PACIFIC RIM NATIONAL PARK

The Geology of Long Beach Segment

The Geology of LONG BEACH SEGMENT
PACIFIC RIM NATIONAL PARK
and its approaches

The story of the beaches, mountains and other scenery

A. H. Lang and J. E. Muller

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ABOUT THIS BOOK

This booklet deals mainly with the Long Beach segment of the park because that is the first part to be developed. A little information is included for the Broken Islands and West Coast Trail segments. Geological aspects of the scenery along the main route across Vancouver Island to the park, and at nearby Alberni Inlet, are also described because they provide features of great interest not found in the park itself.

The booklet is intended for readers having no previous knowledge of geology, as well as for those who have. Technical terms are avoided as much as possible, and are explained where first used. Short outlines of the main geological principles applicable to the region are included as an aid to understanding local descriptions.

THE AUTHORS

Arthur H. Lang, Ph.D., F.R.S.C., is a native of British Columbia. He spent 40 years with the Geological Survey of Canada, doing field work in many parts of the country before becoming a Division Chief and Principal Research Scientist. He is the author of more than 100 geological publications, including several for general readers. After semi-retirement in 1970 he undertook continuation of this series of guidebooks to National Parks. He visited the Long Beach segment and its region for about three weeks to obtain first-hand knowledge of the main features.

Jan E. Muller, Ph.D., was born and educated in the Netherlands. After coming to Canada in 1945 he was employed by Shell Oil Company for three years, then joined the Geological Survey of Canada. He has done geological work in many parts of this country and has spent the last eleven years studying Vancouver Island. He is the author of many publications and a special report and maps on Pacific Rim National Park for use of officials of Parks Canada. As the leading authority on the geology of the region his knowledge and collaboration contributed greatly to this booklet.

ACKNOWLEDGMENTS

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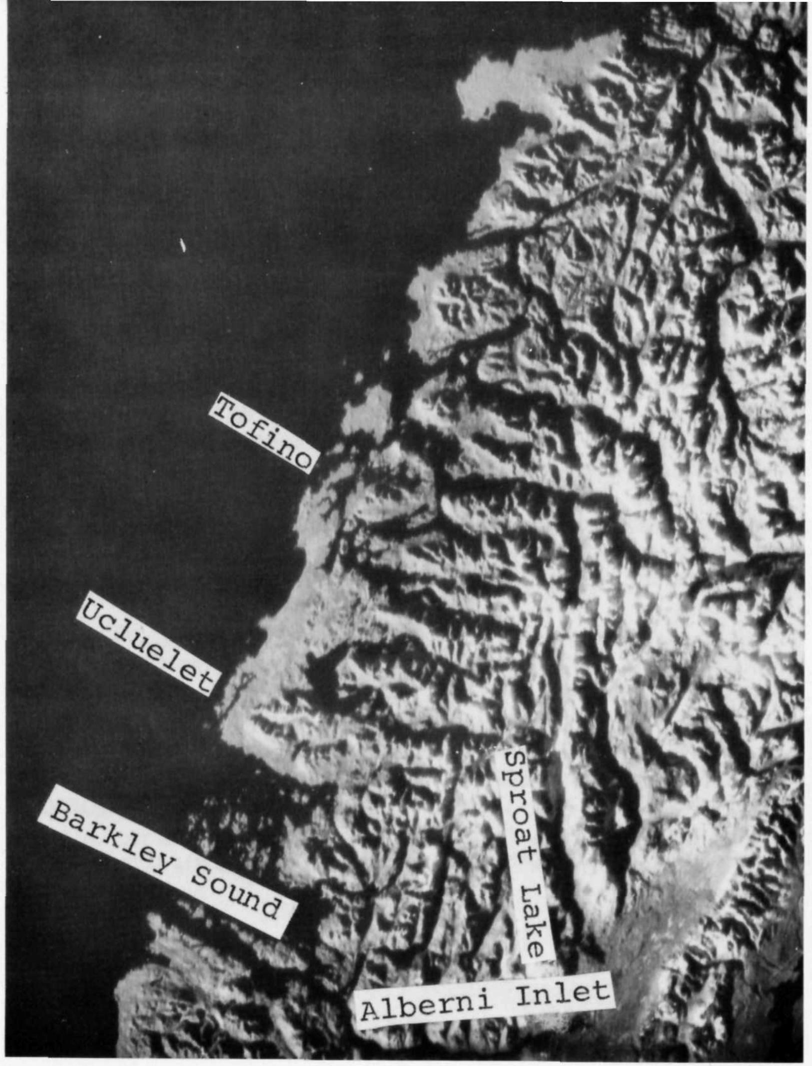
The cover photo was generously supplied by the Government of British Columbia.

The diagrams illustrating formation of fiords and finger lakes are reprinted with kind permission of Macmillan Publishing Co., Inc. from "Things Maps Don't Tell Us" by Armin K. Lobeck 1956.

The maps and two diagrams were drawn by G.R. Dumas.



The difference between the mountains and the coastal plains appears strikingly on this photo taken from the ERTS satellite at a height of 900 kilometres.

INTRODUCTION

Splendid, contrasting coastal and mountain scenery is offered by Pacific Rim National Park and its vicinity. The varied scenery results from its geological history. Even a limited grasp of this will allow fuller appreciation of the landscapes, and add to the enjoyment of visits.

The park is being developed in three segments, separated by stretches of Barkley Sound. The northern, Long Beach segment, is the most advanced and most accessible. Its most popular attractions are exceptionally fine beaches. Spectacular features along and near the drive to this segment are mountains, long narrow lakes occupying glaciated valleys, and Alberni Inlet, a fiord rivalling those of any part of the world.

Besides being the basis of the scenery, geology is of great importance as a fundamental aspect of the ecology of various localities. The bedrocks, and the gravels, sands and soils that cover most of them, are fundamental to environmental studies, which are now receiving more attention than formerly, both by the general public and by scientists and administrators.

Although intended mainly to provide information for those having little or no knowledge of geology, and to arouse further interest in the story behind the scenery, this booklet will serve as a means of 'orientation' for amateur and professional geologists. They will find the varied conditions in and near the park, and the excellent exposures to be found in places, appealing to different interests and specialties.

Collecting specimens of minerals or rocks within the park is prohibited; the importance of leaving occurrences so that they can be studied in their natural settings by later visitors is obvious.

BOUNDARIES AND DEVELOPMENT

Pacific Rim National Park, generally only a few miles wide, extends intermittently for about 80 miles along the west coast of Vancouver Island between Tofino on the north and Port Renfrew on the south. The park is divided into three distinct parts: the northerly Long Beach segment, the central Broken Islands segment, and the southerly West Coast Trail segment.

The 56-square-mile Long Beach segment extends most of the way between Tofino and Ucluelet, which are 26 miles apart by road. The irregular north border stretches from Point Cox to Tofino Inlet. The south boundary is at Wya Point, which forms the south end of Florencia Bay. Details of the boundary are shown on Map 3.

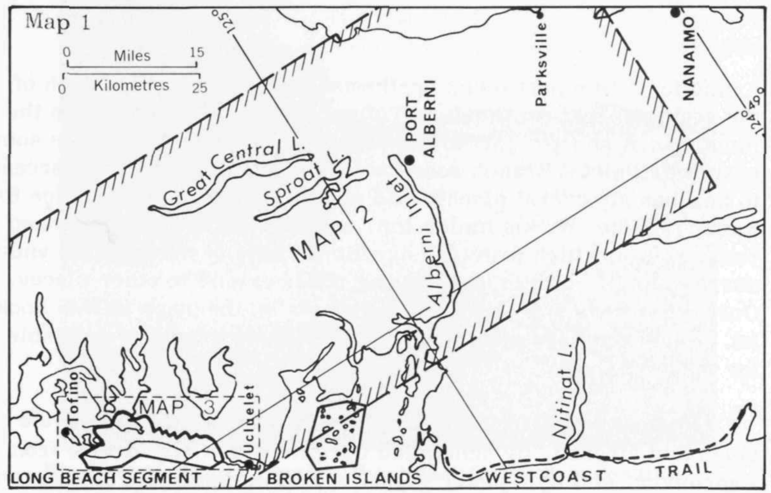
The beaches near Ucluelet attracted some vacationers years ago when travel was by coastal steamers. Later, when it became just possible to reach Ucluelet and Tofino by automobile several years ago, the popularity of the beaches increased so greatly that a provincial Long Beach park was established. This was transferred to Parks Canada in 1972; and later the boundaries were somewhat altered. Further development was undertaken and visitors were permitted, but the park has not yet been proclaimed officially. The Long Beach segment is planned to be the most developed of the three, with campgrounds, trailer parks, supervised beaches and "nature trails", as well as fairly large tracts of undeveloped forested and recently logged semiwilderness.

The Broken Islands segment embraces a group of about 100 small islands and rocky islets in Barkley Sound, a large indentation of the coast which forms the entrance to Alberni Canal. Development of some islands with docks, trails and campgrounds for use by visitors is proposed, but most are intended to be nature sanctuaries.

The West Coast Trail segment extends southeastward along the coast for 45 miles from Cape Beale, the southwest corner of Barkley Sound. Most of this segment is narrow. It is named from a famous trail used years ago to assist survivors from the many wrecks that occurred along this dangerous coast. After improvements in communications, such as radio, the trail became disused except by back-packing hikers, leaving the area one of the most unspoiled coastal wildernesses in North America. Plans are that it shall remain so, except for minimal improvements to make the trail safe for hiking, and establishment of a few primitive campgrounds.

ACCESS

The Long Beach segment is usually reached by automobile via Parksville on the Island Highway (No. 1) along the east side of Vancouver Island. Parksville is 91 miles north of Victoria and 23 miles past Nanaimo. From Parksville a hard-surfaced highway (No. 4) leads to Alberni, a distance of about 30 miles, and from there to the west coast, a further distance of about 65 miles. Near the southeast border of Long Beach segment the highway reaches



Map 1. Sketch map of part of southern Vancouver Island showing the three segments of Pacific Rim National Park and locations of the geological maps included in this booklet.

The slightly uneven surface of the Estevan Coastal Plain appears in the foreground of this view from Radar Hill. Lone Cone and Catface Mountain form part of the background.

a junction. One part turns northwest, extends through much of the segment, and continues to Tofino, which is 21 miles from the junction. A shorter part of the highway, 5 miles long, leads southeast to Ucluelet. Branch roads within the segment provide access to beaches at several places, and also to Tofino Airport, Grice Bay, Kennedy Lake, Wickaninnich Inn, and Radar Hill, an abandoned radar station which provides excellent views of the segment and its surroundings. Trails and logging roads extend to other places. Only a few branch roads could be shown on the maps in this booklet. Several others are shown in the general brochure available for the park.

Other ways of reaching Long Beach segment are by private boats and aircraft, by scheduled but infrequent air service from Vancouver, and by a motor vessel operating between Port Alberni and Ucluelet several days a week.

THE SURFACE OF THE LAND

Vancouver Island is a region of contrasts in which rugged highlands, often snow-capped, alternate with long, narrow valleys whose bottoms generally contain lakes or arms of the sea. Most of the coastal areas are, in further contrast, long but relatively narrow lowlands, commonly 150 to 250 feet above sea level. One of these, Nanaimo Lowland, extends from the south end of the island to a point beyond Campbell River and on it are the towns of Nanaimo and Parksville. This lowland and the mountains to the west can be seen well from the Vancouver-Nanaimo ferries.

Rocky headlands protect the beaches from excessive erosion by helping to break the force of storm-waves and along-shore currents and winds.

The Beaufort Range, which lies between Parksville and Alberni, includes Mount Arrowsmith. Rising 5, 962 feet above sea level, it is the highest point in southern Vancouver Island.

Another lowland, the Estevan Coastal Plain, stretches along much of the west coast and in it is Pacific Rim National Park. Most visitors see parts of the Nanaimo Lowland first, then have close views of mountains and valleys after leaving Parksville and driving to the park, and have more distant views of them from vantage points within the park.

The Estevan Coastal Plain. Most of the part of this plain occupied by the Long Beach segment is flat and covered by gravel, sand and soil. Along the coast the waves have attacked this loose material and redistributed much of it to form magnificent sandy beaches with some parts composed mainly of pebbles and cobbles. The beaches are flanked by rocky "points" or headlands where bedrock has been exposed by wave action. In much of the northern part of the section bedrock is at or close to the surface, forming a fairly flat plain above which a few hills such as Vargas Cone and Radar Hill rise slightly higher than the general level. The coast here is rocky and irregular, with many small "points" and coves. Grice Bay is a large tidal estuary where extensive mud flats are exposed at low tide. Remnants of another rocky plain are represented by the tops of the islands of the Broken Islands Group and the coast near Cape Beale. From the coast the Pacific Continental Shelf

generally extends seaward for 20 miles or more but beyond this the ocean deepens abruptly. The shelf is about 50 miles wide off the entrance to the Strait of Juan de Fuca.

The Mountains. Most of Vancouver Island is occupied by the Vancouver Island Ranges which, with those of Queen Charlotte Islands, are the westernmost parts of the Canadian Cordillera and are lower than the ranges along the nearby mainland. Although some of the Vancouver Island ranges trend northwestward, conforming with the general shape of the island, other ranges and ridges are differently oriented because local geological conditions caused the deep intervening valleys to be eroded in those directions.

Timberline is at about 3,500 feet but many of the slopes have been logged, much bedrock being exposed between areas of "second growth" trees and other vegetation.

The mountains of southern Vancouver Island are mainly 4,000 to 5,000 feet above sea level. Most are bold and rocky with fairly steep slopes and roundish rather than angular upper parts. When driving westward from Parksville the first mountains seen are those of the Beaufort Range, dominated by Mount Arrowsmith*. Its elevation of 5,962 feet makes it the highest peak in the southern part of the island. Its summit is 4 miles south of Cameron Lake, which lies in a pass crossed by the highway before it descends into Alberni Valley. After leaving this valley the highway follows the north shore of Sproat Lake, flanked to the north by a ridge culminating in Mount Porter, and to the south by Mount Anderson. About 4 miles past the west end of Sproat Lake the highway begins to swing southward around the lower flank of Mount Gibson, then follows the valley of Kennedy River, with the Mackenzie Range to the east and scattered peaks to the west.

*This mountain was named in honour of a family of English geographers and map publishers which issued several early maps of western Canada.

Looking northwestward from several points in the Long Beach segment prominent features north of the park are Mount Colnett and Lone Cone on Meares Island, and the Catface Range beyond the entrance of Bedwell Sound.

The various types of landscapes have interesting geological explanations. Before discussing the regional and local geology the basic principles involved are discussed briefly in the next few pages.

SOME GEOLOGICAL FUNDAMENTALS

The earth is several billion years old, and ever since its beginning its crust has been subjected to many changes. Most of these changes happened very slowly, tended to occur in cycles, and are still going on in various places. Processes such as erosion, transport of material resulting from erosion, deposition of sediments and lavas, and the effects of earthquakes, can be observed constantly or periodically at appropriate places on the earth's surface. Good examples of erosion and of movement of sediments can be seen in the park. Other processes have operated and are operating deep within the crust; ancient effects of such processes can now be seen where the rocks have been eroded deeply, such as in the 'roots' of former mountain chains.

The Vastness of Geological Time. Knowledge of the origin of sedimentary rocks, and the thick sequences of such rocks observed at various places, caused early observers to realize that the earth must be much older than was generally supposed. It was noted that fossils, the remains of extinct animal and vegetable life, were characteristic of the age of the sedimentary rocks in which they were buried. Sedimentary rocks found anywhere on earth can thus be used as scattered pages of the history of the earth, which have been reconstructed in broad outline by generations of geologists. Thus it was realized that an enormously thick total sequence of beds had been laid down, and that such an accumulation must have required many millions of years. Another way in which fossils indicated great age was that it was soon realized that they represented a gradual development from primitive to advance forms of life, which could have occurred only during very long periods of time.

In the present century, research on minerals containing certain elements that disintegrate slowly at known rates has not only corroborated the general principle that the earth is very old, but has permitted reasonably accurate dating for many rocks and geological events. The oldest rocks from the earth's crust that have been dated in this way yielded ages between 3 and 4 billion years.

As no sign of the original crust of the earth has ever been found it must have been even older, so these dates are reasonably in accord with estimates of astronomers and physicists that our planet was formed about 5 billion years ago. This estimate has recently been confirmed in a general way by the dating of samples from the moon.

Early geologists decided that the succession of strata in Europe could be assigned to eras* of time and that these could be sub-divided into periods. Soon it was shown that these divisions could be applied to other continents, thus permitting a standard geological 'calendar' to be used. More recently the methods of dating minerals have permitted fairly accurate ages to be assigned. Some of these are shown in the accompanying table, which deals mainly with the younger subdivisions represented in the geological history of Vancouver Island.

Erosion and Deposition

Erosion, and the moving and deposition of its products, are closely connected with the atmosphere and have operated on the earth's crust ever since the first rains and winds appeared. Everyone has noticed the way in which winds raise clouds of dust which is dropped elsewhere. Sand dunes can be seen along many lake and seashores, as well as in deserts. In the latter the "sand-blast" effect of wind-blown sand on rock outcrops is readily visible.

The most effective agents of erosion, transport and deposition are related to the precipitation cycle, in which the evaporation of bodies of water causes clouds which are carried over the land to produce rain or snow which become run-off or underground water, most of which eventually accumulates in bodies of water where evaporation is repeated. Water does some eroding of rock surfaces by dissolving soluble minerals or rocks, and by the expansive force of water that freezes after penetrating cavities and

*Geological terms are underlined where first used and explained.

cracks. More effective are the ways water loosens soil or gravel to permit slides, the eroding of the banks and bottoms of streams by moving water, and the erosion of lakeshores and seashores by waves. Wave erosion results partly from direct hydrostatic pressure of hurtling water, and partly from the abrasion of sand, pebbles and boulders carried in the water. Only a little observation along valley-sides or streams will show at least small-scale examples of slides or slumping, or the way in which streams undercut their banks, erode the outsides of bends and form bars and shallows on their inner sides. Similarly, observations along the shores of lakes or the ocean, especially during storms, show the slow erosion of beaches and headlands.

The removal of the products of erosion by water is mainly by the transport of mud, silt, sand and pebbles, and partly by material dissolved in the water. Also, cobbles and boulders are rolled along by large streams. Deposition takes place in the bed of a stream where the force of the current lessens, as in the slack water on the inside of a bend, or at a delta such as is commonly formed where a tributary enters another stream or a stream enters a lake.

A SIMPLIFIED GEOLOGICAL CALENDAR

Eon	Era	Period	Epoch	Approximate years since beginning
	Cenozoic	Quaternary	Recent	5 to 10 thousand
			Pleistocene	2 to 3 million
		Tertiary		65 million
	Mesozoic	Cretaceous		135 million
		Jurassic		190 million
		Triassic		225 million
	Paleozoic			570 million
Precambrian				3-5 billion or more

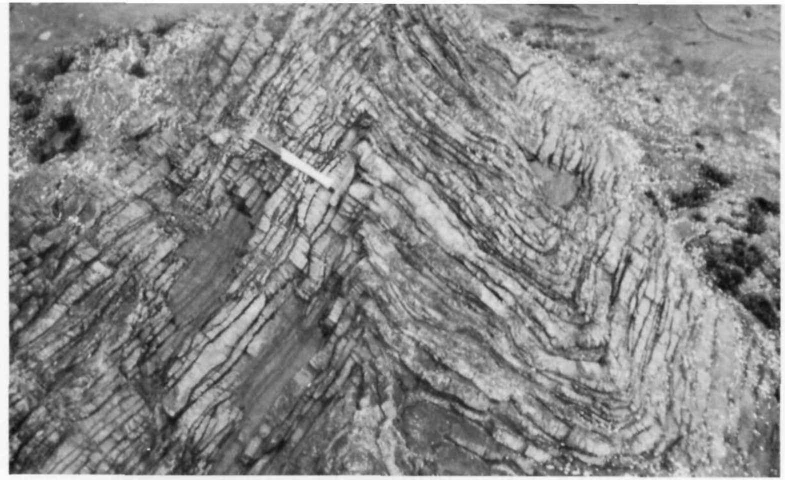
Stronger currents are required to carry coarser debris, therefore sorting generally occurs, causing gravels to be deposited in stream beds and parts of some deltas, and sand in some slacker stream beds or near the shore of an ocean or lake. Some mud is deposited in very sluggish streams, but it is mainly carried into the deeper parts of oceans or lakes; it is sometimes carried far by currents, such as the one issuing from Fraser River.

Thus land areas are worn down slowly and sediments accumulate either on land, in fresh water, or in the sea. These processes are accompanied by slow rising of the eroded land and a corresponding sinking of the larger sedimentary basins, because of the increased weight on the yielding material deep beneath them.

Some sediments consist of thick layers of similar composition, but most show at least faint stratification and many are clearly made up of strata of different colours and compositions. Sediments are compacted by the weight of overlying beds, and the grains are commonly cemented by carbonate or silica dissolved in water passing through the tiny pores left after even great compaction. In these ways unconsolidated sediments gradually become hard sedimentary rocks, such as shale formed from mud, sandstone from sand, conglomerate from gravel, and limestone from calcium carbonate. Argillite, a common rock on Vancouver Island, is massive, dark-coloured and a little harder than shale.

Movements in the Crust

The crust of the earth is about 15 to 40 miles deep in continental regions and 5 miles deep under the oceans. Beneath the crust is a zone called the mantle which behaves plastically when subjected to pressures for a long time. The temperature of the crust increases with depth and, although the pressure of overlying rocks keeps most hot parts of the crust rigid, in other parts where pressures are released or temperatures are raised sufficiently, the rocks become melted or nearly so, and some are squeezed in various directions.



Intense 'chevron' folding on Francis Island, at south end of Ucluth Peninsula, a short distance outside the park.

The ability of parts of the crust and mantle to yield, for the reasons just mentioned, causes basins and the margins of continents, on which large quantities of sediments are being deposited to sink slowly – probably only an inch or so in 1,000 years – but, nevertheless, sufficiently to allow accumulation of the great thicknesses of sedimentary strata now visible in many districts. As sedimentary basins sink, corresponding slow rises occur in the neighbouring land areas which are gradually made lighter by erosion and removal of the eroded particles of rock. In these ways the simplest movements in the crust – downwarpings and upwarpings – are caused. More complicated movements involving the squeezing together of strata produce folds and other kinds of crumpling.

Both vertical and squeezing movements are generally accompanied by development of large and small cracks or fractures in the rocks. Small ones can be seen in most rock outcrops. Many are cracks only, but many others, called faults show evidence that the rock at one side was moved with respect to the other. For some minor faults the matching, displaced strata can be seen in a single outcrop or in adjacent ones. Along many other faults, how-

Massive greywacke traversed by a minor fault. The log in the foreground lies in the fault-zone which is eroded more deeply than the rocks flanking it.

ever, displacements of hundreds or thousands of feet, or even miles, have been shown by careful geological mapping. Earthquakes result from vibrations caused by the movement of rocks along faults.

Combinations of upwarping and large-scale folding and faulting cause rocks formed in various sedimentary basins to be slowly cast up to form the first or "primary" stage of mountain chains. The increased eroding power given to streams by such uplifts, together with other factors, soon cause primary mountains to be carved into the peaks, ridges and valleys of a secondary stage of sculptured mountains. Many of the mountain systems present today show evidence of having undergone two or more such cycles each consisting of sedimentation, uplift and folding, erosion down to a fairly level surface, and then covering by marine or land-type sediments to begin a new cycle.

The causes of the squeezing and other sideways forces involved in the formation of mountains are the subject of various theories. Those included in what are called 'plate tectonics' and 'sea-floor spreading' are gaining wide acceptance. According to these concepts molten rock from the mantle wells up into the mid-ocean crusts, forming new crust and forcing a plate of oceanic crust to creep slowly on the upper part of the mantle. Where this plate pushes against a continental plate zones of faulted and otherwise deformed rocks result, and the oceanic crust is bent downward to be consumed by melting into the mantle.

Igneous Rocks

Rocks that crystallized from a molten or almost molten state, are called igneous after the Latin word for fire and are of two main kinds: fine-grained volcanic rocks that rose in a volcano or fissure and flowed on land or the ocean floor, and plutonic rocks that crystallized far below the surface, generally as part of mountain-forming events, and were later exposed by deep erosion. Most plutonic rocks are coarsely crystallized, such as granite with which everyone is familiar. Most of the plutonic rocks of Vancouver

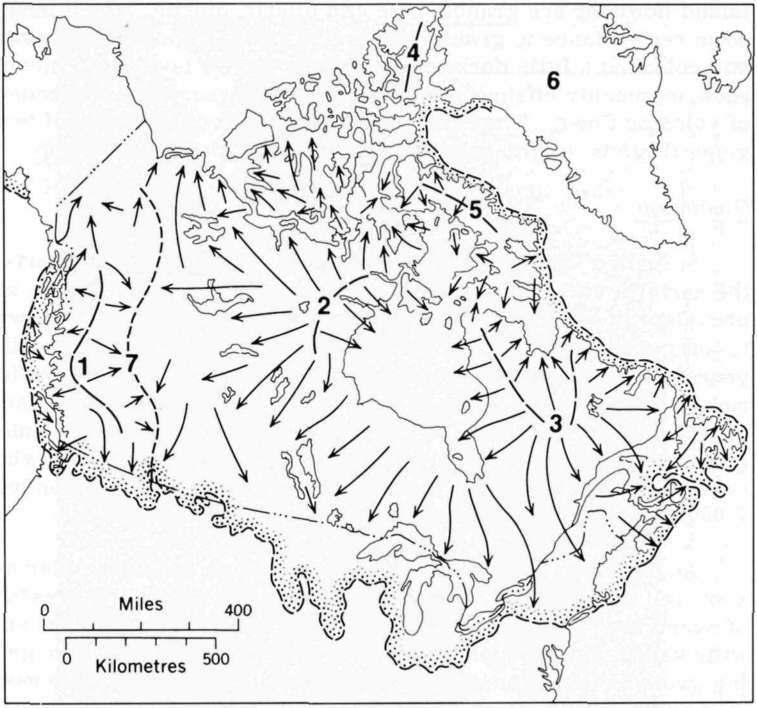
Schooner Cove appears at the right of this air photo. Several "surf channels" eroded by waves along weak fault zones in the rocks indent the coast at the left of the photo. NAPL photo.

Island however are granodiorite and quartz diorite, which bear some resemblance to granite but are of partly different composition and coloured a little darker. Dykes are narrow bodies of igneous rock, commonly offshoots from masses of coarser rock or 'feeders' of volcanic flows. They fill cracks in other rocks and are of two general kinds: light-coloured felsite and dark-coloured trap.

Glaciation

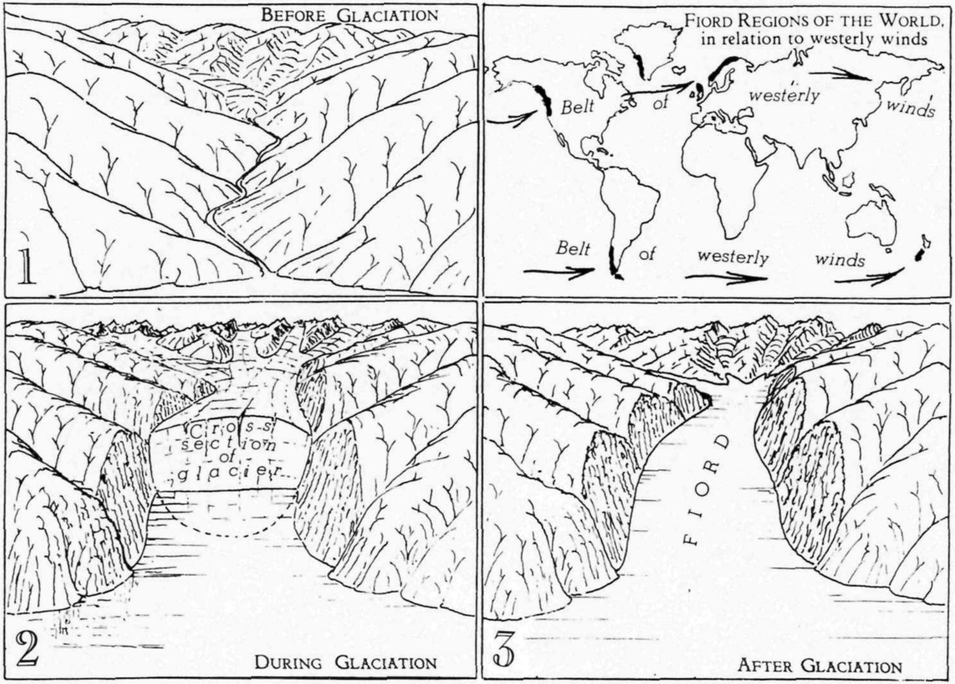
So-called "ice ages" happened occasionally over some parts of the earth in very ancient geological times, but the effects now so prevalent in much Canadian scenery were caused by ice that began to form at the beginning of the Pleistocene epoch about three million years ago. We cannot say exactly when it ended, because the ice melted away gradually, at different times in different places, and is still present in some high or northern parts of Canada. Geologists have agreed, however, that so far as this country as a whole is concerned, Pleistocene time may be regarded as having ended 7,000 years ago. The epoch since then is called Recent.

As the early Pleistocene climate became colder and colder more snow fell in winters than melted in summers. Under the pressure of overlying snow the older snow recrystallized into glaciers and wide sheets of ice which flowed slowly away from the higher gathering grounds where snowfall was greatest. Then the climate moderated and the ice melted away. In many parts of Canada such cyclic changes were repeated four times during the Pleistocene epoch, with the result that much of the country was subjected to four major glaciations, each of which lasted about 100,000 years. During the intervening times, which were longer, the climate was as warm or warmer than that of today, as is shown by the remains of plants found in "interglacial" sediments. Because each glacial advance tended to wipe away the evidence of earlier ones, most of the effects seen today are those of the last glaciation. Its ice moved outward from several main gathering grounds or "cores", one along the crest of the Cordillera and the others east of the Cordillera. The ice is estimated to have been as much as 10,000 feet thick in some regions but only 5,000 feet on Vancouver Island.

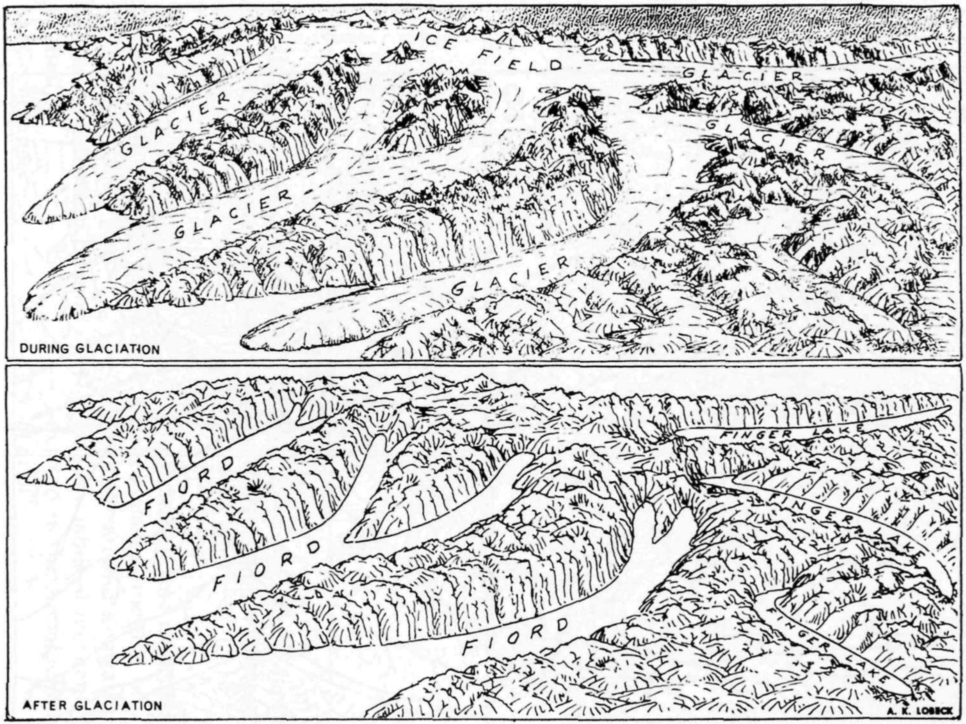


Greatest extent of glaciation of North America during the last ice-age. The ice spread outward from six "ice ridges" numbered as follows:

1. Cordilleran
2. Keewatin
3. Labrador
4. Queen Elizabeth Islands
5. Baffin
6. Greenland
7. This dashed line indicates the approximate juncture of Cordilleran and Keewatin ice. An unnumbered ice-centre existed in the Appalachian region.



Fiords occur where normal valleys, as shown in diagram 1, were deepened and straightened by erosion caused by large tongues of ice that spread from an ice cap during the last ice age, and extended as far as the coast. Sea water entered the valley after the ice melted. Fiords are most common along west coasts, where belts of westerly winds caused heavy precipitation and larger glaciers.



Long, narrow 'finger' lakes, of which Sproat Lake is an example, lie in basins formed by tongues of ice (valley glaciers) that melted before reaching the coast. Finger lakes are generally farther inland than fiords, where it is probable that slightly lesser precipitation resulted in smaller glaciers.

Alberni Inlet is an excellent example of a fiord, formed when a huge valley glacier moved down an earlier valley carved by an ancient river. This oblique airphoto shows the head of the inlet. NAPL photo.

At its maximum it extended west into the northern part of United States.

Glacial effects were varied. Some put the finishing touches on Tertiary rock surfaces by polishing, scraping, gouging, and plucking away rock fragments frozen into the ice. In most places the amount of rock removed varied from mere polishing to perhaps a few tens of feet, but some valleys, mainly in the Cordillera, were deepened more than that, and also straightened, by large glaciers that formed in them. Another effect was the removal of most of the marine and shoreline deposits that had accumulated during the latter part of Tertiary time; those that remained were protected by being submerged below sea-level. The products of glacial erosion were carried along by advancing ice, in some cases for only short distances, but in others very far from their places of origin, as can be proved by pebbles and boulders of distinctive rocks whose place of origin is known. Unstratified debris, commonly containing boulders, was left as till. The melting of glaciers caused floods of meltwater which carried and deposited large quantities of 'rock flour', silt, sand, and gravel that had been frozen in the ice. Some of these floods took place in former valleys, some cut new channels, some spread across flat land, and some entered the sea to form deposits of clay and stony clay.

COMPARISON WITH OTHER PARKS AND REGIONS

Pacific Rim National Park and the surrounding area differs, both in topography and geology, from other Canadian regions and the National Parks in them. Before the geology of southern Vancouver Island is discussed a little more fully it will be helpful to consider briefly the ways in which this park is related to the geological pattern of the country, and to other parks.

Excepting the North, Canada is divided into five main regions: the Canadian Shield, a complex array of Precambrian rocks; the Interior and St. Lawrence Lowlands, where flat-lying sedimentary rocks rest on 'platforms' which are vast, deeply buried extensions of the Shield; and the Appalachian and Cordilleran belts of mountains and plateaus. In addition there are coastal plains along parts of the Pacific coast, so narrow that they are included with the Cordilleran belt in this broad scheme, and the Atlantic and Pacific Continental Shelves fringing the coasts.

The Shield, the Interior and St. Lawrence Lowlands, and the parks in them, obviously differ greatly from the area covered in this booklet. The Appalachian region is distinct from the Cordilleran in that its mountains, having been formed in Paleozoic times, are much older than the mountains of the Cordilleran region and have been undergoing erosion for a much longer time. Thus, although some fairly high and decidedly spectacular scenery is found in parts of the Appalachian region, as at Gros Morne National Park, even this is low compared with most of the Cordilleran region.

The Canadian Cordilleran region is part of the longest mountainous belt of the earth's crust, bordering the Pacific along the west sides of South America and North America, through the Aleutians and southward through Japan and New Zealand. Since late Precambrian times, for many hundreds of millions of years, this general belt has been subjected to a long series of changes that were of different kinds and occurred at different times and at different places. This activity slowly caused mountains to be developed, some at two or more distinct times in the same part of the belt.

The mountain-building events, which are still going on in places, included the raising of islands above the sea, the erosion of these new lands, and the carrying of the results of erosion into the sea. In certain places lavas poured from volcanoes and fissures, either on land or on the bottoms of seas. Areas covered by seas were uplifted above sea level from time to time and other land areas were depressed below sea level. Earthquakes caused large and small faults in the rocks, which were also folded by squeezing stresses. Combinations of uplifting, faulting and folding raised large segments of rocks to stand as ridges or plateaus, which were eroded to form mountains and valleys. In certain places these processes were accompanied by the development of plutonic and much-altered metamorphic rocks.

The Cordilleran belt includes all of British Columbia and the western part of Alberta. This part of the belt is divided into three main zones which trend northwest. The main feature of the western zone is the Coast Mountains along the coastal part of the mainland. Farther west are the ranges of Vancouver Island and the Queen Charlotte Islands. The western zone is made up mainly of late Paleozoic and Mesozoic volcanic and sedimentary rocks which were subjected to great mountain-building stresses in the Jurassic period, many bodies of plutonic rocks being formed at that time. Later, Cretaceous and Tertiary sediments were deposited in local basins. The early mountains were worn down, uplifted and dissected into new valleys and ridges. Thus one of the interesting features of the western zone is that it is composed of 'second-generation' mountains, many of which have smooth or roundish shapes because plutonic rocks tend to be eroded in that way.

The Rocky Mountains form the eastern zone in British Columbia and Alberta. These mountains are composed almost entirely of sedimentary rocks which originated in late Precambrian, Paleozoic and Mesozoic seas. These rocks were uplifted thousands of feet by faulting and folding, mainly in early Tertiary time. The Rockies,

being much younger than the mountains of the western zone, are still in their first cycle of formation. The sedimentary rocks form mountains of two main shapes depending on the ways in which folding and faulting have arranged the beds. As is well shown in Banff, Jasper and other parks in the Rockies, beds lying at fairly steep angles form 'saw-tooth' mountains or ridges, one side representing the slope of the bedding and the other side resulting from cracks perpendicular to the bedding. The second shape occurs in flat-lying strata, where cracks perpendicular to the bedding causes blocky forms sometimes called 'castle' or 'layer-cake' mountains.

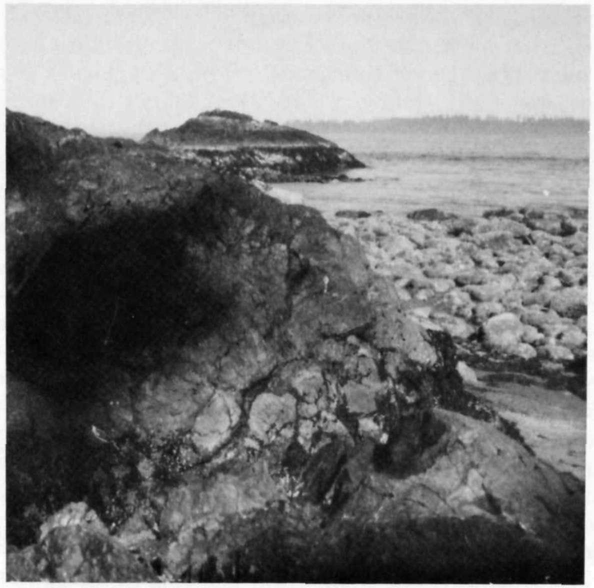
The Rockies are bounded on the west by a deep, straight valley called the Rocky Mountain Trench. Extending almost the entire length of British Columbia, it contains the upper parts of the Kootenay, Columbia, Fraser and other rivers. Between the Trench and the Coast Mountains lies a wide central zone containing a variety of mountains and plateaus formed of rocks of many kinds. Some of the most widespread are crystalline types altered from other rocks by great heat and pressure. Glacier and Mount Revelstoke National Parks, the only parks in the central zone, are chiefly in the high Selkirk Mountains. Most of the mountains in these parks are composed of altered, crystalline rocks which were generally eroded into irregular, spiky peaks and ridges. Lying in an area of heavy precipitation, the mountains of these two parks, and particularly those of Glacier Park, are covered by many snowfields and active glaciers.

Even this short outline shows that Pacific Rim is the only National Park, excepting those along the Atlantic, which features sea beaches. The fiords nearby are flanked by mountains higher than those of Newfoundland. The highlands of Vancouver Island display the complex geology and shapes of 'second-generation' mountains. Perhaps of greatest significance to geologists, the park itself, and the extensions of the coastal plain in which it is set, are underlain by a fairly narrow, complex strip of rocks called the Pacific Rim Belt. This is unique in Canada and is considered an excellent example of the results of 'sea-floor spreading'.

OUTLINE OF GEOLOGICAL EVENTS IN THE PARK AND REGION

Although the geological history of Vancouver Island is complicated, it can be summarized into seven phases. To help understand these, the geological units of the accompanying geological maps are numbered so as to correspond with these phases. The oldest recognizable phase was the deposition of lavas and sediments during Paleozoic times, mainly on the bottom of seas. These deposits were compacted and hardened into rocks and then greatly altered to a complex mixture of rocks of different kinds. The second phase included the deposition of thousands of feet of sediments and lavas early in the Mesozoic era. The third phase, at about the middle of Mesozoic time, began with upheavals which cast the volcanic and sedimentary rocks into mountains standing above the sea. These were then worn down by erosion to a fairly flat surface. The mountain building was accompanied by the formation of large and small bodies of plutonic rocks mainly of 'intermediate' composition such as granodiorite. In the fourth phase low areas or 'basins' on the eroded surface were covered by large lakes and swamps. In these various basins thousands of feet of sediments, including peat, were deposited in late Mesozoic times. The remains of the resulting sedimentary rocks lie above the old erosion surface. During the fifth phase, which occupied much of the Cenozoic era, submarine lavas poured out in places, faults were formed in older rocks and some land may have emerged from the sea. Much sand and silt which became sedimentary rock was deposited along the western margin of what is now Vancouver Island. The Vancouver Island Ranges appear to have been uplifted to about their present height in late Tertiary times. Streams, whose erosive power was increased greatly by this uplifting, caused the upland surface to be eroded into ridges, peaks, plateaus and valleys in about the same positions as those of today. At times during this phase sediments were deposited along the edge of the ocean that surrounded the uplands more or less as it does now.

The sixth phase, during the late part of Cenozoic time, was one of glaciation. This resulted in the re-shaping of the topography of the fifth phase almost to the shapes to be seen today. The ice is estimated to have left the coast near the park about 13,000 years ago, and much less than that in the nearby uplands. The seventh and last phase, which is still going on, consists of events that have taken place since the melting of the ice and the deposition of debris by glacial flood waters. This phase has consisted mainly of erosion by waves and streams, the formation of beaches, and the elevation of the land as much as 250 feet above the sea.



'Pillows' in volcanic rock of Karmutsen Formation. Pillows form when hot lava is erupted under water and forms large blobs of soft red-hot material with a skin of congealed lava.

LOCAL EXAMPLES OF GEOLOGICAL PHASES

Early Rocks (Phase 1)

The oldest rocks found on Vancouver Island, altered sedimentary and volcanic rocks of late Paleozoic age, are relatively young compared with many more easterly parts of the Cordillera, where late Precambrian or early Paleozoic rocks are exposed. The lack of exposures of older rocks may be because the part of the earth's crust from which the island developed did not become an area of deposition until late Paleozoic times or, alternatively, there may have been earlier basins whose deposits were either destroyed or became unrecognizable by later geological processes or are now buried too deeply to be exposed anywhere. Much-altered rocks of this phase, called the Westcoast Complex and including some rocks of plutonic origin, have been found in the Long Beach segment, north and east of Grice Bay. They also form islands in the Broken Islands segment and outcrop in places along the shore of the West Coast Trail segment.

Early Mesozoic Rocks (Phase 2)

Volcanic rocks of early Mesozoic (Triassic) age, known as the Karmutsen Formation, outcrop at many places. An excellent exposure, consisting of black rock consolidated from lava, can be seen as a roadside cliff at the south shore of Cameron Lake, roughly midway between Parksville and Alberni (see Map 2). The best and safest way to observe these is to drive past the cliff, park near the west end of the lake, and walk back to the rock exposures. Triassic volcanic rocks are also exposed at many places near the highway between Alberni Valley and Kennedy Lake, and at the west side of that lake. Similar rocks, together with some altered limestone, outcrop on small hills between Grice Bay and Kennedy Lake. Triassic limestone can be seen readily in a small quarry along the highway near the west end of Ucluelet.

Steeply dipping bands of interbedded volcanic and sedimentary rocks a little younger than those just described form Ucluth

'Ribbon chert is exposed at low tide at Box Island at the north end of Wickaninnish Bay. The layers of chert consist of silica hardened from a gel deposited on the sea floor after a volcanic eruption.

Peninsula, the headland between Long Beach and Florencia Bay, part of the headland between Wickaninnish Bay and Schooner Cove, and islands near that cove. The ages of these rocks are Jurassic and early Cretaceous. Some of these rocks are dense, hard, light green volcanics. Others are sedimentary beds of chert one to two inches thick lying between thin, black beds formed from ancient mud. The chert, best exposed on Box Island north of Schooner Cove, consists mainly of silica. It is green, grey, black or reddish brown, but on weathered surfaces it appears bright white and grey. It is believed to have formed from silica-gel deposited on the floor of the ocean after submarine volcanic eruptions. In most places there is more black argillite, formed from the mud, than there is chert. The layers of the two kinds of rock are generally folded intensely.

Ancestors of the Present Mountains (Phase 3)

In some parts of Vancouver Island evidence shows that late Paleozoic rocks were folded into mountains and worn down by erosion before Triassic rocks were deposited on the eroded surface. This may have been the case in the region now occupied by the park but the evidence is not clear.

Much more significant were mountain-building and volcanic eruptions that took place in Mesozoic time, mainly in the early and middle parts of the Jurassic period. Then the Paleozoic, Triassic and earlier Jurassic rocks were faulted and uplifted to form ranges, probably mainly as chains of islands, that extended over all the present area of Vancouver Island, as well as Queen Charlotte Islands and much of the mainland.

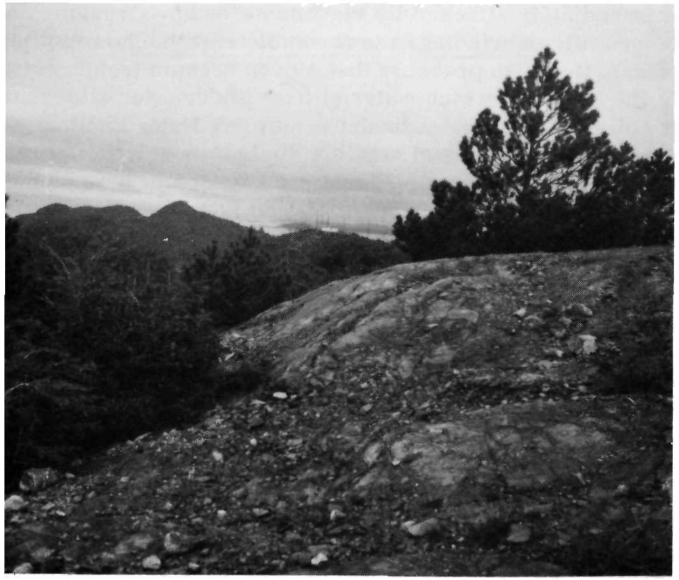
The Jurassic volcanic activity was accompanied by development, far below the surface, of bodies of plutonic rocks of 'intermediate' composition, mainly of types called granodiorite and quartz diorite. These rocks have not been found in Long Beach segment, but a mass is exposed on a ridge along the north shore of Sproat Lake; other bodies have been mapped between Sproat Lake and the park.

Late Jurassic and Cretaceous Sediments (Phase 4)

The volcanic and granitic mountains formed in Jurassic time were immediately attacked by vigorous erosion. Volcanic and, later, granitic debris began to accumulate in the surrounding shallow seas. It is also probable that a deep oceanic trench existed along the coast, in which material from underwater slides and mudflows collected. These sediments (unit 4 of Maps 2 and 3) along with the oceanic chert and argillite (unit 2) now form the rocks along the coast of the park. They are exposed in the northwest part of the Long Beach section, between Point Cox and Portland Point, in a band on the headland between Long Beach and Florencia Bay, and also in two bands on Ucluth Peninsula.

The age of these rocks is either late Jurassic or earliest Cretaceous. The beds of conglomerate are coarse, and include cobbles mainly of hard chert, with some of limestone and porphyry. Examples of the conglomerate can be seen on Radar Hill but are best exposed outside the park, on a bluff in the middle of Cox Bay. The rock between the cobbles, and the finer-grained beds themselves, are mainly greywacke. This is a gritty rock somewhat like sandstone, but darker coloured and containing angular rather than rounded grains. These sedimentary rocks have been mashed severely - more so than is usually the case in folded mountain chains, individual beds having lost all continuity. Sediments occurring in this way are called a melange (from the French word for mixture).

A large basin of sedimentation existed in the Nanaimo region during later Cretaceous times. Here many thousands of feet of shale, sandstone and other sedimentary rocks were formed under alternating brackish and marine conditions. Several coal seams in these strata were vital sources of coal during the days of steam-navigation on the Pacific coast. Mining was begun in 1852 and was later carried out on a large scale for many years, but only a little has been produced recently.



At Radar Hill conglomerate containing pebbles and cobbles originated as coarse gravel many millions of years ago. It later became hard rock that resisted erosion well, leaving a hill a little higher than its surroundings. The surface of the rock was scraped by a glacier during the last ice age. Vargas Cone and Receiver Hill, other examples of more than usual resistance to erosion, can be seen in the background.

Sheared argillite and greywacke one mile south of Wya Point. After shearing, the rock was displaced by two small faults.

A sequence of Cretaceous sediments was deposited in a basin that extended northwesterly through the present site of Alberni. Remnants of this sequence have been traced from a point about 8 miles southeast of Alberni to about 23 miles northwest of the town. As these rocks lie beneath the bottom of Alberni Valley, which is largely floored by glacial drift and younger river deposits, they are not well exposed near the highway.

LEGEND

Note: The numbering of geological units corresponds with those of the geological phases discussed in the text.

PLEISTOCENE

6 Glacial and stream deposits

TERTIARY

5 Granitic rocks; granodiorite

MESOZOIC

4 Sedimentary rocks; sandstone, shale, coal

3 Granitic rocks; granodiorite

2 Volcanic and sedimentary rocks; basalt, shale, andesite, limestone

PALEOZOIC

1 Granitic and metamorphic rocks; quartz diorite, schist, gneiss, limestone

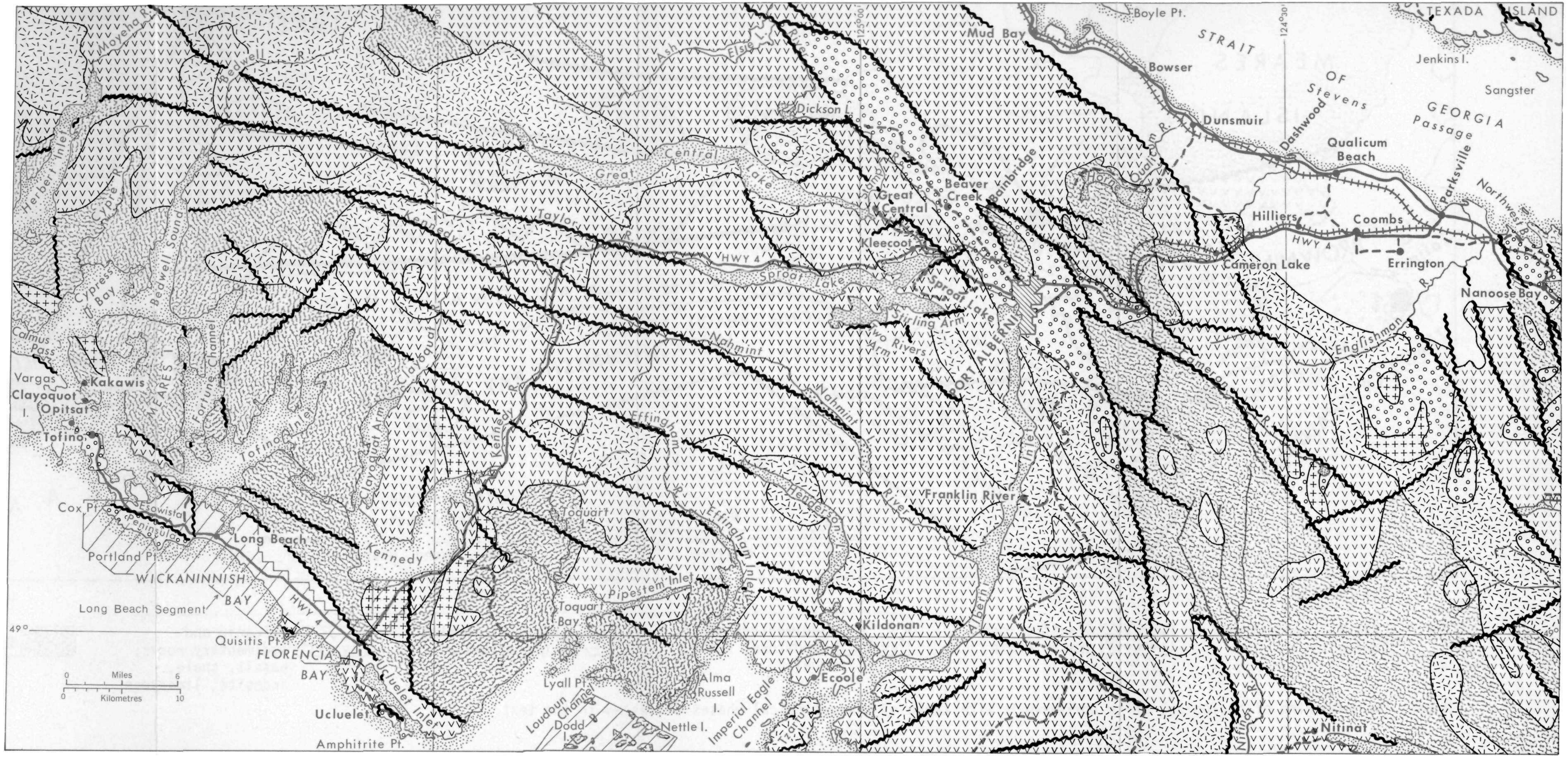
Formation contact

Fault

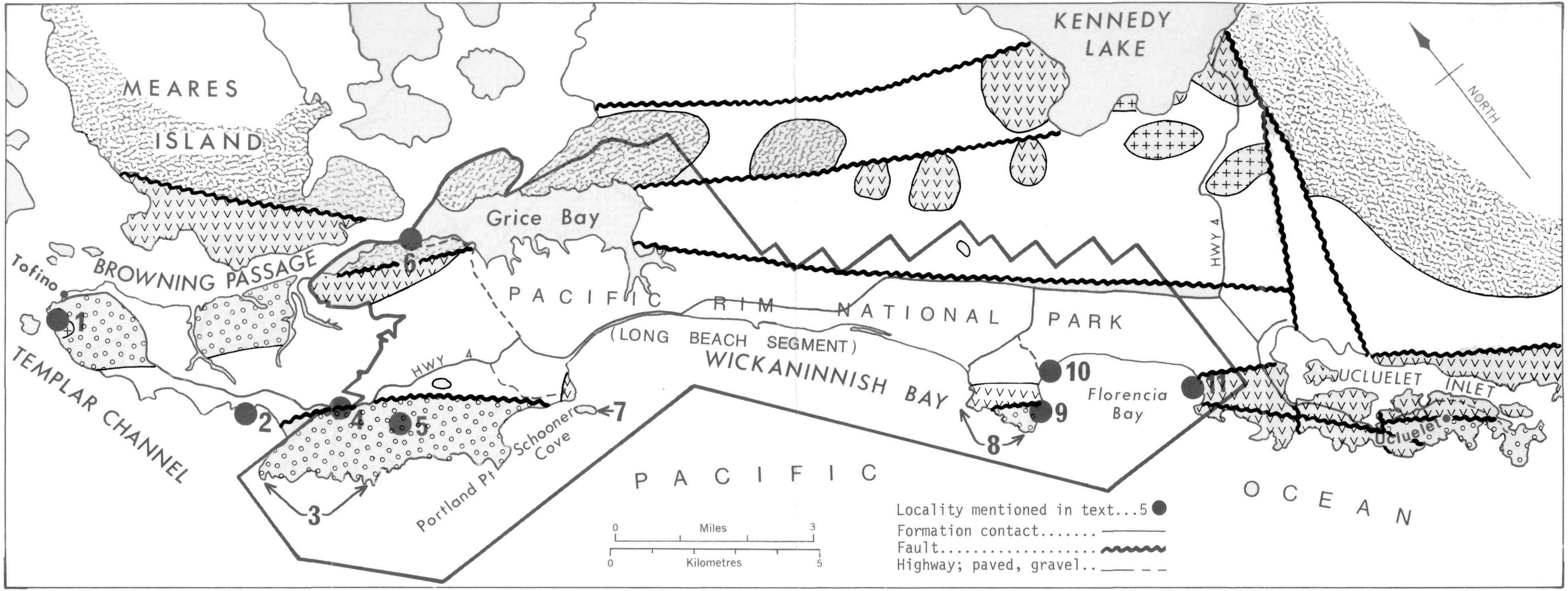
Highway; paved, gravel

Railway

Pacific Rim Nat. Park



Map 2. Generalized geology of region between Tofino and Parksville.



PLEISTOCENE	TERTIARY	MESOZOIC			PALEOZOIC
6 Glacial and stream deposits	5 Granitic rocks; granodiorite	4 Sedimentary rocks; sandstone, shale, coal	3 Granitic rocks; granodiorite	2 Volcanic and sedimentary rocks; basalt, shale, andesite, limestone	1 Granitic and metamorphic rocks; quartz diorite, schist, gneiss, limestone

Note: The numbering of geological units corresponds with those of the geological phases discussed in the text.

Map 3. More detailed geological map of Long Beach Segment

POINTS OF INTEREST NUMBERED ON MAPS

(1) Good exposures at the shore near Tofino, north of the park, show the contact of a small granitic body. When molten, this surged up into sedimentary rocks (argillite and greywacke). Some dykes of granitic material, as well as veins of quartz, entered the argillite.

(2) Outcrops north of Pacific Paradise Resort include greywacke and conglomerate. These rocks were formed from sand and gravel derived from the erosion of islands and washed into deeper water, probably in Cretaceous time. The composition of the sand and cobbles indicates that these islands were made up of volcanic rocks, chert and minor amounts of granitic rocks.

(3) The coast south of Point Cox is composed of rocks of approximately the same age as those at Point 2. Like almost all rocks of the park, they have been sheared and faulted severely. Of special interest to hikers are the deep surf-channels that have been eroded along northeasterly-striking faults. These may be difficult to cross at high tide.

(4) Excellent exposures of 'stony clay' can be seen at the Tofino gravel pit. The upper part of the pit-wall consists of marine till, a sediment laid down in seawater below melting 'rafts' of floating ice. As they melted, silt as well as boulders dropped on the seafloor in disorderly arrangement. Some silty, non-stony layers indicate times when the sea did not carry ice-rafts. The stony clay overlies fluvioglacial gravels, deposited in front of the advancing ice sheet.

(5) Radar Hill is composed of greywacke and conglomerate. At the top of the hill, above the road and the old buildings, good glacial striations show that, in Pleistocene time, ice covered the hill and moved south-southwestward across it. When looking north from the hill, try to visualize that all the low country was covered by ice but that the mountains (from left to right: Catface Mountain, Lone Cone, and Mount Colnett) protruded above the ice.

(6) Exposures of the Westcoast Complex, the oldest rocks in the area, occurring at the site of a wartime dock north of the airport, can be reached by a gravel road. The Complex consists of old volcanic rocks that, after their formation, were buried deeply in the crust and altered to 'greenschist'. Radiometric dating of these rocks has revealed their complex history. They probably erupted about 260 million years ago in early Permian time, but were altered 190 million years ago, at the beginning of Jurassic time, when great masses of plutonic rocks were formed in other areas.

(7) Box Island, which is not an island at low tide, provides excellent exposures of 'ribbon-chert' composed of almost pure silica. One theory explains the chert-layers as having been a gelatinous layer of silica deposited on the ocean bottom at some distance from deep underwater eruptions of lava.

(8) The coast south of Wickaninnish Bay is composed of sedimentary rocks that were deposited in deep oceanic waters. They are argillite, chert and siltstone and are severely crumpled, sheared, and faulted. Original bedding has been almost completely obliterated. Geologists call such formations 'melange'.

(9) Along this part of the coast many surf-channels have been eroded in soft, broken rock lying along fault zones. Also of interest are several caves near the northeast side of a bay immediately east of Quisitis Point. There is one two-pronged cave whose north end follows a shear zone dipping steeply to the south, and whose south end was eroded in a bed of soft, limy sandstone. A small hole connects the two prongs.

(10) Glacial deposits are well-exposed at Florencia (Wreck) Bay. The north end of the cliffs is composed of bedded stony clay, probably laid down in the sea, in front of the continental ice sheet. The clay is fine glacial 'rock flour' carried in the ice and dropped when it melted. Boulders carried by masses of floating ice dropped into the clay when they melted. The

clays are overlain by sand and gravel exposed in the cliffs farther south. These were formed in flood plains in front of the retreating ice.

(11) The south end of Florencia Bay, near the end of Willowbrae Trail, is the only place in the park at which exposures of 'pillow lava' have been found. Such roundish blobs of mafic rock are commonly formed when hot lava issues under water. The pillows, originally soft, hot lava encased in a skin of congealed material, accumulated on the seafloor. The pillows contained many cavities formed as gas-bubbles, which became filled with epidote, a yellow mineral.

Sedimentary rocks (unit 4) and granitic rock (unit 5) exposed immediately south of Tofino. A mass and tongues of early Tertiary granite penetrated, when molten, argillite of Mesozoic age.

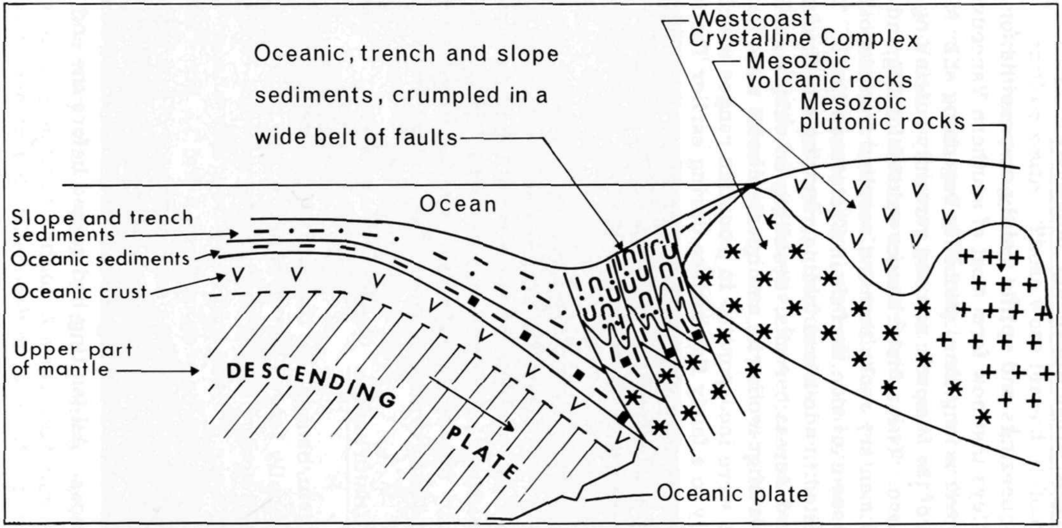
The Last Great Upheavals (Phase 5)

The crustal squeezings and uplifts mainly responsible for the mountains and valleys that now form most of southern Vancouver Island took place over a long time, probably beginning at or slightly before the end of the Mesozoic era and certainly continuing well into the Cenozoic era. These disturbances caused folding and faulting of the sedimentary rocks that had resulted from deposition on the ancient Jurassic erosion surface in Cretaceous times. The disturbances resulted in additional folding, faulting and fracturing of the Triassic and Jurassic rocks, resulting in very complex structures. Bodies of granodiorite and quartz diorite were formed. The various rocks were incorporated in mountain ranges which were eroded slowly to a fairly flat surface during earlier Tertiary time. In several areas along the Tertiary Continental Shelf of Vancouver Island sediments of mid-Tertiary age were deposited. These were uplifted in later Tertiary times to form coastal plains.

During the latter part of Tertiary time, and probably also in the early part of the Pleistocene epoch, the Tertiary erosion surface was uplifted slowly to about the elevation of the present mountain tops and remnants of plateaus. The increased eroding power of streams caused by this uplift carved this surface into approximately the present configuration of mountains, ridges and valleys.

Faults and Other Disturbances

The various disturbances that the rocks have undergone resulted in an unusually large number of faults, the main ones being shown on the accompanying maps. As a result of these movements the rocks are divided into many irregular-shaped 'fault blocks', many of which can be seen on Maps 2 and 3. Some faults undoubtedly were formed during the earlier phases of mountain building and uplift, but most either occurred initially or were affected by later movements during the late Cretaceous and early Tertiary disturbances. All faulting had ceased before the end of Tertiary time.



Imaginary cross-section showing how the development of western Vancouver Island is explained by the theory of plate tectonics. According to this an "oceanic plate" composed of the oceanic crust and upper part of the mantle is moving slowly east. As it impinges on the edge of the continent, zones of intensely altered, crumpled and faulted rocks are formed and the oceanic plate is forced downward and melted into the deeper part of the mantle.

Most faults are steep-sided and trend northwest, but some trend northeast or north. The most prominent fault in the region separates Alberni Valley from Beaufort Range for a distance of 45 miles. Within the Long Beach segment the longest known fault trends northwesterly parallel with and a short distance northeast of the highway to Tofino. This fault, which is now almost everywhere covered by glacial deposits, caused the greywacke-conglomerate unit in the northwestern part of the segment to be dropped down, and therefore preserved from complete erosion; older uplifted rocks outcrop northeast of the fault. A zone of northeast-trending faults extends from the east end of Kennedy Lake to the west end of Ucluelet Inlet.

The rocks of the park, especially the sedimentary rocks, have been faulted so intensely that individual layers can be traced for only short distances. Within such distances they may exhibit intricate folds or crumples. No folds large enough to show on a geological map are present.

A possible explanation for the conditions just described is offered by the theories of plate tectonics and sea-floor spreading. These theories suggest that a zone of underthrusting along the Pacific Coast caused an oceanic trench beneath which, in a great fault-zone, sedimentary rocks of oceanic and trench origins were ground up between moving oceanic and continental plates, resulting in melange such as is found at some places along the coast of the park.

Changes Made by Glaciers (Phase 6)

Almost every scene in the region resulted partly from the erosional or depositional effects of glaciers. The ways in which such masses of ice formed, flowed, sculptured rocks and deposited coverings of gravel, sand and clay have already been outlined. It was also mentioned that in the Pleistocene epoch, which began about 3,000,000 years ago, ice covered much of Canada during four main separate glaciations, but that most of the glacial effects now seen resulted from the last one. This is the case on Vancouver

Island, where little evidence of glaciation in mid-Pleistocene time has been found and signs of the last main glaciation are plentiful. Most of the effects actually within the Long Beach segment are depositional, but spectacular erosional effects can be seen along and near the highway to the park and, in the park, glacial erosion is well exhibited on top of Radar Hill and at other places.

As the weather grew colder at the beginning of the last main glaciation 'pockets' of ice began to form in basins near the summits of mountains. Some of these 'alpine' glaciers gradually extended down mountain valleys that had been cut by late Tertiary erosion, and some of these smaller 'valley' glaciers joined one another to flow in larger forms down the main valleys. At about the same time snowfields that had accumulated on upland surfaces developed into ice caps, which sent lobes flowing down to augment the valley glaciers. A great mass of ice formed in the Strait of Georgia between Vancouver Island and the mainland, and during the maximum stage the ice on the mainland was continuous with ice covering the Strait and much of the island. On the east coast of the island the ice reached an elevation of 5,000 feet, and it thinned to a thickness of about 1,000 feet on the west coast. Striations indicate that it flowed southwesterly over Radar Hill. Many mountains projected above the ice cap. Examples are Mount Arrowsmith, the higher ranges at both sides of Kennedy River, and Catface Mountain, Lone Cone and Mount Colnett near Tofino. Almost all the ice melted a few thousand years ago but small alpine glaciers remain in a few central parts of the island.

Erosional Effects

The largest and most spectacular glacial effects in the region are 'U'-shaped valleys that were modified from earlier, pre-glacial ones. Before the coming of the ice the streams flowed in steep-walled canyons or in straight 'V'-shaped valleys, because of the rapid eroding power of the swiftly-flowing streams on the upper parts of the land surface that was uplifted about the end of Tertiary time. The glaciers that later flowed down these valleys, however, occupied the entire valleys filling them from side to side.

Not only did the scraping effects of these glaciers deepen the valleys somewhat, they also straightened them by wearing off corners, and they gouged the lower walls of the valleys to produce the 'U' shapes so characteristic of glaciated valleys.

Some of the valleys that became 'U'-shaped were fairly high in the uplands. In some instances the upper parts of pre-glacial streams flowed in opposite directions from a mountain pass; when a valley glacier was forced through such a pass it eroded it more deeply than elsewhere, forming what is called a 'through' 'U'-shaped valley. An example is occupied by Cameron Lake, along which the highway between Parksville and Alberni passes. From suitable places in Long Beach segment and on clear days, the profiles of other high 'U'-shaped valleys can be observed along the skyline; a prominent example seen when looking east is probably part of the valley of Cowichan Lake.

Vancouver Island abounds in larger and deeper 'U'-shaped valleys, those that the ice excavated below the present level of the sea forming beautiful fiords, and those above sea level forming what are called 'finger' lakes because of their long, narrow shapes. In the West Coast Trail segment there is an unusual combination of these forms - Nitinat Lake - a lake in a valley that was excavated well below sea level by a valley glacier which did not extend its deep cutting quite to the present coast, so at high tides sea water enters the lake through a narrow passage in rock.

Alberni Valley and two of its large tributaries provide readily accessible examples of a large fiord (Alberni Inlet) and finger lakes (Sproat Lake and Great Central Lake). These features have had complicated histories of which only the main points can be touched upon here. The northeast wall of Alberni Valley resulted from erosion along a fault. This valley is also parallel with boundaries between geological units. These bedrock features probably provided conditions that were easier to erode than the nearby rocks, thus causing the location of a main valley in late Tertiary time. The present Alberni Inlet, as well as Sproat Lake and Great Central Lake, cross geological units instead of paralleling them.

The presence of the late Tertiary valleys that undoubtedly existed at these places may have been influenced by faults or zones of fracturing that have not been recognized because they are covered by overburden and water. Another possible explanation is that rivers flowed at these locations before the land was uplifted, and were able to maintain their courses as the land was uplifted. Huge valley glaciers filled the late Tertiary Alberni Valley and its larger tributaries, forming a branching system of slowly moving ice that modified them to their present shapes. According to Fyles, during the time of maximum glaciation at least some of the ice in Alberni Valley came from the large glacier in the Strait of Georgia. Later, as the ice became thinner, this connection was eliminated by the presence of the Beaufort Range, causing the Alberni system of valley glaciers to be fed by an ice cap that probably had its centre in high mountains near Buttle Lake. After further melting and thinning the Alberni system became separated and, later, ice appears to have occupied Alberni Valley after it had melted completely from Sproat Lake and Great Central Lake. These lakes have been preserved because natural dams of glacial drift were deposited along the flank of the ice in Alberni Valley, and perhaps also because the central parts of the lakes were excavated by the ice more deeply than at their eastern ends.

Excellent views of Sproat Lake can be seen along the highway to the park, which follows the north shore for more than 15 miles. A short branch road leads to Great Central Lake. A good idea of Alberni Inlet can be obtained by driving to Port Alberni, but this fine example of a fiord is well worth seeing from the boat that travels between Port Alberni and Ucluelet. This trip is not only scenic but geologically instructive, as the steep, glaciated walls of the valley and the way it has apparently been straightened into a few long stretches can be seen. Many of the tributary valleys are of the type called 'hanging' because their pre-glacial slopes have been changed by the flow of ice down Alberni Valley.

The weight of the covering ice, which has been estimated to have been up to 800 feet thick in the Pacific Rim region, caused Vancouver Island to sink and sea level to rise. As a result the

lower parts of the coastal plain were submerged and only the higher hills such as Radar Hill and Vargas Cone stood as islands. A veneer of clay was laid on the submerged plain at this time. The sea extended into Alberni Valley, where marine sediments of Pleistocene age have been found as high as 300 feet above present sea level.

In places along the Tertiary coast the slow erosion of waves, probably aided to some extent by the erosion of streams entering the sea, cut benches or 'marine platforms'. The surface of the greywacke-conglomerate unit in the northwest part of Long Beach section, the islands of the Broken Islands section, and the rocky lowland near Cape Beale are examples of such platforms probably formed in late Pleistocene time and modified by still later erosion.

Depositional Effects

Various kinds of drift deposited by the ice as it advanced and retreated, or by the great floods of meltwater issuing from the disintegrating glaciers, can be observed in many places. Examples occur in road-cuts along the highway between Parksville and Cameron Lake and farther along this route. However, because depositional effects are the main glacial features in the Long Beach segment, only they will be outlined here. Eastwood, who studied these deposits, concluded that, as the main ice sheet which covered the region melted away, masses of stagnant ice were left in the valleys, and that a particularly large mass occupied the basin now filled by Kennedy Lake. Meltwater from surrounding ice that was disintegrating carried sand, silt and other debris across the top of the Kennedy Lake block and deposited them on the plain between the lake and the sea. In this way much of the plain was covered by a mantle of sand, gravel and clay, as can be seen along roads in the park and particularly along the cliffs behind Florencia Bay. Boulders were carried on 'rafts' of ice detached from glaciers, and dropped amid the sand and gravel when the 'rafts' melted. Only the lower parts of the higher, rocky hills on the plain were covered by glacial drift.

This gravel pit operated by the town of Tofino, near the crossing of the north boundary of the park by the highway, shows two important kinds of deposits resulting from the last ice age. At the lower left side of the pit are stratified 'outwash' gravel deposited by a flood of meltwater as the glaciers melted away. Overlying these gravels are faintly stratified beds of clay deposited in the sea when the land was lower than at present, after sinking under its load of ice. The clay, together with a few boulders, were carried over the surface of the sea on 'rafts' of ice and dropped where they melted.

A good exposure of different kinds of glacial drift can be seen at a gravel pit close to the point where the highway to Tofino crosses the north boundary of the Park.

Persons especially interested in glacial features can visit kames, eskers, kettles and other phenomena in the area between the east coast of Vancouver Island and the Beaufort Range by referring to descriptions by Fyles in Memoir 318 which is listed at the end of this booklet.

Recent Features (Phase 7)

The main events that have influenced landscapes in and near the park since the Pleistocene ice melted have been the formation of the beaches, the erosion of rocky shores, and the uplifting of the land which is partly responsible for the beaches and other shoreline features. The release of the load of ice by melting caused Vancouver Island to rise, but not to its pre-Glacial level. The sea, therefore, entered many glaciated valleys, such as Alberni and Tofino inlets.

At the time of maximum sea level the entire Long Beach segment, except for Radar Hill and other hills west of the airport, was submerged. Kennedy Lake was an arm of the sea but protected from it by a chain of islands, now rocky hills that stand above the plain of sand and gravel deposited between the lake and Wickaninnish Bay. The old islands and marine terraces are particularly visible when viewed from the highway before reaching the park, by looking westward across Kennedy Lake. Deposits of this sea also form the sand and gravel that cover the inland area northeast of Florencia Bay.

Sand dunes occur in places, particularly behind Schooner Cove. These should not be disturbed by careless walking or in other ways, in order to protect the vegetation that is trying to establish on them.

The glacial stoney clay and 'outwash' gravels that underlie much of the park, and whose erosion provides the sand of the beaches, are well exposed along Florencia Bay. Note ripple marks on surface of sand in foreground. These were caused by the current of the retreating tide.

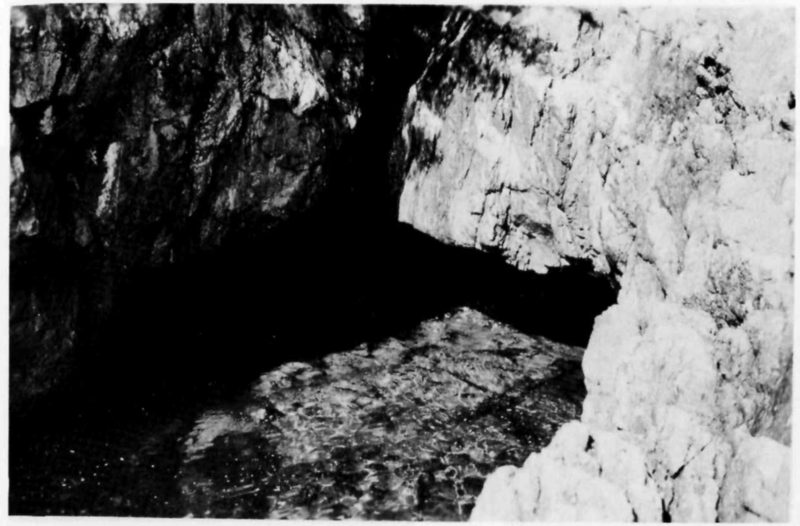
The mouth of a small creek entering Florencia Bay is lined by cobbles carried from the nearby cliff during freshets.

Origin of Beaches

The beaches resulted and are resulting essentially from wave erosion at the base of the uplifted deposits of glacial clay, silt, sand and gravel, and the sorting and redeposition of this material by the backwash of the waves. Cliffs of glacial deposits, 50 to 60 feet high, and apparently more compacted or cemented than in some other parts of the segment, are particularly prominent close to the shore of Florencia Bay. Elsewhere the deposits have been worn back to form gentle slopes instead of cliffs. Whether a beach consists mainly of sand, small pebbles, larger pebbles, or cobbles, is partly a matter of the nature of the glacial deposits in the immediate vicinity, but may be the result of two other factors. One is that the ebbing tides tend to carry sand and silt away from a beach, leaving pebbles or cobbles behind; then rising tides bring much of the sand and silt back. Also, strong winds blowing along shore or at an angle to it, move sand and silt away from part of a beach, and winds in the opposite direction return some of this material. The material composing a beach is, accordingly, partly changeable and dependent on tides and winds.

Most of the erosion of the glacial deposits has been caused by waves. This has been augmented in places by slumps where beds of unstable clay became saturated with rainwater.

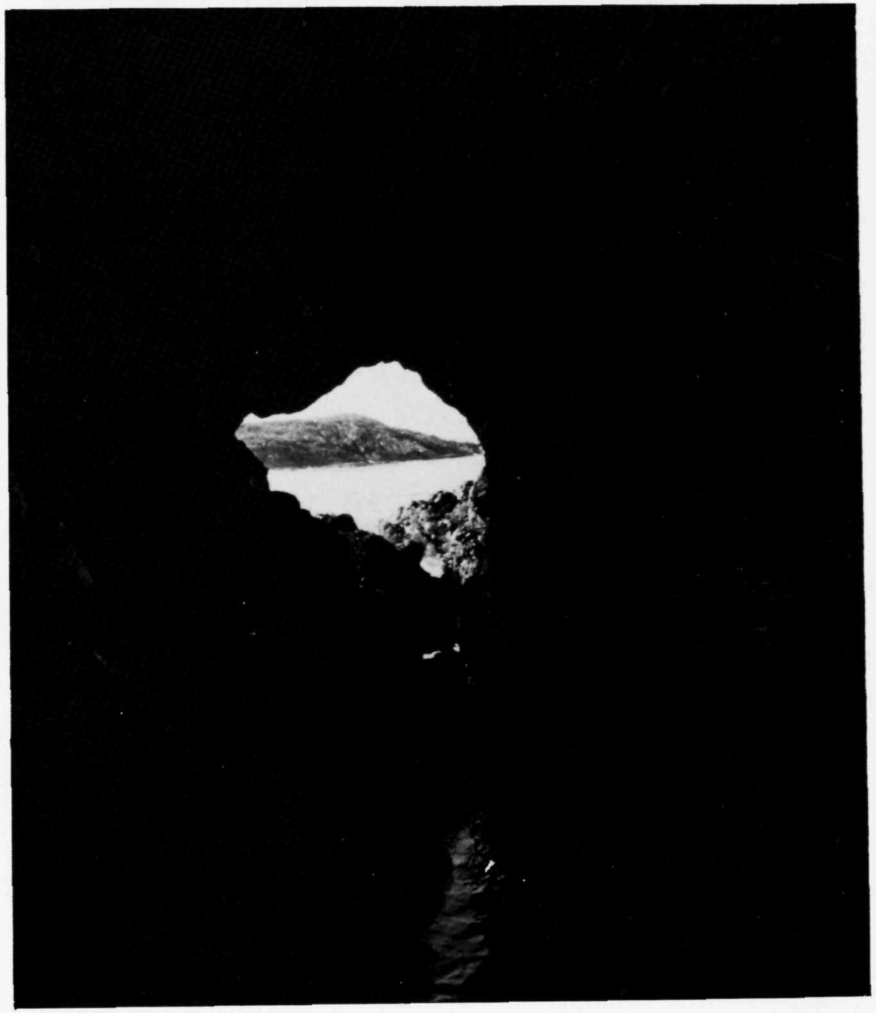
Some of the cliffs of glacial 'outwash' show stratification of sandy, pebbly and cobbly layers.



Waves eroded this sea cave at Quisitis Point.
Photo by Parks Canada.

The headlands act as breakwaters in protecting the beaches themselves from excessive erosion by crashing storm waves and strong winds, and also because the tides have a strong northwestward 'set' or current probably caused by the large flow of water entering the ocean from Fraser River.

A variety of ripple-marks can often be seen in the sandier beaches and on the bottom of shallow water. White streaks composed of tiny shell fragments are common along the beaches and streaks of black sand occur in many places particularly along Florencia Bay. The latter are composed of the iron mineral magnetite which is a common minor constituent of plutonic rocks and sediments derived from their weathering. Thus magnetite in



small quantities is widespread in the gravels behind this and other shores and, being heavier than ordinary sand, it tends to be sorted into streaks between ordinary sand.

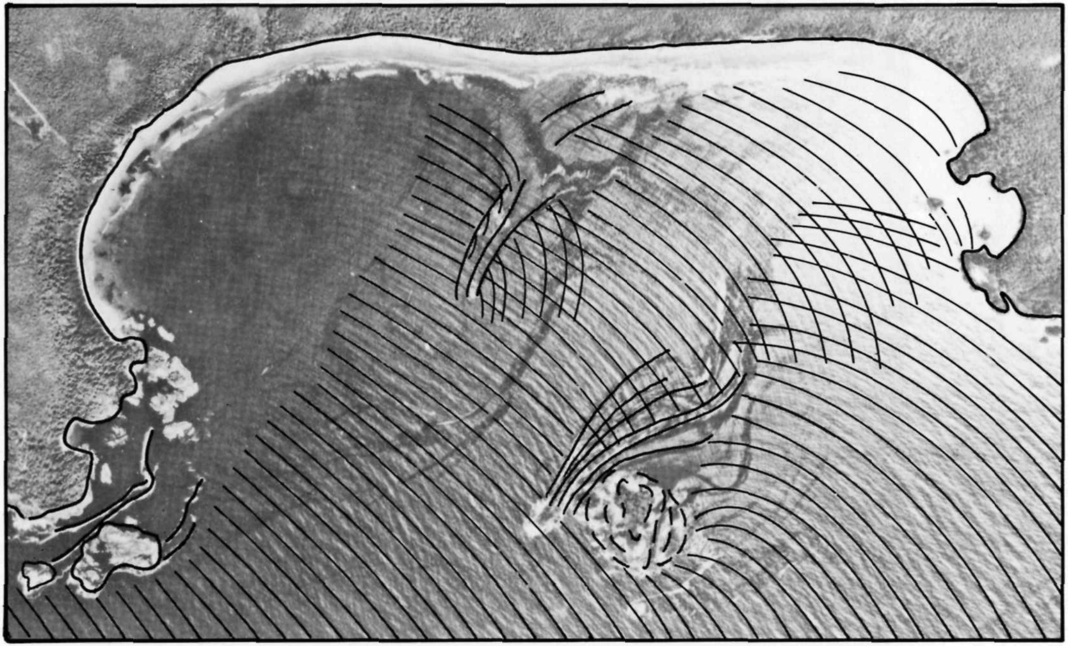
Erosion of Rocky Shores

The headlands and the stretches of rocky shore between Point Cox and Portland Point and along Ucluth Peninsula contain many interesting examples of the erosion of waves acting on rocks of different hardnesses or structures. Some of these can be explored fairly easily by walking from nearby beaches; others require long walks and climbs over rocky shorelines.

There are small sea caves between Quisitis Point and the north end of Florencia Bay and in some of the coves north of the Radar Beaches. Arches formed of resistant rock left after underlying, less resistant rock was worn away, occur at the south end of Florencia Bay and at Green Point. Water spouts, also called blow-holes, occur where strong waves are sprayed upward through narrow channels in rocky shores as at Portland Point, south of Long Beach, and south of Florencia Bay. The stretches of rocky coast contain many small coves or 'surf channels' where waves have eroded indentations along faults which provided rock more readily eroded than the unsheared rock. There are more such faults than can be shown on the geological maps.

Little imagination is required, particularly during storms, to understand how shore erosion – one of the most fundamental geological processes – is gradually changing the shape of the coast and providing additional sediment for deposition.

← Rock arches such as this one at the south end of Florencia Bay were caused by waves that eroded the less durable part of rock exposures, when relative sea level was a little higher than at present. Photo by Parks Canada.



The arc shapes of bays is believed to be partly caused by concentric swell-wave patterns centred on reefs, as illustrated on this air photo and diagram of Florencia Bay.

EPILOGUE

The descriptions on the previous pages, brief though they are, will enable you to view scenes with more discernment for the processes that caused them and are slowly changing them. Anyone who visits the seashore notices the short rhythms of waves, tides and alternations between calms and storms. Only a little more observation is needed to observe how the sea is attacking beds of sand and gravel, re-distributing them, and, more slowly, eroding the rocky islands and shores. You now also have some insight into the vastly slower geological rhythms that cause cycles of erosion, sedimentation, eruption of lava, formation of granite and other crystalline rocks, and the squeezing, rising and sinking of the earth's crust. The glaciation that modified the landforms comparatively recently was part of cyclical alternations of climate, for there were ice ages long before the last one.

Vancouver Island is a land born from the sea and the depths of the crust during the last 300 million years or so. It is slowly being eroded and returned to the sea as sediments that will eventually be cast up as new mountains or drawn down to lose their identity by transformation into recrystallized or molten rock. Reflection on these matters, and learning to see some of the proofs of them displayed by landscapes and rock exposures, impresses us with the immense power, persistence and duration of geological processes and leads to better understanding of our environment and our transitory place in it.

SOURCES OF ADDITIONAL INFORMATION

Topographic Maps and Hydrographic Chart

Available from Canada Maps Office, Department of Energy, Mines and Resources, Ottawa, Ontario, K1A 0E9

Alberni and Cape Flattery Sheets (92F and 92C), Scale 1: 250, 000. These are general, contoured maps covering all of Pacific Rim National Park and the country between it and Parksville.

Tofino Sheets, West and East Halves, and Ucluelet Sheet, East Half (92F/4, W½; 92F/4, E½; 92C/13, E½), Scale 1: 50, 000. These are more detailed maps including the Long Beach segment.

Barkley Sound and Approaches, Scale 1: 77, 918. A hydrographic chart of the coast of Pacific Rim National Park as far south as Tsusiat Lake.

Geological Literature and Maps

Geology and Mineral Deposits of Alberni Map-Area, British Columbia (92F), by J. E. Muller and D. J. T. Carson; Geol. Surv. Canada, Paper 68-50, 1968 (Out-of-Print). A preliminary report on bedrock geology and mineral deposits of the part of Vancouver Island lying between Parksville and Tofino, including the part of Long Beach segment north of Florencia Bay, and most of Alberni Inlet. It is accompanied by a geological map on the scale 1: 250, 000 (approximately 1 inch to 4 miles) which is still available, Price $1. 00.

Geology of Pacific Rim National Park, by J. E. Muller; in Report of Activities, April to October 1972, Geol. Surv. Canada, Paper 73-1A, p. 29-37. A short preliminary report on the Long Beach part of a special study made for the National Parks Service. Contains important additions to data in Paper 68-50, and data on the part of Long Beach segment lying south of the area of that paper.

Victoria Map-Area (92B, C), Pacific Rim National Park, Vancouver Island, B. C., by J. E. Muller; in Report of Activities, April to October 1973, Geol. Surv. Canada, Paper 74-1, Part A, p. 21-23. A short summary of the geology of the Broken Islands and West Coast Trail segments.

Surficial Geology of Horne Lake and Parksville Map-Areas, Vancouver Island, British Columbia, by J. G. Fyles; Geol. Surv. Canada, Memoir 318, 1963. A detailed account of the glaciation and glacial deposits of the area between Parksville and the east end of Sproat Lake, as far south as Alberni. Accompanied by two maps (1111A and 1112A).

Fiord-Land of British Columbia, by M. A. Peacock; Bulletin, Geol. Soc. Amer., vol. 46, p. 633-696, April 1935. Geological descriptions of many of the fiords of Vancouver Island and the mainland, including more data on Alberni Inlet than is included in this booklet.

Geological Fundamentals

A Guide to Geology for Visitors in Canada's National Parks, by David M. Baird, published by Parks Canada. An excellent outline of the principles of geology written in readily-understandable style and illustrated by photos of features in various National Parks.

General Information

General information on the park can be obtained by writing or visiting the following addresses:

Park Superintendent,
Pacific Rim National Park,
Box 280,
Ucluelet, B. C.

Parks Canada,
400 Laurier Avenue West,
Ottawa, Ontario.
K1A 0H4.

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