DEPARTMENT OF GEOLOGY
UNIVERSITY OF BRITISH COLUMBIA

THE GEOLOGY OF THE BELTIAN ROCKS OF THE CORDILLERA IN CANADA

by

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approved

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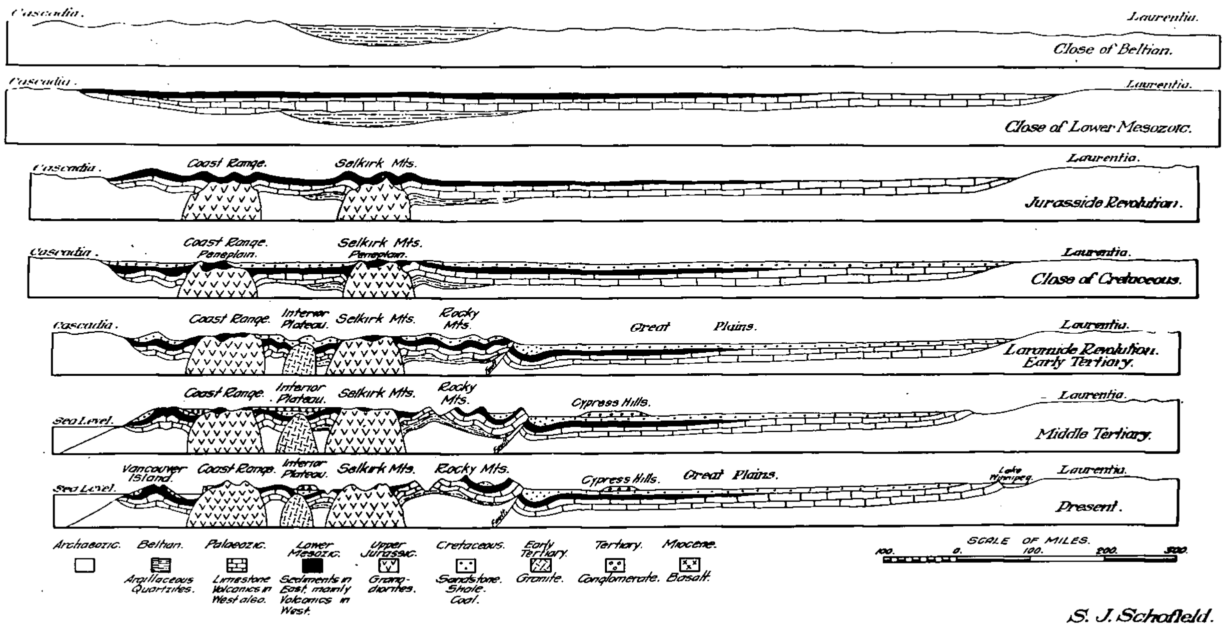
DIAGRAM ILLUSTRATING THE GEOLOGICAL HISTORY OF THE CANADIAN CORDILLERA.



S. J. Schofield.

FRONTISPIECE.

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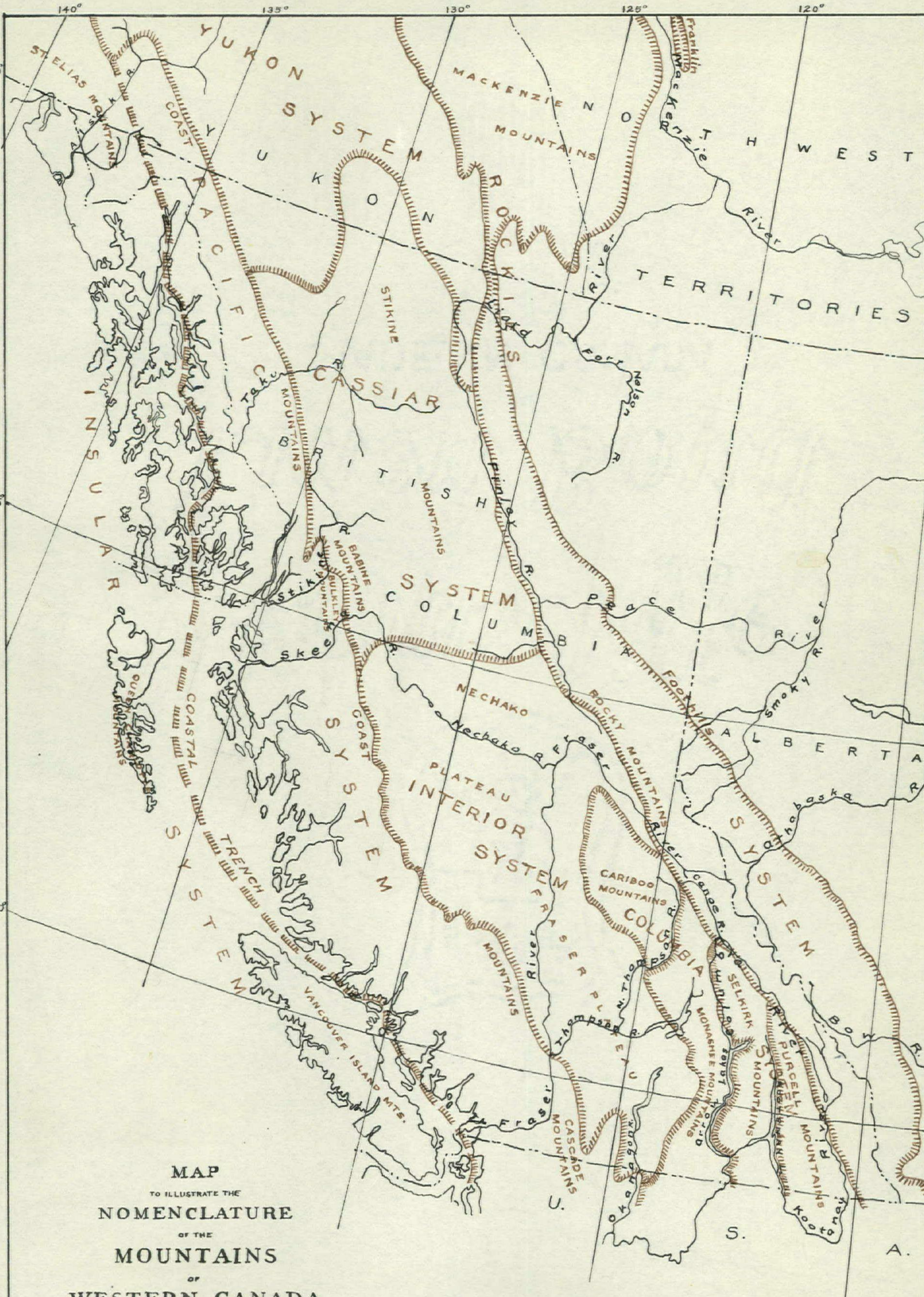
INTRODUCTION

This paper presents a brief review of the literature on the pre-Cambrian formations of the Canadian Cordillera, an investigation by the writer of a number of thin sections of rocks from the Shuswap terrane east of Vernon, B.C., and a new grouping of the Beltian formations in Canada proposed by Dr. S.J. Schofield of the University of British Columbia.

It has not been possible to devote as much time to a review of the literature as the subject deserves. Within the period from 1871 to 1914 a new school of pre-Cambrian geology had its beginnings and found recognition. The first Canadian geologists to work in the Cordillera brought with them a conception of the pre-Cambrian as a complex, a necessary result of the long experience most of them had had in the pre-Cambrian of eastern Canada, and it was to be more than forty years before the great thicknesses of, comparatively, slightly altered and little disturbed but unfossiliferous sediments of the Canadian Cordillera were to be recognized as older than Lower Cambrian. The result of compressing this important period into the single chapter that is devoted to it cannot be other than unsatisfactory but it is fundamental to the present concept of the geology of the Beltian and some reference to it is therefore essential.

The petrography of the Shuswap rocks has been taken from the writer's Bachelor's thesis, submitted to the Department of Geology, Queen's University, in 1932. A number of thin sections of Purcell sediments were examined as part of the preparation for this paper. The fineness of grain characteristic of these rocks, however, prevented the finding of any important features not already described by Daly and Schofield. Nor was there sufficient time to make chemical analyses. Reference to what results were obtained is contained in Chapter V.

Acknowledgments are made to Dr. C.E. Cairnes, of the Geological Survey of Canada, for the loan of the thin sections of the Purcell sediments, and to Dr. S.J. Schofield, of the University of British Columbia, for the use of his bibliography and for the assistance he has given throughout the preparation of this thesis.



MAP
TO ILLUSTRATE THE
NOMENCLATURE
OF THE
MOUNTAINS
OF
WESTERN CANADA

Natural Scale $\frac{3}{16,000,000}$

CHAPTER I

GEOLOGICAL HISTORY.

The first interpretation of the geological record of the Canadian Cordillera was advanced by G.M. Dawson[1] in 1901 and modified by R.A. Daly[2] in 1912. Both believed that

1 Dawson, G.M.- Geol.Soc.Am., Vol.12, 1901.
2 Daly, R.A.- Geol.Surv., Can., Mem.38, 1912.

Dawson's Shuswap terrane had been the source of Palaeozoic sediments. Increased knowledge of the distribution of sediments in the region led to a new interpretation, advanced by S.J. Schofield[3] in 1923, which abandoned the Shuswap terrane

3 Schofield, S.J.- "The Geological Record of the Cordillera in Canada". Trans.Roy.Soc., Can., Vol.17, 1923, Sec.IV.

as the source of sediments and postulated the existence of an ancient land mass which he named "Cascadia". This section is a resume of Dr. Schofield's hypothesis.

"During Beltian times, the eastern shoreline of Cascadia extended northwestward along a line marked approximately by the Okanagan Lake, through northern British Columbia into Alaska. It is not known how far east the basin which lay to the east of the ancient land mass extended. At least it included the area now occupied by the Rocky mountains as well as by the Franklin mountains to the north. However, I do not think that the Beltian basin of sedimentation reached the Laurentian highlands".

The eastern coastline of Cascadia receded comparatively rapidly during early Palaeozoic time until, in the late

Ordovician or early Silurian, it extended along a line a little west of the present coast of North America. In the shallow sea to the eastward, extending to the shores of the Laurentian Highlands, sedimentation continued to the end of the Palaeozoic and into the early Mesozoic. The presence of local conglomerates, in different parts of the region and of varying age, shows that this shallow sea was fluctuating but there is no evidence of any major disturbance throughout this long interval.

The Triassic and Jurassic sediments are remarkable for the large quantity of volcanic material contained in them. Therefore, during these periods, Cascadia, or the basin, must have been the scene of great volcanic activity, particularly on its eastern coast. That the eastern coast had been mountain-built is shown by the existence of granite pebbles in the Silurian of southeastern Alaska and in the Upper Triassic conglomerate on Gravina Island, Alaska.

At the close of the Jurassic a period of mountain building took place, the Jurasside Revolution. It is reasonable to suppose, in view of later events, that this disturbance was an eastward continuation of that which had supplied the granite to the east coast of Cascadia. Four mountain chains appeared in the basin of sedimentation:

(a) The Vancouver Island - Queen Charlotte Island range.

The Coast Range of British Columbia.

(b) The Sierra Nevada range in the United States.

(c) The Selkirks and their extension southward into the Bitterroot and Clearwater ranges.

(d) The Alaskides on the northern border of Cascadia.

Granitic intrusion accompanied the folding of the sediments.

The Vancouver Island - Queen Charlotte Island range, the Coast Range and the Selkirks, as well as Cascadia, to confine the discussion to the Canadian area, supplied sediments to an eastern and a western basin on the flanks of the highlands throughout the Cretaceous. An elongation of these mountain chains northwestward divided the Cretaceous sediments into three main basins:

(a) The Vancouver Island - Queen Charlotte Islands basin, between Cascadia and the Coast Range.

(b) The Interior Plateau basin, between the Coast Range and the Columbia-Selkirk range.

(c) The Rocky Mountains - Great Plains basin, between the Selkirk range and the Laurentian Highlands.

The occurrence of granite pebbles in the Cretaceous of all three basins shows that the batholiths of the three chains were all unroofed. "The overlap of later Cretaceous sediments on the older folded Jurassic and Triassic rocks on Queen Charlotte and Vancouver Islands, point to a steady enlargement of the Cretaceous basins in Upper Cretaceous times. The presence of Cretaceous rocks in the valleys of the Coast Range, such as those of Harrison lake and Kitsumgallum river, shows that the Coast Range may have been in the past submerged by the close of the Cretaceous. From this it may be concluded that the four great Jurassic mountain chains were reduced to a condition approximating peneplanation by the close of the Cretaceous period".

In early Tertiary time the orogenic movements of the Laramide revolution affected the whole region of the Cordillera and the Great Plains. The peneplaned Jurassic mountains were uplifted, the basins of sedimentation were folded to form new mountain chains and vertically uplifted to form the Great Plains. The folding of the western basins was accompanied by intrusions of granite, now exposed in limited areas in the Rocky Mountains, the Interior Plateau of British Columbia and in the Yukon. Small basins of sedimentation persisted in Lower Tertiary time in the Vancouver Island, Interior Plateau, Rocky Mountain and Great Plains regions. Local orogenic movements uplifted these basins at the close of the Oligocene; it is possible that the rest of British Columbia was uplifted at the same time.

"The period following that of compression at the close of the Oligocene was one of tension caused by the sinking of the Pacific basin, thus causing a stretching of the area adjacent to the Pacific Coast. The sinking of the Pacific area, either by downwarping or by faulting, marked the last appearance of the Pacific land mass Cascadia which sank beneath the waters of the Pacific ocean. On the continent, the stretching of the land mass produced fissures which permitted the outpouring of the vast floods of lava which marked the Miocene of British Columbia...... "

The Tertiary closed with the glacial age of the Pleistocene and the depression of the Pacific Coast, if not of the whole Cordillera. Vulcanism decreased.

With the gradual disappearance of the great Pleistocene ice fields, remnants of which still exist, the coastal areas have been steadily rising. Definite records of an uplift of 450 feet have been obtained.

CHAPTER II

EARLY WORK.

Systematic exploration of the Cordillera in Canada began with reconnaissance surveys by the Canadian Pacific Railways Company in 1871; the first party left Victoria on July 20 of that year.[1] Regardless of the route selected, the railroad was to cross a broad belt of practically uninhabited territory from which no revenue could be drawn; the possibility of the existence of ore deposits in this belt offered the quickest solution of the considerable problem of revenue. The then Director of the Geological Survey of Canada, Dr. A.R.C. Selwyn, was able, therefore, to obtain authority to carry on geological exploration in the wake of the railroad reconnaissance parties. Dr. Selwyn,[2] with James Richardson as assistant, formed a party which also left Victoria in July, 1871.

1 Fleming, Sanford - "Expeditions to the Pacific". Trans. of the Roy. Soc. of Can., 1889, Sec.II, p.135.

2 Selwyn, A.R.C.- Geological Survey of Canada, Report of Progress, 1871-2.

Selwyn's survey followed the Fraser River from Yale to Cache Creek, from Cache Creek via the Cariboo Road to Cariboo; from Cache Creek via Kamloops and the North Thompson River to Tete Jaune Cache and on to Leather Pass. A "Granite Gneiss and Mica-Schist series" is described as a unit. "The talcose, micaceous schists of the Cariboo region, and the base rocks of the Selkirk Mountains and the Gold Range probably belong to the same series. The stratification in the rocks of this series is often obscure, and they are much broken and disturbed[1]......" No attempt was made to define the age of

1. Selwyn, A.R.C.- Geol.Surv.Can., Rept. of Progress, 1871-2.

these rocks; Selwyn believed them to be the oldest rocks in the area. He describes similarly altered rocks in 1875 in an area north-east of Prince George.[2]

2 Selwyn, A.R.C.- Geol.Surv.Can., Rept. of Progress, 1875-6.

In 1878 G.M. Dawson[3] reported a highly altered series

3 Dawson, G.M.- Geol.Surv.Can., Rept. of Progress, 1877-8.

of rocks surrounding the Shuswap Lakes,extending southward to about halfway to the north end of Okanagan Lake and from there south-eastward to the gold range. He referred them to the Huronian of eastern Canada, with the reservation that they may be correlated with the Cascade Crystalline series of the Coast Range, Carboniferous in age. It is of interest to note here that C.E. Cairnes of the Geological Survey, whose work in that area is the most recent, believes that these rocks may be as young as Carboniferous.[4] Dawson gives here the first

4 Cairnes, C.E.- Personal Communication.

description of pre-Cambrian rocks, as such, in the Canadian Cordillera.

In the April and May issues of the Geological Magazine for 1881, G.M. Dawson[5] reviews the knowledge of the

5 Dawson, G.M.- "Geology of British Columbia". Geol.Mag. 1881, pp.1-19.

geology of British Columbia. He writes of the oldest rocks as follows: "Still older rocks, which may indeed represent part of the Archean of the fortieth parallel area, are known to occur, but about them little has yet been certainly determined. They appear in the Gold Range and in the region between it and the Rocky Mountains. The rocks appear to be gneisses and granites, holding orthoclase feldspar, and with abundant quartz and mica, very often garnetiferous and coarsely crystalline. They were originally classed with the schistose gold-bearing rocks of Cariboo and their representatives elsewhere, but we have already found reason to believe that these schists are much newer.......[1] The 'pre-Cambrian' becomes more closely

1 Dawson, G.M.-"Geology of British Columbia". Geol.Mag., 1881, pp.1-19.

confined to the highly altered schists and gneisses.

H. Bauerman[2], in 1885, reported on "The Geology of

2 Bauerman, H.- Geol.Surv.Can., Ann.Rept. 1882-4, pp.1-41B.

the Country near the 49th. Parallel of North Latitude West of the Rocky Mountains". He mapped as pre-Cambrian a "porphyritic and syenitic gneiss" on the east side of Osoyoos Lake, "gneiss, quartzite, mica- and hornblende-slate all finely laminated and irregularly contorted, greenstone and feldspathic porphyry dykes in very great numbers, both in gneiss and in shaly rocks" between Rock Creek and Colville and a formation consisting chiefly of granite gneiss between the Spokane and Moyic rivers. He mapped the unfossiliferous "bluish-gray and green finely granular siliceous slates" with their "several apparently interstratified beds of amygdaloidal and compact trappean rocks" east of the Moyic river, en masse as Palaeozoic.

In 1885 G.M. Dawson[3] described an unfossiliferous

3 Dawson, G.M.- Geol.Surv.Can., Ann.Rept. 1885, Pt.B.

and only slightly altered series of rocks between latitudes 49° and 51°30', the region including R.A. Daly's 49th Parallel section of 1912 from Kootenay river to Waterton lake, the eastern part of S.J. Schofield's Cranbrook Map Area (1915), J. Walker's Windermere Map Area (1926) east of the Kootenay river, and most of C.D. Walcott's Bow river area (1910), the oldest rocks of which are now held to be pre-Cambrian in age. Their comparatively unaltered condition led Dawson to believe that they were Palaeozoic and the presence of middle Cambrian fossils on Vermillion and Kicking Horse passes indicated that the unfossiliferous beds were of Cambrian age.

In 1886 R.G. McConnell[1] measured a section across

1 McConnell, R.G.- Geol.Surv.Can., Ann.Rept. 1886, Vol.2, Pt.D.

the Rocky Mountains, following the line of the Canadian Pacific Railway along the Bow and Kicking Horse valleys from Golden eastward to Banff, from where it leaves the railway and follows the Devils' Lake valley to its gap. The rocks were an eastward continuation of Dawson's formation of 1885.

Since the determination of the age of these slightly altered and unfossiliferous beds was to be one of the major problems of Canadian Cordilleran geology, these first descriptions by Dawson and McConnell are of particular interest. "Under this name (Cambrian) a great series of beds forming the lowest members of the section in this part of the Rocky Mountains is classed. The rocks are generally quartzites, quartzose, argillaceous and calcareous shales, and slates of very varied texture and color. Limestones, conglomerates and bedded greenstones (Diabase?) are also present, but of minor importance. The thickness of the series...... (on South Kootenay Pass) is estimated as at least 11000 feet. ..... the base of the section is not anywhere seen. ..... In lower parts of the series zones of red beds are prominent. These show pseudomorphs of salt crystals, mud-cracks and other evidences of conditions similar to those indicated by the Triassic rock, but no fossils have been obtained from them. .... The conglomerates were seen for the most part in connection with the Cambrian anticlinal of the upper portion of the Bow Valley. They are characterized by pebbles of milky or semi-transparent quartz, together with pieces similar in size of fresh-looking whitish felspar, and the matrix contains an abundance of pale mica. These constituents have evidently been derived from some not far distant exposures of coarse granitic or gneissic rocks. Fragments are also found of dark, lustrous schist. Rocks of the character of those largely developed on Shuswap lake and in the Gold Range would afford such material."[1] McConnell[2] found

1 Dawson, G.M.- Geol.Surv.Can., Ann.Rept. 1885, Pt.I B.
2 McConnell, R.G.- Geol.Surv.Can., Ann.Rept. 1886, Vol.2 Pt.D.

that Dawson's conglomerate divided a basal and unfossiliferous member, consisting mainly of "a great series of dark-coloured argillites, associated with some sandstones, quartzites, and conglomerates near the top of the formation", which he named "Bow River series" from an overlying "Castle Mountain series" near the base of which lower Cambrian fossils were found. The two series are angularly conformable.

Dawson[1] correlated these rocks with the Cambrian of

1 Dawson, G.M.- Can.Rec.Sci., 1886, p.4.

C.D. Walcott in the Grand Canyon of the Colorado river in Arizona, the Chuar and Grand Canyon groups: "The occurrence of thick beds of parti-colored shales, the abundance of ripple-marks and mud-cracks throughout, and especially the evidence (in the Grand Canyon group) of contemporaneous volcanic activity, in the form of interbedded greenstones, constitute points of identity with the series here described." However, in 1886, Walcott[2] proposed that the Grand Canyon and Llano

2 Walcott, C.D.- Am.Jour.Sci., Vol.XXXII, 1886, p.138.

series be correlated with the Keweenaw series and the whole placed in a system of pre-Cambrian age, the Keweenaw to include, besides the original Keweenaw of Lake Superior, the Llano series of Texas, and Chuar and Grand Canyon series of Arizona. This grouping necessitated the existence of a Keweenawan land mass extending from the Lake Superior region south to central Texas and westward to central northern Arizona. This land mass furnished the sediments of the lower and middle Cambrian and disappeared beneath the sea in the upper Cambrian. This explained the existence of middle and upper Cambrian fossils in beds immediately overlying unfossiliferous strata. That this theory, at first, made but little impression on Canadian geologists is shown in a paper by G.M. Dawson[3] published the

3 Dawson, G.M.- Can.Rec.Sci., 1886, p.4.

same year. He mentions Walcott's recent paper but writes of the oldest rocks in the Canadian Rockies as follows: "The old crystalline rocks form no part of the Rocky Mountains..... The lowest rocks here represented are quartzites, slates and shales more or less indurated, with occasionally true schists of a sub-crystalline character, forming a series several thousand feet in thickness and referable, so far as the scanty fossil evidence shows, to the Cambrian." The only rocks accepted as of pre-Cambrian age were those highly altered formations around the Shuswap lakes, and east of Osoyoos lake.

In 1888 G.M. Dawson[1], R.G. McConnell and W. Ogilvie

1 Dawson, G.M.- Geol.Surv.Can., Ann.Rept. 1887-88, Pt.B.

made a reconnaissance survey around the Lewes and Pelly rivers, up the Stikine river to Telegraph Creek, and via Dease lake to the junction of the Dease and Liard rivers, from Francis lake via the Upper Pelly river to the head waters of the Lewes, and from there by way of Chillcoot pass to the head of Lynn Canal. Despite lack of fossil evidence the oldest rocks were referred to the Palaeozoic.

In the same year Amos Bowman[2], in reporting on the

2 Bowman, Amos - Geol.Surv.Can., Ann.Rept. 1887-88.

lode gold possibilities of the Cariboo District, described metamorphic formations which extend from the north and east arms of Quesnel lake to the head waters of the Swift river, a distance of about forty miles. These he divided into two series on the basis of the apparent extent of metamorphism: "The characteristic rocks ...... appear to be related, and separable only by regarding the more crystalline as an older and underlying member". The older he referred to the Archean, the younger to the Cambrian.

In 1889 G.M. Dawson[1] described a series of mica-

1 Dawson, G.M.- Geol.Surv.Can., Ann.Rept. 1889.

schists, gneisses, hornblende-schists, hornblende gneisses and coarsely crystalline marbles distributed throughout an area along the Illicilliwaet river to Revelstoke, bordering the Columbia river and Arrow lakes to the junction of the Kootenay river, following the Kootenay east to Kootenay lake and from there northward to its head. He correlated these rocks, on lithological evidence, with the rocks surrounding the Shuswap lakes, which were referred to the Archaean,and named them the Shuswap series. Overlying the schists and gneisses are less metamorphosed sediments which are correlated, lithologically, with the Adams lake series to the west; and intermediate series, confined to the south-east shore of Upper Arrow lake correlates with the Niskonlith of the Shuswap lakes area. Although fossils were lacking in them, both here and in the Shuswap lakes country, Dawson believed the rocks younger than the Shuswap series to be Palaeozoic in age, probably lower Cambrian to Carboniferous. This belief was based on analogy between these and similar-appearing rocks of known age occurring elsewhere.

R.G. McConnell[2] described crystalline schists along

2 McConnell, R.G.- Geol.Surv.Can., Ann.Rept. 1889.

the Pelly-Yukon valley. "They bear a strong general resemblance to the Archaean rocks,recently described by Dr. Dawson....."

A.P. Coleman's[3] paper on the 'Big Bend' of the

3 Coleman, A.P.- Trans.Roy.Soc.Can., 1889, Sec.IV.

Columbia river, where the river encloses the Selkirk mountains on three sides, refers mica- and hornblende-schists, garnetiferous sericite-schists and schistose limestones to the Archean. He notes a resemblance between certain quartzites and soft green schists in this area and those described by R.G. McConnell[1] in the western part of Bow pass but makes no further

1 McConnell, R.G.- Geol.Surv.Can., Ann.Rept. 1886, p.25D.

comment upon their age.

Continuing his work upon the base of the North American Cambrian, C.D. Walcott[2] came to certain conclusions

2 Walcott, C.D.- Am.Jour.Sci., Vol.XXXVII, 1889.

which were to have a far reaching effect on the pre-Cambrian of the Cordillera. First, he defined the base of the Cambrian as the zone of the Olenellus fauna. Second, he showed that beneath this zone there were unaltered sediments still in existence: "The section laid bare in the Grand Canyon of the Colorado, beneath the great unconformity at the base of the known Cambrian, shows 12,000 feet of unaltered sandstone, shales and limestone that, I think, were deposited in pre-Cambrian time......"

In 1890, G.M. Dawson[3] made a reconnaissance across

3 Dawson, G.M.- Bull.Geol.Soc.Am., 1891, Vol.2, pp.165-176.

the Selkirk mountains along the line of the Canadian Pacific railway. He referred the gneisses and crystalline schists to the Shuswap series, Archean in age.

In 1891, J.P. McEvoy[4] mapped the gneisses and mica-

4 McEvoy, J.P.- Geol.Surv.Can., Summ.Rept. 1891.

schists around Shuswap, Long (Kalamalka), Mable and Sugar lakes as a continuation of the Shuswap terrane.

G.M. Dawson's paper, "Note on the Geological Structure of the Selkirk Range"[1] discusses the pre-Cambrian in some

1 Dawson, G.M.- Bull.Geol.Soc.Am., Vol.2, 1891.

detail and contains the first reference by a Canadian geologist to Walcott's conclusions. With reference to his Adams Lake series, which overlies his Shuswap series of Cuchean age, he wrote: "The peculiar lithological character (which, taken by itself, might be supposed to indicate that the rocks should be classed as upper parts of the Archean) of these Adams Lake schists is thus believed to depend chiefly on the dynamic metamorphism resulting from extreme pressure which has affected the volcanic components of the Palaeozoic, where these have been included in the strict flexures of the Gold system". In direct reply to Walcott's statement that a series of unaltered sandstone, shales and limestone underlies the Cambrian, he wrote: "In a late paper on the stratigraphical position of the Olenellus fauna Mr. C.D. Walcott has suggested that the Bow River series of the Canadian Rocky Mountains may be regarded as 'Algonkian'. He does not, however, appear to have been aware of the fact, above alluded to, that the Olenellus fauna characterizes both the upper part of this series and the lower part of the Castle Mountain group. With this circumstance in evidence, together with the complete stratigraphical conformity of the two series, the writer cannot but regard it as more in consonance with the conditions, so far as these are known, and therefore as more philosophical to include, for the present at least, the whole of this great conformable mass of rocks, to its base, under the name Cambrian. In Utah and Nevada, where Mr. Walcott's observations on the western Cambrian have chiefly been made, it seems that the beds classed as 'Algonkian' likewise in general conformably underlie those in which the Olenellus fauna is known, the conditions being apparently in most cases similar to those here described. On the propriety of the use of the new term in regions with which he is not personally familiar the writer wishes to offer no opinion, but he may take the opportunity of stating that he has met with no rocks in Canada to which its application can be considered at present appropriate, either in the interest of precision in the expression of facts already ascertained, or because of the discovery of heretofore unrecognized relations as between the older formations."

In 1896, R.G. McConnell[1] referred to the Shuswap series a terrane of mica-gneisses, schists and crystalline limestones occurring along the Finlay and Omineca rivers, in northern British Columbia.

In 1897, G.M. Dawson[2] discussed his "Archean" as follows: "Rocks referable to the Archean obtain a considerable development in British Columbia, but it has not so far been found possible to recognize definitely the Laurentian and Huronian systems. Where they have been noted and examined, chiefly in the Gold ranges and Interior plateau, they have been

1 McConnell, R.G.- Geol.Surv.Can., Ann.Rept., Vol.VII, 1894.

2 Dawson, G.M.- The Handbook of Canada, 1897.

distinguished as the Shuswap series. They include rocks resembling the Fundamental Gneiss of the east in character and composition, together with crystalline limestones, quartzites and gneissic rocks resembling those of the Grenville series and evidently representing metamorphosed sediments. At this distance from the typical developments of the Laurentian, it is not to be expected that any precise parallelism in mineral composition and degree of alteration can be established, but that these rocks really are Archean has been determined by their unconformable infraposition to the lowest Palaeozoic strata."

In a marginal note on his "Shuswap Sheet"[1], issued in 1898, Dawson reiterates his conviction that the Shuswap series is referable to the Fundamental Gneiss.

1 Dawson, G.M.- The Shuswap Sheet, Geol.Surv.Can., 1898.

In 1899, R.W. Brock[2] described "Shuswap-like" schists and gneisses in the vicinity of Lower Arrow lake and in so describing them was the first to cast doubt upon the reference of such rocks, in the interior of British Columbia, to the Shuswap series since it was described and named by Dawson in 1889.

2 Brock, R.W.- Geol.Surv.Can., Summ.Rept. 1899.

The influence of the reputation of G.M. Dawson, as an authority on the geology of British Columbia, may be gauged from the report by J.P. McEvoy[3] on the rocks of the south-western part of East Kootenay: "While no fossils were found to determine the age of these beds, and from their appearance they

3 McEvoy, J.P.- Geol.Surv.Can., Summ.Rept. 1899.

might belong either to the Carboniferous or Devonian, the fact that Carboniferous rocks are known to occur in many places in the southern interior of British Columbia, and that so far there is no positive information as to the existence of the latter, is perhaps sufficient reason to provisionally class them as Carboniferous." He refers some neighbouring beds to the Cambrian, but in spite of the lack of fossils in unaltered rocks in which they might well be expected his report contains no hint of the possibility of their being older than the Cambrian. Had Dawson not correlated his older formations so definitely on lithological grounds, had he not confined his pre-Cambrian to the highly metamorphosed rocks and had his reputation for sound work been less than it was, such a loose correlation could never have been seriously offered. It is true that McEvoy was a topographer rather than a geologist, but the correlation was accepted and published by the Geological Survey of Canada.

In 1899, Walcott[1] defined the term "Algonkian" as a

1 Walcott, C.D.- Bull.Geol.Soc.Am., 1899, pp.199-244.

term given by the U.S.G.S.[2] to the period embracing the time

2 U.S.G.S., Bull.81, 1891, p.362.

of deposition of the clastic rocks older than Cambrian. The base of the Algonkian is the lowest of the recognizable clastic rocks, the base of which rests upon the Archean. He included in the Algonkian the Belt terrane of Montana, the Grand Canyon series of Arizona, the Llano series of Texas and the Avalon terrane of Newfoundland. An investigation of the lower Cambrian-Beltian contacts as exposed in the Belt mountains of Montana disclosed the following information: "..... a great stratigraphic unconformity between the Cambrian and the Belt formations; that the Belt terrane was divisible into several formations, and that fossils occurred in the Greyson shales nearly 7000 feet beneath the highest beds of the Belt terrane." The first statement of the fact that unaltered pre-Cambrian formations exist in the Canadian Cordillera is contained in this paper: "Beneath the lowest horizon carrying the Olenellus fauna of the Cordilleran region of the United States and British Columbia there is a great series of slates, sandstones and, occasionally, thin-bedded limestones in which no trace of life has been discovered. What their relations are to the Belt series of Montana and the Grand Canyon series of Arizona is unknown as in no locality have they been seen in contact."

In 1900 J.P. McEvoy[1] reported on a strip of territory extending from Edmonton westward through the Yellowhead pass in the Rocky Mountains, down the Fraser river to Tete Jaune Cache and from there to the head waters of the Canoe river. He describes two conglomerates, one on the Miette river, the other between Tete Jaune Cache and Canoe river, which he correlates lithologically with Dawson's Bow River conglomerate. The unfossiliferous slates, quartzites and limestones are correlated with the Bow River series (Cambrian); a series of garnetiferous mica-schists, micaceous eruptives and

1 McEvoy, J.P.- Geol.Surv.Can., Ann.Rept. 1898, pp.1-41D.

gneisses is referred to the Archaean because of its similarity to the Shuswap series. He reports pegmatite veins up to fifty feet in thickness cutting the schists and gneisses but no conclusions affecting the age of the metamorphosed rocks, nor even of their metamorphism, is drawn from the association of these veins with garnetiferous schist.

In 1901, R.G. McConnell[1], reporting on "The Klondike

1 McConnell, R.G.- Geol.Surv.Can., Ann.Rept. Vol.XIV, 1901.

Gold Fields", described three pre-Cambrian formations. The oldest, the 'Nasina" series, consists of quartzites, quartz-mica-schists, green chlorite- and actinolite-schists and bands of crystalline limestone, the green chlorite- and actinolite-schists representing intrusives and extrusives younger than the sediments, occurring in the Yukon River valley between Fort Selkirk and Fortymile river. Next in age, and intrusive into the Nasina series, is the "Klondike" series of sericite schists, and ordinary and augen gneisses representing altered quartz and granite porphyries, and chlorite- and amphibolite-schists representing basic porphyries; a gneissic phase, the "Pelly" gneisses is everywhere associated with them. The Klondike series crosses the central portion of the Klondike District, northwest to southeast in a band of from ten to twenty miles in width, bordered on both sides by the Nasina schists. The third formation, the "Moosehide" diabase, found in the lower Klondike valley, on Moosehide mountain, to the north, and on the western bank of the Yukon river, opposite Moosehide mountain, is a somewhat sheared diabase which he considered nearly the equivalent of the Klondike series in age.

In 1904, Jos. Keele[1] described a series of quartzites,

1 Keele, Jos.- Geol.Surv.Can., Ann.Rept. 1904, Pt.A, p.18.

mica-schists and graphitic schists of sedimentary origin near Mayo lake in the country surrounding the head waters of the Stewart river which he correlated with McConnell's Nasina series. A younger quartz-porphyry, altered to sericite schist, is correlated with the Klondike series.

In the same year McConnell[2] described his "Kluane"

2 McConnell, R.G.- Geol.Surv.Can., Ann.Rept. 1904, Pt.A., p.1.

series, principally quartz-mica-schists of sedimentary origin, which occur in the Kluane hills along the north shore of Kluane lake in southwestern Yukon. The Kluane series is intruded by the Coast Range batholith.

It is noteworthy that these Yukon formations, though agreeing in their characteristics with the Shuswap terrane of Dawson, were not so named. The fashion of referring highly metamorphosed rocks to the Shuswap series was becoming obsolete.

In 1906 Walcott[3] correlated the Algonkian formations

3 Walcott, C.D.- Bull.Geol.Soc.Am., Vol.17, 1906, pp.1-26.

of northwestern Montana, the Belt series in British Columbia east of the Kootenay river, the Niskonlith and Adams lake series of the Shuswap lakes area, and the Castle Mountain and Bow River series on the 51st parallel. "From the known presence of upward of thirty thousand feet of pre-Cambrian unaltered sediments in Montana and Idaho, on the strike of the strata of the Adams Lake and Niskonlith series, it appears to be more probable that the Niskonlith and most of the Adams Lake (Selkirk) series are of pre-Cambrian age and to be correlated with the Belt terrain as developed in northwestern Montana and northern Idaho....... The Creston and Kitchener quartzites appear to belong to the lower portion of the Algonkian section....... From the presence of Lower Cambrian fossils in the Bow River series of McConnell it is believed that this series was laid down in the erosion interval between the Algonkian and the Middle Cambrian in Montana."

In 1909 G.S. Malloch[1] divided the oldest rocks

1 Malloch, G.S.- Geol.Surv.Can., Summ.Rept. 1909, pp.126-127.

between Tete Jaune Cache and Fort George, along the Fraser river, into a Shuswap group of schists and gneisses, a Lower Cambrian Bow River series and an Upper Cambrian Castle Mountain series of relatively slightly altered rocks. He suggests that the Shuswap group represent metamorphic phases of grey quartzites of the Castle Mountain series.

In 1910 Walcott[2] found a fine quartz conglomerate,

2 Walcott, C.D.- Smithsonian Misc. Coll., Vol.53, 1910, pp.423-431.

one hundred feet thick, at the base of the Lower Cambrian in the Bow River valley. Beneath the conglomerate he found two sandstone formations to which he gave the names "Hector" and "Canal Creek". These rocks were formerly included in McConnell's Cambrian Bow River series. The Hector and Canal Creek formations were correlated with the Camp Creek and Kintla-Sheppard formations "which lie beneath the Cambrian and above the Siyeh limestone in Montana, southwestern Alberta and southeastern British Columbia."

In 1911 R.A. Daly[1] reported on a reconnaissance of

1 Daly, R.A.- Geol.Surv.Can., Summ.Rept. 1911, pp.165-174.

the Shuswap terrane in the vicinity of the Shuswap lakes. Important changes in the conception of the relationship of the Shuswap series to overlying formations were made: (1) the Shuswap series is a thermally metamorphosed facies of the Niskonlith and Adams Lake series, the alteration being due to pre-Beltian granites; (2) the Adams Lake and Niskonlith series are not Cambrian but pre-Beltian; (3) the term "Shuswap series" was enlarged to include all pre-Beltian rocks; (4) the name "Niskonlith" was dropped as a designation for any of the rocks so named by Dawson since these rocks were of differing ages. An important result of Dr. Daly's work in this area was his recognition of the fact that the "Shuswap" schists and gneisses are not necessarily a separate entity but that they may be highly altered facies of neighbouring formations. The lithological similarity between the Shuswap series and the "Fundamental Gneiss" of eastern Canada, the basis of Dawson's belief that the series is Cuchean, is thus, by inference, shown to be meaningless.

In 1912 Daly[2] described the rocks occurring along the

2 Daly, R.A.- Geol.Surv.Can., Mem.38, 1912.

49th Parallel from the Pacific coast to the Great Plains. The basal formations of his column are those of the Priest River terrane, quartzites, dolomites, phyllites and schists, which he tentatively correlated with Dawson's Niskonlith of the Shuswap lakes area. The similarity of this terrane to pre-Cambrian strata in the United States is noted, and the terrane is so mapped. Rocks younger than the Priest River are described under the names Summit series, Purcell series, Galton series and Lewis series, all of which are described later. The base of the Summit series is the Irene conglomerate which Daly described as marking an unconformity between the Summit series and the Priest River terrane: "The colour, composition and general field habit of the quartzite, phyllite and dolomite pebbles clearly show their derivation from the underlying Priest River terrane." Correlation of all the unfossiliferous formations is on the grounds of lithology and the errors in age determination,which have since been discovered, are the inevitable outgrowths of the lithological correlations by Dawson and McConnell of the formations to the north. These formations are placed, for the most part, in the Palaeozoic. Walcott's arguments for their pre-Cambrian age are reviewed and denied. The great limestone (Siyeh) beds which occur in many parts of the region are described as chemical precipitates[1] which could not be expected to hold fossils.

1 Daly, R.A.- Op.cit., Pt.II, p.670.

In 1914 S.J. Schofield[2] discovered a section near Elko, B.C., in which the pre-Cambrian-Palaeozoic contact is well exposed. Evidence derived from an investigation of this contact enabled Schofield to show that all of Daly's unfossiliferous formations were to be referred to the pre-Cambrian in age. Daly's Moyie River section[3] was altered by the

2 Schofield, S.J.- Geol.Surv.Can., Mus.Bull. 2, 1914, pp.79-91.

3 Daly, R.A.- Geol.Surv.Can., Mem.38, 1912.

differentiation of the rocks there grouped as Kitchener into two formations,- one, named the "Aldridge", older than the Creston formation of the Purcell series; the other younger, for which the name "Kitchener" was retained.

Dr. Schofield's paper defined the pre-Cambrian essentially as it is now conceived. The formations of south-eastern British Columbia, by reason of the comparatively large amount of work done on them, must be taken as the type sections to which other unfossiliferous strata of the Cordillera in Canada are to be referred for correlation.

Bancroft correlates the Irene conglomerate with the Toby conglomerate of the Windermere.[1] If this correlation is correct the Summit series is of Windermere age, at least in part, and the Priest River terrane may be either Beltian or pre-Beltian. The writer is not conversant with Dr. Bancroft's evidence in support of the correlation.

Drysdale,[2] in 1917, discovered Carboniferous fossils in the Laurie formation of Daly's[3] "Beltian" in the Selkirk mountains. Since the formations of the Albert Canyon division, in which the Laurie is included, are mutually conformable, it is probable that all of Daly's "Beltian" above the unconformity with the Shuswap series, the Albert Canyon division and the Glacier division, are Palaeozoic in age.

The problem of the age of the Shuswap series is reviewed in a later chapter.

1 Geol.Surv.Can., Mem.148, 1926, p.18.

2 Geol.Surv.Can., Mem.117, 1920, p.18.

3 Daly, R.A.- Geol.Surv.Can., Mem.68, 1915.

CHAPTER III

CLASSIFICATION AND DESCRIPTION OF FORMATIONS.

The pre-Cambrian formations of the Canadian Cordillera are grouped, in this chapter, as Schistose and Non-Schistose Beltian after a scheme outlined by S.J. Schofield. The division is based, as the names suggest, on the predominance of schistose and gneissic or of massive rocks in each series.

Map 1. shows that the schistose Beltian forms a more or less continuous band that parallels the trend of the Cordillera from the 49th parallel into the Yukon. It is associated with areas in which batholithic intrusion has occurred. The non-schistose Beltian, on the other hand, is found in areas in which igneous rocks are comparatively scarce. This relationship suggests that the thermal metamorphism of pre-Cambrian sediments in the Canadian Cordillera is due to the Mesozoic and Tertiary intrusions rather than to igneous activity in pre-Cambrian times. This possibility is discussed in the chapter devoted to the problem of the Shuswap series.

The correlation of pre-Cambrian of south-eastern British Columbia, as regards the Lewis and Galton series in particular, follows that given by Schofield.[1]

1 Schofield, S.J.- Geol.Surv.Can., Mus.Bull. 2.

Non-Schistose Beltian.

The non-schistose Beltian rocks are the Galton and

PLATE II.

Correlation of the Non-Schistose Beltian.

1. Field Map-Area.		2. Windermere and Lardeau Map-Areas.	3. Purcell Range.	4. Purcell Trench to Pend D'Oreille River	5. Rocky Mountains B.C.	6. Clarke and Lewis Ranges 49th Parallel
Conformable with L. Cambr. in places.	Unconformity		Erosion Surface		Unconformity	Erosion Surface.
	Windermere Series	Lardeau.				
	Windermere Series	Badshot.				
	Windermere Series	Hamill.		Wolf etc(?)		
Hector and Corral Creek	Windermere Series	Horsethief.		Monk Irene Volcanics		
	Windermere Series	Toby Conglomerate.		Irene Conglomerate.		
	Unconformity			Unconformity		
	Purcell Series, Upper	Mount Nelson.			Roosville.	
	Purcell Series, Upper	Dutch Creek.	Gateway.		Phillips. Gateway.	Kintla Sheppard.
	Purcell Series, Lower		Purcell Lava.		Purcell Lava.	Purcell Lava.
	Purcell Series, Lower		Siyeh.		Siyeh.	Siyeh.
	Purcell Series		Kitchener		Wigwam MacDonald Hefty Altyn	Grinnell. Appekuny Altyn
	Purcell Series		Creston			
	Purcell Series		Aldridge	Priest River Terrane.		

1. Allan, J.A.- G.S.C., Mem.55.
2. Walker, J.F.- G.S.C., Mem.161.
3. Schofield, S.J.- G.S.C., Mus.Bull. No.2.
4. Walker, J.F.- G.S.C., Mem.148.
5. Schofield, S.J.- G.S.C., Mus.Bull. No.2.
6. Daly, R.A.- G.S.C., Mem.38.

Lewis series of the International Boundary, from Kootenay river eastward to the eastern front of the Clarke range, the Purcell series of southern East Kootenay, the Windermere series in the northern part of Kootenay district, and the Hector and Corral Creek formations of the Bow River area. The most complete section of the Beltian is afforded by the Windermere and the older Purcell series.

PURCELL SERIES.[1]

1 Schofield, S.J.- Personal Communication.

The Purcell Series is an ancient group of sediments deposited on the western side of the Rocky Mountain geosyncline. They consist of a great thickness of fine-grained quartzites, argillaceous quartzites, argillites and limestones, all forming a remarkably homogeneous series. Shallow water characteristics, including ripple-marks, rain-pits and mud-cracks are common at various horizons. The series extends southward across the International Boundary into Idaho and Montana; the northern limit has not been definitely determined; the western limit is obscured by batholithic intrusion but it probably is represented in the schistose rocks in the Selkirk mountains; the sediments pass unconformably under the Palaeozoic formations of the Rocky mountains to the east.

Aldridge Formation: The Aldridge formation is at the base of the Purcell series. It consists of dark grey argillaceous quartzites and purer quartzites and argillites in beds a fraction of an inch to several feet in thickness. These rocks weather to a rusty brown colour. They are exposed to a thickness of over 8000 feet; the base is not known.

<u>Creston Formation</u>: The Aldridge formation passes by gradual transition into the overlying Creston formation. The Creston is dominantly orgillaceous quartzites, quartzites and argillites in beds of about one foot in thickness. Green and purple coloring is common. These rocks are often characterized by a peculiar interrupted banding (~~Fig.~~ Plate XI) which is not precisely duplicated in any other formation of the Purcell series. The weathered surface is greyish in tone. The thickness is 4500 feet.

<u>Kitchener Formation</u>: The Creston formation passes by insensible gradation into the Kitchener formation. The Kitchener is essentially a limestone formation, with limy quartzite and argillite. The limestones contain the "molar tooth" structure (~~Fig.~~ Plate XIII), caused by a leaching of soft carbonate from between irregular siliceous bands, the mode of formation of which is not known. The Kitchener formation is 4500 feet thick.

<u>Siyeh Formation</u>: The Siyeh formation conformably overlies the Kitchener. The lower part is composed of thin-bedded, green and purple, mud-cracked metargillites and sandstones. About 2000 feet above the base occur thin-bedded and massive siliceous, concretionary limestones, grey on fresh fracture and weathering grey and buff. They reach a thickness of about 1000 feet. The limestones are succeeded by purple and green mud-cracked metargillites in thin beds. The thickness is 4000

feet.

Purcell Sills: The Purcell sills is a group of tabular intrusive bodies which were intruded between the horizontal strata of the Purcell series and were later tilted with the series. The sills vary in composition from a hypersthene gabbro through intermediate types to a very acid granite or granophyre; the texture varies from fine-grained to porphyritic. The sills are present in greatest abundance in the Aldridge formation and occur occasionally in the Creston and Kitchener and sparingly in the Siyeh.

Purcell Lava: The Purcell lava overlies, and in places is interbedded with, the Siyeh formation. It is principally an amygdaloidal basalt and because of a similarity in composition it is believed to represent an extrusive phase of the Purcell sills. The thickness of the flows varies from 50 feet to 300 feet.

Gateway Formation: This formation rests conformably upon the upper member of the Purcell lava. The lower part consists of alternating bands of concretionary, siliceous dolomite and limestone weathering buff and massive light-grey quartzites. These are succeeded by thin-bedded sandy argillites, which are characterized by the presence of casts of salt crystals in abundance, and greenish-grey siliceous argillites. The thickness is about 1000 feet.

Phillips Formation: The Gateway formation passes gradually into the overlying Phillips formation which consists of dark purplish and red metargillites, sandy argillites and sandstones. The thickness is 500 feet.

Roosville Formation: The Phillips formation is overlain conformably by the Roosville formation which is composed mostly of massive, laminated, green, siliceous metargillites weathering greenish grey and rusty brown. Mud-cracks are abundant at all horizons. The thickness is 1000 feet.

Mount Nelson Formation: The Mount Nelson formation rests conformably upon the Dutch Creek formation which is the northern extension of the Roosville, Phillips and upper part of the Gateway. It comprises a succession of crystalline magnesian limestones and slates and has at its base, and also near the upper eroded surface, massive white quartzites. It is overlain unconformably by the Windermere series and has an observed thickness of 3,400 feet.

WINDERMERE SERIES.[1]

1 Walker, J.F.- Geol.Surv.Can., Mem.148, 1926.
Geol.Surv.Can., Mem.161, 1929.

The Windermere series is Late Pre-Cambrian in age and lies unconformably above the Mount Nelson formation of the Purcell series. The basal Toby conglomerate and the Horsethief formation are in the Windermere map area in the vicinity of lake Windermere in the east Kootenay district; the Hamill series, Badshot formation and the Lardeau series occur in the Lardeau map area, a long, irregular strip of country reaching from the north end of Kootenay lake northwestward across

Selkirk mountains to Columbia valley at Revelstoke. Besides the basal conglomerate, the series consists of slates, pebble conglomerate, quartzites, schists, limestones and phyllites apparently in unbroken succession.

Toby Conglomerate: The Toby conglomerate is the basal member of the Windermere series. It overlies, unconformably, both the Mount Nelson and, in one place, the Roosville formations of the Purcell series. It is extremely variable; in places the matrix is largely slate through which are scattered fragments of slate and shale and occasional boulders of limestone and quartzite. The materials composing the conglomerate have not travelled far and in all cases the boulders can be identified with underlying rocks of the Purcell series. Many of the boulders are rounded but many also are subangular and angular, indicating rapid erosion and transportation. The boulders and fragments vary from four to five feet down to pebbles and shingle; the average size is from four to ten inches. The formation varies in thickness from 50 to 2000 feet.

Horsethief Formation: The Horsethief formation conformably overlies the Toby conglomerate. It is made up in large part of grey, green and purplish slate with several lenticular beds of coarse quartzite and pebble conglomerate and numerous thin interbeds of blue-grey, crystalline, and mostly non-magnesian, limestone, which occur at different horizons but form a relatively small part of the whole formation. Most of the pebbles are quartz and quartzite but a few are limestone;

all are well sorted and closely packed. The average maximum size of the grains is one and one-half inches. The Horsethief formation varies in thickness from 4000 to 5000 feet.

Hamill Series: The Hamill series rests conformably on the Horsethief formation. It is a succession of strata varying in nature from quartzite to schist and limestone; a great thickness of quartzite is taken as the base.

Badshot Formation: The Badshot formation is a grey, crystalline, sometimes siliceous limestone, in places well bedded, at other points massive. It is conformable with the Hamill series and varies from 150 to several hundred feet in thickness.

Lardeau Series: The Lardeau series conformably overlies the Badshot formation. It lies in a great synclinal trough northwest of Kootenay lake, a heterogeneous assemblage of metamorphosed sediments. The lowest member is a black carbonaceous rock, a slate, phyllite or schist depending upon the degree of metamorphism, succeeded by grey to greenish phyllites and schists, calcareous in part, and these in turn are overlain by a fine-grained, highly carbonaceous siliceous rock, weathering with a vesicular appearance. The latter resembles an igneous rock in appearance but has been determined as of sedimentary origin by Walker.[1]

1 Walker, J.F.- Geol.Surv.Can., Mem.161, 1929, p.11.

BOW VALLEY PRE-CAMBRIAN ROCKS.[1]

1 Walcott, C.D.- Smithsonian Misc.Coll., Vol.53, No.7, 1910.

Bow Valley, Alberta, is underlain by unaltered sedimentary strata of pre-Cambrian age from Hector lake to the vicinity of Cascade station on the Canadian Pacific Railway. These are shale and sandstone formations to which the names Hector and Corral Creek formations have been applied. The base of the formations is not known; they are unconformably overlain by a middle Cambrian conglomerate on the south slopes of Castle Mountain. They are roughly correlative with the Windermere series.[2]

2 Schofield, S.J.- Personal communication.

Corral Creek Formation. The basal formation is composed of hard quartzitic sandstones overlain by coarse-grained light-grey sandstone in massive layers with some interbeds of fine quartz conglomerate. The base has not been recognized. The measured thickness is 1320 feet.

Hector Formation: The Hector formation conformably overlies the Corral Creek. At the base is a reddish purple, arenaceous, siliceous shale with greenish bands. Over this is a massive bedded conglomerate, quartz pebbles and fragments of grey pinkish limestone in a coarse sandstone matrix. "This is evidently a deposit made from material brought down by a river reaching back into the hills of that epoch. The presence of limestone is very important, as it indicates limestones below any exposures of the pre-Cambrian rocks of the Bow Valley."[3]

3 Walcott, C.D.- Smithsonian Misc.Coll., Vol.53, No.7,1910,p.42B.

Overlying the conglomerate are beds of greenish, purple, dark-grey and black arenaceous and siliceous shales. The Hector formation is 1300 feet thick.

SUMMIT SERIES.[1]

[1] Daly, R.A.- Geol.Surv.Can., Mem.38, 1912, p.141 et seq.

The Summit series was described by Daly in 1912. It is a succession of conglomerates, effusive greenstones, quartzites, sandstones, phyllites and siliceous grit in the Selkirk mountains, at the 49th Parallel. The correlation of the basal formation, the Irene conglomerate, with the Toby conglomerate, by Bancroft, refers the Summit series to the Windermere in age.

Irene Conglomerate: The Irene conglomerate is the basal member of the Summit series. It marks an unconformity with the underlying, schistose, Priest River terrane. Coarse conglomerate is the highly dominant constituent of the formation. The pebbles are squeezed and well water-worn, ranging in size from coarse sand-grains to bouldery masses a foot or more in diameter. The cement is a schistose, crystalline mass, probably derived from greywacke or very muddy sand. The character of the pebbles indicates that the conglomerate was derived from the eroded Priest River terrane. The formation is more than 5000 feet thick.

Irene Volcanics: Through interbedding, the conglomerate is transitional into the overlying Irene Volcanic formation, a great mass of basic lava flows. Intercalated in the lava flows are a few subordinate layers of basic tuff, a thick band of conglomerate-breccia and a strong bed of dolomite. The mass has been greatly altered and schisted by dynamic metamorphism. It is 6000 feet thick.

Monk Formation: The Monk formation conformably overlies the Irene Volcanics. The rocks are phyllitic slate, phyllite, schistose conglomerate, sheared quartz conglomerate, schists, slate and grit, 5,500 feet in thickness.

Wolf Formation: The Wolf formation is predominantly quartzite with sandstone and a feldspathic quartz grit or conglomerate, conformably overlying the Monk formation. It is 2,900 feet thick.

Dewdney Formation: By insensible gradation the Wolf formation passes into the conformably overlying Dewdney formation, banded quartzites, of a finer grain than those of the Wolf, with two bands of coarse conglomerate, greatly subordinate to the quartzites in thickness. The Dewdney formation is 2000 feet thick.

Ripple Formation: The Ripple formation conformably overlies the Dewdney. It is a uniform, hard, very heavily plated white quartzite, a principal feature of which is the occurrence of extremely well preserved ripple-marks at various horizons. It is 1,650 feet thick.

Beehive Formation: The Ripple quartzite passes abruptly into the conformably overlying Beehive formation. The dominant rock-type is a thin to medium-bedded, light greenish grey quartzite, weathering rusty brown with thin, though numerous interbeds of dark greenish, siliceous metargillite, weathering dark brown or dark grey; ripple-marks, sun-cracks and annelid trails are plentiful. Over this bed are thinner beds of grey and white quartzite, light grey limestone, phyllites and siliceous metargillites. The thickness is 7000 feet.

Lone Star Formation: The Beehive formation merges gradually into the overlying Lone Star formation. This formation consists principally of dark-grey or greenish-grey, often carbonaceous phyllite, with some greenish sericite-quartz schist and thin interbeds of light-grey quartzite. The whole formation is highly metamorphosed. It is 2000 feet thick.

GALTON AND LEWIS SERIES.

The Galton series lies in the MacDonald and Galton ranges and the Lewis series in the Clarke range of the Rocky mountains at the 49th Parallel. A number of formations are common to both and to the Purcell series described above. The correlation table for the Galton and Lewis series is given here and the description of formations is confined to those not found in the Purcell series.

Galton Series	Lewis Series
Unconformity with Lowest M.Cambrian)	
Roosville, 1000 feet	Erosion surface
Phillips, 500 feet	

(Galton Series)	(Lewis Series)
Gateway, 2,025 feet	Kintla, 800 feet Sheppard, 600 feet
Purcell Lava	Purcell Lava
Siyeh, 4000 feet	Siyeh, 4,100 feet
Wigwam, 1,200 feet MacDonald, 2,350 feet Hefty, 775 feet	Grinnell, 1,600 feet Appekung, 2,600 feet
Altyn, 650 feet	Altyn, 3,500 feet Waterton, 200 feet

Waterton Formation: The Waterton formation is the oldest known formation of the Lewis series. It consists of a strong, massive, dark grey dolomite, resembling, in hand specimen, a thick-bedded argillite.

Altyn Formation: The Altyn formation overlies the Waterton conformably in the Lewis series and is the oldest known formation of the Galton series. The rock types include arenaceous magnesian limestones, dolomitic sandstones, dolomitic grits and pure dolomites, named in the order of relative importance.

Hefty Formation: The Hefty formation conformably overlies the Altyn in the MacDonald range. The dominant rock-type is a heavily bedded red or reddish-grey sandstone, occasionally somewhat calcareous. Its mass is interrupted by thin beds of red shale and by rarer light greenish-grey, brown-weathering quartzites. Sun-cracks and ripple-marks are common at various horizons.

MacDonald Formation: The MacDonald formation conformably overlies the Hefty. The formation is notably homogeneous in respect to the main lithological features; the principal rock-type is a highly siliceous argillite or metargillite.

Wigwam Formation: Conformably overlying the MacDonald is the Wigwam formation, fairly homogeneous red or brownish-red sandstones, interrupted by partings of red, siliceous metargillite. The bedding is generally thin. Throughout the formation sun-cracked, ripple-marked,sometimes cross-bedded, horizons occur.

Appekung Formation: The Appekung formation conformably overlies the Altyn in the Clarke range. It is a mass of highly siliceous argillite, in general of a dark grey color and thin-bedded. There are several definite horizons of a whitish quartzite from 15 to 20 feet thick. The strata are frequently ripple-marked and occasionally coarse-grained, but nowhere conglomeratic.

Grinnell Formation: The Grinnell formation, conformably overlying the Appekung, is predominantly a shaly argillite, exhibiting ripple-marks, mud-cracks and the irregular surfaces of shallow water deposits. It may be a phase of the Appekung with the line of distinction between them diagonal to the stratification.[1]

1 Willis, B.- Bull.Geol.Soc.Am., Vol.13, 1902, p.322.

Sheppard Formation: The Sheppard formation conformably overlies the Purcell lava in the Clarke and Lewis ranges. It is dominantly dolomitic with interbeds of quartzite, argillite and basic, amygdaloidal, lava. It has been well silicified.

Kintla Formation: The Kintla formation conformably overlies the Sheppard formation. It is a sequence of deep-red argillaceous quartzites and siliceous shales, with marked white quartzites and occasional calcareous beds.

FRANKLIN MOUNTAINS.

M.Y. Williams[1] describes a shale formation underlying grits, conglomerates and sandstones in the Franklin mountains. The younger beds are correlated, by lithological similarity, with Schofield's Cambrian near Cranbrook, B. C., and, on the assumption that the conglomeratic phase indicates a basal unconformity, the shales are tentatively referred to the pre-Cambrian.

1 Williams, M.Y.- Summ.Rept. 1922, Pt.B, p.75.

The Schistose Beltian.

In this division are included all the presumably Beltian formations which have undergone a high degree of metamorphism. It must be realized that, with the exception of the Priest River terrane at the 49th Parallel, no evidence has been produced to prove that any of these formations are definitely pre-Cambrian in age. Formations of Carboniferous age rest conformably upon the schistose formations throughout British Columbia; in the Yukon (60° N Lat.) area they are overlain by fossiliferous Middle Cambrian rocks. No definite correlation has been made throughout the schistose belt and it is doubtful that these formations represent a common period of deposition.

Partly because of the ambiguity existing in regard to the age of so many of these formations and partly because of the marked lithological similarity that exists throughout, type sections have been selected. These are the Priest River terrane at the 49th Parallel; Cairnes' pre-Cambrian between Slocan and Upper Arrow lakes; Daly's Shuswap terrane at Shuswap lake; Uglow's Barriere, Fennel and Badger Creek formations in the North Thompson valley; the Cariboo series of Johnson and Uglow; the pre-Cambrian of the Finlay river area as described by Dolmage; and the Yukon, Mount Stevens and Tindir groups in Yukon Territory as described by Cockfield. All the supposedly pre-Cambrian schistose terranes omitted in this section have been referred to in previous chapters and a detailed description here would entail much repetition without adding to the clarity of discussion.

PRIEST RIVER TERRANE.[1]

1 Daly, R.A.- Geol.Surv.Can., Mem.38, 1912, p.258.

The Priest River terrane outcrops at, and to the eastward of, the head waters of Priest river, in the southern Selkirk mountains. Schofield[2] had correlated it with the

2 Schofield, S.J.

Aldridge formation of the Purcell series. Daly has subdivided the terrane into several irregular belts, A, B, C, D, E, F and G, running, in general, meridionally and following the strike of the bedding planes. The terrane has been intruded by the Ryckert and Bayonne batholiths which Daly assigns to the Jurassic and Tertiary respectively.

Belt A: This is a heterogeneous group of rocks including biotite, chlorite and sericite schists; sheared, compact quartzites; and dolomites. The micaceous schists occupy most of the belt; sericite quartzites are next most abundant; the dolomites occur as thin bands intercalated in schist and quartzite.

Belt B: The next belt, to the east, is similar to Belt A but here the dolomite is the dominant rock type.

Belt C: This belt is composed, essentially, of well and thinly foliated phyllites, chlorite-sericite schists and phyllitic biotite-sericite schists, all tending toward a dark greenish-grey colour. No dolomite was found. Within the staple rocks there occur strong bands of dark grey, intensely sheared, quartzite in which was found an opaque black dust believed to be carbon.

Belt D: This is dominantly a more or less sheared quartzite compact in texture and varying in colour from white to pale greenish-grey. Within the quartzite beds are numerous, though thin, intercalations of sericitic and chloritic schists along with beds of dolomite. The belt is intruded by the

Bayonne batholith and near the contact large foils of biotite and muscovite have developed.

Belt E: Belt E is composed of acid sediments more highly metamorphosed than those of Belt D. The dominant type is a highly sericitic schist in which large biotite foils have been extensively developed along the planes of schistosity. The general ground mass of the rock is a felt of quartz and abundant sericite, with round or hexagonal biotite plates ranging from 1 mm. to 3 mm. in diameter. Pale-reddish anhedral garnets often accompany the biotite plates. In the biotite schists is one band of amphibolite about one hundred feet thick that is evidently a sheared and metamorphosed basic intrusive. A second altered basic intrusive occurs as a hornblende chlorite schist.

Belt F: Like Belt D, this belt is composed of sheared quartzite with subordinate interbeds of mica schist. The quartzite, however, is more nearly a true quartz schist. A band of garnet-bearing amphibolite occurs near the contact with the Ryckert batholith.

Belt G: This belt is essentially composed of glittering, coarse to medium grained mica schists, varying in colour from light to dark greenish-grey and dark rusty brown. The average phase is distinctly more ferruginous than any of the other six belts. As a rule the schists are well banded and the bands are believed to represent true bedding. The original sediments were doubtless chiefly argillites, more or less rich in silica, with subordinate thin interbeds of sandstone. Their existing metamorphic equivalents are muscovite biotite schists carrying variable and often important amounts of red garnet, yellow epidote and tourmaline.

SLOCAN AND UPPER ARROW LAKES AREA.[1]

1 Cairnes, C.E.- Geol.Surv.Can., Summ.Rept. 1928, Pt.A, p.96.

A series of crystalline schists interbedded with massive, light-coloured quartzite, crystalline limestone, greenstone and paragneisses, lying unconformably beneath the Mesozoic Kaslo series, is referred to the pre-Cambrian. No formation name has been assigned to it and no correlation with individual neighbouring pre-Cambrian formations is offered.

The crystalline schists are medium- to coarse-grained rocks distinguished by their lustrous appearance and schistose structure. Meta-crystals of staurolite, scapolite and garnet are fairly common; red garnets are particularly abundant in some beds.

The quartzites are light-coloured, massive, well-bedded rocks in which there is commonly quite an abundant development of biotite and garnet.

The limestone beds are coarsely crystalline, white rocks carrying more or less quartz. Small flakes of graphite are commonly present and other secondary minerals include garnet, diopside and epidote.

The paragneisses appear as a gradational phase between the crystalline schists and the associated gneissic intrusives of the Nelson batholith and they represent a more or less completely digested product of the older rocks.

A belt of greenstone schist, several hundred feet wide, crosses Upper Arrow lake south of St. Leon and Pingston creeks. This greenstone has the appearance of an altered volcanic rock. It is overlain by granular, quartz-biotite schists carrying, in places, large crystals of feldspar and what appear to be deformed and altered rock fragments as well as occasional well-rounded pebbles of quartzite.

SHUSWAP TERRANE.[1]

1 Daly, R.A.- Geol.Surv.Can., Mem.68, 1915, p.10 et seq.

The Shuswap terrane comprises the oldest formations in the area lying between Golden and Kamloops along the main line of the C.P.R.

Tonkawatla Formation: The Tonkawatla paragneiss is the oldest formation in the terrane as exposed along the railway section. They are massive, relatively homogeneous schists, resembling orthogneiss in appearance, greenish grey, strongly micaceous and visibly feldspathic as well as quartzose. The beds range from a few inches to a hundred feet and more in thickness. Intercalated with the schisted beds are thin layers of pale-grey to white, medium-grained limestone; quartz, biotite, muscovite, talc, chlorite and diopside are developed. The formation outcrops only where the Tonkawatla valley joins the Columbia river valley, just west of Revelstoke.

Chase Formation: This is a series of banded, though massive, calcareous quartzites. The actual base is not known. The dominant rock is white to pale grey or bluish-grey quartzite, generally charged with grains of calcite and of various silicates of metamorphic origin. The latter include diopside, tremolite, microcline, titanite and muscovite. The formation is at least 3000 feet thick.

Salmon Arm Formation: The Salmon Arm formation conformably overlies the Chase quartzite. The principal rock type is a garnetiferous muscovite-biotite-quartz schist. The garnets are poikilitic and form the nucleii of knots developed in the schist. Orthoclase or other alkaline feldspar and plagioclase in small grains are relatively rare accessories. The thickness is 1,800 feet.

Sicamous Formation: The Salmon Arm formation is transitional into the overlying Sicamous limestone. This limestone is typically impure and schistose, bluish-grey to dark grey in colour. The grain varies from fine to medium. Generally a few quartz and pyrite granules are accessory, but the chief impurities are carbon and sericite (or talc?). The characteristic dark colour is given by disseminated carbon dust which appears in practically all of the limestone. It is 3,200 feet thick.

Bastion Formation: The Sicamous limestone passes gradually into the younger Bastion formation. The lower part of the formation is chiefly composed of phyllites. Interbedded with them are several beds of white to dark grey or blackish limestone, in general more massive than the Sicamous limestone. In the upper part of the formation, beds of sericitic quartzite and of dolomitic metargillites interrupt the phyllites. At several horizons, varying from near the base upward, thick zones of talc schist, chlorite schist, and epidotic or zoisitic schists, bearing quartz and chlorite, were observed. Intense metamorphism has so obscured the bedding that the thickness could not be determined, but it is estimated at 5000 feet.

Tshinakin Formation: The Tshinakin is a limestone formation conformably overlying the Bastion schists. It is a true marble. The lower limestone is generally massive but interrupted at intervals of about 20 feet by schistose zones. It is cream-coloured, yellowish-white or bluish-grey and, rarely, pure white. Carbonaceous material is nearly, or quite, absent. A band of grey phyllite, about 800 feet thick and similar to the interbeds in the lower limestone, passes gradationally into the upper. The upper limestone is essentially like the lower but with a greater proportion of interbedded schists.

Adams Lake Formation: The upper Tshinakin limestone is directly and conformably overlain by the Adams Lake formation. The Adams Lake consists chiefly of green schists derived by metamorphism from basic eruptives. At several horizons these schists carry thin intercalations of limestone and quartzitic schists. The thickness is estimated as 10,000 feet.

NORTH THOMPSON VALLEY.[1]

1 Uglow, W.L.- Geol.Surv.Can., Summ.Rept. 1921, Pt.A, p.76.

The lower formations in this district, the Badger Creek, Fennell and Barriere, in ascending order, are classed as pre-Cambrian or late Palaeozoic. They are intruded by acid igneous rocks presumably correlative with the Coast Range intrusives. They are unconformably overlain by Eocene sediments.

Badger Creek Formation: This is a series of metamorphosed, sedimentary and volcanic rocks, now largely schistose. The rock types are hornblende schist; fine-grained dolomite and limestone in thin beds; silicified argillite; quartz slate; dolomitic quartzite; micaceous, thin-bedded, flaggy quartzite, biotite schist and a schistose andesitic tuff which is gradational into the overlying Fennell formation. The thickness is 3,500 feet.

Fennell Formation: This formation consists chiefly of a complex of altered basic rocks of intrusive, extrusive and fragmental characters. The rocks are chlorite schist; slightly schistose, fine-grained greenstone with beds of schistose tuffs; a probable meta-basalt; ellipsoidally weathered greenstone associated here and there with sill-like and dyke-like masses of altered hornblende gabbro, and narrow lenses and beds of fine-grained white limestone or dolomite within the greenstone. The thickness is not given in Dr. Uglow's report.

Barriere Formation: The Barriere formation conformably overlies the Fennell. The dominant rocks are grey and black-banded argillite; brownish-weathering, fine-grained, sericitic quartzite; brownish to buff coloured sericitic schist; fine-grained, white to grey, massive limestone; dolomitic quartzite; schistose quartz pebble conglomerate; silicified argillite; talc schist; white, glistening, fissile, sericite schist; greyish green tuff; and schistose amygdaloidal basal. The thickness is very uncertain due to strike-faulting.

CARIBOO SERIES.[1]

1 Johnson, W.A. & Uglow, W.L.- Geol.Surv.Can., Mem.149, 1926, p.11 et seq.

The Cariboo series underlies most of the Barkerville map-area. The only available information regarding the age of the series is that it lies unconformably beneath the Slide Mountain series of Mississippian age. The much greater metamorphism of the Cariboo series, pointing to a period considerably antedating the Mississippian, as well as the lithological similarity of the members of the Cariboo series with the Beltian rocks, suggests that the Cariboo series is possibly of Beltian age. The basal formation is the Richfield, which is successively overlain by the conformable Barkerville and Pleasant Valley formations.

Richfield Formation: This formation constitutes the main part of what is popularly known as the "Cariboo schists". True schists, however, form only a small element. The formation consists of massive quartzite, fine quartz pebble conglomerate, micaceous quartzite, quartz slate, quartz sericite schist, sericite schist, carbonaceous and clay slate with minor intercalations of limestone, calcareous argillite, and silicified tuff, all derived from mainly quartzose sediments. The thickness is over 8000 feet. The base is not known.

Barkerville Formation: The chief rocks of this formation are limestones presenting characteristics which vary according to the intensity of their deformation. The rocks are a thickly bedded, fine-grained, massive, grey, unmetamorphosed type, associated with a medium-grained, buff-coloured, crystalline type and with a thinly bedded argillaceous variety. Where the limestone shows evidences of intense minor folding, it is slaty. In many places, also, the rock is of autoclastic character, and blocks of angular grey limestone are separated by a lighter-coloured filling of coarser-grained calcite. Most of the exposures show veinlets of white calcite. The thickness is 2500 feet.

Pleasant Valley Formation: The members of this formation are essentially argillaceous, the dominant type being a clay slate, varying in colour from grey to pale brown to black, and possessing a well developed cleavage. A thickness of 5000 feet to the erosion surface is known.

FINLAY RIVER AREA.[1]

1 Dolmage, Victor - Geol.Surv.Can., Summ.Rept. 1927, Pt.A, p.25.

The oldest rocks in the vicinity of the Finlay river are mainly quartz-mica schist, mica quartzite and acid gneiss, with a few small bands of impure limestone and lenses of hornblende gneiss. All three main types are essentially quartz-mica rocks, with small quantities of feldspar and garnet. The quartz-mica schist constitutes about three-quarters of the whole. Gneisses occur at only a few localities; they are probably orthogneisses. The limestones form a minor part of the formation and occur as thin, well-bedded lenses. The thickness of the series is not known.

YUKON GROUP.[1]

1 Cockfield, W.E.- Geol.Surv.Can., Mem.123, 1921, p.12 et seq.

The name "Yukon Group" was applied by D.D. Cairnes[2]

2 Cairnes, D.D.- Geol.Surv.Can., Mem.67, 1914, pp.40-44.

to the metamorphosed rocks of both sedimentary and igneous origin along the Yukon-Alaska boundary north of the Yukon river. Cairnes considered them to be definitely pre-Cambrian; Cockfield[3], however, suggests that the correlation is not

3 Cockfield, W.E.- Geol.Surv.Can., Summ.Rept. 1926, Pt.A, p.4.

sufficiently definite throughout the area and that, in consequence, there exists some doubt as to their age. He concludes, because of lack of evidence to the contrary, that they are probably pre-Cambrian. The group includes the Nasina series, oldest, Klondike series and the Pelly gneisses. It is exposed as a whole along the International boundary[4], and in the Sixtymile and Ladue rivers[5], Dezadeash[6] and Aishihik Lake[7] areas.

4 Cairnes, D.D.- op. cit.
5 Cockfield, W.E.- Geol.Surv.Can., Mem.123, 1921.
6 Cockfield, W.E.- Geol.Surv.Can., Summ.Rept. 1927, Pt.A, p.1.
7 Cockfield, W.E.- Geol.Surv.Can., Summ.Rept. 1926, Pt.A, p.1.

The Nasina and Klondike series occur at Keno Hill[1] in the Mayo

1 Cockfield, W.E. - Geol.Surv.Can., Summ.Rept. 1923, Pt.A, p.1.

district.

Nasina Series: The Nasina series is made up of gneissoid quartzites, quartz-mica and mica and graphitic schists, sheared conglomerates and crystalline limestone. In the least altered portions, the constituents of these various rocks have a parallel arrangement, giving to the rocks a laminated appearance; in the most altered portions the rocks are completely recrystallized into fine-grained gneisses and schists, distinguished only with great difficulty from the altered igneous rocks. The sheared conglomerates make up only small portions of the formation and apparently represent a coarser facies of the quartzite. The crystalline limestone is a grey or greenish-blue to white marble, much sheared and disturbed. The development of a gneissoid quartzite, a quartz-mica schist, or a mica schist, is believed to be dependent, not so much upon the degree of metamorphism, as upon original differences in composition.

Klondike Series: This group consists of light-coloured sericite schists with subordinate amounts of chloritic schists. These schists resemble, in appearance, the most completely recrystallized rocks of the Nasina, on the one hand, and the most sheared of the granite gneisses on the other. The white, light yellow, or light green sericite schists are the most abundant rocks. These possess a marked foliation accentuated by the development of secondary minerals as a necessary accompaniment to the pronounced dynamic agencies to which they have been subjected. The chlorite schists are fine-grained rocks showing abundant chlorite and epidote. They occur both as bands alternating with the sericite schists and as masses.

Amphibolites: This name is used to designate a class of schistose, pre-Cambrian rocks of dark greenish colour and basic composition. Some of them are older than the granite gneiss with which they always occur, but others may be differentiates from the magma which gave rise to the gneiss. The largest area of these amphibolites and gneisses (Pelly) lies along the Sixtymile river, eastward from the Boundary and forming an area six miles long and five miles wide.[1]

1 Cockfield, W.E.- Geol.Surv.Can., Mem.123, 1921, p.20.

The colours range from various shades of green to nearly black. The composition ranges from that of a diorite to as basic as a pyroxenite. Quartz is absent, or present only in small amounts; hornblende, biotite, pyroxene and plagioclase make up the greater portions of the rocks.

Pelly Gneisses: These orthogneisses vary greatly in texture, composition and general appearance, in the field, passing from fine-grained schist into a coarse-grained granite gneiss. Areas and bands of augen gneiss, frequently alternating with the granular variety, are light brown to reddish rocks, consisting of porphyritic individuals of feldspar, and occasionally quartz, scattered through a groundmass of fine-grained material, which is highly sheared, with the development of abundant mica on the planes of schistosity. The feldspar crystals are drawn out into lenticular areas of granulated material, or, more frequently, exhibit only incipient signs of crushing. In many of these rocks a milky-white quartz, apparently secondary, occurs with rounded or lenticular outlines or filling in the space between foliation planes.

TINDIR GROUP.[1]

1 Cockfield, W.E.- Geol.Surv.Can., Summ.Rept. 1924, Pt.A, p.4.

The Tindir group is exposed in the Upper Beaver River area, Mayo district, Yukon. Its age has not been definitely determined save that it is pre-Ordovician. Cockfield tentatively refers it to the pre-Cambrian.

The group is subdivided into two formations, which have not, as yet, been named. The lower formation consists of quartzite, slate, limestone and conglomerate; the upper consists of calcareous sandstone, slate, argillite and limestone. The quartzites are white, light grey, or blue and are much less metamorphosed than are those of the Yukon group. Interbedded with them are bands and beds of white, crystalline limestone. The limestone, in places, attains a thickness of more than fifty feet. The slates are red, green, grey or black and included in them are thin beds of quartzite and conglomerate, and more massive beds of white or grey crystalline limestone. The calcareous sandstone is associated with dolomitic sandstone and limestone, slates and argillites. These rocks weather a dull red to brown. Associated with the slates are dark-coloured or black argillites.

MOUNT STEVENS GROUP.[1]

1 Cockfield, W.E.- Geol.Surv.Can., Mem.150, 1926, Pt.A, p.8.

The rocks of this group are extensively developed in the western part of Whitehorse district, Yukon. There is no direct evidence as to the age but their relationships to later igneous rocks which cut them show that, in all probability, they are the oldest rocks in the district.

The members of the Mount Stevens group consist of sericite schists, chlorite schists, greenstone schists, sericitic quartzites, gneissoid quartzites, hornblende gneisses and crystalline limestone.

Sericite Schists: These are light grey, soft, fissile rocks of a bright, glistening appearance due to the amount of mica they contain.

Chlorite Schists: The chlorite schists are pale to dark green, soft, friable rocks, occasionally with a reddish cast due to the presence of limonite.

Greenstone Schists: The greenstone schists are fine to medium-textured greenish rocks, prevailingly firm and compact, that have, apparently, been derived from andesites.

Sericitic Quartzites: These are dark greenish, fine-grained rocks with close foliation. They are of sedimentary origin.

Gneissoid Quartzites: The gneissoid quartzites are prevailingly light grey to white, with a common development of colour banding. They have a fine, gneissoid structure. They contain grains of quartz intergrown with feldspar which is much altered to sericite and calcite.

Hornblende Gneisses: The hornblende gneisses are fine to coarse-textured rocks with a decided gneissoid structure. These rocks have the appearance of crushed basic intrusives and were probably derived from gabbros and granodiorites.

CHAPTER IV.

THE SHUSWAP PROBLEM.

The age of the Shuswap series was definitely placed by Dawson as Archaean[1]: "The Shuswap series proper is evidently

1 Dawson, G.M.- Geol.Surv.Can., Shuswap Sheet, 1898.

referable to the Archaean and is much like the Grenville series of the Laurentian of Eastern Canada. This resemblance extends to its manner of association with the foliated rocks that resemble the 'Fundamental Gneiss' of the same region." In Chapter II of this paper the evidence gathered by later workers, throwing grave doubt on the reliability of Dawson's correlation, has been reviewed. This chapter will review the more significant evidence in detail.

In 1914 S.J. Schofield[2] examined an area west of

2 Schofield, S.J.- Geol.Surv.Can., Summ.Rept. 1914, p.31.

Kootenay lake. Field evidence showed that Daly's Priest River terrane, considered by him to be Archaean, is, in part at least, a metamorphosed equivalent of the Aldridge formation of Beltian age. "The Priest River terrane and the Aldridge formation are rocks of the same formation differing only in degree of metamorphism."

C.W. Drysdale, in 1916, substantiated Schofield's statement[3]: "The Priest River terrane, instead of being

3 Schofield, S.J.- Trans.Roy.Soc., Can., Vol.XVII, Sec.IV, 1923, p.82.

Archaean, is considered to be Beltian and simply the hydrothermally metamorphosed extension of the Purcell series across the Purcell trench as originally shown on the West Kootenay map. The metamorphism is due to batholithic invasion which in this locality appears to conform closely to the regional structure, the formation swinging to parallel the granite contacts. The terrane includes the folded and domed Kitchener, Creston and Aldridge members of the Purcell series cut here and there by granite and complementary dykes from the large adjacent masses of granite...... In the Purcell trench no evidence was found of a pronounced regional break or fault with a downthrow which may measure 20,000 to 30,000 feet (Daly)....... The Irene conglomerate is not considered to be the base of the Belt terrane in Canada (Daly) but simply the base of a younger series than the Purcell."

In 1920, Schofield[1], in his report on the Ainsworth

1 Schofield, S.J.- Geol.Surv.Can., Mem.117, 1920, p.14.

Mining Camp, discusses the age of the "Shuswap" rocks of that area in the following words: "In 1914 as a result of the study of the series of rocks lying east of Kootenay lake and west of the western limit of the Cranbrook map area the writer found that the Purcell series passed conformably under the rocks designated as Shuswap by Dawson. Hence this series exposed on the eastern and western slopes of Kootenay lake in the vicinity of Ainsworth must be later in age than the Purcell series and cannot be Shuswap or pre-Beltian. The abundant sills of pegmatite in the so-called Shuswap series are unmetamorphosed, whereas the series itself consists entirely of highly metamorphosed rocks. These pegmatites, becoming more numerous as the terrane is descended on the lower slopes of Kootenay lake and along the shores of the lake itself, are genetically associated with the Nelson granite of Jurassic age. In the old report, the contact between the so-called Shuswap series and the later rocks was placed where the pegmatite sills cease to appear in the associated schists; but for the reasons given above it will be seen that these sills cannot be used in determining or delimiting the age or stratigraphic relationships of the so-called Shuswap series and the later rocks and that the schists that have been called Shuswap rocks are really metamorphosed equivalents of sediments which are Beltian or post-Beltian in age. In the Ainsworth area the Ainsworth series consists of a conformable set of sedimentary rocks which underlies conformably the rocks of the Slocan series which are Pennsylvanian in age. Hence the Ainsworth series is Carboniferous or pre-Carboniferous and probably post-Beltian in age."

M.F. Bancroft spent several years in the correlation of the rocks exposed on the west shore of Kootenay lake with those of the Lardeau and their continuation northward to the C.P.R. main line at Revelstoke, in the Selkirk mountains. He found[1] that the oldest rocks were divisible into a basal series

1 Bancroft, M.F.- Geol.Surv.Can., Summ.Rept. 1921, p.109A.

(Shuswap of Dawson) and a younger series of sediments (Niskonlith of Dawson). Of the age relationship he writes: "There can be no doubt that a considerable time interval is represented between the basement rocks and the Slocan (Niskonlith) series." Schofield[2], however, in discussing this age relationship,

2 Schofield, S.J.- Trans.Roy.Soc.Can., Vol.XVII, Sec.IV, p.87.

disagrees with Bancroft: "This contact was carefully studied by the writer at Ainsworth. It is clear that the two series are conformable..... no evidence was found of a time interval at the same contact in the Ainsworth section where the same fossiliferous rocks (Slocan series) overlie the basement rocks." Bancroft gives no evidence to support his view.

In 1928, C.E. Cairnes[1], reporting on a reconnaissance

1 Cairnes, C.E.- Geol.Surv.Can., Summ.Rept. 1928, p.97A.

between Upper Arrow and Slocan lakes, postulates an unconformity between pre-Cambrian crystalline schists and the overlying Kaslo series of volcanic and basic intrusives, mesozoic in age: "The general structure of the pre-Cambrian rocks lends strength to the view that they are separated by a great unconformity from succeeding sedimentary and volcanic formations. Their average dip is low as compared with that of later formations and their strike does not everywhere conform with the northwesterly trend of deformation of the younger rocks...... The age of these older rocks is referred, tentatively, to the late pre-Cambrian on the basis of lithological similarity with rocks of that age appearing along the shores of Kootenay lake and extending northerly and northwesterly into Lardeau country." No intrusive is described as pre-Cambrian.

In 1915, R.A. Daly[2] described an unconformity between

2 Daly, R.A.- Geol.Surv.Can., Mem.68, 1915, p.62.

the Shuswap series and the overlying Albert Canyon division at Albert canyon on the main line of the C.P.R. He described the basal quartzite of the Albert Canyon division as unconformably overlying an orthogneissic sill of the Shuswap terrane. "The orthogneissic sill is riven by numerous dykes of aplite and pegmatite of typical Shuswap habit..... Their injection entirely antedated the Beltian system, in which neither sill, nor dyke of granite, aplite, or pegmatite was found at any horizon within the area covered. The salic injections cutting the orthogneiss are truncated by the old erosion surface limiting the great body above." H.C. Gunning[1] reported on this contact

1 Gunning, H.C.- Geol.Surv.Can., Summ.Rept. 1928, p.150A.

in 1928 and disputed the existence of an unconformity in the following words: "The section proves that the fresh granitic dykes, including aplites and pegmatites that cut the gneisses, also cut the overlying sediments. No unconformity was noted. Daly divided the intrusives into an older granite of pre-Beltian age and a younger, Jurassic, granite. Gunning[2]

2 Gunning, H.C.- Idem., p.151A.

referred the older granite, the orthogneiss of the complex, to the Mesozoic.

During the field seasons of 1929 and 1930 the writer worked, under Dr. C.E. Cairnes, in the area surrounding Mable and Sugar lakes which lie about 35 miles south-east of Shuswap lake. There the metamorphic Shuswap series underlies a series of less altered rocks correlated by Dawson with his Niskonlith to the north. The sill-sediment complex strikes north-south, the so-called Niskonlith strikes east-west. Where the complex passes into the overlying rocks the strikes swing more nearly northwesterly and may even be east-west in places. The

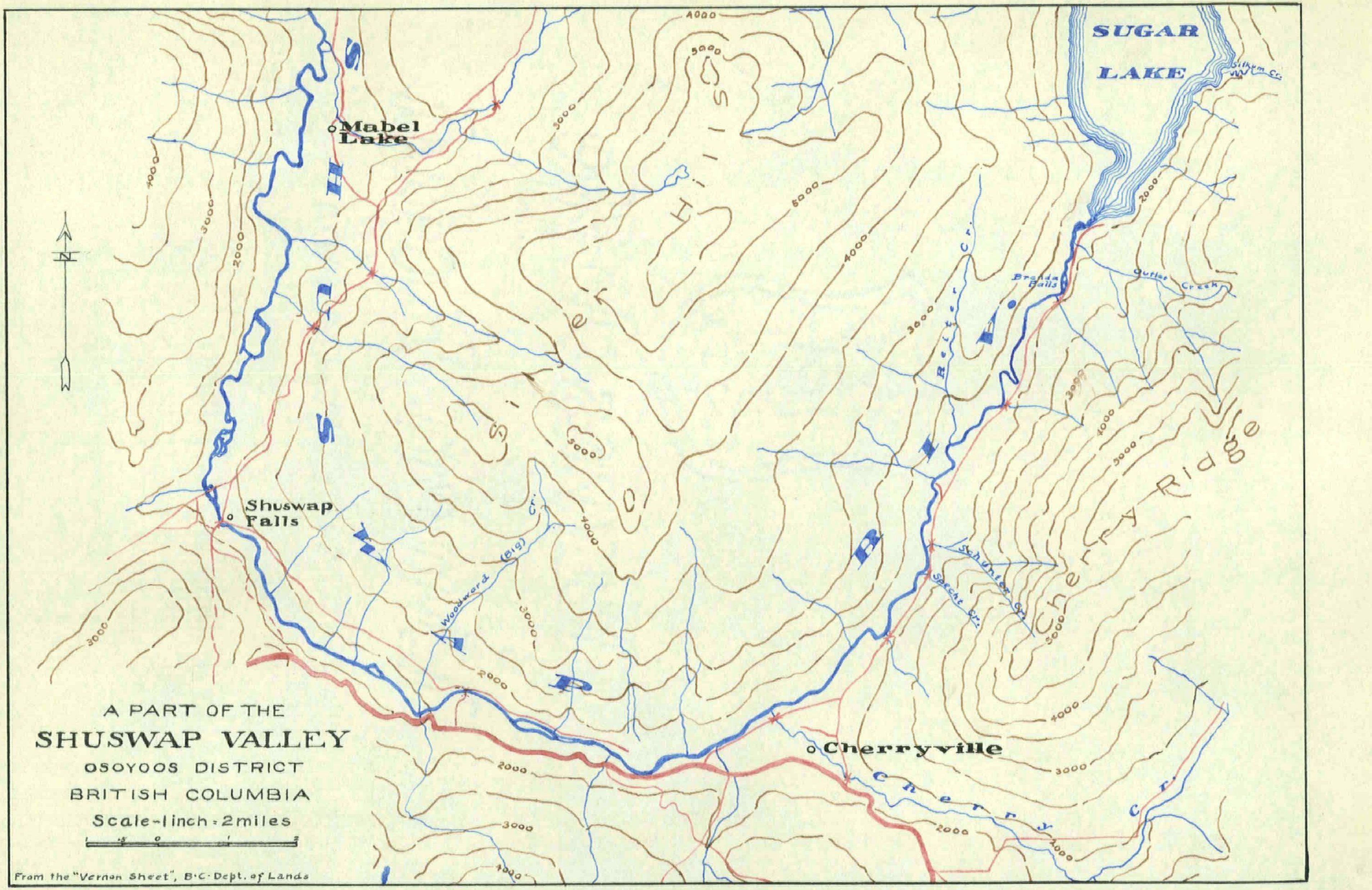

SUGAR LAKE
Mabel Lake
Shuswap Falls
Cherryville
Cherry Ridge
SHUSWAP RIVER
Silver Hills
Woodward (Big) Cr.
Reiter Cr.
Schunter Cr.
Specht Cr.
Cherry Cr.
A PART OF THE
SHUSWAP VALLEY
OSOYOOS DISTRICT
BRITISH COLUMBIA
Scale-1 inch = 2 miles
From the "Vernon Sheet", B.C. Dept. of Lands

PLATE III.

difference in attitude of the two series would indicate an unconformity. The varying strikes near the contact are to be expected if pressure is applied through the medium of an uneven surface. Dr. Cairnes, however, inclines to the belief that the apparent unconformity is structural rather than stratigraphic.[1]

1 Cairnes, C.E.- Personal communication.

Whether or not an actual unconformity exists, it is evident that the intrusive responsible for the complex also affected the so-called Niskonlith; evidences of the bleaching of both quartzites and argillites, silicification of limestones, and gradations between true argillite and quartzite and rocks hardly discernible from acid igneous types are quite common. Seven thin sections were examined of rocks, several of which, in the field, were commonly mistaken for intrusives, and in every case save that of an obvious pegmatite these proved to be of sedimentary origin. No evidence was found of an intrusive older than late Mesozoic.[2] The details of the microscopic examination of

2 Cairnes, C.E.- Geol.Surv.Can., Summ.Rept. 1931, pp.67A and 70A.

the thin sections are as follows.

Seven specimens of the complex from type exposures were examined microscopically. One of these, taken from the south side of the river, just east of Shuswap Falls, is grey in colour and well banded, resembling, in hand specimen, a banded quartzite. The weathered surface shows effects of differential weathering; the more siliceous band shows comparatively little alteration while the other is pitted and, in some places, entirely removed from between the adjacent bands for a distance inwards of about 1/8 of an inch.

In thin section this rock is seen to be composed largely of quartz and a carbonate, in alternating layers. The carbonate shows considerable alteration, which makes the certain determination difficult; it appears to be dolomite. Magnetite grains are fairly prominent and, while they are distributed throughout the section, tend to concentrate in the carbonate bands. Cyanite is present, largely within the carbonate bands, though a few grains lie in the quartz layers, included in individual quartz grains. A few grains of augite and a little muscovite also occur. It is noteworthy that whereas bands of almost pure carbonate are observed, there appears to be no silica layer which does not contain particles of every other mineral present. The quartz grains are uniform in size and interlock both with one another and with grains of the other minerals. A slight amount of granulation is noticeable between some of the carbonate grains, but, on the whole, the rock has been well recrystallized.

The second specimen, taken from an outcrop about two hundred feet above the Shuswap River on the hill to the south, about a mile east of Shuswap Falls, is similar in colour and structure to the rock just described. It is, however, garnetiferous. The garnets measure about an eighth of an inch in diameter and are red in colour.

Examined in thin section, the rock proves to be composed chiefly of quartz and feldspar, with secondary biotite developed in bands. The garnets show fracturing. The fractures are filled with quartz. The feldspar is badly weathered and could be determined only as a member of the plagioclase group, with a small amount of orthoclase. Accessory minerals are chlorite, hornblende and magnetite.

The contrast between these two specimens is of some importance since they have been taken from outcrops similar in appearance and sufficiently close together to allow of the supposition that they are exposures of one continuous rock mass. The carbonate, so abundant in the first, is missing in the second; magnetite is comparatively large and abundant in the first, it is finely disseminated and scarce in the second. Chlorite is absent from the first, but present in small amounts in the second. The second is garnetiferous . The carbonates and some of the iron may have combined to form garnet of the variety andradite. The biotite is beginning to go over to chlorite. This suggests that the intensity of metamorphism increases eastward from Shuswap Falls, i.e. towards the lens of pegmatite south of Woodward Creek.

On the Silver Hills, west of Shunters Creek, is a brittle schistose rock showing, in hand specimen, extensive development of biotite. There is a suggestion of a banding, at an angle to the schistosity, marked by layers of a more distinctive silvery sheen.

Quartz is the most dominant mineral. With the quartz is a small quantity of orthoclase. These two minerals form a groundmass, fine and even grained, in which lie ideomorphic basaltic hornblende, hypideomorphic biotite and muscovite and garnet and allotriomorphic tourmaline. The muscovite is aligned in the plane of the schistosity, in places bent around grains of quartz feldspar and biotite flakes have been observed included in quartz grains. Clusters of small biotite flakes, tourmaline and quartz grains, bounded by bent flakes of muscovite occur occasionally in the section.

The great predominance of quartz in the groundmass, together with the presence of crystals of garnet, tourmaline and mica and the occurrence of the clusters mentioned above which suggest altered and recrystallized pebbles, indicate that this rock has been derived from a sediment, probably an impure sandstone. The garnet and hornblende show considerable fracturing and slight displacement, indicating that movement within the schist continued after they had formed. It is noted, however, that the hornblende and biotite are not orientated parallel to the planes of schistosity, as is the muscovite, but are mutually parallel at a high angle to the schistosity.

Three of the specimens are from a cliff on the west side of the Shuswap River, about a mile below Sugar Lake. The first was taken near the top of the cliff at an elevation of 3800 feet. It is a fine-grained, laminated quartzose rock, directly underlying a phyllite.

Examined in thin section, the rock proves to be composed of about eighty per cent quartz, with muscovite and serpentine derived from chrysolite in about equal proportions. The muscovite and serpentine occur at or near the planes of the laminae. The quartz grains are interlocked.

1. Leith, C.K., and Mead, W.J., Metamorphic Geology, p.225.

Underlying this rock, and exposed to 200 feet below it, is a fine-grained, quartzose and calcareous formation. The rock breaks with a conchoidal fracture.

Microscopic examination shows the rock to be made up, principally, of interlocking grains of quartz, with about twenty per cent calcite, a few grains of a badly altered pyroxene (diopside?) and a small amount of finely disseminated magnetite. In several places quartz was intrusive into the calcite grains and, in one instance, included a calcite grain. At least some of the quartz, then, is later than the calcite, although the enormous predominance of quartz in this rock renders it unlikely that the original mass was ever a limestone. It was, more probably, a calcareous sandstone.

At an elevation of 3500 feet, on the same cliff, a sill of pegmatite was found. The feldspars are orthoclase and oligoclase.

On the Mabel Lake road, just north of Mabel Lake P. O., there occurs a well banded rock, of alternating siliceous and micaceous layers. There is a tendency towards concentration of the biotite at the contacts between the bands, but in some places there is interpenetration and consequent blurring of these contacts.

Microscopically the bands differ in several respects. The siliceous band is composed of evenly sized grains of quartz, orthoclase, microcline, a plagioclase feldspar near the composition of labradorite, a small amount of biotite and some disseminated magnetite. The micaceous band consists of quartz, orthoclase, albite, diopside, biotite, tourmaline and a larger amount of magnetite. The albite was determined from measurements of the angle, from the traces of pericline and albite twinning on 100, and from extinction angles. Both bands are even grained, the siliceous being slightly finer. In both the grains are interlocking.

The biotite in the micaceous layer has been fractured and crumpled. It frequently includes grains of feldspars.

This rock is interpreted as an example of lit-par-lit injection. The feldspars in the siliceous layer, orthoclase, microcline, labradorite, are typical of an igneous rock; the proportion of silica is not too great; what can be observed of an order of crystallization is the normal one for an igneous rock. On the other hand, the association of albite[1] and diopside[2] in the micaceous layer, together with the presence of secondary biotite, leads to the conclusion that such bands are metamorphosed sediments.

1 Winchell, A.N.- Elements of Optical Mineralogy, Pt.II, p.329.
2 Winchell, A.N.- Ibid., p.185.

Chemical Analyses.

Partial chemical analyses were made of the first two rocks described in the preceding section, from the vicinity of Shuswap Falls.

	I	II	III	IV
SiO	40.29	57.55	36.65	49.81
Al_2O_3	3.09	0.65	3.03	5.17
Fe_2O_3	9.14	0.92	0.82	29.17
CaO	16.90	9.28	22.12	2.43
MgO	8.48	8.01	3.44	0.95
	77.90	76.41	66.06	87.53

I. From Shuswap Falls.

II. From one mile east of Shuswap Falls.

III. Sandstone from Westphalia.

IV. Ferruginous Sandstone from Folkestone, England.

Clarke, F.W.- Bulletin 330, U.S.G.S., p.461.

A salient feature of the correlations reviewed above is the persistence of the fact that rocks of the "Shuswap" type in central and southern British Columbia are found to conformably underlie formations of Carboniferous age. The field work done along this contact shows that an unconformity exists for a not precisely defined distance between Albert Canyon and Ainsworth, the formations becoming conformable at these points. There is nothing in this fact alone which denies the hypothesis that the sedimentary rocks of the complex are late pre-Cambrian in age, and that is the hypothesis commonly agreed upon. If this is so, why is there no definite evidence of pre-Carboniferous strata in the vicinity of Albert Canyon and at Ainsworth?

Another point of interest is that the oldest rocks above Cairnes' "Great Unconformity" between the Slocan and Upper Arrow lakes are Mesozoic in age. With the exception of the Priest River terrane, the complex has not been definitely shown to be pre-Cambrian in any locality. If it is assumed that the complex, in the type area, does represent sediments of a single period of deposition, all that is definitely known of the series is that it is pre-Carboniferous. The hypothesis of Dawson, that the complex is Archaean, must be definitely abandoned and in future the burden of proof of the existence of pre-Beltian rocks in the Canadian Cordillera must rest with the geologist who makes that assertion.

Because of the widespread acceptance of Dawson's correlation of the complex, many formations, the age of which is obscure and may well remain so, have been referred to the Archaean and the term "Shuswap" has thus become firmly embedded in the literature. It is scarcely conceivable, in the light of present knowledge, that all, or any, of these formations will prove to be of the same age. In regard to age the term "Shuswap" is meaningless, but fortunately it has been applied only to rocks which have suffered a high degree of metamorphism and in that regard the meaning is definite. Deprived of any age-significance, then, it may be retained, without adding to confusion, in the geological nomenclature of the Canadian Cordillera.

The present status of the term "Shuswap" can be summarized as follows:

1. It is applied to formations which are not all of the same age.

2. Over a wide area the "Shuswap" terrane is definitely not Archaean and may be post-Beltian.

3. No "Shuswap" formations are known to be Archaean.

CHAPTER V.

BELTIAN CLIMATE AND CONDITIONS OF SEDIMENTATION.

The chief factors governing the possible deductions in regard to climate and conditions of sedimentation from indurated sediments are grain size, shape of grain, surface structures (such as rain-pits, ripple-marks, mud-cracks), cross-bedding, and colour.

Twenhofel[1] discusses the significance of various

1 Twenhofel, W.H.- "Treatise on Sedimentation", 1932.

colours on fresh rock surfaces as follows: Black is due largely to incomplete decay of organic matter under more or less anaerobic conditions in marshes, wet (and cold) plains, lakes, particularly those with no annual overturn, very shallow waters of tideless or almost tideless seas, and in deep holes of the seas and the ocean. Greys, if dark, have something of the significance of black, but the lighter shades have a much wider range of origin. If the deposits are continental, several environmental conditions are possible. They may be those of a delta, of parts of the neritic bottom or of the continental slopes, or they may have been deposited in very deep water. Colours altering from one bedding unit to another are considered characteristic of continental deposits - river flood plains, alluvial fans, deltas, etc. - but it is known that such combinations also are found in the deposits of the neritic environment. Green, when not due to green detritals, indicates chiefly the more or less altered pyroclastics or the glauconitic muds and sands of slightly reducing and slowly accumulating areas of the sea. Red colours, yellow, buff, purple, brown, etc., imply that deposition took place under climatic conditions of hot and dry seasons alternating with rainy seasons, or under conditions of general dryness, deposition in the latter case occurring in a region and climate marginal to the region of origin of the sediments or in the same region, but in a geologic epoch subsequent to that in which the materials became red.

The characteristics of the formations of the Purcell and Windermere series, affording the most complete section of definitely Beltian rocks in the Canadian Cordillera, will be used to deduce the conditions of Beltian sedimentation.

Aldridge Epoch: The brown-weathering grey quartzites indicate the presence of ferrous iron. The grains are angular and small. In the neighbourhood of Goat river[1] conglomerate forms an important part of the formation. The examination of

1 Schofield, S.J.- Geol.Surv.Can., Mem.76, 1915, p.98.

thin sections showed a few very angular grains of feldspar. The sediments, then, were deposited in shallow water under semi-arid conditions of climate. The materials were not transported very far and were derived from an igneous rock, probably of a very acid type.

Creston Epoch: The sediments are finer in grain than those of the Aldridge. The grains are angular and feldspar is more prominent. The dominant colours are green and purple.

Climatic conditions, then, are becoming more arid, or else the water is shallowing. The presence of argillites in this formation, in conjunction with the presence of angular grains of feldspar, shows that the water was deepening.

<u>Kitchener Epoch</u>: The limy nature of this formation, with the thick beds of limestone, points to fairly deep water sedimentation. On the whole, the grains are much better rounded and feldspar is quite rare. These sediments then, have been transported farther than those of the Aldridge and Creston. This suggests that the land surface from which the sediments are coming has become appreciably lower in elevation above sea-level. The colours of the shallow water phases, the calcareous quartzites, are those characteristic of alternating wet and dry seasons under tropical conditions.

<u>Siyeh Epoch</u>: Evidently a great change in conditions took place with the coming of Siyeh time. The colours of the sediments are greyish-green, red, purple and brown. The formation is dominantly of somewhat calcareous mud-rocks. Fossil rain-prints, mud-cracks and ripple-marks are common. The grains are dominantly of quartz and no fresh feldspar was seen in thin-section. Ripple-marks showing the characteristics of interference ripple-marks[1] (Plate X) are common. Kindle has found

1 Kindle, E.M.- Geol.Surv.Can., Mus.Bull. No.25, 1917, p.34.

that such ripple-marks are formed in shallow water in which the ordinary wave generated by the action of the wind on the surface is split up into two or more sets of oscillations moving in different directions. They are never seen along a straight, uninterrupted shore-line[1]. The presence of mud-cracks over a

1 Kindle, E.M.- Ibid., p.36.

wide area suggests a great tide-flat, alternately left exposed to the action of a drying-wind and later covered by shallow water, so shallow that its ripple action did not appreciably bevel the edges of the mud-cracks (Plate XI). The existence of deep rain pits (Plate X) shows that there were seasons of heavy rainfall. The rock colours indicate arid conditions and their alternation suggests that, in part, they may be delta deposits. It may be assumed, then, that the land surface supplying the sediments has undergone considerable uplift since Kitchener time. If a high range of mountains existed near the borders of the Siyeh sea, during the season in which westerly winds prevailed the precipitation would be on the mountain tops and to the west or landward side, since the westerly winds would lose their moisture while crossing the range. The wind crossing the shoreline during this season would therefore be a drying wind. During a season of easterly prevailing winds the opposite effect would obtain and the coast would have a relatively humid climate. It is interesting to note that in these beds we have the first hint of a large river flowing from the old land mass.

Deposition of the Beltian sediments was interrupted at the close of Siyeh time by the outpouring of the Purcell lava, accompanied by the intrusion of the Purcell sills into the Aldridge sediments. The Purcell lava surface projected above the surface of the sea, though slightly, since about 18 inches of conglomerate mark the division between it and the angularly conformable overlying Gateway formation.

Gateway Epoch: The Gateway is characterized by ripple-marks, mud-cracks and abundant casts of salt crystals. Therefore conditions were not much different than during Siyeh time.

Phillips Epoch: Continental conditions of deposition continued.

Roosville Epoch: Continental conditions of deposition continued.

Green coloration becoming more prominent in the Phillips and Roosville formations, suggests that the climate was becoming less arid. These formations are not, now, present in the Purcell range.

Mount Nelson Epoch: A fluctuation of sea level took place during this epoch which resulted in the deposition of limestone. At the close of this epoch the sea seceded.

The old land again sank beneath the sea at the beginning of Windermere time and the Toby conglomerate was deposited. The materials of the conglomerate show evidences of very short transportation.

Horsethief Epoch: Green and purplish colours and coarse and fine sediments show that the climate was probably semi-arid with the depth of the sea varying from fairly shallow to deep, with shallows predominating.

<u>Hamill Epoch</u>: Similar conditions obtained. Deep water became more prevalent.

<u>Badshot Epoch</u>: The sea-level has risen and most of the deposition was in deep water.

<u>Lardeau Epoch</u>: The black, carbonaceous rock at the base may indicate either land or very deep sea conditions. In view of the absence of limestone it is more probable that continental conditions obtained. It is also probable that the very shallow border of an almost tideless sea is represented. There evidently was life in this sea.

SUMMARY.

The Beltian sediments, as they are known at present, were deposited along the shallow margin of a sea bordering a high range of mountains. Wide tide flats, similar to those now existing around Hudson Bay, extended from the mountainous coast. The climate was tropical, with alternating wet and dry seasons.

CHAPTER VI.

RELATIONSHIP TO YOUNGER FORMATIONS.

To the Sediments.

CAMBRIAN:

In the Cranbrook map-area the Lower Cambrian strata lie nonconformably upon different members of the Beltian.[1] A disconformity is exposed at Elko, B.C. The evidences of a disconformity are as follows:

1. Absence of the Toby conglomerate and the Horsethief formations present in the Windermere area to the north.

2. A Cambrian marine transgression is inferred in the deposition of the Burton formation of Lower Cambrian age since this influence is in harmony with other sections of the Rocky Mountain geosyncline.

3. The conglomerate at the base of the Burton is composed chiefly of hematitic material with pebble-like shape and minor quantities of quartzite and quartz in a hematitic cement. A concentric structure suggesting concretions characterizes some of the hematitic constituents of the conglomerate. All the hematitic pebble-shaped elements probably represent subsequent erosion and concentration of the hematite deposits which occur abundantly in the underlying pre-Cambrian series. The quartzite pebbles are identical with the quartzites of the underlying Phillips formation. The occurrence of these pebbles

1 Schofield, S.J.- Geol.Surv.Can., Mus.Bull. No.35, 1922.

already metamorphosed before the deposition of the Burton, indicates a time interval between the depositions of the Roosville and Burton formations.

4. The grit which overlies the conglomerate is characterized by the abundance of milky-white quartz pebbles evidently derived from the erosion of quartz veins which are known to be present in the underlying Roosville formation and in other members of the pre-Cambrian series. Green pebbles of the Roosville siliceous metargillites are also present, and since they are metamorphosed similarly to the metargillites of the underlying Roosville, it supports the idea that the Roosville was metamorphosed before the Burton was laid down.

In the section where non-conformable relationship obtains, six miles east of Cranbrook, B.C., the following field evidence is present:

1. The Cambrian rocks form a syncline whose axis strikes a little north of east and plunges toward the east, whereas the underlying Beltian rocks strike north and south with a dip to the east. In the immediate vicinity of the contact the strikes of the two groups are at right angles to each other. The underlying series exhibits an extremely well-marked shearing whose strike corresponds in general to the axial strike of the overlying syncline of Cambrian rocks.

2. The basal member of the lower Cambrian series is a well-bedded, massive conglomerate, the well-rounded pebbles of which are composed chiefly of quartz and of the underlying pre-Cambrian rocks. This conglomerate is 600 feet thick and shows

ripple-marks, and, in some places, cross-bedding.

3. The underlying Beltian rocks are siliceous metargillites, green and purple in colour, and are characterized by abundant mud-cracks and ripple-marks, evidence of shallow water deposition. The Cambrian rocks are of marine deposition.

4. The Beltian rocks are well-indurated, siliceous metargillites whereas the Cambrian rocks of similar nature are soft shales.

5. The varying thickness of siliceous metargillites of the Siyeh formation, between the Purcell lava and the basal conglomerate of the Cambrian, shows that erosion has permitted the Lower Cambrian rocks to rest on different horizons of the pre-Cambrian.

DEVONIAN:

Near Cranbrook the Devonian rests disconformably on the Siyeh formation of Beltian age[1]. The horizon of the Devonian is probably the Jefferson limestone which rests with concordance of dip upon the Gateway, Purcell lava and Siyeh formations of the Beltian. The evidence for the disconformity is as follows:

1. The Jefferson limestone rests in patches upon different stratigraphic horizons.

2. The base of the Jefferson consists of sandy limestone.

3. The non-appearance of the formations Phillips, Roosville, Burton and Elko, suggests an erosion interval between the Gateway formation and the Jefferson limestone.

1 Schofield, S.J.- Geol.Surv.Can., Mem.76, 1915, p.53.

CARBONIFEROUS:

In the Lardeau area (117° 27' W Long., 50° 31' N Lat.) Bancroft[1] describes a break between the basement rocks of

1 Bancroft, M.F.- Geol.Surv.Can., Summ.Rept. 1921, Pt.A, p.109.

Windermere age and the Milford series of Carboniferous age. The contact is a disconformity and was determined principally on the basis of the difference in metamorphism of the two series.

A contact between presumably Beltian rocks and rocks of Carboniferous age is described as unconformable by Uglow.[1]

1 Uglow, W.L.- Geol.Surv.Can., Mem.149, 1926, p.37.

His evidence is as follows:

1. "There is some discordance of strike and dip between the two series. Discordance of strike is shown on the geological map due west of Mount Murray, where the Guyet formation lies across the contact of the Barkerville and Pleasant Valley formations.

2. The Guyet conglomerate rests on an erosion surface of the Cariboo series, and contains pebbles and boulders of the underlying formations of that series. The basal part of this conglomerate is clayey and somewhat schistose, and appears to grade into the underlying slate and schist. This part, therefore, is the result of the metamorphism of an old residual mantle of clayey decomposition products.

3. Pebbles of folded, crenulated, slaty and schistose rocks in the conglomerate are proof of the metamorphism of the Cariboo series before the deposition of the base of the Slide Mountain series. Pebbles of medium-grained intrusive rocks

indicate that erosion removed a considerable thickness of the underlying rocks before the formation of the conglomerate.

4. There is a decided difference in the degree of metamorphism to which the rocks of the two series have been subjected. The Cariboo series is characterized by quartzite, slate and schist, whereas the Slide Mountain series is made up pf indurated shale, chert and massive, fossiliferous limestone.

5. Felsite and quartz porphyry dykes, much replaced by siderite, occur only in Cariboo series.

6. There is an absence, in the Slide Mountain series, of large quartz veins which are such characteristic features of the Cariboo series.

7. The Mount Murray sills occur abundantly in the upper series and very sparingly in the lower, or Cariboo series.

8. Placer gold was found in the Guyet conglomerate, but the boundaries of the rich placer fields of the area do not include any of the country underlain by the Slide Mountain series."

To the Intrusives.

DEVONIAN:

Devonian diorite and diabase masses intrude the Nasina series in the Mayo district, Yukon.[1]

1 Cockfield, W.E.- Geol.Surv.Can., Summ.Rept. 1921, Pt.A., Map.

Pyroxenite and peridotite are reported[2] as cutting

2 Cairnes, D.D.- Geol.Surv.Can., Summ.Rept. 1915, Pt.A, p.41

members of the Mount Stevens group in the Wheaton district, Yukon. They are tentatively referred to the Devonian in age.

JURASSIC-CRETACEOUS:

Granite intrusives, genetically related to the Coast Range batholith, intrude members of the Yukon and Mount Stevens groups in south western Yukon.

The Omineca batholith of post-Carboniferous, and presumably of Jurassic[1], age cut the pre-Cambrian rocks along the Finlay and Omineca rivers. West of the Finlay river and south of Fort Grahame, pegmatite dykes penetrate the schists, usually along the strike.

1 Dolmage, Victor,- Geol.Surv.Can., Summ.Rept. 1927, Pt.A, p.28.

The Mesozoic intrusives of southern central British Columbia, as regards the areas of pre-Cambrian and presumably pre-Cambrian rocks, are either known to be or may be assumed to be genetically related to the Nelson batholith. All the schistose Beltian rocks in this region are intruded by these granites. An interesting feature in the neighborhood of Kootenay lake is that the metamorphosed sediments surrounding the huge sub-circular intrusive mass dip toward it. Schofield[2] believes that this phenomenon shows that the sediments were folded into a geanticline before the intrusive penetrated them. This would require that the magma progressed through the overlying folded sediments by the method of overhead stoping.

2 Schofield, S.J.- Personal communication.

TERTIARY:

The Kuskanax batholith which Cairnes believes to be possibly of Tertiary age[1] since it post-dates the Nelson

1 Cairnes, C.E.- Geol.Surv.Can., Summ.Rept., 1928, Pt.A, pp.96 and 104.

batholith, intrudes schistose Beltian rocks east of the Upper Arrow lake. The chief types are syenite and granite.

RELATIONSHIP BETWEEN THE INTRUSIVES AND THE METAMORPHISM OF THE BELTIAN.

The areas in which the pre-Cambrian (?) formations are classed as "Schistose Beltian" are those in which the above intrusives are known to be present (Map 1). The descriptions of the various members of the Schistose Beltian bring out two important considerations; first, the extent of metamorphism varies directly with the prominence of intrusives in any area; second, the rock minerals of the Schistose Beltian always include those characteristic of contact metamorphism. Therefore it may be concluded that contact metamorphism, if not the only factor, has been the dominant influence in producing the schists and paragneisses.

G.M. Dawson[2] and, later, R.A. Daly[3] have advanced a

2 Dawson, G.M.- Bull.Geol.Soc.Am., Vol.12, 1901, p.64.
3 Daly, R.A.- Geol.Surv.Can., Mem.68, 1915, p.44.

theory of static metamorphism to account for part of the metamorphism. It is based on the frequency with which the schistosities parallel the bedding planes in these pre-Cambrian rocks and postulates that the metamorphism is due to load without movement. It follows then, since there is no movement, that pressure must have been equal in all directions. If pressure is ~~ss~~ equal in all directions, the metamorphic minerals would not necessarily all have the same orientation; and schists and paragneisses, therefore, probably would not result, save locally. Two laws of physical chemistry must be considered; first, that under conditions of uniform pressure those minerals will form which have the greatest density; second, that under conditions of non-uniform pressure those minerals will form that have one greatest dimension and that dimension will lie in the direction of least pressure. It is the minerals which are to be expected under the conditions of the second law that are the characteristic secondary minerals of the schistose pre-Cambrian.

The theory of "Static Metamorphism", insofar as it affects the Schistose Beltian, may be discarded; first, because it does not explain a number of facts; second, because it is unnecessary to the explanation of the origin of these rocks.

ADDENDUM.

The review of the modern literature on the pre-Cambrian of the Cordillera in Canada, of which this paper is a too brief summary, has shown that save for those formations classed as Non-Schistose Beltian, and the Priest River terrane of the Schistose Beltian, there are no formations definitely known to be of pre-Cambrian age. Lack of fossils and high metamorphism have formed the basis of the correlations, but, in view of the nature of the bulk of the sediments, the high degree of metamorphism to which they have been subjected and the comparative paucity of field work, these are unreliable criteria.

In the several areas where supposedly pre-Cambrian formations conformably underlie beds known to be Carboniferous in age, there is in no instance a sufficient thickness of sediments to account for the Devonian, Silurian, Ordovician and Cambrian strata, to say nothing of pre-Cambrian, which may be logically assumed to be present. In this connection reference to Plates IV, V and VI will show that the structure of the Shuswap terrane along the main line of the C.P.R. (Plate VI) resembles more closely the structure of the Windermere (Plate V) than that of the Purcell series (Plate IV). It is well known that deeply buried rocks deform less than the less deeply buried and that faulting is more characteristic of younger formations in the same period of movement. It is quite possible that the "Schistose Beltian", except the Priest River terrane, is of Palaeozoic age.

The term "Beltian" is becoming as much of a vogue as the term "Shuswap" was until a few years ago. Unfortunately, however, the later term has not been confined to rocks of a definite type, as was "Shuswap" and the age relationships are, in the majority of instances, no more definite. It is obvious that confusion will, in time, ensue and the literature may thus be encumbered with one more meaningless term. It is suggested, therefore, that the term "Beltian" be confined to those formations the pre-Cambrian age of which is definitely ascertained, and the term "Shuswap" be revived to apply to all the highly metamorphosed formations of uncertain age.

FOSSILS OF THE BELTIAN.

In the Cordillera the Beltian rocks are called the Belt terrane where fossil remains have been discovered. The fossils[1] occur in the Greyson formation, a belt of calcareous shales, at a horizon approximately 7,700 feet beneath the summit of the Belt terrane at its maximum development.

The fauna include four species of annelid trails and a variety that appears to have been made by a minute mollusc or crustacean. There also occur in the same shales thousands of fragments of one or more genera of Crustaceans. All the specimens are very much compressed and flattened, and often large fragments of the tests have been broken by a movement in the

1 Walcott, C.D.- Geol.Soc.Am., Vol.10, 1899, p.235.

shale subsequent to their imbedment in the mud. The most interesting feature of the fauna is the occurrence of undoubted organic remains and the presence of a crustacean of a much higher type than most palaeontologists would have predicted for this horizon. The specimens include Helminthoidichnites (?) neihartensis, H. (?) spiralis, H. (?) meeki, Planolites corrugatus, and P. superbus, all trails in the shales of Proterozoic age. Specimens of Merostomata have also been described by the same author.

The most important is the Genus Beltina under which name are classed the fragmentary remains of a Crustacean, which, as far as can be judged from what is known of it, is referable to the Merostomata. Thousands of fragments were collected from the calcareous Greyson shales. The species is called Beltina danii.

Fossils from the Aldridge formation of southeastern British Columbia have been described by Burling[1] who states

1 Burling, L.D.- Geol.Surv.Can., Summ.Rept. 1916, p.58.

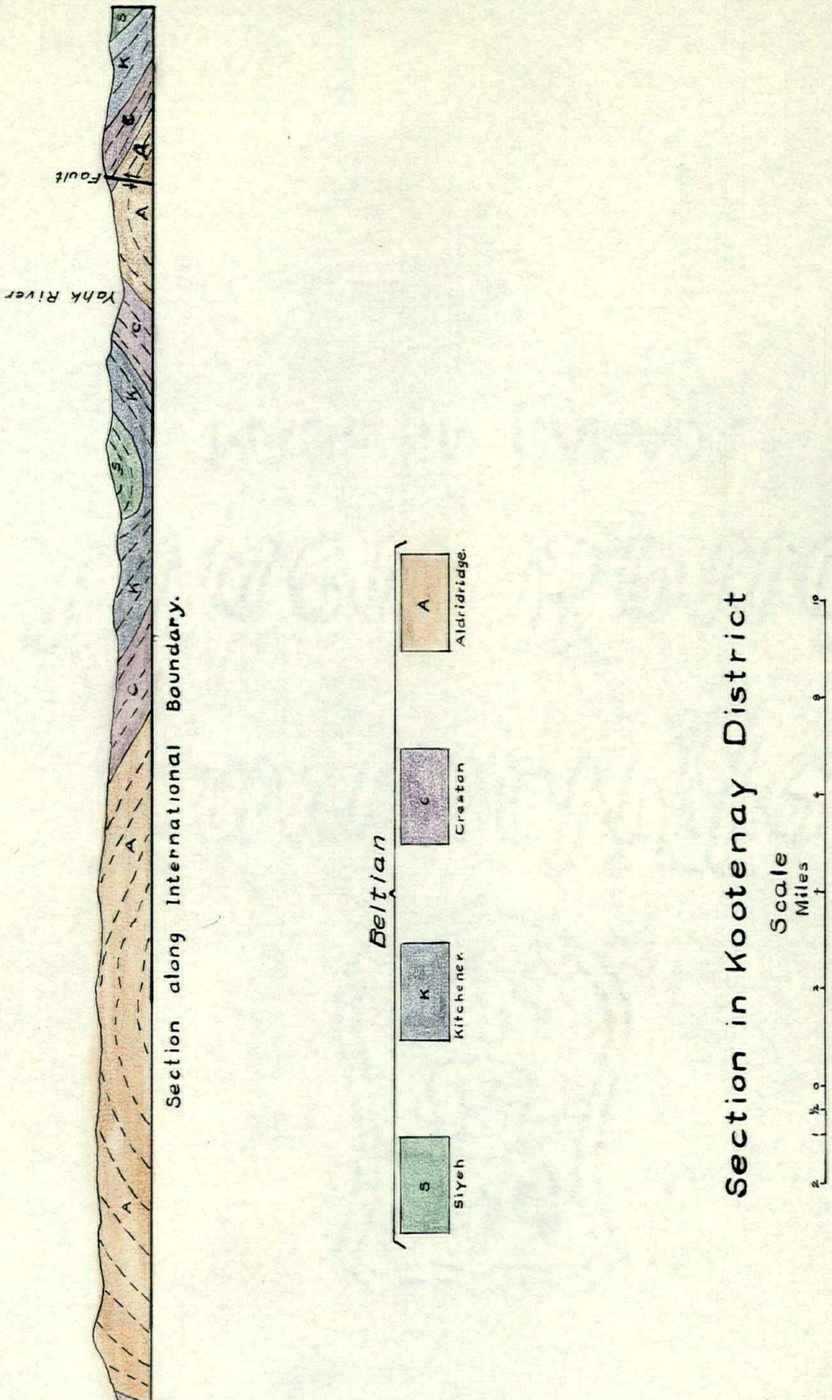
that the fossil occurs near the top of the formation. This fossil appears to represent a specimen of Beltina.

Specimens of Beltina danii were discovered by Daly in the Altyn formation[2] of Proterozoic age. Reporting on the

2 Daly, R.A.- Geol.Surv.Can., Mem.38, 1912, p.65.

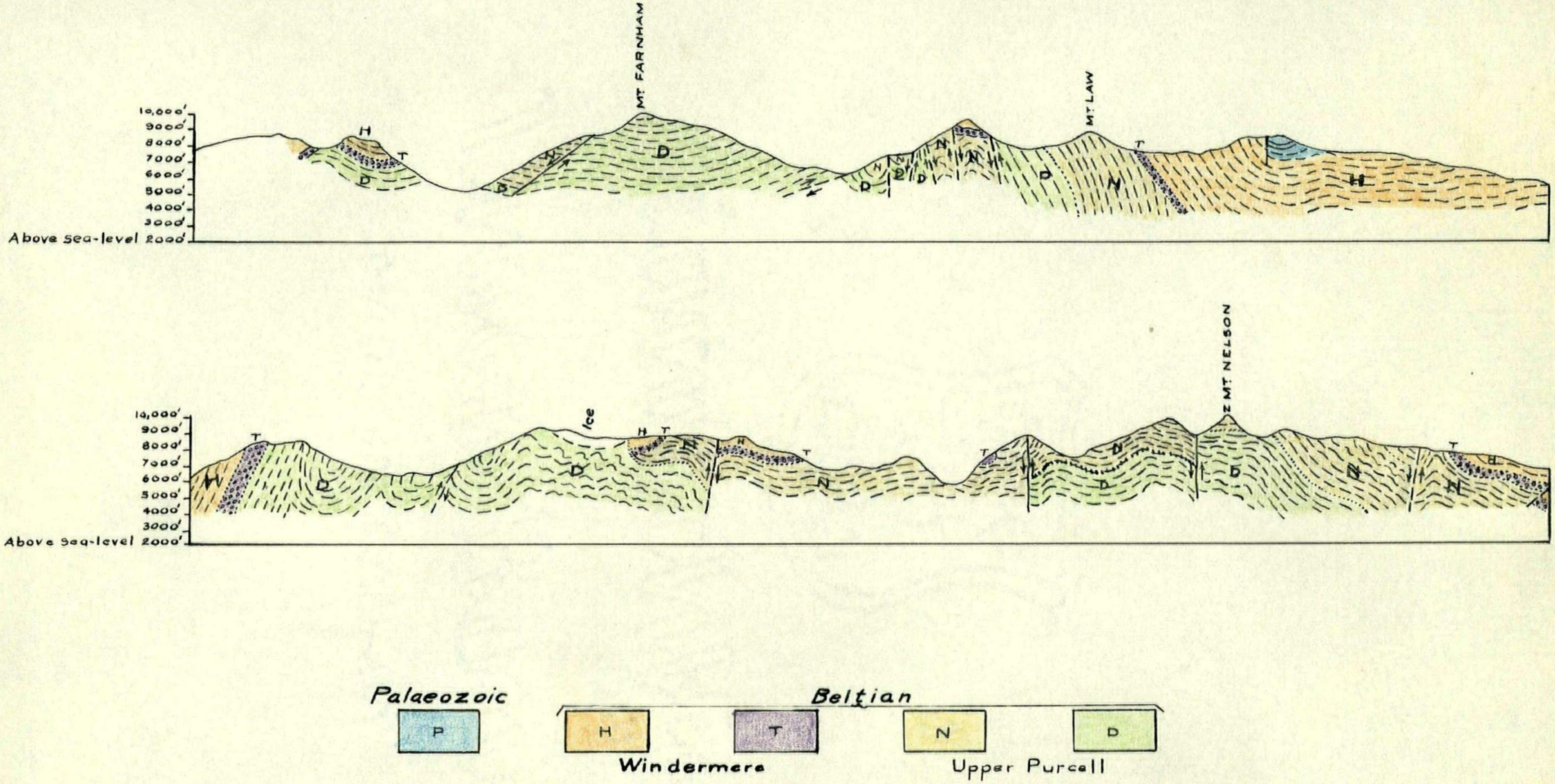
collection, Walcott stated that the mode of occurrence is similar to that of the Greyson shales of the Algonkian (Proterozoic) in the Belt Mountains of Montana. Hundreds of broken fragments of the carapace of the crustacean are distributed evenly through the rock. Occasionally a segment or fragment of what appears to be one of the appendages is sufficiently well preserved to identify it.

PLATE IV.



Section in Kootenay District

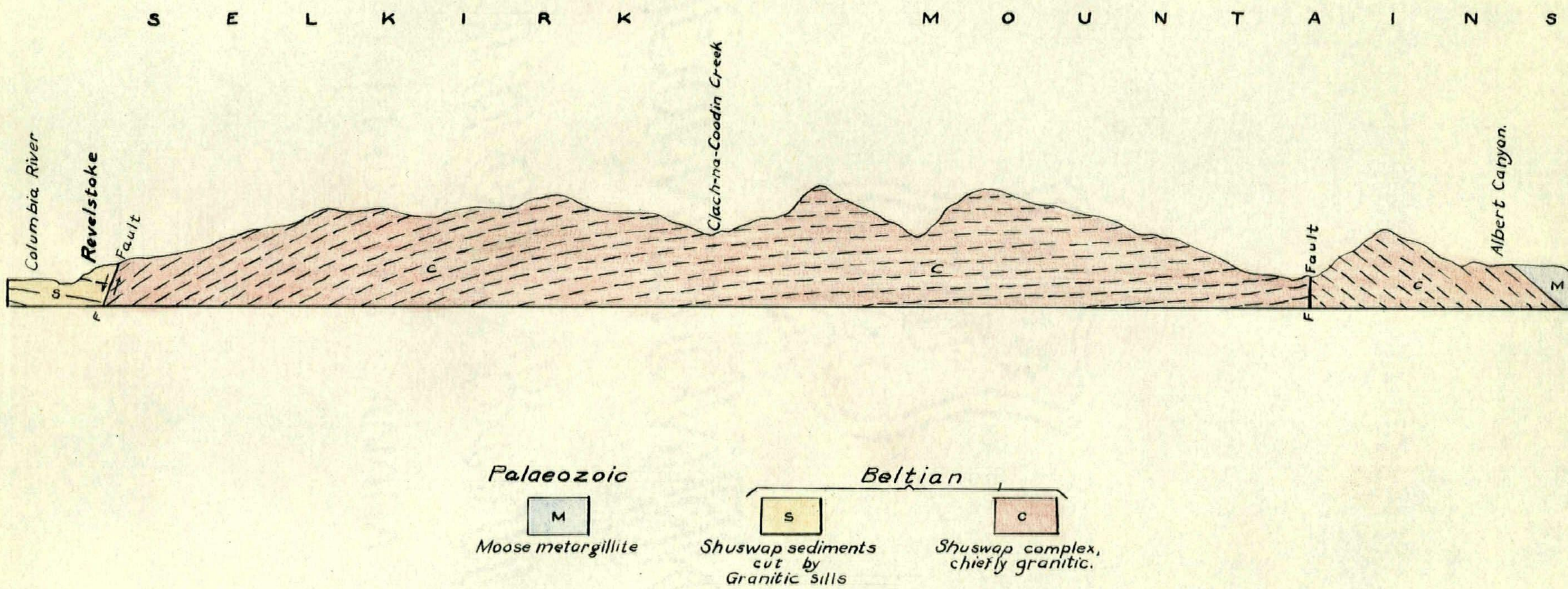
PLATE V.



Structure Sections in the Windermere

Scale
Miles

From G.S.C. Mem. 148, J.F. Walker.



Structure Section in the Selkirk Mountains

Horizontal and Vertical scale

Miles

1 ½ 0 1 2 3 4 5 6 7 8 9 10

Modified from G·S·C· Mem. 68, R·A·Daly.

PLATE VI.

PLATE VII.

Magnification 120 X.

Fig. 1. Aldridge quartzite, showing angular plagioclase feldspar with quartz and sericite. Note angularity of grains. X nicols.

Fig. 2. Aldridge quartzite, showing sericitized feldspar and grains of magnetite in a quartz-mica ground mass. X nicols.

PLATE VII.

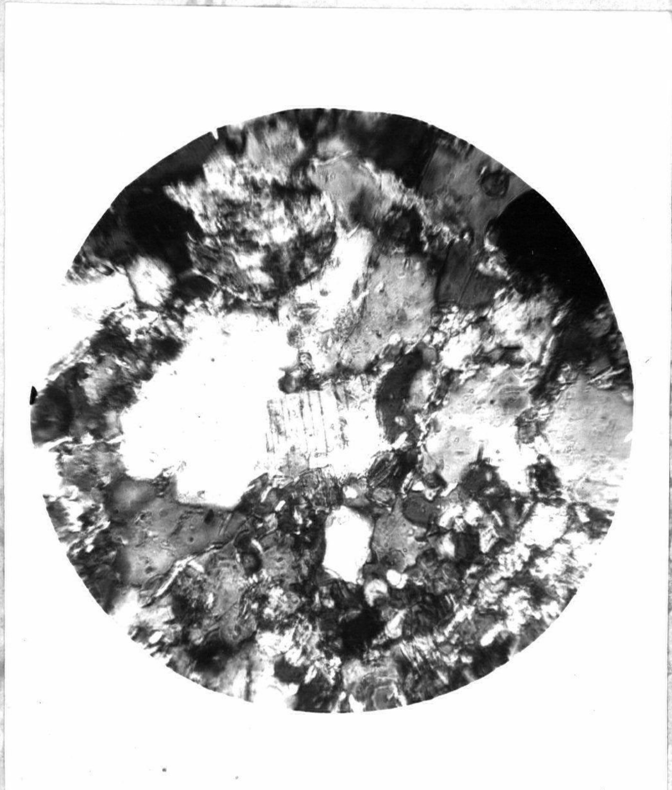


Fig. 1

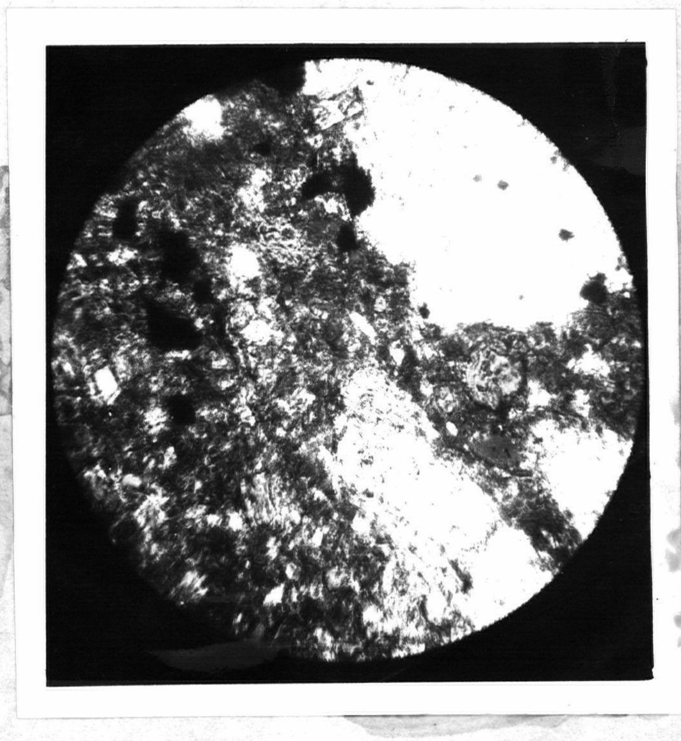


Fig. 2

PLATE VIII.

Magnification 120 X.

Fig. 1. Creston quartzite, showing angular basic feldspar in a ground mass of quartz with some sericite. Note angularity of grains. X nicols.

Fig. 2. Siyeh metargillite, showing magnetite and sericitized feldspar.

PLATE VIII.

Fig. 1

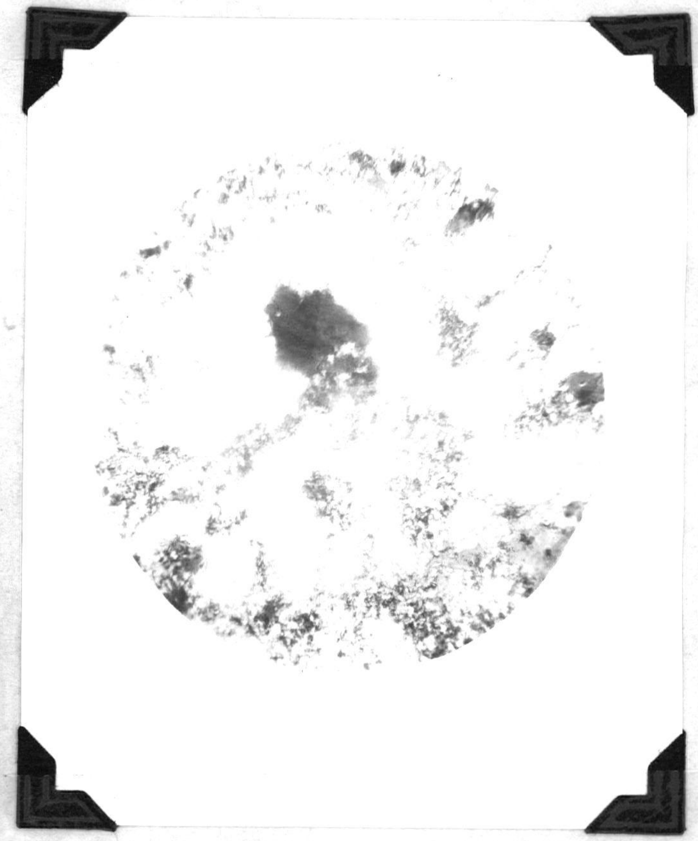


Fig. 2

PLATE IX.

Magnification 120 X.

Fig. 1. Kitchener quartzite, showing sericitized feldspar in fine ground mass, chiefly quartz. X nicols.

Fig. 2. Kitchener limestone, showing quite well rounded grains.

PLATE IX.

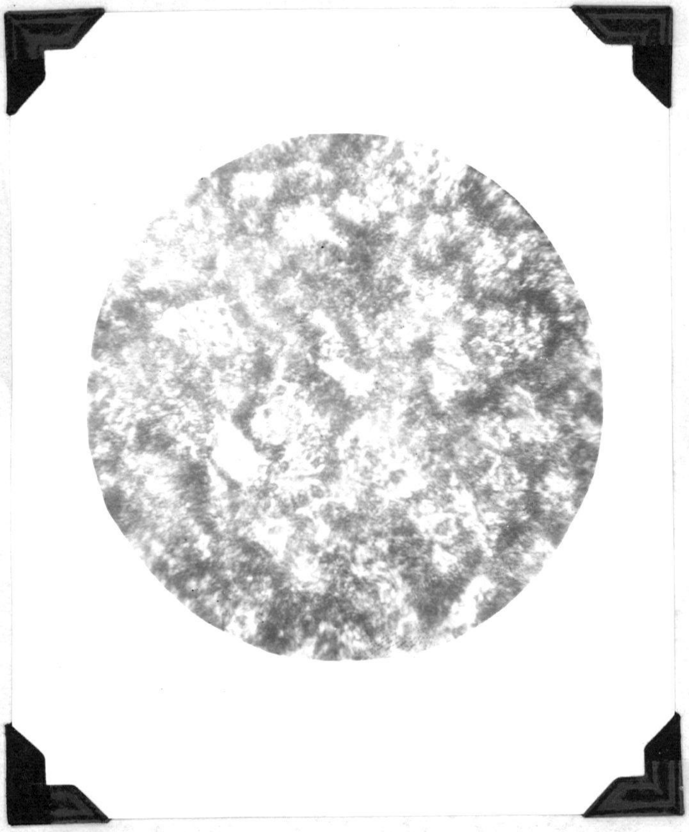


Fig. 1

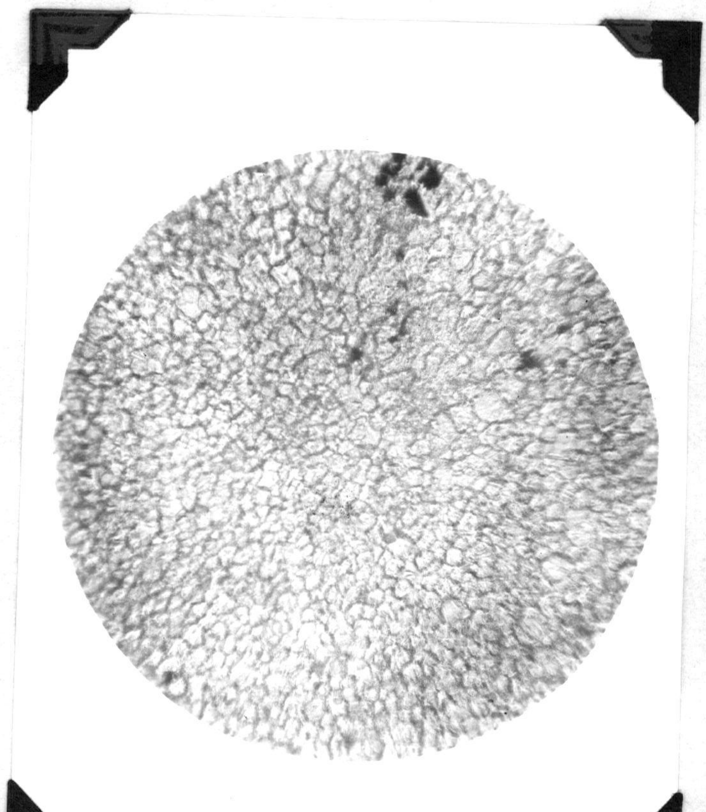


Fig. 2

PLATE X.

~~Magnification 120 X~~.

Fig. 1. Interference ripple marks and rain-pits on Siyeh metargillite.

Fig. 2. Interference ripple marks in unconsolidated sand. After Kindle, G.S.C., Mus. Bull. 25, p.99.

PLATE X.

Fig. 1

Fig. 2

PLATE XI.

~~Magnification 120 X.~~

Fig. 1. Mud-cracks in Siyeh metargillite.

Fig. 2. Interrupted banding typical of the Creston formation.

Fig. 3. Waterfall on dip-plane of Aldridge quartzite, Cherry Creek, East Kootenay.

PLATE XI.

Fig. 1

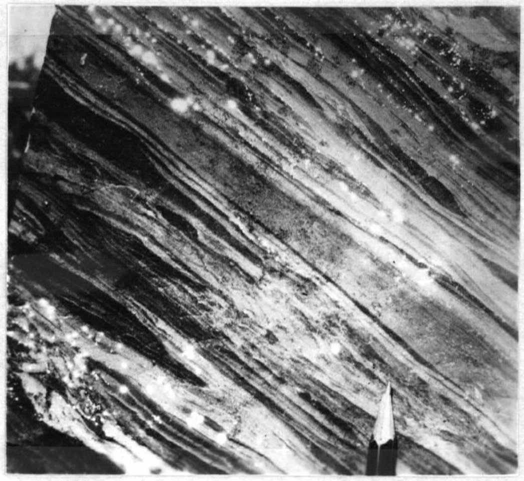


Fig. 2

Fig. 3

PLATE XII.

~~Magnification 120 X~~.

Fig. 1. Incompetent argillite interbedded with competent quartzite; Cherry Creek, East Kootenay.

Fig. 2. Fault in Aldridge quartzite; Weaver Creek, East Kootenay.

Fig. 3. Aldridge beds on Perry Creek, East Kootenay. Note the flat-lying attitude.

PLATE XII.

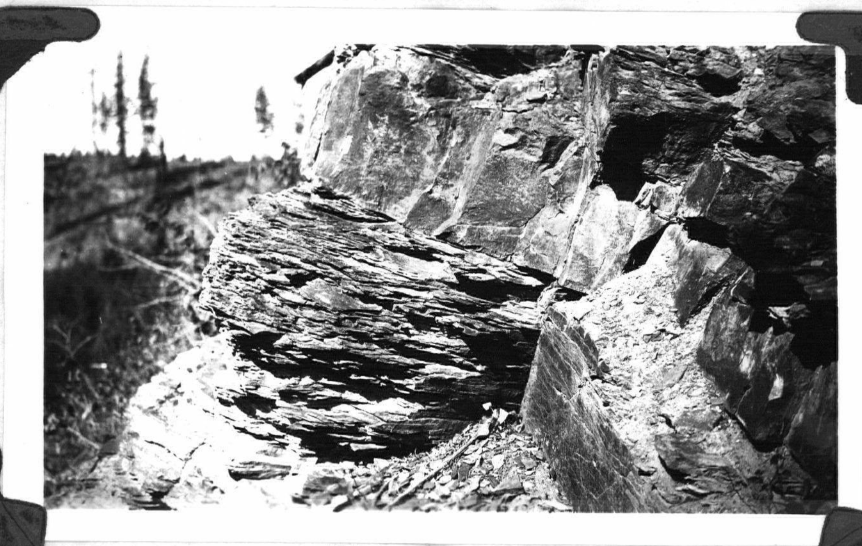


Fig. 1

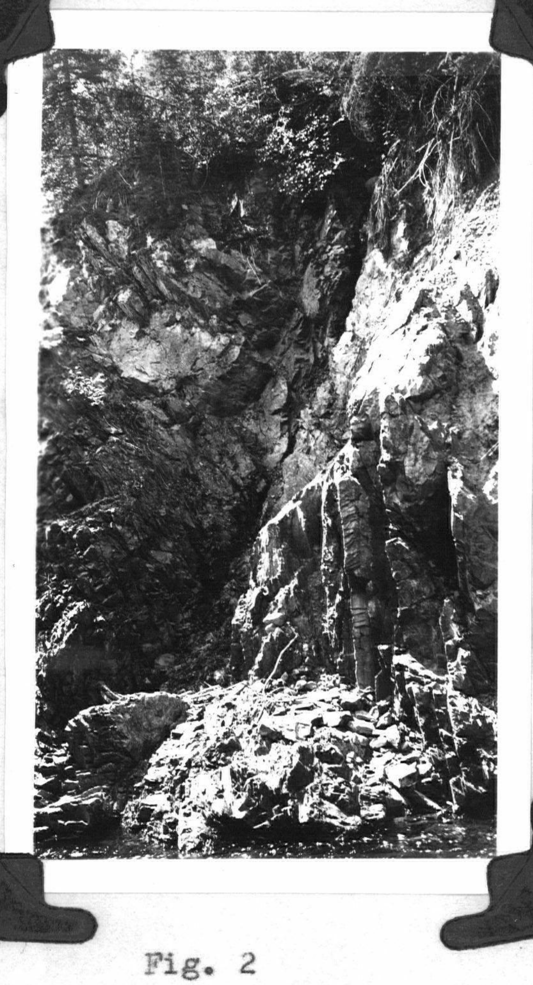


Fig. 2

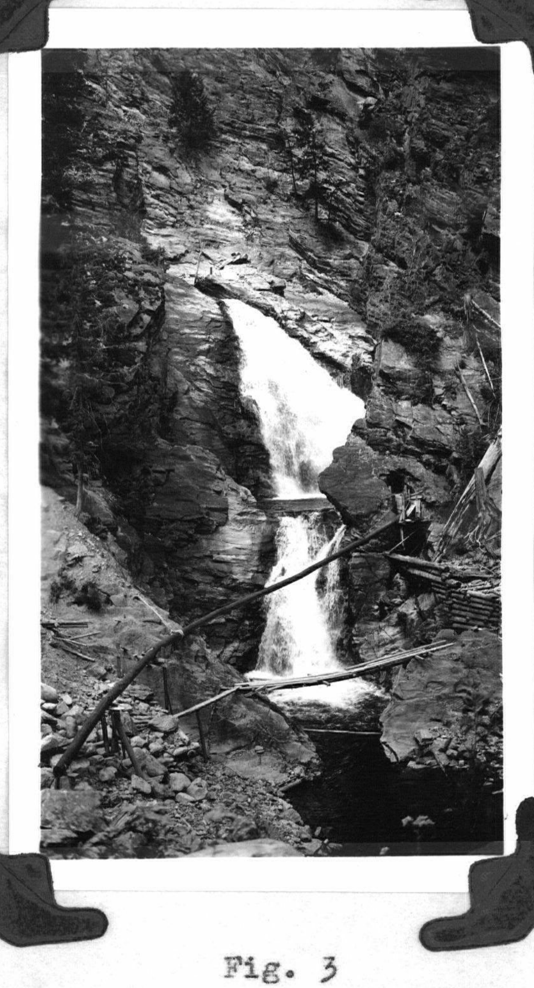


Fig. 3

PLATE XIII.

~~Magnification 120 X.~~

Fig. 1. Steeply dipping Creston quartzite, East Kootenay.

Fig. 2. Vertical Creston quartzite, East Kootenay.

Fig. 3. "Molar Tooth" structure typical of Kitchener limestone; Upper Moyie Lake, East Kootenay.

PLATE XIII.

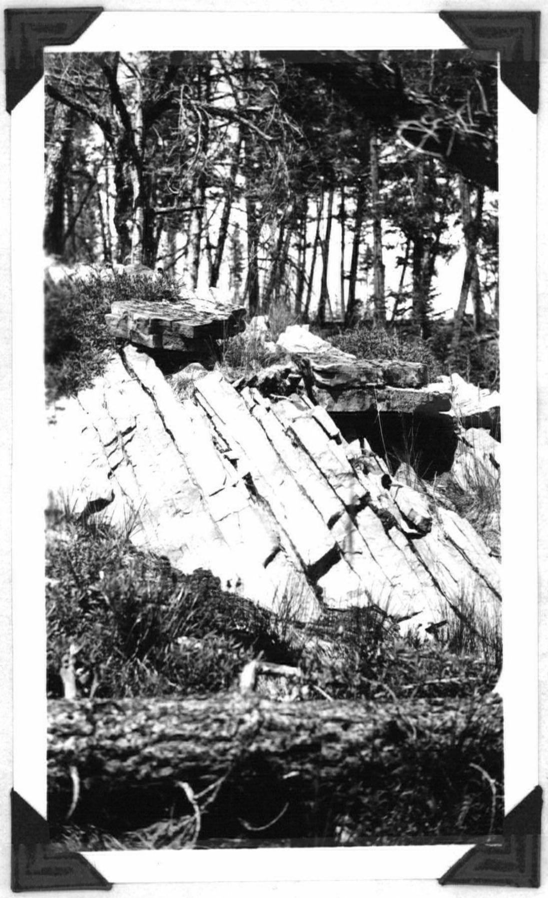


Fig. 1

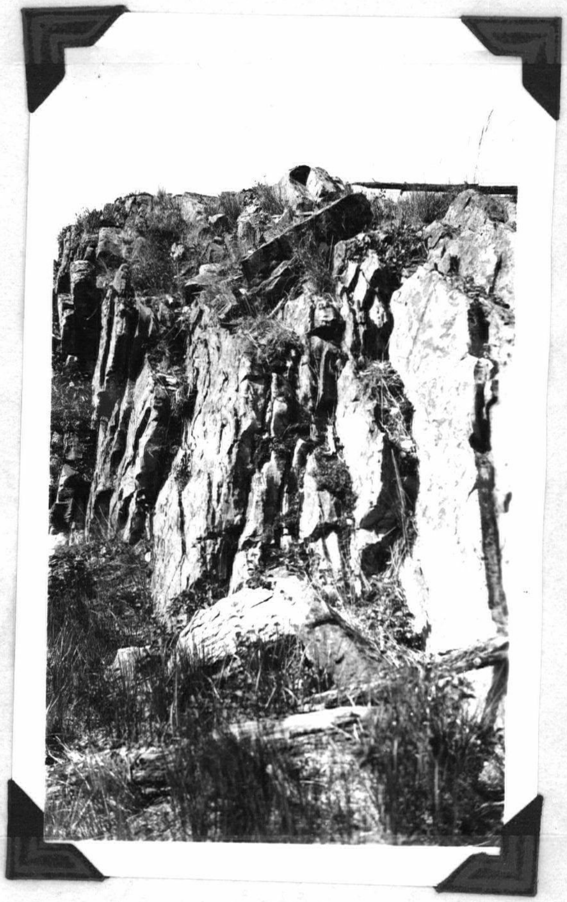


Fig. 2

Fig. 3

PLATE XIV.

~~Magnification 120 X.~~

Fig. 1. Coast Range west of the Bridge River area, Lillooet district.

Fig. 2. Spanish creek, Cariboo district.

Fig. 3. Morehead lake, Cariboo district.

PLATE XIV.

Fig. 1

Fig. 2

Fig. 3

PLATE XV.

~~Magnification 120 X.~~

Fig. 1. Typical topography of the Cariboo district.

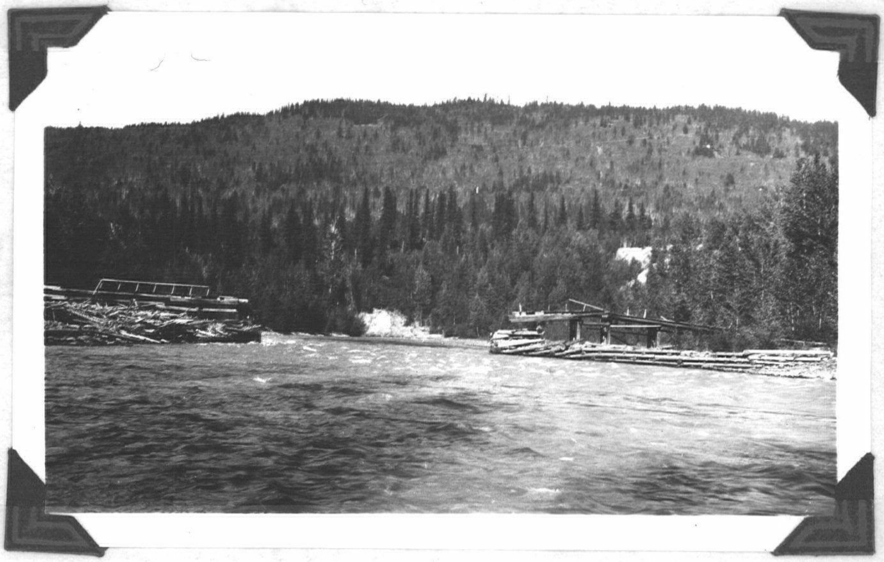
Fig. 2. Wrecked bridge where the old road from Quesnel to Barkerville crossed the South fork of the Quesnel River.

Fig. 3. Quesnel Forks, one of the camps established during the gold rush of 1859.

PLATE XV.

Fig. 1

Fig. 2



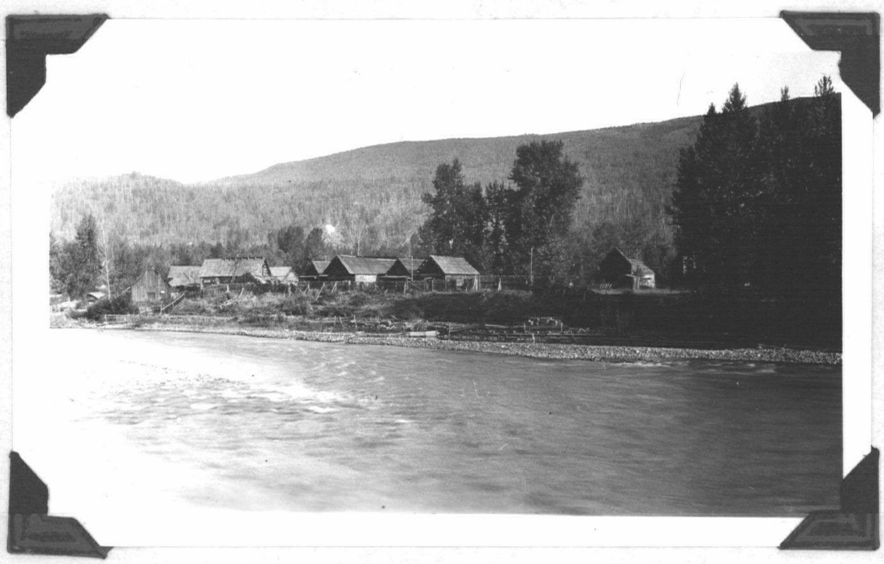


Fig. 3

PLATE XVI.

~~Magnification 120~~ X.

Fig. 1. Okanagan valley near Armstrong, B. C. Note the scarcity of vegetation on the southerly slopes, picture facing southwest.

Fig. 2. Coldstream valley, facing east. Note the uniformity of the hilltops.

Fig. 3. Kalamalka lake, Vernon, B. C.

PLATE XVI.

Fig. 1

Fig. 2

Fig. 3

PLATE XVII.

~~Magnification 120 X~~.

Fig. 1. Looking east near Lightning peak, west of Lower Arrow lake.

Fig. 2. Lightning Peak.

Fig. 3. Facing north from Lightning peak. Note the plateau-like appearance.

PLATE XVII.

Fig. 1

Fig. 2

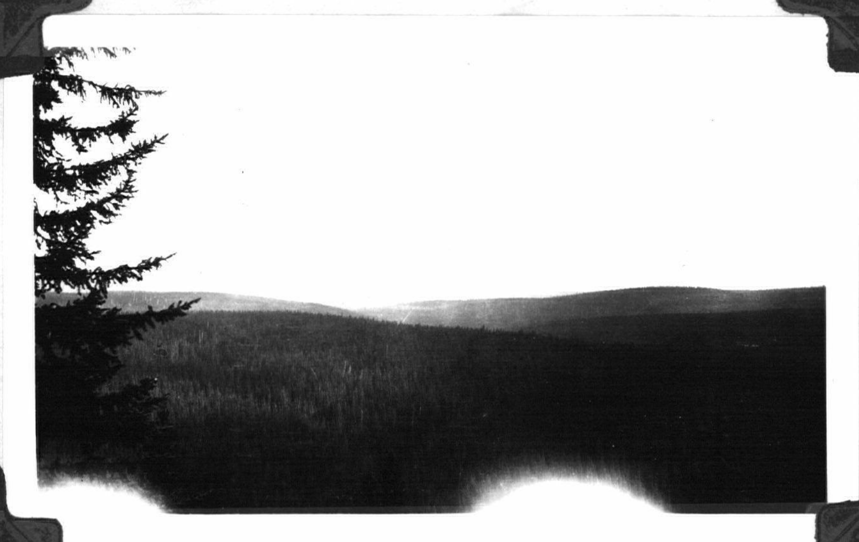


Fig. 3

PLATE XVIII.

~~Magnification 120 X.~~

Fig. 1. Monashie creek in a canyon in Nisconlith rocks. 35 miles east of Vernon, B. C.

Fig. 2. Purcell Mountains from the Rocky Mountain trench near Cranbrook, B.C.

Fig. 3. Rocky Mountains from the Rocky Mountain trench near Cranbrook, B.C. Mount Fisher in the centre.

PLATE XVIII.

Fig. 1

Fig. 2

Fig. 3

PLATE XIX.

~~Magnification 120 X.~~

Fig. 1. Valley of Perry creek, East Kootenay, showing how the creek has cut down into the U-shaped valley left after the retreat of the ice.

Fig. 2. St. Mary's prairie, East Kootenay.

Fig. 3. Typical Rocky Mountain topography east of Banff, Alberta. Note the serrated peaks.

PLATE XIX.

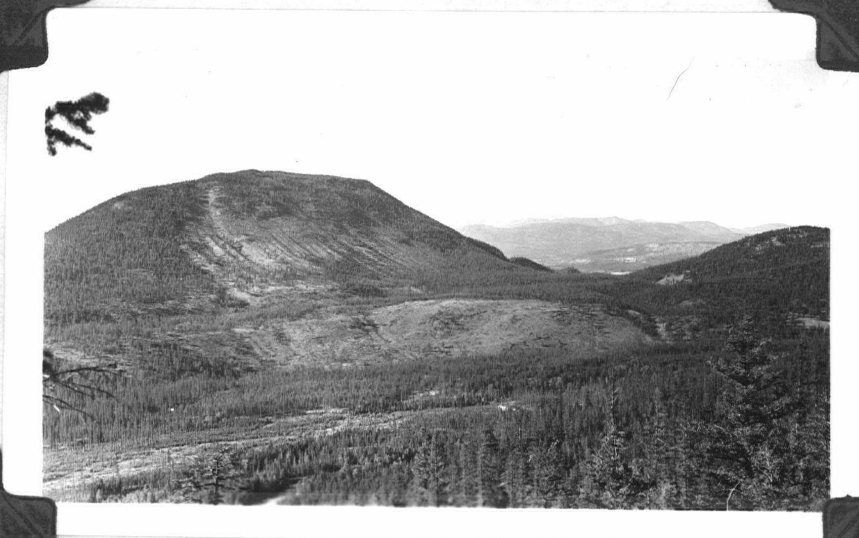


Fig. 1

Fig. 2

Fig. 3

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DEPARTMENT OF LANDS
HONOURABLE T. D. PATTULLO, MINISTER
J. E. UMBACH, SURVEYOR GENERAL
BRITISH COLUMBIA
Scale, 1/2,000,000
31.56 miles to 1 inch
Kilometres
1923
MAP I
G. G. AITKEN, CHIEF GEOGRAPHER
NON-SCHISTOSE BELTIAN
SCHISTOSE BELTIAN
MESOZOIC INTRUSIVES
LEGEND
Cities VIC
Government Agents Offices Ash
Mining Recording Offices Yale
Sub-Mining Recording offices Hedley
Post Offices Sardis
Railway Stations Haig
Villages Camborne
Lighthouses
International Boundary
Interprovincial Boundaries
Land District Boundaries
Park Boundaries
E. & N. Ry. Grant, Dom. Ry. Belt & Peace River Block Boundaries
Hospitals
Radio Stations
Telegraph Lines
Telephone Lines
Railways
Railways, under construction
Roads, main
Trails
Elevation of lakes, mountains, etc. in feet above sea level
INDEX OF POST OFFICES
The Index Figures denote the geographical degree quadrilaterals in which the Post Offices are located. In this indexing system the south east corner of each quadrilateral is used as the initial point of reference.
Example:—Prince George, 53-122, lies between the 53rd and 54th parallels
YUKON
NORTH WEST TERRITORIES
CASSIAR
PEACE RIVER
CARIBOO
COAST
LILLOOET
KOOTENAY
YALE
NEW WESTMINSTER
RUPERT
ALBERTA
PACIFIC OCEAN
DIXON ENTRANCE
PRINCE RUPERT
QUEEN CHARLOTTE ISLANDS
GRAHAM ISLAND
HECATE STRAIT
QUEEN CHARLOTTE SOUND
VANCOUVER
VICTORIA
NANAIMO
WASHINGTON
IDAHO
MONTANA
UNITED STATES
INSET VICTORIA SEATTLE
TESLIN LAKE
ATLIN LAKE
BABINE LAKE
TAKLA LAKE
FRANÇOIS LAKE
PORTLAND CANAL

MAP 2.

LEGEND

QUATERNARY

Q — STRATIFIED CLAY AND SAND

INTRUSIVES

2 — *TERTIARY (?)* — SALMON RIVER MONZONITES

I — *POST-TRIASSIC* — KUSKANAX BATHOLITH

MESOZOIC

K — *TRIASSIC* — KASLO SERIES

MESOZOIC-PALAEOZOIC

M — MILFORD SERIES

PALAEOZOIC

W — *DEVONIAN* — WARDNER FORMATION

PRE-CAMBRIAN

WINDERMERE

L — LARDEAU SERIES

BADSHOT FORMATION

H — HAMILL SERIES

T — HORSETHIEF FORMATION

TOBY AND IRENE CONGLOMERATES

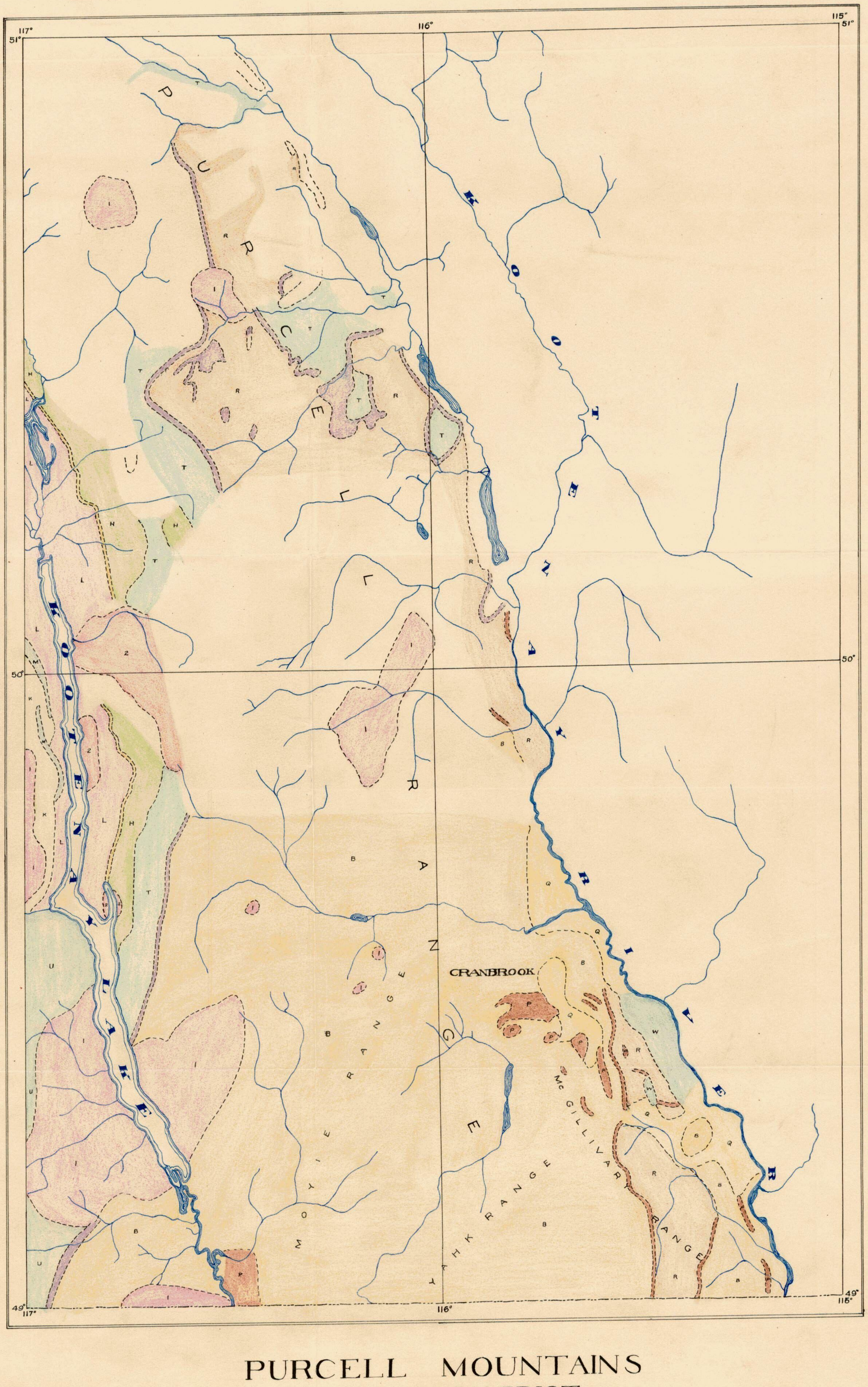
U — UNDIVIDED WINDERMERE SUMMIT AND PEND OREILLE SERIES

PURCELL

R — PREIST RIVER TERRANE, MOUNT NELSON, ROOSVILLE, PHILLIPS AND GATEWAY FORMATIONS

P — PURCELL LAVA AND SILLS

B — SIYEH, KITCHENER, CRESTON AND ALDRIDGE FORMATIONS

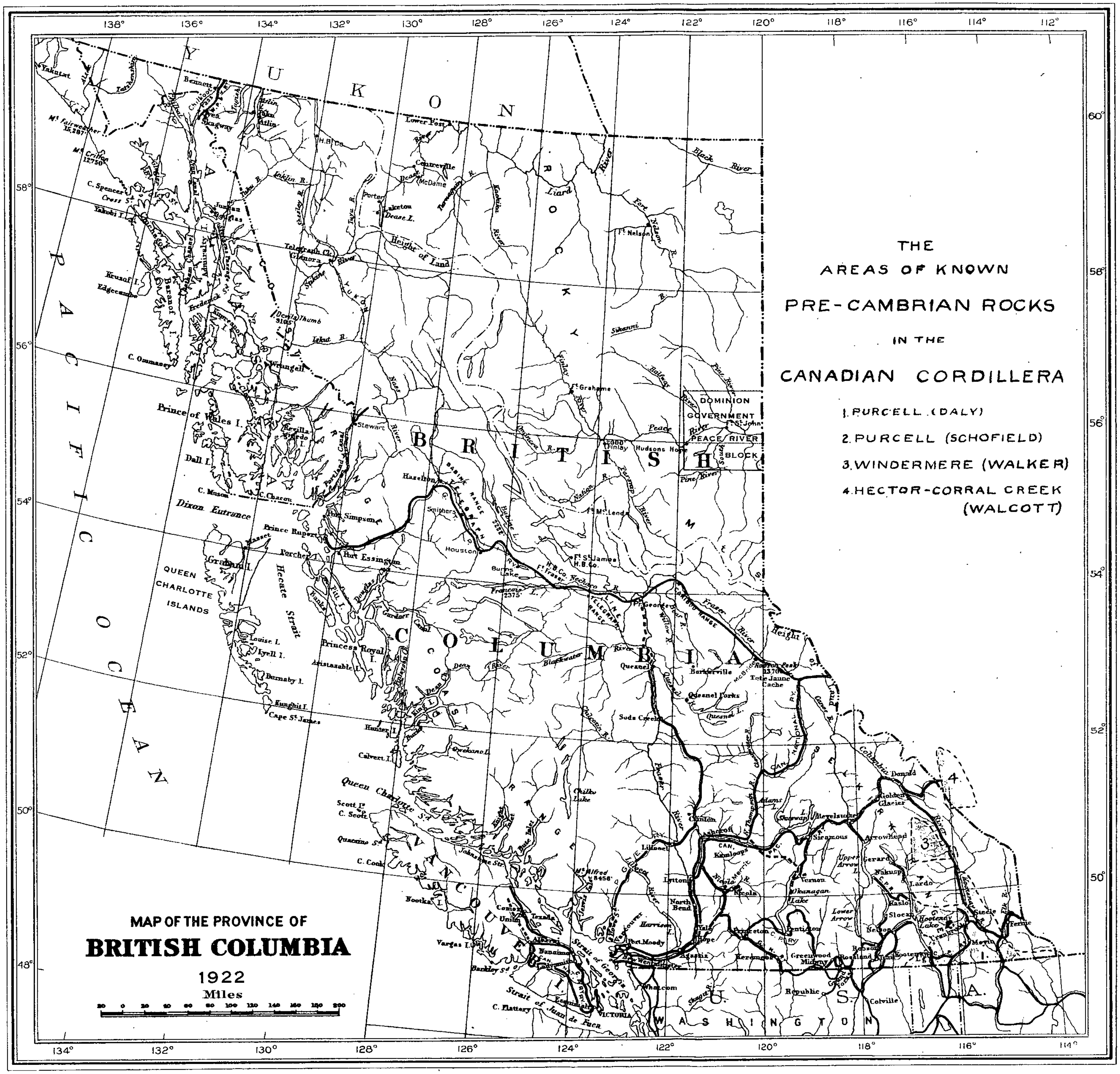


PURCELL MOUNTAINS
KOOTENAY DISTRICT
BRITISH COLUMBIA

Scale $\frac{1}{500,000}$

Miles

MAP 3.



GEOGRAPHIC BRANCH, B. C.

SECTION AT THE FORTY-NINTH PARALLEL, By R.A. Daly.

Scale: [illegible] – 0·9864 Statute Miles to 1 Inch

Miles