THE GEOLOGY AND STRUCTURE OF THE WEST KOOTENAY COMPOSITE BATHOLITH.

by

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THE GEOLOGY AND STRUCTURE OF THE WEST KOOTENAY COMPOSITE BATHOLITH.

CHAPTER 1.

INTRODUCTION.

General Statement

The area discussed in the following paper embraces one of the most geologically interesting and economically important portions of British Columbia.

This paper is an attempt by the writer to prepare an account of the general geology and structure of the West Kootenay batholithic area. It is an outcome of the study of the literature dealing with the geology of the region, the information being drawn largely from the publications of the Geological Survey of Canada.

It has not been the intention to trace in detail the development of the present knowledge of the geology, but rather to describe briefly, and in order of age, the various formations found within the area, and, from a study of the evidence thus collected, to draw up a correlation table to illustrate the probable relations of the different formations to one another.

Following this an outline has been given of the writer's conception of the geological history of the area from the time of earliest recorded deposition to the present. The data upon which this history is based has been drawn from the accounts by various authors of the sequence of events which have taken place, both locally within the area, and over the surrounding regions.

Finally certain aspects of the intrusion and structure of the composite batholith itself are discussed, and tentative deductions are drawn.

The economic geology has merely been touched upon, the writer having confined his studies chiefly to the general, structural, and historical aspects. The ore bodies and their relationship to the batholith are being dealt with in detail by Mr. Price in another paper.

Acknowledgments.

The writer is greatly indebted to Dean R.W.Brock and Professor S.J.Schofield, of the Department of Geology, University of British Columbia, for their kind and helpful assistance, guidance, and advice, freely given at all stages of the preparation of this thesis.

Acknowledgment is also due to Mr. P.Price for his courtesy in furnishing the writer with information regarding the attitude of many of the formations.

Location and Area.

The area dealt with in this paper lies in southeastern British Columbia and embraces approximately 15,300 square miles. As may be seen on the accompanying map, the northern boundary is an east-west line passing through the town of Arrowhead, at the head of the Upper Arrow Lake. It is bordered on the south by the International

Boundary line at the 49th parallel of latitude. Its eastern and western borders are respectively the 116° and 119° parallels of longitude.

It should be noted that certain Lower Palaeozoic rocks in the vicinity of Lake Windermere, near the northeast border of the sheet, have been intentionally omitted from the descriptive matter, as they are not considered to bear any relation to the problem.

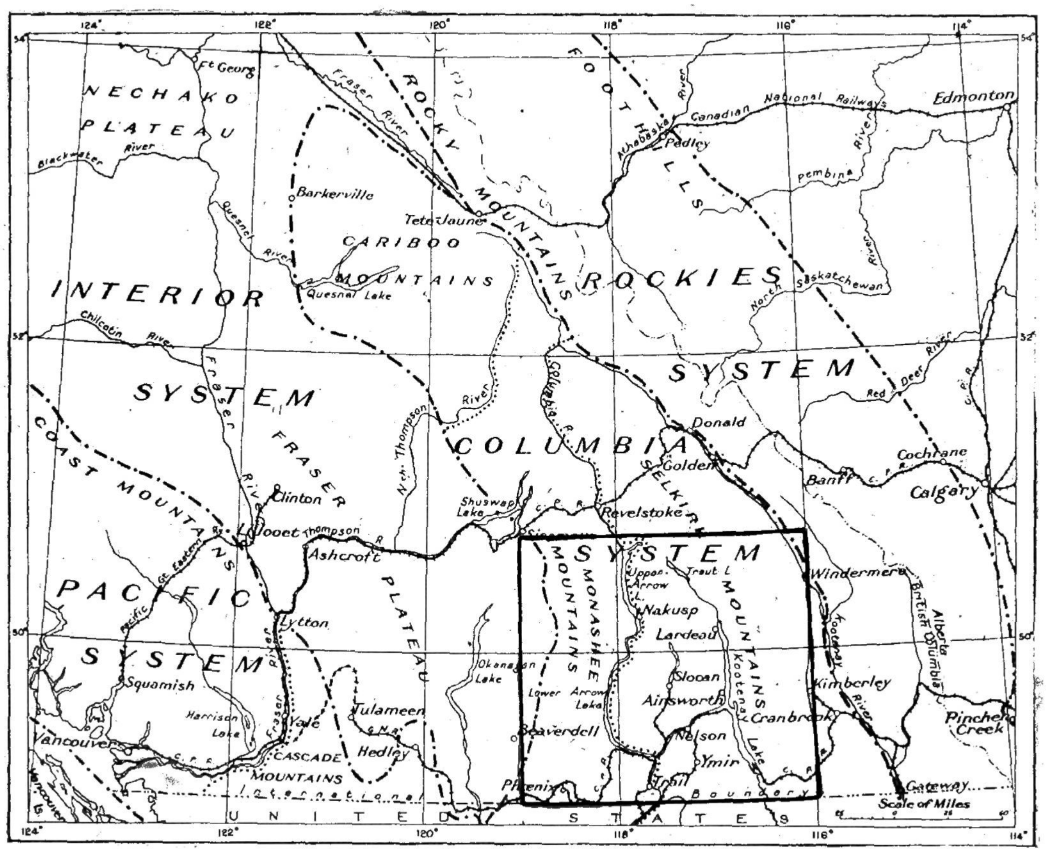

Fig. 1. Index Map, shewing location of area dealt with in this paper.

CHAPTER 11.

TOPOGRAPHY.

Regional

The Geographic Board of Canada[1] has divided the Canadian Cordillera into three main belts, namely the Eastern, Central and Western.

The Eastern and Western belts which are characterised by pronounced Alpine topography, are separated from one another by the Central Belt, which, in contrast, is in the general form of a plateau of much lower relief, though locally assuming a mountainous character.

The Western Belt has been subdivided into the Pacific System, including the Coast Range, and into the Insular System, that of the islands along the coast of British Columbia and southern Alaska. The chief topographical feature of this belt is the Coast Range batholith, a great mass of granitic rocks, trending northwest and terminating in the south near the 49th parallel of latitude.

The Central Belt in southern British Columbia is represented by the Interior Plateaus. This plateau region conforms to the Cordilleran trend of north-westerly and south-easterly direction. In British Columbia it extends from the International Boundary to about the 56th parallel of latitude, and is about 500 miles long by 100 miles wide.

It is characterised by a rolling upland topography, into which are carved deep valleys. The plateau owes its present form primarily

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1. Nomenclature of the mountains of Western Canada, 1918.

to the uplift and dissection of an ancient peneplain. Its northern boundary consists of an irregular group of ranges at the 56th parallel, extending from the Rocky Mountains to the Coast Range. In the south it terminates against the Okanagan, Skagit, and Hosameen Range, and the Midway Mountains. It is bounded on the east by the mountain ranges of the Columbian System, and on the west by those of the Pacific System.

The Eastern Belt of the Canadian Cordillera consists of, from east to west, the Rocky Mountains, Selkirk, and Columbia Systems. Three first rank valleys separate these ranges.

These valleys are as follows:-

(1) Rocky Mountain Trench, separating the Selkirk from the Rocky Mountain System. This remarkable structural depression, extending in British Columbia from the International Boundary to the Yukon, is occupied by turn by the Columbia, Canoe, Fraser, Parsnip, Finlay and Kechika rivers.

(2) Purcell Trench, lying between the Purcell Range (the eastern division of the Selkirk Range) and the Selkirk Range proper. It is chiefly occupied by the Kootenay Lake, and also by the north flowing Kootenay River, and the south flowing Duncan River. To the north it joins the Rocky Mt. Purcell Trench near Golden.

(3) The third of the first rank valleys is occupied by the south flowing Columbia River, whose widened portions form the Arrow Lakes. This valley joins the Rocky Mountain Trench at about the 52nd parallel of latitude, and lies between the Selkirk Range on the east and the Columbia Range on the west.

Local.

The area embraced by this paper includes the southern portions of the Purcell, Selkirk and Columbia Ranges, and the south-eastern extremity of the Interior Plateau.

The dominating topographic feature is that of the granitic batholith, which, from the point of its maximum elevation of some 9,000 feet, in the Kokanee Mountains, slopes off in all directions.

Three main valleys, having a general northerly trend, form intermontaine depressions. These are the Rocky Mountain Trench, the Purcell Trench, and the Columbia Valley. Between the last two a smaller trough is occupied by the Slocan Lake.

One great transverse valley extends from Proctor to Castlegar, its eastern portion forming the West Arm of Kootenay Lake, and its western, the Kootenay River. It thus connects the drainage systems of the Purcell and Columbia Valleys.

The higher peaks are devoid of vegetation, and present a rocky serrated appearance.

Valley head cirques and basins are common throughout the mountains, these cirques being generally occupied by small and clear lakes of great beauty.

Below the timber line the topography becomes more subdued, the mountain flanks appearing as long wooded foot hills. Talus slopes extending fanwise downward mark bare patches devoid of timber. In the valley bottoms small fertile areas of alluvial soil support thriving agricultural communities.

CHAPTER 111

GENERAL GEOLOGY

DESCRIPTION OF FORMATIONS.

General Statement

The geology of the area consists, in brief, of a series of sedimentary and igneus rocks, generally highly metamorphosed and deformed, and ranging in age from Pre-Cambrian to Lower Mesozoic.

Into these have been intruded granitic batholiths of Upper Jurassic and Eocene age.

Overlying portions of this older complex are a series of Lower Tertiary sediments and volcanic extrusives. These are cut by a number of monzonitic and syenitic batholiths and stocks, ranging in age from late Oligocene to Miocene. Capping portions of all the older rocks is an irregular covering of glacial till and recent alluvial deposits.

The precise correlation of the different formations has been rendered extremely difficult owing to the scarcity of reliable fossiliferous horizons, and to the profound degree of metamorphism which the rocks have undergone. Nevertheless, a certain lithological and structural similarity has frequently been found to be common to various sets of formations, and this has led the writer to offer a tentative correlation table. This table is a combination of facts and probabilities, and carries a heavy burden of hypothesis, which, however, is unavoidable when dealing with a district where most of the sedimentary formations cannot be closely dated by fossils. It should be borne in mind that the general succession of the formations has been stated with probably more certainty than their correlation with the recognised geological systems. It is the belief of the writer, however, that the table is of value, in illustrating the probable relationship to one another of various rock formations occurring in widely separated districts, and in the dating of the various formations in the light of the evidence obtained from the most recent and detailed field work.

Pre Carboniferous Record.

Priest River Terrane.

Distribution. The Priest River terrane is a term given by Daly[1] to a series of highly metamorphosed sediments along the International Boundary, between Kootenay Lake and Irene Mountain. From the Boundary Line the rocks of the terrane extend northwest for a distance of about 10 miles, when they are cut off by the intrusion of the Bayonne Batholith.

Lithology. The rocks making up this metamorphic complex consist of a variety of sediments which are now metamorphosed into mica, schists, quartzites, sericite quartz-schists, chlorite schists, dolomites, and phyllites. Amphibolites, representing metamorpohsed intrusives, form a very small proportion of the rock types. Daly has divided

1. Daly, R.A., Mem. 38 Geol. Surv. Can. p.258.

the series lithologically into seven belts, naming them from A to G, Belt A being the youngest. The series is, as yet, entirely unfossiliferous.

Structure. The structure is very complex, but in general is one of north south striking beds, dipping vertically or steeply eastward, the total thickness of the series being at least 18,000 feet. Block faulting has played a minor part. The intrusion of the Bayonne and Rykert batholiths has profoundly metamorphosed the schists of the Priest River terrane near the contacts, with the development of large foils of biotite and muscovite. The beds become progressively younger from east to west.

Age and Correlation. Daly, in his study of the geology along the International Boundary, dated the rocks of the Priest River terrane as Pre Beltian (Archaen), and stated that a great unconformity existed between the youngest member of the Priest River terrane and the base (Irene conglomerates) of the SummitSeries. According to Schofield[1], the Priest River terrane is not Archaen in age, but Beltian, and represents the hydrothermally metamorphosed extension of members of the Purcell Series to the east of the Purcell Trench. Belts A, B, and C are believed to pepresent the Kitchener; D and E, the Creston; and

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1. Schofield, S.J. Personal communication.

F & G the Aldridge formation, all of the Purcell series of Beltian age.

Drysdale,[1] in 1916, reached the same conclusion as did Schofield regarding the Beltian age of the Priest River terrane.

The Purcell Series.

General Statement and Distribution. The Purcell series[2] consists of a group of non-fossiliferous rocks of Pre Cambrian (Beltian) age, and is made up of a great thickness of fine grained quartzites, argillaceous quartzites, argillites and limestones. That they were probably deposited under shallow water conditions in a slowly sinking basin, the Rocky Mountain geosyncline, is shown by the presence of ripple marks and mud cracks at various horizons. Casts of salt crystals indicate that during at least part of the time of deposition, semi arid conditions prevailed. South of the International Boundary rocks of the Purcell series are found in Idaho and Montana; the northern limit, however, has not been determined, due to lack of geological exploration. To the east the series passes inconformably beneath Upper Palaeozoic formations of the Rocky Mountains. To the west the metamorphosed equivalents of the Purcell series are probably represented by the Priest River, and the lower part of the Summit series of Daly.[3]

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1. Drysdale, C.W. Summ. Rept. Geol. Survey. Can. 1916, p.61

2. Schofield, S.J. Mem. 76, Geol. Survey. Can. 1915.
3. Daly, R.A. Mem. 38, Geol. Survey. Can., 1912.

Contemporaneous with these ancient sediments are flows of highly altered basalt (Purcell lava), and injected and differentiated sills, varying in composition from hypersthene gabbro to very acid granite. All the formations of the series are conformable with one another.

The following is Schofield's geological column of the Purcell series in the Cranbrook map area.

Erosion Surface.

Pre Cambrian	Gateway	2,000' +
	Purcell lava	300'
	Siyeh	4,000'
	Kitchener	4,500'
	Creston	5,000'
	Aldridge	8,000' ±
	Base unexposed	

Lithology. A summary of the lithology of the members of the Purcell series in the Cranbrook area is as follows:

(a) Aldridge formation. The Aldridge formation is composed of a series consisting chiefly of argillaceous quartzites, together with purer quartzites and argillites. The argillaceous quartzites which represent about three quarters of the whole formation, consist of rather fine grained rocks, dark grey on fresh fracture. Owing to a rather high contact of iron oxide, these outcrops weather to a rusty brown colour, this being one of the best criteria for field determination. The series occurs in beds of an average of one foot in thickness.

On a branch of the Goat River, the Aldridge formation includes several beds of conglomerates, made up of waterworn pebbles, varying in size up to two inches in diameter, and consisting of black slates, gray quartzites, and an altered volcanic rock.

On Mark Creek, six inches of grey talcose limestone is exposed. Metamorphism has been slight, and where the formation has been intruded by granite stocks of the Nelson batholith, a narrow aureole of knotted schists has frequently developed.

In the west the rocks are of a distinctly coarser type, including, as they do, many beds of conglomerate, while in the east the rocks are all fine grained argillaceous quartzite, with some argillaceous limestones, and no conglomerates have been observed.

The Aldridge formation isof considerable economic importance, because of the occurrence of silver-lead-zinc deposits, such as those of the Sullivan and St. Eugene mines.

(b) Creston Formation. Overlying conformably the Aldridge and having a 500-foot thick transition zone, is the Creston formation, consisting of a succession of greyish argillaceous quartzites, intermediate in character between the dark rusty weathering rocks of the Aldridge and the calcareous thin bedded rocks of the Kitchener formations. The series is made up of argillaceous quartzites and purer quartzites and argillites, in beds of approximately one foot in thickness. The predominating rock in the series is the purer quartzite, weathering grey.

As in the case of the Aldridge, metamorphism has been very slight, though the intrusion of granitic stocks has caused a similar development of knots of carbonaceous material.

From west to east the texture becomes progressively finer, as does that of the Aldridge formation.

(c) Kitchener formation. The Kitchener formation is characterised by its comparatively high lime content. The rocks consist essentially of calcareous and argillaceous quartzites, quartzites, and limestones, the whole weathering yellowish brown to grey. A peculiar weathering structure is characteristic of the argillaceous limestones where unusual depressions are formed, - those on the surface parallel to the bedding planes being linear and about one quarter of an inch wide and half an inch deep, while those on surface, perpendicular to the bedding, are irregular and occasionally vermicular in form. These depressions are probably caused by differential weathering of the purer calcareous phases.

The formation is conformable with the underlying Creston, and grades into it through a 500 ft. transition zone.

(d) Siyeh Formation. The Siyeh formation may be divided into an upper and lower division, each approximately 2,000 feet thick.

The lower is composed chiefly of thin bedded mud cracked, green and purple metargillites. Black metargillites, weathering to a rusty brown colour are also present. North of Upper Moyie Lake and near the base of the Siyeh formation a 200 ft. thick bed of massive conglomerate outcrops. The constituent pebbles of this conglomerate are varied and include greenish grey argillaceous quartzites, brownish red sandstones, white quartzites, and greatly altered amygdaloidal and non-amygdaloidal basalt. Their origin is uncertain, particularly in regard to the basalt, as no older volcanic rocks have been found in place in the series. Overlying this interesting conglomerate is a chocolate brown sandstone, made up of grains of the same material as that of the conglomerate.

The upper division of the Siyeh consists first of 1000 ft. of thin bedded and massive, siliceous, concretionary limestones, grey when freshly fractured, and weathering to grey and buff. Succeeding these are thin beds of purple and green mud-cracked metargillites and flows of basalts.

The Siyeh formation overlies conformably the Kitchener, with a 300 ft. thick transitional zone. The top of the Siyeh is placed at the base of the Purcell lava with which it is in conformable contact.

(e) Purcell Lava. The lithology of these flows is very varied. The rock consists mainly of a highly altered porphyritic or amygdolidal basalt. The porphyritic basalt is characterised by the presence of large labradorite phenocrysts in a groundmass of decomposed hornblende and labradorite. The colour is greyish green, the phenocrysts making up a great part of the rock. The amygdaloidal basalt, on the other hand, is of a dark green to black colour, weathering dark rusty brown, the filling of the amygdules being chiefly quartz and occasionally hematite. The porphyritic and amygdaloidal basalts grade into one another. The base of the flow resembles very strongly a volcanic breccia, though it may possibly be a flow breccia. It is composed of angular and sub-angular fragments of the two types of basalt described above.

(f) Gateway formation. Overlying conformably the Purcell lava is the Gateway formation. The base consists of a fine grained grit composed chiefly of pebbles from the Purcell lava, together with a small proportion of quartzite. Upon these are thin alternating beds of conglomerates & silicous limestone.

The limestone, which is concretionary, weathers a buff colour. With the limestones are found some dolomites, with which are interbanded purple shales and grey sandstones. Capping these are narrow beds of sandy argillites, weathering greyish brown and containing numerous casts of salt crystals. The presence of these casts is a characteristic peculiar to the Gateway formation. With these sandy argillites are interbands of quartzites and heavy buff weathering sandstone.

The Gateway formation is in sharp contrast, both lithologically and in its general appearance, with the Siyeh formation, shewing that changing conditions of deposition took place during the interval of time occupied by the extrusion of the Purcell lava.

(g) The Purcell Sills. The lithology of the Purcell sills serves as an excellent illustration of gravitational differentiation. Three main rock types are represented, grading through intermediate forms into one another. These are in ascending order of acidity (1) Gabbro, (2) Quartz-diorite, or Transition Rock, and (3) Granite. A brief description of the lithology of these three rock types is as follows:

(1) Gabbro. In its most basic form this rock is a hypersthene gabbro of dark grey colour and granite texture. The essential constituent minerals are labradorite and pyroxene, the labrodorite occurring in lath-shaped individuals.

The following is an analysis by M.F.Connor of the hypersthene gabbro:

SiO_2 ..50.36	MnO ...0.20	H_2O ...0.05
TiO_2 ...0.90	MgO ...3.67	H_2O ...0.71
Al_2O_3..13.63	CaO ..11.50	P_2O_5...0.07
Fe_2O_3...2.22	Na_2O...2.54	99.98
FeO 8.38	K_2O ...0.75	S.G. 2.970

Acid differentiates are frequently found in the interior of the basic sills, in the form of a granitic phase consisting of long needles of hornblende in a ground mass of micropegmatite. Associated with the more basic sills are small irregular aplitic dykes, passing into quartz veins and representing extreme differentiation of the gabbro magma.

(2) Quartz-diorite, or Transition Rock. This rock, which represents the transition phase between the granite and the gabbro, is of a light greyish-green colour, and macroscopically is seen to contain quartz, feldspar, hornblende, and biotite. The following analysis is given by Daly[1]

SiO_2	52.63	Na_2O	1.41
TiO_2	0.62	K_2O	2.29
Al_2O_3	16.76	H_2O	0.12
Fe_2O_3	2.86	H_2O-	1.17
FeO	10.74	P_2O_5	0.33
MnO	0.38	CO_2	0.10
MgO	4.33	S.G.	2.954
CaO	6.17		

(3) Granite. By gradual stages, involving a decrease in hornblende and an increase in quartz and micropegmatite, the quartz diorite passes into a granophyre. The position of the granophyre in

1. Daly, R.A. Festschrift zum siebzigsten Geburtstage, von H.Rosenbush, 1906, p.217.

the sills is at, or very near, the upper contact, in contrast with that of the gabbro which by gravitational differentiation is found near the basal contacts. There is no direct relation between the thickness of the granite and that of the sills, and many of the narrower sills are predominately granite, while certain other sills of considerably greater thickness are of entirely basic composition.

The following analysis of the granophyre is given by Daly[1]

S_1O_2	71.69	CaO	1.66
T_1O_2	0.59	Na_2O	2.48
Al_2O_3	13.29	K_2O	2.37
Fe_2O_3	0.83	H_2O	0.14
FeO	4.23	H_2O	1.31
MnO	0.09	P_2O_5	0.07
MgO	1.28	CO_2	0.13
			100.16
	S.G.		2.773

Stratification according to density is of a striking nature, and is of two kinds. Those found nearer the International Boundary line appear to have an upper and lower zone of gabbro, while an intermediate zone - the centre of the sill - consists of a more granitic phase, the transition being gradual.

1. Daly, R.A., Am. Jour. Sci., 4th ser., vol. 20, 1905. p.193.

The second type, which is well represented at St. Mary Lake, consists of an upper granitic zone, passing transitionally into a lower one of gabbro.

Structure of the Purcell series. The Purcell series, to the east of the Purcell Trench, is characterised by a structural complexity - folds and faults are numerous. The regional folding is that of north and south trending anticlines and synclines. With certain exceptions the folds are gentle, and are the result of compression from an east and west direction.

A later period of tension caused normal faulting in a north-east south-west system; this took place probably during the Jurassic period of batholithic intrusion.

The last great period of faulting, when the Cranbrook fault developed, is believed to have occurred during the Early Tertiary (Larimide) time.

Igneus activity in middle Beltian time resulted in the injection of the Purcell sills into the lower members of the series, particularly those of the Aldridge. This was accompanied by the outpouring of the Purcell lava at the close of the Siyeh. This lava has proved to be a valuable horizon marker for field correlation purposes.

Age and Correlation. The Purcell series was originally described by Dawson[1] in 1885, who considered it to be of Cambrian age. Fourteen years later McEvoy[2], in a further examination of the series, reached

1. Dawson, G.M. Ann. Rept., Geol. Sur. Can., 1885, p.148B
2. McEvoy, J., Summ. Rept. Geol. Sur. Can., 1895, p.87A

the same conclusion regarding the age as did Dawson.

As a result of later and more detailed examination, Schofield[1,2] placed the series entirely in the Pre Cambrian. The dating of the series depends upon stratigraphical & lithological evidence, the rocks being, as far as is known, unfossiliferous. The evidence for a Pre-Cambrian age is, briefly, as follows:

In 1921 shales containing Olenellus fauna were found in the vicinity of Cranbrook. Underlying these was a basal conglomerate (Cranbrook conglomerate) which rested in distinct unconformity upon the Siyeh formation. At Elko, B.C., another section shewed the Cranbrook conglomerates (Lower Cambrian) lying disconformably upon the Roosville formation. The Roosville is the upper member of the Purcell series in the Rocky Mountains, and is separated from the top of the Gateway formation by 500 feet of rock belonging to the Phillips formation.

It is therefore evident that the whole Purcell series is Pre-Cambrian in age.

Within the map area the Purcell series may be correlated with the whole of Daly's Priest River terrane, and with Daly's Irene conglomerates and volcanics at the International Boundary to the west of Kootenay Lake.

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1. Schofield, S.J., Mem 76, Geol. Sur. Can., 1915, p.41

2. Schofield, S.J., Bull. 35, Geol. Ser. No.42, Geol. Sur. Can., 1922.

Summit Series.

Distribution. The Summit Series occurs as a belt of rocks of about 18 miles in width at the International Boundary, and lying about midway between the Columbia and Kootenay Rivers. From the International Boundary it tapers rapidly to its northern extremity at a point about 10 miles south of Proctor.

Lithology. The series is composed of a great thickness of unfossiliferous metamorphical sediments, now represented by quartzites, phyllites and conglomerates, together with an important horizon of lava flows. The following is Daly's table of formations of the Summit series, as exposed along the International Boundary Belt:

Formation	Thickness in feet Top, erosion surface	Dominant rocks.
LoneStar	2,000	Phyllite and quartzite.
Beehive	7,000	Quartzite
Ripple	1,650	Quartzite
Dewdney	2,000	Quartzite with conglomerate
Wolf	2,900	Siliceous grit, sandstone and conglomerate.
Monk	5,500	Quartzite, phyllite, and conglomerate
Irene Volcanics	6,000	Effusive greenstones.
Irene Conglomerates	5,000	Conglomerate
	32,050	

Base, unconformity with Priest River terrane.

Structure. The members of the series have a general north-south strike with nearly vertical dips, and closely conform in attitude to the flanking Priest River terrane on the east, and to the Pend d'Orielle group on the west. Large granitic stocks from the Nelson batholith cut the series in various places, the elongation of these intrusives being, on the whole, parallel to the general trend of the formation.

Age and Correlation. On the West Kootenay Map Sheet, the Summit series has been mapped as Cambrian to Silurian , and correlated with Dawson's Lower Selkirk Series of the Northern Selkirk Mountains. Daly definitely assigned all of the Summit series below the Wolf formation to the Beltian, the Wolf formation being considered to be either Beltian or Cambrian in age, while the Dewdney, Ripple, Beehive, and Lonestar formations were tentatively referred to the Cambrian.

The Irene conglomerates, the basal member of the Summit series, were considered by Daly to be the base of the Beltian in Canada.

According to Drysdale[1] this is not the case. He concludes that "The Irene conglomerate is not considered to be the base of the Belt terrane in Canada, but simply the base of a younger series than the Purcell, of probably Lower Cambrian age. It may prove to be the western equivalent of the Bow River and Siyeh(?) conglomerates, east of the axis of uplift."

Schofield[2] considers the Irene conglomerate and Irene volcanics

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1. Drysdale, C.W. Summ. Rept., Geol. Sur. Can., 1916, p.61.

2. Schofield, S.J. Personal communication.

to be the western equivalents of the Siyeh formation and Purcell lava respectively, of Beltian age, and has suggested the following tentative correlation of the Summit series with the Purcell series to the east of the Purcell Trench.

Division	Period	Summit Series	Purcell Series.
Palaeozoic (pre Carboniferous		Lone Star Beehive Ripple Dewdney	
	Lower Cambrian	Wolf Monk	Cranbrook conglomerates
Beltian		Irene Volcanics Irene Conglomerates	Purcell Lava Siyeh

There appears to be no doubt that the lower part of the Summit series is Beltian in age. In regard to the upper part, it has been found impossible to assign it to any definite age. It is conformably overlain by the Pend d'Oreille group (Carboniferous to Pre Carboniferous). The whole series has been cut by Jurassic intrusives, and has been upturned by the crustal movements which took place at the close of the Jurassic. In the writer's opinion it is very probable indeed that the upper part of the Summit series represents the southern extension of the Ainsworth series on the west shore of Kootenay Lake.

In the interests of simplicity the Summit series is, in this paper, divided broadly into an upper or Pre Carboniferous division, and a lower, or Beltian division. The dividing line being considered to be marked by the contact of the Monk and Wolf formations.

Ainsworth Series.

Distribution. The term Ainsworth series was first used by Schofield[1] in reference to a group of metamorphosed sedimentary and volcanic rocks lying conformably beneath the Slocan series, and exposed along the west shore of Kootenay Lake. The base is not known, while the top has been placed arbitarily at a transitional and conformable contact with the base of the massive Silver Hoard limestone, the lowest member of the Slocan series.

To the north the Ainsworth series extends ~~to~~ beyond the area dealt with in this paper. The series has been traced southward to the West Arm of Kootenay Lake, near Balfour, but it is probably represented still further south by the younger members of the Summit series.

The eastern boundary is marked by a line running approximately northward from Crawford Bay, on the east shore of Kootenay Lake, into the Lardeau district, where it follows the Duncan Valley.

The western boundary is in general coincident with the eastern boundary of the Slocan series, which has been traced to the west of Kootenay Lake and up the Trout Lake Valley.

1. Schofield, S.J., Mem. 17, Geol. Surv. Can., 1920.

The stratigraphical column of the Ainsworth series in the Ainsworth map area is as follows:

Formation	Thickness in feet.
Josephine formation	3,000.
Ainsworth formation	600.
Princess formation	1,250.
Early Bird formation	2,300.
Point Woodbury formation	1,800.
Base unexposed.	6,250.

Lithology. The rocks composing the series consist of alternating schists, quartzites and limestones. All formations are conformable with one another, and the whole series has an average dip of about 35° to the west.

(a) Point Woodbury formation. This ~~in~~formation which is well exposed at Point Woodbury, eight miles south of Kaslo, is composed of rusty weathering micaceous quartzites and garnetiferous mica schists, and is intruded by gneissic granite and pegmatite dykes, which closely follow the bedding planes.

(b) Early Bird formation. The rocks of the Early Bird formation consist typically of massive thick bedded blue-grey limestones, separated by thin layers of mica schist.

The limestone has proved to be very resistant to erosion, and along the lake shore forms abrupt cliffs. It is rough to the touch and weathers to a rusty brown colour.

(c) Princess formation. The Princess formation is made up of glittering mica schists, frequently garnetiferous, and interbeds of micaceous quartzites. The lithology of the formation is very similar to that of the Point Woodbury formation. The outcrop of the quartzites are generally stained with brown iron oxide, while the schists weather to a brown micaceous earth.

(d) Ainsworth formation. The predominating rock of this formation is a greyish-white massive limestone. Black shaly members and some white marble make up the remainder. The gradation from the Princess formation below is transitional.

(e) Josephine formation. The Josephine formation embraces a succession of mica schists at the base, succeeded by thin bedded quartzites and green hornblende schists, interbedded with long lenses of limestone. Capping these are staurolite schists.

The hornblende schists probably represent metamorphosed basic volcanic ash beds and are of great economic importance, because of the occurrence of the Highland and Florence ore bodies at the base of their lower contact with the associated quartzites.

The upper member of the Josephine is a black coloured rusty weathering andalusite schist, containing numerous knots of highly altered and sheared andalusite and staurolite crystals.

Structure. The general strike of the series is north and south, with a north-westerly trend in the Lardeau district.

The average dip of the rocks is from 30° to 50° to the west, though locally the dip may be much steeper. In general the planes of schistosity are coincident with the bedding.

The total thickness has not been determined, but it is undoubtedly very great. In the Ainsworth district alone it is, according to Schofield, 6250 feet, but there is, in addition, the far greater thickness beneath and to the east of Kootenay Lake.

The series has been intruded by several stocks of Nelson granodiorite and also by numerous dykes of pegmatite, originating either from the Nelson granodiorite, or from unroofed bodies of Valhalla granite.

Age and correlation. The upper member of the Ainsworth series underlies conformably rocks of the Slocan series of Pennsylvanian age. On the east side of Kootenay Lake the Ainsworth series includes rocks originally mapped on the West Kootenay map-sheet as Shuswap. The base of this series was found in 1914[1] to overlie conformably the Beltian rocks of the Purcell series. The conclusion is, therefore, that the series is not older than Beltian and not younger than Carboniferous. In all probability it is of early Palaeozoic age.

The Ainsworth series may be tentatively correlated with the schists of the Summit series, occurring between the West Arm of Kootenay Lake, and the International Boundary.

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1. Schofield, S.J., Geol. Sur. Can., Summ. Rept., 1914, p.136.

Duncan Series.

Distribution. The Duncan series occupies a belt about six miles in width on the west slope of the Duncan River Valley. It is bounded on the east by the Duncan River, on the north by stocks of granodiorite beyond the map-area, and on the south by the head of Duncan Lake.

Lithology. The rocks of the series consist almost entirely of grey quartzites of a very uniform character.

Structure. The general structure is that of a north-west and south-east striking, closely-folded, anticline. On its western flank the series is faulted against the "lime dyke"[1], a limestone member of the Slocan series.

Age and correlation. The age of the Duncan series is very doubtful. It is considered by Bancroft to be Pre-Carboniferous, and probably Palaeozoic, though possibly Pre Cambrian. The series is entirely unfossiliferous.

Carboniferous Record.

Pend d'Oreille Group.

Distribution. The Pend d'Oreille group in British Columbia occupies a wide area at the International Boundary, extending from a few miles to the west of the Columbia River, to a point near Lost Mountain.

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1. Bancroft, M.F., Personal communication.

Northward the exposure tapers rapidly to its northern boundary, about five miles east of Nelson. On the east the group is flanked by the upper member of the Summit series, and on the west by the great area of Rossland volcanics.

<u>Lithology.</u> The rocks of the Pend d'Oreille group consist of a variety of highly metamorphosed carbonaceous phyllites, quartzites, amphibolites, metargillites, and metamorphosed tuffs, together with lenses of crystalline limestone. The group has been intruded by large outliers of the Nelson granodiorite batholith, near the contacts of which the sedimentary members of the group have been metamorphosed to andalusite and mica schists.

<u>Structure.</u> The structure of the group is that of a north-south striking homocline. Dips are very steep, most of the beds lying in a nearly vertical position. Owing to the degree of metamorphism to which the group has subjected little information regarding the detailed structure is known. The group is at least 5,500 feet thick, and overlies, conformably, the Summit series.

<u>Age and correlation.</u> No fossils have yet been found in the rocks of the Pend d'Oreille group, and so no definite decision regarding the age can be reached. The limestone members, however, closely resemble fossil-bearing calcareous beds of the Mount Roberts formation of Rossland, fifteen miles to the west. The limestone members of the group have also been correlated by Daly with Dawson's Cache Creek

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1. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912.

formation in the Kamloop's district[1], the upper members of which contain fossils of Pennsylvanian age, while the lower members may be somewhat older than the Carboniferous. It is very possible that the Pend d'Oreille group may also be correlated with many of the highly metamorphosed rocks in the Boundary district, and, in the vicinity of Grand Forks, as suggested by Bancroft[2], with members of the Slocan series, which lie on the same trend to the north.

The Pend d'Oreille group is considered tentatively to be of Carboniferous age, its lower members, however, may quite possibly be somewhat older.

Grand Forks Schists.

Distribution. The Grand Forks schists cover an area of about thirty square miles in the vicinity of the town of Grand Forks, near the International Boundary. They are bounded on the east by the Cascade batholith, and on the north and west by rocks of the Pheonix volcanics and the Attwood series. Their distribution on the American side of the Boundary line is not known.

Lithology. The Grand Forks schists are a complex compound of a series of highly altered extrusives of a basic nature, together with intrusives of the gabbro-diorite type, and possibly some sedimentary

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1. Dawson, G.M., Bull. Geol. Soc. Am. Vol. 12, 1901, p.70
2. Bancroft, M.F., Summ. Rept., Geol. Sur. Can., 1912, p.29B.

argillaceous rocks; lenses of crystalline limestone are also present. The whole has been so thoroughly recrystallized that its original composition is often very doubtful. According to Daly[1], "These have been metamorphosed to ever-varying phases of amphibolite, fine-grained orthoclase bearing hornblende schist, hornblende-epidote-plagioclase schist, actinolite schist, and biotite diorite gneiss. Along with these, thick lenses or pods of white crystalline limestone are interbedded. The limestone is, as yet, unfossiliferous, but resembles the Carboniferous limestone occurring about Rossland".

Structure. Owing to the intensive metamorphism, very little detail of the structure is known. The metamorphism is probably largely due to the intrusion of the underlying Cascade batholith of Jurassic age.

Age and correlation. This complex is entirely unfossiliferous, but the limestone members resemble, lithogically, the Carboniferous limestone of Rossland. The series has been intruded by the Cascade batholith and the Smelter Stock, both Jurassic in age.

The dating of the Grand Forks schists is very uncertain, but in the interests of simplicity they are here referred to the Carboniferous and correlated rather doubtfully with the Mount Roberts formation of Rossland, with the Pend d'Oreille group, and with certain other schistose formations along the International Boundary.

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1. Daly, R.A., Mem. 38, Geol. Surv. Can., 1912, p.379.

Sutherland Schists.

Distribution. The Sutherland schistose complex occupies the great part of the east shore of Christina Lake. It is bounded on the north and south by members of the Rossland volcanic group, and on the east by the Coryell batholith.

Litholigy. The oldest rocks of the complex consist of highly crystallised schists of sedimentary origin, and include garnetiferous schist, phyllite, biotite-epidote schist, andalusite-biotite schist, and actonilite-biotite schist. With these are interbedded a few large lenses of light grey to white marble, and some brecciated greenish quartzite. A few basic intrusive rocks occur in irregular bands.

Structure. The structure of the complex appears to be utterly confused, no regularity being found in the attitude of either the bedding or planes of schistosity. Besides the intrusion of the Coryell batholith, the complex has been cut by the somewhat earlier, and more basic bodies of Fife and Baker gabbro.

Age and correlation. No fossils have yet been found in the sedimentary members. Daly[1] mentions that the quartzite and limestone resembles the Carboniferous quartzite add crinoidal limestone of Little Sheep Creek, and the more staple phases of the Pend d'Oreille group. The complex is cut by gabbros of Lower Jurassic (?) age. It seems probable that the Sutherland schists and the Grand Forks schists are

1. Daly, R.A., Mem. 38., Geol. Sur. Can., 1912, p.321.

very closely related, and of about the same age. The Sutherland schists are here tentatively referred to the Carboniferous.

Anarchist Series.

Distribution. In the map area the Anarchist series occupies about 9 sq.miles near the south west corner of the sheet, ten miles west of Midway. To the west of the sheet, however, it is exposed over a considerably larger area, extending nearly to Osoyoos Lake & making up the rocks of the Anarchist Plateau.

Lithology. The rocks of the Anarchist series consist of a group of highly metamorphosed sediments, dominantly quartzite and phyllitic slates; with these are lesser amounts of greenstones, and a few isolated pods of limestone. The quartzites, which are very hard, are of a grey to green colour, and, where badly sheared, are extremely fissile. The colour of the phyllite is generally dark grey, but varies through greenish and bluish tints. Greenstone which occurs in massive to schistose bands probably represents both intrusive and extrusive basic rocks.

The limestone, which is low in magnesia, is of a light bluish-grey colour, and occurs in pods up to 200 ft. in thickness.

Structure. The series is highly metamorphosed, and little of the original structure remains. The metamorphism is believed to be of dynamic rather than of igneous origin[1].

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1. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912. pp.391-392.

Age and correlation. As would be expected from the degree of metamorphism, no fossils have yet been discovered in the Anarchist series. Daly[1], however, refers this series to the Carboniferous, on lithological and structural evidence, and correlates them with the Carboniferous of Rossland as follows:

"This oldest group (Anarchist series) is almost certainly the same as that which crops out at intervals between the Columbian River and Midway, and, in the Rossland district, bears obscure fossils referred to Carboniferous species."

Daly also correlates the Anarchist series, lithologically, with similar but fossiliferous rocks of definitely Carboniferous age, in the Skagit range, near Chilliwack. The Anarchist series are, therefore, very probably Carboniferous in age.

Knob Hill Group.

Distribution. The Knob Hill group occurs as small scattered outcrops, averaging about 1 square mile in size, in the vicinity of Phoenix. On the Boundary Creek sheet they have been mapped as porphyrite tuffs, conglomerates, and ash beds of Palaeozoic age.

Lithology. The group forms a complex of highly altered rocks, chiefly of igneous origin. The predominant rock types are cherts, tuffs and porphyrites; with these are breccias and a few lense like masses of limestone and argillite. The general colour is dark greenish grey to dark grey, weathering to a somewhat lighter tone.

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1. Daly, R.A. Mem. 38, Geol. Sur. Can., 1912, p.422.

Structure. In the Phoenix area, the group,appears to be in the form of a north and south trending syncline, the thickness being at least 1,200 ft. The contact with the overlying Attwood series is a conformable one. The rocks are massive, and due to the absence of bedding and banding, a satisfactory stratigraphic sequence cannot be worked out.

Age and correlation. No unconformity was found between the rocks of the Knob Hill group and those of the overlying Attwood series of Carboniferous age. Le Roy[1] has assigned the Knob Hill group to the Palaeozoic, but states that they are probably but little older than the Attwood series. The writer, in the interests of simplicity, has provisionally assigned them to the Carboniferous.

Franklin Group

Distribution. The Franklin group has been mapped in detail in the Franklin map area by Drysdale[2], where it outcrops over a total area of about 8 square miles, in the vicinity of Tenderloin, Franklin, and McKinley Mountains. On the West Kootenay Reconnaissance sheet, the Franklin group has been mapped,with other and younger formations, under the general legend of Rossland volcanics.

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1. Le Roy, O.E., Mem. 21, Geol. Sur. Can., 1912, p.19.

2. Drysdale, C.W., Geology of the Franklin Mining Camp, British Columbia Mem. 56, Geol. Sur. Can., 1915.

Lithology. The term Franklin group embraces a complex of metamorphic rocks of both igneous and sedimentary origin. They consist of altered tuffs and greenstones, cherty quartzites, and silicified argillites.

The argillites, which form the oldest members of the group, contain obscure plant remains.

Structure. Owing to the massive character of the formations, the large proportion of eruptive material and the extent to which the members of the group have been chloritised and silicified, the original structure has been greatly obscured. The argillites and quartzites, however, appear to have a general strike ranging from north to north-west, with dips from 35° to 60° toward the west and south-west. Jointing is well developed, but schistosity appears to be absent.

Age and correlation. Lithologically, the rocks of the Franklin group resemble the tuffs, greenstones and argillites of the Knob Hill group at Phoenix[1], of Upper Palaeozoic, probably Carboniferous age. Furthermore, the Franklin group resembles, somewhat, the Boston Bar series, occurring south of the Kamloops map sheet, and described by Dawson[2].

Dawson correlated the Boston Bar group provisionally with the Cache Creek series, of Carboniferous, and, in part, possibly Pre Carboniferous age. The Boston Bar series, however, contains schists, which are absent in the Franklin group. The Franklin group underlies conformably and intimately the Gloucester formation of Carboniferous age, and will itself be referred tentatively to the Carboniferous.

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1. LeRoy, O.F., The Geology & Ore Deposits of Phoenix, Boundary district, B.C. Geol. Sur. Can., Mem. 21, 1912, p.50
2. Report on Kamloops Map sheet. Ann. Rept. Geol. Sur. Can. vii, Pt.B 1896, p.446.

Mount Roberts Formation.

Distribution. The rocks comprising the Mount Roberts formation have been mapped in detail on the geological sheet of the Rossland Mining Camp.[1] They occur in north-south trending bands chiefly on the slopes of Little Sheep Creek Valley, two miles to the west of Rossland, while smaller exposures lie about one mile to the north and to the south of the town.

Lithology. The Mount Roberts formation consists largely of slates, generally highly silicified, in part carboniferous, and in part arenaceous and calcareous. Metamorphosed tuff beds are also included in the formation. In the less altered exposures, such as those lying in the vicinity of Little Sheep Creek, near the west border of the Rossland map sheet, the slates are considerably softer than the more silicified and lighter coloured varieties eastward on Red and Monte Christo Mountains. In the calcareous beds on the eastern slope of O.K.Mountain, Drysdale,[2] in 1906, found fossils of Carboniferous age.

Structure. The Mount Roberts formation has a general north-south strike, with local variations, and a dip of from 10° to 60° to the west. The thickness is at least 1,200 feet. Faulting along east and west planes is common, especially in the west, and flexures are shewn along the contacts with the younger augite porphyrite. In some parts the strata are cross bedded.

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1. Brock, R.W. & Young, G.A. Rossland Mining Camp, B.C., Map No.1004, Geol. Sur. Can. 1909.
2. Drysdale, C.W., Geology & Ore Deposits of Rossland, B.C., Mem. 77, Geol. Sur. Can., 1915, p.199.

Due to later and intensive batholithic intrusion and to mountain building forces, metamorphism of the formation has been very considerable, particularly in areas where the bedding lies perpendicular to the surface of the batholithic contact.

Age and correlation. The discovery of fossils by Brock on O.K.Mountain proves the Mount Roberts formation to be of Carboniferous age. The formation is correlated by Drysdale[1] with the Knob Hill and Brooklyn formations at Phoenix[2], and Dawson's Cache Creek group, in the Kamloops district[3]. To the east it is probably represented by at least part of the Pend d'Oreille group.

Attwood Series.

Distribution. The Attwood series occurs in the Boundary district and occupies an area of about fifteen square miles. The chief exposure extends from a point one mile south of Deadwood, in a south-easterly direction to the International Boundary, with an average width of two miles.

Other smaller outcrops lie between Smelter Lake and Deadwood. On the Boundary Creek sheet the series has been mapped by Brock[4] under the term "Palaeozoic argillites and altered argillites". In the Lake

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1. Drysdale, C.W., Geol. & Ore Deposits of Rossland, B.C. Mem. 77, Geol. Sur. Can., 1915, p.25
2. Leroy, O.E., Geol. & Ore Deposits of Phoenix, B.C., Mem. 21, 1912, p.30-34.
3. Dawson, G.M., Report on Area of Kamloops map sheet, Ann. Rept., v.vii, Geol. Sur. Can., 1894, p.37B.
4. Brock, R.W., Map No, 828, Geol. Sur. Can., 1905.

maps of Daly[1] and LeRoy[2], the name Attwood has been given, after Attwood Mountain, which is largely made up of these rocks.

Lithology. The series consists of argillites, limestones, tuffs, and quartzites, all more or less metamorphosed. In the Phoenix area, LeRoy has subdivided the series into an upper and lower formation. The upper, which has been named the Rawhide formation, is composed entirely of grey to black carbonaceous argillites, while the lower, the Brooklyn formation, consists chiefly of limestone and its contact metamorphosed.equivalents, together with some argillites and tuffs.

Structure. The series has been considerably metamorphosed and jointing and faulting is a prominent feature. No information regarding the thickness is available.

Age and correlation. The Attwood series has been provisionally correlated by Daley and LeRoy with the Carboniferous series in the Rossland Mountains. It probably represents the remnants of a once continous Carboniferous formation, which originally extended over much of Southern British Columbia.

Slocan Series.

Distribution. As may be seen on the accompanying map, the Slocan series occupies a wide area between the Upper Arrow Lake and Duncan River.

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1. Daly, R.A., Mem. 38, Map No.83 A, Geol. Sur. Can. 1912.

2. LeRoy, O.E., Geol. & Ore Deposits of Phoenix, Boundary district, B.C., Mem. 21, Geol. Sur. Can., 1912.

To the south the series occurs as a long, narrow belt, extending from Kaslo to Coffee Creek, and bordered on the east by the Nelson granodiorite batholith, and on the west by the Ainsworth series.

Lithology. The Slocan series consists of slates, argillaceous quartzites, and limestones, with intermediate gradational types. The limestones are the predominating rocks in the eastern part of the series.

At Ainsworth, Schofield[1] has subdivided that portion of the Slocan series occurring there, into the following formation.

Slocan Series	Skyline formation.....	Mainly argillites, some argillaceous limestones (in places fossiliferous)
	Silver Hoard .... formation	Limestones, argillites

Structure. The Slocan series has a maximum thickness of 15,000 feet and overlies conformably the Ainsworth series to the east. The rocks dip on an average of about 30° to 45° to the west and south-west. Between Trout Lake and the Upper Arrow Lake, the Slocan series has been intruded by a batholith of Valhalla granite, and somewhat further south by the Kaslo schists.

Age and correlation. Carboniferous fossils have been discovered in various horizons of the Slocan series, leaving little doubt that the series is Carboniferous in age.

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1. Schofield, S.J., Mem. 117, Geol. Sur. Can., 1920, p.15.

The Slocan series may be correlated with some certainty with the Cache Creek formation, and probably with the Mount Roberts formation, and part of the Pend d'Oreille group.

Cache Creek formation.

Distribution. The Cache Creek formation occurs near the north west corner of the map area in two exposures. The larger of these, occupying about one hundred square miles, is in the vicinity of Monashee and Eureka Mountains, while the other and smaller area, ten miles to the eastward, underlies White Valley and Camels Hump Mountain. Outside of the sheet, to the north-west, in the vicinity of Shuswap Lake and elsewhere, the formation occupies a considerably greater area.

Lithology. The Cache Creek formation, as named and described by Dawson[1], consists of an upper, or Marble Canyon, limestone formation, and a lower division, composed of dark argillites, greywackes, and quartzites, together with altered volcanic rocks, originally diabase and amphibolite.

Structure. The Cache Creek formation, in the map area, is characterised by lack of definite stratigraphic sequence, and has been considerably disturbed by later orogenic movements.

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1. Dawson, G.M. Report on the area of the Kamloops Map Sheet, B.C. Ann. Rept. Geol. Sur. Can., 1894. p.3 B. Also British Columbia Shuswap Sheet. Map No.604, Geol. Sur. Can., 1894.

Age and correlation. The upper member of the Cache Creek series has been found to contain Fusilina, and certain other fossils of Carboniferous age. According to Dawson, the whole series is probably Carboniferous, but there is a possibility that the lower members may be somewhat older. For the purpose of this paper, however, the entire series is considered to be Carboniferous in age, and may be tentatively correlated with many formations of similar age to the east and south, including the Slocan series, the Pend d'Oreille group, and the Franklin group.

Gloucester Formation.

Distribution. The Gloucester formation occurs in the area covered by the Franklin map sheet (Map no.97a) in three distinct bands, exposed over a total area of about four miles, chiefly in the valleys occupied by Franklin and Gloucester Creeks. Its extension beyond that area covered by the map sheet is not believed to be great. Economically the formation is important, as with it are closely associated the contact metamorphic ores of the Camp.

Lithology. Lithologically, the Gloucester formation consists of a light grey marble, characterised by small dark glistening crystals of calcite, oval or round in shape, and scattered through a finer ground mass. The limestone exposed opposite the mouth of McKinley Creek, contains district crinoidal remains, as well as those of an obscure fossil resembling Fusilina.

Structure. The formation has a general north and south trend, with steep dips to the west. The thickness is not more than 300 feet. It overlies conformably and with interbedded lenses, the Franklin group.

Age and correlation. The Gloucester limestone has been correlated by Drysdale[1] with the upper member (Marble Canyon limestone) of the Cache Creek series. This correlation is based chiefly on the similarity of the fossil remains, those from the Gloucester formation, however, being very poorly preserved; and also upon the lithological similarity of the two limestones. Drysdale further correlates the Gloucester formation with the Attwood series in the Boundary district, which Daly refers to the Carboniferous of Rossland. The Gloucester formation is cut by cupolas of the Upper Jurassic Nelson granodiorite, and lies beneath the early Tertiary rocks of the Kettle River formation.

There seems little doubt that the Gloucester formation is Carboniferous in age.

Little Sheep Creek Limestone.

Distribution. These beds are exposed over a small area on Little Sheep Creek, five miles south of Rossland. They are of importance because they contain recognisable fossils in a terrane where such are rare.

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1. Drysdale, C.W. Geology of the Franklin Mining Camp, B.C. Mem. 56. Geol. Sur. Can., 1915. pp.51-53.

Lithology. The beds consist of blue-grey to white limestone, much brecciated and highly crystallised. Lenses of chert and quartz, together with true quartz veins are also present. Poorly preserved crinoid stems were found by Daly[1] in the limestone, while McConnel, during the mapping of the Trail sheet, found in the limestone blocks of an overlying volcanic breccia, a species of Londsdalia, of Carboniferous age.

Structure. The general structure is very obscure, strikes, where observed, ranging from N.55° E to N.80° E., with dips of about 60° to the north. The beds are overlain by breccia of the Rossland volcanics, in which are found blocks of the underlying Little Sheep Creek limestone.

Age. The Little Sheep Creek limestone has been referred tentatively by Daly to the Carboniferous. It may be correlated with some degree of certainty with the Mount Roberts formation of Carboniferous age.

Mesozoic Record.

Phoenix Volcanics.

Distribution. The Phoenix volcanic group extends over a considerable area in the Boundary district, from Smelter Lake to west of the town of Greenwood, and occupies nearly one half of the area covered by

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1. Daly, R.A., Mem. 38. Geol. Sur. Can., 1912. p.320.

the Boundary Creek sheet[1]. It is cut by granitic stocks and interrupted by patches of older metamorphosed sediments.

Lithology. The group[2] "consists of green tuffs and volcanic conglomerates and breccias, fine ash and mud beds, flows of green porphyrite, and probably some interbedded limestone and argillites". The greater part of the volcanic breccia consists of pebbles and boulders of porphyrite material, together with those of limestone argillite jasper and chert. The limestone gragments are believed to have been derived from the underlying Attwood formations.

Structure. The structure of the group is extremely obscure, so great has been the metamorphism due to igneous intrusions;and little information is available regarding the stratigraphic arrangement of the different beds and flows. The porphyrite appears to be a little later than most of the pryoclastics.

Age and correlation. Daly[3] considers the group to range from Carboniferous to Triassic, probably the latter, and correlates them with certain of the Rossland volcanics. The presence of blocks of the Carboniferous Attwood limestone in the tuffs and agglomerates would certainly point to an age not older than Upper Carboniferous, also the

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1. Brock, R.W., Boundary Creek Mining district, Map. No.828, Geol. Sur. Can. 1905.

2. Brock, R.W., Ann. Rept. Geol. Sur. Can., 1902, p.97.

3. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.385.

Phoenix volcanic rocks are less crumpled and sheared than those of the Attwood formation. The volcanics are cut by the Cascade batholith and the Smelter stock, both of Jurassic age. The group is, therefore, provisionally referred to the Triassic.

Rossland Volcanic Group.

Distribution. The term Rossland volcanics was originally used by Brock and McConnel[1] to describe a large area of massive and brecciated volcanic rocks of Carboniferous and Mesozoic age. These rocks are chiefly developed in a broad irregular belt in the Rossland Mountains, from Christina Lake to Nelson. Other and smaller areas are found:- (1) North of Grand Forks; (2) in the Franklin area; (3) at Deer Park on the Lower Arrow lake; and (4) on Silver Mountain, twenty miles west of the head of Slocan Lake. It must be remembered that much of what was originally mapped as Rossland volcanics has, as a result of later and more detailed mapping, been locally renamed, as for example, the Phoenix Volcanics, north of Grand Forks, and the Sutherland schists on the east shore of Christina lake.

Lithology. The Rossland volcanics, as originally described by Brock, consist of augite porphyrite, augite and hornblende-andesites, fine-grained diabase, augite porphyrite, agglomerates, tuffs, and ash

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1. West Kootenay Map Sheet. Geol. Sur. Can., 1904.

rocks, with some bands of slate and limestone. In the Rossland[1] and Ymir[2] Camps the group is represented by augite porphyrite, agglomerate, and tuffs. In the Rossland Mountains, near the International Boundary, Daly[3] found the Rossland volcanic rocks to consist of a great variety of latites, with subordinate amounts of andesites and basalts.

<u>Structure.</u> As a result of the severe orogenic stresses and contact metamorphism of intruding batholiths, the beds are generally upturned and have complisated structures.

The latitic phase of the lavas appears to have been least affected by metamorphism. No information regarding the thickness of the group is available.

<u>Age and correlation.</u> The Rossland volcanic group is provisionally placed by Drysdale in the Triassic. Daly states that it is certain that the volcanics were erupted during at least two different periods. The oldest lavas, ash beds and agglomerates are believed to be contemporaneous with, or to have followed closely, the deposition of the Carboniferous rocks of the Mount Roberts formation. The augite porphyrites resemble, in many respects, the rocks of the Nicola group, Kamloops district[4] of Triassic age. At Paterson, B.C. a younger

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1. Drysdale, C.W., Mem. 77., Geol. Sur. Can., 1915 p.200
2. Drysdale, C.W., Mem. 94., Geol. Sur. Can., 1917 p.29
3. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912 p.324.
4. Drysdale, C.W., Summ. Rept., Geol. Sur. Can., 1912 p.133

member of the Rossland volcanic group was found by Daly to enclose a metamorphosed shale containing plant remains. From an examination of these fossil plants, Penhallow[1] definitely dated that horizon as Lower Cretaceous (Kootenay) age.

Until the various members of the Rossland volcanics as a whole have been mapped in more detail, it seems best to follow Drysdale's plan of referring the whole group, provisionally, to the Triassic.

It seems evident then that the Rossland volcanic group is of at least two different ages. The older members include the augite porphyrite, agglomerate and tuffs, and are probably Upper Carboniferous to Triassic in age, while the younger and more massive latites and associated rocks are referred to the Cretaceous. In the absence of more detailed mapping, it has been found impossible to make a satisfactory separation of the two groups.

Wallace Group.

Distribution. Within the map area the Wallace group occurs as irregular patches, about eight miles to the east and north-east of Beaverdell, in the vicinity of Kloof and Mosher ridges. The extension of the group eastward is not known.

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1. Mem. 77, Geol. Sur. Can., 1915. pp.203-211.

Lithology. The Wallace group includes a complex of metamorphosed volcanic rocks, with subordinate sediments, schists, and coarse-grained intrusives. The volcanic rocks consist chiefly of dark-grey, rusty weathering augite andesites, occasionally porphyritic. The sedimentary members include white limestone, fine-grained grey to reddish hornfels, and dense reddish grey to black tuffs. The schists are green to greyish in colour, and are thinly foliated. Cutting the other rocks of the groups are coarse-grained dykes of saxonite and olivine gabbro, which have, in places, altered to schists.

Structure. The total thickness of the group is not known, the base being unexposed. The maximum thickness of the beds of tuff has been estimated to be 1,100 feet, while that of the limestone to be 200 feet. The oldest rocks are the limestones and hornfels. The whole group has been metamorphosed by orogenic forces, and by the later intrusions of the West Kettle and Beaverdell batholiths, and consequently little of the detailed structure remains.

Age and correlation. No fossils have yet been discovered in the rocks of the Wallace group. According to Reinecke[1], the members of this group may belong to three different geological periods. The limestones and some of the schists are considered to be the oldest rocks and are correlated with the lower part of the Rossland volcanics, the Sutherland schists, and the Attwood and Anarchist series, all of Carboniferous age. The middle division includes the andesitic flows

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1. Reinecke, L., Mem. 89, Geol. Sur. Can., 1915 p.41.

and tuffs, and the coarse-grained basic intrusives; these are correlated with the upper part of the Rossland volcanic group, and the Phoenix group, of Mesozoic age.

The youngest members of the Wallace group are the dykes and sills of diorite porphyries, which may be related to the West Kettle Jurassic batholith.

The Wallace group, as a whole, has been referred by Reinecke broadly to the Mesozoic.

Hall Series.

Distribution. The Hall series occupies about eight sq. miles in a narrow north-south trending belt on the ridge about the west bank of the Salmon River, north of Ymir.

Its northern extension has not been traced beyond the limit of the Ymir map sheet[1]; to the south it tapers and is finally cut off by a monzonite chonolith at a point two miles south-west of the town of Ymir.

Lithology. The rocks of the Hall series consist of continental deposits of coarse to fine arkosic conglomerates, made up of pebbles of quartzite, greenstones, argillites, quartzgrains and feldspaltic material. With these conglomerates are interbeds of reddish sandstone and carbonaceous shale.

Structure. The maximum thickness of the series is about 8,000 feet, the members having a general north-south strike, and dipping steeply

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1. Drysdale, C.W., Map No.175 A., Geol. Sur. Can., 1916.

to the west. The whole series has apparently been infolded with contemporaneous volcanic rocks of the Rossland group.

Age and correlation. The Hall series, which is unfossiliferous, has been provisionally referred by Drysdale[1] to the Triassic, and correlated with Dawson's Nicola series in the Kamloops district.

The rocks are fresher and less altered than those of the Carboniferous Pend d'Oreille group found in the vicinity. They resemble, lithologically, the Nicola fossiliferous series of Triassic age, grading into Jurassic; and finally they have been intruded by granodiorite and monzonite stocks of Jurassic age.

Milford Series.

Distribution. This series occupies a narrow belt in the Slocan and Lardeau areas, near Milford Peak.

Lithology. The Milfors series, which resembles closely in its lithological character the Slocan series, is composed of argillaceous quartzites and limestones. The quartzites are commonly flinty and of a dull grey to purple colour.

Structure. The series occurs as a syncline along the Blue Ridge, and is bounded on the east by the Ainsworth series, and on the west by the Slocan series and the belt of Kaslo schists.

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1. Drysdale, C.W., Mem. 94. Geol. Sur. Can., 1917, p.29.

Age and correlation. The Milford series has been placed in the Jurassic, on the basis of Belmenite fossils found at the heads of Davis and Cooper Creeks. No other Jurassic sediments are known to occur within the area.

Jurasside Pre-batholithic Intrusives.

Distribution. The pre-batholithic intrusives include the following phases:-

(1) Kaslo Schists, in the Slocan and Lardeau districts.

(2) Lardeau diabase schists, Lardeau district.

(3) Baker and Fife gabbros, on east shore of Christina Lake.

(4) Diorite porphyrite tongues, Rossland Camp.

(5) Pyroxenite dykes, Rossland district and Ymir Camp.

Lithology. These intrusives, which are forerunners of the main Nelson granodiorite batholiths, are characterised by a comparatively basic composition. This supports the theory that each of the great batholiths is preceded and followed by basic differentiates, the main batholithic intrusive representing the most generally acidic phase of the cycle.

The following is a very brief summary of the lithology of each of the intrusives tabulated above:

(1) Kaslo Schists. A variety of basic igneous material, including intrusive breccia, serpentine, porphyrite (augite and hornblende) diorite and gabbro.

(2) Lardeau Diabase Schist. Grey to greenish igneous rocks with interbands of sedimentary material.

(3) Baker & Fife Gabbros. The Baker gabbro is a greenish-black hypidiomorphic rock composed of biotite, diallage, and basic labradorite.

The Fife gabbro, which has the same general colour and structure as that of the Baker intrusive, is composed of bytownite and two bisilicates.

(4) Rossland Diorite Porphyrite. The diorite porphyrites consist of light grey to greenish-black porphyritic rocks, composed of slender prisms of dark hornblende and pyroxene, together with lath-like feldspars, the whole lying in a fine greyish crystalline ground mass.

(5) Pyroxenite Dykes. The pyroxenite, which has a very limited distribution, is of a dark grayish black colour, with a hackly fracture, and is composed of crystals of augite, the crystal faces being generally curved.

Structure. The size of these intrusives ranges from extremely large bodies, such as the Kaslo schist, which resembles in form a single immense dyke, or a number of closely parallel dykes; through the small stocks and chonoliths of the Baker and Fife gabbros; down to the very limited dyke-like exposure of the pyroxenite. The diorite porphyrite tongues take the form of a dyke and border phase of the Nelson granodiorite.

The Kaslo schist and the Lardeau diabase schist have conformed rather closely to the attitude of the intruded Slocan series, the remainder of the intrusives under consideration appear to be largely cross cutting. All of these igneous rocks, with the possible exception of the pyroxenite, shew evidence of later orogenic forces, the Kaslo and Lardeau schists being particularly sheared and mashed.

Age and correlation. The pre-Jurasside batholithic intrusives are considered to be all of Jurassic age, and slightly older than the Nelson granodiorite batholith whose intrusion took place during the Upper Jurassic. They represent the first evidences of plutonic activity connected with the Jurasside revolution, which resulted in the building of the Selkirk and Purcell Ranges.

The evidence bearing upon the age of the individual intrusives may be summarised as follows:-

Concerning the Kaslo schists Bancroft[1] states that "This Slocan batholith of basic magma was intruded considerably in advance of the West Kootenay or Nelson batholith ...." It has been found cutting the Milford series (Jurassic) and is itself cut by apophyses of Nelson granodiorite in the Lardeau district.

The Lardeau schists have been placed by Bancroft[2] as Post-Carboniferous and Pre-Nelson granite, and are considered by Schofield[3] to

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1. Bancroft, M.F., Summ. Rept., Geol. Sur. Can., 1919 p.43 B.
2. Bancroft, M.F., Summ. Rept., Geol. Sur. Can., 1918 p.35 B.
3. Schofield, S.J., Personal communication.

bear a similar relationship to the Nelson granite, as does the nearby Kaslo schist.

The Baker & Fife gabbros are placed by Daly, tentatively, in the Cretaceous. Schofield[1] considers them to be an earlier differentiate from the Nelson granodiorite.

The diorite porphyrite at Rossland cuts the Rossland volcanics (Triassic) and is intruded by the monzonite, which is slightly older than the Nelson granodiorite. It is considered to represent a border and dyke facies of the granodiorite[2].

Jurasside Batholithic Intrusives.

Distribution. As is shewn on the accompanying map, the Jurasside batholithic intrusives have a very wide distribution, and form about three-quarters of the igneous rocks composing the West Kootenay composite batholith.

The rocks, on the whole, have a very constant mineralogical composition, and are typically represented by granodiorites. The intrusion took place during the Jurasside revolution.

The batholithic intrusives includes the following minor phases:

(1) Trail batholith - (Trail and Rossland)

(2) Cascade batholith, of sheared granodiorite (near Grand Forks)

(3) Rykert batholith (On International Boundary, west of Purcell Trench)

1. Schofield, S.J., Personal communication.

2. Drysdale, C.W., Mem. 77, Geol. Sur. Can., 1915. p.215.

(4) Bayonne batholith (10 miles north-west of Rykert batholith)

(5) Osoyoos batholith (south-west corner of map sheet)

(6) West Kettle batholith (Beaverdell Camp)

(7) Monzonite stocks and chonoliths (Rossland Mountains, Ymir Camp, and south of Franklin)

(8) Smelter stock (Grand Forks)

(9) Bunker Hill and Lost Creek stocks (south of Salmo)

(10) Midway granodiorite stock (Midway)

(11) Gneissic granite (Ainsworth)

(12) East Kootenay stocks.

Lithology. The typical rock known as the Nelson granodiorite has been referred to by Brock[1] as follows: "The Nelson granite, which has been carefully studied, is a sort of a granite representative of the monzonite group of rocks, intermediate between the alkali and lime-soda series of rocks, and about on the boundary between granite and diorite".

The Nelson granodiorite is typically of a light grey colour, and shews large phenocrysts of pink feldspar (Orthoclase). In texture it varies from fine to extremely coarse-grained, and is occasionally porphyritic. It is generally uncrushed, though, in certain localities (Cascade batholith), it may be greatly sheared abd resemble a mica schist. The monzonite in the Rossland Camp and elsewhere represents a facies of the same intrusion.

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1. Brock, R.W., Ann. Rept., Geol. Sur. Can., 1902-1903. p.101A.

The following are analyses of some of the various intrusives:

	1	2	3	4	5	6
SiO_2	66.46	70.78	60.27	68.43	64.80	54.43
TiO_2	0.27	0.20	0.63	0.20	0.40	0.70
Al_2O_3	15.34	15.72	17.17	15.80	15.74	16.51
Fe_2O_3	1.68	0.36	2.36	1.06	2.29	2.79
FeO	1.83	1.61	3.67	1.85	2.44	5.20
MnO		0.30	0.14	0.10	0.10	0.10
MgO	1.11	0.46	2.45	1.46	2.09	3.55
CaO	3.43	1.92	6.49	4.08	5.20	7.06
SrO		Tr.	0.04	0.02		
BaO		0.01	0.04	0.09		
Na_2O	4.86	3.48	2.92	3.47	3.55	3.50
K_2O	4.58	5.23	3.25	2.51	2.17	4.36
H_2O	0.29	0.35	0.38	0.58	1.40	1.25
P_2O_5	0.08	0.26	0.20	0.7		0.20
CO_2						0.10
S						0.23
Total	99.93	100.41	100.01	99.72	100.18	100.04
Sp. Gr.		2.654	2.785	2.708		

(1) Nelson Granodiorite, Kokanee Mountain, Collector R.W.Brock, Analyst Dr. Dittrich.

(2) Rykert batholith	Collector R.A.Daly	Analyst	M.F.Connor.
(3) Bayonne batholith	" R.A.Daly	"	M.F.Connor.
(4) Osoyoos batholith	" R.A.Daly	"	M.F.Connor.
(5) West Kettle batholith	" L.Reinecke	"	M.F.Connor.
(6) Monzonite (Rossland)	" R.W.Brock	"	M.F.Connor.

Structure. The granodiorite occurs predominately as batholith and stocks and intrudes rocks ranging in age from Beltian to Carboniferous. It forms the core of the West Kootenay composite batholith. On the whole the rock is comparatively uncrushed, but in places has yielded to later crustal stresses by mashing, with the production of a gneissic and schistose structure. Near its roof rocks it has, in places, yielded by brecciation and shearing, resulting in mineralisation along the shear zones.

Shatter zones at the contact of the intrusive and its country rock are a common feature, and are particularly well developed near Trail and on Bluebell Mountain, east of Riondel. Within these zones a progressive gradation is found, from the plutonic rock, through a zone characterised by a network of apophyses cutting the sediments, to the unintruded country rock.

The most noticeable feature, however, on a broad scale, is the manner in which the regional strike of the sedimentary roof and wall rocks sweeps in parallel arrangement around the intrusive contact. This is particularly noticeable along the eastern, northern, and north-western borders of the batholith.

The inference to be drawn from the structural phenomena is that the magma entered under great pressure, causing displacement of the surrounding rocks, and that intrusion took place, not only by stoping and assimilation, as evidenced by shatter zones and unoriented roof pendants, but also by some form of laccolithic displacement. This feature, which is also characteristic of the Valhalla Eocene batholith, will be discussed more fully in a later chapter.

Age and correlation. The Nelson granodiorite is believed to have been intruded contemporaneously with the Jurassic period of mountain building, and to be of Upper Jurassic age.

The youngest fossiliferous rocks cut by the Nelson granodiorite are those of the Mount Roberts and Slocan formations, of Carboniferous age.

Schofield[1], from a study of the sedimentation of the Rocky Mountains to the east, obtained further evidence regarding the Jurassic age of the granodiorite, and of the contemporary age of the orogenic disturbance which formed the Purcell and Selkirk Mountain Ranges.

Schofield's evidence and conclusions on this question are as follows:

Table Shewing Character of Sediments

Period	Formation	Condition of deposition	Lithological character
Tertiary	Paskapoo	Freshwater	Sandstones
	Edmonton	Brackish & freshwater	Sandstones and shales
	Bearpaw	Marine	Shales
Upper Cretaceous	Belly River Series	Brackish	Sandstones and shales
	Colorado	Marine	Shales
	Upper Blairmore	Sub aerial	Sandstones, conglomerates (granite and chert pebbles)

(Continued)

1. Schofield, S.J., Mem. 117, Geol. Sur. Can., 1920, p.12-23

Table Shewing Character of Sediments (ctd)

Period	Formation	Condition of deposition	Lithological character
Lower Cretaceous	Lower Blairmore	Sub aerial	Shales and conglomerates (quartzite and chert pebbles.
	Kootenay	Sub aerial	Sandstones and shales coal shales
Upper Jurassic	Fernie shales	Marine	Shales
Devonian and Carboniferous		Marine	Limestones and quartsites
Lower Palaeozoic		Marine	Limestones and quartzites
	Disconformity		
Pre Carboniferous (Beltian)	Purcell series Galton series	Continental	Mainly quartzites and argillaceous quartzites

"It will be seen from the above table that conglomerates are first found in great amount at the base of the Blairmore formation. The pebbles in conglomerates consist of quartzites and chert derived from the quartzites of Beltian rocks, which make up the great part of the Selkirk Range. Evidently, in Lower Blairmore times, the Selkirk Range was approaching the maximum of elevation and was undergoing rapid erosion. The Upper Blairmore formation also consists of conglomerates and sandstones, but in them, in addition to pebbles of quartzite and chert, pebbles of granite occur for the first time and in great "abundance. The presence of the granite pebbles at this horizon is interpreted to mean that the Selkirk Range was unroofed during Upper Blairmore times, and that the Nelson granite, which forms the core of the Selkirk Range in Southern British Columbia, was exposed to rapid erosion. Hence it is established that the first intrusion of granodiorite into the Selkirk Range took place before the deposition of the Upper Cretaceous. The superposition of the marine Fernie shales upon the marine Devono-Carboniferous limestones suggests that the period of stability which prevailed throughout British Columbia until the Triassic was interrupted during the Upper Jurassic. The Selkirk Mountains received their initial form probably at the close of the Jurassic, or in early Kootenay times. If mountain building and orogenic movements are contemporaneous, it may be concluded that the first intrusion of granodiorite in the Selkirk Range commenced towards the close of the Jurassic and continued until the mountain building reached its maximum in Kootenay time"

The monzonite, occurring as stocks and chonoliths in the Rossland Camp and elsewhere in the Rossland and Nelson Range, is considered by Brock[1] to have closely preceded the main batholithic intrusion of Nelson granodiorite.

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1. Brock, R.W. Personal communication.

Jurasside Post Batholithic Intrusives.

Distribution. Included under this heading arethe lamprophyric and complementary aplite dykes of the East Kootenay, Ainsworth, Slocan, and Lardeau districts; the lamprophyric dykes of Rossland, the hornblende andesite porphyry dykes of Beaverdell Camp, and the dunites of the Rossland Mountains. All of the occurrences are too small to plot to the scale of the accompanying map.

Lithology. With the exception of a minor proportion of aplitic types the intrusives are of a distinctly basic nature. The basic dykes of the Kootenay, Ainsworth, Slocan and Lardeau regions are commonly composed of camptonite, weathering dark greyish brown; these are accompanied by aplitic dykes of similar habit. The Rossland lamprophyres include minettes, kersantites, vogesites, spessartites, and odonites.

The hornblende andesite porphyries of the Beaverdell Camp are composed of phenocyrsts of lath-shaped hornblende, and of feldspar, in a dark fine-grained ground mass.

The Rossland Mountain dunite is characterised by the absence of associated chromite, otherwise it is a very typical representative of the dunite group of rocks. Alteration of the dunite to serpentine has been common.

Structure. The intrusives are, as far as is known, all very small, and take the form of dykes; in this they differ from the pre-batholithic intrusives, many of which are very large indeed. In general they are found to cut both the older sedimentary rocks and the batholith itself.

Age and correlation. The Jurassic post batholithic intrusives, are understood to represent the final phase of igneous intrusion associated with the cooling stages of the Nelson granodiorite batholith, were injected in late Upper Jurassic or early Cretaceous times.

The camptonite and similar basic dykes are considered by Bancroft[1] to have been intruded slightly later than the complementary aplite dykes. In the Ainsworth area[2], the camptonite dykes cut the Slocan (Carboniferous) sediments and carry inclusions of Nelson granite, of Upper Jurassic age. They are placed by Schofield, tentatively, as very late Jurassic or early Cretaceous, and as being probably associated with the earlier cooling stages of the Nelson granodiorite batholith, the later cooling stages of which resulted in the formation of the ore bodies.

The Rossland lamprophyric dykes followed the intrusion of the granodiorite and monzonite[3].

The hornblende andesite porphyries of Beaverdell Camp cut the West Kettle batholith (which has been correlated with the Nelson granodiorite), and from their position with reference to the West Kettle batholith are considered by Reinecke[4] to be related to it.

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1. Bancroft, M.F., Summ. Rept., Geol. Sur. Can., 1919. p.46B
2. Schofield, S.J., Mem.117, Geol. Sur. Can., 1920. p.24
3. Drysdale, C.W., Mem. 77, Geol. Sur. Can., 1915, p.30.
4. Reinecke, L. Mem. 79, Geol. Sur. Can., 1915, p.43-44.

There has been some doubt regarding the precise age of the dunite bodies. Daly[1] has mapped them tentatively as Cretaceous, and mentions that a small dunite dyke cuts a stock of the Cascade batholith of Upper Jurassic age. Schofield[2] is of the opinion that the dunite is associated in age and origin with various other Jurasside post-batholithic intrusives, and this view has been adopted by the writer.

These basic intrusives in general, represent the fulfillment of the hypothesis that great periods of granitic batholithic invasion are opened and closed by a minor injection of more basic differentiation. This point will be discussed more fully in a later chapter.

Little Sheep Creek Sediments.

Distribution. The rocks in question occupy an area of about one-half square mile, on Little Sheep Creek, at the point where it crosses the International Boundary, south of Rossland. Like the older formation, about one mile up stream, the area of these stratified rocks is comparatively insignificant, but the fact that the beds contain recognisable fossils makes them of some importance for correlation purposes.

Lithology. The rocks consist of black and red argillite, with which are interbedded grey sandstone and angular conglomerate. Layers of black quartzite sandstone, carrying sulphides, are also found.

The shaly members were found to contain poorly preserved fossil

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1. Daly, R.A., Mem. 38. Geol. Sur. Can., 1912. p.373.

2. Schofield, S.J. Personal communication.

ferns, possibly Upper Palaeozoic in age.

Structure. The beds are at least 600 feet thick, and the structure of the series seems to be that of a broken and mashed anticline plunging to the north. Exposures are very poor, and the whole series is so crumpled that a proper interpretation is difficult.

Age and correlation. The fragments of fossil ferns were examined by Penhallow, who tentatively correlated the series with the Lower Cretaceous strata of the Pasayten River. Daly[1] refers the series to the Lower Cretaceous (?) possibly Eocene, and it is to the Lower Cretaceous that the series are provisionally referred in this paper.

Tertiary Record.

Laramide Batholithic Intrusives.

Distribution. The Laramide batholith occupies a very extensive area within the map sheet, and makes up nearly one quarter of the igneous rocks forming the West Kootenay batholith. It has been mapped under the general legend of Valhalla granite, of which it is largely composed.

As will be seen on the accompanying map, the chief occurrences are to the west of the Lower Arrow Lake, and in the Lardeau; to the east of the Upper Arrow Lake[2]. Other stock-like masses of considerable

1. Daly, R.A., Mem. 38. Geol. Sur. Can., 1912. p.323.

2. Brock, R.W. Personal communication.

size occur within the Nelson granodiorite itself, between the Lower Arrow Lake and Kootenay Lake, and also in the vicinity of Christina Lake. In the Beaverdell Camp, on the western border of the map, the Valhalla granite is represented by the Beaverdell batholith of Reinecke[1].

Lithology. The Valhalla granite, named after the Valhalla Mountains, where it is typically developed, has been examined by Brock[2] and described by him in the explanatory notes accompanying the West Kootenay Map Sheet, as follows:

"This is a medium-grained, light-coloured, very quartzose granite. The feldspars are orthoclase, microcline and plageoclase (albite to andesine). Microgranitic intergrowths of quartz and feldspar are common. Green biotite and hornblende are the coloured constituents. Apatite, titanite, orthite, zircon, and iron ore are common. Near Gladstone Mountain it is a typical granodiorite. Here a column of basic feldspar often forms the core of a hornblendic prism. 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."

The Beaverdell batholith is composed typically of a medium, even-grained, white quartz monzonite. Its texture varies from a fine-grained holocrystalline rock facies, to a coarsely porphyritic rock,

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1. Reinecke, L., Mem. 79, Geol. Sur. Can., 1915.

2. Brock, R.W., Map Sheet No.792, Geol. Sur. Can., 1904.

having large phenocrysts of pink orthoclase.

The following two analyses of the Beaverdell quartz monzonite have been made by Mr. M.F.Connor, of the Department of Mines. (A) represents an analysis made upon a specimen of the porphyritie variety, while (B) represente an analysis of the fine-grain roof type.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	MnO
(A)	70.20	15.40	1.00	1.02	0.60	2.00	4.58	4.67	0.30	0.25	0.03
				- 100.05							
(B)	69.16	15.92	1.54	0.92	0.33	0.64	5.06	5.97	0.60	0.20	0.06
				- 100.40							

Structure. With the exception of the Lardeau batholith, which cuts the Slocan series of sedimentary rocks, the Valhalla granite chiefly occurs as an intrusive body within the Nelson granodiorite.

The general elongation of the various masses of Valhalla granite is to the west of north, and conforms closely to the Cordelleran trend. In the Lardeau district the strike of the Slocan series swings round parallel to the contact of the great intrusion of Valhalla granite. This suggests strongly that, as in the case of the older Nelson granodiorite, displacement of the surrounding rocks has resulted from the great outward pressure of the batholithic magma at the time of intrusion.

Age and correlation. The Valhalla granite is considered to be Eocene in age, and to have accompanied the great crustal disturbances occurring during the Laramide revolution at the close of the Mesozoic.

There is, however, no direct fossiliferous evidence to definitely assign this granite to any one particular age. It has been observed to have cut the Nelson granodiorite bodies, and is, on the whole, less crushed. The Valhalla granite has been cut by the Miocene pulaskite and is therefore Pre-Miocene. The great lithological difference between the highly siliceous Valhalla granite, on the one hand, and the pulaskite on the other, suggests that a considerable period of time must have seperated these two intrusions, to allow such marked variation in the composition of the abyssal magma to have taken place. Elsewhere throughout the world the crustal disturbances of the Laramide revolution have been accompanied or closely followed by batholithic intrusion, and so it seems very probable then, that the intrusion of the Valhalla granite was associated with the crustal folding and uplift of the Laramide revolution.

The Beaverdell quart-monzonite batholith which is considered by Brock[1] to be a phase of the Valhalla granite; has been placed in the Eocene by Reinecke,[2] who associates the batholith with the crustal disturbances of the Laramide revolution.

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1. Brock, R.W., Personal communication.
2. Reinecke, L. Mem. 79, Geol. Sur. Can., 1915, p.52

Kettle River Formation.

Distribution. The Kettle River formation within the map area occurs in the Boundary and Franklin[1] districts. In the Boundary district, where it has been mapped and described by LeRoy[2] and Daly[3], the formation is found in isolated patches in the vicinity of Phoenix and Midway. It is probable that many unmapped areas occur elsewhere in the Boundary district.

Lithology. In general the Kettle River formation consists of continental deposits of conglomerate feldspathic sandstone, shale, arkosic grits, and waterlaid acidic tuffs. In the Boundary district the formation also includes thin seams of lignite coal. Locally, as at Phoenix, the tuffaceous beds may be absent. Plant remains of Early Tertiary age have been found in the Kettle River formation at Phoenix and near Midway.

Structure. The thickness of the deposits varies considerably. In the Franklin district the maximum thickness is 500 feet.

In the Boundary district, the thickness of the formation, as given by Daly, is 2100 feet.

The following is Daly's section:

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1. Drysdale, C.W. Mem. 56, Geol. Sur. Can., 1915.
2. LeRoy, O.E. Mem. 21, Geol. Sur. Can., 1912
3. Daly, R.A. Mem. 38, Geol. Sur. Can., 1912.

"Top, conformable contact with overlying Midway lavas.

1000	feet	Fossiliferous, grey, feldspathic sandstones with interbeds of shale
900	feet	Coarse conglomerate.
200	feet	Coarse arkose-breccia (a local deposit)
2100	feet	

Base, unconformable contact with underlying Anarchist series, and with pre-Tertiary plutonic intrusives."

Faulting has, in general, been very slight, but the beds are gently folded.

Age and correlation. The Kettle River formation is Oligocene in age. The age was determined by Penhallow[1] as the result of his examination of fossil plants collected by Daly from the Kettle River formation, west of Midway. The Kettle River formation has been correlated with Dawson's Coldwater group in the Kamloops area. It is possible that the Beaver Mountain sediments of the Rossland Mountains may be a remnant of the Kettle River beds to the east, the lithological similarity of the formations, and the association of contemporary vulcanism is significant.

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1. Penhallow, D.P. A Report on the Fossil Plants from the International Boundary Survey for 1903-1905, collected by R.A.Daly. Trans. Roy. Soc. Can., Third series. Vol. 1, 1907, p.318-327.

Curry Creek Series.

Distribution. In the map area the Curry Creek series occupies a small patch of at least one square mile on Kloof Ridge, eight miles east of Beaverdell.

Lithology. The series consists of a great thickness of conglomerates overlain by fine-grained white tuffs. Interbedded with the conglomerates are arkosic sandstones and volcanic breccia. The conglomerates are composed of granitic pebbles from the West Kettle and Beaverdell batholiths, those from the West Kettle batholith being the more abundant. A lense of tuff in the conglomerate was found to contain a single fossil plant.

Structure. The series, which is made up of 2,500 feet of conglomerate, overlain by 200 feet of tuff, lies unconformably upon a weathered surface of the Wallace group. The beds strike north and south, and dip at low angles to the east. Faulting with a down-throw of 500 feet has been observed.

Age and correlation. The single fossil plant found in the series was referred broadly to the Tertiary. According to Reinecke[1] the Curry Creek series corresponds closely in its lithology and character to the fossiliferous Kettle River formation at Phoenix. It differs from it, however, by the presence of tuffs, which are absent in the Kettle River formation to the south.

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1. Reinecke, L., Mem. 79, Geol. Sur. Can., 1915. p.56.

Reinecke has placed the Curry Creek series in the Oligocene, and has correlated it with the Kettle River formation.

Lake and Sophie Mountain Conglomerates.

Distribution. In the Rossland Mountains, and near the International Boundary, four patches of Tertiary conglomerates have been examined. The first of these lies one mile south-west of Lake Mountain, and covers about one-third of a square mile; another one crowns the summit of Sophie Mountain, and has an area of slightly more than one square mile; while the third and fourth bodies, of much smaller size, outcrop at Monument 172 and 169 respectively, on the Boundary line.

Lithology. The conglomerate at all exposures is composed of rounded to angular pebbles, ranging in size up to one foot in diameter. They include pebbles of greenish-grey quartzite, vein quartz, phyllite, and slate. Pebbles of the neighbouring Rossland volcanics are also to be found in all the conglomerates, with the exception of those of Lake Mountain, where they are absent. The cement in all cases appears to be of a sandy nature, often ferruginous. The Spohie Mountain conglomerate is alone fossiliferous, a bed of sandy shale being found to contain poorly preserved Dicotyledonous leaves.

Structure. The attitude of the beds is very variable. The thickness as shewn at Lake Mountain is at least 300 feet, while that at Monument 172 is about 200 feet. The formations, on the whole, are much brecciated. Proceeding westward, the conglomerates at the various outcrops become finer in texture, are made up of smaller and more rounded pebbles, and contain a greater proportion of volcanic material.

Age and correlation. The fossil leaves from the Sophie Mountain conglomerate are very probably of Tertiary age, possibly Miocene. They also indicate a fresh water origin of the sediments. While the various outcrops may have been deposited at widely different times, Daly[1] advances the hypothesis that they represent deposition by Pre-Miocene and Post-Jurassic mountain streams flowing westward from the site of the present axis of the Selkirk Range. The Lake Mountain body has been intruded by an apophysis of the Sheppard (Miocene) granite. These conglomerates have, therefore, been provisionally referred by Daly to the Lower Tertiary.

Beaver Mountain Sediments.

Distribution. The Beaver Mountain sediments occur in three small patches, interbedded with the volcanics of the same name, on Beaver Mountain, fifteen miles east of Rossland.

Lithology. These sediments consist of black and brown thin bedded shales and thin bedded to massive sandstones, grey and greenish in colour. A conglomerate composed of pebbles of granite, quartz, and

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1. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.352

slate outcrops over a small area near Champion station. The shale and sandstone members contain fossil plant stem and leaves, which are, unfortunately, of no diagnostic value.

Structure. The group is at least 1000 feet thick, the beds striking east and west and dipping at low angles to the south. A great deal of faulting has taken place.

Age and correlation. The Beaver Mountain sediments, like the contemporaneous Beaver Mountain volcanics, have been assigned by Daly[1] to the Tertiary. The general character of the deposit is similar to the Eocene(?) fossiliferous beds at Little Sheep Creek, and in some respects to the Kettle River formation in the Boundary district.

Tertiary Volcanics.

Distribution. Under the term Tertiary Volcanics are included the Midway volcanics of the Boundary district and Franklin Camp, the Nipple Mountain series of the Beaverdell area, and the Tertiary volcanics of the West Kootenay and Shuswap map sheets. These patches of volcanic rock represent isolated erosion remnants of the eastern border of the great lava flow which extends over much of the Interior Plateau of British Columbia, and forms the traps of the Columbia Lava Plain of the States of Washington, Idaho and Montana.

1. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.353.

Lithology. The Tertiary volcanics consist of sub-aerial flows of acid and basic lavas and associated pyroclastics. In general the earlier extrusions were of an acidic nature, while those following became progressively more basic in composition. This gradation is well illustrated by a study of the occurrence at the Franklin Camp[1], where the oldest flow is a rhyolite and the last expression of volcanism is represented by alkalic basalt. Within the Boundary Belt Daly[2] has described nine different types of lava, and mentions the occurrence of several horizons of agglomerates and tuffs. These lavas vary from an analcitic lava to an olivine basalt, and are accompanied by basic dykes and sheets. The Nipple Mountain series, in the vicinity of Beaverdell, consisting of unaltered lava flows and dykes (olivine basalts, biotite andesites and dacites), have been considered by Reinecke to correspond to the middle part of Daly's Midway volcanic group.

Structure. The lava flows in general have conformed to the structure of the Tertiary sediments, upon which they were laid down. They appear to have flowed into the valleys and lowlands existing during Oligocene and early Miocene times, and, as may be seen on the accompanying map, the flow remnants lie chiefly towards the western border, where the topography tends to become less mountainous as it grades into the Interior Plateau. It is a remarkable thing that erosion has spared any remnants at all in the mountainous structure of the Selkirk Range.

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1. Drysdale, C.W., Mem. 56, Geol. Sur. Can., 1915. p.85
2. Daly, R.A. Mem. 38, Geol. Sur. Can. 1912, p.398.

<u>Age and correlation.</u> Regarding the Tertiary volcanics mapped on the West Kootenay sheet, Brock[1] states that: "The series is no doubt identical with the Tertiary volcanic rocks of Miocene age of the Kamloops and Shuswap map sheets, and to similar rocks of the Okanagan and Boundary Creek districts."

Referring to the later and more detailed mapping of smaller areas, the writer has collected the following evidence bearing upon the age of the various occurrences.

(1) At Midway, the Midway volcanics overlie conformably the follliliferous Kettle River formation (Oligocene).

(2) In the Beaverdell Camp the Nipple Mountain lavas correspond petrographically with the lowest lavas described by Daly at Midway, which vary from olivine basalt to trachyte. Reinecke consequently places the Nipple Mountain lavas tentatively in the Oligocene, or, if they are unconformable with the underlying Curry Creek series (Oligocene), a point upon which he is doubtful, in the Miocene.

(3) The volcanic flows at Franklin Camp are of, at least, two different ages. The older of these consists of rhyolite and tuffs, and is contemporaneous with the underlying Kettle River formation of Oligocene age. The second and later flow of trachytes, trachytic basalt, and basalts, with associated tuffs, which have been named the Midway volcanic group, (after similar flows in the vicinity of Midway), is believed to be associated with the intrusion of the monzonite (Oligocene ?) stocks. This later flow is correlated by

Drysdale with Dawson's period of Miocene vulcanism in the Kamloops[1] district.

The following is Dawson's provisional scheme for the Tertiary volcanis rock and associated sediments, in the Kamloops district:

Later Miocene	Upper volcanic groups (maximum thickness)	3,100 feet
	Tranquille beds (maximum thickness)	1,000 "
Earlier Miocene	Lower volcanic group (maximum thickness apart from centre of eruption)	5,300 "
Oligocene	Coldwater group at Hart Creek	5,000 "
		14,400 feet

Drysdale, as mentioned above, has corrlated his younger flow with the whole of Dawson's Tertiary volcanics of both earlier and later Miocene age. It appears to the writer that the later Franklin flow should be correlated, not with the whole of Dawson's Tertiary volcanics, but only with his Upper volcanic group, and that the earlier rhyolite flow be correlated with Dawson's Lower volcanic group.

The evidence for this proposed correlation depends upon (1) the fact that both at Franklin and in the Kamloops district there have been flows of two distinct ages, and (2) the earlier flow in both districts is contemporaneous with known Oligocene sediments. The absence, in the Franklin Camp, of the equivalent of the intervening

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1. Dawson, G.M. Rept. on Kamloops Map Sheet, Ann. Rept., Geol. Sur. Can., 1894, p.71B.

Tranquille beds does not, necessarily, weaken the evidence submitted above.

Petrographically, however, Dawson's Lower volcanic group, consisting chiefly of augite porphyries and agglomerates, differs in a marked degree from the rhyolites of the Franklin Camp, though it is possible that extrusions of similar age might vary greatly in composition from place to place. On the other hand, Dawson's Upper volcanic group is petrographically similar to the later Franklin flow, both being composed of basalts and trachytes.

It is the writer's tentative conclusion, then, that the Tertiary volcanics are of at least two different ages (1) an earlier extrusion of Lower Miocene, possibly Oligocene age, connected with the Laramide revolution, and (2) a later extrusion of probably Middle or Upper Miocene age, genetically related to the Rossland alkali syenite batholith.

Beaver Mountain Volcanics.

Distribution. The Beaver Mountain volcanics are situated on Beaver Mountain, about fifteen miles east of Rossland. They occupy an area of about thirty square miles. The group has been mapped and described by Brock and McConnell[1] on the West Kootenay sheet, and later by Daly[2]

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1. Brock, R.W., & McConnell, R.G., West Kootenay Sheet, Geol. Sur. Can., 1904.

2. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.352.

<u>Lithology.</u> The volcanics are composed of flows and pyroclastics. The flows are made up of augite andesite and olivine free basalt, chiefly of the former. The pyroclastics represent the same lavas in a brecciated condition, together with subordinate amounts of black shale, slate, grey sandstone, marble and quartzite. With this group are associated contemporaneous fresh-water sediments (Beaver Mountain sediments.)

<u>Structure.</u> The group has been profoundly disturbed, but is rarely schistose, and the rocks, as a whole, are considerably fresher than those of the underlying Rossland volcanics. The thickness of the pyroclastics is, at least, 1,000 feet, the beds being upturned and dips vary all the way up to 90°.

<u>Age and correlation.</u> The group has been described by Brock as being comparatively recent, and dated as Post-Cretaceous, while Daly has mapped them as Tertiary, but mentions the possibility of them being Mesozoic in age. They will here be considered to be of Middle to Upper Tertiary age, possibly Miocene, and correlated tentatively, with the Midway volcanic group, of which they are very probably a remnant.

<u>Oligocene Intrusives.</u>

<u>Distribution.</u> The Oligocene intrusive rocks include the small porphyritic monzonite stock of Rossland Camp; the Salmon River mon zonite (porphyritic) stock near Ymir, the monzonite stocks of the

Franklin Camp, and the monzonite porphyry and small dykes of augite porphyrite and olivine basalt of the Boundary district.

Lithology. The intrusive rocks referred to the Oligocene period are mainly porphyritic monzonites.

Typically, the porphyritic monzonites of Rossland and Ymir districts are of a greenish-grey to grey-black colour, with stout phenocrysts of pyroxene and biotite in a ground mass of dense feldspatic material. The Franklin occurrence is somewhat darker in colour, and non-porphyritic.

The Boundary district porphyritic monzonite differs from the above types in that the phenocrysts are of light-grey feldspar, with a dense ground mass of the same composition.

The olivine basalt of the Boundary district is a porphyritic dyke rock, dark-grey in colour, with phenocrysts of plagioclase, pyroxene, and olivine, in a dense ground mass. The augite porphyrite, which has a similar habit, consists of phenocrysts of black pyroxene, in a finer ground mass of feldspar and biotite.

Structure. All the intrusives of this age are comparatively small, and assume the form of stocks and dykes.

The rocks are, on the whole, distinctly fresher and less brecciated than any of the older intrusives. It is possible that some of the stocks of porphyritic monzonite may represent old volcanic necks, as pointed out by Drysdale in his description of the Rossland[1]

1. Drysdale, C.W., Mem. 77, Geol. Sur. Can., 1915 p.236.

and Ymir[1] occurrences. The Salmon River stock at Ymir, which has a sharply defined pulaskite core, particularly suggests an ancient volcanic pipe.

Age and correlation. Daly[2] has referred the Salmon River monzonite stocks to the Post-Eocene (Miocene?), and considers them to be correlated with cupola stocks of the Coryell batholith. Drysdale[3], however, has provisionally referred all the Salmon River and Rossland porphyritic monzonites to the Oligocene early crustal movements, and the writer has adopted this viewpoint. The Franklin monzonite cuts the Oligocene Kettle River formation and is cut by the younger Miocene intrusives.

In the Boundary district LeRoy[4] has placed all his Tertiary intrusives, tentatively, in the Miocene. They occur in the following order, commencing with the oldest - olivine basalt, augite, porphyrite, monzonite porphyry, and pulaskite porphyry.

Elsewhere within the map area the porphyritic monzonites have marked the upper limit of the Oligocene intrusives, and so the writer has very tentatively correlated the Boundary district monzonites with those of Rossland, Ymir and Franklin. If this is correct, it

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1. Drysdale, C.W., Mem. 94, Geol. Sur. Can., 1917, p.39
2. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.317.
3. Drysdale, C.W., Mem. 94, Geol. Sur. Can., 1917, p.40.
4. LeRoy, O.E., Mem. 21, Geol. Sur. Can., 1912, p.29.

follows that the olivine basalt and augite porphyrite, which are still older than the monzonite porphyry, but cut the Oligocene volcanic rocks, must also be Oligocene in age.

It seems, however, that the division between the Oligocene and Miocene plutonic rocks is more or less arbitary, and the question of the dating of these intrusives still remains open, but the intrusives described above very probably represent the earlier stages of plutonic activity connected with the Oligocene and Miocene revolution.

Miocene Intrusives.

Distribution. The Miocene intrusives, which have been mapped on the West Kootenay sheet as Rossland alkali syenite, cover a very considerable area, as may be seen on the enclosed map, and represent the last period of batholith invasion within the Kootenays.

Included under the general term of Miocene intrusives are the following rock formations:

(1) The Coryell batholith, Sheppard granite, and lamprophyre dykes of Rossland Camp and district, including Ymir Camp.

(2) Pulaskite porphyry, shonkinite pyroxenite and augite syenite of Franklin Camp.

(3) Pulaskite porphyry of the Boundary district.

(4) All other intrusives mapped on the West Kootenay map sheet as Rossland alkali syenite.

Lithology. The dominant rock type is that of a hornblende syenite (pulaskite), as represented by the Coryell batholith, between Christina

Lake and Rossland, the typical Rossland alkali syenite of the West Kootenay sheet; and the core of the Salmon River stock of Ymir. In its more porphyritic phases it occurs as the pulaskite porphyry of the Boundary district, and the porphyritic syenite of Franklin and of Rossland.

In colour the rock is reddish to pale pink, the predominating minerals being glassy pink and greyish feldspar.

Another very important and slightly younger rock type is the granite porphyry (Sheppard granite of Daly). It occurs as large stocks to the south and south-east of Rossland, and as dykes in Rossland and Ymir Camps.

Typically, the Sheppard granite is a medium grey rock, containing tabular feldspar and rounded quartz, phenocrysts, with small flakes of biotite, the whole embedded in a fine-grained bluish-green ground mass.

The following are analyses of typical specimens of A, Coryell syenite,[1] and B, Sheppard granite[2].

	A	B		A	B		A	B
SiO_2	62.59	77.09	MgO	1.30	0.12	H_2O at 110° C	0.30	0.03
TiO_2	0.54	0.05	CaO	1.99	0.63	H_2O above 110° C		0.07
Al_2O_3	17.23	13.04	SrO		None	P_2O_5	0.11	0.10
Fe_2O_3	1.51	0.82	BaO		None	CO_2	Tr.	
FeO	2.02	0.26	Na_2O	5.50	3.11	Cl	Tr.	
MnO	Tr.	Tr.	K_2O	6.74	4.50	SO_3	Tr.	
							99.83	99.82

1. Drysdale, C.W., Mem. 77. Geol. Sur. Can., 1915, p.239.
2. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.355.

The remaining rock types, which are relatively unimportant as regards areal distribution, take the form of small chonoliths, dykes and sills; they include the shonkinite pyroxenite and augite syenite of Franklin Camp, and the lamprophyre dykes of Rossland, and the West Kootenay district generally.

The shonkonite pyroxenite, which is a black differentiate from the augite syenite, consists of large augite plenocrysts in a ground mass of pyroxene and feldspar. The augite syenite is a medium grey, feldspathic rock, of trachytic structure, due to the arrangement of tabular orthoclase crystals.

The youngest intrusives of all, the lamprophyre dykes[1], include "fourchites, camptonites, monchiquites, and mica lamprophyres".

Structure. These intrusives vary in size and form from batholith-like bodies to dykes. The larger masses in particular are uncrushed and of fresh appearance. They are elongated parallel to the Cordelleran trend, of north-west to south-east folding. Contact metamorphism by the batholith has been considerable. Daly[2] notes that around the borders of the Coryell batholith the traps of the Rossland volcanics have been converted into various schistose types, whose planes of schistosity are wrapped in peripheral arrangement around the batholith, over an exomorphic zone up to 600 yards in width.

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1. Brock, R.W., Explanatory notes of West Kootenay map sheet, 1904.
2. Daly, R.A., Mem. 38, Geol. Sur. Can., 1912, p.362.

Age and correlation. On the West Kootenay sheet the Rossland alkali granitic rocks have been mapped as Tertiary in age.

The Coryell batholith (pulaskite) has been referred by McConnell, Brock, and Daly to the Tertiary, and, from its generally uncrushed state, is believed to be later than the Laramide revolution, and to have accompanied the Oligocene and Miocene crustal disturbances.

At Ymir, the pulaskite occurs as the core of the Salmon River porphyritic monzonite stock of Oligocene age, and is considered by Drysdale to be younger than the monzonite. At Franklin and Phoenix Camps dykes of pulaskite porphyry cut the rocks of the Kettle River formation and the Midway volcanic flows, both of Oligocene age.

It has been observed that the Sheppard granite cuts the Lake Mountain conglomerate (Lower Tertiary); also the pulaskite in the Rossland Mountains, and is, therefore, younger than both of these formations.

The basic dykes are mentioned in the Explanatory Notes to the West Kootenay map sheet as being younger than all the other rock types grouped under the term "Rossland alkali-granitic rocks". Drysdale mentions that in the Rossland Camp the basic dykes cut all the veins and rock formation in the mines.

The Miocene intrusives, particularly those of the pulaskite and Sheppard granite type, are considered to represent the main batholith connected with the Miocene and late Oligocene period of crustal disturbances. Similar batholithic invasion took place at this time, farther to the west, when the Similkameen and Chilliwack granodiorite batholiths were intruded.

The basic dykes which followed the batholith represent the final and basic phase of this last cycle of plutonic activity within the area.

Glacial, Interglacial, and Recent Deposits.

Inasmuch as this paper deals primarily with a study of the bedrock geology, the superficial deposits will only be referred to very briefly here.

Distribution. These formations chiefly occur in the valley basins and lowlands generally, where they are accumulating or, as in the case of the older deposits, have been protected from erosion.

Lithology. The deposits include (1) Glacial till, consisting of boulder clay gravels and large erratics, lying as a thin mantle over large areas; (2) Interglacial deposits, chiefly fine stratified silts, sands, and gravels, often containing plant remains; (3) Recent alluvial deposits and soil.

CHAPTER 1V.

GEOLOGICAL HISTORY.

Introductory Statement

The data for the preparation of the following geological history has been obtained from a study of the history of the surrounding region, as well as that of the immediate area. The field evidence, as recorded by the rocks, is, in many parts, very poor indeed, especially is this so in regard to the records of the earlier periods. Fossilliferous horizons are rare, and intense metamorphism has obscured much of the original structure. Added to this is the fact that a great proportion of the rocks are of igneous origin. However, from an examination of the field evidence, and a study of the geological histories included in the various memoirs relating to the area and surrounding regions, a general conception has been obtained regarding the sequence of the most important geological events, and a summary of this forms the following account.

Pre-Carboniferous History.

(a) Beltian. The earliest record within the map area is one of Beltian seddmentation, when, in a moderately shallow continental sea, the Aldridge quartzite formation was laid down. Deposition during the entire Beltian took place in a slowly sinking geosynclinal basin. This basin of sedimentation, which has been traced in a north-westerly direction to Alaska, had, as its western shoreline during Beltian times, the old land of Cascadia.[1] This eastern shore line of Cascadia extended in a north-westerly direction from a line approximately through the Arrow Lakes into northern British Columbia, and marked the border of a great land mass stretching westward to beyond the present British Columbia coast line. The products of erosion from the uplands of Cascadia supplied the material for the sediments of the Purcell series.

During the Creston epoch the sea became shallower, mud flats made their appearance, the sediments became somewhat more siliceous, and local contemporaneous erosion took place. This was followed by deeper water conditions with the deposition of calcareous material during the Kitchener epoch. Again the sea receded, exposing vast mud flats, which by their mud-cracked surface indicate an arid climate during Siyeh times.

Alternations of deep and shallow water sedimentation continued throughout the remainder of the Siyeh epoch. Near shore conditions of deposition close to the old shore line of Cascadia are shown by the coarse Irene conglomerates of Siyeh age in what is now the Nelson Range. An interruption of the steady process of Beltian sedimentation took place at the close of the Siyeh, with the outflow of Purcell lava and Irene volcanics.

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1. Schofield, S.J., Trans. Roy. Soc. Can., Vol. 17, 3rd Ser. 1923, p.93

This period of vulcanism was accompanied by the injection of the Purcell sills, chiefly into the consolidated members of the Aldridge formation.

Following the period of vulcanism, sedimentation in the synclinal basin resulted in the deposition of the Gateway formation composed of siliceous argillites. The presence of abundant casts of salt crystals, together with ripple marks and mud cracks indicate sedimentation in a shallow, strongly saline, sea, under arid climatic conditions.

The rocks laid down during the last period of Beltian sedimentation within the map area have been removed by erosion, but in the Rocky Mountains to the east they are represented by the Phillips and Roosville formations of suncracked and ripple marked argillites.

(b) Lower Cambrian. During the lower Cambrian, deposition of rather coarse siliceous material appears to have taken place, when the phyllites, quartzites, and conglomerates of the Wolf and Monk formations of the Summit series are believed to have been laid down. Near Cranbrook, just to the east of the sheet, the Cranbrook conglomerates were deposited unconformably upon the rocks of the Siyeh formation, and on the Roosville formation at Ram Creek and Elko.

(c) Palaeozoic (Mid Cambrian to Devonian) Very little is definitely known regarding the geological history of the region over this great period of time,

During the early Palaeozoic times the eastern shore line of Cascadia had receded slowly westward, until by the early Silurian, it lay somewhat to the west of a line through Vancouver and Queen Charlotte Islands. From Cascadia eastward to the Laurentian Highlands a shallow and continous sea extended, and in this basin more or less continous sedimentation took place during Palaeozoic and early Mesozoic times[1]

Into a portion of this marine synclinal basin were deposited silts, clays, limestones, sands and gravels, later to be metamorphosed into the metargillites, schists, marbles, quartzites and conglomerates of the Ainsworth, Duncan, and Upper Summit series.

Alternations of deep and shallow water conditions during deposition are indicated by the varying texture of the sediments, while the absence of unconformities point to a long period of crustal stability.

Carboniferous History.

The Carboniferous period was one of steady deposition of great thicknesses of sedimentary rocks throughout British Columbia, Yukon and Alaska, and represents, perhaps, the greatest period of submergence to which British Columbia has been subjected. The sea which covered practically the whole map area was probably warm and shallow, and in it primitive fauna abounded. Low areas of marshy land were exposed

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1. Schofield, S.J., Trans. Roy. Soc. Can., Vol. 17, 3rd Ser., 1923, p.94.

from time to time as a result of minor retrogressions of the sea during the lower Carboniferous, as shewn by plant remains in the argillites of the Franklin group.

During the earlier period of sedimentation coarse textured arenaceous and argillaceous material was laid down, and later, as deeper water conditions prevailed, the more calcareous matter was deposited.

The rocks laid down during the Carboniferous period of sedimentation include the Pend d'Oreille schists and limestones of the Nelson Range; the Ainsworth, Slocan, and Cache Creek formations of the Slocan, Ainsworth, Lardeau and Shuswap Lake districts; the Mount Roberts formation and Sutherland schists of the Rossland Mountains; the Franklin and Gloucester formations of the Franklin Camp, and the Anarchist series, Attwood formation and Grand Forks schists of the Boundary district.

Toward the close of the Period some crustal unrest commenced, corresponding in a lesser degree to the great disturbances of the Appalachian revolution in the east. Uplift and minor folding elevated portions of the area above the sea, as in the Rossland mountains; and the older rocks were deformed and in part metamorphosed. This was probably accompanied by some minor volcanic activity, when the oldest lavas and tuffs of the Rossland and allied volcanoes flowed upon the newly exposed land. It was not, however, until the Mesozoic that vulcanism reached its maximum.

Mesozoic History to the Jurasside Revolution.

The earlier Mesozoic history is characterised by a higher relief of the region and the consequent vigorous erosion of the newly uplifted land surface. The main and most striking feature, however, was extensive and repeated outpourings of basaltic lava, accompanied by the intrusion of numerous small sills and dykes, and the ejection of great quantities of volcanic ash. It was during this period that the great part of the Rossland and Phoenix volcanics, and the Wallace group of Beaverdell, were formed, together with the injection of the augite porphyrite sills and dykes.

Intervals of quiescence prevailed between the outbursts of volcanic activity and continental deposits of gravels, sands and muds were laid down. Remnants of these inter-volcanic periods of sedimentation are represented by the Hall series, near Ymir; portions of the Wallace group of Beaverdell;& small interbeds of sediments in the Rossland mountains.

During the Jurassic and prior to the Jurasside revolution an area of marine sedimentation must have existed in the north, at least to a limited extent, where the Belmnite bearing sediments of argillaceous quartzite and limestone of the Kilford series, in the Slocan and Lardeau districts, were laid down.

The Jurasside Revolution.

In British Columbia generally, during the Upper Jurassic, the rocks of the great basin of sedimentation, stretching from Cascadia (west of what is now the Pacific Coast), eastward to beyond the present site of the Rocky Mountains, became folded and uplifted into the great mountain chains of the Vancouver Island - Queen Charlotte Island Range, the Coast Range, and the Selkirk Range. This folding was accompanied by the intrusion of the Coast Range batholith, and the primary West Kootenay batholith.

Turning to the geological history immediately within the map area; the Upper Jurassic period was characterised by great structural changes and plutonic activity. The period of vulcanism had practically subsided, and the original Selkirk Range was slowly raised into major folds whose axial planes trended in a general northerly to northwesterly direction.

Into this zone of crustal weakness the great batholith of Nelson granodiorite advanced slowly upward. Preceding the main batholithic body were a number of minor intrusives of basic differentiates, which are now represented in more or less metamorphosed states, by the Kaslo and Lardeau schists, the Baker and Fife gabbros, and the diorite porphyrite and pyroxenite of the Rossland Mountains.

Following these, the main batholithic intrusion of granodiorite worked its way upward by a combination of stoping, absorption, and displacement of the invaded rock, and crystallised beneath a considerable thickness of roof rocks. During the earlier cooling stages of the batholith lamprophyre dykes, the products of a late basic differentiation, were intruded into the invaded rock. The final or pneumatolitic stage of cooling resulted in the mineralization of fissures and the formation of a large number of important ore bodies.

It was largely during the Jurasside revolution that the older sediments and volcanics are believed to have been tilted and folded into their present attitudes[1], and their metamorphism is considered to have resulted from a combination of the mountain building forces and the thermal metamorphism of the underlying batholith.

Cretaceous History to the Laramide Revolution.

The Cretaceous opened with rapid erosion of the newly formed Selkirk and Purcell ranges, the resulting sediments being deposited chiefly in the Cretaceous geosyncline, which extended over the present site of the Rocky Mountains and Great Plains.

The granitic batholith was partially unroofed, and the area reduced to a peneplain out of which projected monodanocks, which, at the present time, form the higher peaks such as Kokanee Mountain.

Small basins of fresh water deposition existed locally, of which the Little Sheep Creek sediments in the Rossland Mountains are a remnant.[2] The climate was subtropical, but cooling toward the close.

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1. Schofield, S.J. Personal communication.
2. Drysdale, C.W. Mem. 56, Geol. Sur. Can., 1915 p.147.

During the Upper Cretaceous crustal movements commenced which culminated in the Laramide revolution.

The Laramide Revolution.

The Laramide Revolution extending from the close of the Cretaceous into Eocene times affected the region by uplift with contemporary deformation and batholithic intrusion.

The Cordillera as a whole was profoundly influenced by orogenic movements. To the west of the map area the southern portion of the Interior Plateau was uplifted and its surface carved into deep valleys by erosion, while to the east, folding and uplift of the geosyncline commenced, the Rocky Mountains portion was warped into folds and broken by overthrust faults, and the Great Plains were raised out of the sea.

Within the map area many important changes took place. Vertical uplift caused the rejuvenation of the streams and deep valleys were cut into the peneplain. Deformation and weakening of the crust paved the way for large scale igneous activity, and into these zones of strain the Valhalla granite batholith was intruded. To the west the Beaverdell batholith represents a granodiorite phase of the same intrusion.

Towards the close of Eocene times the climate was probably cool and humid, as shown by the sediments at the base of the Kettle River formation at Franklin, which contain striated and facetted boulders and beds of light coloured leached sediments.

Oligocene History.

The Oligocene period opened with erosion of the uplands wide spread deposition of gravels, sands and muds in extensive fresh water lakes. The sediments in these old lake beds make up the rocks of the Kettle River formation, which now occupy isolated patches throughout the southern and western portions of the map area. These lakes had a still wider distribution to the west, where they flooded the broad valleys of the Interior Plateau, and deposited, with many other formations, the Coldwater group of the Kamloops district.

The climate during this time was probably mild, and supported luxuriant vegetation, as shewn by the numerous beds of lignite and subtropical fossil plants in the Kettle River formation at Midway.

The presence of tuffs interbedded with these sediments indicate that intermittently the air was laden with volcanic ash, as a result of the preliminary and explosive stages of the great period of vulcanism to follow.

The period closed with orogenic movements and the intrusion of porphyritic monzonite stocks, some of which may possibly represent the cooled magmas in the deeper zones of old volcanic pipes; and so during this time, the earliest lavas of the Midway volcanic group may have been extruded.

Miocene History.

The early Miocene was a period of wide-spread volcanic activity, during which time the area was in part covered by a considerable thickness of lava flows, referred to locally as the Midway Volcanic Group, and generally as the Tertiary Volcanics. These flows form merely a part of the great volcanic extrusion which covered large areas of the Interior Plateaus of British Columbia, and formed the rocks of the Columbia Lava Plain to the south.

Towards the close of this period of vulcanism, crusted deformation took place accompanied by large scale batholithic invasion of pulaskite and pulaskite porphyry, when the Coryell batholith and the Rossland alkali-syenite bodies were intruded. These were preceded by more basic dykes of shonkinite pyroxenite and allied types.

At this time the vein fissures originally formed during the Jurasside revolution were fractured, and the second main period of mineralization took place as a result of the alkaline mineralising solution given off from the pulaskite intrusives. Many of the important gold deposits, including those of Rossland,[1] were formed at this time.

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1. Drysdale, C.W. Mem. 77, Geol. Sur. Can., 1915, p.248.

Following the period of batholithic intrusion and mineralisation was the intrusion of the Sheppard granite porphyry stocks and dykes, representing, probably, a later differentiation of more siliceous magma from the main intrusive body of syenetic composition.

The final stages of igneus activity within the area are represented by lamprophyre dykes, which are believed to have followed very closely the intrusion of the Sheppard granite.

The Miocene closed with a long period of crusted stability, during which vigorous erosion took place, removing much of the sediment and volcanic Tertiary rocks.

Pliocene and Quaternary History.

During Pliocene and early Pleistocene times a general regional upwarping of the late Tertiary erosion surface took place, thus rejuvinating the drainage which resulted in the carving of deep gorges in the old upland surface.

The Quaternary period was marked by a general refrigeration and glaciation. Isolated ice caps are found in the area to the present day, one of these being the rather extensive Kokanee Glacier. The Pliocene valleys were smoothed and modified by the scouring action of the advancing ice cap. At least one, possibly more, interglacial periods took place, with the deposition of alluvial silts. Plant fossils found in the St. Mary silts, near Cranbrook, indicate very mild climatic conditions during the first retreat of the ice.

Following the final glacial period stream erosion became active, and dissection of the alluvial gravels, sands, and silts took place with the formation of river terraces. In the lowlands soil accumulated from the action of frost, rain, and humus.

CHAPTER V.

THE WEST KOOTENAY COMPOSITE BATHOLITH.

General Statement.

This chapter is devoted to a theoretical consideration of certain interesting features of the batholith and its relationship to the intruded crust. From these considerations, hypotheses have been tentatively advanced to attempt to explain the cause of some of the phenomena noted.

Methods of Intrusion.

It is the writer's belief that the West Kootenay batholiths reached their present position within the earth's crust by a combination of the three following methods of intrusion:

(a) By stoping and abyssal assimilation.

(b) By marginal assimilation.

(c) By displacement of the intruded rocks.

(a) Stoping Method and Abyssal Assimilation. Excellent examples of magnetic stoping are to be found at the batholithic contacts throughout the area. The shatter-zone at the contact of the Trail batholith is, however, a particularly fine exmple of this method of intrusion. There two concentric belts of mixed rocks lie between the main batholith and the encircling and unintruded Rossland volcanics. The outer and wider of these consists of the volcanic rocks intruded by countless intersecting apophyses, originating from the batholith, forming a network of dykes. The inner belt is composed largely of the granitic intruding rock in which are xenoliths from the invaded rock. These two belts are graditional into one another. This example furnishes a good illustration of arrested stoping during the last cooling stages of the batholith.

The blocks of intruded rock thus rifted off sank into the main body of viscous magma and became assimilated in the deeper and hotter zones .

(b) Marginal Assimilation Method. Marginal assimilation of the wall rocks as an aid to magmatic advance has been an important factor. It has been noted, particularly in regard to the pulaskite in the Boundary district, that in the contact zone there is a rapid transition over a short linear distance from a zone of a dyke network to one characterised by isolated and rounded xenoliths of the intruded rock. This would indicate that fusion and assimilation of the wall rocks took place on a large scale both near the intrusive contact as well as at abyssal depths.

(c) Displacement of the Intruded Rocks. The arrangement of the general strikes and dips around the north, east and south-east borders of the West Kootenay batholith furnish strong presumptive evidense to support this method of intrusion.

As is shewn on the geological maps accompanying this paper, the regional strike of the intruded formations follow in broad sweeping curves round the batholithic contact.

This structural feature suggests very strongly that the batholith entered under sufficient pressure to displace the surrounding rocks from their original attitude prior to the intrusion, and is proof that batholiths may not be necessarily entirely cross-cutting in their relationship to the intruded rocks.

That the batholith entered under a very considerable pressure seems evident from the fact that in the West Kootenay district the granitic mass is found on Kokanee Peak at an elevation of over 9,000 feet above the present sea level. In addition, there is the far greater pressure required to raise this mass from the zone of flowage or asthenosphere, which lies 60 to 75 miles beneath the surface of the earth's crust.

The deformation of the surrounding rocks by the plutonic mass may have been greatly facilitated by the fact that during batholithic advance the mountain building forces were still active, and the stress required to cause laccolithic displacement by the magma may have been furnished, in part, by a component of those same orogenic forces.

Lithological Character of Intrusives.

A very striking feature of the batholithic intrusives of the West Kootenay is the manner in which each of the periods of batholithic invasion, with the possible exception of that of the Laramide, has been preceded and followed by minor intrusives of a more basic nature. This feature is particularly well illustrated by a study of the plutonic rocks related to the Jurasside and Oligocene-Miocene revolutions. The generalised sequence of the Jurasside intrusives in the West Kootenay batholithic province may be stated as follows, commencing with the youngest:

	Lamprophyre dykes (camptonite, etc)
	Aplitic dykes.
Jurassic	Nelson granodiorite - batholith
	Gabbros, altered basalts and dunites as chonoliths and dykes

The sequence of the Oligocene-Miocene intrusives is as follows:

	Lamprophyre dykes
	Aplitic dykes
Miocene	Granite porphyry, stocks and dykes
	Pulaskite batholiths and stocks.
	Porphyritic monzonite stocks.
Oligocene	Augite porphyrite dykes and sills
	Olivine basalt dykes

Further to the West, in the Skagit Range, near Chilliwack, the same general sequence has been recorded by Daly[1] as follows:

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1. Daly, R.A. Mem. 38. Geol. Sur. Can., 1912, p.552.

Post Miocene	Diabase dykes
	Camptonite and syenite porphyry dykes
	Syenite porphyry (?) dykes (?)
Miocene	Monzonite stock
	Chilliwack granodiorite batholith
	Slesse dionite stock
	Skagit harzburgite intrusives
Oligocene	Dunite and gabbro dykes

In general, therefore, it appears that periods of large scale plutonic activity are opened by the intrusion of smaller basic bodies and closed by that of acid and basic complementary dykes.

No instance has been recorded within the area of any batholithic intrusion having been immediately preceded by lencocratic dykes.

Origin of the Present Elevation of the Selkirk Range and of the Intrusion of Tertiary Batholiths.

The hypothesis is here advanced that the Selkirk Mountains owe the greater part of their present elevation to post-folding, vertical uplift, which took place during the Laramide and Oligocene-Miocene revolution; and further, that the axis of maximum uplift was coincident with the zone of Tertiary batholithic intrusion within the Selkirk Range.

It will be recalled that the Selkirk Range was first mountain-built during the Upper Jurassic, and that during the Cretaceous this newly-built Range was peneplained nearly to base level.

This implies that the Selkirk Range, at the close of the Cretaceous, was reduced to a plain whose mean elevation was very little above sea level. How then is it that the old Cretaceous peneplain of the Selkirk Range is now found at an average elevation of some 6,000 feet? The solution may, in part, be found in the structure across the Selkirk, Rocky Mountains, and the Great Plains.

At the western end of this section lies the Selkirk Range, whose average summit level is at approximately 6,000 feet elevation.

Eastward the section passes through the Rocky Mountains with a mean summit elevation of approximately 8,000 feet. Near the eastern end of the section, however, the elevations become less and less as the foothills of Alberta are crossed and the Great Plains reached, until at Winnipeg, the land elevation is only about 800 feet above sea level.

Schofield[1] in a recent paper has put forward the hypothesis that the Rockies owe their present ~~maximum~~ mean elevation of approximately 8,000 feet to a combination of 4,500 feet due to folding, and 3,500 feet to later vertical uplift. This is shown by the fact that the land elevation of the foothills in the vicinity of Calgary, east of the Rocky Mountains, is approximately 3,500 feet, this elevation

1. Schofield, S.J., Roy. Soc. Can. 1923, Sect IV p101

having taken place since the Cretaceous, as indicated by the presence of marine sediments near Calgary, of Cretaceous age. Hence only the remaining 4,500 feet can be attributed to elevation by folding, the balance being due to subsequent vertical uplift.

Extending this principle to include the Selkirk Range to the west, the following data may be tabulated:

Mean elevation of Cretaceous peneplain of Selkirk Range	6,000 feet
Mean summit elevation of Rocky Mountains	8,000 feet
Elevation of Rocky Mountains, due to vertical uplift.	3,500 feet
Elevation of Great Plains at Winnipeg (vertical uplift only).	800 feet

If these points be plotted to scale with proportionate horizontal distances, it will be found that the points representing 6,000 feet elevation of the Selkirk, 3,500 feet elevation in the Rockies, and 800 feet elevation at Winnipeg, lie very nearly on a straight line, this line having an eastward slope.

Disregarding the effects of subsequent erosion, this suggests that tilting of the earth's crust has taken place on a vast scale, the "hinge" about which this tilting took place lying along a line somewhat to the west of Winnipeg, possibly nearer Regina, and the point of maximum uplift being in the vicinity of the Selkirk Range.

West of the Selkirks the Post-Cretaceous surface slopes off towards the west and north-west, as the Interior Plateau is reached, indicating that some regional tilting of the old Cretaceous land surface has taken place from the Selkirk Range toward the west. This feature again supports the hypothesis that the line of maximum elevation of Post-Cretaceous folding is coincident with the axis of the Selkirk Range.

It should be noted here, however, that a great part of the difference of elevation between the Cretaceous rocks at Calgary and those at Winnipeg is due to erosion. Nevertheless, there is little doubt that at least part of this difference of elevation is also due to Post-Cretaceous filting. In the Interior Plateaus and the western flank of the Selkirk Range, the persistance of outcrops of the Lower Tertiary sediments and volcanic flows indicates that subsequent erosion cannot alone have been responsible for the general westerly slope of the Cretaceous peneplain.

Assuming then, that the evidence submitted above is correct, it would appear that a long gentle flexure of the earth's crust has taken place during Post-Cretaceous times, this flexure extending from a point west of Okanagan Lake, to a point west of Winnipeg. The line of maximum elevation, and therefore of maximum tension, appears to be coincident with the present Selkirk Range. This might furnish an explanation for the comparative localisation of the north-west and south-east trending batholiths of Eocene Valhalla granite, and Miocene pulaskite, which have evidently entered a relatively narrow zone of crustal weakness.

CHAPTER VI.

SUMMARY AND CONCLUSIONS.

The following results have been obtained from the investigations described in this paper:-

(1) A description has been given of the essential details of all the important rock formations occurring within the area. The descriptions, particularly of those of the sedimentary rocks, have been necessarily very brief, due to the large number to be described. It is believed, however, that the more important facts of each have been brought out. It is hoped that this work will be of some material value in presenting, for the first time, in a single paper a general conception of all the important rock types to be found within the region.

(2) A map and section has been constructed on a scale of 7.89 miles to the inch. It is a compilation of a number of individual maps and descriptions of portions of the region, the information being drawn chiefly from the publications of the Geological Survey of Canada.

(3) A general correlation table has been prepared, based upon the results of the numerous geologists who have worked within the area dealt with in this paper. Several new correlations have beem made depending upon the probable relationships apparent from a

consideration of the area as a whole.

(4) The geological history of the area has been outlined, and the more important events have been described in some detail. For the preparation of this history the writer has availed himself of the data given in those publications dealing not only with the area itself, but also of those dealing with the wider and more general consideration of the Cordillera as a whole.

(5) Several important features of the batholiths have been presented, and the following conclusions have been reached:

(a) The methods of intrusion by which the batholithic mass has reached its present position within the earth's crust are believed to be three-fold, namely, by stoping and abyssal assimilation; by marginal assimilation; and by displacement of the intruded rocks.

Daly, in his recent work on "Igneous Rocks and their Origin"[1] considers that all batholiths are entirely cross-cutting in their relationship to the intruded rocks. The evidence within the West Kootenay batholithic area, however, points very strongly to a most decided displacement of the wall and roof rocks resulting from magmatic pressure. This is indicated by the manner in which the regional strike of the sedimentary rocks closely parallels the contacts of the batholith.

The smaller bodies, such as stocks, on the other hand, are

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1. Daly, R.A. "Igneous Rocks and their Origin", 1914.

distinctly cross-cutting. It is the writer's belief that in order to displace the sedimentary rocks from their normal attitude, the intrusive body must be batholithic in rank, and further, that batholiths, during the early stages of advance, are nearly entirely cross-cutting.

This becomes more evident when it is remembered that the stocks of the Kootenay district are really batholithic cupolas, the forerunner of the main batholith, and that they do not present a sufficiently large surface to have any appreciable thrusting effect upon the intruded rocks. Their action may be likened to that of a giant punch, the batholith to that of a wedge.

An alternative explanation may be that the advancing cupolas entered the original and perhaps comparatively narrow zone of weakness, where assimilation and stoping of the crust was able to keep pace with magmatic advance. Later, as the main batholith followed, it is possible that its margins extended beyond the original zone of weakness, and consequently magmatic advance by stoping and assimilation was retarded, due to the less fractured nature of the strata. Increasing pressure would then be built up to bear upon the wall rocks, sufficient to result in the deformation of the bedding planes to a position approaching parallelism to the surface of intrusion.

The above considerations are, however, entirely theoretical, and are merely put forward as a possible solution to the problem.

(b) It has been pointed out that the West Kootenay batholiths have, in common with similar intrusives elsewhere, a basic pre-batholithic phase followed by an acid and basic post-batholithic phase. Several instances were given, the most typical example being that of the Jurasside batholithic cycle.

(c) From a consideration of the structure extending from the Interior Plateaus to the eastern border of the Great Plains, the conclusion has been drawn that the Selkirk Range owes practically its entire elevation to vertical uplift following Cretaceous peneplanation.

The axis of uplift and therefore of flexure is conceived to be coincident with the axis of the Selkirk Range, and its position is thought to explain the localisation of the Walhalla granite batholiths in this comparatively narrow zone along the Cordilleran trend.