THE GOVERNMENT OF
THE PROVINCE OF BRITISH COLUMI

Landforms of British Columbia

A Physiographic Outline

by
Stuart S. Holland

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FOREWORD

British Columbia has more variety in its climate and scenery than any other Province of Canada. The mildness and wetness of the southern coast is in sharp contrast with the extreme dryness of the desert areas in the interior and the harshness of subarctic conditions in the northernmost parts. Moreover, in every part, climate and vegetation vary with altitude and to a lesser extent with configuration of the land. Although the Province includes almost a thousand-mile length of one of the world's greatest mountain chains, that which borders the north Pacific Ocean, it is not all mountainous but contains a variety of lowlands and intermontane areas.

Because of the abundance of mountains, and because of its short history of settlement, a good deal of British Columbia is almost uninhabited and almost unknown. However, the concept of accessibility has changed profoundly in the past 20 years, owing largely to the use of aircraft and particularly the helicopter. There is now complete coverage by air photography, and by far the largest part of the Province has been mapped topographically and geologically. In the same period of time the highways have been very greatly improved, and the secondary roads are much more numerous. The average citizen is much more aware of his Province, but, although knowledge has greatly improved with access, many misconceptions remain on the part of the general public as to the precise meaning even of such names as Cascade Mountains, Fraser Plateau, and many others.

This bulletin is an authoritative account of the major land subdivisions of British Columbia. It defines the boundaries of the various mountain, plateau, or plain areas, many of them for the first time. Agreement has been reached with the Canadian Permanent Committee on Geographical Names, with Provincial Government officials, and with geologists and the various sorts of map-makers whose knowledge of the Province is most thorough. In particular, close attention has been paid to H. S. Bostock's " Physiography of the Canadian Cordillera, with Special Reference to the Area North of the Fifty-fifth Parallel," which has heretofore been the chief authority, and any departures from that work have been fully discussed with Dr. Bostock.

The form of presentation, and much of the subject-matter, is a reflection of the mind and the interests of the writer, who is a field geologist with a broad knowledge of the Province. Thus the reader is aware throughout of the principal processes that have formed the land as we now see it, and of the reasons for much of the character of the scenery and landforms. Concluding are five short essays that are written to clarify the text, and a complete glossary of terms. This bulletin is more than an enunciation of physical boundaries and is, it is hoped, a source book for the better knowledge and understanding of the face of British Columbia.

The average reader will surely find much to interest him, though he may care little about the precise boundaries of the Spatsizi Plateau, the Tagish Highland, or of other places he may never visit. Literally thousands of air photographs have been examined in the preparation of this bulletin, and many of the finest photographs available have been chosen to illustrate each subdivision mentioned in the table of contents. It is suggested that the reader study the photographs and their captions and refer to the text (Chapter II) for further description. The five essays of Chapter III are written to be read alone, but constant reference to the illustrations and descriptive text makes them more interesting. This is not the sort of bulletin to be read and digested at one sitting.

The technical references are believed to be complete. There are, however, publications such as The Canadian Alpine Journal, Canadian Geographic Journal, and others that have not been mentioned but will furnish interesting auxiliary reading. This bulletin, it should go without saying, should spur interest in the general study of geology and physiography.

H. SARGENT,
Chief, Mineralogical Branch.

TABLE OF CONTENTS

ILLUSTRATIONS

TABLE

PLATES

* This number locates the picture on Figure 9, page 97.

LANDFORMS OF BRITISH COLUMBIA

CHAPTER I.—INTRODUCTION

British Columbia is the westernmost Province of Canada. It lies on the Pacific Coast of North America, stretching from the International Boundary at the 49th parallel to the Yukon Border at the 60th, a distance of 790 miles. On the west it is bounded along half its length by the Pacific Ocean and for the remainder by the narrow mountainous strip of southeastern Alaska. On the east it is bounded by the Province of Alberta along a boundary which follows the watershed of the Rocky Mountains northwestward to the 120th degree of longitude and thence northward along that meridian to latitude 60 degrees north. The area of the Province is 366,255 square miles, of which 6,976 square miles is covered by lakes. It is second only to Quebec in size and is 9.5 per cent of the area of Canada.

There is a great variety of topography within this vast region that extends through 11 degrees of latitude and that extends across the full width of the Canadian Cordillera from the Interior Plains to the Pacific Ocean. Although the Province is largely mountainous, with land rising from sea-level to a maximum elevation of 15,300 feet at the summit of Mount Fairweather, nevertheless there are extensive plateaus, large plains and basins, and areas of prairie. The contrasts and similarities that extend over great expanses of country and the nature of the terrain itself deserve to be far better known. To grasp this information requires that the Province be subdivided into units which are topographically alike and that the landforms be described in such a way that their origins are understood.

This bulletin is concerned with the physical features of the Province, such as plains, plateaus, or mountains, as well as valleys, cirques, or volcanic cones; these are the landforms which combine to make the topography of the Province. Their description, classification, correlation, and origin comprise the study of geomorphology,* which is a branch of the broad field of geology as well as that of physiography. Essentially therefore what follows in this bulletin is the geomorphology of British Columbia.

A geologic time scale and a glossary of terms are included in an appendix for the convenience of non-technical readers.

DEVELOPMENT OF LANDFORMS

The topography of British Columbia is constantly changing as the various features of the landscape are attacked by erosion. The landforms seen today represent only a stage in a continuously repeated cycle of events during which the land surface is lowered and destroyed only to be re-elevated or rebuilt at some later time.

A study of landforms makes it possible for the observant eye to piece together much of the recent history of the earth by disclosure of erosional effects and major crustal movements. By so doing the course of future modifications may be predicted. Landscapes provide a record of the earth's history that is important to a geologist or geomorphologist, but the same record may be read by an observant

* The term "physiography" was formerly used in this sense, but now it is generally used with a wider meaning to embrace geomorphology, climatology, and oceanography. The word "physiographic" is well established in such uses as "physiographic subdivision" or "physiographic history," which refer only to landforms, and is used here in preference to "geomorphologic," which is synonymous but cumbersome.

traveller. If he so wishes, his enjoyment of scenery and of general travel may be considerably enhanced through an understanding of the origins and development of landforms.

The development of landforms (geomorphology) is governed by factors that can be grouped under three headings—(1) process, (2) character of bedrock, and (3) orogenic or structural history.

The agents of erosion—streams, ice, wind, and chemical decomposition—are constantly at work breaking down the rock which forms the land surface, allowing it to be transported elsewhere and deposited. Thus the surface in one place is being lowered and elsewhere is being built up. At intervals there may be periods of mountain-building or crustal movement which may elevate or depress the land surface and in so doing may accelerate or diminish the rate of erosion. Volcanic episodes are not uncommon, at which time the land surface may be built up by the accumulation of large cones of lava and fragmental materials or by the outflowing of large volumes of molten lava over the surface, filling in the low areas and creating extensive lava plains. At all times the surface of the land is being modified, subject to the complex interplay of several factors, and the resulting landforms are influenced at all times by the nature and structure of the bedrock.

Influence of Process

Stream erosion under moist temperate climatic conditions has been the dominant process in developing British Columbia landforms. The wearing-down and sculpturing of the earth's surface by the forces of stream erosion and the transportation and disposal of the waste products are familiar to all. The details of the process, the progression of events, and the characteristic landforms are described in standard textbooks.*

The rate at which stream erosion takes place varies according to the regional climate, especially the amount of rainfall, the gradients of the streams, and the surface relief of the land. Twice in the recent past the relief has been greatly increased through uplift of the land, once during the early Tertiary and again at the end of that period, and, as a consequence, those were times of greatly accelerated stream erosion. Throughout British Columbia, differences in climate and relief have resulted in the production of greatly diverse landforms by stream erosion.

In British Columbia the second most important agent of erosion has been glacial ice. Glaciers are a prominent feature in many parts of the Provincial landscape, and the work they do in sculpturing the higher regions and contributing gravels and silts to the streams is apparent to anyone who has seen them at close range. Almost all of our glaciers are now retreating, and it is obvious that their erosional activity has declined in very recent time. However, during the Pleistocene the surface of the land was profoundly affected by a continental ice-cap that covered all of British Columbia. The effects of Pleistocene glaciation are evident in every landscape—landforms resulting from ice erosion are present in many places, and much of the land is mantled with the products of erosion. An almost universal veneer of ground moraine is concentrated locally into minor landforms, and the deposits left by meltwater streams are to be seen on all sides. Reference is made to glaciation in all descriptions that follow, and a section on glaciation appears on pages 99 to 105.

* Cotton, C. A., "Landscape," *Whitcombe and Tombs, Ltd.*, 1948
Davis, W. M., "Geographical Essays," *Dover Press*, 1954.
Dury, G. H., "The Face of the Earth," *Penguin Books*, 1960.
Lobeck, A. K., "Geomorphology," *McGraw Hill*, 1939.

In the short interval, about 10,000 years, since the disappearance of the bulk of the Pleistocene ice, stream erosion has again become an active agent of landscape development. The time interval is too short to result in extensive modification of the landscape, but some very striking small-scale features have nevertheless developed, such as post-glacial canyons in solid rock and rapid downcutting of gravel deposits and of valley fill.

Landforms of volcanic origin are comparatively minor features, but volcanic activity has been important through much of the geological history of British Columbia, the last eruption being only about 300 years old. As volcanic features have a singular interest, they are the subject of special treatment on pages 117 to 120.

Influence of Bedrock

Much of the late geological history of the Province is recorded by landforms, many of which are sculptured on bedrock by the forces of erosion. The correct interpretation of their origin requires some knowledge of the character and the distribution of bedrock, both of which influence the course of erosion and to a degree govern the nature and distribution of the resulting landforms.

The different kinds of rock, whether igneous, sedimentary, or metamorphic, are affected by erosion in different degree. The properties of rocks, such as hardness, solubility, and homogeneity, determine their response to erosion. Structures, including such features as the intensity and orientation of folding, or the presence of faults, shear zones, joint systems, regionally developed cleavage, and zones of alteration, all influence the course of erosion and combine to determine the character of the erosional form, the landform. One has only to contrast the appearance of the uniform dome-like mountains carved from great masses of almost monolithic granite in the Coast Mountains (*see* Plate XA) with the strongly castellated and layered mountains composed of folded and faulted sedimentary rocks in the Park (Main) Ranges of the Rocky Mountains (*see* Plate XXXVA) to appreciate the very great influence exercised by the nature and characteristics of the bedrock.

In describing bedrock geology it is customary to group rocks according to their age, but this does not necessarily provide a satisfactory basis for the comparison of topographic features. Alternatively, in order that direct comparison of one area with another may be made, it is here proposed to group the rocks of the Province on the basis of the physical characteristics that influence the over-all form of the topography. Thus Precambrian and Cretaceous folded sedimentary rocks are grouped in order to emphasize their physical characteristics rather than their age. As a result, it is possible to present a series of six diagrams which outline areas having, as a common denominator, similar bedrock characteristics. The age of any rock is disregarded in dividing the Province into areas which are dominantly underlain by:—

(1) Intrusive igneous rocks (Fig. 2).
(2) Flat-lying or gently dipping sedimentary rocks (Fig. 3).
(3) Flat-lying or gently dipping lava flows (Fig. 4).
(4) Folded and faulted sedimentary rocks (Fig. 5).
(5) Folded and faulted volcanic and sedimentary rocks and some igneous intrusions (Fig. 6).
(6) Foliated metamorphic rocks (Fig. 7).

(1) Intrusive rocks are petrographically variable, but physically they are sufficiently uniform that, under normal circumstances, they are fundamentally homogeneous. As a consequence, landforms developed on this sort of rock by similar forces look remarkably alike though they may be geographically far apart. The homogeneity of large intrusions may be partly destroyed by the presence of roof

pendants which, because of their sedimentary laminations, tend to produce an oriented topography.

Some intrusions have a primary gneissic structure, which is the result of parallel orientation of minerals, and which may be sufficiently pronounced to influence the topography. A common feature of large batholiths, and one well illustrated in the Coast Intrusions, is the presence on a regional scale of well-developed joints. These fractures are sufficiently prominent to influence the orientation of valleys and ridges and to give a pronounced rectilinear pattern to the topography (*see* Plates VIA and XLVIII).

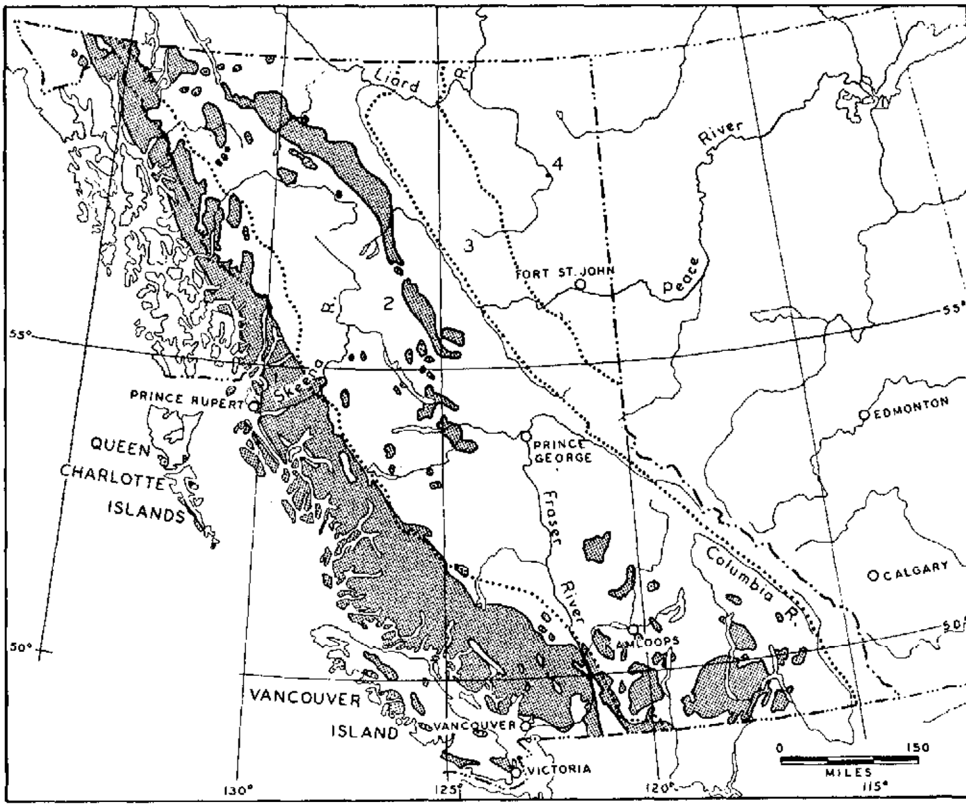

Figure 2. Diagram showing the main areas of intrusive igneous rock.

Areas of dominantly intrusive rocks are shown in Figure 2. Such rocks occupy a very large area in the Coast Mountains, and their presence explains similarities in topography that extend over a length of almost 1,000 miles. Intrusive rocks are extensively exposed in the Cassiar-Omineca Mountains, across the southern part of the Province, and in the southern part of the Columbia Mountains. Smaller areas of intrusive rock are scattered throughout the interior of British Columbia from the International Boundary to the Yukon Border, and on Vancouver Island and the Queen Charlotte Islands.

Intrusive rocks, wherever they occur and despite local peculiarities of erosion, impart a characteristic appearance to the landforms developed on them.

(2) Sedimentary rocks consist of successions of similar or diverse beds. In general, they consist of layers a few feet, or possibly tens or even hundreds of feet, thick, with physical characteristics that may persist for many miles. When the sedimentary beds are flat lying or only very gently dipping, the topography has a dis-

tinctive mesa-like or step-like form. For example, erosion of an extensive flat-lying bed of cliff-forming sandstone or conglomerate may result in an essentially flat upland surface surrounded by escarpments related in height to the thickness of the resistant bed (*see* Plate XXXVIII). Alternatively, areas underlain by flat-lying shales, which are more readily eroded, commonly display a uniformly low relief. Plateaus, plains, and areas of low relief are commonly associated with areas of flat-lying sedimentary rocks.

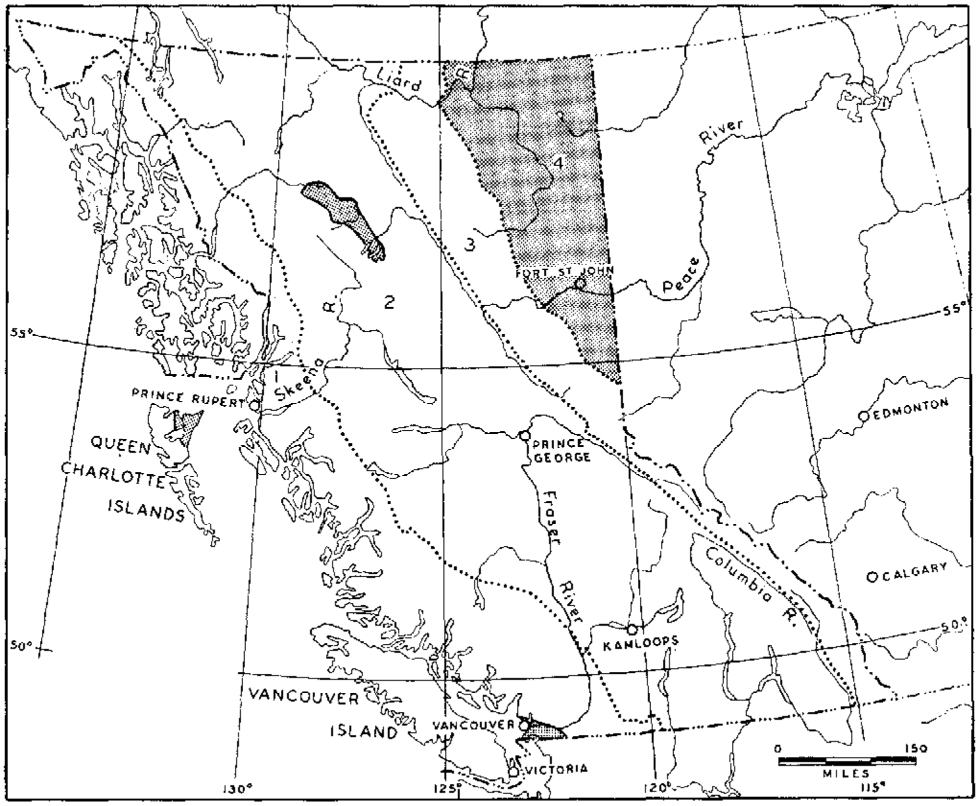

Figure 3. Diagram showing the main areas of flat-lying or gently dipping sedimentary rocks.

Areas of flat-lying or only very gently dipping sedimentary rocks are shown on Figure 3. By far the largest area is in the northeastern corner of the Province, where such rocks underlie the country east of the foothills of the Rocky Mountains. Other areas are the Spatsizi Plateau at the head of the Stikine River, the north-east tip of Graham Island, and the delta of the Fraser River downstream from Chilliwack.

(3) Molten lava erupted from a single volcanic vent or from a number of fissures may spread over considerable areas. When erupted, the lava is fluid and mobile, and extensive individual flows may be essentially flat or have a slope that represents the original flow gradient. Lava flowing out over the land surface fills in the lower areas and eventually may accumulate to considerable thicknesses. In this way a flat surface may be built up on an older surface of some relief, and a plateau of constructional origin is formed.

Consolidated lava is resistant to erosion, and flat-lying flows resemble flat-lying resistant sedimentary beds inasmuch as they produce a plateau topography.

As lava cools and consolidates, it characteristically develops a vertical columnar jointing, the columns being at right angles to the cooling surface. This vertical jointing is so well developed that dissection of a succession of lava flows often produces a step-like profile, the treads being controlled by the individual horizontal flows, and the risers by the vertical joints in them. Vertical cliffs, each the height of a flow's thickness, or escarpments hundreds of feet high, are characteristic of areas of dissected lava.

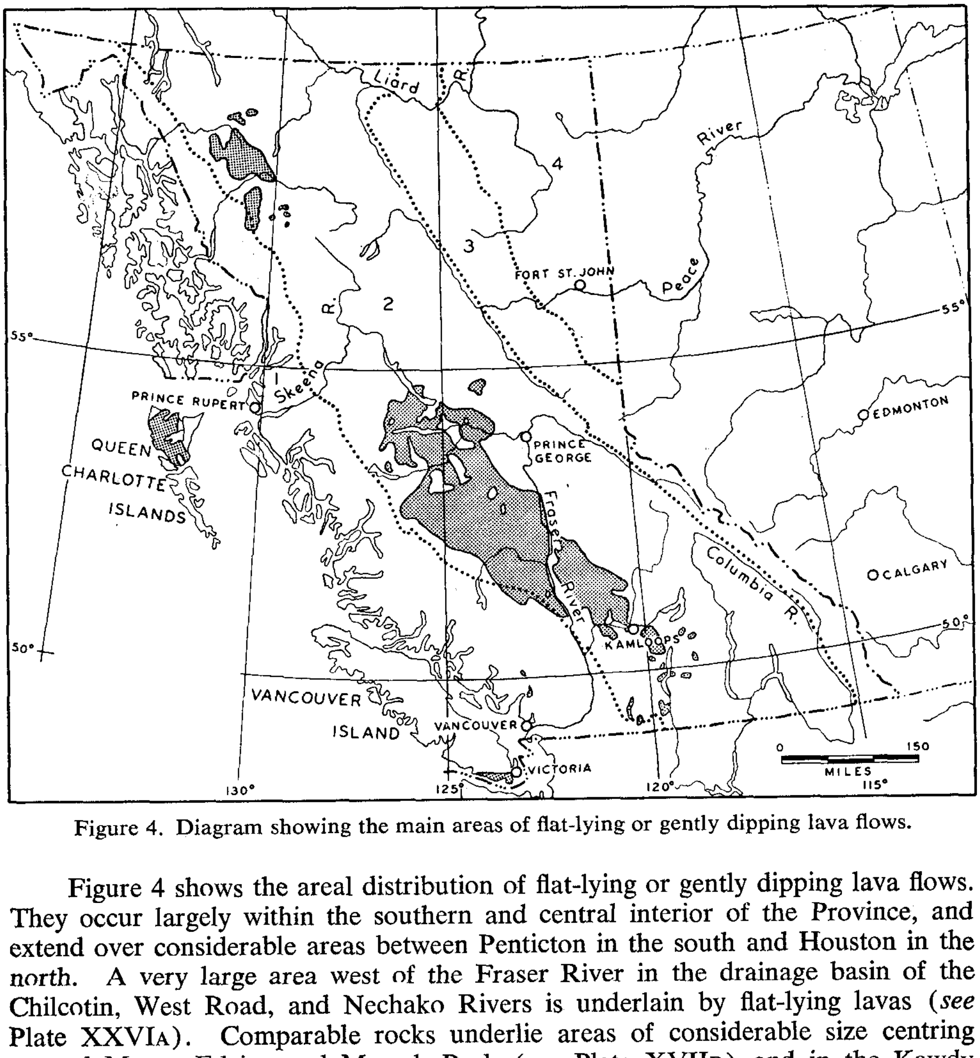

Figure 4. Diagram showing the main areas of flat-lying or gently dipping lava flows.

Figure 4 shows the areal distribution of flat-lying or gently dipping lava flows. They occur largely within the southern and central interior of the Province, and extend over considerable areas between Penticton in the south and Houston in the north. A very large area west of the Fraser River in the drainage basin of the Chilcotin, West Road, and Nechako Rivers is underlain by flat-lying lavas (*see* Plate XXVIA). Comparable rocks underlie areas of considerable size centring around Mount Edziza and Meszah Peak (*see* Plate XVIIB) and in the Kawdy Plateau west of Tuya Lake. Gently dipping lavas underlie a somewhat smaller area in the northwest part of Graham Island (*see* Plate IIC).

(4) The tilting of sedimentary rocks allows the differences in resistance between beds to control the topography. Streams erode the softer beds faster, and consequently peaks and ridges are underlain by more resistant beds than are the valleys and depressions. Folding and faulting of sedimentary rocks develop structures in which tilted beds may extend for many miles, and erosion of this sort of terrain results in topography of a very strongly linear character. The

streams tend to develop a trellis pattern, with long stretches parallel to the strike of the rocks and short lateral tributaries that are parallel to the direction of dip and enter the main streams at right angles. Ridges and ranges follow the strike of the formations. Topography of this type is particularly well displayed in the foothills of the Rocky Mountains, at the heads of the Sikanni Chief, Prophet, Tuchodi, and Tetsa Rivers (*see* National Topographic System* Sheets 94B and 94K).

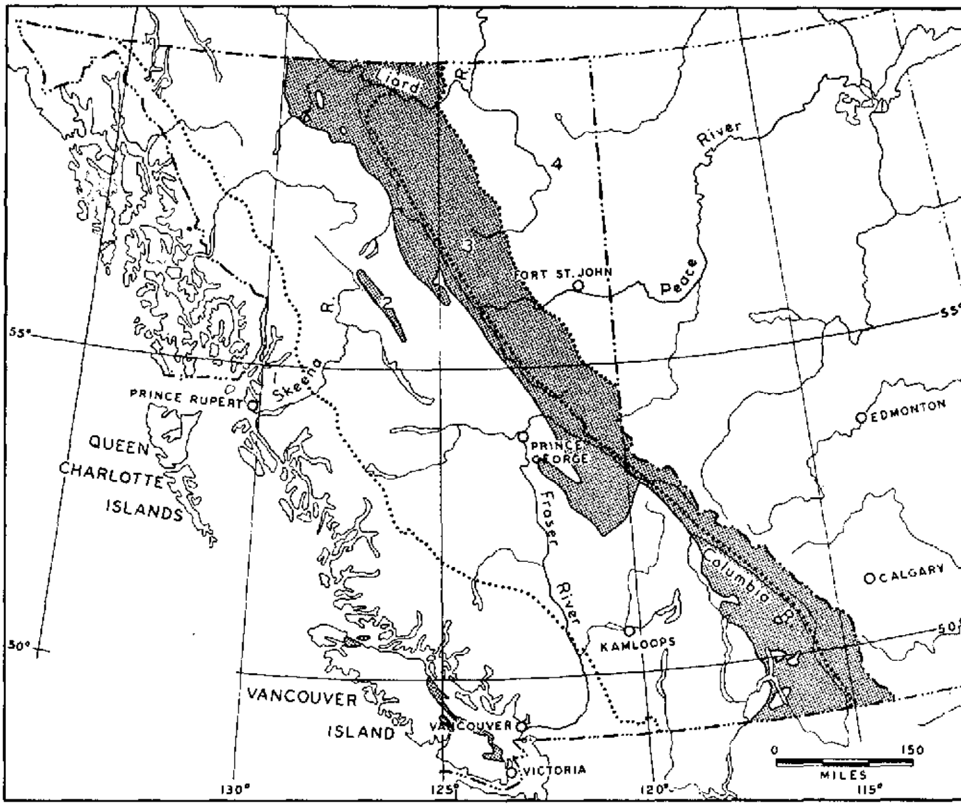

Figure 5. Diagram showing the main areas of folded and faulted sedimentary rocks.

The main areas of folded and faulted sedimentary rocks, shown on Figure 5, are in the Selkirk, Purcell, and Rocky Mountains in the southeastern part of the Province, in the Rocky Mountains and their foothills in the northeast, and west of the Rocky Mountain Trench in north central British Columbia. A belt of such rocks lies along the east side of Vancouver Island, extending southeastward from Campbell River to the Gulf Islands.

(5) During most of post-Devonian time in British Columbia, both sedimentary and volcanic materials were deposited in the central and western parts of the Province, in a general area stretching from Vancouver Island and the Queen Charlotte Islands to the Rocky Mountain Trench and west of a line running southeastward to Kootenay Lake. The rocks in this general area comprise heterogeneous sedimentary rocks, including greywackes, argillites, limestones, and cherts, all intercalated with lavas and fragmental volcanic rocks. Such successions of mixed rocks differ markedly from the entirely sedimentary successions farther east, and erode somewhat differently because of their diversity. Within areas of such rocks there

* In the body of this report a National Topographic System Sheet will be designated N.T.S. Sheet.

are lithologic differences from place to place, but there is nevertheless an over-all similarity of the landforms.

The erosion of a folded succession of volcanic and sedimentary rocks develops landforms with some of the linear characteristics of folded sedimentary rocks, but with other characteristics contributed by the diverse volcanic rocks, which are hard and resistant to erosion and in which jointing is a more dominant property than layering or bedding. As a consequence, volcanic rocks tend to produce landforms more like those on granite and other intrusive rocks than those on sedimentary rocks.

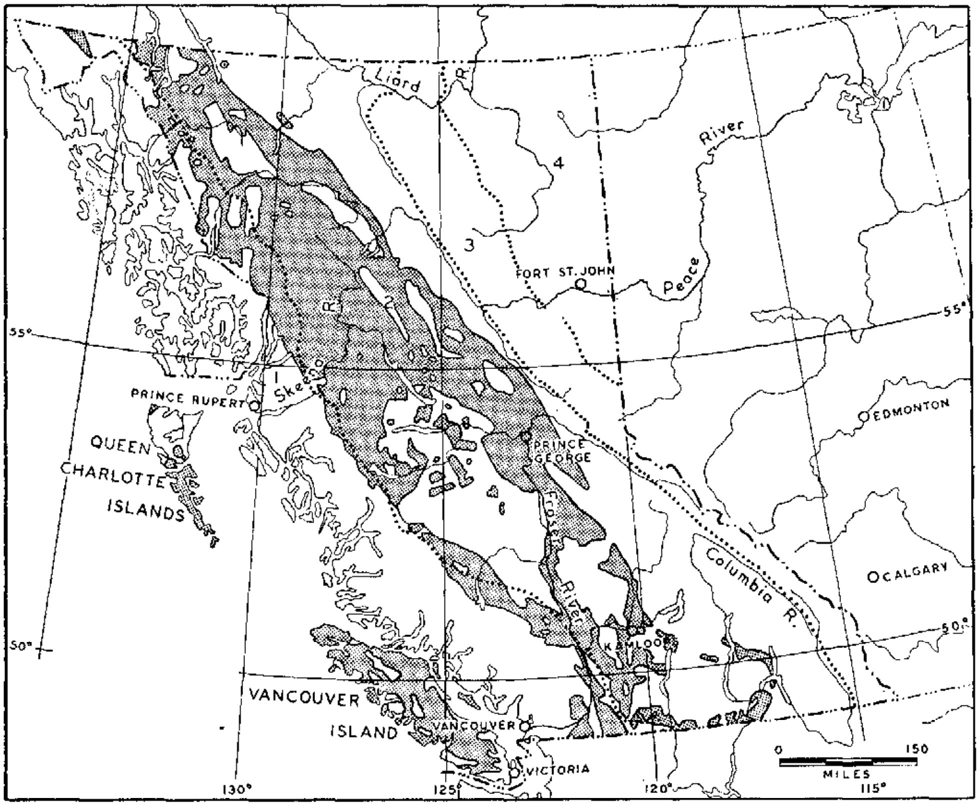

Figure 6. Diagram showing the main areas of folded and faulted sedimentary and volcanic rocks.

Folded and faulted sedimentary and volcanic rocks of great variety occur on Vancouver Island, Queen Charlotte Islands, as roof pendants and septa within intrusive rocks of the Coast Mountains, and in belts and isolated areas east of the Coast Mountains and west of the Rocky Mountain Trench throughout the length of the Province (*see* Fig. 6). The largest single area extends northward from the vicinity of Whitesail Lake into the drainage basins of the Skeena, Nass, and Stikine Rivers.

(6) In British Columbia the group of foliated metamorphic rocks includes a number of rock types which are mostly of sedimentary derivation. As a result of various metamorphic processes, they may have been partly or completely recrystallized, their original sedimentary characteristics may have been destroyed, and their primary stratification replaced by a mineral layering which may transect earlier bedding. Metamorphic rocks in this group contain a variable amount of igneous

material and are resistant to erosion. Their response to erosion is similar to that of granitic rocks but differs in the one important respect that they possess mineral orientation and structural characteristics that give alignment and orientation to the landforms. The foliation may be gently or strongly folded, and this difference may be reflected in the topography. Thus, structurally controlled dip slopes in the Shuswap terrain are gently dipping in contrast to the more steeply dipping slopes in the Horseranch Range.

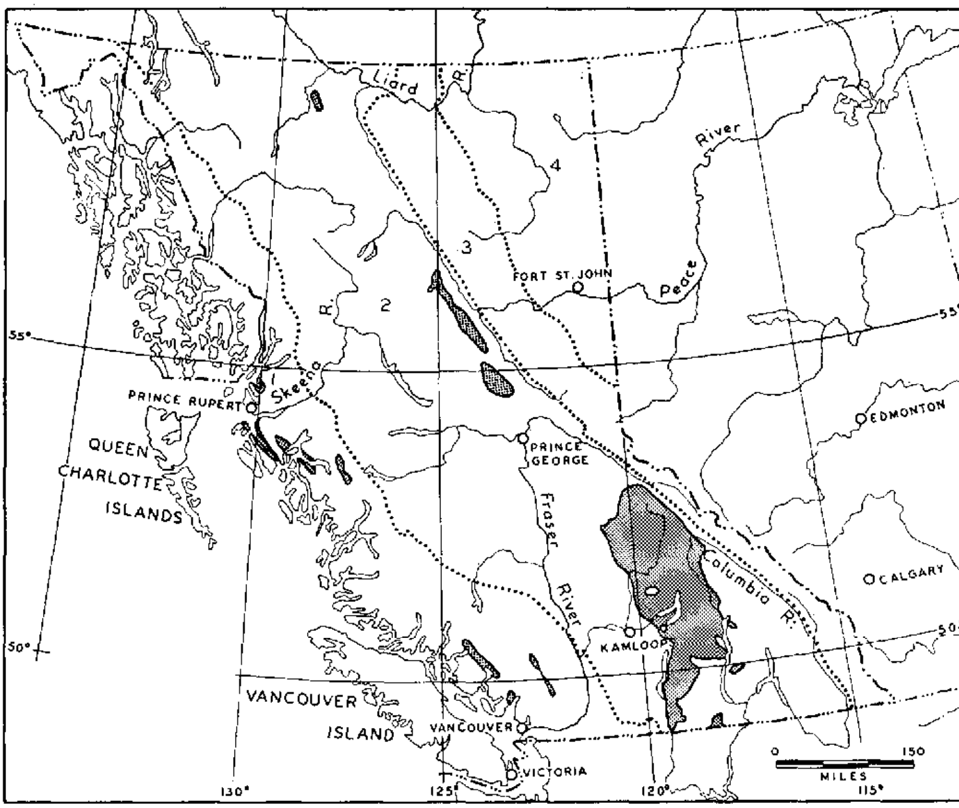

Figure 7. Diagram showing the main areas of foliated metamorphic rocks.

The main area underlain by foliated metamorphic rocks is the Shuswap terrain, shown on Figure 7 as extending northward from Osoyoos to Quesnel Lake and Tête Jaune. Similar rocks border Carp Lake, extend in a belt northwestward from the Wolverine Range, underlie the Horseranch Range in northern British Columbia, and form roof pendants in the Coast Mountains.

Influence of Orogenic History

Landforms reflect the deformation that a region has experienced. The fundamental reason for the difference between the gentle relief of the Interior Plains and the varied and rugged topography of the Cordillera is the difference in type of crustal movement that the two regions have undergone. In the Plains Region, since early Palæozoic times, movements have always been vertical (epeirogenic), with only minor warping of the crust. Because of this fact the sedimentary rocks laid down in that region are still flat lying or only very gently tilted (*see* Plate XXXVIII). In contrast, movements within the Cordillera have been orogenic (mountain-building), that is, compressive or tangential to the crust, so that sedimentary rocks are folded and faulted. These crustal movements have been localized largely in belts, in some of which there may have been recurrent activity over a long period of time, during sedimentation and after. This localization of movement has affected not only the character of the sedimentary rocks laid down in each belt, but also the structures that are produced in them (*see* Plates XXXIIB and XXXIIIB). A variety of structures of different ages and orientations has been impressed upon the earth's crust because of changes of position of the active belts in the course of geologic time.

The present landforms are greatly influenced by the fact that regional uplift* in the late Tertiary was differential in amount. The differential uplift accounts for the contrast between the moderate to low topographic relief of the plateau areas of central British Columbia and the strong relief of the adjoining Coast Mountains and Columbia Mountains (*see* Plate XIB). It also accounts for regional differences in height of the surface of the Interior Plateau, for the low area in the Coast Mountains between the Nass and the Bella Coola Rivers, and the low area in the Rocky Mountains between the Peace River and Mount Sir Alexander.

[References: *Geol. Surv., Canada,* Map 932A, Geological Map of British Columbia; *Geol. Surv., Canada,* Ec. Geol. Series No. 1, " Geology and Economic Minerals of Canada," 1957, pp. 283–392, " The Cordillera Region "; *B.C. Natural Resources Conference Atlas of British Columbia,* 1956, Map No. 3, Geology; White, W. H., " Cordilleran Tectonics in British Columbia," Bull., *Am. Ass. Pet. Geol.,* Vol. 43, No. 1, 1959, pp. 60–100; Wheeler, J. O., " Mesozoic Tectonics of South Central Yukon," Proc., *Geol. Ass. Canada,* Vol. II, 1959, pp. 23–43; Gabrielse, H., and Wheeler, J. O., " Tectonic Framework of Southern Yukon and Northwestern British Columbia," *Geol. Surv., Canada,* Paper 60-24.]

SUMMARY OF PHYSIOGRAPHIC HISTORY OF BRITISH COLUMBIA

A very large part of the Canadian Cordillera in British Columbia—that part lying west of the Rocky Mountain Trench — was involved in the Coast Range orogeny, which lasted from earliest Jurassic time through to post Lower Cretaceous. It was a time of mountain-building, involving folding and faulting on a regional scale and the intrusion of granitic batholiths in the Insular Mountains, Coast Mountains, Cassiar-Omineca Mountains, and Columbia Mountains. Subsequent erosion in the mountains was sufficiently deep to remove the cover of sedimentary rocks from the batholithic cores. The unroofing of the batholiths took place contemporaneously with the deposition of Upper Cretaceous and early Tertiary sediments in two basins, one of which included Vancouver Island, the Gulf of Georgia, and the Queen Charlotte Islands, and the other occupied the Rocky Mountain area.

The Rocky Mountains occupy the site of a geosyncline, whose western border roughly coincides with the line of the Rocky Mountain Trench. It was the site of sedimentary deposition during the Palæozoic and Mesozoic eras. The Rocky Mountain orogeny, post-Paleocene in age, terminated sedimentation in the basin and built the Rocky Mountains, and a cycle of erosion was initiated that has persisted without interruption to the present.

During the Tertiary the entire Cordilleran region was subjected to erosion, except for small basins of marine sedimentation in the Puget Trough and on the northeast tip of Graham Island, and small basins of fresh-water sedimentation through central British Columbia. By Miocene time it is known that in central British Columbia there had been developed a land surface of moderate relief

* Note.—This late Tertiary regional uplift and the consequent erosion and modification of the Tertiary surface is a common denominator of all physiographic units of British Columbia. Further reference to it may be found on pages 45 and 55.

(1,500 to 2,000 feet) which truncated flat or gently dipping Tertiary sediments and lavas (Princeton and Kamloops Groups) of Eocene* age. Erosion continued until late Tertiary, and the land surface was locally modified by the accumulation of basaltic lavas and associated volcanic products of shield volcanoes, and by flows of olivine basalt that are Miocene and younger.

Throughout the Province the land surface of erosional and depositional origin that had evolved by late Miocene time was differentially uplifted during the Pliocene. The surface, which had some initial relief, was incised by the streams, whose erosion was rejuvenated, and considerable additional relief was produced. The differential uplift and erosion of the late Tertiary established the present arrangement of mountains, plateaus, plains, etc. It was this late Tertiary topography that during the Pleistocene was covered by glacial ice and was modified by it to produce the landscape of today.

[References: Guidebook for Geological Field Trips in Southwestern British Columbia, prepared by *Geological Discussion Club,* Vancouver, March, 1960; *Geol. Surv., Canada,* Ec. Geol. Series No. 1, " Geology and Economic Minerals of Canada," 1957.]

SYSTEM OF SUBDIVISION

British Columbia possesses a great diversity of landforms, ranging from unmodified Recent lava plains to intensely glaciated mountains. Any description of landforms, in terms of their origin, to be of value to geographers, teachers, tourists, or others, requires the application of some unifying system of classification. The physiographic subdivisions of the Province, as outlined on the map of the Province, Figure 1, and described in detail in the following text are natural regions in which there are similarities in the landforms resulting from (1) similar processes of erosion and deposition, (2) similarities of bedrock response to erosion, and (3) similarities of orogenic history. These factors provide the basis for outlining the major physiographic subdivisions of the Province in which common denominators of topography exist. Further subdivision of these major units is possible, and undoubtedly will be made when specific detailed studies of the areas provide the necessary information.

Previous Work

The earliest important contributions to the physiography of British Columbia are in the writings of G. M. Dawson, who for many years worked in the Province whilst a member of the Geological Survey of Canada. Most of his ideas are brought together in " The Later Physiographic Geology of the Rocky Mountain Region in Canada," published by the Royal Society of Canada in Transactions, Volume 8, Section IV, 1890, pages 3 to 74.

One of the first attempts at physiographic classification and systematization of the nomenclature of the Canadian Cordillera along the 49th parallel was made by R. A. Daly in Geological Survey of Canada Memoir 38, Part 1, 1912. Although some details of nomenclature are changed, much of Daly's scheme is retained in the present bulletin.

An important contribution was the publication by Leopold Reinecke of " Physiography of the Beaverdell Map-area and the Southern Part of the Interior Plateaus of B.C.," Geological Survey of Canada, Museum Bulletin No. 11, 1915.

* Mathews, W. H., and Rouse, G. E., *Science,* Vol. 133, April, 1961, p. 1079.

Field work by members of the Geological Survey of Canada in all parts of the Province provided detailed information which was collected by H. S. Bostock and elaborated by him through the study of numerous aerial photographs; it was published as "Physiography of the Canadian Cordillera, with Special Reference to the Area North of the Fifty-fifth Parallel" in Geological Survey of Canada Memoir 247. This work, since its publication in 1948, has served as the standard reference for the physiography of northern British Columbia and the Yukon.

Sources of Information

The present report follows the schematic framework of classification and nomenclature established by Bostock in Memoir 247. Additional details of geology and physiography over a large part of the Province are available in the published geological maps and reports of the Geological Survey of Canada.

Basic topographic information is available from published contoured topographic maps. The National Topographic System Maps, at 4 miles to the inch and with a contour interval of 500 feet, now cover a large percentage of the Province, with only a few sheets not available. More detailed topography is available in some parts at 1 and 2 miles to the inch with 100-foot contours.

An extremely valuable contribution is the Relief Map of British Columbia, Map 1JR, issued in 1960 by the Department of Lands and Forests, Victoria, at 30 miles to the inch. The Department of Lands, Forests, and Water Resources has also published six landform maps of British Columbia—Sheets 1B, 1D, 1E, 1F, 1G, 1K—covering the entire Province at a scale of 10 miles to the inch.

Vertical aerial photographs of most of the Province are available in the Air Photo Library of the Department of Lands, Forests, and Water Resources, Victoria. This report has benefited greatly from study of many thousands of oblique aerial photographs taken by trimetrogon camera at 16,000 to 18,000 feet altitude along several hundred flight lines throughout most of the Province. These photographs are also in the Air Photo Library of the Department of Lands, Forests, and Water Resources, Victoria. Prints are available for loan or may be purchased. They include photographs of great interest and great excellence, and a large number of them have been used to illustrate this report.

The writer wishes to acknowledge the very great help and co-operation of H. S. Bostock, of the Geological Survey of Canada, Ottawa, during the preparation of this report. In addition, benefit has been derived from critical comments and suggestions by R. G. Campbell, Jon Muller, and J. Souther, of the Geological Survey of Canada, and by W. H. Mathews, of the University of British Columbia.

Selection of Boundaries

When confronted with the problem of drawing a map showing the boundaries of the various subdivisions of the Cordillera, it is necessary to select somewhat arbitrarily certain types of features as the boundaries between units. On the accompanying map and in descriptions in Chapter II, boundaries separating units are drawn in the majority of instances along the following features:—

(1) Major or minor physical features such as the Kootenay Lake-Duncan River-Beaver River valley, Fraser River valley between Chilliwack and Lytton, Arrow Lake-Columbia River valley, and Chukachida River-Thudaka Creek-Finlay River valley.

(2) Geologic structural lines such as the Rocky Mountain Trench, Pinchi Lake fault zone, Louis Creek fault zone, and Pelly Creek lineament.

(3) Hypsometric lines (that is, lines of equal elevation or a line that approximates the position of the contour line), such as the 2,000-foot contour limiting the Fort Nelson Plain, the 3,000-foot contour outlining the Liard Plain and Fraser Basin, and the 5,000-foot contour marking the upper limit of the Nechako Plateau. In some instances, lines of types (1) or (3) may coincide with structural lines.

(4) Geological contacts, such as the contact of the Upper Cretaceous sedimentary rocks in the Suquash and Alberni Basins, and the eastern edge of the Misinchinka schists in the Misinchinka Ranges.

ILLUSTRATIONS

The text very largely describes the boundaries of the various units and indicates something of their physiographic history, but the photographic illustrations in this report are perhaps equally important. The accompanying map, Figure 1, is a special edition of the Department of Lands, Forests, and Water Resources Map 1JP. It shows the physiographic subdivisions of the Province in which the landforms in general appearance and origin are essentially alike.

The outlines of the physiographic subdivisions were transcribed from boundaries located on National Topographic System Map sheets at 4 miles to the inch and with 500-foot contours. Anyone wishing specific topographic information should obtain these more detailed maps either from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa, or from the Chief Geographer, Department of Lands, Forests, and Water Resources, Victoria.

The photographic illustrations convey a far better picture of the character of the terrain than could be done by words alone. The position and line of sight of each is shown by numbered arrows on Figure 9.

The photographic illustrations are prepared from oblique aerial photographs taken from aircraft flying at altitudes of 16,000 to 18,000 feet. The photographs are very largely those taken by the Air Survey Division of the Department of Lands, Forests, and Water Resources, Victoria. Copies of these photographs or the ones listed under " References " may be ordered from the Air Photo Library, Department of Lands, Forests, and Water Resources, Victoria. Some are reproduced through courtesy of the Royal Canadian Air Force, copies of which may be obtained from the National Air Photo Library, Department of Mines and Technical Surveys, Ottawa. The photographs are selected to illustrate characteristic features of the landscape in all parts of the Province.

Those who wish additional oblique aerial photographs of areas not illustrated here may obtain index maps from the Air Photo Library, Department of Lands, Forests, and Water Resources, Victoria, which show the flight lines and picture numbers for ordering. A very large part of the Province is covered by oblique photography, and where these pictures are available, they, together with topographic maps, provide an extremely valuable source of information for detailed physiographic studies. Nevertheless, in some areas oblique photographic coverage is poor or lacking. These are the Selkirk and Purcell Mountains, Rocky Mountains and Foothills north of Golden, Omineca and Cassiar Mountains, and Queen Charlotte Islands.

The geological diagrams, Figures 2 to 7, are adapted from the geological map published in the British Columbia Atlas of Resources, B.C. Natural Resources Conference, 1956.

The glacial diagram, Figure 10, is adapted from the map of glacial geology in the same atlas.

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CHAPTER II.—PHYSIOGRAPHIC SUBDIVISIONS OF BRITISH COLUMBIA

British Columbia lies within two of the five major physiographic subdivisions of Canada—the Canadian Cordilleran Region and the Interior Plains Region. The Canadian Cordillera is predominantly mountainous and includes all the mainland westward from the eastern margin of the foothills of the Rocky Mountains, as well as Vancouver Island and the Queen Charlotte Islands. The northeastern corner of the Province, some 10 per cent of the area, lies east of the Rocky Mountain Foothills and is predominantly flat or with low relief. Its plateaus, prairies, plains, and lowlands are part of the Interior Plains Region.

A. Canadian Cordillera

The Cordillera, though comprising many physiographic units, has three major subdivisions, which run the length of the Province in a northwesterly direction (*see* Fig. 8). These subdivisions are called "Systems." The Western System

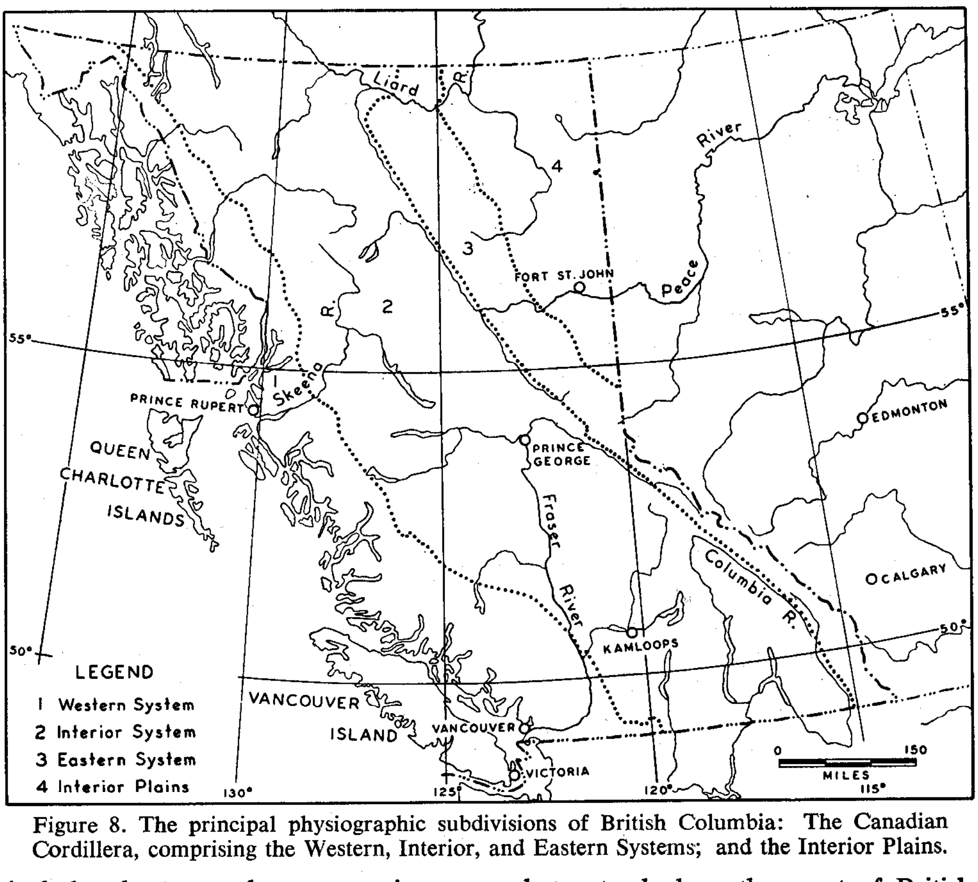

Figure 8. The principal physiographic subdivisions of British Columbia: The Canadian Cordillera, comprising the Western, Interior, and Eastern Systems; and the Interior Plains.

includes the tremendous mountain ranges that extend along the coast of British Columbia from the State of Washington to the Yukon, as well as the mountain ranges of Vancouver Island and the Queen Charlotte Islands. The Eastern System comprises the Rocky Mountains and the Rocky Mountain Foothills. Between these two flanking mountain systems is a region of plateaus, low basins, highlands, and rugged mountains, all of which are included within the Interior System.

The western boundary of the Eastern System lies along the Rocky Mountain Trench, a remarkable structural and topographic feature which extends from the 49th parallel northwestward for 900 miles, almost to the Liard River (*see* Plate XXII and Fig. 12). The eastern boundary of the Western System is not so clearly defined, but is a line drawn to separate the various ranges of the Coast Mountains from a succession of flanking mountains, highlands, and plateaus on the east. Although in some instances there is a gradual transition between Western and Interior Systems, elsewhere the transition is abrupt, and a clear-cut separation may be made, using a boundary drawn along the eastern side of the Coast Mountains in the approximate position of the 5,000-foot contour (*see* Plate XIB).

I. WESTERN SYSTEM

The Western System in British Columbia includes all that part of the Province lying west of a rather sinuous boundary-line running northward from Keremeos through Lytton to Smithers and thence to Telegraph Creek and Atlin. It consists essentially of the mountainous mainland coast, but included within the System are a number of low-lying areas along the coast, as well as the mountains of Vancouver Island and of the Queen Charlotte Islands.

There are three major subdivisions of the Western System. These are, from west to east, the Outer Mountain Area, the Coastal Trough, and the Coast Mountain Area.

The Outer Mountain Area comprises the St. Elias Mountains in the extreme northwesterly corner of the Province and the Insular Mountains of the Queen Charlotte Islands and Vancouver Island.

The Coastal Trough is a low-lying area which is partly submerged beneath the sea. It is flanked on the west by the mountains of Vancouver Island and the Queen Charlotte Islands and on the east by the heights of the Coast Mountains. It includes the Georgia and Hecate Depressions; it extends northwestward through southeastern Alaska as far as Chatham Strait and southeastward through Washington as the Puget Depression.

The Coast Mountain Area flanks the Coastal Trough on the east and extends on the mainland for the full length of the Province, forming a barrier of mountains as much as 100 miles across. It includes the Coast Mountains, which extend 900 miles northwestward from their southern boundary at the Fraser River, as well as a small northern prong of the Cascade Mountains of Washington and Oregon that crosses into British Columbia and extends north as far as Lytton.

The very large area of the Coast Mountains is divided into three smaller units which are natural groupings of individual ranges. These are the Boundary Ranges, lying between the Yukon Border and the Nass River; the Kitimat Ranges lying between the Nass River and the Bella Coola River; and the Pacific Ranges lying between the Bella Coola River and the Fraser River.

OUTER MOUNTAIN AREA

St. Elias Mountains

The St. Elias Mountains lie in the curve of the Gulf of Alaska and are readily visible from the sea in clear weather, when they are seen to rise abruptly to great heights as a white wall of mountains. They extend northwestward from Cross Sound and Lynn Canal to Cook Inlet.* These mountains include some of the most rugged country in North America and include the summits of Mount Fairweather

* Brooks, A. H., *U.S.G.S.*, Prof. Paper No. 45, 1906, p. 29.

(15,300 feet) on the Alaska-British Columbia Boundary, the highest peak in British Columbia; Mount St. Elias (18,008 feet) on the Alaska-Yukon boundary; and Mount Logan (19,850 feet) in southwestern Yukon, the highest peak in Canada and second only to Mount McKinley (20,300 feet) in the Alaska Range, the highest peak in North America.

In British Columbia the St. Elias Mountains extend along the Alaska-British Columbia Boundary between Mount Fairweather and Mount Jette. Their boundary with the Coast Mountains is along the Tatshenshini, Kelsall, and Chilkat Rivers. Within British Columbia they comprise the Fairweather Ranges, Icefield Ranges, Alsek Ranges, and the Duke Depression.

The mountains along the Alaska-British Columbia Boundary southwest of a line drawn from the head of Tarr Inlet along Melbern Glacier to the Alsek River culminate in Mount Fairweather (15,300 feet) (*see* Plate I), and constitute the *Fairweather Ranges.* The ranges lie in a coastal belt of heavy precipitation and are very largely covered with glaciers and snowfields. Much of the height of the Fairweather Ranges is due to Pleistocene and Recent uplifts totalling as much as 5,000 feet.

The valley of the Alsek River (*see* Plate IIA), the only breach in the mountain front between Cross Sound and the Copper River, serves as the southeastern and eastern boundary of the *Icefield Ranges,* which extend northwestward from the Alsek River to Mount St. Elias and Mount Logan and for the most part lie within Yukon Territory. These ranges, too, are very largely covered with glaciers and snowfields and, together with the Fairweather Ranges, constitute one of the least explored sections of the Province.

The *Alsek Ranges* extend southeastward from the Alsek River and lie to the east of the Fairweather Ranges. They are separated from the Coast Mountains on the northeast by the Kelsall and Tatshenshini Rivers. In contrast to the Fairweather and Icefield Ranges they are considerably lower in general summit level, about 6,500 to 8,500 feet in elevation, and they carry a much smaller mantle of snow and ice. Their serrate peaks have been sculptured by cirque action, and the major valleys especially have been modified strongly by the movement of ice along them. The creeks and rivers are heavily charged with sediments from melting glaciers, and most streams are aggrading; they flow in intricate and ever-changing courses over their valley trains (*see* Plate IIA). The valley flats of the lower Alsek and Tatshenshini Rivers are more than a mile wide and present formidable barriers to travel by foot.

The low timberline and general lack of vegetation in many parts, coupled with many evidences of stagnant and receding ice, give the appearance of a land just emerging from its glacial cloak.

The *Duke Depression,* a physiographic unit more prominently developed in the Yukon, is a belt of broad smooth slopes, almost plateau-like in character. The general trend of the depression is parallel to the Kluane Ranges, which lie along its northeastern side and which are separated by it from the main mass of the St. Elias Mountains. However, the extension of the Duke Depression into British Columbia is only a very minor feature and is represented by the uppermost reaches of the Tatshenshini River valley at an elevation between 3,000 and 4,000 feet.

[References: Watson, K. deP., "Squaw Creek-Rainy Hollow Area," *B.C. Dept. of Mines,* Bull. No. 25, 1948; N.T.S. Sheet 114P, Tatshenshini River.]

[Photographs: B.C. 687:58, 76; B.C. 688:13, 31, 35, 82; B.C. 691:26.]

Insular Mountains

The Insular Mountains comprise the Queen Charlotte Mountains on the Queen Charlotte Islands and the Vancouver Island Mountains on Vancouver Island.

Queen Charlotte Mountains

The Queen Charlotte Mountains consist of two units—the Queen Charlotte Ranges, which form the mountainous backbone of the Islands and lie mostly along their western side, and the Skidegate Plateau, an elongated belt of plateau-like country flanking them on the east.

The Queen Charlotte Mountains lie to the southwest of a more or less direct line drawn from Copper Bay at the northeast end of Moresby Island, south of Dead Tree Point, thence through Juskatla Inlet and past the south end of Naden Harbour to Beresford Bay. This boundary separates the low-lying northeastern corner of Graham Island, the Queen Charlotte Lowland, from the section of greater relief which includes the rest of the Islands.

The *Queen Charlotte Ranges* (*see* Plate IIB), of which only the San Cristoval Range is named, extend southeastward from Rennell Sound to Cape St. James. The eastern margin of the ranges, between Vertical Point on Louise Island and Rennell Sound, closely follows a zone of faulting. Only the Slatechuck Mountain mass, part of the main ranges, lies east of the fault zone.

The highest peaks on the Islands are Mount Needham (3,500+ feet) in the southwestern part of Graham Island, Mount Kermode (3,500+ feet) on the west side of Louise Island, Mount de la Touche (3,600+ feet) just south of Tasu Sound, and an unnamed peak (3,700+ feet) just south of Mosquito Lake. The general summit elevation diminishes southward as the ranges plunge into the sea at Cape St. James. The core of the ranges between Tasu Sound and Nagas Point and of the high range between Skidegate Channel and Rennell Sound is granitic. Much of the rest of the ranges is underlain by Triassic and Jurassic volcanic rocks.

Despite the fact that their maximum relief is only about 3,700 feet, the Queen Charlotte Ranges are extremely rugged, their serrate peaks having been sculptured by cirque glaciers long since melted away. The cirque erosion has produced topographic forms at all elevations down to and below sea-level.

The *Skidegate Plateau*, some 10 miles wide and 100 miles long, is a dissected plateau whose eastward sloping surface reaches 2,500 feet elevation (*see* Plate IIC). It is bounded by the Queen Charlotte Ranges on the west and the Queen Charlotte Lowland on the east. It extends between Louise Island on the southeast and Beresford Bay at the northwestern tip of Graham Island. From Louise Island northward to Yakoun Lake the surface of the plateau cuts across Mesozoic rocks; farther north tilted Paleocene lavas underlie the plateau surface.*

The Islands show signs of intense glaciation. An ice-sheet with a local centre of accumulation, rather than one of mainland derivation, sculptured the terrain below 3,000 feet. Only matterhorn peaks above that height may have projected through the ice-sheet as nunataks. In a late stage, glaciers moved westward and eastward from an ice divide lengthwise of the Islands. Eastward-moving ice modified the topography north of Cumshewa Inlet and coalesced with other glaciers to move northward and northwestward across the Queen Charlotte Lowland and finally westward out to sea across the Lowland past the northern end of the Skidegate Plateau (*see* Fig. 10).

* Personal communication, A. Sutherland Brown.

[References: MacKenzie, J. A., "Geology of Graham Island," *Geol. Surv., Canada,* Mem. 88, 1916; Sutherland Brown, A., "Physiography of Queen Charlotte Islands," *Can. Geog. Jour.*, Vol. LXI, No. 1, 1960, pp. 30–37; Sutherland Brown, A., and Nasmith, H., "Glaciation of the Queen Charlotte Islands," *Can. Field Naturalist,* Vol. 76, No. 4, 1962, pp. 209–219; Map No. 2F, "Queen Charlotte Islands," *B.C. Dept. of Lands and Forests,* 1954, 1 in. to 4 mi. Complete coverage also available on N.T.S. sheets at 1:50,000 with 100-foot contours.]

Vancouver Island Mountains

All of Vancouver Island except for a narrow strip of lowland along the eastern and northern coast is included within the Vancouver Island Mountains of the Insular Mountains. The lowland areas, the Nanaimo Lowland and Nahwitti Lowland, are parts of the Coastal Trough and lie below 2,000 feet elevation, their boundary with the mountains being drawn along the line of the 2,000-foot contour.

The Vancouver Island Mountains consist of the Vancouver Island Ranges comprising the dominantly mountainous part of the Island; the Alberni Basin, a low-lying area inland from the head of Alberni Canal; and the Estevan Coastal Plain, a very narrow strip of coastal plain along the western and southwestern coast.

The highest peaks of the *Vancouver Island Ranges* are the Golden Hinde (7,219 feet), Elkhorn Mountain (7,200 feet), Mount Victoria (7,095 feet), and Mount Colonel Foster (7,000 feet), all in the central part of the Island. Summit elevations diminish to northwest and southeast, with no peaks higher than 5,000 feet lying northwest of Nimpkish Lake or southeast of Cowichan Lake. Between these two lakes lie the most rugged ranges on the Island.

The Vancouver Island Ranges (*see* Plate IIIA) are composed of a heterogeneous group of pre-Cretaceous sedimentary and volcanic rocks folded about northwesterly trending axes and intruded by numerous granitic batholiths. The mountains are the result of the mature dissection of a Tertiary erosion surface of low relief (*see* p. 45). Extensive remnants of this surface are to be seen in the vicinity of the Nanaimo Lakes in Strathcona Park, on San Juan Ridge, and at low levels south of the San Juan River (*see* N.T.S. Sheets 92 F/1 and F/11). Near the Nanaimo Lakes the surface has an elevation of about 3,000 feet, with monadnocks rising as much as 2,000 feet above it. Westward toward the centre of the Island, dissection is more and more advanced and less of the Tertiary surface remains. It was the erosion leading to formation of this Tertiary surface that supplied the Oligocene and early Miocene sediments which were deposited on a coastal plain along the west coast of the Island. Pre-Pleistocene uplift and dissection of the surface produced an extremely rugged topography in the central and northern parts of the Island, where uplift was greatest. This topography was modified by glaciation during the Pleistocene, at which time high serrate peaks were sculptured by alpine glaciers, upland surfaces below 4,000 feet* were modified by the continental ice-sheet, and lower valleys were deepened and modified by the erosion of valley glaciers.

Conspicuous features of southern Vancouver Island are fault-line scarps and fault-controlled valleys such as those of Cowichan Lake, San Juan River, Loss Creek, Bear Creek, and Leech River. In the Cowichan Lake area† it has been shown that structurally controlled valleys follow post-Upper Cretaceous fault zones.

[References: Hoadley, J. W., "Geology and Mineral Deposits of the Zeballos-Nimpkish Area," *Geol. Surv., Canada,* Mem. 272; Gunning, H. C., "Buttle Lake Map Area," *Geol. Surv., Canada*, Sum. Rept., 1930, Pt. A, pp. 56–78; Gunning,

* Hoadley, J. W., *Geol. Surv., Canada*, Mem. 272, p. 7.
† Fyles, J. T., B.C. Dept. of Mines, Bull. No. 37, p. 9.

H. C., "Geology and Mineral Deposits of Quatsino-Nimpkish Area," *Geol. Surv., Canada,* Sum. Rept., 1929, Pt. A, pp. 94–143.]

[Photographs: B.C. 664:20, 49; B.C. 666:20, 38, 58, 102; B.C. 673:17, 40; B.C. 1553:98; B.C. 1555:10.]

The *Alberni Basin* (*see* Plate IIIB) extends northwestward from Port Alberni and has a length of about 25 miles and a width of 5 to 8 miles. It is a low-lying area of low relief drained by the Ash, Stamp, Sproat, and Somass Rivers into the Alberni Canal. It is sharply bounded on its eastern side by an abrupt fault-line scarp along the western front of the Beaufort Range. On the north, west, and south the 1,000-foot contour line marks for the most part its boundary with the surrounding mountainous terrain.

The basin is underlain by Upper Cretaceous sedimentary rocks. These have eroded more readily, and as a consequence lie at lower elevations than the older volcanic and intrusive rocks which surround them.

[Reference: MacKenzie, J. D., "Alberni Area," *Geol. Surv., Canada,* Sum. Rept., 1922, Pt. A, pp. 51–68; Fyles, J. G., "Surficial Geology of Horne Lake and Parksville Map Areas," *Geol. Surv., Canada,* Mem. 318, 1963, pp. 4–8.]

A narrow coastal plain, the *Estevan Coastal Plain* (*see* Plate IV), 1 to 2 miles wide for the most part, extends along the west coast of Vancouver Island, from Bunsby Islands east of Brooks Peninsula southeastward for almost 170 miles to Cullite Cove, 8 miles southeast of Carmanah Point. Much of the coastal plain is less than 150 feet above sea-level and is interrupted by irregular hills and isolated knolls seldom more than 250 feet high. The plain is divided into sections by various inlets, and reaches its greatest width of 6 to 8 miles at Hesquiat Peninsula.

Where the coastal plain is underlain by relatively soft Tertiary or Pleistocene and Recent deposits, its surface is flat and almost featureless, but where it is underlain by harder rocks of the Vancouver Group, it is much more uneven, with bluffs and protruding hummocks.

The Tertiary rocks of the coastal plain are gently dipping Oligocene and early Miocene sandstones, more or less continuously exposed northwest of Cullite Cove. These rocks were deposited on an early Tertiary erosion surface contemporaneously with the dissection of the same surface where it was upwarped east of the coastline. Between Cullite Cove and Sooke Inlet the early Tertiary erosion surface can be clearly seen truncating the older rocks (*see* N.T.S. Sheets 92 C/9 and C/10), but Tertiary sedimentary rocks, which at one time almost certainly existed, have been stripped off almost completely, leaving a few remnants in protected areas.

The flat surface of the coastal plain is the result of late Tertiary erosion of the soft sediments, but insufficient time has elapsed for a comparable feature to develop on the adjacent hard rocks.

[References: Jeletzky, J. A., "Tertiary Rocks of the Hesquiat-Nootka Area," *Geol. Surv., Canada,* Paper 53-17; *B.C. Dept. of Lands and Forests,* N.T.S. Sheets 92 C/9 and C/10 at 1 in. to 1 mi.; *Dept. of Mines and Technical Surveys,* N.T.S. 92 SW at 1 in. to 8 mi.; Hoadley, J. W., "Geology and Mineral Deposits of the Zeballos-Nimpkish Area," *Geol. Surv., Canada,* Mem. 272, 1953.]

[Photographs: B.C. 677:98.]

COASTAL TROUGH

The Coastal Trough extends northwestward through British Columbia as a structurally controlled topographically low belt from Puget Sound and the San Juan Islands in Washington to Dixon Entrance, a distance of more than 500 miles. It lies between the Insular Mountains on the west and the Coast Mountains on the east.

The extension of the trough through southeastern Alaska is marked by low-lying areas or areas underlain by Tertiary rocks. It terminates finally at Chatham Strait, which is the site of a major north-striking fault.

The Coastal Trough has a width of 75 miles between Graham Island and Porcher Island, is constricted to a width of 10 miles at Sayward in Johnstone Strait, and broadens to about 30 miles at Campbell River. It is 100 miles wide at the re-entrant of the Fraser River, where it extends eastward to a point just west of Hope. The constriction at Sayward, the Seymour Arch,* divides the Trough into a northern section, the Hecate Depression, and a southern section, the Georgia Depression. The line of the 2,000-foot contour is used arbitrarily as the boundary between the lowlands and the mountains.

Hecate Depression

The Hecate Depression between Johnstone Strait and Dixon Entrance is very largely beneath sea-level, being occupied by Queen Charlotte Strait, Queen Charlotte Sound, Hecate Strait, and Dixon Entrance. Between Graham Island and Porcher Island the sea floor beneath Hecate Strait does not lie below a depth of 300 feet, but depths greater than 1,200 feet are reached farther south in Hecate Strait and to the north in Dixon Entrance, where ice-gouged troughs extend across the Depression. The parts of Hecate Depression above sea-level are the Queen Charlotte Lowland on Graham Island, the Nahwitti Lowland on northern Vancouver Island, and the Hecate Lowland along the mainland coast and on the offshore islands.

Queen Charlotte Lowland

The northeastern part of Graham Island, northeast of a line between Copper Bay and Beresford Bay, is low, with little relief, and constitutes part of the Hecate Depression. Northward from Lawn Hill (560 feet) and east of Masset Sound the terrain is very largely below 500 feet elevation, while west of Masset Sound the surface rises gradually but stays well below 1,000 feet. The boundary between the Skidegate Plateau on the southwest and the Queen Charlotte Lowland on the northeast is marked by the generalized line of the 500-foot contour between Copper Bay and Masset Inlet. Northwestward from Masset Inlet the generalized line of the 1,000-foot contour is more suitable. For about 50 miles northwest of Copper Bay the boundary more or less coincides with the trace of a fault which has been postulated on both geological and geophysical grounds. Drainage on the lowland surface is poorly organized. A very large percentage of the area is muskeg and the timber cover is sparse.

Except for the extreme northeastern tip of Graham Island, the area of the Argonaut Plain, the lowland is underlain by early Tertiary basaltic lavas and late Tertiary sedimentary rocks covered with a thin veneer of till. Most of the lava flows do not exceed 100 feet in thickness, and many have well-developed columnar jointing; they dip seldom more than 20 degrees to the east. The gentle rise of the lowland surface westward from Masset Sound probably is the surface reflection of the gently east-dipping flows.

The movement of glacial ice across the lowland is shown by drumlin-like forms and flutings, which at Juskatla Inlet and the head of Masset Inlet indicate a northeast direction of travel. The direction changes progressively to more westerly, and striations at the mouth of Masset Inlet trend north 10 degrees west. The ice eventually joined with ice from Alaskan and mainland glaciers which flowed through Dixon Entrance past and over Langara Island in a westerly direction.

* Bostock, H. S., *Geol. Surv., Canada*, Mem. 247, p. 89.

The extreme northeastern tip of Graham Island is underlain largely by late Tertiary sedimentary rocks overlain by several hundred feet of Pleistocene and Recent unconsolidated sands and gravels. This is the *Argonaut Plain* (*see* Plate VA), a glacial outwash plain of post-Pleistocene age whose surface lies at and below about 550 feet elevation and has only slight relief. The plain is younger than the last ice advance and, because it is not overridden, shows no glacial modification of the unconsolidated materials.

The beach bordering the lowland between the entrance to Masset Sound and Dead Tree Point, a distance of more than 75 miles, is a remarkable feature (*see* Plate XLVB.) It is an almost continuous wide sand beach for the entire distance. The material has been derived from the erosion of unconsolidated Pleistocene materials along the east coast. Under the influence of the prevailing southeast wind and current, the material is transported northward along the beach to form Rose Spit. From there the material is transported westward, building the north coast beaches as far west as Masset Sound.

Strong winds have produced sand dunes along the north and east coast beaches. The dunes may extend inland for several hundred yards beyond the back beach area.

[References: MacKenzie, J. D., " Geology of Graham Island," *Geol. Surv., Canada,* Mem. 88, 1916; Sutherland Brown, A., " Physiography of the Queen Charlotte Islands," *Can. Geog. Jour.,* Vol. XLI, No. 1, 1960, pp. 30–37; Sutherland Brown, A., and Nasmith, H., " Glaciation of the Queen Charlotte Islands," *Can. Field Naturalist,* Vol. 76, No. 4, 1962, pp. 209–219.]

Nahwitti Lowland

The northern tip of Vancouver Island, lying north of a line between Englewood and Quatsino Sound, is below 2,000 feet in elevation, except for a few isolated summits. It is an area of low relief lying within the Hecate Depression.

The high Vancouver Island Ranges end abruptly along the southern boundary of the Nahwitti Lowland, giving way to an area of low relief and of low rounded hills (*see* Plate VB), in which remnants of the dissected Tertiary erosion surface slope northward to sea-level between Cape Scott and Cape Sutil.

The area was overridden by ice, and it is evident from roches moutonnées on the ridge northeast of Rupert Inlet that ice from the mainland moved southwestward and westward across Queen Charlotte Strait, to discharge seaward along Quatsino Sound and Holberg Inlet.

Within the lowland there is a roughly triangular area, bounded by lines extending between Englewood, Quatsino, and Port Hardy, which has a gently rolling surface seldom exceeding 1,000 feet in elevation. This is the *Suquash Basin,* which includes Malcolm and Cormorant Islands, and is underlain by gently dipping Upper Cretaceous coal measures. The southern margin of the basin is a westerly striking fault along the abrupt front of the Hankin and adjoining Bonanza and Franklin Ranges.

Erosion of the soft Cretaceous sedimentary beds has produced the low-lying gentle topography within the Suquash Basin, whereas volcanic rocks of the older Vancouver Group, being harder and more resistant, underlie the somewhat higher ground within the Nahwitti Lowland.

[Photographs: B.C. 664:52, 57.]

Hecate Lowland

A strip of low-lying country, including both mainland coast and adjacent islands, extends along the eastern side of the Coastal Trough southward from Prince Rupert to Vancouver. A constriction of the trough at Sayward separates a northern section, the Hecate Lowland, flanking the Hecate Depression, from a southern section, the Georgia Lowland, flanking the Georgia Depression. The eastern boundary of the lowland is arbitrarily taken as a generalized line along the 2,000-foot contour.

The Hecate Lowland (*see* Plate VIIA) is 10 to 25 miles wide and includes considerably less of the mainland than it does of the islands of the archipelago. The large islands, such as McCauley, Banks, Aristazabal, Price, and Calvert and many others, lie within it.

Summit levels within the lowland are below 2,000 feet, except for a few isolated high areas on Banks Island, Campania Island, Hunter Island, and Calvert Island that protrude above the general level.

A striking feature within the lowland is the accordancy of summits that represent remnants of an erosion surface of late Tertiary age which truncates granitic and older rocks alike and which has been warped upward to the east. It is well displayed on an east-west profile drawn through Cape Caution. The old erosion surface rises gradually and then progressively more steeply as the high Coast Mountains are reached. The amount of dissection increases eastward as the relief increases. Remnants of the surface diminish in size and number as the mountains are approached, until ultimately the old surface is completely obliterated.

Within the lowland, as for example on the west side of Pitt Island, the topography may be quite rough even though the total relief is not great. In contrast, however, there are areas north of Cape Caution, on the west side of Calvert Island, on Aristazabal Island, Campania Island, and Banks Island where a flat low plain, mostly below 100 feet elevation, is underlain by a variety of rocks, of which granite predominates. This constitutes the *Milbanke Strandflat** (*see* Plate VIA). Many of these low areas display numerous well-marked lineaments and are occupied by large expanses of muskeg where drainage is poorly established.

The lowland has been heavily glaciated, and bare bedrock everywhere shows the sculpturing effects of ice erosion. Cirque glaciation at sea-level is a remarkable feature in an area extending from Banks Island south to Cape Caution, and is an indication of the level reached by snowline during the late Pleistocene.

[References: Dolmage, V., " Coast and Islands of British Columbia between Douglas Channel and the Alaskan Boundary," *Geol. Surv., Canada,* Sum. Rept., 1922, Pt. A, pp. 9–34; Dolmage, V., " Coast and Islands of British Columbia between Burke and Douglas Channels," *Geol. Surv., Canada,* Sum. Rept., 1921, Pt. A, pp. 22–49; N.T.S. Sheet 103A.]

[Photographs: B.C. 472:70; B.C. 501:23, 34, 46; B.C. 502:34, 56; B.C. 663:43; B.C. 644:113; B.C. 1207:75; B.C. 1403:92.]

Georgia Depression

The Georgia Depression is separated from the Hecate Depression by the Seymour Arch, which is a high area between Sayward and Menzies Bay where the Tertiary erosion surface was warped upward along a transverse axis. It is dissected by the valley of the Salmon River and by the valley occupied by Johnstone Strait-Discovery Passage. The Georgia Depression is partly submerged beneath the Strait of Georgia and Puget Sound, and includes the Georgia Lowland along the mainland coast and the Nanaimo Lowland along the east coast of Vancouver Island.

Recent studies made for the Institute of Oceanography at the University of British Columbia disclose two areas of distinctive submarine topography in the Strait of Georgia.† They are interpreted as reflecting the different geology on either side of

* Gulicher, A., 1958, p. 160.
Evers, W., *Jour. Geol.*, Vol. 70, No. 5, 1962, pp. 621–633.

† Manuscript Report No. 14, 1963, Institute of Oceanography, *University of British Columbia.*

the strait. It is suggested that the boundary between the two areas is also the boundary between two structural regions. Further studies of this sort will contribute greatly to the physiographic knowledge of the submarine topography on the continental shelf.

Glaciation within the Georgia Depression was intense. Ice pouring westward from the Coast Mountains and eastward from the Vancouver Island Ranges coalesced in the strait to form a glacier which flowed southeastward and southward, and escaped to sea westward through Juan de Fuca Strait. The depression in part is of structural origin, but in part was over-deepened by ice erosion. Low-lying rock surfaces were stripped of weathered material and were shaped, while elsewhere glacial materials were deposited as ground moraines or as outwash plains, of which Hernando, Savary, and Harwood Islands are remnants.

[Reference: Bancroft, J. A., " Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound," *Geol. Surv., Canada,* Mem. 23, 1913.]

[Photograph: B.C. 673:42.]

Georgia Lowland

The Georgia Lowland south of Sayward includes parts of numerous islands as far south as the Malaspina Peninsula north of Powell River. From there southeastward a narrow strip on the mainland 2 to 10 miles wide, together with the few offshore islands, constitutes the lowland. High areas between Sayward and Menzies Bay, on Quadra Island, and on Texada Island lie within the Georgia Depression, rising as monadnocks above the prevailing lowland surface.

The Strait of Georgia and Johnstone Strait essentially follow the contact between the granitic rocks of the Coast Intrusions of Jurassic age and older rocks of the Vancouver Group and others which lie to the west. The Georgia Lowland is underlain by granitic rocks as well as by inliers of older formations.

As in the Hecate Lowland to the north, accordant summits represent remnants of a dissected late Tertiary erosion surface, which is warped and rises gradually eastward from Georgia Strait until it is sufficiently high in the Coast Mountains to be completely dissected and destroyed. In an intermediate zone between elevations of 2,000 and about 4,000 feet, some small remnants of the Tertiary erosion surface may still be seen (*see* N.T.S. Sheets 92 G/12 and G/13), but it is below 2,000 feet elevation within the Georgia Lowland that remnants are more extensive and are to be seen as gently sloping upland surfaces (*see* N.T.S. Sheet 92 K/6).

The *Fraser Lowland* (*see* Plate VIB) is a part of the Georgia Lowland, from which it differs in being a low-lying area of depositional rather than erosional origin. Its triangular shape includes the delta of the Fraser River, extending eastward from Point Grey for 70 miles to Laidlaw, thence southwestward to the coast at Bellingham. The area is bounded on the north by the Pacific Ranges of the Coast Mountains and on the southeast by the Skagit Range of the Cascade Mountains, all of which rise abruptly from the plain.

The Fraser Lowland in the New Westminster area is described by Armstrong in Geological Survey of Canada Paper 57-5. It " consists of extensive low hills (in this report called uplands) ranging in elevation from 50 to 1,000 feet separated by wide, flat-bottomed valleys. The uplands are of four main types: (1) a core of unconsolidated deposits with rolling, hummocky surfaces of glacial till and glacio-marine deposits; (2) a core of unconsolidated deposits with commonly flat, terraced surfaces of glacial outwash; (3) a core of bedrock overlain by a thin mantle of glacial and glacio-marine deposits; and (4) raised marine deltas with a possible core of bedrock . . . .

" Flat-bottomed valleys up to 3 miles wide separate the uplands. The major valleys, which range in elevation from a few feet to 75 feet above sea-level, are as follows: the present valley of the Fraser River; the valley occupied by the Pitt River from Pitt Lake to the Fraser River; the valley occupied by the Alouette River from north of Haney to the Pitt River valley; Burnaby Lake-Still Creek valley; upper Nicomekl River-Salmon River valley; lower Nicomekl River-Serpentine River valley; and the lower part of Campbell Creek valley. All the valleys, with the exception of the Burnaby Lake-Still Creek valley and the present valley of the Fraser River, are former embayments of the sea and were not cut by the streams now occupying them."

The Fraser Lowland includes the delta area of the Fraser River. It has been the site of sedimentary deposition since the late Cretaceous. Deep drilling has shown that the granitic basement is overlain by as much as 15,000 feet of late Cretaceous, Tertiary, and Quaternary sedimentary rocks. These rocks lie unconformably above the Coast Intrusions, and the surface of unconformity is a late Cretaceous to middle Eocene erosion surface. Along the north side of the lowland, parts of this surface are visible in the present topography as a long 15-degree slope. During part of the Tertiary the old surface was saved from destruction by its sedimentary cover, but it was exhumed and made visible by the eventual stripping by erosion of most of the sedimentary rocks.

The area has had a very complex Pleistocene and Recent history involving marine and non-marine, glacial and non-glacial deposition. During several glacial advances, ice accumulated to depths of as much as 7,500 feet, and during each major glaciation the land was depressed relative to the sea. The submergence of the land surface based on the occurrence of marine fossils amounted to 575 feet and is interpreted to have been as much as 1,000 feet* during the Vashon glaciation.

Recent deposits, still in the process of formation, consist of deltaic, channel, and flood-plain deposits of the Fraser River as it builds its delta seaward at the rate of about 28 feet† a year.

[References: Johnston, W. A., " Geology of Fraser River Delta Map-area," *Geol. Surv., Canada,* Mem. 135, 1923; Armstrong, J. E., " Surficial Geology of Vancouver Area," *Geol. Surv., Canada,* Paper 55-40; Armstrong, J. E., " Surficial Geology of New Westminster Map-area," *Geol. Surv., Canada,* Paper 57-5; Mathews, W. H., and Shepard, F. P., " Sedimentation of Fraser River Delta," *Am. Ass. Pet. Geol.,* Vol. 46, No. 8, 1962, pp. 1416–1443.]

[Photograph: B.C. 495:100.]

Nanaimo Lowland

The Nanaimo Lowland (*see* Plate VIIB) is a strip of low-lying country, below 2,000 feet elevation, which extends southeastward for 175 miles along the east coast of Vancouver Island from Sayward on Johnstone Strait to Jordan River west of Victoria. Denman, Hornby, Gabriola, Galiano, Pender, and Saturna Islands are included in the lowland, which reaches its maximum width of 20 miles between Galiano Island and Shawnigan Lake. The lowland lies on the western side of the Georgia Depression and is largely underlain by sedimentary rocks of the Nanaimo Group of Upper Cretaceous age. It is flanked on its western side above the 2,000-foot contour line by the Vancouver Island Ranges, along a boundary which for at least 70 miles roughly coincides with a major fault zone.‡

* Armstrong, J. E., and Brown, W. L., *Geol. Soc., Am.,* Bull. Vol. 65, 1954, p. 362.
† This is the calculated rate of advance at a depth of 300 feet.
‡ Buckham, A. F., *Geol. Surv., Canada,* Paper 47-22.

The lowland consists of many low, wooded cuesta-like ridges separated by narrow valleys. The northwesterly elongation of the ridges and of the Gulf Islands is the result of differential erosion of the Upper Cretaceous sedimentary rocks. The ridges are underlain by hard sandstone and conglomerate beds, and the valleys are eroded in shales and softer rocks or along fault zones. In the south between Saanich Inlet and Jordan River, the lowland is underlain by granitic and other older rocks, which are more resistant to erosion. This fundamental difference in bedrock is reflected in somewhat greater elevations and in different topographic forms.

The lowland was overridden by ice during the Pleistocene, and the direction of ice movement is shown by the form of many rock surfaces. The already low relief was further reduced by glacial erosion and by the deposition of a fairly thick mantle of glacial and fluvio-glacial materials. Uplift of the land since the ice retreat has led to rejuvenation of streams and in many instances to the cutting of narrow box canyons in the lower courses of streams approaching the sea.

[References: Clapp, C. H., "Geology of Victoria and Saanich Map-areas," *Geol. Surv., Canada,* Mem. 36, 1914; Clapp, C. H., "Geology of the Nanaimo Map-area," *Geol. Surv., Canada,* Mem. 51, 1914; Clapp, C. H., "Sooke and Duncan Map-areas," *Geol. Surv., Canada,* Mem. 96, 1917; Fyles, J. G., "Surficial Geology, Oyster River," *Geol. Surv., Canada,* Map 49-1959; Fyles, J. G., "Surficial Geology, Courtenay," *Geol. Surv., Canada,* Map 32-1960; Fyles, J. G., "Surficial Geology of Horne Lake and Parksville Map-areas," *Geol. Surv., Canada,* Mem. 318, 1963.]

[Photographs: B.C. 673:40, 52; B.C. 1206:102; B.C. 1555:79.]

COAST MOUNTAIN AREA

Coast Mountains

The Coast Mountains extend along the mainland coast of British Columbia as an unbroken mountain chain, from their south end at the Fraser River northwestward for about 950 miles to the northern boundary of the Province. The mountains extend a further 50 miles into the Yukon, giving them a total length of approximately 1,000 miles. Their width ranges from a minimum of 35 miles to a maximum of 100 miles.

On the west the Coast Mountains, between the mouth of the Fraser River and Chatham Strait, are flanked by the Coastal Trough, whose eastern boundary is the 2,000-foot contour line. Between Lynn Canal and the Yukon Border the Coast Mountains are separated from the St. Elias Mountains on the west by the valleys of Chilkat River in Alaska and of Kelsall and Tatshenshini Rivers in British Columbia.

The eastern boundary of the Coast Mountains is the boundary between the Western and Interior Systems. For the greater part of its length, from the Yukon Border to Lytton, the boundary is drawn between mountains on the west and plateaus and highlands on the east. Although in places there may be transition between the two systems, the separation of one from the other is along a fairly easily determined line. In the extreme north the Coast Mountains are flanked by a transitional belt of highlands (Tagish and Tahltan Highlands) extending south to the Iskut River. Between the Iskut River and the head of the Bell-Irving River the Coast Mountains for 25 miles are flanked by a range which is part of the Interior System—the Klappan Range of the Skeena Mountains. Farther south the border is against the Nass Basin and Hazelton Mountains. From Eutsuk Lake to the head of the Yalakom River the Coast Mountains border the Nechako and Fraser Plateaus with a sharply defined front rising above the plateau surface. On the extreme south the Yalakom and Fraser Rivers mark the eastern boundary of the Coast Mountains.

The Coast Mountains comprise sedimentary and volcanic rocks of middle Jurassic and older age that have been intruded by a composite batholith comprising multiple intrusions of rocks that are essentially granodiorite and quartz diorite in composition—the Coast Intrusions. The eastern contact of the Coast Intrusions is a somewhat irregular line extending southeastward from Taku Arm of Tagish Lake, passing west of Tulsequah, through Stewart, the west ends of Whitesail and Eutsuk Lakes, and the south ends of Chilko and Taseko Lakes to Lytton. Within the Coast Mountains there are ranges, particularly on the west, formed very largely of granitic rocks as well as ranges which are largely composed of sedimentary and volcanic rocks but whose cores may be stocks or batholiths of granitic rock. To the south of the Nass River the eastern contact of the Coast Intrusions provides a satisfactory boundary between the Hazelton Mountains and the granitic mountains of the Kitimat Ranges on the west. It also provides a boundary between the Chilcotin Ranges and the rest of the Pacific Ranges on the west.

Division of the mountains into three natural units is made along the Nass River valley and along the Burke Channel-Bella Coola River valley. The northern section, comprising the Boundary Ranges, has a high proportion that is glacier-covered and culminates in the high peaks of Mount Ratz (10,290 feet) and Kates Needle (10,002 feet) north of the Stikine River; the central section, comprising the Kitimat Ranges, has a few peaks between 8,000 and 9,000 feet, but most summits are below 8,000 feet; and the southern section, comprising the Pacific Ranges, has numerous peaks higher than 9,000 feet. The Pacific Ranges culminate in Mount Waddington (13,177 feet) and the surrounding mountain masses centring around Mount Silverthrone (9,700 feet), Mount Queen Bess (10,700 feet), and Monmouth Mountain (10,470 feet). Summit elevations in the Coast Mountains on the whole decrease northward from a culmination just north of the Stikine River and decrease southward from the culmination of Mount Waddington. Summit elevations are low in the area between the Nass River and the Bella Coola River.

Further subdivision of the Coast Mountains may be made by using as boundaries the valleys of a number of major rivers which rise east of the axis of the mountains and flow across them westward to the sea. In addition to the Nass and Bella Coola, there are the Taku, Whiting, Stikine, Unuk, Bear, Skeena, Dean, Klinaklini, and Homathko Rivers, whose valleys break the mountain units into smaller blocks.

Boundary Ranges

The Boundary Ranges (*see* Plates VIIIA, VIIIB, and XLIA) comprise the dominantly granitic mountains along the Alaska-British Columbia Boundary, extending northwestward from the Nass River.

In the northern section, in particular north of the Iskut River, the Boundary Ranges are bordered by the Tagish and Tahltan Highlands. The highlands form mountainous transition belts lying between the high rugged granitic mountains along the Alaska Boundary and the essentially 5,000-foot upland surface of the Yukon and Stikine Plateaus respectively.

The ranges have a core of intrusive granitic rocks which are flanked along the eastern margin by sedimentary and volcanic rocks of Palæozoic and Mesozoic age. Granite is extensively exposed along the axis of the ranges. Mixed assemblages of Triassic and Jurassic greywackes and volcanic rocks predominate along the eastern contact of the batholith.

The high peaks are serrate. The summit level is somewhat lower in the ranges east of the granitic contact. There are noticeable topographic differences between the erosion forms in sedimentary rocks and in granitic rocks, the sedimentary rocks tending to produce a sharp topography that is more irregular than that of the granitic ranges farther west. The ranges south of Taku River, at the head of the Whiting River, and between the heads of the Sheslay, Tahltan, and Chutine Rivers, are extremely rugged. The slopes below 3,500 and 4,500 feet are heavily forested, and scenic features of glacial origin, such as cirques, hanging valleys, and over-steepened slopes are everywhere present.

The Boundary Ranges reach their greatest heights in the granite peaks of Mount Ratz (10,290 feet), Mussell Peak (10,260 feet), Noel Peak (10,040 feet), and Kates Needle (10,002 feet) north of the Stikine River. South and west of Bowser Lake the highest summits are Mount Jancowski (9,800 feet) and Mount Patullo (8,951 feet), but elsewhere in the ranges the summits range between 7,000 and 8,500 feet in elevation. The fact that the summits are close to the coast and that the streams draining them fall rapidly to sea-level emphasizes the great relief in the mountains.

In the ranges between Stewart and Mount Foster (north of Skagway) a very high percentage of the area is under a cover of glacial ice, through which isolated peaks project as nunataks. The Taku Icefield (*see* Plate XLIA) is a very large icefield which extends southward from Skagway to the Taku River. From it the Meade, Eagle, and Mendenhall Glaciers and others flow westward to the sea, the Llewellyn Glacier flows eastward to Atlin Lake, and the Tulsequah Glacier flows southward to the head of Tulsequah River. Another extensive icefield lies north of Iskut River and south of the heads of Scud River and Mess Creek; other icefields lie between the Unuk and Salmon Rivers and between the heads of the Kitsault and Bear Rivers.

Timberline is at an elevation of 3,500 to 4,000 feet, and below that level the slopes are heavily forested and underbrush is dense.

The ranges have been heavily glaciated, the high peaks have matterhorn forms produced by well-developed cirque glaciation, peaks and ridges below about 6,500 feet are rounded and subdued by the effects of ice-sheet erosion, and valley walls have been steepened and spurs truncated so as to produce typical U-shaped profiles. The steep topography, combined with heavy undergrowth below timberline, makes the region exceedingly difficult for ground travel.

During the Pleistocene the land was heavily loaded with ice, and near the coast was submerged beneath the sea. Deposits of marine origin occur at elevations up to 100 feet above present sea-level along the Taku River, and terraces and benches up to 500 feet above sea-level may be delta deposits of marine origin that indicate a submergence of 500 feet. In the Alice Arm and Portland Canal areas, marine clays, deltas, and old beaches now at a considerable height above sea-level indicate a maximum submergence there of 485 feet below present sea-level.

The ranges are crossed by the Taku, Whiting, Stikine, Iskut, Unuk, Bear, and Kitsault Rivers. These are antecedent rivers whose valleys, incised before the Pleistocene, served as main drainage-ways for the westward flow of glacial ice. The valleys were over-deepened by the passage through them of very large amounts of ice, with the formation of the many hanging valleys which are characteristic of the region. Cirque erosion was an important phase of the late stage of glaciation, and large well-developed cirque basins carved on the north and northeast sides of peaks and ridges are characteristic of the landscape.

A remarkable feature of the ranges between Portland Canal and the Nass River is the abundance of northeasterly trending lineaments in the granitic rocks. These are marked by Observatory Inlet and by the Kincolith, Iknouk, and Nass Rivers, as well as by numerous minor topographic features visible on aerial photographs.

[References: Kerr, F. A., " Taku River Map-area," *Geol. Surv., Canada,* Mem. 248, 1948; Kerr, F. A., " Lower Stikine and Western Iskut River Areas," *Geol. Surv., Canada,* Mem. 246, 1948.]

[Photographs: B.C. 510:44; B.C. 541:23; B.C. 681:105; B.C. 893:19; B.C. 899:102; B.C. 952:87.]

Kitimat Ranges

The Kitimat Ranges (*see* Plates XA, XLIIB, XLIIIB, and XLVIB) comprise the granitic mountains which extend from the Nass River southward for more than 200 miles to Burke Channel and Bella Coola River. They are flanked on their western side by the Coastal Trough and on their eastern side by the Hazelton Mountains. They include the mountains on the island archipelago and mainland, rising from the sea to heights of 6,000 to 8,000 feet.

The highest peaks in the ranges are Atna Peak (9,040 feet) just east of Kitimat and Thunder Mountain (8,797 feet) just north of the Bella Coola River. For the most part, the peaks are between 6,500 and 7,500 feet and are characteristically round-topped, dome-like mountains (*see* Plate XA) with cirques on their north and northeastern sides. These round-topped mountains, many of which were overridden by the ice-sheet, present a rather uniform summit elevation above which the higher matterhorns project.

These ranges have considerably fewer glaciers than those to the north and south, and no extensive icefields remain. Nevertheless, they have been heavily glaciated, and a remarkable feature of them is that cirque erosion along their western margin reached sea-level.

Major rivers (*see* Plates XLIIIB and XLVIIB) cross the ranges in valleys that are a few hundred feet above sea-level, creating a relief of 5,000 to 8,000 feet.

The mountains are very largely eroded in the granitic rock of the Coast Intrusions and bold, impressive, massive mountains of monolithic granite, almost devoid of small-scale jointing, are a common feature in the ranges. The granite in places has a sheeting developed on a grand scale, so that dome-like mountains have huge plates peeling from their sides and tops. Many of the erosional forms in these ranges rival those of the Yosemite in design and grandeur.

Fiords which penetrate the heart of the ranges and which are a characteristic feature of them are treated more extensively on pages 115 and 116.

Topographic maps and aerial photographs of the Kitimat Ranges display numerous large-scale lineaments. The lineaments take the form of long straight valleys or channels, the alignment of short valleys along a straight line, or the straight-line alignment of smaller features such as cliffs, lakes, and valleys. Grenville Channel is one of a set of northwesterly trending lineaments which are essentially parallel to the coastline. Many of them are controlled by belts or septa of older sedimentary and volcanic rocks within the dominantly granitic terrain. Another prominent set of lineaments is at right angles to the first and transverse to the direction of the coastline. The direction of the set running parallel to the grain of the coastline shows from south to north a progressive change, corresponding to the compound curved plan of the coastline.* It is interpreted as being directly related to the trend of fold axes in belts of pre-batholithic rocks.

[References: Dolmage, V., "Coast and Islands of British Columbia between Douglas Channel and the Alaskan Boundary," *Geol. Surv., Canada,* Sum. Rept., 1922, Pt. A, pp. 9–34; Dolmage, V., "Coast and Islands of British Columbia between Burke and Douglas Channels," *Geol. Surv., Canada,* Sum. Rept., 1921, Pt. A, pp. 22–49; Duffell, S., "Whitesail Lake Map-area," *Geol. Surv., Canada,* Mem. 299, 1959; Duffell, S., and Souther, J. G., "Terrace," *Geol. Surv., Canada,* Map 11-1956.]

[Photographs: B.C. 384:80; B.C. 386:12; B.C. 413:14; B.C. 469:8, 24; B.C. 473:41, 57, 112; B.C. 501:78; B.C. 531:34, 65; B.C. 1402:95.]

* Peacock, M. A., *Geol. Soc., Amer.,* Bull. Vol. 46, 1935, p. 656.

Pacific Ranges

The Pacific Ranges (*see* Plates IX, XB, XIIA, XIIB, XLIB, XLIIA, and XLVIA) comprise the essentially granitic mountains extending southeastward from Burke Channel and Bella Coola River for about 300 miles to the Fraser River. The ranges have a width of 80 to 100 miles between their western boundary along the Coastal Trough and their eastern boundary with the Interior System. On the western side the summit levels diminish to the west with the downward slope of the dissected late Tertiary erosion surface. The boundary between the Pacific Ranges and the Hecate and Georgia Lowlands is along the generalized line of the 2,000-foot contour. On the east the Pacific Ranges between Atnarko River and the head of the Yalakom River are flanked by the Fraser Plateau, from which the mountain front rises abruptly (*see* Plate XIB). From the head of the Yalakom River the eastern boundary is along the Yalakom and Fraser Rivers, which separate the Pacific Ranges from the Camelsfoot and Clear Ranges, and from the Cascade Mountains.

The Pacific Ranges contain the highest peaks in the Coast Mountains. From Mount Saugstad (9,608 feet) just south of the Bella Coola River, peaks rise to 9,700 feet at Silverthrone Mountain west of the Klinaklini River, to 13,177 feet at Mount Waddington (*see* Plate IX), and to 12,800 feet at Mount Tiedemann between the Klinaklini and Homathko Rivers. There are a number of 10,000- to 11,000-foot peaks between the Homathko River and Chilco Lake and south to the head of the Lillooet River. South and southeast from Wedge Mountain (9,484 feet) and Mount Garibaldi (8,787 feet) the summit elevations diminish as the edge of the mountains is approached. The mountain front rises from the Fraser Lowland on a long slope of about 15 degrees, which, in part, is an exhumed pre-Eocene erosion surface* on which Eocene and younger sediments had been deposited (*see* p. 37).

Drainage in the Pacific Ranges is to the coast by way of the Bella Coola, Kingcome, Klinaklini, Homathko, Southgate, Toba, Squamish, and Lillooet Rivers and their tributaries. These have cut major low-level valleys through the mountains, dividing them into blocks.

Bedrock structures have controlled the drainage pattern. In places within the granite a trellis-type pattern is parallel to regionally developed sets of joints or faults. Further structural control of drainage and of landforms is illustrated east of Cape Caution, where maps and aerial photographs show prominently developed easterly and northwesterly lineaments, represented by alignments of inlets, lakes, and stream valleys. The Owikeno lineament (*see* Plate XLVIII) has a length of about 60 miles westerly from Mount Silverthrone. Another remarkable lineament can be seen on aerial photograph B.C. 566:55 to extend in a northwesterly direction for at least 20 miles along Lillooet River between Pemberton Meadows and the junction of Meager Creek.

The high peaks are sculptured by cirque glaciers. Many projected as nunataks above the Pleistocene ice-cap, whose upper surface over the Pacific Ranges was from 5,000 to 8,000 feet above sea-level. Lower summits were covered by the ice-sheet at its maximum, and many of these are rounded and domed even though they are scalloped by cirques on their northeastern sides. Evidence of tremendous ice erosion is everywhere to be seen.

Extensive icefields remain in the areas around Mount Silverthrone, Mount Waddington, between the Homathko and Southgate Rivers, and at the head of the Lillooet River. These icefields are now receding and are small compared to their former extent, but they are an impressive indication of how much of British Columbia looked 10,000 years or more ago.

There is a noticeable difference between the heavy vegetation in the western ranges, where the rainfall is high, and in the eastern ranges, where the rainfall is

* "Guidebook for Geological Field Trips," prepared by *Geological Discussion Club*, Vancouver, 1960, p. 12.

lighter and where, approaching the Fraser River, the slopes are openly timbered, with little or light undergrowth.

[Reference: Burwash, E. M. J., " Geology of Vancouver and Vicinity," *University of Chicago Press,* 1918.]

[Photographs: B.C. 398:66; B.C. 457:68; B.C. 496:30, 35, 57; B.C. 498:40, 109; B.C. 499:82, 111; B.C. 528:64; B.C. 551:60; B.C. 554:116; B.C. 566:55; B.C. 983:88; B.C. 994:36, 52; B.C. 996:60; B.C. 999:31; B.C. 1051:37; B.C. 1402:23, 40; B.C. 1406:67.]

The *Chilcotin Ranges* (*see* Plates XIA and XIB) lie along the east side of the Pacific Ranges and are a subdivision of them. They extend southeastward from the head of the Klinaklini River to Lillooet. They are very largely composed of non-granitic rocks and lie east of the eastern contact of the Coast Intrusions. On their east the Chilcotin Ranges are flanked by the Fraser Plateau and, southeast of Churn Creek, by the Camelsfoot Range, which lies within the Fraser Plateau. The boundary between plateau and mountains is sharply defined (*see* Plate XIB) by a narrow transition zone. Between the Klinaklini River and the north end of Taseko Lakes the generalized line of the 5,500-foot contour serves as a boundary, and between Taseko Lakes and the head of the Yalakom River the boundary is more or less along the 6,000-foot contour. The Yalakom River, which follows the Yalakom fault northwest of Moha, separates the Shulaps Range of the Chilcotin Ranges from the Camelsfoot Range of the Fraser Plateau.

High points in the ranges include Mount Tatlow (10,058 feet) west of Taseko Lakes, Taseko Mountain (10,047 feet) east of Taseko Lakes, and Big Dog Mountain (9,391 feet) and Shulaps Peak (9,446 feet) in the Shulaps Range.

The Chilcotin Ranges are underlain by a great variety of non-granitic rocks. The ranges between Tatlayoko and Taseko Lakes consist very largely of northeasterly striking Mesozoic volcanic and sedimentary rocks. Between Taseko Lakes and the Fraser River, Palæozoic and Mesozoic sedimentary and volcanic rocks are intruded by small granitic stocks, and Big Dog Mountain and Shulaps Peak are the highest points of an intrusion of peridotite of Triassic age.

The Chilcotin Ranges rise progressively higher in approaching the granite ranges to the west. For the most part, they display a combination of high serrate peaks rising above lower rounded summits and gently sloping areas of undissected upland. Glaciation has scalloped the northern slopes and modified the valley profiles. Timberline is between 6,000 and 6,500 feet. The ranges experience a rainfall of 40 inches or less, and, as a result, timber is only moderately heavy and undergrowth is relatively sparse.

[References: Dolmage, V., "Chilko Lake and Vicinity," *Geol. Surv., Canada,* Sum. Rept., 1924, Pt. A, pp. 59–75; Dolmage, V., "Gun Creek Map-area," *Geol. Surv., Canada,* Sum. Rept., 1928, Pt. A, pp. 78–93; Leach, G. B., "Geology and Mineral Deposits of the Shulaps Range," *B.C. Dept. of Mines,* Bull. No. 32, 1953; Cairnes, C. E., " Geology and Mineral Deposits of the Bridge River Mining Camp," *Geol. Surv., Canada,* Mem. 213, 1937; Duffell, S., and McTaggart, K. C., "Ashcroft Map-area," *Geol. Surv., Canada,* Mem. 262, 1952; Tipper, H. W., "Taseko Lakes," *Geol. Surv., Canada,* Map 29-1963.]

[Photographs: B.C. 393:53; B.C. 457:79; B.C. 550:107; B.C. 566:68, 85, 108; B.C. 567:30; B.C. 656:47; B.C. 922:5; B.C. 982:80; B.C. 983:53.]

Cascade Mountains

The Cascade Mountains constitute a large physiographic unit of the northwestern United States. They extend northward from the northern border of California, through Oregon and Washington, and extend a prong northward into British

Columbia. The mountains along the 49th parallel from Cultus Lake eastward to the valley of the Similkameen River make up three ranges of the Cascade Mountains. They extend northward to Lytton, a distance of 85 miles, and are bordered on their western side by the Fraser River and the Fraser Lowland.

The Cascade Mountains are separated by the Fraser River from the Pacific Ranges of the Coast Mountains on the north (*see* Plate XIIIA). The Cascade Mountains on the east are flanked by and merge in the Kamloops Plateau. Their western boundary is clearly defined by the Fraser River, but their eastern margin is a transition zone through which summit elevation progressively diminishes and the degree of dissection decreases as the Kamloops Plateau is approached. The boundary separating mountains and plateaus follows the Nicoamen River from its mouth, thence more or less along the 5,000-foot contour west of Prospect Creek to the head of Tulameen River and the head of Skagit River, thence down Copper Creek and east from its mouth across to the Ashnola River, thence northeastward past Crater Mountain to the valley of the Similkameen River.

The Cascade Mountains comprise the Skagit Range extending along the 49th parallel between Cultus Lake and the Skagit River, the Hozameen Range between Skagit River and Pasayten River, its extension northward from Coquihalla River to Lytton, and the Okanagan Range between Pasayten River and Similkameen River.

The Cascade Mountains are composed of Palæozoic and Mesozoic sedimentary and volcanic rocks, strongly folded and metamorphosed and intruded by granitic batholiths. The summits of the peaks and ridges attain an approximately uniform elevation, and it has been inferred that the mountains have resulted from the dissection of a late Tertiary erosion surface.*

In Oregon and Washington the highest peaks in the Cascade Mountains rise above the general summit level. They are the peaks of Mount Baker (10,827 feet), Glacier Peak (10,436 feet), Mount St. Helen, Mount Hood, etc., and all are volcanic cones built up by the accumulation of Pleistocene and Recent lava and ash upon the Tertiary erosion surface.

In British Columbia the highest peaks are Mount Outram (8,000 feet), Stoyoma Mountain (7,486 feet), Tulameen Mountain (7,499 feet), Grass Mountain (7,580 feet), and Frosty Mountain (7,950 feet) in the Hozameen Range; Silver Peak (6,808 feet), Mount Cheam (6,913 feet), and Welch Peak (7,733 feet) in the Skagit Range; and Crater Mountain (7,522 feet), Lakeview Mountain (8,261 feet), Snow Mountain (8,507 feet), and Haystack Mountain (8,541 feet) in the Okanagan Range. These peaks represent monadnocks on an elevated Tertiary erosion surface of low relief.

The peaks and high ridges are serrate and show the effects of intense alpine glaciation. Cirque basins are particularly noticeable on north and northeast slopes of peaks and ridges. At lower elevations between 6,000 and 7,000 feet there are rounded ridges and dome-shaped mountains which were overridden by ice at the maximum of the Cordilleran ice-sheet. The valleys were occupied by glaciers, and truncated spurs, hanging valleys, mountain tarns, and glaciated rock surfaces are common.

Since the Pleistocene, ice has completely left the Okanagan and Hozameen Ranges, and only a few small glaciers remain in the Skagit Range.

[References: Cairnes, C. E., " Coquihalla Area," *Geol. Surv., Canada,* Mem. 139, 1924; Rice, H. M. A., " Geology and Mineral Deposits of the Princeton Map-area," *Geol. Surv., Canada,* Mem. 243, 1947.]

[Photographs: B.C. 496:95; B.C. 498:25; B.C. 499:109; B.C. 653:55; B.C. 651:4, 6.]

* Willis, Bailey, *U.S.G.S.*, Prof. Paper 19.

PHYSIOGRAPHIC HISTORY OF THE WESTERN SYSTEM

The early sequence of events in the area of the Western System is one of marine sedimentation interrupted by periods of volcanic eruption during the Palæozoic and early Mesozoic eras. This culminated in a period of mountain-building and intrusion of granitic batholiths along the axes of the Insular Mountains and the Coast Mountains, in Upper Jurassic and Lower Cretaceous time.

Sediments derived from the erosion of these mountains in Cretaceous time were deposited in flanking basins under marine and brackish-water environments. The granitic cores of the mountains were exposed, and the late Cretaceous land surface resulting from the erosion was probably one of very low relief.

This ancient erosion surface was differentially uplifted at the beginning of the Tertiary, along two axes of greatest uplift which corresponded with the earlier axes of batholithic intrusion along the sites of the present Insular and Coast Mountains. Separating them was a trough which lay along the site of the present Coastal Trough.

Sediments of Tertiary age were deposited within this ancestral Coastal Trough, together with lava and the fragmental products of Tertiary volcanism in southeastern Alaska, the Queen Charlotte Islands, and southern Vancouver Island. Tertiary sediments were also deposited on a shelf fringing the western side of the Insular Mountains on Vancouver Island.

Continued erosion during the Tertiary resulted in further unroofing of the Coast Intrusions on the mainland, and the reduction of the land to a surface of generally low relief that was co-extensive with a similar surface in the interior of the Province. Undoubtedly, however, there were areas of hard or more resistant rock which withstood erosion, and monadnocks remained a thousand feet or more above the general level. Flowing westward across the country were the ancestors of all the present rivers that cross the Coast Mountains to the sea. These are the Taku, Stikine and Iskut, Nass, Skeena, Bella Coola, Klinaklini, Homathko, and Fraser Rivers.

The late Tertiary surface of low to moderate relief was again differentially uplifted during the Pliocene along the same two longitudinal axes which correspond essentially with the present axes of the Insular Mountains and the Coast Mountains. Between the two was a low area which became the Coastal Trough. Eastward from the Pacific the old surface rose from sea-level to the crest of the Insular Mountains, descended to sea-level, rose to the crest of the Coast Mountains, and finally descended to the level of the Interior Plateaus. A cross-axis connects the high massifs centring around Mount Waddington with Victoria Peak on Vancouver Island, and is represented by the Seymour Arch, which constricts the Coastal Trough in the vicinity of Sayward. Northward there is a cross-sag, represented by the lower summit levels of the Kitimat Ranges and the low area occupied by Queen Charlotte Sound. Still farther north the old surface rises to culminate in the area of 10,000-foot peaks around Mount Ratz north of the Stikine River.

The Pliocene uplift rejuvenated the erosive power of all the streams. Incision of the streams began at their mouths and progressed upstream. It resulted in the dissection and the partial to almost complete destruction of the late Tertiary surface, and the production of a mountainous topography of mature relief before the onset of Pleistocene ice.

The major rivers flowing westward to the sea were able to maintain their courses across the rising axis of the Coast Mountains. These valleys provide access to the interior of British Columbia from the west.

Although glacial erosion during the Pleistocene greatly modified the preexisting topography by sharpening the high peaks, rounding and softening the lower ones, and widening and deepening the valleys, the essential topographic framework was nevertheless present before the coming of the ice. Great volumes of glacial materials were deposited in the form of an almost universal mantle of drift on valley sides and bottoms, as outwash plains of glacial sands and gravels, and as ice marginal deposits in the waning stages of glaciation.

The land stood at a high level before the onset of the Pleistocene. The great load of glacial ice, with a thickness of as much as 8,000 feet in some areas, depressed the land with respect to its earlier level. With the melting of the ice and the consequent lightening of the load, the land has risen in Recent time, essentially to its former position. The rise has been unequal, ranging from a few tens of feet to a few hundred. Streams have been rejuvenated because of the rise, with the result that box canyons have been cut in the lower courses of many of them.

[References: "Guidebook for Geological Field Trips," prepared by *Geological Discussion Club,* Vancouver, March, 1960; Kerr, F. A. "Lower Stikine and Western Iskut River Areas," *Geol. Surv., Canada,* Mem. 246, 1948; Kerr, F. A.. "Taku River Map-area," *Geol. Surv., Canada,* Mem. 248, 1948.]

II. INTERIOR SYSTEM

The interior of British Columbia, between the Coast Mountains and the Rocky Mountains, contains a great diversity of landforms. These include low-lying plains and basins, plateaus in varying stages of dissection, highlands, and mountains of many sorts, all parts of the Interior System. Despite divergencies in physical appearance, common denominators of geology and of physiographic development bring coherence to the group as a whole, and distinguish it from the flanking systems to the west and east.

On the west the Interior System is flanked by continuous mountains from the 49th parallel to the Yukon Border. These are the Cascade Mountains and the Coast Mountains of the Western System. Separation of the two systems is readily made along a sinuous boundary running southeastward from the south end of Atlin Lake to Ningunsaw Pass, thence to Aiyansh and Terrace, and southward along the eastern side of the Coast Mountains to Charlotte Lake, the north end of Taseko Lakes, Lillooet, Lytton, and Keremeos.

On the east the Interior System is flanked by the Liard Plateau north of Liard River and by the Rocky Mountains south of Liard River. The boundary separating the two systems extends between the Liard Plain and the Liard Plateau, skirts the northern Rocky Mountains, and runs southeastward along the eastern side of the Rocky Mountain Trench to the 49th parallel.

The Interior System takes in a very large part of British Columbia and the Yukon, and for convenience of description three major subdivisions of that part west of the Rocky Mountain Trench have been made. The Northern Plateau and Mountain Area is very largely in the Yukon, but part of it extends into northern British Columbia as the Yukon Plateau and Liard Plain. The Central Plateau and Mountain Area largely lies north of latitude 55 degrees north. Its southern boundary, between Whitesail Lake and the mouth of the Nation River, is along the northern edge of the Nechako Plateau. The Southern Plateau and Mountain Area includes large areas of plateau in central and southern British Columbia and the highlands and mountains in the southeastern part of the Province.

NORTHERN PLATEAU AND MOUNTAIN AREA

The Northern Plateau and Mountain Area extends into northern British Columbia as the southern part of the Yukon Plateau, comprising parts of the Tagish Highland, of the Teslin and Nisutlin Plateaus, and of the Liard Plain.

Tagish Highland

Extending between the Coast Mountains and the Yukon and Stikine Plateaus, from the Taku River northward into the Yukon, is a mountainous area, intermediate in elevation and relief between the plateaus on the east and the mountains on the west. It is a belt of transition between plateau and mountains, in which there are numerous areas of gently sloping upland. In this belt the late Tertiary erosion surface, which forms the upland surface of the plateaus, is warped upward to the west, and becomes progressively more dissected westward, so that in the Coast Mountains few, if any, undissected upland surfaces remain.* Where the belt is sufficiently wide, it is designated the Tagish Highland† (*see* Plates XIIIB and XVB for an example of the gradation of plateau through highland into mountains, by increasing dissection of the upland surface). The highland has a maximum width of 25 miles measured northwest from Fantail Lake and a minimum width of about 5 miles at Taku River.

The Tagish Highland is underlain very largely by Palæozoic and Mesozoic sedimentary and volcanic rocks, folded about northwesterly trending axes and lying east of the eastern margin of the Coast Intrusions. The Tagish Highland is characterized by areas of relatively smooth, gently rolling upland surface lying, for the most part, between 5,000 and 6,500 feet, with local peaks rising above. The high points within the highland are largely domed mountains standing between 6,000 and 7,000 feet elevation, the highest being Paradise Peak (7,215 feet) east of Sloko Lake. The area is incised to an elevation of about 2,200 feet by rivers tributary to Atlin and Tagish Lakes, and to elevations of less than 500 feet by Taku River and its tributaries. The valleys are wide and U-shaped, and many to the west of Atlin are occupied by lakes. The relief in the Tagish Highland is variable, depending on whether it is measured in relation to the drainage of the Taku River or of the Yukon River. It ranges from about 3,500 feet to as much as 5,000 feet.

The area was covered by ice during the Pleistocene, and at its maximum extent the Cordilleran ice-sheet reached an elevation between 6,000 and 6,500 feet. In the area west of Atlin Lake the direction of ice movement was northerly and northwesterly.

During deglaciation, cirque basins were eroded largely on the northern and eastern sides of the peaks and ridges, generally at elevations above 5,500 feet.

[References: Wheeler, J. O., "Whitehorse Map-area," *Geol. Surv., Canada,* Mem. 312, 1961; Aitken, J. D., "Atlin Map-area," *Geol. Surv., Canada,* Mem. 307, 1959; Kerr, F. A., "Taku River Map-area," *Geol. Surv., Canada,* Mem. 248, 1948, pp. 16, 40–41.]

[Photographs: B.C. 687:12; B.C. 899:53, 79, 92, 102, 107.]

Teslin Plateau

The Teslin Plateau extends southward from the Yukon into British Columbia. On the west the plateau is bordered by the Tagish Highland along a line running southeast from Talaha Bay on Tagish Lake to Atlin Lake and thence to the south end of Atlin Lake. From there the Teslin Plateau is separated from the Taku Plateau on the south by the valley of O'Donnel River, Silver Salmon River, and Taysen Creek to Nakina. From Nakina the boundary runs northeastward to the

* Kerr, F. A., *Geol. Surv., Canada,* Mem. 248, 1948, p. 113.

† The word "highland" was suggested by its use in Washington for a physiographic unit which extends northward into British Columbia. *See* discussion on page 72.

south end of Teslin Lake, which separates the Teslin Plateau on the west from the Nisutlin Plateau on the east.

The Teslin Plateau (*see* Plate XIVA) consists of an upland surface which rises to heights of between 6,000 and 7,000 feet and whose two highest summits are Mount Barham (6,868 feet) west of Surprise Lake and Mount Snowdon (6,987 feet) west of Teslin Lake. It is dissected into large isolated blocks by the wide valleys of Atlin Lake, Surprise Lake, Gladys Lake, and tributary valleys of the main rivers. There is a moderate relief within the region between the upland areas and the levels of Atlin Lake at 2,192 feet, Teslin Lake at 2,239 feet, and Surprise Lake at 3,092 feet.

The widely flaring valleys and gently sloping upland surfaces have been glaciated, and cirques have scalloped the north and east sides of peaks and ridges. Ice moving northward along Teslin Lake valley eroded drumlin-like forms in bedrock and moulded drumlins in the glacial materials on the west side of the lake. Numerous small lakes occupy glacially formed depressions south and west of Teslin Lake and along the valleys of Hall Lake, Gladys River, and Gladys Lake-Snafu Creek. At one stage some ice evidently moved southwestward down the upper valley of Nakina River and thence by the Taku River valley to the sea.

[Reference: Aitken, J. D., "Atlin Map-area," *Geol. Surv., Canada,* Mem. 307, 1959.]

[Photographs: B.C. 681:67, 87; B.C. 691:111; B.C. 694:1.]

Nisutlin Plateau

The Nisutlin Plateau (*see* Plate XIVB) extends southward into British Columbia between Teslin Lake on the west and the Cassiar Mountains on the east as a prong about 40 miles long and about 20 miles wide.

Several high points in the area lying between 4,000 and 5,000 feet represent an old erosion surface which is incised to the level of Teslin Lake (2,239 feet) by the Jennings and Swift Rivers. Much of the country is low lying and covered with glacial drift, and numerous small lakes occupy depressions in the drift. Ice escaping outward from the Stikine Plateau moved northward and northeastward across this part of the Nisutlin Plateau.

[Photographs: B.C. 893:40, 50; B.C. 954:12.]

Liard Plain

The Liard Plain (*see* Plate XVA) is a low area of slight relief lying within the drainage area of the Liard River and its tributaries. The elevation of the Liard River is just below 1,500 feet at the Liard Bridge (Mile 496) and is almost 2,000 feet at Lower Post. The surface of the Liard Plain is largely between 2,500 and 3,500 feet, but 4,000 feet is reached at a very few points. The plain is surrounded on all sides by a ring of plateaus and mountains rising to considerably greater heights. The only break in the ring is where the Liard River valley flows past the northern end of the Rocky Mountains. In British Columbia the plain is bounded on the west and southwest by the Dease Plateau, the boundary between the two being along the 3,000-foot contour line. On the south the plain merges in the Rocky Mountain Trench, and the two are arbitrarily separated at the junction of the Turnagain and Kechika Rivers (2,000 feet elevation). On the southeast the plain is bounded by the Rabbit Plateau, running along a line northeastward along Boya Creek past Fishing Lakes to the mouth of Smith River. East of Smith River and north of Liard River it is bounded by the Liard Plateau.

The plain in British Columbia extends for 100 miles along the Yukon Border and for 20 to 30 miles south of it.

The Liard Plain was completely covered by glacial ice, which moved across it. The present surface is very largely the product of glacial processes, and the effect of post-glacial erosion is to be seen only in the 50 to 100 feet of incision along the major streams. As the ice moved across the plain, it shaped and modelled bedrock and drift alike in drumlin-like forms parallel to the direction of ice movement (*see* Plate XXXVIIA). Numerous depressions were gouged, which now are occupied by the many shallow lakes dotting the plain. Eskers and morainal features are clearly displayed on air photographs and topographic maps or may be seen a short distance south of the Alaska Highway at a point 20 miles east of Lower Post (*see* Plate XVA).

It is evident that ice escaping northward from the Cassiar Mountains flowed northward down the Dease River valley and swung northeastward around the northern end of the Horseranch Range to flow northeastward (north 67 degrees east) and eastward across the Liard Plain past Mount Monckton (3,948 feet) (*see* Fig. 10). Some ice may at one stage have moved southeastward up the Rocky Mountain Trench toward Aeroplane Lake. Escape from the plain evidently was eastward down the valley of the Liard River past the Hotsprings (Mile 497) and northeastward across the Liard Plateau from the vicinity of Smith River Airport.

[Reference: Gabrielse, H., "McDame," *Geol. Surv., Canada,* Paper 54-10.]

[Photographs: B.C. 893:102; B.C. 954:82, 87, 88, 117; B.C. 955:9, 59.]

CENTRAL PLATEAU AND MOUNTAIN AREA

The Central Plateau and Mountain Area comprises the Stikine Plateau, Skeena Mountains, Nass Basin, Hazelton Mountains, Cassiar Mountains, and the Omineca Mountains.

STIKINE PLATEAU

The Stikine River, between the Coast Mountains on the west and the Cassiar Mountains on the east, drains a large area of dissected plateau country named the Stikine Plateau. On the north the Stikine Plateau merges in the Yukon Plateau along an arbitrary line between Atlin and Teslin Lakes. It is bounded on the west by the Boundary Ranges, on the south by the Skeena Mountains, into which it passes by transition through a progressively more elevated belt of greater dissection (*see* Plate XIXB), and on the east by the Stikine Ranges and the northern Omineca Mountains. For the most part, the Stikine Plateau lies below the level of the surrounding mountains on the west, south, and east.

The Stikine Plateau is subdivided into seven units having distinct geographic and geologic characteristics. These are the Tahltan Highland and the Taku, Kawdy, Nahlin, and Tanzilla Plateaus north of the Stikine River and the Klastline and Spatsizi Plateaus to the south.

Tahltan Highland

The Tahltan Highland (*see* Plates XVB and XLVIIA) extends southeastward along the western side of the Stikine Plateau between the Taku River and the head of the Iskut River. It is a transition zone between the plateaus and the Boundary Ranges of the Coast Mountains. The highland is about 5 miles wide on the Taku River and widens southward to a maximum of about 30 miles where crossed by the Stikine River.

Between the Taku and Sheslay Rivers the highland consists of gently sloping upland surfaces lying between 5,000 and 6,000 feet, with a few peaks rising higher. They are remnants of an erosion surface which has been dissected into blocks, some of which are of considerable size.

Between the Sheslay and Iskut Rivers the degree of dissection is somewhat greater, and the amount of undissected upland much less. Sharp peaks rise to elevations of 7,267 and 7,690 feet northeast of Yehiniko Lake and to 8,386 feet at Hankin Peak between Mess Creek and Iskut River. The shield volcano at Mount Edziza rises to an elevation of 9,143 feet, well above the general level of upland surface, and dominates the surrounding terrain.

The relief within the Tahltan Highland is controlled by the depth of incision reached by the Taku and Stikine Rivers and their tributaries, which flow at elevations ranging from less than 500 feet in the main valleys to about 2,500 feet at Trapper Lake, Mess Lake, and Mowdade Lake.

The eastern edge of the highland is dominated by the great shield volcano culminating in glacier-clad Edziza Peak (*see* Plate XLVIIA). Pleistocene and older eruptions of lava and ash built the dome-like mountain above the general plateau level and poured lava over an area 50 miles long and 10 miles wide on the east side of Mess Creek. The 9,143-foot peak is a composite volcano, but much of its mass appears to be made of older rocks, over which the flows form probably a relatively thin veneer.

" Lava flows and volcanic ejectamenta of post-Glacial to modern age form conspicuous bodies along the east side of and within the Coast Mountains from Telegraph Creek to Unuk River. Several flows, poured from outlets on the flanks of Edziza Peak, blanket the north, east, and south slopes of that mountain, and some have advanced into the present forest near Buckley Lake and Nuttlude Lake. Small flows and remnants of flows are confined to the inner canyon of the Stikine River, overlying glacial and river deposits. Cinder cones and breccia pipes, very friable but quite unmarred by erosion, are conspicuous features of the Edziza-Spectrum Range area."*

The Spectrum Range, which extends south of Edziza Peak, is included within the Tahltan Highland. It is named for the brilliantly coloured altered lavas which underlie it.

Glaciation during the Pleistocene was intense, and glaciers still occupy peaks south of Mount Edziza. The upper limit of Cordilleran ice reached an elevation of about 6,500 to 7,000 feet. Above that elevation, peaks have sharp matterhorn appearances due to the intense cirque erosion that ensued; below that elevation, when the ice cover disappeared, cirque erosion was largely restricted to northern and eastern aspects. The main valleys of the Taku, Sutlahine, Tahltan, Stikine, and Iskut Rivers and Mess Creek served as discharge avenues for glacial ice and were straightened and considerably modified by its passage.

[References: Kerr, F. A., " Lower Stikine and Western Iskut River Areas," *Geol. Surv., Canada,* Mem. 246, 1948; " Stikine River Area," *Geol. Surv., Canada,* Map 9-1957.]

[Photographs: B.C. 538:75; B.C. 541:2, 7; B.C. 695:100; B.C. 698:33.]

Taku Plateau

The Taku Plateau (*see* Plate XVIA) lies east of the Tagish and Tahltan Highlands and is flanked on the east by the Kawdy and Nahlin Plateaus.

* *Geol. Surv., Canada,* Map 9-1957, marginal note.

The plateau is a late Tertiary erosion surface of low relief extending across Palæozoic and Mesozoic sedimentary and volcanic rocks intruded by granites. The surface has been elevated, and has been dissected by the major streams. Within the plateau large areas of flat to gently sloping upland lie at and below 5,000 feet. This level serves to differentiate the plateau from the highlands to the west, in which the amount of undissected upland becomes progressively less as it rises to higher elevations.

The Taku Plateau is very largely drained by the Taku River and its tributaries flowing westward into the Pacific Ocean. The gradients of these rivers are very much steeper than those of streams tributary to the Yukon River that drain the Teslin Plateau on the north. As a consequence, the Nakina River has been able to capture streams that formerly flowed northward across the Teslin Plateau into Atlin or Teslin Lake.* The Nakina River has effected a considerable reversal of drainage by incising steep-walled canyons in the bottoms of widely flaring valleys.

The Taku Plateau was covered by glacial ice, which smoothed the profiles of upland surfaces and valleys. Cirque erosion at a late stage of glaciation sculptured the northern slopes of high points projecting above the general upland surface in the Menatatuline Range.

[References: Kerr F. A., "Taku River Area," *Geol. Surv., Canada,* Mem. 248, 1948; Souther, J. G., "Geology, Tulsequah," *Geol. Surv., Canada,* Map 6-1960.]

[Photographs: B.C. 899:74, 91; B.C. 952:13, 55, 65, 105.]

Kawdy Plateau

The Kawdy Plateau (*see* Plate XVIB) lies on the west side of the headwaters of the Tuya River between the Taku Plateau and the Cassiar Mountains. The upland surface of the plateau is largely unwooded and, for the most part, is at about 5,000 feet elevation. The surface is largely an undissected late Tertiary erosion surface which, between Jennings River and Kedahda River, was locally upwarped to 7,000 feet, and subsequently dissected to form the Atsutla Range.

"The surface of the Kawdy Plateau, 600 to 700 square miles in area, is a gently rolling upland of low relief developed by erosion, mainly on highly folded Palæozoic rocks. A large area lying near the south-western flank of the Atsutla Range has broad, flat summits. These extensive flat areas are the surface of a peneplain and the gently sloping summit surfaces of the mountains in the south-western part of the Atsutla Range may be relics of a peneplain." Presumably the peneplain was uplifted differentially and was subsequently eroded in places to give rise to the larger-scale features of the present topography. The southwestern front of the plateau may be situated along a fault or a sharp monoclinal fold.

"On the Kawdy Plateau conical or flat-topped mountains of agglomerate, tuff, and lava, of the Tuya formation built by central eruptions, rest on the peneplain. . . . Some of the volcanics of the Tuya formation are associated with glacial deposits and at least a part of the volcanism is evidently of Pleistocene age."†

A conspicuous feature of the Kawdy Plateau west and southwest of Tuya Lake are the flat-topped, steep-sided volcanoes, called tuyas, which are built up on the plateau surface. There are seven or more in the area, and the highest of them, Kawdy Mountain (6,372 feet) (*see* Plate XVIB), rises almost 2,000 feet above the local plateau level.

* *Geol. Surv., Canada,* Mem. 307, 1959, pp. 5–6.
† Watson, K. DeP., and Mathews, W. H., *B.C. Dept. of Mines*, Bull. No. 19, 1944, p. 34.

The tuyas consist of nearly horizontal beds of basaltic lava capping outward-dipping beds of fragmental volcanic rocks; they have a most interesting origin. It is thought that they were formed by volcanic eruptions in lakes which had been thawed through the Pleistocene ice-sheet by underlying volcanic heat. The lavas capping the mountains were extruded after the volcanoes were built above lake-level, and the outward-dipping beds were formed by the chilling of the lava when it reached the water's edge.

In the Pleistocene the area was covered by several thousand feet of ice, which moved westward across the plateau to the head of the Nahlin River and then swung northwest and north to escape down the Teslin Valley. In its wake it left a widespread mantle of drift, which is modelled into numerous drumlin-like hills and into depressions occupied by the numerous small lakes between Tachilta Lakes and Teslin Lake.

[References: Watson, K. DeP., and Mathews, W. H., "Tuya-Teslin Area, Northern British Columbia," *B.C. Dept. of Mines,* Bull. No. 19, 1944; Mathews, W. H., "Tuyas, Flat Topped Volcanoes in Northern British Columbia," *Am. Jour. Sci.,* Vol. 245, 1947, pp. 560–570.]

[Photographs: B.C. 692:110; B.C. 695:22, 44, 56; B.C. 699:92.]

The *Atsutla Range* (*see* Plate XVIIA) is 40 miles long by 15 miles wide between the Jennings River and the Teslin River. It lies within the Kawdy Plateau and rises above the general plateau level of 5,000 feet to a maximum elevation of 7,056 feet.

The range has an unroofed core of granitic rocks intrusive into older, closely folded Palæozoic and Mesozoic Formations. The sharp peaks are glacially sculptured, but many gently sloping upland surfaces are remnants of the uplifted and dissected Tertiary erosion surface of the Kawdy Plateau.

"Extensive modification of the land forms of the Tuya-Teslin Area by the ice-sheet is not evident. The mountain valleys of the area appear to have been widened and deepened, but it is believed that much of this erosion was accomplished by local glaciers which existed before and after the ice-sheet. The numerous cirques and small hanging valleys on the northern and eastern slopes of many of the mountains are likewise attributable to local glaciers. The ridges which apparently were not buried by these glaciers show little or no rounding, although the presence of erratics testifies that they were covered by the ice-sheet."*

[Photographs: B.C. 692:96; B.C. 695:2.]

Nahlin Plateau

The Nahlin Plateau (*see* Plate XVIIB) lies between the Sheslay River on the west and Tuya River on the east. It adjoins the Tahltan Highland on the southwest, and on the northeast is arbitrarily separated from the Kawdy Plateau along a line running from Nahlin Crossing up the Nahlin River and across to the Tuya River just south of the Tachilta Lakes.

The area is drained by the Nahlin and Sheslay Rivers flowing into the Taku River, and by the Tuya and Tahltan Rivers flowing into the Stikine River.

The area is dominated by the great shield volcano of Level Mountain, whose unwooded, low dome-shaped mass, almost circular and 20 miles in diameter, culminates in Meszah Peak, elevation 7,101 feet (*see* Plate XVIIB). The gentle slopes of the mountains parallel the gently outward-dipping thin basaltic lava flows. There has been some dissection of the dome by stream erosion, and late-stage cirque glaciers have scalloped some of the valley headwalls.

* Watson, K. DeP., and Mathews, W. H., *B.C. Dept. of Mines,* Bull. No. 19, 1944, p. 37.

The northward movement of ice across the plateau is shown by the drumlin-like forms along the Sheslay Valley north of Sheslay and northeast and east of Level Mountain.

[References: "Stikine River Area," *Geol. Surv., Canada,* Map 9-1957; Watson, K. DeP., and Mathews, W. H., "The Tuya-Teslin Area, Northern British Columbia," *B.C. Dept. of Mines,* Bull. No. 19, 1944.]

[Photographs: B.C. 698:36, 44, 76.]

Tanzilla Plateau

The Tanzilla Plateau lies east of the Tuya River, north of the Stikine River, and west of the Cassiar Mountains. The plateau is a partly dissected erosion surface (*see* Plate XIXA), which reaches heights of 6,200 feet west of Dease Lake and of 6,348 feet at Snow Peak. The erosion surface was one of low relief and was formed on closely folded sedimentary and volcanic rocks. The plateau is partly dissected by tributaries of the Dease River flowing northward to the Liard and by the Tuya, Tanzilla, and Stikine Rivers. The elevation of Dease Lake and the head of Tanzilla River at about 2,500 feet creates a maximum relief of about 3,850 feet at Snow Peak.

The Tanzilla Plateau represents a transition between the thoroughly dissected Cassiar Mountains on the east and the little dissected Kawdy and Nahlin Plateaus to the west. It is an area of widely flaring valleys, and rounded ridges and peaks passing eastward into the serrate peaks and higher uplands of the Cassiar Mountains.

The high peaks west of Dease Lake extending from Mount Coulahan (6,191 feet) southward to Snow Peak (6,348 feet) constitute the French Range. Between the Tanzilla River and Stikine River is the Hotailuh Range, whose cirqued peaks reach 6,100 feet at Thenatlodi Mountain and 6,256 feet at a nearby unnamed mountain.

[References: Kerr, F. A., "Dease Lake Area," *Geol. Surv., Canada,* Sum. Rept., 1925, Pt. A, pp. 75–99; "Stikine River Area," *Geol. Surv., Canada,* Map 9-1957; Gabrielse, H., Souther, J. G., and Roots, E. F., "Dease Lake," *Geol. Surv., Canada,* Map 21-1962.]

[Photographs: B.C. 695:73, 81.]

Klastline Plateau

The Klastline Plateau (*see* Plate XVIII) lies south of the Stikine River and is bounded on the west by the Tahltan Highland and on the south by the Klappan Range of the Skeena Mountains. The plateau is separated from the Spatsizi Plateau to the east at the constriction between the Eaglenest Range and Three Sisters Range by a line running northward from Mount Brock (6,971 feet).

The rolling upland surface of the Klastline Plateau represents the late Tertiary erosion surface, which is so widespread in the Stikine Plateau. The surface was formed by late Tertiary time on Palæozoic and Mesozoic sedimentary and volcanic rocks, with only a few small intrusive stocks known. Much of the plateau surface is unwooded or is only sparsely covered with clumps of spruce and willow.

The plateau lies above 5,000 feet elevation and rises to peaks over 6,000 feet. It has been incised to below 2,500 feet by Mess Creek, to 2,654 feet in the valley of Kinaskan Lake, below 3,000 feet by Klappan River, and below 2,500 feet by the Stikine River.

The Klastline Plateau passes by transition into the Klappan and Eaglenest Ranges on the southeast and east (*see* Plate XIXB), where some large, gently sloping areas of upland remain undissected. The boundary of the plateau on the north is the Stikine River, which for 50 miles upstream from Telegraph Creek (±500 feet) flows in a steep-walled canyon many hundreds of feet deep. The canyon was eroded by the river probably after it was diverted from its old channel by Pleistocene and Recent lava flows originating at Mount Edziza.

Glacial ice, which once covered the plateau, now remains as a capping of Edziza Peak in the Tahltan Highland to the west, but its erosional and depositional effects are visible over the entire plateau surface. Cirques are cut into northern and eastern peaks and ridges, and upland surfaces have been subdued by erosion and the deposition of drift. Modification of drainage has resulted from the ice occupation, and numerous lakes occupy basins created in drift-blocked valleys. Drumlin-like forms in the upper Iskut River valley (*see* Plate XVB), from Mowdade and Kinaskan Lakes southward, indicate that ice poured southward from the Klastline Plateau down the Iskut River valley from an ice divide that existed somewhat north of Nuttlude Lake (*see* Fig. 10).

[Reference: "Stikine River Area," *Geol. Surv., Canada*, Map 9-1957.]

[Photographs: B.C. 537:64, 85, 108; B.C. 538:13, 45, 87; B.C. 695:89.]

Spatsizi Plateau

The Spatsizi Plateau (*see* Plate XIXC) is an area of wide, drift-filled valleys and open, gently rolling upland surfaces extending from Mount Brock on the western end in a curve to Thutade Lake on the southeast. The plateau is drained by the Stikine and Finlay Rivers and is enclosed by mountains. On the southwest the plateau is flanked by the Skeena Mountains, on the east by the Omineca Mountains, and on the northeast and north by the Cassiar Mountains.

The plateau is almost entirely underlain by sandstone, shale, conglomerate, and minor coal of Upper Cretaceous and Paleocene age. The rocks are mainly gently warped to flat lying, but along their southwestern border they have been folded across widths of a mile or more into overturned and recumbent structures which are probably related to movement along a thrust fault along their contact with older rocks.

The gently sloping upland surfaces of the plateau represent remnants of the late Tertiary erosion surface. Its slopes have been at least partly controlled by the gently dipping beds, and its surface was differentially uplifted and raised to a maximum of 7,000 feet on Skady Mountain and others. Characteristic features of the plateau are the wide drift-filled valleys that are only sparsely timbered, the Stikine River flowing at or just below 3,500 feet elevation, and the Finlay River below 4,000 feet, with gentle slopes leading up to unwooded upland areas.

The pre-Pleistocene topography was only slightly modified during and since the Pleistocene. The region was covered by ice to a height of about 7,000 feet, some of which moved out from the plateau in a northerly and northeasterly direction up Tucho River.

[Reference: "Stikine River Area," *Geol. Surv., Canada*, Map 9-1957.]
[Photograph: B.C. 538:31.]

Physiographic History of the Stikine Plateau

The Tertiary was a time of widespread attack by subaerial erosion. Throughout British Columbia during that time the land was being reduced in elevation by the erosion of the various river systems of the country. By late Tertiary the land surface had been reduced to one of variable but generally low to moderate relief.

This old land surface, which is an erosion surface rather than one built up through deposition of sedimentary or volcanic materials, is represented in the Stikine

Plateau (*see* Plates XVIA, XVIB, and XVIIB) by flat and gently sloping upland surfaces at and above 5,000 feet. These upland surfaces are remnants of the late Tertiary erosion surface which in the Stikine Plateau extended across the Tagish and Tahltan Highlands (*see* Plates XIIIB and XVB) and probably across the Boundary Ranges as well.*

During the Pliocene there was a general uplift of western North America, and the late Tertiary erosion surface was uplifted differentially to elevations that range from about 5,000 feet in the Taku and Kawdy Plateaus to 7,000 in the Spatsizi Plateau and Tagish Highland. This uplift rejuvenated the erosive power of the streams, and during late Pliocene but pre-Pleistocene time the surface was dissected by them. The degree of dissection varies greatly—in regions such as the Spatsizi, Nahlin, and Kawdy Plateaus there are wide areas of little or no dissection (*see* Plates XVIIB and XIXA), whereas in regions such as the Taku Plateau and Tagish Highlands, in which the degree of dissection is considerably greater, the Tertiary erosion surface is now represented by rather small isolated fragments of gently sloping upland (*see* Plate XVB). The depth of incision together with the amount of original relief of the Tertiary erosion surface produce the present relief. This varies greatly, ranging from small local relief in the Kawdy and Spatsizi Plateaus, where incision and dissection are slight, to moderate relief in the Taku Plateau and Tagish Highland, where the depth of incision is great.

A considerable number of centres of volcanic activity lie within the Stikine Plateau. These during the late Tertiary, Pleistocene, and Recent were active, and piles of volcanic material, both lavas and fragmentals, accumulated locally on the late Tertiary erosion surface. They are represented by the shield volcanoes and associated lava flows of Mount Edziza and Level Mountain, by the tuyas in the Kawdy Plateau, and by volcanic cones rather widely distributed (*see* Fig. 1).

During the Pleistocene the plateau was completely covered by glacial ice, which eroded upland surfaces and deposited a veneer of drift over most of the country. Late-stage cirque glaciation sculptured many of the peaks and ridges at higher levels. The well-developed drainage systems established during the long period of erosion in the Tertiary were disorganized by the effects of glaciation. Blockage by ice or drift diverted the drainage of Dease Lake, which in pre-Pleistocene time was by Tanzilla River into the Stikine River, northward into the Liard. Within the plateau, depressions of glacial origin are occupied by numerous lakes, and drainage in many instances is poorly established.

Since the Pleistocene the major rivers and their tributaries have resumed the incision and headward erosion which were initiated by the Pliocene uplift, and the drainage systems are recovering from their disorganization in the Pleistocene.

SKEENA MOUNTAINS

The Skeena Mountains (*see* Plates XIXC and XXA) constitute the mountainous area in the northern interior of British Columbia, extending from Telkwa on the Bulkley River northward for 230 miles, almost to the Stikine River. They are 90 miles wide between Bowser Lake on the west and Tatlatui Lake on the east. The mountains are bounded on the west by the Tahltan Highland, Boundary Ranges, and Nass Basin, on the south by the Nechako Plateau, on the east by the Omineca Mountains, and on the north by the Stikine Plateau.

The Skeena Mountains are a distinctive unit, being formed very largely of folded sedimentary rocks of Upper Jurassic and Lower Cretaceous age. The principal rocks are black fine-grained argillite and shale, and dark greywacke. Limestone, or rocks directly of volcanic origin, are absent; igneous intrusions are few in number and

* Kerr, F. A., *Geol. Surv., Canada,* Mem. 246, 1948, p. 13.

mostly in the Babine Range. The rock structures are extremely complex, the major folds averaging about 4 per mile with many overturned and recumbent outlines. Only in parts of the Groundhog Range, upper Skeena Valley, and Eaglenest Range do broad open folds predominate. Structures in the easily eroded argillite are more complex than in the resistant peak-forming greywacke. Typically the valleys and saddles in the Skeena Mountains are characterized by tight complex folding, whereas the broader massifs are commonly gently contorted or in places flat lying, an indication perhaps that major longitudinal faults, to which folding may be related, lie along the valleys. Most of the fold axes are nearly horizontal or plunge gently northwest.*

The mountains are drained by the Stikine, Nass, and Skeena Rivers and their tributaries, and are divided into ranges by prominent northwesterly trending valleys whose size and rectilinear pattern are characteristic of the region. The valley bottoms lie between 2,500 and 4,000 feet elevation, and are generally wide and drift-filled. Peaks range for the most part between 6,000 and 7,000 feet, the highest being Nation Peak (7,741 feet) in the Eaglenest Range, Oweegee Peak (7,540 feet) in the Oweegee Range, Melanistic Peak (7,710 feet) in the Tatlatui Range, Shelagyote Peak (8,090 feet) and Motase Peak (7,910 feet) in the Sicintine Range, Kisgegas Peak (7,700 feet) in the Atna Range, and Netalzul Mountain (7,645 feet) in the Babine Range.

The peaks and high ridges present a serrate and jagged profile which has been developed by intense alpine glaciation, through the production of cirques on their northern and eastern sides. Remnant glaciers still remain along the crests of high ranges, the greatest amount of ice being in the Atna and Sicintine Ranges, the two highest. The valley profiles have been modified by valley glaciers, tarns and hanging valleys abound, and the mountains everywhere show the erosional effects of cirque and valley glaciers.

On the north the Skeena Mountains pass by transition into the Spatsizi Plateau. In this zone, particularly on the northern limits of the Klappan and Eaglenest Ranges, gently sloping areas of upland are remnants of the dissection of the late Tertiary erosion surface (*see* Plate XIXB).

Some flat and gently sloping upland areas in the northern Klappan Range are underlain by Tertiary lava flows, which spread eastward from vents near Edziza Peak.

On the south, where the mountains adjoin the Nechako Plateau, the Babine, Atna, Sicintine, and Bait Ranges, with their 6,500-foot and higher peaks, present a front which rises abruptly above the plateau level, which is at 4,000 to 4,500 feet. The boundary is sharp and is drawn along the generalized 5,000-foot contour.

The Skeena Mountains were almost entirely covered by the Pleistocene ice-sheet, which rounded the ridges and summits below 6,000 feet. The most striking glacial effects within the mountains are the result of cirque and valley glaciation during the final recession of the Cordilleran ice-sheet. A legacy of Pleistocene ice occupation is the derangement of drainage from previously established lines. The zigzag course of the Skeena River downstream from Kuldo, in which the river cuts across the northern top of the Babine Range in three different places, evidently was determined by the presence of ice in adjoining valleys. The present drainage of Babine Lake (2,332 feet) northward into the Skeena River below Kisgegas rather than through the old portage route across to Stuart Lake (2,230 feet) must be the result of ice or morainal damming.

[References: " Stikine River Area," *Geol. Surv., Canada*, Map 9-1957; Buckham, A. F., and Latour, B. A., " The Groundhog Coalfield," *Geol. Surv., Canada*, Bull. No. 16, 1950.]

[Photographs: B.C. 507:53; B.C. 508:115; B.C. 522:101; B.C. 534:58, 82, 94; B.C. 535:51, 118; B.C. 538:4, 56, 95; B.C. 541:82.]

* *Geol. Surv., Canada*, Map 9-1957, marginal note.

Nass Basin

The Nass Basin (*see* Plate XXB) is an irregularly shaped area of low relief, for the most part lying below 2,500 feet elevation, which is drained by the Nass River and its tributaries and by the Kitwanga and Kispiox Rivers, tributaries of the Skeena. The basin extends from the junction of Teigen Creek with the Bell-Irving River southeastward for 130 miles to the Skeena River at Hazelton. The maximum width of the basin, northeasterly at Swan Lake, is about 25 miles.

The basin is encircled by mountains, the Boundary Ranges on the west, the Hazelton Mountains on the south, and the Skeena Mountains on the east. The mountains rise abruptly from the gently rolling floor of the basin, as is displayed strikingly on N.T.S. Sheet 103P. A prominent northeasterly trending lineament lies along the southeastern margin of the basin (*see* Plate XXIA). Rocks underlying the basin are dominantly volcanic members of the Hazelton Group.

The basin is flat or gently rolling, rising gradually to 5,148 feet at Mount Bell-Irving and 4,000 feet at several other points. Meziadin Lake (806 feet) and Bowser Lake (1,027 feet) lie on the western side of the basin. The floor of the basin is dotted with hundreds of small lakes which, together with the drainage pattern, display a well-developed southeasterly trend that swings to southwesterly below Cottonwood Island on the Nass River. The basin was occupied by glacial ice, and the numerous lake basins of glacial origin and many of the stream courses are parallel to drumlin-like forms developed by ice movement.

Ice from the Boundary Ranges and the Skeena Mountains poured down the Bell-Irving River into the Nass Basin and escaped by Kispiox Valley and Kitwanga Valley into the Skeena, also by way of the Nass River valley southwestward to the sea beyond Aiyansh. Some moved through the gap past Lava Lake, and some pressed over the mountains and down Cedar River to escape by way of Kitsumkalum Lake valley to Kitimat Valley. The strongly developed lineation displayed by drift forms and sculptured rock is an inheritance of the flow of Pleistocene ice (*see* Plate XXIA).

A feature of very great interest is the outpouring of Recent lava from a vent at the head of Tseax River. The vent is 3½ miles east of the north end of Lava Lake on the Columbia Cellulose road north of Terrace. Lava flowed down the tributary to the main valley of Tseax River, damming it and creating Lava Lake. The lava from there flowed northward for almost 12 miles to the Nass River, being confined for part of the distance within the narrow valley of Tseax River. On reaching the Nass Valley the lava spread out and formed an almost flat lava plain about 7 miles long and 3 miles wide along the south side of the Nass River (*see* Plate XLVIIB). The northern margin of the flow constricts the Nass Valley for several miles below Aiyansh and rises in cliffs along the south side of the river.

The precise age of the lava eruption is not known, but is thought to be not greater than 300 years. Vegetation has only begun to encroach upon the lava, and there has been little or no erosion of the lava. The surface retains its original characteristics, marked by irregular fragments of flow breccia, ropy lava surfaces, and collapse features where the upper crust has broken into subsurface caverns.

This remarkable feature is readily accessible by road north of Terrace.

[References: " Stikine River Area," *Geol. Surv., Canada,* Map 9-1957; N.T.S. Sheets 93M, 103P, and 104A.]

[Photographs: B.C. 468:87; B.C. 505:74, 102; B.C. 508:5, 20, 33, 76; B.C. 541:34.]

Hazelton Mountains

The Hazelton Mountains lie east of the Kitimat Ranges of the Coast Mountains and extend southeastward from the Nass River and Nass Basin for about 150 miles to Eutsuk Lake on the southern side of the Chikamin Range. Along their eastern side the Bulkley Valley separates the Bulkley Ranges of the Hazelton Mountains from the Babine Range of the Skeena Mountains. From Telkwa south to Eutsuk Lake the Hazelton Mountains are flanked by the Nechako Plateau. The plateau very largely lies below 5,000 feet elevation and, although there may be a narrow transition belt between the plateau and the mountains, it is convenient to use the line of the 5,000-foot contour as the boundary between the two.

The high points in the mountains are the Seven Sisters (9,140 feet) east of the Skeena River, Brian Boru (8,200 feet) in the Rocher Déboulé Range, Hudson Bay Mountain (8,400 feet) at Smithers, and Tsaydaychuz Peak (9,085 feet) in the Patullo Range. The majority of the peaks lie between 6,500 and 7,500 feet. Drainage of the northern mountains is by way of the Nass and Skeena Rivers and their tributaries, so the relief is fairly high. From Morice Lake southward the drainage is to the east by way of tributaries of the Fraser River, and the relief is generally less because it is controlled by the elevation of the major lakes, such as Morice (2,614 feet), Tahtsa (2,765 feet minimum), Whitesail (2,765 feet minimum), and Eutsuk (2,817 feet).

The mountains lie east of the eastern contact of the Coast Intrusions and very largely are underlain by Mesozoic sedimentary and volcanic rocks intruded by isolated stocks and small batholiths of granitic rock of Cretaceous age. The Hazelton Mountains comprise a number of mountain masses and ranges separated by prominent valleys. Many of the ranges and smaller units have cores of granite.

The Hazelton Mountains comprise the Nass Ranges between the Skeena and Nass Rivers, the Kispiox Range surrounded by and rising out of the Nass Basin, the Bulkley Ranges between the Skeena and Bulkley Valleys and Morice Lake, and the Tahtsa Ranges between Morice Lake and the west end of Eutsuk Lake.

Nass Ranges

The Nass Ranges (*see* Plate XXIA) lie west of the Skeena River and south of the Nass Basin. A most remarkable feature of their northwest boundary is the prominent northeasterly trending lineament that lies for about 30 miles along the southeast side of the Nass Valley.

The ranges comprise serrate peaks below 7,000 feet elevation and rounded summits and ridges below 6,000 feet. The area was heavily glaciated; the higher peaks are sculptured by cirque glaciers, as are most of the north and northeast slopes of the ridges and lower peaks. Ice draining from the Nass Basin moved across the ranges and poured southwestward down Cedar River to the Kitsumkalum Valley, scouring the valley as it moved.

The source of the lava forming the Recent lava plain in the Nass Basin is in Tseax River in the Nass Ranges.

[References: Duffell, S., and Souther, J. G., " Terrace Area," *Geol. Surv., Canada,* Map 11-1956; Hanson, G., " Reconnaissance between Skeena River and Stewart," *Geol. Surv., Canada,* Sum. Rept., 1923, Pt. A, pp. 29–45; Hanson, G., " Reconnaissance between Kitsault River and Skeena River," *Geol. Surv., Canada,* Sum. Rept., 1922, Pt. A, pp. 35–50.]

[Photographs: B.C. 468:58, 70, 75; B.C. 505:32.]

Kispiox Range

The Kispiox Range is a somewhat elliptical mountain mass 18 miles long and 8 miles wide that rises from the Nass Basin between the Kitwanga and Kispiox Rivers to an elevation of 6,876 feet at Kispiox Mountain.

The range is composed of folded sedimentary and volcanic rocks of Triassic and Lower Cretaceous age that are intruded at Hazelton Peak by a small granitic stock.

The peaks are serrate in profile and show the effects of late-stage cirque glaciation. On the eastern and southern sides of the mountain mass the slopes are strongly glaciated by ice that flowed down the valleys of the Kispiox and Skeena Rivers.

[Reference: Armstrong, J. E., " Preliminary Map, Hazelton Area," *Geol. Surv., Canada,* Paper 44-24.]

Bulkley Ranges

The Bulkley Ranges lie east of the eastern contact of the Coast Intrusions, south of the Skeena River, and west of the Bulkley River. South of Telkwa the ranges pass by transition into the Nechako Plateau along a generalized line about at the 5,000-foot contour.

The ranges include the Seven Sisters group of peaks (maximum elevation 9,140 feet), Rocher Déboulé Range (Brian Boru Peak 8,200 feet), Hudson Bay Mountain (8,400 feet), Telkwa Range (maximum elevation 7,672 feet), Howson Range with peaks to 8,500 feet, and other unnamed ranges. Most of these ranges and mountain groups have central stocks of granite. The high peaks are sculptured by cirques and glaciers, some of which still cling to peaks in the Howson Range, the Seven Sisters, and other peaks near the Skeena River.

Back from the Skeena River the individual ranges are bounded by wide flaring valleys such as those of the Zymoetz and Telkwa Rivers, flowing at elevations between 2,000 and 2,500 feet. These wide valleys become more prominent in the eastern part of the Bulkley Ranges and are noticeably different from the narrow, deep glaciated valleys of the Kitimat Ranges on the west.

In the Pleistocene, ice covered the area to an elevation of 6,000 to 7,000 feet. An ice divide near Smithers separated ice which moved down the Bulkley and Skeena Valleys to Terrace and thence down the Kitimat Valley to the sea, from ice which moved southeastward up the Bulkley River valley onto the Nechako Plateau and thence eastward toward the Rocky Mountains (*see* Fig. 10).

[References: Kindle, E. D., " Mineral Resources, Hazelton and Smithers Areas," *Geol. Surv., Canada,* Mem. 223, 1940; Sutherland Brown, A., " Geology of the Rocher Déboulé Range," *B.C. Dept. of Mines,* Bull. No. 43, 1960.]

[Photographs: B.C. 468:39; B.C. 505:65; B.C. 522:114; B.C. 523:97; B.C. 525:9, 18.]

Tahtsa Ranges

The Tahtsa Ranges (*see* Plate XXIB) lie east of the eastern contact of the Coast Intrusions, flanking the Kitimat Ranges from Morice Lake southward for about 40 miles to the west end of Eutsuk Lake. The ranges represent a belt 10 to 15 miles wide of essentially non-granitic mountains between the Nechako Plateau on the east and the dominantly granitic Kitimat Ranges on the west.

The highest point in the ranges is a peak of 8,103 feet east of Nanika Lake. The rest of the high peaks generally range between 7,000 and 7,500 feet. The peaks and ridges are serrate and exhibit the sculptural effects of cirque glaciation; many of the highest peaks still carry cirque glaciers on their northeast sides.

The mountains are divided into westerly trending ranges. They lie between major valleys that are occupied by lakes which, from north to south, are Morice, Nanika, Tahtsa, Troitsa, Whitesail, and Eutsuk. These lakes are between 2,614 and 3,100 feet in elevation and drain eastward into tributaries of the Fraser River.

These valleys are at a fairly high level, and consequently the relief is considerably less than it is in the adjoining Kitimat Ranges on the west, where the Kemano and Kitlope Rivers flow at less than 1,000 feet elevation.

The lakes, which are prominent features of the Tahtsa Ranges, occupy ice-modified valleys whose western ends are in the granitic mountains of the Kitimat Ranges and whose eastern ends lie in the Nechako Plateau. Ice which accumulated in the mountains to the west flowed eastward across the Tahtsa Ranges and through these easterly trending valleys onto the Nechako Plateau and thence eastward toward the Rocky Mountains.

[Reference: Duffell, S., "Whitesail Lake Map-area," *Geol. Surv., Canada,* Mem. 299, 1959.]

CASSIAR MOUNTAINS

The Cassiar Mountains in the northern interior of British Columbia extend southeastward from the Yukon Border for 230 miles to the bend of the Finlay River, where, at latitude 57 degrees 40 minutes north, they adjoin the Omineca Mountains. The mountains have their greatest width of 100 miles between the Three Sisters Range at the head of the Tanzilla River and the Rocky Mountain Trench. The mountains are bounded on the west and north by the Nisutlin Plateau, on the west and southwest by the Stikine Plateau, on the northeast by the Liard Plain, and on the east by the Rocky Mountain Trench. They are separated from the Omineca Mountains by the through valley occupied by Chukachida River, Cushing Creek, Thudaka Creek, and Finlay River. Mount Cushing (8,676 feet), the most prominent peak in this vicinity, is in the Omineca Mountains just south of the transverse valley.

The Cassiar Mountains are divisible into four major units: the Dease Plateau on the northeast, adjacent to the Liard Plain; the Stikine Ranges, the extensive mountains whose central part is composed of granitic rocks of the Cassiar batholith; the Kechika Ranges flanking the Rocky Mountain Trench north of Sifton Pass; and the Sifton Ranges flanking the Trench west of the Fox River.

Dease Plateau

The Dease Plateau consists of moderately high, flat-topped ridges and rounded mountains separated by widely flaring valleys lying between the higher, more rugged mountains of the Stikine Ranges and the low, gently rolling lowland of the Liard Plain. A distinctive subdivision within it, the Horseranch Range, lies east of the Dease River. The plateau, with a width of about 20 miles, extends from Looncry Lake and Deadwood River valley along the northeast side of the Stikine Ranges for 75 miles to the Yukon Border, and thence into Yukon Territory. It is broken into two segments by the valley of the Dease River, which allows a prong of the Liard Plain to extend southward to the junction of Rapid River with the Dease.

The plateau lies essentially between 3,000 feet, the level of the Liard Plain, and 5,000 feet, above which elevation only three rounded summits project. The western boundary of the plateau is drawn along the generalized line of the 5,000-foot contour, separating the Stikine Ranges, which project well above 5,000 feet, from the Dease Plateau, which, for the most part, lies below. Southeast from Black Angus Creek the northeast boundary of the plateau is essentially an extension of the western side of the Rocky Mountain Trench.

The plateau is underlain by folded Palæozoic sedimentary rocks. Pleistocene ice rounded the summit peaks and ridges and covered the area with an extensive mantle of drift.

The *Horseranch Range* is a discrete unit within the Dease Plateau. It is a range composed of sedimentary gneisses in a doubly plunging anticline whose western front along the valley of the Dease River is a fault. The range stands well above the rest of the Dease Plateau, with most peaks rising to more than 6,000 feet and the highest to 7,300 feet. Steep-walled cirques which scallop the eastern side of the range are occupied in several instances by tarn lakes.

[Reference: Gabrielse, H., "McDame Map-area," *Geol. Surv., Canada,* Mem. 319, 1963.]

Stikine Ranges

The Stikine Ranges (*see* Plates XXIIIA and XXIIIB) extend northwestward from their southern end at the Chukachida River for about 275 miles, their northern end being in the Yukon 45 miles north of the border. Their greatest width is 85 miles, between the Three Sisters Range and Dall Lake.

They are bounded on the southwest by the Stikine Plateau along a sinuous line which, at about 5,000 feet elevation, separates gently rolling plateau from maturely dissected mountains. On the northeast the ranges are bounded by the Dease Plateau and Kechika Ranges. The boundary with the latter is a prominent through valley, a lineament which leaves the Trench at Sifton Pass and runs past the west end of Denetiah Lake, past Dall Lake to Deadwood Lake.

The ranges have a core of granitic rocks which constitute the Cassiar batholith, a composite batholith of Jurassic or Cretaceous age. The granitic rocks intrude folded sedimentary and volcanic rocks of Palæozoic and Mesozoic age.

The ranges are drained by tributaries of the Finlay, Stikine, Kechika, Turnagain, Dease, and Liard Rivers. Many of these valleys are wide, drift-filled, and widely flaring, and the mountains are broken by them into irregularly shaped ranges.

The highest peaks in the ranges are in the granitic mountains between Thudaka Creek and Turnagain River. The highest elevation (8,900 feet) is in the Thudaka Range southwest of Obo Lake; others of 7,900 and 8,000 feet elevation lie between it and Sharktooth Mountain (8,765 feet) just west of Dall Lake. Northward from King Mountain (7,900 feet) at the head of Turnagain River are Glacial Mountain (7,565 feet) in the Three Sisters Range and Quartz Mountain (7,548 feet) near McDame. There is little diminution of summit height northward to Simpson Peak (7,130 feet), which lies just south of the Alaska Highway at Swan Lake (2,760 feet).

The peaks and ridges above 6,000 feet are sharply scalloped by cirque glaciers. The cirques are especially prominent on the north and northeast sides of ridges and peaks whose southern slopes may be quite gentle and rounded (*see* Plate XXIIIA). Below 6,000 feet the ridges and summits are rounded and the forms are softened and less harsh. South of Sharktooth Mountain the mountain valleys are narrow and have fairly steep glaciated walls, and it is evident that valley glaciation was more intense in the ranges there. North of the Turnagain River the valleys become progressively wider and more gently flaring. There the country is characterized by rounded summits and wide drift-filled valleys. The elevation of the valley bottoms is between 3,500 and 4,500 feet, so that although the peaks may be rugged the relief is not excessive.

At the head of the Eagle River, some 8 to 15 miles westerly from Eaglehead Lake, there is a group of five or more cinder cones of Pleistocene age. "The cones are generally elliptical in plan and conical in section . . . their symmetrical shape and long, black, talus slopes make them conspicuous landmarks in the region."*

Although the country was covered by the Pleistocene ice-sheet, the obvious glacial effects are largely those of late-stage cirque activity.

* Hanson, G., and McNaughton, D. A., *Geol. Surv., Canada,* Mem. 194, 1936, p. 11.

Detailed studies made around several placer camps in the Stikine Mountains indicate that the late Tertiary erosion surface, which was one of moderate relief, was uplifted prior to the Pleistocene and that a stage of canyon-cutting preceded the occupation by ice (compare with p. 55).

[References: Kerr, F. A., "Dease Lake Area," *Geol. Surv., Canada,* Sum. Rept., 1925, Pt. A; Hanson, G., and McNaughton, D. A., "Eagle-McDame Area, Cassiar District," *Geol. Surv., Canada,* Mem. 194, 1936; Holland, Stuart S., "Placer-gold Deposits, Wheaton (Boulder) Creek," *B.C. Dept. of Mines,* Bull. No. 2, 1940; Hedley, M. S., and Holland, Stuart S., "Reconnaissance in the Area of Turnagain and Upper Kechika Rivers," *B.C. Dept. of Mines,* Bull. No. 12, 1941; Gabrielse, H., "Geology, Cry Lake," *Geol. Surv., Canada,* Map 29-1962; Gabrielse, H., Souther, J. G., and Roots, E. F., "Geology, Dease Lake," *Geol. Surv., Canada,* Map 21-1962; "Stikine River Area," *Geol. Surv., Canada,* Map 9-1957.]

[Photographs: B.C. 893:63; B.C. 954:23.]

Kechika Ranges

The Kechika Ranges lie along the northeastern side of the Stikine Ranges and flank the Rocky Mountain Trench from Sifton Pass northwestward for about 110 miles, almost to the Deadwood River. Their eastern boundary is the edge of the Trench, and their western boundary is drawn along the lineament extending between Sifton Pass and Deadwood Lake. At their northern end the summit level gradually diminishes and the mountains merge in the Dease Plateau along an arbitrary line drawn northeastward from Looncry Lake and along the Deadwood River valley.

The highest peaks in the ranges lie between Moodie Creek and Mount Winston (7,736 feet), where a hard Lower Cambrian quartzite forms several 7,500-foot summits. To the north the summits diminish to the Dease Plateau, and to the south peaks of 6,500 feet extend in northwesterly trending ranges.

The ranges are drained by the Kechika and Turnagain Rivers and their tributaries. Some tributaries, such as the Frog River and Denetiah and Moodie Creeks, cut at right angles across the northwesterly trend of the ranges, breaking them into blocks.

The Kechika Ranges are underlain by folded Precambrian and Palæozoic sedimentary rocks, dominantly quartzite, limestone, and slate. The high peaks and ridges have been sharply sculptured by cirque glaciers and the valley profiles are modified by valley glaciers. Summits and ridges below 6,000 feet are generally rounded and subdued by erosion of the ice-sheet.

[References: Hedley, M. S., and Holland, Stuart S., "Reconnaissance in the Area of Turnagain and Upper Kechika Rivers," *B.C. Dept. of Mines,* Bull. No. 12, 1941; Gabrielse, H., "Geology, Kechika," *Geol. Surv., Canada,* Map 42-1962.]

Sifton Ranges

The Sifton Ranges lie north of the Finlay River and flank the Rocky Mountain Trench and Fox River between Ware and Sifton Pass, and wedge out against the southern tip of the Kechika Ranges. On their western side they are bounded by the Obo River lineament, which extends northward past Johiah Lake to Airplane Lake, close to the head of Paddy Creek.

The ranges present a harsh and rugged appearance from the Trench, and from Mount Balourdet (7,247 feet) to Mount Slocomb there is a succession of 7,500-foot peaks. The ranges are underlain by metamorphic rocks, comprising quartzite and a variety of schists and gneisses, which account for the physical character of the ranges. Small granitic intrusions are known to occur in the vicinity of Spinel Lake.

These ranges are more akin to the Finlay Ranges to the south than they are to the Kechika Ranges to the north, from which they differ lithologically and structurally.

The high peaks of the Sifton Ranges were intensely glaciated, but no cirque glaciers remain.

Omineca Mountains

The Omineca Mountains extend southward from the Cassiar Mountains in the northern part of the central interior of British Columbia. They are bounded on the west by the Spatsizi Plateau between the Chukachida River and Thutade Lake, and by the Skeena Mountains between Thutade Lake and Bear Lake, on the southwest and south by the Nechako Plateau between Bear Lake and the Nation River, and on the northeast by the Rocky Mountain Trench. On the north the Omineca Mountains are arbitrarily separated from the Cassiar Mountains by the valleys of Chukachida River, Cushing Creek, Thudaka Creek, and Finlay River, although there is complete topographic and geologic continuity between the two.

The mountains have a core of granitic rock of the Omineca Intrusions. This is a composite batholith of Upper Jurassic or Lower Cretaceous age intruding sedimentary, volcanic, and metamorphic rocks of Proterozoic to Jurassic age. Post-batholithic sedimentary rocks of Cretaceous and Tertiary age occur in isolated basins of deposition.

The Omineca Mountains are divided into three units: the greater part of the mountains, between Mount Cushing on the north and Nation Lakes on the south, have a central batholithic core and are named the Swannell Ranges; on their northeast, and separated from them by the Pelly Creek lineament, are the Finlay Ranges; on their southwest, and separated from them by the Pinchi Lake-Omineca fault, are the Hogem Ranges.

Swannell Ranges

The Swannell Ranges extend southeastward from Mount Cushing (8,676 feet) to the Nation Lakes, a distance of about 200 miles. Their greatest width, between Bear Lake and the mouth of Ingenika River, is 85 miles. The lateral boundaries of the ranges are structurally controlled lineaments. The Pelly Creek lineament* is an extremely prominent topographic feature extending northwestward from the mouth of the Omineca River for several hundred miles. Southeast of the Finlay River along Pelly Creek, past Tomias Lake, and along the Mesilinka River to its mouth, it separates the Swannell Ranges from the Finlay Ranges. Structurally controlled topographic features provide the southwest boundary between the Swannell Ranges and Hogem Ranges. The boundary follows a series of depressions and valleys which coincide with the Pinchi Lake fault zone, and its extension northwestward is along the Omineca fault, thence by Sustut Lake and Moose Valley to Thutade Lake. The summit level gradually diminishes to the south, and the mountains merge in the Nechako Plateau along a sinuous line between Bear Lake and the mouth of Nation River.

The highest points in the ranges are the several granitic peaks at the northern end—Mount Cushing (8,676 feet), Bronlund Peak (8,511 feet), and Fleet Peak (7,630 feet). Farther south the high points lie between 6,000 and 7,000 feet elevation.

* Roots, E. F., *Geol. Surv., Canada*, Mem. 274, 1954, p. 196.

The area is drained by the Finlay, Mesilinka, Ingenika, and Omineca Rivers, and by tributaries flowing into the head of the Skeena River. Valley bottoms lie between 3,000 and 4,000 feet, so that the relief, even in the most rugged sections, is less than it is in the Coast Mountains.

The mountains were glaciated throughout, but with an intensity that varied with altitude and general location. Mountain peaks and ridges below 6,000 feet are rounded, but at progressively greater heights the peaks are more serrate and show the sculptural effects of cirque glaciation. In the ranges near the Finlay River the valley profiles are U-shaped and hanging valleys are to be seen, but in the vicinity of the Omineca River ice erosion, except for late-stage cirque glaciation, was far less pronounced. A mantle of drift was left in the valley bottoms, and many low-level lakes resulted from its irregular distribution. Many derangements of the pre-glacial stream pattern resulting from the ice occupation are described by Roots* in the Aiken Lake area.

A few remnants of the late Tertiary erosion surface are to be seen in the McConnell and Wrede Ranges, but farther east the landscape is completely mature; the old erosion surface is completely dissected and no remnants of it remain.

The relation between topography and geology is illustrated by the coincidence of the highest peaks and mountain crests with the axis of the batholith. There are, moreover, close topographic and geologic similarities between the Wolverine, Tenakihi, Ingenika, Tucha, and Fishing Ranges, all of which lie on the eastern side of the Omineca Intrusions and are eroded from highly metamorphosed rocks of late Precambrian and early Palæozoic age.

[References: Lord, C. S., " McConnell Creek Map-area," *Geol. Surv., Canada*, Mem. 251, 1948; Armstrong, J. E., "Fort St. James Map-area," *Geol. Surv., Canada*, Mem. 252, 1949; Roots, E. F., "Geology and Mineral Deposits of Aiken Lake Map-area," *Geol. Surv., Canada*, Mem. 274, 1954.]

Finlay Ranges

The Finlay Ranges lie between the Pelly Creek lineament and the Rocky Mountain Trench, and extend for 130 miles along the Finlay River northward from the mouth of the Omineca River to the mouth of Obo Creek. The ranges have a width of 15 miles.

Peaks ranging from 6,000 feet to just over 7,000 feet are eroded from limestones, quartzites, and highly metamorphosed schists of late Precambrian and Cambrian age. The structural trend of the rocks controls the northwesterly direction of the ranges.

The ranges were glaciated, but no ice remains. The peaks and ridges were rounded during the maximum transgression of the Cordilleran ice-sheet. Later cirque and valley glaciers left their characteristic imprint upon the topography.

The Finlay Ranges are geologically and structurally continuous with the Sifton Ranges to the north, from which they are separated along strike by the valley of the Finlay River.

[References: Dolmage, V., "Finlay River District," *Geol. Surv., Canada*, Sum. Rept., 1927, Pt. A; Roots, E. F., "Geology and Mineral Deposits of Aiken Lake Map-area," *Geol. Surv., Canada*, Mem. 274, 1954.]

Hogem Ranges

The Hogem Ranges lie to the west of a line that follows the Pinchi Lake-Omineca fault and extends north to Thutade Lake by way of Sustut Lake and

* Roots, E. F., *Geol. Surv., Canada*, Mem. 274, 1954, p. 19.

Moose Valley. North of Bear Lake the ranges are flanked by the Skeena Mountains, and south of it by the Nechako Plateau. Between Thutade Lake and the south end of Takla Lake, the Hogem Ranges are 140 miles long and have a maximum width of 30 miles.

At the northern end the Axelgold Range is eroded from Palæozoic and Mesozoic volcanic and sedimentary rocks; the Connelly Range, however, is composed of Upper Cretaceous or Paleocene sedimentary formations lying on the eastern limb of a syncline. Erosion of the gently dipping beds has resulted in gently sloping ridges and in mountain slopes parallel to the dip, with abrupt cliffs cutting across the dip slopes. In the south the Sitlika, Vital, and Mitchell Ranges are underlain essentially by limestone and argillite of late Palæozoic (Permian) age, intruded by granitic rocks of the Omineca Intrusions.

The highest peaks are Sustut Peak (8,100 feet), west of Sustut Lake near the northern end, and Tsitsutl Mountain (6,600 feet), west of the south end of Takla Lake. All the peaks are cirqued on their northern sides and stand sharply above widely flaring valleys.

The Hogem Ranges differ only in degree from the Swannell Ranges by having topographic forms less influenced by granitic rock. Because they are flanking ranges and lateral to the axis of greatest uplift, their summit elevations are generally not so high as those in the Swannell Ranges.

[References: Lord, C. S., "McConnell Creek Map-area," *Geol. Surv., Canada,* Mem. 251, 1948; Armstrong, J. E., "Fort St. James Map-area," *Geol. Surv., Canada,* Mem. 252, 1949; Roots, E. F., "Geology and Mineral Deposits of Aiken Lake Map-area," *Geol. Surv., Canada,* Mem. 274, 1954.]

ROCKY MOUNTAIN TRENCH

The Rocky Mountain Trench (*see* Plates XXII, XXIVA, and XXXIVB) is a remarkable topographic feature which extends northwestward from the 49th parallel almost to the Liard River, a total distance of almost 900 miles. For the first 450 miles, from the Montana Border to the McGregor River, the Rocky Mountain Trench is a continuous, somewhat sinuous valley lying between the Columbia Mountains on the west and the Rocky Mountains on the east. This valley is from 2 to 10 miles wide and is occupied by the southward-flowing Kootenay River, northward-flowing Columbia River, southward-flowing Canoe River, and northward-flowing Fraser River. The divides between the headwaters of these rivers are low. In this southern stretch the eastern wall of the trench is the western front of the Rocky Mountains, and the western wall of the trench is the eastern front of the Columbia Mountains.

At the McGregor River, however, the line of the Rocky Mountains is breached, and the bold mountain front on the eastern side of the trench is offset about 15 miles northeast. At the same place the western wall of the trench disappears, and the trench merges in the Fraser Basin at an elevation of 2,000 feet. The southern half of the Rocky Mountain Trench, which for 450 miles was continuous and clearly defined, ends here, even though the structure which it follows may continue northwestward past Mount Averil and McLeod Lake as the McLeod Lake fault zone.*

The northern half of the Rocky Mountain Trench begins on the north side of the McGregor River, at the divide between James Creek and the Parsnip River, and continues northwestward to the point where, at the junction of the Kechika and Turnagain Rivers, the trench merges in the Liard Plain. The northern segment of the trench is flanked on the west at its southern end by the McGregor

* Muller, J. E., and Tipper, H. W., *Geol. Surv., Canada,* Map 2-1962.

Plateau and the Nechako Plateau, and northward from the Nation River by the Omineca and Cassiar Mountains. From Arctic Lake near the head of the Parsnip River the eastern wall of the trench is formed by the unbroken western front of the Rocky Mountains, and the trench is a continuous straight valley from 2 to 9 miles wide occupied by the northward-flowing Parsnip River, the southward-flowing Finlay River and Fox River, and the northward-flowing Kechika River. Sifton Pass (3,273 feet) is the highest divide along the entire length of the trench.

The trench is a structurally controlled erosional feature. The trench structure is very largely unknown, but it is complex and unquestionably differs from one place to another. There is little doubt that the break in the trench at McGregor River is the result of erosion controlled by two major structures. As a topographic feature the trench existed early in the Tertiary, and Tertiary sediments were deposited in it. It is known that during Tertiary time the headwaters of the Peace and Liard Rivers flowed on the site of the trench, as did the pre-glacial Fraser River. The southern trench was probably drained by the south-flowing Columbia and Kootenay Rivers. It developed as an erosional form during the Tertiary by streams whose courses were antecedent to the building of the Rocky Mountains. They were antecedent also to the uplift of the mountains on the western side of the trench. The erosion of the trench was completed by the end of the Pliocene. It was occupied by ice and its form modified, but the main effect of glacial occupation was the derangement of previously established drainage systems. The streams became established in their present courses with the waning of the ice, and during the post-glacial period have incised themselves to varying depths into the deeply drift-filled floor of the trench.

[Reference: " Rocky Mountain Trench Symposium," *Can. Inst. Min. & Met.*, Trans., Vol. LXII, 1959, pp. 152–172.]

[Photographs: B.C. 187:91; B.C. 762:110; B.C. 766:37; B.C. 1949:24; B.C. 1950:23.]

SOUTHERN PLATEAU AND MOUNTAIN AREA

The Southern Plateau and Mountain Area includes most of the central and southern interior of British Columbia lying south of latitude 55 degrees north. It is the part of the Province best known to travellers because of its ready accessibility by a network of highways and railways. The area is divisible into two parts: one of low to moderate relief comprising the basins, plateaus, highlands, and mountains of the Interior Plateau; and the second the mountainous area of the Columbia Mountains.

Interior Plateau

The Interior Plateau is one of the major physiographic divisions of the Province, with a length of 560 miles and a maximum width of 235 miles. It is encircled by mountains, being flanked on the west by the Coast and Cascade Mountains, on the north by the Skeena and Omineca Mountains, and on the east and southeast by the Rocky Mountains and Columbia Mountains. On the northeast the plateau merges in the Rocky Mountain Trench, but elsewhere there is a transition between plateau and flanking mountains (*see* Plate XXVIIb). On the east the transition between the partly dissected plateau and the Columbia Mountains is through a belt up to 50 miles or more wide. In it the plateau is more highly dissected, and the belt is sufficiently large and distinctive to be separately designated as a highland. Elsewhere the transition between plateau and mountains is fairly rapid, and the boundary is drawn where the plateau is completely dissected and the country is truly mountainous.

The Interior Plateau is almost entirely drained by the Fraser River and its tributaries; only minor drainage is to the Skeena, Peace, and Columbia Rivers.

The Interior Plateau consists of the following units: the Fraser Basin, the Nechako Plateau, the Fraser Plateau, and the Thompson Plateau, and to the east of these the Quesnel Highland, the Shuswap Highland, and the Okanagan Highland which lie along the western side of the Columbia Mountains.

Fraser Basin

The Fraser Basin is an irregularly shaped area of low relief lying below the surface of the Nechako Plateau. On the northeast the basin merges in the Rocky Mountain Trench at an elevation of about 2,000 feet; elsewhere its boundary is drawn along the generalized line of the 3,000-foot contour. The basin extends from Williams Lake northward to McLeod Lake and from Fraser Lake eastward to Sinclair Mills.

Its flat or gently rolling surface lies for the most part below 3,000 feet and is covered with drift and has few exposures of bedrock. The surface is incised by the Fraser River and its tributaries; the river at Prince George is at an elevation of 1,850 feet. On much of the surface the drainage is poorly organized, and numerous lakes and poorly drained depressions are present.

The area was occupied by ice whose movement created drumlins and drumlin-like forms in the glacial drift. The many hundreds of drumlins present indicate an eastward and northeastward movement of ice in the area north of Prince George, and a movement northward from Quesnel (*see* Fig. 10).

Eskers were formed by meltwater during the waning stages of glaciation in the Fraser Basin. The largest is the MacKinnon compound esker north of Carp Lake about 35 miles long in a northeasterly direction. The Stuart River compound esker is 25 miles long and 1 to 2½ miles wide, and west of Prince George the Bednesti compound esker about 15 miles long was formed by southeastward-flowing meltwater during a stage in the existence of glacial lakes.

As the ice melted, the pre-glacial drainage channels were blocked with drift and wasting ice, and, in basins centred about Prince George, Fort St. James, and Vanderhoof, ice-dammed lakes formed at levels below 2,600 feet. Varved clays were deposited in these glacial lakes, above the surface of which the tops of some drumlins projected as islands. The glacial-lake clays have been shown by soil surveys to underlie more than 750,000 acres. The area west and north of Prince George occupied by the three glacial lakes has been called the *Nechako Plain.**

The shape of the Fraser Basin and the slope of surfaces within it indicate that the basin was eroded by a northward-flowing ancestral Fraser River† which flowed through the McLeod Lake gap and was a tributary of the Peace River. The ancient Fraser River history is complex, as may be judged from the fact that early Tertiary (Eocene and Oligocene) sediments were deposited by southward-flowing streams‡ and that later Tertiary (Miocene) sediments, at least from the mouth of the West Road River north, were deposited by northward-flowing streams.§ The river development was further complicated as late as the Pliocene by eruptions of lava, whose effects are unknown.

Until a complete study of the Fraser River has been made, it will not be possible to date the reversal of flow of the river between Prince George and Riske Creek and to state definitely whether it was reversed by a rapidly eroding southward-flowing

* Armstrong, J. E., and Tipper, H. W., *Am. Jour. Sci.*, Vol. 246, 1948, p. 285.

† Lay, Douglas, *B.C. Dept. of Mines*, Bull. No. 3, 1940, p. 3.

‡ Lay, Douglas, *B.C. Dept. of Mines*, Bull No. 11 (Part II), 1941, pp. 39, 40, 45.

§ Lay, Douglas, *B.C. Dept. of Mines*, Bull. No. 11 (Part II), 1941, pp. 52, 53; Tipper, H. W., *Geol. Surv., Canada*, Map 49-1960.

river in pre-Pleistocene time or whether it was established when the pro-glacial lake in the vicinity of Prince George was drained. It is possible that during the last stage of the disappearance of the ice, sufficient ice existed from Summit Lake northward to prevent the resumption of flow in that direction. Drainage, as a consequence, would then have been forced to escape southward from Prince George. At Prince George the channel of the present river now is some 700 feet below the upper level of the glacial-lake clays (*see* p. 110 for further discussion).

[References: Armstrong, J. E., " Fort St. James Map-area," *Geol. Surv., Canada,* Mem. 252, 1949; Armstrong, J. E., Map 980A, " Carp Lake," *Geol. Surv., Canada;* Tipper, H. W., " Prince George," *Geol. Surv., Canada,* Map 49-1960; Tipper, H. W., " Quesnel," *Geol. Surv., Canada,* Map 12-1959; Muller, J. E., and Tipper, H. W., " McLeod Lake," *Geol. Surv., Canada,* Map 2-1962; Lay, Douglas, " Fraser River Tertiary Drainage-history in Relation to Placer-gold Deposits," *B.C. Dept. of Mines,* Bull. No. 11 (Part II), 1941; Armstrong, J. E., and Tipper, H. W., " Glaciation in North Central British Columbia," *Am. Jour. Sci.,* Vol. 246, 1948, pp. 283–309; Farstad, L., and Laird, D., Soil Survey Report No. 4, *Canada Dept. of Agriculture,* 1954.]

[Photographs: B.C. 520:92; B.C. 761:36; B.C. 763:38, 48; B.C. 765:107; B.C. 921:104.]

Nechako Plateau

The Nechako Plateau (*see* Plate XXIVB) is the northernmost of the three plateau subdivisions of the Interior Plateau. It is an area of low relief, with great expanses of flat or gently rolling country, in places almost completely undissected but elsewhere incised to the level of the Fraser River and its tributaries. The plateau surface lies between 4,000 and 5,000 feet elevation.

The Nechako Plateau is bounded on the west by the Hazelton Mountains and on the north by the Skeena and Omineca Mountains. The plateau passes by rapid transition into the mountains, and the boundary is drawn along the generalized line of the 5,000-foot contour. On the east it is bounded by the Fraser Basin, the line of separation between the two being the 3,000-foot contour. On the south the separation from the Fraser Plateau is along the West Road River.

Over much of the plateau, flat or gently dipping Tertiary lava flows cover the older volcanic and sedimentary rocks of the Takla and Hazelton Groups and intrusive rocks of Upper Jurassic and Cretaceous age. Glacial drift is widespread and a high percentage of bedrock is obscured.

The plateau was occupied by ice, which, in moving across it, marked the surface with thousands of grooves and drumlin-like ridges which are parallel to the ice flow. From the general vicinity of Ootsa Lake the ice moved eastward and northeastward toward the Rocky Mountains near McLeod Lake. Ice moved southeastward along the Babine Lake valley and then veered to the northeast (*see* Fig. 10). Numerous depressions left on the plateau surface after the ice retreat are now occupied by myriads of lakes, from small ponds to lakes the size of Babine, which is the second largest lake in the Province.

Noticeable features of the plateau surface are eskers and meltwater channels; many of the latter are now dry. These features are observed only on aerial photographs or on the ground, because the 500-foot contour interval on the available topographic maps is too large to display features of such low relief.

In the southwestern part of the Nechako Plateau, between Whitesail Lake and the West Road River, several round-topped ranges project above the general upland surface at 5,000 feet. An elevation of 7,396 feet is reached at Michel Peak in the Quanchus Range, of 6,319 feet on Fawnie Nose in the Fawnie Range, and of 7,065 feet at Nadina Mountain. These are monadnocks on the late Tertiary erosion surface, resulting from the resistance to erosion of granitic stocks and their aureoles of altered (hornfelsed) rock.

There are numerous outliers of the Nechako Plateau lying within the Fraser Basin. These are remnants of the plateau surface which were not destroyed during the dissection of the plateau and the erosion of the Fraser Basin below the higher level.

A small area of plateau on the eastern margin of the Nechako Plateau, and lying between the offset ends of the northern and southern sections of the Rocky Mountain Trench, is designated the *McGregor Plateau* (*see* Plate XXV). Along its eastern side is the valley of the upper Parsnip River and of McGregor River; on its western side is the valley occupied by the Crooked River between Summit Lake and McLeod Lake. On the southwest it is cut off by the valley of the Fraser River, and on the southeast it is cut off by the cross-valley between the McGregor River and the Torpy River.

This plateau lies above 3,000 feet elevation, and in the northern part mostly below 4,000 feet, but in the southern half it rises to a maximum height of 6,866 feet east of Longworth. Northwest of the McGregor River the surface is an eastward extension of the Nechako Plateau, which was separated from it by the ancestral Fraser River flowing northward through the McLeod Lake gap. South of McGregor River the terrain is similar to the Fraser Plateau between the Fraser and Bowron Rivers, though it is somewhat more completely dissected by the Torpy River.

[References: Armstrong, J. E., " Fort St. James Map-area," *Geol. Surv., Canada,* Mem. 252, 1949; Duffell, S., " Whitesail Lake Map-area," *Geol. Surv., Canada,* Mem. 299, 1959; Tipper, H. W., " Nechako River Map-area," *Geol. Surv., Canada,* Mem. 324, 1963; Muller, J. E., and Tipper, H. W., " McLeod Lake," *Geol. Surv., Canada,* Map 2-1962.]

[Photographs: B.C. 468:33; B.C. 523:61, 80; B.C. 763:40; B.C. 766:9.]

Fraser Plateau

Most of the Fraser Plateau (*see* Plate XXVIA) lies west of the Fraser River. It includes the Chilcotin country, and the road from Williams Lake to Anahim Lake crosses the central part of it. The part east of the river is cut into by the Fraser Basin along the Quesnel River and San Jose River. The plateau extends south from the West Road River to a boundary with the Thompson Plateau that is determined by the southern limit of the largely undissected flows of late Miocene plateau basalt. It is flanked on the west by the Coast Mountains (*see* Plate XIB), abuts the Nechako Plateau on the north and the Thompson Plateau on the south, and on the east is flanked by the Quesnel Highland.

The Fraser Plateau is a flat and gently rolling country having large areas of undissected upland lying between 4,000 and 5,000 feet. To the southeast the upland surface rises gradually to 6,000 feet along the margin of the Chilcotin Ranges and west of and south of Canim Lake.

The boundary with the Coast Mountains is sharply transitional, but in places it may be a belt that is several miles wide. From Taseko Lakes northwest it is drawn along a line roughly at the 5,000- to 5,500-foot contour running between the north end of Taseko Lakes and One Eye Lake. From Taseko Lakes east the boundary is drawn roughly at the 6,000-foot contour because the plateau surface is warped upward in this vicinity. On the east the boundary between the Fraser Plateau and Quesnel Highland has been arbitrarily drawn along the 5,000-foot contour. There is no definite division between the two because of the gentle eastward rise of the dissected upland surface of the plateau and its continuation across the highland to the mountains.

A large part of the plateau is underlain by flat or gently dipping late Miocene or Pliocene olivine basalt flows. The flows have steep escarpments along rivers and creeks and almost horizontal upper surfaces. Flat plateau areas separated by near-vertical cliffs are characteristic of lava regions. The existing lava is largely between elevations of 3,000 and 4,500 feet and represents remnants of a large lava plain from which tongues extended outward along major valleys and depressions.

Much of the plateau is covered with glacial drift, and possibly less than 5 per cent of bedrock is exposed. The glacial drift has been modelled into drumlin-like forms by the movement of ice across it. These and the eskers provide much of the low relief on the plateau surface. The ice moved across the Fraser Plateau eastward and northeastward from the vicinity of Anahim Lake, and northeastward to northward from the area between Chilco Lake and the mouth of the Chilcotin River (*see* Fig. 10). Striations on Mount Alex Graham (5,455 feet), 35 miles west of Williams Lake, trend north 25 degrees east, and farther east at The Dome (4,517 feet) trend north 10 degrees east.

A remarkable belt 5 miles wide containing many ice-marginal meltwater channels trends northwestward from Clinton for 15 miles. It is visible on aerial photograph R.C.A.F. A13320:118.

A number of ranges worth special mention lie within the confines of the Fraser Plateau and project above the general plateau level. In the vicinity of Anahim Lake three shield volcanoes of late Miocene age form the Rainbow Range, Ilgachuz Range, and Itcha Range. These volcanoes have built up dome-like piles of lava and fragmental rocks to a height of 8,130 feet at Tsitsutl Peak in the Rainbow Range, 7,873 feet at Far Mountain in the Ilgachuz Range, and 7,760 feet at Mount Downton in the Itcha Range. The Rainbow Range is a low dome-like cone about 20 miles in diameter, with Anahim Peak (6,160 feet) an obsidian plug on its northeast flank. The Ilgachuz Range is 15 miles or more in diameter, and the Itcha Range (*see* Plate XXVIA) is 10 miles wide and about 40 miles long. All have been dissected by late Tertiary, pre-Pleistocene stream erosion.

Three ranges on the southwestern side of the Fraser Plateau lie between it and the border of the Coast Mountains along the Yalakom and Fraser Rivers. These are the Camelsfoot Range between the Yalakom and Fraser Rivers, the Marble Range east of the Fraser River and north of the Marble Canyon, and the Clear Range east of the Fraser River and south of the Marble Canyon.

The Camelsfoot Range and the Clear Range are separated from the Coast Mountains by the structural line of the Fraser River fault, which in this section is a graben. The Camelsfoot Range (*see* Plate XXVIB) reaches summits in excess of 7,500 feet at Yalakom and Red Mountains and at Nine Mile Ridge, presents a steep front along the Yalakom River, and slopes more gently eastward to the Fraser. The Marble Range east of the Fraser River is characterized by bold castellated peaks and ridges of pale grey Upper Permian limestone. This limestone, the upper member of the Cache Creek Group, extends northward from the Cornwall Hills on Upper Hat Creek to Big Bar Creek and beyond. The Clear Range extends southward from Pavilion Lake to Lytton. From its axis, with high points of 7,640 feet at Blustry Mountain and 7,650 feet at Cairn Peak, it has a steep front along the Fraser River to the west and a somewhat more gentle slope down into the Hat Creek valley on the east where transition to the plateau is gradual.

[References: Campbell, R. B., "Quesnel Lake (West Half)," *Geol. Surv., Canada,* Map 59-1959; Tipper, H. W., "Quesnel," *Geol. Surv., Canada,* Map 12-1959; Tipper, H. W., "Anahim Lake," *Geol. Surv., Canada,* Map 10-1957;

Johnston, W. A., and Uglow, W. L., "Placer and Vein Gold Deposits of Barkerville," *Geol. Surv., Canada,* Mem. 149, 1926.]

[Photographs: B.C. 466:117; B.C. 516:99; B.C. 517:81; B.C. 542:6, 33; B.C. 566:81, 108; B.C. 567:64; B.C. 1409:20, 66.]

Thompson Plateau

The Thompson Plateau (*see* Plate XXVIIA) is the most southerly of the plateau areas in the southern Interior, extending southward for about 150 miles from its boundary with the Fraser Plateau at Clinton and having a width of 75 to 90 miles. It includes much of the familiar and well-travelled country in the vicinity of Kamloops, Princeton, and Merritt, as well as the Okanagan and North Thompson Valleys.

The plateau is bounded on the west and south by the Clear Range and the Cascade Mountains. There is complete transition between the plateau and the adjoining mountains because the rise of the plateau surface toward the mountains is gradual, with progressively higher summit levels and greater dissection of the plateau surface. The boundary between them is an arbitrary line. On the southeast and east the plateau is bounded by the Okanagan and Shuswap Highlands, and there, too, the boundary is transitional. The boundary with the Okanagan Highland, between Osoyoos and the Coldstream Valley, is north along the Okanagan Valley to Penticton, thence northeastward along the northwest side of Little White Mountain and the west side of the Buck Hills and down McAuley and Harris Creeks to the Coldstream. From Vernon northwestward the boundary with the Shuswap Highland is along the Louis Creek fault zone to Barriere and thence northward along the North Thompson River.

The Thompson Plateau has a gently rolling upland of low relief, for the most part lying between 4,000 and 5,000 feet, but with prominences of more resistant rock rising above it to 5,952 feet at Gnawed Mountains, 6,630 feet at Mount Thynne, 6,684 feet at Cornwall Hills, 5,653 feet at Swakum Mountain, 6,220 feet at Chuwhels Mountain, 6,218 feet at Lodestone Mountain, 6,545 feet at Pennask Mountains, 6,688 feet at Tahaetkun Mountain, 7,227 feet at Mount Brent, and 7,372 feet at Apex Mountain. This upland represents the late Tertiary erosion surface that has been dissected by the Thompson River and its tributaries and by the Similkameen and Okanagan Rivers tributary to the Columbia.

The plateau contains a great diversity of rocks; stocks of granitic rock intrude sedimentary and volcanic formations of Palæozoic age. Flat-lying or gently dipping early Tertiary (Eocene) lavas obscure large areas of older rocks and their gentle dips to a large extent are reflected by step-like slopes and large unbroken plateau areas.

The area was occupied by Pleistocene ice, and a thick mantle of drift covers bedrock over a large part of it. Movement of the ice over the plateau produced drumlin-like forms oriented southeasterly and southerly. From a divide just north of Clinton, ice moved southeastward and southward along the length of the Thompson River (*see* Fig. 10). The Pleistocene ended with a gradual stagnation and a wasting of the ice in place. As a consequence, ice marginal meltwater channels were quickly made, used temporarily, and then abandoned. On many slopes a series of channels was formed at successively lower levels as ice surfaces wasted. Such channels are to be seen on the walls of the Okanagan Valley and in the Merritt area. The irregular melting of stagnant ice lobes in the larger valleys created numerous temporary glacial lakes into which silt-laden streams discharged. The white silt banks seen in many parts of the southern interior, particularly in the

Thompson and North Thompson River valleys, on lower Okanagan Lake, and elsewhere are remnants of silt beds deposited in extensive glacial lakes which occupied depressions along the front or sides of the wasting ice lobes as the ice-sheet melted and retreated northward, northeastward, and northwestward across the Thompson Plateau.

[References: Rice, H. M. A., "Geology and Mineral Deposits of the Princeton Map-area," *Geol. Surv., Canada,* Mem. 243, 1947; Cockfield, W. E., "Geology and Mineral Deposits of Nicola Map-area," *Geol. Surv., Canada,* Mem. 249, 1948; Duffell, S., and McTaggart, K. C., "Ashcroft Map-area," *Geol. Surv., Canada,* Mem. 262, 1952; Jones, A. G., "Vernon Map-area," *Geol. Surv., Canada,* Mem. 296, 1959; Fulton, R. J., "Merritt Area," *Geol. Surv., Canada,* Map 8-1962; Nasmith, H., "Late Glacial History and Surficial Deposits of the Okanagan Valley, British Columbia," *B.C. Dept. of Mines,* Bull. No. 46, 1962; Mathews, W. H., "Glacial Lakes and Ice Retreat in South Central British Columbia," *Roy. Soc., Canada,* Trans., Vol. XXXVIII, Sec. IV, 1944, pp. 39–57.]

[Photographs: B.C. 356:57; B.C. 498:37; B.C. 651:20, 68, 83; B.C. 653:71.]

Along its eastern margin, where the Interior Plateau borders the Columbia Mountains, the upland surface of the plateau is upwarped and rises from 5,000 feet elevation to more than 6,000 feet across a zone that is 30 to 50 miles wide. The degree of dissection of the upland is greater where the upland surface is higher. There is thus a zone that is transitional between the Interior Plateau on the west, where the degree of dissection is low to moderate, and the Columbia Mountains on the east, where dissection and destruction of the elevated upland surface is complete. The transition zone is sufficiently large to deserve a separate designation and is called a "highland," the name being adopted from the "Okanogan Highlands," the name established for the southern extension of this feature in Washington.* Thus a highland could be described as an elevated region that is intermediate in elevation between a plateau and the adjoining mountains, in which the dissection is well advanced but which retains in its gently sloping uplands the remnants of a widespread, uplifted, and dissected erosion surface of low relief.

The highlands on the east side of the Interior Plateau consist of the Quesnel Highland north of Mahood Lake, flanked by the Cariboo Mountains on the east; the Shuswap Highland between Mahood Lake and Coldstream Valley, flanked by the Monashee Mountains; and at the extreme south the Okanagan Highland, flanked on the east by the Monashee Mountains and extending southward across the 49th parallel into the State of Washington.

Quesnel Highland

The Quesnel Highland (*see* Plate XXVIIB) lies on the western side of the Cariboo Mountains and east of the Fraser Plateau, and extends from Bowron Lake on the north to Mahood Lake on the south. It has a length of 100 miles and a width of about 30 miles. Two isolated remnants of the highland lie north of Two Sisters Mountain in the vicinity of Narrow Lake.

In the Quesnel Highland there are upland areas which are remnants of a highly dissected plateau of moderate relief. In the highland these remants rise gradually from about 5,000 feet on the western side to over 6,500 feet on the eastern side and become progressively more dissected in that direction. The highest points are Roundtop Mountain (6,763 feet), Mount Tinsdale (7,027 feet), Mount Stevenson (7,358 feet), Takomkane Mountain (7,057 feet), Mount Watt (8,265 feet), and

* Culver, H. E., "Geology of Washington," *Washington Div. of Geol.,* Bull. No. 32, 1936, p. 18.

Mount Perseus (8,361 feet). The Snowshoe Plateau east of Barkerville is a large remnant of the uplifted and dissected erosion surface of late Tertiary age.

The area in large part is underlain by closely folded schistose sedimentary rocks of Proterozoic and Lower Cambrian age containing infolds of volcanic and sedimentary rocks of Carboniferous and Permian age. In part there is a relationship between topography and the type of underlying bedrock; limestone and quartzite formations form many of the high peaks.

Pleistocene ice covered most of the high areas and consequently most summits are rounded, but cirques which developed on the northern and northeastern sides during the late stage of glaciation have sharpened the profiles of the highest peaks. Valley glaciers truncated spurs and deposited glacial material over much of the area.

At the southern end of the Quesnel Highland and in the immediately adjoining areas, there are several volcanic landforms that are clearly visible on aerial photographs. When the area is more accessible, they will present points of interest for the venturesome tourist.

There are four or more volcanic vents within a 20-mile radius of the south end of Clearwater Lake. From a conical vent on the southwest side of Ray Mountain, lava flowed down Falls Creek for 6 miles or more, almost to the outlet of Clearwater Lake. Three vents on Spanish Creek west of the head of Donald Creek poured lava down Spanish Creek for 6 to 8 miles. Pyramid Mountain (3,590 feet), almost on the 52nd parallel, is a perfect small cinder cone. The east end of Kostal Lake is blocked by a small breached cinder cone. All these volcanic features are of such recent age that subsequent erosion has hardly modified their original forms.

" The twin peaks of Takomkane Mountain are formed from a cinder cone of olivine basalt that rests on the glaciated surface of the main mountain mass. The cone is about 300 feet high, and from it a flow extends about one-half mile to the northwest. The cone is chiefly built of vesicular cinders and bombs of olivine basalt as much as 2 feet long by 1 foot in diameter. . . . The mountain had obviously been glaciated before the cone was built, and the presence of erratic boulders and minor sculpturing of the cone indicate that it was also glaciated after. All facts indicate that the cone and flows were formed late in the Pleistocene epoch."*

[References: Map No. 1GL, " East Central British Columbia," *B.C. Dept. of Lands and Forests;* Sutherland Brown, A., " Geology of the Antler Creek Area," *B.C. Dept. of Mines,* Bull. No. 38, 1957; Campbell, R. B., " Quesnel Lake (West Half)," *Geol. Surv., Canada,* Map 3-1961; Campbell, R. B., " Quesnel Lake (East Half)," *Geol. Surv., Canada,* Map 42-1961.]

[Photographs: B.C. 482:29, 91; B.C. 487:32; B.C. 765:79.]

Shuswap Highland

The Shuswap Highland (*see* Plate XXVIIIA) extends southward from Mahood and Murtle Lakes to the Coldstream Valley east of Vernon, and lies between the Thompson Plateau on the west and the Monashee Mountains on the east. It is 140 miles long and 50 miles wide. The western boundary of the highland is along a line from the east end of Canim Lake along Mann Creek to Barriere, and thence to Vernon along a lineament coinciding with the Louis Creek fault zone. The eastern boundary is along a line from Blue River down the upper Adams River and across to the head of Anstey Arm of Shuswap Lake, thence via Three Valley to Mabel Lake and Shuswap River to Sugar Lake.

The Shuswap Highland consists of gentle or moderate sloping plateau areas rising from 5,000 to over 7,000 feet, dissected by the Clearwater, North Thompson,

* *Minister of Mines, B.C.,* Ann. Rept., 1957, p. 20.

Adams, and Shuswap Rivers and their tributaries into large polygonal upland tracts. The valley sides are commonly steep because of glacial erosion, and the total relief may be fairly great even though the local relief in the uplands is moderate.

The Shuswap Highland reaches heights of 8,945 feet at Mount Mahood, 9,000 feet at Trophy Mountain, 8,640 feet at Dunn Peak, 7,390 feet at Pukeashun Mountain, and 6,749 feet at Park Mountain. The high points are progressively lower to the south. Most ridges and summits are rounded, and despite the height of much of the terrain the country lacks the jagged sawtooth profiles of the mountains to the east.

The effects of glaciation in the region were largely to soften and reduce the upland relief while steepening and deepening the valleys. Cirque glaciation on northeastern exposures was a minor feature.

Numerous large lakes, such as Murtle, Adams, Shuswap, and Mabel Lakes, occupy some of the major valleys of the area, and these, as well as the rather extraordinary pattern of the drainage, quite obviously diverted from its pre-glacial flow, are legacies of Pleistocene ice occupation.

[References: Jones, A. G., " Vernon Map-area," *Geol. Surv., Canada,* Mem. 296, 1959; Uglow, W. L., " Geology of the North Thompson Valley Map-area," *Geol. Surv., Canada,* Sum. Rept., 1921, Pt. A, pp. 72–106; Walker, J. F., " Clearwater River and Foghorn Creek Map-area," *Geol. Surv., Canada,* Sum. Rept., 1930, Pt. A, pp. 125–153.]

[Photographs: B.C. 359:103; B.C. 487:111; B.C. 490:19, 39.]

Okanagan Highland

The Okanagan Highland (*see* Plate XXVIIIB), the most southerly of the three highland subdivisions, extends southward from the Coldstream Valley for 85 miles to the 49th parallel and thence into the State of Washington. It lies between the Monashee Mountains on the east and the Thompson Plateau on the west. The eastern boundary of the Okanagan Highland is the valley of the Kettle River. The western boundary has been drawn arbitrarily and is somewhat difficult to define, because there are no natural features to follow between Penticton in the Okanagan Valley and Lumby in the Coldstream Valley.

The Okanagan Highland includes rounded mountains and ridges and gentle open slopes on an upland surface reaching 7,118 feet at Mount Moore, 7,000 feet at Jubilee Mountain, 7,603 feet at Big White Mountain, 7,004 feet at Greyback Mountain, 7,550 feet at Baldy Mountain, and 7,372 feet at Apex Mountain. The area is drained and dissected by the Okanagan and Kettle Rivers and their tributaries. Much of the area is underlain by gently dipping Shuswap gneisses, the differential weathering of which has produced gentle step-like slopes.

Pleistocene ice covered the highland, but erosion by it was not great; some rounding of surfaces was effected and a widespread mantle of drift was deposited. Meltwater channels developed at successively lower elevations along the sides of Okanagan Valley as the elevation of the ice surface was reduced. Marginal lakes formed along the sides of the melting ice lobe and streams deposited their loads in them as deltas and accumulations of silt. These latter form the white cliffs which are particularly prominent along southern Okanagan Lake (1,123 feet). The late glacial history and the origins of many minor topographic features are described in detail in British Columbia Department of Mines and Petroleum Resources Bulletin No. 46, 1962.

[References: Nasmith, H., " Late Glacial History and Surficial Deposits of the Okanagan Valley, British Columbia," *B.C. Dept. of Mines,* Bull. No. 46, 1962; Reinecke, L., " Physiography of Beaverdell Area," *Geol. Surv., Canada,* Mus. Bull. No. 11, 1915.]

[Photographs: B.C. 804:45; B.C. 805:14.]

Almost universal throughout most of central British Columbia are the flat or gently sloping upland surfaces that are characteristic of the plateaus and highlands. They are remnants of the very widespread late Tertiary erosion surface which was uplifted and dissected.

During the Tertiary, British Columbia was almost continuously subjected to subaerial erosion by streams. Some early Tertiary sediments were laid down in isolated lake basins and valleys on a surface of mature relief. Later, extensive Miocene and early Pliocene* lava plains of low relief were formed, as plateau basalt filled some valleys and spread across large areas in the Fraser and Nechako Plateaus. Thus by mid-Pliocene the land surface was one of low relief, transecting a wide variety and age of rocks.

The land was elevated differentially in the Pliocene, stream erosion was rejuvenated, and the late Tertiary erosion surface was incised and dissected in varying degrees. The lava plains were slightly eroded before the streams were rejuvenated, and to the west, along the mountain front, incision of the plateau basalt has dated the uplift as post early Pliocene. In the course of the uplift the land surface now represented by the uplands of the Interior Plateau was elevated to 5,000 feet above sea-level in the Nechako and Fraser Plateaus, to 6,000 feet at the edge of the Chilcotin Ranges and in the Quesnel Highland, and to over 7,000 feet in the Shuswap Highland. The main valleys were deeply incised as a result. The amount of incision was progressively less as the valley heads were reached, and in some instances, as on the west side of the Fraser Plateau, the amount of pre-Pleistocene incision of the rivers was slight or had scarcely begun.

Dissection of the upland surface took place contemporaneously with incision of the streams. Dissection varied widely throughout the Interior Plateau, being dependent largely upon the depth to which stream incision had progressed and the elevation to which the late Tertiary surface had been raised. The degree of dissection was greatest in the highlands along the eastern plateau margin, was less in the Thompson Plateau, and least in the western side of the Nechako and Fraser Plateaus, in which large areas of upland to this day remain undissected and scarcely incised.

The amount of dissection of the land is related to the depth of incision of the streams, and this in turn determines the dominant landform of a region. Thus plateaus result where the degree of dissection is low to moderate and where considerable areas of flat or gently sloping upland remain (*see* Plates XVIII, XXIVB, and XXVIA). Highlands represent a transition between plateaus and mountains and result where the degree of dissection is fairly high and where the flat and gently sloping upland surfaces are small and at higher elevations (*see* Plates XVB and XXVIIIA). Mountains result where the dissection of the old surface is complete or where only a few small remnants of it are preserved (*see* Plates XIXB and XXVIIB).

The plateaus and highlands of the Interior Plateau were formed by the dissection in the Pliocene of the late Tertiary erosion surface. Most of the Interior Plateau consists of plateaus, but on the east, where there is a gradual transition to the Columbia Mountains, a belt of highlands has resulted. On the west, however, where the transition between plateau and Coast Mountains is abrupt (*see* Plate XIB), there is no belt of highlands.

The Tertiary era ended with the land standing comparatively high, and with a climatic change that brought on a period of refrigeration, the Pleistocene or Glacial epoch.

In the Pleistocene the Interior Plateau was occupied by an ice-sheet whose upper surface was in excess of 8,000 feet. There was some erosion of valleys in the

* Mathews, W. H., *University of B.C.*, Dept. of Geology, Report No. 2, 1963.

highlands, but the main effects of ice occupation were the deposition of drift over the plateau surfaces and the moulding of drumlins from it. With the wasting of the ice, meltwater channels were occupied temporarily by large streams which long since have disappeared or are greatly diminished in size. After the disappearance of the ice, numerous depressions and blocked valleys were left, which now are occupied by the many lakes of the region.

[Reference: Reinecke, L., "Physiography of the Beaverdell Area," *Geol. Surv., Canada,* Mus. Bull. No. 11, 1915.]

Columbia Mountains

The Columbia Mountains constitute a highly mountainous area 160 miles wide and 380 miles long in the southeastern interior of the Province. They lie west of the Rocky Mountain Trench, and on their western side are flanked by the highland belt of the Interior Plateau. The boundary between the mountains and the trench is distinctly marked by the clean-cut wall of the trench, but the western boundary of the mountains is an arbitrarily selected line because of the transitional nature of the highlands (*see* p. 72). The boundary is drawn from the trench at Slim Creek southward along Bowron and Spectacle Lakes, thence along Hobson and Clearwater Lakes and along Murtle Lake to Blue River. From Blue River the boundary runs down Adams River and across to Anstey Arm of Shuswap Lake, thence by way of Craigellachie and Three Valley to Mabel Lake, across by Tsuius Creek to Shuswap River, then to Sugar Lake and by Monashee Pass to the Kettle River, which is followed southward to the 49th parallel.

The Columbia Mountains include a variety of rocks, ranging from Precambrian metamorphic rocks, mostly of sedimentary derivation, through Palæozoic and Mesozoic sedimentary and volcanic formations, all of which are intruded by a considerable number of granitic stocks and batholiths of varying size. Topographic differences between individual ranges are in part due to altitude and in part due to differences in erosion of the rocks involved.

The Columbia Mountains are drained by the Fraser, North Thompson, Columbia, and Kootenay Rivers and their tributaries. Valleys of several of these rivers divide the Columbia Mountains into their four major subdivisions—the Cariboo Mountains, Monashee Mountains, Selkirk Mountains, and Purcell Mountains.

Cariboo Mountains

The Cariboo Mountains (*see* Plate XXVIIIc) occupy the northernmost part of the triangular-shaped area of the Columbia Mountains. They lie east of the Quesnel Highland and west of the Rocky Mountain Trench and the through valley occupied by the North Thompson River, Albreda River, and Camp Creek. The mountains occupy an area 130 miles long between Blue River and Slim Creek and a maximum of 70 miles wide.

Southward from Slim Creek the summit level gradually increases to Mount MacLeod (8,500 feet) near Goat River, Mount Kaza (8,350 feet), Mount Matthew (8,506 feet) east of Sandy Lake, and Mount Spranger (8,700 feet). The highest peaks of the ranges are in the Premier Group, which lies south of Tête Jaune at the heads of the North Thompson, Raush, and Azure Rivers. Of the several peaks there in excess of 10,000 feet, the highest is Mount Sir Wilfrid Laurier (11,750 feet).

The mountains are drained by the Fraser and North Thompson Rivers and their principal tributaries, the Bowron, Cariboo, Goat, Clearwater, Azure, Raush, and Canoe Rivers, flowing at elevations chiefly between 2,000 and 3,000 feet. The high total relief and the massive boldness of the mountains provide some striking mountain scenery. Strongly glaciated valleys which were subsequenly blocked by glacial debris contain the basins of Bowron, Isaac, Lanezi, Hobson, Quesnel, Azure, and Clearwater Lakes.

The Cariboo Mountains are composed of sedimentary rocks and metamorphosed sedimentary rocks of Proterozoic and Lower Cambrian age. Although some limestone is present, the principal rock type is quartzite in members of great thickness. The rocks are folded about northwesterly striking axes into overturned folds which in turn may be faulted parallel to their strike. The resistant quartzites to a large degree influence the topographic forms developed. In the Clearwater area "the character and structure of the underlying formations have noticeably affected the configuration of the present surface. On the upland surface where underlain by the metamorphic series the peaks are sharp and the ridges continuous, where underlain by granite the peaks are more massive and rounded and the ridges irregular or radiating from a central mass."*

The Cariboo Mountains comprise a number of longitudinal ranges trending northwestward parallel to the strike of the underlying sedimentary rocks. Individual mountains and mountain ranges rise to high serrate peaks of heights to 11,750 feet that are glacially sculptured and are separated by steep-walled glaciated valleys that commonly form a trellis pattern controlled by the underlying bedrock. The axis of the mountains lies to the east of Isaac Lake and runs southeastward through the Premier Group.

The mountains were intensely glaciated, and peaks higher than 8,000 feet projected through the Pleistocene ice-cap as nunataks which were subjected to intense frost action and cirque attack. There are some rounded summits and ridges below 7,000 and 7,500 feet, but intense late-stage cirque glaciation on the northern and northeastern slopes has produced many sharp peaks and sawtooth ridges which characteristically combine gentler southerly and southwesterly slopes with steep and abrupt northerly and northeasterly slopes. The intensely glaciated trunk valleys exhibit U-shaped profiles, while tributary valleys are hanging in relation to them (*see* Plate XXVIIIc).

[Reference: Sutherland Brown, A., "Geology of the Cariboo River Area," *B.C. Dept. of Mines,* Bull. No. 47, 1963.]

[Photographs: B.C. 387:65; B.C. 482:59; B.C. 487:62, 86; B.C. 765: 37, 58.]

Monashee Mountains

The Monashee Mountains (*see* Plate XXIXA) occupy a northerly trending area 250 miles long and for the most part 25 to 30 miles wide, lying between the Selkirk Mountains on the east and the Cariboo Mountains and the Shuswap and Okanagan Highlands on the west. The Monashee Mountains are widest at their southern end between the Kettle and Columbia Rivers, a width of 55 miles. The boundary with the Selkirk Mountains, southward from Boat Encampment, is along the Columbia River-Arrow Lakes valley.

The mountains comprise a number of individual ranges which have a northerly to northeasterly trend south of latitude 50 degrees 30 minutes, but which swing to a northwesterly trend farther north. This northwesterly trend is parallel to the bounding Columbia River as far north as Goldstream. North of Goldstream the boundaries of the Monashee Mountains—namely, the North Thompson and Al-

* *Geol. Surv., Canada,* Sum. Rept., 1929, Pt. A, p. 281.

breda Rivers on the west and the Columbia River on the east—occupy northerly and northeasterly valleys crossing the topographic and geologic grain of the country.

The Monashee Mountains are underlain by sedimentary and metamorphic rocks, largely gneissic rocks of the Shuswap terrain, by Palæozoic and Mesozoic sedimentary and volcanic rocks, and by batholiths and stocks of Lower Cretaceous and younger age. The Shuswap rocks are widespread between Shuswap and Sugar Lakes; meta-sedimentary rocks of Proterozoic and Lower Cambrian age underlie the northern ranges, while the southern ranges are largely underlain by intrusive rocks and foliated gneisses.

The highest peak in the mountains near the north end is Hallam Peak (10,560 feet), and the next highest is Gordon Horne Peak (9,562 feet) northwest of Goldstream. South of Revelstoke there are seven peaks over 9,000 feet in the Gold Range, of which Mount Odin (9,751 feet) is the highest and the southernmost. To the south the peaks are progressively lower, with elevations of 8,791 feet at Mount Fosthall, 7,400 feet at Whatshan Peak, and 7,440 feet at the Pinnacles. In the Midway Range the extreme height is 7,390 feet at Mount Tanner, and from it a number of peaks over 7,000 feet extend southward to Almond Mountain (7,604 feet), south of which the summit level declines to just above 5,000 feet. In the Rossland Range the highest point is Old Glory Mountain, elevation 7,795 feet.

The mountains are drained by the North Thompson, Fraser, and Columbia Rivers and their tributaries, flowing at elevations largely between 1,500 and 3,000 feet. The relief is greatest to the north, being 8,000 feet between Mount Odin and the Columbia River, 8,600 feet between Hallam Peak and the Canoe River, about 5,000 feet in the Midway Range between Mount Tanner and the Kettle River, and even less farther south near the 49th parallel.

The high mountains, especially those in the northern ranges, are mostly massive and bold sharp peaks separated by deep, steep-sided valleys. Peaks above 8,000 feet projected through the Pleistocene ice-sheet and were subjected to intense cirque glaciation which produced matterhorn-like peaks. Lower summits were covered by ice at one stage and subsequently have been sculptured by cirque and valley glaciers to sharp peaks and sawtooth ridges. It is only in the southern ranges at elevations below 7,000 feet that rounded or only moderately pointed summits prevail. The valleys, especially those parallel to the southerly moving ice, were intensely glaciated, with considerable modification of their longitudinal and transverse valley profiles. On the retreat of the ice a mantle of drift, deeper in the valley bottoms than on the sides, was left everywhere.

A few cirque glaciers in the Gold Ranges and in the ranges north of Revelstoke remain as reminders of the former extensive Pleistocene ice cover.

[References: "Kettle River (East Half)," *Geol. Surv., Canada,* Map 6-1957; Little, H. W., "Geology, Kettle River," *Geol. Surv., Canada,* Map 19-1961; Jones, A. G., "Vernon Map-area," *Geol. Surv., Canada,* Mem. 296, 1959; Little, H. W., "Nelson Map-area (West Half)," *Geol. Surv., Canada,* Mem. 308, 1960.]

[Photographs: B.C. 489:60; B.C. 490:107; B.C. 804:94.]

Selkirk Mountains

The Selkirk Mountains (*see* Plate XXX) lie directly to the east of the Monashee Mountains in an area about 220 miles long and 40 to 50 miles wide. They lie within the big bend of the Columbia River and are flanked on the west by the Monashee Mountains and on the east by the Purcell Mountains. The boundary with the Monashee Mountains is along the valley which, south of Boat Encampment, is occupied by the Columbia River and the Arrow Lakes. The boundary with the Purcell Mountains is along the through valley which extends southward from the Rocky Mountain Trench and contains the Beaver River, Duncan River, Duncan Lake, Kootenay Lake, and Kootenay River.

The mountains comprise a number of individual ranges which in the south trend northeastward, at and north of Nelson trend northward, and in the north trend northwestward. They form a curve convex to the east, which is the topographic expression of the Kootenay Arc, a major structure of the underlying bedrock.

In the northern Selkirk Mountains the bounding valleys of the Columbia River north of Goldstream and the upper Duncan and Beaver Rivers cut across the topographic and geologic trends of the mountains. Although those valleys provide the physical basis for separating the northern Monashee, Selkirk, and Purcell Mountains, the northern ranges of all three mountains are, geologically and topographically, very much alike.

The Selkirk Mountains are underlain by a variety of rocks: by Proterozoic and Lower Palæozoic sedimentary and metamorphic rocks, by gneiss of both sedimentary and igneous origin, by late Palæozoic and Mesozoic sedimentary and volcanic rocks, and by granitic stocks and batholiths of Cretaceous and early Tertiary age. The Proterozoic and Lower Palæozoic rocks include prominent quartzite and limestone members which are resistant to erosion and form many of the highest peaks. Carnes Peak (10,000 feet), Mount Moloch (10,198 feet), and Mount Sir Sanford (11,590 feet) are limestone, as are the highest peaks in the Badshot Range north of Trout Lake—Mount Badshot, Mount Templeman, and Mount Abbot.

The sedimentary rocks are complexly and as a rule isoclinally folded about axes that regionally have an arcuate trend, convex to the east, which is reflected in the trends of individual ranges.

The Proterozoic and Lower Palæozoic sedimentary and volcanic rocks form most of the mountains north of Trout Lake. Triassic sedimentary rocks (Slocan Group) occupy an east-west belt between Nakusp and Kaslo, and, with Jurassic rocks, form a broken irregular area southwest of Nelson. The Kuskanax batholith occupies a large area south of Trout Lake, and most of the area between Silverton and Trail is underlain by the Nelson batholith and associated gneiss. Differences in the underlying rocks provide topographic differences between the various ranges.

The Selkirk Mountains contain some very high and very rugged mountain country. North of the Illecillewaet River there are a number of 10,000-foot peaks, and the highest peak in the mountains is Mount Sir Sanford (11,590 feet) in the Sir Sanford Range at the head of Gold River. Between the Illecillewaet River and the Trout Lake–Lardeau River valley there are many 10,000-foot peaks and three over 11,000 feet, of which Mount Dawson (11,123 feet) in the Dawson Range at the head of Incomappleux River is the highest. The highest peak in the Slocan Ranges is Kokanee Peak (9,200 feet); in the Valhalla Range, Gladsheim Peak (9,275 feet); farther south the summits are below 8,000 feet.

The northernmost mountains are the highest, and in the Selkirks and adjoining mountains it would appear that the greatest amount of late Tertiary uplift was in the area extending from Tête Jaune on the north to Windermere on the south.

The area is drained by the Columbia and Kootenay Rivers and their tributaries. The Illecillewaet River cuts transversely across the northern Selkirks, and the Trout Lake-Lardeau River valley crosses them mainly parallel to the individual ranges and the geologic structure. Slocan River, Slocan Lake, and the through valley to Nakusp serve to separate the Slocan Ranges on the east from the Valhalla Ranges on the west. The Salmo River separates the Nelson Ranges, west of south Kootenay Lake, from the Bonnington Ranges, which lie east of the Columbia River.

The amount of relief is governed by the elevations at which the rivers are flowing, and these in turn are controlled by various lake-levels, such as 1,379 feet at Lower Arrow Lake, 2,235 feet at Kinbasket Lake, 1,753 feet at Slocan Lake, 2,400 feet at Trout Lake, and 1,765 feet at Kootenay Lake.

The ranges north of Trout Lake are extremely rugged and have high relief. The peaks are sharp and are separated by deeply incised glaciated valleys. There are few interconnecting ridges. The high peaks projected through the Pleistocene ice-sheet and still hold numerous icefields and glaciers which have sculptured the summits in typical fashion. The sedimentary and metamorphic rocks of the region have a northwesterly trend, which controls the direction of the ranges and has imposed a trellis-like pattern upon the drainage.

South of Trout Lake the area is largely underlain by intrusive rocks, which Cairnes remarks in the Slocan Mountains " show the strong relief characteristic of a mountainous topography in a late adolescent stage of erosion. . . . The areas of Nelson granite and Kaslo series are normally more rugged and sharper in outline than those underlain by sediments of the Slocan series."* The Slocan Ranges are characterized by long, uniformly steep, heavily timbered slopes rising through about 5,000 feet to angular peaks and sharp narrow interconnecting ridges. Cirque glaciers have sculptured the peaks, and high ridges and valley glaciers have facetted the spurs.

South of Nelson the several ranges comprising the southern Selkirk Mountains do " not show the rugged alpine topography of the Slocan, Lardeau, and more northerly ranges of the system. The mountains of the southern Selkirks [*see* Plate XXIXB] are more subdued and rounded than those of the north with fewer rugged peaks and serrated ridges and without the youthful glacial forms due to higher uplift and more recent sculpture by mountain glaciers. In this portion of the Selkirks there are practically no glaciers and the ranges form a transition belt of mountains connecting the high and rugged Canadian Selkirks with the low, subdued mountain ranges of the same system which border the Columbia lava plain in Washington state. . . . Glacial forms, including cirques, arêtes, trough-shaped valleys, truncated spurs, hanging valleys, roches moutonnées, and valley terraces, are prominent topographic features in the landscape."†

[References: Wheeler, J. O., " Rogers Pass Map-area," *Geol. Surv., Canada*, Paper 62-32; Little, H. W., " Nelson Map-area (West Half)," *Geol. Surv., Canada*, Mem. 308, 1960; Gunning, H. C., " Geology and Mineral Deposits of Big Bend Map-area," *Geol. Surv., Canada*, Sum. Rept., 1928, Pt. A, pp. 136–193; Walker, J. F., and Bancroft, M. F., " Lardeau Map-area," *Geol. Surv., Canada*, Mem. 161, 1930; Cairnes, C. E., " Slocan Mining Camp," *Geol. Surv., Canada*, Mem. 173, 1934; Drysdale, C. W., " Ymir Mining Camp," *Geol. Surv., Canada*, Mem. 94, 1917; Walker, J. F., " Geology and Mineral Deposits of Salmo Map-area," *Geol. Surv., Canada*, Mem. 172, 1934; Fyles, J. T., and Eastwood, G. E. P., " Geology of the Ferguson Area," *B.C. Dept. of Mines*, Bull. No. 45, 1962.]

[Photographs: B.C. 489:82, 107.]

Purcell Mountains

The Purcell Mountains occupy an elongate triangular area 190 miles long and 50 miles in maximum width. The Purcell Mountains lie east of the Selkirk Mountains and are separated from them by the long through valley occupied by the Beaver River, Duncan River, Duncan Lake, and Kootenay Lake. On the east they adjoin the Rocky Mountain Trench.

* Cairnes, C. E., *Geol. Surv., Canada*, Mem. 173, 1934, p. 22.
† Drysdale, C. W., *Geol. Surv., Canada*, Mem. 94, 1917, p. 7.

The Purcell Mountains (*see* Plate XXXIA) include some extremely high and rugged mountainous country, and the highest peak, Mount Farnham (11,342 feet), is only slightly inferior in height to Mount Sir Sanford (11,590 feet), which is the highest in the Selkirk Mountains. The ranges at the north end of the Purcell Mountains gradually increase in summit level south from Beavermouth, reaching their maximum heights in the area between the heads of Bugaboo and Findlay Creeks in Mount Farnham (11,342 feet), Jumbo Mountain (11,217 feet), Hamill Peak (10,640 feet), and Mount Findlay (10,780 feet). The northern ranges are inferior in height to the ranges in the Selkirk Mountains due west in Glacier Park, whereas due west of the highest Purcell Mountains lie the somewhat lower Slocan Ranges of the Selkirks. South of Mount Findlay, summit heights diminish gradually, Mount Loki (9,090 feet), northeast of Riondel, and Mount Evans (8,949 feet), southwest of St. Mary Lake, being the highest. At the International Boundary the summit heights are in the vicinity of 7,000 feet and the topography is comparatively subdued.

The axis of the mountains lies closer to their western margin than to their eastern. Westward drainage is by short steep streams, whereas eastward drainage is on gentler gradients by longer tributaries. Along the east side of Kootenay Lake the tributary creeks flowing in narrow deep valleys have carved out a series of narrow ridges running east and west, ranging in elevation from 7,000 feet on the ends overlooking the lake to 8,000 feet and higher on the eastern ends.

The mountains are drained by tributaries of the head of the Columbia River and by the Kootenay River and its tributaries. Kootenay Lake at 1,755 feet elevation and Columbia Lake at 2,852 feet elevation are significant heights in the drainage systems, above which the mountains rise to a maximum regional relief of about 8,000 feet.

The Purcell Mountains are underlain by sedimentary and metamorphic rocks, largely of Proterozoic age but extending upward into the Lower Palæozoic, which are intruded by batholiths of granitic rocks. The sedimentary and metamorphic rocks comprise thick quartzite, argillaceous quartzite, argillite, and limestone members; the lithology is far more uniform in the Purcell Mountains than in the Selkirks. The rocks are involved in overturned and frequently complex folds about axes which regionally have an arcuate plan, being northeasterly in the south, northerly in the central ranges, and northwesterly in the north. The trends of individual ranges are controlled by this fundamental bedrock structure.

The northern ranges contain rugged high peaks which are massive and bold when composed of quartzite or granite, and sharp and pinnacled when composed of slates. The highest peaks projected above the Pleistocene ice-sheet, whose level lay at 8,000 feet in the north and at about 7,000 feet in the south. The peaks were shaped by intense cirque glaciation, and active cirque glaciers are still present on some of the highest peaks. The summits are separated by deep, steep-sided glaciated valleys, and interconnecting ridges are few and mostly serrate. In the southern Purcell Mountains south of Mount Findlay and Skookumchuck Creek " the mountains up to 7,000 feet are rounded and well wooded to the summit, higher ones are commonly extremely rugged, and those carved out of granite or massive quartzites are climbed only with extreme difficulty. Near the International Boundary few peaks rise above 7,000 feet and the topography is comparatively subdued. To the north, where the elevation of the higher peaks is 8,000 or 9,000 feet, the terrain is extremely rugged. A feature that causes the abrupt relief and consequent steepness of the mountains is the deeply incised valleys that reach far back into the heart of the range."*

" Glacial striae, erratics, and glacial debris occur at all elevations up to 8,000 feet.

* Rice, H. M. A., *Geol. Surv., Canada,* Mem. 228, 1941, p. 2.

" Striae, roches moutonnées, and like phenomena indicate that this ice sheet moved in a generally southerly direction, but with a tendency to follow the main topographical features such as the Purcell and Rocky Mountain Trenches. Thus the ice on the east flank of the Purcell Range moved southeast and that on the west flank southwest. It seems probable that the land surface overlain by the ice was one of high relief, with the principal ridges and valleys in much the same positions as those of today. Over these mountains and ridges and over the ice filled transverse valleys the ice sheet, although thick, apparently moved as a unit. As it thinned down, the underlying topography assumed control and a stage of valley and alpine glaciation ensued. During this stage the ice sheet broke up into lobes which flowed down the principal valleys.

". . . the ice sheet in the floor of the Rocky Mountain Trench disappeared by a process of stagnation, breaking up into units and melting away in situ. The results of this process are apparent in the huge kettles, kames, etc., that line much of the floor of the trench."*

[References: Schofield, S. J., " Geology of Cranbrook Map-area," *Geol. Surv., Canada,* Mem. 76, 1915; Walker, J. F., " Geology and Mineral Deposits of Windermere Map-area," *Geol. Surv., Canada,* Mem. 148, 1926; Walker, J. F., " Kootenay Lake District," *Geol. Surv., Canada,* Sum. Rept., 1928, Pt. A, pp. 119–135; Evans, C. S., " Brisco-Dogtooth Map-area," *Geol. Surv., Canada,* Sum. Rept., 1932 Pt. AII, pp. 106–176; Rice, H. M. A., " Nelson Map-area (East Half)," *Geol. Surv., Canada,* Mem. 228, 1941; Reesor, J. E., " Lardeau Area," *Geol. Surv., Canada,* Map 12-1957; Reesor, J. E., " Dewar Creek Map-area with Special Emphasis on the White Creek Batholith," *Geol. Surv., Canada,* Mem. 292, 1958; Leech, G. B., " St. Mary Lake Area," *Geol. Surv., Canada,* Map 15-1957; Rice, H. M. A., " Cranbrook Map-area," *Geol. Surv., Canada,* Mem. 207, 1937.]

[Photographs: B.C. 898:80, 82; B.C. 899:3, 18.]

III. EASTERN SYSTEM

The Eastern System is the easternmost of the three primary subdivisions of the Canadian Cordillera in British Columbia and flanks the Interior System along its eastern side. The boundary between the two lies along the Rocky Mountain Trench and along the eastern side of the Liard Plain. On its eastern side the Eastern System in turn is flanked by the Interior Plains of Central Canada. The northeastern part of the Province extends across the full width of the Eastern System and into the Interior Plains, but southeast of the Narraway River the eastern margin of the Eastern System lies in Alberta, and for a length of 450 miles only the western part of the System is in British Columbia.

The Eastern System is a mountainous belt extending northwestward along the entire length of the Province from the 49th parallel for 900 miles to the 60th parallel. It has a width of 50 miles at its narrowest section at the head of the Murray River and a width of 90 miles between Sifton Pass and the Tetsa River.

The Eastern System consists of the Arctic Mountain Area, the Mackenzie Mountain Area, and the Rocky Mountain Area. The Mackenzie Mountain Area lies largely in the Yukon and District of Mackenzie, and only a small part of one of its subdivisions, the Liard Plateau, extends southward into British Columbia as far as the Liard River. The northern limit of the Rocky Mountain Area is the Liard River, from which it extends southeastward for 850 miles to the 49th parallel. The Rocky Mountain Area is divided into the Rocky Mountains and the Rocky Moun-

* Rice, H. M. A., *Geol. Surv., Canada,* Mem. 228, 1941, p. 3.

tain Foothills. The foothills are lithologically and structurally different from the Rocky Mountains, and in northeastern British Columbia the topographic separation of the two mountain belts is distinct.

MACKENZIE MOUNTAIN AREA

Liard Plateau

The Liard Plateau (*see* Plate XXXIb) extends southward into British Columbia from the Yukon, where it has a considerably greater extent. On the west the plateau is bordered by the Liard Plain, the boundary being drawn east of the Smith River along the general line of the 2,500-foot contour. On the east the plateau merges in the Interior Plains, the boundary being drawn northward from the junction of the Toad and Liard Rivers along the general line of the 2,000-foot contour. The Liard River forms the southern boundary of the Mackenzie Mountain Area. It separates the lower heights of the Liard Plateau from the higher elevations of the Rocky Mountains lying south of the river. It also marks a line along which north-trending bedrock structures north of the river are truncated by northwesterly trending Rocky Mountain structures south of the river. Geologically, the Liard Plateau is at the southern termination of the Mackenzie Mountain structures.

The plateau is underlain by sedimentary rocks ranging in age from Devonian to Triassic. The rocks are folded about southerly plunging axes which trend essentially north, veering slightly east of north at the Yukon Border.

The Liard Plateau has its maximum height of 5,595 feet at a peak on the north side of Grayling River, about 30 miles northwest of Hells Gate. For the most part, the plateau consists of rounded and flat-topped summits and timbered ridges lying below 5,000 feet elevation, gradually diminishing in height to the east. Northerly and northeasterly trending summit levels are controlled by the trends of some of the more resistant underlying formations. The upland surface is incised to elevations below 2,500 feet by the Grayling, Scatter, and Crow Rivers, which are tributary to the Liard, whose elevation at the mouth of Smith River is 1,450 feet.

The area was covered by the Pleistocene ice-sheet, and the ice, as did the glacial meltwater, escaped eastward down the Liard Valley (*see* Plate XXXVIIa) from a gathering area to the southwest. Ice which moved northeastward and eastward across the surface of the plateau left drumlin-like forms east of the Smith River Airport (*see* N.T.S. Sheet 94m).

[Reference: Kindle, E. D., " Geological Reconnaissance along Fort Nelson, Liard, and Beaver Rivers," *Geol. Surv., Canada,* Paper 44–16.]

[Photographs: B.C. 952:65; B.C. 957:59; R.C.A.F. T27L:119; R.C.A.F. T27R:101.]

ROCKY MOUNTAIN AREA

Rocky Mountains

The Rocky Mountains extend in a northwesterly direction along the eastern side of the Province for 850 miles between the 49th parallel and the Liard River. Their western boundary is the Rocky Mountain Trench, which, except for the interruption at the McGregor River, exists as a continuous valley for the entire distance. On the east the Rocky Mountains are flanked by the Rocky Mountain Foothills, which are not everywhere inferior in height to the main mountains.

The boundary between the Rocky Mountains and foothills follows a structural line between belts that differ in both lithology and rock structure. As a consequence, there may be fundamental topographic differences between the two.

Specifically, the boundary between the Rocky Mountains and the Rocky Mountain Foothills for the most part is along the easternmost fault on which Devonian and (or) Permo-Carboniferous limestones are thrust over Mesozoic formations. The boundary extends southeastward from the Liard River at Sulphur Creek, past Stone Mountain and through Mile 389 on the Alaska Highway, thence more southerly to pass just east of the Tuchodi Lakes and just east of Redfern Lake on Besa River, crosses the Peace River at the mouth of the Nabesche River, and crosses the Pine River at the upper Pine River bridge east of Mount Solitude. The boundary then veers more to the southeast, and crosses the Alberta-British Columbia Boundary 15 miles northeast of Mount Ida. Southeast of Mount Ida the interprovincial boundary follows the continental divide between Pacific and other drainage, and the eastern margin of the Rocky Mountains is in Alberta.

In Alberta the boundary between the Rocky Mountain Front Ranges and the western margin of the foothills is taken as the McConnell thrust north of the Highwood River, and the Livingstone and Lewis thrusts south of the Highwood River.

The Rocky Mountains are underlain very largely by sedimentary and metamorphic rocks, which range from Proterozoic to Cretaceous in age. The youngest rocks are exposed in the foothills, and progressively older rocks lie to the west. The predominant rocks of the Rocky Mountains are Palæozoic and Proterozoic limestones, quartzites, schists, and slates. In contrast, the foothills contain a predominance of Mesozoic, especially of Cretaceous, formations. Two formations of volcanic origin are known to occur, one of possible Mississippian age and the other Lower Cretaceous. The intrusive rocks are so few that they have no regional geomorphic significance.

During the Pleistocene the ranges were covered to heights of 7,000 to 8,000 feet by continental ice, the erosional effects of which are slight compared to the modifications wrought by alpine and valley glaciers. These have produced characteristic glaciated alpine scenery comparable to famous localities in Europe. In the southern Rocky Mountains there is an area where the Cordilleran ice reached a height of only 6,500 feet. There are as a consequence considerable areas above that elevation that were unglaciated.*

There are four divisions of the Rocky Mountains in Canada in their 850-mile length between the International Boundary at the 49th parallel and the Liard. These are the Border Ranges between the International Boundary and a line between Elko and North Kootenay Pass; the Continental Ranges extending northwestward from a line between Elko and North Kootenay Pass to Jarvis Creek just north of Mount Sir Alexander; the Hart Ranges between Jarvis Creek and the Peace River; and the Muskwa Ranges between the Peace River and the Liard River.

Border Ranges

The southernmost ranges of the Rocky Mountains in Canada are the Border Ranges. They lie south of a line running from Elko along the southern edge of the Fernie Basin to North Kootenay Pass and are an extension north of the International Boundary of the Montana Ranges of the physiographic subdivision named in the United States the Northern Rocky Mountain Province. Along the International Boundary from west to east the Border Ranges in Canada are the Galton, MacDonald, Clarke, and Lewis Ranges. The extensions into Montana of the

* Stalker, A. M., *Geol. Surv., Canada,* Map 31-1961.

Galton and MacDonald Ranges are named the Whitefish Range, the southern extension of the Clarke Range is called the Livingstone Range, and only the Lewis Range has the same name on both sides of the border.

The Border Ranges lying within British Columbia are the Galton and MacDonald Ranges, and the western part of the Clarke Range.

The *Galton Range* lies between the Rocky Mountain Trench and the Wigwam River. Its length between the Elk River and the boundary is 22 miles, and its maximum width at the south is 8 miles. High peaks of 7,000 and 7,500 feet rise along a straight abrupt front above the Trench, whose general terrace elevation is about 3,000 feet. The Galton Range is a comparatively simple synclinal block of late Proterozoic argillaceous sedimentary rocks bounded by a steep fault-line scarp along the Rocky Mountain Trench and by the Wigwam fault along the valley of the Wigwam River.

The *MacDonald Range* (*see* Plate XXXIIB) lies between the Wigwam and Flathead Rivers and south of the Fernie Basin, whose southern limit is at Lodgepole and McLatchie Creeks. The range consists of a number of northwesterly trending ridges whose trend is dominated by the northwesterly strike of the sedimentary formations and of the numerous faults.

The highest mountains, with elevations of 7,500 feet, rise above the Wigwam River valley at 4,000 feet and the Flathead River valley at 4,500 feet. This relief displays moderate, timbered slopes on the argillaceous and silty rocks and steep, comparatively bare slopes where limestone predominates. For example, there is considerable contrast between Outlier Ridge, which consists of argillite, siltstone, and sandstone, Inverted Ridge, which is predominantly limestone, and Trachyte Ridge, in which limestone beds are intruded by several syenitic and trachytic intrusions.

The lower Flathead River valley is eroded in a structural basin underlain by nearly flat to moderately dipping, poorly consolidated early Tertiary sedimentary rocks. These rocks extend up to elevations of 6,000 feet, and because of their poor consolidation produce gentle slopes within the valley.

The *Clarke Range* (*see* Plate XXXIIIA) extends eastward from the Flathead River valley beyond the Alberta-British Columbia Boundary to terminate along the Lewis thrust in southwestern Alberta. Only the western third of the range lies in British Columbia.

The range consists of a great thickness (15,000 feet or more) of late Precambrian sedimentary rocks consisting of argillite, siltstone, sandstone, and limestone in resistant beds of considerable thickness. These rocks are warped in a broad synclinal basin lying above the Lewis overthrust. They form bold, massive mountains to heights of 8,600 feet in British Columbia, with gentle dip slopes and steep, impressive scarp slopes on resistant formations.

The western edge of the Clarke Range is a fault-line scarp along the Flathead fault. The mountains descend abruptly to the broad flat valley of the Flathead River at about 4,500 feet elevation.

The mountains are fretted by wide steep-walled cirques at elevations of 5,500 and 6,000 feet cut into the gently dipping sedimentary rocks of the 7,500- to 8,500-foot mountain summits. These broad cirque basins at the heads of wide glaciated valleys are surrounded by impressive cliffs of light-grey limestone and darker quartzite and argillite, and are an outstanding feature of the Clarke Range.

Tourists in British Columbia are unable to see the natural beauty of the western part of Clarke Range, but a visit to Waterton Lakes National Park in Alberta offers an opportunity to see the equally spectacular eastern side of the Clarke Range.

[References: Price, R. A., "Fernie Map-area (East Half)," *Geol. Surv., Canada,* Paper 61-24; Leech, G. B., "Fernie (West Half)," *Geol. Surv., Canada,* Map 11-1960; Hume, G. S., "Waterton Lakes-Flathead Valley Area," *Geol. Surv., Canada,* Sum. Rept., 1932, Pt. B, pp. 1–20; Stalker, A. M., "Surficial Geology, Fernie (East Half)," *Geol. Surv., Canada,* Map 31-1961; Ross, C. P., "Glacier National Park and Flathead Region," *U.S.G.S.,* Prof. Paper 296, 1959; Alden, W. C., "Physiography and Glacial Geology of Western Montana," *U.S.G.S.,* Prof. Paper 231, 1953.]

Continental Ranges

The Continental Ranges extend southeastward from Jarvis Creek and the head of Kakwa River at approximately 54 degrees latitude to their southern termination along a line from Elko running along Elk River, Lodgepole and McLatchie Creeks to Flathead River, and thence through North Kootenay Pass to Carbondale River. They are about 400 miles long and 60 miles wide.

The Continental Ranges are the best known of the Rocky Mountains. They are crossed by railways and highways through the Yellowhead, Kicking Horse, and Crowsnest Passes, and over the years have been visited by mountaineers, surveyors, geologists, and tourists, so that the more accessible parts of them have become very well known. Southward from Mount Sir Alexander (10,740 feet) and Mount Ida (10,472 feet) at the head of the McGregor River they include many 10,000- and 11,000-foot peaks as well as Mount Robson (12,972 feet), the highest summit in the Canadian Rockies.

In the south, between Yellowhead Pass and North Kootenay Pass, there are numerous geological descriptions of various parts of the Continental Ranges of the Rocky Mountains. Geologists have made a longitudinal division of the mountains into three structural units* whose lithologic and topographic differences are sufficient to justify their use as physiographic subdivisions. These are the Front Ranges, which lie on the east and are flanked immediately on their east by the Rocky Mountain Foothills, the Park (Main) Ranges, and on the west the Kootenay (Western) Ranges, which lie between the Kootenay-White River lineament and the Rocky Mountain Trench.

The *Front Ranges* (*see* Plate XXXIIIB) of the Rocky Mountains consist of a number of longitudinal ranges whose topographic continuity is very largely influenced by the presence of certain rock formations whose positions in turn are largely controlled by underlying fold and fault structures. In the south the Front Ranges are defined geologically as lying west of the McConnell and Livingstone faults and east of the Castle Mountain fault.

Between Intersection Mountain and the vicinity of Mount Assiniboine and Kananaskis Lake the ranges lie entirely within Alberta. Farther south their trend veers southward, and the westernmost of the Front Ranges are in British Columbia. In the vicinity of Crowsnest Pass the Front Ranges in British Columbia are the High Rock Range along the British Columbia-Alberta Boundary (*see* Plate XXXIIIB), Erickson Ridge and the Flathead Range on the east side of Fernie Basin, the range on the west side of Fernie Basin that includes Mount Hosmer,† and the Lizard Range. In fact, the Front Ranges, that farther north are a marginal feature, do not continue south of Crowsnest Pass, but instead follow the structural trend of the Fernie Coal Basin diagonally across the full width of the Rocky Mountains to Elko.

* North, F. K., and Henderson, G. G. L., *Alta. Soc. Pet. Geol.,* Guidebook No. 4, 1954, p. 16.
† Idem, p. 20.

The Front Range structures consist of a succession of overthrust sheets lying between southwesterly dipping faults which slice the great limestone formations of the Upper Devonian and Carboniferous into a number of blocks. Erosion of these geologically complex blocks has produced the numerous parallel ranges which constitute the Front Ranges, each range being composed mostly of thick southwesterly dipping limestones. The resistant limestone forms 30- to 45-degree dip slopes facing southwest, and steep scarp slopes facing northeast. Late Pleistocene cirque glaciation has accentuated the sharpness of the topography of the east- and northeast-facing scarps. The Front Ranges form striking mountain units that rise abruptly above broad glaciated longitudinal valleys which separate them.

In the south many of the valleys separating individual ranges are underlain by soft, more easily eroded sandy and shaly rocks of Jurassic and Cretaceous age. These low areas of Mesozoic rock for the most part are too small to be separately designated. However, west of Erickson Ridge and Taylor Range and east of the range flanking the west side of the Elk River there is a structural basin in which Jurassic and Cretaceous rocks occur. This is the Fernie Basin (*see* Plate XXXIVA), which has a length of 65 miles and a maximum width of 15 miles near the south end. The east and west boundaries of the Fernie Basin are fault-controlled.

North of the railway bend at Natal the Fernie Basin is very largely the valley of the Elk River with flanking ridges such as Natal Ridge (7,000 feet) and Fording Mountain (6,000 feet) along the eastern side. South of Natal the basin widens, and elevations of 7,000 feet are reached on Fernie Ridge and east of the head of Coal Creek. There the rocks lie in a gentle open syncline. The gently sloping uplands at elevations above 5,000 feet are being incised by tributaries of the Elk River, Michel and Morissey Creeks, and the Flathead River. The general aspect of the Fernie Basin is one of moderate relief, in which gently sloping uplands descend by more abrupt lower slopes to the levels of the Elk and Flathead Rivers and their tributaries.

[References: Leech, G. B., "Geology, Fernie (West Half)," *Geol. Surv., Canada,* Map 11-1960; Price, R. A., "Fernie Map-area (East Half)," *Geol. Surv., Canada,* Paper 61-24.]

[Photographs: B.C. 891:73; R.C.A.F. T31R:175; R.C.A.F. T31L:164, 167, 174, 184, 196.]

The *Kootenay (Western) Ranges* of the Rocky Mountains (*see* Plate XXXIVB) lie between the Rocky Mountain Trench and the Kootenay-White River lineament. From the mouth of the Kicking Horse River to the Bull River the length of these ranges is 140 miles and their maximum width is 18 miles. The Kootenay (Western) Ranges include the Brisco, Stanford, and Hughes Ranges. The ranges are characterized by geologic structures of very great complexity, unlike structures known elsewhere in the Canadian Rockies.

The Stanford Range is described as being representative of the ranges at large. The Stanford Range is dominated by a number of northwesterly trending, almost parallel structural ridges. These are deeply incised and partly dissected by transverse valleys which contain trunk streams or tributaries to streams that occupy the longitudinal valleys between the ridges. The ridge tops are at elevations between 5,200 and 8,000 feet and range in character from some that are broad and rounded to others that are narrow and almost knife-edged.

"Within the range the local relief is from about 2,500 to 4,000 feet, but, adjacent to the Rocky Mountain trench or Kootenay River valley, the local relief is commonly about 4,500 feet and may be as much as 6,000 feet. The highest summit in the Stanford Range, Indianhead Mountain, has an elevation of about

8,820 feet, and the lowest point in the area, on the Columbia River at the north boundary, has an elevation of 2,618 feet. The maximum relief is thus about 6,200 feet.

"The drainage pattern of the creeks and rivers to a certain degree reflects the underlying structure. In the Stanford Range many of the oblique or transverse parts of the major creeks are located along oblique or transverse faults.

"Glacial erosion features, such as U-shaped valleys, hanging valleys, and cirques, have not been observed in the Stanford Range. However, it is probable that ice at one time completely covered the entire range because erratics are found up to elevations of 7,500 feet.

". . . the area was covered by a continental ice-sheet that produced a very limited amount of erosion. The ice disappeared probably by stagnation and melting . . . the Stanford Range does not appear to have been subject to a late-stage alpine glaciation."*

[Photographs: B.C. 891:94; B.C. 894:32, 45; R.C.A.F. T31R:162, 166.]

The *Park (Main) Ranges* of the Rocky Mountains (*see* Plates XXXVA, XXXVB, and XXXVIA) begin as a physiographic and structural unit at the Bull River just north of Fernie and extend northwestward for about 375 miles to Mount Sir Alexander (10,740 feet) at the head of McGregor River. A high percentage of their area lies within the boundaries of the several National and Provincial parks that lie along the Alberta-British Columbia Boundary. The ranges become topographically prominent northwest of the Palliser River; 10,000- and 11,000-foot peaks abound, and almost all the highest peaks of the Canadian Rockies are included. The highest peak in the Rocky Mountains is Mount Robson (12,972 feet), in the Park Ranges north of the Canadian National Railway. The ranges are crossed by both the Canadian Pacific and Canadian National Railways, and it is the scenic grandeur of the Park Ranges that is publicized and known to thousands of tourists. On the Canadian Pacific Railway they extend from Leanchoil and the Beaver River to the Castle Mountain thrust 12 miles west of Banff, a width of about 40 miles. On the Canadian National Railway they extend from the Trench at Jackman to the Pyramid (Castle Mountain) fault zone 3 miles northeast of Jasper, a width of about 35 miles.

The Park (Main) Ranges are largely underlain by sedimentary and metamorphic rocks of late Precambrian and Lower Palæozoic age. Thick cliff-forming limestone and quartzite formations of Cambrian age form many of the mountains. The rocks in the Park Ranges are somewhat less deformed than are those of the Front Ranges to the east and of the Kootenay (Western) Ranges to the west. Although the details of structure are not thoroughly known, the rocks in the Park Ranges mostly are involved in rather gentle, open folds lying between westerly dipping thrust faults, and it is this structure that is characteristic. The flat to gently dipping beds, especially of the thick quartzite or limestone formations, produce massive monumental and castellated peaks, of which Mount Robson is the outstanding example (*see* Plate XXXVA).

The ranges are dissected and drained by tributaries flowing westward into the Fraser, Columbia, and Kootenay Rivers and eastward into the Peace, Athabasca, North Saskatchewan, Bow, and other rivers. The great relief and the great heights within the ranges provide world-renowned alpine scenery. The topography is extremely rugged. Mature dissection of the region has reduced interstream areas to narrow knife-like ridges. The peaks are commonly matterhorn in form (for example, Mount Assiniboine) and are erosion forms of truly alpine type, being

* Henderson, G. G. L., *B.C. Dept. of Mines*, Bull. No. 35, 1954, pp. 11, 12.

sculptured by high-level cirque glaciers. Ice descending into the valleys and moving outward from its source has modified the valley outlines and has, through differential erosion, created the hanging-valley relationships so characteristic of glaciated mountainous terrain. In many places glacially oversteepened mountain slopes are so unstable that erosion is proceeding rapidly, with production of huge talus piles that cover much of the gentle lower slopes.

[References: North, F. K., and Henderson, G. G. L., "Geology of Southern Rocky Mountains of Canada," *Alta. Soc. Pet. Geol.,* Guidebook No. 4, 1954; Sorenson, M. K., "Rocky Mountain Trench," *Alta. Soc. Pet. Geol.,* Guidebook No. 5, 1955; Allan, J. A., "Geology of Field Map-area," *Geol. Surv., Canada,* Mem. 55, 1914; Warren, P. S., "Banff Area," *Geol. Surv., Canada,* Mem. 153, 1927; MacKay, B. R., "Geology of the National Parks of Canada," *Can. Geog. Jour.,* April, 1952; Baird, D. M., "Yoho National Park," *Geol. Surv., Canada,* Misc. Rept. No. 4, 1962.]

[Photographs: B.C. 759:31; B.C. 766:44; B.C. 767:28, 32; B.C. 891:11, 73; B.C. 894:32; B.C. 896:46; B.C. 1204:90; B.C. (0):465; R.C.A.F. T31L:148.]

Hart Ranges

The ranges between Mount Sir Alexander and the Peace River constitute the Hart Ranges. They are only moderately rugged and, except for Sentinel Peak (8,200 feet) and Mount Drysdale (7,950 feet), do not exceed 7,500 feet in height (*see* Plate XXXVIB). They contrast very sharply with the majestic mountain groups to the south, and are considerably lower than ranges north of the Peace River. The Hart Ranges constitute a central belt of lower elevation in the Rocky Mountains that is the topographic equivalent of the Kitimat Ranges in the Coast Mountains.

The Hart Ranges have a length of 180 miles between Mount Sir Alexander and the Peace River and a width ranging between 18 and 40 miles. The ranges are crossed at their narrowest part by the Hart Highway and the Pacific Great Eastern Railway, by the Peace River to the north (*see* Plate XLIVA), and by the little-known route through the Monkman Pass to the south. Their geology and structure are imperfectly known except by a few oil exploration geologists.

Where crossed by the Hart Highway there is a perfectly apparent natural division of the Hart Ranges at Azouzetta Lake, between the Murray and Solitude Ranges on the east and the Misinchinka Ranges on the west. It is evident, moreover, to all who are familiar with the southern mountains that the Hart Ranges differ greatly from the Continental Ranges. The differences are primarily the result of fundamental changes in the stratigraphy and structure of the rocks, and of the differences in amount of the late Tertiary uplift and dissection.

The Murray Range has a width of 4 miles on the Hart Highway and rises to 6,686 feet above well-timbered lower slopes. The western face of the range is a dip slope of about 40 degrees, and the northeast scarp is fretted with cirques with steepened headwalls and some basins occupied by tarn lakes. The range on both sides is bounded by southwesterly dipping thrust faults.

The Solitude Range is 3 miles wide. It is bounded by thrust faults and is essentially composed of a block of rather complexly folded Upper Palæozoic limestone having a dip slope facing southwest and a cirque-sculptured scarp slope on the northeast.

These two ranges are topographically and structurally similar to the Front Ranges of the Continental Ranges and occupy the same frontal position on the western side of the Foothills. When more information is available about the eastern margin of the Rocky Mountains, it should be possible to outline a belt of Front Ranges for a considerable distance northwestward from their presently known limit northeast of Mount Robson.

The *Misinchinka Ranges* lie between Azouzetta Lake and the Rocky Mountain Trench and extend from the Peace River southeastward for 150 miles, at least as far as Fontoniko Creek. They have a width of 15 miles and constitute an important division of the Rocky Mountains. The ranges coincide in position with the Misinchinka schists, of late Precambrian and Cambrian age, which lie in a belt along the east side of the Rocky Mountain Trench, and the subdued topography of the ranges is a direct reflection of the character of these rocks.

The thick quartzite and limestone formations that give character to the Park Ranges diminish in thickness in the vicinity of Mount Sir Alexander, and northwestward their place is taken by the schistose rocks of the Misinchinka Group. These rocks are unable to support the precipitous slopes and castellated forms that are characteristic of the ranges to the southeast, and as a consequence the whole aspect of the mountains has changed.

The Misinchinka Ranges characteristically have rounded wooded summits ranging up to 6,500 feet (*see* Plate XXXVIB). They are drained by creeks flowing westward into the Parsnip River and by creeks flowing eastward into tributaries of the Peace. A characteristic of the westward-flowing creeks is their parallelism, and their trend of south 30 to 40 degrees west, a direction which is oblique to the Trench. This direction, which is structurally controlled, appears consistently along the Trench wherever the Misinchinka schists occur.

The upper surface of the continental ice-sheet during the Pleistocene stood between 6,000 and 7,000 feet in the region between Mount Sir Alexander and the Peace River. Unquestionably some of the rounded summits were overridden by northeastward-moving ice, and some were little affected by alpine and valley glaciation.

The combination of greatly lessened elevation and relief, of different lithology and structure, and of reduced alpine and valley glaciation have resulted in a subdued alpine topography which is most unlike the familiar Rocky Mountains of the south.

[References: Stott, D. F., "Cretaceous Rocks between Smoky and Pine Rivers," *Geol. Surv., Canada,* Paper 60-16; Muller, J. E., "Geology, Pine Pass," *Geol. Surv., Canada,* Map 11-1961; Tipper, H. W., and Muller, J. E., "Geology, McLeod Lake," *Geol. Surv., Canada,* Map 2-1962.]

[Photographs: B.C. 759:108; B.C. 761:9; B.C. 763:96, 102; B.C. 767:13; B.C. 1949:19.]

Muskwa Ranges

From the Peace River the Rocky Mountains extend northwestward to their termination at the Liard River. These are the Muskwa Ranges, which have a length of 260 miles and widths of 20 miles at the Peace River and 70 miles at Sifton Pass. Their western edge is along the northwest-trending Rocky Mountain Trench, and their eastern edge runs almost north from the Peace River, being controlled by northerly trending bedrock structures and an in echelon expansion eastward of the eastern ranges. This divergence results in the greatly expanded width between Sifton Pass and Mount St. Paul.

From the Peace River, summit elevations increase gradually to Mount McCusker (8,393 feet) at the head of the Sikanni Chief River. Farther north a number of high peaks include Mount Redfern (8,879 feet), Lombard Peak (8,300 feet), Mount Lloyd George (9,570 feet), Mount Stalin (9,500 feet), and the highest, Mount Churchill (10,500 feet), at the head of Churchill River and 40 miles south of the Alaska Highway at the Toad River. From Mount St. George (8,500 feet) just south of the Alaska Highway, the summit level decreases northward to below 7,000 feet in the Terminal Range south of the Liard River. Eventually the northern Rocky Mountains merge in the Rabbit Plateau in the northwest and terminate at the Liard River (*see* Plate XXXVIIA) against the Liard Plateau, both of which lie for the most part below 5,000 feet elevation.

The mountains are crossed by the Liard and Peace Rivers (*see* Plate XLIVA), which are long-established routes of travel, and by the Alaska Highway, which follows the Tetsa, MacDonald, Toad, and Trout River valleys. Access from these routes has provided a framework of geological information. Elsewhere in the Muskwa Ranges, although topographic maps are available, geological and structural information is generally unavailable. As a consequence, too little is known to enable a rigid structural subdivision to be made.

A belt of Misinchinka schists extends along the western side of the Muskwa Ranges for 120 miles northwestward from the Peace River to the mouth of the Kwadacha River near Fort Ware. This belt of schist is about 5 miles wide and is the extension north of the Peace River of the Misinchinka Ranges. Streams crossing the belt enter the Trench along a south 35 degrees west direction. The high point along the belt is Deserters Peak (7,430 feet), just east of Deserters Canyon on the Finlay River. Summit heights underlain by these rocks are lower than those in the bolder limestone and quartzite ranges to the east.

On their eastern side the Muskwa Ranges are eroded largely in Devonian and Permo-Carboniferous limestones. They are bold castellated ranges of considerable relief which, in the vicinity of the headwaters of the Prophet and Muskwa Rivers, appear to have undergone a minimum of late-stage alpine and cirque glaciation.

A distinctive physiographic unit within the northern ranges extends for an unknown distance southward from the Alaska Highway at Mile 432. The area is underlain largely by a succession of quartzites, conglomerates, slates, and phyllitic limestones (Kechika Formation) which are late Precambrian and Cambrian in age. These rocks underlie an area which, between the head of Toad River and the Tetsa River, is 30 miles wide but which may expand to a width of 50 miles between the Tuchodi Lakes and Mount Lloyd George. It includes the high peaks of Mount Churchill (10,500 feet), Mount Roosevelt (9,500 feet), and Mount Stalin (9,500 feet), and extends southward at least to Mount Lloyd George (9,570 feet) and surrounding high peaks. Quartzites in the succession underlie many of the high peaks of a region that is very little known. Comparable rocks (Kechika and pre-Kechika Formations) are exposed west of Muncho Lake and Trout River in the core of the Terminal Range, which is a northwesterly plunging anticlinorium.

The high area south of the Alaska Highway has been strongly eroded by alpine and valley glaciers, and it is evident from topographic maps that the valleys of Gataga River, Toad River-Muncho Lake, Racing, Muskwa, and Kwadacha Rivers served as escape routes for ice which accumulated in the high area centring around Mounts Lloyd George, Churchill, Roosevelt, and Stalin. The high grey quartzite and limestone mountains of great relief with glacially sculptured cirques and alpine valleys present scenery comparable to that in the Park (Main) Ranges of the southern Rocky Mountains.

The Alaska Highway, between the eastern front of the Rocky Mountains at Mile 389 and the Muncho Lake valley, crosses two ranges which consist of fault blocks lying above westerly dipping thrust faults. These ranges are physiographically and structurally similar to the Park Ranges and are formed from thick Silurian and

Devonian limestones that are thrust up and over younger rocks. The ranges comprise castellated limestone peaks facing northeastward with dip slopes on their southwestern sides. The eastern side of Muncho Lake valley presents a remarkable dip slope on southwesterly dipping limestone beds. Between the two ranges is an area of low to moderate relief along Nonda Creek and Racing River, eroded in soft upper Devonian shales and Lower Triassic shales and sandy limestone lying above the cliff-forming Ramparts Formation.

The crossing of the northern Rocky Mountains along the Alaska Highway, although scenic and most interesting, lacks the overwhelming grandeur of the high country around Mount Churchill between the heads of the Gataga, Toad, Tuchodi, Kwadacha, and Muskwa Rivers.

Longitudinal valleys of considerable width and length are prominent features of the Muskwa Ranges. They are eroded parallel to the structural trend along lines of faulting or along belts of softer, more easily eroded rock. These longitudinal valleys give the drainage a pronounced trellis pattern which varies from region to region, depending upon the character and distribution of the underlying formations.

Glaciation in the northern ranges was uneven in intensity. The high area around Mount Churchill evidently was a local centre of accumulation from which valley glaciers moved outward along the several major valleys, and late-stage alpine and valley glaciation has left its mark upon the topography. Some areas within the Muskwa Ranges show little or no evidence of glacial erosion—continental ice did not erode them nor was there late-stage cirque or alpine glaciation. However, the former presence of an ice cover is revealed by the almost universal veneer of drift.

The *Rabbit Plateau* is an area of gradually diminishing summits transitional between the Muskwa Ranges and the Liard Plain. It is the topographic equivalent of the Dease Plateau that occupies a similar transitional position between the Cassiar Mountains and the Liard Plain.

The Rabbit Plateau is triangular in shape and extends for about 50 miles between Fishing Lake and the Kechika River, with a maximum width of about 20 miles. It is bounded on the northwest by the Liard Plain and on the southeast by the Rocky Mountains along a southwesterly line between Fishing Lake and the Rocky Mountain Trench just south of Horneline Creek.

The plateau (*see* Plate XXXIIA) consists of low wooded ridges rising to an even skyline elevation of 4,000 to 5,000 feet and has a relief of 2,500 to 3,000 feet. The area is drained by the Rabbitt and Vents Rivers, and tributaries of the Kechika River.

The plateau is underlain by northwesterly plunging folded sedimentary rocks of lower Palæozoic (Cambrian) to Devonian and Precambrian age. The plateau is geologically the same as the Muskwa Ranges directly southeast, but is lower in summit elevation because the late Tertiary erosion surface was tilted northward and merges in the Liard Plain.

[References: Williams, M. Y., "Geological Investigations along the Alaska Highway between Fort Nelson and Watson Lake," *Geol. Surv., Canada,* Paper 44-28; Gabrielse, H., "Geology, Kechika," *Geol. Surv., Canada,* Map 42-1962; Gabrielse, H., "Geology, Rabbit River," *Geol. Surv., Canada,* Map 2-1961; Irish, E. J. W., "Geology, Halfway River," *Geol. Surv., Canada,* Map 22-1963; McLearn, F. H., and Kindle, E. D., "Geology of Northeastern British Columbia," *Geol. Surv., Canada,* Mem. 259, 1951; Laudon, L. R., and Chronic, B. J., "Palæozoic Stratigraphy," *A. A. P. G.,* Bull. Vol. 33, No. 2, 1949, pp. 189–222; Odell, N. E., *Can. Geogr. Jour.,* Feb., 1949.]

[Photographs: B.C. 187:104; B.C. 194:54; B.C. 955:103, 120.]

Rocky Mountain Foothills

The Rocky Mountain Foothills (*see* Plates XXXVIIB and XXXIXA) lie along the eastern margin of the Rocky Mountains in a continuous belt from the 49th parallel to the Liard River. In the south the foothills are in Alberta, but the belt enters British Columbia just north of latitude 54 degrees, at the headwaters of the Narraway and Wapiti Rivers, and continues northwestward for about 400 miles to their northern termination at the Liard River. The belt of foothills ranges from a width of 15 miles where crossed by the Muskwa River to 45 miles at the head of the Pine and Sekunka Rivers.

The western boundary of the foothills for the most part is along a structural line which follows the trace of the easternmost major fault that thrusts Palæozoic over Mesozoic formations. This fault normally brings thick cliff-forming Palæozoic limestones into position to form typical grey limestone Front Ranges, which stand out prominently on topographic maps and are easily distinguished on the ground. The eastern boundary of the foothills, especially between the Narraway and Peace Rivers, is a series of southwesterly dipping in echelon thrust faults which separate strongly folded and faulted sedimentary formations of the foothills from flat-lying or gently dipping formations of the plains.

The foothills are entirely underlain by sedimentary rocks that in northeastern British Columbia are largely of Mesozoic age, but throughout their length range from Precambrian to Tertiary. The rocks are folded about northerly to northwesterly trending axes and are cut by southwesterly dipping thrust faults. Bedrock has a strongly developed structural grain which is closely reflected by the character of the topography.

There is a lack of uniformity in the foothill belt because of the occurrence of Triassic limestones and calcareous siltstones and sandstones in one section and of Cretaceous sandstones and shales in another. In addition, the intensity of structural deformation, by folding and faulting, becomes less pronounced eastward from the mountains. These geologic differences are expressed topographically, and as a consequence it is possible to divide the foothills into a belt of inner foothills, on the west, that are higher and more rugged than a belt of outer foothills, on the east, that have a more moderate relief and a more subdued topography. In general the inner foothills are composed of closely folded and faulted Triassic and Lower Cretaceous resistant formations and the outer foothills of more gently folded and only slightly faulted Cretaceous rocks.

The highest peaks and longitudinal ridges occur where resistant quartzite of Lower Cretaceous age or silty limestones of Triassic age are prominent, whereas the lower peaks and valleys are eroded in the softer interbedded shales.

Elevations of summits and high longitudinal ridges mostly range from 6,000 to 7,000 feet, the highest being Mount Laurier (7,712 feet) near the head of the Halfway River. Summits increase in height southward from the Liard River to the area between the heads of the Prophet and Pine Rivers and then diminish southward where the Monteith quartzite is thinner.

The structural grain of the bedrock has resulted in prominently developed northwesterly trending longitudinal ridges and a trellis pattern of drainage (*see* N.T.S. Sheet 94G). Valleys are eroded along belts of soft rock and along fault zones and are generally wide and flaring. They lie at 2,500 to 3,000 feet elevation, producing a variable and moderate relief.

The foothills were occupied by continental ice during the Pleistocene, and easterly trending valleys were glaciated by ice moving outward from the mountains. The northwesterly trending valleys generally were not eroded, but they, like the others, received a mantle of drift when the ice disappeared. Cirque glaciers developed locally, as a rule only on the northeastern sides of peaks above 5,000 feet (*see* Plate XXXIXA). By and large the foothills display landforms only slightly modified by glaciation.

[References: Hage, C. O., " Geology Adjacent to the Alaska Highway between Fort St. John and Fort Nelson," *Geol. Surv., Canada,* Paper 44-30; Pelletier, B. R., " Geology, Tetsa River," *Geol. Surv., Canada,* Map 29-1959; Pelletier, B. R., " Triassic Stratigraphy, Rocky Mountain Foothills," *Geol. Surv., Canada,* Paper 60-2; Stott, D. F., " Cretaceous Rocks between Smoky and Pine Rivers," *Geol. Surv., Canada,* Paper 60-16; Pelletier, B. R., and Stott, D. F., " Trutch Map-area," *Geol. Surv., Canada,* Paper 63-10; Mountjoy, E. W., " Mount Robson (Southeast) Map-area," *Geol. Surv., Canada,* Paper 61-31.]

[Photographs: B.C. 1204:52, 58, 69, 73; B.C. 1950:74.]

B. Interior Plains

Somewhat more than 10 per cent of the area of British Columbia lies east of the Rocky Mountain Foothills. This part of northeastern British Columbia, comprising plateaus, plains, prairies, and lowlands, is essentially an area of low relief. It is part of the Interior Plains, which is an extensive region of central Canada extending from the International Boundary to the Arctic Coast and from the eastern foothills of the Rocky Mountains to the edge of the Canadian Shield.

In northeastern British Columbia the boundary between the Cordilleran Region and the Interior Plains is easily defined between the higher longitudinal ridges of the Rocky Mountain Foothills and the lower plateaus or cuestas of the plains. The boundary follows a series of in echelon thrust faults which separate the more closely folded and faulted rocks of the foothills from dominantly flat-lying or gentle east-dipping rocks of the plains. The boundary crosses the Liard River west of the mouth of Toad River and runs southeastward to cross the Alaska Highway at Mile 371, thence southward on the west side of Prophet River past Klingzut Mountain and Bullhead Mountain to cross the Peace River between Hudson Hope and Portage Mountain. The boundary continues southeastward between Bullmoose Mountain (6,627 feet) and Gwillim Lake to the junction of Belcourt Creek and Wapiti River.

The Interior Plains of northeastern British Columbia are underlain by sedimentary rocks very largely of Cretaceous age. The rocks for the most part belong to the Fort St. John Group, comprising a thick sequence of shales with several sandstone members near the top, the Dunvegan Formation, which is essentially a hard cliff-forming sandstone, and the Smoky Group, comprising interbedded shales and sandstones. The rocks are flat lying or gently dipping, and as a consequence extensive plateau areas and cuestas develop on the more resistant sandstone members (*see* Plate XXXVIII). The interbedded shale is soft and more readily eroded, and one finds Fort St. John (Buckinghorse) shale underlying most of the low areas. The gentle warps and fold structures of the plains geology manifest themselves in correspondingly gentle hills, domes, plateaus, cuestas, and other landforms.

The Interior Plains in northeastern British Columbia are represented by the Alberta Plateau and its subdivision, the Fort Nelson Lowland.

Alberta Plateau

A flat and gently rolling upland (*see* Plates XXXVIII, XXXIXB, and XLIVB) lies east of the Rocky Mountain Foothills and in large part stands at elevations between 3,000 and 4,000 feet. It is a natural continuation into British Columbia of the Alberta Plateau,* a physiographic unit which is also present in northern Alberta.

* Camsell, C., and Malcolm, Wyatt, *Geol. Surv., Canada,* Mem. 108, 1919, pp. 17–19.

The Alberta Plateau in British Columbia is drained and incised by the Liard and Peace Rivers and their tributaries. The elevation of the Liard River is less than 1,000 feet at the mouth of the Fort Nelson River and of the Peace River about 1,475 feet at the mouth of the Kiskatinaw, and incision has proceeded upstream on tributaries away from the two main rivers. The upland surface of the Alberta Plateau has been only partly dissected, and parts of it have been destroyed. Those parts (especially in the drainage basin of the Fort Nelson River) where the surface is reduced to below 2,000 feet elevation constitute the Fort Nelson Lowland, the boundary between the two being arbitrarily drawn at the 2,000-foot contour. Commonly this is along a scarp upheld by one of the Cretaceous sandstone members.

The upland surface is flat or gently rolling. It lies for the most part between 3,000 and 4,000 feet elevation, and rises to 5,000 feet between the Prophet and Muskwa Rivers, whereas in northwestern Alberta a large proportion is between 2,000 and 3,000 feet.

Drainage over part of the upland surface is poorly organized; there are large areas of muskeg, and streams meander across the surface eventually to join one of the trunk streams. North of the Peace River much of the drainage is controlled by the Halfway, Beatton, Sikanni Chief, Prophet, Muskwa, Fort Nelson, and Petitot Rivers. These have incised themselves below the upland surface into the soft Fort St. John shale.

Between the Prophet and Muskwa Rivers and north of the Sikanni Chief River there is an area of gentle folding in which the rivers are incised into shales that underlie a capping of Sikanni sandstone. As a consequence a distinctive cuesta topography has been developed. The gentle slopes of the cuestas generally face east and are structurally controlled by the gently east-dipping sandstone. A steep scarp slope faces west and falls away into a lower area generally underlain by Fort St. John shale. The Alaska Highway from Beatton River north for 50 miles is located along the crest of a cuesta, west of which a low area about 10 miles wide lies between the cuesta scarp and the edge of the foothills.

The plateau for the most part is heavily wooded, but along the Peace River considerable areas, generally below 2,500 feet elevation, are flat or gently rolling and are only lightly wooded. Much of this riverside country has been cleared and is under cultivation (*see* Plate XXXIXB).

The plateau was glaciated during the Pleistocene. Ice from the Keewatin centre of accumulation moved southwestward across the Alberta Plateau to the foothills and left a veneer of glacial till containing distinctive Keewatin boulders. After the maximum expansion of Keewatin ice and its retreat, piedmont and valley glaciers flowing eastward from the Rocky Mountains moved outward onto the plateau to leave moraines in a narrow belt along the eastern edge of the foothills. Ice movements can be interpreted from glacial fluting in the ground moraine and by the elongation of drumlins. The minor relief on the plateau surface results from these features.

As the ice waned, channels discharged glacial meltwater into valleys, some of which were still blocked by ice. The Peace River valley was occupied by a proglacial lake which at one stage had its level at approximately 2,750 feet. This old lake, called Lake Peace, had shorelines now traceable mainly by old beach lines and gravel occurrences. A lower and younger stage developed when the outlet was at 2,260 feet. Sediments were deposited in this lake basin to a thickness of about 100 feet (*see* Plate XLIVB). Post-Pleistocene erosion has incised the trunk rivers to their present elevations.

[References: Mathews, W. H., " Ground-water Possibilities of the Peace River Block," *B.C. Dept. of Mines,* Ground-water Paper No. 3, 1955; Mathews, W. H., " Quaternary Stratigraphy and Geomorphology of the Fort St. John Area," *B.C.*

Dept. of Mines and Petroleum Resources, 1963; Camsell, C., and Malcolm, Wyatt, " Mackenzie River Basin," *Geol. Surv., Canada,* Mem. 108, 1919; McLearn, F. H., and Kindle, E. D., " Geology of Northeastern British Columbia," *Geol. Surv., Canada,* Mem. 259, 1951.]

[Photographs: B.C. 1090:60; B.C. 1197:96, 111; B.C. 1204:58; B.C. 1206:78; B.C. 1207:13, 32; R.C.A.F. T25R:192.]

Fort Nelson Lowland

The dissection of the Alberta Plateau by the Liard and Peace Rivers and their tributaries has produced lowland areas, below 2,000 feet elevation, that are designated the Fort Nelson Lowland and the Peace River Lowland. The Peace River Lowland extends into British Columbia as a small digitate area along the main river and its tributaries. It occupies a large area in northern Alberta.

The Fort Nelson Lowland (*see* Plate XLA) is an area of extremely low relief, in places flat and in places very gently rolling, that lies below an elevation of 2,000 feet. The boundary with the Alberta Plateau is the line of the 2,000-foot contour, which in many places is along a sandstone scarp formed by one of the several Cretaceous sandstone members underlying the plateau. The lowland lies within the drainage basins of the Fort Nelson, Hay, and Petitot Rivers, but over large areas drainage is not well established and lakes and muskegs abound (*see* Plate XLB). The Fort Nelson and Petitot Rivers are incised as much as 500 feet below the general level of the lowland, which is at about 1,500 feet elevation. Elsewhere streams meander across a surface which has remained unmodified since its emergence from the covering of Pleistocene ice.

Between the Fort Nelson and Petitot Rivers and extending northwestward from Kotcho Lake is an area of somewhat higher ground 100 miles long and 30 miles wide that reaches an elevation of 2,465 feet on the Etsho Escarpment. It could be considered as an outlier of the Alberta Plateau.

A topographic feature which extends southwestward from Petitot River at the 123rd meridian to the Fort Nelson River is an alignment of cuesta ridges reaching a height of 2,376 feet at their highest. The ridges have an eastward-facing scarp slope and a gentle west-dipping dip slope. This line of cuestas is the topographic expression of Mississippian limestone and Permian chert members brought to the surface by the Bovie fault, which extends southward into British Columbia from the Northwest Territories,* where it has been geologically mapped for 25 miles north of the border.

The lowland is for the most part underlain by flat or gently dipping Cretaceous shales and sandstones, but exposures of bedrock are rare. The topography for the most part reflects the gentle structures in the underlying rocks. However, geologic mapping in the Yukon indicates that between the eastern edge of the Liard Plateau and the Bovie fault there is an area of some structural complexity in which the flat structures of the plains give way to northeasterly trending folds and faults which are not fully expressed topographically. It is apparent that the eastern limit of mountain structures does not coincide precisely with the physiographic boundary of the plains. Any further subdivision of the plains in this area should be made on the basis of geology.

During the Pleistocene the Fort Nelson Plain was covered by a continental ice-sheet (the Keewatin) whose centre of accumulation lay west of Hudson Bay. Ice moved westward and southwestward across the lowland, transporting boulders and drift from Precambrian areas far to the east. The lowland is veneered with glacial drift upon which is impressed a well-developed lineation parallel to the direction of

* Douglas, R. J. W., and Norris, D. K., *Geol. Surv., Canada,* Paper 59-6.

ice movement. Elongate drumlins and glacial flutings are clearly visible in air photographs of the lowland, but their relief is only very slight, and consequently they are not represented by the 500-foot contours on the present 4-mile topographic maps. Aerial photographs show extensive areas of ground moraine and pitted outwash, with lakes occupying the undrained depressions and a complex of glacial meltwater channels related to the disappearance of the last ice (*see* Plate XLA). Many of these channels are occupied by small streams quite unrelated in size to the channels that they occupy. The complexities of Pleistocene and post-Pleistocene history have yet to be disclosed by detailed studies on the ground and of aerial photographs of the region.

[References: Douglas, R. J. W., and Norris, D. K., " Fort Liard and La Biche Map-areas," *Geol. Surv., Canada,* Paper 59-6; Camsell, C., and Malcolm, Wyatt, " Mackenzie River Basin," *Geol. Surv., Canada,* Mem. 108, 1919.]

[Photographs: B.C. 1194:50, 59, 77; B.C. 1198:71, 72; B.C. 1200:27, 80; B.C. 1201:33, 41, 48.]

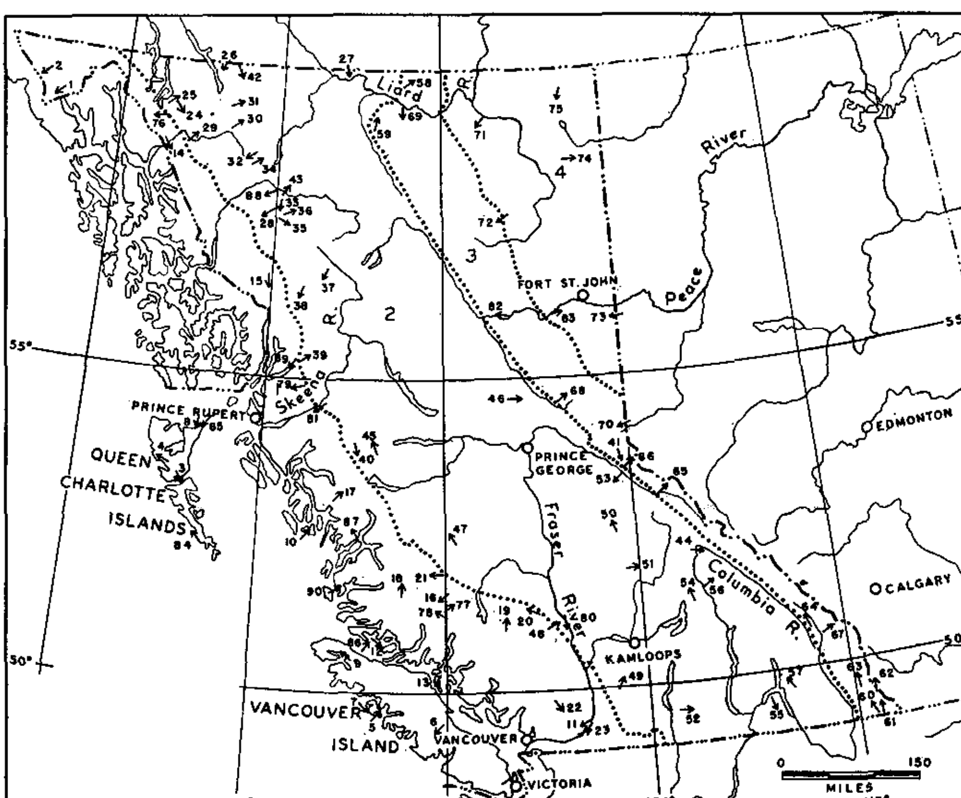

Figure 9. Index map showing the location and orientation of photographic illustrations.

CHAPTER III.—SPECIAL ASPECTS OF THE BRITISH COLUMBIA LANDSCAPE

British Columbia spans a thousand-mile length of the Canadian Cordillera and of the vast cordilleran mountain chain that extends along the western side of North America. Its position is not unique, and yet certain features of the landscape give the Province a special flavour and set it apart topographically from the rest of the Cordillera. These features are five in number. No other large segment of the Cordillera has been so completely covered during the Pleistocene with glacial ice, as a consequence of which the landscape in all parts of the Province shows the effects of glacial erosion and deposition. The pre-glacial topography, the product of erosion by the various river systems, shows deviations from normal river patterns that are the result of stream piracy on a major scale. The fiord coastline is taken very much for granted by the local inhabitants, yet it is comparable in dimension and grandeur to the world-famous coasts of Norway, Patagonia, New Zealand, and elsewhere. To these special features of landscape—namely, glaciation, drainage, and coastline—may be added Tertiary volcanic activity and lineaments. Of these, none is in any way unique or restricted to this region, but they nevertheless combine to give distinction and character to British Columbia landscapes. In the following pages these five features are treated separately to unify and give meaning to the scattered references made to them in Chapter II.

GLACIATION IN BRITISH COLUMBIA

There is abundant evidence that the earth's climate has been continuously changing in an extremely complex way. Warm periods have been succeeded by cold, and more than once in the geologic past conditions have been sufficiently severe to produce a glacial period. The latest of these refrigerated periods began with the Pleistocene epoch, about one million years ago. The Pleistocene is the time interval on the geological calendar when glaciation was widespread, not only in British Columbia, but over large areas in the northern and southern hemispheres. Even in regions that were not glaciated there was sufficient change in the Pleistocene climate to one that was cool and moist so that the plants, animals, and physical history were affected.

A background knowledge of glaciation is important in the consideration of landforms in British Columbia because the Province was intensely glaciated during the Pleistocene. Almost the entire Province was covered by ice which, at its maximum extent, covered all but some of the highest mountain peaks and parts of the northern and southern Rocky Mountains. The topography everywhere shows the effects of glacial erosion and deposition. In this Province, as in eastern North America, Europe, and other parts of the northern hemisphere, the glacial history was probably complex, but the visible effects of glaciation are almost entirely those of the last, Wisconsin stage.

Glaciation in British Columbia resulted in the eventual accumulation of enough ice to form an ice-sheet of continental dimensions. The growth, culmination, and decline of this Cordilleran ice-sheet was in response to world-wide factors of climatic control. Climatic cycles during the Pleistocene produced cyclic advances and recessions of glaciers and resulted, in some parts of the world, in four glacial stages of ice advance separated by three interglacial stages of ice recession and partial deglaciation.

Glaciation in British Columbia differed from much of the rest of Canada in that the ice-sheet occupied an initially mountainous terrain. In mountain regions the cycle of glaciation is considered to begin with the formation of small cirque glaciers which, by continued growth, expand into mountain and valley glaciers. Further expansion of the ice produces a mountain ice-cap whose movement is controlled by the underlying topography. Finally, at the maximum stage the land is occupied by a regional ice-sheet whose movement and extent are controlled mainly by climatic factors and are largely independent of the underlying topography. As the ice cover diminishes, there is regression to the mountain ice-cap and then the valley glacier stages, and the last ice to remain is in small cirque glaciers as in the beginning of the cycle.

In each of the several stages of the glacial cycle the erosional and depositional landforms are distinctly different. Mountain glaciers produce the numerous forms so typical of high alpine scenery, particularly horn-shaped peaks, serrate ridges, high-level U-shaped divides (cols), and cirque basins with their steep head walls (*see* Plates VIIIA, IX, XIIA, and XLIB). Valley glaciers modify valley profiles by faceting the spurs and producing the characteristic U-shaped cross-section of glaciated valleys (*see* Plates XXVIIIC and XLIIB). Hanging valleys result from the differential erosion of main and lateral valleys (*see* Plate XLIIA). Through valleys are eroded by outlet glaciers composed of ice moving outward from an area of accumulation. Valley glaciers produce characteristic depositional forms, such as the terminal and lateral moraines left upon disappearance of the ice. Features of glacial erosion and deposition are common in the mountain ranges across the length and breadth of British Columbia. They are such an integral part of the landscape that many residents assume they are universal in mountainous regions and do not realize they are unique to glaciated mountains.

When a mountain ice-cap is present, ice covers and moves over all but the highest peaks and ridges (*see* Plate XLIA). In so doing it rounds the ridge-tops, it covers and produces dome-shaped summits (*see* Plate XA), and may destroy or greatly modify the glacial forms of earlier stages. At the maximum stage, when a regional ice-sheet covers the land, erosion is not great and the tendency is for the relief to be reduced rather than increased. A widespread mantle of drift was deposited by the Pleistocene ice-sheet in British Columbia. As the ice continued to flow from its gathering grounds, it rode over ground moraine and produced in it drumlin-like forms and flutings which are parallel to the direction of movement. The Interior Plateau (*see* Plate XXV), Stikine Plateau (*see* Plate XVIIA), and Liard Plain (*see* Plate XXXVIIA) all display these features to a remarkable degree.

Keewatin Ice-sheet

The Interior Plains region of northeastern British Columbia was occupied by ice that accumulated in the Keewatin area west of Hudson Bay and, moving outward in all directions, spread westward and southwestward to cover all the Fort Nelson Lowland and Alberta Plateau (*see* Fig. 10). The western margin of the Keewatin ice-sheet lay along the eastern front of the Rocky Mountain Foothills, although some ice may have pushed westward into the foothills and mountains. The Keewatin ice-sheet had reached its maximum extent and its front had receded before Cordilleran ice moved eastward from the Rocky Mountains and overlapped a narrow zone formerly occupied by Keewatin ice. The zone of overlapping was involved in a complex glacial history as a result of fluctuations of the fronts of the two ice-sheets. The detailed mapping of such a zone in southwestern Alberta* illustrates the sort of glacial activity that took place all along the mountain front.

The Keewatin ice produced little erosion in British Columbia, and evidence of its former extent lies in the varied deposits of drift containing boulders derived from eastern sources. In some areas the drift is fluted parallel to the direction of ice

* Stalker, A. M., *Geol. Surv., Canada,* Map 31-1961.

movement, and regional studies of the movement may be made from aerial photographs, which are readily available.

Keewatin ice melted from the land when its source of supply failed. The ice-sheet lay stagnant and wasted away in place, producing great volumes of meltwater which accumulated into streams and flowed northward across the Fort Nelson Lowland to discharge into the Liard and Mackenzie Rivers. These meltwater channels were a prominent though temporary phase of the ice disappearance. After the meltwater diminished, the channels remained (*see* Plate XLA), and they are occupied now by underfit streams that carry only the present normal run-off and consequently are quite out of proportion in size to the channels they occupy.

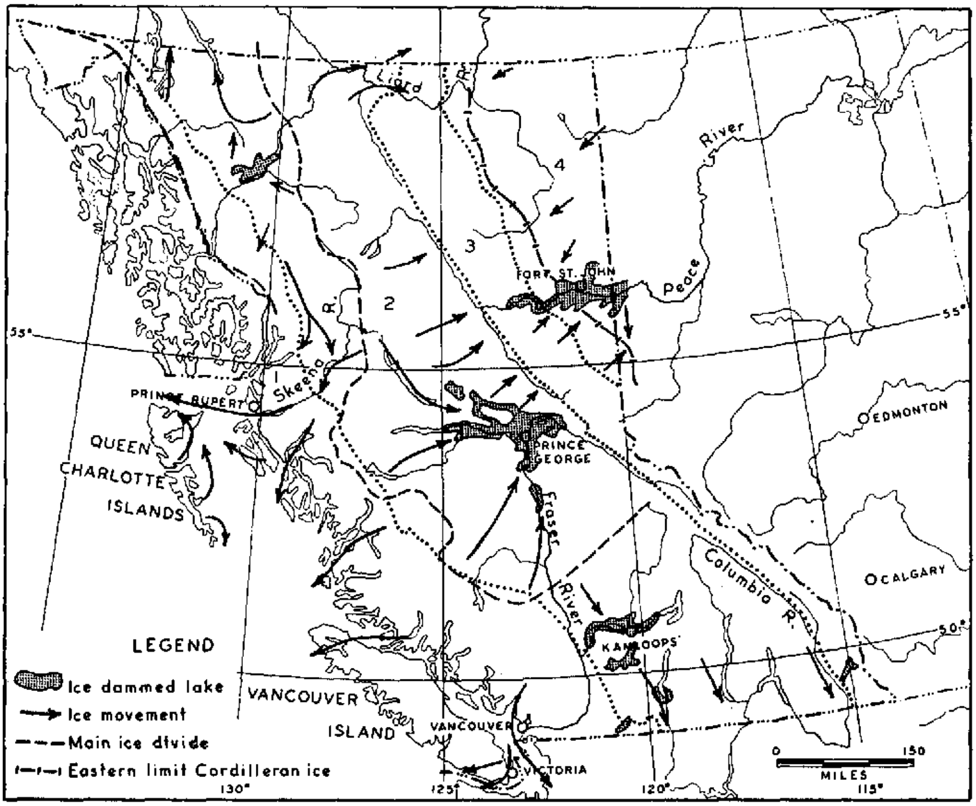

Figure 10. Diagram showing the directions of movement of glacial ice and location of post-Pleistocene pro-glacial lakes.

Cordilleran Ice-sheet

The Cordilleran Region in British Columbia was entirely covered by the Cordilleran ice-sheet. The ice reached its maximum extent later than did the Keewatin ice-sheet. The Pleistocene began with the accumulation of ice at several major centres and numerous subordinate ones. The distribution of present-day glaciers to a degree indicates where the major centres were located. These were in the Coast Mountains north of Portland Canal, in the Pacific Ranges between Bella Coola and Garibaldi, in the northern Selkirk and Purcell Mountains, and in the Rocky Mountains north of Banff. Others were on the Queen Charlotte Islands, Vancouver Island, northern Cassiar Ranges, northern ranges of the Rocky Mountains, centring about Mount Churchill, and in the Premier Group of the Cariboo Mountains. An important centre, not indicated by present-day glaciers, was in the Kitimat Ranges. The snowline reached a low altitude along the coast between Cape Caution and Banks Island, as revealed by cirque basins at sea-level in the Kitimat Ranges and Hecate Lowland. This was a large centre of ice accumulation from which ice moved eastward and northeastward across the Interior Plateau and also westward across the Hecate Depression.

Ice accumulated at the various centres as mountain, cirque, and valley glaciers that eroded their typical landforms. All the mountain belts exhibit in varying degrees glacial landforms produced by cirque, mountain, and valley glaciers. Areas of highest summits in the Coast Mountains, Columbia Mountains, and the Rocky Mountains display these features to the greatest extent (*see* Plates XIIA and XXX).

Ice accumulated gradually by the coalescing of numerous ice-tongues into ice-caps, and the rounded ridges and domed summits characteristic of mountain ice-cap erosion are displayed over wide areas in the Kitimat Ranges (*see* Plate XA), in parts of the Cassiar and Omineca Mountains, and in the Hart Ranges. This type of topography may have been partly destroyed or completely obliterated in some areas by intense late-stage cirque and alpine glaciation.

Eventually the entire Cordilleran region was covered with ice whose surface reached a maximum elevation over the southern interior of more than 8,000 feet.* At this stage of maximum ice coverage, movement of the ice was largely independent of the underlying topography, and was controlled to a large extent by climatic factors.

Ice Movement

Ice moved across British Columbia from the Coast Mountains, and in the plateau areas of the interior it left evidence of its direction of movement in the orientation of drumlins and flutings (*see* Plate XXV). The ice moved in a general easterly direction across the Nechako and Fraser Plateaus (*see* Fig. 10). Farther to the north, ice moved southeastward parallel to Babine Lake and then swung eastward in a great arc south of Stuart Lake. From the area between Whitesail Lake and Anahim Lake, ice moved eastward and northeastward across the Nechako Plateau to the Rocky Mountains. From Chilko Lake, Taseko Lakes, and Williams Lake ice moved northeastward and northward to join the main flow, which in part overrode the Misinchinka and Hart Ranges between the McGregor and Peace Rivers (*see* Plate XXXVIB) and debouched onto the Alberta Plateau in a fan-shaped area west of Dawson Creek.

Farther north ice moved onto the Nahlin, Kawdy, Teslin, and Nisutlin Plateaus and moved generally in a northwesterly direction over the plateaus into Yukon Territory. On the east side of the Cassiar Mountains ice moved northeastward and eastward across the Liard Plain (*see* Plate XXXVIIA), escaping down the valley of the Liard River and across the surface of the Liard Plateau.

On the Thompson Plateau, south of an ice divide which lay between Clinton and Williams Lake, ice moved southeastward and southward across the surface of the plateau to escape southward into the State of Washington.

Elsewhere the ice has recorded the direction of its movement by the landforms it created, and one may discern that ice moved southward down the Iskut River valley from the vicinity of Kinaskan and Kakiddi Lakes; southward through the Nass Basin and down the Nass, Skeena, and Kitimat River valleys; northwestward through Hecate Strait and westward through Dixon Entrance past the northern part of Graham Island; westward from the mainland across the northern end of Vancouver Island; southward and southeastward down the Strait of Georgia and southwestward across the southern end of Vancouver Island; and, as the Puget Lobe, southward down Puget Sound into Washington.

* Glacial Map of Canada, *Geol. Surv., Canada,* Map No. 1253A, 1968.

Both the Atlas of British Columbia Resources and the Glacial Map of Canada show the known details of ice movement. Direction of movement across the plateaus is well displayed on aerial photographs, but information from the mountain belts is far from complete.

After the Cordilleran ice-sheet waned, it was succeeded by a stage of alpine and cirque glaciation. The intensity of this glaciation and its localization was largely controlled by a combination of altitude and climatic factors. Where precipitation was heavy, as in the Fairweather, Boundary, and Pacific Ranges, this stage was most intense (*see* Plates I, VIIIB, and IX). Where the precipitation was less heavy, as in the Park (Main) Ranges of the southern Rocky Mountains and in the Tagish and Tahltan Highlands, there is a noticeable difference in the degree of alpine erosion (*see* Plates XIIIB and XVB). In areas such as the Omineca, Cariboo, and Chilcotin Mountains cirque glaciation was active only on the northern and northeastern (protected from the sun) sides of mountain summits (*see* Plate XXA). In some areas in the southern and northern Rocky Mountains and in the Okanagan, Shuswap, and Cariboo Highlands, low precipitation prevailed, and there is little or no evidence of late-stage cirque glaciation (*see* Plates XXVIIA, XXVIIIB, and XXXIB).

Evidence has accumulated to indicate that there were at least two major advances of the Cordilleran ice-sheet, separated by an interglacial stage* and that in some peripheral areas there were three or more.†

Information of this sort is derived largely from a study of the glacial materials, and it is only rarely that the landforms themselves reveal the great complexities of glacial events. Actually, the landforms that we observe are very largely the erosional or depositional products of the last ice advance (the Wisconsin stage).

One aspect of glacial history, that is not always evident from the observation of present landforms, is that most of the major valleys of the Province were eroded to considerable depths, and in some instances were greatly overdeepened by the passage of valley glaciers through them. Subsequently the valleys have been partly filled with unconsolidated sands and gravels, in many cases to considerable depths, and it is only when a valley has been re-excavated, where drill-holes for dam foundations, ground-water, or other purposes are put down, or where lake soundings are recorded that the great depth to bedrock in the valley bottoms becomes known. For example, information from an oil well at Commotion Creek discloses that bedrock lies beneath 1,081 feet of Recent and Pleistocene unconsolidated sediments below the Pine River; downstream from Hudson Hope, bedrock is at a depth of 320 feet below the Peace River, which flows over unconsolidated sands and gravels; and in Okanagan Lake (elevation, 1,123 feet) the maximum sounding is 760 feet, while at Enderby about 1,300 feet of Pleistocene and Recent unconsolidated sediments was encountered in a drill-hole. The greatest amounts of overdeepening are in the coastal fiords. A sounding of 2,574 feet recorded from Finlayson Channel and one of 2,898 feet near the south end of Chatham Strait indicate that local overdeepening of more than 2,000 feet has taken place.

Melting of the Ice

The Cordilleran ice-sheet disappeared at the end of the Pleistocene, and, as the land emerged from beneath its cover of ice, drainage was re-established. The ice-sheet in its waning stage became stagnant through lack of accumulation in the source areas, and wasted away in place. As a consequence there are numerous small-scale features related to the final stages of the disappearance of the ice.

* Armstrong, J. E., and Tipper, H. W., *Am. Jour. Sci.*, Vol. 246, 1948, p. 306.
† Halstead, E. C., *Geol. Surv., Canada,* Water Supply Paper No. 327, 1957, p. 8.

The escaping meltwater eroded channels which were later abandoned as ice levels were lowered and permanent drainage lines were established. These channels may be seen at high elevations on valley walls or crossing plateau surfaces, and may cut across rock spurs well above the present level of drainage (*see* Plate XXVIIIA).

Large volumes of meltwater were released as the ice melted, and in many places ice marginal lakes were formed about stagnant masses of ice lying in the valleys. Sediments deposited in the lakes remained as terraces and abandoned deltas when the water-level was lowered. Many such lakes were ephemeral, and disappeared when the ice blocks finally melted. Other more permanent ones occupy basins which were created during the Pleistocene. The major lakes, such as Atlin, Babine, Whitesail, Quesnel, Okanagan, etc., occupy basins parallel to the direction of ice flow, and in all instances the basins were overdeepened by valley glaciers. Smaller lakes, many of them very beautiful and world famous, such as Lake Louise, are tarns occupying rock basins excavated in the mountains by cirque glaciers. There are in addition many hundreds of small lakes occupying shallow depressions in areas of drumlinized till, or kettles in areas of glacial outwash.

One of the most widespread effects of the glacial occupation of the country is the derangement of drainage, in some instances on a major scale. Derangement of drainage was due largely to the blocking of pre-glacial drainage channels by ice lobes and glacial moraines which forced the water to flow contrary to its pre-glacial direction. When this took place on a regional scale, it resulted in major shifting of the watershed between the Fraser and Peace River drainage basins, disturbances of drainage in the area between Shuswap Lake and the north end of Okanagan Lake, and creation of unusual stream patterns such as are followed by the Kootenay, Nass, and Skeena Rivers (*see* pp. 56, 67, 110, 111).

Post-glacial Effects

At the maximum stage of ice occupation the ice reached an elevation of more than 8,000 feet over the southern interior of the Province. The great weight of ice overloaded the earth's crust, and, as a consequence, the land surface was depressed with respect to sea-level. Regionally, the amount of the depression was proportional to the depth of ice cover. The amount of depression is considered to have been at least 1,000 feet at the Fraser River delta.*

Since the ice-sheet disappeared the land has risen with respect to sea-level and has essentially regained equilibrium. The rise in some places may be measured by the occurrence of marine shells and marine sediments above present sea-level. This rise accelerated erosion in the lower courses of post-glacial streams, and as a consequence canyons in rock or in valley fill have been incised. Because there was unequal ice loading during the Pleistocene, there was an unequal rise of the land when the ice melted. A differential uplift of as much as a few feet per mile has tilted the old shorelines of glacial Lake Peace from their original (Pleistocene) horizontal positions.

The length of time that has elapsed since the disappearance of glacial ice varies from place to place. Some places are still covered by ice which might be considered a last remnant of the Pleistocene ice cover, and some areas, such as Tarr Inlet at the head of Glacier Bay, have only within the last several decades emerged from beneath the ice. In general, however, the Pleistocene is considered to have ended about 10,000 years ago. It is by means of radio-carbon age determinations that precise time measurements are made. Using this method, wood from the

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* Armstrong, J. E., and Brown, W. L., *Geol. Soc. Am.*, Bull. Vol. 65, 1954, p. 362.

base of the Sumas till in the Fraser River delta was found to be 11,300 ±300 years old. This, in effect, is the date of the last Pleistocene ice advance there.

The geological time interval immediately following the Pleistocene is called the Recent. It began about 10,000 years ago with a warm dry period, the "climatic optimum," which in turn was followed by a cool moist period that resulted in the "little ice age." In British Columbia the climax of the "little ice age" was about 450 years ago,* at that time mountain glaciers advanced to their maximum extent since the Pleistocene. The recession of glaciers from the limits reached during the "little ice age" has varied from place to place, but in general it began within the last 200 years. The climate of British Columbia is becoming progressively warmer, and the present recession of glaciers, which has been at an accelerated rate since 1920, is merely the latest episode in this "little ice age." It may mark the end, or it may not. The uncertainty is not resolved by recent studies of temperature records, which indicate that the rising curve of average annual temperatures reached a peak in 1940 and since then has fallen.†

[References: Nasmith, H., "Late Glacial History and Surficial Deposits of the Okanagan Valley," *B.C. Dept. of Mines,* Bull. No. 46, 1962; Flint, R. F., "Glacial Geology and the Pleistocene Epoch," *John Wiley & Co.,* New York; Kerr, F. A., "Quaternary Glaciation in the Coast Range," *Jour. Geol.,* Vol. 44, 1936, pp. 681–700; Davis, N. F. G., and Mathews, W. H., "Four Phases of Glaciation from Southern British Columbia," *Jour. Geol.,* Vol. 52, 1944, pp. 403–413; Armstrong, J. E., and Tipper, H. W., "Glaciation in North Central British Columbia," *Am. Jour. Sci.,* Vol. 246, 1948, pp. 283–310; Armstrong, J. E., "Surficial Geology of New Westminster Map-area," *Geol. Surv., Canada,* Paper 57-5; Atlas of British Columbia, *B.C. Natural Resources Conference,* 1956, Map No. 4, "Glacial Geology;" Glacial Map of Canada, *Geological Association of Canada,* 1958; Mathews, W. H., "Glacial Lakes and Ice Retreat in South Central British Columbia," Trans., *Roy. Soc., Canada,* Vol. 38, Sec. IV, 1944, pp. 39–57; Mathews, W. H., "Fluctuations of Alpine Glaciers in Southwestern British Columbia," *Jour. Geol.,* Vol. 59, No. 4, 1951, pp. 357–380; Hansen, H. P., "Post Glacial Forests in South Central and Central British Columbia," *Am. Jour. Sci.,* Vol. 253, 1955, pp. 640–658; Heusser, C. J., "Late Pleistocene Environments of North Pacific North America," *Am. Geogr. Soc.,* Spec. Publ. No. 35, 1960; Matthes, F. E., "Glaciers" in Hydrology, edited by O. E. Meinzer, *Dover Publications,* 1942.]

[Photographs: B.C. 360:49; B.C. 501:94; B.C. 893:19; B.C. 983:53; B.C. 1406:11; B.C. 2005:30; B.C. 2007:3; B.C. 2214:46, 68, 88.]

RIVERS OF BRITISH COLUMBIA

Rivers are most important in British Columbia, a land that is largely mountainous and where more than 75 per cent of the surface lies above 3,000 feet elevation. They permit the crossing of mountain ranges on water gradients in major valleys, and thus provide easy access to all parts of the country. Furthermore, they provide migration routes for spawning salmon, opportunities for the development of hydro-electric energy, water for agricultural and domestic use, and in other ways contribute to the economy. However, it is the role of rivers as agents of erosion and transportation in the development of the landforms of British Columbia that justifies specific descriptions of the river systems in this section.

* Mathews, W. H., *Jour. Geol.,* Vol. 59, No. 4, 1951, p. 378.
† Simons, W. D., *U.S.G.S.,* Prof. Paper 424B, 1961, p. B 17.

Table I.—Principal Rivers of British Columbia

	Principal Tributaries	Drainage Area in British Columbia (Square Miles)	Length (Miles)	Flow in Cubic Feet per Second		
				Average	Maximum	Minimum
Yukon River Drainage Basin						
Tagish Lake	.....	4,076	.....	.....	.....	.....
	Atlin River	2,260	.....	3,030	9,830	623
	Partridge River	.....	.....	*	*	*
Teslin Lake	.....	5,016	.....	.....	.....	.....
	Jennings River	.....	.....	*	*	*
	Gladys River	737	.....	*	2,130	83
Takhini River	.....	429	.....	*	*	*
Mackenzie River Drainage Basin						
Liard River[1]	.....	55,374	.....	35,200	223,000	5,100
	Dease River[2]	.....	.....	4,070	21,300	458
	Fort Nelson River	17,200	260	*	97,000	400
	Kechika River	.....	.....	*	*	*
	Toad River	.....	.....	*	*	*
Peace River[4]	.....	49,595	.....	47,100	407,000	4,400
	Finlay River	16,600	250	24,700[3]	211,000	2,260
	Parsnip River	7,750	145	13,800[3]	75,700	2,720
	Beatton River	.....	.....	202[5]	*	*
	Halfway River	.....	.....	890[6]	*	*
	Pine River	.....	.....	4,340[7]	*	*
Hay River	.....	2,927	.....	*	*	*
	Kotcho River	.....	.....	*	*	*
Coastal Drainage						
Alsek River	.....	2,656	60	*	*	*
Bella Coola River[11]	.....	1,934	.....	4,320	28,700	474
Dean River	.....	3,379	.....	*	*	*
Homathko River	.....	2,140	.....	9,290[3]	111,000	950
Klinaklini River	.....	2,035	.....	*	*	*
Nass River[8]	.....	8,046	236	28,700	192,000	860
Taku River[9]	.....	6,673	140	10,500	60,200	880
Stikine River[10]	.....	19,445	335	26,100	120,000	1,420
Skeena River[12]	.....	21,038	360	30,700	330,000	1,830
Unuk River	.....	.....	.....	7,820[13]	*	*
Fraser River Drainage Basin						
Fraser River[14]	.....	89,310	850	93,100	536,000	12,000
	Bridge River	.....	.....	3,570	*	*
	Chilcotin River	.....	146	3,330	16,800	275
	McGregor River	940	.....	*	18,900	1,540
	Nechako River	.....	287	10,300	37,900	1,400
	Quesnel River	4,690	.....	7,790	40,400	980
	Stuart River	5,400	258	4,310	16,000	720
	Thompson River	21,600	304	26,400	127,000	4,360
	West Road River	4,630	.....	*	11,300	216
Columbia River Drainage Basin						
Columbia River[15]	.....	39,770	459	98,270	550,100	18,000
	Canoe River	.....	.....	*	*	*
	Illecillewaet River	.....	.....	*	*	*
	Spillimacheen River	580	.....	1,300	11,000	111
	Kootenay River[16]	.....	276	30,200	142,000	3,270
	Okanagan River	2,870	.....	686	2,830	74
	Pend d'Oreille River	.....	.....	26,706	171,300	2,500
	Similkameen River	3,550	.....	2,245	38,700	120

* Not recorded.
1 Near Lower Post.
2 At McDame in 1958–59.
3 In 1958–59.
4 Near Taylor.
5 On August 1, 1959.
6 On April 18, 1959.
7 On October 10, 1958.
8 At Aiyansh.
9 At Tulsequah in 1958–59.
10 At Telegraph Creek in 1958–59.
11 At Hagensborg.
12 At Usk.
13 On July 30, 1959.
14 At Hope.
15 At International Boundary.
16 At Nelson.

British Columbia includes the drainage basins of four major river systems (*see* Fig. 11): those of the Yukon River flowing northward and northwestward through Yukon and Alaska into the Bering Sea, the Mackenzie River flowing northeastward and northward through northern Canada into the Arctic Ocean, and the Fraser and Columbia Rivers flowing southward and southwestward into the Pacific Ocean. In addition, there are a number of coastal rivers that flow westward into the Pacific Ocean. Drainage areas and volumes of flow are tabulated in Table I.

The main rivers—the Liard, Peace, Fraser, and Columbia—acquire their characteristics from the regions which they drain. Peculiarities of flow depend on climate and the distribution of precipitation, while stream patterns are influenced by the structural features of the underlying bedrock. The influence of bedrock manifests itself in the quite obviously structurally controlled pattern of the Columbia River, in contrast to the very largely dendritic pattern of the Fraser River system. It may be fortuitous, but it is notable that the headwaters of all four major rivers flow at some place and in one direction or another in the Rocky Mountain Trench.

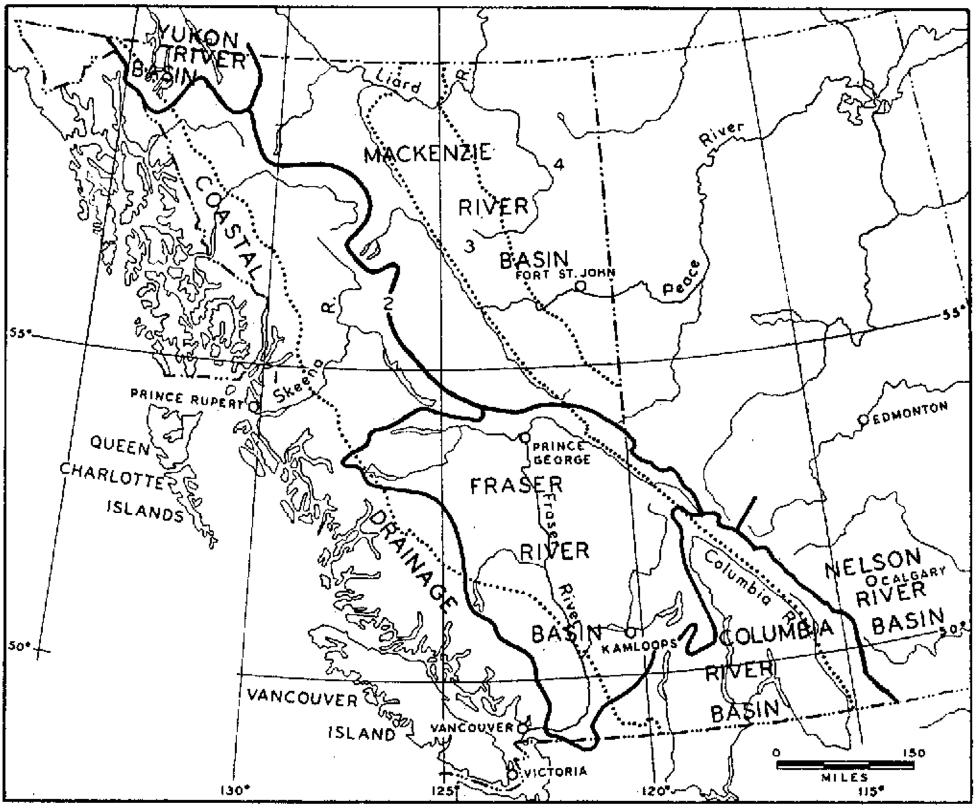

Figure 11. Diagram showing the drainage basins within British Columbia.

All the river systems in British Columbia have had a long and eventful development. The major systems were initiated early in the Tertiary and were rejuvenated by late Tertiary uplift. At that time the Liard River maintained its course around the northern end of the rising Rocky Mountains, and the Peace River continued to flow directly across them in the region of their minimum uplift. The courses of the Kootenay, Columbia, Fraser, and Peace Rivers have been profoundly influenced by stream piracy on a regional scale, as a direct result of differing rates of headward erosion in the several river systems.

Derangement of drainage occurred during the Pleistocene, when, in the waning stages of ice occupation, ice-tongues blocked valleys, pro-glacial lakes were formed, and valleys were filled with outwash materials to depths of hundreds of feet.

Mackenzie River Drainage Basin

The Liard and Peace Rivers and their tributaries, parts of the Mackenzie River system, drain some 108,000 square miles in northern and northeastern British Columbia. The greater part of the Omineca and Cassiar Mountains, the Liard Plain and Plateau in British Columbia, the Rocky Mountains north of Monkman Pass, the Rocky Mountain Foothills in British Columbia, and the Alberta Plateau and Fort Nelson Plain lies within the drainage basin of the Mackenzie River.

Only a small part of the Liard River lies within British Columbia—a length of about 250 miles, from a point a few miles above Lower Post at the confluence of the Dease River to a point 25 miles below the junction of the Fort Nelson River. The elevation of the Liard River at Lower Post is 1,965 feet, at Whirlpool Canyon just below the mouth of Coal River it is 1,500 feet, at the junction of Toad River 15 miles below Hells Gate it is 1,000 feet, and it is about 750 feet where the Liard crosses the border into the Territories.

Downstream from Lower Post, along its course across the Liard Plain, the Liard River flows on an easy gradient, incised 50 to 75 feet below gravel terraces on either side (*see* Plate XVA). Downstream from the Alaska Highway Crossing at Mile 496 the Liard enters a canyon, skirts around the northern end of the Rocky Mountains, and runs through a succession of rapids before resuming a more placid flow downstream from Hells Gate.

In its course through British Columbia the Liard River is joined from the south by the following major tributaries: the Dease River rising at Dease Lake (elevation 2,425 feet) and flowing 115 miles northeastward, the Kechika River flowing northwestward for 145 miles from Sifton Pass (elevation 3,273 feet), the Toad River flowing 105 miles from an elevation of 5,000 feet at its head, and the Fort Nelson River rising in the northern Rocky Mountains at an elevation of 4,500 feet near Mount McCusker and flowing 310 miles northward into the Liard.

The headwaters of the Liard River, upstream from the confluence of the Kechika, are on the western side of the Rocky Mountains and the Liard Plateau. The course of the river was established before the uplift of the mountains. Its position was maintained during mountain-building in the Paleocene and again during the re-elevation of the region in the Pliocene.

The Peace River is formed by the junction at Finlay Forks (elevation almost 2,000 feet) of the Finlay and Parsnip Rivers, both of which rise on the western side of the Rocky Mountains, the Finlay at Thutade Lake (elevation 3,264 feet) at the southern end of the Spatsizi Plateau on the western side of the Omineca Mountains, and the Parsnip (elevation 4,000 feet) southwest of Mount Vreeland. Downstream from Finlay Forks the Peace River cuts through the Rocky Mountains (*see* Plate XLIVA) and Rocky Mountain Foothills without serious interruption by rapids, except in the 14-mile length of the Peace River Canyon at Hudson Hope, where the river cuts across the eastern margin of the foothills. The present canyon is the result of Pleistocene diversion of the river from its earlier course, which was through the Rocky Mountain Portage north of the canyon.

East of the mountain front the river receives the Halfway and Beatton Rivers as major tributaries on the north side and the Pine and Kiskatinaw Rivers on the south. In the stretch downstream from Hudson Hope the river is flowing just below 1,500 feet elevation, incised some 700 feet or more below the adjacent plateau surfaces (*see* Plate XLIVB).

The Parsnip and Finlay Rivers were involved in the erosion of the Rocky Mountain Trench, in which late Cretaceous or Paleocene rocks (Sifton Formation) occur. It is concluded that their regional courses as well as that of the Peace River were established very early in the Tertiary, and that all three are antecedent to the late Tertiary (Pliocene) uplift of the Rocky Mountains. Also the upper Finlay River, above Ware, is antecedent to the latest uplift of the Omineca Mountains in the late Tertiary.

At an early stage in the development of the Peace River system, it is thought that the Nechako Plateau, Fraser Basin, and upper Fraser River above Dome Creek drained northward through the Crooked River depression into the head of the Peace River. The history of the capture of this drainage by the southward-flowing Fraser River is not known, but it was an important event in the evolution of both the Peace and Fraser River systems.

Yukon River Drainage Basin

A small part of northern British Columbia, some 10,000 square miles comprising parts of the Tagish Highland, Teslin Plateau, Nisutlin Plateau, Kawdy Plateau, and Cassiar Mountains, lies within the drainage basin of the Yukon River.

The drainage area is dominated by Tutshi Lake (2,320 feet), Tagish Lake (2,152 feet), Atlin Lake (2,192 feet), Gladys Lake (2,915 feet), and Teslin Lake (2,239 feet), into which most of the drainage flows and from which, on the Yukon side of the border, the Lewes and Teslin Rivers flow northward into the Yukon River. These lakes provide a stable base level of erosion, and the headward erosion of drainage tributary to them is at a low rate. In contrast, the rapid headward erosion of the Taku River and its tributary the Nakina has led to the capture of streams formerly draining northward either into Atlin, Gladys, or Teslin Lakes. It is expected that these Pacific rivers will continue to expand their drainage basins at the expense of the Yukon River system, and that further captures of northerly flowing tributary streams will be effected.

Most of the Yukon River drainage basin in British Columbia is drained by small streams, of which the Jennings River is the largest. It rises at Jennings Lakes (3,800 feet) in the Cassiar Mountains and flows westward for the most part across the Kawdy Plateau for 70 miles into the south end of Teslin Lake.

Fraser River Drainage Basin

The Fraser River rises at Moose Lake in the Park (Main) Ranges of the Rocky Mountains, flows northwestward to the Rocky Mountain Trench at Jackman and along the Trench to Sinclair Mills (*see* Plate XXII). Thence it swings around the north end of the Cariboo Mountains and flows southward through the Fraser Basin and Fraser Plateau, being flanked at various heights above the river by gravel and silt terraces. Southward from Quesnel the river becomes more and more constricted as the river becomes more deeply incised below the surface of the plateau which rises to the south. At Soda Creek, the downstream limit of early navigation on the upper Fraser, the river flows at 1,390 feet elevation, with the valley walls rising steeply to the floor of the Fraser Basin at about 3,000 feet. Downstream from this point the river is constrained by a gorge 1,000 feet or more deep incised in the bottom of the main valley. Below Big Bar the river leaves the Fraser Plateau and begins to flow through more mountainous country, with the Camelsfoot Range on the west and the Marble Range on the east (*see* Plate XLIIIA). Farther south the river has the Pacific Ranges on the west and the Hozameen and Skagit Ranges on the east and south (*see* Plate XIIIA). Its total length from headwaters to the sea is 850 miles.

On its way the Fraser is successively joined by the McGregor, Nechako, West Road, Quesnel, Chilcotin, Bridge, and Thompson Rivers, its major tributaries. The Fraser River drainage basin is 89,310 square miles in area, all within the Province, and is second in size to that of the Mackenzie River in British Columbia.

Elevations within the system are 3,386 feet at Moose Lake, 1,850 feet at Prince George, 2,817 feet at Eutsuk Lake, 2,380 feet at Quesnel Lake, 3,842 feet at Chilko Lake, 2,480 feet at Clearwater Lake, 1,137 feet at Kamloops Lake, and 30 feet at Harrison Lake. These and numerous other lakes within the system serve as temporary base levels of erosion controlling stream gradients.

Almost the entire Fraser River system lies east of the Coast Mountains, and throughout its history the river has maintained its course across them. In its flow through the mountains, downstream from Big Bar, the Fraser River is confined in a canyon, which between North Bend and Yale is narrow, steep-sided, and gorge-like in profile. In this section rocky slopes rise from river-level to summits of 7,000 feet. The river is constricted and, on a grade of about 8 feet in a mile, flows tumultuously between rock walls. A feature of the Fraser River below Lytton is that most of its tributaries are hanging with respect to the main stream and enter it at steep gradients through rock gorges or by a succession of cascades. It is quite evident that downward erosion on the smaller tributaries failed to keep pace with that on the main stream during the late Tertiary uplift of the mountains.

In part at least the Fraser River downstream from Lillooet is a subsequent stream whose course is governed largely by the structure of the rocks over which it flows, for in this stretch between Lillooet and Boston Bar the river coincides with the trace of the Fraser River fault zone. It is apparent also that the composition of the rocks have had a determining effect on the shape of the valley, which is wide in the soft sedimentary rocks and sheared granitic rocks, but is narrow in the massive granitic rocks.

Long continued erosion, acting through the Tertiary, produced by the beginning of Pliocene time a valley with widely flaring sides and a floor several hundred feet above the present stream bed. When Pliocene uplift took place, and the Coast Mountains and the adjacent region were differentially elevated, erosion by the river was revived and excavation of the gorge was begun. A well-defined topographic break on the slopes of spurs 1,500 to 2,000 feet above the present river marks the point at which the present canyon intersects the older valley slope.

The Fraser River canyon that one drives through on the Trans-Canada Highway between Hope and Lytton is the gorge that was eroded during the Pliocene and was slightly modified by Pleistocene glaciation.

The drainage of the Fraser River and its tributaries does not have everywhere the normal pattern of a southward-flowing stream. The upper stretch of the Fraser River above Sinclair Mills flows northwestward in the Rocky Mountain Trench before swinging to the south at Prince George, and the Bowron, Willow, Cottonwood, and Quesnel Rivers have a generally northerly and northwesterly flow, such as might be initiated on a northward-sloping land surface. Similarly, on the west side of the river north of Riske Creek, tributaries such as Narcosli Creek and the West Road, Chilako, and Endako Rivers have northerly and northeasterly directions of flow. South of Riske Creek, tributaries, on the other hand, including the Chilcotin, Bridge, and Thompson Rivers, have a southerly direction of flow and are part of a normal south-flowing dendritic stream pattern. It is apparent that at one time a divide existed, somewhere in the vicinity of Riske Creek, between a south-flowing ancestral Fraser River and a north-flowing segment that perhaps drained by way of McLeod Lake valley into the Peace River (*see* p. 67). This discordant pattern, in combination with geologic evidence, is interpreted to mean that the present course of the upper Fraser River is the result of river piracy on a grand scale at a time that is not precisely known, but that possibly was post-Miocene.*

The Pleistocene and Recent history of the river is not fully documented. During the Pleistocene the entire area was completely covered with ice which, as it melted, gave rise to streams that occupied temporary meltwater channels at various heights above the present river and its tributaries. South of the ice divide in the vicinity of Dog Creek (*see* p. 102), at a time when the valley of the Fraser River was blocked with ice to a level of about 3,500 feet, meltwater escaped by way of Canoe Creek and the falls at the head of The Chasm, across the head of Bonaparte River into Deadman River, and built a huge delta into glacial Lake Kamloops, ultimately escaping southward through the Okanagan Lake valley.

Main valleys were blocked during the waning of the ice, and pro-glacial lakes were formed along the sides or against the front of the wasting ice. The levels of these lakes fell as the ice melted and their outlets were lowered. The lakes diminished in size and eventually disappeared as the ice melted completely and drainage was re-established.

In the vicinity of Quesnel, Prince George, Vanderhoof, and Fort St. James, extensive areas were occupied by pro-glacial lakes, whose surface levels ranged from 2,600 down to 2,450 feet. The Thompson River valley from Spences Bridge upstream as far as Shuswap Lake was occupied by glacial Lake Kamloops, whose elevation ranged from 1,800 to 1,600 feet. Three stages in the development of glacial lakes in the Nicola River valley in the vicinity of Merritt are delineated by deltas and wave-cut benches. The lakes, named Lake Quilchena at 3,450 feet, Lake Hamilton at 3,150 feet, and Lake Merritt at 2,450 feet, drained northward into the Salmon and Thompson Rivers and southward into the Tulameen and Similkameen Rivers, because the Fraser River valley was still occupied by ice. The lakes disappeared with the disappearance of valley ice, and as the Fraser River re-incised its valley in a deep fill of glacial materials which had been deposited during the Pleistocene.

When the complex history of development of the Fraser River system is fully known, the interplay of river piracy, late Tertiary and Pleistocene vulcanism, and glacial diversion will make a most interesting story.

Columbia River Drainage Basin

The Columbia River drainage basin has a total area of 259,000 square miles, of which 39,550 square miles are in British Columbia. The river has a total length of about 1,210 miles, of which the upper 459 miles lie within the Province.

The Columbia River has its source in Columbia Lake (elevation 2,664 feet) in the Rocky Mountain Trench. It flows northwestward for 195 miles through the wide but gradually narrowing valley of the Trench before making its great bend around the northern end of the Selkirk Mountains. From there it flows southward between high ranges of the Selkirk and Monashee Mountains to enter Upper Arrow Lake (elevation about 1,400 feet) at Arrowhead. Downstream from the outlet of Lower Arrow Lake the Columbia is joined by its chief tributary, the Kootenay, at Castlegar and flows southward past Trail to cross the International Boundary into Washington.

The Kootenay River rises in the Rocky Mountains and enters the Rocky Mountain Trench at Canal Flats. It flows southeast through the Trench into Montana and around a loop past Libby and Bonners Ferry, to re-enter British Columbia south of Creston and flow into the south end of Kootenay Lake at 1,740 feet elevation.

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* Tipper, H. W., *Geol. Surv., Canada,* Map 49-1960, marginal notes; Lay, Douglas, *B.C. Dept. of Mines,* Bull. No. 3, 1940, p. 8; Trettin, H. P., " Miocene-Pliocene Plateau Basalts," *B.C. Dept. of Mines,* 1961, unpublished manuscript.

It flows out the west arm of Kootenay Lake and crosses the Selkirk Mountains to join the Columbia River at Castlegar. This southern looping of the Kootenay River and the northern looping of the Columbia around the north end of the Selkirk Mountains are not normal stream patterns and probably are the result of post-glacial diversion and major stream piracy. The details of drainage history are not fully known, and the partial interpretation that headward erosion of the ancestral Columbia River beheaded and captured part of the head of Kootenay River to form the " Big Bend " of the Columbia only suggests what the general explanation might be.

Smaller tributaries of the Columbia that drain an important part of southern British Columbia are the Kettle, Okanagan, and Similkameen Rivers. These rivers drain the southern parts of the Monashee Mountains and the Interior Plateau.

Coastal Drainage

A number of rivers in the western part of British Columbia rise on the eastern side of the Coast Mountains and flow westward through them to the sea. Of them the largest are the Alsek, Taku, Stikine, Nass, Skeena, Dean, Bella Coola, Klinaklini, and Homathko Rivers, of which the Stikine, Nass, and Skeena are the largest.

The Stikine River rises in Laslui Lake (about 3,900 feet elevation) in the southern part of the Spatsizi Plateau and flows 335 miles westward across the Stikine Plateau and through the Coast Mountains to the sea, a few miles north of Wrangell, Alaska. During its course across the plateau it is joined by the Klappan, Tanzilla, Tuya, and Nahlin Rivers, which drain much of the Stikine Plateau. In the Boundary Ranges close to the Alaska Border it is joined by the Iskut River, which drains the southern part of the Tahltan Highland and a segment of the Boundary Ranges. The river has a normal dendritic pattern, which developed during the long period of erosion in the Tertiary and which was maintained against the Pliocene uplift of the Coast Mountains.

An interesting and scenic stretch of the Stikine River is the Grand Canyon upstream from Telegraph Creek, through which the river flows for 40 miles, in part between near-vertical lava walls rising to heights of several hundred feet. The canyon was eroded in Recent time by the river after it was forced from its old valley by the outpouring of fluid basaltic lavas from Mount Edziza (*see* p. 50).

The Nass River rises at about 3,900 feet on the eastern side of the Klappan Range in the northern part of the Skeena Mountains. It flows southwestward for about 236 miles to the ocean at Nass Bay on Portland Inlet (*see* Plate XLVIIB). The river drains part of the western side of the Skeena Mountains and flows through the Nass Basin, where it is joined on the north by the Bell-Irving River and on the south by the Cranberry River. Much of its drainage basin is within an area of heavy precipitation, so that despite the fact that its drainage area is less than half that of the Stikine, its average flow is comparable.

The river downstream from Aiyansh for a length of about 5 miles is flanked on the south by vertical cliffs of black basaltic lava of very recent age. The lava is derived from a small cone on Tseax Creek 3 miles east of Lava Lake, from which flows and scoriaceous material poured northward down the creek valley, forming a lava plain where the larger valley of the Nass was reached and forcing the Nass River against the northern side (*see* p. 57).

The Skeena River rises at an elevation of more than 4,000 feet in the northern Skeena Mountains east of the head of the Nass River. It flows southward and westward for 360 miles to the sea just south of Prince Rupert (*see* Plate XLIIIB). It drains most of the Skeena Mountains, the western part of the Nechako Plateau, the Bulkley and Nass Ranges, and the northern Kitimat Ranges by its chief tributaries, the Babine, Kispiox, Bulkley, Zymoetz, Kitsumkalum, and Ecstall Rivers.

Its pattern of flow within the mountains has developed normally, and in the Skeena Mountains the valleys are in part controlled by bedrock structures. Where the river drains the western part of the Nechako Plateau by the Babine and Bulkley Rivers, it has done so by stream piracy and through glacial derangement of tributaries that formerly were part of the Nechako River drainage.

The Stikine, Nass, and Skeena Rivers drain most of northwestern British Columbia. They have maintained their courses across the Coast Mountains and, with their steep gradients, have expanded their drainage basins at the expense of the Yukon, Mackenzie, and Fraser systems, which surround them. There is no doubt that the coastal rivers will continue to maintain this trend.

[References: Andrews, G. S., "British Columbia's Major River Basins," Trans., *14th B.C. Natural Resources Conference*, 1963, pp. 23–43; British Columbia Atlas of Resources, 1956, Map No. 4, Glacial Geology, and Map No. 8, Water; Mathews, W. H., "Glacial Lakes and Ice Retreat in South Central British Columbia," Trans., *Roy. Soc., Canada,* Vol. 38, Sect. 4, 1944, pp. 39–57; Camsell, C., "Grand Canyon of Fraser River," Trans., *Roy. Soc., Canada,* Sect. 4, 1920, pp. 45–59; Schofield, S. J., "Origin of the Rocky Mountain Trench," Trans., *Roy. Soc., Canada,* Sect. 4, 1920, pp. 61–97; Dawson, G. M., "Later Physiographic Geology of the Rocky Mountain Region," Trans., *Roy. Soc., Canada,* Sect. 4, 1889; Water Power of Canada, *Dept. of Northern Affairs and National Resources,* 1958; Water Powers of British Columbia, *Dept. of Lands and Forests,* 1954; Water Resources Paper No. 128, "Pacific Drainage," *Dept. of Northern Affairs and National Resources;* Water Resources Paper No. 127, "Arctic and Western Hudson Bay Drainage," *Dept. of Northern Affairs and National Resources.*]

[Photographs: B.C. 395:17; B.C. 522:113; B.C. 695:111; B.C. 899:92; B.C. 1087:30; B.C. 1402:10; B.C. 1407:64.]

COASTLINE OF BRITISH COLUMBIA

British Columbia is flanked to seaward by the continental shelf of North America. The sharply defined edge of the platform runs from Dixon Entrance along the west coast of the Queen Charlotte Islands, past Queen Charlotte Sound, and 10 to 30 miles offshore west of Vancouver Island. On the west side of Moresby Island the coast falls off steeply along a fault which bounds the continental platform there and which may extend southeastward along the edge of the platform west of Vancouver Island. Dixon Entrance, Hecate Strait, Queen Charlotte Strait, and the Strait of Juan de Fuca lie on the continental shelf, which is crossed by troughs glacially excavated to depths below 100 fathoms.

The Pacific coast of British Columbia is essentially a structurally controlled fiord coastline. The deeply indented coastline (*see* Plate XLVIA), the flooded glaciated valleys (*see* Plate XLVIB), and the glacial cirques at and below sea-level (*see* Plate VIA) are characteristic features of glaciated coastlines in mountainous regions. The coastline was submerged by ice loading during the Pleistocene, and has only recently emerged. Recent marine shells in the Fraser Valley at an elevation of 575 feet above sea-level demonstrate the amount of post-glacial emergence of the coastline there. It is thought that at present the sea-level and land are in equilibrium.

Shoreline Features

The recent emergence of the present coastline from beneath its covering of Pleistocene ice, less than 11,000 years ago, accounts for the general lack of shoreline features of marine origin. Beaches are scarce because the bedrock exposed along most shorelines is so resistant that little erosion has taken place in the short time since the Pleistocene (*see* Plate VIA). The only extensive beaches are on the west coast of Vancouver Island between Ucluelet and Tofino, along the north and east coasts of Graham Island, and along the east coast of Vancouver Island. They have developed along stretches of shallow depth where unconsolidated glacial materials and easily eroded Tertiary rocks have provided an abundant supply of sand to them. Elsewhere, steeply plunging submarine slopes have not allowed beaches to be retained.

On the west coast of Vancouver Island, beaches are invariably associated with areas of Tertiary sediments or with occurrences of unconsolidated glacial materials. At Florencia Bay and Wickaninnish Bay wide sandy beaches have resulted from wave attack on Pleistocene till and outwash sands and gravels extensively exposed along the shoreline. Both beaches are exposed to the open ocean and to violent wave attack, which constantly cuts into the sea cliffs of unconsolidated material to provide sand and coarse materials which accumulate on the beaches.

At Long Beach strong southwesterly winds have blown sand eastward to form an area of dunes several hundred feet wide and several miles long.

Extensive post-Pleistocene beaches have been developed along the north and east coasts of the northeastern part of Graham Island. The beaches are at the present sea-level and in some instances may be as much as 30 feet above it. Except for the bedrock at Skonun Point, Yakan Point, and Tow Hill, the entire distance between Entry Point and Rose Spit, a distance of 26 miles, is continuous wide sandy beach (*see* Plate XLVB). The foreshore is broad, 500 feet or more, because of the combination of gentle slope and wide tidal range. The backshore area, which may be several hundred feet or more in width, abuts a succession of beach ridges, elongated parallel to the shoreline, that represent post-Pleistocene sea-level stands that are higher than the present.

The beaches extend down the east coast of Graham Island from Rose Spit to Tlell, a distance of 43 miles. To the mouth of Oeanda River, 16 miles south of Rose Spit, the foreshore area is steeper and narrower than on the north coast and the material is more gravelly. Northwesterly trending sand dunes extend for several hundred feet back from the backshore. No bedrock is exposed between Oeanda River and Rose Spit. Low cliffs (cutbanks) of unconsolidated Pleistocene material extend southward from Fife Point. The beaches of the east coast are being formed from the erosion of unconsolidated glacial outwash materials along the shore. Sand derived in this manner is transported northward along the coast by longshore drift to extend Rose Spit northward into Dixon Entrance. The spit appears to have started at the base of Argonaut Hill and to have grown northward for 12 miles to its present position, possibly in more than one stage.

"Wave and current action on the east coast is transporting material northward to Rose Spit, thence westward along the north coast toward Masset Inlet. . . .

"The sand of the north and east coast beaches clearly is derived from Pleistocene deposits which have been eroded by wave action along the east coast south of Argonaut Hill. In places, pebbles on the north coast beaches are derived by erosion from outcroppings of Tertiary formations at Skonun Point, Yakan Point, and Tow Hill. The Pleistocene deposits were probably derived in part from Tertiary sediments and volcanics of Graham Island, but part of the material no doubt comes from more distant sources."*

Sea cliffs for the most part are developed along sections of coastline where there are occurrences of readily eroded rocks such as the softer Cretaceous and Tertiary shales and shaly sandstones, or extensive accumulations of till and glacial

* Holland, Stuart S., and Nasmith, H. W., "Investigation of Beach Sands," *B.C. Dept. of Mines*, 1958.

materials. Along the west coast of Vancouver Island, sea cliffs occur in bays on the Tertiary sediments, between headlands of more resistant crystalline rocks, or where the coastal plain is being attacked and cut into by erosion, producing low cliffs in the more resistant sandstone and conglomerate beds of Oligocene age. Along the east coast of Vancouver Island south of Campbell River, there are occurrences of relatively soft Upper Cretaceous formations and of unconsolidated glacial materials which are susceptible to marine erosion. Wave attack on such materials produces sea cliffs, and in so doing provides detritus for beaches, bars, spits, and similar shoreline features.

Sea cliffs on the Queen Charlotte Islands present a striking contrast to those on Vancouver Island. On the west coast of Moresby Island even the most resistant rocks may be facetted to heights of 500 feet by steep sea cliffs, product of fierce wave attack upon the fully exposed coast (*see* Plate XLVA). However, the submarine slopes are far too steep for the detritus to accumulate as beaches.

In general it can be stated that, except for the relatively few places where erosion of weaker materials is taking place, the coastline of British Columbia is rugged and resistant, and drops off rapidly into deep water with only minor accumulations of beach materials (*see* Plate XLVIA).

Fiords

The outstanding features of the British Columbia coast are its numerous fiord inlets (*see* Plate IIIA, XLVIB, and XLVIII). The mainland from Howe Sound to Portland Canal is indented by fiords, as are the west coast of Vancouver Island and the coasts of the Queen Charlotte Islands, except for the northeast corner of Graham Island.

The fiords on the mainland rank in size and scenic grandeur with the world-famous fiord coastlines of Norway, Patagonia, and the South Island of New Zealand. The fiords are half a mile to 2 miles wide and have steep glaciated sides that rise from the water's edge in long unbroken slopes to summits at 6,000 to 8,000 feet. Along their length, water cascades over falls and down rock faces, and landslides on steep slopes frequently have bared the granitic rocks of all vegetation. On clear days when the all too prevalent low clouds are swept away, the scenery along the many lonely fiords is majestic.

Some of the inlets are unusually long. Burke Channel extends 56 miles into the heart of the Coast Mountains, Dean Channel is 60 miles long, and the head of Gardner Canal is about 120 miles from the outer coast at Otter Pass.

". . . on a map the simplest fiords are seen to be straight, narrow waterways. A few of the fiords are smoothly and gently curved, but in the majority of cases changes of course occur by abrupt deflections through high angles, giving a cranked plan in which the several reaches of the fiord conform to two dominant directions that are usually, but not invariably, inclined at nearly a right angle.

". . . the fiord pattern of the coastland . . . two simple two-component patterns can be distinguished: a dominant pattern consisting of elements arranged longitudinally [northwesterly] and transversely [northeasterly] to the trend of the coastland, giving a rudely rectangular network of varying orientation; and a subordinate pattern composed of linear elements forming a second roughly rectangular pattern oriented obliquely to the first [that is, northerly and easterly]. Since one direction of the dominant pattern runs with the grain of the coastland, the pattern may be described as concordant. . . ."*

Soundings along the fiords almost invariably indicate a shoaling near their mouths produced by a threshold which may be of bedrock or of unconsolidated

* Peacock, M. A., *Geol. Soc., Am.*, Bull. Vol. 46, 1935, p. 655.

materials, with a deeper basin on the inner side. Soundings along the fiords are not everywhere available, but depths are mostly greater than 50 fathoms. The deepest recorded sounding in British Columbia waters is 418 fathoms* (2,508 feet) in Finlayson Channel on the east side of Swindle Island. This is comparable to the remarkable sounding of 483 fathoms (2,898 feet) in southeastern Alaska at the southern end of Chatham Strait.

The fiord system is a product of intense glaciation of a mountainous coastline. Pre-glacial valleys on the western side of the Coast Mountains were occupied by Pleistocene ice and served as escape routes for ice flowing westward to the sea from the high area of accumulation along the crest of the mountains. The moving ice eroded the valley walls to their present steep profiles, and the great thickness of ice eroded the bottoms of trunk valleys to considerable depths below sea-level. Then, as the ice left the valleys they were invaded by the sea to produce the drowned fiord system of today.

Sea-level Changes

Changes in the relative height of sea-level have taken place along the western margin of British Columbia continuously during the geologic past, and as a consequence the position of the coastline has changed constantly.

During Tertiary time no marine Tertiary sedimentary rocks were deposited in British Columbia except in basins between the Queen Charlotte Islands and the mainland, at the mouth of the Fraser River, and as coastal plain deposits along the west coast of Vancouver Island. This implies that the mainland stood well above sea-level and that the coastline during the Tertiary remained in much the same general position as it is now. In the same period there were changes in the height of land above sea-level. The Tertiary opened and closed with uplifts which rejuvenated the erosive power of the rivers. The effects of the uplifts are expressed topographically by many features along and inland from the coast. Despite the reduction of the land surface by erosion, the land stood relatively higher at the close of the Tertiary than it did at the beginning.

Changes in sea-level have continued to take place during and since the Pleistocene. They are not well known, are variable from place to place, and are complicated by the fact that they involve the interplay of three factors: (*a*) isostatic adjustments of the crust, (*b*) tectonic movements of the crust, and (*c*) eustatic movements of sea-level.

Isostatic adjustments of the earth's crust took place in response to its loading with the great accumulation of Pleistocene ice and its unloading with the subsequent melting. The ice load depressed the land, which subsequently rose as the ice finally melted. It is generally considered that the isostatic readjustment of the land was nearly contemporaneous with the melting of the ice load, and that today equilibrium has been reached. The total isostatic depression of the land due to ice load has been estimated to have been at least 1,000 feet in the Fraser Valley.†

Tectonic movements of the crust in response to mountain-building forces may produce either uplift or depression of the land. Tectonic movements in the Haines area of Alaska produce a rise of the land of approximately 0.08 foot per year as determined by studies of tidal gauges. No conclusion can be derived from gauge records in the vicinity of Vancouver or Victoria.

Eustatic changes of sea-level took place during the Pleistocene as glaciers grew or diminished and water was withdrawn from the ocean or returned to it with a corresponding fall or rise of sea-level. The eustatic rise of sea-level since the

* Pickard, G. L., Trans., *Roy. Soc., Canada*, Vol. L, Ser. III, 1956, pp. 47–58.
† Armstrong, J. E., and Brown, W. L., *Geol. Soc., Am.*, Bull. Vol. 65, 1954, p. 362.

Pleistocene probably has been between 400 and 500 feet in total amount. It, of course, is related to the world-wide distribution of snow and glacial ice. Currently it is believed that in stable regions in post-glacial time the sea has not risen appreciably above its present level and that it has risen continuously, though perhaps intermittently, up to modern time. This rising sea-level has affected the British Columbia coast during the last 10,000 years.

The combination of these factors operating during and since the Pleistocene has resulted in changes of sea-level, whose net effect, measured by beach deposits and Recent marine fossils at various heights above sea-level, has been a post-Pleistocene emergence of the land of 485 feet at Stewart, 500 feet at Campbell River, 465 feet at Qualicum, 470 feet at Nanaimo, 424 feet on Texada Island, 300 feet at Victoria, about 300 feet in Alberni Basin, 575 feet at Vancouver, 50 feet along the west coast of Vancouver Island, and 20 to 30 feet on Queen Charlotte Islands.

[References: Twenhofel, W. S., " Recent Shoreline Changes along the Pacific Coast of Alaska," *Am. Jour. Sci.*, Vol 250, 1952, pp. 523–548; Peacock, M. A., " Fiord-land of British Columbia," *Geol. Soc., Am.*, Bull. Vol. 46, 1935, pp. 633–696; Guilcher, A., " Coastal and Submarine Morphology," *Methuen & Co.*, London, 1958; Flint, R. F., " Glacial and Pleistocene Geology," *John Wiley & Sons,* New York, 1957; Fairbridge, R. W., " Eustatic Changes in Sea Level," in Physics and Chemistry of the Earth, Vol. LV, *Pergamon Press,* 1961, pp. 99–185; Bancroft, J. A., " Geology of the Coast and Islands, Strait of Georgia to Queen Charlotte Sound," *Geol. Surv., Canada,* Mem. 23, 1913; Dolmage, V., " Coast and Islands of British Columbia between Burke and Douglas Channels," *Geol. Surv., Canada,* Sum. Rept., 1921, Pt. A, pp. 22–49; Fyles, J. G., " Surficial Geology, Oyster River," *Geol. Surv., Canada,* Map 49-1959; Pickard, G. L., " Physical Features of British Columbia Inlets," Trans., *Roy. Soc., Can.*, Vol. L, Ser. III, 1956, pp. 47–58.]

[Photographs: Shoreline Features—B.C. 667:107; B.C. 1499:46, 52; B.C. 1919:46, 57; B.C. 2248:2, 5; B.C. 2250:27, 98; Fiords—B.C. 501:111; B.C. 516:34; B.C. 663:95; B.C. 666:71; B.C. 674:15; B.C. 996:19; B.C. 1403:108.]

VOLCANIC LANDFORMS IN BRITISH COLUMBIA

British Columbia lies within a belt in which there has been volcanic activity since mid-Tertiary time. In the same belt there are active volcanoes in Alaska today, and there have been active volcanoes in the Cascade Mountains of Washington and Oregon within historic time. There is no historic record of volcanic activity in British Columbia, but there is evidence of some activity within the last few hundred years, and much activity has been sufficiently recent that the characteristic volcanic landforms, such as cones, shield volcanoes, explosive calderas, and lava plains, have been little modified by erosion or glaciation. The locations of a great many volcanic landforms are shown on Figure 1.

The late Miocene and early Pliocene* was a time of considerable volcanic activity in the interior of British Columbia, when numerous lava flows of basaltic composition spread over great areas of the Interior Plateau and Stikine Plateau. Several centres of eruption in the western part of the Fraser Plateau are prominent features of the landscape. These are the huge accumulations of lava flows and fragmental materials in the large shield volcanoes which constitute the Rainbow Range and the Itcha (*see* Plate XXVIA) and Ilgachuz Ranges. These are domes 10 to 15 miles across that stand 3,000 feet above the general level of the plateau.

* The age of the plateau basalts has been determined by potassium-argon measurements (*see* Mathews, W. H., *University of British Columbia,* Dept. of Geology, Report No. 2, 1963).

Although they have been dissected by late Tertiary stream erosion and subsequently glaciated, their original shape has been largely preserved.

Flat-lying or very gently dipping olivine basalt flows underlie great expanses of the Nechako and Fraser Plateaus. The plateau surface in many instances coincides with an original flow surface, and the minor relief is due mostly to erosion within the veneer of glacial drift. Dissection by streams has produced canyons and step-like slopes which are controlled by vertical jointing within the horizontal flows.

Rising 2,000 and 4,000 feet respectively above the general level of the Stikine Plateau are the two shield volcanoes of Meszah Peak (7,010 feet) (*see* Plate XVIIB) and Mount Edziza (9,145 feet) (*see* Plate XLVIIA). They are dominantly pre-Pleistocene in age and have been partly dissected and glaciated, yet they retain much of their original shape, only slightly modified by later processes. At Mount Edziza, however, volcanic activity has continued into Recent time—a number of small, perfectly formed, breached volcanic cones lie between elevations of 4,500 and 7,000 feet on the slopes leading up to the peak, and distinct lava flows extend northward and eastward down the mountain slopes toward Buckley and Nuttlude Lakes.

Prominent features of the Kawdy Plateau between Meszah Peak and the Atsutla Range are isolated flat-topped conical mountains called "tuyas" (*see* Plate XVIB and pp. 51–52). These are volcanoes which melted their way up through the Pleistocene ice-sheet and which, because of the peculiarity of their origin, differ in form and constitution from normal volcanic cones.* There are in addition a considerable number of small yet easily discernible cinder cones on the Kawdy and Tanzilla Plateaus and on the western margin of the Cassiar Mountains.

Extending in a line northward from Mount Garibaldi to the head of the Bridge River are numerous centres of Pleistocene and Recent volcanic activity (*see* Fig. 1). The main centres of volcanic accumulation are represented by conspicuous mountains as well as by lava fields and other volcanic features. Mounts Cayley, Meagher, and others, in large part, are piles of volcanic materials which have been modified by erosion. Recent explosions (probably less than 6,700 years ago) at centres at the head of the Bridge and Lillooet Rivers cast a great volume of coarse white pumice over an extensive area of the Bridge, Yalakom, and upper Lillooet Rivers.

The summit of Mount Takomkane (east of Williams Lake) is a cinder cone 300 feet high of olivine basalt lying on a glaciated granitic surface. In the area south of Clearwater Lake a number of interesting volcanic landforms include Pyramid Mountain (3,590 feet), which is a perfect small cinder cone, a small breached cinder cone blocking the east end of Kostal Lake, and several explosion pits nearby. Lava from a conical vent on the southwest side of Ray Mountain flowed down Falls Creek for 6 or more miles almost to the outlet of Clearwater Lake, and lava from three cones in the valley of Spanish Creek flowed 6 to 8 miles down Spanish Creek, where, in addition, there is an explosion caldera. Thus in a comparatively small area south of Clearwater Lake, volcanic activity in Pleistocene and Recent time has produced features of importance and of considerable geologic and scenic interest.

Two volcanic centres have recently been mapped† on the eastern edge of the Fraser Plateau. One, 3 miles east of Mount Brew, is a nearly perfect volcanic cone that could be post-Pleistocene. The other, south of Keno Lake, is a cone that is much modified by glacial erosion and is Interglacial or pre-Pleistocene in age.

* Mathews, W. H., *Am. Jour. Sci.*, Vol. 245, 1947, pp. 560–570.
† Campbell, R. B., *Geol. Surv., Canada,* Map 3-1961.

A small volcanic cone with associated ash and pyroclastic rocks occurs in the Nazko Valley west of Quesnel.* The cone is extinct and the fragmental rocks rest on glacial till—proof of its post-Pleistocene age.

A volcanic cinder cone forms Kitasu Hill (860 feet), which lies on the Milbanke Strandflat on the southwest peninsula of Swindle Island (Plate VIA). The perfect cone has a small summit crater and a lava flow extending eastward from it to Higgins Passage. It is quite unaffected by glaciation and evidently is post-Pleistocene. Twenty miles to the southeast, on Lake Island at the entrance to Mathieson Channel, a conical peak about 1,000 feet high is composed of brown volcanic tuffs which rest on glaciated surfaces of quartz diorite. It and thin flows on nearby Lady Island are also post-Pleistocene in age.

A period of volcanism that extended from about Middle Tertiary to Recent time is represented in the Hogem Ranges by necks, dykes, and lavas of basalt and basaltic glass along a line lying east of Bear Lake. The youngest phases of activity are represented by deposits of pumice, ash, cinders, and other pyroclastic material, quite obviously post-Pleistocene in age, that form cone-like peaks 1¾ miles northeast and 6½ miles southeast of The Thumb.

South of the Nass River, lava from a small cone near the head of Tseax River flowed westward for several miles to block the main valley of Tseax River and create Lava Lake; it then flowed northward into the Nass Valley, expanding into a lava plain 7 miles long and 3 miles wide (*see* Plate XLVIIB). The lava is thought to be not older than 300 years. It is so recent that it is very largely devoid of vegetation, and the original surface features of the several flows, such as ropy lava and scoriaceous breccia, are clearly visible. Colonization of the lava, first by lichens and later by mosses, ferns, and larger plants, is proceeding slowly.

Farther to the northwest, in the Boundary Ranges between the Iskut and Unuk Rivers, there are several small centres from which lava flowed southward into the Unuk River valley, constricting it and forming the second and third canyons on the Unuk River and the canyon on the Iskut River downstream from Forrest Kerr Creek.

Hoodoo Mountain on the north side of the lower Iskut River " is one of the most magnificent and interesting mountains in northern British Columbia. It does not possess the rugged outline of its neighbours, but largely retains the shape characteristic of volcanoes. In general, it rises with gentle slopes of 10 to 20 degrees to a crater, now ice-filled, at an elevation of more than 6,500 feet. Except for minor irregularities caused by erosion, any contour line is practically a circle. About the middle of the south side two great vertical cliffs each rise for several hundred feet; over them streams drop in magnificent falls. The west side presents an irregular series of vertical cliffs of which the lower are as much as 700 feet in height. Hoodoos, needle-like pyramids up to 500 feet in height, and other odd monumental forms, give the mountain a weird appearance. . . .

" The volcano erupted in the centre of an old valley that must have drained to the Iskut about 3 miles above the present Hoodoo River. . . . Successive outflows from the volcano repeatedly disrupted the drainage, so that the flanking streams and glaciers have had a difficult struggle to maintain their channels."†

It is believed by Kerr that some of the very thick flows were the product of damming brought about by chilling of the lava in contact with glacial ice. The oldest lavas flowed out onto a glaciated surface and were thought to have been extruded when ice surrounded the mountains to at least an elevation of 3,500 feet. Later flows were probably extruded during an interglacial period because they

* Tipper, H. W., *Geol. Surv., Canada,* Map 12-1959.
† Kerr, F. A., *Geol. Surv., Canada,* Mem. 246, 1948, p. 41.

occupy canyons eroded to a considerable depth. " It is quite possible, therefore, that volcanic activity may have been initiated either early in Glacial time or prior to the onset of glaciation. The evidence at hand seems to indicate that the volcano was active up to some time within the last few hundred years; and it may still be merely dormant rather than extinct."*

Near Atlin olivine basalt and related pyroclastic rocks form the cone of Ruby Mountain west of Ruby Creek, and some lava has flowed down the creek almost to Surprise Lake. This lava, partly post-Pleistocene in age, consists of thin olivine basalt flows, each 5 to 15 feet thick and totalling about 120 feet in thickness. The lava lies above gold-bearing gravels and forms a canyon along the creek. Two fans of scoriaceous material on the west side of the creek evidently represent the latest outpouring from the Ruby Mountain cone. On the east side of Ruby Creek there is one small cinder cone. These occurrences occupy a small area and are the northernmost evidence of late volcanic activity in British Columbia.

[References: Aitken, J. D., "Atlin Map-area," *Geol. Surv., Canada,* Mem. 307, 1959; Black, J. M., "Atlin Area," *B.C. Dept. of Mines,* unpublished manuscript; Kerr, F. A., " Lower Stikine and Western Iskut River Areas, British Columbia," *Geol. Surv., Canada,* Mem. 246, 1948; Lord, C. S., " McConnell Creek Map-area," Mem. 251, *Geol. Surv., Canada,* 1948, p. 43; " Stikine River Area," *Geol. Surv., Canada,* Map 9-1957; Hanson, F. A., " Reconnaissance between Skeena River and Stewart," *Geol. Surv., Canada,* Sum. Rept., 1923, Pt. A, p. 39; Dolmage, V., " Coast and Islands of British Columbia between Burke and Douglas Channels," *Geol. Surv., Canada,* Sum. Rept., 1921, Pt. A, p. 29; Davis, N. F. G., " Clearwater Lake Area," *Geol. Surv., Canada,* Sum. Rept., 1929, Pt. A, p. 290; Mathews, W. H., " Geology of Mount Garibaldi," *Geol. Soc., Am.,* Bull. Vol. 69, 1958, pp. 161–198; Mathews, W. H., " Mount Garibaldi, A Pleistocene Volcano," *Am. Jour. Sci.,* Vol. 250, 1952, pp. 81–103; Watson, K. DeP., and Mathews, W. H., " The Tuya-Teslin Area," *B.C. Dept. of Mines,* Bull. No. 19, 1944; Cotton, C. A., " Volcanoes as Landscape Forms," *Whitcombe and Tombs, Ltd.,* Christchurch, 1952.]

[Photographs: B.C. 502:6, B.C. 866:34, 49; B.C. 984:59, 64; B.C. 985:26; B.C. 986:90; B.C. 1374:28; B.C. 1744:10; B.C. 1919:38.]

MAJOR LINEAMENTS OF BRITISH COLUMBIA

Lineaments are extremely common features in the landscape of British Columbia. They are normally on so large a scale, however, that they may be difficult to recognize on the ground. Many have lengths measured in scores of miles, and consequently are most frequently discovered through study of topographic maps (*see* N.T.S. Sheets 92M and 103A) or aerial photographs (*see* Plate XLVIII), or by direct observation from an aircraft in flight.

A lineament is an alignment of topographic features that is structurally controlled; that is, it is governed by or directly related to some geologic structure. It may consist of some straight or gently curved topographic feature, such as an alignment of valleys, wind gaps, scarps, or ridges, whose origin is controlled by faults, joints, bedding, geologic contacts, foliation, or lineation.† Drumlins and glacial flutings are not lineaments because, although they may be strongly linear in their arrangement, they are not structurally controlled.

Few studies of lineaments in British Columbia have been made, and no published results are available. However, their study and investigation is useful, par-

* Kerr, F. A., *Geol. Surv., Canada,* Mem. 246, 1948, p. 45.
† Billings, M. P., " Structural Geology," *Prentice Hall,* New York, 1954, p. 160.

ticularly for those interested in the structure of areas for which geologic maps are inadequate or lacking.* It is possible to point out the occurrence of numerous lineaments, but owing to deficiencies in geological information it is not always possible to interpret their structural significance correctly.

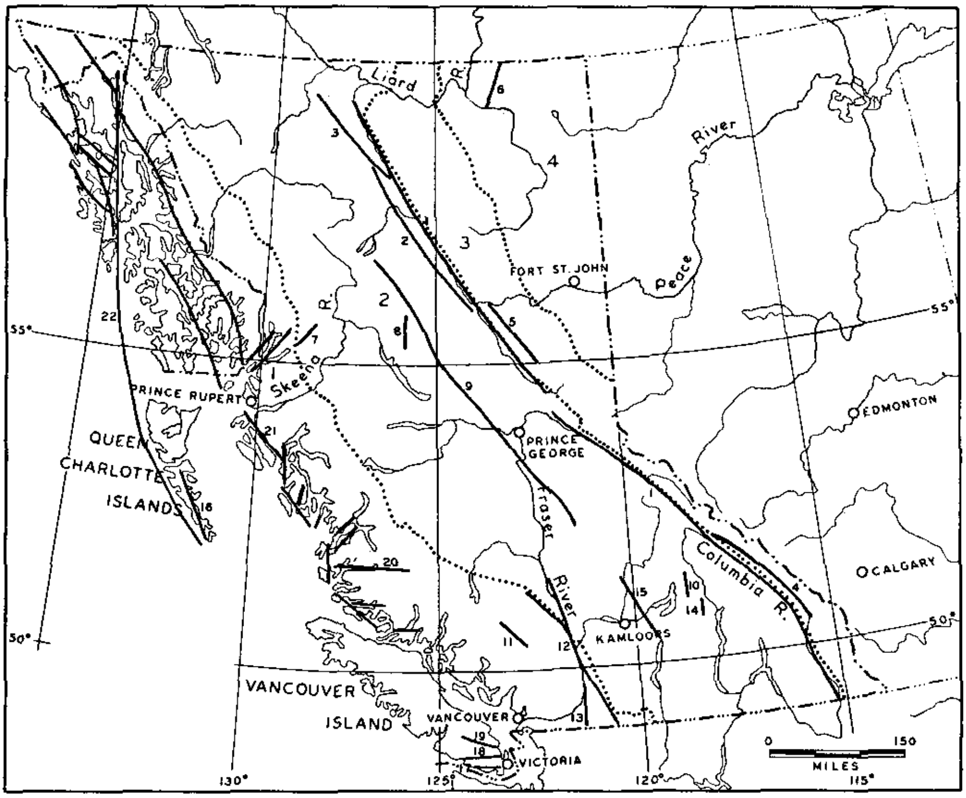

Figure 12. Diagram showing the location of major lineaments.

Figure 12 shows the locations and lengths of the major lineaments whose descriptions follow.

By far the longest and most prominent lineament in the Province is the *Rocky Mountain Trench* (1)† (*see* Plates XXII, XXIVA, and XXXIVB). It extends along the western front of the Rocky Mountains in a northwesterly direction for 900 miles, from the International Boundary almost to the Liard River (*see* p. 65). The structures controlling the Trench are complex, variable from section to section, and not very well known.

" In certain areas the dominant controlling structure is thrust faulting, whereas in other areas it is normal faulting, and in still others strike-slip faulting is indicated. Although the type of faulting varies, there is no area that has been investigated along the Trench in which faults are not observed or required by the relationships on either side. If this is true of the unmapped areas as well, then a linear zone of faulting about 1,000 miles long is indicated. Individual faults within this zone may control the structural relationships and the position of the Trench locally, but the gross shape and regional structural relationships are controlled by the zone of faulting as a whole."‡

* In 1962 an important mineral discovery was made by prospecting along one of the large lineaments in the Hecate Lowland.

† This number locates the lineament on Figure 12.

‡ Symposium on the Rocky Mountain Trench, *Can. Inst. Min. & Met.*, Trans., Vol. 62, 1959, p. 162.

The second most prominent lineament is the *Pelly Creek lineament* (2), which diverges from the Rocky Mountain Trench and follows valleys occupied by the Omineca River, Mesilinka River, Pelly Creek, and Obo River and Lake. North of Johiah Lake it appears to join the *Dall Lake lineament* (3), which leaves the Rocky Mountain Trench at Sifton Pass and follows valleys occupied by Frog River, Denetiah Lake, Dall Lake, and Deadwood Lake to the north end of the Horseranch Range, a distance of almost 150 miles.

The Pelly Creek lineament between the Parsnip River and the intersection with the Dall Lake lineament has a length of 200 miles. In the Aiken Lake area " the Pelly Creek lineament represents an east-dipping plane of weakness which has formed the axial plane of an overturned fold, or, where movement is greater, an underthrust fault which meets the major faults of the Rocky Mountain Trench at depth."*

The *White River lineament* (4) diverges southeast from the Trench at the mouth of the Bush River and follows valleys occupied by Succour and Blackwater Creeks and the Beaverfoot, Kootenay, and White Rivers for a distance of 110 miles. The White River lineament is localized along the White River Break, which is a " major longitudinal fault zone that limits the Western Ranges sub-province [of the Rocky Mountains] on the northeast."† Throughout its length the fault zone lies entirely within Cambro-Ordovician shale of the McKay Group and is marked by a wide belt of highly sheared calcareous phyllite.

Topographic maps and aerial photographs of the Rocky Mountains and Rocky Mountain Foothills reveal the close relationship between stream patterns and bedrock structures. Minor structures, such as joints in the Misinchinka schists, are reflected in the drainage pattern of southwesterly flowing tributaries of the Parsnip River (*see* N.T.S. Sheet 93 O) while the major overthrusts which separate the several Front Ranges appear as topographic lineaments. Sheet 93 O shows a prominent lineament (5), at least 75 miles long, followed by Clearwater and Callazon Creeks, Link and Mountain Creeks, and Burnt River, which marks the trace of a westerly dipping overthrust that bounds the Murray Range on its northeast side.

The *Bovie lineament* (6) is the only prominent lineament in the Fort Nelson Lowland (*see* N.T.S. Sheet 94 O). It is a north-northeasterly trending alignment of cuestas extending for 50 miles between the Fort Nelson and Petitot Rivers. The Bovie lineament has resulted from the thrusting of thick, hard Permian chert and Mississippian limestone eastward over the softer Buckinghorse Formation by the Bovie fault. The west-dipping chert and limestone form the cuestas, whose eastern faces are fault-line scarps parallel to the Bovie fault.‡

The southeast side of the Nass Basin at Dragon Lake is delineated by a northeasterly trending lineament (7), well shown on Plate XXIA and having a length of at least 18 miles. The lineament is emphasized by the erosion by glacial ice which flowed outward from the basin and westward down the Nass River valley. The controlling structure is not known, but its trend is parallel to prominently developed northeasterly lineaments, such as those followed by the Iknouk and Kincolith Rivers and Observatory Inlet, that are well displayed on N.T.S. Sheet 103 P and in photograph B.C. 469:96. These lineaments follow a major joint direction in the granitic rocks of the Coast Intrusions.

Erosion along the Takla fault,§ which is about 40 miles long, has produced a northerly trending lineament (8), which is not recognizable on topographic maps at 4 miles to the inch, but which is recognizable on aerial photographs of the region (*see* B.C. 460:70).

* Roots, E. F., *Geol. Surv., Canada,* Mem. 274, 1954, p. 196.
† Henderson, G. G. L., *B.C. Dept. of Mines,* Bull. No. 35, 1954, p. 43.
‡ Douglas, R. J. W., and Norris, D. K., *Geol. Surv., Canada,* Paper 59-6, 1959, p. 17.
§ Armstrong, J. E., *Geol. Surv., Canada,* Mem. 252, 1949, p. 119.

The *Pinchi fault* and its northwesterly continuation, the *Omineca fault*, has been mapped as a geological feature from Pinchi Lake northwestward for 180 miles to the Niven River. It has produced a lineament (9) which extends as a rather sinuous line of depressions and valleys. The controlling structure is a southwesterly dipping overthrust fault which has moved Permian rocks upward on the west side with respect to Mesozoic formations on the east.* This overthrust eventually may be found to link with a comparable thrust along the southwestern side of the Spatsizi Plateau. Its extension has been mapped for about 180 miles southeastward to the vicinity of Horsefly River. Its known length of 350 miles makes this fault one of the major structural features of the Province.

A trellis drainage pattern is prominently developed in the sedimentary and metamorphic rocks in the Monashee Mountains east of the head of Seymour Arm of Shuswap Lake (*see* N.T.S. Sheet 82 M). Several conspicuous southerly trending lineaments are present, one of which (10), well shown in photograph B.C. 489:60, comprises the aligned valleys occupied by the head of Ratchford Creek, Myoff Creek, and Perry River. Many of these northerly lineaments are Tertiary faults along which andesitic and rhyolitic dykes have been introduced.

A northwesterly trending lineament (11) along the northern wall of the Lillooet River valley (*see* photo B.C. 566:55) lies upstream from Pemberton Meadows and extends for about 20 miles. It is the northernmost of several in the locality and may represent a fault zone along which there may have been movement of Recent age.

The *Fraser River fault zone* has been mapped along the Fraser River as far north as Big Bar. It has several strands, one of which runs up the Yalakom River, and is represented by a well-defined lineament (12) that is visible on topographic maps as well as on aerial photographs of the region (*see* B.C. 498:41). The overall movement along the fault zone was to elevate the western side (Coast Mountains) with respect to the eastern side (Marble, Clear, and Hozameen Ranges).†

A well-defined northerly trending lineament (13) which lies within the Fraser River canyon and extends southward from Spuzzum for 22 miles to Hope is clearly seen on photograph B.C. 589:18. It continues over Silver Peak to the north end of Chilliwack Lake, a further 20 miles. It is a dip-slip fault whose trace south of Hope has been partly obliterated by the intrusion of the Chilliwack batholith.‡

A southeasterly trending fault-controlled lineament (14) extends 20 miles from Three Valley Lake to the head of the Shuswap River.§ The lineament is occupied by Wap Creek, the head of Shuswap River, and the lower part of Vanwyk Creek.

An extremely well-defined lineament (15) follows the trace of the northwesterly trending *Louis Creek fault zone*,|| which extends from the north end of Okanagan Lake to the North Thompson River at Barriere, a distance of 70 miles. The lineament is marked largely by the valleys of Louis and Bolean Creeks and by minor topographic features.

There are several major northwesterly lineaments on Moresby Island. The longest (16) is localized along a fault that extends partly submerged from Louscoone Inlet in a northwesterly direction through Burnaby Strait and east of Tanu to Louise Island, a distance of 60 miles. A second lineament, which may be con-

* Lord, C. S., *Geol. Surv., Canada*, Mem. 251, 1948, p. 50; Armstrong, J. E., *Geol. Surv., Canada*, Mem. 252, 1949, p. 117.

† Duffell, S., and McTaggart, K. C., *Geol. Surv., Canada*, Mem. 262, 1952, p. 87; Trettin, H. P., *B.C. Dept. of Mines*, Bull. No. 44, 1961, p. 99.

‡ Read, P. B., *Geol. Soc., Am.*, Abstracts, Vol. 71, No. 12, Pt. 2, 1960, p. 2072.

§ Jones, A. G., *Geol. Surv., Canada*, Mem. 296, 1959, p. 123.

|| Rice, H. M. A., and Jones, A. G., *Geol. Surv., Canada*, Paper 48-4.

trolled by a branch fault, extends from Beresford Inlet to Talunkwan Island, a distance of 20 miles.

On southern Vancouver Island there are a number of prominent lineaments. Two outstanding ones have an almost east-west trend. One, the *Leech River lineament* (17) (*see* photo B.C. 1533:14), extends from the west coast at the mouth of Loss Creek for 35 miles to the mouth of Goldstream Creek. It follows the valleys of Loss Creek, Wye Creek, Bear Creek, Leech River, Old Wolf Creek, and Goldstream Creek, all of which are along the trace of the Leech River fault. The *San Juan lineament* (18) extends from Port Renfrew in an easterly direction for about 35 miles to the west arm of Shawnigan Lake. It follows the valleys of San Juan River, Clapp Creek, and Koksilah River, which are eroded along the trace of the San Juan fault.

The Cowichan Valley, occupied by Cowichan River and Lake and by Nitinat River tributaries, is a curving fault-controlled lineament (19) with a northwesterly trend and a length of 40 miles. It is only one of a number of fault-controlled valleys with that general trend.

Lineaments are extremely well displayed in maps and aerial photographs of the Hecate (*see* Plate VIA) and Georgia Lowlands and of the fiord section of the Kitimat and Pacific Ranges, by the alignment of river valleys, waterways, lakes, ridges, and various scarps or depressions.

Of the great many lineaments displayed along the coastline, the *Owikeno lineament* (20) deserves mention. It is well shown on N.T.S. Sheet 92M and in Plate XLVIII by the easterly trending alignment of Elizabeth Lake, Hardy Inlet, Owikeno Lake, and Machmell River for a length of more than 50 miles. The photograph shows major joints parallel to the Owikeno lineament crossing a northerly trending lineation which is the topographic expression of bedding in a roof pendant.

Grenville Channel lineament (21), 65 miles long, is the longest of the northwesterly trending lineaments on the coast. There are northeasterly trending lineaments such as that of Portland Inlet and Observatory Inlet, 60 miles long, as well as northerly ones such as those of Douglas Channel, Laredo Inlet, and Fitzhugh Sound.

Peacock's study of the fiords of the British Columbia coast indicates that they are structurally controlled by "axes of folds, the strikes and contacts of geological formations, and the directions of joints, goes, faults, dikes, mineral veins, and shear zones of the surrounding country."*

"Severe folding has affected the pre-batholithic rocks [whose] . . . principal fold-axes trend in general northwestward with considerable local sinuosity in sympathy with the composite crescentic plan of the coastland. This trend is the same as that of the longitudinal (concentric) component of the concordant pattern [*see* p. 115]. . . . A study of the available reconnaissance geological maps of the coastland reveals many fiord features strictly following the strike of the local formations and the linear contacts between different formations. Grenville Channel, an unusually straight and narrow passage (lat. 53° 30′), marks a boundary between granitoid and slaty rocks along 30 miles of its typical longitudinal course."*

". . . All four principal fiord trends are represented by fracture lines; the longitudinal [northwesterly] and transverse [northeasterly] components of the concordant pattern are most strongly represented; the meridional [northerly] component of the discordant pattern is less commonly repeated; the east-west

* Peacock, M. A., *Geol. Soc., Am.*, Bull. Vol. 46, 1935, pp. 656, 657, 658, 660.

component of the discordant pattern is feebly represented except in the vicinity of latitude 51°, where it is the most prominent one."* That direction has been emphasized by erosion of glacial ice moving westward from the high gathering grounds of the Silverthrone, Waddington, and Homathko massifs.

"There is, thus, an impressive correspondence of the pattern of the valley and fiord systems of the coastland to the underlying pattern of folds, fractures, and faults."*

The Denali fault is a structure which has served to localize a major lineament of northwestern North America. From Alaska the *Denali lineament* (22) extends through the Yukon as the Shakwak Valley as far as Dezadeash Lake and thence it turns southeastward up the Tatshenshini River. In British Columbia it follows the valley of Blanchard River and Mansfield Creek and thence down the Kelsall River to the head of Chilkat Inlet. From there the lineament is submerged beneath Lynn Canal and Chatham Strait past Dixon Entrance and thence along a submarine valley immediately offshore from the west coast of the Queen Charlotte Islands.†

The Denali fault is interpreted as being a major zone of faulting which is continuous though multibranched. Movement along the fault has been intermittent over a long period of time and has continued through to the present. Recent earthquakes in the vicinity of Anchorage, Yakutat Bay, and the Queen Charlotte Islands resulted from movements along it. It is suggested by St. Amand‡ that the strike-slip movement on the fault is about 150 miles, but other evidence§ has been presented to indicate that the amount of movement may not be quite so great and that some of it may be high angle thrusting.

[References: Wilson, J. T., "An Approach to the Structure of the Canadian Shield," Trans., *Am. Geoph. Union,* Vol. 29, 1948, pp. 691–726; Gross, W. H., "A Statistical Study of Topographic Linears and Bedrock Structures," Proc., *Geol. Ass. Can.,* Vol. 4, 1951, pp. 77–88; Twenhofel, W. S., and Sainsbury, C. L., "Fault Patterns in Southeastern Alaska," *Geol. Soc., Am.,* Bull. Vol. 69, 1958, pp. 1431–1442.]

[Photographs: B.C. 468:83; B.C. 469:59, 96; B.C. 489:60; B.C. 498:40; B.C. 501:48, 111; B.C. 502:72; B.C. 566:55; B.C. 589:18; B.C. 975:88; B.C. 1207:85; B.C. 1231:73, 80; B.C. 1404:21.]

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* Peacock, M. A., *Geol. Soc., Am.,* Bull. Vol. 46, 1935, pp. 656, 657, 658, 660.
† St. Amand, P., *Geol. Soc., Am.,* Bull. Vol. 68, 1957, pp. 1343–1370.
‡ St. Amand, P., *Geol. Soc., Am.,* Bull. Vol 68, 1957, p. 1366.
§ Twenhofel, W. A., and Sainsbury, C. L., *Geol. Soc., Am.,* Bull. Vol. 69, 1958, pp. 1431–1442.

APPENDIX A.—GEOLOGIC TIME SCALE

Era	Period	Approximate Number of Years Ago*
Cenozoic.	Quaternary. Recent. Pleistocene (Ice Age).	 Last 10,000 10,000 to 1,000,000
	Tertiary. Pliocene. Miocene. Oligocene. Eocene. Paleocene.	(Millions) 1 to 13 13 to 25 25 to 36 36 to 58 58 to 63
Mesozoic.	Cretaceous. Jurassic. Triassic.	63 to 135 135 to 181 181 to 230
Palæozoic.	Permian. Pennsylvanian and Mississippian. Devonian. Silurian. Ordovician. Cambrian.	230 to 280 280 to 345 345 to 405 405 to 425 425 to 500 500 to 600
Proterozoic.	Keweenawan. Huronian.	600 to 2,000
Archæan.	Temiskaming. Keewatin.	2,000 to 4,800

* Science, April 14, 1961, p. 1111.

APPENDIX B.—GLOSSARY*

Aggrade—to build up by the deposition of material in a stream bed. *See* Plate IIA.

Antecedent—streams that are not diverted by structures which grow athwart their course are said to be antecedent; that is, they are antecedent to the uplift. *See* Plate XLIVA.

Anticline—an arch-like fold of bedded or layered rock.

Arête—an acute and rugged crest of a ridge or of a mountain spur such as that between two cirques. *See* Plates I and IX.

Basin—the drainage area of a large river and its tributaries.

Batholith—a body of intrusive rock more than 40 square miles in extent.

Bed—a small division of layered sedimentary rocks marked by a more or less well-defined divisional plane from its neighbours above and below.

Breccia—a rock consisting of angular fragments cemented together. The pebbles of a conglomerate are water-worn.

Breccia pipe—a vertical or highly inclined lenticular, oval or round opening in rocks that has been filled by angular rock fragments.

Cinder cone—a conical elevation formed by the accumulation of volcanic ash or clinker-like material around a volcanic vent. *See* Plate VIA.

Cirque—a deep steep-walled amphitheatre-like recess in a mountain caused by glacial erosion. *See* Plate XXIXB.

Coastal plain—a plain which has its margin on the shore of the sea and represents a strip of recently emerged sea bottom. *See* Plate IV.

Col—a low pass or saddle on the divide between two drainage systems.

Contour line—an imaginary line on the ground, every point of which is at the same elevation.

Cordillera—the great mountain region of western North America between the Interior Plains and the Pacific Ocean.

Cuesta—a gently sloping structural plain terminated on one side by an abrupt slope or scarp.

Dip—the angle of inclination from the horizontal of a stratum or any planar feature.

Dissection—the work of erosion that destroys the continuity of an even surface by cutting ravines or valleys into it. When the dissection is complete, no remnants of the original surface remain.

Drift—any rock material, such as boulders, till, gravel, sand, or clay, transported by a glacier and deposited directly by it or deposited by or in water derived from the melting of glacier ice.

Drumlin—an elongate or oval hill of glacial drift whose long axis is parallel to the direction of flow of a former glacier. *See* Plate XXV.

Dyke—a tabular body of igneous rock that cuts across other rocks.

Erosion surface—a land surface produced by erosion rather than by deposition. *See* Plates XVB and XXXVIII.

Esker—a narrow sinuous ridge of gravelly or sandy stratified drift deposited by a stream in association with glacier ice. *See* Plate XVA.

Eustatic—pertaining to simultaneous, world-wide changes in sea-level.

Fault—a fracture or fracture zone along which there has been displacement of the two sides relative to each other.

Fiord—an inlet resulting from the sea entering a deeply excavated glacial trough after the melting away of the glacier. *See* Plate XLVIB.

* Definitions largely adapted from "Glossary of Geology," *American Geological Institute*, 1957.

Floodplain—the portion of a river valley, adjacent to the river channel, which is covered by water when the river overflows its bank at flood stages. *See* Plate VIB.

Fluting—smooth gutter-like channels or deep smooth furrows worn in the surface of ground moraine or rock by glacial action. *See* Plate XXV.

Fluvioglacial—pertaining to streams flowing from glaciers or to the deposits made by such streams. *See* Plate VIIIB.

Fold—a bend or flexure in layered rock.

Foliation—laminar or layered structure in metamorphic rocks.

Foothill—a hill at the foot of a mountain or of higher hills. Usually used in the plural.

Formation—a sedimentary formation is a lithologically distinctive product of continuous sedimentation. It is part of a succession of strata that is a convenient unit for the purposes of mapping, description, and reference—one or more formations may be deposited during the time interval represented by one of the periods on the geologic time scale on page 126.

Geomorphology—the study of the description, classification, correlation, and origin of landforms.

Geosyncline—a great downward flexure of the earth's crust—the site of deposition of sedimentary and perhaps volcanic rocks over a long period of time.

Glacial lake—lake lying against or on a glacier. *See* Plate XLIA.

Glacier—a field or body of ice formed in a region where snowfall exceeds melting. It shows evidence of past or present flow. *See* Plate I.

Gneiss—a coarse-grained, banded, metamorphic rock.

Goe—the place left on a sea coast through the removal by wave action of a block of rock originally bounded by more or less vertical joint planes.

Graben—a block, generally much longer than wide, that has been downthrown along faults relatively to the rocks on either side.

Ground moraine—a moraine with low relief and no distinctive structure.

Group—a subdivision of sedimentary rocks, based on lithologic features and comprising two or more formations; also an assemblage of mountain peaks without the linear arrangement of a range.

Hanging valley—a tributary valley whose floor is higher than the floor of the trunk valley which it joins. *See* Plate XLIIA.

Highland—elevated or mountainous land; more particularly, an elevated region whose upland surface is not completely dissected. *See* Plate XXVIIIA.

Icefield—a general designation for ice-caps, highland glaciers, or other extensive and irregular areas of glacier ice. *See* Plate XLIA.

Incise—to cut down into, as a river cuts into a plateau. *See* Plate XXXIXB.

Inlier—an area of older rocks surrounded by younger (may be produced by erosion of the crest of an anticline).

Intrusion—a body of igneous rock that invades older rock.

Isostatic—being in hydrostatic equilibrium.

Joint—a fracture or parting which interrupts abruptly the physical continuity of a rock.

Landform—includes all the features, such as plain, plateau, and mountain as well as hill, valley, canyon, and alluvial fan, that make up the surface of the earth. Most of these features are the products of erosion, but the term includes also all forms that are due to sedimentation and to movements within the crust of the earth.

Lineament—an alignment of topographic features along some geologic structure. *See* Plates XLVIII and XXIA.

Lineation—in rock the parallel orientation of structural features that are lines rather than planes. It may be expressed by the parallel orientation of the long dimensions of minerals or of pebbles, cleavage-bedding intersections, or fold axes.

Lowland—includes the extensive plains or country lying not far above sea-level, in general less than 1,000 feet altitude, but marked off by their contrast with the higher lands of the mountains rather than by any special altitude. The surface may be undulating or hilly. *See* Plate VIIB.

Matterhorn—a sharp horn-like or pyramid-shaped mountain peak somewhat resembling the Swiss peak of that name. It is a product of erosion by cirque glaciers. *See* Plates XLIB and XIIA.

Mature—a stage in the cycle of erosion, between youth and old age, when streams have reached a gentle gradient and valleys are wide and deep.

Meltwater—water resulting from the melting of snow or of glacial ice.

Metamorphism—the mineralogical and structural adjustment brought about in solid rocks by changes in physical and chemical conditions.

Monadnock—by long continued erosion a land surface may be reduced to an almost level plain, but there still may be a few hills or mountains which, having escaped final destruction, still rise conspicuously above the plain—these are monadnocks. *See* Plate XXIVB.

Moraine—an accumulation of drift, built chiefly by the direct action of glacier ice.

Nunatak—a hill or peak which was formerly surrounded but not overridden by glacial ice; one which now projects through the surface of a glacier. *See* Plate XLIA.

Orogeny—the process of forming mountains by folding and faulting.

Outwash—stratified drift deposited by meltwater streams beyond active glacier ice.

Outwash plain—the surface of a broad body of outwash. *See* Plate XLIA.

Overthrust—a thrust fault with low dip and a large displacement that is generally measured in miles.

Peneplain—a land surface worn down by erosion to a nearly flat or undulating plain.

Physiography—originally, the systematic examination of landforms and their genetic interpretation. This meaning is now conveyed by geomorphology, and physiography is considered to include climatology and oceanography as well as geomorphology.

Piedmont—lying or formed at the base of mountains, as a piedmont glacier.

Piracy—the diversion of the upper part of a stream by the headward growth of another stream, also called stream capture, stream robbery, and beheading.

Plain—an area of level or nearly level land. *See* Plates VA and XLVIIB.

Plateau—an elevated area of comparatively flat land which may be partly dissected by valleys. *See* Plate XXXVIII.

Prairie—a treeless and grassy plain. *See* Plate XXXIXB.

Pro-glacial lake—a lake of glacial origin lying beyond the ice front.

Pyroclastic—a general term applied to volcanic materials that have been explosively ejected from a volcanic vent.

Range—a chain of mountains or hills.

Rejuvenate—to stimulate, as by uplift, to renew erosive activity; said of streams.

Relief—the difference in elevation between the high and low points of a land surface.

Roche moutonnée—a rounded hummock or boss of rock smoothed and striated by glacial action.

Scarp—an escarpment, cliff, or steep slope of some extent along the margin of a plateau, terrace, or bench. *See* Plate XXXVIII.

Sea cliff—the wave-eroded cliff on the shoreward margin of a beach or terrace that is subject to wave attack. *See* Plate XLVA.

Serrate—a saw-tooth profile, as of a ridge.

Sheeting—gently dipping joints that are essentially parallel to the ground surface; they are more closely spaced near the surface and become progressively farther apart with depth. Sheeting is especially well developed in granitic rocks.

Shield volcano—a broad, gently sloping volcanic cone of flat domical shape, usually several tens or hundreds of square miles in extent, built chiefly of overlapping and interfingering basaltic lava flows. *See* Plates XXVIA and XVIIB.

Snowline—the limit of height at which snow is permanent throughout the year.

Stock—a body of plutonic rock that covers less than 40 square miles; it commonly has steeply dipping contacts.

Strandflat—a low coastal platform that abuts higher terrain on the landward side; it may be partly submerged and its altitude depends partly on recent vertical movements of the coast. *See* Plate VIA.

Strike—the bearing of the intersection of an inclined plane with the horizontal.

Structural—pertaining to, part of, or consequent upon geologic structure, as a structural valley.

Subsequent stream—one that has grown headward by retrogressive erosion along a belt of weak structure; used also for streams which have been thus developed in one cycle and persist in the same course in a following cycle.

Syncline—a fold in rocks in which the strata dip inward from both sides toward the axis; the opposite of anticline.

Talus, scree—the heap of coarse waste at the foot of a cliff or a sheet of waste covering a slope below a cliff. *See* Plate XXIXB.

Tarn—small mountain lake or pool occupying an ice-gouged basin on the floor of a cirque—a cirque lake. *See* Plate XB.

Tectonic—pertaining to the rock structure and external forms resulting from the deformation of the earth's crust.

Terrain—tract or region of ground immediately under consideration.

Thrust fault—a reverse fault that is characterized by a low angle of inclination to the horizontal. *See* overthrust.

Till—non-sorted and non-stratified glacial stony clay.

Timberline—the height on mountains above which there are no trees.

Trellis drainage—arrangement of parallel tributary streams generally flowing at right angles into a trunk stream.

Tuya—flat-topped, steep-sided volcano consisting of horizontal beds of lava capping outward-dipping beds of fragmental volcanic rocks. *See* Plate XVIB.

Underfit—a stream is underfit when it is too small to have eroded the valley it now occupies. *See* Plate XLA.

Uplands—elevated land surfaces, exclusive of valleys, that are represented by flat-topped ridges and gently sloping areas. They are remnants of an erosion surface produced during an earlier erosion cycle and subsequently dissected. *See* Plate XVIA.

Uplift—elevation of any extensive part of the earth's surface relative to some other part; opposed to subsidence.

Upwarp—an area that has been uplifted, generally as a broad dome or anticline.

U-shaped valley—a glacial trough or glaciated valley having a flat floor and extremely steep sides, with a cross-ection like the letter " U." *See* Plate XLIIB.

Valley train—the outwash material deposited by the stream in the valley below a glacier. *See* Plate IIA.

Volcanism, volcanic activity—the natural processes resulting in the formation of volcanoes, volcanic rocks, lava flows, etc.

INDEX

The place names listed are those of physiographic rather than geographic importance. Many are to be found only on more detailed maps, such as the N.T.S. 1:250,000 maps. Each mountain of which the elevation is given is listed.

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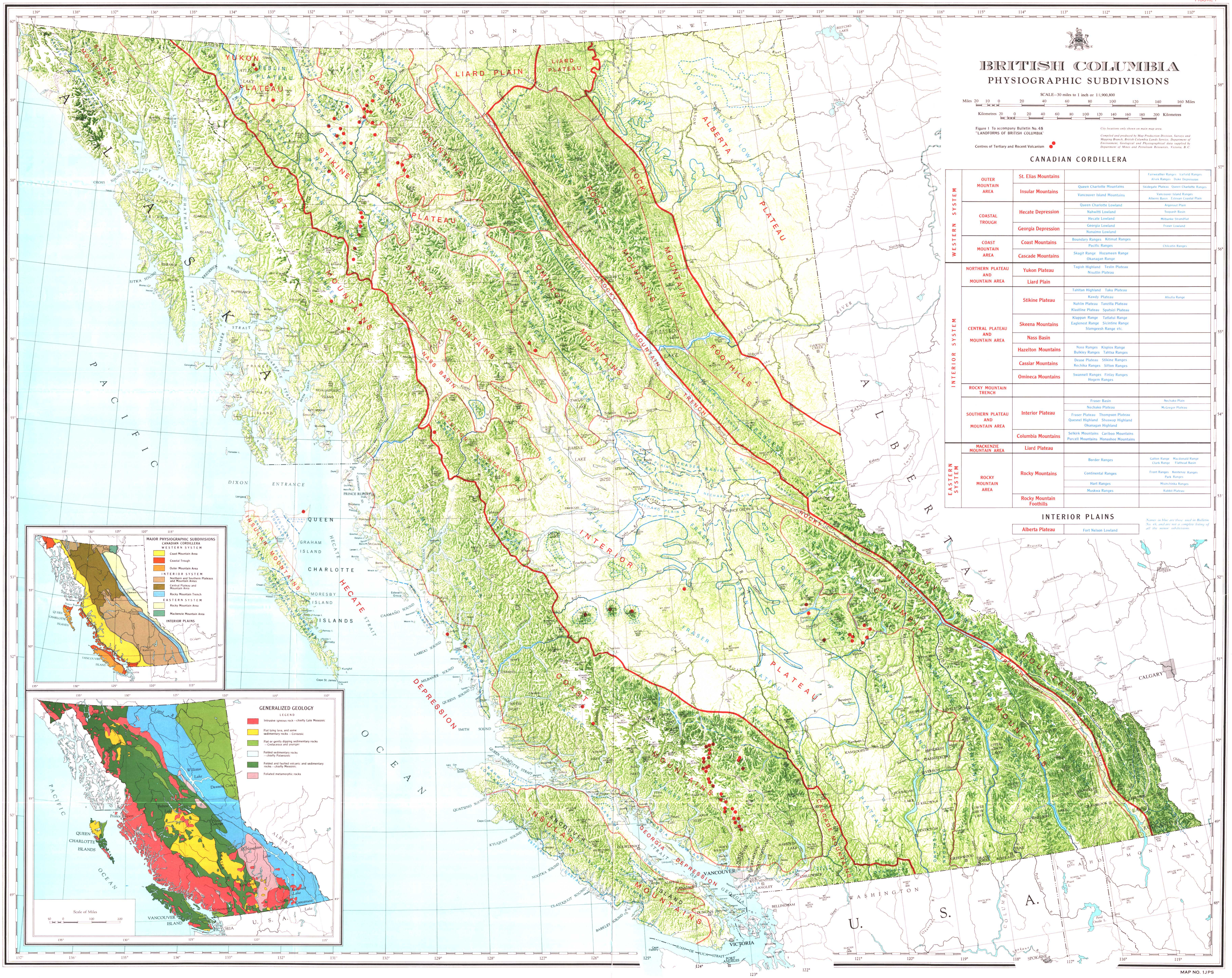
FIGURE 1
BRITISH COLUMBIA
PHYSIOGRAPHIC SUBDIVISIONS
SCALE—30 miles to 1 inch or 1:1,900,800
Miles 20 10 0 20 40 60 80 100 120 140 160 Miles
Kilometres 20 0 20 40 60 80 100 120 140 160 180 200 Kilometres
Figure 1 To accompany Bulletin No. 48 "LANDFORMS OF BRITISH COLUMBIA"
Centres of Tertiary and Recent Volcanism
City locations only shown on main map area.
Compiled and produced by Map Production Division, Surveys and Mapping Branch, British Columbia Lands Service, Department of Environment. Geological and Physiographical data supplied by Department of Mines and Petroleum Resources, Victoria, B.C.
CANADIAN CORDILLERA
WESTERN SYSTEM
OUTER MOUNTAIN AREA
St. Elias Mountains
Fairweather Ranges Icefield Ranges Alsek Ranges Duke Depression
Insular Mountains
Queen Charlotte Mountains
Skidegate Plateau Queen Charlotte Ranges
Vancouver Island Mountains
Vancouver Island Ranges Alberni Basin Estevan Coastal Plain
COASTAL TROUGH
Hecate Depression
Queen Charlotte Lowland
Argonaut Plain
Nahwitti Lowland
Suquash Basin
Hecate Lowland
Milbanke Strandflat
Georgia Depression
Georgia Lowland
Fraser Lowland
Nanaimo Lowland
COAST MOUNTAIN AREA
Coast Mountains
Boundary Ranges Kitimat Ranges
Pacific Ranges
Chilcotin Ranges
Cascade Mountains
Skagit Range Hozameen Range Okanagan Range
INTERIOR SYSTEM
NORTHERN PLATEAU AND MOUNTAIN AREA
Yukon Plateau
Tagish Highland Teslin Plateau Nisutlin Plateau
Liard Plain
CENTRAL PLATEAU AND MOUNTAIN AREA
Stikine Plateau
Tahltan Highland Taku Plateau
Kawdy Plateau
Atsutla Range
Nahlin Plateau Tanzilla Plateau Klastline Plateau Spatsizi Plateau
Skeena Mountains
Klappan Range Tatlatui Range Eaglenest Range Sicintine Range Slamgeesh Range etc.
Nass Basin
Hazelton Mountains
Nass Ranges Kispiox Range Bulkley Ranges Tahtsa Ranges
Cassiar Mountains
Dease Plateau Stikine Ranges Kechika Ranges Sifton Ranges
Omineca Mountains
Swannell Ranges Finlay Ranges Hogem Ranges
ROCKY MOUNTAIN TRENCH
SOUTHERN PLATEAU AND MOUNTAIN AREA
Interior Plateau
Fraser Basin
Nechako Plain
Nechako Plateau
McGregor Plateau
Fraser Plateau Thompson Plateau Quesnel Highland Shuswap Highland Okanagan Highland
Columbia Mountains
Selkirk Mountains Cariboo Mountains Purcell Mountains Monashee Mountains
EASTERN SYSTEM
MACKENZIE MOUNTAIN AREA
Liard Plateau
ROCKY MOUNTAIN AREA
Rocky Mountains
Border Ranges
Galton Range Macdonald Range Clark Range Flathead Basin
Continental Ranges
Front Ranges Kootenay Ranges Park Ranges
Hart Ranges
Misinchinka Ranges
Muskwa Ranges
Rabbit Plateau
Rocky Mountain Foothills
INTERIOR PLAINS
Alberta Plateau
Fort Nelson Lowland
Names in blue are those used in Bulletin No. 48, and are not a complete listing of all the minor subdivisions.
MAJOR PHYSIOGRAPHIC SUBDIVISIONS
CANADIAN CORDILLERA
WESTERN SYSTEM
Coast Mountain Area
Coastal Trough
Outer Mountain Area
INTERIOR SYSTEM
Northern and Southern Plateaus and Mountain Areas
Central Plateau and Mountain Area
Rocky Mountain Trench
EASTERN SYSTEM
Rocky Mountain Area
Mackenzie Mountain Area
INTERIOR PLAINS
GENERALIZED GEOLOGY
LEGEND
Intrusive igneous rock—chiefly Late Mesozoic
Flat lying lava, and some sedimentary rocks—Cenozoic
Flat or gently dipping sedimentary rocks—Cretaceous and younger
Folded sedimentary rocks—chiefly Palaeozoic
Folded and faulted volcanic and sedimentary rocks—chiefly Mesozoic
Foliated metamorphic rocks
Scale of Miles
PACIFIC OCEAN
ALASKA
ALBERTA
U. S. A.
WASHINGTON
MONTANA
YUKON
N.W.T.
QUEEN CHARLOTTE ISLANDS
VANCOUVER ISLAND
DIXON ENTRANCE
HECATE STRAIT
YUKON PLATEAU
LIARD PLAIN
LIARD PLATEAU
STIKINE PLATEAU
CASSIAR MOUNTAINS
COAST MOUNTAINS
SKEENA MOUNTAINS
OMINECA MOUNTAINS
NASS BASIN
HAZELTON MOUNTAINS
ROCKY MOUNTAINS
ROCKY MOUNTAIN TRENCH
ROCKY MOUNTAIN FOOTHILLS
ALBERTA PLATEAU
INTERIOR PLATEAU
COLUMBIA MOUNTAINS
INSULAR MOUNTAINS
HECATE DEPRESSION
GEORGIA DEPRESSION
CASCADE MOUNTAINS
PRINCE RUPERT
PRINCE GEORGE
KAMLOOPS
VANCOUVER
VICTORIA
CALGARY
MAP NO. 1JPS