THE GEOLOGY OF THE ROCKY MOUNTAINS

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C O N T E N T S

CHAPTER III

GENERAL GEOLOGY

CHAPTER IV

THE STRUCTURE OF THE ROCKY MOUNTAINS

CHAPTER V

HISTORICAL GEOLOGY

INTRODUCTION

A paper on the geology of so large an area as that occupied by the Rocky mountains will necessarily be somewhat in the nature of a written reconnaissance. Though the subject may suffer from the lack of detailed treatment, yet there is considerable value in grouping the known geological facts of a system as a whole. Such is the aim of this paper.

Considerable geological work has been done in the Rocky mountains, but the great majority of it has been confined to the areas contiguous to the main line of the Canadian Pacific Railway and south to the 49th parallel. Enough has been done throughout the area to afford a general idea of the geology of the entire system. Vast areas, however, are still unexplored by the geologist and a very attractive field of study offers itself in these mountains. It is attractive because of the many problems there that still await solution, because the comparatively little deformed strata and their generally conformable nature should render the solution not too difficult, because it is almost a virgin field of study and because of the richness of the fossil record.

The writer wishes here to express his appreciation for helpful criticism, advice and time given by Dr. Schofield during the preparation of this thesis.

CHAPTER I.

GENERAL DESCRIPTION OF CORDILLERA OF NORTH AMERICA

The Rocky Mountains, forming as they do, only a unit of the great mountain system of western North America, can be best discussed after the general physiography of that system is outlined and the relationship of the part to the whole is made clear. Hence, before beginning a detailed description of the Rockies themselves, the geography and geology of the entire Cordillera will be briefly outlined.

That no definite nomenclature has been accepted for this great system is evidenced by the fact that as many as twenty-six different names are recorded in the literature and on maps, in some cases the name of Rocky Mountains being given to the entire area. The admirable suggestion of Daly[1] that the name be the Cordillera of North America will be followed in this paper.

The Cordillera forms one of the grandest mountain systems on the globe, covering an area of over 2,300,000 square miles. By way of contrast it might be stated that the area of the Andes is about 1,000,000 square miles, the Himalayas 300,000 square miles, and the Alps 70,000 square miles. The Cordillera of North America stretches from Alaska in the north to Central America in the south and east to west from the Great Plains to the Pacific.[2]

1. Daly, R.A. Geol.Surv.Can.Mem.38. 1912. P.18
2. Idem P.17

This vast sea of mountains is neither structurally nor physiographically one unit, but on the contrary shows a great complexity in these characteristics. It has, however, two great general structural zones known as the Eastern and Western Geosynclinal Belts, having as a general dividing line a narrow area roughly parallel to the summits of the Canadian Selkirks. Eastward to the Plains sedimentary forms are dominant and almost entirely included in one huge structure called the Rocky Mountain Geosynclinal Prism. This reaches from Alaska to Arizona. Paralleling this and west of the Columbia lies the Western Geosynclinal consisting mainly of sediments of post Mississipian age.[1]

The Cordillera may be conveniently divided into a number of topographic units.[2] These are:

1. The Coast Ranges. .....including the Queen Charlotte Islands, Vancouver Island, the Olympics of Washington, the Coast Ranges of Oregon, the Coast Ranges of California and the axis of the Californian Peninsula.
2. The Great Pacific Trough.....formed by Hecate Strait, Georgia Strait, Puget Sound, the Cowlitz and Williamette valleys in Washington and Oregon, the Great Valley of California and the Gulf of California.
3. Belt of high mountains.....which includes the Coast Range of British Columbia, the Cascades of Washington and Oregon, the Sierra Nevadas, the San Gabriel and San Bernardino ranges of California and the Sierra Madre Occidental of Mexica.

1. Schofield, S.J. Geol.Surv.Can. Guide Book No.9.1913. p.20
2. Jones and Bryan, North America, 1924. p.136

4. A great area of plateau and irregular mountain masses... made up of the interior plateaus of Alaska, Yukon and British Columbia, the Columbia and Colorado Plateaus, the Great Basin and Range Provinces of the United States and the Northern Basin of Mexico.

5. The Rocky Mountains of Canada and the United States.

A few general features characterise the entire system:[1]

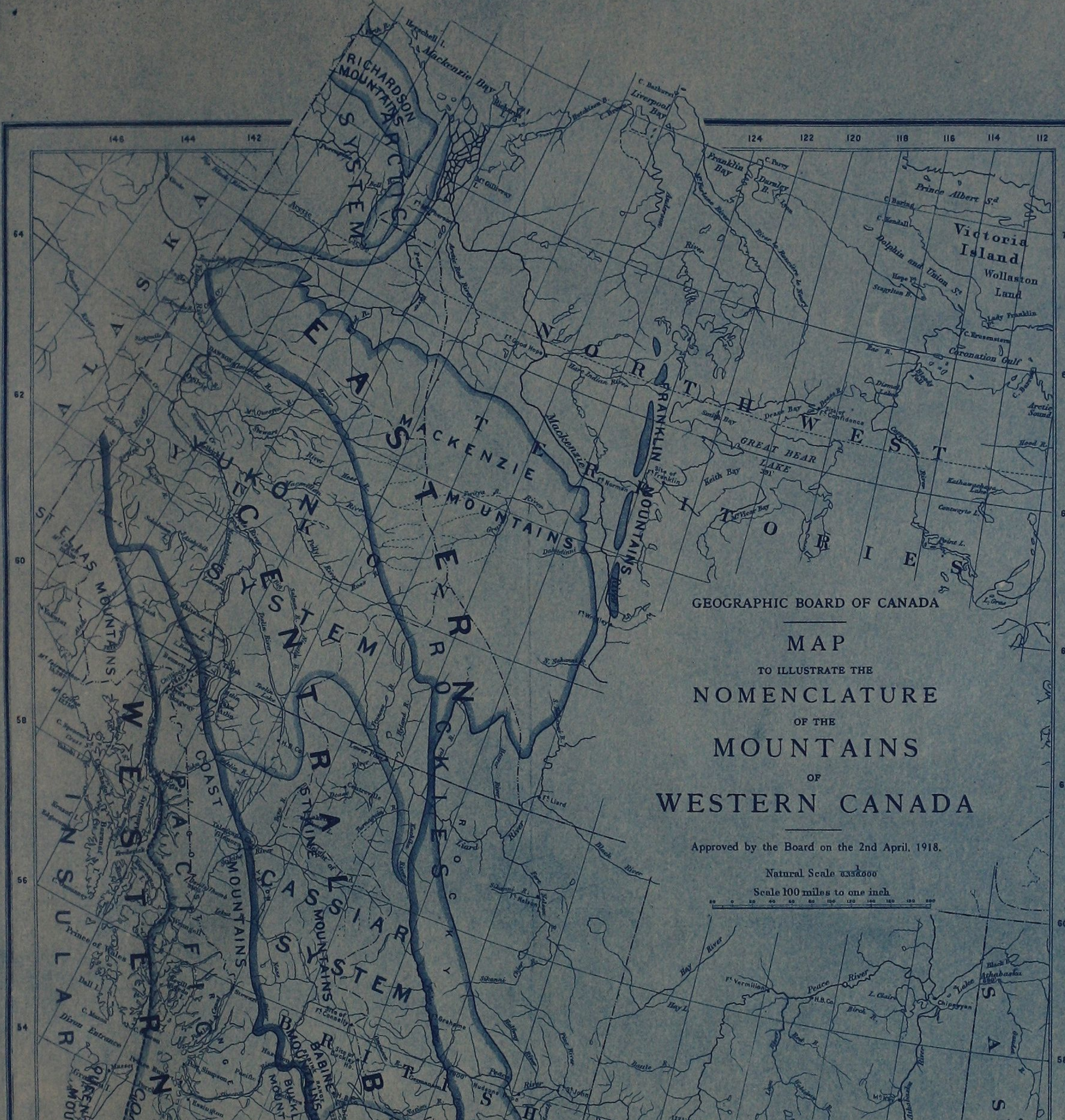
1. A continuity of the main physiographic features.
2. A decreasing width northward of the Cordillera.
3. Decreasing height northward.
4. The extraordinarily continuous trough-like water valleys whose trend is almost north-westerly.

General Description of Topographic Units

The Coast Ranges.

The Coast Ranges occupy the western borderland of the United States. In Canada they are located west of the main land and form Vancouver Island and Queen Charlotte Islands. In British Columbia they form one structural unit and are known as the Insular System, of which the Queen Charlotte Islands form the northern range. This range, which trends N.28° W, is about 180 miles long and averages twenty miles in width. It is separated from the mainland by the submerged northern part of the Pacific Coast Downfold called here Hecate Strait.

1. Jones and Bryan, North America. p.492.



GEOGRAPHIC BOARD OF CANADA

MAP
TO ILLUSTRATE THE
NOMENCLATURE
OF THE
MOUNTAINS
OF
WESTERN CANADA

Approved by the Board on the 2nd April, 1918.

Natural Scale $\frac{1}{6336000}$

Scale 100 miles to one inch

CLASSIFICATION OF BELTS, SYSTEMS, MOUNTAINS OR PLATEAUS, AND RANGES, GROUPS OR PLATEAUS, FORMING THE CORDILLERAS OF CANADA.

WESTERN BELT			CENTRAL BELT			EASTERN BELT		
SYSTEM	MOUNTAINS OR PLATEAUS	RANGE, GROUP OR PLATEAU	SYSTEM	MOUNTAINS OR PLATEAUS	RANGE, GROUP OR PLATEAU	SYSTEM	MOUNTAINS OR PLATEAUS	RANGE, GROUP OR PLATEAU

The Queen Charlotte Island range, in the main, is made up of resistant metamorphic and crystalline rocks. It is rugged with steep glaciated slopes with rounded, rarely serrated summits which vary from 3,000-5,000 feet in height. In the northern part of the range are low areas underlaid by sediments and volcanics generally less resistant than the older rocks. The largest of these low areas forms the north east section of Graham Island.[1]

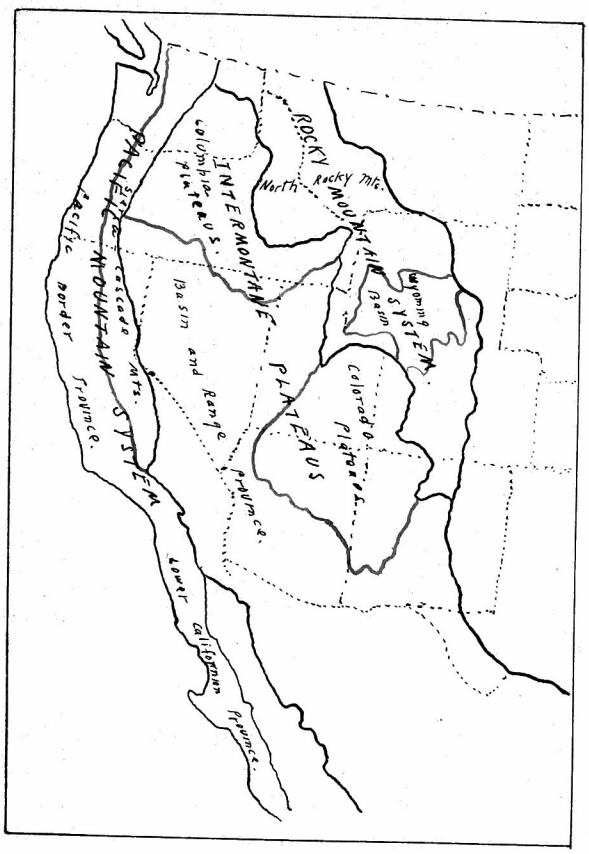
The Vancouver Range constitutes the whole of Vancouver Island, trending N.55° W. The island is 290 miles long and 50 to 80 miles broad. Its insular nature is due to the Pacific Coast Downfold to the east and a smaller transverse downfold to the south which strikes N.70° W, and is now occupied by the Strait of Juan de Fuca. The elevation of the mountains of the island is about 1,500 feet near the southern coast. This increases rapidly northward, where in many parts it reaches 4,000 feet with old residuals attaining an elevation of 5,000 and 7,000 feet.

The materials are deformed, metamorphic, volcanic and sedimentary rocks intruded and replaced by many irregular bodies of granitic rocks and fringed along both coasts with fragmental sediments resting unconformably on metamorphic and granitic rocks.[2]

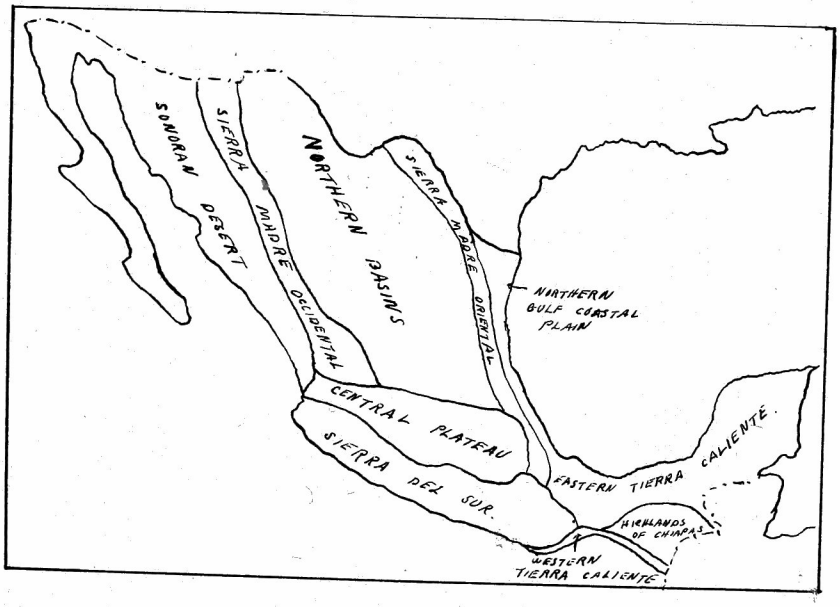
The Olympic range of Washington is still very imperfectly known due to the density of its forests. The Oregon mountains consist of Cretaceous and Tertiary beds which have

1. Clapp, C.H. Geol.Surv.Can. Sum.Rep. 1912. p.17
2. Idem. Idem. Guide Book.No.8.Pt.III. p.280

Plate II.



Physiographic Regions of the Cordillera of the United States. (After Blackwelder).



Physiographic Regions of Mexico.
(After Jones and Bryan) .

been only moderately folded. The Olympics rise to a height of 8,000 feet. The Oregon mountains are lower and less continuous. These ranges are crossed successively by the Chenalis, Columbia and Umpqua rivers.[1]

Extending between the Coast Ranges of Washington and Oregon and those of California is a small transverse range .. the Klamaths. Its materials are granites intruded into Devonian, Carboniferous and later rocks.[2]

South of the Klamaths the Coast Range is again continued in California. Similar to the ranges in the north, the relief is not great, being on an average from 3,000 to 4,000 feet with isolated peaks reaching 6,000 feet. They expose Cretaceous and more recent rocks, lava flows and igneous intrusives, the whole broadly deformed and dissected. The most important agent in the present general relief has been block faulting. The western edge of the dissected block on which the Coast Ranges are developed is a submarine line 600 feet deep. West of this, the surface falls 8,000 feet or more into the Pacific abyss. The eastern edge overlooks the Great Valley 50 to 100 miles from the coast. Between these major scarps are a number of longitudinal valleys outlined in parallel faults and set somewhat oblique to the coast line so that the extremities of the ridges reach the coast in bold promontories and the ends of the valleys in low bays.

The southernmost part of the Coast Ranges is formed by the Sierra Madre Mountains and the Mountains of Lower

1. Blackwelder, E. Geol.U.S.A. p.191
2. Diller, J.S.,U.S.G.S. Bull.102.

California. While not continuous with the Coast Range of California, they are similar in materials and history.

The Pacific Coast Downfold

Like the Coast ranges, the Pacific Coast Downfold preserves its north-south trend with few interruptions, the greatest being the Klamath Mountains. North of this range, it consists of Hecate Strait, the Strait of Georgia, Puget Sound, and the Cowlitz and Williamette Valleys. It is continued southward by the Great Valley of California, of which the structure deserves some comment. Prior to the Pliocene, this valley was already existent, but the thrusting and folding of the ranges to the east and west of it during that period accentuated the depression by a sharp closing in. Since that time there has been a continuous deposition of fluviatile and sub-aerial sediments of alternating sand, gravel, clay and loess until the large area of 400 miles long and 50 miles wide has been filled 1,000 feet or more.[1]

Completing the long Pacific depression is the Gulf of California with the Sonoran Desert to its east.

Belt of High Mountains

Included by Spencer[2] in the Belt of High Mountains are the Kuskokwin Mountains, the Alaskan Range, the Kenai Mountains, the St. Elias Range and the Nutzotin Mountains all of Alaska. Stated briefly, this writer's opinion is that the uniform summits found over the greater portion of the Pacific

1. Drake, N.F. Jour. of Geology. Vol.5. 1897. p.573
2. Spencer, A.C. Geol. Soc. Am. Vol.14. 1903. p.118

Mountain System in the north are representatives of elevated peneplains which have suffered deep dissection. He arrives at this conclusion mainly because the peneplains of the different portions of the coastal mountains and the inland plateaus can be correlated with one another. The Pacific Province was raised, after the production of the peneplain by erosion extending through Eocene time, mainly by uplifts of a continental character. Regional elevation, which was accompanied by warping, flexure or displacement, elevated tectonic blocks which have not been effaced by subsequent erosion. Tangential compression has not been the cause of this mountain building.

The most southerly portion of the Alaskan coast ranges is the low range in the Alexander Archipelago. Northward is the St.Elias Range, the southern end of which is overlapped by the Coast Range of British Columbia to the east just before that range merges into the plateaus of the interior. The St.Elias Range averages 150 miles wide and beyond its culminating peaks divides into two ranges, the Skolai and the Chugash. Skolai on the east continues to the vicinity of Mount Wrangell. North-east of this volcano lies the Nutzotin range which also has a north-west trend. The Alaskan range overlaps the Nutzotins which continue north-west as far as Mount Kimball where their axis assumes a westerly direction as far as Mount McKinley, the highest mountain of North America. Here the range turns south westerly gradually diminishing in height towards Cook Inlet. Occupying the Alaskan Peninsula is

the Aleutian Range and to the north is the little known Kuskokwin Mountains.

The Coast Range of British Columbia is a deeply dissected granitic ridge 50 to 100 miles wide and 1,000 miles long, rising from the sea with few intervening plateaus to 4,000-5,000 feet and increasing to 7,000-8,000 feet in the axis of the range. The height as a rule is uniform with few outstanding summits. Deep, ice-worn, steep-sided valleys penetrating the range in all directions are one of its characteristic features. A fiord system is well developed along the coast with fiords penetrating the range to a depth often exceeding 100 miles. This range is essentially a complex batholith of late Jurassic or early Cretaceous age cutting, enclosing and flanking masses of Paleozoic and earlier Mesozoic strata.[1]

In the same general topographic area as the Coast Range of British Colombia, though not a continuation either physically or geologically, are the Cascades of Washington and Oregon. Two subdivisions exist, the dividing line being in the general vicinity of Mt. Rainier. Both north and south divisions are uplifted masses of peneplained, metamorphosed Paleozoics. The main deformation and uplift took place in Tertiary times. With the uplift, north and south warpings gave rise to three ranges and two intermediate valleys. In relief, the Cascades consist of a 75 mile wide, dissected, rather flat-topped range with somewhat accordant altitudes of about 5,000 feet. Extending north and south rather toward

1. McConnell, R.G. Geol.Surv.Can. Guide Book No.10. p.6

the eastern side of the Cascades are numerous volcanic cones rising 3,000 to 4,000 feet above the general level of the range.

The main feature of this belt of high mountains in California is formed by the great Sierra Nevadas. Their continuation in northern California is known as the Cascade and Lava Sheet Mountains, while in the south they branch into the San Gabriel and San Bernardino ranges.[1] The Sierra Nevadas are composed of a complex series of rocks of many ages which have been close folded, metamorphosed, subjected to repeated volcanism and peneplained. They were folded at the close of the Paleozoic with much igneous intrusion. At the close of the Jurassic they were compressed, folded and uplifted with batholithic intrusions and much metamorphosed. During the Cretaceous and Tertiary, peneplanation occurred, and at the end of the Tertiary a great uplift with much faulting and shearing, accompanied by wide lava flows took place. The main crest of this rugged range varies between 6,000 and 13,000 feet with a maximum height in one peak of 18,000 feet.

In Mexico, the Sierra Madre Occidental continues the province southward. Coming first into evidence at the international boundary, this range extends south to the Rio Grande de Santiago, where it adjoins the volcanic plexus of Southern Mexico. Its history is somewhat linked up with

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1. Drake, N.F. Jour.of Geology. Vol.5. 1897. p.573

the central table land of Mexico, but it suffered greater uplift and a more general volcanism. A narrow, deeply dissected tableland forms the highest mountain belt and is almost smothered in the igneous flows which accompanied its uplift.[1]

Area of Plateaus and Mountain Masses

The province of plateaus is represented in Alaska by the Interior Plateau. This is a broad Arctic slope lying between the Pacific Mountain System and the North Easterly Mountain Ranges. Though the relief is considerable the elevations are less than the bordering ranges and are often rounded and of an accordant summit level.[2]

In the Yukon territory the Plateau system is a continuation of the Alaskan with a general width of 250 to 300 miles. In the main it consists of a folded basement of Cretaceous limestone cut by quartz monzonite or granite upon which rests a great thickness of Tertiary lavas.

A mountainous area in northern British Columbia forms a general division between the interior plateaus of Yukon and British Columbia. The plateau region of the latter province has a general elevation of 3,000 to 4,000 feet and is formed of a succession of plateau surfaces, some of great extent but broken by deeply cut valleys of a drainage system whose main channels lie 1,000 feet or more

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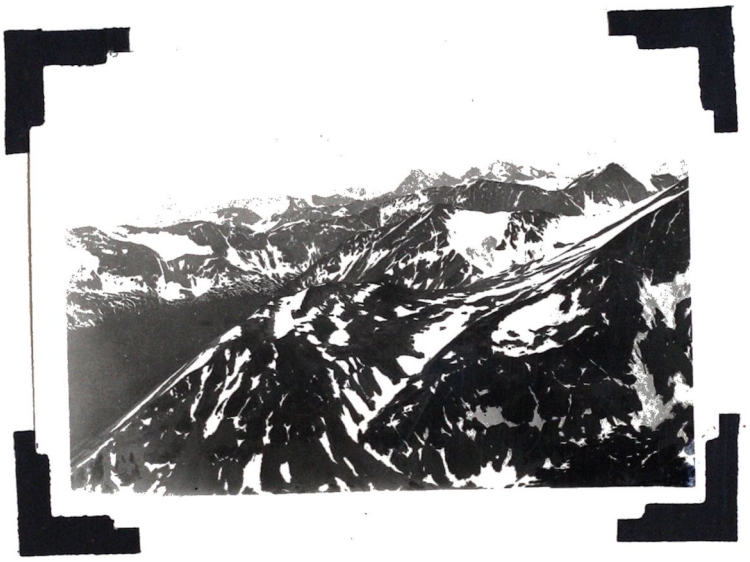
1. Jones and Bryan, North America. p.428.
2. Idem. p.510.

View over the Coast Range from a point on the South Branch of the Kleena Kleene river.

View over the Interior Plateaus from the same point as above

Plate III.



below the remnants of the upland surface. Along its western border, the plateau region in places directly adjoins the Coast Range, but in others is separated from it by high, rugged mountain ranges such as the Cascade Mountains of southern British Columbia, which in turn are separated from the Coast Range by the deeply intrenched Fraser Valley. Along its eastern side the plateau region is bordered by a series of mountains divided into mountain groups by long, deep valleys trending north-westward and northward, and separated from the Rockies by the Rocky Mountain Trench. Toward the south the eastern bordering mountain assemblage broadens to include the exceedingly rugged Selkirk Range, whose higher summits rise to elevations of 11,000 feet and more, and finally in the vicinity of the International Boundary the interior plateau surface is reduced to a comparatively narrow width by the encroaching mountain groups on both sides.

In respect of geologic structure Ransome[1] says: "It is impossible in the present state of knowledge to make any satisfactory generalization of the geologic structure of the Interior Plateaus of Canada and Alaska." In general, the structure is complex and much work remains to be done before the number, age and relative importance of deformational epochs can be known. The most marked effects are those referable to late Mesozoic time. Although part of the

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1. Ransome, F.L. Problems of American Geology, 1913. p.336

intermontane region of Canada was covered by Cretaceous deposits, geologic descriptions of that area as a rule fail to present clear evidence of deformation due to the Laramide revolution. Most workers, however, seem to agree that the general plateau character of this surface dates in part at least from early Tertiary time, and the fact that much of the area from the International Boundary north to the 55th parallel is covered by nearly horizontal lavas of mid-Tertiary age indicates that the belt of interior plateaus has been a fairly rigid mass throughout the Tertiary.[1]

Continuing the Interior Plateau area south of the 49th parallel is the Columbia Plateau. It lies between the Cascades to the west and the Bitter Root Mountains on the east, and to the south is bounded by the extension of fault block ranges from Nevada. It consists essentially of great Tertiary lava flows of an intermittent nature which reach thicknesses up to 4,000 feet. These lavas buried a rugged topography as is shown in some of the deeper canyons and by the fact that the Blue Mountains of eastern Oregon rise like a great island above the general lava level.[2] After the flows came the rise of the Cascades with minor warpings of the plateau itself.

South of the Columbia Plateau is the Great Basin and Range Province. Its area is roughly 800 miles north and south and 500 miles east and west, and includes all Nevada,

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1. Ransome, F.L. Problems of American Geology. 1913. p.336
2. Idem p.339

most of Utah, and much of Arizona and New Mexico. It is formed of a large number of isolated north and south trending ranges, most of which, tilted and block faulted, are masses of previously folded and peneplained sedimentaries, some real deserts and the Great Basin of Nevada and Utah. The origin of the Basin and Desert Ranges is generally regarded as due mainly to extensive and vigorous deflation on a region that had been previously flexed and profoundly faulted and then planed off, bringing narrow belts of resistant rocks into juxtaposition with broad belts of weak rocks, the former now forming the desert highlands and the latter the desert low-lands and intermont plains.[1]

The Mexican Plateau occupies a great part of Central Mexico, and lies between the Sierra Madre Occidentals and Orientals. It stretches from the United States boundary almost the entire length of the country. Its structure is summed up by Suess in the statement that "it is a broken, folded land of much the same type as the Basin Ranges." There is no real orographic boundary between the provinces of United States and Mexico, though the beds entering into the structure of the Great Basin Ranges are Jurassic or older, whereas the beds of the Mexican Plateau are chiefly Cretaceous with the Paleozoics unrepresented. The geology of all Mexico is much alike in that the area was submerged entirely during the Cretaceous, emerging at the close of the

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1. Gilbert, G.K. U.S.G.S. Prof.Paper 153. 1928. p.7.

period. This uplift was accompanied by much north and south close folding and faulting. It was worn to a peneplain in early Tertiary times. The raising and tilting of this peneplain with accompanying extensive volcanism makes the present Mexico.

The Colorado Plateaus[1]

Included in the southern part of the United States Rockies is a series of wide uplands...the Colorado Plateaus. They lie between the Great Plains to the east and the Basin Range Province to the west. On the south they merge into the Mexican Plateau, and to the north they terminate irregularly against several ranges of the Rockies. Their general elevation is about 6,000 feet, and in some cases reaches 7,000, but they are notable for the continuous height of wide areas. Their structural characteristics are the general horizontal nature of their sedimentary strata, and a great north and south series of faults, by which huge blocks of these still roughly horizontal strata have been at various periods elevated or depressed. Topographically, they consist of a great number of individual plateaus of varying elevations, bounded by deep canyons, fault scarps, and erosion cliffs. R.T.Hill[2] says: "An area of strata so extended, lifted so high without serious deformation since Algonkian time, is most remarkable. Yet but a short distance

1. Ransome, F.L. Problems of American Geology. pp.331-334
2. Hill, R.T. quoted in Ransome, idem. pp.332-333

both to the north and to the south.....in the Rocky Mountains and in the Mexican Plateau, we have examples of intense mountain folding and deformation."

The United States Rockies

The Rocky Mountain System of the United States north of the Colorado Plateaus is very complex and contains a large number of separate ranges. The rocks vary in age from pre-Cambrian to Tertiary and all varieties are represented. The area gives evidence to having been at different times subjected to many forces indicated by intrusive masses, large and small, by volcanic flows, by profound faulting and overthrusting and by folding. The periods of deformation are confined chiefly to post Cretaceous times and eight periods are known. The geology is consequently very complex and does not permit of treatment in as short a space as is available in this paper.

The Endicott Mountains[1]

The Endicott Range of Alaska forms the most northerly range of the Cordillera. It extends in an almost east-west direction across Alaska. The mountains rise to a generally uniform elevation of 6,000 feet, suggesting a much dissected plateau. The northern slope descends abruptly to the edge of the gentle Arctic slope and meets it at an elevation of about 2,500 feet. The rocks are mainly sediments of an age

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1. Ransome, F.L. Problems of American Geology. p.296

from Silurian to Upper Cretaceous. The folding is generally open except on the north side, where overturning and considerable faulting occurs. The deformation seems to be post-Cretaceous on the whole.

The Mackenzie Range[1]

South of the Endicotts and not included here in the British Columbia Rockies is the Mackenzie Range. It extends from the lowland between the Yukon and Porcupine Rivers in the north-west to the Liard River in the south, and attain a maximum width of 300 miles. Elevations vary from 2,800 to 8,000 feet. These mountains consist of crystalline metamorphic rocks probably pre-Cambrian to Cretaceous with comparatively small masses of intrusive rock. Their structure is mostly of open folds though sometimes close and overthrust to the west.

Eastern Cordillera in Canada

"The Eastern division (of the Cordillera in Canada) consists from west to east of the Columbia, Selkirk and Rocky Mountain systems. The great intermontane depressions which individualise the above ranges are the Selkirk depression, occupied by the south-flowing Columbia River, which separates the Columbia Range from the Selkirk Range; the Purcell trench, occupied for the most part by Kootenay Lake, which subdivides the Selkirk system, and the Rocky Mountain trench, occupied in its southern part by the south-flowing Kootenay river, and in its northern part by the Columbia river which flows northward and crosses the main line of the Canadian Pacific Railway at Golden. This trench

1. Ransome, F.L. Problems of American Geology. p.296.

"separates the Selkirk system from the Rocky Mountain system, the most eastern mountain system of the Canadian Cordillera." [1]

An important part of the Selkirk system is the Purcell range. Schofield[2] describes it as an elliptical-shaped group of mountains about 250 miles long by 60 miles wide, lying between the Rocky Mountain trench and the Purcell trench.

Describing the topography of the Selkirks, Schofield[3] writes:

"In a view from one of the higher peaks of the Selkirk range, the most striking feature is the series of almost unbroken ridges, having an approximate elevation of 7,000 feet. The ridges trend in all directions without relation to the underlying structure, and evidently represent the remnants of an uplifted and dissected peneplain. Numerous peaks having elevations of from 8,000 to 9,000 feet project above this old land surface, and great valleys have been carved to a depth of 6,000 feet below it."

The rocks of the Selkirk system consist of pre-Cambrian, Paleozoic and Mesozoic sediments intruded by great masses of granite. Sedimentation went on fairly continuously from Beltian times to Upper Jurassic times when the Jurasside revolution occurred. Peneplanation followed, but further uplift took place at the same time as the building of the Rocky Mountains.[4]

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1. Schofield, S.J. Geol.Surv.Can. Memoir 117. 1920. p.7
2. Idem Memoir 76. 1915. p.8
3. Idem Memoir 117. 1920. p.61
4. Idem Royal Soc.Can., Trans.& Proc. 1923. p.92

The Rocky Mountain system forms the most eastern belt of the Canadian Cordillera. As discussed in this paper, it stretches from the 49th parallel to the Liard River, and has an average width of 40 to 50 miles. It is made up of a series of ranges in north and south "en echelon" relationship to one another.

The rocks are almost entirely sedimentary of ages from Beltian to Cretaceous. These have been almost continuously deposited. Uplift took place in the early Tertiary and both folding and faulting, thrust and normal, were involved in their uplift.

CHAPTER II.

THE TOPOGRAPHY AND PHYSIOGRAPHY OF THE ROCKY MOUNTAINS

General Features

The Rocky Mountains proper form the eastern part of the Cordillera from Yukon in the north to the Colorado Plateaus in the United States. In British Columbia and Alberta they extend from the International Boundary north some 850 miles to the Liard River. They are bounded on the west by the Rocky Mountain trench, and on the east by the foothills. The system has an average width of 50 miles between the 49th and 53rd parallels. Northward it diminishes to about 40 miles at the Peace river, decreasing still more to the Liard. The general trend of the system is north 35° West, and the strike is roughly sub-parallel to the western side of the continent. It is made up of a number of parallel ranges and ridges which, in a general way, lie "en echelon," the more northerly segment being situated slightly west of the one to the south.

The ruggedness of the topography varies in different latitudes, and although the highest point in the entire Rockies is found in Pike's Peak, which is 14,147 feet high, yet the most highly sculptered ridges and ranges occur

between the Crowsnest pass and the Robson district. Here the summits attain an average height of about 10,000 feet. Robson Peak, the highest peak of the Canadian Rockies, has an elevation of 12,792 feet.

A very definite western boundary of the Rockies exists in the Rocky Mountain trench, which forms one of the most prominent depressions of the entire Cordillera. It extends from south of the 49th parallel at least to the Liard river, a distance of nearly 1,000 miles. Throughout its length it is the course for numerous rivers of varying sizes flowing either north or south. Northward from the International Boundary it is occupied by the Flathead river (north flowing), the Kootenay (south flowing), the Columbia (north), the Fraser (north), the Parsnip (north), the Finlay (south), the Kachika (north), and the Highland (south).

Quoting Schofield:[1]

> "One of the most peculiar features of the trench, whose walls on both sides rise on an average 4,500 feet above the valley floor, is the fact that it is occupied by streams which vary greatly in size. For example, the Kootenay river enters the trench as a large river from the north, while less than a mile away from this point, the north flowing Columbia has its beginning in two small lakes. In the same manner, the south flowing Canoe rises and continues as a very small river to join the mighty Columbia in the trench. From these examples, which might be greatly amplified, it can be seen that the size and depth of the valleys which unite linearly to form the Rocky Mountain trench bear no relationship to the size of the streams which occupy them, which is contrary to the results of normal stream erosion.

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1. Royal Soc. of Canada. 1920. Pt. III. p.63-64

"The general trend of the regional drainage is toward the trench, except in the case of the Kootenay River and the Columbia River, which break through the western wall of the trench and reach the Pacific, while the Peace river cuts through the eastern wall and finally reaches the Arctic.....

"The width of the trench averages 4 to 6 miles but in places .....is much greater. The floor of the trench is usually flat or slightly rolling, and is covered generally by the unconsolidated gravels and silts of the Cenozoic. The walls of the trench usually rise abruptly from the floor, especially on the eastern side, where it is usually precipitous. This feature is the most noticeable in the southern part of the trench."

The line of demarcation between the prairies and the mountains is even more pronounced from latitude 49° to latitude 53° than the westerly limit of the mountain system. A prominent escarpment, 2,500 to 3,000 feet high, in places almost perpendicular, and composed largely of massive-bedded gray limestone strata, sharply defines the mountain topography from the rounded-topped ridges, for the most part covered with vegetation, that form the inner foothills. This topographical feature is the result of overthrusting which occurred during the period of mountain building. The more massive rocks of the west were thrust in a northeasterly direction over the softer strata forming the understructure of the plains. At certain places along the base of this escarpment the plane along which the faulting occurred is exposed, and is generally known as the Lewis Overthrust. North of the Athabasca river, this front escarpment is not so marked because the extent of overthrusting

was not so great, the faults having to a certain degree been replaced by folds.

Stewart's[1] general description of the foothill region is:

> "The foothills form a belt, averaging 10 to 20 miles in width, bordering the east side of the Rockies for practically their entire length. They form a distinct topographic feature, though they gradually merge into the plains to the east. The mountains generally rise abruptly from the foothills, but in a few places the two are so nearly alike in height that they can be distinguished mainly by the lack of soil and vegetation on the limestones and quartzites forming the front range."

The base level of the Rockies on the foothills side is much higher than on the western side. On the east, as ascertained by taking the average level at which the larger streams leave the mountains proper and pass into the foothill region, it is about 4,360 feet. On the west, the average elevation of the Columbia-Kootenay valley is approximately 2,450 feet. In consequence of this difference, the passes traversing the Rockies have a steep and sudden descent to the west of the watershed in contrast to the more gradual slope to the east.

Due to their structure, the Rocky Mountains may be divided into two topographic areas trending parallel with the system. The boundary between these is approximately on a line north and south from Banff. The mountains in the eastern division derive their form from the fact that they are thrust blocks with a sharp eastern face and gently

1. Stewart, J.S. Geol.Surv.Can. Mem.112. 1919. p.11

dipping westerly slopes; those in the western are in the main the results of open folding and hence present the appearance of folded mountains modified by erosion and some normal faulting.

The forms assumed by typical mountains are well summarised by Allan:[1]

> "The influence which the rock structure has had upon the present scenery in the Rocky Mountains is so marked that brief mention must be made of it here. The type of sculpturing produced by weathering depends on the composition of the rock and also on the existing structure. Seven distinct types of mountains can be recognised in this area:
>
> (1) "Mountains composed of horizontal strata tend to weather into pyramid forms, usually broadbased, sloping regularly to the apex. The slopes depend on the character and thickness of the composing strata. Examples are formed principally along the watershed range, such as Robson, Pyramid, Geikie, Forbes, Lyell, Temple, Deltaform and Assiniboia.
>
> (2) "In slightly inclined strata the pyramid outline is slightly lopsided, as seen in the Aylmer, Goodsir, Ball, Balfour or Crowsnest.
>
> (3) "When the strata is moderately inclined the block type of mountain is produced, as in Rundle, Cascade, Roche Miette and many peaks in the first three ranges of the Rockies.
>
> (4) "In vertical or steeply dipping strata, mountains like Edith, Hole-in-the-Wall or Spike Peak are produced.
>
> (5) "Anticlinal mountains are rare, as uparched strata soon become incised and eroded along the central axis. Knobs like Stoney Squaw at the south end of Cascade Mountain illustrate this type rather poorly.

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1. Allan, J.A. Can.Alpine Journal, 1917.

(6) "Synclinal mountains are common and indicate mature erosion since the syncline at one time occupied the trough between up-arched masses of rock. Folding Mountain, President Range, Castle Mountain Range and the range in which Mt.Molar and Mt.Hector are situated give examples of this type.

(7) "When thick beds of resistant rock are interbedded with less durable strata, "weather terraces" are formed, as seen in Amiskwi Peak, Pilot, Redoubt, and also in Mt.Molar. This last type is closely related to those mountains which belong to either the first or second classes."

Ranges of the Rocky Mountains

The Rocky Mountains consist of numerous ridges and ranges. Only a general summary of these can be given here, due mainly to the fact that they are still largely unexplored and often without names, especially in their more northern portions.

At the 49th parallel, Daly[1] has recognised four ranges. The most easterly or front range of the Rockies in northern Montana extends into Canada for about three miles. At that distance from the boundary the mountain front turns sharply to the west and runs in that direction for about six miles, presenting a steep face to the north. Beyond, the continuity of the mountains is broken by the deep depression occupied by Waterton lakes and Waterton river. To the west of the depression rises the Clarke range, which forms the front range north to the valley of the Castle river. West of the Clarke range, the Flathead river flows. The

1. Daly, R.A. Geol.Surv.Can. Mem.38. 1912. Pt.1. p.29

MacDonald Range lies west of it. This range is separated from the Galton, the most westerly range of the system at the 49th parallel, by the Wigwam River. The northern limit of the MacDonald Range is placed on Dawson's[1] map at the North Kootenay pass and the Galton at Elk River.

Mountains between the North Kootenay and Kananaskis passes[2]

Beyond the North Kootenay and the Crowsnest passes, the mountains become well defined. The Livingstone range, continued farther northward by the Highwood range, forms the outer ridge of the mountains, and extends with slight interruption for a distance of 80 miles to the Elbow river. A second limestone ridge is formed by the Flathead and High Rock ranges, which lie nearly parallel to the first and have, like it, a slight convexity eastward. The Elk mountains continue this line to the sources of the Elbow, where the space between this and the outer range is nearly filled by the intercalated Misty range. Farther west, the Wi-suk-i-tshak range forms a third imperfect parallel range. Beyond this is the very high and rough range to the west of Elk river, between which and the Hughes range, bordering the trench, a wide area is not well known.

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1. Dawson. Geol.Surv.Can. Ann.Rep. 1885. Pt.B. p.22
2. Idem.

Mountains between Kananaskis and Vermilion Passes[1]

The mountain region between the upper part of the Elbow river and Kananaskis pass on the south, and the Bow river and Vermilion pass on the north, lacks the wide Cretaceous valleys found in the part last described. It is composed of 8 to 10 main ranges, with but two wide intervening valleys, one running from the head of Kananaskis to Spray river, the other holding the headwaters of the south flowing Kootenay. The parallelism of these ranges is not less well marked, but their continuity is frequently interrupted both by transverse valleys and by an echelon-like arrangement which exists among them.

Fisher's range here constitutes the western front of the mountains. Behind it a second ridge is formed by a somewhat irregular range which ends in the Pigeon mountain on the Bow. The Opal mountains and connecting elevations ending in Mt.Rundle form a third range, while the Kananaskis and Goat ranges with Terrace mountain, constitute a fourth. The Spray and Bourgeau mountains are the best known portions of a fifth parallel, and a sixth runs northward from Pilot mountain but dies out before reaching the White Man's pass. The Blue mountains and connecting mountains ending in Mt. Ball on the Vermilion pass, form a wide and somewhat irregular seventh range. Between this and the important

1. Dawson, G.M. Geol.Surv.Can. Ann.Rep. 1885. Pt.B. p.22

ridge formed by the Mitchell and Vermilion ranges there are probably two short intercalated ranges, of which the ends are seen on the Cross river. The Brisco and Stanford ranges constitute the western elevations of the Rockies in this part, and are wider and more persistent than most of the ranges mentioned above.

North of the Bow river and Vermilion pass the parallelism of the constituent ranges is continued in the Fairholme mountains, the Palliser and Saw Back ranges. The Bow range and Naputtehk mountains, cut across by the Kicking Horse pass, together form a very massive range, which, to the west, in the vicinity of the Pass, become broken up into rather irregular groups of mountains. The lofty Ottertail mountains are continued to the north-west by two ranges, the Van Horne mountains and Mt.Hunter range. The Beaverfoot range, really a continuation of the Brisco range, fronts on the Columbia Valley.

Ranges north to the Peace

The mountain ranges northward of the areas already described have not been so specifically mapped and named as those to the south. The front range north of the Sawback and Palliser ranges is the Bighorn, and at the western border of the Rockies, the Spencer range lies north of the Van Horne. The general topographic features are carried on north to the Liard though the area becomes narrow. The

Takakkaw Falls, Yoho Valley.

Lake Minnewanka, near Banff.

Plate IV.

mountains to the Yellowhead pass are extremely rugged and contain many high peaks and great snow fields. The elevations culminate in Robson Peak beyond which they become lower as the Liard river is approached.

Drainage

In the Rocky mountains is found the watershed between the eastward and northward flowing streams which reach either the Hudson Bay or the Arctic, and the waters draining into the Pacific. Two interesting examples are found in the Peace and the Liard rivers which cut across the entire system. The watershed follows no direct course, paralleling the general trend of the ranges, but shows a considerable variation in its directions. Dawson[1] says:

> "No single ridge or system of elevations constitutes the watershed range in this part of the mountains (49th to 53rd parallels), nor does the portion of the mountains characterised by the greatest connected areas of high mountain country and crowned by the higher peaks coincide with it."

In the main, the divide is nearer to the Rocky Mountain trench than to the foothills. The slope to the trench is much steeper as well as shorter than the slope to the plains, hence the rivers draining into the trench are short and swift, and those flowing easterly are longer and larger and have a more gradual gradient.

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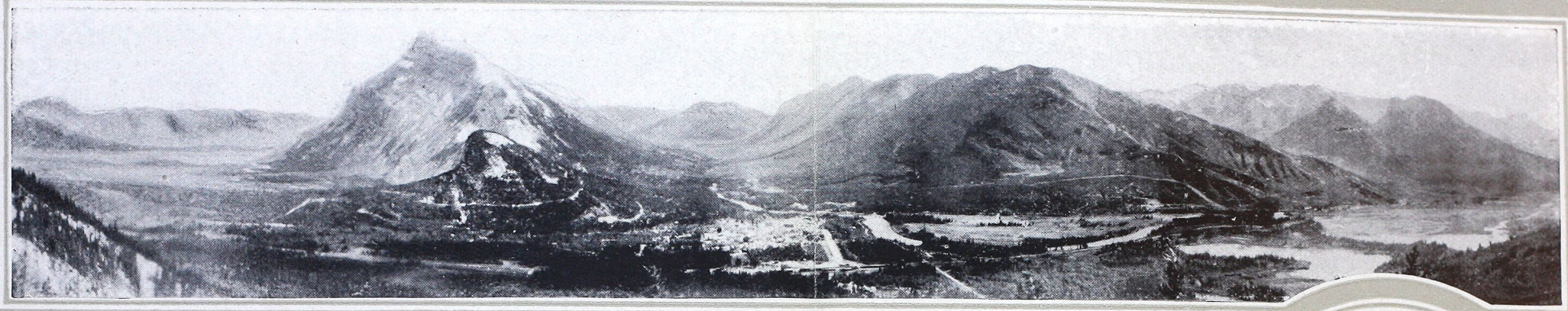
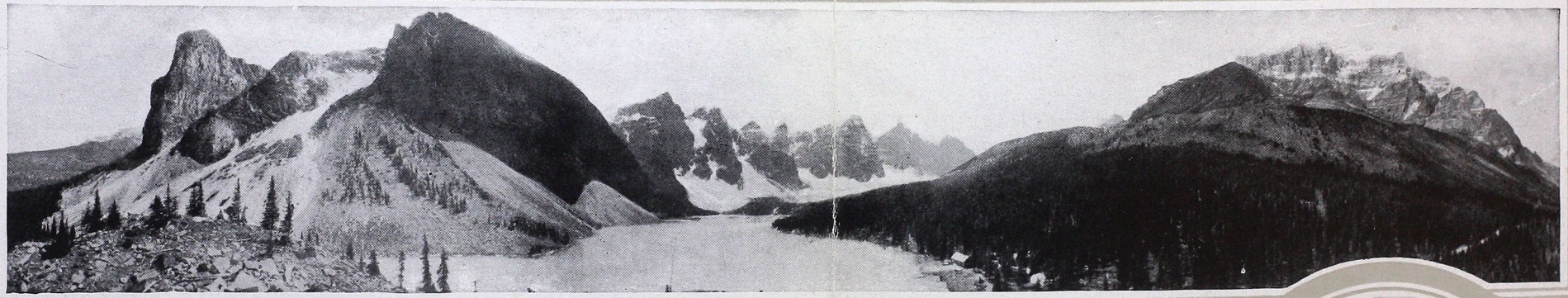
1. Geol.Surv.Can. Ann.Rep. 1885. Part B. p.23

Looking across the Bow River; Mount Rundle at the left, Sulphur Mountain at the right.

Moraine Lake and the great circle of the Ten Peaks.





the Elk, Kootenay and the Flathead which are all southward flowing rivers.

The Bow follows a rather remarkable course. After flowing in an anticlinal valley it turns eastward and breaks completely across the series of ridges which form the Sawback range. There it reaches an important Cretaceous infold, and after following it for a number of miles to the south-east, again turns nearly at right angles, and breaking through the outer ranges, reaches the foothills.

The North Saskatchewan and the Athabasca rivers are among the largest rivers draining the Rockies. Their main streams cut quite sharply eastward through the ranges while numerous tributaries drain longitudinal valleys.

The Peace and the Liard are the sole examples of rivers cutting entirely across the Rockies. The Peace drains not only the mountains in this part, but moreover receives the waters from areas drained by the Parsnip, Finlay and Omineca rivers. At the Liard the Rocky System breaks sharply and only continues northward as the MacKenzie mountains 100 miles further east. The Liard occupies this break, carrying through it water from regions to the north, south and westward. Quoting McConnell[1]:

> "Rising in a country west of the Rocky mountains, the Liard falls rapidly toward the east, the difference in elevation between the mouth of the Dease and MacKenzie being 1,650 feet..... The Rocky mountains.....are consequently interrupted in this part of their length.

1. Geol.Soc.Can. Ann.Rep. 1888-1889. p.34D

Plate VI.

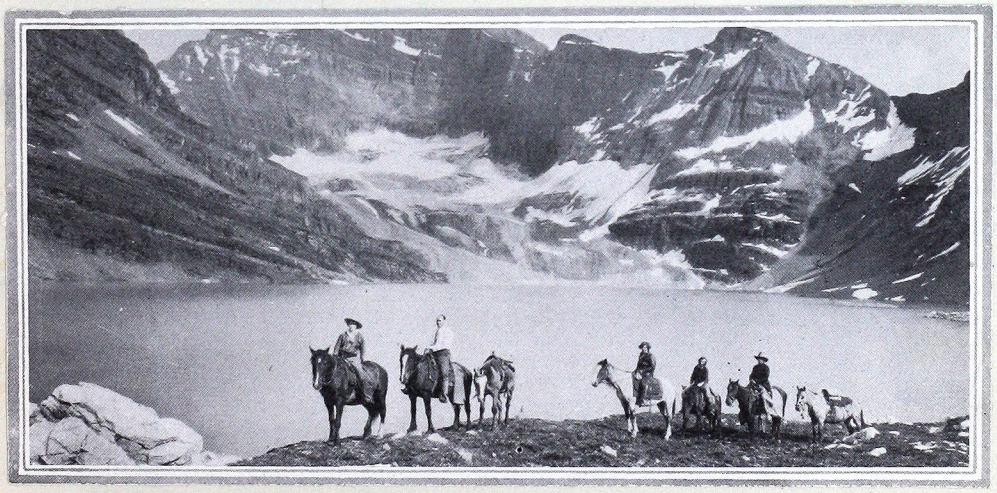
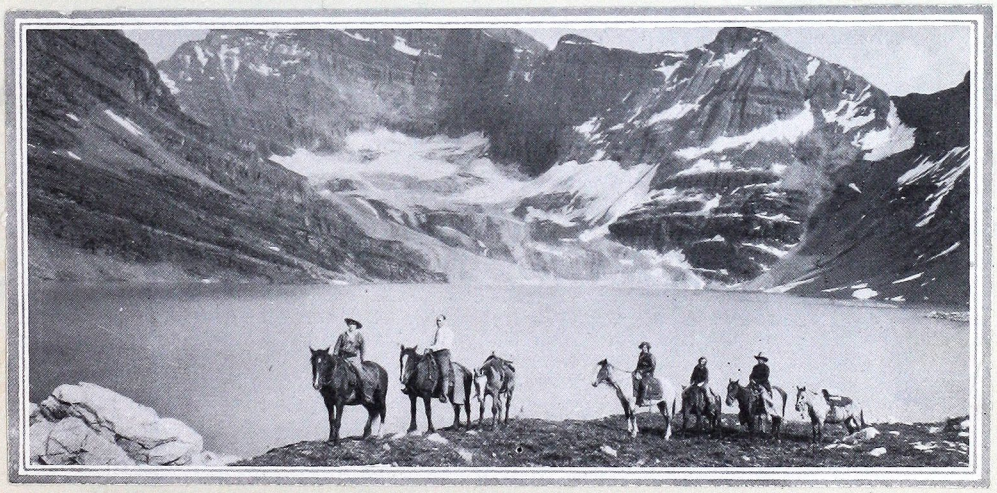


Plate VI.



"The width of this persistent range probably averages throughout about 50 miles; and its main physical and geological features are almost identical in all parts of its length....

"South of the Liard the bare limestone ridges are ranged in parallel lines and are surmounted by sharp zig-zag knife edges or jagged serrated crests. The ridges have a general strike of N.30° W. The spur of the mountains which crosses the river consists of a greyish and moderately compact limestone."

As would be expected in a mountain system of parallel ranges such as are found in the Rockies, the valleys and basins are well developed. Particularly in the area of the main line of the C.P.R. and southward, large north and south depressions occur. The larger of these valleys are occupied by the more important rivers of the system. Superficial deposits of glacial drift and alluvium are common features and many of the valleys of the south and eastern parts are floored with infolded Mesozoic rocks, in places containing coal seams. All the valleys have the typical U-shape consequent on glacial action. The topography of the major trunk valleys has been much changed by the morainal debris left by the disappearing valley glaciers. In many cases the outlets of these valleys became blocked and in the lakes formed behind these barriers, gravels, sands and clays were deposited. These deposits are exposed in terraces along the sides of the larger valleys.

Emerald Lake.

Lake O'Hara.

Plate VII.

Lakes

The lakes found in the Rockies are neither large nor numerous. They possess, however, an excellence of scenic beauty which rivals that of any portion of the globe.

> "Glaciers have been the cause of the formation of the Rocky Mountain lakes. Three prominent types might be mentioned. Those occupying rock basins carved out by glacial action such as Lake Agnes at Laggan, Turquoise and Margaret on the upper Bow, Lake Magog at Mt.Assiniboine and Berg Lake at Robson Peak.
>
> "Such lakes as Moraine, Louise, Minnewanka, Kinney, Maligne, Pyramid and Waterton occupy basins formed behind morainal detritus. A third type of lake is represented by such as Hector, Bow, Emerald, Gloria and Marvel. The barrier in this case consists of the outwash of gravel and sand from the front of the ice."[1]

Glaciers

So high a system of mountains is naturally productive of glaciers and ice fields in abundance throughout its length. The presence of great glaciers in the C.P.R. section has increased the value of this area as a tourist resort due to their addition to the attractions of mountaineering. At present the glaciers of the Rockies are retreating, and notable diminutions in length have taken place within living memory.

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1. Allan, J.A. Can.Alpine Journal. 1917

Parks

It were needless here to elaborate on the beauty of scenery in the Rockies. That is well attested to by the fact that they contain no less than seven national parks which have been set aside because of the unusual attractiveness of the areas which they embrace. Their qualities are set forth by numerous booklets issued by the railroad companies, in glowing terms, which are fortunately well supplemented by excellent views. The parks may be reached either by rail or motor road, the latter of which are rapidly opening the mountains more and more to travellers.

CHAPTER III.

GENERAL GEOLOGY

Introduction

The Rocky Mountains are formed almost entirely of sediments. In comparison to most mountain systems the strata are relatively undisturbed and little metamorphosed. The strata are remarkably conformable and no great erosional breaks are known. Beltian rocks are represented mainly in the region contiguous to the 49th parallel. Paleozoic sediments occur throughout and constitute the bulk of the exposed rocks. Mesozoic formations are found chiefly in the eastern division and north of the Kootenay Pass. Tertiary rocks are recorded in the Kishenena valley in the southern Rockies and in the Rocky Mountain trench in the vicinity of the Finlay river. Pleistocene and Recent are found as superficial deposits in the valleys and basins. Igneous rocks are conspicuous by their scarcity and are not known north of the area of the main line of the C.P.R.

Representative Tables of Formations

1. Sections at the 49th Parallel[1]

Lewis Series		Galton Series	
		Lowest Middle Cambrian	
		Disconformity	
	Beltian		
		Roosville	1,000'
		Phillips	500'
Kintla	800')		
Sheppard	600')	Gateway	2,025'
Purcell Lava	260'	Purcell Lava	310'
Siyeh	4,100'	Siyeh	4,000'
Grinell	1,600'	Wigwam	1,200'
Appekunny	2,600'	MacDonald	2,300'
		Hefty	775'
Altyn	3,500'	Altyn	650'
Waterton	200'		
Total:	13,420'	Total:	12,100'

1. Daly, R.A. Geol.Surv.Can. Memoir 38.

2. **Section at North Kootenay Pass**[1]

Devonian	Jefferson limestone	500'
Disconformity		
Middle Cambrian		425'
Disconformity		
Pre-Cambrian	Lewis Series	

3. **Section at Elko**[2]

Devonian	Jefferson limestone	300'
Disconformity		
Middle Cambrian	Elko formation	90'
" "	Burton "	80'
Lower Cambrian	Burton "	17'
" "	Cranbrook conglomerates	1'
Disconformity		
Pre-Cambrian	Galton Series	

4. **Section at Ram Creek**[3]

Middle Cambrian	Elko formation	1,000'
	Burton ")	
	)	475'
Lower Cambrian	" ")	
	Cranbrook conglomerates)	1,220'
Unconformity		
Late Pre-Cambrian	Toby "	40'
Disconformity or Unconformity		

1. Adams & Dick, Can.Commission 1915. pp.8-13
2. Schofield, S.J. Geol.Surv.Can. Mem.76. 1915. p.42
3. (Idem Idem Mus.Bull.35. 1922. p.15
   (Walker, J.F. Idem Mem.148.1926. p.17

4. Section at Ram Creek (Continued)

Beltian----------	Roosville	formation	1,000'
	Phillips	"	400'
	Gateway	"	1,500'
	Siyeh	"	500'
	Purcell lava	"	50'
	Siyeh	"	4,000'
	Kitchener	"	4,500'
	Creston	"	5,000'
	Aldridge	"	5,000'
	Base unexposed		

5. Section at Blairmore[1]

Recent and Pleistocene--Superficial deposits

Cretaceous----------	Allison Creek sandstone	1,900'
	Benton formation	2,700'
	Crowsnest volcanics	1,150'
	Blairmore formation	2,500'
	Kootenay "	565'
Jurassic----------	Fernie shales	750'
Devono-Carboniferous		10,000'

6. Section in Flathead Area[2]

Recent and Pleistocene-Superficial deposits

Tertiary----------	Kishenena formation	700'
Cretaceous----------	Flathead beds) Elk conglomerates)	6,500'
	Kootenay formation	3,500'
Jurassic----------	Fernie shales	3,000'
Triassic(?)----------		2,500'
Carboniferous ---------		2,000'
Devono-Carboniferous---		3,000'

1. Leach, J.J. Geol.Surv.Can. Sum.Rep. 1911. p.193
2. Rose, B. Idem Idem 1917. p.29-C

7. Section at Windermere[1]

Recent	Alluvium	
Pleistocene	Glacial drift	
Unconformity		
Silurian	Brisco formation	) 260'
Richmond	Beaverfoot "	)
	(?) Wonah quartzite	167'
Disconformity		
Lower Ordivician	Glenogle shales	2,000'
Lower Ordivician) Upper Cambrian)	Goodsir formation	300'
Upper Cambrian	Ottertail "	1,000'
Unconformity		
Late Pre-Cambrian	Horsethief "	) 4,000'
	Toby conglomerate	) 50-2,000'

8. Section at Lake Minnewanka, Banff[2]

Cretaceous	Upper Ribboned sandstone	) 550'
	Kootenay	2800'
	Lower " "	'
Jurassic	Fernie formation	
Triassic	Spray River "	1,500'
Permian	Rocky Mountain quartzite	600'
Pennsylvanian and Mississippian	Rundle formation	1,500'
Mississippian	Banff "	1,200'
Devonian	Minnewanka"	1,000'

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1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. p.7
2. Shimer, H.W. Idem Mus.Bull.No.45.1926.p.3
(Cretaceous found east at Bankhead)

8. **Section at Lake Minnewanka, Banff (Continued)**

Age (?)	Ghost River formation	300'
Cambrian	Cathedral "	

9. **Section in Field Map Area**[1]

Pleistocene	Superficial deposits	
Post Cretaceous	Igneous complex	
Silurian	Halysites beds	1,850'
Ordovician	Graptolite shales	1,700'
	Goodsir shales	6,040'
Upper Cambrian	Ottertail	1,775'
	Chancellor	4,500'
	Sherbrooke	1,375'
	Paget	360'
	Bosworth	1,855'
Middle Cambrian	Eldon	2,728'
	Stephen	640'
	Cathedral	1,595'
Lower Cambrian	Mt. Whyte	390'
	St. Piran	2,705'
	Lake Louise	105'
	Fairview	600'
Conformable in some places		
Pre-Cambrian	Hector	4,590'
	Corral Creek	1,320'

10. **Section at Roche Miette**[2]

Recent and Pleistocene	Superficial deposits
Lower Cretaceous	Kootenay formation
Jurassic	Fernie shales

1. Allan, J.A. Geol.Surv.Can. Mem.55. 1914. p.60
2. Dowling, D.B. Idem Sum.Rep. 1911. p.205

10. **Section at Roche Miette (Continued)**

Triassic and Permian	
(Carboniferous ((Devonian	3,000'
Silurian (?)	
Cambrian	

11. **Section in Robson Peak Area**[1]

	Walcott		Burling	
Ordovician--------	Robson	3,000'	Unnamed	375'
Upper Cambrian----	Lynx	2,100'	Lynx	5,000'
Middle Cambrian---	Titkana	2,200'	Titkana	2,500'
	Mumm	600'	Absent	
	Hitka	1,700'	Absent	
	Tatay	800'	Tatei	1,000'
	Chetang	900'	Chetang	950'
			Adolphus	400'
Lower Cambrian----	Hota	800'		
	Mahto	1,800'	Mahto	1,200'
	Tah	800'	Mural	1,000'
	McNaughton	500'	Unnamed	400'
	Disconformity			
Pre-Cambrian -----	Miette			

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1. (Walcott, C.D. Smith, Inst. Misc.Coll. Vol.57.No.12. 1913. pp.327-343
(Burling, L.D. Geol.Soc.Am. Vol.34. 1923. p.726

DESCRIPTION OF FORMATIONS

BELTIAN

The oldest rocks known in the Canadian Rockies are the northern continuation of the Belt Series of Montana and Idaho. The age is Algonkian. Included by Walcott[1] in the Beltian are the strata which occur between the general unconformity that marks the base of the Cambrian, whether Lower, Middle or Upper Cambrian, and another unconformity at the top of the basement complex, which he classified as Archean.

Beltian formations are represented best in the Rockies in the vicinity of the International Boundary where they make up the bulk of the ranges and consist of 13,000 feet of sediments with the base of the series unexposed and the top lost by erosion. The strata, known as the Lewis Series in the eastern part of the Rocky mountains and the Purcell Series in the west, consist very largely of argillites, now siliceous and partly recrystallised, but with one very thick horizon of impure limestone and argillite in the upper part. Other thick, siliceous limestone or dolomite formations occur in the eastern part of the section and the associated strata on the whole are finer grained than the corresponding beds to the west. In the upper part

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1. Walcott, C.D. Geol.Soc.Am. Vol.10. 1899. p.200

basaltic lavas a few hundred feet thick occur at the same general constant horizon.

The Beltian is exposed northward to North Kootenay Pass where it disappears under later rocks. It is found along the Rocky Mountain trench north to Windermere Lake, and in the trench in the vicinity of Finlay river. It outcrops in the Bow River area and at Yellowhead Pass, and it is probable that with further exploration it may be found to underlie the entire Rocky System in Canada, especially since probable Beltian rocks outcrop in the MacKenzie mountains.[1]

In a survey of formations of the Rocky Mountains, the problem of the limited occurrences of Beltian rocks in areas other than that contiguous to the 49th parallel, is one that suggests itself as worthy of detailed analysis.

Beltian Rocks at the 49th Parallel

The Lewis Series[2]

Waterton Formation

The Waterton dolomite is the oldest known rock on the 49th parallel. It is exposed at the point where Oil Creek falls into Waterton Lake. Here it is conformably overlain by the Altyn.

It consists of an exceptionally strong and massive dark grey carbonate rock, weathering dark grey to brownish

1. Williams, M.Y. Geol.Surv.Can. Sum.Rep. 1922. p.75-B
2. After R.A.Daly, Idem. Mem.38. 1912. pp.42-82

grey and sometimes buff.

Borings for oil near Oil Creek show 1,500 feet of the Lewis Series not outcropping.

Altyn Formation

Exposures of the Altyn are known chiefly along Oil Creek where it is 3,500 feet thick. The rock may be called a dolomite and contains arenaceous magnesian limestones, dolomitic sandstones, dolomitic grits and pure dolomites in order of relative importance.

A tripartite division is recognised: an upper member of thin-bedded, siliceous dolomite, a middle member of thick-bedded, massive, arenaceous dolomite and a lower member of generally thin-bedded, siliceous dolomite containing sandy beds towards the base.

In this formation have been found numerous fragments of what are probable fossils which have been identified as Beltina danaii by Walcott. If true fossils, they are one of the oldest species yet described. They may have some value as horizon markers.

Appekunny Metargillite

The Appekunny is generally found exposed in the cliffs throughout the Clarke and Lewis ranges. Willis[1] says:

"It occurs everywhere above the Altyn limestone along the eastern front of the Lewis Range above

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

Flathead Valley, and is there the lowest member of the series seen from Kintla Lakes southward to MacDonald Lake."

A complete section is found on a ridge south of Oil City.

This formation is a mass of highly siliceous, argillaceous sediment. The content of silica is often so great that the rock might well be called an impure quartzite.

Grinnell Metargillite

The Grinnell argillite outcrops continuously along the eastern side of the Lewis Range and its spurs. It occurs in its proper stratigraphic position between the forks of the Belly River and west in the northernmost extremity of the Lewis Range. In the Clarke Range it outcrops in the vicinity of Upper Kintla Lake.

The formation is a mass of red rocks of predominantly shaly argillaceous character. The beds are generally ripple-marked, exhibit mud-cracks and the irregular surface of shallow water deposits.

Siyeh Limestone

Conformably on the Grinnell is the conspicuous Siyeh formation. It constitutes the principal upper part of the Lewis Range and forms the massive peaks between Waterton and the North Fork drainage lines. Due to its capping of resistant Purcell lava, and its own resistant

nature it stands up in precipices thousands of feet in height.

> "The Siyeh is in general an exceedingly massive limestone, heavily bedded.....It is dark blue or greyish, weathering buff, and is so jointed as to develop large rectangular blocks and cliffs of extraordinary height and steepness."[1]

Prominent in the Siyeh is a molar-tooth structure caused by the weathering of layers of calcium carbonate with the consequent relief of ribs of siliceous, magnesian limestone.

Sheppard Dolomite

Conformably on the Purcell Lava in the Lewis and Clarke Ranges is a group of strata called the Sheppard quartzite by Willis[2]. It is generally distributed throughout these ranges.

Though the colour, compactness and general habit of the Sheppard rock are those of an impure, flaggy quartzite, thin sections show it to be largely composed of dolomite, and that quartz occurs as minute grains rather evenly distributed throughout the mass. The staple rock is then a siliceous dolomite or dolomitic quartzite.

Kintla Metargillite

In the field the Kintla formation is a conspicuous element of the Lewis Series. Stratigraphically, the

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1. Willis, B. Bull. Geol.Soc.Am. Vol.13. 1902. p.323
2. Idem p.324

highest known member of the series, the Kintla commonly occurs on the higher summits and thus above tree line.

It consists of thin bedded argillite and subordinate quartzite. An amygdaloidal lava flow of 40 feet is found near the bottom. A special feature of the argillite is the great abundance of casts of salt crystals. Ripple marks and sun cracks are abundant.

Features of the Series

Quoting Daly:[1]

> "The recurrence of microperthite found in most of the clastic beds through the entire Lewis Series shows that probably one great crystalline terrane furnished the detritus during the deposition of the whole series.....The great freshness of the feldspars in most of the beds suggests that the erosion of that terrane and the process of sedimentation were rapid..... It is probable that the climate in which disintegration overtook chemical weathering was arid. The presence of salt crystals in the Kintla rocks strengthens the probability."

The Galton Series[2]

Westward from the Flathead River, the mountains are composed principally of the Galton Series which is the western extension of the same stratified series that form the peaks and massifs of the Clarke and Lewis Ranges. Some of the formations are clearly continued and bear the same names, others contain enough individual characteristics

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1. Geol.Surv.Can. Mem.38. 1912. p.83
2. After Daly. Geol.Surv.Can. Mem.38. 1912. pp.97-112

to merit special names, while some formations outcrop only in the MacDonald range.

Altyn Dolomite

West of the Flathead, the Altyn outcrops in two localities - on the ridge overlooking the Flathead from the west and culminating in Mt.Hefty where 650 feet are shown at one point, and in a canyon six miles west of the Hefty ridge. Here 120 feet are exposed.

Stratigraphic relations and composition are similar to the Upper member of the Lewis Altyn. In each case the rock is a siliceous dolomite.

Hefty Quartzite

In the MacDonald range the Altyn is conformably overlain by a group of strata which are exposed at the same two localities.

The staple rock of the formation is a heavily-bedded red or reddish-grey, fine grained sandstone. As a rule it has not metamorphosed to a true quartzite. Sun cracks and ripple marks are common at various horizons.

The formation passes upward with some abruptness into the MacDonald limestone, and there is some dovetailing with the Altyn below. From its position and petrographic nature it is likely that the Hefty is the coarser grained equivalent of the lower Appekunny in the Lewis Series.

MacDonald Metargillite

Above the Hefty formation is a thick division of beds which indicates long continued deposition of rather uniform sediments. These rocks underlie an extensive part of the MacDonald range.

The formation is notably homogeneous, the principal rock phase throughout being a highly siliceous argillite or metargillite. Sun cracks and ripple marks are abundant in many horizons from summit to base.

Wigwam Sandstone and Metargillite

Two exposures of the Wigwam are known near the International boundary.

The formation consists of a mass of fairly homogeneous red or brownish-red sandstone, interrupted by partings of red, siliceous metargillite. Sun-cracked, ripple-marked and sometimes cross-bedded horizons are found.

The Wigwam is evidently the western equivalent of the Grinnell of the Lewis Series.

Siyeh Limestone

The general equivalence of the Lewis and Galton Series is, lithologically, most evident in the thick formation overlying respectively the Grinnell and Wigwam beds. Great similarity is obvious in age, composition, structure and

origin. More or less complete sections are found on the eastern slope of the Rocky Mountain trench, along Phillip's Creek and Wigwam River.

The general nature is like that of the Lewis Siyeh, namely, a massive limestone with argillaceous layers. Sun cracks and ripple marks are numerous and molar-tooth structure is very prominent.

Gateway Metargillite and Quartzite

A striking difference in the character of the Lewis and Galton series is to be found in the nature of the beds lying conformably on the Purcell Lavas in the respective ranges. In the Galton, the beds between the Purcell Lava and the red beds equivalent to the Kintla of the Lewis, have a much greater total thickness than the Sheppard and a quite different composition. The formation includes two members of unequal thickness. The lower member, resting immediately upon the Purcell Lava, contains beds suggesting an identity of origin with the Sheppard. It is 125 feet thick.

The upper member is about 1,850 feet. It is a fairly homogeneous mass of thin-bedded, highly siliceous metargillite. Ripple marks, sun cracks and salt crystal casts are plentiful.

The position, composition and general structure of the lower dolomitic member are features directly correlating it with the Sheppard formation of the eastern ranges.

The Sheppard thus thins rapidly to the west. The thick upper member of the Gateway, carrying abundant salt crystal casts, is almost certainly of contemporaneous origin with the lower part of the Kintla, and like it, was doubtless deposited as a continental deposit in an arid climate.

Phillips Metargillite

The Phillips consists for the most part of about 500 feet of dark, purplish or brownish-red, fine-grained to compact metargillite and metasandstone, in thin, alternating beds.

The general composition, colour and field relations of the Phillips are so similar to those of the upper part of the Kintla that they are, in the main, stratigraphic equivalents can hardly be doubted.

Roosville Metargillite

The Roosville forms the highest member of the Galton series. In the boundary area it outcrops on a peak near Phillip's Creek Cascade. Erosion has removed the upper part of the formation, but 600 feet of the beds remain.

The formation is essentially made up of thin-bedded, siliceous metargillite. Numerous sun cracks and ripple marks exist.

The materials of the upper member of the Galton as well as the others, show evidence of static metamorphism,

though the older and deeper members naturally are in a more advanced state, but it is clear that the Roosville, like the Kintla of the Lewis, has been buried beneath thousands of feet of still younger strata, doubtless including the heavy Devonian and Carboniferous limestones.

The formation appears to be younger than any beds belonging to the Lewis series. It may be the equivalent of an unexposed upper division of the Kintla, or may represent the western extension of a distinct formation.

Beltian Rocks at Ram Creek[1]

Most of the Pre-Cambrian rocks of Ram Creek section have been described either under the Lewis series or the Galton series. Only those formations which do not occur in those series will be dealt with.

> "The various members of the Purcell series from the Aldridge to the Roosville have been recognised as far north as the vicinity of Ram Creek on the east side of the Rocky Mountain trench."[2]

Aldridge Formation

The Aldridge formation is made up of a series of argillaceous quartzites, purer quartzites and argillites. The argillaceous quartzites form about three-quarters of the whole series and occur in beds with an average thickness

1. Schofield, S.J. Geol.Surv.Can. Mus.Bull.No.35.1922.p.11
2. Walker, J.F. Idem. Mem.148. 1926. p.7

of one foot. They are fine-grained rocks, dark grey to black on fresh fracture, and weather rusty brown, which is the most distinctive feature of the formation as a whole.

Creston Formation

The Creston formation passes by gradual transition into the overlying Creston quartzites. It embraces a succession of greyish argillaceous quartzites and purer quartzites whose beds average about one foot in thickness. They are light grey on fracture and weather in greyish tones in contrast with the rocks of the underlying Aldridge formation.

Kitchener Formation

In comparison with the underlying Creston and Aldridge formations, the most notable feature of the Kitchener is its content of lime. It consists of calcareous and argillaceous quartzites and impure limestones in beds about 6 inches thick.

Toby Conglomerate

> ".....In the Ram Creek section, a remnant of the Toby conglomerate rests conformably on the Roosville formation.....Two and a half miles to the north, the 40 feet of shale and conglomerate represented in the Toby conglomerate, increases to a thickness of 800 feet....."[1]

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1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926 p.17

The nature of the Toby conglomerate is extremely variable. The matrix may be largely slate, limestone or of a siliceous nature. The boulders may vary as much. The percentage of boulders to matrix is also variable.

The materials composing the conglomerate has not travelled far. In all cases the boulders can be identified with the underlying series. The average size of the boulders is about 4 to 10 inches.

Pre-Cambrian Rocks at Windermere[1]

Only one pre-Cambrian formation has been identified in the Rocky Mountains in this area. It is of an age later than the youngest of the Galton Series.

Horsethief Formation

The Horsethief formation, of late pre-Cambrian age, outcrops at intervals along the front of the Stanford Range from Windermere Creek south to Upper Columbia Lake.

It is made up in large part of grey, green and purplish slate with several lenticular beds of coarse quartzite and pebble conglomerate . The numerous thin interbeds of blue-grey, crystalline, and mostly non-magnesian limestone, which occur at different horizons, form but a relatively small part of the whole formation.

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1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. p.14

Walker[1] places the age of the Horsethief formation as later than that of the Roosville. He correlates the Hector and Corral Creek formations with the Horsethief in preference to correlation with the Kintla-Sheppard.

Pre-Cambrian Rocks in the C.P.R.Main Line Area

Beltian[2] rocks extend throughout the bottom and lower slopes of the Bow River valley from Bow Peak to Cascade on the C.P.R. East of Mt.Hector and in the Mt. Richardson-Ptarmigan Peak mass, they rise in high hills both east and west of Pipestone River and continue eastward across Corral and Baker Creeks before passing beneath the Cambrian on the north slopes of Castle Mountain. The width varies from 3 to 6 miles.

These rocks were grouped by McConnell as part of the Bow River series.[3]

Corral Creek Formation[4]

Corral Creek rocks are the oldest exposed in the C.P.R.section. The formation consists of a grey sandstone underlain by a coarser quartzitic sandstone with an arkose-like conglomerate at the base. The nature of the conglomerate suggests shallow water or near shore conditions of origin.

1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. p.19
2. Walcott,C.D. Smith, Mis.Coll. Vol.53. No.7. p.427.
3. McConnell,R.G. Geol.Surv.Can. An.Rep. 1885. p.29-D.
4. Allan, J.A. Geol.Surv.Can. Sum.Rep. 1912. p.170

Hector Formation[1]

The beds of the Hector consist of grey, purplish and greenish shale interbedded with bands of conglomerate. The best exposure is in the Bow Range east of Storm mountain, where it has a thickness of 4,590 feet. It thins toward the north-west.

The contact with the Cambrian is conformable in the Bath Creek valley, but uncomformable at two other places examined.

Pre-Cambrian Rocks in Robson Peak Area

Walcott[2] reports Pre-Cambrian or Beltian rocks in the Yellowhead Pass area. Here the topography of both these and the Cambrian rocks bears a striking resemblance to those of the Bow River Valley.

Miette Formation[3]

On both sides of the Yellowhead Pass the Miette occurs in rounded, wooded ridges that rise some 3,000 feet above the Pass.

The rocks consist of massive grey and greenish siliceous shales. Most of them suggest deposition of sand in muddy waters.

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1. Allan, J.A. Geol.Surv.Can. Sum.Rep. 1912. p.170
2. Walcott, C.D. Smith. Misc.Coll.Vol.57. No.12. p.340
3. Idem Idem Idem.

An erosional unconformity exists between the Miette and the Cambrian above. The thickness is 2,000 feet.

Pre-Cambrian Rocks of the Finlay River Area[1]

Rocks, probably of Pre-Cambrian age, are found on the east wall of the Rocky Mountain trench from the Peace River north to the Fox River.

The rocks 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 more abundant of the three principal rocks is the quartz-mica schist which constitutes about three-quarters of the whole.

THE CAMBRIAN

The Rocky Mountains are comprised in a very large part of Paleozoic rocks, and of these the Cambrian is the most complete and widespread. With the exception of the area at the 49th parallel, it is found throughout the entire system from the North Kootenay Pass to the Peace and the Liard. During all of Cambrian it is likely that a sea way occupied the whole length of this now mountainous area.

No complete section of the Cambrian is found south of the C.P.R. Lower Cambrian is known in the Flathead area

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1. Dolmage, V. Geol.Surv.Can. Sum.Rep. 1927. Pt.A. p.25-A

at Elko, and at Ram Creek; Middle Cambrian only at North Kootenay Pass, Upper Columbia Lake, Elko and Ram Creek and Upper Cambrian only in the Windermere area. The classic Cambrian area of the Cordillera, and indeed one of the finest Cambrian exposures of the earth, is found in the area of the main line of the C.P.R. where this system of rocks is complete in 18,000 feet of sediments. Northward, in the Robson Peak area, the Cambrian is probably also fully represented where 12,000 feet of strata are found. On the Peace and Liard, McConnell reports rocks similar to his Castle-Bow series.

Cambrian at North Kootenay Pass[1]

Cambrian rocks have been found in the vicinity of north Kootenay Pass. They are composed of brownish limestones of unmeasured thickness. Fossil evidence places their age as Middle Cambrian. Here they are separated from the Kintla of the Beltian below by 200 to 300 feet of reddish white sandstones with a conglomeratic layer containing pebbles of white, opalescent quartz up to one-half inch diameter. This conglomerate marks a disconformity between the formations.

Cambrian Rocks of the Flathead Area[2]

Conglomerate of the same type as found at North

1. Adams & Dick. Can.Comm.Conservation. 1915. p.13
2. Rose, B. Geol.Surv.Can. Sum.Rep. 1917. p.296

Kootenay Pass is found at the top of the Beltian in the Flathead area. The conglomerate and the limestone above it are placed provisionally in the Lower Cambrian by Rose[1].

Cambrian Section at Elko[2]

Burton Formation. (Lower and Middle Cambrian)

The Burton formation rests on the Roosville with no structural discordance, yet with evidence of unconformity at the base.[3]

It consists mainly of greenish-black, calcareous shales with interbedded siliceous limestone bands. A thin conglomerate is found at the base. Schofield[4] places the lower 17 feet in the Lower Cambrian and the upper 60 feet in the Middle Cambrian.

Elko Formation (Upper Cambrian)

The Elko rests conformably on the Burton. Its rocks are siliceous limestone and siliceous dolomite of about 90 feet thickness. Walker[5] places it in the Upper Cambrian.

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1. Rose, B. Geol.Surv.Can. Sum.Rep. 1917. p.296
2. Schofield, S.J. Geol.Surv.Can. Mem.76. 1915. pp.43-47
3. Idem. Idem. Mus.Bull.No.35. 1922. p.13
4. Idem. Idem. Idem. p.15
5. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. pp.17 & 21.

Cambrian Section at Ram Creek[1]

The only occurrence of Cranbrook Conglomerates of any appreciable thickness in the Rocky Mountains is known at Ram Creek.

Cambrian formations thicken greatly from Elko to Ram Creek.

Cranbrook Conglomerates

The Cranbrook is formed of massive white quartzite and a conglomerate mainly of quartz pebbles. The lower 5 feet contain rounded fragments of underlying Beltian rocks.

The formation rests with unconformity or disconformity on the Beltian. Its age is Lower Cambrian.

Burton Formation

The Burton formation is found in greater thickness at Ram Creek than at Elko. It grades from Lower Cambrian to Middle Cambrian.

Elko Formation

The Elko formation at Ram Creek is 1,000 feet thick. Its age is Upper Cambrian.

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1. Schofield, S.J. Geol.Surv.Can. Mus.Bull. No.35. p.15

Cambrian at Windermere[1]

Only Upper Cambrian rocks are exposed in the Windermere area because "the Ottertail formation overlaps here the complete Cambrian section as developed in the Rocky Mountains and rests on the Horsethief formation."[2]

Ottertail Formation

The Ottertail formation is well exposed along the western face of the Stanford Range. It is made up of thick and thin-bedded, magnesian, crystalline limestone. It is a distinct lithologic unit throughout the Stanford range. The thickness varies from 2,000 feet south of Fairmont Springs to 270 feet on the east end of Law Ridge.

Within the Windermere area the Ottertail formation rests on the Horsethief, in some places conformably, and other unconformably, and underlies the Goodsir conformably. In general it is the equivalent of the Ottertail formation of the Field map area, 40 miles distant along the strike of the strata. Walcott has used the word Lyell (?) in describing this formation in the Stanford Range. The correlation with the Lyell is made over a gap of 100 to 132 miles and across the summit of the Rocky Mountains.

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1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. p.21
2. Idem Idem p.21

"South from the Windermere area the formation is traceable for 25 miles to Ram Creek. It is the Elko formation of Schofield's Ram Creek section and of the described sections on Grainger and Sabine Mountains. In its southward extension from the Windermere area, the Ottertail rests successively on the Cranbrook quartzites, east of Sabine mountain, and the Burton or Mt. Whyte formation on Grainger mountain at Ram Creek."[1]

Goodsir Formation

In the Windermere area the Goodsir formation is found throughout the Stanford range, varying in thickness and character. It is composed of shales with interbedded limestones.

The formation is considered to be the lithologic and stratigraphic equivalent of the Goodsir formation of the Field map area and of the Sabine and Mons formations of Walcott.

Its age is considered as including both Upper Cambrian and early Ordivician horizons.

The Cambrian in the Main C.P.R.Section

"The Cambrian is complete in the C.P.R.section with both lower and upper contacts exposed. There is a total of 18,578 feet which represents one of the thickest Cambrian sections yet measured in the world. It consists essentially of 3,800 feet of siliceous beds, chiefly quartzitic sandstone; 10,275 feet of calcareous and dolomitic limestone, and 4,500 feet of shale, much of which is calcareous."[2]

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1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. p.23

2. Allan, J.A. Idem Guide Book No.8. Part 2. p.172

Description of Formations (After Walcott)[1]

Lower Cambrian

Fairview

Type Locality:	North-east slope of Fairview mountain.
Character:	Grey Quartzitic sandstones.
Thickness:	600'.
Organic Remains:	Unknown.

Lake Louise

Type Locality:	Both sides of Lake Louise, at its upper end; well shown in north-west and north sides of Fairview Mountain.
Character:	Siliceous shale.
Thickness:	105' at upper end of Lake Louise.
Organic Remains:	Lower Cambrian.

St.Piran

Type Locality:	South-east slope Mt.St.Piran. The basins of Lake Agnes and Mirror Lake are both excavated in this formation.
Character:	Mainly grey quartzitic sandstones with a few bands of siliceous shales.
Thickness:	At Mt.St.Piran 2,640'.
Organic Remains:	Lower Cambrian in upper portion.

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1. Walcott, C.D. Smith. Mis.Coll. Vol.53. No.1. pp.2-5.

Mt.Whyte

Type Locality:	Mt.Whyte above Lake Agnes and eastern slopes of Pope's Peak southwest of Mt.St.Piran.
Character:	Alternating bands of limestone and siliceous and calcareous shale.
Thickness:	North slope of Mt.Bosworth 390'.
Organic Remains:	Lower Cambrian.

Middle Cambrian

Cathedral

Type Locality:	Cathedral Mountain and Cathedral Crags, east of Mt.Stephen and south-east of Mt.Bosworth.
Character:	Massive arenacious and dolomitic limestone.
Thickness:	Cathedral Mountain 1,600'. Mt. Stephen 1,800'.
Organic Remains:	Middle Cambrian.

Note: In this formation the Monarch mine at Field is located, also other mineral prospects.

Stephen:

Type Locality:	Bluish-grey and greenish-grey limestone and shale bands about 2,700 feet above railroad track on north and east sides of Mt.Stephen near Field.
Character:	Limestones and shales, calcareous and siliceous. Includes "Ogygopsis" and "Burgess" shales.
Thickness:	Mt.Stephen 562'. Local development of "Ogygopsis" shales at summit.
Organic Remains:	Middle Cambrian.Burgess shale prominent for its variety of organic remains.

Eldon

Type Locality:	Upper massive limestone of Castle Mountain, one or two miles north of Eldon switch on C.P.R.
Character:	Massive, arenaceous, dolomitic limestone with a few bands of purer bluish-grey limestone.
Thickness:	Castle Mountain, 2,728'.
Organic Remains:	Middle Cambrian.

Upper Cambrian

Bosworth

Type Locality:	Ridge extending north-west from Mt. Bosworth and south-east base of Paget Peak.
Character:	Arenaceous, dolomitic limestones, massive, thin-bedded and shaly with bands of purple and grey, siliceous shales.
Thickness:	Mt. Bosworth, 1,055'.
Organic Remains:	None observed.

Paget

Type Locality:	South-east slope of Paget Peak beneath the Sherbrooke formation which forms the high cliffs of Paget Peak and Mt. Daly. The Paget breaks down more readily than the Sherbrooke, presenting a slightly broken cliff line.
Character:	Thinly bedded bluish-grey and oolitic limestones.
Thickness:	At Mt. Bosworth 360'.
Organic Remains:	Upper Cambrian fauna.

Sherbrooke

Type Locality:	West slope of Mt.Bosworth, overlooking Sherbrooke Lake, 5 miles north of Hector.
Character:	Bluish-grey, arenaceous, dolomitic, massive and thin bedded limestones with a few oolitic layers and cherty inclusions.
Thickness:	At Mt.Bosworth, 1,375'.
Organic Remains:	Upper Cambrian.

Note: This formation includes the highest beds in the Bow Range in the vicinity of Hector Pass. The remaining Cambrian formations are all exposed in the western portion of the C.P.R. section between the Bow Range and Columbia Valley.

Chancellor[1]

The Chancellor formation floors the Ottertail Valley, underlies the Ottertail range and makes up a large portion of the Van Horne range.

It consists essentially of shales. The uppermost 2,500 feet are metargillites, well cleaved along the bedding planes. These shales become much more highly cleaved toward the base of the formation so that the lowermost 2,000 feet consist chiefly of phyllites, slates with argillites and a few interbedded layers of shaly limestone.

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1. Allan, J.A. Geol.Surv.Can. Guide Book.No.8. Pt.2. p.179

Ottertail[1]

The Ottertail consists almost entirely of blue limestone, massive toward the top and rather thin-bedded toward the base. It has a thickness of over 1,725 feet in the Ottertail range, where it is well exposed in an almost perpendicular escarpment along the east side of the range. This limestone represents the highest series in the Cambrian in the western section of the C.P.R.section.

The Cambrian in Robson Peak Area[2]

The area examined by Walcott in the Robson Peak area lies between Robson Peak and Moore Pass, a distance of 9½ miles.

Lower Cambrian

McNaughton

The McNaughton rests unconformably on the Beltian rocks. It consists of a light-grey, massive-bedded quartzitic sandstone.

Tah

Tah rocks are hard, green and purple siliceous shales with irregular beds of grey and purple, compact limestones interbedded in the central portion.

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1. Allan, J.A. Geol.Surv.Can. Guide Book No.8. Pt.2. p.179
2. Walcott, C.D. Smith. Mis.Coll, Vol.53. No.12

Mahto

Massive bedded quartzite sandstones with thin-bedded hard sandstones and dirty, greyish-brown shales in thin bands.

Hota

Massive-bedded arenaceous limestone in great bands of light and dark grey colour.

Middle Cambrian

Chetang

Bluish-grey, thin-bedded limestones.

Tatay

Massive-bedded grey siliceous and arenaceous limestones.

Hitka

Alternating bands of grey, thin-bedded arenaceous limestones and siliceous, arenaceous and argillaceous shales.

Mumm

Massive-bedded, grey siliceous limestone, weathering to grey and buff tints on cliffs.

Titkana

Massive-bedded, bluish-grey limestone in thin layers, interbedded with grey, siliceous, buff-weathering limestone that occurs in bands 50 to 100 feet thick.

Upper Cambrian

Lynx

Thin-bedded, bluish-grey limestone with interbedded bands of light grey shale and at the base a band of about 200 feet of grey, greenish and reddish-brown shale.

Cambrian Rocks in the Finlay River Area[1]

East of the Rocky Mountain trench in the Finlay River area the Rocky mountains consist largely of limestone. Where studied, it is for the most part quite pure and white or grey.

No fossils have been found in the limestones, but because of their position above the schists, McConnell[2] considered them to be a part of the Castle Mountain group.

ORDOVICIAN

Early and Middle Ordovician rocks only are represented in the Canadian Rockies. They are found in the Windermere, C.P.R. and Robson Peak areas. Southward they decrease in thickness and disappear, but apparently extend an indefinite distance northward.

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1. Dolmage, V. Geol.Surv.Can. Sum.Rep. 1927. p.26-A
2. McConnell, R.G. Geol.Surv.Can. An.Rep.Vol.7. 1894

Ordovician Rocks in Windermere Area[1]

Glenogle Shale

This formation is found north and south of Windermere Creek. The lower part of the formation is chiefly black shale with interbeds of a hard, mud rock and bluish limestone. The upper part grades from a sandy shale to a thin-bedded, argillaceous sandstone. This sandy shale is missing in the more westerly exposures.

This formation is considered to be the stratigraphic and lithologic equivalent of the graptolite shales of the Field map area. Burling gave the name Glenogle to these shales in 1922.[2] An unbroken section has not yet been found at or near Glenogle.

Wonah Quartzite

In the Windermere area the Wonah occurs in a few places along the eastern part of the Stanford range. It is the stratigraphic equivalent of the quartzites at the base of the Halysites beds of the C.P.R.area. It rests, in the Windermere area, on what appears to be an erosion surface of the Glenogle shales and at two localities on the Goodsir. It is separated from the formations below by a considerable

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1. Walker, J.F. Geol.Surv.Can. Mem.148. 1926. pp.24,25.
2. Burling, L.D. Geol.Mag. Vol.59. 1922. p.456

time interval, but is overlain conformably by the Beaverfoot-Brisco formations, the lower of which is of Richmond age. The Monah, then, may be of early Richmond age and can hardly be as old as Chazy.

Beaverfoot-Brisco Formations

These two formations are found throughout the Stanford range in the Windermere area. They consist of thick to moderately thin-bedded crystalline and semi-crystalline limestones. The beds are the stratigraphical equivalent of the Halysites beds of the Field area. The Beaverfoot are of Richmond age and the Brisco of Silurian, but in the Windermere area they are transitional and it is impossible to make an accurate division.

Ordovician of the Main C.P.R.Area

Goodsir Formation[1]

This formation is well exposed in Mt. Goodsir, where it is 6,040 feet thick. It lies conformably on the Ottertail and consists at the base of 3,000 feet of alternating hard and soft bands of argillaceous, calcareous and siliceous shales. The upper part of the formation consists of banded cherts, cherty limestones and dolomites, thin-bedded and very dense. The beds in this series become very highly sheared in the Beaverfoot valley and the range to the west.

1. Allan, J.A. Geol.Surv.Can. Guide Book No.8. Pt.2. p.180

Glenogle (Graptolite) Shales

These shales consist of black, carbonaceous and brown, fissile shales at the top, underlain by grey shales which grade into the underlying Goodsir formation.

The thickness of this formation varies, and the lower contact is ill-defined, but a thickness of at least 1,700 feet is represented, in which are found faunas of Beekmantown and Chazy age. Glenogle shales occur as two infolded bands in the Beaverfoot range.

Ordovician Rocks of the Robson Peak Area[1]

Robson Limestones

The Robson formation is considered to extend from the summit of Robson Peak some 3,000 feet down. This thickness was estimated by a view from Billing's Butte. The rocks are light-grey, thin-bedded limestones, forming massive strata on cliff exposures. The formation lies conformably on the Upper Cambrian.

Burling[2] disagrees with Walcott in most particulars regarding all formations of this area and especially in respect of the Robson.

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1. Walcott, C.D. Smithsonian Misc.Colls.Vol.57.No.12.p.331
2. Burling, L.D. Bull.Geol.Soc.Am. Vol.34. 1923. p.727

SILURIAN

Silurian strata of Clinton age, consisting mainly of limestones more than 1,000 feet thick, have been found in the mountains bordering the Rocky mountain trench south of the Kicking Horse river. Beds of this age appear to be absent farther east. They may continue northward along the western ranges of the Rocky mountains.

Silurian of the Windermere Area

Brisco Formation

This formation has already been described under the Ordivician of this area.

Silurian of the C.P.R.Area[1]

Halysites Beds (Brisco Formation)

> "These beds are the stratigraphic equivalent of the limestone part of the Halysites beds of McConnell and Allan. Burling first referred to these beds as being of Richmond age, and in 1922 gave the name Beaverfoot to them. Walcott has given the name Brisco to the Silurian beds, but in the Sinclair Canyon section, as reported by Walcott, and in the Windermere map area the Richmond is transitional into the Silurian."[2]

The Halysites beds consist chiefly of dolomitic limestone and white quartzite. This formation lies

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1. Allan, J.A. Geol.Surv.Can Guide Book No.8. Pt.2. p.181
2. Walker, J.F. Idem. Mem.148. 1926. p.32

conformably upon the Graptolite beds. The character of the rock sharply distinguishes it from the older strata. The formation is terminated above by a fault contact or by an erosion surface. A measured section gave 1,850 feet. The white quartzite is over 900 feet thick. It is infolded with the Graptolite beds in the Beaverfoot range. Some of the beds of dolomitic limestone are highly fossiliferous; corals are most abundant, but crinoids, brachipods and gastropods are also present.

This is the youngest formation exposed to the west of the Continental Divide, along this section of the Rocky Mountains.

DEVONIAN

> "In Devonian time, perhaps after a general withdrawal of the sea, the whole eastern Cordilleran region was again submerged, and in this sea, which presumably extended far to the east, were deposited calcareous strata attaining in places a thickness of several thousand feet. The Devonian beds have been recognised at intervals from the International Boundary line in the south to the Alaska-Yukon boundary in the north, but nowhere have either the earliest or the latest Devonian faunas been found, and as in the case of the earlier Paleozoic horizons, the western edge of the basin of deposition seems to have lain not far west of the edge of the Rocky Mountains. The Devonian beds in the south and in various places in the eastern part of the Rocky Mountains rest on late Pre-Cambrian or Cambrian strata, but in the western part of the Rocky Mountains they in places succeed Silurian beds."[1]

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1. Young, G.A. Geol.Surv.Can.Geology & Economic Minerals of Canada, 1926, p.151

Devonian of the Galton Range[1]

At the eastern edge of the drift covered Tobacco Plains a block of Devonian limestone has been faulted down into contact with the Gateway formation. The main fault which limits the block on the east can be rather sharply located, the strikes of the limestone and the Gateway metargillite being nearly at right angles. The apparent thickness of the strata is about 1,600 feet. Of this 300 feet represent dolomitic quartzite, occurring at the base of the section.

Fossils from the limestone indicate it to be of Devonian age. The quartzite contains no fossils but is probably of Devonian age also. The greater part of the limestone can be correlated with the Jefferson limestone of Montana.

Devonian and Mississippian Limestones of the MacDonald Range[2]

Great displacements on the western side of the Flathead trough have dropped Devonian and Mississippian limestones down into contact with the oldest members of the Galton Series. The result of this faulting is that a long slab-like block of Altyn, Hefty and MacDonald beds is bounded on both sides by Mississippian limestone. The younger fossiliferous

1. Daly, R.A. Geol.Surv.Can. Mem.38. 1912. p.110
2. Idem Idem Idem. p.113

limestones form two masses separated by the slab and may be referred to as the western and eastern blocks.

The western block is not well exposed. The limestone is dark, bluish-grey, massive, rarely showing stratification planes. Fossils seem to indicate its age as Upper Mississippian. The eastern block is composed of both Devonian and Mississippian limestones, greatly broken by step-faults, with down-throw to the east. The combined thickness of the Devonian and Mississippian is probably well over 1,000 feet.

Devono-Carboniferous of the Crowsnest Area[1]

The great Devono-Carboniferous series of rocks are found widespread in the Crowsnest Pass area, where they have not as yet been separated. Here they form the main range of the Rocky Mountains separating the Crowsnest coal areas of British Columbia from those of Alberta, also a minor range, the Misukishak or Erickson ridge, near Michel, and the high mountains of the MacDonald range west of the Flathead valley.

The rocks consist largely of evenly-bedded, compact, grey limestone, and lie conformably under the Fernie shales, The upper portion is of a light coloured quartzite and siliceous limestone. It may probably be correlated with the Rocky Mountain quartzite at Banff. A section, measured at the Crowsnest station, gives a thickness of about 10,000 feet with the base not exposed.

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1. Rose, B. Geol.Surv.Can. Sum.Rep. 1915, 1916, 1917.

Contact with the underlying Middle Cambrian is known only in the vicinity of North Kootenay Pass. The rock here overlying the Cambrian is a massive, unfossiliferous limestone, and above this the first fossils are Devonian. The fossils toward the top of the series are all of Carboniferous age.

In the Flathead area, MacKenzie[1] divides the rocks into a Devono-Carboniferous and a Carboniferous formation. The thickness of the former he places at 3,000 feet.

Devonian at Elko[2]

Devonian limestones, probably of Jefferson age, rest with a disconformity on the underlying Elko of the Cambrian. The staple rock is a massive, dark-grey limestone, weathering a whitish-grey colour. The thickness is 300 feet.

Devonian Rocks in the C.P.R.Area

Ghost River Formation[3]

Between the Cambrian and the Devonian of the C.P.R. section is a formation of 300 feet of thin-bedded and shaly, buff-coloured, magnesium limestone lying conformably between the superjacent Devonian beds and the Middle Cambrian beds beneath. Lack of fossils prevent its assignment of a

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1. MacKenzie, J.D. Geol.Surv.Can. Mem.87. 1916. p.15
2. Schofield, S.J. Idem. Mem.76. 1915. p.48
3. Shimer, H.W. Idem. Mus.Bull.No.42. p. 2

definite age. Some observers have considered it lithologically similar to the Silurian beds farther west, and others have placed it in the Devonian.

Minnewanka Formation

Two Devonian formations were originally recognised in the C.P.R.section, the Intermediate limestone and the Lower Banff limestone of McConnell,[1] Shimer,[2] and Allan.[3] Kindle[4] grouped the two formations into one and substituted the name Banff limestone and dolomite. His chief reason for the re-naming and re-grouping of these formations was because he regarded the dolomitization as being largely of subsequent or secondary origin. Shimer[5] later changed the name to Minnewanka. That nomenclature and classification have been accepted here as appearing to be the most satisfactory.

The Minnewanka limestone and fauna are found in the front ranges north from the Bow river to the Athabasca.

The lower 1,000 feet consist of thin-bedded magnesian limestones; the upper 1,900 feet of massive, grey limestones with shale interbedded.

The whole formation is regarded as being approximately the equivalent of the Jefferson limestone of Montana.

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1. McConnell, R.G. Geol.Surv.Can.An.Rep. 1886. p.15-D
2. Shimer, H.W. Bull.Geol.Soc.Am. Vol.24. 1913. p.234
3. Allan, J.A. Geol.Surv.Can. Sum.Rep. 1912. p.168
4. Kindle,E.M. Pan-Am.Geologist. Vol.42. 1924.pp.113-124
5. Shimer, H.W. Bull. Geol.Soc.Am. Vol.24. 1913. p.234.

Devonian of Roche Miette[1]

The Devonian at Roche Miette is constituted of heavily-bedded limestones. It is similar to the Devonian of the Bow River area.

CARBONIFEROUS

"The Devonian beds of the Rocky mountains in many localities are followed by Carboniferous strata ranging in age from Mississippian to late Pennsylvanian. In districts about Banff, the Carboniferous measures have a total thickness of nearly 5,000 feet and consist of a lower argillaceous member, a middle limestone member and an upper sandy member.[2] The whole succession is conformable, but sudden changes in the character of the fossil faunas indicate temporary withdrawals of the sea. The upper sandstone or quartzitic horizon appears to occur as far south as the International Boundary and presumably this persistent horizon with the underlying limestones extends northward through the whole length of the Rocky Mountains....."[3]

Carboniferous of the Flathead Area[4]

Carboniferous rocks underlie a considerable area in the district about the Flathead river. Their thickness is about 2,000 feet.

The rocks are wholly limestones of various kinds. They are mostly light weathering, grey to black rocks, the latter owing their colouring to bituminous matter, which also gives them a strongly foetid odour when struck. They are

1. Dowling, D.B. Geol.Surv.Can. Sum.Rep. 1911. p.206
2. Shimer has since placed this member in the Permian.
3. Young, G.A. Geol.& Econ.Minerals of Can. 1926. p.153
4. MacKenzie, J.D. Geol.Surv.Can. Mem.87. 1916. p.16

found as flaggy, thin-bedded and massive layers, with platy parting parallel to the stratification.

The formation lies conformably on the Devono-Carboniferous, and is set off from the formation above by a disconformity.

The fossil content, which contains, among other genera, Productus, Fenestella, Spirifer, Tripophyllum, Ptilopora, Batostomella and Derbya, makes it evident that the formations range from upper Mississippian to lower Pennsylvanian in age.

Carboniferous of the C.P.R.Section[1]

The Carboniferous in this section is found in the mountains in the vicinity of Lake Minnewanka.

Banff Formation (Lower Banff Shale)

This formation is of Mississippian age and rests conformably on the Minnewanka limestone. It is predominantly a dark grey to black calcareous shale, weathering brownish, which changes at the top to a shaly limestone difficult to distinguish from the overlying limestones. The thickness is 1,200 feet.

Rundle Formation (Upper Banff Limestone)

For the Upper Banff limestone Kindle[2] proposes the name Rundle formation. Shimer[3] uses the same term but divides

1. Shimer, H.W. Geol.Surv.Can.Mus.Bull.No.42. p.6
2. Kindle, E.M. Pan-Am.Geologist. Vol.42. 1924. p.123
3. Shimer, H.W. Geol.Surv.Can. Mus.Bull. No.42. p.2

the Rundle into a Pennsylvanian upper two-thirds and a Mississippian lower third. He describes the beds as thin-bedded light to dark grey limestones, becoming more shaly downwards until they merge into the Banff shales.

The formation is over 2,300 feet thick and has good exposures in the Sawback and Cascade ranges.

Carboniferous at Roche Miette[1]

Carboniferous limestones, sandstones and shales in thick beds are found in the Roche Miette area. The thickness is about 3,000 feet. The formation may be regarded as the equivalent of the Rundle and Banff formations at Lake Minnewanka.

PERMIAN

Permian beds are known in the area about Lake Minnewanka, and north at Roche Miette Dowling describes a formation as Triassic-Permian. It is probable that the white quartzitic rock mentioned by Young[2] as extending southward to the International Boundary as upper Carboniferous is Permian. If this is so, Permian rocks extend the entire length of the Rocky system on the eastern part.

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1. Dowling, D.B. Geol.Surv.Can. Sum.Rep. 1911. p.206
2. Geol.& Econ.Minerals of Can. Geol.Surv.Can. 1926. p.153

Rocky Mountain Quartzite

Allan[1] classes this formation as Pennsylvanian; Shimer,[2] on faunal evidence, places it in the Permian. The thickness of this formation in the Sawback Range is 800 feet. It thickens rapidly to the east and 1,200 feet are exposed at Lake Minnewanka.

The formation is an alternation of light grey quartzite and light-grey limestone, the former predominating in the upper part, the latter in the lower, where it merges imperceptibly with the Rundle limestone. The uppermost 50 feet contain considerable conglomerate with rounded quartzite and calcareous pebbles up to 2 inches in diameter.

MESOZOIC

TRIASSIC

"In the Banff district, the Carboniferous (Permian) beds are overlain disconformably by about 15,000 feet of sandstone and shale of marine origin and Triassic age. Beds of this age may extend throughout the length of the Rocky mountains. They have been recognised along the Peace and Liard rivers and occur in the western ranges of the Mackenzie mountains. In these various areas the Triassic beds, though deposited after an interval of emergence from the sea, are essentially conformable with the underlying Paleozoic strata."[3]

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1. Allan, J.A. Geol.Surv.Can. Guide Book No.8. Pt.2. p.183
2. Shimer, H.A. Idem. Mus.Bull. No.42. 1926. p.6
3. Young, G.A. Geol.& Econ.Minerals of Can. Geol.Surv.Can. 1926. p.153

Triassic of Flathead Area[1]

Rocks tentatively assigned to the Triassic epoch are the surface formation of a considerable area in the western portion of the district about the Flathead river. The thickness is about 2,500 feet.

The formation is strikingly homogeneous wherever it has been observed. It consists throughout of white or pale grey, very fine, even compact sandstone. Where unweathered, the rock is pale grey, with a sub-vitreous lustre, simulating a quartzite.

Though good exposures showing contact with formations above and below are not known, structural relations indicate a disconformity below and conformity with the Fernie above.

The formation is barren of fossils and on stratigraphical grounds is placed in the Triassic.

Triassic in Banff Area

Spray River Formation

The Upper Banff shale which Allan[2] places in the Permian, Kindle[3] and Shimer[4] place in the Triassic and call the Spray River formation. This is an alternation of heavy-bedded, light grey, calcareous arenaceous shales. At

1. MacKenzie, J.D. Geol.Surv.Can. Mem.87. 1916. p.20
2. Allan, J.A. Geol.Surv.Can.Guide Book No.8. Pt.2. p.183
3. Kindle, E.M. Pan-Am.Geologist. Vol.42. 1924. p.115
4. Shimer, H.A. Geol.Surv.Can. Mus.Bull. No.42. 1926. p.2

frequent intervals throughout the entire thickness occur many ripple marks, mud flows, minor crossbedding and mud cracks.

The contact with the formations above and below is conformable. Good exposures occur at Rundle mountain, where a thickness of about 1,400 feet has been found.

Area at Roche Miette

Triassic rocks at Roche Miette have already been described under Permian.

McConnell[1] recognised Triassic rocks on the Peace and Liard on reconnaissances through those areas.

JURASSIC

From the 49th parallel northward to the Athabasca river, and probably farther, the Triassic, or where they are absent, late Paleozoic strata, are succeeded by the dark marine shales of the Fernie formation of Jurassic age. The Fernie beds in places rest conformably on the underlying strata, but the presence in places, of a few feet of basal conglomerate holding fragments of Paleozoic strata indicates that, preceding Fernie time, considerable areas lay above the sea, and were subjected to erosion. The Fernie measures in the eastern ranges of the Rocky mountains are less than 1,000 feet thick, but near the International Boundary increase in thickness to the west, where in places they are more than

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1. McConnell, R.E. Geol.Surv.Can. An.Rep. Vol.7. 1894.p.31-C
   Idem Vol.4. 1888.p.44-D

3,000 feet thick. The Fernie appears to grade into the overlying Kootenay. The composition of the thin basal conglomerate at the base of the Fernie indicates that the strata of the land mass to the west were sufficiently domed or folded to permit agents of erosion attacking different formations.

Workers in the Fernie have correlated formations to such good effect that one name applies to this formation throughout the great areas it covers in the Rockies. This has been aided by the presence of the Kootenay above with its coal measures.

Jurassic in the Crowsnest Pass Area[1]

Fernie Formation

The Fernie formation is found evenly distributed throughout the Crowsnest Pass area, and commonly occurs in the valleys and basins of this district.

The formation consists in the main of shale containing Jurassic fossils; brown-black, grey-black, thinly laminated and fissile shales predominate, and a persistent band of quartzite, 50 to 100 feet thick, is found at the base. At the top, the Fernie becomes arenaceous, and alternating bands of brownish sandstone and shale lead up to a massive, coarse-grained sandstone above which are plant remains and coal seams. The base of this heavy sandstone is used as a dividing line between the Fernie shales and the overlying Kootenay formation.

1. Rose, B. Geol.Surv.Can. Sum.Rep.1917. p.30

The Fernie is over 3,000 feet thick in the Elk river valley but thins toward the east where a maximum thickness of 700 to 800 feet occurs in the Crowsnest coal areas on the Alberta slope of the mountains.

Jurassic in the Banff Area

Fernie Formation[1]

The Fernie holds much the same character all through the Rocky mountains. In the Banff area it consists of black and dark brown siliceous shales thinly laminated. West of Banff its distribution is limited, lying on the Spray river formation. East of Banff, and on the north side of the Cascade trough, it forms a band about 1,500 feet thick.

Jurassic at Roche Miette[2]

Fernie Shales

Typical Fernie shales with sandstones interbedded are found in the Roche Miette area.

CRETACEOUS

> "The Fernie strata appear to grade into the overlying Kootenay formation, which is non-marine in origin, holds thick coal seams and consists largely of alternations of crossbedded sandstones and dark shales. The Kootenay formation

1. Allan, J.A. Geol.Surv.Can. Guide Book No.8. Pt.2. p.184
2. Dowling, D.B. Geol.Surv.Can. Sum.Rep. 1911. p.206

decreases in thickness from west to east; the greatest thickness is 5,000 feet. The coal bearing Kootenay measures are preserved in places along the whole length of the Rocky mountains, but in some localities are separated from the Fernie beds by a thick series of sediments. The Kootenay strata are considered to be of Lower Cretaceous age and to be separated by a considerable time interval from the underlying marine Jurassic, despite the seeming gradation of one formation into the other. The marked increase in thickness, in a westward direction, of both the Fernie and Kootenay beds, indicates that the source of the clastic materials composing these formations lay to the west. Sandstones and conglomerates in the Kootenay lead to the general conclusion that, commencing in late Jurassic time, the part of the Cordillera lying west of the Rocky mountains was withdrawn from the sea and was subjected to differential movements of gradually increasing intensity, so that the region affected assumed a mountainous character.

"Along the eastern border of the Cordilleran region the deposition of sediments was a continuous process from the Kootenay period in later Lower Cretaceous time, to the close of the Upper Cretaceous, and the strata of this long interval are displayed throughout the length of the Rocky mountains. In the southern part of these mountains, the coal-bearing Kootenay beds are overlain by the Blairmore formation consisting of interbedded sandstones and shales with bands of conglomerate and having a thickness of 2,000 to 3,000 feet, increasing in amount westward. The upper part of this formation may be of Upper Cretaceous age. Along the Crowsnest pass, the Blairmore is overlain by bedded tuffs and agglomerates which attain a maximum thickness of 1,100 feet. These beds are found within a limited area, outside of which the Blairmore is overlain by marine shales of Colorado age. These beds, in places 3,000 feet or more thick, are succeeded upwards by the Allison beds of fresh and brackish-water origin, possibly corresponding to the Belly River beds of the plains region to the east.....The thickness of the Cretaceous strata is 20,000 feet or more, and this great volume of clastic material, spreading far to the east, was derived from the then rugged region to the west."[1]

1. Young, G.A. Geol.& Econ.Minerals of Can.Geol.Surv.Can. 1926. p.157

The Cretaceous of the Crownest Pass Area

Kootenay Formation[1]

The Kootenay is found widespread in the Crowsnest region, both in Alberta and British Columbia.

The formation is made up of alternating sandstones, shales and coal seams with considerable conglomerate toward the top of the section. Massive, coarse-grained and cross-bedded, grey sandstones stand out prominently. The formation is sub-aerial in origin as is shown by the character of the sediments, coarse, cross-bedded and ripple-marked sandstones, fossil land plants and shales associated with coal seams. It is difficult to designate an upper limit of the formation as the strata above is much the same except that the sandstones are coarser and there are a number of conglomerate bands.

A section on the Elk river escarpment north of Morrissey shows 216 feet of coal in 3,200 feet of strata. To the north, in the Upper Elk valley coal basin, the Kootenay reaches a thickness of 3,500 feet. In the Flathead valley there are about 1,100 feet of strata, and at Blairmore, Alberta, the thickness has diminished to 450 feet.

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1. Rose, B. Geol.Surv.Can. Sum.Rep. 1917. p.30-C

Blairmore Formation[1]

The Blairmore formation is confined in its distribution to the eastern part of the Crowsnest pass area and mainly to Alberta. Here it overlies the Kootenay without any evidence of unconformity unless the conglomerate at the top of the Kootenay should mark a short cessation of deposition.

The formation consists essentially of sandstones and conglomerate varying greatly in colour and texture with one thin bed of bluish shaly limestone towards the middle of the series which is very persistent in the Blairmore area.

Marked differences in thicknesses take place in comparatively short distances. In the Blairmore area 2,100 feet are represented.

Elk Conglomerates and Flathead Beds[2]

In the districts about the headwaters of the Flathead river and on some of the higher mountains east of the Elk river, rocks of Blairmore age are found and are known as the Elk conglomerates and Flathead beds.

They are formed by the gradation of the Kootenay strata upward into conglomerates, coarse sandstones and shales. These beds have been called the Elk conglomerates to distinguish them from the less conglomeratic strata below

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1. Leach, W.W. Geol.Surv.Can. Sum.Rep. 1911. p.195
2. Rose, B. Idem. Idem. p.31-C

and above. The rocks above the Elk conglomerates are mostly green, and reddish shales and sandy shales interbedded with sandstones and some conglomerates. It is this upper part that is known as the Flathead beds.

The combined thickness of the two formations is 6,500 feet.

Benton (Colorado) Formation[1]

The Crowsnest volcanics rest on the Blairmore formation. Conformably on these is the Benton formation. It occurs widely in the Blairmore area.

The rocks are almost wholly dark grey to black fissile clay shales. Near the top of the lower third of the measures occurs a bed of very hard, fine to medium grained quartzitic sandstone, ordinarily from 10 to 20 feet thick, but in the vicinity of North Kootenay pass 150 feet. Above this band the measures are more arenaceous. The thickness of the Benton averages 2,000 feet, in places reaching 3,000 feet.

Allison (Belly River) Formation[2]

The Allison beds lie conformably on the Benton shales and stratigraphically are the youngest of the bed rock formations of the Blairmore area except that "in certain districts it is overlain by an assemblage of shales and sandstones, in

1. Leach, W.W. Geol.Surv.Can. Sum.Rep.1911. p.197
2. Idem Idem Idem p.198

places 10,000 feet thick, whose higher beds are presumably of very late Upper Cretaceous age."[1] In the Alliaon, sandstones predominate, mostly white or light grey, sometimes pale green, massive or with shaly structure, often laminated and crossbedded and rather soft. Some considerable beds of dark grey shales occur, also several beds of light green, plastic shales.

The top of these beds is not known, but about 2,000 feet are exposed on the west branch of the South Fork river.

Cretaceous in the Banff Area[2]

Lower Ribboned Sandstone

The Cretaceous beds are exposed along the eastern base of Cascade mountain. The Lower Ribboned sandstone consists of alternating bands of brown-weathering sandstone and shale. This formation follows the bottom of the Cascade trough and is exposed on the road between Bankhead and the west end of Lake Minnewanka. The beds here are about 1,000 feet thick.

Kootenay

The Kootenay here is similar to the corresponding formation described above. It consists of 2,800 feet of sandstone and shale enclosing several workable seams of coal. Particularly good coal measures occur at Canmore and a considerably high grade bituminous coal has been mined at

1. Young, G.A. Geol.& Econ.Minerals of Can.Geol.Surv.Can.1926 p.158
2. Allan, J.A. Geol.Surv.Can.Guide Book #8.Pt.2.p.185

Bankhead.

Upper Ribboned Sandstone

This formation consists of thin-bedded sandstones and shales. It is exposed at the eastern base of Cascade mountain. The beds are wedged between the coal measures below and a thrust plane above. Some of the uppermost Cretaceous beds were planed away when the older beds were thrust over them. There are about 550 feet of beds exposed in Cascade mountain, but this formation becomes thicker to the north-west and south-east of this section.

Cretaceous in Northern Areas

In the Roche Miette area the typical coal-bearing Kootenay rocks of the mountains and foothills occur. The top of the formation is not present.

Cretaceous beds probably occur in the little known Peace and Liard sections of the Rocky mountains. McConnell[1] has recognised Mesozoic rocks on both slopes of the mountains in the Liard river area.

TERTIARY

Kishenena Formation of the Flathead Area[2]

The Kishenena formation underlies a large portion of the Flathead trough. It is known to extend from the 49th parallel northward beyond Beryl lakes.

1. McConnell, R.G. Geol.Surv.Can. An.Rep.Vol.4.1888.p.44-D
2. MacKenzie, J.D. Idem Mem.87. 1916. p.31

Little information is available in regard to the thickness of these beds. They apparently reach a thickness of 1,500 feet and may be much thicker.

These sediments may be divided into two facies. The first consists of coarse gravels and sands with some clay, is cross-bedded and lenticular in character and contains many thin seams of lignite. The second facies is made up of partially consolidated, very fine-grained, evenly-laminated, fossiliferous, freshwater limestones, alternating with fine clay beds and very thin seams of lignite.

Fossil evidence, though not absolute, at least strongly supports the conclusion that the Kishenena is of Eocene age. Willis[1] holds that these beds are freshwater lake sediments.

PLEISTOCENE AND RECENT

The description given in Guide Book 8 of Pleistocene and Recent deposits of the C.P.R. area is typical of all such deposits in the Rocky mountains.

> "The unconsolidated material is represented by three types of deposits as shown in the section. The fluviatile and lacustrine deposits appear in terraces about the sides of the larger valleys, while the former also floors the broad plains of the main streams such as the Bow, the Kicking Horse, the Beaverfoot and the Yoho.
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> "Glacial till veneers the more gradual slopes of the various ranges, to an elevation at least 9,000 feet above sea level."[2]

1. Willis, B. Geol.Soc.Am. Vol.13. 1902. p.327
2. Allan, J.A. Geol.Surv.Can. Guide Book 8. Pt.2. p.186.

Tertiary Rocks in the Finlay River Area. [1]

Three small areas of unmetamorphosed Tertiary sediments occur in the Rocky Mountain trench in the Finlay River area. They extend from the mouth of the Ingenika river north to the mouth of the Fox and probably beyond.

The rocks consist of coarse conglomerate and sandstones, being clearly derived from the underlying formation. Plant remains determine their age as Tertiary.

1. Dolmage, V., Geol. Surv. Can., Sum. Rept. Part A. 1927.

IGNEOUS ROCKS

Igneous rocks are not common in the Rocky mountain region, though there is a possibility that this may be accounted for by the great thickness of the sediments and the comparative youthfulness of the system. Igneous rocks are limited to three lava flows and three intrusives.

Purcell Lavas[1]

The Purcell lavas have been traced from south-east of Altyn, Montana and from heights overlooking Waterton Lake all the way to the eastern summits of the Purcell range on the International Boundary.

Summary of Lithological Features

Galton range	Clarke range	Lewis range
60' amygdaloid	260' amygdaloid	35' amygdaloid in Sheppard 40' amygdaloid in Kintla
40' coarse breccia	Total lava 260'	18' massive amygdaloid flow
200' amygdaloid with phenocrysts	Dykes and sills cutting Siyeh immediately below	40' ropy lava passing below into pillow lava
90' non-vesicular porphyry		Total lava 58'. Dykes and sills cutting Siyeh immediately below
390'		

1. Daly, R.A. Geol.Surv.Can. Mem.38. 1912. pp.207-220

the Livingstone range to the east and the main range of the Rocky mountains to the west. Good exposures occur near the towns of Blairmore and Coleman.

The contact between Blairmore measures and the volcanic rocks is a gradational one. The beds often pass gradually from greenish sandstones and shales into well stratified tufaceous rocks and the exact contact can often not be placed at any given horizon. A gradational relationship occurs also between the volcanics and the Benton above. The Crowsnest rocks are finer and thinner bedded toward the top and the transition becomes difficult of detection.

> "At the time the deposition of the Crowsnest volcanics began, the area the now cover was occupied by a shallow sea probably of fresh water, containing low marshy lands. There is no recognised evidence to show whether the vents emptied into the air or were submarine; any cones that may have been built up above sea level would naturally be destroyed during the incursions of the sea in Benton time. The thickness of the deposits in relation to their lateral extent seems to indicate that the beds are due to the simultaneous effect of several small volcanoes of moderate activity, rather than to the action of one large vent. The eruptions were of the explosive type, unaccompanied by flows except very locally, and took place in continual sequence during a relatively short period of time. By far the greater part of the ejected material fell into the sea and there was deposited in more or less well stratified beds."[1]

The Crowsnest volcanics consist of fragmental stratified pyroclastic rocks which exhibit several primary types occurring as fragments. These are, in order of abundance, trachytes, blairmorites and latites. The

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1. MacKenzie, J.D. Geol.Surv.Can. Mus.Bull.No.4. p.13

trachytes are soda-rich varieties. Aegerine-augite trachyte and melanite trachyte have been recognised as separate types. The blairmorites are unusual rocks, ultra alkaline, soda-rich porphyries, characterised by primary analcite in large quantities up to 71%. The primary types have been altered only slightly.

The fragmental volcanic rocks consist of both mineral and rock fragments of varying sizes and associations characterised by minerals typical of alkaline rocks, orthoclase, sanidine, soda orthoclase, aegerine-augite, analcite, melanite, titanite, etc.

The maximum thickness of this formation is 1,150 feet, measured near Crowsnest mountain. A constant decrease in thickness is shown from this vicinity toward the north, south, and more rapidly, toward the east. The overthrusting of the west conceals outcrops there.

Jurassic Tuffs

> "In the quarry section at Blairmore and on the Castle river is a bed of green tuff 50 feet wide in the latter section. This is the earliest appearance of volcanic material in the Mesozoic sediments of the Northern Rocky mountain system."[1]

It corresponds to the great flood of volcanic rocks which occur in Western British Columbia in the Jurassic.

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1. McLearn, F.H. Geol.Surv.Can. Sum.Rep. 1915. p.111

Ice River Intrusive[1]

The Ice River intrusive is the largest intrusive body in the Rocky mountains. It is located on the Ice River and is exposed for about 12 square miles. Its form is that of an asymmetrical laccolith with a stock-like conduit.

The igneous mass as a whole is alkaline. The various types together with their transitional phases form a complete series between two widely separated extremes. The one end of the series which is most highly alkaline is represented by a light-grey or greenish-grey nepheline syenite. In this normal type the relative amounts of feldspar vary, and with the addition of sodalite the rock becomes a light, bluish-grey, sodalite nephelite. At the other end of the series is a jacupirangite. This rock is black and lacks all light coloured minerals. The distribution of this type is not as well defined in the field as the nepheline syenite and it passes into pyroxenite when pyroxene becomes the essential and practically the only mineral present. A type intermediate between these two extremes is an ijolite which is made up essentially of nephelite and aegirite-augite.

There is a marked contrast in the field between these three main types, but when the numerous transitional phases are included, no sharp line of division can be made and the complex affords a continuous petrographic series.

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1. Allan, J.A. Geol.Surv.Can. Mem.55. p.105-195.

The age of the intrusive is believed to be post-Cretaceous as determined by structural and correlation evidence.

Cross River Intrusive

On the Cross river are "numerous large masses of greenish-grey diorite (?) somewhat resembling the intrusive of Ice river but apparently not, like that, a nepheline syenite. They have derived from an intrusion of the same material,.....Associated with and cutting the diorite are quartz veins carrying copper pyrite."[1]

Bull River Intrusive

> "North of the Bull river.....a low, isolated hill was found to be composed of a remarkable crystalline rock which is evidently intrusive. It is chiefly composed of well-formed orthoclase feldspar crystals which are pinkish in colour and in some cases nearly an inch in length..... It may be regarded as a variety of quartz porphyry in which the quartz is, however, observable under the microscope only."[2]

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1. Dawson, G.M. Geol.Surv.Can. An.Rep.No.1. 1885. p.116-B
2. Idem Idem Idem p.151-B

Correlation Table — Rocky Mountains

	1 Lewis Series	2 Galton Series	3 N Kootenay	4 Elko	5 Ram Creek	6 Blairmore	7 Flathead Cabinet	8 Windermere	9 Field	10 Beaverfoot	11 Misinchinka	12 Rocky Mountain	13 Robson Peak
Tertiary									Ice River Intrusives				
Cretaceous						Alberta Group 1,000 Dakota 7 [illegible] C. [illegible] and Kootenay 7 [illegible] Blairmore 1,5[illegible] Kootenay 55	Ice Creek Intrusives with Kootenay Rocks Kootenay 3,000				Upper Kootenay 3,000 Mid Kootenay 3,000 Lower Kootenay 800	Kootenay	
Jurassic						Fernie 750	Fernie 2000				Fernie 500	Fernie	
Triassic							Spray 2,000				Spray Fm 50	Spray Fm 1,[illegible] (?)	
Permian	Permian										Fairy Dunlop Rock 80	Triassic	
Carboniferous	Mississippian	Mississippian									Rocky Lake Ls 150 Mountain Ridge Ls	Carbon Fernie 3,000	
		Devonian					Carbon f Fernie 2,000				Banff 200	Carbonif. [illegible]	
Devonian			Devonian	Devonian 300		Devon C & Devonian 10,000	Devon Carbonif. or 3,000				Mississippian 1,000 Devon Rocks 700	Devonian 100	
Silurian								Bow 7,750	Hailey Intrs & Ls 1,000	Bow			
Ordovician	Richmond							Beaverfoot		Beaverfoot			
	Lower							Wenk Quartzite 67		Wenk Quartzite			Robson 300
Upper Cambrian					Stratford Elko 90	Stratford 2,000		Glenogle Shale 2,000 Cambrian 300	Glenogle to Stephen 700 Cambrian 400	Eager Wenk			
								Ottertail 1,900	Ottertail 1,[illegible]	Ottertail 3,[illegible]			
									Chancellor 400 Ottertail 375 Eager 300 Beaverfoot 850				Lyell 3,[illegible]
Middle Cambrian									Eldon 2,775				
									Stephen 600 Cathedral 950				Tidwa 2,700 Nasa 600 Hota 2,700 Tatay 800 Chancellor 400
			Cambrian	Elko 60	Bertha 300								Hota 700
Lower Cambrian				Bertha 90	Bertha 300				Mt Wilson 350 St Piran 2,300 Lake Louise 150 Appleyard 600				Mahto 1,800 Mahto 2,400 Mahto 2,400 Pika 2,400 Bullingtonia 200 Bullingtonia 200
				Cambrian 1	Cambrian 400		Lower Cambrian		Cathedral to Takakkaw				
Lower Cambrian	Pre-Cambrian Series			Pre-Cambrian only	Pre-Cambrian only								
								Hamill of 4,000	Ice Tor 4,500				Mahto
					Takakkaw 400			Takakkaw 2,000	Ice of Ice Ch 2,500				
Purcell Series	Upper	Pre-Cambrian											
		Bonnington 400 Beaverfoot 600			Bonnington 400 Beaverfoot 300	Bonnington 400 Beaverfoot 300							
	Lower	Purcell Lava 250 Depth 4,00	Purcell Lava 500 Depth 4,000	Lower Series		Purcell Lava 50 Depth 4,000							
		Bonnington 1,600 Mt Harkness 2,400 Aldyn 1,500 Walterdale 7,500	W Group 2,300 Mt Harkness 2,500 W Fm 750 Aldyn 650			Ki Lower 4,500 Creston 5,000 Ala Aldyn 5,000							

1 Daly, R.A. Geol. Surv. Can. Memoir 38 2. Ibid. 3. Adams and Dick Can. Comm. 4. Schofield S.J. Geol. Surv. Can. Mem. 39 5. Schofield S.J. Geol. Surv. Can. Mem. Bull. 35 and Walker J.F. Geol. Surv. Can. Mem. 126.

6. Leach W.W. Geol. Surv. Can. Sum. Rpt. 1911 7. Rose R. Geol. Surv. Can. Sum. Rpt. 1917 and Reference 10 Geol. Surv. Can. Mem. 87 8. Walker J.F. Geol. [illegible] Mem. 42 9. Allen J.A. Geol. Surv. Can. Mem. 35. 10. Wilson C.D. Trans. Can. Inst. 6(1) 1903 p. 1.

11. Stamer P.W. Geol. Surv. Can. Mem. Bull. 87 and unpublished B.A. 1962 12. Dowling D.B. Geol. Surv. Can. Sum. Rpt. 1911 13. Walker J.F. Geol. Surv. Can. Mem. 126.

CHAPTER IV.

THE STRUCTURE OF THE ROCKY MOUNTAINS

INTRODUCTION

The disturbance which uplifted the Rocky Mountains was one last of the great tectonic movements of the Cordillera. The cause of the movement is related to the causes for all mountain building and is a problem which is still far from solution. The theory of a shrinking or compacting earth is one of the more plausible theories. In such a case the entire globe is affected with a consequent deformation of shell. This need not rule out the factor of isostatic balance but leaves it as a factor determining where deformation shall be most expressed and when it shall occur.

Those parts of the earth which react to the greatest extent are the heavier oceanic segments. They are depressed much more than continental segments and to such a degree that continental segments are forced up or at least left in greater relief than before movement began.[1]

According to this theory, the greatest application of the force would occur along the edges of the continents with deformation in those regions. Such a theory suggest the permanence of continents and of the sites of mountain ranges.

Thus might have risen the Rocky Mountains. One objection to this theory is that the Rockies are found far inland. But it is known that deformation of an area increases its resisting power. The areas between the Rocky Mountains and the coast were already considerably deformed and yielded to pressures less easily than the Eastern Geosyncline.

1. Chamberlin, R.T. Jour. Geology, Vol. XXXII. No. 7. pp. 545 - 574.

This explanation does not rule out the possibility of rising isogeothermal lines having had some share in uplift of the sediments into a great mountain system.

Chamberlin [1] applies the wedge theory of disatrophism to the uplift of continents and mountain systems. Hence he explains the Rocky Mountains by a vigorously contracting earth breaking the area in the form of a great wedge and, in the shortening, lifting the wedge above the level previously assumed. This explanation would involve overthrust faulting on both eastern and western edges. Though such exists on the eastern side, his contention that overthrusting is also a feature of the western edge receives the support of but a few of the investigators of that area.

The general features of Rocky Mountain structure are similar in the greater part of the mountains. The whole system forms a great synclinorium. The eastern edge is marked from the Peace River to the 49th parallel by an almost continuous overthrust. The eastern ranges are the result of thrust faulting which raised great blocks with sharp eastern escarpments and gently-dipping western slopes. The central ranges are formed of gently-folded sediments cut by a few great normal faults. The western ranges are marked by close and overturned folds and many great faults. The Rocky Mountain Trench is partly a structural feature and partly the result of erosion.

Structure of the Southernmost Rockies [2]

MacKenzie divides the section of the Rockies, lying between the 49th parallel and the Crowsnest Pass district into three structural areas, a western, a central, and an eastern.

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1. Chamberlin, R.T. Jour. Geology Vol.XXXlll No.8, pp. 755 - 792
2. MacKenzie, J.D. Royal Soc.Can., Proc. & Trans.1922.Pt.lV.p.97-130.

Western Area

This area lies between the Elk and the Kootenay Rivers on the west and the Flathead River on the east. In its southern part it is characterized by homoclinal fault blocks separated by large normal faults. Northward, folding predominates over normal faulting.

Central Area

At the 49th parallel the central structural area is a great syncline of pre-Cambrian strata. This structure holds north to the vicinity of North Kootenay Pass. In this distance it is separated from the area to the west by a great normal fault or zone of faults along the east side of the Flathead Valley. These faults have a downthrow to the west. The area is narrowed towards the Crowsnest Pass by the western swing of the Lewis overthrust.

Eastern Structural Area

The third and eastern area consists of the foothills and mountains of western Alberta adjacent to the Crowsnest Pass. Here the rocks are Cretaceous with the exception of some Devono-Carboniferous strata in the Pass. Structurally it is characterized by numerous, nearly parallel, reverse, strike faults, of great lengths and unusual steepness. With them are associated strong folds.

The reverse faults of the eastern area are notable in many respects. They are very long and generally parallel the strike of the rocks. Unusually little disturbance and breakage has taken place in their parting surfaces and no preliminary folding is indicated. On the whole, they have a very high angle of dip, and their strike is quite straight. Twenty-two faults near Blairmore give an average dip of over 70°. They afford good illustrations of the imbricate structure described by Cadell.

The Lewis Overthrust

A large part of the Clarke Range has been bodily thrust over younger strata to the east so that its massive Beltian rocks rest on Cretaceous. This great thrust has been named the Lewis Overthrust. Oil borings near Waterton Lake disclose Cretaceous shales under 1,500 feet of siliceous dolomite of the Beltian, thus giving the thrust a known width of 15 miles, and if the oil and gas of the Flathead Valley emanate from Cretaceous beds below, the thrust would have a width of 40 miles representing the operation of a gigantic force by which the entire Clarke Range was torn from its foundations and thrust for a great distance.

Longitudinally, the thrust extends from the Boundary to latitude 50°, a distance of 85 miles, and is thought to continue almost to the Peace River. It lies at the base of the front ranges north to North Kootenay Pass where it passes behind the Livingstone Range. Everywhere it reverses the normal order of strata. Those strata above it are not greatly disturbed but those immediately below have been intensely folded and faulted by the thrust stresses from the southwest. The dip of the thrust westward is gentle.

The age of the thrust can not be fixed precisely. That it took place before the deposition of the conglomerate of Miocene age of the Cypress Hills seems established. It was probably one of the latest effects of the compressive stresses of the Laramide Revolution, the age of which is placed not earlier than the uppermost Cretaceous and not later than the latest Eocene.

General History of the Structure

Willis [1] advances a rather involved history of the structure of the Front Ranges. This has been well summarized by Daly [2] as follows:

"1. The 'Algonkian' strata were reduced to a peneplain in early Cretaceous time. This old erosion surface subsided beneath the Benton sea, which extended as far west as about the longitude of Waterton Lake.

"2. During Dakota and Benton time there was a very gentle and broad upwarp of the Front Ranges area, accompanied by sedimentation in a sea which covered only the eastern part of the belt now occupied by the Lewis Range.

"3. At the close of the Laramie (presumably at the time of the general Laramide revolution) there was a single upwarp of the 'Algonkian' and overlying Cretaceous beds, forming an unsymmetric fold with steeper dip on the east.

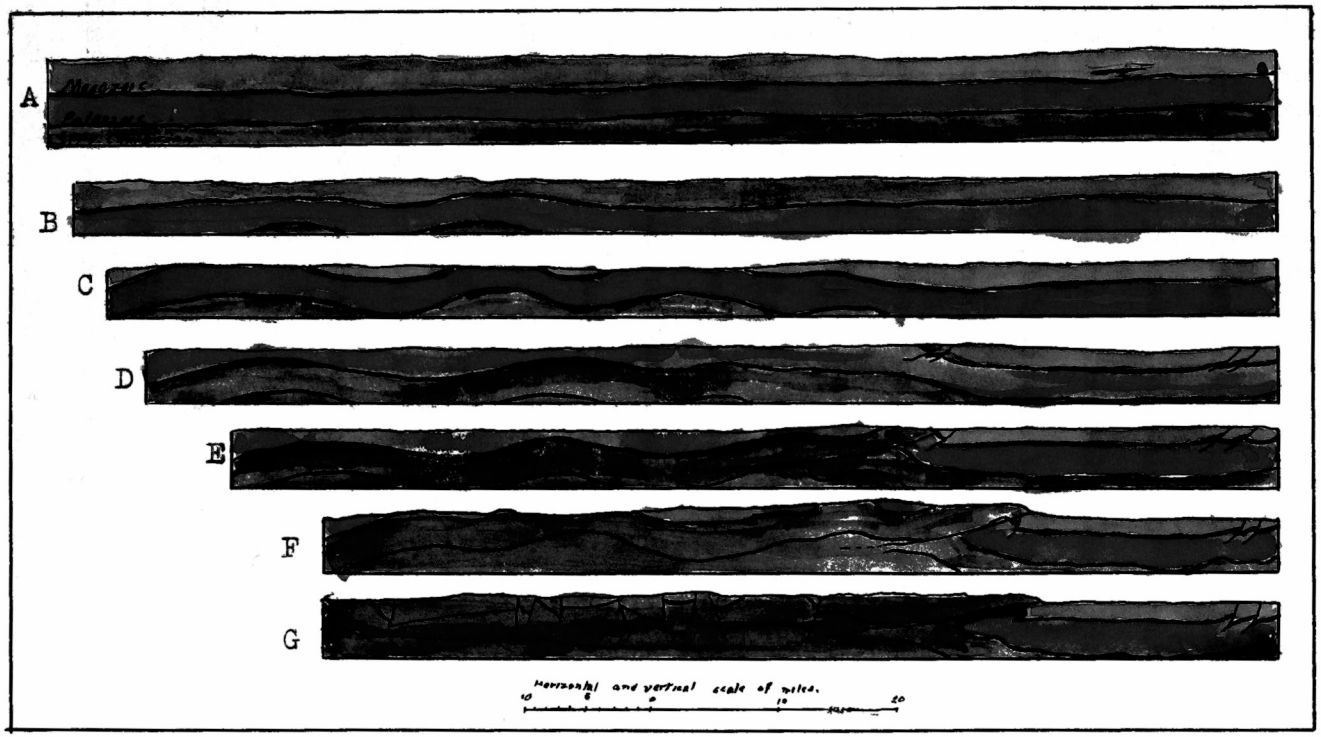
"4. During the early Tertiary there was a long period of crustal repose during which the upturned rocks were all more or less perfectly planed and the Blackfoot erosion cycle completed. The peneplain was most perfect on the soft Cretaceous rocks, but there was probably ' low hilly, post-mature relief on the Algonkian (Lewis Series) rocks.'

"5. In the mid-Tertiary the great Lewis overthrust took place, whereby the greatly eroded 'Algonkian' block of the Front Ranges and the equally broad mass of the Belton-MacDonald group were uplifted.

"6. Apart from local normal faulting, the subsequent history of the region has consisted in steady erosion, leading to a mature mountain topography."

The earliest strata consisted of pre-Cambrian, Paleozoic and Mesozoic rocks. In the vicinity of the 49th parallel the flat-lying beds were gently folded, first in the west and near the point of force. Gradually the folds steepened and thickened. Continued pressure folded the Mesozoic beds to the east. All the beds in the west were raised to a considerable height and the Mesozoic were probably much broken. Since that

1. Willis, B. Geol. Soc. Am. Vol. 13, 1902, pp. 341 - 349
2. Daly, R.A. Geol.Surv.Can. Mem. 38, p.607.



The progressive development of the Rocky Mountain structures at the 49th Parallel.

A. Conditions immediately preceding the Laramide revolution.
B. Structure at an early stage in the compression.
C. Uplift in the west and steepening of folds by continued compression.
D. Reverse faults develop in eastern, less competent strata.
E. Continued compression causes pronounced overthrusting and steepening of reverse faults
F. Extensive displacement on the Lewis Overthrust.
G. Generalized present structure; ill strates normal faulting caused by relaxation of compression. (After MacKenzie, Royal Soc. Canada, Proc. and Trans. 1922).

time they have been eroded. Continued pressures caused the less competent beds of the east to fault and thrusts developed, but resistance increased and the Lewis Overthrust took up the strain.

At the end of the period of compression the western areas were high but not greatly deformed being disposed in moderate folds. Following the relaxation of the pressure, a series of normal faults took place in the west, the deep Flathead valley being one result. There a lake formed and the Tertiary Kishenena beds were laid down.

In the North Kootenay Pass section the structure differs in the facts that Mesozoic rocks are found in the western division, that the central structural area is narrow and that reverse faults are very numerous in the east. The chief feature of the structural development was the appearance of soles from some of the reverse faults. Movement along these caused rotation on the reverse faults thus giving them the steep dip before mentioned. Normal faulting occurred in the west consequent to relaxation.

Structure in the C. P. R. Section[1]

The Rocky Mountains in the area crossed by the 51st parallel are divided by radical differences in structure into three distinct geological provinces.

Eastern Section

The eastern section has been broken by a number of nearly parallel longitudinal fractures into a series of oblong orographic blocks and these are titled and shoved over one another into the form of a westerly

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1. McConnell, R.G. Geol. Surv. Can. An. Rep. 1886.

dipping monocline. In the section examined by McConnell [1] were seven principal faults, besides some of minor importance, and six well-defined blocks, the latter resting on one another in regular succession from west to east. The thrust producing these crust movements and dislocations came from the west and must have been highly energetic in its action, as some of the breaks are of huge proportions and are accompanied by displacements of many thousands of feet. The faulted region is now about 25 miles wide and was probably 50 before faulting took place. Overturned folds are present but are small and of minor importance. The great earth rents seem to have been produced without much preliminary bending. The tilted blocks form a series of more or less parallel ridges running lengthwise with the chain, but the intervening depressions are true valleys of erosion and although their direction is determined by the course of the fault, are due to unequal hardness of the formations.

Thrust Faults

One of the largest and most important of the thrust faults occurs along the eastern base of the chain and brings the Cambrian over the Cretaceous of the foothills. This fault has a vertical displacement of more than 15,000 feet and an estimated horizontal displacement of the Cambrian beds of about seven miles in an easterly direction.

Central Section

The characteristic structural feature of the central mountain area in the C. P. R. section is open folding. In places great faults displace the strata.

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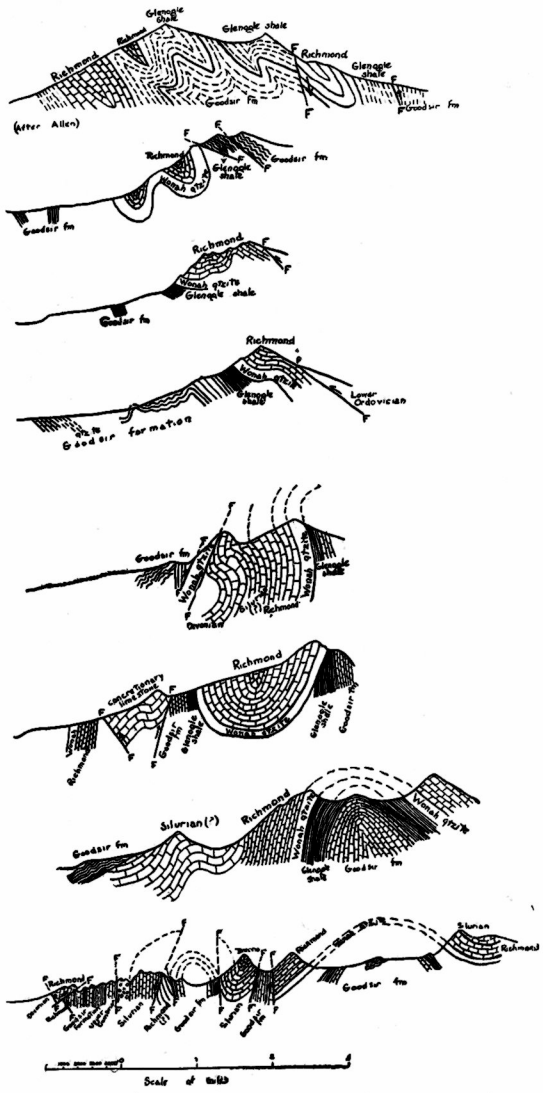
1. McConnell, R.G. Geol. Surv. Can. An. Rep. 1886, P. 310.

Structure sections across the Beaverfoot and Brisco ranges.
(After Shepard. Jounnal of Geology, Vol. 34, 1926).

Plate IX.


Richmond
Glenogle shale
Glenogle shale
Richmond
Glenogle shale
Goedair fm
Goedair fm
(after Allen)
Richmond
Glenogle shale
Goedair fm
Goedair fm
Richmond
Glenogle shale
Goedair fm
Richmond
Lower Ordovician
Goedair formation
Goedair fm
Richmond
Richmond
Silurian(?)
Richmond
Goedair fm
Goedair fm
Silurian
Richmond
Goedair fm
Scale of miles

" The formations of the Ottertail Van Horne, Bow and Castle Mountain ranges are flat-lying, gently undulating or dipping to the south-west." 1

Western Area

The western area of the Rocky Mountains has been intensely deformed. This is strikingly shown in the Beaverfoot and Brisco ranges where the folds are dominantly, although not entirely isoclinal.

" Intense folding occurs (in the Field map area) only in areas underlain by softer rocks, such as in the valley of the Ottertail and in that of the Beaverfoot and in the range of the same name. Anticlinal, synclinal, open, closed, symmetrical, and assymmetrical folds were noted. The latter as a rule are overturned towards the south-west." 2

" Faulting is also an important and prominent structural feature in the Field map area. The faults are normal in character, and in this respect the westward slope of the Rocky Mountain system in this latitude differs from the eastern slope, in which reversed and overthrust faults prevail.

" There are two principal systems of faults represented. The one which includes most of the large breaks has a northwest and south-east trend, which corresponds to the major axis of the mountain folds. The other system has a north and south trend and the faults are apparently younger than the others. There are numerous minor breaks and slips which are not of significant importance." 3

Summary of the Structure of the C.P.R. Section

The C.P.R. section of the Rocky Mountains is characterized in its eastern part by a series of great fractures and thrust faults, in the centre by broad, sweeping folds, and in the west by normal faulting, by folding and crumpling, accompanied by the development of cleavage planes, and a limited amount of metamorphism. Among its other more important

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1. Allan, J.A., Geol.Surv.Can., Sum. Rep. 1912, p.125
2. Allan, J.A., Geol.Surv.Can., Mem.55, p.199
3. Allan, J.A. idem p.202

features, may also be notes the absence of unconformities, the relatively smaller amounts of disturbance in the central part of the range than towards the edges, the want of similarity in the sequence of the formations east and west of the axis and the prevalence and great thickness of the sediments.

Area in the Yellowhead Pass

Little information is available in respect of the Rocky Mountain in the Yellowhead Pass section. It is probable that it is similar to that found in the Banff-Golden area. McEvoy[1] in his necessarily hasty examination of the area between Edmonton to Tete Jaune Cache gives no detailed description of structure. In places he noted overthrust faults and sharp folding. He seems to doubt the fact of an overthrust on the eastern front. He writes:[2]

> " On the Brazeau, the transition from the mountains to the level plains is abrupt. No folding or crushing is to be seen but a straight uplift without contortion of the beds and apparently without overthrust, for although the talus from the limestones hides the line of contact with the Cretaceous rocks of the level country beyond, these rocks are both found in place in the bed of the stream in positions which seem to preclude the possibility of a lateral movement of any extent."

This evidence does not seem enough to preclude the possibility of a feature of structure which is so prominent in the front ranges to the south of this area.

Dowling says of the structure here:[3]

> " The general structure of the Rocky Mountains from the International Boundry north to the Saskatchewan River is that of a series of westerly dipping fault blocks of similar strata resting against each other. A repetition of form and of strata, and a continuity in the

1. McEvoy, J.D. Geol.Surv.Can. An. Rep. Vol. XI. 1898. p.40 D.
2. idem
3. Dowling, D.B. Geol.Surv.Can. Sum.Rep. 1911 p.202

ranges, therefore, obtains, but in going northward, more diversity in the form of the blocks is noticeable. The uniform westerly dip and regular repetition of beds is to a great extent replaced by folding of the strata, while a greater variety in the outline of the ridges is apparent.

" The Roche Miette district forms a part of the outer ranges of the Rocky Mountains and is crossed in an east-west direction by the deeply eroded valley of the Athabasca River, into which drain several streams flowing between the tilted and folded blocks of strata that form the ranges.

" The drainage channels that are cut through the mount ins or foothills in many instances seem to owe their origin to breaks in the upthrusted blocks."

Peace River Area

In a hurried reconnaissance of the Peace River, McConnell[1] noted:

" The rocks exposed along the pass consist principally of greyish Paleozoic limestones striking in a north-west direction and dipping persistently to the south-west. Repetition of parts of the limestone series caused by overthrust faults, occur at several points.

" Immediately east of the main range, exposures of yellowish-weathering calcareous sandstone, probably of Cretaceous age, occur in the banks of the river. These are replaced going westward, by greyish limestones dipping steeply to the west. The junction between the limestone and the sandstone is concealed in the valley, but there is little doubt, from the relative position of the two formations, that the contact is a faulted one and that the Paleozoic limestone of the mountains here, as elsewhere along the eastern boundry of the range, are thrust up over the Mesozoic rocks of the foothills.

" The Peace River section through the Rocky Mountains, thus resembles the Bow River section through the same range, in the predominance of limestones and in the persistent westerly dips due to repetition of the beds by overthrust faulting, but differs from it in its absence of beds newer than the Triassic and in the gradually increasing age of the rocks from east to west."

1. McConnell, R.G. Geol.Surv. Can. An. Rep Vol.VII, 1894. p.32C.

Liard River

Quoting McConnell [1]

" The line of crumpling and upheaval to which this range is due die away at the Liard."

Approaching the mountains from the west the beds are horizontal but are soon thrown into almost vertical attitudes and have the appearance of a sharp anticlinal. Mesozoic strata are found on both sides of the range.

Structure of the Rocky Mountain Trench [2]

Schofield writes; [3]

" The Rocky Mountain Trench is the most remarkable structural feature of the Canadian Cordillera. It extends from the 49th parallel of latitude at least to the boundary between British Columbia and Yukon."

The Trench is the result of normal faulting which took place in the later stages of the mountain-building and of erosion.

" Thus the Rocky Mountain Trench may be divided into two portions, a northern one which includes the Peace River drainage, due to normal river erosion, and a southern portion which is due to faulting primarily." 4

Section of Trench at 49th Parallel

The Trench at the 49th parallel is the result of a normal fault of large throw on the east side and a small reverse fault on the western side. The block consists of a long, narrow mass, which has been tilted on a longitudinal axis which was nearer the western border of the block so that its inclination is to the east.

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1. McConnell, R.G. Geol.Surv.Can. An. Rep 1888-89 Part D p 46
2. Schofield, S.J. Royal Soc.Can., Proc.& Trans. 1920. Pt.IV. p.66
3. Idem p.113
4. Daly, R.A. Geol.Surv.Can. Mem.68, 1915.

Section at Bull River

The structure at Bull River is a continuation of that farther south at the boundary line.

Section at Canal Flats

The structure is a normal fault with the apparent downthrow on the western side bringing the Beltian-Kitchener formation into contact with the Mid-Cambrian Elko formation. The throw is purely a matter of conjecture and may be in the neighbourhood of 10,000 feet.

Section at Golden

Describing the structure of the Trench at Golden Daly says:[1]

" The master fault of the Trench is normal with downthrow on the north-east."

Section from Surprise Rapids to Lake Timbaskis

Faulting in the Trench has brought Paleozoic rocks on the east side to a level with Archean rocks on the west.

Section from Tete Jaune Cache to Big Bend of the Fraser

At Tete Jaune Cache, shearing and crushing of the rocks exposed in the floor of the Trench has occured. This breakage is considered to be related in age to similar shearing and faulting which have determined the Trench to the south. The Bow River Series borders on the north-east slope of the trough from Tete Jaune Cache to Goat River. Northward from this river the rocks on both sides are of similar age.

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1. Daly, R.A., Geol. Surv. Can. Mem.68, 1915. p.113.

Daly writes: [1]

> " Thus, for at least 250 miles of its length the Rocky Mountain Trench is located on a continuous zone of faulting which is characterized by very great upthrow on the west."

Other views of the structure of the Trench have been taken by, Shepherd in articles in the Journal of Geology 1922 and 1926. Space does not permit a detailed exposition of his theories. Quoting him in part: [2]

> " Structurally the Trench has hitherto been considered as a sort of graben or at least the product of normal faulting ..... "

> " The Rocky Mountain Trench does not appear to be the unit in development and structure that it has been thought to be. It appears instead to have been produced partly by normal erosion, partly along lines of structural weakness, and partly by the escarpment of a fault. Even is this last instance, the faulting is probably of the thrust rather than of the normal type." 3

Shepherd's second paper[4] discusses the geology of the Trench and the ranges east of it between the towns of Windermere and Golden. The structure is complex with much isoclinal folding and thrust faulting. A comparative study is afforded by cross-sections of the Beaverfoot-Brisco Ranges. A series of transverse faults have helped produce some intravalley ridges, but were not important in developing the Trench. A huge breccia, several hundred feet thick and miles in extent, is found at many places along a vertical bedding-plane fault which probably has several miles of displacement. Part of the Trench has a horst type of structure, rather than the graben type of structure.

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1. Daly, R.A. Geol.Surv.Can. Mem 68 1915, p.113
2. Shepherd, F.P. Jour. Geology, vol.30, 1922. p.131
3. Idem p.139
4. Idem vol.34, 1926 p.623

" That much of a tremendously long depression like the Rocky Mountain Trench should be located along a horst would seem remarkable, but in this connection it is interesting to note that in a reconnaissance of the Omineca-Findlay Rivers, 400 miles farther north along the same Trench, McConnell found the same general relations of older rock within the Trench and younger on each side. " 1

1. Shepherd, F. P. Jour. Geol. Vol. 34. 1926, p. 641.

CHAPTER V.

HISTORICAL GEOLOGY

The Rocky Mountain area has had a remarkable history. During the millions of years of Beltian, Paleozoic and Mesozoic history it was mainly an area of deposition. In a comparatively short period of time this sea bottom was elevated into a great mountain system. Revolutionary changes took place to occasion such a transition. These changes will be discussed in the pages following.

Depositional History.

The history of the Rocky Mountains is closely linked up with that of other parts of the Cordillera. That relationship has been discussed by Schofield[1] in a paper on the record of the Canadian Cordillera. In this paper he suggests, for the first time, the occurrence of a land mass, Cascadia, in an area now occupied by the waters of the Pacific Ocean. During Beltian times a narrow basin of sedimentation stretched northwestward through the eastern part of British Columbia to Yukon and Alaska. A Paleozoic and early Mesozoic basin of sedimentation extended from Cascadia eastward to the Canadian Shield. During the Jurassic revolution the Selkirk Mountains appeared and in Cretaceous times a basin of sedimentation lay to the east of the Jurasside Selkirks.

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1. Schofield, S.J. Royal Soc.Can. Proc. & Trans. 19[illegible] Pt.IV. p.79

Beltian Depositional History

"During Beltian times a narrow basin of sedimentation stretched northwestward through the eastern part of British Columbia" 1.

This included all the area now occupied by the Canadian Rockies.

"That a land mass was not far distant to the west is indicated by conglomerates in the western range of the mountains near Bull River. No conglomerates are found at the vicinity of the 49th parallel, but in the neighbourhood of Field, Walcott and Allan describe minor thicknesses of fine conglomerates or coarse sandstones. Daly states that limestones of Beltian age become relatively more abundant to the east." 2.

Thus the Beltian was a time of practically continuous sedimentation. This sedimentation is generally regarded as having taken place in shallow waters as is evidenced by the prevalence of ripple marks, mud cracks, and casts of salt crystals in the rocks.

"Divers opinions are held as to the origin of the Belt Series by those who have worked in them. The Kintla, Grinnell and probably the Appekunny are certainly of continental origin as shown by their unmistakable characteristics. The dolomites are stated by Daly to be the chemical precipitates in marine basins while Walcott suggests that they are of epicontinental origin and precipitated in fresh water through the agency of algae. Whatever its origin this pre-Cambrian series forms a unit, though opinions differ as to how distinct it is from the succeeding Paleozoic series." 3.

Paleozoic Deposition

MacKenzie[4] has thus summarized opinions in respect to the contact of Beltian and Paleozoic rocks :

"Walcott considered them to be separated by a lengthy period of uplift and erosion, while Daly states the view that these two series form a simple Paleozoic-Beltian geosynclinal prism, which is only locally interrupted by unconformities. Evidence that there was as interval of erosion is given by Schofield. At Elko he found the lowest Middle Cambrian, Burton formation,

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1. Schofield, S.J. Royal Soc.Can. Proc. & Trans.1923 Pt.IV. p.92.
2. Schofield, S.J. Idem p.93.
3. MacKenzie, J.D. Royal Soc.Can. Proc. & Trans.1922 Pt.IV. p.99.
4. MacKenzie, J.D. Royal Soc.Can. Proc. & Trans. p.99.

lying without angular discordance on rocks which he assigns to the pre-Cambrian. Further evidence of a break in sedimentation is given by Adams and Dick, and Rose also recognizes a disconformity at the base of the Paleozoic. In the summer of 1921, Schofield discovered a conglomerate at the base of the Cambrian containing Olenellus and resting on Beltian rocks."

Though sedimentation may have been interrupted at the end of the Beltian, the break was followed by a long period of desposition. In respect of this point Schofield[1] says:

"In this basin (of which the Rocky Mountain area was a part) sedimentation was almost continuous throughout the Paleozoic and early Mesozoic periods. Local disconformities are present throughout the basin, but in general it may be said that no land mass sufficiently high to furnish any great amount of sediments rose above this continental sea. No folding or orogenic movements interrupted the process of sedimentation in the basin as no structural unconformity has been recorded from the sediments which collected in this Paleozoic and early Mesozoic geosyncline."

The sedimentation was marine resulting in the accumulation of immense thicknesses of fossiliferous limestones, shales and sandstones. In the area about the Crowsnest Pass and southward, rocks representative of the time from lower Pennsylvanian to the lower Jurassic are absent.

"It is supposed that from the beginning of the Permian to lower Jurassic this region was land-, a terrane of low relief, mainly of limestones but with some sandstones - undergoing subaerial weathering with probably but little loss of the products of rock disintregration".[2]

North of the Crowsnest area, however, sedimentation went on until the latter part of the Paleozoic when according to MacKenzie[3]

"Near the close of the Paleozoic era the Rocky Mountain synclinal was broadly uplifted without appreciable deformation."

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1. Schofield, S.J. Royal Soc.Can. Proc.& Trans. p. 94.
2. MacKenzie, J.D. Royal Soc.Can Proc.& Trans. p.100.
3. MacKenzie, J.D. Idem

Mesozoic Deposition

It is probable that a general sinking took place in the Rockies in the early part of the Mesozoic. Triassic formations

"May extend throughout the length of the Rocky Mountains".[1]

Jurassic sediments are widespread. An interpretation of the history of the Jurassic period in the southern part of the Rockies is given by MacKenzie[2] thus :

> "From the varying thickness and uniform character of the sediments formed in the Fernie it is apparent that great volumes of fine mud were delivered to this sea by rivers flowing from low land to the west, and there may have been several large estuaries along the western edge of the marine basin at that time - A thin bed of a greenish rock which McLearn has termed tuff occurs in the Fernie district. If its designation as tuff be correct, it marks the first evidence of igneous action in the Rocky Mountain area since the pre-Cambrian Purcell lavas."

Despite the seeming gradation of the Fernie formation into the Kootenay, these formations are considered to have been separated by a considerable time interval.[3] During this time the marine waters must have gradually withdrawn and widespread fresh water basins succeeded them. In these shallow lakes the Kootenay measures were laid down.

> "The western exposure of Kootenay strata are notably coarser than those occurring farther east - The rejuvenated streams (from a western land mass) spread over the newly exposed soft lake sediments, and removed a portion of them, covering the remainder with a veneer of cherty and quartzitic pebbles - The gravel was spread evenly over an enormous extent of territory and is now found overlying the Kootenay formation throughout the southern Rocky Mountains." 4

A quotation from Young has already been given under the general description of the rocks of that period and need not be repeated here.

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1. Young,	J.A.	Geol. & Econ. Min. of Can.	p.154
2. MacKenzie	J.D.	Royal Soc. Can. Proc. & Trans.	p.100
3. Young	J.A.	Geol. & Econ. Min. of Can.	p.155
4. MacKenzie	J.D.	Royal Soc. Can. Proc. & Trans.	p.102

In this, like MacKenzie, he points out that orogenic movements, in late Jurassic time in an area west of the present Rocky Mountains, gave rise to the conglomerates of the Cretaceous and was the reason for the increasing thickness of Cretaceous sediments in a westward direction.

The whole depositional history of the Rocky Mountains may well be summarized in the words that Daly[1] uses of the history of the area at the 49th parallel:

> " It would be probable that during the Mesozoic, this part of the Cordillera was never far above sea level. From the earliest pre-Cambrian in the Rocky Mountains to the Upper Cretaceous or early Tertiary, a stretch of time representing most of the recorded geologic history of the globe, there is no evidence in this region for more than relatively slight uplifts and depressions with no more deformation than that consequent of differential subsidence."

Structural History.

Some comment on the history of the structural development of the Rocky Mountains had already been made under the discussion of structure and hence that history need be dealt with in a broad way.

Shortly after the close of the Cretaceous the great Rocky Mountains were built. The erection of this mountain system occupied a period of very short duration in comparison to the time required for the accumulation of the materials out of which they are built. The period of their rise is stated by Schofield[2] to be :

" Post-Upper Cretaceous and pre-Upper Eocene."

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1. Daly, R.A. Geol. Surv. of Can. em.30 1912 p.607
2. Schofield S.J. Royal Soc. of Can. 1923 . Proc. & Trans. Pt.IV. p101.

The orogenic history of the Rocky Mountains as stated by MacKenzie [1] and others in brief is that compression from the west first gently folded the western area of the system. Further pressure folded it more, but, by thickening the folds caused them to become stronger, with the result that the pressure was taken up in the eastern ranges by thrust faulting on a large scale. Continual pressure caused the great Lewis Overthrust along with a revolution of the imbricate fault blocks giving them steeper dips. Following compression came relaxation with normal faulting.

Somewhat divergent views are held by other workers. Willis suggested the more complicated history already mentioned.

Dowling [2] has also proposed a different view of the orogenic history of the Rocky Mountains from the commonly accepted view. His interpretation will be briefly summarized. The sinking of the Rocky Mountain geosynclinal would have the tendency to cause tension at its western margin. A final result would be normal faulting. With the break and consequent relaxation of tension, an upwarping of the fault scarp would occur and great displacement would be the result. The present division of the system into a western area of older rocks and an eastern area of younger formations indicates a great normal fault at the edge of the Cretaceous basin. A fault is now known which once had a displacement of 30,000 feet. Thus at the beginning of Cretaceous times a long block appeared in the western area of the Rockies. This block is now present and extends from Fernie northward. It is widest at Castle Mountain and is known at Jasper Pass where Mt. Robson has been carved from it. The western Rocky Mountains

1. MacKenzie, J.D. Royal Soc. of Can. Proc. & Trans. 1922 Pt. IV.
2. Dowling, D.B. Royal Soc. of Can. Proc. & Trans. 1922 Pt. IV. p.175.

are formed from this block and have taken their present form subsequent intense sculpturing and a gentle folding caused by compression in the late Eocene. Accompanying this Eocene folding came the intrusion of the Ice River complex.

A period of tension at the end of the Eocene is not evident and the drainage of the western mountains has an age earlier than that time. In the late Eocene occurred the elevation of the plains and the formation of a great anticlinorium in the western part of the Rocky system. Fault blocks dipping west were further inclined and, being hinged near the Rocky Mountain Trench, have caused its present graben structure.

The age of the major normal fault which divides the Rocky Mountains in age and materials is to be judged especially from the coarse sediments of the Kootenay and the Elk conglomerates. These conglomerates dwindle in thickness eastward. The age of the faulting can then be set as

> " The beginning of the Cretaceous with probably a major period of movement at the close of the Kootenay period." 1

Eastern Division

Deposition continued in the Eastern Division of the Rockies during all of Cretaceous time under varying conditions.

The folding and faulting of the mountains occurred in the late Eocene.

History of Drainage [2]

It is probable that prior to, or in early Cretaceous times orogenic movements took place in an area somewhat west of the Rocky Mountain Trench. The highland thus formed were peneplained before the end of the period.

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1. Dowling, D.B. Royal Soc. of Can. Proc. & Trans.1922. p.181
2. Schofield, S.J. Royal Soc. of Can. Proc. & Trans.1920.Pt.IV. p.90-97.

Rivers flowing eastward through them eroded headward to the interior basin to their west. Included in these rivers were probably the ancestral rivers of the present Liard, Peace and the rivers now flowing eastward through the Yellowhead, Kicking Horse and Crowsnest Passes. The ancestors of the Kootenay and Columbia were also present in Cretaceous times.

With the uplift of the Rockies in the Eocene many of the streams continued to flow eastward and to cut their valleys across the rising mountains. Such rivers were those in the valleys of the present Peace, Athabasca, Bow, and Crowsnest Rivers. Some of the streams were unable to maintain their course eastward and became tributaries to the larger rivers. Such streams, separated by divides, occupied portions of the depression which later became the Rocky Mountain Trench.

Normal faulting in the Eocene changed the drainage courses considerably. Faulting in the Trench does not extend north of the Big Bend of the Fraser and hence the Liard and the Peace continued their courses undisturbed, but the rivers which crossed the faulted area had their drainage diverted into the Trench. Its rivers then flowed southward. The normal faulting also caused a divide to appear in the former through valleys of the Rocky Mountains with the result that short streams now flowed westward into the Trench. Gradually these streams pushed their watersheds eastward. Thus were formed such rivers as the Kicking Horse and the Elk. By continual pushing of the headwaters eastward, they were enabled to form the western portions of the numerous passes through the mountains.

Glacial History.

The glacial history of the Rocky Mountains is not yet fully worked out. Dawson [1] has stated that there were at least two glacial periods. Speaking of the Purcell range, Schofield [2] says :

> "The records of the first Glacial period, if ever present in the Purcell range, have been removed during the erosion periods which followed this advance of the ice.....
> The climate after the first retreat of the ice, as indicated by the plant fossils found in the St.Mary silts, was, according to Mr.Arthur Hollick, milder than that of middle United States. This period of comparative warmth was followed by another refrigeration of the whole Cordillera."

Movement of the ice in the Rocky Mountains was in the main southward and continued only a short distance east of the foothills. A considerable modification of topography was effected in the formation of U-shaped valleys, lakes, lateral and terminal morraines. Glacial action still continues in the higher altitudes though present glaciers are in retreat.

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1. Dawson, G.M. Royal Soc. of Can. Proc. & Trans. 1891, Vol8. Pt. IV. pp.3 - 74.
2. Schofield,S.J. Geol.Surv. Can., Mem. 76, 1915, p. 103.

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