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CANADA

DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH

BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

MEMOIR 247

# PHYSIOGRAPHY OF THE CANADIAN CORDILLERA, WITH SPECIAL REFERENCE TO THE AREA NORTH OF THE FIFTY-FIFTH PARALLEL

BY

H. S. Bostock

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
1948

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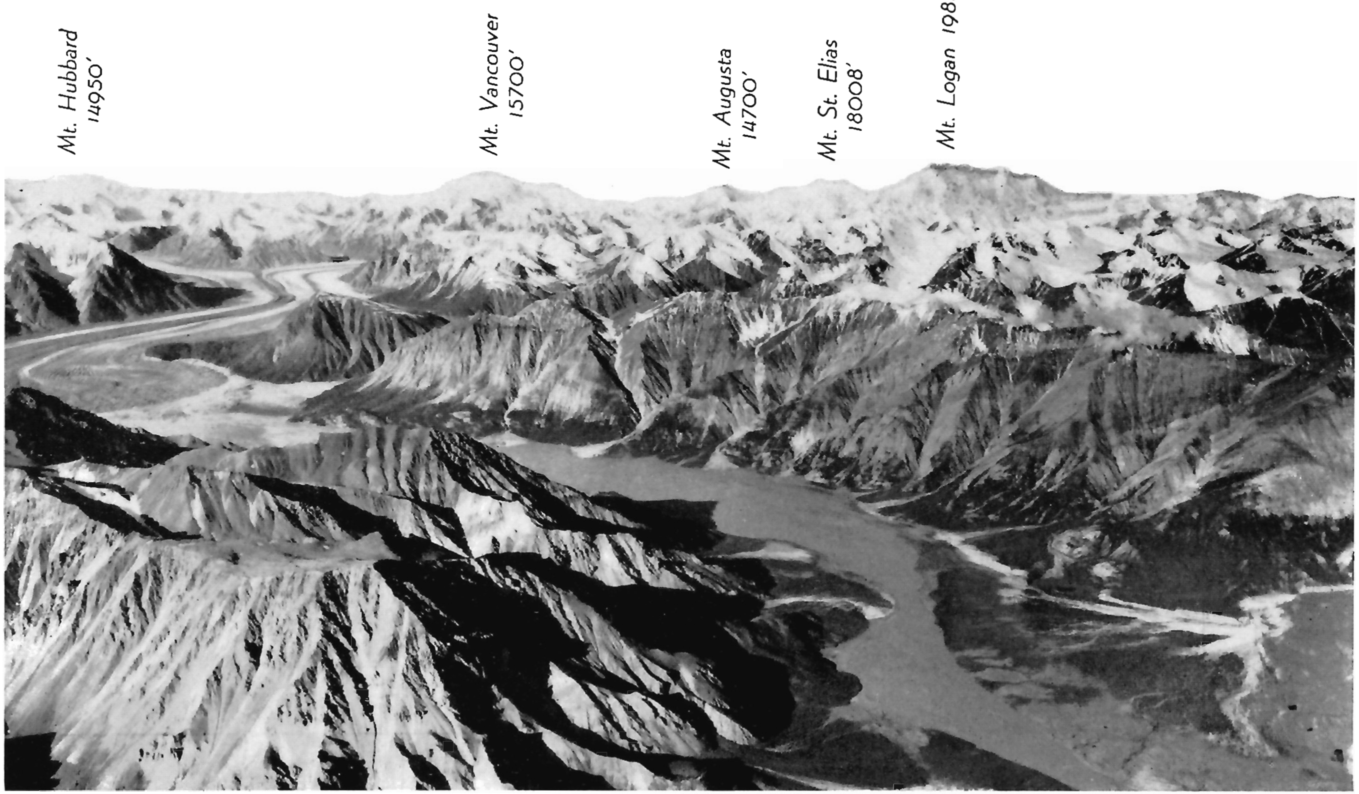


St. Elias Mountains: view from an elevation of 12,300 feet looking southwest up Slims River and Kaskawulsh Glacier into St. Elias Mountains. The great block of Mount Logan, on right skyline, is about 70 miles distant. Photo by Royal Canadian Air Force; negative T6-118L.

[1] All pictures, unless otherwise stated, were taken from an elevation of 20,000 feet.

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## PREFACE

Until recent years little information has been available on the physiographic features of the Canadian Cordilleran region north of the fifty-fifth parallel. Farther south, in the more settled and closely mapped parts of British Columbia, particularly in the vicinity of the International Boundary, physiographic subdivisions are well recognized, and their relations to geological formations and to dominant structural trends have received much specific as well as incidental attention in numerous published reports and maps. Elsewhere in the province, however, and in the adjoining Yukon, information has been confined mainly to local and relatively accessible areas, particularly about mining centres of some consequence, and to widely separated routes covered by exploratory surveys. The onset of the recent war and consequent imperative attention to the various strategic factors involving this Cordilleran chain led to widespread trimetrogon air photography in the northern part of the region by the United States Army Air Force and the Royal Canadian Air Force, which has made possible physiographic interpolations over vast areas hitherto unmapped.

The present report is based in part on the author's acquaintance with many parts of the Canadian Cordillera and, in greater part, on careful study of many thousands of air photographs. Its chief purposes are to bring general order and continuity to the physiography of the entire Cordilleran region in Canada; to establish a broad terminology throughout on which subsequent more detailed studies may be based; and to acquaint the interested public with the characteristic topographic features of this great mountainous region. The report itself carries many photographs of the more isolated parts, which will serve to supplement the written account, and the accompanying map will, it is hoped, be a useful source of reference to the main physiographic subdivisions and their nomenclature. The Geographic Board of Canada and its British Columbia representative have afforded valuable co-operation in the selection of the geographic names adopted.

GEORGE HANSON,
*Chief Geologist, Geological Survey*

OTTAWA, June 30, 1947

# Physiography of the Canadian Cordillera, With Special Reference to the Area North of the Fifty-Fifth Parallel

## INTRODUCTION

This report names, outlines, and describes the larger physiographic units of the Canadian Cordillera north of the fifty-fifth parallel. South of this parallel the main features are comparatively well known and delineated, and their names have become generally established. They are described here only so far as is necessary to indicate their relationships and continuity with those to the north, which have as yet received comparatively little attention. Except for an area north of the sixty-fourth parallel and southwest of a line from Bonnet Plume Lake to where Old Crow River crosses the 141st Meridian, western Canada north of the fifty-fifth parallel was covered from 1941 to 1944 by flights of trimetrogon air photographs, first by the United States Army Air Force and later by the Royal Canadian Air Force. These photographs embrace many large areas of which no map had formerly been made, and no account written. At intervals during the past 3 years an attempt has been made by the writer to use these photographs, readily available in the National Air Photograph Library of the Bureau of Geology and Topography, to study the main physiographic features of the Cordilleran region north of the fifty-fifth parallel and to delineate their boundaries. Though in the time available it has been possible to examine only about one-quarter of the 100,000 air photographs available for study, all parts of the region covered by these photographs have been viewed from one direction or another.

The new information gathered has shown that the general physiographic outlines indicated by earlier explorations are broadly correct, but has made subdivision and delineation possible to a much greater degree than formerly. It has been found that the earlier systems of nomenclature require revision, and that many new names are necessary for features hitherto little known or seldom mentioned. In some instances the boundaries of areas covered by established names are vaguely defined, or different names may apply to the same areas on different maps. The whereabouts and limits of features known by such widely accepted names as Stikine, Omineca, Mackenzie, and Ogilvie Mountains are, for example, only vaguely and conflictingly shown. For these reasons it was apparent, at an early stage in this work, that it was impossible to describe even the main features without constructing a more complete scheme of nomenclature than had heretofore been employed.

The scheme and nomenclature adopted here retain the names and limits of relief features shown on existing maps so far as they apply or can be applied to the existing facts. Final conclusions on many points were reached through the kind co-operation of the Geographic Board of Canada, for whose assistance, and in particular that of the chairman, Mr. F. H. Peters, and the British Columbia representative, Mr. W. G. H. Firth, the writer wishes to express his grateful appreciation.

For a study of this kind, photographs alone are insufficient; maps and written accounts are very necessary. Unfortunately, as much of the area dealt with is relatively unexplored, few maps, on any scale, except within certain specific areas, have been published. For the present report, a base map on a scale of 1 inch to 8 miles was compiled from available information by the Hydrographic and Engineering Surveys Branch of the Department of Mines and Resources, but in many parts main features of relief and drainage had to be revised or plotted by the writer for the first time from the air photographs before the physiographic features could be properly delineated. Much of the region had never been mapped, nor referred to in any reports, and the geology could be only surmised from a few widely spaced explorations.

The parts of this report dealing with areas north of 55 degrees have been compiled mainly from the air photographs, publications having been used as accessory information to check and amplify the data drawn from the pictures. South of 55 degrees fewer air photographs have been studied, and publications, including topographical maps of the Dominion and Provincial Governments, have been the chief source of information. Throughout the report reference has been given to all publications made use of, except maps.

Almost all the air photographs were taken from an elevation of about 20,000 feet above sea-level. Being trimetrogon photographs, they show a complete traverse from the horizon on one side of the aeroplane to that on the other side, by means of the overlapping of three pictures taken simultaneously in a line across the direction of flight. The central photograph is directly below the aeroplane, and, provided the machine is flying in a horizontal plane, is essentially a "vertical" photograph, with the two side views overlapping "obliques" that reach to the horizon on each side. Successive exposures are usually synchronized with the speed of the aeroplane to give approximately two-thirds overlap. The scale in the centres of the vertical pictures is approximately 1½ inches to a mile. As much of the photography, particularly by the United States Army Air Force, was carried on under pressure of time, light conditions were poor on many flights. Many of the pictures, too, in northern Yukon show the ground covered with snow, making recognition of features difficult. A pair of clear adjacent side pictures examined under a stereoscope give a splendid broad view, but the detail sometimes desirable may not be obtained, due to the small scale of the photographs. The prominence and clearness of the features vary with the intensity and direction of the light at the time, as well as with the snow condition. A lake several miles long in flat country, conspicuous in the far distance in one flight, may be almost invisible in the pictures of a much closer flight taken in a different light. Some features of geological structures show up well in parts of the mountains and in areas of little overburden, but one flight may suggest a different form of structure from another, depending on light conditions and the angle of view. Recognition of key features is, consequently, often difficult. The geology is important in classifying many physiographic forms, but for some vital areas it was found impossible to obtain more than a hint of it from the air photographs. The side pictures give very good impressions of the territory seen, but features of considerable relief close to the line of flight may not appear impressive, whereas less significant ones 8 to 12 miles away stand out well.

## SYSTEM OF SUBDIVISIONS AND NOMENCLATURE

Several descriptive accounts of the Canadian Cordillera have appeared in the past.[1-6] The last of these, published in 1918 by the Geographic Board of Canada, gives a plan of nomenclature for the mountains of western Canada. The term "Cordillera", as applied to the whole of the mountainous area of western Canada, was adhered to from former writers. The scheme divided the Cordillera into three belts: an Eastern Belt, a Central Belt, and a Western Belt. Each belt was subdivided into mountain systems and these, in turn, into mountains and plateaux. These were further subdivided into ranges, groups, hills, and plateaux, and so on down to the individual mountains, hills, peaks, and plateaux. The term "group", applied to a range of mountains or cluster of peaks, has never been widely accepted and is not commonly understood. It will be noted, however, that the term "plateau" was used for features ranging in scope from those of regional extent to others of limited, local significance. In the south, where the Cordillera were best known, the scheme was fitted to the facts and has been generally accepted except, perhaps, in the application of the terms "belt" and "system"; but in the central and northern Cordillera, where little was then known of even the major features and their boundaries, the scheme required revision and adjustment in order to provide a consistent pattern for the entire region.

In the scheme presented in this report, the term "system" replaces "belt" as used by R. A. Daly[7] in southern British Columbia, and the term "area" is used in somewhat the same sense as "system" in the Geographic Board scheme. Otherwise, however, the names and terms used are mainly those of the Geographic Board or those hitherto in general acceptance, except where information resulting from the present study has required a new name or some modification to the limits of an area previously named.

## THE CANADIAN CORDILLERA

The Canadian Cordillera forms a part of the great systems of mountains that border the Pacific in North and South America. Within Canada it occupies a large, northwesterly trending area varying from 350 to 400 miles in width and more than 1,650 miles long. It lies between the Interior Plains on the east and the Pacific Ocean and Alaskan boundary on the west, where for more than two-thirds of its length it follows the 141st Meridian in the north and the coastal summits of the St. Elias and Coast Mountains farther south. Its southern limit in Canada is the International Boundary with the United States along the Forty-ninth Parallel and Georgia and Juan de Fuca Straits. Its northern boundary is the Arctic Ocean.

The Canadian Cordillera forms the watershed between the Pacific Ocean on the west, the Arctic Ocean on the northeast, and the Gulf of Mexico on the southeast. As a whole, it is also an area of precipitation, which robs the moist westerly winds of water and leaves the western side of the Interior Plains relatively arid.

The general form of the Canadian Cordillera resembles that of a great wall rimmed by mountain battlements on each side, with an elevated platform

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[1] Selwyn, A. R. C., and Dawson, G. M.: Descriptive Sketch of the Physical Geography and Geology of the Dominion of Canada; Geol. Surv., Canada, 1884.

[2] Dawson, G. M.: The Physical Geography and Geology of Canada; The Handbook of Canada issued by the Publication Committee of the Local Executive of the British Association, Toronto, 1897.

[3] Daly, R. A.: North American Cordillera, Forty-Ninth Parallel; Geol. Surv., Canada, Mem. 38, pp. 17-42 (1912).

[4] Dowling, D. B.: An Outline of the Physical Geography of Canada; Appendix to the 13th Ann. Rept. of the Geographic Board of Canada, 1914.

[5] Brooks, A. H.: U.S. Geol. Surv., Prof. Paper 45, p. 28 (1907).

[6] Geographic Board of Canada: Nomenclature of the Mountains of Western Canada (1918).

[7] Daly, R. A.: Op. cit.

between. The Eastern system forms the battlements on the northeast, and the Western system those on the southwest. Between these the plateaux[1] and mountains of the Interior system make up the elevated platform.

The three systems are broadly different in their geological structure, as well as topographical character. The Eastern system is formed almost entirely of sedimentary strata; the Interior system comprises a mixture of volcanic, sedimentary, and metamorphic rocks, invaded by numerous intrusive bodies; and the Western system, though exhibiting a broad similarity to that of the interior areas, is dominated by great bodies of intrusive rocks lying mainly along its eastern flank. Differences in geology allied with different histories of uplift and subsidence, only vaguely discerned at present, have developed distinct topographies in the three systems.

## EASTERN SYSTEM

The Eastern system is made up of three parts, namely, the Rocky Mountain, Mackenzie Mountain, and Arctic Mountain areas. In the south, the Rocky Mountain area extends to Liard River where it is followed north by the Mackenzie Mountain area. The latter curves in a great arc from Liard River to the west side of Peel River near the sixty-sixth parallel where it, in turn, is succeeded by the Arctic Mountain area, the latter extending north and then west to the 141st Meridian.

In the south, the east boundary of the Eastern system coincides with the border between the Rocky Mountain Foothills and the Interior Plains, and is determinable within reasonable limits. Farther north it follows approximately along Liard River to South Nahanni River where Liard River flows eastward into the Interior Plains. From here to near the mouth of North Nahanni River it is well marked by the east front of the Mackenzie Mountain area, which rises abruptly from the plains. Near the mouth of North Nahanni River it crosses Mackenzie River. From this point it sweeps in a broad arc northward and westward to near Fort Good Hope where it again crosses the Mackenzie. Between the two crossings the border is along the east side of the ridges, hills, and mountains that rise west and southwest of the Interior Plains. As these have not yet been mapped topographically or geologically, and from the photographs seem to rise *en échelon* and are widely separated in places, the position of the border is not yet clearly definable, but appears to parallel Mackenzie River at a distance of 15 to 30 miles.

From where it crosses Mackenzie River south of Fort Good Hope the boundary between the Eastern system and the Interior Plains is drawn westward to Peel Plateau, a distance of some 40 miles. For this distance it traverses country in which no topographical feature marks its presence, and the surface of the Interior Plains merges with that of the adjacent unit of the Eastern system, Mackenzie Plain, a long, valley area that projects southward to the west of the most eastern mountain ranges. From where it meets Peel Plateau the border follows the edge of this upland area northwestward and then northward along the west side of Mackenzie River Delta to the Arctic Ocean or Beaufort Sea.

The western boundary of the Eastern system is well marked in the south by the Rocky Mountain Trench. North of Liard River this boundary is much more difficult to define, through dearth of information and lack of any such distinct topographic feature. It is believed that it should separate the mountains

[1] "Plains" and "plateaux" in this report denote areas that exhibit relatively even surfaces, or remnants of such surfaces, whether their structure be horizontal or complex. The degree of relief distinguishes between them, and, as a generalization for the region dealt with, the relief of plains is measured in hundreds of feet and that of plateaux in thousands of feet.

formed wholly of sedimentary rocks from those containing metamorphic and intrusive rocks, as the former exhibit a considerably more youthful stage of erosion than the latter. This distinction is apparent in British Columbia, and also appears to be applicable in the north. Keele[1] stated that the line is 40 miles east of the watershed at the head of Keele River. He points out that the mountains to the west bear evidence of long continued differential erosion, whereas to the east they have a more youthful appearance. Accordingly, the boundary is drawn on the east side of the intrusions of Hyland Plateau and thence through Keele's line to Bonnet Plume River northeast of all intrusions reported to the present, except for some diabase dykes. Northward it is continued along the west side of Richardson Mountains to where it meets the Arctic Plateau. From there it bends westward and follows a poorly defined course first between Arctic Plateau and Porcupine Plain and, farther west, between the southern border of British Mountains and the plateau to the south. The presence of intrusions in British Mountains at the 141st Meridian and of a single small one in Richardson Mountains, must, in this instance, as in the case of the Ice River intrusions near Field, British Columbia, be regarded as an exception for the Eastern system. On the other hand, it may prove better, with the accumulation of more exact information, to carry the west boundary of the Eastern system north to the Arctic Ocean from Richardson Mountains, and to include British Mountains and most of Arctic Plateau in the Interior system, or to place it with Brooks Range of Alaska in a separate Northern system with characteristics of its own.

The west boundary of the Eastern system as outlined above cuts off the southwest part of the great area of mountains formerly regarded as the Mackenzie Mountains, and places it in the Selwyn Mountains of the Interior system with the other mountains with which it corresponds more closely in physiography and geology; it also separates Ogilvie Mountains from Mackenzie Mountains, with which they were formerly grouped.

## Rocky Mountain Area

The Rocky Mountain area includes the Rocky Mountain Foothills, Rocky Mountains, and Rocky Mountain Trench. It stretches as a belt 60 to 100 miles wide, 900 miles from the Forty-ninth Parallel northwestward to Liard Plateau and Plain. All three divisions are approximately parallel and equal in length.

### ROCKY MOUNTAIN FOOTHILLS

Rocky Mountain Foothills, or the Foothills as they are commonly called, are 15 to 40 miles wide east to west and separate the mountains from the Interior Plains. Although mainly composed of rounded hills, they contain within their area outlying mountain ridges nearly as high and rough as those of the main mountain area to the west.

In their southern part, and as far north as Sikanni Chief River, the eastern front of the Foothills is well marked and coincides with the first zone of faulting and folding west of the rocks of the Interior Plains. The Foothills are entirely of sedimentary origin. They include Palæozoic and Tertiary formations in many parts and some rocks of Precambrian age in the south, but the great bulk of them is composed of Mesozoic strata. These rocks are typically folded and faulted in narrow parallel belts. In the south the constituent formations are largely soft Cretaceous or early Tertiary beds whose lack of resistance to erosion

[1] Keele, J.: "A Reconnaissance across the Mackenzie Mountains on Pelly, Ross, and Gravel Rivers, Yukon and Northwest Territories"; Geol. Surv., Canada, Pub. No. 1097, pp. 17-18 (1910).

gives the rounded profiles generally characteristic of the Foothills. In places, however, structures bring up hard Triassic and Palæozoic beds, and these form mountainous ridges within the Foothills. North of Peace River hard lower Mesozoic beds are exposed to a greater extent than to the south, and give the Foothills, particularly on the west side, a mountainous character. Near Sikanni Chief River the first belt of close folding disappears and with it the front ridge of hills, so that the width of closely folded strata is narrowed from there northward, the place of the front ridge being taken by high plateaux and mesas of more gently dipping Cretaceous sediments.[1], [2]

### ROCKY MOUNTAINS

The Rocky Mountains stand between the Foothills and Rocky Mountain Trench, which marks their west boundary. They form a remarkably continuous wall of mountains traversed by only one stream, Peace River. On the east their boundary with the Foothills is well defined, as it follows the first chain of ranges of upfaulted, massive, Palæozoic limestone and quartzite, whose resistance to erosion has given the mountains their particularly rocky and rugged character. For the greater part, the mountains consist of ridges with a northwesterly alinement nearly parallel with that of the entire Rocky Mountain area. Their thick, competent strata have broken and warped to form larger units than those comprised of Foothills strata. The ridges are separated by deep valleys cut along zones weakened by folds to erosion, fractures, and the presence of relatively soft strata. They are mainly formed of Palæozoic sediments, but include some of Late Precambrian age.

The Rocky Mountains are approximately 50 miles wide from the Forty-ninth Parallel northward to Yellowhead Pass. Beyond this, they gradually narrow until they reach a minimum width of less than 25 miles at Peace River. Still farther north their west boundary continues northwesterly along the trench, but their east boundary swings to nearly north and, in consequence, they broaden in this direction to reach their greatest width of more than 85 miles.

The Rocky Mountains form the continental divide from the Forty-ninth Parallel to about 150 miles north of Yellowhead Pass. Farther north the divide lies west of the Rockies, which are drained on that side by tributaries of Peace and Liard Rivers.

South of Peace River, the Rocky Mountains are divisible into three parts. In the southern and central parts they are rugged, and the greater peaks, many more than 10,000 feet high, including Mount Robson (12,972 feet), the highest known peak of the Eastern system, form the continental divide. In the northern part, south of Peace River, the mountains narrow, their elevations decrease, no really great peaks are present, and they are characteristically less rugged.

North of Peace River, where the Rocky Mountains are least known, they comprise a border zone (Plate II) surrounding a central area. The central area, 130 miles long and 30 miles wide, extends from about 20 miles southwest of Redfern Lake to 15 miles south of Muncho Lake, and is high and very rugged (Plate III). It contains many peaks with elevations of more than 9,000 feet, according to present information, and is crowned by Churchill Peak, 10,500 feet high. Within it are many ice-fields and alpine glaciers, none more than a few miles in extent, the largest observed being those east of Quentin, Haworth, and Chesterfield Lakes. This central area is largely composed of great thicknesses of massive strata, probably limestone, and the big peaks resemble those of the

[1] Williams, M. Y.: Geological Investigations along the Alaska Highway from Fort Nelson, British Columbia, to Watson Lake, Yukon; Geol. Surv., Canada, Paper 44-28 (1944).

[2] Hage, C. O.: Geology Adjacent to the Alaska Highway between Fort St. John and Fort Nelson, British Columbia; Geol. Surv., Canada, Paper 44-30 (1944).

PLATE II

Rocky Mountains: view northeast from within the northern Rocky Mountains near the head of Muskwa River, showing a general absence of glacial features. Photo by United States Army Air Force; negative 32.1-L135 2-2010.

PLATE III

Rocky Mountains: view southwest across the southern part of the northern interior of the Rocky Mountains near Redfern Lake, showing the border of the more rugged central area, and alpine glaciers. Photo by United States Army Air Force; negative 32.1-R130 2-2010.

more southern areas. No intrusions have yet been reported in this northern part, but copper occurrences east of Fort Grahame suggest the presence of intrusions not far below the surface.[1]

The border zone surrounds the central area for a width of 15 miles or more. It consists of lower and less rugged mountains and contains no glaciers. In general, the elevations of its summits decrease from the central area outwards. North of Sikanni Chief River, these summits in places retain remnants of an old erosion surface that truncates their tops. In the northern part of the zone, as the elevations decrease, areas in which the old erosion surface, here a rolling upland, remains, become more and more common as the boundary of the mountains is approached.

At the north end of the border zone, the Rocky Mountains are cut off sharply by Liard Valley. Southwest, from nearly opposite the mouth of Smith River to Kechika River, the northern ends of the mountain ridges disappear more gradually, and the boundary between them and Liard Plain is less distinct, though viewed from a distance at an elevation of 20,000 feet a general belt is apparent where the ridges increase their elevation southward more rapidly to become mountains. Between Rabbit and Kechika Rivers the outer ridges of the mountains continue northwest along the side of the Rocky Mountain Trench, with summits at 4,000 to 5,000 feet or more, as far as the fifty-ninth parallel, where they finally merge with Liard Plain. Terminus Mountain, 6,250 feet high, forms the northwest corner of the truly mountainous country.[2]

In the northern and northwestern parts of these border zone mountains the general parallelism of valleys and ridges is less marked. From Rabbit River a large valley extends obliquely to join that of Gataga River 25 miles above its mouth, and continues into the mountains as an outstanding valley feature that sends deep branches through the central area, joining with the valleys draining to Toad and Muskwa Rivers.

Farther south the border zone adjacent to the Rocky Mountain Trench consists of parallel ridges and valleys. As the trench is approached, the elevations of the ridges decrease, and the intervening valleys become broader, that next to the trench being nearly as large as the trench itself.[3]

An area of less relief than usual lies in the border zone mountains around the head of Sikanni Chief River and south to the head of Graham River, and the boundary between it and the Foothills is indefinite. Farther south the boundary follows Nabesche River, but in this whole northern area the mountains of the border zone greatly resemble those of the Foothills.

Though the Rocky Mountains as a whole, due to their easterly position in the Cordillera, receive a small precipitation, they contain alpine glaciers in their higher parts, notably in the south. The largest glaciers are those of Columbia Icefield near the fifty-second parallel where several of the highest peaks are grouped. To the north, where the mountains on the west form a more solid barrier, the precipitation is small, glaciers are small, and timber-line, which reaches to nearly 8,000 feet in the south, is only 4,500 to 5,000 feet above sea-level.

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[1] Dolmage, V.: Finlay River District, B.C.: Geol. Surv., Canada, Sum. Rept. 1927, pt. A, p. 36 (1928).
[2] Hedley, M. S., and Holland, S. S.: Reconnaissance in the area of Turnagain and Upper Kechika Rivers, Northern British Columbia; B.C. Dept. Mines, Bull. No. 12, 1941.
[3] Dolmage, V.: Finlay River District, B.C.: Geol. Surv., Canada, Sum. Rept. 1927, pt. A, pp. 19-41 (1928).

Throughout the Canadian Cordillera the general uniformity of elevations of the higher peaks of any area is a striking feature. This is notably true of the Rocky Mountains north of Peace River where remnants of an old land surface are well shown in the views of the mountains and foothills in many places.

During Pleistocene time the Rocky Mountains appear to have been an area of relatively light precipitation, as they are today. In the south, valley glaciation was extensive and the level of the ice was high. Northward the effects of glaciation seem to have been less pronounced, and in some areas north of Peace River no features attributable to glaciation can be detected in the photographs. Exploring prospectors have reported that in travelling eastward into the mountains from the Rocky Mountain Trench no evidence of glaciation could be seen on some of the higher levels, and the ice from the trench appeared to have pushed eastward up some valleys.[1]

## ROCKY MOUNTAIN TRENCH

The Rocky Mountain Trench is the great valley that lies directly west of the Rocky Mountains and forms their west boundary throughout their length (Plates IV and V). Beginning south of the Forty-ninth Parallel and reaching to Liard Plain, where it disappears, the trench has a length of more than 900 miles, and is the longest valley feature of the Cordillera. Except in the central part mountains rise on one or both sides of the trench, presenting wall-like slopes, particularly on the northeast side, and giving the valley its name. Throughout its length it is remarkable for the general persistence of its trend, which averages north 30 degrees west and has a maximum variation in its slightly sinuous plan of from north 20 degrees west to north 45 degrees west.

Though the trench is regarded as a continuous feature, its central part, between Tête Jaune Cache and Fort McLeod, is indistinctly bounded; there its southwest wall is breached for about 170 miles, and opens into the Interior Plateau; and its northeast wall is irregular and broken, the front of the Rocky Mountains here comprising several relatively low ridges. The indistinctness is also due to lack of alinement of the southern and northern parts as they approach the central part. The southern part follows a line too far northwest, and the northern part, though it expands southward into the Interior Plateau, points southeastward into the flank of the Rocky Mountains.

For most of its length, the floor of the trench lies between 2,000 and 3,000 feet above the sea, the highest point being at Sifton Pass, elevation 3,273 feet, and the lowest points where Fraser and Peace Rivers (Plate IV) leave it at a little below 2,000 feet. The floor of the trench varies in width from 2 to more than 10 miles, where it is walled by mountains on both sides, and in several places ridges of hills along the central part rise 1,000 feet or more above the floor. At the north end of the Rocky Mountains the Cassiar Mountains recede from the western side of the trench, which opens out into Liard Plain where its boundaries disappear. Farther northwest, for some distance, the upper part of Liard River Valley marks the general alinement of the trench, but no trench-like valley exists, and finally even this course is diagonally blocked by Pelly Mountains.

[1] Armstrong, J. E.: Geol. Surv. Canada; personal communication (1946).

PLATE IV

Rocky Mountain Trench: view northwest across the Rocky Mountain Trench at Finlay Forks, showing the narrow gap through the Rocky Mountains followed by Peace River. Photo by United States Army Air Force; negative 38.1-R37 2-2010.

PLATE V

Rocky Mountain Trench: view southwest across the northern part of the trench. The first ridge of the Rocky Mountains shows in the foreground, beyond which is Kechika River in the Trench. The first mountains beyond the Trench are part of the Kechika Ranges, and the Stikine Ranges of the Cassiar Mountains show in the distance with scattered alpine glaciers. Photo by United States Army Air Force; negative 32.1-R65 2-2010.

## Mackenzie Mountain Area

Mackenzie Mountain area comprises mountains, plateaux, and plains in the Eastern system, believed to be wholly composed of sedimentary rocks between Liard River and the east front of Richardson Mountains a few miles west of Peel River, on the south and north respectively, and the Interior Plains on the east. The position of the west boundary between this area and Selwyn Mountains of the Interior system, based on the conception given in a preceding paragraph, is only approximately located except on Keele River. This is due to the lack of any well-defined, bordering feature, such as the Rocky Mountain Trench, and to the fact that it traverses one of the least explored areas of the Cordillera.

Mackenzie Mountain area is of more varied character than the Rocky Mountain area, with which it was formerly regarded as a continuous unit. It contains within it Liard Plateau, Franklin Mountains, Mackenzie Plain, Mackenzie Mountains, and Peel Plateau. Liard Plateau is a relatively low block of the Eastern system, a subdued platform between the Rocky Mountain area on the south and Mackenzie and Franklin Mountains on the north, towards which it slopes gently upward. Franklin Mountains comprise the first ranges of hills and mountains to break the general level of the Interior Plains. They stand out to the east well in front of Mackenzie Mountains, the main feature of the area, and are separated from them by a broad valley, Mackenzie Plain, which is a long, narrow, and nearly isolated strip of the Interior Plains. In the north, Peel Plateau stands in a somewhat similar position to that of Liard Plateau in the south.

### LIARD PLATEAU

North of Liard River the Eastern system is continued by Liard Plateau, the southern unit of Mackenzie Mountain area. This is an area of broad, even-topped ranges of hills rising in their higher parts to about 4,500 feet above sea-level and presenting a distinct accordance of summit levels. A few of these ranges are of mountainous character. In the central and southern parts of the plateau area the ranges are separated by wide, rolling, valley areas, most of which drain southeastward. The slopes of much of the valley areas have elevations of about 3,000 feet, and the valley floors in them are 1,500 to 2,500 feet above sea-level. The plateau, so far as known, is underlain by the same Palæozoic and Mesozoic sedimentary formations as in the Rocky and Mackenzie Mountains.[1] The separate ranges show a general tendency to parallelism, as in the Rocky Mountains, but are more widely spaced. In places, notably on the upper part of Beaver River, the ranges of hills have the plan of horseshoes formed by the hard strata of open folds 15 miles or more across.

To the north, Liard Plateau is bounded by the valley of South Nahanni River and its tributary, Flat River. On the east its boundary runs northeastward and then north on the west side of Liard River from opposite the mouth of Toad River to South Nahanni River. In this respect it continues the habit of the front of the Foothills in following the first distinct folding west of the Interior Plains. North of Toad River, the folds strike northeasterly[2] as far as a point west of Fort Liard, where they strike north. The front folds, west and north of Fort Liard, become sharper and rise to form distinct, mountain ridges, Liard and Labiche Ranges, along the east front of the plateau, which could be regarded as the extreme south end of Franklin Mountains. The west boundary of the plateau follows up Smith River through Toobally Lakes to Caribou River.

[1] Williams, M. Y.: Geological Investigations along the Alaska Highway from Fort Nelson, British Columbia, to Watson Lake, Yukon; Geol. Surv., Canada, Paper 44-28 (1944).
[2] Kindle, E. D.: Geological Reconnaissance Along Fort Nelson, Liard, and Beaver Rivers, Northeastern British Columbia and Southeastern Yukon; Geol. Surv., Canada, Paper 44-16 (1944).

South of Toobally Lakes the boundary is relatively distinct between Liard Plateau on the east and Liard Plain on the west.[1] North of Toobally Lakes it is well defined but still discernible within a distance of a few miles. The surface of the plain rises on the west to that of Hyland Plateau, and the two plateaux are difficult to separate. Nevertheless, there are differences between their surfaces that serve in general to distinguish them. Liard Plateau is wholly underlain by sedimentary rocks, as shown in the alinement of its ridges. Hyland Plateau, on the other hand, contains intrusions and is an area of groups of rolling hills irregularly arranged and rarely showing alinement.

In its northern part Liard Plateau exhibits more relief and appears to be higher than elsewhere, valleys draining to South Nahanni River being more deeply incised and narrower. In its northwest corner, west of Meilleur Creek, though the summits show an accordance of elevations the general appearance is very rough. East of Meilleur Creek, tablelands standing up prominently among the large, steep-sided valleys of Jackfish River and its tributaries reach to more than 5,000 feet in elevation and are composed of relatively horizontal strata. The rugged aspect of this section viewed from ground level has earned it the name of Tlogotsho Range, but seen from the air the impressive feature is the old erosion surface that truncates the summits of large areas into tablelands.

Most of the plateau appears to have been covered by Pleistocene ice, and lower parts seem to have been well scoured.

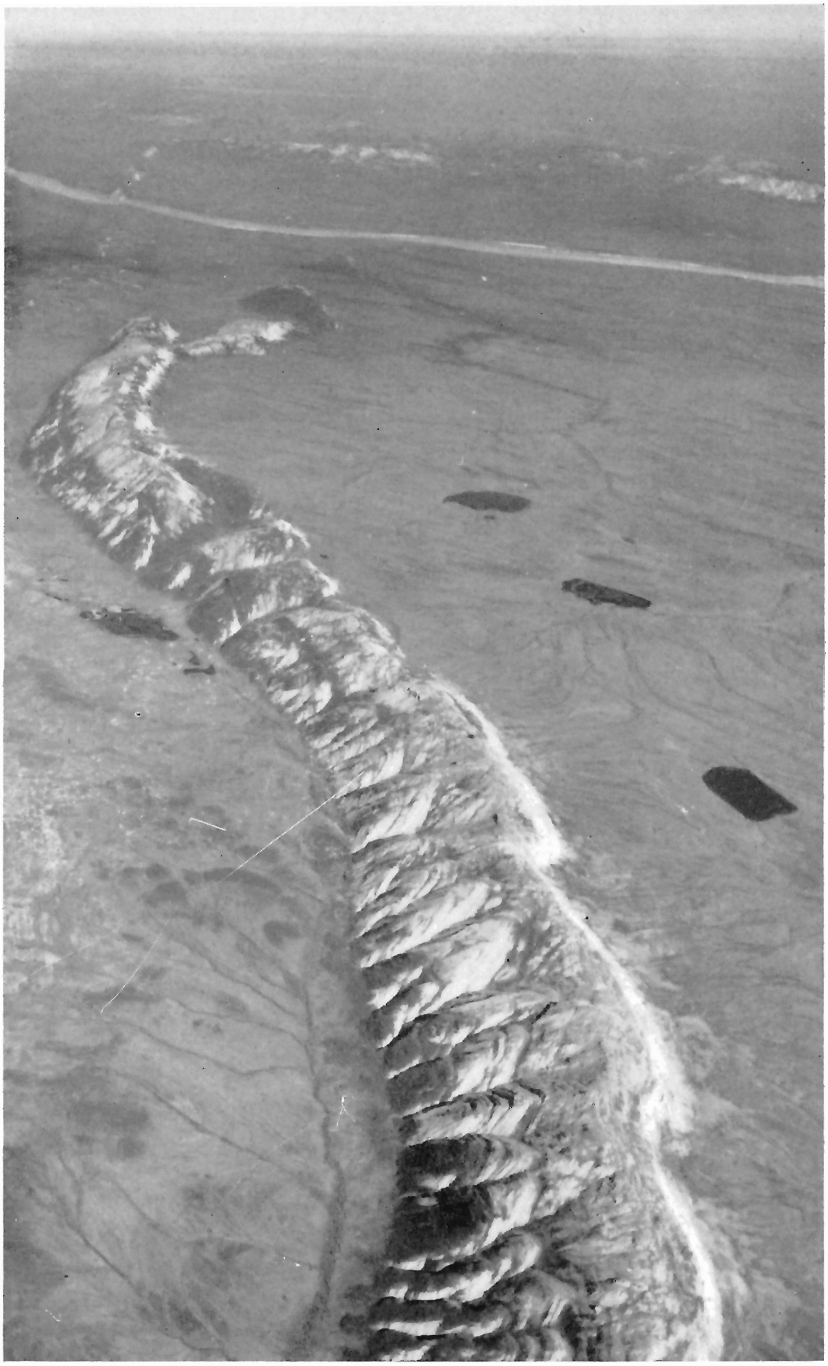
## FRANKLIN MOUNTAINS

Franklin Mountains extend from Nahanni Butte at the mouth of South Nahanni River north and west to a few miles south of Fort Good Hope. In their general plan they form an elevated and broken tract of country more than 400 miles long and as much as 30 miles wide. They appear to represent the easternmost zone of mountain structures bordering the Interior Plains, but insufficient information is available to indicate that this applies to their entire length. West of Franklin Mountains the boundary with Mackenzie Plain is fairly well defined, though irregular, and in general marks the position west of which structures again become relatively open, and where the older formations sink beneath nearly flat-lying Cretaceous and Tertiary sediments that cover much of the plain. The mountains comprise four ranges: Nahanni Range, between the two Nahanni Rivers; Camsell Range, between North Nahanni River and Fort Wrigley; McConnell Range, from Willowlake River to the north end of the east shore of Brackett Lakes; and Norman Range, from Bear Rock at the mouth of Great Bear River to Mackenzie River between East Mountain and Beavertail Mountain. These four ranges are not in line. McConnell Range stands out to eastward as a main outer arc in the north supported on the west at the north end by Norman Range and at the south end by Camsell Range. Nahanni Range continues the trend of McConnell Range southward, but is separated from it by a gap of low hills of flat-lying rocks from Willowlake River to Camsell Bend, and forms a minor arc in the south supported on the west by Camsell Range at the north end and by Liard Range, the front of Liard Plateau, at the south end.

*Nahanni Range.* Nahanni Range rises in the extreme south of Franklin Mountains at Nahanni Butte, and extends north to where it is cut off at Camsell Bend of Mackenzie River. At its south end it is formed of two parallel ridges, the more westerly of which passes northward first into a narrow plateau and then

[1] Williams, M. Y.: Op. cit.

PLATE VI



Camsell Range, Franklin Mountains, and Mackenzie Plain: view north along the northern spur of Camsell Range, and over the Mackenzie Plain. The site of Fort Wrigley, Mackenzie River, and Roche-qui-trempe-à-l'eau show in the left distance, and the southern end of McConnell Range beyond the river. Photo by Royal Canadian Air Force; negative T12-15R.

into Mackenzie Plain. The easterly ridge rises abruptly at Nahanni Butte from the Interior Plains to an elevation of 5,000 feet and forms a remarkable, narrow, rugged wall 6 to 10 miles wide, the eastern front of which appears to mark the line of an important fault.[1] Near the northern end the wall is pierced by two, deep, narrow gaps, each floored by a lake several miles long.

*Camsell Range.* At its south end Camsell Range rises from Mackenzie Plain a few miles upstream from the mouth of North Nahanni River. Here it comprises two narrow ridges within the bend of the river and a broad ridge west of the bend. Northward it widens into a belt of three or more sharp, nearly parallel ridges, more than 4,000 feet in elevation, composed of thick-bedded strata and having an aggregate breadth of nearly 30 miles. Most of the east faces of these ridges are rocky and precipitous, but those facing west are smooth and sloping. The ridges are separated and cut across by deep valleys, some of which appear to have been occupied at some former time by North Nahanni and Root Rivers. North of Root River the range is continued toward Fort Wrigley by a single, high, narrow, rocky ridge (Plate VI). This ridge ends before it reaches Mackenzie River, but its place is taken *en échelon* northwest of Wrigley River by a short ridge through which Mackenzie River has cut at Roche qui-trempe-à-l'eau.

On the east, Camsell Range is flanked by an embayment of the Interior Plains, which penetrates the general line of the front of Franklin Mountains between Willowlake River and Lone Mountain. This area comprises a low plain partly occupied by Mackenzie River and backed by hills and plateaux that reach elevations of more than 1,000 feet on the east and 2,000 feet on the west in front of Camsell Range.[2]

*McConnell Range.* The south end of McConnell Range rises east of Fort Wrigley and reaches heights of 5,000 feet. Here the range is about 20 miles wide, and is composed of three or more ridges of broken mountainous country. Some of the summits have accordant, smooth tops, suggestive of an old and elevated plateau surface. The mountains continue northerly to Great Bear River where they narrow to a single ridge that is crossed by this river at St. Charles Rapids. South of Great Bear River several other streams heading east of the range cut across it to Mackenzie River.[3] Northwestward from St. Charles Rapids, the ridge disappears in a distance of about 40 miles along the east side of the valley of Kelly[4,5] and Brackett Lakes.

*Norman Range.* Norman Range rises at Bear Rock west of the mouth of Great Bear River and extends northwestward, separated from the northern end of the McConnell Range by the broad depression containing Brackett River and Brackett Lakes. In its southern part, north of Great Bear River, Norman Range is formed of two main summits, 10 and 16 miles east respectively of Mackenzie River. The elevations of these summits are about 2,000 feet. The west ridge facing the river is the more marked, that to the east being of a more subdued character. As Mackenzie River bends west to the mouth of Carcajou River, the range conforms at a distance of several miles to where it trends east and west and spreads out into three major ridges. East Mountain, Rat Hill, and Beavertail Mountain, and a belt of hills about 15 miles south of Fort Good Hope.

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[1] Hage, C. O.: Geological Reconnaissance Along Lower Liard River, Northwest Territories, Yukon, and British Columbia; Geol. Surv., Canada, Paper 45-22 (1945).

[2] Williams, M. Y.: Exploration East of Mackenzie River, Between Simpson and Wrigley, N.W.T.: Geol. Surv., Canada, Sum. Rept. 1921, pt. B, p. 57 (1922).

[3] Camsell, C., and Malcolm, W.: The Mackenzie River Basin; Geol. Surv., Canada, Mem. 108 (1919).

[4] Hume, G. S.: Mackenzie River Area, District of Mackenzie, Northwest Territories; Geol. Surv., Canada, Sum. Rept. 1923, pt. B, p. 6 (1924).

[5] Hume, G.S., and Link, T.A.: Canol Geological Investigations in the Mackenzie River Area, Northwest Territories and Yukon; Geol. Surv., Canada, Paper 45-16 (1945).

The turn of Mackenzie River to the north just below the mouth of Carcajou River cuts off the range, and no topographical feature continues it west of the main river.

During Pleistocene time the area of Franklin Mountains was overridden by ice moving across it to the Mackenzie Plain from easterly directions. Glacial erratics lie on the very top of Cap Mountain at an elevation of 5,000 feet, showing that the surface of the ice stood at least that high.[1] Features suggesting a lack of glaciation were not noted anywhere in these mountains except perhaps in the sharp, ragged crests of parts of Nahanni Range. According to the interpretation of the topography, the two lake gaps in the northern part of this range formed important channels of flow through the range from the southeast.

### MACKENZIE PLAIN

Mackenzie Plain is a long area of relatively low elevation and relief compared with the ranges on either side, and can be broadly described as a valley. It appears to be a strip of the Interior Plains left almost undisturbed within the Mackenzie Mountains area when the front structures emerged from the plains far out in front of the main area of deformation. Though relatively subdued topographically it contains features of varied forms and origins. In the south it is blocked by Liard Plateau a few miles south of South Nahanni River. From there it extends northward and northwestward in a long sweep to where it bends north again around the end of Norman Range and widens to join the Interior Plains. On the west its boundary follows the front of Mackenzie Mountains (Plate VII). The front forms a continuous, sweeping curve from South Nahanni River northward and westward beyond the plain. It is well marked by the abrupt rise of the mountains above the plain except between Redstone and Carcajou Rivers where a relatively low area in the mountains lies behind it.

On both sides of Mountain River a strip of ground higher than average for the general level of the plain borders Mackenzie Mountains, and is a narrow, southeast extension from Peel Plateau (Plate VII). The boundary between plain and plateau is regarded as extending from the west side of Mountain River northwestward to follow a gentle scarp west of Ramparts River.

In its southern part Mackenzie Plain is a valley about 15 miles wide between Nahanni Range and Mackenzie Mountains, and broadens to nearly 30 miles at North Nahanni River. It maintains this breadth to near Keele River and then widens northward to 60 miles, south of Great Bear River. Norman Range, rising north of this river west of McConnell Range, narrows the plain again to 30 miles, and this width is maintained to where it swings to the north to join the Interior Plains.

The greater part of Mackenzie Plain has a rolling surface elevated above the valleys of the main streams that run through it. The surface slopes prevailingly from Mackenzie River up to the mountains in the west. The general evenness of this surface is varied by low parallel hills and valleys in the northern part, and, locally, by small plateaux, rounded hills, and east-facing scarps. In addition, several notable features are exhibited. A mountainous area with a deeply cut, irregularly radial drainage lies midway between the two Nahanni Rivers. It is, apparently, an elliptical dome structure 22 miles long and 15 miles wide. A second, smaller, broken dome structure is suggested by the topography between North Nahanni and Root Rivers adjacent to the west flank of Camsell Range. North of Fort Wrigley, much of the plain consists of flat-lying or gently

[1] Williams, M. Y.: Exploration East of Mackenzie River, Between Simpson and Wrigley, N.W.T.; Geol. Surv., Canada, Sum. Rept. 1922, pt. B, p. 71 (1923).

PLATE VII

Mackenzie Plain: view south from the mouth of Carcajou River where it enters the Mackenzie, across the northern part of Mackenzie Plain. In the near distance is the elevated part of the plain, which is continuous with Peel Plateau. Beyond, and entrenched in this elevated area, Mountain River can be seen debouching from Mackenzie Mountains, which rise along a characteristically abrupt front. Photo by Royal Canadian Air Force; negative T4-157R.

folded Cretaceous and Tertiary strata through which Palæozoic rocks project to form the chief elevations and irregularities. In MacKay Range, south of Fort Norman, for instance, an anticline of Palæozoic rocks projects through the Cretaceous strata and stands as a conspicuous ridge 1,000 feet or more above the surrounding plain.[1] Along the west side of the plain, between Carcajou and Mountain Rivers, the older rocks form a number of prominent hills along anticlines[2] where they rise through the Cretaceous (Plate VII). In most places on the east side of Mackenzie River a narrow belt of plain, broken here and there by hills, slopes up to the McConnell Range south of Great Bear River or to Norman Range north of this river. Though the area bordering Mackenzie River between Camsell Bend and Roche qui-trempe-à-l'eau is cut off by Camsell Range, it is considered a part of Mackenzie Plain, which it resembles in all general characteristics.

Mackenzie River and its major tributaries are entrenched in narrow, steep-sided valleys 200 to 500 feet below the general surface of the plain. The main river and notably the tributaries from the west occupy most of their valley floors, except for the islands in them and narrow flats on one side or the other. At Ramparts above Fort Good Hope, an old river channel lies to the west, beginning at the mouth of Hume River and extending in an arc 8 miles from Ramparts to nearly opposite Hare Indian River. This channel, though it is too large to have been cut by Hume and Ramparts Rivers, seems too small for the present Mackenzie. Probably earlier in post-Pleistocene time Mackenzie River was divided and this represented a second channel before the present one cut down and captured its waters.

The main part of Mackenzie Plain was covered by ice during Pleistocene time. In the south it is possible that higher parts of the plain sheltered by the wall of Nahanni Range on the east and bordered by arid mountains on the west may have suffered only slight glaciation or may even have remained uncovered. North of North Nahanni River the ice pushed northwesterly across the plain against Mackenzie Mountains and into their valleys[3], and northward to the Arctic, leaving abundant evidence of its passage in characteristic topographic forms and glacial deposits.

## MACKENZIE MOUNTAINS

The area occupied by Mackenzie Mountains includes as well some broad depressions and plateaux, so that the topography is more diversified than in any other such unit of the Eastern system, and contrasts with that of the Rocky Mountains. The boundary of Mackenzie Mountains on the east and north, with Mackenzie Plain and Peel Plateau, follows a sweeping curve through 90 degrees in 500 miles from South Nahanni to Bonnet Plume Rivers. The boundary is marked by a distinct topographic break or front for most of its length except between the points where Redstone and Carcajou Rivers cross it. Between these rivers the front is not distinct, as the area behind it in the mountains rises gently and continues somewhat the same type of topography as in the plain. The southwest boundary is drawn southeast from where Bonnet Plume River leaves the mountains to a point about 40 miles down Keele River from its head. Thence it curves southward to meet the boundary between Liard and Hyland Plateaux. This boundary separates, so far as is known, the mountains containing intrusions and metamorphic rocks on the southwest from those consisting only of

[1] Hume, G. S., and Link, T. A.: Canol Geological Investigations in the Mackenzie River Area, Northwest Territories and Yukon; Geol. Surv., Canada, Paper 45-16, p. 48 (1945).
[2] Hume, G. S.: Personal communication, 1946.
[3] Keele, J.: A Reconnaissance Across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers; Geol. Surv., Canada, Pub. No. 1097, p. 45 (1910).

sedimentary rocks on the northeast. No continuous topographic feature marks this line, but in places major valleys are parallel with and close to it. Directly northeast of the line the mountains are as a whole distinctly more youthful in appearance and more closely spaced. In the south, the boundary between the mountains and Liard Plateau follows the lower part of South Nahanni River and its tributary, Flat River.

In neighbouring areas on both flanks of Mackenzie Mountains, and particularly in the north, long periods of Palæozoic and Mesozoic time are very scantily represented if at all in the sedimentary section, which seems to be some tens of thousands of feet thinner than in the Rocky Mountains.[1] This may account in part for the differences in topography and structure. It suggests, too, that in northern Mackenzie Mountains, where the Palæozoic-Mesozoic section is believed to be thinnest, and no intrusions are apparent in the air photographs, areas of Precambrian strata may be exposed.

Mackenzie Mountains are divisible into two main parts--a front arc of mountains on the northeast, known as Canyon Ranges, and the main body of the mountains to the southwest, Backbone Ranges. Canyon Ranges are 400 miles long and as much as 40 miles wide. They are composed of mountains of smooth profiles, plateaux, and widely separated low ranges. To the west, the rugged mass of Backbone Ranges rises along a fairly distinct line roughly concentric with the outer boundary between Mackenzie Plain and Canyon Ranges. West of Arctic Red River, the position of the boundary is uncertain. East of this river it follows what appears to be an important fault for many miles, and features in places suggest that this may be found to be true of other parts.

A remarkable, radiating drainage pattern characterizes Mackenzie Mountains and parts of the adjacent units of both the Mackenzie Mountain area and the Interior system. Inspection of the map shows the drainage fanning out from southeast along South Nahanni River through east to northeast at Keele River, and thence continuing its swing to north, and finally northwest at Bonnet Plume River. The geometric figure is centred near Macmillan Pass, and has a curved boundary that is nearly the arc of a semicircle. The arc that governs its radii follows a line a few miles beyond the northeast front of Mackenzie Mountains. In swinging through 180 degrees from South Nahanni to Bonnet Plume Rivers the radii vary in length from 220 to 250 miles along the chord to about 160 miles in their medial position near Keele River. The drainage pattern is by no means perfect; some of the adjacent lines included as radii are nearly parallel, and the borders of the area are not sharply delineated but only generally apparent. The directions of Willowlake River and Mackenzie River above Camsell Bend extend the radii beyond the arc in that section, and south of South Nahanni River in Liard Plateau several streams with courses parallel with the South Nahanni seem to extend the area of the pattern in that direction, and the same is true at the other extremity beyond Bonnet Plume River.

### *Canyon Ranges*

The name Canyon Ranges is given to this part of Mackenzie Mountains by reason of the numerous canyons cut by the major streams in the older floors of their valleys as they traverse and leave these ranges. The old floor levels seem, from the photographs, to correspond to the main surface of Mackenzie Plain. The more important canyons are those of Arctic Red, Carcajou, Redstone, Root, and North Nahanni Rivers.

[1] On the northeast this refers to the section in the northern part of Mackenzie Plain of which information has been obtained from G. S. Hume, J. S. Stewart, and C. O. Hage. On the west it is brought out by the writer's work in recent years in the Mayo district, not yet published, and by reports of J. Keele, C. Camsell, and W. E. Cockfield.

PLATE VIII

Canyon Ranges, Mackenzie Mountains: view of the northern part of Canyon Ranges between Arctic Red and Snake Rivers, looking south from the border of the mountains. Note the increase of glacial sculpturing towards the interior of the ranges. Photo by Royal Canadian Air Force; negative T4-116R.

PLATE IX

Mackenzie Mountains: view looking south into northwestern part of Mackenzie Mountains up one of the heads of Snake River. The border between Peel Plateau and the mountains shows in the foreground. Photo by Royal Canadian Air Force; negative T4-130R.

The area covered by Canyon Ranges may be subdivided into three parts. In the northwest is a continuous mass of ranges including small areas of plateau. The central part, beginning southeast of Mountain River, is formed on its northwest side mainly of high plateaux and alternating mountain ridges. The general elevation decreases appreciably toward Keele River, south of which is a large, relatively low area of hills and broad valleys, with less prominent plateaux. In the south part, which lies south of Redstone River, the country rises and again becomes mountainous. It is characterized towards the north by broad valleys separated by rough ridges of mountains, but farther south the valleys become narrower and south of North Nahanni River they no longer occupy the greater part of the area.

Photographs of the Canyon Ranges were taken late in April or early in May before the thaw had set in, and most of them show a very light snowfall. The snow cover thickens slightly along the front overlooking Peel Plateau and Mackenzie Plain, and their highest parts close to Backbone Ranges show considerable snow. The evidence of glaciation in Canyon Ranges as a whole is distributed in much the same areas as the present snowfall. Very little glacial ice seems to have originated in these ranges, but valley glaciers extended through them from the gathering grounds to the west in and beyond Backbone Ranges. Ice from the Interior Plains also pushed westward against and into them, covering their lower parts, notably near and south of Keele River.[1]

In the northwest part of Canyon Ranges, west of Arctic Red River, the mountains are rugged (Plates VIII and IX). Along their northern edge creeks flow north, in broad, well-developed valleys whose sides slope in steadily decreasing grades to a narrow flood-plain along the medial line. No moraines, terraces, lakes, nor other features generally regarded as evidence of glaciation were noted in their front ranges between Arctic Red and Snake Rivers. However, some of the higher ridges exhibit cirques, and these become progressively more developed as the Backbone Ranges are approached. The valleys of the master streams, including Bonnet Plume, Snake, and Arctic Red Rivers, and their main branches, which reach into Backbone Ranges, have great, trench-like valleys, U-shaped in cross-section and lakes in them.

In the central part of Canyon Ranges, from south of Mountain River to Redstone River, the major features are plateaux, and remnants of an old erosion surface are widespread and conspicuous on the summits. In the northern parts of this area, the plateaux are high, and in some places in a youthful stage of dissection. The Plains of Abraham (Plate X), a well known feature of the Canol Road, constitutes one of these plateaux. They form a tableland more than 6,000 feet high, composed of nearly horizontal strata in the central part of a broad anticline whose axis strikes northwesterly parallel with the general trend of the ranges. The streams cutting into the tableland have V-shaped valleys. In some instances the heads of these valleys appear to be due to normal erosion, but in others they show a semicircular plan, suggesting carving by small, local glaciers into partly developed cirques. On both flanks, where the dips steepen, the harder strata form rows of "flat-iron" mountains with their peaks in some places truncated by the same old erosion surface as that of the plateau, but in others projecting above it. Southward the old surface slopes towards Keele River and the summits are lower. Keele River occupies a broad depression across the middle of Canyon Ranges. Along the border of Mackenzie Plain between Carcajou and Redstone Rivers, the low, undulating surface of the plain is separated by a valley, followed for a few miles by Keele River, from a belt of somewhat higher hills on the west with summits reaching elevations of 2,000

[1] Keele, J.: A Reconnaissance Across Mackenzie Mountains on Pelly, Ross, and Gravel Rivers; Geol. Surv., Canada, Pub. 1097, pp. 45-46 (1910).

PLATE X

Canyon Ranges, Mackenzie Mountains: view from an elevation of 13,000 feet of Canyon Ranges on the upper reaches of Carcajou River, showing part of the Plains of Abraham near the Canol Road. Photo by Royal Canadian Air Force; negative T17R-151.

and 3,000 feet. West of these hills the plateau surface is more apparent as it rises towards the border of Backbone Ranges. Here the summits have elevations of 4,000 to 5,000 feet, and are best described as plateaux. The old surface is distinct on them, but is undulating, and the valleys between the plateaux are deeply cut. The higher parts of the plateaux on the west have a truly mountainous relief. Here, too, Canyon Ranges seem to be built of horizontal and gently dipping strata forming broad structures similar to those of the Plains of Abraham. Towards Redstone River the plateaux disappear, and the ranges are composed from east to west of, first, mountainous ridges 2,000 to 3,000 feet high, and then a broad rolling valley area bordered on the west by a narrow ridge of low mountains. This, in turn, is succeeded by the valley of Wrigley Lake, about 16 miles wide and walled on the west by the mountainous front of Backbone Ranges. In this part the ridges appear to follow sharp anticlines with broad synclines between them.

South of Redstone River the mountain ridges converge, narrowing the valleys and the whole of Canyon Ranges southward to about 15 miles at the west fork of Root River. These ridges at Dahadinni River and on the south fork of Root River contain two conspicuous dome structures of asymmetrical elliptical plan, having broad, blunt north ends and tapering south ends. As Canyon Ranges cross North Nahanni River, the persistence of direction apparent in the valleys and ridges that start south of Keele River becomes less marked. The front ridge adjacent to Mackenzie Plain declines and ends a few miles south of North Nahanni River, and at their south end Canyon Ranges terminate in an area of broken country inseparable from Backbone Ranges.

Canyon Ranges in the air photographs show very little evidence of glacial modification south of Redstone River, except in the main valleys that cross them from west to east. The great transverse valleys of the main streams such as Redstone, Root, and North Nahanni Rivers have their courses deeply cut into canyons in the floors of their valleys.

### *Backbone Ranges*

Backbone Ranges form the rugged summit of Mackenzie Mountains. Their boundaries have already been defined as nearly as they can be with the limited available information. As a whole they constitute a compact group of mountains, with few broad valleys and almost no plateaux nor remnants of former land surfaces. Rock stratification is conspicuous in all parts, and exhibits their structures to a unique degree. The watershed between Mackenzie and Yukon Rivers is to the southwest of these mountains except in their extreme northwest corner.

The elevations of a few peaks are known, and in the most parts they seem to reach about 7,000 feet. Near the head of Arctic Red River and near South Nahanni River the general summit level rises in gentle swells, and peaks 1,000 to 2,000 feet or more higher have been reported in these two areas.

There is a difference between the northern and southern Backbone Ranges. In the north in several views the mountains resemble a vast ploughed field (Plate XI) in which the uniformity of level and parallelism of the closely spaced ridges and narrow valleys are striking characteristics. The valleys of Snake and Arctic Red Rivers are great, persistent trenches cutting across the main trend of the mountains. This is particularly true of the valley of Arctic Red River, which is transverse to the general structures and ridges and is a great U-shaped valley deepened considerably in its upper part, perhaps by glaciation, so that it has a relatively gentle grade in these ranges to well within its headwaters.

PLATE XI

Backbone Ranges, Mackenzie Mountains: view southeast across Backbone Ranges from southwest of the junction of Twitza and Keele Rivers. Photo by Royal Canadian Air Force; negative T20L-154.

PLATE XII

Backbone Ranges, Mackenzie Mountains: view north from midway between North and South Nahanni Rivers. The streams in the picture flow to North Nahanni River. Photo by Royal Canadian Air Force; negative T22R-44.

The structures of this northern part of Backbone Ranges, besides having a general strike parallel with the main trend of the mountains, appear to be distributed in narrow belts of close folding separated by broader belts of more open folds, though not as open as those referred to in Canyon Ranges.

Southward, along the ranges across Keele River, no distinct change was observed to as far as the drainage basin of Redstone River. Here, however, the texture of the topography and geologic structures becomes coarser (Plate XII). The southern head of Redstone River and the heads of Root and North Nahanni Rivers have great valleys with floors 1 or 2 miles wide, and are open, U-shaped in cross-section. These valleys and their main branches cut across at least two outstanding anticlines; one, on the west of Redstone River and between it and the head of South Nahanni River, is about 20 miles wide; the other, between the heads of Root and North Nahanni Rivers on the east and Redstone River on the west, is about 35 miles wide. These anticlinal structures are very flat in their central parts, the strata lying almost horizontally or dipping gently across large areas. Stratification is shown with remarkable clearness, and the structures have been carved into steep mountains. The effects of glacial erosion are notably apparent in the more westerly anticline where a remarkable biscuit-board pattern of cirques rimmed by precipitous walls and surmounted by fantastic pinnacles has been cut from a great thickness of horizontal strata, apparently massive limestones.

The northeastern flank is an area of relatively light precipitation containing few glaciers. In Pleistocene time, this flank was only lightly carved by alpine glaciation, though the main valleys that traverse them show extensive valley glaciation. To the southwest precipitation increases, many small alpine glaciers are present today, and carving by Pleistocene ice is marked.

## PEEL PLATEAU

Peel Plateau is a great triangular terrace occupying the angle between the north front of Mackenzie Mountains and the east front of Richardson Mountains and overlooking the Interior Plains on the northeast. The evenness of most of its surface is a striking feature. Its northeast boundary is a scarp facing Mackenzie Delta, the Interior Plains, and Mackenzie Plain. It extends as a narrow sloping step in front of Richardson Mountains along the west side of Mackenzie Delta and Peel River from 24 miles north of Rat River to Satah River. From there the boundary sweeps in a broad curve east and southeast to near Mountain River. Throughout this distance, nearly 250 miles, the scarp rises conspicuously 200 to 1,000 feet, except between Arctic Red and Ramparts Rivers where it becomes indistinguishable in a broad slope. The southern boundary of the plateau is well defined along the foot of Mackenzie Mountains, and the western boundary is marked by the front ridges of Richardson Mountains and the southeast extremity of Porcupine Plateau.

The evenness of the plateau is interrupted in the south and west by hills standing above its surface. Between Snake and Arctic Red Rivers these hills form two terraces (Plate XIII), one above the other, superimposed on the main surface of Peel Plateau, so that approached from the direction of the Interior Plains three steps may be observed, namely, the bottom step onto the main surface of the plateau, then the middle step onto the lower of the terraces, and finally the top step to the surface of the higher of the two terraces. The main surface of the plateau, the bottom step, truncates the upturned edges of Palæozoic and Mesozoic strata and is, therefore, a surface of erosion. The same appears to be true of the surface of the middle step, but information is lacking. This step is not well defined, the steepening of the topography that

PLATE XIII

Peel Plateau: view south across Peel Plateau to Mackenzie Mountains between Arctic Red and Snake Rivers. Areas of the top step of the plateau stand up conspicuously in the central part of the picture. Photo by Royal Canadian Air Force; negative T5-185R.

marks its outer boundary being only discernible in some views, and it does not stand above the main surface conspicuously as the top step does above it. It is most distinct between Peel and Arctic Red Rivers, where it extends more than 50 miles north from the front of Mackenzie Mountains. Areas of hills between Snake River and Trevor Range appear to represent the level of the middle step.

The top step consists of a group of undulating plateaux separated, by a broad, poorly defined valley, from Mackenzie Mountains to the south. These plateaux are composed of horizontal strata whose bedding shows conspicuously on the bare upper slopes around their promontories. They have rounded profiles, are dissected by V-shaped valleys, exhibit no sculpturing by glaciation, and are evidently the remnants of a large continuous area of horizontal strata formerly capping this part of Peel Plateau.

In the southwest part of Peel Plateau the hills standing above its main surface, such as Trevor Range, appear to be formed of folded resistant strata extending along structures trending northwest from Mackenzie Mountains. North and west of Peel River, a few small hill areas closely parallel or diverge southeastward from the front of Richardson Mountains, and north of Caribou River the plateau surface swells into a broad, smooth, gently sloping, dome-like hill about 10 miles long.

In the extreme southwest corner of Peel Plateau a broad, shallow depression, Bonnet Plume Basin, lies between Peel River and the first slopes of the mountains to the south. Its surface is below that of the plateau to the north and east and of the extremity of Porcupine Plateau on the west. A part of it, at least, is underlain by Tertiary strata[1] overlying folded Palæozoic sediments.[2]

The dissection of Peel Plateau is, as a whole, in a youthful stage. The main streams have their heads in the mountains, and have cut their courses to fairly steady grades in canyon-like valleys where their stream beds occupy nearly half the valley floors. The exceptions are where Bonnet Plume and Wind Rivers cross Bonnet Plume Basin. Peel River is 600 to 1,000 feet below the plateau for some hundreds of miles. Its valley varies in different parts of this distance from youthful and canyon-like, where the rock is resistant, to mature and broad in areas of soft rock, and this is also true of some of the other main streams. Between the mouths of Bonnet Plume and Snake Rivers some of the meanders of Peel River are entrenched in the plateau. Two, certainly, and perhaps three stages of entrenchment are recorded by rock terraces in the canyon-like valley of Arctic Red River near where the river leaves the plateau. The heads of the larger streams that gather their waters on the plateau, notably tributaries of Arctic Red River, occupy serpentine courses in broad, shallow valleys, and the streams only become entrenched as they approach the main rivers.

Peel Plateau appears to have been covered by Pleistocene ice except, perhaps, for its highest levels, such as those of the third step, and some small areas, such as the summits of Trevor Range. The scouring effect of glaciation was light. Some areas of the plateau in Yukon, west of Peel River, show no sign of ice action in the air photographs, but others are covered by a thick mantle of drift studded with kettle-holes and lakes. The border of the ice is believed to have been close to the edge of Richardson Mountains. Ice movement seems to have been northwest along Mackenzie River, west on upper Peel River, and north down lower Peel River. The western parts of the plateau seem to have become clear of ice at an earlier date than those in the east, enabling the

[1] Camsell, C.: Peel River and Tributaries; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. CC, p. 24 (1906).

[2] Hume, G. S., and Link, T. A.: Canol Geological Investigations in the Mackenzie Area, Northwest Territories and Yukon; Geol. Surv., Canada, Paper 45-16, p. 62 (1945).

drainage to cut a great canyon-like river course from Arctic Red River drainage basin near Many Beaver Lake across the present watershed to the great bend of Snake River.

## Arctic Mountain Area

Arctic Mountain area is comprised of Richardson and British Mountains, Arctic Plateau, and the Arctic Coastal Plain.[1] It is bordered on the east by Peel Plateau and Mackenzie Delta. On the south it is cut off from Selwyn Mountains by the southeast end of Porcupine Plateau, and on the west and southwest it is bounded by Porcupine Plain.

The Arctic Coastal Plain is here included in the Arctic Mountain area to complete the description of the physiography west of Mackenzie Delta, though perhaps it is not part of the Cordillera.

As in other parts of the Eastern system, the Arctic Mountain area is underlain mainly by sedimentary rocks, but small intrusions are known in British Mountains and in the northern part of Richardson Mountains.

### ARCTIC COASTAL PLAIN

The Arctic Ocean is bordered by patches of narrow, low, coastal plain (Plate XIV), bounded on the land side by a scarp of cliffs 20 feet or more high.[2] A second plain or plateau surface extends inland from the top of the scarp and is regarded as the main coastal plain. It rises gently southward for 6 to 12 miles. Small lakes and ponds are spotted over this main, or raised, coastal plain from Mackenzie Delta to Firth River except where the larger streams, such as Blow and Babbage Rivers, have developed flood-plains and deltas as they approach the sea and appear to have obliterated them. West of Firth River they are absent even between the larger streams, and the surface of the plain appears more even than to the east. Many of these lakes and ponds are remnants of lagoons of former shorelines, several of which parallel the coast as far inland as 8 to 10 miles, near Babbage River. Those still farther inland appear to have had a different origin.

### ARCTIC PLATEAU

South of the Arctic Coastal Plain the land rises to a rolling surface and the area it covers is referred to as the Arctic Plateau.

In some parts of its length, particularly east of Babbage River, the boundary between the Arctic Coastal Plain and Arctic Plateau rises as a gentle scarp. Southward the plateau surface sweeps up to the bordering mountain ranges and into the gap between Richardson and British Mountains (Plates XV and XVI) where it is studded with scattered ridges of hills and low mountains, some of which by the general level of their tops suggest the presence of a former higher erosion surface. The ridges in this gap strike northwesterly, fanning out in harmony with the structural trends of the mountains to east and west. These ridges indicate that the plateau is largely underlain by folded strata, probably sedimentary rocks. A few scattered lakes and ponds lie along the valley of Babbage River, which has a relatively narrow course in the plateau. About midway between Richardson and British Mountains, a small, rugged area stands above the plateau (Plate XV), most of it formed of steeply dipping strata striking north.

[1] For continuation westward of the units of the Arctic Mountain area *See* Ebbley, Jr., N: Min. and Met., Sept. 1944, p. 418.

[2] O'Neill, J. J.: Report of the Canadian Arctic Expedition, 1913-18, vol. XI, pt. A, p. 11 (1924).

PLATE XIV

Arctic Coastal Plain: view north over the Arctic Coastal Plain, and showing the east end of Herschel Island in the extreme left background. Photo by Royal Canadian Air Force; negative T29R-35.

PLATE XV

Arctic Plateau: view south over the Arctic Plateau between Richardson and British Mountains. Photo by Royal Canadian Air Force; negative T29L-36.

PLATE XVI

Richardson Mountains: view south from the Arctic Plateau over some of the highest and most rugged parts of Richardson Mountains. Photo by Royal Canadian Air Force; negative T5-22L.

Little information is available on the areas where British Mountains, Arctic Plateau, and Porcupine Plain have common boundaries. The plateau country appears to extend around the southeast end of British Mountains (Plate XVI), and to merge with the areas that rise from the flats of Porcupine Plain. A belt of rolling, hilly country separates the mountains and the plain along the 141st Meridian. In aspect it resembles both Arctic and Porcupine Plateaux, but the presence of intrusions in it just west of the meridian suggests that it is part of Porcupine Plateau, and that it should be placed in the Interior system. The boundary between the Eastern and Interior systems here is, therefore, tentative, and may require considerable revision in the light of more information.

Drainage irregularities show in the air photographs east of Firth River along the northern edge of Arctic Plateau as far as 20 miles from the sea. They include ponds, small lakes, and abandoned drainage channels extending northwesterly across the divides between the present stream valleys. To the south and west beyond Firth River they are not apparent, nor are lakes or ponds present on the second coastal plain. These features are not as fresh as the glacial forms of southern Yukon, due, perhaps, to greater age, generally softer materials, or Arctic conditions of erosion. They are thought by the writer to be of glacial origin, and as such would indicate that the ice pushed westward along the lower part of Arctic Plateau and Arctic Coastal Plain as far as about Firth River, and that Herschel Island may owe its existence to morainic deposits.

### RICHARDSON MOUNTAINS

Richardson Mountains form a remarkably straight, and, except in their broad north end, narrow belt of rough country between Peel Plateau on the east and Porcupine Plain and Arctic Plateau on the west and they form a continuous watershed throughout their length. The greater part of these mountains presents the aspect of closely spaced hills with smooth profiles, broken only here and there by alined outcrops of harder strata crowned by scattered crags. For the most part, Richardson Mountains are no more rugged and are lower than the southern foothills of the Rocky Mountains, which they resemble somewhat in their bare slopes, and their position adjacent to areas of relatively low relief—Mackenzie Delta, Peel Plateau, Arctic Plateau, and Porcupine Plain—is partly responsible for their being termed mountains.

Richardson Mountains have their highest points and greatest width, about 40 miles, west of Mount Goodenough (Plate XVI), and here the central area is truly rugged, containing sharp ridges with steep, rocky slopes and spurs, separated by deep V-shaped valleys. On the flanks of this central area the mountains revert to their typically less rugged character. Here most of the strata appear to dip at angles of 25 to 40 degrees, and many of the ridges are asymmetrical, with gentle dip slopes and steeper faces where the beds are exposed. Towards their northern extremity these mountains form roughly parallel ridges striking north and merging in that direction with the surface of Arctic Plateau. They do not turn westward to parallel the coast, as suggested in some early reports.

Southward from their rugged area, Richardson Mountains narrow to 25 miles at Rat River Portage and to 12 miles opposite Road River. From Vittrekwa River to the south end of the mountains, at Peel River, they continue as a narrow belt. Fifty miles from their north end they become lower, and it is doubtful if any points in them south of Rat River reach an elevation of 4,000 feet. Commonly the mountains have steep, smooth slopes, only few rough outcrops even on their ridge tops (Plate XVII), and some of their ridges are long and even and, viewed from the air, resemble immense road embankments. These

PLATE XVII

Richardson Mountains: view north from the southwest edge of Richardson Mountains. The valley in the foreground was probably occupied by a finger of Pleistocene ice that pushed up the valley northwest from Peel River Valley. Photo by Royal Canadian Air Force; negative T4-80R.

features suggest a former erosion surface truncating their tops. On the west side, Richardson Mountains rise from Porcupine Plain as a belt of low foothills 5 to 10 miles wide. These hills mark the first upturned strata, and are followed by successively higher, steeper ridges as the mountains are entered. On the east the border is more sharply defined, appearing in some views as a scarp, as far south as Vittrekwa River. From there southward spurs of hills diverge southeastward from the main line of the mountain front and disappear in Peel Plateau.

As topographic features Richardson Mountains are distinctly separated from Mackenzie Mountains by Peel Plateau, but at their south end the structural trends seen in the ridges of Richardson Mountains, particularly on the southeast flank, diverge southeastward, and can be traced some distance across Peel Plateau toward ridges between Bonnet Plume and Snake Rivers, suggesting that structurally Richardson Mountains are a northward continuation of Mackenzie Mountains.

The rocks described from Richardson Mountains are sedimentary[1-4]. They include a thick section of sandstones and shales overlying sandstones and quartzites. The upper part at least of this section is of late Mesozoic age. No fossils have been obtained from the lower strata, and the rugged central area of the northern part of the mountains remains completely unexplored from the ground. Except for a small intrusion that will be referred to later, no intrusive rocks are known, though mention of granitic boulders has been made by Ogilvie, Isbister, and Petitot. Air photographs of a rugged area about 6 miles in diameter, at the heads of Little Bell and Rat Rivers north of McDougall Pass, show massive and apparently unstratified rocks. When first noted in the pictures, these were thought to represent an intrusion, but reports deny any float of intrusive rocks in the streams draining from it.[5] A dioritic intrusion is, however, exposed for a width of a quarter of a mile or more on the west side of Mackenzie Delta near Mount Goodenough, and dykes have been found in a few scattered localities along the east side of Richardson Mountains.[6]

No evidence of Pleistocene glaciation was noted in the southern interior of Richardson Mountains. The ice pushed from the east across Peel Plateau and was joined by ice from the south coming from Mackenzie and Selwyn Mountains mainly down the valleys of Snake, Bonnet Plume, and Wind Rivers. This ice moved up Peel River past the south end of Richardson Mountains and spread finger-like glaciers up two tributary valleys to the northwest along the border of the mountains to the edge of Porcupine Plain (Plate XVII).

Along the east side of Richardson Mountains the ice does not seem to have built up moraines, except in parts of Peel Plateau previously mentioned. It may have pushed into McDougall Pass (1,200 feet high) where a few small lakes probably owe their existence to glaciation, though no mention of this origin is made in reports. Camsell gives the maximum elevation of the ice on Mount Goodenough as about 3,000 feet.[7] The ice pushed on north and around the north end of the mountains and northwestward along the Arctic Coastal Plain. If any part of Richardson Mountains suffered Pleistocene alpine glaciation, its action was very light. Excellent pictures of the north sides of Mount Goodenough and

[1] McConnell, R. G.: Report on an Exploration in the Yukon and Mackenzie Basins, N.W.T.; Geol. Surv., Canada, Ann. Rept. vol. IV, pt. D, 1888-89, pp. 27-28, 119-120 (1890).
[2] Ogilvie, W.: Exploratory Survey of Part of the Lewes, Tat-on-duc, Porcupine, Bell, Trout, Peel, and Mackenzie Rivers; Dept. of Interior, 1889, pt. VIII, p. 65 (1890).
[3] Camsell, C.: Report on the Peel River and Tributaries; Geol. Surv., Canada, No. 951, pt. CC, p. 45 (1906).
[4] Hume, G. S., and Link, T. A.: Op. cit., p. 64.
[5] Hamilton, F. J.: personal communication (1945).
[6] Spivak, J.: personal communication, 1946.
[7] Camsell, C.: Peel River and Tributaries; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. CC, p. 40 (1906)

higher peaks to the west show no indication of cirques, the mountain torrents occupying steep, V-shaped valleys with interlocking spurs. Photographs taken on August 4 show very little snow left in these mountains, bearing evidence of the lightness of precipitation.

### BRITISH MOUNTAINS

British Mountains constitute the east end of an extensive mountain region in northern Alaska known as Brooks Range. In Canada, British Mountains rise rather abruptly from Arctic and Porcupine Plateaux on the north and south respectively. Where Arctic Plateau continues around the mountains to the southeast and south it is higher and has more relief, so that, as the elevations of British Mountains decrease gradually in this direction (Plate XVIII), the boundary of the mountains is less distinct than on the north and south. The highest and broadest part of British Mountains in Canada is near the International Boundary, where they have peaks reaching elevations of more than 6,000 feet (Plate XIX). Their ridges are long, and have a general northwesterly, parallel alinement, but they are connected in many places by high, transverse saddles near where they merge with the Arctic Plateau. The ridges at the southeast end of British Mountains bend southward as though to parallel those of Richardson Mountains. British Mountains are traversed by Firth River from southwest to northeast, and an irregular depression, interrupted by isolated ridges, extends northwest from Arctic Plateau close to their axis nearly to Firth River. Several streams cross the depression, and their valleys are connected by broad wind gaps. Throughout these mountains the valleys are deep and V-shaped in cross-section, and air photographs show no sign of alpine or other glaciation. The mountains are composed mainly of sedimentary rocks, but contain small intrusions close to the 141st Meridian.[1]

## INTERIOR SYSTEM

The Interior system forms the great intermediate unit of the three systems of the Canadian Cordillera. It stretches from the Forty-ninth Parallel 1,300 miles northwest nearly to the Arctic Ocean and into Alaska beyond the 141st Meridian. Its average width in Canada is about 200 miles, but it broadens in Yukon to more than 300 miles.

The Interior system is composed of several major and minor mountain and plateau areas, but for much of it these areas are arranged in three pairs of segments transverse to the general trend of the Cordillera. Each pair consists of a mountain area on the east, underlain largely by old rocks, including thick sections of Precambrian sediments and later intrusive rocks, and a less mountainous plateau area on the west, formed to a greater extent, except in the north, of younger rocks and less intrusive material. Beginning in the south, the first of these pairs is the Southern Plateau and Mountain area, composed of Columbia Mountains on the east and the Interior Plateau on the west. The second pair is the Central Plateau and Mountain area composed of Omineca and Cassiar Mountains on the east and Skeena and Hazelton Mountains and Stikine Plateau on the west. In the north, the Northern Plateau and Mountain area is more difficult to subdivide satisfactorily owing to its complexity in both topography and geology, and to the meagre information available for much of it. In its southern part it is composed of a pair somewhat similar to those of the areas to the south, at least topographically, consisting of Selwyn Mountains

[1] Maddren, A. G.: Geologic Investigations along the Canada-Alaska boundary; U.S.G.S., Bull. 520, pp. 297-314 (1912).

PLATE XVIII

British Mountains, Arctic Plateau, and Porcupine Plain: view south from the southeast edge of British Mountains, showing the outer ranges of these mountains in the middleground, and a part of the Arctic Plateau that lies between them and the Old Crow (Porcupine) Plain, spotted with lakes, in the distance. Photo by Royal Canadian Air Force; negative T29L-53.

PLATE XIX

British Mountains: view of British Mountains looking north across Firth River. Photo by Royal Canadian Air Force; negative T15R-77.

on the northeast and Yukon Plateau on the southwest. Yukon Plateau, however, spreads out irregularly to include many and diverse features, and its geology is extremely varied. The remaining northern part of the area includes no defined pair, but is composed of Ogilvie Mountains in the south and Porcupine Plateau and Plain to the north.

Throughout the Interior system the mountains on the east side of each pair of physiographic units are approximately as high as those of the Eastern system to the east or northeast. They constitute a belt of relatively heavy precipitation, commonly known in southern British Columbia as the second wet belt, whereas the plateau areas to the west of the mountains are relatively dry, sheltered as they are by the mountains of the Western system.

## Southern Plateau and Mountain Area

The Southern Plateau and Mountain area consists of Columbia Mountains on the east and the Interior Plateau to the west and northwest. The name Columbia Mountains is here used to embrace the ranges west of the Rocky Mountain Trench and south of the big bend of Fraser River, which together form the mountain unit of the first or most southerly "pair" referred to above. The Interior Plateau comprises the area of southern British Columbia commonly referred to as the belt of Interior Plateaus, or Plateaux, and forms the plateau unit of the same pair. In this report the Southern Plateau and Mountain area is only described at sufficient length to indicate its relation to the present general scheme of Cordilleran subdivision.

### COLUMBIA MOUNTAINS

Columbia Mountains form a great wedge between the Interior Plateau on the west and the Rocky Mountain Trench on the east. They are separable into four major subdivisions, namely, Purcell, Selkirk, Monashee, and Cariboo Mountains, by great diagonal valleys. Columbia Mountains are composed mainly of crystalline rocks—largely altered Precambrian sediments and Mesozoic intrusions. They exhibit more relief than the Rocky Mountains to the east, rising in many places to more than 8,000 feet above their major valley floors. In places remnants of an old erosion surface, probably extending from the Interior Plateau, are apparent in these mountains. The heavy precipitation they receive maintains many ice-fields and glaciers along their main ridges, and in Pleistocene time their valleys were deeply scoured by ice, which reached to near the tops of their lower summits.

### INTERIOR PLATEAU

The Interior Plateau is 30 to 40 miles wide in the south between Monashee and Cascade Mountains. It broadens northward to where it extends from the Coast Mountains on the west 200 miles eastward around Cariboo Mountains to the Rocky Mountain Trench, occupying the entire distance between the Eastern and Western mountain systems. Its northwest boundary, 500 miles from the Forty-ninth Parallel, follows an irregular line from Morice Lake in the southwest to the trench 40 miles south of Finlay Forks in the northeast. The plateau is drained mainly by Fraser River, but parts also drain to Skeena and Peace Rivers in the north, and Columbia River in the south.

The Interior Plateau consists essentially of rolling uplands separated from each other by deep valleys. In its southern part the upland, an old erosion surface, lies from 4,000 to 6,000 feet above sea-level, but decreases in elevation and relief northward. North of the fifty-fourth parallel it is 3,500 to 5,000 feet high, and for more than 60 miles north of Nechako River only a few points reach an elevation of 5,000 feet.

The Interior Plateau is divisible into two parts, Fraser Plateau in the south and Nechako Plateau in the north. No very distinct features separate them, but their boundary is placed at about the fifty-third parallel. In Fraser Plateau the upland surface is high and the main valley floors are low, presenting a greater relief than in Nechako Plateau to the north. This general difference in relief is the most notable distinguishing characteristic.

In Nechako Plateau the valleys are broad, and the divides are composed of rounded hills that seldom reach more than 1,000 feet above the surrounding country. A plain with a general elevation of 2,300 feet occupies a large area between Fort St. James on the west and Prince George on the southeast. In this plain the main river valleys are broad and shallow, and the courses of their streams are entrenched in narrow inner valleys 50 to 400 feet below the general level of the plain.[1] Towards the north boundary of the plateau the hills are higher, and distinct areas of upland occur at elevations of 4,000 to 5,000 feet, but the valleys occupy the larger areas. Thus, the greater part of Nechako Plateau is cut below the upland surface apparent on the adjacent mountains and on isolated high areas within it. The border between the plateau and the mountains to the north is drawn where mountains occupy considerable areas above the upland surface and the valleys below this surface no longer form the larger areas. This is an arbitrary position, as the upland surface continues to be a notable feature of the southern parts of Omineca, Skeena, and Hazelton Mountains to the north and northwest.

To the east, south, and west of the Interior Plateau the upland surface rises towards the bordering mountains, and in places can be traced far into them, so that here, too, as in many other places in the Cordillera, the boundaries between plateaux and mountains must be placed arbitrarily within ill-defined zones.

In most parts of Fraser and Nechako Plateaux monadnocks stand on the upland as isolated mountains or small ranges of mountains. In a few places in the western part the surface appears to be warped into domes that may be structural or may be volcanic accumulations resting on the upland surface. These "domes" have been partly dissected into mountains above the surrounding plateau, as for instance, Ilgachuz Range.

The present, generally low precipitation of the Interior system was probably also a feature of Pleistocene time. The entire Interior Plateau appears to have been covered by ice that moved into it from neighbouring areas of high precipitation. At its maximum the ice moved in southerly directions in Fraser Plateau and eastward in Nechako Plateau.[1]

## Central Plateau and Mountain Area

A great expanse of mountains and plateaux lies between the Eastern and Western systems, and between the Southern and the Northern Plateau and Mountain areas of the Interior system. It constitutes the Central Plateau and Mountain area, consisting of a well-defined eastern mountain belt, Omineca and Cassiar Mountains, and a western area of mountains and plateaux, Skeena and Hazelton Mountains and Stikine Plateau.

[1] Armstrong, J. E.: Geol. Surv., Canada, personal communication (1946).

The Central and Northern Plateau and the Mountain areas have no distinct dividing line, the Central area being a southward extension of the larger area to the north. The boundary between them is drawn arbitrarily along the edges of their subdivisions, and approximates the sixtieth parallel.

### OMINECA AND CASSIAR MOUNTAINS

Omineca and Cassiar Mountains constitute essentially a continuous belt of mountains stretching northwest along the west side of the Rocky Mountain Trench and Liard Plain from the Interior Plateau to Yukon Plateau. The belt is bordered on the south and west by Nechako Plateau, Skeena Mountains, and Stikine and Nisutlin Plateaux. The Omineca-Cassiar batholith of granitic rocks forms the backbone of these mountains. Though several of the main streams draining them head at or beyond the west boundary and flow eastward through the mountains, no features serve to separate the belt into distinct subdivisions, but it has been found practicable to draw the boundary between the Omineca Mountains and the Cassiar Mountains at the valley of Finlay River where the chain is appreciably narrower than elsewhere in its length.

The boundaries between the mountains and the plateaux to the west are indefinite, and the positions indicated on the map are debatable in many places. For instance, in the Dease Lake[1] country, it is drawn east of Dease Lake, though this places mountains in the plateau areas. Farther south the mountain area is shown bulging southwest to include part of Hotailuh and Three Sisters Ranges, though considerable areas of plateau lie northeast of them.

The heads of Stikine River reach the western slopes of Omineca and Cassiar Mountains for about half their length, but except for Pitman and Chukachida Rivers, which head near the axis of the mountains, do not penetrate them for more than a few miles.

#### *Omineca Mountains*

Omineca Mountains comprise three main divisions, Finlay, Swannell, and Hogem Ranges.

*Finlay Ranges.* On the east along the Rocky Mountain Trench, Finlay Ranges include Wolverine, Butler, and Russel Ranges. These are separable from Swannell Ranges to the west along a line from near Manson creek north up Pelly Creek and thence to Finlay River. Finlay Ranges are notable for the smooth profiles that characterize their slopes and most of their summits in contrast with the ruggedness of other parts of Omineca Mountains. The general plan of each of their main ranges shows a single backbone ridge approximately parallel with the Rocky Mountain Trench with spurs projecting normally from it. Except for a small granitic stock between Mesilinka and Swannell Rivers they are composed mainly of Precambrian and Palæozoic sedimentary rocks, with areas of Mesozoic strata along their west flank. The only glacier noted is near Swannell River, and as a whole the ranges show only little evidence of glacial erosion.

*Swannell Ranges.* West of Finlay Ranges, Swannell Ranges, comprising Tenakihi, Ingenika, and other, unnamed ranges west of Russel Range, are extremely rugged, and are mainly composed of the rocks of the Omineca-Cassiar batholith, flanked on the west by, mainly, Mesozoic and Upper Palæozoic strata and on the east by Mesozoic, Palæozoic, and Precambrian strata. Many of their peaks are more than 8,000 feet high, and these contain many small ice-

[1] Kerr, F. A.: Dease Lake Area; Geol. Surv. ,Canada, Sum. Rept. 1925, pt. A, p. 77 (1926).

fields and glaciers. The valleys between the ranges are large, and many of their valley floors are from 4,000 feet to nearly 5,000 feet above sea-level. The valleys form an irregular, somewhat rectangular pattern, with a main northwesterly trend, the mountains standing in groups among them rather than as long ridges. Remnants of a former erosion surface show in only a few places, notably along the west side approaching Spatsizi Plateau and south of Thutade Lake. The mountains appear to occupy an area that had marked relief before the advent of Pleistocene ice, which served further to increase this relief and ruggedness. The valleys are heavily scoured, and alpine glaciation was general but relatively light on the eastern slope of the mountains. At the headwaters of Ingenika River glacial erratics have been found to elevations of 7,200 feet.[1]

*Hogem Ranges.* Hogem Ranges are separated from Swannell Ranges along an irregular boundary from Manson River on the west side of Wolverine Range northwestward up Omineca River and beyond to near the south end of Thutade Lake. The geology of Swannell and Hogem Ranges is much the same, but less of the batholith is exposed in Hogem Ranges, and large areas of flat-lying Cretaceous rocks form plateaux in their northern parts. Peaks in Hogem Ranges, however, have lower elevations, and extensive areas of an old erosion surface, stepped up above the general level of Nechako Plateau, remain around their higher parts. Along the southern edge of the ranges, near Tchentlo and Chuchi Lakes, this surface is so extensive that it is questionable whether a large part of these ranges would not be more correctly referred to as a separate plateau. The general aspect, however, is that of mountains, and no suitable division could be found. In the western part of Hogem Ranges glacial striæ and erratics found on summits more than 6,000 feet high indicate that the general movement of the ice was from west to east.[2] The only alpine glaciers are on Comb Peak, but cirques occur in many parts of the mountains.

### *Cassiar Mountains*

Cassiar Mountains, in their general features, are the northward continuation of Omineca Mountains. They are divided here into Stikine Ranges and Kechika Ranges, and a fringe of plateau country, Dease Plateau, is included with them.

*Kechika Ranges.* Along the Rocky Mountain Trench, Kechika Ranges are the northward extension of Finlay Ranges, and like them consist of more or less parallel ridges with moderately even summits, and are composed of old sedimentary rocks, here mainly of Palæozoic age. The only intrusive rocks known are those of a small stock at their south end. Kechika Ranges contain no glaciers, and appear to have been relatively lightly glaciated in Pleistocene time.[3]

*Stikine Ranges.* Stikine Ranges are separated from Kechika Ranges along a line from Obo River north through to Dall Lake Valley, down Turnagain River to Sandpile Creek, and thence to Red River. The batholithic core apparently continues throughout their length, flanked by the same belts of strata as in Omineca Mountains to the south. Stikine Ranges also show the same type of drainage pattern, and the tendency to grouping rather than alinement of peaks.

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[1] Lord, C. S.: Geol. Surv., Canada, personal communication (1946).

[2] Armstrong, J. E.: Geol. Surv., Canada, personal communication (1946).

[3] Hedley, M. S., and Holland, S. S.: Reconnaissance in the Area of Turnagain and Upper Kecheka Rivers, Northern British Columbia; B.C. Dept. Mines, Bull. No. 12, 1941.

Remnants of a plateau surface are noticeable along the westerly flank of the mountains and become progressively apparent northward, appearing on both sides beyond Turnagain River.

On the west side of Stikine Ranges the area at the head of Turnagain River containing Three Sisters Range consists, to a notable extent, of plateau country, and a part of it would be placed in Stikine Plateaux were it not for Three Sisters Range. Near the sixtieth parallel, at the heads of Jennings, Tuya, and Blue Rivers, the upland surface of the bordering plateaux has only begun to be dissected, and the entrenchment of the valleys has not yet reached the foot of the mountains. The valleys between the mountains extend with gentle, flattening grade into the plateau, where they are open and shallow. The mountain spurs between the valleys slope down to the undulating hills of the plateau without break in their profiles. Thus this area lacks the deeply entrenched valleys that are such a characteristic feature of most of these ranges, and of the Canadian Cordillera as a whole.

Farther north, between the heads of Swift and Rancheria Rivers, the valleys are entrenched below the plateau surface as in the south, but at the northern extremity of these ranges the stream heads are again at the level of the old surface that surrounds the mountains.

Small alpine glaciers exist in the southern part of Stikine Ranges. In Pleistocene time the ice covered them to an elevation of 6,500 feet. The upper levels show only light glacial erosion, but the main valleys are deeply scoured[1].

*Dease Plateau.* On the northeast side of Stikine Ranges, the place of Kechika Ranges is taken by a belt of lower, even-topped summits, which constitutes Dease Plateau. The plateau as a whole resembles a partly dissected "terrace" in front of Stikine Ranges overlooking Liard Plain, and in places, notably in the north, its front stands distinctly above the surface of the plain. The plateau is intersected by the valleys of the tributaries of Liard River emerging from the mountains, and holds on its surface isolated mountains or groups of mountains. Its upland surface appears to be one with that of Nisutlin Plateau to the north.

## SKEENA AND HAZELTON MOUNTAINS AND STIKINE PLATEAU

Skeena and Hazelton Mountains and Stikine Plateau occupy the space between Omineca and Cassiar Mountains and the Western system, with the Interior Plateau bounding them on the south and Yukon Plateau on the north.

This unit is made up of Stikine Plateau in the north, Skeena Mountains in the south, and Hazelton Mountains in the southwest. Nass Basin, which forms a separate feature, is grouped with these mountains.

### *Hazelton Mountains*

Hazelton Mountains comprise Bulkley and Nass Ranges. The former[2] constitutes the southern end of the unit, and they stand encompassed by great valleys on the northwest, north, and east, and emerge with Nechako Plateau in the south and with the Coast Mountains on the southwest. On the northwest these mountains stand close to the Coast Mountains, from which they are separated by the valley of Zymoetz and Clore Rivers. On the east they are separated from Skeena Mountains by Bulkley Valley. To the north, across

[1] Johnston, W. A.: Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 37-48 (1926).
[2] Kerr, F. A.: The Physiography of the Cordilleran Region of Northern British Columbia and Adjacent Areas; Trans. Roy. Soc., Canada, 3d. ser., vol. XXX, sec. IV, p. 145 (1936).

Skeena Valley, Nass Range stands in a similar position, separated from the Coast Mountains by a major valley that extends north from Skeena Valley along Cedar and Tseax Rivers to join the valley of Nass River.

Bulkley and Nass Ranges contain peaks more than 8,000 feet high, and several ice-fields and glaciers. The southern part of Bulkley Range slopes to lower elevations on approaching Nechako Plateau.

*Nass Basin*

Nass Basin is a large depression lying north of Nass Range and against the Coast Mountains. It is a great, timber-covered valley more than 20 miles wide. Its floor is rolling and some of the hills on it reach elevations of about 4,000 feet. On all sides mountains slope steeply into the basin except on the north where an old erosion surface apparent on the hill summits of the basin rises to those at the south end of Strata Range in Skeena Mountains. Several large valleys open into the basin; those from the west, north, and northeast are deep and narrow, but in the south Nass and Kispiox Rivers flow from it by very broad valleys.

*Skeena Mountains*

Skeena Mountains include many ranges, most of which have established names such as Babine, Atna, Sicintine, Tatlatui, Slamgeesh, Strata, Klappan, and Eaglenest. These ranges are closely spaced, but distinct, being separated by a network of valleys, of which the main ones trend northwest and are broad and deep. In several places they are continuous through these mountains, with low divides between the Stikine drainage and that of Nass and Skeena Rivers. The main ridges and ranges parallel this general direction, and narrower, deep, transverse valleys cut across them, particularly in their easterly part, developing, thereby, a nearly rectangular drainage pattern. Some of the transverse valleys are occupied by master streams, showing striking instances of lack of drainage adjustment.

The higher peaks of most of these ranges reach to 8,000 feet. They present a skyline of rugged peaks showing a general uniformity of elevation. Remnants of one or more old, undulating erosion surfaces are apparent in parts of these mountains. In some places a surface is tangential to the tops of the peaks, and a lower surface is apparent in the nearly uniform elevation of many high spurs and saddles. Along the northern border of the mountains a surface is more apparent than elsewhere, truncating many of the higher peaks in the interior of these mountains and gradually losing elevation to merge with that of Stikine Plateau. On the east this surface appears to be the same as that in the southern ranges of Omineca Mountains and the northern eminences of Nechako Plateau.

Between Skeena and Coast Mountains a narrow tract of lower country exhibiting a rolling surface characteristic of plateaux extends up Bell-Irving River from Nass Basin to the valley of Iskut River and thence north along this valley to where it merges with Stikine Plateau.

Skeena Mountains are composed almost entirely of Mesozoic sedimentary and volcanic rocks, with small intrusions in places and Tertiary volcanic rocks along their northern border.

During Pleistocene time the ice covered wide areas of Skeena Mountains, and their lower levels and main valleys were much scoured. In the southeastern part of these mountains there is evidence of a marked decrease in the intensity of ice action above elevations of 5,000 to 5,500 feet on the ridges, but the valleys suffered much alpine glaciation.[1] At present ice-fields and glaciers are scattered through nearly all their ranges, though few of them are judged to be more than 3 miles long.

*Stikine Plateau*

Stikine Plateau is a great area of plateaux drained largely by Stikine and Taku Rivers. It is bounded on three sides by mountains and extends northwestward to join with Yukon Plateau in forming a great belt of plateau country spreading on through Alaska. The boundary between Stikine and Yukon Plateaux is drawn for convenience along an arbitrary line from the south end of Atlin Lake to the south end of Teslin Lake, so that except for small areas near these lakes no part of Stikine Plateau is drained by Yukon River.

Stikine Plateau is comprised of several parts, each a plateau in itself. These are Spatsizi, Klastline, Nahlin, Tanzilla, Kawdy, and Taku Plateaux. Spatsizi Plateau forms a distinct area projecting southeastward along the drainage of upper Stikine River between Cassiar and Omineca Mountains and Skeena Mountains. The other plateaux lying adjacent to one another are not such distinct units.

Nearly all of Stikine Plateau was covered by Pleistocene ice to a height of about 6,500 feet, only a few isolated mountains in the plateau areas being high enough to project above it.[2] Today the glacier on Edziza Peak is the only one worthy of note within the general area of the plateau.

*Spatsizi Plateau.* This occupies a broad basin between Omineca and Cassiar Mountains on the northeast and Skeena Mountains on the southwest. It consists of several tablelands, or individual plateau units, which are in a youthful stage of dissection (Plate XX), and are separated from each other by a network of large valleys.[3] This is particularly typical of the plateau on the south side of Stikine Valley. The surface of the tablelands is gently undulating, and most of it is above timber-line, which has an elevation of nearly 4,500 feet. The valleys that separate the tablelands are deep and U-shaped, and extend from the mountains to the south towards the main valley of Stikine River. Several of the tablelands are broad, and for more than 20 miles across them streams occupy only shallow open valleys. Except for short distances in the lower parts of the streams draining from them, dissection of some of these tablelands has hardly begun. Scattered, rounded hills and several isolated mountains stand up prominently above the plateau surface of the tablelands. Southwestward and towards Thutade Lake the level of the plateau rises. Areas between the major valleys become smaller; their surfaces have more relief; and rough mountains standing above the plateau surface take up more and more space. The boundary between the plateau and the mountains is unusually indefinite. Patches of country dominated by the undulating surface of the plateau are still apparent southeast of Thutade Lake and in places along a narrow belt southwest of the lake connecting with areas in Hogem Ranges. The northeast side of Spatsizi Plateau is more dissected and rises more rapidly from the entrenched valley of Stikine River to Omineca and Cassiar Mountains. Westward the plateau is continuous into Stikine Plateau beyond the narrow neck formed by Eaglenest and Three Sisters Ranges.

[1] Armstrong, J. E.: Geol. Surv., Canada, personal communication (1946).

[2] Johnston, W. A.: Gold Placers of Dease Lake Area, Cassiar District, B.C.; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 47-48 (1926).

[3] "Tableland" is used here and later in referring to broad, youthfully dissected uplands of either horizontal or complex structure.

PLATE XX

Spatsizi Plateau, Stikine Plateau: view northeast over Laslui Lake at head of Stikine River and across Spatsizi Plateau and main Stikine Valley to Cassiar Mountains in the distance; the border of Skeena Mountains is in the immediate foreground. Photo by United States Army Air Force; negative 37 2-R 117 2-2010.

Spatsizi Plateau is composed of flat-lying strata, mainly sediments, found to the southeast to range through the upper parts of Cretaceous into Paleocene time.[1] Along the southwest side of the plateau adjacent to Skeena Mountains these strata are upturned and crumpled along a persistent fault zone several miles wide that extends through Thutade Lake northwestward to Stikine River.

*Klastline Plateau.* This plateau lies between Stikine River Valley on the north and Skeena and Coast Mountains on the east, south, and west. It is similar to the adjacent Spatsizi Plateau, though its tablelands are not as distinctive and extensive as those to the east, and its surface is more irregular. The area is more dissected by major valleys. On the west side, adjoining the Coast Mountains, Edziza Peak rises prominently to an elevation of more than 9,100 feet at the north end of a high relatively even-topped ridge. This mountain is a broad, glacier capped volcanic pile.[2] From the ridge the lava surface spreads northward, sloping to plateau level and filling parts of the adjacent valleys. The evenness of the lava surface on the slopes of Edziza Mountain is broken by several small volcanic cones, one of which is remarkable for its perfect symmetry and lack of erosion. Viewed from above, the surface of the slopes of Edziza Mountain shows clearly the original pattern of the lava as it flowed from its vents, only slightly modified, if at all, by subsequent erosion.

In the western part of Klastline Plateau the Cretaceous rocks that make up most of its east side are replaced by older Mesozoic and some late Palæozoic sediments and volcanic rocks as well as granitic intrusions, all of which underlie the lavas.

*Tanzilla Plateau.* Tanzilla Plateau stands between Tuya River on the west, Stikine River on the southwest, and Stikine Ranges on the northeast. In its northern part, starting from these river valleys, it rises toward the ranges as a broad, smooth surface to where it approaches Dease Lake[3,4], and then becomes undulating and is broken by isolated mountains and groups of peaks that reach elevations of more than 6,000 feet. The plateau continues east of Dease Lake for several miles to Stikine Ranges, and Dease Lake and the valleys of the lake and Tanzilla and Stikine Rivers are deeply entrenched below it. South of the lake Hotailah Range also stands on its surface. Commencing at Tuya Lake, at an elevation of about 3,500 feet, the valley of Tuya River cuts into the plateau whose even surface continues westward on Kawdy and Nahlin Plateaux.

*Nahlin Plateau.* This plateau is bordered by Tuya River on the east, Sheslay River on the west, and Nahlin River on the north. It is a broad tableland of nearly horizontal lava flows with a small mountain range, Level Mountain, near its centre. The surface of the tableland is approximately 4,000 feet high. It is remarkably flat and much of it is poorly drained. The heads of the streams flow in very shallow valleys on the surface of the plateau, and do not cut down into it until they approach the major valleys. The evenness of the surface of this plateau, and to a less extent the other units of Stikine Plateau adjacent to it, may be partly due to the filling of the valleys by volcanic rocks of Tertiary to Recent age, which form much of Stikine Plateau. Level Mountain rises above the plateau surface, reaching an elevation of nearly 6,000 feet, and is

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[1] Lord, C. S.: Geol. Surv., Canada, personal communication.
[2] Kerr, F. A.: The Physiography of the Cordilleran Region of Northern British Columbia and Adjacent Areas; Trans. Roy. Soc., Canada, 3rd ser., vol. XXX, sec. IV, p. 143 (1936).
[3] Johnston, W. A.: Gold Placers of Dease Lake Area, Cassiar District, B.C.; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 44 (1926).
[4] Kerr, F. A.: Dease Lake Area, Cassiar District, B.C.; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 77 (1926).

reported to be carved from flat-lying lavas.[1] Viewed in the distance in photographs, this range stands prominently above the plateau, and is probably a centre of extrusion.

*Kawdy Plateau.* Northeast of Nahlin River, whose valley is cut deeply into the lavas, exposing the underlying rocks, Kawdy Plateau[2] occupies a large area stretching to the northeast, west of Tuya River (Plate XXIII). It is very like Nahlin Plateau, much of it being remarkably flat and quite undissected. The same group of flat-lying lavas as on Nahlin Plateau are the rocks of a large part of its surface, though here these rocks appear to be only a thin veneer over older rocks, which also outcrop in places. Several mountains of volcanic rocks, some having mesa-like forms, rise above its surface to elevations, in some places, of more than 6,000 feet. Most of its surface is 4,000 to 4,500 feet high, treeless, drift covered, and dotted with small lakes and swamps.

Northeastward, Kawdy Plateau extends in among the ranges of Cassiar Mountains. To the north it rises slightly, and is broken by Atsutla Range, which is regarded as an outlier of Cassiar Mountains. On the southeast it is separated from Tanzilla Plateau by Tuya River Valley. West of Kawdy Plateau the south end of the valley of Teslin Lake is flat-floored, 8 to 10 miles wide, and covered by numerous ponds and lakes up to 3 miles long, among which a few hills stand out conspicuously. The floor is between 2,300 and 3,000 feet high and fully 1,000 feet below the surface of the adjacent plateau, which rises steeply above it.

*Taku Plateau.* A rudely triangular area of plateau country bounded by Sheslay River, the Coast Mountains, and the north boundary of Stikine Plateau, is drained by Taku River, and is referred to as Taku Plateau. This area is transitional between the remarkably distinct Nahlin and Kawdy Plateaux and the higher, more broken Teslin Plateau, the southern unit of Yukon Plateau.[3]

## Northern Plateau and Mountain Area

In the Northern Plateau and Mountain area, the Interior system broadens to its greatest width and contains its most diversified features. It consists of two major elements, a great mountainous tract, Selwyn and Ogilvie Mountains, and a lower, more extensive plateau tract, Yukon Plateau. The former is, perhaps, the least known part of the Canadian Cordillera, as only a few explorations have been recorded, and much of Selwyn Mountains and most of Ogilvie Mountains have not been photographed. South of the sixty-fourth parallel Yukon Plateau is, however, one of the better known parts of the Interior system. A large part of it has been covered by topographical maps on scales of 1 inch to 4 miles, or larger, with 500-foot contours, and more than 24,000 square miles have been geologically mapped on the same scales.

In Canada, Ogilvie Mountains cut off the northern extremity of Yukon Plateau, composed of Porcupine Plateau and Plain, but in Alaska, west of the 141st Meridian, the plateau country sweeps westward and around the end of Ogilvie Mountains to join and include this otherwise isolated area of plateau country.

In the southeast corner of the Northern Plateau and Mountain area, Liard Plain lies as an isolated unit of the Cordillera without any diagnostic feature to determine its association with any one of the adjacent systems or areas. It is, consequently, included here solely for convenience.

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[1] Watson, K. DeP., and Mathews, W. H.: The Tuya-Teslin Area, Northern British Columbia; B.C. Dept. of Mines, Bull. No. 19, 1944.

[2] Watson, K. DeP., and Mathews, W. H.: Op. cit., p. 47.

[3] Cockfield, W. E.: Explorations between Atlin and Telegraph Creek, B.C.; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 25 (1926).

Hyland Plateau lies adjacent to Liard Plain on the north. Though as a plateau it shows many resemblances to Yukon Plateau, it is isolated from it by Selwyn Mountains and so treated separately. In its rocks and drainage pattern it appears to be more closely associated with these mountains than with other adjacent units.

### LIARD PLAIN

Liard Plain is a large basin, for the most part less than 3,000 feet high, with much of its central area at an elevation of about 2,200 feet (Plate XXI). It is rimmed on all sides by plateaux and mountains, and from them the tributaries of Liard River flow onto the plain from all directions except the east. Liard River and its main tributaries have entrenched their courses in narrow valleys below the general level of Liard Plain to a degree that in less mountainous regions would raise this unit to the status of a plateau, but here, with the relief of the plateaux around it measured in thousands of feet and its own in hundreds of feet, there is no question of its classification as a plain. It is an area of low, wooded hills with broad timbered flats between, and is underlain by Palæozoic sedimentary rocks on which lie basins of Tertiary lavas and coal-bearing strata[1,2]. The greater part of its lower areas is mantled by thick deposits of glacial drift for which it formed a general area of deposition during the close of Pleistocene time. The drift is more than 200 feet thick in many places. Glacial and post-Glacial stream courses, marked by eskers, abandoned canyons, and broad gravel beds (Plate XXI) extend across it southward towards Liard River and eastward on both sides of the river, but notably on the north side.

### HYLAND PLATEAU

As mentioned in the description of Liard Plateau, there are fundamental differences of geological structure and topography between Hyland and Liard Plateaux. The surface of Hyland Plateau bears a distinct resemblance to parts of those plateaux that make up Yukon Plateau, notably Pelly Plateau. Granitic intrusions are reported in it and in Logan Mountains to the north, and the drainage of these mountains continues across the plateau without noticeable change of pattern. These factors serve to separate Hyland Plateau from Liard Plateau to the east, and place it in the Interior system in close relationship to the entire area of Selwyn Mountains, despite the fact that the surfaces of these two plateaux are more or less continuous and without marked change in elevation. The boundary, however, is roughly discernible along a persistent line running north from Toobally Lakes.

The surface of Hyland Plateau is formed of rolling hills rising to an elevation of 4,000 feet, and of broad valleys showing structural alinement in only a few places. Along the southern border of the plateau the surface merges with that of Liard Plain along a slightly steepening slope. West of Rock River four mountain groups stand in line above the plateau a few miles north of its southern boundary, and emphasize its general increase in relief from that of the plain. These hills rise to between 5,000 and 6,000 feet above sea-level, and are separated by broad valleys, including those of Hyland and Coal Rivers. Northwestward the general surface of the plateau rises towards Logan Mountains. Hyland, Coal, and Rock Rivers emerge from these mountains in broad, nearly straight valleys, between ridges. In the plateau the ridges

[1] Williams, M. Y.: Geological Investigations along the Alaska Highway from Fort Nelson, British Columbia, to Watson Lake, Yukon; Geol. Surv., Canada, Paper 44-28 (1944).

[2] Lord, C. S.: Geological Reconnaissance along the Alaska Highway between Watson Lake and Teslin River, Yukon and British Columbia; Geol. Surv., Canada, Paper 44-25 (1944).

PLATE XXI

Liard Plain: view looking southeast over Liard Plain. In the distance, on the left is Hyland River, which flows from left to right to join Liard River. The first ridges of the Rocky Mountains are in the far distance. Elevation of camera, 13,000 feet. Photo by Royal Canadian Air Force; negative T17L-51.

rise steadily northward to the mountains, the boundary being drawn across the ridges along a northeasterly trending line that marks the approximate position where the plateau surface is replaced by one of higher, steeper undulations on the tops of the ridges. This line is remarkably straight, though it follows no distinct break either on the ridges or in the valleys between. In the northeast corner of the plateau the topography is more broken and has greater relief where the plateau is drained by tributaries of South Nahanni River.

No account of any exploration is available of Hyland Plateau and the only information of its geology must be deduced from adjacent areas or from reports of prospectors. All parts of Hyland Plateau were overridden by Pleistocene ice, but in contrast with Liard Plateau, which appears to be relatively lacking in drift deposits, Hyland Plateau, like Liard Plain, was an area of deposition. A mantle of glacial drift is spread over much of it, and great trains of glacial outwash clog the floors of the main valleys.

## SELWYN MOUNTAINS

Selwyn Mountains rise above Yukon Plateau along an irregular front, and embayments of the plateau country extend far into them, notably in the area along the border between Hess and Logan Mountains.

So far as known, Selwyn Mountains are formed of much the same rocks as adjacent parts of the plateau, including Precambrian, Palæozoic, and Mesozoic strata, and intrusive rocks, the last serving to distinguish them from Mackenzie Mountains to the east. Like their counterparts to the south—Columbia, Omineca, and Cassiar Mountains—Selwyn Mountains mark a belt of relatively high precipitation. Their northeastern boundary is that between the Eastern and Interior systems in these latitudes, and has already been described.

Only a few accounts of explorations in Selwyn Mountains have been published. In 1902, McConnell, with Keele as his assistant, explored their border on the upper part of Macmillan River[1]. In 1905 Keele explored their edges around the heads of Stewart River[2], and Camsell traversed their northwestern parts by Braine Pass[3]. In 1907 and 1908 Keele crossed Selwyn Mountains by way of Ross and Keele Rivers[4]. Later, in 1924, Cockfield mapped a small part at the head of Beaver River[5]. Air photographs as yet only cover these mountains to a little north of the sixty-fourth parallel, except for a few flights east of Bonnet Plume Lake taken while the snow was on the ground.

Selwyn Mountains are divisible into three major parts: Logan Mountains, approximately south of Ross River; Hess Mountains, between Ross and Stewart Rivers; and Wernecke Mountains, from Stewart River to Hart River, or thereabouts.

### *Logan Mountains*

Logan Mountains are divided into two groups of ranges approximately along latitude 62 degrees 30 minutes, the group to the south being compact and rugged as compared with the other (Plate XXII).

[1] McConnell, R. G.: The Macmillan River, Yukon District; Geol. Surv., Canada, Sum. Rept. 1902, pt. A, pp. 22-38.
[2] Keele, J.: Report on the Upper Stewart River Region, Yukon; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. C, pp. 1-23 (1906).
[3] Camsell, C.: Report on the Peel River and Tributaries, Yukon and Mackenzie; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. CC, pp. 1-49 (1906).
[4] Keele, J.: A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers; Geol. Surv., Canada, Pub. No. 1097, pp. 1-54 (1910).
[5] Cockfield, W. E.: Upper Beaver River Area, Mayo District, Yukon; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 1-18 (1925).

PLATE XXII

Logan Mountains: view southeast across Logan Mountains showing Brintnell Lake on the left centre and South Nahanni River on the extreme left. Photo by Royal Canadian Air Force; negative T22L-81.

On the west side of the southern group the mountains rise abruptly along the valley of Frances River and Frances Lake to elevations of more than 8,000 feet, and peaks of about the same height or higher occur at intervals eastward within the group, a few more than 9,000 feet high being reported near South Nahanni River. The drainage of the southern group is radial from a watershed in the northwestern part, from which the streams flow northwest to Pelly River, southwest to Frances River, south by Hyland and Coal Rivers to Liard River, and north, east, and southeast by South Nahanni River to the Liard. Hyland and Coal Rivers and their tributaries reach northward through the central part of the group and divide it into several broad northerly trending ranges, at the southern ends of which are remnants of an undulating surface that disappear northward as the elevations of the peaks increase. The river valleys are deeply entrenched between the ranges, and their floors are a mile or so wide in the central part of the group and widen southward. In Pleistocene time these valleys were scoured in their northern parts, which are relatively bare of drift, but farther south are widely strewn with glacial deposits. The higher parts of this southern group have been much carved by alpine glaciers, and today they contain many small glaciers and ice-fields, two or three more than 3 miles wide.

The western front of Logan Mountains northward from Frances Lake becomes first broken by big valleys and then indented by broad embayments of plateau that isolate the ranges. North of the arbitrary line between the two groups this isolation is marked, and the general elevation of the mountain peaks is somewhat lower. The part of the northern group between Pelly, Ross, and South Nahanni Rivers is a broad ridge of highlands much of which is covered by the old erosion surface of the adjacent Pelly Plateau. In this part the valleys of the main streams are shallowly entrenched below the plateau surface, and the mountains project above the surface back from the rims of the valleys. To the east South Nahanni Valley is entrenched below the plateau surface, but the latter continues northeast of the valley and covers a large area around O'Grady Lake. The upper part of South Nahanni Valley is relatively open and shallow and the mountains stand back on both sides. Downstream, to the southeast, the valley deepens and narrows, and the mountains increase in elevation and close in on both sides as it enters the southern group of Logan ranges.

Most of Logan Mountains has been covered by air photographs, but no written account of ground exploration is available, except along their western border from Frances Lake southward[1]. Their western front range has a core of large granitic intrusions. In their southeast part two large granitic intrusions are reported by prospectors, and others are reported at the heads of Ross, South Nahanni, and Keele Rivers[2,3]. In their central part and northwest of Brintnell Lake intrusions of light-coloured rock are apparent in the photographs. As a whole, and in great contrast with the adjacent Mackenzie Mountains, stratification is seldom apparent, although the intrusions are surrounded by rocks believed to be mainly of sedimentary origin, and of Palæozoic and Precambrian ages.

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[1] Dawson, G. M.: Report on an Exploration in the Yukon District, N.W.T., and adjacent Northern Portion of British Columbia, 1887; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. I, Rept. B, pp. 108-114 (1889).

[2] Keele, J.: A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, Yukon and Northwest Territories; Geol. Surv., Canada, Pub. No. 1097, p. 41 (1910).

[3] Kindle, E. D.: Geological Reconnaissance along the Canol Road, from Teslin River to Macmillan Pass, Yukon; Geol. Surv., Canada, Paper 45-21 (1945).

*Hess Mountains*

Hess Mountains constitute a group of ranges separated by a network of big valleys (Plate XXIII) and depressions that trend approximately north 60 degrees east and north 55 degrees west. The ranges are composed of rugged mountains, but in many places around their borders and in the valleys between them remnants of an old erosion surface are apparent. The mountains stand above this surface, which continues westward into Yukon Plateau. Many of their higher peaks are judged to reach elevations in excess of 7,000 feet, and Keele Peak about 8,500 feet above sea-level and standing conspicuously above those around it, is the highest recorded peak. In the northeast part of Hess Mountains a great valley about 50 miles long, in appearance similar to some parts of the Rocky Mountain Trench, trends northwesterly through the mountains from the east slope of Mount Keele to the head of Stewart River. Hess, Rogue, and Stewart Rivers all occupy parts of the floor of this valley, which is close to the Yukon-Mackenzie divide.

There has been very little exploration of Hess Mountains and their geology is judged from the reports[1-7] dealing mainly with adjacent areas and information gleaned from air photographs. Hess Mountains appear to be formed of stratified rocks, mainly of sedimentary origin, and of scattered intrusive stocks of granitic rocks. The greater part of the stratified rocks are of Palæozoic age, and smaller parts of Mesozoic and Precambrian ages. In this, the geology of these mountains is much the same as that of Logan Mountains, except that, as the total thickness of Mesozoic and Palæozoic strata seems to thin northward, it might be supposed that more Precambrian strata are exposed. Weight is added to this supposition by the presence of iron formation, typical of the Precambrian strata of the Lake Superior region, outcropping in the northern part of these mountains, in Wernecke Mountains, and in widespread drift to west, north, and east. Wernecke, who first explored Hess and Wernecke Mountains by plane, reported that the iron formation is exposed in a major anticline that extends from near Bear River, a tributary of Wind River, southeastward across the head of Stewart River and along the side of the great valley east of Keele Peak.[8] He examined a locality near the northwestern end of the anticline, where a granitic intrusion has been found, and judged that the iron formation lay at the top of a section of Precambrian strata, but was uncertain whether it represented the top of the Precambrian or the bottom of the succeeding, fossiliferous Palæozoic strata.

Keele Peak and the larger peaks of many of the ranges of Hess Mountains appear to be formed of granitic intrusions.

In Pleistocene time the ice reached everywhere to at least an elevation of 5,000 feet on the west flank of Hess Mountains, but most of their peaks appear to have stood above it. It gathered in alpine ice-fields and glaciers on the peaks, coalesced on the lower levels into a sheet studded with nunataks, and flowed outward, mainly westward, in valley glaciers[9,10].

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[1] McConnell, R. G.: The Macmillan River, Yukon; Geol. Surv., Canada, Ann. Rept., vol. XV, 1902-3, pt. A, pp. 22-38 (1906).

[2] Keele, J.: Report on the Upper Stewart River Region, Yukon; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. C (1906).

[3] Camsell, C.: Report on the Peel River and Tributaries, Yukon and Mackenzie; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. CC, pp. 23 and 46 (1906).

[4] Keele, J.: A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, Yukon and Northwest Territories; Geol. Surv., Canada, Pub. No. 1097, p. 41 (1910).

[5] Cockfield, W. E.: Silver-Lead Deposits of Beaver River Area, Yukon; Geol. Surv., Canada, Sum. Rept. 1923, pt. A, pp. 22-24 (1924).

[6] Cockfield, W. E.: Upper Beaver River Area, Mayo District, Yukon; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 1-8 (1925).

[7] Kindle, E. D.: Geological Reconnaissance along the Canol Road from Teslin River to Macmillan Pass, Yukon; Geol. Surv., Canada, Paper 45-21, second edition (1946).

[8] Wernecke, L.: personal communication (1940).

[9] McConnell, R. G.: Op. cit., pp. 34-36.

[10] Keele, J.: A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, Yukon and Northwest Territories; Geol. Surv., Canada, Pub. No. 1097, pp. 45 and 46 (1910).

PLATE XXIII

Hess Mountains and Pelly Plateau: view north over Lewis, Field, and Sheldon Lakes, and Mount Sheldon (centre of picture). The Canol Road winds along Ross River Valley and disappears as it bends northward to cross Macmillan River Valley in the middle distance. Beyond the Macmillan, Hess Mountains rise, with Mount Keele showing white in the right distance. Photo by Royal Canadian Air Force; negative T9-94L.

*Wernecke Mountains*

The ranges between the headwaters of the upper parts of Stewart and Hart Rivers constitute Wernecke Mountains. Formerly these ranges had no separate name, but were included with the name "Ogilvie Mountains" to the west. The present separation is based on two factors: first, a major valley cuts through from the upper part of Beaver River to Hart River and thence northwestward, providing thereby a suitable dividing line; secondly, east of this valley intrusions have been reported, whereas west of it, except south of the Yukon-Peel watershed, none is known.[1] However, in view of the lack of more definite information the position of this boundary must be regarded as tentative.

Wernecke Mountains contain part of the Mackenzie-Yukon divide, but this lies mainly near their southern border and the greater area of the mountains drains north to Peel River. Though the highest elevations recorded for them are between 6,000 and 7,500 feet, so little is known that it is uncertain where the highest peaks are. A group of peaks near Snake River, at about latitude 64 degrees 40 minutes, has been reported to be 10,000 feet high, but some doubt has been thrown on this figure recently. To the southeast, near the borders of Wernecke, Hess, and Mackenzie Mountains, distant views in air photographs indicate a gentle rise suggesting one of the highest areas of either Selwyn or Mackenzie Mountains. This also forms a culmination area from which streams flow to Hess, Stewart, Bonnet Plume, Snake, Arctic Red, Mountain, and Keele Rivers.

From the northeast flank of Wernecke Mountains the streams drop steeply into the head of Arctic Red River. To the north and west they have gentler gradients, and follow a network of broad, high-level valleys. Most of the headwater streams of these high-level valleys flow southwest and, subsequently, according to their ultimate destination, turn west to the Stewart, northwest to the Bonnet Plume, or northwest and then north to Snake River. These three rivers occupy big valleys, distinctly U-shaped in cross-section and uniform in breadth. Their levels are high, much of their upper parts being above timber-line, probably about 3,500 feet above sea-level. They are connected by many large wind gaps that serve to divide the mountains into distinct ranges.

Wernecke Mountains are formed of the same rocks as Hess Mountains. In their northeast part the stratification of the rocks stands out well in air photographs, even under considerable snow cover, and close folding is apparent, but to westward stratification and structure show in very few places. East of Bonnet Plume Lake small intrusions can be seen in the air photographs, and show the same laccolithic forms as the basic intrusions near Keno Hill.

In Pleistocene time the ice moved down the valleys to the southwest and north from the divides in Wernecke Mountains. About 50 miles to the south-west, beyond the mountains, the surface of the ice lay as high as 5,000 feet above sea-level.[2] To the north, where it left the mountains in Wind River Valley, the surface reached an elevation of about 3,500 feet, and was at least 1,000 feet higher in Braine Pass[2,3]. A few small glaciers and ice-fields are present today in these mountains.

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[1] Bostock, H. S.: Preliminary Map, Upper McQuesten River, Yukon; Geol. Surv., Canada, Paper 43-9 (1943).
[2] Bostock, H. S.: Mayo, Yukon; Geol. Surv., Canada, Map No. 890A (1947).
[3] Camsell, C.: Report on the Peel River and Tributaries, Yukon and Mackenzie; Geol. Surv., Canada, Ann. Rept., vol. XVI, pt. CC, pp. 15, 21-25 (1906).
[4] Cockfield, W. E.: The Upper Beaver River Area, Mayo District, Yukon; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, p. 3 (1925).

### OGILVIE MOUNTAINS

Ogilvie Mountains include what is probably the largest area in the Cordillera of which neither records of exploration nor photographs are available. Accounts of explorations, mapping, and air photography only apply to the border parts of these mountains. This is largely due to the fact that they are not penetrated by any navigable stream or natural route of travel, and that no important discovery of gold has drawn attention to them.

Ogilvie Mountains extend from a few miles west of the 141st Meridian eastward to about Hart River. They were named after William Ogilvie, who crossed them on the west in 1888.[1] In 1911 and 1912, D. D. Cairnes traversed their western tip on his survey of the International Boundary.[2] In 1918 and 1919, W. E. Cockfield penetrated these mountains as far as the head of North Klondike River.[3] Their reports and maps constitute the only descriptions of these mountains.

On the basis of the meagre knowledge available, Ogilvie Mountains appear to be divisible into two parts. Along the southwest side is a belt about 35 miles wide containing intrusions of granitic and basic rocks. To the northeast of this is the main body of the mountains, 60 miles wide and 160 miles long, composed, to all appearances, entirely of sedimentary rocks.

The southwest belt rises from Tintina Valley along a remarkably straight front that is cut into segments by the larger streams flowing out of the mountains normal to it. Between these streams the front of each segment commences as a gentle slope and sweeps up in a steadily steepening incline to where it reaches an elevation of about 5,000 feet on the outer ends of the ridges. The mountains, as a whole, have a rugged aspect, and consist of long, branching ridges connecting precipitous peaks flanked by deep valleys. In places between elevations of 5,000 and 6,000 feet the ridge tops display rolling surfaces, above which the peaks, both along the borders and in the interior of the mountains, rise to from about 6,300 feet to a little more than 7,100 feet above sea-level. Except, however, for these surfaces the mountains show no evidence of having been planated.[4] In their interior parts, Pleistocene ice formed local ice-fields and valley glaciers, which did not extend beyond the south borders of the mountains, and decreased in extent and number to the west. Cirques are a feature of these mountains, but no present glaciers are reported.

Almost nothing is known of the main body of Ogilvie Mountains. Viewed from its borders, peaks can be seen rising far in the interior, but all to approximately the same elevation as in the nearer ranges, and no outstanding peaks have been reported. It is believed that the effects of Pleistocene glaciation dwindled northward and westward, though to the northeast some valley glaciers pushed to near the borders of the mountains.

### YUKON PLATEAU

Yukon Plateau has a more varied topography than Interior and Stikine Plateaux. Its broad area, which exhibits a general evenness of summit levels so characteristic of these plateaux, is interrupted to a much greater extent by

[1] Ogilvie, W.: Exploratory Survey of part of the Lewes, Tat-on-duc, Porcupine, Bell, Trout, Peel and Mackenzie Rivers; Dept. of the Interior, Canada, Ann. Rept. 1889, pt. VIII, sec. 3, pp. 51-67 (1890).

[2] Cairnes, D. D.: Geology of a portion of the Yukon-Alaska Boundary between Porcupine and Yukon Rivers; Geol. Surv., Canada, Sum. Rept. 1911, pp. 17-33 (1912).

Geology of a portion of the Yukon-Alaska Boundary between Porcupine and Yukon Rivers: Geol. Surv., Canada, Sum. Rept. 1912, pp. 9-11 (1913).

The Yukon-Alaska International Boundary, between Porcupine and Yukon Rivers; Geol. Surv., Canada, Mem. 67 (1914).

[3] Cockfield, W. E.: The Silver-Lead Deposits of the Twelvemile Area, Yukon; Geol. Surv., Canada, Sum. Rept. 1918, pt. B, pp. 15-16 (1919).

Explorations in the Ogilvie Range, Yukon; Geol. Surv., Canada, Sum. Rept. 1919, pt. B, pp. 1-3 (1920).

[4] Cockfield, W. E.: Explorations in the Ogilvie Range, Yukon; Geol. Surv., Canada, Sum. Rept. 1919, pt. B, p. 2 (1920), and unpublished contour map.

individual mountains and by ranges of various sizes, the largest of which are those of Pelly Mountains. The plateau is more cut up, too, by large, persistent valleys. Another feature, not noted farther south, and which separates Yukon Plateau into two general areas of differing topography, is the limit of glaciation.[1] Both in detail and in its larger features the topography is strikingly different in the glaciated and unglaciated areas.

These irregularities and distinctions serve to divide Yukon Plateau into many physiographic units that, however, may be grouped into four main divisions, referred to here as the Eastern, Southern, Western, and Northern Yukon Plateaux. The Eastern Yukon Plateau is composed of the units northeast of Tintina Valley; the Western Yukon Plateau includes glaciated areas in its southern part, but its main distinction is that it contains the unglaciated country southwest of Tintina Valley; the Southern Yukon Plateau lies partly south of and partly wedged between the Eastern and Western Yukon Plateaux; and includes Pelly Mountains; and the Northern division lies north of Ogilvie Mountains. So far as Canada is concerned, the Northern Yukon Plateau is a completely isolated plateau area, but in Alaska, Yukon Plateau spreads around the west end of Ogilvie Mountains and joins with the Northern Yukon Plateau.

### *Tintina Valley*

Tintina Valley is a great valley feature comparable with the Rocky Mountain Trench, and is considered separately as a unit of Yukon Plateau. It extends from St. Cyr Range northwest across the 141st Meridian into Alaska, with a variation in direction of only a degree or two, namely, north 57 degrees west at the 141st Meridian and north 47 degrees west at its southeast end 10 degrees farther east, due to convergence of longitude in these northern latitudes. In its regular trend, general accordance of floor levels, and straight-walled sides, it resembles the Rocky Mountain Trench, whose continuation it has been supposed to be. Air photographs, however, show that these two trenches are neither in alinement, nor connected by any important valley through the main chain of Pelly Mountains, which extends diagonally across the direction followed by the Rocky Mountain Trench.

Tintina Valley at its southeast end is a straight, narrow valley in Pelly Mountains, and broadens to about 8 miles in width near Ross River (Plate XXIV). From its head in St. Cyr Range to northwest of Tay River, first St. Cyr Range and then, beyond a large gap, Glenlyon Range form a well-defined southwest wall. In the same distance the northeast side is broken and except in a few places, as at Rose Mountain, does not exhibit a well-defined wall-like character. From Tay River to Macmillan River the valley is more open on both sides, but for 20 miles northwest of Macmillan River, Tintina Valley has a truly trench-like character, and is, at it narrowest, about 3 miles wide. Farther northwest it broadens with nearly straight sides between hills broken at intervals by large tributary valleys, including those of Stewart and South Klondike Rivers between which it reaches its maximum width of 14 miles. For 100 miles southeast of the 141st Meridian, Tintina Valley is walled by the front of Ogilvie Mountains on the northeast, and by an equally straight but lower and broken front formed by Klondike Plateau on the southwest. Throughout its length, beyond St. Cyr Range, its floor elevations are between 1,400 and 2,700 feet.

[1]"Limit of glaciation" here refers to the boundary of the last, well-marked Pleistocene glaciation, generally regarded as Wisconsin in age. Evidence of earlier, and somewhat more extensive, Pleistocene glaciation has been found in three localities at Victoria Creek, north of McArthur Range, and at Dublin Gulch. In each of these the locality is close to the "Wisconsin" limit, and in areas considerably beyond this limit, which have been mapped geologically, the evidence is all against the presence of any Pleistocene glaciation.

PLATE XXIV

Tintina Valley and St. Cyr Range, Pelly Mountains: view southwest over Ross River Post and across the junction of Ross and Pelly Rivers in Tintina Valley to St. Cyr Range. Note the wall-like front in which Pelly Mountains rise from Tintina Valley. Lapie River comes down from its valley in the mountains on the right to join the Pelly. The Canol Road and construction roads can be seen on the left. Photo by Royal Canadian Air Force; negative T15R-157.

Tintina Valley does not at present form a master drainage channel, but is occupied at intervals by parts of Pelly River, Little Kalzas River, Crooked Creek, Stewart River, Clear Creek, Flat Creek, and Klondike River.[1] For most of its length, particularly northwest of Crooked Creek, it appears to have been the main channel of Yukon River drainage earlier in the present cycle of erosion. Differential uplift and the advance of Pleistocene ice across the valley from the east have both played important parts in forcing its drainage to escape to the west. This habit of main streams breaking westward from large established valleys is apparent in all the major streams southwest of Tintina Valley, with the exception of Lewes River below Lake Laberge, which breaks northeastward to join first Teslin River and then Big Salmon River, and, farther downstream, White River, where it empties into the Yukon.

The drainage of Yukon Plateau shows two distinct, rectangular patterns. Southwest of Tintina Valley the main and persistent lines of the pattern strike northwesterly, and are connected at irregular intervals along easterly to northeasterly courses. Several pronounced valleys, including Shakwak, Nisling River, Teslin River, and Tintina Valleys, mark the main northwesterly lines, and some equally persistent but less pronounced valleys, whose courses nearly parallel these lines, lie between the major valleys and are marked by shallower depressions occupied for short distances by minor streams. All these valleys show some degree of convergence northwestward, directions of trend varying between approximately north 50 degrees west, for Tintina Valley, and north 20 degrees west for some of the other valleys.

On the northeast side of Tintina Valley the drainage pattern is, as a whole, much less regular. The main lines trend easterly to northeasterly, but are not as straight nor as persistent as the northwest lines on the southwest side of Tintina Valley. In some areas on the northeast side the pattern forms remarkably regular parallelograms, with angles of approximately 60 and 120 degrees, but in general this regularity is not marked and in some parts it becomes almost indiscernible.

In the southeastern part of Tintina Valley, where Lapie River enters it, the southwest wall of the valley follows a major fault.[2] In places northwest of Ross River to Macmillan and McArthur Ranges, contacts and faults parallel the valley.[3] Between Macmillan and McArthur Ranges, and where Klondike River flows along it, the valley coincides with important geological boundaries. Northwestward from north of Macmillan Range the greater part of the valley is floored with great masses of gravel, sand, and clay showing some degree of consolidation in places. Beneath these, northwest of Klondike River, gently warped, early Tertiary coal measures outcrop at intervals for more than 80 miles in the valley floor, showing that at least this part of the valley has been a depression for a very long time.

### *Eastern Yukon Plateau*

The Eastern Yukon Plateau is an area of plateau country lying between Selwyn Mountains on the northeast, Pelly Mountains on the south, Tintina Valley on the southwest, and Ogilvie Mountains on the north. This plateau area is broken by many isolated mountains and small mountain ranges, particularly in its northern, central, and extreme southeastern parts. The Eastern Yukon Plateau comprises three plateau areas, Pelly Plateau on the southeast, Macmillan Plateau in the middle, and Stewart Plateau on the north.

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[1] McConnell, R. G.: The Macmillan River, Yukon District; Geol. Surv., Canada, Ann. Rept., vol. XV, pt. A, p. 24 (1906).

[2] Kindle, E. D.: Geological Reconnaissance along the Canol Road from Teslin River to Macmillan Pass, Yukon; Geol. Surv., Canada, Paper 45-21, second edition, p. 8 (1946).

[3] Johnston, J. R.: A Reconnaissance of Pelly River between Macmillan River and Hoole Canyon, Yukon; Geol. Surv., Canada, Mem. 200 (1936).

*Pelly Plateau.* This plateau lies between the northern part of Frances Lake and an arbitrary line northwest of and parallel with Ross River Valley. Most of it consists of rolling uplands whose general elevations increase northeastward from less than 4,000 feet, near Tintina Valley, to more than 5,000 feet near Logan Mountains. The valleys of the main rivers are entrenched in it 1,000 feet and more. Towards their heads these valleys, and their tributaries open to form relatively shallow depressions across the plateau surface, which is here less dissected than most parts of Yukon Plateau. Between upper Pelly and Ross Rivers, the surface is unbroken by any conspicuous mountain from Tintina Valley and Pelly Mountain to a line between Mount Sheldon and Pelly Lakes. Approximately along this line the plateau surface rises more steeply as a gentle or subdued step. To the northeast its regularity is broken by small mountainous areas that overlook Ross River Valley or lie scattered to the southeast. In this direction, too, the plateau surface continues into the mountains between mountain groups that stand along the general line of the front of Logan Mountains. To the southeast of upper Pelly River the plateau includes several small mountain areas separated by a network of large valleys occupied by small streams. Pelly Plateau is underlain by stratified rocks, mainly Palæozoic sedimentary and volcanic types. Intrusions are also present, but their size is not known. The entire plateau, except, perhaps, for some isolated mountains in its southeast part, was covered by pleistocene ice. In general the ice moved westerly, deflected locally by topography[1], but some ice north of Frances Lake may have escaped southward.

*Macmillan Plateau.* Macmillan Plateau stretches from near Ross River to Macmillan River. It includes Mount Sheldon, and Anvil, South Fork, and other small mountain ranges, and, as a whole, is a broken, mountainous area of plateau with a higher general elevation than that of most of Pelly Plateau. Characteristically, it is composed of mountains and small mountain groups that rise above an undulating plateau surface that forms high tablelands around them on the tops of their projecting spurs, and below which a network of valleys has been entrenched. In the central part of Macmillan Plateau, Tay River meanders in a broad timbered depression below the level of the plateau surface. The Palæozoic rocks of the neighbouring Pelly Plateau extend into Macmillan Plateau, but are intruded there by a granitic batholith that forms the greater part of the southwest half. Pleistocene ice filled the valleys, but many of the mountainous areas between them, particularly those in the northwest, stood above the glaciers as nunataks.

*Stewart Plateau.* The plateau area between Macmillan River and the southern fronts of Ogilvie and Wernecke Mountains is occupied by Stewart Plateau. A large part of this plateau has been mapped topographically and geologically. All of Stewart Plateau is broken into tablelands by a network of deeply cut, broad valleys. Some of these tablelands are remarkably level and little dissected, the streams on them flowing in open valleys with relatively gentle gradients. Others, notably in the western part of the plateau, north of McQuesten River, which is mainly unglaciated, are, as a whole, deeply and intricately dissected by their streams, and tablelands are almost non-existent. The plateau itself is represented mainly by long, connected ridges, with very even, though narrow, summits. The valleys are deep and narrow to the heads of the stream, where they rise steeply and end abruptly. This type of dissection is typical of the unglaciated regions, but is lacking in the glaciated areas of Yukon Plateau.

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[1] Kindle, E. D.: Op. cit., p. 8.

In the east part of Stewart Plateau, and in other, similar glaciated areas, glaciation seems to have been a major factor in developing the present topography. Here the larger valleys have been accentuated, and form a network surrounding tablelands on which the tributary valleys are shallow where the ice-cover was thin or lacking. Isolated mountains or small ranges crown the higher parts of most of the tablelands. The best known of these are McArthur Range in the southwest and Gustavus Range in the north. Many of these tablelands are bounded by nearly parallel sides, producing, in plan, the parallelogram form mentioned in a preceding paragraph. A few are triangular or curved. The positions of the major valleys are closely connected with structural features, either anticlines, fault zones, or non-resistant strata, and the mountains are formed of hard quartzite members, granitic intrusions, or rocks hardened by contact metamorphism.

In several places in these tablelands are records of two, and in a few places three, distinct erosion surfaces. North and west of McQuesten River, where the topography is not modified by glaciation, these are well shown. The erosion surface recognized widely across Yukon Plateau is apparent here at an elevation of about 4,250 feet, but the elevation of this surface varies by as much as several hundred feet, depending on the proximity to elevated areas on the one hand or to main valleys on the other. The main valleys are entrenched about 2,000 feet below this surface. Above this surface, at an elevation of about 5,000 feet, and generally a little higher, a second erosion surface is apparent, truncating the tops of the lower mountains and the spurs of the higher ones. Above this again, a third surface shows on the tops of the higher mountains at about 5,800 feet or more above sea-level. Eastward in other parts of the plateau, where the same sequence of surfaces is apparent, they are higher and their levels more widely separated. As in the lowest of these three surfaces, the upper two vary greatly in degree of development in different parts. Commonly they are undulating, and it is only here and there that they are relatively flat and stand out distinctly as separate surfaces.

The rocks of Stewart Plateau are mainly metamorphosed sediments, and are believed to be Precambrian. They are overlain along Macmillan River by upper Palæozoic sediments, and granitic stocks intrude them in places. Pleistocene ice moved westward across the plateau, covering all parts in the east but those more than 5,000 feet high. West of a line through the mouth of Hess River nunataks become more extensive as the ice, pushing westward, its surface declining and its volume dwindling away, split into tongues following the main valleys, and ended at about the mouth of McQuesten River. In McArthur and Gustavus Ranges numerous alpine glaciers extended down the valleys to join the main ice-sheet that surrounded the ranges.

Drift deposits, attributed to glaciation that antedated the last advance of the ice, have been found by the writer in two places in this plateau. These are remnants of glacial till in the upper part of Dublin Gulch, and large patches of drift on the north side of McArthur Range. Both places are beyond the limit of the last glacial advance and at a high level.

### *Southern Yukon Plateau*

The Southern Yukon Plateau is made up of four units: Teslin, Nisutlin, and Lewes Plateaux, and Pelly Mountains. On the south and southeast it is bounded by Stikine Plateau, Cassiar Mountains, and Liard Plain, on the northeast by Pelly Plateau and Tintina Valleys, and on the west by the Coast Mountains and the Western Yukon Plateau. The boundary between the Southern and Western Yukon Plateaux follows a line drawn arbitrarily from the northeast corner of the Coast Mountains to the southeast corner of the unglaciated area and thence along the west border of glaciated country north to Tintina Valley.

*Teslin Plateau.* Teslin Plateau is an elevated area on the north side of the divide between Yukon and Taku Rivers. It is an area of high and partly dissected tablelands separated by a network of big valleys, and in this resembles the eastern part of Stewart Plateau. The valleys of Lewes and Teslin Rivers, by which the plateau is drained, are entrenched to elevations of between 2,100 and 2,300 feet in tablelands that exhibit an undulating upland surface between 4,500 and 5,000 feet high. In the southern part, between Atlin and Teslin Lakes, there is a concentration of higher ground where the tablelands are less dissected and where a few small mountain areas reach elevations in excess of 6,000 feet.

On the east, Teslin Plateau is bounded by the valley of Teslin Lake and River. On the south it merges with Stikine Plateau. The plateau surface, so conspicuous and well preserved on Stikine Plateau, seems to be the same as that on the tablelands of Teslin Plateau, but on the latter it is higher and more dissected. On the west, the surface rises and is lost in the Coast Mountains. Northwestward it becomes more dissected, the upland areas are reduced, and broad valleys such as those of Marsh Lake and Lewes, Watson, and McClintock Rivers occupy a large part of the area.

The plateau is formed mainly of Palæozoic strata, including much limestone in the south. In the north these rocks are overlain by Mesozoic beds, including both sedimentary and volcanic rocks. Bodies of intrusive rocks of different compositions and ages, and also some Tertiary volcanic rocks, are scattered over the plateau. All but perhaps the highest peaks of Teslin Plateau, those more than 6,500 feet high, were covered by Pleistocene ice, which moved northward, except along the southern fringe of the plateau where it may have moved to Taku River.

*Nisutlin Plateau.* This plateau lies east of Teslin Lake and Big Salmon Range. It includes, on its west side, the broad, flat depression of Nisutlin River Valley. To the north it is bounded by St. Cyr Range, and to the east by Liard Plain and Cassiar Mountains. A wide view of its main northern part shows a broad, elevated surface into which dissection has hardly commenced and on which Cassiar and Pelly Mountains stand. The heads of Wolf, Nisutlin, and Liard Rivers have shallow valleys, and their entrenchment below the upland surface is not noticeable until they near Liard Plain or the broad valleys of Nisutlin River and Teslin Lake on the west. The upland surface appears continuous with those of Stikine and Dease Plateaux on each side of Cassiar Mountains. South of Quiet Lake, Nitsutlin River Valley and its tributaries are broad, open, and largely filled with drift. The plateau is underlain by Palæozoic sedimentary and metamorphic rocks, perhaps of Precambrian age, intruded by the Cassiar batholith. Pleistocene ice probably covered all of it.

*Lewes Plateau.* In general, Lewes Plateau is a broad depression between the western ranges of Pelly Mountains on the east and gently rising plateau areas on the other sides. Its west boundary is drawn approximately along the limit of glaciation, where the change in topographic texture that distinguishes it from the plateaux to the west becomes apparent. The plateau is divisible into two parts along Little Salmon River and a line from there through Tatchun Lake. The southern part consists of a broad, irregular depression underlain by relatively nonresistant, folded Mesozoic sediments flanked by tougher, late Mesozoic volcanic rocks that form Semenoff Hills on the northeast and Miners Range on the southwest. In this part the upland surface is apparent as an accordance of summit levels of many separate hills over wide areas rather than as tablelands or long, connected, even ridges. Its average elevation is 3,500 to 4,000 feet, about 500 feet lower than the surrounding plateaux towards which it rises. Within it is a network of big valleys and broad areas reduced below the upland surface, and only a few scattered peaks, besides those of Miners Range, project prominently above it.

The north side of Little Salmon River Valley rises steeply to tableland areas that slope and diminish in size northward to two broad hollows between which Ptarmigan Mountain, a remnant of high plateau with its summit at an elevation of 4,500 feet, rises conspicuously. The greater part of the two hollows lies less than 2,500 feet above sea-level, and a uniformity of summit levels is apparent at an elevation of about 3,300 feet. The hollows open into Tintina Valley to the east and northwest of Macmillan Range, and do not appear to owe their origin to the erosion of nonresistant formations, as does the depression to the south. This northern part of Lewes Plateau is built mainly of ancient metamorphic rocks on the northeast and a belt of Mesozoic rocks on the southwest, both invaded by granitic intrusions, with small areas of overlying Tertiary volcanic rocks.

Several small areas north of Little Salmon River and, perhaps, in Miners Range appear to have escaped glaciation in Pleistocene time, but elsewhere the plateau was completely covered by ice.

*Pelly Mountains.* Pelly Mountains occupy a large, V-shaped area in the southern part of Yukon Plateau. The apex of the V points northwesterly, and is formed of Glenlyon Range, whereas the two arms are made up of Big Salmon Range and St. Cyr and other ranges on the southwest and east respectively.

Glenlyon Range (Plate XXV) is separated from the other ranges by the valley of Little Salmon Lake and Magundy River and a wedge of high tableland between Little Salmon and Drury Lakes. The northern parts of Big Salmon and St. Cyr Ranges form a continuous area of mountains, their common boundary being drawn along a straight, deep, narrow valley. Southeastward, this valley widens into that of Big Salmon River and Quiet Lake, and the ranges diverge, the northwest part of Nisutlin Plateau forming a wedge between them. Big Salmon Range trends about south 25 degrees east and St. Cyr Range south 65 degrees east. These also appear to be the trends of their main geological structures.

Along the borders of the ranges of Pelly Mountains the upland surface of the adjacent plateaux is conspicuous, forming tablelands and long, smooth-topped spurs. Glenlyon Range, particularly at its north end, contains high tablelands at elevations of between 4,500 and 5,500 feet. Its mountains stand above this surface, and in places have on them remnants of at least one, higher, older surface.

Igneous rocks, mainly granitic but including some basic and ultrabasic types, outcrop along the backbones of the ranges of Pelly Mountains. They intrude a great section of stratified rocks, including quartzites, schists, gneisses, slates, greenstones, sandstones, and limestones, believed to range in age from Precambrian to Mesozoic, the bulk being probably Palæozoic. Small patches of Tertiary sedimentary and volcanic rocks overlie all these rocks.

St. Cyr Range itself forms the main unit of Pelly Mountains, being 180 miles long and 40 miles wide. Its backbone is rugged and high, notably so along its main axis from the head of Magundy River to that of the north fork of Liard River. Its highest peaks are near the northwest end and may reach elevations of more than 8,000 feet. Other peaks, probably exceeding 7,000 feet, are scattered along this backbone. A few, small, alpine glaciers are present on

PLATE XXV

Glenlyon Range, Pelly Mountains: view north across Drury Lake to Glenlyon Range. Note the glacial scouring along the sides of the valley. Photo by Royal Canadian Air Force; negative T7-132L.

the highest peaks. In Big Salmon Range, two peaks are a little more than 7,000 feet high, and the highest peak in Glenlyon Range is believed to be about 7,500 feet above sea-level.

East of the southeast end of Tintina Valley, that part of Pelly Mountains that extends towards Frances Lake is of less rugged and compact character. In it considerable areas of rolling upland surface are separated by a network of valleys entrenched about 1,000 feet below it. These areas are surmounted by isolated mountains and groups of mountains, such as the peaks of Campbell and Simpson Ranges. The main backbone of St. Cyr Range continues to the southeast, and Simpson Range forms the extremity close to Frances River as a straight, but broken line of scattered peaks about 6,000 feet high.

Large, U-shaped valleys run deep into all ranges of Pelly Mountains, and some, as those of Big Salmon and Magundy Rivers and Harvey Creek, traverse the ranges completely.

In Pleistocene time the main ice surface of the last glaciation stood at an elevation of more than 6,000 feet in most of Pelly Mountains and, perhaps, considerably higher on the southwest side of St. Cyr Range. Its surface was lower westward along that side of Big Salmon Range where the ice was moving west and northwest. The northeast side of St. Cyr Range is an area of relatively light precipitation compared with the southwest side, and some features suggest that the ice was lower, perhaps as much as 1,000 feet lower, on that side, or that it was an area where the ice had little movement. A large part of Glenlyon Range stood above the main surface of the ice as nunataks (Plate XXV). Alpine glaciers extended northeastward from the higher parts of these nunataks to coalesce with the main ice moving northwest down Tintina Valley. Similar conditions prevailed in parts of Big Salmon and St. Cyr Ranges, but the general level of the ice rose to the south and southeastward and less of these ranges stood above it[1-4].

### *Western Yukon Plateau*

The Western Yukon Plateau is bounded on the northeast and southwest by Tintina and Shakwak Valleys respectively. The Alaskan boundary along the 141st Meridian limits it on the west, and on the east it is bounded by the Southern Yukon Plateau and the northwestern part of Tintina Valley. With the exception of nunataks in the Southern Yukon Plateau these boundaries enclose all unglaciated areas in Yukon Plateau southwest of Tintina Valley.

The Western Yukon Plateau comprises, from north to south, three main units, Klondike and Kluane Plateaux and Shakwak Valley. The boundary between the two plateaux extends northwest from the southeast corner of the unglaciated area to Nisling River Valley, which it follows to Donjek River, and then pursues an irregular, northwesterly course to the 141st Meridian. This boundary places the main part of the unglaciated area south of Tintina Valley in Klondike Plateau, whereas Kluane Plateau contains only nunataks and mountainous embayments of unglaciated country, though these occupy large areas in its northern and central parts. Klondike Plateau is uniform in character, and only Dawson Range forms a distinct major feature in it. Kluane Plateau, on the other hand, is quite variable in character, four subdivisions, including two mountain ranges and two basin areas, being distinguished in it,

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[1] Bostock, H. S.: The Mining Industry of Yukon, 1931; Geol. Surv., Canada, Sum. Rept. 1931, pt. A, p. 2 (1932).
[2] Bostock, H. S., and Lees, E. J.: Laberge Map-area, Yukon; Geol. Surv., Canada, Mem. 217, p. 4(1938).
[3] Johnston, J. R.: A Reconnaissance of Pelly River Between Macmillan River and Hoole Canyon, Yukon; Geol. Surv., Canada, Mem. 200, p. 5 (1936).
[4] Kindle, E. D.: Geological Reconnaissance along the Canol Road from Teslin River to Macmillan Pass, Yukon; Geol. Surv., Canada, Paper 45-21, second edition, p. 8 (1946).

as well as several minor features. In the south Shakwak Valley is one of the great valley features of the Canadian Cordillera, resembling the Rocky Mountain Trench and Tintina Valleys in its direction and dimensions, though not as long.

*Klondike Plateau.* This plateau is cut into segments by the valleys of the master streams that traverse it, and its striking characteristic is the topographic similarity of all these segments, a similarity that may be largely due to the lack of glaciation of the plateau. It also shows throughout a character of dissection distinct from that of the glaciated plateaux to the east and the partly glaciated Kluane Plateau to the south (Plate XXVI). The topography is a maze of deep, narrow valleys separated by long, smooth-topped ridges whose elevations are very uniform, and which are remnants of an old uplifted erosion surface. This surface shows gentle undulations rising here and there along converging ridges to culminate in monadnocks that consist of dome-like eminences or groups of relatively smooth-sloped mountains, including Dawson Range. In places, too, the ridge summits slope into basins below the general surface of the upland.

The tops of the ridges are rounded, and drop with increasing steepness or with stream-lined curves into deep, narrow, V-shaped valleys on each side. Commonly, the valleys have steady gradients of less than 100 feet a mile to within a few miles of their heads, where they rise more and more steeply and the valley floors disappear. Wind gaps are rare, the ridges being continuous or connected by high saddles. In Dawson Range, and on some of the monadnocks, are remnants of one, and probably two, higher level, erosion surfaces. Streams issuing from Dawson Range have similar profiles to those elsewhere in the plateau, but as they approach to within about 500 feet of the level of the upland surface their gradients again become more gentle for 2 or 3 miles, and their valley floors widen. Above this again, gradients steepen to their extreme headwaters.

The courses of Yukon River and its tributaries present problems in drainage development affecting the whole of the Yukon Plateau, and particularly Klondike Plateau. Lewes and Pelly Rivers unite at Fort Selkirk to form the main stream of Yukon River. From the fort, the Yukon flows westward, ignoring the broad area of relatively open, low country to the east, including Tintina Valley, into a deep, narrow-floored valley cut diagonally across a spur of Dawson Range to join White River. White River has developed a similarly anomalous course in cutting its way north across a relatively high plateau from Wellesley Basin, which opens to the west into a broad, low valley to Tanana River in Alaska. From White River, the Yukon swings northeast across the end of the same spur to meet Stewart River in a wider floored, northwest-trending valley that can be traced northwest and southeast for many miles beyond where it is occupied by these rivers. Yukon River flows in this valley to near Sixtymile River, which meets it from the west, and then turns north along a narrower valley to reach Tintina Valley near the 141st Meridian. Abandoned valleys extend toward the lower areas on the east, and the courses of the tributaries show that the drainage pattern of this part of Yukon Plateau has gone through some major changes in the present cycle of erosion. The incision of Yukon River Valley to a depth of 1,000 to 2,000 feet or more for many miles across the spur of Dawson Range and its tributaries in a terrain of relatively resistant rocks has required time, perhaps reaching back into the Tertiary period.

PLATE XXVI

Klondike Plateau: view northeast down White River to its junction with Yukon River, which enters the view from the right and towards the left is joined by Stewart River. This picture shows the type of dissection of Yukon Plateau in the Klondike and surrounding areas. Photo by Royal Canadian Air Force; negative T1-36R.

Subsequent to the establishment of Stewart River, and probably Yukon and White Rivers, in their present courses, a period of aggradation set in during which Stewart River Valley between Tintina Valley and its mouth was filled to at least 2,500 and perhaps 3,500 feet above sea-level with 1,200 to 2,000 feet or more of stream deposits, mainly gravels. This resulted in the rivers flowing widespread across divides, as, for instance, from Stewart River into Indian River.[1] Southeast of Rosebud Creek large deposits of gravels have been found to and above an elevation of 3,500 feet.[2] Aggradation was followed by renewed erosion and re-excavation by most of the main streams of their former valleys. The changes of base level accompanying this erosion has led to the formation of bedrock terraces by the entrenchment of Yukon River below its former valley floor, 60 to 100 feet at the mouth of Stewart River,[3] 300 feet at Dawson, and deeper farther downstream[4] to where its meanders have become entrenched as it approaches Tintina Valley at the 141st meridian. This entrenchment ends in Stewart River Valley at about the mouth of Rosebud Creek. These changes in the base level of erosion, as recorded by the deposits and bedrock terraces, appear to be only one instance from a record of incessant oscillation during the present cycle of erosion suggested by many examples of similar deposits and terraces spread over Yukon Plateau but only casually noted to date.

No glaciers exist in Dawson Range, whose highest point is Apex Mountain at an elevation of 6,634 feet. Pleistocene ice, on its last advance, pushed against the east side of the southeast end of the range, where it reached a maximum elevation of nearly 4,000 feet, Cirques in the valley heads around Apex Mountain are evidence of a group of small alpine glaciers in Pleistocene time. The longest of these, at the head of Selwyn River, extended 4 miles down the valley to where it left a small terminal moraine.[5] At the southeast end of Dawson Range, in the valley of Victoria Creek beyond the limit of the last glaciation, there is evidence of earlier and somewhat more extensive glaciation in the form of remnants of glacial till beneath pay-streaks of the placer deposits.[6]

Klondike Plateau is composed mainly of metamorphosed sedimentary and igneous rocks of Precambrian and Palæozoic ages, small areas of Mesozoic volcanic rocks, and large areas of later granitic intrusions. These older rocks are all overlain by early Tertiary volcanic and sedimentary beds that were warped and faulted before the upland surface truncated the upturned strata. Around Fort Selkirk volcanic rocks, late Tertiary to Recent in age, poured into the valleys after the dissection of the upland surface.

*Kluane Plateau.* Kluane Plateau forms the northwest continuation of the region occupied by the Coast Mountains, the boundary separating them being drawn, for practical purposes, along the north reach of Kusawa Lake. Northwest of this boundary an old upland surface, apparently that seen elsewhere in Yukon Plateau, becomes the dominant feature of the topography, and continuous areas of rugged mountains diminish.

Kluane Plateau is divisible into several parts. In the southeast a part of it is cut off from the rest by the great east-west valley of Takhini and Dezadeash Rivers, here referred to as Takhini Valley. The plateau surface in this part is exceptionally high, being 5,500 feet and more above sea-level and crowned by several scattered peaks between 6,500 and 7,000 feet high. North-

[1] Bostock, H. S.: Geol. Surv., Canada, Map 711A, Ogilvie, Yukon Territory (1943).
[2] Bostock, H. S.: Geol. Surv., Canada, unpublished work.
[3] Bostock, H. S.: Geol. Surv., Canada, unpublished work.
[4] McConnell, R. G.: Report on the Klondike Gold Fields; Geol. Surv., Canada, Ann. Rept., vol. XIV, 1901, pt. B, p. 8 (1905).
[5] Bostock, H. S.: Preliminary Map, Selwyn River, Yukon; Geol. Surv., Canada, Paper 44-34 (1945).
[6] Bostock, H. S.: Carmacks District, Yukon; Geol. Surv., Canada, Mem. 189, p. 48 (1936).

westward, but still south of Takhini Valley, the elevations of the plateau and peaks decrease to 700 feet lower. Here, too, the undulating plateau is cut into tablelands by a network of deep valleys. In this part, however, the topography of the mountains ends, in general, at Kusawa Lake, the Coast Range batholithic rocks continuing for nearly 30 miles beyond the lake as a belt of nearly the same breadth as that which they maintain in the mountains. Beyond this point the intrusive belt narrows abruptly to a strip about 10 miles wide, which extends northwesterly across the arms of Kluane Lake to White River.

Northwest of Takhini Valley Kluane Plateau consists of two topographic basins separated by an elevated area. One basin includes Aishihik Lake and the area to the southeast. The other encloses Wellesley Lake and extends to the west and south of that lake.

Aishihik Basin is a broad, rolling depression lying for the most part between 4,000 and 5,000 feet above sea-level, and has a general slope northeast to Lewes Plateau and Nisling River. Except for a number of rather widely separated valleys, whose floors are about 3,000 feet high, its dissection is not marked, and between Sekulmun and Aishihik Lakes and east of the latter broad stretches of rather smooth rolling plateau have a relief of about 1,000 feet without distinctly entrenched valleys. A few isolated mountains and mountain groups, with elevations in excess of 6,000 feet, stand upon it. Pleistocene ice reached to a height of about 5,000 feet above sea-level in the southern part of the basin, and moved northwestward along Aishihik Lake to near Nisling River. The ice also overflowed northeastward through gaps in the divide between Aishihik Lake and Nordenskiöld River. A great part of the basin is drift covered.

A large part of Wellesley Basin has an elevation of about 2,000 feet, and appears to have been reduced below the level of the upland. On the east, south, and west the lower parts of the basin rise towards the surrounding areas, on which the former upland surface is apparent. The north border of this basin is marked by a relatively abrupt rise to the ridges of Klondike Plateau. A great part of the basin is drift covered. The part around Wellesley Lake is marked by innumerable kettle-holes occupied by ponds and small lakes, and the main valleys are filled with stream deposits, mainly glacial outwash. Pleistocene ice pushed into the basin through the big valleys leading to it from the south, and spread over it. At the north side it pushed up to hills at the border of Klondike Plateau, reaching an elevation of at least 2,400 feet north of Snag Creek on the west of White River Valley. It thrust tongues down the valleys of Donjek and White Rivers for short distances beyond the basin. South of Wellesley Basin the general level of the summits, interrupted by deep valleys, rises towards St. Elias Mountains.

Between Aishihik and Wellesley Basins the plateau rises northeast of Shakwak Valley to a wide upland composed of two broad mountainous ridges trending northwest, Ruby and Nisling Ranges, separated by a high, shallow trough parallel with Shakwak Valley. The old erosion surface of Yukon Plateau is the dominating feature of the upland, but is more undulating than in most plateau areas. It is dissected and deeply trenched by the main creek valleys. Its broad, treeless highlands are reminiscent of Spatsizi Plateau tablelands, but the relief is too great to apply that term. Ruby Range, a ridge of mountains whose peaks reach elevations of about 7,000 feet, stands on the southwest side of this upland. On the northeast side of the upland, Nisling Range, a somewhat similar, but smaller, parallel ridge of mountains, overlooks Nisling River Valley, but here only a few peaks are more than 6,000 feet high, and the general elevation of the summits is lower. The bottom of the shallow trough between these two ridges is furrowed by a deeply entrenched central valley drained by streams running to the north arms of Kluane Lake, to the north end of Sekulmun Lake, and to the lower end of Kluane River. On each side shallower valleys dissect the surface. These drain in the same directions except on the north, where they are tributary to Nisling River. The high upland surface, notable here for its broad, rolling character, changes to a much dissected surface of the Klondike Plateau type where it slopes to Nisling River. During the last glaciation the ice overrode the lower parts of the southwest side of the upland and spread through the entrenched valleys, splitting and reuniting its tongues in the valleys of the trough, but it appears to have advanced through only three valleys in Nisling Range sufficiently far to reach that of Nisling River.

Ruby Range is composed of granitic intrusions of the Coast Range batholith bordered by, and surrounding as roof pendants, quartzites, schists, and limestones probably of Precambrian age. To the north, Nisling Range is formed of the same rocks, but northeast of Aishihik Lake these are replaced by Mesozoic volcanic rocks. West of Donjek River, although intrusions persist, less metamorphism is apparent in the older strata, which are here regarded as Palæozoic in age, though fossil evidence is lacking. West of White River greenish volcanic rocks of probable Mesozoic age overlie the Palæozoic formations.

*Shakwak Valley.* This is one of the great trench-like valleys of the Cordillera. It extends, on a bearing between north 50 and 60 degrees west, from Primrose River east of Kusawa Lake, along Kluane Lake to beyond White River, where it is lost in the broad valley that is continuous with that of Tanana River in Alaska. It is more than 200 miles long and some 10 miles wide at its maximum, near the southeast end of Kluane Lake. Its northeast side rises irregularly in places in steep bluffs, and in others in subdued hills to the level of the plateau surface. Its southwest side rises in a wall, like a great fault scarp, to the rugged summits of Kluane Ranges, the outer ridge of St. Elias Mountains (Plate XXXII). As in Tintina Valley and the Rocky Mountain Trench several large streams occupy it for varying distances and then debouch from it. In Pleistocene time the valley formed a large trough where the ice from the great glaciers of St. Elias Mountains coalesced and spread before it pushed on through the gaps in the ranges to the north. As a consequence, it has been heavily scoured in its narrower parts and elsewhere mantled by widespread drift deposits.

Shakwak Valley follows a very continuous and important geological boundary, probably a fault, as only west of White River do the same rocks occur on opposite walls. and SE of Dezadeash L.

*Northern Yukon Plateau*

The Northern Yukon Plateau consists of two main units, Porcupine Plateau and Porcupine Plain. The boundary between them is not well defined, but is placed where the first distinct hills rise above the surface of the plain.

*Porcupine Plateau.* Porcupine Plateau occupies, broadly, the area between Old Crow and Porcupine Rivers on the east and the 141st Meridian on the west. A fringe of plateau along the southern slope of British Mountains and a triangular area extending southeastward from the main part of the plateau to the border of Peel Plateau are included with it. Two low ranges of mountains, Keele and Old Crow Ranges, lie within Porcupine Plateau and form parts of it.

On the south, Porcupine Plateau is bordered by Ogilvie Mountains, and on the east and north by Porcupine Plain. The plateau as a whole is an area of rolling, widely spaced hills with a relief of more than 1,000 feet. The hills are composed of resistant rocks of a great area of sedimentary strata. South of Keele Range, along the 141st Meridian, many hills rise to an elevation of about

3,700 feet, and have broad, flat tops, remnants of a former erosion surface, now the upland surface of the plateau. In the floors of the hollows between the hills many of the larger streams have canyon-like valleys 300 to 500 feet deep.[1]

In Keele Range the upland surface is remarkably well preserved, and exhibits an evenness indicating that peneplanation was nearly complete in this locality. The range consists of northeasterly striking ridges, suggesting folds plunging in that direction and spaced 8 to 12 miles from anticline to anticline. The highest elevations, judged from air photographs, are believed to exceed 5,000 feet. The range disappears northeastward. North of the range and eastward along the border of Porcupine Plain, Porcupine Plateau consists of relatively gently sloping hills, among which only an apparent general uniformity of summit elevations, at about 2,200 feet, suggests the presence of a former erosion surface. Near the 141st Meridian, and for 20 miles or more upstream, Porcupine River is entrenched 500 feet below a gently rolling surface that shows notable evenness for a few miles back on each side of the river valley, and lies altogether below the upland surface.

Old Crow Range stands a few miles back from the rim on the north side of the entrenched valley of Porcupine River. It resembles Keele Range in its planation and extends from the 141st Meridian to Old Crow River. Its core is formed of a granite mass that is 23 miles wide at the meridian.[2] Elevations reach to 3,000 feet or higher. North of the range, Porcupine Plateau continues as a rolling area of widely spaced hills that dip under the broad flat of Old Crow River in Porcupine Plain and rise again along the southern edge of British Mountains.

The plateau country southeast and east towards Peel River and Hungry Lake, consists of long ridges that, as elsewhere in the plateau, show a general uniformity of elevation and follow the resistant strata exposed by folds. The ridges rise from the flatter country of Porcupine Plain along the front folds, and in a general way resemble those of the southern Rocky Mountain Foothills. They stand as a curving belt of foothills 15 to 25 miles wide, maintaining strikes parallel with the adjacent parts of Ogilvie Mountains in the southeast to Keele Range in the north. East of the head of Porcupine River, Ogilvie Mountains rise along a definite line in steeper, higher ridges to the south of this foothills belt.

In the lower parts of Porcupine Plateau, notably between Ogilvie and Keele Mountains, Palæozoic and Precambrian rocks are overlain in part by Cretaceous strata.[3]

From the southeast part of Porcupine Plateau, Peel River has a short, steep course to sea-level, relative to that of Porcupine River, and, as a consequence, Peel River has been capturing drainage from Porcupine River wherever topography and bedrock structure facilitate the process. In its aggressive erosion, Peel River has eaten its way westward from the mouth of Wind River, entrenching a large valley below the level of those of Porcupine River and its tributaries to the north. In the east end of this valley it has cut a canyon 10 miles or more long. Air photographs show that the upper part of the canyon is cut along a soft bed in steeply southward-dipping strata, and it is so deep and narrow that the south wall, in photographs taken from almost vertically over it, appears to overhang and conceal the river in places. West of the canyon, Peel River has captured, on its south side, Hart, Blackstone, and Ogilvie Rivers, whose courses indicate that they were formerly branches of

[1] Cairnes, D. D.: The Yukon-Alaska International Boundary between Porcupine and Yukon Rivers; Geol. Surv., Canada, Mem. 67, p. 32 (1914).
[2] Maddren, A. G.: Geologic Investigation along the Canada-Alaska Boundary; U.S. Geol. Surv., Bull. 520K (1912).
[3] Cairnes, D. D.: Op. cit., p. 29.

Porcupine River, and on its north side several creeks heading with Eagle River. But on the north bank farther west, upstream beyond Blackstone River, Porcupine River has retained its tributaries, which have their heads on the very brink of Peel River Valley.

Only in the extreme southeast part of Porcupine Plateau, along Peel River Valley and around Hungry Lake, is any evidence of Pleistocene glaciation apparent. Air photographs of Peel River Valley as far upstream as Blackstone River indicate that the ice pushed westward and northwest south of Richardson Mountains from Wind River Valley across this area and up Peel River to near the mouth of Blackstone River. The ice also extended two fingers up tributary valleys northwestward around the south end of Richardson Mountains. The southwest finger reached a little beyond small lakes draining into the head of Eagle River.

*Porcupine Plain.* Porcupine Plain is a long, shallow depression between Porcupine Plateau on the southwest and Richardson Mountains, Arctic Plateau, and British Mountains on the east and north. The plain can be subdivided into several parts, each with distinctive physiographic features. A line drawn across Porcupine River a few miles north of the mouth of Bell River would divide it into two main units, and the sixty-seventh parallel affords an approximate subdivision of the southern of these units into Bell Basin on the north and Eagle Plain on the south. The northerly unit is interrupted by ranges of low hills of folded strata that extend across it from Porcupine Plateau, in general prolongation of Keele Range, northeasterly to Arctic Plateau and Richardson Mountains, and divide the unit into three or more[1] basins of which Old Crow Plain, on the northwest, is the largest. Other, much smaller basins are apparently present along Driftwood River and the lower part of Fishing River between the hills.

Eagle Plain is 60 miles wide, east and west, and 120 miles long. In general aspect it is a low plateau, uplifted some 200 to 400 feet above Porcupine River where it leaves the plain (as judged from air photographs, no ground measurements being available), and in a youthful stage of dissection. No hill or elevated point breaks the evenness of its surface. Porcupine and Eagle Rivers and their main tributaries are entrenched in the plain, and between them the divides are broad and flat, their surfaces, sloping gently at first, fall with increasing steepness into narrow little valleys of the headwaters. The valley floors widen and the streams begin to meander as they gather volume from their many branches. The drainage pattern is dendritic, but also shows a vague parallelism and distribution suggestive of broad, very gentle, geologic structures.

To all appearance the rocks that are nearly flat lying in the central and greater part of Eagle Plain are tilted at low angles near the edges of this plain. The only lakes or ponds observed are oxbows along the main streams and isolated little ponds characteristic of creek valleys in unglaciated areas. Unless the Pleistocene ice pushed farther north into the heads of Eagle River than is evident from the air photographs, no parts of this plain were glaciated.

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[1] The southeasterly part of the unit has not yet been photographed.

North of the sixty-seventh parallel, Bell Basin is a low area, 25 to 30 miles in diameter, around the junctions of Eagle, Bell, and Porcupine Rivers. Its surface is dotted with ponds, lakes, and swamps, and is flat. The rivers are cut below the levels of the plain in banks of clay[1] 20 to 30 feet high.

To the north, for about 12 miles below Bell River, an area of low hills separates Eagle Plain and Bell Basin from those basins to the northwest, including Old Crow Plain. The Driftwood River basin is a low, undulating area that stretches along Porcupine River from about 12 miles below Bell River to near the Old Crow and north on each side of Driftwood River for about 30 miles. Parts of it are spotted with ponds and lakes. On Porcupine River, a mile below Driftwood River, a low ridge is formed of unwarped strata in an anticlinal swell that plunges gently south beneath the plain. The surface strata of the ridge are unbroken by denudation.[2] Along Porcupine River in this area the rocks are sediments in various degrees of consolidation. At their base, below Bell River, some quartzite, perhaps Palæozoic in age, outcrops, overlain by Cretaceous shale and sandstone, succeeded in turn by Tertiary shale, sand, and clay. All these rocks show some warping, and in places the lower strata are considerably folded.[3] Spreading from Fishing River west to near Bluefish River, about 12 miles south of Porcupine River, there appears to be a broad, shallow, undulating depression also containing several lakes.

A low chain of hills crosses Old Crow River from the east end of Old Crow Range, and seems to extend between Old Crow and Driftwood Rivers northeast toward the northwest corner of Richardson Mountains. These hills separate Old Crow Plain from the Driftwood River basin. Old Crow Plain is a great, flat area thickly spotted with lakes and ponds that occupy probably more than 30 per cent of its surface (Plate XXVII), but end around the borders of the plain, where the ground rises towards the hills. The lakes and ponds follow a rectangular pattern whose general lines are approximately northwest and northeast. Each pond or lake tends to be rectangular or formed of adjacent large and small rectangles. Actually their sides are not straight but gently curving, and the corners are rounded. East of Old Crow River some of the ponds are more nearly long, isosceles triangles with their apexes to the southeast. The outlines of others overgrown by vegetation show clearly. Except along the banks of large streams and in a few suitable areas the plain is nearly treeless, and its main cover of vegetation is reported to be mosses and tundra plants. The streams avoid the lakes and ponds, flowing between them or out of them, but only in a few places from one lake to another or through a lake or pond. Banks of "muck" (rotted vegetation and silt) and moss, 10 to 20 feet high, parallel the shores of many of the lakes a short distance back from the water's edge. In places two adjacent lakes appear to have a low ridge between them whose form suggests that it has been pushed up by the expansion of the ice in the lakes. Some of the larger lakes are known to be very shallow and this is believed to be true of most of them. Old Crow River and its main tributaries meander elaborately in valleys entrenched 60 to 125 feet below the level of the plain on which the lakes lie. Their cutbanks expose light bluish and yellowish silts, with a thick layer of muck above them that forms the soil of the plain.[4]

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[1] McConnell, R. G.: Report on an Exploration in the Yukon and Mackenzie Basins, N.W.T.; Geol. Surv., Canada, Ann. Rept., vol. IV, 1888-89, pt. D, p. 121 (1890).
[2] Ibid., p. 126.
[3] McConnell, R. G.: Op. cit., p. 128.
[4] Kirk, E. A.: Royal Canadian Mounted Police, Old Crow Detachment, personal communication (1945).

PLATE XXVII

Old Crow Plain, Porcupine Plain: view of a part of Old Crow Plain showing its characteristic rectangular lake pattern. Photo by Royal Canadian Air Force; negative T14L-144.

## WESTERN SYSTEM

The Western system of the Cordillera in Canada includes all land areas southwest of the Interior system. It is a belt of mountainous country more than 1,100 miles long, from the Forty-ninth Parallel to the 141st Meridian, and varies in breadth from about 100 miles in Yukon to 200 miles in British Columbia. Its eastern border with the Interior system is not marked by readily recognizable, persistent topographic features, but in places at wide intervals important valleys occur along it. In the intervals between these valleys the old erosion surfaces of the plateaux of the Interior system rise into it, and the border has no defined position within a belt as much as 10 or even 20 miles wide.

The Western system is bisected by a broad depression formed by Dixon Entrance in the islands on the west, and a long saddle in Coast Mountains on the east. The depression does not break the continuity of the system to the same degree that Liard Plateau and Plain do in separating the Rocky and Mackenzie Mountains of the Eastern system. The same areas continue northward across it, and in Coast Mountains the saddle is only a part of the mountains having lower summits and traversed by the deep, narrow valleys of Skeena and Nass Rivers in their courses to the sea.

Longitudinally, the Western system in British Columbia is made up of three parts: the Coast Mountain area on the northeast, formed of the ranges of Cascade and Coast Mountains; the Outer Mountain area on the southwest, formed of the mountainous parts of Vancouver and Queen Charlotte Islands; and the Coastal Trough,[1] a depression lying between the two mountain areas. Northwestward the Coast Mountain area continues along the Alaskan boundary into Yukon, where it ends. The Outer Mountain area is regarded as being continued along the ranges of the Alaskan coast islands and St. Elias Mountains. Between the northern parts of these two mountain areas the Coastal Trough, which widens northwestward in British Columbia, narrows abruptly at Dixon Entrance and extends as a narrow arm northwestward from the east side of the entrance into southeastern Alaska[2,3]. Farther northwest, in the corner of British Columbia where the southwest border of the Coast Mountain area is again in Canada, the boundary between the mountain areas is no longer represented by such a prominent feature. The mountains on both sides are here close together, and the boundary is drawn along the valley that extends northwest from Kelsall River, flowing to Lynn Canal, to Tatshenshini River, and thence north to Shakwak Valley at Dezadeash Lake. McConnell places the boundary in the valley of Klehini River, but this does not accord as well with the geological boundaries as evidenced by more recent work[4-7]. Northwest of this lake the Western system in Canada is only represented by St. Elias Mountains, which directly overlook Yukon Plateau on their northeast flank.

### Coast Mountain Area

The Coast Mountain area, from the Forty-ninth Parallel in the southeast to where it descends to Kluane Plateau in the northwest, a distance of 1,000 miles, is, as a whole, a continuous barrier of extremely rugged mountains broken only by great canyon-like valleys. The area is divided by Fraser River Valley into two unequal parts: Cascade Mountains, in the southeast corner, is the

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[1] Clapp, C. H.: Sooke and Duncan Map-areas, Vancouver Island; Geol. Surv., Canada, Mem. 96, pp. 23-24 (1917).
[2] Buddington, A. F., and Chapin, T.: The Geology and Ore Deposits of Southeastern Alaska; U.S.G.S., Bull. 800, p. 19 (1929).
[3] Wright, F. E. and C. W.: The Ketchikan and Wrangell Mining District, Alaska; U.S.G.S., Bull. 347, pp. 21-22 (1908).
[4] McConnell, R. G.: Rainy Hollow Area, B.C.; Geol. Surv., Canada, Sum. Rept. 1913, p. 29 (1914).
[5] Wright, C. W.: The Porcupine Placer District, Alaska; U.S.G.S., Bull. 236, p. 14 (1904).
[6] Buddington, A. F., and Chapin, T.: Op. cit., Pl. 2 (1929).
[7] Watson, K. DeP.: Personal communication. Report to be entitled "The Rainy Hollow-Squaw Creek Area, Northern British Columbia", now in preparation for the Department of Mines, B.C.

smaller of these, and the Coast Mountains, to the northwest, much the larger. The Cascade Mountains as a whole are lower and less rugged than the ranges of Coast Mountains. In addition, the Coast Mountains are formed largely of granitic intrusive rocks of the Coast Range batholith, whereas other rocks predominate in the Cascades. Cascade Mountains continue south across the Forty-ninth Parallel into the United States where they have a much larger area than the part in Canada.

### CASCADE MOUNTAINS

The Cascade Mountains in Canada form a triangular area between Fraser River, Fraser Plateau, and the line of the Forty-ninth Parallel. The boundary between the mountains and the plateau is placed arbitrarily, and, as drawn, includes mountain areas in which summits stand distinctly above the general surface of the plateau. These, in the west, lie mainly above an elevation of 6,500 feet, and in the east above 7,000 feet, the plateau being higher in that direction. The mountains are composed of several ranges, which are grouped into three main units, Okanagan Range on the east, Hozameen Range in the middle, and Skagit Range on the west.[1]

The peaks of Okanagan Range reach to 8,500 feet above sea-level, and even higher in a few places. Those of Hozameen Range are somewhat lower. The mountains of both ranges have been carved from what seems to have been areas of great, rolling, nearly flat-topped hills that stood above the surface of Fraser Plateau to the east and north. In Okanagan Range much of the old hill surfaces remain, and the summits are not generally precipitous except where they have been extensively carved by alpine glaciers. The surface of Fraser Plateau is nearly 7,000 feet high around the borders of Okanagan Range, and somewhat lower to the west. The heads of creeks in the range are in valleys whose floors are near the level of the plateau surface, but within short distances they begin to drop steeply to the major tributaries of Similkameen River, which forms the base-level of all the drainage from the range. The valleys of the major streams are deep; relief reaches a maximum west of Keremeos of more than 6,000 feet, but is more commonly about 3,000 feet or less, particularly in the western part of the range.

Skagit Range, on the west, is the most extensive of the three ranges, but as a whole is lower than Okanagan Range. Most of its higher peaks barely reach an elevation of 7,500 feet, though its highest point is more than 8,500 feet above the sea. It forms the divide between streams that, on the west, flow almost directly into Fraser River near sea-level, and those that drain by longer routes, some eastward and then northerly via Nicola and Thompson Rivers to Fraser River and others by tributaries of Similkameen River to Columbia River. In it an old erosion surface is apparent in the even summit levels of its ridges, though the highest peaks stand above this surface. Both east and west of the divide the ridge tops and spur summits are even and high to where they drop abruptly to the main drainage valleys. This affords a relief of 6,000 feet or more in many localities on the west side, where the deeply cut, precipitously walled valleys have almost direct access to Fraser River. A few small alpine glaciers exist in the southwest part of Skagit Range.

Hozameen Range constitutes a transition between Okanagan and Skagit Ranges, but, being on the interior side of the divide, more resembles Okanagan Range.

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[1] Smith, G. O., and Calkins, F. C.: A Geological Reconnaissance across the Cascade Range near the Forty-ninth Parallel; U.S.G.S., Bull. 235, p. 14 (1904).

Cascade Mountains are composed of a basement of late Palæozoic and early Mesozoic volcanic and sedimentary rocks, which have been intruded, in mainly later Mesozoic time, by rocks varying widely in composition from dunite to granite. These are overlain by late Mesozoic and Tertiary sedimentary and volcanic rocks, accompanied by some intrusions.

In Pleistocene time the ice at its maximum in Cascade Mountains overrode peaks as high as 8,500 feet above sea-level on the northeast side of Okanagan Range,[1] though its surface was probably lower during most of the period. It moved southward from Fraser Plateau up the slope of the plateau surface and against the drainage on the north side of the mountains. Its principal outlets were by lower Similkameen River Valley to the southeast, through the gaps at the heads of Ashnola, Pasayten, and Similkameen Rivers, around Skagit Range and through saddles in it, and down valleys like that of Coquihalla River to Fraser River. A period of alpine glaciation followed at some time after the main ice-sheet had ceased to advance, and alpine glaciers flowed down the slopes of valleys—in Okanagan Range the direction was mainly northward opposite to that of the main ice-sheet—and developed cirques in the mountains and U-shaped profiles in the upper parts of the valleys they occupied.

In the southern part of Skagit Range the upward limit of glaciation seems to have been at an elevation of about 6,500 feet[2], whereas valley and alpine glaciation appear to have been more intense than farther east, reflecting the steeper gradients and probably the greater precipitation in Skagit Range.

## COAST MOUNTAINS

Viewed in their broadest aspect the Coast Mountains constitute a wide upwarp cut into blocks by deep, through valleys and dissected to a rasp-like surface by tributary valleys. Throughout their length no distinctive physiographic characteristics separate them into major units, but the saddle opposite Dixon Entrance lies about midway in their length and separates them into two main parts. The saddle extends from Skeena River to Observatory Inlet, and is too long to form a suitable dividing line in itself. Though the two parts differ in some respects, they are not sharply separable, and Skeena River Valley, close to the south side of the saddle, forms a better boundary than any other feature. The part of the mountains south of this valley is called Pacific Ranges, and that part north of and including the saddle, Boundary Ranges.

The differences between the two groups of ranges will appear in their detailed description, but those of principal interest may be mentioned here. Pacific Ranges occupy a broader area and their higher peaks are, on an average, about 1,500 feet higher than those of Boundary Ranges. Approximately nine-tenths of the Pacific Ranges is carved from the granitic rocks of the Coast Range batholith, whereas these rocks make up less than one-third of Boundary Ranges. Glaciers and ice-fields are scattered over Pacific Ranges, but in Boundary Ranges, north of Observatory Inlet, they form in addition a continuous belt broken only near the valleys of Stikine, Whiting, and Taku Rivers and White and Chilkoot Passes.

The Coast mountains are dissected by a network of great, deep, U-shaped valleys, many of which traverse completely through them. They have gentle grades, and their floors attain elevations of only a few hundred feet. The valleys appear to follow approximately three general directions—northwest, northeast, and north, and locally an east-west direction. The valleys of the better mapped areas show a polygon pattern of rectangles and parallelograms,

[1] Bostock, H. S.: Geol. Surv., Canada, Map 341A, "Keremeos" (1940).
[2] Cairnes, C. E.: Coquihalla Area, British Columbia; Geol. Surv., Canada, Mem. 139, p. 17 (1924).

and with more mapping this will probably be seen to apply throughout the mountains. The drainage of the Interior system as well as that of the Coast Mountains is carried through the ranges by many of these great valleys, such as those of Fraser, Klinaklini, Skeena, Stikine, and Taku Rivers. A few major valleys, such as that from Kitimat on Douglas Channel to Aiyansh at the southwest corner of Nass Basin, have no through stream but cut through the mountains across the direction of the main drainage.

Between the major valleys the ranges of the Coast Mountains stand up as great, steep-walled blocks at the perimeters of which the tributary streams drop abruptly to the floors of the main valleys.[1] Although the general pattern of the ridges shows some arrangement, the great peaks are irregularly scattered; in one place a high solitary peak rises dominant over a block or group of mountain blocks whose other peaks show a general uniformity of summit level; in another place this general summit level is interrupted and overshadowed by an irregular group of such high peaks. The highest peaks are not arranged along the axis of the mountains with any regularity, but isolated peaks almost as high as those along the interior of the Coast Mountains stand here and there on the eastern border near the Interior system.

The low elevations of the major valleys and the characteristic, abrupt rise of the mountains above them to elevations rivalling the higher peaks on the divides afford the great relief that is such a notable feature of these mountains as compared with that of the Interior and Eastern systems. Relief in many parts is 8,000 feet and more. A good example is Kates Needle, 10,002 feet high, rising almost directly from Stikine River only a few feet above sea-level. Throughout their length, in the interior of Coast Mountains, the steep valley sides rise to extremely rugged summits, ornamented with sharp needles and fantastic shapes to such a degree as to make the summits of the Rocky Mountains appear relatively smooth.

### *Pacific Ranges*

Pacific Ranges comprise the largest part of the Coast Mountains, and in combined height and area represent the greatest mountain mass in Canada. They rise abruptly within a few miles west of Fraser Valley to reach elevations of more than 9,000 feet (such as Skihist Mountain, 9,660 feet) and so overtop Skagit Range by more than 1,000 feet. Farther northwest these ranges increase in elevation, and become grouped into mountain blocks separated by deep, through valleys. Few of these blocks or ranges fail to be crowned by peaks more than 9,000 feet high, and the majority contain peaks well over 10,000 feet. The highest is Mount Waddington, whose massive ridge, 13,260 feet above sea-level, exceeds the highest peak of the Rocky Mountains. Several of these ranges hold large ice-fields in their central parts from which glaciers flow through gaps between the surrounding peaks to reach far down toward sea-level through the valleys that radiate from them. The largest ice-field in these ranges whose dimensions are known is that around Mount Waddington. It is approximately 20 miles long, north to south, and 15 miles wide. In addition, a host of isolated, smaller ice-fields and alpine glaciers are scattered in these ranges, particularly among their western summits.

A view of Pacific Ranges from a high ridge or peak gives the impression that most of the summits rise to an even surface above which few project. Only here and there does a great peak such as Monarch Mountain, 11,714 feet high, or a group of great peaks, such as Mount Waddington and its satellites, stand

[1] Dolmage, V.: Chilko Lake and Vicinity, British Columbia; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, p. 61 (1925).

above the uniformly elevated points on the horizon. This feature, so characteristic of the mountains of the Cordillera, is thought here to be evidence of the presence of a former, upwarped, well-developed erosion surface out of which the mountains have been carved. Further evidence of such an old surface is apparent south of Skeena River. There a remarkably even erosion surface, seen in air photographs, rises from the sea on the west coasts of the northern part of Banks Island, Porcher Island, and neighbouring islands and bevels the summits as it slopes upward inland. Though many pronounced valleys dissect it, the surface truncates large areas on the islands along their southwest parts. Landward the valleys become deeper and broader, the elevation of the surface increases, its areas diminish and are only apparent on hilltops and, farther inland, on mountain summits. Still farther within the interior of the ranges only small areas of rolling surface remain, and along the axis of the mountains the accordance of summit levels is all that is left to represent this surface. From the northern part of Banks Island southeast for about 100 miles the mountains rise abruptly along a line east of Banks and Estevan Islands from a relatively level lowland, and elevations of the mountains increase gradually inland[1].

Much of the interior parts of the Pacific Ranges remains unsurveyed, and only those parts readily accessible from the sea or the interior have been mapped. By reason of the fact that many of the great valleys that cut through these ranges are fiords, occupied by the sea for one-third to one-half or more of their length, much of the southwest side of the mountains has been mapped along these valleys. Complete mapping may exhibit a more intricate system of dissecting valleys in these ranges than is apparent from present maps.

The drainage of the northeast side of Pacific Ranges is gathered in the north by the tributaries of Skeena and Fraser Rivers, and in the south by those of Fraser River, but in the central part of the ranges several streams, including Klinaklini, Bella Coola, and Dean Rivers, extend through these ranges to the plateaux of the Interior system and gather the drainage from the northeasterly, interior slopes of the mountains.

Perhaps no mountain area of equal size in the world is so solidly built of granitic rocks as these Pacific Ranges of the Coast Mountains. According to present geological maps more than nine-tenths of their area is underlain by rocks of the Coast Range batholith, which reaches its greatest breadth of 120 miles or more about midway of the ranges. A bordering fringe on the southern interior side of these ranges is, however, composed of Mesozoic volcanic and sedimentary rocks and some metamorphic equivalents intruded by satellites of the batholith. This area contains on its southeast side, along the edge of the batholith, a row of high peaks formed of the intruded rocks. Near Charlotte Lake the batholith spreads eastward into the Interior Plateau for several miles, but in general the contact of the batholith approximates the northeastern border of Pacific Ranges.[2] Several roof pendants, some more than 30 miles long and 10 miles wide, of Mesozoic and other rocks lie within the interior area of the batholith and about in line with its general trend.

During Pleistocene time Pacific Ranges were probably largely covered by ice. Although no attempt has yet been made to indicate what parts stood above the ice, the upward limit of glaciation was probably at least as high in the southern parts of these ranges as in Okanagan Range, where it reached an elevation of 8,500 feet. Glacial erosion was particularly active in these mountains. Their position along the sea coast gave them a great and continual supply of snow, which, with the short distances and steep grades to sea-level,

[1] Dolmage, V.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 24 (1922); Sum. Rept. 1922, pt. A, p. 11 (1923).
[2] Dolmage, V.: Tatla-Bella Coola Area, Coast District, B.C.; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 156.

resulted in rapid ice flow and intense erosion. Thus was developed the great network of valleys, with long fiords in their seaward parts commonly excavated to 2,000 feet and more below present sea-level.

As in Cascade Mountains, the widespread glaciation was followed by a period of alpine glaciation that may have continued to the present in the large existent ice-fields.

### *Boundary Ranges*

The main characteristics of Boundary Ranges resemble those of Pacific Ranges, but differ in their relative importance. Both groups of ranges are similar as regards ruggedness, ice-fields, glaciers, trench-like valleys, fiords, and great relief, and to the degree that they contain a large proportion of granitic rocks, but Boundary Ranges are distinct from Pacific Ranges in being a narrower group, and, as a whole, about 1,500 feet lower, their highest recorded peak being Mount Ratz, 10,290 feet above sea-level. The Coast Range batholith is exposed in less than half of their area, and volcanic and sedimentary rocks predominate. Ice-fields and glaciers cover a very considerable part of these ranges, stretching continuously for 80 and 100 miles in two areas along their backbones (Plate XXVIII).

Though the International Boundary Surveys cover a large part of Boundary Ranges to the west of their main axis and have given much information not available for Pacific Ranges, these ranges still include some of the least known areas in the Cordillera.

The southern end of Boundary Ranges is north of Skeena River at the saddle previously referred to. This area is only partly mapped. It is mountainous, but it is apparently the lowest part of the Coast Mountains, and no glaciers are shown in the mapped parts. Oscar Peak, 7,560 feet above sea-level, is its highest recorded point.

North of Nass River to Observatory Inlet, the mountains are similar to those south of the river, but beyond the inlet they rise, and the chain of ice-fields and glaciers, of which Cambria Snowfield is the first unit, begins. Northwestward, elevations rise sharply to more than 8,000 feet, and south of Iskut River, where its lower reaches traverse the mountains east to west, the highest recorded point is Mount Pattullo, with an elevation of 8,944 feet. The north side of this group of peaks and ice-fields is unmapped. Along the International Boundary elevations decrease toward the lower reach of Iskut River.

To the north of the lower valley of Iskut River, a large block of mountains, Spectrum Range, stands mainly unmapped between the upper reaches of Iskut River on the east and Stikine River on the west (Plate XXIX). It appears to be a typical block of Coast Mountains, and Mount Hickman, 9,700 feet high, close to its centre, is shown on maps as its highest peak, with others almost as high along its western edge.[1] On the east and northeast flanks of Spectrum Range the summits are generally topped by a relatively smooth upland surface that slopes in harmony with that of Stikine Plateau to the east.[2] These smooth tops diminish in area westward and disappear about 10 miles from the margin of the plateau.

Several unnamed ranges form the part of Boundary Ranges between Stikine and Taku Rivers.[3] As a whole, they are high and rugged, and exhibit excessive

[1] Kerr, F. A.: Preliminary Report on Iskut River Area, British Columbia; Geol. Surv., Canada, Sum. Rept. 1929, pt. A, pp. 36 and 37 (1930).

[2] Kerr, F. A.: The Physiography of the Cordilleran Region of Northern British Columbia and Adjacent Areas; Roy. Soc., Canada, 3d. ser., vol. XXX, sec. IV, p. 141 (1936).

[3] Kerr, F. A.: Explorations between Stikine and Taku Rivers, B.C.; Geol. Surv., Canada, Sum. Rept. 1930, pt. A, pp. 47-49 (1931).

PLATE XXVIII

Coast Mountains: view southwest across the summit of Boundary Ranges. Only the foreground of the picture is in Canada. In the centre and left Taku Glacier flows down to the sea in Alaska. This view shows a typical part of the ice-fields that stretch along the summit of these ranges. Photo by United States Army Air Force; negative 36 1-R30 2-2010.

PLATE XXIX

Coast Mountains: view up Stikine River Valley. The end of Flood Glacier shows in left foreground. The mountains on the right are those of the Spectrum Range, and Stikine Plateau shows faintly in the distance. Photo by United States Army Air Force; negative 41 3-R78 2-2010.

steepness and great relief such that along parts of their main valleys slopes rise 6,000 to 8,000 feet within less than 2 miles (Plate XXX). Both their ruggedness and their extensive cover of snow and ice decrease eastward from the International Boundary, and, as in Spectrum Range, areas of smooth upland surface encroach upon their eastern flank.[1] There are, however, groups of high peaks in their northeastern parts that rival those along the Boundary in these features. North of the lower reach of Chutine River these ranges are divided, nearly parallel with their main trend, by a valley extending northwest along the upper reach of Chutine River to the south and north branches of Whiting River and thence to Taku River, near the Boundary. That part of the ranges west of Stikine Valley and southwest of the dividing valley comprises a broad, unbroken ridge from the lower part of Stikine River to Whiting River, a distance of 100 miles, capped by a continuous ice-field and glaciers. From Whiting River to Taku River the ridge continues, but is lower, more dissected by valleys, and its ice-fields are not continuous. In the southern part, west of Stikine Valley, the ridge includes several peaks more than 10,000 feet high, but northward the elevations decline, most of them being between 7,000 and 8,000 feet high. Northeast of Chutine River, beyond the dividing valley, the mountains form a detached parallel ridge, but here they are dissected into block-like ranges by large valleys. In these ranges, the peaks attain elevations of between 8,000 and 9,000 feet, and in a few places, are higher.[2] These elevations persist to the brink of Taku Valley, exceeding those to the west, on the ridge along the Boundary, by more than 1,000 feet.

A similar group of ranges extends northwest from Taku River to the broad saddle in which White and Chilkoot Passes cross Boundary Ranges. The highest recorded peak in this group of ranges is Devils Paw, 8,584 feet above sea-level. These ranges, like those between Stikine and Whiting Rivers, are capped by a continuous ice-field and glaciers for more than 80 miles.

Northwest of White and Chilkoot Passes, Boundary Ranges are typical of the Coast Mountains. Their highest point is a rugged, massive peak, 8,300 feet in elevation, near Kusawa Lake, and a few other neighbouring peaks reach a height of a little more than 8,000 feet. Here the Coast Mountains reach their northwest limit, and are wrapped around to the northwest by plateau country. The boundary between mountains and plateau is unusually indefinite in a broad transition area of high plateaux surmounted by groups of mountains. The general aspect of their transition area is very like that along the northeast boundary of Okanagan Range, and of many other areas where mountains are bordered by plateaux of the Interior system. The upland surface is about 6,000 feet high; the main valleys are cut to 3,000 feet or more below it, and the mountains standing 1,000 to 2,000 feet above the upland surface appear to have been carved into their rugged form by alpine glaciers from ranges of smoothly profiled remnants left by a former erosion cycle. As a result, where the upland surface is at all apparent, even well within the mountains, the plateau-like character of the topography is very noticeable.

From Nass River to Taku River there appears to be an irregular but more or less continuous valley following the eastern front of Boundary Ranges. In the south it is formed by Nass Basin and thence continues along the belt of plateau country along Bell Irving River, which separates Boundary Ranges from Skeena Mountains. Farther north it follows Iskut River, and then breaks across to the drainage of Mess Creek and thence to Stikine River. From there

[1] Kerr, F. A.: The Physiography of the Cordilleran Region of Northern British Columbia and Adjacent Areas; Roy. Soc., Canada, 3d. ser., vol. XXX, sec. IV, p. 141 (1936).
[2] Kerr, F. A.: Explorations between Stikine and Taku Rivers, B.C.; Geol. Surv., Canada, Sum. Rept. 1930, pt. A, pp. 47-49 (1931).

PLATE XXX

Coast Mountains: view northeast over Boundary Ranges northwest of Stikine River Valley. The deep valleys of Chutine River and its tributaries in the centre of the picture illustrate the characteristic steep relief of these ranges. Photo by United States Army Air Force; negative 39 1-R87 2-2010.

it continues across to the upper parts of Sheslay River and down the lower part of Inklin River to Taku River. Lack of contour maps and other information prohibits the proper evaluation of this feature at present.

Boundary Ranges are carved in part from huge thicknesses of volcanic rocks, with minor quantities of sediments, all of Mesozoic age, and from thinner sections of Upper Palæozoic volcanic and sedimentary rocks. Some metamorphic types including, perhaps, rocks of Precambrian age are also found in these ranges. All these rocks are intruded by the Coast Range batholith, which on the average has less than one-third of its width in Pacific Ranges. Where the batholith is crossed by Stikine River in Boundary Ranges its main body is only 10 miles wide, but the trace of its contact is much less regular than to the south, and its true magnitude beneath the surface is indicated by the presence of numerous large and small satellitic masses on either side of the main body. North of Taku River the batholith widens, the main body reaching a width of 60 miles at the sixtieth parallel. Farther north, it is less well exposed, due to numerous roof pendants and to the presence of areas of older rocks that extend into it from either flank. It narrows to about 40 miles where it crosses Kusawa Lake at the northwest extremity of the Coast Mountains.

In Pleistocene time, glaciation was very active in Boundary Ranges, and ice probably covered all but the highest parts. At its maximum this ice moved westward and eastward from near the summits of the ranges, much of that moving eastward subsequently turning to escape west through the great valleys such as that of Stikine River.[1] Some ice that pushed east into the Central Plateau and Mountain area escaped northward from the neighbourhood of Atlin Lake[2] in the north and, judging by the configuration of the valleys as they appear from air photographs, southward in the south. Active glaciation on a diminished, still considerable, scale has continued in these ranges, with periods of oscillation up to the present extensive stage of alpine glaciation.

## Coastal Trough

Most of the Coastal Trough in Canada is submerged beneath the epicontinental sea of the Pacific coast, but in the south, along the shores of the Strait of Georgia and on the east part of Queen Charlotte Islands, lowlands border it and form a part of it. Between the Strait of Georgia in the south and Queen Charlotte and Hecate Straits in the north is an arch in the floor of the trough that brings it above sea-level, so that it is made up of three parts, the Georgia depression in the south, the Seymour arch in the middle, and Hecate depression in the north. Along each side of Georgia depression the mountains rise with distinct fronts, and the same is partly true in Queen Charlotte Islands on the west side of Hecate depression, but elsewhere areas bordering the Coastal Trough rise from it without displaying any abrupt feature.

North from Seymour arch the Coastal trough appears to widen to where, at Queen Charlotte Islands, it is some 60 to 70 miles wide, including Queen Charlotte Lowlands and Hecate Strait. North of Dixon Entrance in Alaska the east side of the trough is continued by a narrow arm extending along the southwest side of the Coast Mountain area, but the trend of the southwest boundary projected northwestward would pass to seaward of the southwest side of the Alaskan Islands. If extended southeastward, the general line of the Alaskan ranges grouped here in the Outer Mountain area would project along the Coastal Trough close to Rose Point of Queen Charlotte Islands. These

[1] Kerr, F. A.: Glaciation in Northern British Columbia; Trans. Roy. Soc., Canada, 3d ser., vol. XXVIII, sec. iv, pp. 17-31 (1934).

[2] Gwillim, J. C.: Report on the Atlin Mining District, British Columbia; Geol. Surv., Canada, Ann. Rept., vol. XII, 1899, pt. B, p. 13 (1901).

trends suggest that the ranges of the Alaskan Islands rise from the broad floor of Hecate depression *en échelon* along a line inside that of those on Queen Charlotte Islands, and that the trough divides in the north part of Hecate depression, sending a westerly fork northwest across Dixon Entrance.

### *Georgia Depression*

Georgia depression is mainly submerged, but parts of it rise above the sea as islands in the Strait of Georgia and as lowlands on Vancouver Island and the mainland. Altogether the depression is about 25 miles wide. The main part above sea-level is the lowland or coastal plain along the east shore of Vancouver Island. This is a low area between the sea and the mountain front of Vancouver Island Ranges. It averages 8 miles in width and is 100 miles or more long. Much of it slopes from the sea to the mountains, but in the northern part some shallow valleys parallel the coast. Except close to the mountains few parts of it are more than 500 feet above sea-level. The depression is underlain by Mesozoic sedimentary and volcanic strata including Cretaceous coal measures. In Pleistocene time the ice moving southward along the depression overrode the lowland and left a mantle of drift deposits on its surface. Since the disappearance of the ice an uplift of 250 to 400 feet[1], affecting most, if not all, of Vancouver Island, has resulted in the emergence of most of the islands in the Strait of Georgia and the coastal plain.

In the southern parts of the Georgia depression elevations on some of the smaller islands and on the fringe of Vancouver Island reach 1,000 and even 2,000 feet. The area containing them resembles a dissected plateau more than a coastal plain, and in a more detailed account it might be treated as a separate physiographic unit.

### *Seymour Arch*

Northwestward from the Georgia depression the floor of the Coastal Trough rises above sea-level as the broad Seymour arch, and the mountain fronts that define the borders of the depression merge into the hilly topography of the arch. The arch connects the mountains on either side as an "isthmus" that is somewhat similar topographically. It consists mainly of small islands and peninsulas, but also includes the border of Vancouver Island along Salmon River. Some of the islands are low, but most of them are hilly and some are mountainous, reaching heights from 2,500 to 4,700 feet above the sea, those with the highest elevations extending northward from each side of Salmon Bay. Remnants of an old erosion surface truncate their summits, so that the arch is a warped and much dissected plateau.

The main contact of the Coast Range batholith coincides approximately with the northeast border of the trough in most of the Georgia depression, but towards the north it diverges on a more westerly course from the border on a direct line, crossing channels and islands of the arch and the northeast shoulder of Vancouver Island. Southwest of the batholith the rocks are sedimentary and volcanic strata of Mesozoic age similar to those that cover most of Vancouver Island. In Pleistocene time the trough was probably completely filled by the ice when at its maximum height, ice that had come from the ice-fields and glaciers of the Coast Mountains on the northeast and to a less extent from those of Vancouver Island Ranges on the southwest. The arch appears to have formed

[1] Clapp, C. H.: Geology of Victoria and Saanich Map-area, Vancouver Island, B.C.; Geol. Surv., Canada, Mem. 36, pp. 8-14 (1913). Sooke and Duncan Map-areas, Vancouver Island; Mem. 96, p. 25 (1917).

a divide extending northeast from Chatham Point, and to have deflected the ice from the Coast Mountains to the Strait of Georgia to the southeast, and to Queen Charlotte Strait to the northwest[1,2].

### *Hecate Depression*

The Hecate depression is a broad hollow reaching from Queen Charlotte Ranges and Skidegate Plateau on the west to the slopes of the Coast Mountains, beginning with the outer islands on the east. The only parts of the depression exposed are the lowlands of Queen Charlotte Islands and places along the border of the mainland.

Queen Charlotte Lowlands extend approximately from Cumshewa Head on Moresby Island to Beresford Bay on Graham Island.[3] They are rolling areas of forest, swamp, and shallow lakes out of which in some places mesa-like hills rise to 400 feet above sea-level. The east side of the lowlands is underlain by Tertiary sedimentary rocks, and the hills are formed of overlying Tertiary lavas and agglomerates. The same volcanic rocks cover all northwest parts of the lowlands except the extreme northwest corner, which is composed of Mesozoic sedimentary and volcanic strata. During Pleistocene time the lowlands were at least partly covered by ice, which encroached on them from Queen Charlotte Ranges to the southwest. It is not known whether ice from the mainland or Alaskan Island glaciers reached these islands, but there is no evidence of its passage across them.[4]

On the northeast side of Hecate depression Banks Island and other islands lying southeast of it for about 100 miles form a belt of rolling lowland, 10 to 30 miles wide, with elevations generally less than 100 feet, along the border of Pacific Ranges.[5] The lowland is composed of numerous islands, mainly of granite rocks and largely bare of soil, and is considered part of the depression.

## **Outer Mountain Area**

The Outer Mountain area includes all the ranges of Vancouver, Queen Charlotte, and the southeastern Alaskan Islands and St. Elias Mountains. These fall into three main groups: Insular Mountains in the south, consisting of the ranges of Vancouver and Queen Charlotte Islands; Alaskan Island mountains, embracing the ranges of the Alaskan Islands west of the northeast arm of the Coastal Trough in Alaska; and St. Elias Mountains, the ranges on the mainland northwest of Lynn Canal. In this report only the Insular Mountains and St. Elias Mountains in Canada are dealt with.

### INSULAR MOUNTAINS

The Insular Mountains consist of the ranges of two mountainous island groups, Vancouver Island and some neighbouring islands and the Queen Charlotte Islands. These mountains are known as Vancouver Island Ranges and Queen Charlotte Ranges respectively.

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[1] Dawson, G. M.: Report on a Geological Examination of the Northern Part of Vancouver Island and Adjacent Coasts; Geol. Surv., Canada, Ann. Rept., 1886, pt. B, p. 102 (1887).

[2] Bancroft, J. A.: Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound, B.C.; Geol. Surv., Canada, Mem. 23, p. 50 (1913).

[3] Mackenzie, J. D.: Geology of Graham Island, British Columbia; Geol. Surv., Canada, Mem. 88 (1916).

[4] Dawson, G. M.: Report on the Queen Charlotte Islands; Geol. Surv., Canada, Rept. of Prog. 1878-79, pt. B, pp. 89-91 (1880).

[5] Dolmage, V.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 24 (1922); Sum. Rept. 1922, pt. A, p. 11 (1923).

### *Vancouver Island Ranges*

The greater part of Vancouver Island is composed of the mountains of Vancouver Island Ranges. On the southwest of the Georgia depression, these ranges rise along a persistent front extending northwest and southeast. On their southwest side they drop steeply to the sea, and in places to small disconnected areas of a narrow, coastal plain. In the north the ranges end abruptly along an east-west line through the mouth of Quatsino Sound. North of this sound the island consists of patches of plain separated by low rolling ranges of hills whose highest point is 2,417 feet above the sea.

Vancouver Island Ranges are formed of many small mountain areas separated by deep, U-shaped valleys, some of which extend across the island and, in some places such as Alberni Inlet, have floors that are partly below sea-level. The mountains characteristically show remnants of a subdued, rolling surface that resembles that of the plateaux of the Interior system and truncates their summits. This plateau surface has been uplifted and maturely dissected.[1] In the southern part of the island the plateau surface was peneplaned, with only a few rounded hills rising above it before it was uplifted some 1,500 feet. In the central part of the island the evenness is less marked, and the surface noted in the ranges is roughly 5,000 feet or more above the sea. Here the ranges have their greatest relief. Their highest summits, which reach 7,200 feet in Golden Hinde and Elkhorn Mountains, rise more than 6,000 feet above the adjacent valleys, and along the axis of the ranges many summits more than 6,000 feet high hold small alpine glaciers on their northern slopes.

Vancouver Island is underlain mainly by Mesozoic sedimentary and volcanic rocks, though in the south a considerable area of upper Palæozoic sedimentary and volcanic rocks is exposed. All these rocks are intruded by acid and basic rocks that form large bodies along the backbone and southwest flank of Vancouver Island Ranges. During Pleistocene time the island is believed to have been almost covered by an ice-cap that had its apex along the axis of the ranges and flowed from it to the Pacific Ocean, in part by the Strait of Georgia and Queen Charlotte Strait, and in part by the major valleys across the island.

### *Queen Charlotte Ranges*

The Queen Charlotte Ranges include the mountains of Graham, Moresby, and Louise Islands and other islands of the Queen Charlotte Island group, and the Skidegate Plateau area of Graham Island. They constitute the northern end of the Insular Mountains, which disappear to the north at Dixon Entrance 50 miles southwest of the Alaskan Island mountains. The general trend of the ranges is about northwest, continuing that of Vancouver Ranges at the south end, but swings to more nearly north toward the north end, though not sufficiently to fall into alinement with Alaskan Island mountains.

Mountains are the main topographic features of the Queen Charlotte Islands, and occupy most of the southern islands and about half of Graham Island. They are rugged, and are broken by deep valleys into a number of irregular, block-like ranges. In most parts of these ranges the peaks show a local uniformity in height. The majority are about 3,000 feet high, except at the north and south ends of the island chain where they are 2,000 and 2,600 feet above sea-level. The highest points are 3,945 feet in the southern part of Graham Island and 3,810 feet in the northern part of Moresby Island. Some patches of perennial snow are found on the higher peaks, and timberline is at an elevation of 1,300 feet.

[1] Clapp, C. H.: Sooke and Duncan Map-area, Vancouver Island; Geol. Surv., Canada, Mem. 96, p. 24 (1917).

The southern part of Queen Charlotte Ranges, including almost all of Moresby Island, is composed of Mesozoic sedimentary and volcanic rocks. These are intruded in a number of places near the north and south ends of Graham Island by dioritic stocks.[1] On Graham Island the northern two-thirds of the ranges are composed of Tertiary lava flows and agglomerates. In Pleistocene time the ranges were covered, in part at least, by ice and glaciers that flowed from them along the fiords of the west coast and through Skidegate Channel.

Skidegate Plateau lies between Queen Charlotte Ranges and the lowlands to the east on the southern part of Graham Island. It is a rolling area with summit levels ranging to 1,200 feet above sea-level in its southern part, and to 1,800 feet in its northern and northwestern parts. The plateau is mainly composed of Mesozoic sedimentary and volcanic rocks, and was traversed by ice from the Queen Charlotte Ranges during the Glacial epoch.

### ST. ELIAS MOUNTAINS

Viewed on a perfect day from Dawson Range, 100 miles or more to the northeast, St. Elias Mountains appear as a broad swelling on the horizon out of which giant peaks project like islands of ice and snow. When haze and smoke shroud the lower levels, these peaks, high in the crystal clear atmosphere above, are sometimes still to be seen, a line of magnificent icebergs floating on the denser air. These are the highest mountains of Canada, and together are the largest group of great peaks in North America. For Canada, at least, and perhaps for the world, they have unique characteristics, and possess a distinct grandeur of their own. Above a sea of lesser peaks and wide ice-fields the great peaks stand solitary or in compact, isolated groups. Besides their colossal size, this individual aloofness adds much to the impressiveness of their vast, wild, and icy beauty, and contrasts them sharply with the jumbled rivalry of summits around many of the main peaks of the Coast, Rocky, and Mackenzie Mountains, and other mountains of the Canadian Cordillera. Many of these individual peaks and groups are block-like in form, rising on nearly every side with precipitous cliffs, not to pinnacle-like tops, but to broad, still steep, though relatively gentler, summit areas. This gives them an appearance of stupendous massiveness from all directions. Another outstanding feature is the mantle of snow and ice that even in summer cloaks a great part of them. It spreads unbroken over their gentler, summit areas, smoothing the contours of their upper slopes and concealing bedrock. As the slopes steepen downward, it overhangs the edges of precipices in great cliffs of ice from which it cascades in mighty avalanches thousands of feet to the broad fields of snow and ice below, where it feeds the glaciers that lead away from between the peaks. Almost the only exposures of rock in all the vast expanse of white and blue around the great peaks are in their precipices. Below these dazzling monarchs a sea of lesser peaks, mighty themselves in other company, form a jagged and rocky platform. Such is a general picture of the dominant features of these great mountains beside which the better known ranges of Canada are dwarfed to relative insignificance.

About half of the area of St. Elias Mountains is in Canada, in southwest Yukon and northwest British Columbia. The remaining half is in Alaska, wrapped around the Canadian part on the southeast, southwest, and west. Most of the great peaks are in Yukon or on the Yukon-Alaska boundary. Besides the ranges of the great peaks these mountains include lesser ranges on their northeast or interior side, so that their entire area in Canada is approximately 90 miles wide and 200 miles long.

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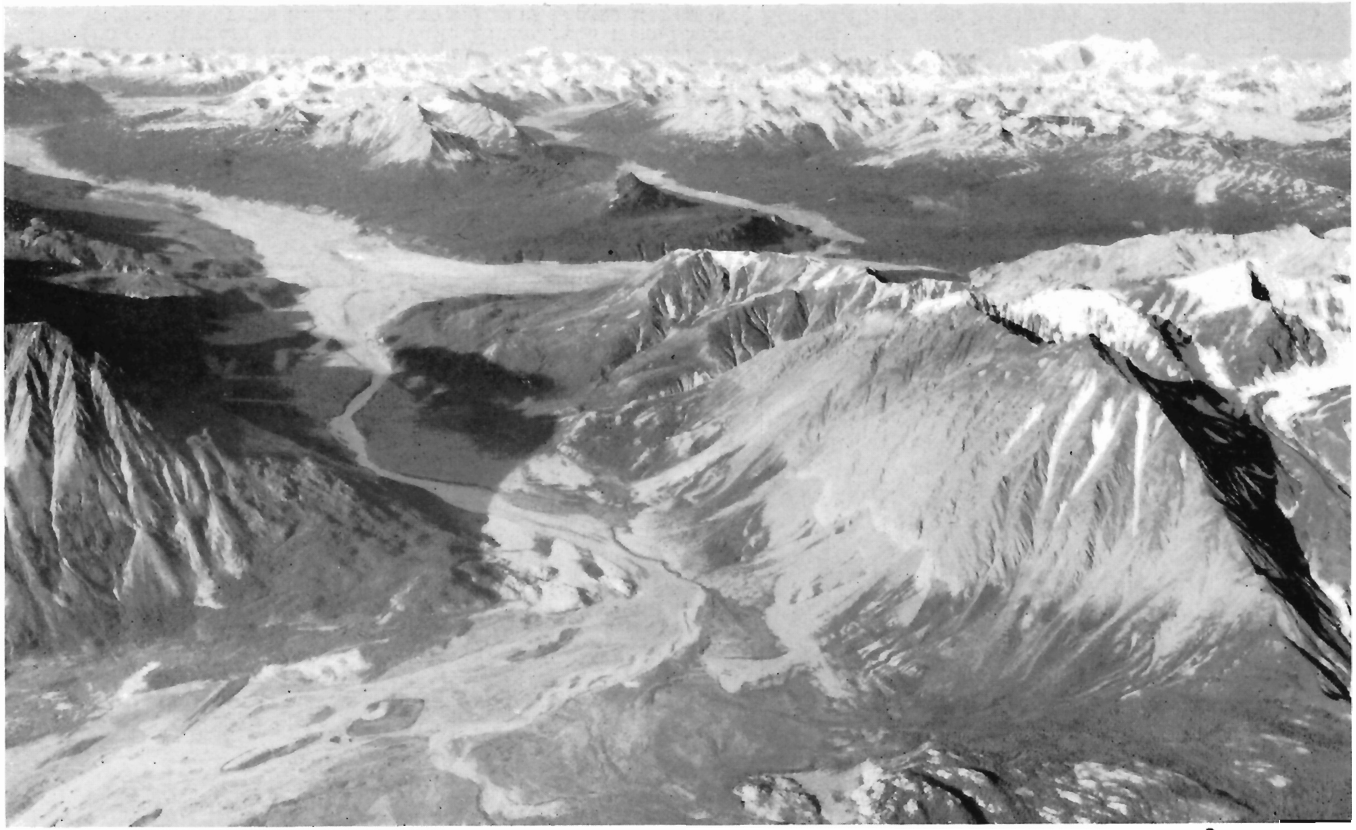
[1] MacKenzie, J. D.: Geology of Graham Island, British Columbia; Geol. Surv., Canada, Mem. 88 (1916).

PLATE XXXI



St. Elias Mountains: view down Alsek River Valley. Kaskawulsh River enters from the right behind the first ridge of mountains, which is part of the Kluane Ranges. The more subdued topography of the Duke Depression shows just beyond Kaskawulsh River, and the Icefield Ranges show on the skyline. Elevation of camera, 12,000 feet. Photo by Royal Canadian Air Force; negative T6-77L.

PLATE XXXII

St. Elias Mountains: view southwest into St. Elias Mountains. In the immediate foreground the wall-like front of Kluane Ranges, between Donjek and White Rivers, rises from Shakwak Valley. The more subdued topography of the Duke Depression appears behind the two ridges of Kluane Ranges, and Klutlan Glacier can be seen on the right. Beyond the glacier Mount Bear, elevation 14,850 feet (Alaska), stands on the skyline, and Mount Wood, 15,880 feet, Mount Lucania 17,150 feet, and Mount Steele, 16,439 feet, are the high peaks of the group to the left. Elevation of camera, 12,000 feet. Photo by Royal Canadian Air Force; negative T7-22L.

The backbone of St. Elias Mountains, which includes the great peaks, forms the Icefield Ranges and Fairweather Range. On its northeast side, from the sixtieth parallel, in the south, northwest to the 141st Meridian, the front ranges form a line of ridges, and are grouped under Kluane Ranges (Plates XXXI and XXXII). A lower, subdued, plateau-like area, Duke depression, extends along the entire southwest side of Kluane Ranges, and separates them from Icefield and other ranges of these mountains. Northwest of Slims River, at the divide to Duke River, Kluane and Icefield Ranges are almost contiguous, and Duke depression is pinched to a narrow waist. Northwest of this divide the depression opens into a broad valley area that continues to expand to where it reaches White River. There it forks and extends two branches across the 141st Meridian: one branch narrows and continues the general line of the depression as the valley of Tchawsahmon Lake, splitting the northeast ridges of Nutzotin Mountains from their main body; and the other branch, bending more to the west, follows up White River as a broad depression separating the main part of Nutzotin Mountains from Icefield Ranges. Kluane Mountains are the southeast extension of the front ridges of Nutzotin Ranges, the main body of which rises as a wedge in the fork of Duke depression to become a major mountain unit distinct from the St. Elias Mountains in Alaska. In this report, however, because of the general close relation between Kluane Ranges and the other units of St. Elias Mountains in Yukon, no separate major unit is made for Nutzotin Mountains and they are treated as a part of Kluane Ranges.

Southeast of the divide between Duke and Slims Rivers, Duke depression follows down Kaskawulsh River Valley and spreads southward, merging with a network of valleys between Alsek River and the southeast boundary of St. Elias Mountains adjacent to the Coast Mountains. The network of valleys cuts the mountains east of Alsek River and south of Kluane Ranges into many smaller and larger ranges. A line drawn up Bates River and thence eastward to Tatshenshini River at the sixtieth parallel would separate the smaller ranges of Duke depression from the larger Alsek Ranges to the south. Alsek Ranges are separated from Icefield Ranges on the west by Alsek River Valley, and from Fairweather Range on the south by the valley of Melbern and Grand Pacific Glaciers.

Little exploration has been carried on in the interior of St. Elias Mountains other than that by the International Boundary Surveys and expeditions of the American Geographical Society[1-3] and the National Geographic Society,[4] whose accounts, maps, and photographs are the only information available for Icefield Ranges.

### *Kluane Ranges*

Kluane Ranges form a narrow, front ridge to St. Elias Mountains. Though they are divided into nine, short, distinct ranges by large, crosscutting valleys, their front is so straight and abrupt for most of its length that, viewed obliquely from Yukon Plateau, the breaks in it are not conspicuous, and the general impression is that of a continuous mountain wall rising from Shakwak Valley. This front, besides being the boundary between Yukon Plateau and St. Elias Mountains, marks a major geological boundary, suggesting that the mountains rise along a fault-line scarp on the southwest side of Shakwak Valley. Between Dezadeash River and Kluane Lake the floor of this valley is higher, and the

[1] Wood, Jr., W. A.: The Wood Yukon Expedition of 1935; Geog. Rev., vol. XXVI, pp. 228-246 (1936).
[2] The Parachuting of Expedition Supplies, An Experiment by the Wood Yukon Expedition of 1941; Geog. Rev., vol. XXXII, No. 1, Jan. 1942, pp. 36-55 (1942).
[3] Sharp, R. P.: Geology of the Wolf Creek Area, St. Elias Range, Yukon Territory, Canada; Geol. Soc. Am., vol. 54, pp. 625-650 (1943).
[4] Washburn, Bradford: Exploring Yukon's Glacial Stronghold; Nat. Geog. Mag., vol. LXIX, No. 6, June 1936, pp. 715-748.

wall-like front is less marked than to the southeast and northwest. Mount Decoeli stands out somewhat northeast of the general line, and the valley side sweeps up in long slopes to the mountain spurs.

Kluane Ranges show a particular type of ruggedness that contrasts with that of other nearby ranges. Their slopes are steep and uniform, with long, straight talus screes. Their ridges are serrated and narrow, and summits tend to be uniform in elevation. Many are nearly 7,000 feet high, and with one or two exceptions the highest peaks of each range are about 8,000 feet in elevation. Southeast of Duke River, Kluane Ranges contain alpine glaciers, some of which, between Slims River and Kathleen Lakes, are 2 miles long. Most of these ranges consist of two or three ridges parallel with the main front and connected by high saddles. Northwest of Slims River the first range comprises one, broad, rough ridge of summits. Beyond Burwash Creek two distinct ridges become apparent, and beyond Donjek River these are separated by a well-defined valley extending to White River. At the west end of this range, adjacent to White River, a third ridge branches off, thereby widening the range. West of White River, Kluane Ranges are continued by Nutzotin Ranges[1], which become a large mountain unit in Alaska. Between White River and the International Boundary these mountains comprise two ridges between Shakwak Valley and the valley of Upper White River, separated by the valley of Tschawsahmon Lake. The northern ridge continues the line of the front of Kluane Ranges and ends 15 miles west of the Boundary with the convergence and junction of Shakwak and Tschawsahmon Valleys. The southern ridge broadens westward and becomes the main part of the mountains west of the Boundary.

### *Duke Depression*

Duke depression, southwest of Kluane Ranges, is an isolated, plateau-like belt characterized by broad, smooth slopes. Together with Kluane Ranges, its relationship to Icefield and Alsek Ranges resembles those of Franklin Mountains and Mackenzie Plain to Mackenzie Mountains.

Throughout its length the general trend of the depression is parallel with Kluane Ranges, but locally its trend diverges westward and, as at Slims River, its boundaries are stepped back to the general line by northerly trending valleys. At the southeast end it merges into the valley of Kelsall River, separating the St. Elias and Coast Mountains. Its southwest side is irregular, and spreads into the ranges on that side. The depression is divided into two parts by the summit between Slims and Duke Rivers.

Southeast of Slims River the Duke depression extends along Kaskawulsh River Valley, on the northeast side of which Kluane Ranges rise steeply along the line of their southwest front. On the other side of the valley a maturer surface of the plateau-like type spreads south over the mountain spurs and along the west side of Alsek River Valley. This surface is apparent nearly to the sixtieth parallel. On the east side of Alsek River the depression broadens and consists of a network of valleys surrounding small ranges and plateaux. On the south the depression is bordered by the valley of Bates River, from which the mountains rise abruptly to peaks 8,000 feet high. From this river the border extends across to the bend of Tatshenshini River at the sixtieth parallel, where the valley of the upper reach of Tatshenshini River flowing northwestward forms the boundary between the Coast Mountain and Outer Mountain areas.[2] From here to the International Boundary a single wide valley forms the narrow southeastern extremity of the depression. This valley begins

[1] Cairnes, D. D.: Upper White River District, Yukon; Geol. Surv., Canada. Mem. 50, p. 39 (1915).
[2] Buddington, A. F., and Chapin, T.: The Geology and Mineral Deposits of Southeastern Alaska; U.S.G.S., Bull. 800, 19 (1929).

in the northwest with that of the upper reach of Tatshenshini River and continues as a broad-floored, elevated valley of mature aspect and relatively gentle gradients. At the northwest end of this valley Tatshenshini River is entrenched in a narrow canyon, and in its southeast parts several other streams flowing to Kelsall and Klehini Rivers are similarly entrenched along parts of their courses as they leave the valley. On the northeast and southwest the valley is bordered by steep mountain slopes, and at about 20 miles from the Boundary it has a more southerly trend and bends to the west of Kusawak Range.

Northwest of Slims River, Duke depression follows Duke River Valley and broadens to a width of several miles where Duke River turns north and cuts through Kluane Ranges. From Duke River to Donjek River the depression is floored by a gently rolling surface at an elevation of about 4,000 feet, below which the larger streams have cut their valleys. This surface shows particularly well on each side of Duke River where, stretching across to Burwash Creek on the west, a broad gap has been carved through Kluane Ranges. Along this section of the depression, Kluane Ranges rise abruptly on the northeast, and on the southwest the front range of Icefield Ranges, Donjek Range, includes a peak 10,075 feet in elevation[1] and several others nearly as high. Near Duke River and to the west of the head of Burwash Creek, a higher, more rolling erosion surface shows at about 6,000 feet above sea-level on some partly isolated mountains in the depression and on the flank of Donjek Range. From Donjek River to Klutlan River the depression continues to widen. On its northeast side Kluane Ranges at first continue their steep front and then, near Tepee Lake, their slopes lengthen and farther west resemble the rolling surface of Kluane Plateau as they sweep down into the depression. The central part of the depression here is a broad, shallow, but relatively steep-walled inner valley in which Tepee Lake lies. To the south a broad, terrace-like area several miles wide and about 4,000 to 5,000 feet high stretches along the front of the mountains, from which spurs extend at right angles down to the terrace. West of Klutlan River the depression continues as the broad valley of upper White River.

### *Alsek Ranges*

Alsek Ranges are the mountains between Alsek River and the valley of Upper Tatshenshini and Kelsall Rivers, and form the front of St. Elias Mountains in place of Kluane Ranges farther north. These ranges begin just north of the sixtieth parallel and extend south to the International Boundary. They have been mapped on the Boundary and along their east border, but are otherwise unphotographed and almost unknown. North of the lower reach of Tatshenshini River, where it flows west to Alsek River, and its tributary, O'Connor River, the ranges are divided into east and west groups by the broad valley of the middle reach of the Tatshenshini where it flows southward. The ranges to the east of this valley do not appear to have peaks more than 7,000 feet high, and contain many alpine glaciers, and several ice-fields and valley glaciers. In their southeast extremity they include Kusawak Range, which here forms a small front ridge to St. Elias Mountains, isolated from the other ranges of these mountains by the southern end of Duke depression in much the same manner as are Kluane Ranges farther northwest.

The valley of the middle reach of Tatshenshini River extends southward from the network of valleys of Duke depression for more than 30 miles to where it is joined by that of O'Connor River. The main part of the middle reach occupies a valley that is about 10 miles wide, and is divided into two inner

[1] Wood, Jr., W. A.: Personal communication, 1946.

valleys by hills about 4,500 feet in height along its medial line. The middle reach of Tatshenshini River follows the inner valley on the east side of these hills, and a lesser stream flows south along the west side.

The mountains on the west side of this large valley rise abruptly from it with a wall-like front extending north and south. They are precipitous, with peaks rising to an elevation of nearly 9,000 feet, and contain many glaciers among them. A few miles south of the sixtieth parallel a deep, transverse valley cuts westward through these ranges from the main valley to that of Alsek River, but is not occupied by any stream of importance.

Little is known of Alsek Ranges south of O'Connor River and the lower reach of Tatshenshini River. Along the International Boundary their highest peak is Mount Bigger, 8,250 feet above sea-level, and many large glaciers debouch from them. They appear in the distance to be rugged and to include many peaks 7,000 to 8,000 feet high.

### *Icefield Ranges*

Icefield Ranges comprise the main body of St. Elias Mountains and embrace all the great peaks except Mount Fairweather. In their general form these ranges themselves resemble a high plateau deeply dissected and surmounted by the great peaks,[1] which appears to be remnants of an older and still higher plateau (Plate I).

Along the northeast side of Icefield Ranges a border area, 15 to 20 miles wide, stands between the Duke depression and Alsek River Valley on one side and the first line of great peaks on the other. This border area rises abruptly to peaks 8,000 and 9,000 feet high, and in places to others with elevations of more than 10,000 feet. The area is deeply dissected by great valleys such as those of the glaciers tributary to Kaskawulsh River. Southwest of Lowell Glacier the area is mainly one of snow and ice, even those parts bare of snow and ice in summer probably not constituting a third of this part of the border area. Along the border area northwest from Lowell Glacier, the mountains become increasingly bare of snow in summer, but perennial snow and ice remain on the more level areas at high elevations, in numerous alpine glaciers and ice-fields, and in the great valley glaciers, Klutlan, Wolf, Donjek, Kluane, Kaskawulsh, and others of lesser size. These glaciers move down valleys walled by bare slopes that receive relatively little precipitation in either summer or winter.

The valleys of the tributaries of Donjek River form a branching system that comprises a large basin in this border area of Icefield Ranges behind Donjek Range. The main trench of upper Donjek River, above Wolf Creek, is nearly parallel with the Duke depression, suggesting that it is a minor depression of similar origin. The northeast side of this valley is steep and straight against Donjek Range, but on the southwest side the mountain spurs projecting between the tributary valleys of the great glaciers rise with more mature profiles.

Several great glaciers reach Alsek River Valley from the northwest in the southeast part of this border area. Lowell Glacier is the first of these encountered in descending the river. It ends in a lake in Alsek River Valley, and air photographs indicate that large fragments have broken from the front of the glacier to form icebergs in the lake. This glacier evidently advanced about 150 years

[1] Many splendid photographs of these mountains are printed in The American Alpine Journal. The articles containing them are:

Bates, R. H.: The Yukon Expedition, vol. II, pp. 427-438 (1936).
Wood, Jr., W. A.: The Ascent of Mt. Steele, vol. II, pp. 439-448 (1936).
Washburn, B.: The Ascent of Mount Lucania, vol. III, pp. 119-126 (1938).
Wood, F. H.: An Attempt on Mt. Wood, St. Elias Range, vol. IV, No. 1, pp. 1-8 (1940).
Wood, Jr., W. A.: Parachutes in the St. Elias Range, vol. IV, No. 3, pp. 341-347 (1942).
Bates, R. H.: Above the Whirlwind, vol. IV, No. 3, pp. 348-354 (1942).

ago and dammed Alsek River, causing it to flood its tributary valleys to an elevation, in Dezadeash River,[1] above that of Marshall creek. Other glaciers farther down Alsek Valley may have blocked the river at the same time, but probably did not raise the water so high. Recent reports from various visitors to the fronts of some of the glaciers of this border area indicate that the lower parts of most of the glaciers are stagnant and melting back, but that the upper parts of some at least are active, as for instance that of Wolf Glacier, which had moved considerably between 1936 and 1941[2,3]. Kaskawulsh Glacier gathers its ice from several large tributaries, and formerly pushed down on its valley to fork and send one branch down Slims River Valley toward Kluane Lake and the other down Kaskawulsh River Valley toward Alsek River. At present its front is a mile or more above the fork of the valleys, at an elevation of about 2,650 feet. The water running from it to Slims River on the northwest side of the front of the glacier is carried by Yukon River drainage about 1,500 miles to Bering Sea, whereas on the southeast side it reaches the Pacific Ocean via Alsek River in about one-tenth of that distance.

Southwest of this border area looms the main platform of Icefield Ranges, its valleys filled high with snow and ice and its great peaks towering above. The great peaks are the outstanding features of this platform. Chief among them are Mount Logan, 19,850 feet high, and four additional peaks, clustered within 8 miles on the same huge mountain block, one east and one west of the peak of Mount Logan, each more than 19,000 feet high, and two others with elevations exceeding 18,000 feet. The other great peaks of the platform are Mount St. Elias, 18,008 feet; Mount Lucania, 17,150 feet; King Peak, 17,130 feet; Mount Steele, 16,439 feet[4]; Mount Bona (in Alaska), 16,420 feet; Mount Wood, 15,880 feet; Mount Vancouver, 15,700 feet; Mount Hubbard, 14,950 feet; Mount Bear (in Alaska), 14,850 feet; Mount Walsh, 14,780 feet; Mount Alverstone, 14,500 feet; McArthur Peak, 14,400 feet; and Mount Augusta, 14,070 feet[4]. In addition, there are many peaks between 12,000 and 14,000 feet high. Some, such as Mount Craig, 13,250 feet, are named, but most of them remain unmeasured, unnamed, and unclimbed.

These great peaks rise out of the surface of snow and ice that forms the ice-fields between them. North of Mount Logan this surface is between 6,000 and 8,000 feet high, and appears to maintain this elevation along the main divides between the heads of Logan, Hubbard, and the other big glaciers northeast of Mount Logan. From these areas the ice-fields slope outward, gently at first and then more steeply as they separate into defined valley glaciers creeping out of the ranges. The ice-fields are fed by the snow that falls directly on them, by masses of ice and snow that cascade off the precipitous slopes of the adjacent peaks, and by tributary glaciers that reach into the alcoves and far up toward the summits of the mountains.

If lines were drawn, one northwest from Mount Alverstone through Mount Steele, and another a little east of north to the fork of Kaskawulsh Glacier, they would mark the approximate position of the divides between the ice moving northeast to Yukon River drainage, that moving easterly to Alsek River, and that moving west and south to the Pacific Ocean. The divide between Mount Alverstone and Mount Steele is well to the northeast of the axis of the area of Icefield Ranges, so that by far the greater part of the ice-fields, which in any case are

[1] McConnell, R. G.: The Kluane Mining District; Geol. Surv., Canada, Sum. Rept. 1904, pp. 4 and 10 (1905).

[2] Wood, W. A.: The Parachuting of Expedition Supplies, An Experiment by the Wood Yukon Expedition of 1941; Geog. Rev., vol. XXXII, No. 1, Jan. 1942, pp. 50 and 51.

[3] Sharp, R. P.: Wolf Creek Glacier System, St. Elias Range, Yukon Territory (Abstract); Geol. Soc., Am., Bull., vol. 52, pp. 1932 and 1933 (1941); The Wolf Creek Glaciers, St. Elias Range, Yukon Territory; Geog. Review, vol. '37 No. 1, pp. 26-52 (1947).

[4] The elevations of these peaks are taken from the published maps. These figures have been checked by a triangulation by Walter A. Wood, who gives Mount Steele an elevation of 16,641 feet and 14,400 feet as a more correct figure for Mount Walsh. Personal communication, 1947.

more broadly spread to the southwest than to the northeast, drains to the Pacific. Southwest of the divide, glaciers and ice-fields appear to cover more than half the surface of the ranges, and most of the remainder is clothed in the perennial snows of the mountain slopes. Northeast of the divide conditions are different, precipitation diminishes, and with it the areas covered by ice and snow in summer, as the border area is approached.

Air photographs taken from elevations of about 12,000 feet from outside Kluane Ranges show the lesser peaks and ridges of Icefield Ranges reaching to an extensive, gently warped surface above which the great peaks project conspicuously. This surface appears to be at an elevation of about 10,000 feet in the west, and to decline eastward to about 8,000 feet. In the absence, however, of general topographic information these elevations are judged from those of scattered peaks and from topographic maps along the International Boundary. Furthermore, the impression of general evenness of the surface is enhanced by the environment. In this region of great altitude and relief, differences of 1,000 or even 2,000 feet among the lesser peaks appear inconsequential, with Mounts Lucania, St. Elias, and Logan towering 7,000 to 9,000 feet and more above them in the background. The relative accordance of summit levels is, nevertheless, a notable feature and bestows on Icefield Ranges the general aspect of a great plateau. Another feature, which is impressive on closer observation of these ranges, is the broad surface of ice-fields and glaciers that fill the wide areas between the peaks and ridges, particularly in the central and southern parts of these ranges. This surface varies from about 5,000 feet in elevation, near Mount St. Elias, to 9,000 feet or more to the north and west and around the slopes of the great peaks. The expanses of unbroken snow conceal whatever depth the valleys beneath them might otherwise exhibit, and add to the already immense relief, giving a false impression that the mountains around them are remnants not yet reduced to the level of this surface. The relatively smooth and rolling character of the upper parts of many of the great peaks, notably the summit area of Mount Logan's mighty block, including those four satellite peaks more than 18,000 feet high mentioned in a previous paragraph, and the long, comparatively even saddle that connects the peaks of Mounts Lucania and Steele, suggest that formerly a surface of more even topography topped these ranges at a level 5,000 to 8,000 feet above that of the lesser peaks.

### *Fairweather Range*

Most of Fairweather Range is in Alaska, and only the northeast slope is Canadian. This slope is composed of a single, big ridge of mountains that culminates in the great peak of Mount Fairweather, 15,300 feet high, on the International Boundary, and the highest peak in any part of British Columbia. Viewed at a distance from the north, the peaks of Fairweather Range, among which, including those in Alaska, a score are more than 10,000 feet high, rise as a great, isolated, closely connected group above a sea of lesser ranges whose highest points nearly all lie between elevations of 8,000 and 9,000 feet. The Canadian part of the range consists in part of ridges radiating from Mount Fairweather and in part of valley glaciers that flow by way of Melbern Glacier to Alsek River, and via Grand Pacific and Ferris Glaciers to Tarr Inlet, which barely reaches across the International Boundary.

The geological exploration of St. Elias Mountains in Canada has been almost entirely confined to Kluane Ranges, Duke depression, and one small area around Wolf Glacier.[1] Kluane Ranges are composed mainly of volcanic rocks, with

[1] Sharp, R. P.: Geology of the Wolf Creek Area, St. Elias Range, Yukon Territory, Canada. Bull. Geol. Soc. Am., vol. 54, pp. 625-650 (1943).

associated shales, slates, sandstones, and limestones, and include sections ranging in age from late Palæozoic to late Mesozoic[1-4]. Limestones, schists, slates and quartzites underlie these formations in places, and some at least are of earlier Palæozoic age. Northwest of Slims River volcanic rocks dominate in the upper group, whereas southeast of Alsek River the rocks are predominantly shales, slates, and sandstones[5,6]. Intrusive stocks, mainly of granitic rocks, occur in all these ranges, but also include a wide range of more basic and alkaline types. Most of these are thought to have been intruded in Mesozoic time, but some may be of Tertiary age. Small areas are underlain by early Tertiary sandstones, clays, and tuffs interbedded with and overlain by lavas.

In the Duke depression southwest of Kluane Ranges the same pre-Tertiary formations are present, and are overlain by extensive, Tertiary sedimentary and volcanic rocks that form a belt that, except for a gap on the southeast of Slims River, may be continuous. To the southeast, at Bates Lake, a great thickness of tilted Paleocene conglomerate, sandstone, and shales form the basal part of most of the Tertiary section. Volcanic rocks first appear interbedded with the upper members of this basal group, and higher in the sections overlie the assemblage as solid masses of lavas. Along each side of Alsek River the volcanic rocks are more abundant, appearing in thick horizontal sections from there northwestward. The Tertiary sediments, northwest of Slims River, include lignite beds and are generally horizontal.

Southwest of the Duke depression the slopes of Icefield Ranges are underlain mainly by Mesozoic and Palæozoic sedimentary and volcanic rocks, and south of Bates Lake, Alsek Ranges appear to be composed largely of these volcanic rocks. The rocks carried in the moraines on the northwest side of Kaskawulsh Glacier are almost entirely of slate, sandstone, quartzite, and limestone. Some granitic and dioritic, plutonic and dyke rocks appear in the medial moraines of the glacier, and more of such rocks may occur on the south side, but the moraines are in general lacking in igneous rocks. Northwest of Donjek River the Tertiary volcanic rocks spread southwest from the depression capping a large area between the valley of Wolf Glacier and Klutlan River, and in air photographs appear to be upturned to the southwest. Below these the older rocks are exposed. On the south side of Wolf Creek granitic rocks intrude the pre-Tertiary rocks, and appear to form the border of a large body perhaps of batholithic dimensions. No geological investigation of the great peaks has been made, but from the reports of mountaineers and the appearance of their cliffs where bedrock is exposed they are believed to be composed largely of granitic rocks.

In Pleistocene time the ice-fields of St. Elias Mountains were higher, and pushed their glaciers out on all sides. On the interior side they extended far out on Kluane Plateau. In all the higher parts of Kluane, Alsek, and Donjek Ranges there appears to have been an upper limit of the ice in some part of later Pleistocene time at an elevation of about 6,000 feet, but with considerable variation in level from place to place due to the influence of local topography on the movement of the ice.

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[1] McConnell, R. G.: The Klaune Mining District; Geol. Surv., Canada, Ann. Rept. 1904, vol. XVI, pt. A, pp. 1-18 (1905).
[2] McConnell, R. G.: Head Waters of White River, Yukon; Geol. Surv., Canada, Sum. Rept. 1905, pp. 19-26 (1906).
[3] Cairnes, D. D.: Exploration in Southwestern Yukon; Geol. Surv., Canada, Sum. Rept. 1914, pp. 10-33 (1915).
[4] Cairnes, D. D.: Upper White River District, Yukon; Geol. Surv., Canada, Mem. 50, 191 pp. (1915).
[5] Cockfield, W. E.: Dezadeash Lake Area, Yukon; Geol. Surv., Canada, Sum. Rept. 1927, pt. A, pp. 1-7 (1928).
[6] Kindle, E. D.: Dezadeash Map-area, Yukon; Geol. Surv., Canada, Paper 47-15 (1947).

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