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Geology of

Lower Jervis Inlet

British Columbia

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Geology of Lower Jervis Inlet

CHAPTER I.—INTRODUCTION

The Coast Mountains trend in a northwesterly direction from Burrard Inlet in *southwestern British Columbia, through southeastern Alaska, into Yukon Territory.* They are bordered on the west by the Pacific Ocean and on the east by the Interior system of plateaux and mountains. The Coast Mountains are more than 1,000 miles long and vary in width from 20 to 120 miles. They are composed largely of granitic rocks, which constitute one of the great plutonic masses of the earth's crust.

Geological knowledge of the interior of the Coast Mountains has been obtained mainly from reconnaissance mapping of the deeply indented coastline. A minor amount of mapping has been done inland, chiefly in the vicinity of valuable mineral deposits. As a result of these studies, it is generally recognized that the core of the Coast Mountains is a plutonic complex rather than a huge single intrusion.

Work was undertaken in lower Jervis Inlet to obtain more information on the interior of the Coast Mountains. Because accessibility was the main reason for studying this area in preference to others, it can be regarded as a randomly selected sample.

LOCATION AND ACCESS

The location of the lower Jervis Inlet area is shown on the index map, Figure 1. It is in the southern part of the Coast Mountains between 49° 37′ and 50° 01′ north latitude and 123° 50′ and 124° 07′ west longitude.

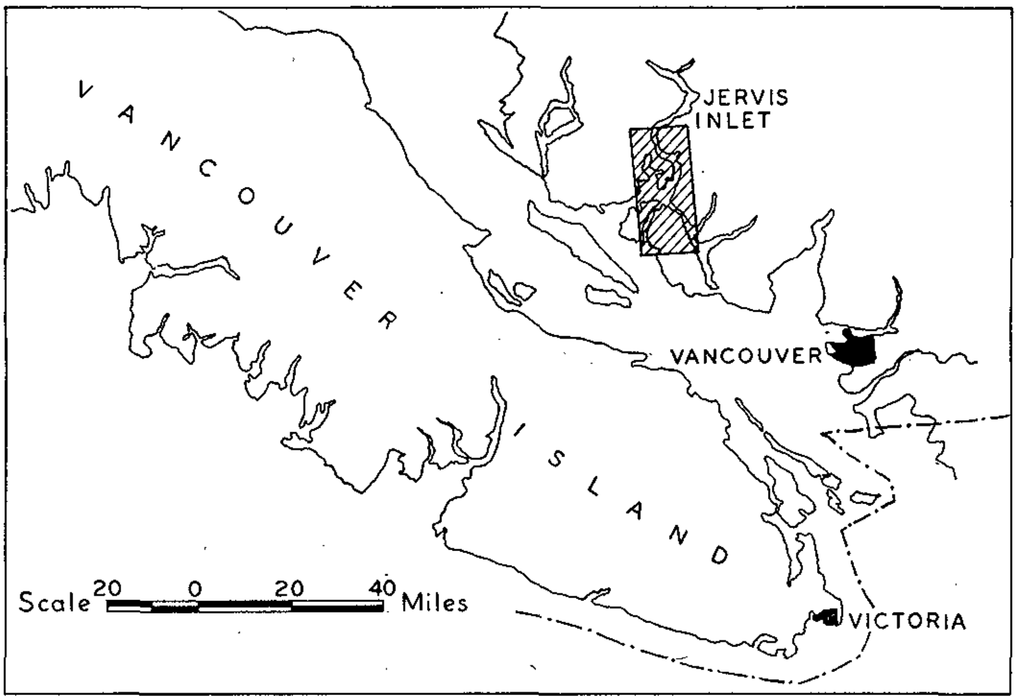

Figure 1. Index map.

The scattered settlement along the shoreline of Pender Harbour in the southwestern corner of the area is the largest in the district. Pender Harbour is 46 miles northwest of

Vancouver and is serviced by road and boat from that port. Buses operate between Vancouver and Pender Harbour, which involves a ferry crossing of Howe Sound between Horseshoe Bay and Gibsons Landing. In 1954 a good gravel road was constructed between Kleindale, on the Gibsons Landing–Pender Harbour road and Earl Cove, on the northwestern shore of the Sechelt Peninsula. This road, which makes possible travel by bus or car and ferry between Vancouver and Powell River, provides entry to a part of the area that was not easily accessible during the course of the mapping programme.

Several logging roads give limited access to parts of the area. From Kleindale a steep narrow road extends 5.6 miles up the western slope of the Caren Range to the Cambrian Chieftain property.

The sea provides access to much of the area. A sturdy 16-foot boat, powered by inboard motor, was used for transportation of men and supplies during the present study.

PREVIOUS WORK

O. E. LeRoy, of the Geological Survey of Canada, made a reconnaissance survey in 1906 of the coastline and adjacent islands from the International Boundary (49° north latitude) north to Powell River. The shores of Jervis Inlet were examined in the course of this work.

R. Blanchard visited Jervis Inlet in 1922 and wrote a brief account that was primarily concerned with the economic possibilities of the northern part of the map-area.

FIELD WORK AND ACKNOWLEDGMENTS

This report is based on about seven months' field work during the summers of 1950 and 1951.

A suitable base map of the area was not available when the field work was being done, consequently it was necessary to use a map with topographic form lines prepared from aerial photographs by the Interim Map Section of the Air Survey Division of the Department of Lands and Forests. After the geological field work was completed, a topographic map of the area was completed by the Topographic Division, Department of Lands and Forests, and this map was used for the final compilation of the geological map, Figure 2.

Because the best exposures of bedrock occur at sea-level and above timberline, a useful preliminary step in the mapping of any part of the area was a careful investigation of the adjacent coastline. Inland, mapping was of a reconnaissance nature. The geology was surveyed by pace and compass and, where possible, locations were obtained by resection.

K. G. Hope assisted the writer throughout the field work. J. F. Lintott served as assistant for part of the 1950 season, and P. R. Wilson for the 1951 season. The writer is indebted to the inhabitants of the map-area for the warm hospitality accorded him and his assistants. Helpful suggestions during the laboratory work and preparation of the manuscript were given by Drs. W. W. Moorhouse, G. B. Langford, P. A. Peach, and Professor A. MacLean of the University of Toronto.

Assays and rock analyses were done by the Analytical Branch of the Department of Mines, Victoria.

PHYSICAL CHARACTER OF THE AREA

The lower Jervis Inlet area is deeply dissected, mountainous country in which the main valleys have been invaded by the sea. This is a characteristic feature of the British Columbia coast and has resulted in a system of inlets that penetrates the mountains for varying distances.

Many of the inlets of the British Columbia coast are typical fiords. Truncated spurs, striated and grooved valley walls, and overdeepened valley basins inland from their thresholds are evidence that glacial erosion was effective during the development of the fiords. It is equally apparent, moreover, that the fiords represent pre-Glacial stream valleys subsequently deepened and otherwise modified by valley glaciers. Certain of the fiords show very abrupt changes in direction, a feature best explained by fluvial erosion, structurally controlled. Instances where the direction of fiords can be related directly to the bedrock geology are found in Jervis Inlet, where the northern part of Prince of Wales Reach coincides with a belt of stratified rocks bordered on either side by granitic rock. Similarly, the northern part of Sechelt Inlet, and probably the whole inlet, is controlled by a contact between stratified rocks and granitic rock.

The mountains in the northern part of the map-area are particularly steep. Fluvial erosion, glacial erosion, and frost action in joints in the granitic rocks have succeeded in making more rugged an already imposing terrain. In places cliffs have formed along bedding planes in steeply dipping sedimentary rocks.

The walls of Hotham Sound and Prince of Wales Reach rise sharply to elevations of 3,500 feet and more. Travel along the northerly trending ridges on either side of and near the head of Hotham Sound is virtually impossible because transverse valleys with nearly vertical walls cut deeply through the ridges. In the northwestern part of the area the rugged character of the country culminates around the matterhorn peak, Diadem Mountain (elevation 5,848 feet). As a consequence, traversing in the northern part of the area is extremely arduous, and routes must be chosen with care in order to avoid accidents.

The southern part of the area presents a relatively subdued form of topography. West of the Caren Range the terrain is hummocky and the relief lower, with only a few rounded hills rising to elevations of more than 1,000 feet.

South of Mount Hallowell (elevation 4,100 feet) the top of the Caren Range is a plateau containing small swampy lakes and ponds and very few outcrops. The western and eastern slopes of the Caren Range are not particularly steep, but jointing in the granitic rocks has resulted in a rude, cliff-and-bench type of topography which complicates climbing.

The main streams, which are in the northern part of the map-area, are Lois River, Vancouver River, Brittain River, and Treat (Beaver) Creek. Brittain River and Treat Creek flow with the grain of the country, their courses being determined by the same belt of stratified rocks that controls the direction of the northern part of Prince of Wales Reach. Lois River flows southward at a small angle to the regional structure, and Vancouver River occupies a transverse valley.

A deep valley extends from McMurray Bay on the west side of Prince of Wales Reach to the northeastern tip of Hotham Sound. It is considered to represent a part of the original "Jervis River" channel that was abandoned when erosion had proceeded to the stage where the directions of the principal stream valleys were largely influenced by structural features or by belts of stratified rock in an otherwise durable, predominantly granitic terrain.

Numerous small streams occupy narrow V-shaped valleys. Others have no well-defined valleys and flow intermittently. Freil Lake, in the north central part of the area, is drained by such a stream. It normally terminates in a spectacular falls, plunging several hundred feet to the waters of Hotham Sound, but during dry summers, such as 1951, the flow is reduced to an intermittent trickle.

Lakes are not common in the northern part of the area, but in the southern part, west of the Caren Range, there are several sizeable bodies of fresh water, of which Sakinaw Lake is the largest, measuring 5½ miles in length.

In spite of extensive logging operations, red cedar, yellow cedar, fir, hemlock, pine, and larch still occur in abundance. Trees of fair size are found to elevations of 3,300 feet. Timberline elevation is approximately 4,600 feet but it varies considerably, depending largely on the slope of the ground. Above timberline, heather and other alpine plants grow where there is sufficient soil. Throughout the area there is a dense undergrowth, composed mainly of alder, willow, salmonberry, blackberry, raspberry, ferns, and devil's-club.

During dry seasons special precautions are taken to prevent forest fires. In 1951 all travel in the woods was prohibited from July 12th to September 10th. On August 22nd lightning started a fire to the northeast of Brittain River. Fanned by a strong northeasterly wind on August 27th, the fire advanced rapidly across the northernmost part of the area, destroying valuable timber and logging machinery.

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CHAPTER II.—GENERAL GEOLOGY

The rocks in lower Jervis Inlet were mapped by Le Roy as granitic rocks of the Coast Range batholith, igneous rock (Texada group) correlated with rocks on Texada Island 10 miles west of the area, or sedimentary rock (Britannia group) correlated with rocks at Britannia Beach some 30 miles east of the southeastern corner of the area. The present work not only confirms the preponderance of granitic rocks in lower Jervis Inlet, but it shows, moreover, that the areas of sedimentary and volcanic rocks are more extensive than was hitherto realized. The names Texada group and Britannia group have not been used to designate the igneous and sedimentary rocks, rather, pending further information, the single unit, Jervis group, is used to include all rocks of pre-batholithic age.

In the table below, map-units 1, 2, 3, and 4 are arranged in what may be a stratigraphic sequence. No fossils were found in the sedimentary rocks and, in a predominantly granitic terrain, the correlation of widely separated masses of steeply dipping, metamorphosed sedimentary and volcanic rocks is difficult and may be impossible.

In mapping an area within the Coast Mountains, it must not be assumed that the task is merely one of differentiation between granitic rock and stratified rock that has been intruded by granitic rock. Such a simple approach is precluded by the fact that the plutonic rocks of the Coast Mountains have been emplaced over a long period of time as a succession of intrusions rather than as a single unit. Thus, it would be entirely possible for a stratified formation to be intruded by one granitic unit and to overlie unconformably an earlier unit in the plutonic sequence. In the map-area, however, the field evidence clearly shows that all the stratified rocks antedate the oldest granitic rocks exposed at the present surface. The only rocks which postdate the Coast intrusions occur in the form of dykes.

Table of Map-units

Age	Map-unit		Description
Jurassic(?) or later.	Coast intrusions.	8	Mainly coarse-grained hornblende granodiorite.
		7	Medium-grained biotite granodiorite.
		6	Main batholithic mass—mainly quartz diorite, granodiorite.
		5	Quartz-feldspar porphyry.
			Intrusive Contact
Age unknown.	Jervis group.	4	Basalt, andesite, and associated pyroclastic rocks; minor limestone, dolomitic limestone, chert, argillite.
		3	Mainly conglomerate, greywacke, sandstone, argillite; greenstone.
		2	Metavolcanic rocks; metasedimentary rocks; metadiabase.
		1	Gneiss.

JERVIS GROUP

Gneiss

(1, Fig. 2)

Gneiss outcrops on the western end of Captain Island in the central part of the map-area. Persistent bands of light-coloured granitic material, ranging in thickness from a fraction of an inch to more than a foot, alternate with dark-grey to blackish, hornblende-rich bands (Plate III (B)). This rock is bordered on the east by a foliated phase of the Coast intrusions.

The bands of the gneiss strike northwestward and dip northeastward at 35 to 50 degrees, and are parallel to the foliation in the bordering granite.

Under the microscope the dark bands of the gneiss are seen to consist essentially of an anhedral mosaic of green hornblende and plagioclase. Quartz occurs in minor amount and brown biotite may or may not be an important constituent. Accessory minerals are sphene, apatite, and magnetite.

The hornblende occurs in ragged elongate grains, as does much of the biotite where present. Probably some of the biotite crystallized contemporaneously with the hornblende. In places, however, fine shreds of biotite rim the hornblende and occupy fractures in that mineral, indicating that some of the biotite is of later origin.

The plagioclase of the dark bands is fresh except for a minor alteration of some of the cores. This alteration is mainly saussuritic, although a little white mica has also resulted. The composition of the plagioclase is andesine, about An_{40}. Bending of the albite twin lamellæ and undulatory extinction are not uncommon features. A few of the larger grains contain inclusions of hornblende and biotite.

The light granitic bands of the gneiss are characterized by an abundance of quartz and plagioclase and a scarcity of hornblende. Fine shreds of epidote and biotite are intimately associated in thin streaks and also occur disseminated through the rock. In places the biotite shows incipient alteration to chlorite. The plagioclase is less clear than in the dark bands. Although it exhibits some alteration to saussurite, a sparse general development of white mica is more common. In the few sections examined, the composition of the plagioclase of the granitic bands is approximately An_{30}. Some normal zoning of the feldspar was noticed in both light and dark bands.

The dark bands of the gneiss are believed to be metamorphosed sedimentary beds. Similar exposures have been examined by the writer in the West Vancouver area, where the rocks have been described in detail by Phemister (1945, pp. 55–58) under the heading " Caulfield Gneiss." To Phemister, " the general structure suggests a sedimentary rock," and he favours the idea that they are metamorphosed tuffs.

Analysis of a specimen from one of the dark bands gave the following results:

	Per Cent		Per Cent
SiO_2	61.60	P_2O_5	0.08
TiO_2	0.55	H_2O+	0.62
Al_2O_3	14.24	H_2O-	0.13
Fe_2O_3	2.38	CO_2	0.04
FeO	4.19	S	*Nil*
MnO	0.16	BaO	0.13
MgO	4.75	ZrO_2	0.10
CaO	6.48		
Na_2O	3.61		100.15
K_2O	1.09		

This analysis does not correspond closely with published analyses (Washington, 1917; Pettijohn, 1949; Grout, 1932) of any igneous or sedimentary rock and undoubtedly reflects reaction between the solid material of the dark bands and invading granitic fluids.

The gneiss is an isolated occurrence in contact only with granitic rock and, therefore, its relationship to the other stratified rocks of lower Jervis Inlet is unknown.

Metavolcanic Rocks; Metasedimentary Rocks; Metadiabase

(2, Fig. 2)

A complex composed of metamorphosed volcanic rocks, sedimentary rocks, and basic sills outcrops on both sides of Prince of Wales Reach, east of Foley Head and Egmont Point. No similar assemblage of rocks is recognized elsewhere in the area.

Sparse outcrops northwest and southeast of the inlet give some evidence of the extent of this complex, but knowledge of its composition has been gained largely from exposure along the shores of the inlet. The rocks of the complex are flanked on both sides by sedimentary rocks of map-unit 3, and its stratigraphic relationship to map-unit 3 is only tentatively established. In the description of map-unit 3 (*see* p. 12) evidence is given to support the belief that the complex represents the upper part of a formation older than map-unit 3, which implies that the complex occupies the central part of an anticline. The base of the complex is not exposed and its thickness is unknown.

On the northern shore of Prince of Wales Reach in the small cove northwest of Sydney Island, the prevailing rock is a massive, dark-green altered volcanic that locally is sheared, silicified, and epidotized. Pyrite is common in such zones. A specimen of these volcanics, obtained from the mainland directly west of Sydney Island, is seen under the microscope to be almost entirely recrystallized. More than 80 per cent of the specimen consists of an intergrowth of a fibrous green amphibole and small irregular grains of plagioclase. A small amount of plagioclase is twinned, and its composition is andesine. Several narrow stringers of epidote, calcite, and white mica traverse the specimen.

Thin-bedded sedimentary rocks belonging to the complex outcrop to the east of these volcanics. Sandy beds are present, but they are minor in quantity. The dominant rock consists of thin beds of dense, fine-grained blackish material alternating with beds of coarser material of dark-greenish colour. Individual beds are measurable in fractions of an inch. On the weathered surface, the rock presents a hackly pitted appearance, the pits occurring as elongate cavities parallel to the bedding.

Under the microscope the blackish material is seen to consist of small irregular grains of quartz that have lost much of their clastic outline and a black opaque substance which may be graphite. These beds represent silt that has been largely recrystallized. The dark-greenish beds consist entirely of secondary minerals which show a marked preferred orientation parallel to the bedding. Varying amounts of amphibole, calcite, quartz, white mica, epidote, and chlorite are present. The calcite is relatively abundant in streaks, and it is obvious that the leaching of this material is responsible for the pitted appearance of the outcrop. It is inferred from their mineral composition that these dark-greenish beds were originally calcareous shale.

Basic sills are particularly numerous on the southern shore of Prince of Wales Reach. They occur as thick masses separated by sedimentary partings, some of which measure only a few feet in thickness. The sills are composed of a dark greyish-green medium- to coarse-grained metadiabase. In the hand specimen, a dark-greenish amphibole is obviously the main constituent.

Two specimens of the sill rock obtained from either shore of Prince of Wales Reach were examined under the microscope. The one from the northern shore is highly altered but exhibits to some extent the texture characteristic of diabase. Some of the lath-shaped crystals of andesine occur poikilitically enclosed in hornblende pseudomorphic after pyroxene. The majority, however, are randomly oriented in a green fibrous mass of secondary amphibole. Many of the laths are bent, while others are fractured and veined by the amphibole. A considerable amount of secondary sphene occurs as patches of tiny grains pseudomorphic after titaniferous magnetite. A very minor amount of pyrite is present. The specimen from the south shore is so highly altered that the original texture is all but obliterated. The rock consists essentially of green fibrous amphibole and plagioclase. In spite of the shearing and alteration, some of the plagioclase partly retains a lath-like outline. In many places the amphibole appears to replace the plagioclase (andesine). A minor amount of the plagioclase is altered to white mica and albite. Small patches of biotite comprise less than 3 per cent of the section. Skeletal grains of a dark opaque mineral, presumably magnetite, are disseminated throughout the section. A very little fine quartz completes the mineral assemblage. This specimen was chemically analysed, with the following results:—

	Per Cent		Per Cent
SiO_2	48.04	K_2O	1.22
TiO_2	1.04	P_2O_5	0.10
Al_2O_3	16.18	H_2O+	2.24
Fe_2O_3	1.43	H_2O-	0.09
FeO	11.02	CO_2	0.06
MnO	0.24	BaO	0.26
MgO	6.59		
CaO	8.60		100.14
Na_2O	3.03		

Norm

	Per Cent		Per Cent
Orthoclase	7.23	Olivine	19.71
Albite	25.68	Magnetite	2.09
Anorthite	26.97	Ilmenite	1.98
Diopside	13.11		
Hypersthene	0.33		97.10

The chemical analysis confirms the petrographic determination that the rock is a meta-diabase.

Conglomerate, Greywacke, Sandstone, Argillite; Greenstone

(3, Fig. 2)

The stratified rocks of the northern part of the map-area are largely clastic sedimentary rocks, ranging from conglomerate to argillite. They occur largely in northwesterly trending bands that dip vertically to steeply eastward. The individual bands are separated either by granitic rocks or by other stratified rocks. These sedimentary rocks have all been assigned to the same map-unit because of their lithological similarity. Such a grouping is tentative because no fossils have been found in them.

The sedimentary rocks of Egmont Point and Foley Head, on either shore of the mouth of Prince of Wales Reach, are almost entirely arenaceous or coarser. Farther north the section across Mount Calder is composed of approximately equal amounts of grey thin-bedded argillites and sandy beds. Still farther north, north of Diadem Mountain, thin-bedded argillites constitute about 85 per cent and sandy beds about 15 per cent of these sediments.

The most instructive cross-section of these sedimentary rocks is exposed around Foley Head. There the beds exhibit the regional northwesterly trend and dip eastward at angles of 30 to 70 degrees. In all, about 3,400 feet of sedimentary and minor interstratified volcanic material is represented, assuming no repetition has resulted through folding or faulting. From east to west around Foley Head a general diminution in grain size is apparent in the sediments. Because the beds dip eastward, this is taken as evidence that the beds are overturned, that these sedimentary rocks overlie the rocks of map-unit 2, exposed to the east, and are in turn overlain by the rocks of map-unit 4, exposed to the west.

The base or eastern end of the Foley Head section consists of coarse sandy material containing abundant granitic pebbles and boulders ranging in size from a few inches to more than a foot in maximum dimension. These granitic fragments have been flattened parallel to a cleavage which, wherever observed, is essentially parallel to the bedding. The conglomerate bed has a thickness of about 200 feet and is of particular interest because its granitic boulders require the existence of a granitic stock or batholith in a near-by landmass prior to the emplacement of the oldest granitic rocks now exposed along lower Jervis Inlet.

No really good marker horizons were found in map-unit 3. Nevertheless, it is interesting to consider the places, other than Foley Head, where granitic fragments have been found in a sedimentary matrix. Two small islands immediately northeast of Sydney Island are composed of arenaceous sediments. The rock at the eastern end of the more easterly of these islands contains granitic pebbles and a few boulders, one of which measured 3 feet in length. Coarse sedimentary rocks outcrop on Miller (One Tree) Islet, the lone rock outcrop between Foley Head and Egmont Point. The beds on the western side of this islet contain flattened granitic pebbles as much as 4 inches in length. Similar pebbles were noted near the base of map-unit 3, in outcrops on Egmont Point.

In an area where the regional trend of the stratified rocks is northwesterly and where transverse faulting is apparently a minor feature, the line of conglomerate occurrences at the east end of Foley Head, Miller Islet, and Egmont Point probably defines a single horizon. It would thus appear that a possible marker has been established at the base of map-unit 3 where it crosses the mouth of Prince of Wales Reach, a distance of more than 2 miles.

The only other locality where granitic boulders are enclosed in a sedimentary matrix is south of Treat Creek on the east shore of Prince of Wales Reach. At the southern border of these sedimentary rocks a small exposure exhibits flattened granitic pebbles as much as 3 inches in length.

Two of the smaller granitic boulders were extracted from the conglomerate on Foley Head and examined under the microscope. The most noteworthy feature of the boulders is their cataclastic texture. Plagioclase occurs as relatively large unzoned grains in a finer-grained aggregate of quartz, biotite, and calcite. Although the plagioclase grains are bent, fractured, and veined by the minerals of the groundmass, a number of them retain at least parts of their original crystal outline. A very few of them, which are not appreciably altered, were determined as oligoclase. Most, however, are badly corroded and irregularly replaced by fine quartz. Many of these grains have a distinct mottled appearance and are in various stages of conversion to albite. Finely divided calcite is a feature of such grains. Epidote is also present in some grains of the altered plagioclase.

In one thin section the relationship of the plagioclase to the other minerals is strongly suggestive of a porphyritic texture, but because this boulder is intensely sheared, and the minerals of the groundmass have been correspondingly well granulated, this texture may be porphyroclastic rather than porphyritic.

Practically all of the quartz is fine-grained. However, in one thin section two large unstrained anhedral grains of quartz contain abundant liquid inclusions which are restricted to the cores. The same section contains two anhedral grains of a mineral with high relief, which is pleochroic in shades of brown, and, although not positively identified, is thought to be allanite. In both sections, apatite is common as small euhedral crystals; sphene and zircon are sparingly present.

The biotite of the groundmass occurs as fine brown shreds that show a marked preferred orientation. A very minor amount of this mineral exhibits incipient alteration to chlorite. Calcite occurs in veinlets and patches interstitial to the plagioclase. A little orthoclase was noted replacing the plagioclase. The orthoclase is altered in part to white mica.

The matrix enclosing the granitic boulders is a greywacke composed of essentially the same mineral assemblage as the boulders. Biotite is much more abundant than in the boulders, however, comprising at least 60 per cent of the matrix. A few quartz and quartz-calcite veinlets are present and a minor amount of chlorite has developed along fractures. Some calcite and a few grains of epidote complete the assemblage.

At least some of the calcite in the boulders is derived from the alteration of the plagioclase, and there is no evidence to suggest that any other mineral has been introduced into the boulders subsequent to their deposition. It was therefore considered of value to obtain an analysis of one of the boulders that had been examined petrographically.

Accordingly, a 1-inch cube was cut from the core of one of these boulders and chemically analysed. The results are as follows:—

	Per Cent		Per Cent
SiO_2	66.22	K_2O	2.06
TiO_2	0.41	P_2O_5	0.06
Al_2O_3	14.26	H_2O+	1.24
Fe_2O_3	0.48	H_2O-	0.16
FeO	3.34	CO_2	1.90
MnO	0.08	S	0.04
MgO	1.96	BaO	0.17
CaO	4.52		
Na_2O	3.50		100.40

Norm

	Per Cent		Per Cent
Quartz	30.30	Magnetite	0.70
Orthoclase	12.23	Ilmenite	0.76
Albite	29.34	Calcite	4.30
Anorthite	10.29		
Corundum	2.55		96.43
Hypersthene	5.96		

Although the analysis of one boulder can hardly be considered representative of all, it is noteworthy that there is no marked difference between this and the chemical composition of the main batholithic mass (map-unit 6) detailed below. The norm, however, is appreciably different, mainly because of the alteration of the plagioclase and the consequent development of calcite. This is reflected in the norm by the decrease in anorthite and the increase in calcite, corundum, and quartz, the normative minerals corresponding to the constituent oxides of anorthite. The normative corundum is also partly due to the high percentage of modal biotite. The relative abundance of this mineral in the rock is responsible for the high percentage of orthoclase in the norm.

A few thin sections of sandy beds were examined in order to establish whether any appreciable metamorphism had occurred. They indicate that, at least locally, the metamorphism has been sufficient to produce a development of fine brown biotite. In a specimen from Egmont Point, a minor amount of what is apparently allogenic hornblende still persists, but a light-green metamorphic amphibole is more abundant. In places this mineral is found rimming the hornblende. The presence of actinolite does not necessarily indicate a relatively high degree of metamorphism, however, as various authors, including Turner and Verhoogen (1951, p. 469), have pointed out that it is a stable constituent of the biotite-chlorite subfacies of the greenschist facies.

In one thin section a higher grade of metamorphism is indicated, but this may be due in part to the proximity of the bed to a granitic contact. This specimen was obtained from the shoreline south of Treat Creek within a few feet of the granitic rock outcropping to the south. This specimen, which is completely recrystallized, exhibits a pavement structure and consists essentially of hornblende, quartz, and plagioclase with minor orthoclase, a very little biotite, and a few grains of sphene. Some of the larger masses of hornblende occur poikoblastically with respect to smaller grains of plagioclase and quartz. A very minor amount of plagioclase occurs in the form of porphyroblasts. This mineral, which is not well twinned, has an index that indicates its composition is within the oligoclase range.

No shaly beds were examined microscopically. They are generally sufficiently indurated to be termed argillites and in several places are slaty argillites. In few places, however, has the secondary cleavage developed to the stage where actual slates have been formed.

Greenstone, where present in a predominantly sedimentary setting, has not been mapped separately. Northwest of Diadem Mountain this rock constitutes the eastern part of the band of Jervis group rocks. It also forms an appreciable part of the sedimentary rocks mapped on both sides of the mouth of Brittain River.

Small exposures of quartzite were observed at McMurray Bay and at one or two other localities.

Quartz and epidote stringers are not uncommon in the sedimentary rocks. Pyrite is relatively abundant along certain horizons in the argillites.

Basalt, Andesite, and Associated Pyroclastic Rock; Minor Sedimentary Rocks

(4, Fig. 2)

Basaltic and andesitic rocks, commonly altered to greenstone, are widespread in lower Jervis Inlet. In the northern part of the map-area they occur along the southwestern shore of Foley Head and along the eastern shore of Prince of Wales Reach, north of Treat Creek.

Foley Head.—The volcanic rocks of Foley Head are considered to be younger than the sediments of map-unit 3, that outcrop on their eastern border. These volcanic rocks are intersected by tongues of granitic rock and now occur in several small separate segments. For the most part they consist of massive dark-green to blackish flow rocks. Here and there, pyroclastic rocks may be recognized, but in general their rather similar appearance to the flow rocks makes it difficult to estimate their amount.

A specimen of the Foley Head volcanic rock was examined under the microscope. The rock is completely recrystallized to an aggregate of fibrous green amphibole, biotite, plagioclase, and quartz. Epidote occurs locally and pyrrhotite is rather common as irregular grains. Although the fragmental nature of the rock is not obvious in the outcrop, it is clearly evident under the microscope. The majority of the fragments are composed of masses of fine greenish amphibole, through which are distributed thin randomly oriented laths of plagioclase. The plagioclase is a basic andesine which is replaced to varying degree by the amphibole. A very minor amount of mica, pleochroic in shades of brown, may be present in the laths as well as in the groundmass of the fragments. Other discrete patches, presumably representing completely altered fragments, consist largely of light-brownish mica which in places surrounds plagioclase. Some of these plagioclase cores are only moderately altered and contain fine needle-like prisms of amphibole; others are riddled with fine quartz.

The matrix enclosing the fragments is composed essentially of the same mineral assemblage as the fragments. No pyroxene is present and nothing which could be determined definitely as primary amphibole was noted. The clastic nature of the rock is disclosed by reasonably well-defined bands that differ from adjacent bands either in size of grain or proportions of the constituent minerals, or both.

The western limit of the volcanic rocks exposed on Foley Head is marked by a layer of pillow lava. This layer, which is 20 feet thick, is cut by narrow dykes and stringers from the adjacent granitic rock. Three other layers of pillow lava, the thickest of which is 100 feet, occur in this westernmost segment of the volcanics. A typical view of the pillows is shown in Plate IV (A). Even in the small area encompassed by Plate IV (A), the pillows vary considerably in size and are characterized by irregular outlines. Actually, they vary in maximum cross-sectional dimension from a few inches to 5 feet and are not sufficiently uniform in shape to use as a criterion for determining the top of a layer. Many of the pillows exhibit an ill-defined radial jointing.

Prince of Wales Reach.—Basic flows and associated pyroclastic rocks outcrop along the east shore of Prince of Wales Reach. The typical flow rock is dark greenish to black and contains scattered feldspar phenocrysts that are generally less than 3 millimetres in maximum dimension. Larger mafic phenocrysts are less common.

Several specimens of the flow rock were examined under the microscope. The texture of the less altered rocks is seriate porphyritic. Basic plagioclase is the most abundant constituent and may comprise as much as 70 per cent of the rock. A specimen from the north shore of Vancouver Bay is thought to be reasonably representative of these rocks. In this specimen the plagioclase is largely sodic labradorite, although some normal zoning to less calcic material was observed. This mineral is altered in varying degree to epidote, white mica, and chlorite. The alteration is most noticeable in the larger crystals, many of which exhibit corroded margins, and the blotchy appearance that is characteristic of plagioclase in the process of conversion to more sodic varieties. Both pyroxene and amphibole were present in the original, unaltered rock. The pyroxene is completely altered to epidote and a minor amount of chlorite, but in places the outline of the primary mineral is remarkably preserved. The primary amphibole is now represented by an aggregate of secondary minerals consisting of a fibrous green amphibole, chlorite, epidote, and zoisite. The same secondary minerals, together with abundant needle-like laths of plagioclase, in large measure comprise the fine groundmass. In addition, however, there is a notable development of leucoxene. A minor amount of pale-green mica is present and quartz occurs sparsely as anhedral grains in small patches. Grains of magnetite are scattered throughout the rock.

The development of epidote and chlorite is a feature of these rocks but, in two specimens, a more intense alteration is indicated. These rocks have been largely recrystallized, but their porphyritic nature is still evident in the hand specimen and a very minor amount of relict hornblende can be observed in both specimens. Chlorite occurs sparingly, and epidote is largely confined to stringers and veinlets in which it is associated with quartz. A fibrous amphibole is the predominant secondary mineral of the groundmass and it also occurs replacing the plagioclase phenocrysts. These phenocrysts retain little of their crystal outline and are extensively altered. Many are saussuritized, a few exhibit a minor development of chlorite as well, and still others are replaced by fine quartz.

Pyroclastic rocks are prominent for about a mile south of the mouth of Perketts Creek, on the east shore of Prince of Wales Reach. Tuffaceous beds are present, but outcrops of coarser material are more common. Fragments of various rock types are present in these agglomeratic exposures, but more are of feldspar porphyries than all other types combined. The fragments are angular to sub-angular (Plate IV (B)), and the greater proportion of them are 2 inches or less in maximum dimension. Some fragments measure 6 inches and a few measure more than 2 feet.

The plagioclase laths in the porphyry fragments are altered to white mica and saussurite. In the few fragments examined under the microscope, the composition of the plagioclase was determined as andesine. The dark-grey aphanitic groundmass in which the fragments are embedded consists largely of white mica, quartzo-feldspathic material, chlorite, and leucoxene. No glass was observed and it is not apparent from the specimens examined whether the matrix should be termed tuffaceous or argillaceous. The angular nature of the fragments, the obvious lack of sorting in these rocks, and their occurrence in a volcanic sequence strongly suggest that they are true agglomerates.

A minor amount of thin-bedded dark-greenish grey to blackish rock outcrops on the eastern shore of Prince of Wales Reach immediately north of Treat Creek. Pyrrhotite and pyrite are abundant in places, and as a result the weathered surfaces of certain of the outcrops are dark reddish-brown. Under the microscope much dark organic material was observed in this rock. Epidote-rich and zoisite-rich bands occur, indicating the probability that the beds were originally limy shales which differed mainly in content of iron.

Sechelt Peninsula.—Altered volcanic rocks of intermediate and basic composition occur in three separate areas in the northern part of the Sechelt Peninsula. For descriptive purposes, they are herein termed the Sakinaw Lake, Ruby Lake, and Caren Range bodies, after their geographic locations.

Each of these three bodies of volcanic rock is surrounded by granitic rock. All are older than the adjacent granitic rocks, but nothing is known of their ages relative to each other or to the volcanics of the northern part of the map-area. Their whole nature is imperfectly known, for they occur in areas more noted for timber than for outcrop.

The Sakinaw Lake and Ruby Lake bodies were located by traverses transverse to their trend. Neither was traversed along strike, and it is possible that the continuity of the long narrow Sakinaw Lake body is more apparent than real. These two bodies have not been outlined farther north than the southeastern shore of Agamemnon Channel, and it is unknown whether they terminate there or extend to the northeastern shore of Nelson Island. Overburden covers much of the east end of the island and, although exposures of greenstone are fairly common in this locality, there is insufficient outcrop to determine the size or nature of the occurrences.

Lack of exposures on the heavily wooded, plateau-like surface of the Caren Range makes the accurate mapping of much of the border of the Caren Range body impossible. Fragmental rocks were observed on the southwestern slope of Mount Hallowell and at two or three other points, but light greyish-green to dark greenish-black, non-fragmental rocks appear to predominate. Problems arise constantly in the examination of these rocks. The coarser varieties have a dioritic aspect and isolated exposures give little clue to their origin, whether intrusive or extrusive. Such diagnostic features as flow structures and vesicles, which would be an aid, have either been obliterated by metamorphism or were never well developed. Numerous basic dykes, similar in appearance to some of the volcanics, constitute a further complication. Dykes of this type are found cutting not only the volcanics but the granitic rocks of the Coast intrusions as well.

Certain mineralogic features of the volcanics of the Sechelt Peninsula are obvious in the hand specimen. Epidote is a common secondary mineral in many of the exposures, occurring in stringers and irregular patches. Chlorite, though less readily discernible than the epidote, is also widely developed. In the coarser-grained rocks, a green amphibole is clearly seen to be one of the principal constituents.

In the specimens examined under the microscope the plagioclase is commonly altered, at least in part, to saussurite and white mica. In places, however, it is sufficiently unaltered that its composition could be determined as andesine or sodic labradorite. Some hornblende is present and, in two specimens, cores of augite were still detectable in this mineral. More abundant than the hornblende, however, is a fibrous green amphibole which has formed at the expense of the hornblende. This amphibole, chlorite, and epidote appear to comprise the principal alteration products.

In the vicinity of the Cambrian Chieftain mineral deposit, limestone, dolomitic limestone, and minor amounts of chert and argillite are intercalated with the volcanic rocks. The limestone occurs in thin beds of white to grey colour and much of it is conspicuously crystalline. The largest exposure of dolomitic limestone is a lens 1,020 feet in length with a maximum thickness of 120 feet. This rock is white to greyish in colour and presents a mottled appearance. Indications of bedding are rather obscure throughout much of this body. Random thread-like epidote veinlets, calcite veinlets, and very sparse fine grains of pyrite comprise the foreign material in this rock.

The magnesia (MgO) content of nine 10-pound samples taken from various parts of the dolomitic body ranged from 18.8 per cent to 21.1 per cent, the average being 19.8 per cent. Thus, the body as a whole is dolomitic limestone; pure dolomite contains 21.86 per cent magnesia.

COAST INTRUSIONS

The granitic rocks in lower Jervis Inlet may be divided into four map-units, all readily distinguishable in the field. They are quartz-feldspar porphyry, quartz diorite and granodiorite comprising the main batholithic mass, biotite granodiorite, and hornblende granodiorite.

Quartz-feldspar porphyry occurs as dykes and sill-like masses. The close genetic relationship of this rock type to the granitic rocks justifies its inclusion in the description of the Coast intrusions.

Rocks of the main batholithic mass show a considerable range in mineralogic composition and a wide range in textures. Quartz diorite and granodiorite predominate and make up a very large proportion of the mass but could not be mapped separately. More detailed mapping might reveal certain criteria that could be used to resolve this large map-unit into smaller units.

The two relatively small masses of biotite granodiorite and hornblende granodiorite are not entirely confined to the map-area. In contrast to the main batholithic mass, they exhibit a uniformity of composition and texture and a noteworthy lack of included material. These more homogeneous portions of the granitic terrain are considered to be later phases in the sequence of Coast intrusions.

Quartz-Feldspar Porphyry

(5, Fig. 2)

The quartz-feldspar porphyry has a dark, fine-grained to aphanitic groundmass containing tabular crystals of feldspar and irregularly rounded to ovoid grains of quartz. Some of the phenocrysts are as much as one-half inch in maximum dimension but the average is less than one-quarter inch. Quartz phenocrysts are locally abundant but, in most places, the feldspar phenocrysts outnumber them by as much as three to one.

The porphyry weathers greyish-white and may be difficult to distinguish from certain porphyritic phases of the main batholithic mass, although the latter generally possess a greater percentage of dark minerals. Where exposed to wave action, the highly sheared variety of quartz-feldspar porphyry has the superficial appearance of a pebbly sandstone.

Small exposures of the porphyry are found south of Vancouver Bay, on the east shore of Prince of Wales Reach, but it is to the north of the bay that this rock type occurs in abundance. The band of volcanic rocks on the west wall of Marlborough Heights is cut by numerous parallel porphyry dykes. Some of these dykes are less than 10 feet in width, but most are considerably larger and some are in excess of 100 feet. They strike slightly south of east and dip vertically to steeply northward and can be traced up Marlborough Heights to the eastern border of the volcanic rocks. They are an imposing sight when viewed from McMurray Bay on the west shore of Prince of Wales Reach, for they stand out as straight, sharply defined white bands against the dark outcrop of the volcanics.

A mass of porphyry trends northwestward across the westernmost part of Princess Royal Reach. It persists to the northern boundary of the map-area, but its extent to the south of the fiord has not been determined. It, therefore, has a length of at least 3 miles and may be considerably longer. The width of this body is slightly less than 1 mile on the north shore of Princess Royal Reach and slightly more than 1 mile on the south shore.

A complete examination of this porphyry mass was prevented by the forest closure of 1951. Princess Royal Reach, however, provides two good cross-sections. These were carefully examined for any evidence of differentiation in the body, but none was found. It might be concluded that this large porphyry mass was the result of a single magmatic injection, for no partings or chilled zones were found within it. However, such features, if they ever existed, may have been obliterated or obscured by shearing, which has resulted in mylonitization, particularly in the eastern part of the body, or by swarms of narrow parallel, mafic dykes that intersect the porphyry and have the same northwestward strike and steep eastward dip as the porphyry (*see* Plate V (A)).

Chemical analyses were made of two samples of porphyry. One of the samples was selected from a dyke, 20 feet wide, the other from a relatively unsheared part of the large porphyry mass on Princess Royal Reach. The distance between the locations of the two samples is 4.5 miles. The results of the analyses lend support to the conclusion reached in the field that the porphyry is everywhere a rather uniform rock. The analyses follow:—

	Princess Royal Reach Body (Per Cent)	Dyke (Per Cent)
SiO_2	73.28	72.18
TiO_2	0.25	0.25
Al_2O_3	13.99	14.28
Fe_2O_3	1.02	0.90
FeO	1.18	1.35
MnO	0.06	0.06
MgO	0.55	0.65
CaO	1.98	2.34
Na_2O	3.62	3.08
K_2O	2.92	3.41
P_2O_5	0.06	0.05
H_2O+	0.68	1.22
H_2O-	0.16	0.18
CO_2	0.11	0.08
S	*Nil*	0.02
BaO	0.15	0.13
Totals	100.07	100.18

Several specimens of porphyry were examined under the microscope. One obtained from the north shore of Princess Royal Reach, near the western border of this large mass, was selected to represent the least sheared part of this body. Twenty per cent of the specimen consists of large subhedral phenocrysts of plagioclase, the composition of which is oligoclase, about An_{15}. Some of the plagioclase contains irregular patches of epidote, suggesting that the orginal composition of the plagioclase was more basic, possibly andesine. A minor amount of white mica and chlorite are also present in the phenocrysts. They show considerable evidence of deformation; many are fractured and, in a few, the albite twin lamellæ are noticeably bent. A noteworthy feature of the plagioclase is that it lacks the marked zoning which characterizes it in the batholithic rocks. Approximately 10 per cent of the specimen consists of quartz phenocrysts. They are generally smaller than the plagioclase, the largest being one-quarter inch in length. All show undulatory extinction and most are badly fractured; some are corroded and indented, the embayments being filled with minerals of the groundmass.

Under low-power magnification, the phenocrysts resemble islands in a swiftly flowing river of fine-grained minerals. The illusion of movement is heightened by the fine lines of green biotite, slightly altered to chlorite, that detour here and there around phenocrysts. This foliation might be considered a primary feature, resulting from movements in the magma, were it not for the phenocrysts. Their deformed nature and lack of orientation substantiate that the foliation is secondary, formed subsequent to the consolidation of the rock.

The groundmass consists essentially of quartz and plagioclase. A few small transparent grains with indices lower than balsam are most probably potash feldspar. Its presence was suspected because the chemical analyses of the sample taken from the same body showed 2.92 per cent potassium oxide.

A more highly sheared specimen of the Princess Royal Reach body shows little appreciable difference in mineralogy. Oligoclase phenocrysts are still present as such, but a few have lost much of their crystal outline. They are remarkably clear. The quartz phenocrysts are badly shattered and are in various stages of disintegration. Quartz, epidote, and pyrite have been introduced into the rock.

A specimen from one of the larger porphyry dykes was also examined under the microscope. The phenocrysts of oligoclase and quartz are enclosed in a matrix consisting essentially of a micrographic intergrowth of quartz and potash feldspar. The matrix has corroded the borders of the phenocrysts and replaced them along fractures. A few of the oligoclase phenocrysts are clear, others are altered to epidote, and still others contain abundant white mica, with or without epidote. Some have the mottled or blotchy appearance common in albitized rocks.

Because the porphyry mass of Princess Royal Reach is known mainly from shoreline exposures and has not been outlined, any consideration of its nature must be tentative. Were it not for the proximity of numerous large dykes of similar distinctive composition, this body might be considered merely as a wide zone of mylonitization in the granitic terrain. The presence of the dykes on the west wall of Marlborough Heights, however, suggests an alternative possibility. They trend directly toward the assumed position of the Princess Royal Reach body on Marlborough Heights and are undoubtedly part of the same intrusion. They may occupy the conduits through which magma rose to form the body on Princess Royal Reach. This mass trends northwestward and dips steeply eastward, in general conformity with the attitude of the layered rocks in the northern part of the map-area. It is thus sill-like and of sufficient size to be a laccolith. Because of the shearing, particularly along the eastern margin of the porphyry body, it is suggested that it may have been intruded between the volcanic rock of the west wall of Marlborough Heights and stratified rocks that have been upthrust by faulting and later eroded away.

Bodies of similar composition and setting are by no means unknown in other parts of the Coast Mountains. Noteworthy are the porphyry dykes of the " belt of dykes " of the Stewart mining camp (Hanson, 1935, p. 27) and the " pre-batholithic sills " in the Britannia map-area. In the latter area, James (1929, pp. 34–44) recognized the close genetic relationship of the sills to the granitic rocks and considered the sills to be " vanguards which the batholith sent far ahead into the overlying strata."

Main Batholithic Mass
(6, Fig. 2)

The main batholithic mass is composed largely of a diverse group of quartz diorites and granodiorites. In spite of its variable nature, no method of resolving the main batholithic mass into smaller units was discovered in the field. This is due partly to the scale of the mapping and partly to the lack of adequate exposures between shoreline and timberline. The impression was gained, however, that the task of subdivision would not be easy, even if appreciably more of the bedrock were exposed, for compositional variations from outcrop to outcrop are not uncommon.

Because of these facts no attempt is made herein to describe specific parts of the main batholithic mass. It seems entirely possible that the compositional variations have a definite spatial relationship to the roof rocks, but this would be difficult to prove where only fragments of the roof remain. It is a simple matter to measure the shortest horizontal distance from a granitic outcrop to the nearest body of older sediments or volcanics, but it is impossible to determine what was the distance to the nearest part of the now-eroded roof.

Numerous specimens of the main batholithic mass were examined under the microscope, and twenty-four specimens, selected to represent the more common variations of granitic rocks encountered in this map-unit, were subjected to micrometric analysis in order to obtain a close approximation to the modal composition of the main batholithic mass (*see* Fig. 3).

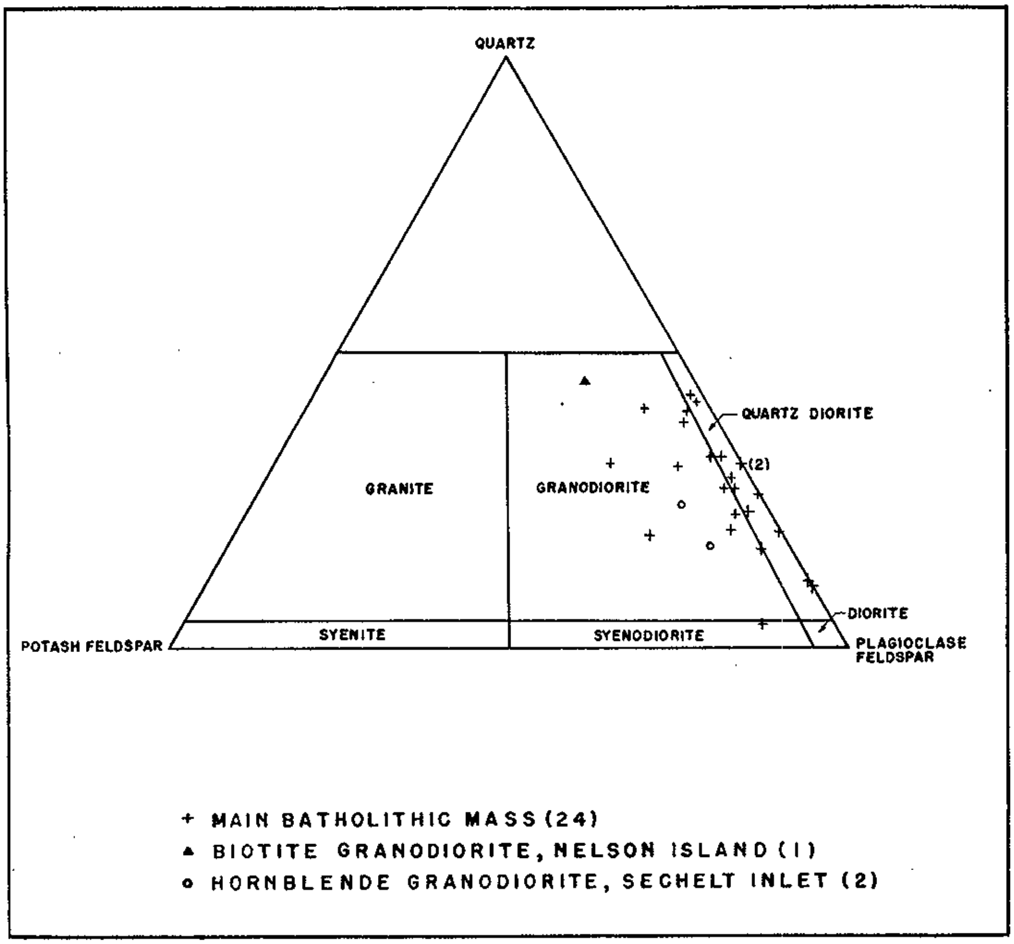

Figure 3. Modes of granitic rocks.

All the specimens examined are composed essentially of plagioclase, quartz, biotite, and hornblende; they differ mainly in the relative amounts of these principal constituents and will not be considered individually. Three features are conspicuous in the specimens examined:—

(1) Evidence of deformation subsequent to emplacement. This is shown either by fracturing in the quartz, curvature in the albite twin lamellæ of the plagioclase, bending of the biotite flakes, or, in a few specimens, by all of these features.

(2) A paucity of potash feldspar. The average content in the twenty-four specimens is 4.3 per cent. Six specimens show a complete absence of potash feldspar, thirteen contain orthoclase exclusively, and five contain microcline exclusively. The highest percentage of orthoclase noted is 8 per cent, and two specimens each contain 18 per cent microcline.

(3) Complex zoning of the plagioclase.

The average modal composition of the twenty-four specimens is as follows:

	Per Cent
Plagioclase	57.0
Quartz	23.0
Potash feldspar	4.3
Ferromagnesians (and secondary minerals derived therefrom)	15.0

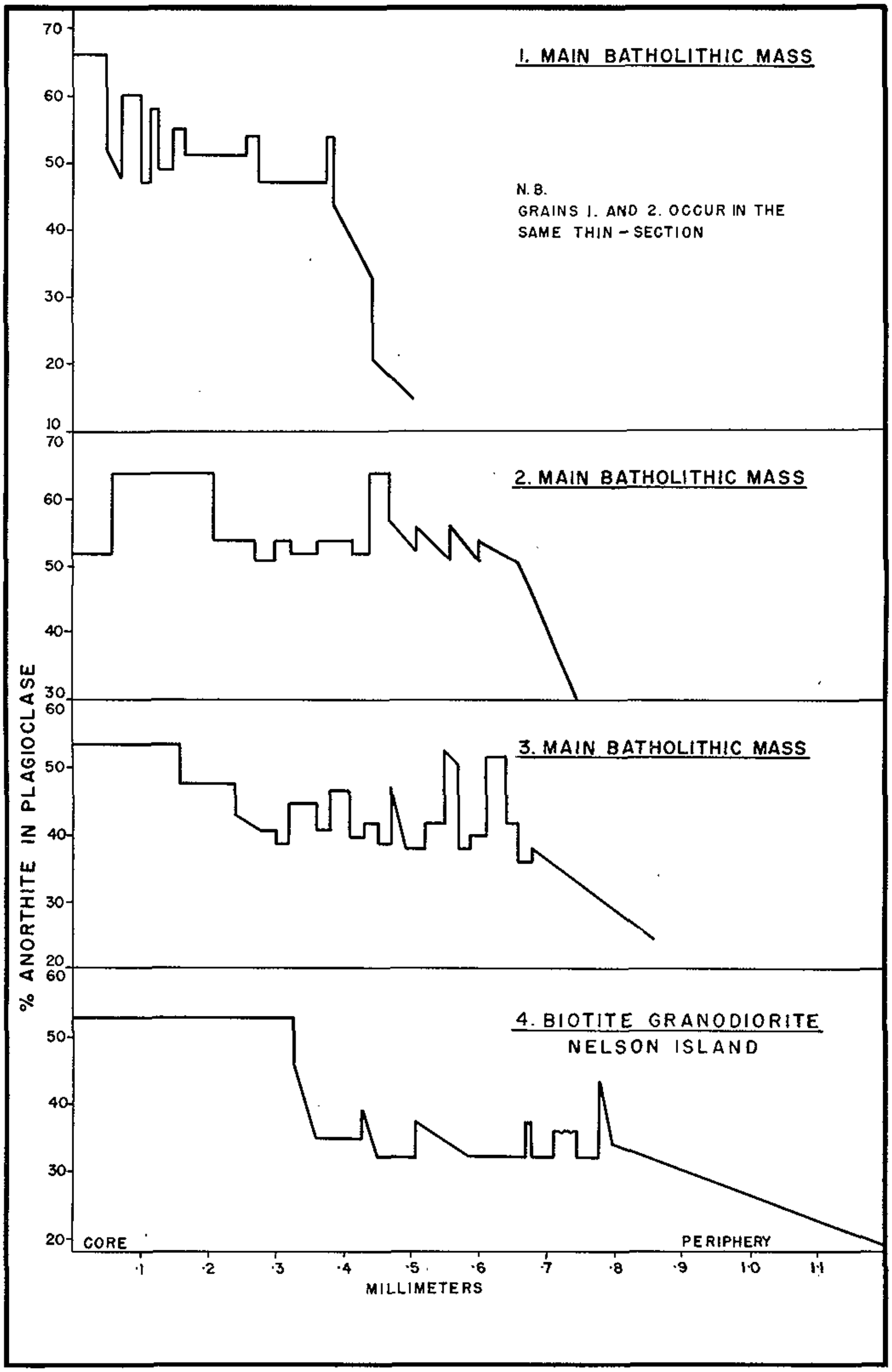

Figure 4. Zoning in plagioclase of granitic rocks.

This " average " rock, according to Johannsen (1931, p. 143), is a granodiorite that is barely outside the quartz diorite field.

Plagioclase, the most abundant constituent of these granitic rocks, is also the best formed, occurring as euhedral to subhedral crystals. Some of the plagioclase is essentially unaltered, but many crystals exhibit incipient saussuritization, especially of the cores, or a light development of white mica. Certain of the more foliated specimens exhibit a distinct orientation of the plagioclase crystals. Zoning is common in this mineral and it is invariably of the oscillatory type. In some specimens, only three or four broad zones are present, but in others six to eight zones are common. In one specimen, several grains with more than thirty zones and one grain with more than fifty zones were observed. Altered cores, corroded and embayed, are a feature of a number of the grains of zoned plagioclase and indicate that the crystallization of this mineral was not everywhere a continuous process.

The compositions of the zones in three individual grains of plagioclase were determined optically by Dr. W. W. Moorhouse, and the results plotted in graphical form (*see* Fig. 4, Nos. 1, 2, 3). These show conclusively that zones of labradorite composition are present. It is noteworthy that, even in two grains (*see* Fig. 4, Nos. 1, 2) in the same thin section, the zoning can be compared only in a general way. All three grains, however, are characterized by a zone of singularly calcic material adjacent to the sodic periphery.

The normative composition of the plagioclase calculated from eight chemical analyses of specimens from the main batholithic mass is An_{44}.

Quartz occurs as anhedral grains interstitial to the plagioclase. The grains of this mineral record all stages of deformation from slight to fairly intense. Unstrained quartz is rare. In a few instances, actual granulation has occurred and the broken grains have been recemented by fine quartz. Liquid inclusions are numerous in the larger quartz grains. Many are restricted to the centres of grains and, being unrelated to fractures, are considered primary. The fact that the primary inclusions are confined to the centres of quartz grains strongly suggests that these grains have been recrystallized at their borders with consequent loss of included material.

Potash feldspar is everywhere anhedral, occurring in small patches around the rims of the plagioclase or, where it is unusually abundant, enclosing the grains of plagioclase. In a few of the specimens a perthitic development was noted in the orthoclase; close examination reveals that both exsolution and replacement types are present. Where microcline is present, it is invariably perthitic, containing thread-like veinlets and small irregular blebs of sodic plagioclase. Several thin sections exhibit good examples of myrmekitic intergrowths (Plate VIII (A)) that appear to replace both the potash and plagioclase feldspar.

Brown biotite and green hornblende are the primary ferromagnesian minerals. These minerals vary greatly in size, degree of crystal outline, and extent of alteration. Chlorite and epidote appear to have formed from the alteration of both primary minerals.

Epidote occurs in all the thin sections and, in a few, constitutes more than 5 per cent of the specimen. It occurs as an alteration of plagioclase, as an alteration of the ferromagnesian constituents, and in veinlets where it has been clearly introduced subsequent to the consolidation of the rock.

Stringers of epidote are a prominent feature in the field, for they are more resistant to erosion than the surrounding granitic rock. They have developed along fractures and, particularly on the Sechelt Peninsula, pink feldspar is commonly associated with the epidote. An examination of the feldspar under the microscope shows that the colour is caused by a fine dust-like alteration of alkali feldspar. The exact nature of this reddish-brown dust is unknown. The fine particles may be of some clay mineral, but the colour suggests that hematite may also be present.

The accessory minerals of the granitic rocks, sphene, magnetite, and apatite, occur interstitially. Sphene is relatively abundant in a number of specimens as euhedral to subhedral crystals, a few of which are twinned (Plate VII (B)). Magnetite and apatite occur in the larger crystals of sphene. In places this mineral contains abundant liquid inclusions. There is some evidence that the sphene formed at a late stage in the crystallization sequence, for it appears to replace the plagioclase in a few of the specimens. A few grains of pyrite and zircon were also noted, the zircon occurring as small grains in quartz and plagioclase.

The granitic rock on the eastern part of Captain Island is distinctive. It is foliated and is characterized by schlieren that strike northwestward and dip northeastward at angles of 35 to 50 degrees. Under the microscope, the cataclastic texture of this rock is obvious. Moreover, quartz rather than plagioclase is seen to be the most abundant constituent. A micrometric analysis of one specimen gave the following results:—

	Per Cent
Quartz	49
Plagioclase	28
Microcline	20
Biotite	3

The microcline occurs as large anhedral grains set in a matrix of fine quartz. It is perthitic, exhibiting both exsolution and replacement types. Unusually well-developed myrmekitic intergrowths replace the microcline (Plate VII (A)). The plagioclase is slightly altered to saussurite and white mica. The biotite occurs as streaks of fine flakes and is, here and there, partly altered to chlorite. Magnetite and apatite occur mainly with the biotite.

Variations in the main batholithic mass are not limited to the mineral assemblage. The rocks exhibit considerable differences in size of grain and extent of foliation. Within a few hundred feet of certain contacts with the stratified rocks and locally elsewhere, the granitic rocks exhibit an obvious foliation which is clearly a secondary feature, resulting from deformation subsequent to emplacement. In general, however, the granitic rocks are characterized by a more subtle foliation that is marked by the preferred orientation of the ferromagnesian constituents and, in places, is further accentuated by the presence of oriented inclusions. This less obvious foliation is considered to be a primary feature resulting from movements in partly crystalline magma. The planes of foliation vary appreciably in strike, but the average strike, from hundreds of readings, is northwestward. They are almost invariably steeply dipping.

The average amount of included material in the main batholithic mass is probably less than 3 per cent of the total area exposed at the surface. Inclusions are generally more abundant in the vicinity of contacts with stratified rock but exceptions are common. Several large granitic outcrops immediately to the east of Klein Lake are actually composed of 50 per cent included material.

The inclusions vary in size, shape, character, extent of alteration, and degree of orientation. In size they range from 1 inch to many tens of feet. Some are angular, others are rounded, and still others occur as rude disks. Some found near contacts with the invaded rocks are not sufficiently altered to obscure their identities and are obviously xenoliths. Others are very much altered and occur as "ghosts." In places it is possible to note all stages of conversion from unaltered rock to a rock essentially of the same composition as the enclosing granitic material (Plate V (B)).

The most abundant type of inclusion is the round to disk-shaped, dark-grey to blackish clot (Plate VI (A)). Outcrops of the main batholithic mass completely devoid of these clots are rather uncommon. The form of these clots is well known, for in places weathering has left them attached precariously to the surface of the outcrop. They are fairly uniform in size, generally less than 18 inches in maximum dimension. The flattened or irregular disk variety is invariably oriented parallel to the planes of foliation in the surrounding rock.

Two clots were examined under the microscope. One specimen was selected from a granitic rock in which biotite is present almost to the exclusion of hornblende; the other from an outcrop in which hornblende is the dominant ferromagnesian constituent. Both thin sections were made sufficiently large to permit examination of clot and surrounding rock and show an identical mineral assemblage in clot and surrounding granitic rock. The sharpness of contact is due partly to the coarser grain of the surrounding material but mainly to the higher proportion of ferromagnesian minerals in the clots.

Similar clots are common in other granitic terrains of the Cordillera, and the problem of their origin has not been solved. Before proposing a theory of xenolithic origin, it would be necessary to prove that some feature in the mineralogy of the clots is clearly anomalous to the surrounding matrix.

Biotite Granodiorite

(7, Fig. 2)

A small body of medium-grained granodiorite outcrops on the south coast of Nelson Island, in the southwestern corner of the map-area. It differs megascopically from the main batholithic mass in the following ways:—

(1) Weathers white to delicate pink in colour in contrast to the grey shades of the main batholithic mass.
(2) Possesses a simple system of joints in contrast to the complex joint pattern and irregular sheeting of the larger mass.
(3) Exhibits almost no foliation.
(4) Contains none of the dark oriented clots that characterize the larger mass.
(5) Contains no mafic dykes and almost no aplitic material.
(6) Contains biotite almost to the exclusion of hornblende.

These features add up to a uniformity that is lacking in the main batholithic mass. In fact, this small body of granodiorite is sufficiently homogeneous that it has been quarried from time to time and the product used as building-stone.

Several specimens of this rock were examined under the microscope. One micrometric analysis was made with the following results:—

	Per Cent
Quartz	40
Plagioclase	35
Orthoclase	14
Biotite	11

This analysis is plotted on the Johannsen diagram (Fig. 3).

The texture of the rock is medium-grained, hypidiomorphic. The plagioclase occurs as euhedral to subhedral crystals and is markedly zoned (Plate VIII (B)). The zoning, which is oscillatory in the specimens examined, is at least as complex as any observed in specimens from the main batholithic mass. The normative composition of the plagioclase in one specimen chemically analysed is An_{26}.

The nature of the zoning in the grain depicted in Plate VIII (B) was studied optically by Dr. W. W. Moorhouse and the results obtained were plotted in graphical form (Fig. 4, No. 4). This grain is more sodic than those examined in specimens from the main batholithic mass, but the form of the graph is similar; apart from the core, which is labradorite, the most basic plagioclase occurs adjacent to the periphery.

The cores of the plagioclase are lightly saussuritized or altered to white mica. Several of the more elongate crystals are noticeably bent through angles up to 10 degrees.

The quartz occurs in large anhedral grains, many of which show strain shadows. Some quartz grains are fractured and have been recemented with fine quartz. The quartz contains abundant liquid inclusions, both primary and secondary.

Large anhedral grains of orthoclase surround smaller plagioclase crystals. The orthoclase is perthitic, containing thread-like veinlets of albite. The plagioclase appears to be replaced by the orthoclase, which is in turn replaced by myrmekitic intergrowths.

Biotite occurs as corroded flakes of brown to yellowish-brown colour. In places it is lightly altered to chlorite. Much of the biotite is bent through small angles. Accessory minerals are apatite, magnetite, and sphene.

This granodiorite is remarkably uniform and contains no dark oriented clots. It does, however, contain a few small, randomly distributed, dark knots. Some of these are irregular in outline but most are rounded. They are generally less than 2 inches in diameter and weather less well than the surrounding granitic rock.

One of the dark knots was extracted, and a thin section examined under the microscope showed precisely the same relationships as were found between the larger oriented clots and the surrounding batholithic material. In other words, the knot differs only from the enclosing granitic matrix in that it is texturally finer-grained and contains a higher percentage of the sole ferromagnesian constituent, biotite. In view of this, it would seem that the origin of the dark clot of the main batholithic mass and that of the dark knot of the Nelson Island biotite granodiorite require similar explanations. The lack of orientation of the knots is to be expected, for the absence of foliation in the smaller mass indicates that mevements in the magma, from which the biotite granodiorite formed, had ceased prior to its consolidation.

The petrography gives definite evidence that the biotite granodiorite has sustained some deformation subsequent to consolidation, but the simple joint pattern in this rock strongly suggests that it has participated in only a small portion of the long and varied history of the Coast intrusions. The jointing consists essentially of three widely spaced sets that intersect at angles near 90 degrees. It has resulted in the formation of large, roughly rectangular blocks that, in places, measure tens of feet along the shortest edge (Plate VI (B)). One set of joints may be termed flat-lying; when examined in detail, however, dips as much as 25 degrees are frequently found. The other two sets vary somewhat in strike but have a general northwesterly and northeasterly trend. They invariably dip steeply and in many places are vertical.

The simplest explanation of this joint system is that it formed as a direct result of the cooling and consequent shrinkage of the rock. Subsequent deformation has not been sufficient to impose more than a few weak irregular fractures on the mass.

Hornblende Granodiorite

(8, Fig. 2)

An elongate northwesterly trending body of granodiorite that intrudes the main batholithic mass outcrops in the southeastern corner of the map-area. Its northernmost extent is on the small islands in the Skookumchuck Narrows of Sechelt Inlet. Where examined immediately to the southeast of the map-area, it is more than 2 miles wide.

No counterpart of this distinctive rock type has been found elsewhere in the area. It weathers a more definite pink than the Nelson Island biotite granodiorite and is the coarsest-grained granitic rock of the map-area. It differs further from the Nelson Island body in that biotite is present in minor amounts, mainly as an alteration product of hornblende.

This body, at least in the map-area, exhibits a rather uniform texture and composition. It contains none of the dark clots of the main batholithic mass nor any of the small round knots of the Nelson Island body. It exhibits little or no foliation, primary or secondary, and does not appear to have been deformed. Joints are not common and, where they do occur, are widely spaced.

Two micrometric analyses were made on specimens of this rock type. It is unlikely that these analyses are as reliable as those made on the relatively finer-grained granitic rocks, but it is believed that they represent a fairly close approximation to the modal composition of this granodiorite.

	Per Cent	Per Cent
Plagioclase	60	68
Quartz	23	17
Microcline	12	11
Ferromagnesians	5	4

These analyses have been plotted on the Johannsen diagram (Fig. 3).

Several specimens were examined under the microscope. Plagioclase occurs as euhedral to subhedral crystals. In places it exhibits a vague zoning, but this feature is not nearly so marked as in specimens from the main batholithic mass or from the Nelson Island biotite granodiorite. The cores of the plagioclase are lightly altered to white mica and a fine dust-like substance which is responsible for the pink colour seen in the hand specimen. It was impossible to determine the nature of this alteration under 800-power magnification; it may be a clay mineral or finely divided hematite.

The composition of the plagioclase, determined optically, is in the oligoclase range. The normative composition from the one specimen chemically analysed is An_{24}.

The borders of the plagioclase are corroded by microcline, which is essentially unaltered. It is perthitic, exhibiting both exsolution and replacement types. Microcline replaces the plagioclase, and both types of feldspar are replaced by myrmekitic intergrowths. These intergrowths, however, are not so abundantly developed as in many specimens from the main batholithic mass.

The quartz is anhedral in outline and lightly fractured. It occurs both as large grains and as small ones interstitial to the plagioclase. It contains many small bubble-like inclusions, the greater proportion of which are secondary and related to incipient fractures.

The hornblende has been largely altered to chlorite, minor biotite, and varying amounts of epidote. Accessory minerals consist of apatite, magnetite, and sphene. In places they occur in close spatial relationship to the secondary ferromagnesian minerals.

Chemical Composition

In addition to the modal analyses mentioned above, twelve chemical analyses were made of specimens chosen to represent the various components of the Coast intrusions. The following selection was made:—

(1) Two specimens of quartz-feldspar porphyry.
(2) Eight specimens from the main batholithic mass. These specimens were chosen at more or less regular intervals and represent a west-east cross-section of the main batholithic mass in the map-area.
(3) One specimen of the biotite granodiorite, Nelson Island.
(4) One specimen of the hornblende granodiorite, Sechelt Inlet.

The analyses of the quartz-feldspar porphyry are included above in the description of this rock type. Detailed results of the other analyses are given in Table I, page .

Two variation diagrams (Fig. 5 and Fig. 6) were constructed, using the results of these analyses. In Figure 5, oxides have been plotted against silica contents; Figure 6 is the type of diagram used by Larsen (1948, p. 142) for the plutonic rocks of the batholith of Southern California. In both diagrams it is possible to pass reasonably smooth curves or, as with CaO, a straight line through or close to points representing percentages of the constituent oxides. The general form of the curves in Figure 6 is similar to that for the plutonic rocks of Southern California, although a wider range of composition is involved there.

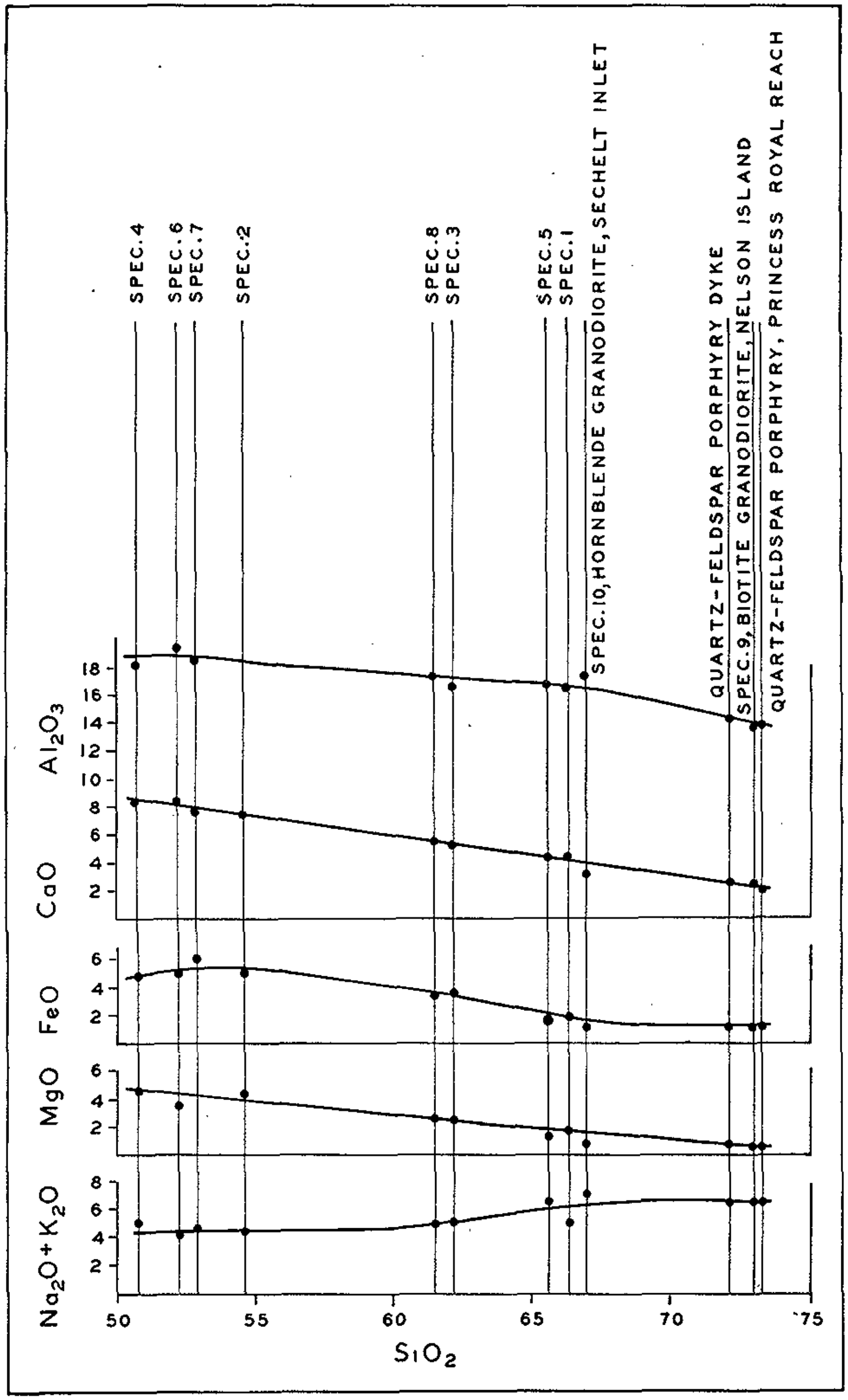

Figure 5. Variation diagram for granitic rocks.

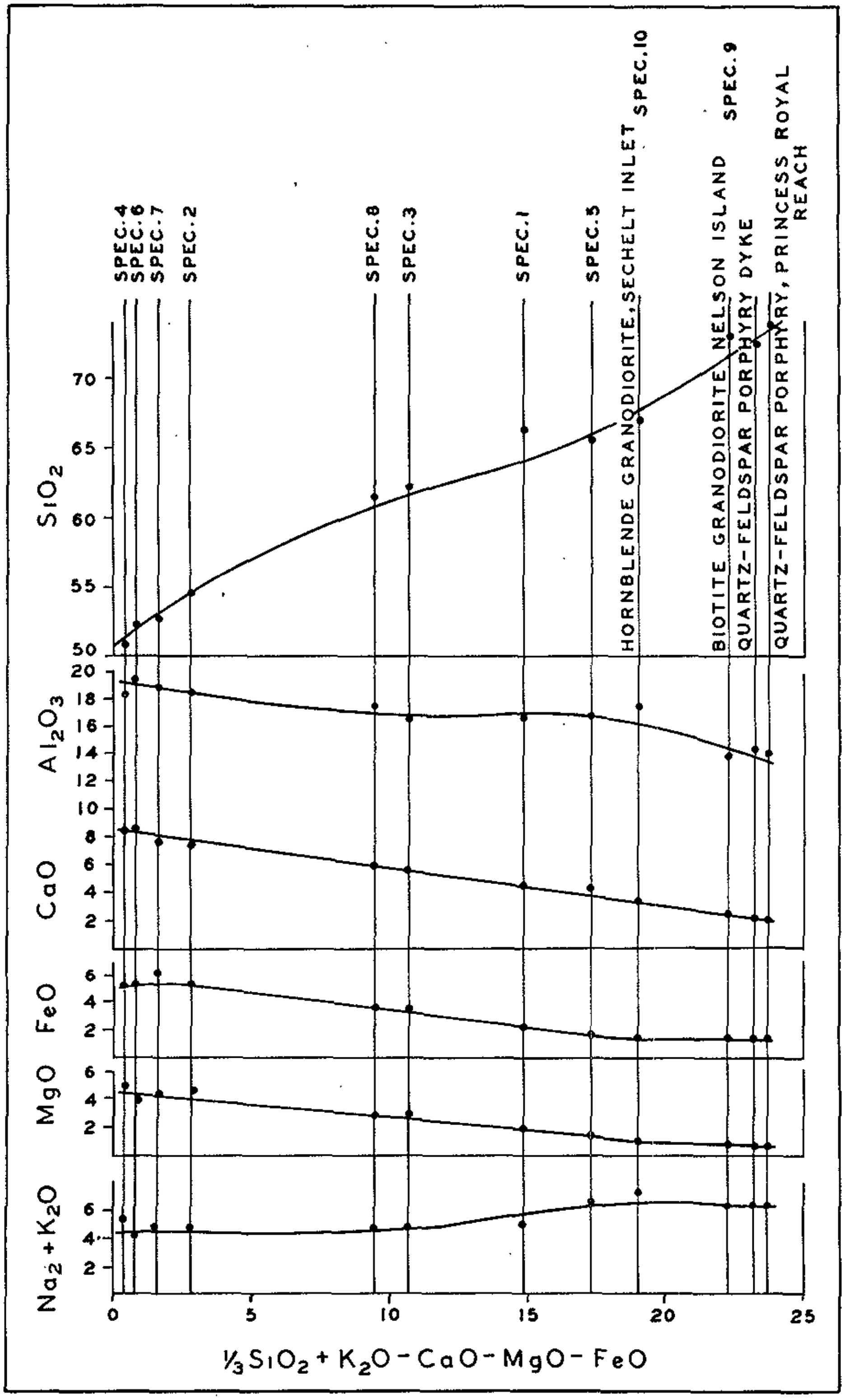

Figure 6. Variation diagram for granitic rocks.

Table I.—Analyses of Various Coast Intrusions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SiO_2	66.34	54.60	62.20	50.76	65.60	52.28	52.88	61.52	73.00	66.94
TiO_2	0.30	0.60	0.52	0.46	0.10	0.82	0.44	0.26	0.18	0.34
Al_2O_3	16.79	18.14	16.62	18.13	16.92	19.24	18.80	17.40	13.84	17.54
B_2O_3	......	0.30	......	......	......	......	......	......	......	......
Fe_2O_3	2.14	2.30	2.31	4.44	2.02	4.00	3.22	2.26	1.04	1.70
FeO	2.00	5.09	3.55	4.96	1.66	5.11	6.13	3.60	1.28	1.20
MnO	0.13	0.16	0.12	0.13	0.08	0.19	0.22	0.12	0.06	0.08
MgO	1.91	4.44	2.70	4.80	1.32	3.73	4.02	2.78	0.91	0.92
CaO	4.66	7.54	5.48	8.44	4.16	8.52	7.72	5.82	2.40	3.04
Na_2O	3.69	2.98	3.54	3.52	4.38	3.64	2.98	3.67	4.02	5.48
K_2O	1.31	1.64	1.55	1.67	2.56	0.62	1.76	1.12	2.51	1.83
P_2O_5	0.13	0.14	0.14	0.25	0.16	0.29	0.20	0.16	0.08	0.10
H_2O+	0.66	1.72	1.22	2.10	0.50	1.28	1.28	1.24	0.60	0.80
H_2O-	0.12	0.19	0.19	0.23	0.11	0.11	0.17	0.15	0.08	0.17
CO_2	......	0.08	0.05	0.22	0.22	0.06	0.18	0.04	0.07	0.07
S	......	......	......	0.07	......	0.15	......	......	......	0.13
BaO	0.09	0.11	0.11	0.06	0.13	0.09	0.03	0.10	0.12	0.12
Totals	100.27	100.03	100.30	100.24	99.92	100.13	100.03	100.24	100.19	100.46

NORMS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Quartz	26.22	6.78	19.08	......	19.56	4.62	3.42	17.70	32.82	20.22
Corundum	......	......	......	......	......	......	......	......	......	1.02
Orthoclase	7.78	9.45	8.90	10.01	15.57	3.34	10.56	6.67	15.01	10.56
Albite	31.44	25.15	29.87	29.34	36.68	30.92	25.15	30.92	34.06	46.63
Anorthite	22.52	31.14	25.02	28.63	18.90	34.19	32.53	27.80	11.95	15.01
Diopside	0.89	5.29	1.83	10.75	......	6.52	4.80	0.89	......	......
Hypersthene	5.82	14.95	9.76	9.74	4.62	10.90	16.22	10.56	3.49	2.30
Olivine	......	......	......	1.44	......	......	......	......	......	......
Magnetite	3.02	3.25	3.25	6.50	3.02	5.80	4.64	3.25	1.62	2.55
Ilmenite	0.61	1.22	0.91	0.61	......	1.52	0.46	0.76	0.30	0.61
Calcite	......	......	......	0.60	0.60	......	......	......	......	......
Pyrite	......	......	......	......	......	......	......	......	......	0.24
Totals	98.30	97.23	98.62	97.62	98.95	97.81	97.78	98.55	99.25	99.14

Locations of Specimens

(1) West shore of Vanguard Bay, Nelson Island.
(2) North shore, Nelson Island.
(3) North shore, Nelson Island.
(4) Northeast corner, Nelson Island.
(5) Northern tip, Sechelt Peninsula.
(6) Eastern shore, Prince of Wales Reach, east of Egmont Point.
(7) Eastern shore, Prince of Wales Reach, east of Egmont Point.
(8) Eastern shore, Prince of Wales Reach, one-quarter mile south of southern contact of sediments exposed south of Treat Creek.
(9) Biotite granodiorite, south shore, Nelson Island.
(10) Hornblende granodiorite, east shore, Sechelt Inlet.
N.B.—Specimens 1 to 8 represent west-east cross-section of main batholithic mass in map-area.

To emphasize the nature of the granitic rock represented by the eight analyses of the main batholithic mass, the following calculations were made:—

(1) An arithmetical average of the eight analyses from the main batholithic mass was converted into normative amounts.
(2) The average chemical composition of 102 rhyolites (Daly, 1933, p. 9) was converted into normative amounts.

These two norms are set forth below, together with Daly's (1933, p. 448) average norm for eighty-seven andesites.

	Main Batholitic Mass	87 Andesites	102 Rhyolites
Quartz	14.70	14.70	34.28
Corundum	----	------	2.55
Orthoclase	10.01	12.23	27.14
Albite	31.96	30.92	28.30
Anorthite	25.30	25.30	0.83
Diopside	2.94	1.76	------
Hypersthene	9.04	8.15	1.16
Magnetite	3.71	4.87	2.09
Ilmenite	0.76	1.52	0.61
Apatite	------	0.62	0.34
Totals	98.42	100.07	97.30

These norms show clearly that, whereas there is no basis whatsoever for comparison between the normative composition of Daly's rhyolites and the main batholithic mass, *a remarkable similarity is evident between the main batholithic mass and* Daly's average andesite.

Emplacement

It is believed that the main batholithic mass was emplaced by passive intrusion, for this method of emplacement appears best in accord with the field evidence. Xenolithic material indicates stoping may have played a minor role, but metasomatism is rejected as having a major part in the emplacement of the Coast intrusions.

The plutonic rocks of Jervis Inlet have little in common with the gneissic granites of shield areas that offer the strongest tangible evidence supporting the theory of a metasomatic origin for some granitic rocks. In shield areas it is common to find gneissic granites grading almost imperceptibly into sedimentary rocks, along strike and across strike. In Jervis Inlet the contacts between granitic rocks and sediments are, in some places, marked by more than the average number of inclusions, but they can hardly be *termed gradational. On the contrary, they are sharp and, apart from minor contact* metamorphism, there is nothing to suggest that either the sediments or the granitic rocks have been particularly affected by the emplacement of the latter.

The intricate zoning exhibited by the plagioclase crystals of the granitic rocks is considered to support a magmatic origin for these rocks. Similarly zoned crystals are a common feature in dacites, rocks of known magmatic origin that have the same composition as much of the main batholithic mass; they are an uncommon feature in normal metamorphic rocks (Turner and Verhoogen, 1951, p. 289).

The inclusions in the main batholithic mass exhibit all stages of conversion to granitic rock. Furthermore, the plagioclase feldspars of the inclusions are identical with those of the surrounding plutonic rock. This is indeed an example of metasomatism on a small scale, but it in no way militates against a theory of magmatic origin for the vast bulk of the granitic rocks. Bowen (1928, pp. 175–223) has discussed at length the behaviour of inclusions in granitic magma and has shown that chemical reaction between the two entities is inevitable.

The norms of the main batholithic mass emphasize the fallacy in an argument that has been used by some who oppose the theory of a magmatic origin for granitic batholiths. This argument is summed up by Holmes who states (1949, p. 91): ". . . if granite magma rose from the depths in quantities corresponding to the enormous volumes of batholiths, it would be by far the most abundant of all magmas. In this case rhyolite should be the most abundant of all volcanic rocks. But it is not." With regard to the Coast intrusions, the answer to this argument is that the known granitic rocks approximate andesite, not rhyolite, in composition, and that andesite occurs in abundance in the circum-Pacific belt.

In considering the probable mode of emplacement of the granitic rocks, three facts are important:—

(1) The invaded rocks have not been appreciably disturbed by the emplacement of the granitic rocks.

(2) In large measure the contacts of the main batholithic mass are parallel to the strata of the invaded rocks.

(3) Granitic sills and dykes are uncommon in the invaded rocks.

These three facts would seem to rule out any theories of emplacement involving forceful intrusion of the main batholithic mass. They further suggest that, throughout much of its existence, the magma played a passive role, moving only in response to external forces. With the initiation of compressive stresses resulting in folding of the roof rocks, pressure would increase beneath the synclines and decrease beneath the anticlines, providing the section as a whole behaved competently. Whether these stresses were solely responsible for the formation of magma in depth is conjectural. Nothing is known concerning the physical nature of the magma in the early stages of intrusion, but it seems reasonable to assume that its fluidity was high. In other words, it would behave essentially as a liquid and would move upward to the anticlinal parts of the fold pattern in response to hydrostatic pressure. A further force, perhaps the main one, would be provided by the difference in specific gravity of the magma and the surrounding consolidated rocks; that is, the volume of magma involved would seem to demand some isostatic adjustment. At this stage of intrusion the magma would perforce push aside the lowermost formations of the cover, but its role would nevertheless be largely passive. En route through regions of ever-decreasing temperature, the magma would continue to crystallize and its mobility would correspondingly decrease. With the freezing of the magma and final equalization of pressures, the upward movement would cease. Field and petrographic data give some evidence of the physical state of the magma during the final stages of emplacement. The variations in mineral assemblage, textures, and intensity of primary foliation indicate that the magma was by no means homogeneous. While large parts were at least partially crystalline, as evidenced by the primary foliation, other parts were less so and some were still mainly fluid. The uniformity of rock and lack of foliation in relatively small areas, such as the south coast of Nelson Island, would seem to indicate that in some places the magma reached its final destination essentially as a liquid.

DYKES

Dykes of younger age than the Coast intrusions are numerous in the map-area. Although they have not been studied in detail, they may be classified generally as follows, in order of decreasing age:—

(1) Greenstone dykes, invariably altered and generally porphyritic.

(2) Aplite dykes.

(3) Basaltic dykes.

The greenstone dykes occur in several shades of green and in texture ranging from very fine to medium grained. In two specimens examined under the microscope, andesine is the principal mineral. It occurs as sparse phenocrysts and abundant small laths. The phenocrysts are highly altered to calcite, epidote, zoisite, and chlorite. The small laths, some of which are markedly bent, are less altered. Other than andesine, the only primary minerals present are quartz and magnetite, both of which occur in minor amount. Interstitial to the plagioclase laths is a fine-grained aggregate in which chlorite, leucoxene, and minor epidote can be recognized.

Narrow pink aplite dykes are common in the granitic rocks and are abundant in the vicinity of Pender Harbour. They are composed of quartz, microcline perthite, and varying amounts of sodic plagioclase, some of which exhibits a vague zoning. In two specimens, a few of the plagioclase laths are bent, indicating that some deformation has occurred subsequent to the intrusion of the dykes. Very minor amounts of biotite or hornblende may be present.

Dense fine-grained, dark-greenish to blackish basaltic dykes cut aplite dykes in the Pender Harbour area and similar dykes occur in great swarms intruding the quartz-feldspar porphyry of Princess Royal Reach (Plate V (A)). In the latter locality, the dykes have been intruded parallel to the planes of shearing in the porphyry. The dykes are narrow, varying in width from a few inches to a few feet and may be composite.

Three specimens of these dykes were examined under the microscope. They are composed of plagioclase, green hornblende, brown biotite, and quartz. The plagioclase is andesine, but cores of labradorite were observed in a few of the grains. Small grains of magnetite and pyrite occur sparingly in these dykes.

CHAPTER III.—STRUCTURAL GEOLOGY

JERVIS GROUP

In the northern part of the map-area, the rocks of the Jervis Group occur over a vertical range of more than 1 mile in narrow, parallel northwesterly trending belts that dip steeply eastward between walls of granitic rock. Some belts persist for many miles along strike. The one that controlled the direction of Prince of Wales Reach has a length of 17 miles in the map-area and continues for an unknown distance to the southeast beyond the head of Treat Creek. The discontinuous belt extending northwestward from Dacres Point through Diadem Mountain is more than 15 miles long; it extends for at least several miles to the northwest of the map-area.

These particular belts, called " inclusions " by Blanchard (1922, p. 68), are analogous to the " screens " (Larsen, 1948) of the batholith of Southern California and the " septa " (Mayo, 1941) of the Sierra Nevada. Phemister (1945, p. 44) used the term " great xenoliths " to describe the isolated masses of invaded rock in the granitic rocks of the Coast Mountains, and others have applied the phrase " roof pendants " to all such bodies, regardless of their form or mode of origin. The conformation, with local deviations, of the attitudes of individual beds and of cleavage, and the trend of belts to a regional pattern, is strong evidence that these belts represent parts of the original roof cover of the batholith that have been separated by erosion from other parts, rather than being forcibly detached during the emplacement of the granitic rocks. The terms " xenolith " and " inclusion " are therefore inappropriate as applied to such belts. Furthermore, the term " roof pendants " defined by Daly (1933, p. 122) as " salients of country rock, with the shapes of inverted pyramids or downwardly directed wedges " is not applicable or descriptive of these belts. In describing the masses of non-granitic rock in the Coast Mountains, Gunning (1950, p. 90) states: " . . . it is very doubtful if some of them should be called pendants at all. They are more like steep-dipping leaves between batholithic walls. . . . Pendants of this type offer about the closest analogy I can think of in B.C. to the ' troughs ' of Archaean lavas and sediments . . . of the Canadian Shield."

If the belts are not remnants of the roof detached during emplacement of the granitic rocks, it is difficult to imagine them as anything other than the most deeply downfolded parts of the invaded roof. In other words, they are predominantly synclinal elements. In the course of the present reconnaissance investigation, it was not possible to outline discrete isoclinal folds in the belts of layered rock, but there is the possibility that, in some instances, these masses represent only limbs or remnants of isoclinal folds. In working along the western flank of the Coast Mountains in southeastern Alaska, Buddington (1929, pp. 289–316) found that the dominant structural characteristic of that region is the isoclinal folding. In general, however, the axes or axial planes of the folds escape detection, and uniform dips occur through wide intervals.

The analogy of the belts to the " septa " in the Sierra Nevada is apparent. Regarding them, Mayo (1941, p. 1079) states that " the metamorphic rocks are remnants of septa that divided the intrusions to unknown depths. During the earliest recorded deformation, the original bedding and other layered structures were thrown into a series of closely appressed, nearly vertical-sided, isoclinal folds. Cleavage developed approximately parallel to the axial planes of the folds and was followed by many small shears and occasional upthrusts." This description is equally applicable to the belts of older rock in the northern part of the lower Jervis Inlet area.

Compared to the masses of roof rock occurring in the northern part of the map-area, those of the Sechelt Peninsula are relatively small. The patchy, irregular outlines of the Sakinaw Lake and Ruby Lake bodies suggest that these remnants persist to no great depth.

Little can be said concerning the internal structure of the poorly exposed Caren Range body. Its highly irregular outline suggests that it occurs as a shallow island cupped in granitic rock. The pyrometasomatic mineralization encountered in the sedimentary rocks of this body does much to substantiate this concept of its form. Of all the masses of invaded rock in the map-area, the Caren Range body seems best suited to the term " roof pendant."

FAULTING

The mylonitization of the Princess Royal Reach quartz-feldspar porphyry, particularly near its eastern margin, was produced in a major fault zone that strikes northwestward and dips steeply eastward .

Transverse faults with minor horizontal dislocation were observed at a number of places in the sedimentary rocks of the northern part of the map-area.

CHAPTER IV.—MINERAL DEPOSITS

During World War I some exploratory work for mineral deposits was done in the northern part of the map-area. Doubtless prospectors were first attracted by the reddish appearance of some of the higher mountains bordering Prince of Wales Reach. By 1917 small crews were engaged in surface work and driving short adits on the more promising showings. In 1922 the status of exploration was summed up by Blanchard (1922, p. 69) in the following words: "Prospecting in the Jervis Inlet region of British Columbia has been less thorough than in most other parts of British Columbia as advantageously situated with respect to tidewater. Most of the work has been confined to scattered surface cuts, and to a few short tunnels. The small amount of prospecting is explained by: (1) the unusual steepness and ruggedness of the topography; (2) the high altitudes in which most of the favourable areas for mineralized showings occur (normally 2,500 to 6,000 feet); (3) the very thorough overburden of soil and vegetation; (4) the very brief working season for surface prospecting; at the higher altitudes it is only two to five months; (5) the lack of government or private trails. . . . Prospecting . . . will not be an easy matter; to reach some of the showings, difficult and dangerous ascents of a thousand feet or more up precipitous cliffs must be made."

With the exception of brief renewals of activity in the years 1927–29 and 1950, the northern part of the map-area has received little attention since the early 1920's.

Activity in the southern part of the map-area dates from 1934, when copper mineralization was discovered to the south of Mount Hallowell on the Caren Range. These showings subsequently became known as the Cambrian Chieftain property.

BASE-METAL DEPOSITS

Diadem Mountain Area

Base-metal mineralization has been discovered at a number of places to the north and west of Diadem Mountain. The locations of these showings are indicated by the numbers [1] to [3] on the accompanying geological map (Fig. 2).

[1] An adit has been driven at the western contact of the batholithic rock with greenstone. The adit penetrates greenstone for a distance of 65 feet on a bearing of south 18 degrees west. A 2-foot shear striking north 70 degrees west and dipping 65 degrees northward is intersected at a distance of 40 feet from the portal. This shear has been followed by a westward drift 25 feet long. Pods consisting of galena, sphalerite, pyrite, and minute amounts of chalcopyrite are exposed in the drift. Two channel samples across the mineralized material gave the following assays:—

Width	Gold	Silver	Copper	Lead	Zinc
	Oz. per Ton	Oz. per Ton	Per Cent	Per Cent	Per Cent
2 feet	*Nil*	3.2	(1)	4.9	2.9
2 „	0.01	3.6	(2)	1.8	5.0

1 Trace. 2 Less than 0.3 per cent.

[2] and [3] Zinc and lesser amounts of lead and copper occur locally in the argillaceous and sandy sedimentary rocks. At [2] an adit has been driven 30 feet in a direction north 3 degrees west along the east wall of a sparsely mineralized zone. Limonite occurs over a width of 15 feet on the outcrop, but the mineralization is essentially confined to the width of the adit. A grab sample from the dump assayed: Gold, 0.01 oz. per ton; silver, 1.8 oz. per ton; copper, less than 0.3 per cent; lead, 2.7 per cent; zinc, 18.6 per cent.

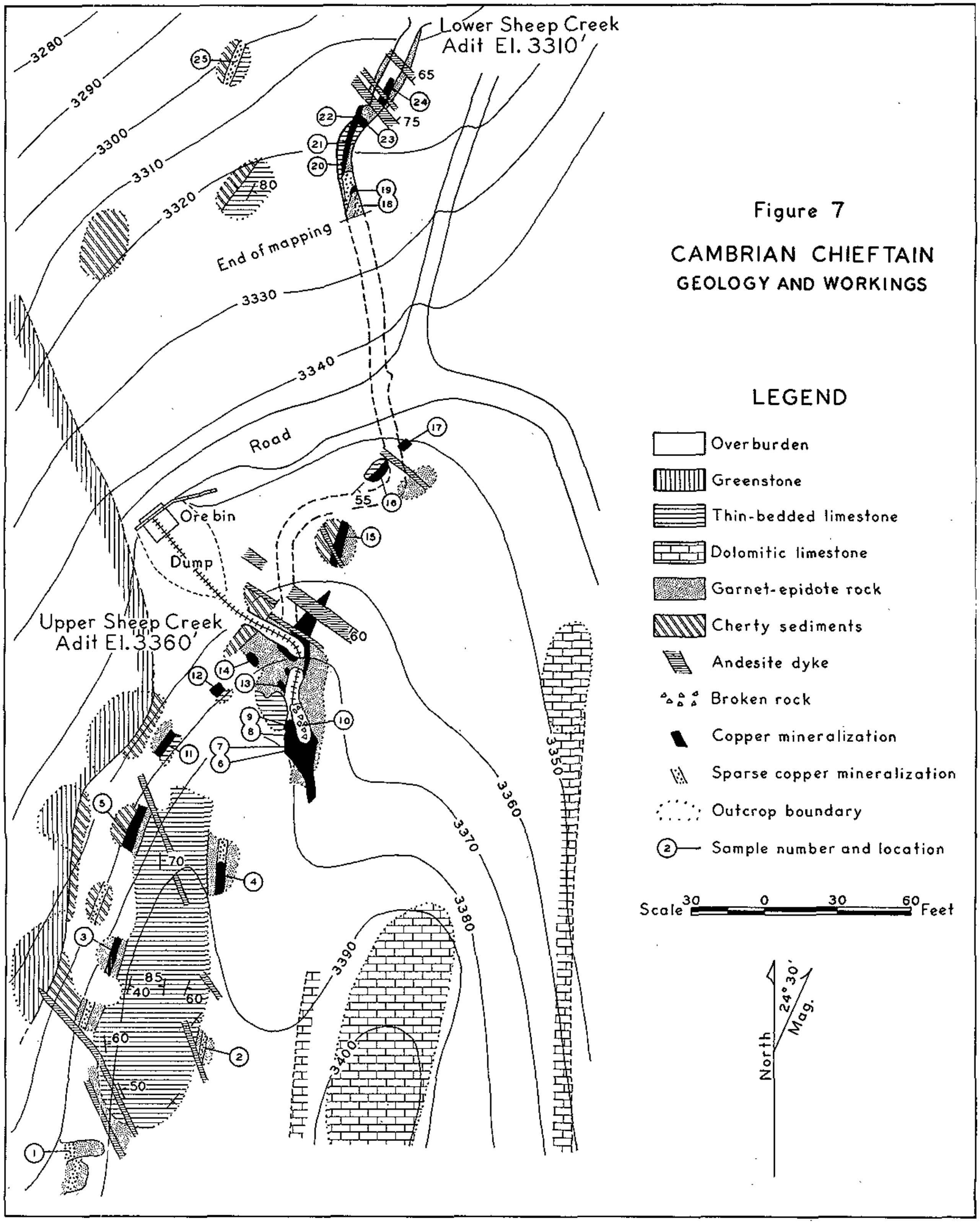

Figure 7

CAMBRIAN CHIEFTAIN
GEOLOGY AND WORKINGS

What is probably the same zone is exposed in a small open-cut 250 feet to the north and 200 feet above the adit. There mineralization occurring across a width of 2 feet assays: Gold, trace; silver, 5.5 oz. per ton; copper, 3.5 per cent; lead, less than 0.3 per cent; zinc, 6.9 per cent.

At [3] an adit has been driven 12 feet in a direction south 30 degrees west and exposes 2.5 feet of high-grade zinc mineralization and minor amounts of galena and chalcopyrite. A sample of this material gave the following assay: Gold, 0.01 oz. per ton; silver, 8.9 oz. per ton; copper, 2.0 per cent; lead, 0.6 per cent; zinc, 27.5 per cent. A large open-cut 200 feet south of this adit exposes a 19-foot width of mineralized material. In the eastern 14 feet of this zone the mineralization is pyritic with a few small patches of chalcopyrite. Galena is present in very minor amounts and sphalerite is only abundant for 4 or 5 inches at the western border of the zone. Continuity of this zone southward is obscured by overburden, but northward there is much rock exposed and very little indication of mineralization. The mineralized zone was sampled from east to west, with the following results:—

Width	Gold	Silver	Copper	Lead	Zinc
	Oz. per Ton	Oz. per Ton	Per Cent	Per Cent	Per Cent
5 feet	*Nil*	(1)	(1)	(1)	0.2
5 „	0.01	0.1	(2)	(1)	1.6
4 „	0.01	6.5	1.6	(2)	0.3
5 „	0.01	11.6	(2)	1.1	6.0

[1] Trace. [2] Less than 0.3 per cent.

[Reference: *Minister of Mines, B.C.,* Ann. Rept. 1950, pp. 172–177.]

Treat Creek Area

Some work was done years ago on a group of seven claims, known as the Copper group, on the steep northeastern slope of Treat Creek. The workings are reported to be in the general vicinity of [4] (Fig. 2). They were not found by the writer. Apparently a small amount of surface work was done on mineralized exposures consisting of magnetite, pyrrhotite, and chalcopyrite.

[Reference: *Minister of Mines, B.C.,* Ann. Rept. 1922, pp. 249–250.]

Sechelt Peninsula

Cambrian Chieftain [5]

This property is located near the top of the steep western slope of the Caren Range, at a general elevation of 3,200 feet. Much of the timber has been burned off and the bedrock is reasonably well exposed. Figure 7 shows the surface geology in the vicinity of the main showings. The rocks are greenstone, limestone, dolomitic limestone, and chert. They trend northward, dip steeply, and are intersected by numerous andesite dykes.

Parts of the thin-bedded limestone have been converted to rock rich in garnet and epidote. Subsequently fracturing has occurred, and chalcopyrite, pyrite, magnetite, and sphalerite have been deposited in the fractures. Small patches of calcite were observed in a few places.

Minerals of secondary origin are fairly common. A little malachite occurs on most of the mineralized outcrops, and films of chalcocite and covellite were observed along some of the stronger fractures in the Upper Sheep Creek adit.

Twenty-four channel samples were taken of the copper-bearing lenses, with the following results:—

Sample No.	Width	Gold	Silver	Copper
	Feet	Oz. per Ton	Oz. per Ton	Per Cent
1	3.0	(1)	0.3	0.5
2	1.0	*Nil*	*Nil*	(1)
3	1.0	*Nil*	*Nil*	(1)
4	3.0	0.01	6.1	5.4
5	3.3	(1)	5.4	2.4
6	5.0	0.02	4.7	13.6
7	3.4	0.01	2.5	6.9
8	5.0	(1)	1.3	4.0
9	5.0	*Nil*	1.8	5.0
10[2]	....	0.04	6.6	16.8
11	3.0	(1)	5.3	12.2
12	1.0	(1)	2.1	13.7
13	5.0	(1)	3.1	9.4
14	5.0	(1)	3.1	6.2
15	2.0	(1)	3.7	8.0
16	5.0	0.01	5.9	17.1
17	3.0	0.01	3.9	12.5
18	1.3	0.01	5.6	8.5
19	1.0	0.02	6.7	7.7
20	1.1	0.01	10.3	26.4
21	2.0	0.01	14.2	34.1
22	2.3	0.02	13.0	30.6
23	1.0	(1)	8.2	16.9
24	0.5	0.01	14.0	27.7
25	1.3	*Nil*	*Nil*	(3)

[1] Trace.
[2] Muck grab sample, Upper Sheep Creek adit.
[3] Greater than a trace but less than 0.3 per cent.

The Cambrian Chieftain has been examined and optioned by various companies. Diamond drilling beneath the surface showings has apparently failed to reveal encouraging quantities of copper ore. From 1949 to 1952 several shipments of near-surface ore, totalling 682 tons, were shipped to Tacoma. Gross contents: Gold, 15 oz.; silver, 2,592 oz.; copper, 97,604 lb.

In 1953 surface work was done on some exposures of zinc mineralization about one-third of a mile due south of the copper showings.

King Midas
[6]

Workings consisting of several old surface cuts in heavily wooded country lie within half a mile of the southeastern shore of Sakinaw Lake. They expose batholithic rock in which pink-weathering feldspar and epidote are conspicuous. Weak shear fractures, trending northeastward to eastward, intersect the rock which is locally mineralized with pyrite, chalcopyrite, specularite, and magnetite.

In 1940 a shipment of 95 tons containing 93 ounces of silver and 5,166 pounds of copper was made from these workings.

[Reference: *Minister of Mines, B.C.,* Ann. Rept., 1937, pp. F 28–F 31; 1950, pp. 170–172.]

GOLD DEPOSITS

[7]

A narrow gold-bearing quartz vein outcrops in the northwestern corner of the map-area on the north side of No Mans Creek at an elevation of 3,600 feet. The vein has a vertical dip and can be traced along strike, north 40 degrees east, for more than 800 feet. For the greater part of this distance the vein is in greenstone, but its north-eastern extremity is in granite rock. The vein does not exceed 9 inches in width and averages 4½ inches. Mineralization is extremely sparse, consisting of pyrite, arsenopyrite, and chalcopyrite. A few specks of gold were observed. Nine samples taken at irregular intervals from southwest to northeast along the vein assayed:—

Width	Gold (Oz. per Ton)	Wallrock
7 inches	*Nil*	Greenstone
2 "	0.42	"
1 "	5.77	"
2 "	1.62	"
5 "	1.68	"
8 "	0.20	"
8 "	0.02	"
8 "	0.01	Granitic
9 "	0.01	"

[8] In 1952 a gold showing was discovered at sea-level on the northwestern shore of Sechelt Peninsula, near the northern end of Agamemnon Channel. Two pits, 4 feet and 6 feet deep, were excavated on weak northeasterly trending fractures in batholithic rock. The fractures contain quartz and in places abundant pyrite. A sample of pyritic material gave the following assay: Gold, 6.21 oz. per ton; silver, 6.4 oz. per ton.

This showing is of no economic importance.

[Reference: *Minister of Mines, B.C.*, Ann. Rept. 1950, p. 177.]

DOLOMITIC LIMESTONE

A body of dolomitic limestone of possible economic importance occurs to the south and east of the copper deposits on the Cambrian Chieftain property (*see* Fig. 7). The minimum indicated length of the body is 1,020 feet and its average width is approximately 100 feet. This body was briefly mentioned on page 17, where it was noted that the magnesia (MgO) content of nine samples taken from various parts of the body averages 19.8 per cent. Complete analyses were performed on six of these samples, with the following results:—

	1	2	3	4	5	6
SiO_2	3.3	5.1	3.4	3.4	2.1	2.9
R_2O_3*	0.5	0.9	0.6	0.6	0.4	0.8
Fe_2O_3	0.6	0.6	0.4	0.4	0.4	0.5
CaO	32.3	31.5	33.1	31.7	30.6	30.9
MgO	19.3	20.0	18.8	20.1	21.1	20.7
H_2O at 105° C.	0.1	0.1	0.1	0.1	0.2	0.1
Ignition loss†	44.0	41.9	43.5	43.6	45.1	44.2
Totals	100.1	100.1	99.9	99.9	99.9	100.1

* R_2O_3 *comprises the oxides (ignited), except iron oxide, that are precipitated when the filtrate (oxidized if necessary) from the silica assay is made alkaline to methyl red on the addition of ammonium hydroxide. It therefore may include oxides of aluminium, titanium, zirconium, beryllium, chromium, quinquavalent phosphorus, quinquavalent arsenic, and quinquavalent vanadium.*

† Ignition loss includes H_2O above 105° C. and CO_2.

This body of dolomitic limestone is easily accessible should the need for such material arise in the coastal area of British Columbia. A road 6.5 miles long already exists between the Cambrian Chieftain property and tidewater at the head of Pender Harbour. Furthermore, the body is well exposed over a vertical range of 200 feet, and in general is ideally situated for quarrying.

Only two other bodies of limestone, high in magnesia, have been reported in the coastal area of British Columbia. A small deposit occurs on West Redonda Island (Goudge, 1946, pp. 161–163), and a body of magnesian to dolomitic limestone has been disclosed on the property of Central Zeballos Gold Mines Limited, Vancouver Island (Stevenson, 1950, p. 46).

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1950, p. 171.]

SUMMARY

Prospecting in the map-area has shown that the rocks of the Jervis group contain small deposits of copper, zinc, lead, and gold. Very small amounts of copper and gold have been found in the batholithic rocks; in addition, occurrences of molybdenite were observed southeast of Sakinaw Lake. Nothing has been found, however, to suggest that the granitic rocks of the map-area warrant further attention by prospectors.

Readily accessible dolomitic limestone, in sufficient quantity to be of potential economic importance, occurs on the Cambrian Chieftain property.

CHAPTER V.—ECONOMIC POTENTIAL OF THE COAST MOUNTAINS CORE SOUTH OF PORTLAND CANAL

The term " core " is applied herein to the central, predominantly granitic part of the Coast Mountains. It is used in contradistinction to " flank."

The flanks of the Coast Mountains have long been recognized as favourable prospecting ground, and the eastern flank, which is entirely in Canada, has proved to be particularly favourable, with the discovery of the Tulsequah, Granduc, Premier, Alice Arm, Bridge River, and B.C. Nickel deposits. In contrast, the core has failed to receive comparable attention.

Between the 60th parallel of latitude and Portland Canal the core is mainly in the territory of Alaska. The part of the core solely in British Columbia extends from Portland Canal to Burrard Inlet; it is this area that is under appraisal.

APPRAISAL

It is difficult to estimate the possibilities of finding new ore deposits in the core of the Coast Mountains because large areas are completely unmapped and the regional geology is relatively unknown. Nevertheless, the available information provides some basis for cautious optimism.

Within the area under appraisal important mineral deposits have been found in four localities: Howe Sound (Britannia mine), Observatory Inlet (Hidden Creek mine), Ecstall River, and Princess Royal Island (Surf Inlet mine).

The Surf Inlet deposits were gold-bearing quartz veins that averaged 0.39 ounce of gold per ton and 0.3 per cent copper for 1,012,067 tons mined. They proved sufficiently productive to sustain a profitable operation for many years. The veins occur largely in quartz diorite, but it is probable that the shear zone in which the veins occur was localized by a narrow septum of older rock.

Gold-bearing quartz veins have been found elsewhere in the granitic rocks. In addition, minor amounts of chalcopyrite, magnetite, molybdenite, and scheelite have been found but, generally speaking, developments to date have yielded little to encourage exploration of the granitic rocks, except along contacts with rocks that they intrude.

The copper-bearing sulphide deposits of Howe Sound, Observatory Inlet, and Ecstall River occur in roof remnants of layered rocks that are surrounded in plan by younger granitic rocks. The deposits of Observatory Inlet and Howe Sound have each yielded more than 100 million dollars in mineral wealth, and the Ecstall River deposits are known to contain at least 8,000,000 tons of similar ore but of lower grade. It is thus apparent that the rocks in which these large sulphide deposits occur are worthy of some scrutiny, and it is therefore important to consider what proportion of the core of the Coast Mountain is composed of them.

From existing maps it would appear that there is definitely a higher proportion of granitic rocks in the Vancouver-Skeena River interval of the Coast Mountains than in the Skeena River-Portland Canal interval. A recent estimate (Bostock, 1948, p. 82), however, that more than nine-tenths of the Coast Mountains core south of Skeena River is composed of granitic rocks would appear to be too high. An interpretation of the latest geological map of British Columbia (*Geol. Surv., Canada,* Map 932A, 1948) is that, at shoreline, at least 15 per cent of the region south of Skeena River is composed of non-granitic rocks. Moreover, it is perhaps reasonable to expect that, at higher altitudes, a greater percentage of these rocks will be found. Furthermore, the work in

Jervis Inlet has shown that small areas of older rock have been overlooked in the rapid coastal survey, and that stretches of coast barren of outcrop are more likely to be underlain by sedimentary or volcanic rocks than by the more durable granitic rocks. Thus, although a great deal more work is required before an accurate estimate can be made, it is probable that as much as 20 per cent of the Coast Mountains core south of Skeena River is composed of non-granitic rocks.

It has been shown that in Lower Jervis Inlet the non-granitic rocks occur largely in narrow, steeply dipping belts that persist over a vertical range of several thousand feet with little change in width. This generalization, applicable to an area chosen at random, demonstrates that the septum or deep remnant is not unique to Britannia or Ecstall River. It should not be assumed, however, that all the roof remnants persist to depths of several thousand feet. The Caren Range body of the Sechelt Peninsula is regarded as a true roof pendant, and other remnants probably occur with essentially the same shallow irregular form. The point, however, is that certain of the remnants do persist to depths of several thousand feet with little evidence of diminution in size and, because they do, there is no justification for a generalization that most deposits found in the older rocks will necessarily bottom in granitic rocks at depths of a few hundred feet.

The remnants of older rock found in the core of the Coast Mountains are small compared to their very productive counterparts in the Canadian Shield. Nevertheless, they are of sufficient size to accommodate very large ore deposits. For example, at Britannia the remnant in which eight very productive orebodies have been found is much smaller in area than some of the other known remnants in the Coast Mountains.

In summary, several points have been presented as a basis for appraisal of the economic potential of the interior of the Coast Mountains. They are:—

(1) Three localities are known in which large sulphide deposits occur.
(2) The sulphide deposits are of similar type; in all, copper is an important constituent.
(3) The sulphide deposits occur within remnants of the eroded roof.
(4) Probably 20 per cent of the core of the Coast Mountains south of Skeena River consists of roof remnants; the proportion of roof rocks in the Skeena River-Portland Canal interval is considerably higher.
(5) Some of the remnants persist to depths of several thousand feet and should not be regarded as roof pendants in the usually accepted sense of that term.
(6) Some of the remnants are of sufficient size to accommodate large deposits.

The logical conclusion is that, pending evidence to the contrary, roof remnants in the Coast Mountains are definitely worthy of consideration in the search for new deposits of mineral, particularly copper.

PRESENT STATUS OF EXPLORATION

The above conclusion would have little significance if the core of the Coast Mountains had already been closely prospected. It has not been. Considerable prospecting has been done from time to time, particularly in the lower, more accessible areas, but systematic geological exploration has been confined to the three roof remnants in which the large sulphide deposits have been found.

Physical difficulties encountered within the region are great and there can be no doubt that, in the past, this has been a major factor in retarding exploration. Probably the greatest deterrent at the present time is the lack of maps, both geological and topographical. A mapping programme in the interior of the range is a formidable task, as indeed the mapping in lower Jervis Inlet proved to be by standard reconnaissance methods, without recourse to aircraft for transportation or geological investigation. Individual aerial photographs covering the area were available and were an aid in planning traverses, but they were of little direct help geologically.

In contrast, the field work in Jervis Inlet could have been done in a fraction of the time and no doubt done more thoroughly if modern tools and techniques had been used. The helicopter has been shown to be a time- and energy-saving tool that can be employed to advantage in mountainous terrain, and a light plane can be extremely useful for reconnaissance work above timberline. Photomosaics of part of the Smith Inlet-Vancouver interval of the Coast Mountains, recently prepared by the Forest Service Branch of the Department of Lands and Forests from photographs taken at an elevation of 35,000 feet, show conclusively that photomosaics can be used to advantage for geological purposes in heavily wooded mountainous terrain. These photomosaics show with remarkable clarity the steeply dipping lineaments in this region. The significance of individual lineaments remains unknown pending geological investigation, but knowledge of their presence and extent is obviously of importance to anyone conducting such an investigation.

Another relatively new tool is colour photography, and pioneer efforts in the Coast Mountains indicate that colour photographs taken in August can be particularly useful for the areas above timberline.

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PLATE I

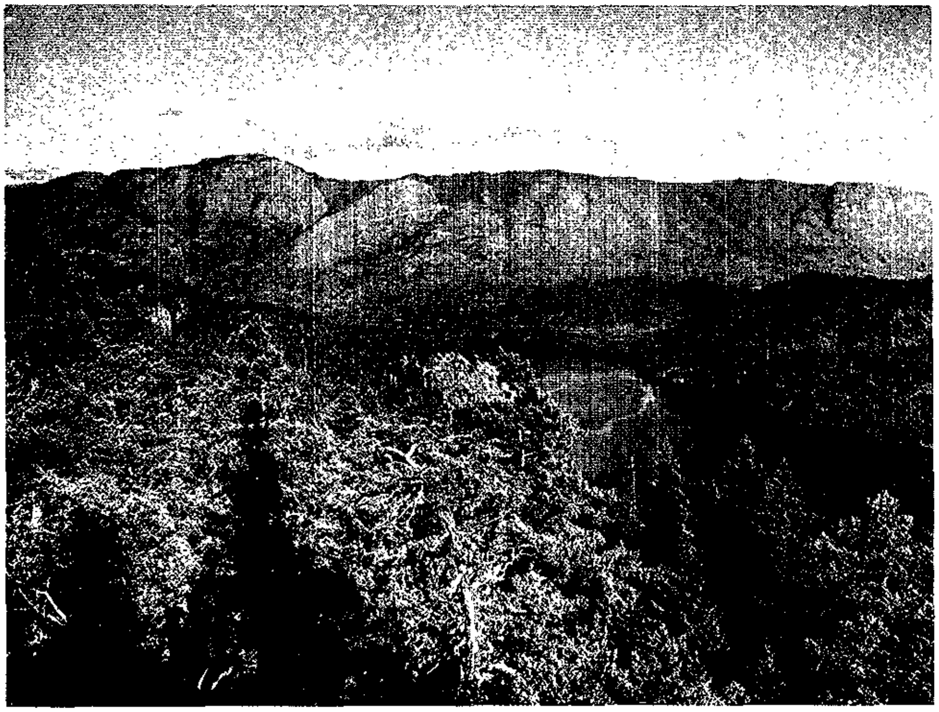
East face of Diadem Mountain. Topographic Division photo.

PLATE II

(A) Northern part of map-area. Hotham Sound upper left. Freil Lake centre. Prince of Wales Reach right. Topographic Division photo.

(B) Southern part of map-area. Sechelt Inlet on left. Mount Hallowell centre. Agamemnon Channel on right. Captain Island in right foreground. Topographic Division photo.

PLATE III



(A) West flank of Caren Range. Mount Hallowell on left. Cambrian Chieftain road left centre. Sakinaw Lake in foreground. Topographic Division photo.

(B) Gneiss, west end of Captain Island. K. G. Hope photo.

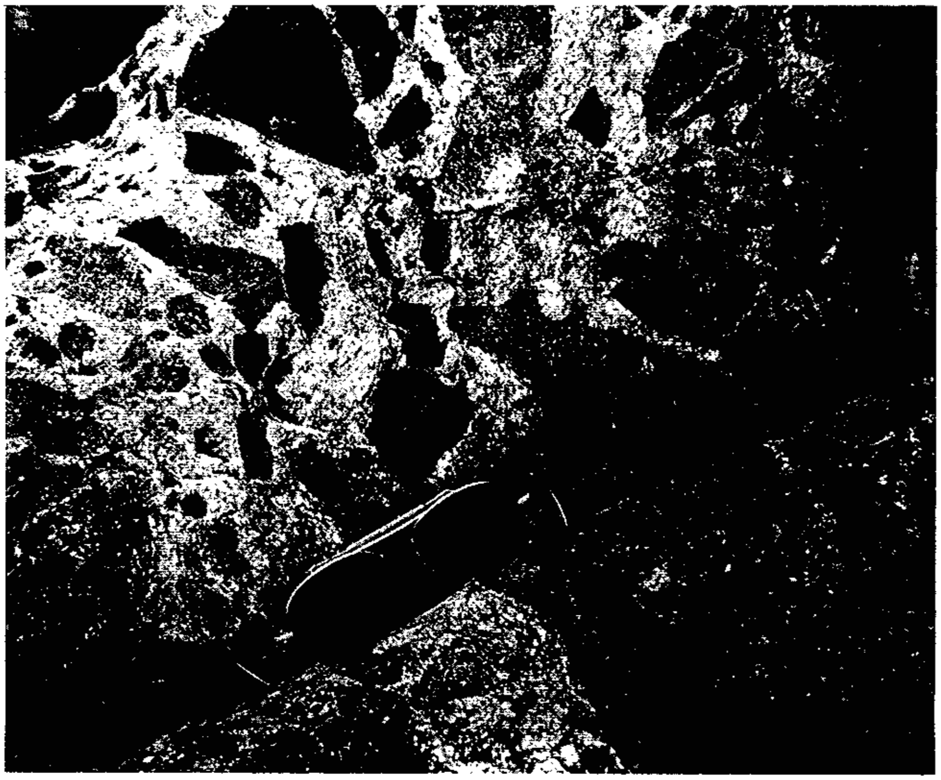
PLATE IV

(A) Pillow lava, Foley Head. K. G. Hope photo.

(B) Agglomerate, south of Perketts Creek. K. G. Hope photo.

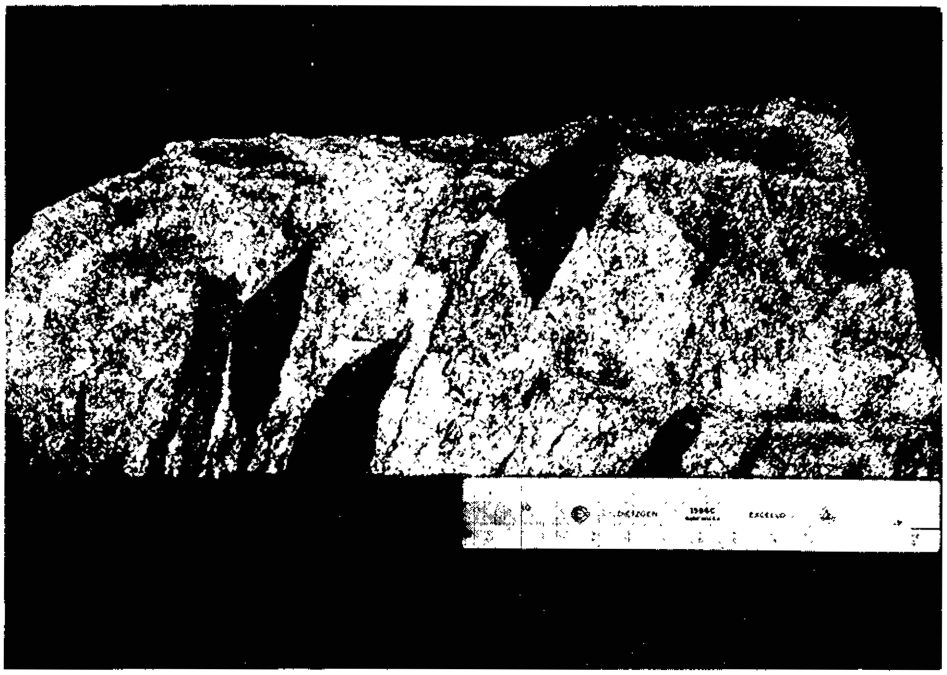
PLATE V

(A) Quartz-feldspar porphyry intruded by basaltic dykes, north shore of Princess Royal Reach.

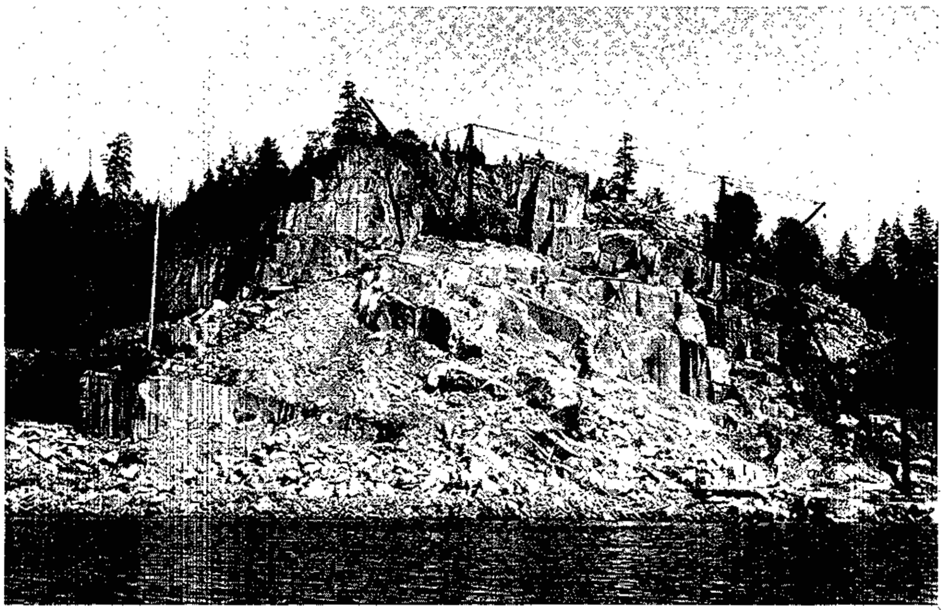


(B) Inclusions in the main batholithic mass. K. G. Hope photo.

PLATE VI

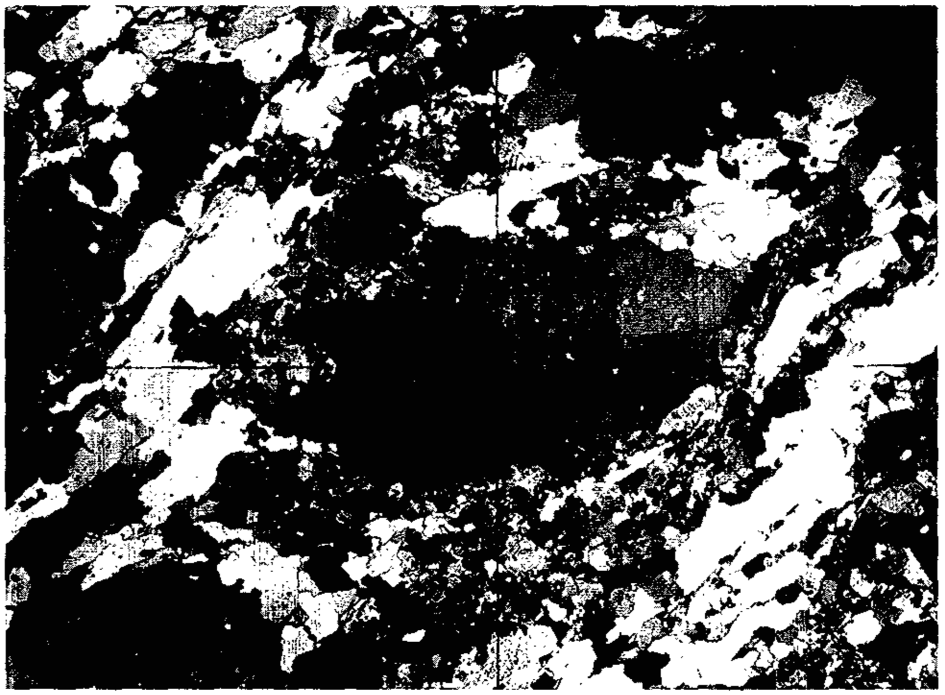


(A) Dark oriented clots in specimen of the main batholithic mass.



(B) Jointing in biotite granodiorite, Nelson Island.

PLATE VII



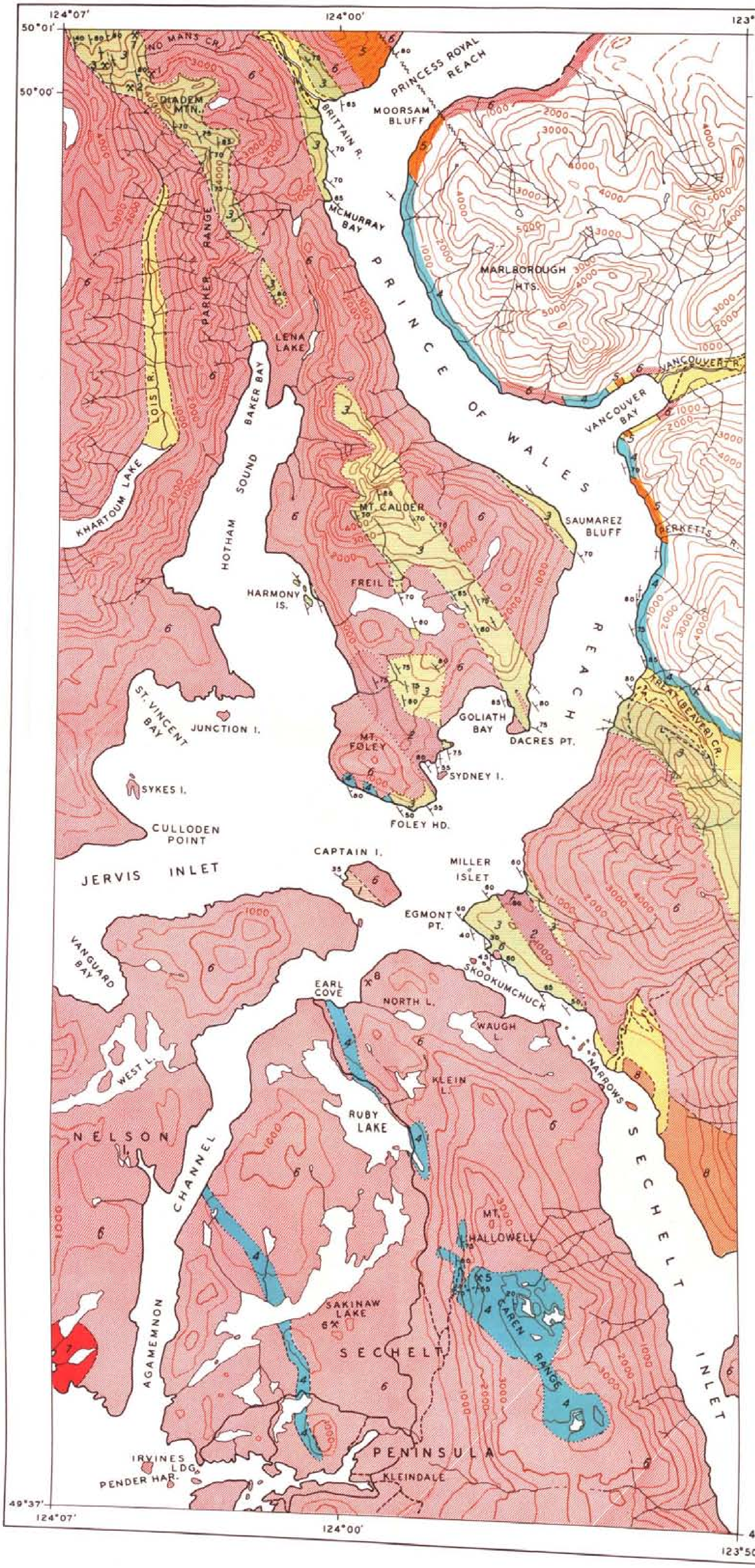
(A) Photomicrograph of granitic rock, eastern end of Captain Island. Microcline enclosing plagioclase and being replaced by myrmekitic intergrowths. Note the cataclastic texture.

(B) Photomicrograph showing twinned sphene enclosing magnetite and apatite.

PLATE VIII

(A) Photomicrograph showing myrmekitic intergrowths.

(B) Photomicrograph showing zoned plagioclase. Note the altered, corroded, and embayed nature of the core.



GEOLOGICAL MAP
OF
LOWER JERVIS INLET
1957

Geology by W. R. Bacon

Scale 1 0 1 2 3 4 5 Miles

Contour interval 500 feet

Approximate magnetic declination 24°30' East

LEGEND

Drift and valley-fill

JURASSIC (?) OR LATER

COAST INTRUSIONS

8 Mainly coarse-grained horneblende granodiorite

7 Medium-grained biotite granodiorite

6 Main batholithic mass; mainly quartz diorite, granodiorite

5 Quartz-feldspar porphyry

AGE UNKNOWN

JARVIS GROUP

4 Basalt, andesite and associated pyroclastic rocks; minor limestone, dolomitic limestone, chert, argillite

3 Mainly conglomerate, greywacke, sandstone, argillite; greenstone

2 Metavolcanic rocks; metasedimentary rocks; metadiabase

1 Gneiss

Geological boundary
defined
approximate
assumed

Attitude of bedding
inclined
vertical

Fault with dip

Prospect (number refers to text)

Main road

Secondary road

#39

To accompany B.C. Department of Mines Bulletin 39 "Geology of Lower Jervis Inlet" by W. R. Bacon.