOIR 39. *No. 35, Geological Series.* Kewagama Lake map-area, Quebec —by M. E. Wilson.

MEMOIR 51. *No. 43, Geological Series.* Geology of the Nanaimo map-area—by C. H. Clapp.

MEMOIR 61. *No. 45, Geological Series.* Moose Mountain district, southern Alberta (second edition)—by D. D. Cairnes.

MEMOIR 41. *No. 38, Geological Series.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick—by Marie C. Stopes.

MEMOIR 53. *No. 44, Geological Series.* Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition) —by D. B. Dowling.

MEMOIR 55. *No. 46, Geological Series.* Geology of Field map-area, Alberta and British Columbia—by John A. Allan.

MEMOIRS—ANTHROPOLOGICAL SERIES.

MEMOIR 48. *No. 2, Anthropological Series.* Some myths and tales of the Ojibwa of southeastern Ontario—collected by Paul Radin.

MEMOIR 45. *No. 3, Anthropological Series.* The inviting-in feast of the Alaska Eskimo—by E. W. Hawkes.

MEMOIR 49. *No. 4, Anthropological Series.* Malecite tales—by W. H. Mechling.

MEMOIR 42. *No. 1, Anthropological Series.* The double curve motive in northeastern Algonkian art—by Frank G. Speck.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 54. *No. 2, Biological Series.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts—by C. K. Dodge.

Memoirs and Reports Published During 1915.

MEMOIRS—GEOLOGICAL.

MEMOIR 58. *No. 48, Geological Series.* Texada Island—by R. G. McConnell.
MEMOIR 60. *No. 47, Geological Series.* Arisaig-Antigonish district—by M. Y. Williams.

Memoirs and Reports in Press, January 20, 1915.

MEMOIR 50. *No. 51, Geological Series.* Upper White River district, Yukon—by D. D. Cairnes.
MEMOIR 56. *No. 56, Geological Series.* Geology of Franklin Mining camp, B.C.—by Chas. W. Drysdale.
MEMOIR 62. *No. 5, Anthropological Series.* Abnormal types of speech in Nootka—by E. Sapir.
MEMOIR 63. *No. 6, Anthropological Series.* Noun reduplication in Comox, a Salish language of Vancouver island—by E. Sapir.
MEMOIR 46. *No. 7, Anthropological Series.* Classification of Iroquoian radicals with subjective pronominal prefixes — by C. M. Barbeau.
MEMOIR 59. *No. 55, Geological Series.* Coal fields and coal resources of Canada—by D. B. Dowling.
MEMOIR 67. *No. 49, Geological Series.* The Yukon-Alaska Boundary between Porcupine and Yukon rivers—by D. D. Cairnes.
MEMOIR 57. *No. 50, Geological Series.* Corundum, its occurrence, distribution, exploitation, and uses—by A. E. Barlow.
MEMOIR 64. *No. 52, Geological Series.* Preliminary report on the clay and shale deposits of the province of Quebec—by J. Keele.
MEMOIR 65. *No. 53, Geological Series.* Clay and shale deposits of the western provinces, Part IV—by H. Ries.
MEMOIR 66. *No. 54, Geological Series.* Clay and shale deposits of the western provinces, Part V—by J. Keele.
MEMOIR 70. *No. 8, Anthropological Series.* Family hunting territories and social life of the various Algonkian bands of the Ottawa valley—by F. G. Speck.
MEMOIR 71. *No. 9, Anthropological Series.* Myths and folk-lore of the Timiskaming Algonquin and Timagami Ojibwa—by F. G. Speck.
MEMOIR 69. No. 57, *Geological Series.* Coal fields of British Columbia—by D. B. Dowling.
MEMOIR 34. *No. , Geological Series.* The Devonian of southwestern Ontario and a chapter on the Monroe formation—by C. R. Stauffer.
MEMOIR 73. *No. , Geological Series.* The Pleistocene and Recent deposits of the Island of Montreal—by J. Stansfield.

Summary Report for the calendar year 1913.

HON. L. CODERRE

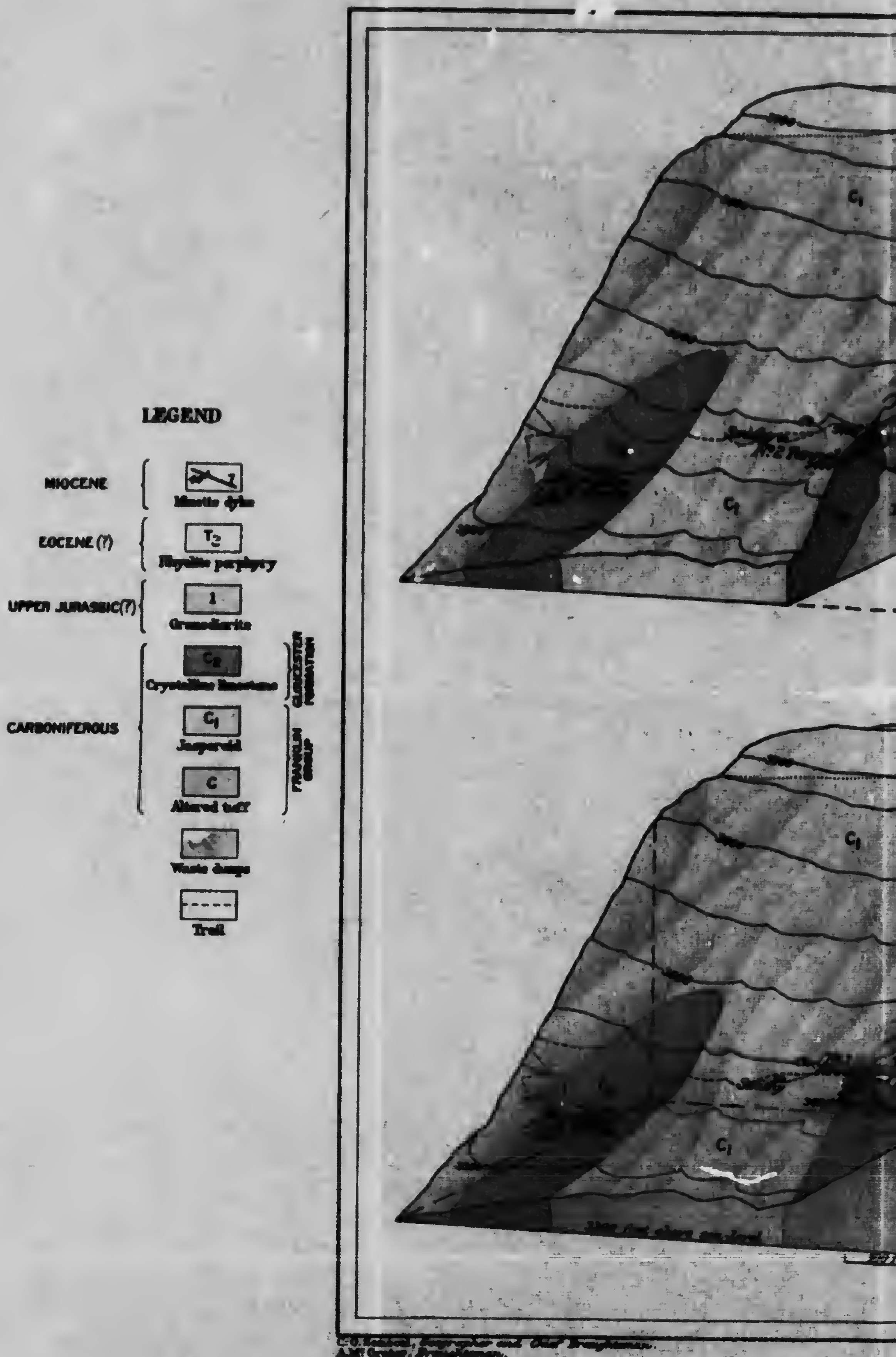


FIG. 16 – BLOCK DIAGRAM OF McKINLEY

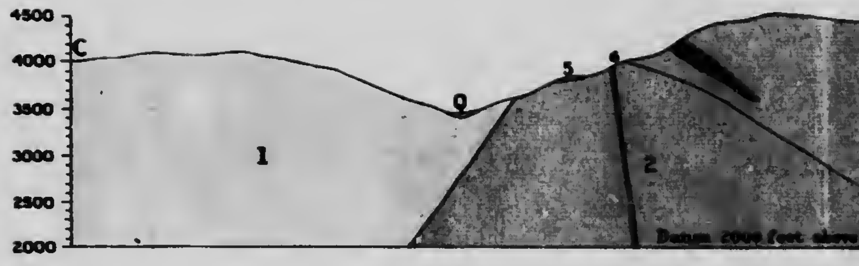
Canada
Department of Mines
...L. Coderre, Minister, R.W. Brock, Deputy Minister

GEOLOGICAL SURVEY

...KINLEY MINE, FRANKLIN MINING CAMP, WEST KOOTENAY, B. C.

Dep

HON. L. CODERRE



Stru

Scale

LEGEND

QUATERNARY

Q — Fluvio-glacial deposits

TERTIARY

MIOCENE

MIDWAY VOLCANIC GROUP

Minette dykes

Pulaskite porphyry and syenite porphyry dykes

T4 — Trachytic flows, alkalic basalt, basaltic tuff

T3 — Earlier trachyte

FRANKLIN CHONOLITH

5 — Augite syenite (*intrusive equivalent of trachytic flows,T4*)

Shonkinite pyroxenite (*intrusive equivalent of alkalic basalt,T4*)

Porphyritic syenite (*intrusive equivalent of earlier trachyte,T3*)

OLIGOCENE

2 — Monzonite (*co-magmatically related to augite syenite*)

EOCENE OR OLIGOCENE

T2 — Rhyolite and rhyolite porphyry

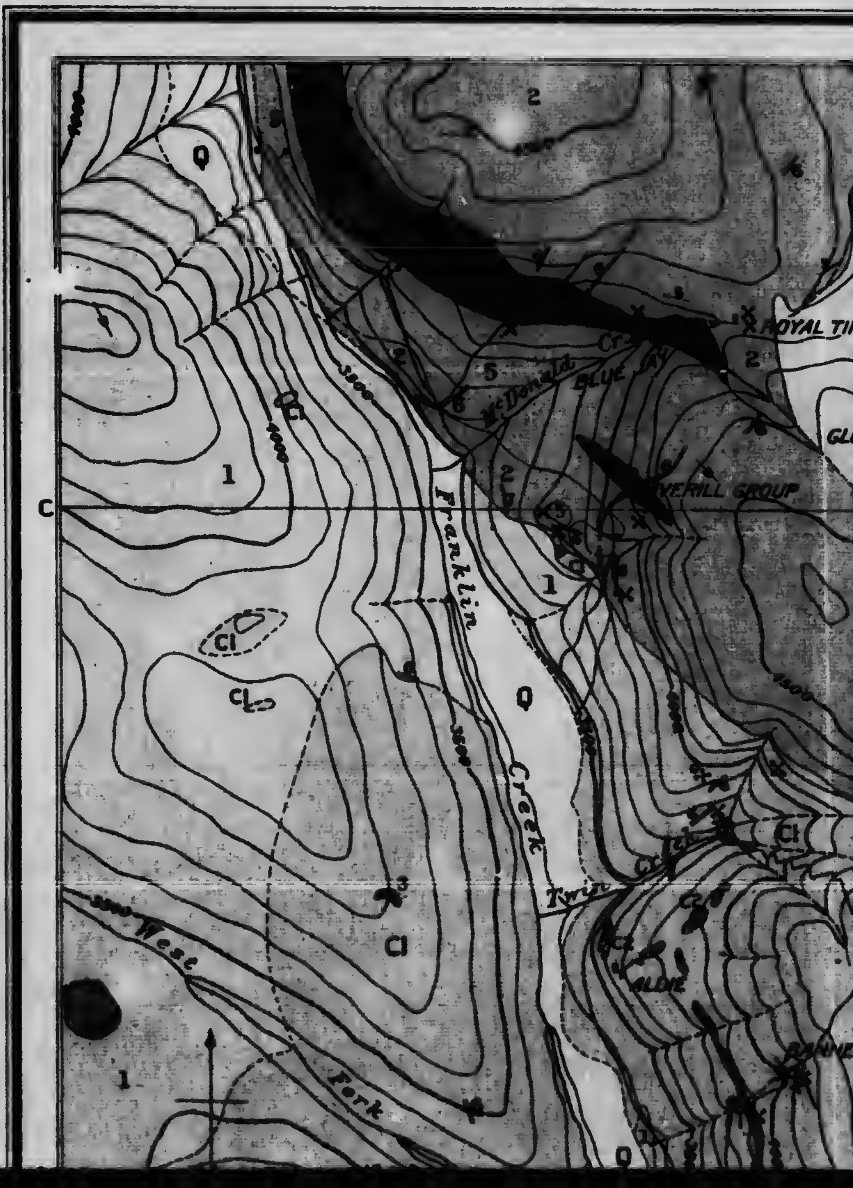
T1 — Kettle River formation (*conglomerate, arkosic grit, acidic tuff*)

...OZOIC

UPPER JURASSIC

1

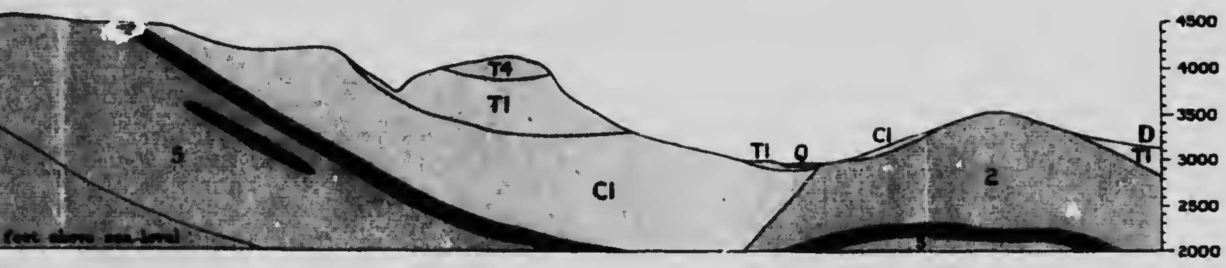
GEOLOGY



Canada
Department of Mines

...ODERRE. MINISTER, R.W. BROCK, DEPUTY MINISTER

GEOLOGICAL SURVEY



Structural section along line CD
Scale, horizontal and vertical 2000 feet to 1 inch

TOPOGRAPHY

LEGEND

Culture

Roads and buildings

Pack trails

Shafts

Bridges

Tunnels

Prospects

Water

MIOCENE

		T1 — Kettle River formation (*conglomerate, arkosic grit, acidic tuff*)
MESOZOIC	UPPER JURASSIC	1 — Granodiorite, gneiss
PALAEOZOIC	CARBONIFEROUS(?)	Gloucester formation (*crystalline limestone*)
		C1 — Franklin group (*greenstone, cherty quartzite, altered tuff*)

Symbols

Fissure vein

Geological boundary (*position exactly determined*)

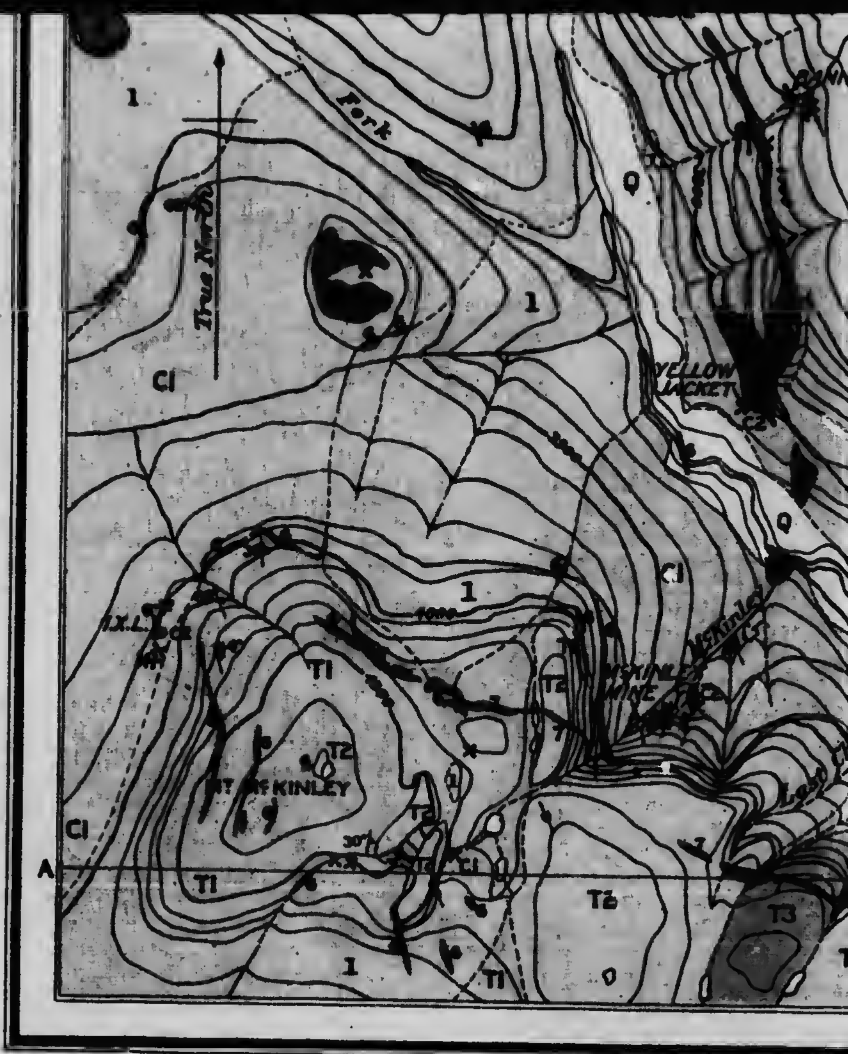
Geological boundary (*position determined within 20 feet*)

Geological boundary (*position assumed*)

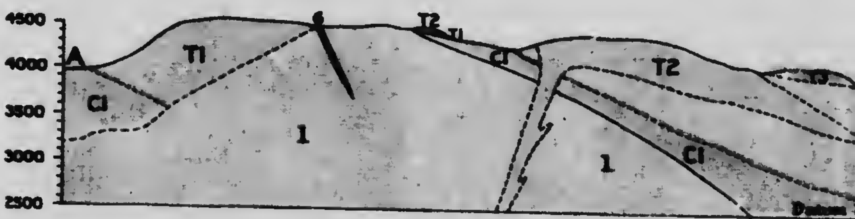
Fault

Dip and strike

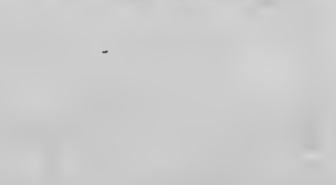
Glacial striae



C.O.Senécal, *Geographer and Chief Draughtsman.*
A.McGregor, *Draughtsman.*



Struct
Scale, h



Scale: 30 miles to 1 inch

To accompany memoir by C.W.Drysdale

FRANKL

WI

BI

Tunnels

Prospects

Water

Lakes and streams

Watercourses
with intermittent flow

Relief

Contours
(showing approximate land forms and elevations above sea-level)
Interval 100 feet

Structural section along line AB
Scale, horizontal and vertical 2000 feet to 1 inch

MAP 97 A
(Issued 1914)

NKLIN MINING CAMP

WEST KOOTENAY

BRITISH COLUMBIA

Scale, $\frac{1}{24,000}$

Feet
0 1000 2000 3000 4000 5000

Metres
0 500 1000

2000 FEET TO 1 INCH

GEOLOGY
C. W. DRYSDALE, 1911.

TOPOGRAPHY
(Control and topography subject to revision)
C. W. DRYSDALE. 1911.

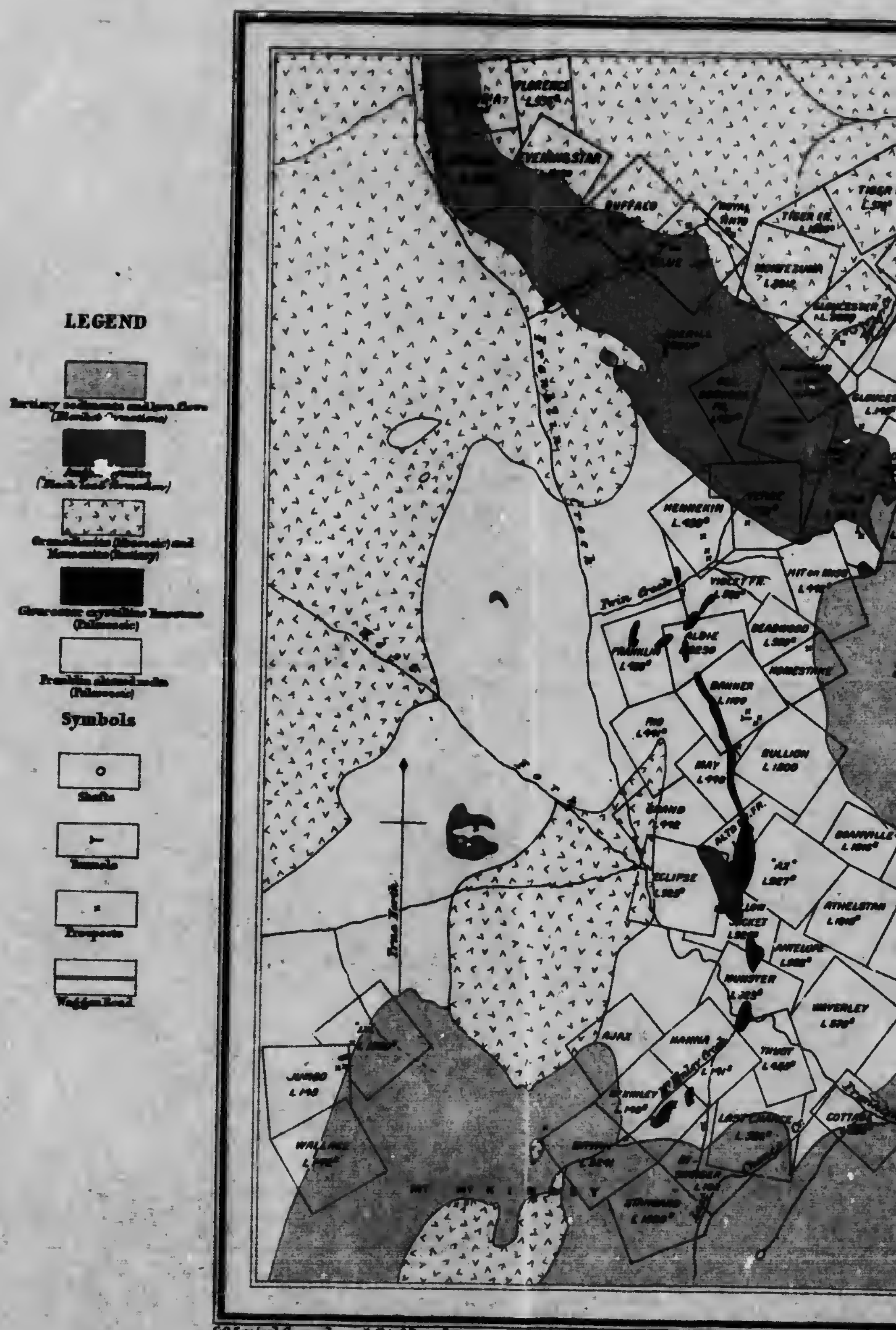
TOPOGRAPHICAL BASE
RATED GRADE 5

Cana

Department

HON. L. CODERRE, MINISTER: R.W.

GEOLOGICAL



MAP 133 A

MINERAL CLAIMS, FRANKLIN MINI

Canada
ment of Mines
STER; R.W. BROCK, DEPUTY MINISTER.

OGICAL SURVEY

OUTLINE MAP

MAP 133 A

MINING CAMP, WEST KOOTENAY, B.C.

Scale of feet