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GEOLOGY

of the

QUEEN CHARLOTTE ISLANDS

BRITISH COLUMBIA

by

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ABSTRACT

The Queen Charlotte Islands are at the western edge of the continental shelf seaward of central British Columbia. The islands have a land area of about 3,840 square miles, which is divided into three main physiographic units: the Queen Charlotte Ranges on the southwest, Skidegate Plateau in the centre, and Queen Charlotte Lowlands on the northeast. In the Pleistocene the islands were intensively glaciated.

The fundamental structural unit of the Queen Charlotte Islands is a thick (15,000+ feet) pillowed basalt of Late Triassic age. The basalts are separated by a flysch-like sequence of Latest Triassic and Early Jurassic age from an explosive porphyritic andesite of Middle Jurassic age and largely marine deposition. Two Cretaceous sedimentary units, the first flysch-like and the second mollasse-like, were deposited and are successively less involved in deformation. A final Early Tertiary period, largely of subaerial volcanism, deposited some 18,000 feet of intercalated columnar alkali basalt floods and sodic rhyolite ash flows. These are gently warped, eroded, and overlain by up to 6,000 feet of Mio-Pliocene sands and shales. Large lineal bodies of hornblende diorite to quartz diorite were emplaced in the Mid to Late Jurassic and a more varied sequence of quartz diorite to sodic granite in the Early Tertiary, mostly along major lineal faults.

Crustal fracturing has been the dominant mechanism of deformation, controlling volcanism, sedimentation, intrusion, and secondary folding. Major northwesterly lineal faults form a pattern related to the Queen Charlotte fault. The trace of the latter is along the continental slope. The major northwesterly faults have been active since at least the Early Cretaceous, and generally they combine right-hand wrench movement with normal east-block-down displacement.

The mineral resources of the islands are extensive. At present pyrometasomatic iron-copper deposits are the most important by several orders of magnitude. Mineable reserves have a gross value of about $200 million. Production has come from two main properties—Tasu and Jedway.

Frontispiece. The west coast of Moresby Island looking south from the entrance to Barry Inlet.

GEOLOGY OF THE QUEEN CHARLOTTE ISLANDS

CHAPTER 1

Introduction

The Queen Charlotte Islands are at the western edge of the continental shelf seaward of central British Columbia. They lie between 52 degrees and 54 degrees north latitude and 131 degrees and 133 degrees west longitude, south of the Alexander Archipelago of southeastern Alaska. In plan the islands form a scimitar-shaped group, convex to the Pacific and handle toward the south. Graham Island, the largest, forms the broad northern part of the blade, whereas Moresby and the lesser islands, Louise, Lyell, Burnaby, and Kunghit, form its tapering southern handle. Langara Island lies at the northwestern tip of Graham Island. The total land area is approximately 3,840 square miles, of which Graham Island is about 2,485 square miles and Moresby Island 1,060 square miles. Figure 2 is a plan showing the major geographic nomenclature and the physiographic units.

The islands are sparsely populated, but what population there is, is concentrated in communities, many of which are really industrial camps. Permanent communities with some continuity of existence are, from north to south, Old Masset, Masset, Port Clements, Tlell, Skidegate, Queen Charlotte, Sandspit, Moresby, Tasu, and Jedway. Masset and Queen Charlotte are the principal towns, and Old Masset and Skidegate the chief Haida communities. All communities are on the east coast or inlets except Tasu, which, when it is fully established, will be the largest of all the communities. The total population in 1961 was 3,014. Since then a sizeable increase has occurred.

Transportation to the islands includes direct daily connection by air to Vancouver and Prince Rupert and weekly connection by Northlands Navigation coastal freighter. In addition, much freight is moved by tug and barge. A public road connects Masset, Port Clements, Tlell, Skidegate, and Queen Charlotte. Private roads connect Juskatla with Port Clements and Sandspit with Moresby. In addition, the logging companies have extensive road systems, principally in the plateau areas from Juskatla to Moresby.

In spite of modern transportation and communication, the islands still are relatively isolated. Indeed the Queen Charlotte Islands are of greater interest in many respects than what might be expected of such a relatively small and undeveloped part of the Province, partly because of their isolation. Economically, however, the islands have paid a high price for it, and have not always fully participated in the well-being of the Province. Even now all industries are entirely extractive with a minimal amount of even rudimentary processing.

The industries are logging, fishing, and mining, with minor tourism for the sport fishery. Other employment is provided by a small amount of service industry and by government agencies. Forestry is concentrated mainly in three big camps—Northwood Pulp Limited (Crown Zellerbach Canada Limited) at Sandspit, Rayonier of Canada at Moresby, and MacMillan Bloedel Limited at Juskatla. Logs are exported to mills along the mainland coast. Fishing is a way of life to the indigenous population and is still a major form of employment. The only cannery on the islands is at Masset, and most of the catch is processed on the mainland. Mining on a big scale is a relatively new industry, dating from the opening of the Jessie open-pit mine of Jedway Iron Ore Limited in 1962. The Tasu mine of Wesfrob Mines Limited is scheduled to open in 1967 and will export copper concentrates as well as two grades of iron concentrates. The reserves at Tasu are sufficient to provide a continuing operation of several decades.

The climate of the islands is mild but stormy. Freezing temperatures are rare and snow ephemeral at sea-level, but a considerable snow pack develops at 2,500 feet and above. Gales may be expected at any season and are repetitive in winter. The climate is humid, but rainfall varies greatly from western fiords to eastern plains, where it is low by coastal British Columbia standards (Masset, 55 inches per year).

The flora and fauna are the subject of several recent detailed studies: The Flora of the Queen Charlotte Islands, by J. A. Calder and R. L. Taylor (1967), Department of Agriculture, Ottawa, and the endemic fauna by J. Bristol Foster (1965), The Evolution of the Mammals of the Queen Charlotte Islands, Occasional Paper No. 14, Provincial Museum, Victoria. As might be expected from the island's isolation, a marked tendency to endemism exists, and the flora and fauna are slightly unusual with a tendency to few species and often large populations of large individuals. The present fauna is the result of expansion by many recent introductions but is still impoverished. Original large land mammals included only a black bear *(Euarctos americanus carlottae)* and the recently extinct Dawson's caribou *(Rangifer dawsoni)*. Sitka deer *(Odocoileus hemionus sikensis)* and Rocky Mountain elk *(Cervus canadensis nelsoni)* have been successfully introduced. Original small land mammals included the river otter *(Lutra canadensis periclyzomæ)*, pine marten *(Martes americana nesophila)*, ermine *(Mustela erminea haidarum)*, two races of dusky shrew *(Sorex obscorus)*, and four races of deer mice *(Peromyscus maniculatus)*. Introduced species include beaver, raccoon, squirrel, and many rodents. A large number of migratory birds visit the islands, and a small number of endemic forest birds occur. Among the most characteristic and common members of the coastal land birds are ravens *(Corvus corax principalis)* and bald eagles *(Haliæetus leucocephalus alaskanus)*. Sitka spruce *(Picea sitchensis)*, western hemlock *(Tsuga heterophylla)*, and red cedar *(Thuja plicata)* are the main trees in the forests, and yellow cypress *(Chamæcyparis nootkatensis)* and shore pine *(Pinus contorta)* are abundant in muskeg or transitional areas. Red alder *(Alnus rubra)* is the main deciduous species and is abundant in moist sites in second growth and along stream courses.

A good history of the Queen Charlotte Islands has yet to be written. General histories of British Columbia give slight attention to the islands. Dawson (1880, pp. 2B–14B) gives a good review of the voyages of discovery as known at that time. A history for school-children covers the salient events (Corday McKay, 1953, British Columbia Heritage Series, Series II, Vol. I, Queen Charlotte Islands). The history of mining is covered briefly in this report on pages 165 to 167.

Place-names in the Queen Charlotte Islands reflect the history and development to a considerable degree. Haida (or Tsimshian) names or slight corruptions of them form a main and characteristic element of geographic names (Cumshewa, Skedans, Kunghit, Skidegate). Other Haida names have been applied recently to features previously unnamed (Yatza Mountain=knife). Many features were named by early European or American navigators for patrons, colleagues, ships, saints' days, etc. (San Christoval Range by Perez, Queen Charlotte Islands by Dixon in 1787 for his Queen or his ship, Langara Island by Caamaño for a Spanish admiral, etc.). Many explorers or their ships have been commemorated in later times (Juan Perez Sound, Mount La Pérouse). G. M. Dawson named many features of the south-eastern coast for 19th-century geologists and scientists (Logan Inlet, Selwyn Inlet, Sedgewick Bay, Darwin Strait, Ramsay Island). Finally, many names for features reflect their character, while others have been suggested by local fishermen (God's Pocket, now Pocket Inlet; Bottleneck Harbour, now Bottle Inlet; Peril Bay, Long Arm, now Inlet).

PREVIOUS GEOLOGICAL WORK

Considering their remoteness, the Queen Charlotte Islands received a considerable amount of geological study prior to the Great War (1914–18). The reason for this was a policy to aid exploration for coal and other mineral deposits, and all studies prior to McLearn's were primarily initiated to this end. The first work was a preliminary study by James Richardson on western Skidegate Inlet in 1872 (1873). The second work was G. M. Dawson's classic study in 1878 (1880), in which he surveyed the whole group of islands except the west coast, travelling in a small motorless schooner in 2½ months. The extraordinary breadth and thoroughness of his studies will never be matched, for, in addition to a lasting geological framework, he studied the flora, fauna, and anthropology. His palæontological collections were studied by J. F. Whiteaves (1883, 1884, 1900), and those of Richardson by E. Billings (1873) and J. F. Whiteaves (1876). Succeeding geological work by R. W. Ells in 1905 (1906) and C. H. Clapp in 1912 (1914) on Graham Island led to the first systematic areal study by J. D. MacKenzie in 1913–14 (1916). During the same period, metallic mineral deposits were studied and reported on by William Fleet Robertson in 1907 and 1909 and later by D. B. Forbes (1913), W. M. Brewer (1915), and G. A. Clothier (1918) in the Annual Reports of the Minister of Mines.

Following 1918, little work was done, except for F. H. McLearn's extensive stratigraphic collecting in Skidegate Inlet in 1921. The results of his work are not all yet published. A summary of the Jurassic stratigraphy was published in 1949 following publication of many papers on Jurassic ammonites, and a monograph on Haida Formation ammonites was nearly completed on his death. Metallic mineral deposits continued to receive some attention from the British Columbia Department of Mines and were reported on by H. Carmichael in 1929 and J. T. Mandy in 1932. Except for an examination of beach sands by S. S. Holland and H. Nasmith, 1957 (1958), no other governmental studies were made until the start of the present project in 1958.

PRESENT INVESTIGATIONS

The project that led to this publication started in 1958. It was designed to aid the search for iron-ore deposits by detailed mapping. Originally it was intended to map only Moresby and adjacent islands, but it was extended in 1961 to include

Graham Island. The writer spent the full field season of the years from 1958 to 1962 and several weeks in 1963, 1964, and 1965 on the project. During 1958 and 1959, work was carried out from a chartered boat working along both coasts of Moresby Island. Parker Calkin in 1958 and W. G. Jeffery in 1959 assisted with the mapping very capably. During 1960, work included the study of the stratigraphy of Cretaceous rocks from Skidegate to Cumshewa Inlet and a reçonnaissance of Graham Island. In June, 1961, the major part of Graham Island was reconnoitred by helicopter, and subsequently in 1961 and 1962 more accessible parts were mapped from roads, inlets, and lakes. Primary attention from 1963 through 1965 was devoted to the iron deposits. During all these years the writer was fortunate to have a succession of capable and resourceful student assistants: in 1958 Oliver Brammall and Michael Sanguinetti, in 1959 Oliver Brammall and R. Perkins, in 1960 and 1961 James S. Christie, in 1962 Thomas E. Burgess, in 1963 Bryan Baxter, in 1964 Robert F. Thorburn, and in 1965 Michael F. Lancaster.

During the course of the project, preliminary results were issued in papers, many of which need revision in the light of later work. In particular the preliminary map of the southern Queen Charlotte Islands (A. Sutherland Brown and W. G. Jeffery, 1960) should be revised, as comparison with the present map will show. An aeromagnetic survey of part of central Moresby Island was flown in 1959 as a part of the over-all project. The maps (AM 59-1 to 59-4) were issued separately.

The field work was greatly aided by many organizations and individuals, including all the local residents with which the writer had any contact. The staffs of mining exploration companies were invariably helpful. In particular the writer is thankful to the following exploration personnel: Alex Smith, J. J. McDougall, Ken Polk, and Roy Hepworth, of Falconbridge Nickel Mines Limited; Newton Cornish, Keith Fahrni, and a succession of Jedway Iron Ore Limited geologists; W. R. Bacon, of Mastodon-Highland Bell Mines Limited; and A. C. Ritchie and William St. C. Dunn, of Silver Standard Mines Limited. The writer would also like to acknowledge services beyond those expectable provided by B.C. Airlines personnel and by Gordon Joliffe, and also the companionship and discussion of J. Bristol Foster, who was conducting biological studies at the same time. I would like to acknowledge the work of many palæontologists who have so materially contributed to this study: Drs. Hans Frebold, T. Tozer, J. A. Jeletzky, J. E. Wagner, and the late Dr. F. H. McLearn, all of the Geological Survey of Canada; Professor Glenn Rouse, of the University of British Columbia; Dr. Roberta K. Smith, formerly at the University of British Columbia; and Dr. David L. Jones, of the United States Geological Survey. Finally I would like to acknowledge the forebearance of my family, who shared in only a small part of the fun but a major part of the disadvantages resulting from this study.

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CHAPTER 2

Physiography and Glacial and Recent Geology

PHYSIOGRAPHY

The Queen Charlotte Islands in many respects are like a model of British Columbia in the sense that most types of landform and physiographic terrains present in the Province are present in miniature in the islands. The range of terrain includes alpine mountains less than 4,000 feet high, dissected and relatively undissected plateau, and forest- or muskeg-covered plains. Shoreline types are as varied as the terrains and range from one that is formed by an abrupt fault-line scarp that rises from abyssal depths to sea-level and some 3,500 feet above, broken only by the entrances of fiords, to continuous wide sandy beaches between emergent and submerged parts of Hecate Lowland.

Many of the forces that shaped the islands are still extant or not long disappeared, so that the connection of process with form is more apparent than in regions that are not wholly so young. " Basement " rocks are Late Triassic, much of the cover is Tertiary, and some is immediately pre-Pleistocene. Fault tectonics have clearly been the dominant force in the structural architecture of the rocks and the formation of the physiographic units, and the islands and adjacent continental slope and shelf are still seismically very active. Tertiary volcanic rocks are so little deformed that the construction of the main part of the plateau area by the effusion of these lavas is still clear. The evidence of the Pleistocene glaciation is ubiquitous and abundant. Shoreline processes that have modified the fringes of the islands are very evident today during the frequent gales.

Physiographic Subdivision

The Queen Charlotte Islands are divided into natural physiographic units with fairly clear boundaries (MacKenzie, 1916; Sutherland Brown, 1960; Holland, 1964). The islands are part of the western system of the Canadian Cordillera and involve two major subdivisions, the Insular Mountains and the Hecate Depression. The Insular Mountains in the Queen Charlotte Islands are subdivided into the Queen Charlotte Ranges and the Skidegate Plateau, and the Hecate Depression is represented by the Queen Charlotte Lowlands. The boundaries between the major units, although slightly irregular in detail, trend over all within 5 degrees of north 45 degrees west, parallel to the west coast of Moresby Island. Figures 1 and 2 show the extent of these units with a few minor subdivisions, the San Christoval Range and the Argonaut Plain.

Queen Charlotte Ranges

The Queen Charlotte Ranges extend from Cone Head on Rennell Sound to Cape St. James and include most of Moresby Island but only a small part of Graham Island. The western boundary is the Pacific coastline; the eastern is along a line from Rennell Sound to Vertical Point on Louise Island.

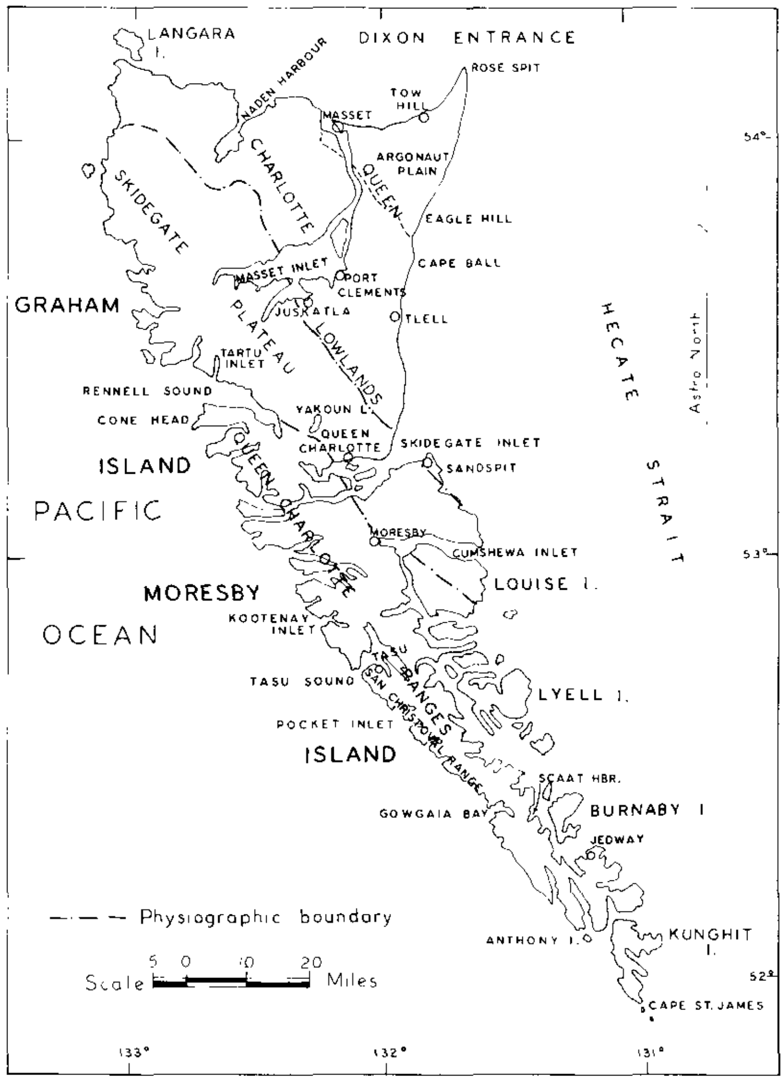


Fig. 1. Index map of the Queen Charlotte Islands.

The seaward coast is an abrupt, straight fault-line scarp that is related to the Queen Charlotte fault (*see* Plate I and Fig. 28) and is substantially the edge of the continental shelf. The submarine topography west of the coast consists of an abnormally steep continental slope that is traversed by an aligned group of canoe-shaped depressions that mark the probable course of the fault. The abyssal depths west of the continental slope are shallower than normal (that is, about 9,000 feet) and form part of the East Pacific Rise. Above sea-level, slopes rise sharply for 1,500 to 3,500 feet. The average slope from the shore to the peak of Mount De la Touche (3,600 feet) is 30 degrees. This western front is abrupt all the way to southern Kunghit Island, where the peaks are but 1,500 feet.

Within the Queen Charlotte Ranges there are three groups of high peaks, only one of which forms a lineal mountain range, the San Christoval Range. This extends from Tasu Sound to Gowgaia Bay from the Pacific to Darwin Sound. It was named by Juan Perez in 1774, and hence is one of the oldest charted features of the British Columbia coast. Mount De la Touche (3,600 feet, named by La Pérouse for his lieutenant) is slightly higher than numerous other unnamed peaks in the range. Most of the range is underlain by granitoid rocks. Another group of high peaks occurs in a triangular area from Security Inlet in the north to south of Kootenay Inlet to Vertical Point in the east. This group includes the following named peaks: Mount Moresby (3,700 feet), Mount Kermode (3,500 feet), Mount Carl (3,000 feet), and Mount Russ (3,000 feet). Most of the high peaks are formed of Triassic volcanic rocks, but some are granitic. The third high group extends from Kano Inlet to Skidegate Channel to Kagan Bay and includes Mount La Pérouse (3,700 feet), Slatechuck Mountain (3,200 feet), and Mount Stapleton (3,500 feet). The northern peaks are formed of granitoid rocks, but the southern of slightly metamorphosed young volcanic rocks.

Beyond these three groups the mountains are mostly 2,000 to 3,000 feet high and, although they have steep slopes, commonly have rounded or bulbous summits. In contrast, mountains anywhere that are higher than 3,000 feet have small matterhorn peaks. Timberline is quite irregular, depending on exposure, slope, and geographic position. It ranges from 2,500 to 3,200 feet, with the higher elevations in the east. In many exposed localities open muskeg, roche moutonnée, and mixed yellow cypress and pine scrub alternate from sea-level to timberline. Elsewhere luxuriant spruce, hemlock, and cedar forests clothe the slopes and the sheltered or well-drained valleys.

The eastern boundary of the Queen Charlotte Ranges runs from Rennell Sound to Vertical Point on Louise Island and, apart from a projection east of Slatechuck Mountain, is fairly straight and follows the Rennell-Louscoone fault zone. In general there is a sharp transition from mountain to plateau or dissected plateau of fairly continuous ridges, but in the area between Long Arm and Mosquito Lake the boundary is not sharply defined. From Vertical Point southward the impression given by the mountainous little islands and intricate pattern of waterways is of a drowned coastline. This contrasts strongly with the east coast along the plateau and lowland areas.

Skidegate Plateau

The Skidegate Plateau extends from Pivot Mountain in the north to Skedans Bay in the south and thus includes a major part of Graham Island but only a small part of Moresby Island. The plateau surface reaches 2,600 feet elevation in the west central part, between Port Channel and Tartu Inlet, and from there slopes very gently to the north and east. Slopes of the surface of more than 250 feet per mile or about 2½ degrees are uncommon. Over most of the area the elevation of the plateau surface is just above 2,000 feet, but adjacent to the lowland boundary it is commonly lower, about 1,500 feet. Also adjacent to the Queen Charlotte Ranges at the northwest and southeast ends where the surface is truncated by the shore, it has sloped down to 1,500 to 1,300 feet. The very steep slope from the shore on Rennell Sound to the plateau surface is noteworthy. It rises at about 40 degrees from shore to 2,000 feet and is believed to be a fault-line scarp. The plateau surface is fairly well dissected, but continuous flat-topped ridges are the characteristic feature of the whole area (*see* Plate IIIA). Glaciation has caused extensive modification by broadening the valleys and rounding the edges of the plateau surface.

The origin of the plateau is complex. The eruption of a great pile of flat-lying lavas in Early Tertiary times over a large part of the plateau would superficially seem to indicate the plateau was essentially constructional. However, the plateau bevels all older rocks, notably the Jurassic volcanic and Cretaceous sedimentary sequences, and the surface over these is continuous with that over the lavas. Furthermore, the Tertiary plateau lava sequence is tilted and can be seen in detail everywhere to be bevelled at a small angle by the erosion surface, which is normally oblique to the strike of the beds (*see* Plate IIIB). Therefore, the surface is erosional and post-Eocene, the probable age of the youngest lavas.

The Skidegate Plateau is the most heavily timbered area in the islands, but in the northern half most of the flat upland surfaces and gentle dip slopes of the lavas are covered with muskeg or alpine meadow. South of the Yakoun River, muskeg and meadow become progressively less important.

The boundary with the Queen Charlotte Lowlands to the northeast extends from Beresford Bay in the northwest to Gray Bay in the southeast. From near the Yakoun River south, the boundary seems simple and corresponds with the Sandspit fault line. Here it is a small scarp 200 to 500 feet high, evident even in the vicinity of the Tlell River, where the plateau surface is lowest and most fragmentary. From the Yakoun River north, the boundary is more complex. In part this is the result of the incision close together of the fiord-like valleys of Juskatla Inlet, Masset Inlet, and Ian Lake, where the boundary has been removed. It is, however, evident on the dividing hills. The main complexity results from the fact that there are two steps from lowland to main plateau. This is evident in the south in a most fragmentary manner but is quite clear between Pivot Mountain and Ian Lake. In this interval the first step occurs at an elevation of 600 feet near Ian Lake to 1,200 feet near Jalun Lake. The second, over the same interval, is at 1,100 feet at the south to 1,600 feet near Jalun Lake. At both steps there is a sudden change in slope that is scarp-like in places. Southwest of the second step the elevations increase to the general plateau level, about 2,100 feet. The northeasternmost step is taken as the boundary between lowland and plateau. The two steps come together at Pivot Mountain and at the McKay Range north of Masset Inlet, making these boundaries particularly prominent. There is a sharp deflection of both steps to the southwest at Naden Harbour.

The relation of the southern part of the boundary to the Sandspit fault is quite clear, for it forms a fault scarp. The origin of the two northern steps is less clear. It may have originated partly from uplift along a series of in echelon faults or from purely erosional processes.

Queen Charlotte Lowland

The Queen Charlotte Lowland flanks the Skidegate Plateau on the northeast and extends from Langara Island to Gray Bay (*see* Plate IV). It includes the largest part of Graham Island but only an insignificant part of Moresby Island. Most of the lowland is well below 500 feet elevation, but in several areas between major inlets it rises smoothly at about 65 feet per mile to the plateau boundary at 500 feet to as much as 1,200 feet near Jalun Lake. Most pronounced is the broad rise between Newcombe Hill (Sialun Bay) and Naden Harbour. A similar broad rise occurs between Naden Harbour and Masset Sound and to a lesser degree Yakoun and Tlell Rivers and Tlell River and Hecate Strait. In the northeastern part of the lowland there is on the Argonaut Plain a number of flat-topped hills between 400 and 500 feet high. Over most of the lowland, including the rises, the dissection is rudimentary, although between Naden Harbour and Langara Island in intensely glaciated older pre-Tertiary rocks it is more advanced and deeper than elsewhere.

Much of the lowland is covered by muskeg surrounded by scrubby pine, yellow cypress, or small spruce. This is true even on hills underlain by hundreds of feet of sand. Only along well-drained slopes such as river valleys does the forest of spruce and red cedar approach that of the plateau area.

A subdivision of the lowland called the Argonaut Plain lies northwest of a line between Masset Harbour and Cape Ball. This line in fact is an ice contact front and the plain a Late Pleistocene outwash plain deposited from streams flowing northeastward from the ice to the southwest. The system of ramifying channels and remnant interfluves shows clearly on air photographs and is shown on glacial and geological maps (Figs. 2 and 5).

The origin of the Queen Charlotte Lowland is as complex as that of the plateau. In part it is similar. The lowland embraces several distinct areas of differing bedrock or history. Northwest of a line from Beresford Bay to Pillar Bay, Jurassic and Cretaceous sedimentary rocks cut by large Tertiary dykes and granitoid plutons form a slightly uplifted peneplane intensely fluted and eroded by Pleistocene ice. From this line to one roughly parallel with the Hancock River, relatively flat-lying Early Tertiary lavas occur also in a slightly uplifted peneplane which to the east is overlapped by Late Tertiary sedimentary rocks. It is relatively clear the bevelling of the peneplane is related to the deposition of the Late Tertiary sediments. It is also likely that the surface was downwarped to the east coincident with deposition, and uplifted in the southwest, partly by Late Tertiary faulting along the Sandspit and related faults. The origin of the Late Pleistocene Argonaut Plain on the top of the earlier onlap of Tertiary sediments has already been mentioned and will be discussed in more detail on page 34.

Minor Features of Topography

Many of the notable minor features of topography are related to the Pleistocene glaciation or to Recent shoreline processes. The major glacial features include the drumlinized lowlands and plateau areas, matterhorn peaks, high- and low-level cirques, catenary valleys, fiords and finger lakes, and a large outwash plain. Most of these have been mentioned in the discussion of the topographic areas, and all will be treated under glaciation.

The shoreline features include ones in current evolution and dead features formed prior to a small post-Pleistocene uplift. This uplift is apparent in all sections of the coast of the islands. Evidence for it includes: Dead sea cliffs along the Sandspit fault from Copper Bay to Shingle Bay and from Masset to the Skonun River; raised stacks at Reef Island, Conglomerate Point, Copper Bay, and from Pillar Bay to Beresford Bay; raised sea caves along the whole of the Pacific coast from Anthony Island north; and raised deltas, terraces, and wave-cut benches from Gray Bay all the way along the east and north coast to Beresford Bay at least. Included with the latter is a wide scroll of beach ridges from Tow Hill to Rose Spit. In addition, Recent fossils have been collected well above present sea-level. The extent of the obvious raised wide benches and terraces is shown on the geological plans and the glacial map. Precise measurement of the uplift is particularly difficult, but everywhere appears to be of the same order, 20 ± 5 feet. Within this limit of accuracy there is no evidence of tilting. Recent evidence on post-glacial sea-level shows a fairly uniform approximately exponential rise to the present level (Shepard, F. P., 1964).

The age of these features judged by shells collected in two places (*see* p. 35) is about 8,000 years B.P. In the interval to the present, according to Shepard's curve (Fig. 2), the rise in sea-level would be about 50 feet, so that the total rise of the islands would have been about 70 feet. This might be thought due to glacial rebound, but the lack of evidence of tilt on the north coast over 55 miles long suggests it is not simple glacial rebound but involves tectonic movement also.

Evolving shoreline features of note are mostly related to the northeast coast, where unconsolidated sands and tills are under vigorous attack by storms, particularly southeast gales. Sea cliffs over 50 feet high from Tlell to Oeanda River (*see* Plate Xc) and nearly 200 feet high at Cape Ball are retreating at a considerable rate, as is shown by historical records. The eroded sands are drifting north and continue to build Rose Spit farther northeastward and to extend bars across stream mouths. Evidence of longshore drift on the north coast is equivocal; if Tow Hill, Skonun Point, and Yakan Point are regarded as groins, then drift is currently to the east; if the direction that streams turn on debouching from the lowland is used as evidence, drift is to the west. This may indicate an ancient drift direction. In any case the north beaches are very broad and longshore drift is less significant, and no cliffs of sand or till are under attack. Sand beaches are virtually continuous from Tlell to Masset. Some sand is blown into dunes behind the beaches on both Hecate Strait and Dixon Entrance shores, but the dunes seem currently to be stabilized. Beach pebbles, however, are vigorously sand blasted, and dreikanter or ventifacts are common on exposed back beaches.

GLACIATION

In the Pleistocene the Queen Charlotte Islands were intensively glaciated during the Fraser (Wisconsin) glaciation. Evidence of earlier stages is either modified or destroyed, but evidence of the latest glaciation is abundant, fresh, varied, and widespread. During this stage the islands were covered by a locally generated ice-sheet, the Queen Charlotte Islands ice-sheet, that was in equilibrium with the Cordilleran sheet in Hecate Lowlands. The glacial features are most obvious in the mountain areas, and glacial deposits best exposed along the northeastern coast bluffs from Tlell to the Oeanda River.

Glacial studies of the Queen Charlotte Islands have been few and only G. M. Dawson's (1880) classic study is of any scope. The number and accuracy of his glacial observations are remarkable and his general outline sound considering the limitations of the time. He (1880, p. 89B) summarized his observations in the following sentence: " We find everywhere in the Queen Charlotte Islands evidence of the descent of glacier ice from the axial range of mountains toward the sea, and little or none of the passage across the group of any more ponderous ice mass." Recently gathered evidence was summarized and illustrated in a paper designed for biologists by Sutherland Brown and Nasmith (1962, pp. 209–219).

The following discussion begins with a description of the glacial features which are chiefly erosional but includes the distribution of erratic boulders, followed by a description of ice movement. Thereafter glacial stratigraphy and palæontology and deglaciation are described, followed by a short summary of the glacial history. Finally post-glacial sea-levels and palæontology are discussed.

Glacial Features

The major landforms have been extensively modified by Pleistocene glaciation. In mountain and plateau areas all valleys have a catenary (U-shaped) profile and many tributary valleys are hanging in relation to trunk valleys. Cirques are found at all elevations, from sea-level to 2,500 feet or more, and are oriented in all directions. Most of the low-level cirques are evident along the west coast. These are largely west facing and seem related to the main period of glaciation. Two generations of high-level cirques are evident; the main and larger ones have their floors at 1,500 to 2,000 feet elevation and are oriented in all directions. They seem related to the main glaciation by their continuity to catenary valleys. Out of the topography so formed, small high-level northeast-facing cirques or nivation hollows have been fretted with sloping floors from 2,500 to 3,000 feet elevation. In general, ridges and peaks below $3{,}000 \pm 200$ feet elevation have rounded or botryoidal (mammillary) shapes characteristic of ones overridden by significant ice masses, whereas peaks above this elevation all show to some degree spiky to matterhorn shapes. All these features can be seen in detailed topographic maps (1:50,000).

Smaller glacial features not evident on the detailed topographic maps include rock drumlins, fluting, roches moutonées, and striæ. These features as a group are widespread and indicate the main pattern of ice movement, which will be discussed later. Orientations measured in the field or on air photographs are shown on the geological maps (Fig. 5) and the glacial map (Fig. 2). Figure 3 is a diagram showing the movement pattern indicated by them. Rock drumlins are an intermediate-sized feature formed principally in shale facies of the Cretaceous Queen Charlotte Group chiefly on the Cumshewa Peninsula in the Skidegate Plateau. They show well on air photographs of logged-off areas but are scarcely recognizable on forested areas or on the ground. Flutings are of similar size but of more lineal nature and are gutter-like channels. They are widely distributed on the lowlands except on the Argonaut Plain and are most highly developed in the northwest corner of Graham Island in an area of folded sedimentary and dyke rocks of varying competency, where they occur between drumlinoid ridges. They are also present, impressed on till and unconsolidated sands and shales of the Late Tertiary Skonun Formation, in the area east of Masset Sound and south of the Argonaut Plain, and on relatively flat-lying lavas of the Early Tertiary Masset Formation west of the sound. Roches moutonées and striæ are present everywhere but are only preserved in soft rocks in special circumstances. The distribution shown on the map indicates their widespread formation and preservation at low elevations from Anthony and Kunghit Islands in the south to Langara Island and Masset Harbour in the north. Striæ have been recognized to 2,500 feet elevation near Mike Inlet, but their preservation under severe frost conditions at these elevations is rare. Roches moutonées, however, are very common to 3,000 feet and more in elevation. In some high passes in the San Christoval Range they indicate movement to the west.

Erratic boulders are distributed from Langara to Kunghit Islands and from west to east. However, they are absent on the Argonaut Plain except along the base of the bluffs of the east coast, where some are exhumed from the underlying till. Large erratics are not commonly observed at the higher elevations. The largest observed was a 6-foot-diameter erratic found near Skaat Harbour at about 1,500 feet. Along the wave-cut benches all around the island, large lag erratic boulders are common. From Skedans to Tlell the shore is covered by erratic boulders. The largest observed was one of Honna conglomerate, 14 by 20 by 25 feet, at Lawn Point lying on Masset basalt. Along the line of projected movement, the closest source is south of Alliford Bay 16 miles distant. The closest known source is 12 miles to the east across the movement grain. Granitic boulders resting on Masset basalt are common all along the north coast. Dawson (1880, p. 93B) thought these erratics foreign to the islands and attributed them to floating ice in spite of observing striæ on protected bedrock on the shore.

Ice Movement

The features just described indicate the direction of ice movement. The direction appears to have been fairly consistent during the whole glaciation, as judged by the close alignment of striæ with roches moutonées, rock drumlins, and flutings where these are observed in the same vicinity. The distribution of erratics is also compatible with the pattern indicated. This pattern shown on Figure 2 and shown diagrammatically on Figure 3 indicates that virtually all the ice traversing the islands was generated on them. In general the ice moved outward from an ice divide along the height of land. The ice flowing westward probably formed a small ice shelf,

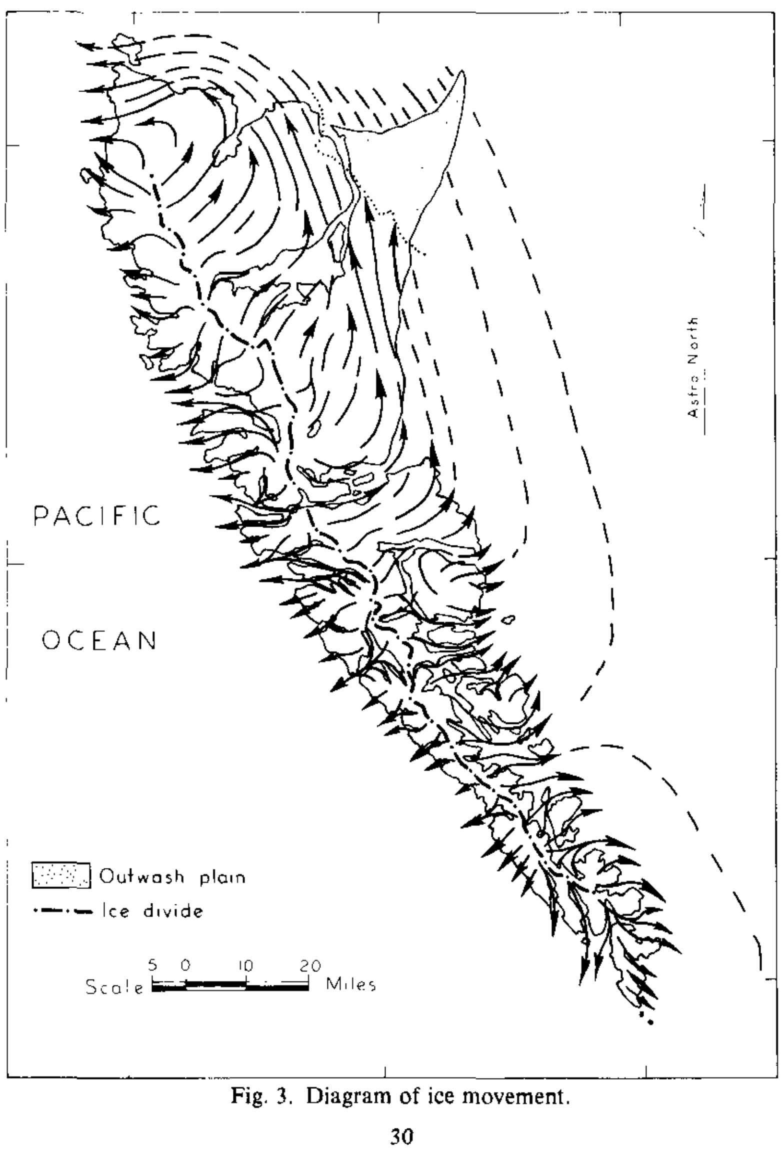


Fig. 3. Diagram of ice movement.

whereas that flowing eastward came into contact with the Cordilleran Ice-sheet in Hecate Lowland and as a result established an equilibrium with that mass. The natural flow of much of the Queen Charlotte ice would have been to the southeast in the direction of the topographic gradient had it not been forced through contact with mainland generated ice into the pattern shown. The actual flow was northwestward except south of Burnaby Island. The vigour of the Queen Charlotte icefield was such that equilibrium was established well off the present shoreline and mainland ice was diverted seaward through Dixon Entrance and Queen Charlotte Sound. At a maximum stage, back pressure from the equilibrium established appears to have built up a field deep enough to partly force extrusion through the passes of the original ice divide toward the west. At this stage a true icefield 3,000 feet or more above present sea-level existed, with only minor snow-clad nunataks protruding above the surface. Major ice shelves formed seaward of Langara and Kunghit Islands.

Glacial Deposits

Glacial deposits consisting of till, marine drift, and stony clays and outwash sands are distributed throughout the islands from Langara Island to Rose Point to Kunghit Island. Along the bluffs from Tlell to the Oeanda River, these deposits are fairly continuously exposed (*see* Plate Xc), revealing a stratigraphy that the scattered good exposures throughout the islands confirm. The bluffs provide the type section.

The stratigraphy of the bluffs is complex in detail but can be reduced to four main members: A lower marine till unit (1), a central sand unit (2), an upper till unit (3), and an uppermost sand unit (4). Figure 4 shows three composite sections illustrating the stratigraphy. The lowest member (1) is composed chiefly (50 to 70 per cent) of dense grey stony silt that contains pebbles, cobbles, and rare boulders, and also a marine fauna of foraminifera and rare dwarf invertebrates. True boulder till comprises some 30 per cent of the unit and occurs in small lenses and extensive beds. Varved or laminated silts and clay form 10 to 20 per cent of the unit and commonly are deformed by décollement folds. The thickest section exposed, about 55 feet, is at Cape Ball. Commonly the member has a laminated silt at the base with an overlying till followed by a thin contorted laminated silt and finally a fairly thick stony silt with some till lenses. The central sand unit (2) is composed of well-bedded grey sands, and cross-bedded sands and minor fine gravel. It is 10 to as much as 40 feet thick at Cape Ball. The upper till (3) is entirely a grey compact sandy lodgement till. It contains common striated boulders up to 1 foot in diameter and 30 to 50 per cent of material coarser than sand. Near Mayer River it is continuous and up to 35 feet thick, but toward the bight north of Cape Ball it becomes thin and discontinuous. The uppermost sand unit (4) is composed wholly of light-yellow outwash sands and gravels, which occur in well-bedded horizontal sets containing prominent internal cross-beds. It is 65 feet or more thick in the vicinity of Eagle Hill. Sands 5 feet or so thick on the top of the higher cliffs near Mayer River above the upper till unit may be equivalent.

At the bight north of Cape Ball an ice contact front was established, and here the stratigraphy is particularly complicated. The lower marine till unit is as always, except the laminated clays are particularly contorted. The central sand unit (2) contains lenses of stony clay, gravel, and minor till, but there is no continuous upper till unit (3). From a point about a mile north of the bight to the Oeanda flood plain, the section consists only of the lower marine till unit and a thick exposure of

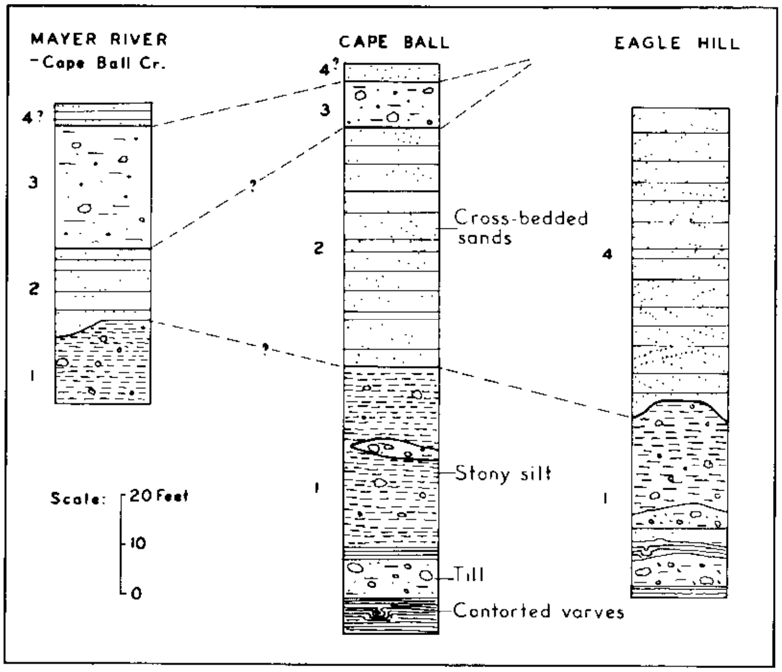


Fig. 4. Composite sections, Pleistocene deposits on northeastern Graham Island.

cross-bedded sands (4). The glacial deposits of the bluffs are cut by channels of late-glacial to Recent age (*see* p. 35). These channels make it difficult to determine whether in fact the central sand unit (2) is a tongue of the main upper sand unit (4) or whether it is separate and truncated by unit 4. The former is considered most likely and is shown on Figure 4.

Elsewhere in the Queen Charlotte Islands, till is widely distributed but, except in road cuts and some stream banks, is not well exposed. Nowhere have any definitely marine deposits been seen much above present sea-level. In many parts of Moresby Island, road cuts expose two distinct tills that differ significantly in fabric, colour, or principal constituent boulders. Rarely are the tills separated by sands, and both appear equally fresh. On Graham Island near Juskatla on the Mamin River there is a good exposure in which 18 feet of sandy till is overlain by 6 to 10 feet of thinly bedded stony clay that is contorted near the top and then by 12 feet of till that is almost all gravel at the bottom. This is overlain by 6 feet of gravel. At the entrance to Naden Harbour a thick exposure of stony silt contains lenses of till and is cut by a channel related to post-glacial high sea-level. Near the mouth of Watun Creek on the road, till and stony silts overlie 10 feet of well-bedded clay above shelly sands. The contact between Pleistocene and the unconsolidated marine Pliocene of the Skonun Formation is difficult to locate in the small cut banks along Masset Sound and equally difficult in well cuttings.

PALÆONTOLOGY AND AGE

The only fossils collected in Pleistocene deposits are from a locality on the shore north of Eagle Hill at the end of the bluffs near the Oeanda flood plain. Here a few dwarfish invertebrates and abundant forams were collected from the lower marine till: 61AB151 and 61AB153 from the main lower bouldery grey stony clay (1), and 61AB152 from a sandy stony clay (1) overlying this and in turn overlain by outwash sands of the uppermost unit (4). The forams were identified by Dr. Roberta K. Smith and the invertebrates by Dr. Frances J. E. Wagner, of the Geological Survey of Canada.

61AB151—*Cardium* sp.
Lunatia pallida Broderip and Sowerby

	61A153	61A152
Astrononion gallowayi	Rare	
Buccella frigida		Rare
Buccella tenerrima	Few	Rare
Cassidulina barbara (=*C. islandica*)	Few	Common
Cassidulina norcrossi	Rare	
Cassidulina teretis	Rare	Few
Cibicides lobatulus	Rare	Rare
Elphidiella arctica	Rare	
Elphidiella nitida	Rare	
Elphidium bartletti	Rare	Rare
Elphidium clavatum	Abundant	Abundant
Elphidium frigidum	Rare	Rare
Epistominella pacifica	Rare	
Epistominella vitrea	Rare	Rare
Fissurina lucida	Rare	Few
Fissurina cf. *F. marginata*	Rare	
Fissurina sp.	Rare	
Globigerina bulloides	Rare	Few
Globigerina pachyderma	Rare	Rare
Lagena gracillima	Rare	Rare
Lagena setigera?	Rare	
Nonionellina labradorica	Rare	
Oolina borealis?		Rare
Oolina melo		Rare
Protelphidium orbiculare	Rare	Rare
?Pseudopolymorphina charlottensis	Rare	
Quinqueloculina akneriana bellatula	Rare	Rare
Quinqueloculina stalkeri	Rare	Rare
Trifarina fluens	Rare	Rare
Triloculina inornata	Rare	Rare
Triloculina trihedra	Rare	

According to Roberta Smith, the foraminiferal fauna indicates a shallow marine cold-water environment of normal salinity with connection to the open ocean. The age indicated is Late Pliocene to Recent.

The age of the glaciation may be judged to be late Pleistocene by the freshness of the erosional features and the unweathered nature of the glacial deposits. This is confirmed by the one radiocarbon age available on material that might closely date the end of glaciation and by the radiocarbon age of shells related to post-glacial high sea-level (*see* p. 36). Regarding the first, Broecker and Kulp (1957, p. 1325) state: " Sample of limnic peat at a depth of 6.6 m in muskeg on Langara Island. Pollen profiles reveal a very early postglacial record. The sample should closely date the retreat of the Cordilleran ice from the ocean border. Submitted by C. J. Heusser. Age (yr) 10,850±800."

The correlation with glacial stratigraphy and chronology of southwest British Columbia and northwest Washington must await further work, but it is virtually certain the glaciation is equivalent to the Fraser (Wisconsin) glaciation (Armstrong, *et al.*, 1965, pp. 321–330). The interesting question is whether the upper till is equivalent to the Sumas drift or not.

Deglaciation

During the late stage in which the upper till was being deposited, an extensive outwash plain, the Argonaut Plain, was built up northeast of a fairly stable ice front extending from Masset to Cape Ball. Two to four hundred feet of sand and gravel was laid down in a complex braided system of channels and flat-topped interfluves that shows well on the air photographs and is represented on the glacial map. The drainage was toward the northeast normal to the front, and an extensive sand delta was built into Dixon Entrance (Mathews, 1958). Sea-level initially was lower than at present, judged by channels cut in the older marine drift and filled with these sands. Bars built of moraine and outwash at the entrance to Cumshewa and Skidegate Inlets may have resulted from a stillstand during earlier withdrawal before the readvance to the Masset-Cape Ball front.

Summary of Glacial History

Much detailed work by specialists would be necessary to form an adequate idea of the glacial history, and this summary will be subject to revision. No definite evidence of pre-Fraser glaciation has been found. The earliest phases of Fraser glaciation are not exposed on the northeast bluffs. It would seem that an intense glaciation more than covering the islands was followed by a period during which extensive marine glacial drift was laid down. Glaciers then retreated and the Cordilleran and Queen Charlotte Islands sheets disengaged. Retreat on the Queen Charlotte Islands may have been to a line from Kumdis Island to the entrance of Skidegate and Cumshewa Inlets. This was followed by a readvance to the line of the ice contact front, and the Argonaut Plain was constructed. After a period of stability, retreat and wasting were probably rapid, but valley glaciers from the higher mountain masses probably existed for some time building small moraines that eventually formed dams creating Yakoun and Mosquito Lakes, etc. Even later the small high-level cirques were formed, most likely during the Little Ice Age (Neo-Pleistocene).

Post-glacial Sea-levels

During the Fraser glaciation there were wide fluctuations of sea-level in relation to the present shoreline because of world-wide or eustatic changes (Shepard, 1964, pp. 574–6) and more local glacial loading and rebound. At the close of the glaciation, channels filled with outwash of the Argonaut Plain indicate sea-level was lower than at present during this deposition. That it was also lower when the ice-sheet had retreated is shown by three former channels of Cape Ball Creek evident between the present mouth and the bight north of Cape Ball. It is also likely that Masset Sound was cut as a river at this stage. Depths in Masset Sound of the order of 100 feet below sea-level are common.

Sea-level must have risen fairly rapidly, and the sluggish channels such as Cape Ball Creek were filled with estuarine deposits to a height some 20 feet or so above present sea-level. Masset Sound remained open because it connected elevations below present sea-level and was subject to a vigorous flush of tides. Two generations of features of slightly different elevation and age are apparent in some localities, but most cannot definitely be distinguished. The estuarine flat of Cape Ball Creek and the flat from Yakan Point to Argonaut Hill are representative of the older slightly higher features. On the Yakan-Argonaut Hill flat a scroll of ancient beach ridges is clearly older than the series from Tow Hill to Rose Point. The approximate elevation of this flat is 25 feet above mean sea-level. Scrolls of beach ridges at Masset and Sandspit also seem to be of two ages, but most of the erosional features cannot be certainly distinguished as to age.

Marine fossils collected from the Cape Ball estuary flat 10 feet above present high sea-level were in the living position and are typical of lower tidal levels, therefore sea-level was at least 25 feet above present mean sea-level. Marine fossils in situ 10 to 20 feet above sea-level were also collected on a creek in Tasu Sound and were observed at Lockeport. Dawson (1880, pp. 94B–95B) collected shells at similar elevations at Naden Harbour and Mamin River in Juskatla Inlet. The following were collected on the creek south of Edwards Creek flowing into Barrier Bay, Tasu Sound:—

62AB148—*Ostrea lurida* Carpenter
Chlamys hindsi (Carpenter)
Hinnites multirugosus Gale
Pododesmus macrochisma (Deshayes)
?*Glans minuscula* Grant and Gale
Lucina acutilineata Conrad
Clinocardium sp.
Protothaca staminea (Conrad)
Saxidomus giganteus (Deshayes)
Macoma nasuta (Conrad)
Gastrana irus (Hanley)
Acmæa mitra Eschscholtz
Diodora aspera (Eschscholtz)
Astræa gibberosa Dillwyn
Trichotropis cancellata Hinds
Bittium
Fusinus barbarensis (Trask)
?*Balanophyllia elegans* Verrill

On the ancient estuary of Cape Ball Creek the following were collected:—

62AB184—*Saxidomus giganteus* (Deshayes)
Platyodon cancellata Conrad
Zirfæa pilsbryi Lowe
Lacuna carinata Gould
?*Trichotropis* sp.
Neptunea lyrata Gmelin
Balanus sp.

Frances J. E. Wagner stated in comment: "These are all shallow water, marine species. The medium-of-midpoints calculation (H. G. Schenck and A. M. Keen: Amer. Philos. Soc., Proc., vol. 77, No. 2, pp. 162–165, 1937) shows samples 62AB7, 62AB47 and 62AB184 to be indicative of water temperatures similar to those prevailing in the region at present. Sample 62AB148 pointed to much warmer conditions, i.e. comparable to those of the Tillamook Bay area of Oregon." Radiocarbon dates for the two samples were performed by the Geological Survey of Canada with the following results:—

GSC-242	8620±150 yr.	62AB184, Cape Ball Creek
GSC-292	8060±140 yr.	62AB148, Tasu Sound

Dr. J. G. Fyles added in comment, "the temperature contrast between 62AB148 and 62AB184 is surprising in view of their similar radiocarbon ages," and he speculated that it might result from the Tasu waters being from the open Pacific in contrast to Hecate Strait.

A feature still younger than the main ones related to high sea-level are wave-cut rock benches that are approximately at present high sea-level. These are normally only apparent in soft or friable rocks. Dawson (1880, p. 96B) speculated that the high level of these benches resulted from protection of the rocks by luxuriant growth of seaweed and shells, but it almost certainly represents a fairly recent small uplift for it is barely awash at highest storm tides.

Glacial Refugia

Biologists of many specialties have thought the Queen Charlotte Islands were either unglaciated, only partially glaciated, or unglaciated in the latest stage. The writer with Hugh Nasmith (1962) considered the problem from the geological point of view. There is little to add now. Clearly nunataks existed at the maximum stage of glaciation, and some steep western slopes between valleys may have been open but others developed cirques with bases at sea-level. In any case the climate would have been a severe arctic one and would not have been a hospitable environment for much of the flora and fauna that is believed to have been preserved.

CHAPTER 3

General Geology

The Queen Charlotte Islands form the northern part of the Insular Tectonic Belt of the Canadian Cordillera. As such they have a stratigraphic and tectonic history very similar to that of Vancouver Island but with differences of timing and facies which become progressively more important from the beginning of the mid-Jurassic.

In the Queen Charlotte Islands, rocks ranging in age from Late Triassic to Recent are exposed. Volcanic rocks dominate the stratigraphic column, but they are widely intercalated with fossiliferous marine sedimentary rocks so that a fairly complete stratigraphic record exists. There were three major periods of volcanism separating four main periods of sedimentation. Plutonism occurred in two main periods. Deposition was more or less continuous from Late Triassic to Late Jurassic, during which time a great pile of submarine basalts was erupted, followed by deposition of a thick limestone and flaggy flysch sequence, and terminated by the second volcanic episode of explosive andesites. The Late Jurassic was a time of major deformation, syntectonic plutonism, and probably uplift and erosion. The second sedimentary episode occurred in the Early Cretaceous, and again flysch-like sediments were deposited in local marine troughs. Further faulting and deformation preceded deposition of the third sedimentary sequence, a molasse-like marine sequence of Albian to Turonian age or younger. The Late Cretaceous was another period of faulting and local folding and uplift. The third volcanic sequence was erupted subaerially in the Early Tertiary and was followed by faulting, post-tectonic intrusion, uplift, and erosion, and coincident with the later deposition of the last sedimentary sequence in the Late Tertiary.

The volcanic, sedimentary, and plutonic rocks have all undergone an evolutionary development with time that in part is parallel and interrelated; they all trend from basic to acid, from quartz poor to quartz rich. The volcanic sequence trends from oceanic tholeiitic basalts through porphyritic andesites to plateau basalts and rhyolitic ash flows. The sedimentary trend shown by the arenites is from quartz-free lithic sandstones to quartz-rich feldspathic sandstones. The plutonic trend is from mafic-rich hornblende diorite to quartz diorite in the syntectonic intervals and from quartz diorite to quartz monzonite and soda granite in the post-tectonic interval. The following table of formations summarizes the stratigraphic nomenclature, chronology, lithology, and key fossils:—

TABLE I.—TABLE OF FORMATIONS FOR QUEEN CHARLOTTE ISLANDS

Era	Age	Stratigraphic Units (Thickness in Feet)		Lithology	Fossils	Intrusive Rocks
Quaternary.	Recent.			Alluvium, organic terrain.		
	Pleistocene.		500±	Marine stony clays, till, outwash sands and gravel.		
	Disconformable to unconformable on Skonun Formation.					
	Pleistocene or Recent.	Tow Hill sills.	200–350	Olivine basalt.		
	Intrusive.					
Tertiary.	Pliocene. Miocene?	Skonun Formation.	6,000±	Marine to non-marine calcareous sandstones to poorly lithified sands, shaly mudstones; minor conglomerate, lignite.	Extensive flora and fauna.	
		Unconformable, possibly interfingering with top of Tartu facies.				
		Masset Formation.	Dana Inlet facies. 5,000+	Submarine? pyroclastic breccias of mixed basic and acid clasts, related volcanic sandstones, lesser porphyry and rhyolite flows.		Post-tectonic batholiths emplaced
			Kootenay Inlet facies. 4,000+	Subaerial rhyolitic ash flow tuffs and tuff breccias, dacitic flows, minor columnar basalt flows.	Wood.	
			Tartu Inlet facies 18,000±: Basalt member. TMC 5,000+	Columnar basalt flows, minor basaltic and acidic pyroclastic rocks.		
			Tartu Inlet facies 18,000±: Rhyolite member. TMB 5,500–7,000	Rhyolite, ash flows, minor columnar basalt flows.		
	Paleocene.		Tartu Inlet facies 18,000±: Mixed member. TMA 6,000–6,500	Basalt breccias and columnar flows, rhyolite air fall and ash flow tuffs and flows?	Age (K–A) on mica in a related sill. Wood.	Feldspar porphyry and gabbro plugs, etc.
	Unconformable contact with all older units.					
Upper Cretaceous.		Queen Charlotte Group. Skidegate Formation.	2,000+	Well-bedded, intercalated, grey shaly siltstone, feldspathic sandstone, and buff-weathering calcareous siltstone.	*Inoceramus* sp.?	
		Conformable contact.				
		Queen Charlotte Group. Honna Formation.	1,300–4,000	Polymictic roundstone conglomerate with granitic cobbles, arkosic grits; shale and sharpstone conglomerate.	*Inoceramus* sp.?	
		Seemingly conformable, probably interfingering to unconformable.				
	Turonian. Cenomanian.	Queen Charlotte Group. Haida Formation. Up to 3,775.	Shale member. 1,075	Grey shale and siltstone, calcareous concretionary shale and siltstone, thin green tuffaceous interbeds.	*Inoceramus labilius?* *Desmoceras (Pseudouhligella) japonicum.*	
	Albian.		Sandstone member. 2,700	Green sandstone, glauconitic wacke, grey sandstone and siltstone, buff concretionary calcareous siltstone, rare pebbly sandstone; basal black and white granule beds.	*Desmoceras (Pseudouhligella) dawsoni.* *Mortoniceras.* *Cleoniceras (Grycia) perezianum.* *Douvilleiceras spiniferum.* *Brewericeras hulenense.* *Leconteites lecontei.*	Syntectonic batholiths exposed.

Contact with Longarm Formation not recognized, highly unconformable on all older units.							
Lower Cretaceous	Barremian and Hauterivian, Late Valanginian.		Longarm Formation. 4,000+		Dominantly dark-grey calcareous siltstone and fine lithic greywacke with *Inoceramus* prisms, basal angular granule beds with roundstones to conglomerate, dark-brown weathering calcareous greywacke, some volcanic rocks.	*Heteroceras.* *Inoceramus quatsinoensis.* *Inoceramus colonicus.* *Simbirskites.* *Craspedodiscus.* *Buchia crassicollis.*	
Conformable to unconformable on Yakoun Formation, highly unconformable to all older units.							
Middle Jurassic.	Callovian.	Vancouver Group.	Yakoun Formation.* 3,000–6,000 (*Highly variable. Type section used.)	E member. 455	Volcanic sandstone, shale, calcareous siltstone; rare pebbly volcanic sandstone.	*Kepplerites.* *Cadoceras.* *Chondroceras?*	Syntectonic batholiths emplaced.
				D member. 800	Tuff, lapilli tuff, crystal tuff, cross-bedded tuffaceous sandstone, pebbly sandstone.		
				C member. 950	Porphyritic andesite agglomerate and crystal tuff.		
				B member. 100+	Shale, tuffaceous shale, and sandstone.	*Stephanoceras.* *Chondroceras.*	Related dykes and sills.
	Bajocian.			A member. 650	Calcite-cemented scoriaceous lapilli tuff.		
			Conformable to slightly unconformable, and intrusive.				
Lower Jurassic.	Toarcian. Pliensbachian.		Maude Formation.	Up to 600	Interbedded grey shale, blocky dark-grey argillite, light-grey calcareous shale, greenish-grey lithic sandstone.	*Harpoceras propinquum.* *Fanninoceras* cf. *kunæ.* *Tropidoceras.* *Eoderoceras* cf. *armatum.*	
			Conformable contact.				
	Sinemurian.		Kunga Formation. Up to 3,400.	Black argillite member. Up to 1,900	Flaggy, graded lithic black argillite, siltstone, and shale; light-grey bioclastic limestone; minor dark-grey lithic sandstone.	Arnioceratids.	
Upper Triassic.	Norian.			Black limestone member. 700–900	Flaggy black carbonaceous limestone, shaly and silty limestone, calcareous argillite, some grey cross-bedded or bioclastic limestone.	*Monotis subcircularis.* *Discophyllites.* *Halobia.* *Homerites, Juvavites.*	
	Karnian.			Grey limestone member. 100–600	Massive grey-weathering limestone, some cherty limestone, clastic limestone, some well bedded.	*Aulacoceras, Arcestes.*	Greenstone sills?
			Conformable contact.				
			Karmutsen Formation.	14,000+	Basalt pillow lavas, pillow breccias, aquagene tuffs; massive basalt flows and sills; minor interlava limestone, less volcanic sandstone and shale; metamorphic equivalents, mostly fine amphibolites.	Crinoid columns.	Related dykes and sills.

STRATIFIED ROCKS

Vancouver Group

The Vancouver Group in the Queen Charlotte Islands includes the Karmutsen Formation, the Kunga Formation, the Maude Formation, and the Yakoun Formation. It is predominantly a volcanic assemblage and, with the exception of a small part of the Yakoun Formation, it is marine. The Karmutsen Formation is a thick accumulation of basaltic pillow lavas and related rocks. It is overlain by two sedimentary units, the Kunga Formation of limestone and argillite and the thin Maude Formation of argillite. The uppermost unit, the Yakoun Formation, is again dominantly a volcanic unit, but is much more variable that the Karmutsen Formation. The Yakoun is dominated by pyroclastic rocks, contains many volcanic sandstones and other clastic sedimentary rocks, and is primarily andesitic and porphyritic. Thus the Vancouver Group contains a widely assorted assemblage of rocks with discrete units of dissimilar nature. The most widespread characteristics, basic to intermediate volcanic nature and marine origin, are not universal, hence the writer was of the opinion that the unit should be abandoned. However, the consensus among geologists concerned with these rocks is that the group should be maintained for the present because of its continuity over a large area. The emphasis in this report is on the separate formations rather than the group.

The Vancouver Group was originally named by Selwyn (1872, pp. 52 and 63) the Vancouver Island Crystalline Series. It was further defined by Dawson (1887, p. 10B) as follows:—

"As a convenient distinctive name for the whole, I shall employ the term *Vancouver Series,* including for the present under this name, not only the entire mass of volcanic materials which unconformably underlie the Cretaceous, but also the interbedded limestones and flaggy argillites and quartzites. This name may also be understood to include the similar beds of the Queen Charlotte Islands, as well as those of the southern part of Vancouver Island, to which it was originally applied by Dr. Selwyn in 1871. If this great mass of rocks should eventually prove separable into Triassic and Carboniferous portions, I would suggest the retention of the name Vancouver series for the former."

Karmutsen Formation

The Karmutsen Formation is a thick accumulation of submarine basic lavas, related clastic rocks, dykes, and sills, and minor limestone. The formation was named Karmutsen volcanics by Gunning (1932, p. 23) and was applied to volcanic rocks below the Quatsino Limestone that were well exposed in the Karmutsen Range of northern Vancouver Island. There is little doubt that the rocks on the Queen Charlotte Islands are the correlatives of those on Vancouver Island.

The Karmutsen Formation is extensively exposed on Moresby and adjacent islands but is rare on Graham Island. The distribution is shown in the diagram, Figure 7. The thickest exposures are between Skidegate and Inskip Channels and along the axis of the Queen Charlotte Ranges from Juan Perez Sound to Lyman Point. The stratigraphy is imperfectly known, but the formation appears to be more than 14,000 feet thick. The base has not been seen. It is conformably overlain by the Kunga Formation.

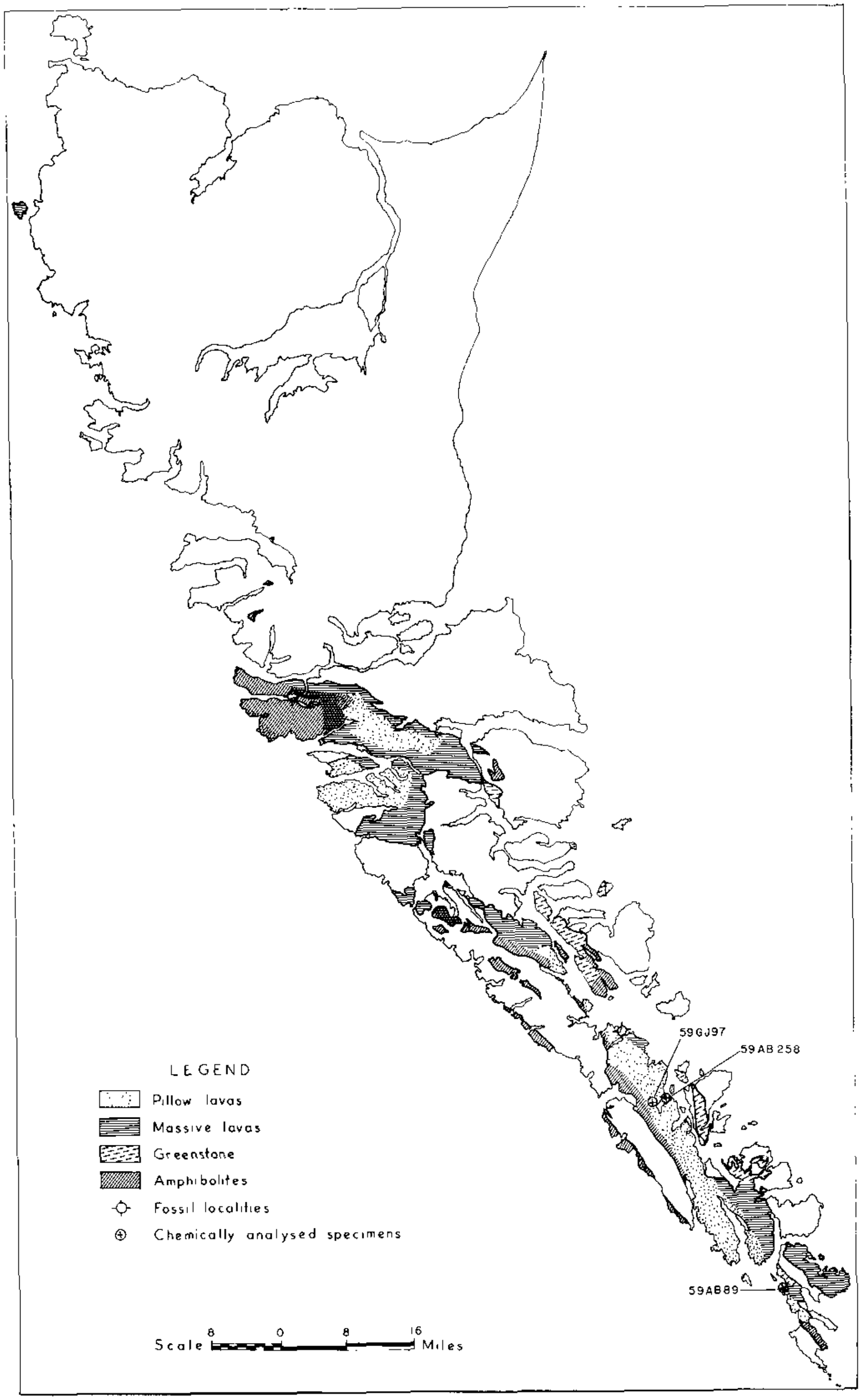


Fig. 7. Karmutsen Formation: Distribution, facies, and special localities.

Lithology.—In the Queen Charlotte Islands this formation is composed of basic volcanic rocks, related clastic rocks, and derived amphibolites and schists. Only a very minor part, much less than 1 per cent, is composed of limestone or exotic rocks. Much of the formation is composed of highly chloritized textureless basic volcanic rocks, greenstone. Much is also composed of massive amygdaloidal slightly chloritized basalt. However, even more of the formation is composed of basaltic pillow lavas, pillow breccias, and related aquagene tuffs (Carlisle, 1963), and these are regarded as the characteristic rocks of the formation (*see* Plate V).

At a distance or on casual inspection the rocks of the Karmutsen Formation appear as massive dark-green to greenish-black rocks that weather a mid reddish brown. Exposures on the seashore tend to be fairly fresh and faceted along the planes of numerous, closely spaced, randomly oriented fractures, whereas those of the uplands tend to be rounded and reddish brown. Closer inspection reveals wide textural variation and lesser mineralogical variation. The massive lavas are commonly amygdaloidal enough for bedding attitudes to be measured, but individual flows can seldom be recognized. In the greenstones, which have probably chiefly been formed from massive flows, neither attitudes, individual flows, nor significant textures can be discerned. In contrast the pillow lavas, aquagene tuffs, and broken pillow breccias are highly textured. The first two are well bedded, but the breccia is unstratified. Coarse basalts, diabases, and fine gabbros occur within the volcanic pile, and most of these probably are sills related to the flows, but definite criteria are seldom seen. Curiously, in the main pillow-lava assemblages, where recognition is most easy, relatively few dykes or sills exist. Many of the flow rocks are finely porphyritic, but coarse or prominent porphyries are rare. The exception is a persistent minor type, a basic porphyry or glomeroporphyry with prominent plagioclase phenocrysts arranged in radiating groups, in groups resembling Chinese characters, or in a semi-random arrangement crudely resembling herringbone tweed. Local descriptive names for such rocks include star porphyry, flowery gabbro, and tweed porphyry. These rocks generally seem to be sills, but in at least one instance they are known to be pillow lavas.

The pillow-lava assemblage that forms such an important part of the formation is composed of several related rock types. Pillow lavas are the most abundant type, broken pillow breccias are common, and aquagene tuff without pillows and isolated pillow breccias relatively rare. All these terms are used as defined by Carlisle (1963, pp. 49–63). Massive lavas form a small part of the pile in some areas but are important in others. From Flamingo Inlet to Werner Bay the pillow-lava assemblage is completely dominant. In this area about 70 per cent of the assemblage is pillow lava, 10 per cent broken pillow breccia, 2.5 per cent aquagene tuff without pillows, 4.2 per cent isolated pillow breccia, and about 13.3 per cent massive amygdaloidal " flows." About Moore Channel the proportions are similar, but massive lavas form about one-quarter of the exposed pile.

The pillows of the pillow lavas in most respects are similar to those described in classic areas (Wilson, 1960). Size in ellipsoidal pillows varies from a minimum of about 6 inches in long axis to about 6 feet. Balloon and bun shapes are most common, but in every extensive outcrop pillows occur that might be called bolsters but that more nearly resemble lava tubes (*see* Plate VA). Many of these, only 1 to 2 feet in section, are exposed over 20 feet before they are covered or eroded. Many of them bifurcate, some of them repeatedly. Ellipsoidal pillows were noted in some cases to be moulded not only to the shape of pillows below, but also to adjacent ones at the same depositional level. In such cases, pillows are rudely cuspate where they impinge against earlier deposited pillows but rounded on their " free " side. Sufficient detailed work in the Queen Charlotte Islands might establish the direction of initial slopes.

The pillows are not especially vesicular nor is the variation in grain size between rim and interior great. Pillows are generally tightly packed but may have minor interstices filled commonly with quartz or quartz, chlorite, prehnite, and pumpellyite. Some of the interstices are in fact breccias formed of peeled fragments of pillow rim with interstitial quartz. Radial or concentric joints are poorly developed. However, sets of three or four parallel internal quartz-filled joints are relatively common. These joints are planar lenses parallel to the plane of the two major axes of the pillows. Accurate dip measurements are much more easily made on them than on the pillows themselves. The joints as a group are centred in the pillow, extend at least half the length of the pillow, and are filled with 1 to 2 inches of quartz in the centre. They appear to be cooling-shrinkage joints formed after the pillows had sufficient strength to maintain their outer shape.

The broken pillow breccia, isolated pillow breccia, and associated aquagene tuff are identical to those fully described by Carlisle (1963, pp. 51 and 55) in correlative rocks at Quadra Island. " The isolated-pillow breccia is a non-stratified, unsorted mixture of whole volcanic pillows, varying widely in form and size, engulfed in a volcanic matrix which itself is a tuffaceous breccia." Broken pillow breccia " consists largely of disaggregated fragments of pillows set in the (tuffaceous) matrix." Aquagene tuff (and the tuffaceous matrices) is defined by Carlisle (1963, p. 61) as one " produced by globulation or granulation through quenching, or both, or by a similar process entirely beneath water or when lava has flowed into water or beneath ice." Characteristically they are laminated.

In the breccias, pillow fragments of very fine-grained basalt are "stony-looking" compared to the coarse tuffaceous matrix and commonly weather a brownish shade more readily than the matrix. The matrix for the breccias is entirely similar to the aquagene tuff without pillows, except that the latter is well stratified. Broken pillow fragments in the matrix and in aquagene tuff are also brown weathering, angular, and very fine grained. Apart from dust the remainder of the matrix is formed of originally glassy shards, globules, and granules that have a light green " reaction " rim about 0.2 to 0.5 millimetre thick and a very dark green interior. Some globules are partially cut by fractures, and these are bordered by double reaction rims. Stony pillow fragments and originally glassy fragments can be recognized to the limit of visibility in hand specimen. The thicker sections of aquagene tuff are well stratified with beds 6 inches to 2 feet thick separated by minor very fine laminated tuffs, which may exhibit fine cross-beds in cut and fill structures. Graded beds are usual in the main strata, and inversely graded sets are common (*see* Plate VB). The thickest tuff member recognized extends from Louscoone Inlet to Flatrock, and the Gordon Islands, where at least 75 feet of tuff rests on pillow lava.

Sedimentary rocks form an insignificant part of the Karmutsen Formation and are mostly of volcanic origin, including possibly the limestones (Kania, 1929). Limestone lenses are fairly common and widely distributed even though they are volumetrically unimportant. They are, however, rare in the thick sections of the pillow-lava assemblage. Most limestone is finely crystalline and textureless, and not very different from the overlying Kunga limestone. In two localities near the base of exposure (eastern Buck Channel and Werner Bay to De la Beche Inlet) tuffaceous crinoidal limestones occur. Here every gradation occurs between fairly pure limestone and pure lapilli tuff in 100 feet or so of strata. Other limestone lenses are a few feet to 200 feet or so thick. The lateral continuity of lenses is not great, but in the upper part of the formation lenses are found repeatedly at about the same horizons. In some localities, limestone lenses are found that have discordant attitudes with over-all gently dipping lava piles. In part these are believed to be rafted blocks.

Fine green tuff-like rocks are found intercalated with limestone and greenstone or massive lavas. They are uniformly fine grained, and though they may be well banded with slight differences in colour, they are dense and not fissile. Graded beds are not evident, nor are reaction rims on clasts. Thus these rocks are unlike the aquagene tuffs in most of their characteristics. They are best displayed at Shuttle Island and Darwin Sound but occur elsewhere. Interlava volcanic sedimentary rocks of entirely local derivation look similar to these rocks but less banded. They may be fairly common though minor, but are difficult to recognize.

Shales or other rocks of terrestrial origin are virtually absent, but in the lower part of the formation exposed from Werner Bay to De la Beche Inlet along Juan Perez Sound some occur near the tuffaceous crinoidal limestone.

Considerable areas of the Karmutsen Formation have been metamorphosed in varying degrees so that relatively little of the original textures remain (*see* Fig. 7). The chloritized textureless greenstone may represent the lowest expression of this metamorphism and coarse amphibolites the highest. The amphibolites are commonly fine grained, black rocks normally rather structureless, though some are finely foliated. Fairly regularly spaced blobs of quartz indicate in some that they were originally pillow lavas, the quartz being that of the interstices. In many localities an alternation of fine- and medium-grained amphibolites may reflect original differences in grain size between sills and flows. In other localities every variation occurs from fine-foliated amphibolities with minor basic pegmatites to true migmatites. Fine amphibolites and amphibolitic migmatites border all the syntectonic batholiths and in addition occupy most of the peninsula between Inskip and Skidegate Channels. Coarse amphibolites are rarer, being mostly in the pendant septum between the San Christoval and Pocket batholiths. Schistose greenstones are found only along major fault zones.

Microscopy.—The Karmutsen Formation is composed overwhelmingly of basalts with uniform composition but considerable variation in macroscopic and microscopic texture. The correlation between macroscopic and microscopic types is excellent, and the chief categories are as follows:—

(1) Very fine nearly holocrystalline basalts with insertal textures=pillow lavas.

(2) Fine diabase with sub-ophitic textures=massive and amygdaloidal lavas, dykes, and sills.

(3) Breccias and tuffs of mixed sideromelane and basalt fragments=broken pillow breccias and aquagene tuffs.

(4) Basaltic breccias, sandstones, and siltstones=interlava sedimentary rocks.

In addition:

(5) Limestone and silty or tuffaceous limestone, a consistent minor part of the unit.

The following table lists the modes of pillow lavas and diabases:—

PILLOW LAVA

	Average of 4
Chloritic phenocrystic pseudomorphs	3.2
Plagioclase	41.8
Pyroxene	31.8
Iron ores	2.7
Semi-opaque matter	19.4
Amygdules (chlorite)	1.2
	100.1

DIABASE

	Average of 8
Phenocrysts—	
Plagioclase	2.9
Pyroxene	0.2
Matrix—	
Plagioclase	43.5
Pyroxene	27.8
Chlorite	18.7
Iron ores	7.1
	100.2

(1) The pillow lavas have textures grading from intersertal to sub-ophitic with randomly oriented plagioclase laths with pyroxenes in part intergranular and in part in sub-ophitic relation. In addition there are minor chloritic phenocrysts pseudomorphic after pyroxene or possibly olivine and intergranular dark-brown semi-opaque, originally glassy material. If distinct iron ores are present, they occur within the semi-opaque devitrified matter. This matter may now be composed mostly of fine chlorite and chlorophaeite or, in slightly metamorphosed specimens, mostly of amphibole. Plagioclase laths average about 0.3 millimetre long and pyroxene crystals about 0.1 millimetre in diameter. Plagioclase may be either calcic labradorite in least altered specimens or oligoclase in more altered specimens. The pyroxene is most commonly pigeonite. Amygdules are rare, small, and commonly chlorite filled.

(2) The diabases are similar but differ in grain size and details of texture and mineralogy. Phenocrysts or glomerophenocrysts of plagioclase seem more common than in the pillow lavas, and pyroxene phenocrysts are common in a few specimens. Sub-ophitic textures are commonest and plagioclase laths are about 1 millimetre long with pyroxene crystals about 0.5 millimetre in diameter. In some specimens, plagioclase is zoned over the whole range of labradorite, but in most it is oligoclase and relatively unzoned. Both pigeonite and augite occur in most specimens, some with a mantled relationship, but augite alone occurs in other specimens. Amygdules are normally present, and in least altered specimens are mostly composed of chlorite or quartz and chlorite; however, pumpellyite, prehnite, and clinozoisite are all common. In addition to rounded amygdules, there are present in most specimens small intergranular irregularly polygonal areas of chlorite. These are relatively free of other minerals or impurities. They commonly showed a zoned growth with a uniform rim and a central area of rosettes or bladed growth toward a central divide. They represent either small crystal-bounded amygdules or, less likely, clots of devitrified glass. Iron ores are more coarsely crystalline and may be in skeletal crystals, not uncommonly partially altered to leucoxene.

(3) Pillow breccias and aquagene tuffs are identical microscopically, except that the breccias contain coarser fragments and are unstratified, whereas the tuffs are composed of fragments generally less than 5 millimetres in diameter which normally occur in graded beds. Both are composed of mixtures of two types of fragments, which will be called basalt and sideromelane respectively. Sideromelane fragments characteristically are shard-like particles with pronounced reaction rims of fairly uniform thickness parallel to the exterior. Four bands and an interior area are present in the larger fragments. These are a peripheral clear colourless band, a clear greenish-yellow band, a brown semi-opaque band, a second clear yellow band, and an interior zone of light-brown semi-opaque matter in some instances showing crude spherules with extinction crosses. Individual bands other than the interior are 0.05 to 0.1 millimetre thick. They may be distorted inward along cracks or about microphenocrysts. The crystallinity of the sideromelane is rudimentary, but some seems to be composed of fine chlorite. Microphenocrysts and glomerophenocrysts of bytownite and pigeonite form perhaps 5 per cent of the larger fragments. The shape of the fragments is shard-like unmodified by comminution, and rarely showing any evidence of compression or flow. Exterior cuspate shapes of broken vesicles are common. The fragments in breccia and tuff are compactly arranged with relatively little interstitial dust. Some open cavities originally existed filled later by quartz, chlorite, or rarely prehnite. The basalt fragments have a similar content of similar phenocrysts set in a dark-brown semi-opaque matrix with some microlites of feldspar. The fragments are angular but

not shard-like, and there are no banded reaction rims. Crystal fragments form a small part of the finer fraction of both tuffs and breccia. Characteristically the feldspars of basalt and sideromelane fragments and crystal fragments in the matrix are almost completely fresh in contrast to those of normal basalts and diabases. All these features are shown on Plate XIIIB, which is a negative projection of a thin-section.

(4) Basaltic sandstone and siltstone are characteristically different than the aquagene tuffs in that they contain no sideromelane but are composed wholly of basalt and diabase and crystal fragments. Normally they are bedded but not in graded sets. Some specimens thought to be fine basalt lava or greenstone in the field were shown to be basaltic sandstones on microscopic inspection.

(5) Limestones of the Karmutsen differ from the lower member of the Kunga Formation only in that some of them are less pure, containing a complete range in quantity of clastic volcanic fragments. Such impure or tuffaceous limestones are more characteristic of members in the lower part of the formation than in the upper.

Progressive grades of alteration of the volcanic rocks are apparent, with the commonest alteration being simply a partial chloritization of plagioclase and pyroxene. The common greenstones of the formation are apparently mostly formed from diabases. More intense alteration with growth of clinozoisite, prehnite, and pumpellyite first in amygdules and later in matrix and phenocrysts is apparently intermediate spatially and in grade to the amphibolitic basalts. The appearance of significant quantities of actinolite or hornblende replacing the mafic minerals or cryptocrystalline matrix may not significantly change the macroscopic appearance, and rocks classed as amphibolites and described under metamorphic rocks (p. 140) are of a yet more intense grade of metamorphism.

Chemistry.—The chemical composition of two relatively fresh pillow-lava specimens and one aquagene tuff is shown on Table II. Also shown are the averages of the two pillow lavas, of all the three specimens, the modes of the pillow lavas, and an average oceanic tholeiitic basalt (Engel *et al.*, 1965, p. 731). The aquagene tuff is composed of fragments less than 3 millimetres in diameter with not more than 20 per cent basalt fragments, the remainder sideromelane fragments with some crystals and matrix. Of the two pillow lavas, 59GJ97 is the freshest and contains unaltered labradorite feldspar, pigeonite, and iron ores. Specimen 59AB89 appeared as fresh in hand specimen, but the plagioclase is oligoclase, the iron ores are altered to leucoxene, and the microphenocrysts to a mixture of chlorite, clinozoisite, and carbonate. Though altered, this specimen is fairly representative of the pillow lavas as they are at present.

The main difference between Karmutsen analyses and Engel's *et al.* average oceanic tholeiitic basalt is in the markedly higher iron and lower magnesia in the Karmutsen. This may be a factor in the origin of the associated magnetite deposits (*see* p. 171).

TABLE II.—CHEMICAL ANALYSES AND MODES, KARMUTSEN FORMATION

	1* 59GJ97	2* 59AB89	3* 59AB258	4	5	6
SiO_2	49.20	52.92	47.22	51.06	49.78	49.94
TiO_2	1.89	2.00	1.87	1.94	1.92	1.51
Al_2O_3	13.52	12.30	14.81	12.91	13.54	16.69
Fe_2O_3	5.11	1.98	2.71	3.54	3.27	2.01
FeO	9.42	9.62	10.04	9.52	9.69	6.90
MnO	0.17	0.20	0.20	0.19	0.19	....
MgO	6.62	3.71	6.55	5.16	5.63	7.28
CaO	10.74	8.89	8.02	9.82	9.22	11.86
Na_2O	1.86	4.50	6.76	3.20	4.38	2.76
K_2O	0.28	0.03	0.52	0.15	0.28	0.16
H_2O-	0.28	0.29	0.84	0.28	0.47	....
H_2O+	0.63	3.02	0.21	1.82	1.29	....
CO_2	0.09	0.27	0.18	0.18	0.18	....
P_2O_5	0.16	0.14	0.15	0.15	0.15	0.16
SO_3	0.007	0.007	0.031	0.007	0.015	....
Totals	99.977	99.877	100.381	99.927	100.095	99.27
Fe_2O_3/FeO	0.54	0.21	0.27	0.37	0.34	0.15
Na/K	6.6	150.00	13.00	21.00	15.60	16.00

MODES, KARMUTSEN PILLOW LAVAS

	1 59GJ97 (Volume per Cent)		2 59AB89 (Volume per Cent)
Phenocrysts	.....		1.1 (altered)
Plagioclase	42.3	$(An_{67\pm})$	45.2
Pyroxene	37.3	pigeonite	17.8
Iron ores	7.4	ilmenite?	....
Semi-opaque mesostasis	12.8		35.9
Quartz	0.2		.....

1—59GJ97=pillow lava, from ridge north of Scaat Harbour at 1,500 feet elevation (*see* Fig. 7 for localities).
2—59AB89=pillow lava, Bowles Point, Kunghit Island.
3—59AB258=bedded aquagene tuff, north shore Scaat Harbour.
4=Average of 1 and 2.
5=Average of 1, 2, and 3.
6=Average oceanic tholeiite (Engel *et al.*, 1965, Table 7, p. 731).
*Analyses 1 to 3 by Analytical and Assay Branch, Department of Mines and Petroleum Resources. Analysts, S. W. Metcalfe and R. S. Young.

Stratigraphy.—Study of the stratigraphy of the Karmutsen Formation was preliminary, nevertheless enough was learned to come to some conclusions. Within the restricted limits of the lithology described, the local stratigraphic sections vary widely. If metamorphic changes are ignored, the main difference from locality to locality is the degree of development of the pillow-lava assemblage. In some areas such as Bigsby Inlet to western Kunghit Island, the pillow-lava assemblage is completely dominant; in others such as about Moore Channel, it is important; and in still others such as eastern Kunghit and Kunga Islands, and Tasu Sound, it is nearly absent (*see* Fig. 7).

Surprisingly enough, in spite of local variations in the stratigraphic column, certain rock types occur at what are judged to be roughly similar positions in different areas. Even more surprising is that the same appears true in regard to the formation on Vancouver Island (Surdam *et al.*, 1963). As a result of further work, some of these rock types might become marker beds. Such rock types include the following:—

(1) A biscuit-coloured massive flow with pyritic amygdules at the top of the formation.
(2) A thin limestone 100 to 200 feet below the top.
(3) A star porphyry 200 to 500 feet below the top.
(4) A limestone member 1,000 to 3,000 feet below the top.

(5) A star porphyry with large poorly developed pillows near the base of the exposed unit; that is, 12,000 to 14,000 feet below the top.

(6) A tuffaceous crinoidal limestone near the base, around 14,000 to 15,000 feet below the top.

The relative development of the various facies of the formation is shown diagrammatically by the structural cross-sections (Fig. 6). The following reconnaissance measured sections illustrate something of the nature of the formation; that is, its great thickness and variability within its limited range. The main section is a composite formed from the ridge west of Island Bay (*see* Plate Vc) and the shore of Scaat Harbour. The local continuity of sections here is good. Unfortunately, although over 14,000 feet of strata is exposed, neither the top nor the bottom of the formation is seen. The lower part of the section is cut by subsidiary faults of the main Louscoone fault zone, and the Kunga Formation is not seen in the vicinity of the top, although it should be only 1,000 to 2,000 feet above.

SECTION OF KARMUTSEN FORMATION AT SCAAT HARBOUR AND RIDGE WEST OF ISLAND BAY

Top of Exposed Section	Thickness in Feet	Thickness from Top of Exposed Section
Broken pillow breccia	100	100
Massive amygdaloidal porphyritic basalt (flow?)	200	300
Broken pillow breccia	700	1,000
Pillow lava with abundant quartz-filled interstices	700	1,700
Fine broken pillow breccia, particles up to 3 inches in diameter	250	1,950
Aquagene tuff	200	2,150
Massive flows or sills	300	2,450
Isolated pillow breccia	200	2,650
Massive basalt flows or sill	200	2,850
Pillow lava with distinct layers of pillows as little as 10 feet thick and minor massive flows	2,000	4,850
Pillow lava with minor amygdaloidal massive flows	2,500	7,350
Pillow lava	700	8,050
Fine broken pillow breccia and aquagene lapilli tuff	100	8,150
Poorly exposed, mostly pillow lava, some massive flows	1,200	9,350
Pillow lava	500	9,850
Small fault.		
Poorly exposed pillow lava	700	10,550
Broken pillow breccia	400	10,950
Isolated pillow breccia	200	11,150
Aquagene tuff-lapilli tuff	50	11,200
Isolated pillow breccia	200	11,400
Pillow lava with small pillows	150	11,550
Pillow lava	1,300	12,850
Poorly exposed, mostly pillow lava	1,200	14,050
Star porphyry flow with large poorly formed pillows	200±	14,250
Louscoone fault system.		

SECTION OF TOP OF KARMUTSEN FORMATION NORTH OF VERTICAL POINT, LOUISE ISLAND

Kunga Formation	Thickness in Feet	Thickness below Kunga Formation
Massive greenstone	150	150
Massive grey limestone	18	168
Buff-weathered basalt with pyritic amygdules	5	173
Dark-green vesicular greenstone	850	1,023
Chloritic pillow lava	50	1,073
Massive limestone	7	1,080
Amygdaloidal greenstone	400	1,480
Base of exposed section.		

SECTION OF TOP OF KARMUTSEN FORMATION ON KUNGA ISLAND

Kunga Formation	Thickness in Feet	Thickness below Kunga Formation
Amygdaloidal and massive greenstone	1,200	1,200
Limestone	30	1,230
Amygdaloidal greenstone, some pillow-like structures	1,500	2,730
Base of exposed section.		

GENERALIZED COMPOSITE SECTION DOUGLAS CHANNEL-MUDGE INLET AREA

	Thickness in Feet	Aggregate Thickness
Broken pillow breccias	400	400
Isolated pillow breccias	400	800
Broken pillow breccias	600	1,400
Pillow lavas	1,200	2,600
Massive flows	550	3,150
Pillow lavas	700	3,850
Massive flows	600	4,450

Origin.—The Karmutsen Formation was erupted entirely in a submarine environment. This is shown by the existence of pillow lavas throughout the pile and by the intercalated limestones primarily at the base and at the top. Furthermore, in contrast to the Masset basalt flows, the massive Karmutsen flows never show any columnar joints. The depth of eruption is problematic. If Moore's (1965) observations regarding the relation between depth of eruption and vesicularity may be applied generally, then the Karmutsen pillow basalts would have been extruded at considerable depth for they have few and small vesicles (that is, 0 to 1 per cent and less than 0.2 millimetre). On the other hand, the diabases may be quite vesicular and appear to represent both sills and massive submarine flows. The depth of effusion thus must remain an open question, but with more than 14,000 feet of lava deposited in a relatively short time there must have been rapid coincident sinking if the first eruptions were not in deep water.

The chemistry of the Karmutsen basalts is essentially similar to oceanic basalts. Comparison with analyses of submarine pillow lavas of Hawaii (Moore, 1965), with dredged samples from the East Pacific Rise (Engel and Engel, 1964) and from the mid-Atlantic Ridge (Nicholls, 1965) shows the basic similarity of Karmutsen lavas to these suites, albeit the data on Karmutsen rocks is very preliminary. In particular the Karmutsen basalts would seem to be what Engel, Engel, and Havens (1965, p. 721) call oceanic tholeiitic basalt, and the Masset basalts (p. 114) would be alkali basalt. (Average K_2O content of Karmutsen pillow lavas is 0.15 compared with 1.15 for Masset flows, and the Na/K ratio is 15.6 for the Karmutsen compared with 3.22 for the Masset.) Whether the names tholeiite and alkali basalt are useful, unambiguous terms (Chayes, 1966) still remains to be decided.

The relationship between pillow lava piles and massive lava piles will require more work before firm conclusions can be reached. Figure 7 shows the distribution of the different facies in plan. Where each facies is shown, it is dominant in the complete section, but minor amounts of each facies occur within the other. The amphibolites and greenstones are metamorphic facies, but the original facies can usually be interpreted. The distribution in time and space suggests that certain vents or vent areas repeatedly produced pillow lavas, whereas others repeatedly produced massive lavas. The pillow lava piles appear to have been lensoid in plan in a more extensive " matrix " of massive lavas. This distribution cannot easily be fitted in with Nayudu's (1962) hypothesis of submarine tholoid formation in which a carapace of sideromelane tuffs surrounds an interior of diabase sills, etc. One is led to imagine that the formation was constructed from a coexisting series of lineal vents, some of which repeatedly produced pillow lavas and their clastic products while others produced massive flows, the two types of vents probably being close enough so their products interfingered.

The effusions of pillow lavas and massive lavas must have stopped almost synchronously. The massive limestone unit of the Kunga Formation is unfortunately not well dated, but the flaggy limestone is. Some variation in the thickness of the massive limestone may represent time differences in accumulation, but there is no evidence of extensive interfingering correlated with variation in thickness of the limestone. In all probability the surface at the completion of eruption was remarkably planar, and thicker sections of limestone may represent either the accumulation in slight hollows or possibly in clastic biohermal settings.

Age and Correlation.—The age of the Karmutsen Formation is poorly defined, although recent work records the presence of more abundant faunas (Givens and Susuki, 1963) but only in the upper part of the unit. This at least is Karnian (Late Triassic), whereas the lower part might be Middle and even Early Triassic. Dawson (1887, p. 10B) originally specifically limited the name Vancouver Series (Group) to the Triassic portions of the volcanic rocks if any should be found to be Late Palæozoic. On Vancouver Island the Karmutsen disconformably or unconformably overlies the Sicker Group, which contains an Early Permian fauna (Sutherland Brown, 1966, p. 83). Hence the Karmutsen Formation may be said to be Karnian and earlier Triassic.

In the Queen Charlotte Islands the only fossils found so far are crinoid columns in tuffaceous limestone on Hutton Inlet and Buck Channel near the base of the exposed unit. These are not diagnostic, but it is possible that this lowest part, including the tuffaceous limestone, some shale, and the star porphyry flow, may actually be Permian (Jeffery, W. G., personal communication). Were this to be the case, these rocks would have to be removed from the Karmutsen Formation.

From Dawson (1880 and 1887) onward, people who have studied the geology of northern Vancouver Island and the Queen Charlotte Islands noted the similarity of the pre-Cretaceous rocks, the Vancouver Group, and specifically correlated the limestone-argillite sequences (Quatsino and Lower Bonanza Formations and the Kunga Formation). Rocks below the Quatsino Limestone in the Nimpkish Lake area were named the Karmutsen Volcanics by Gunning (1932, p. 23). Hoadley (1953, pp. 16–17) collected diagnostic Late Triassic fossils from the upper part of the unit in the Zeballos area, and Jeletzky (1954, p. 12) refers to Karnian fossils collected by him in the upper part of the formation in the Esperanza-Kyuquot area. Both these authors call the unit the Karmutsen Group, but included it in the Vancouver Group. The lithological similarity of the volcanic rocks below the Kunga Limestone to the Karmutsen Formation amounts to identity, so that the writer believes the use of the term Karmutsen is justified, even though no diagnostic fossils have yet been found in these rocks in the Queen Charlotte Islands. The writer, in concert with others working in these rocks, has reduced the unit to a formation.

Kunga Formation

The Kunga Formation is a sedimentary unit composed primarily of limestone and argillite. It rests conformably on the Karmutsen Formation and may be overlain conformably by the Maude Formation or disconformably by the Yakoun Formation. The contact with the Karmutsen Formation is abrupt and that with the Maude Formation transitional over a small thickness. The sedimentation represented by the formation indicates a prolonged cessation of volcanism which was otherwise so dominant in Triassic and Jurassic periods. The unit was first named by Sutherland Brown and Jeffery (1960, p. 2) but was recognized by Dawson (1880) as an entity. The type section is on the northern shore of Kunga Island.

The Kunga Formation ranges in age from Karnian (early Upper Triassic) to Sinemurian (mid Lower Jurassic). The formation is the correlative of the Quatsino Limestone and the Lower Bonanza Formation, as defined by Hoadley (1953, pp. 21–29).

The Kunga Formation is repeatedly exposed over the whole length of the Queen Charlotte Islands as is shown on Figure 8, although rarely in large areas. Maximum measured thicknesses are about 3,000 feet. The best exposures are on the shore such as at Kunga Island, Section Cove, and the west side of Shields Bay, but fairly good ones occur on the creeks north of Yakoun Lake.

Lithology.—The Kunga Formation is divisible into three members of contrasting lithologies: a massive grey limestone member that overlies the Karmutsen Formation; a middle thinly bedded black limestone member; and an uppermost thinly bedded black argillite member.

The grey limestone member is uniform and consists almost entirely of mid grey-weathering crystalline limestone, some thickly bedded (1 to 10 feet), but most quite massive (*see* Plate VIB). The normal fresh limestone is quite dark grey, but commonly, especially near intrusive bodies and ore deposits, is bleached and recrystallized more or less coarsely. Few textures are preserved in the uncrystallized limestone except rare beds of benthonic fossils, coral-like organisms, and gastropods. Black chert nodules 1 to 2 inches long are present in some localities. The contact with the Karmutsen flows is normally abrupt and conformable. Dolomitization is local and rare. Analyses on page 175 are probably typical.

Within the massive limestone in some localities, amygdaloidal greenstones are intercalated (for example, Copper Islands). Some of these can be proven to be sills, but others may be flows which represent the last of Karmutsen-type volcanism. Also one or more limestone beds may occur in the Karmutsen Formation within a few hundred feet of the contact. Some of the variation in thickness of the grey limestone member may be local interfingering of flows and limestone.

The lithology of the black limestone member is more varied than the grey limestone member, but it is dominated by thinly bedded flaggy black carbonaceous limestone (*see* Plate XIIA). Other rock types in rough order of importance include cross-bedded grey calcarenite and fine limestone conglomerate, fissile laminated black limestone, thinly bedded flaggy black argillite, and rare dark-grey lithic sandstone.

The black limestone has very persistent beds varying from 1 to 4 inches thick, along which it splits readily. The beds may have internal inconspicuous laminations. Where lamination and consequent fissility increase, this type grades into the fissile laminated black limestone in which the laminations are clearly due to abundant *Halobia* or *Monotis*. Interbed joints normal to stratification give the black limestone a finely blocky to hackly outcrop along shoreline or creeks. Intercalated with the black limestone are clastic grey limestones which commonly are formed of cross-bedded calcite sands but may include granule beds and pebbly granule beds. These generally occur in thicker lensoid beds (1 inch to 10 feet), which are less persistent laterally than the thin-bedded rocks. Commonly the calcarenites may be 3 inches to 3 feet thick and the granule beds even thicker. The clastic limestones are thickest and relatively most common where the member is thickest. Very commonly the original clastic nature cannot be discerned because of recrystallization. The argillite and lithic sandstone that occur in the member in small amount are identical to that of the overlying member.

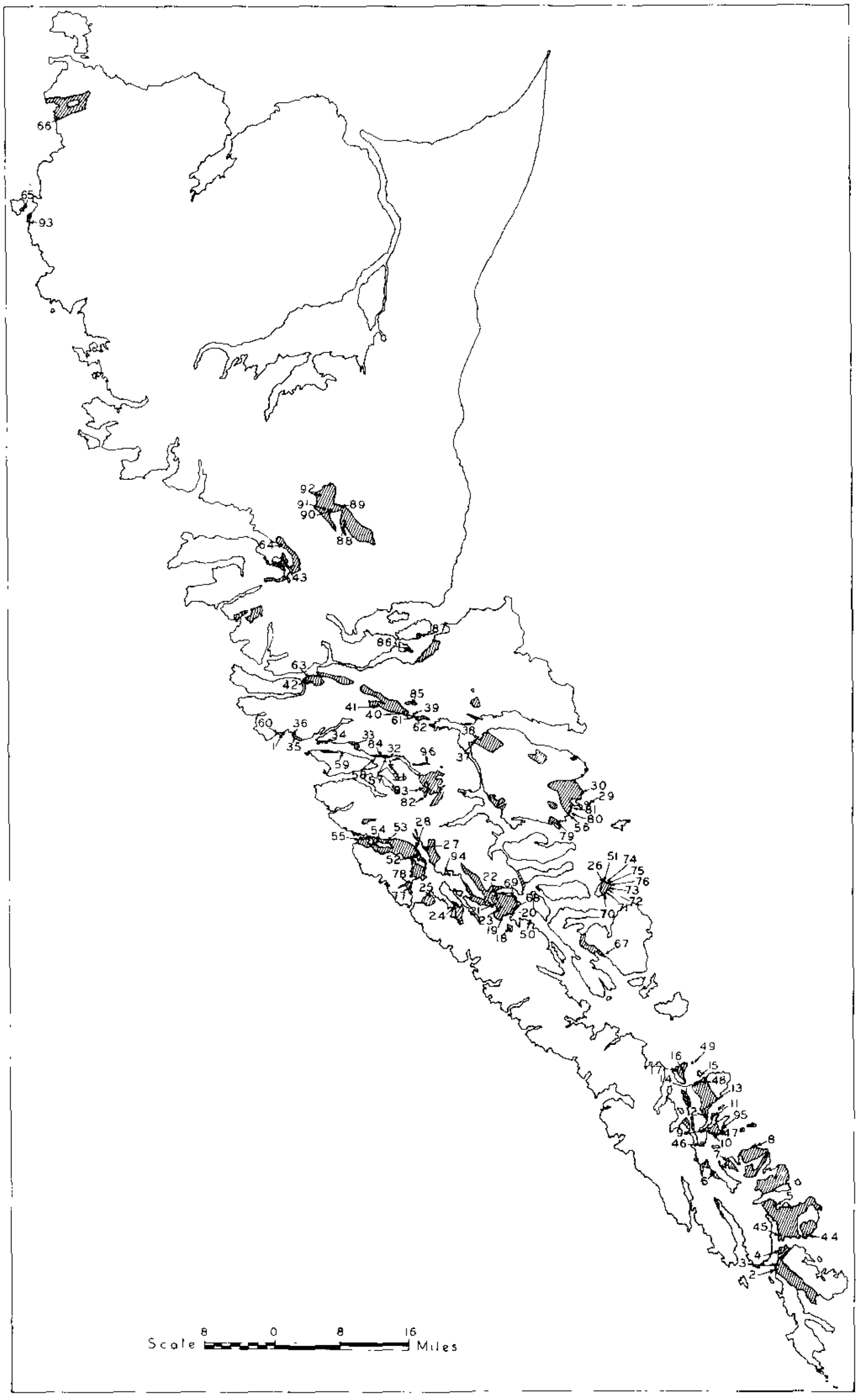


Fig. 8. Kunga Formation: Distribution and fossil localities.

The contact of the grey and the black limestone members is sharp and very evident, whereas that with the argillite member is equally sharp but not as evident. The top of the black limestone member coincides with the top of the *Monotis* beds, which are universally present in good exposures.

The black argillite member is superficially similar to the black limestone member, but the dominant type is thinly bedded flaggy black argillite, and minor types are black limestone, grey clastic limestone, grey cellular-weathering bioclastic limestone, dark-grey lithic sandstone, grey-green thin-bedded calcareous shale. The black argillite is a dense, hard, well-bedded flaggy rock that superficially resembles "ribbon chert" (*see* Plate VIA). Beds are 1 to 4 inches thick and invariably contain good fine internal laminations that, like the beds, are very persistent laterally. The rock splits readily along the beds but not necessarily along the laminæ. The laminæ are quite variable in pattern and nature, but the commonest are caused by intercalation of fine light- to dark-grey laminæ of graded sand or silt in the black finer-grained rock. Also common are distinct variations in fissility and organic content. Some intercalated beds are a chloritic green colour and slightly calcareous and shaly compared to the normal black argillite. Intra-bed joints normal to bedding cause a finely blocky outcrop to all but flat-lying beds. Mild thermal metamorphism bleaches the argillite and produces a rusty-weathering, thin-bedded, light-green, white, and light-purple rock.

Grey clastic cross-bedded limestone and thin-bedded black limestone are fairly common and entirely similar to those of the black limestone member. Dark greenish-grey to black massive lithic sandstone is commoner than in the lower member but never really abundant. It may be calcareous and is virtually free of coarse quartz grains but contains abundant plagioclase and plagioclase-rich volcanic rock fragments. A persistent minor type is a cellular-weathering grey and black, fairly thickly bedded, dense bioclastic limestone. This is common near the base of the member.

The contact of this member with the overlying Maude Formation where present is transitional over a small thickness. Commonly the unit is overlain disconformably or with possible slight unconformity by the Yakoun Formation.

Microscopy.—The basal massive grey limestone member of the Kunga Formation is generally preserved in a recrystallized state composed almost entirely of medium crystalline calcite with very minor dust. Some specimens are less altered and are composed of finely crystalline calcite of average diameter 0.01 millimetre (micrite) containing a small percentage of spheroids of 0.05 to 0.2 millimetre diameter composed of more coarsely crystalline calcite. Some specimens show very slight banding formed by minor variation of crystallinity. Rare specimens are seemingly originally bioclastic. Non-calcareous silt or sand is very rare in all specimens examined.

Microscopically the flaggy black limestone and flaggy black argillite members are composed primarily of similar rock types in differing proportions. The most conspicuous feature of almost all specimens is the marked bedding, lamination, and intercalation of contrasting types. The thickness of laminæ ranges from less than a millimetre to several centimetres or rarely more. Specific names for the various rocks are difficult to assign because of the lamellar intercalation, the general fineness of grain, the semi-opaqueness, and the admixture of clastic and chemical carbonate with plagioclase and rock fragments. Most specimens combine silty fine carbonaceous and calcareous laminæ with less carbonaceous and calcareous silts or sands, many of which show graded bedding. Characteristically quartz sand or silt is virtually absent and fine pyrite everywhere present. In all but the graded beds, microscopic spherules of calcite or chert, etc., are present.

The normal flaggy black limestones are generally composed of two component types of laminæ. The dominant one (1) is a silt-sized clastic limestone composed of minor plagioclase and volcanic rock clasts with a greater quantity of calcite, silt, and minor spherules in a dark semi-opaque carbonaceous and calcareous matrix. The other component (2) is a coarse silt to fine sand containing subequal quantities of plagioclase, volcanic rock, and calcite clasts in a sparser calcareous and semi-opaque matrix, with pyrite but without spherules.

Table III shows the range of mineral composition of the specimens examined and the averages for the two types. The sharp physical boundaries between the two types may obscure recognition of transitional types. The sandy type grades into coarser rocks in thick beds of granules and pebbly clastic limestone of largely bioclastic nature but which contains a large lithic component. In the fine component, thin pelecypod shell fragments commonly with a parallel opaque organic lamella are common and with increasing content grade to highly fissile *Monotis* or *Halobia* beds. Minor amounts of lithic sandstone and cross-bedded bioclastic limestone such as will be described also occur within the member.

The flaggy black argillite member contains similar types but also contains others, notably graded lithic sand and silt beds, cellular-weathering and cross-bedded bioclastic limestones, and medium-grained massive lithic sandstones. Table III shows, for the types described, ranges and averages. The averages are not thought to be truly meaningful in as much as the sampling was inadequate. Most of the flaggy rocks combine in any discrete bed several laminæ of two or three fairly distinct types. It is this that gives these rocks their unique character. These types may be called (1) graded lithic sands and silts, (2) laminated, carbonaceous, calcareous shale, and (3) carbonaceous argillite with calcite, volcanic rock, and plagioclase clasts. Plate XVIA is a negative projection of a thin-section that shows these three types of laminæ. The graded beds (1) are composed of well-sorted sub-angular fine sand or silt (coarsest fragments 0.35 millimetre in coarse beds to 0.05 millimetre in the fine beds) that is dominantly composed of volcanic rock fragments (basalt and trachytic textured fine feldspathic rocks) with much plagioclase and very rare quartz. Calcite clasts, fossil fragments, and spherules are absent, carbonaceous matter scant, but pyrite grains common. These laminæ are readily altered on metamorphism with a general recrystallization into a zeolitic mass being fairly common. Some bands have also been highly pyritized.

The laminated carbonaceous calcareous shale (2) is composed of minor silt of similar composition to the graded beds in very fine semi-opaque calcareous matrix with abundant shreds of opaque organic matter and minor fine pyrite. Spherules are normally present and may form as much as one-quarter of the rock. The carbonaceous argillite (3) is composed of silt of fine volcanic rocks, plagioclase, and calcite in varying proportions with organic opaque shreds and pyrite in a sparse very fine matrix. Spherules are normally present, and recognizable ammonite protoconches are rarely present. Transitional types between (2) and (3) occur, but in section the laminæ are sharply bounded. The graded beds show very minor erosional features along their basal contacts.

The spherules are normally nearly circular in section, but in some slides they are elliptical and probably deformed. They range in diameter from 0.05 to 0.2 millimetre, and none show in section any distinct structure, although crude organization may be apparent. They may be formed of calcite or a very fine mosaic of

TABLE III.—MINERAL COMPOSITION, KUNGA FORMATION

	Flaggy Black Limestone Member				Flaggy Argillite Member								
	(1) Fine Clastic Limestone		(2) Calcareous Siltstone		(1) Graded Beds		(2) Shale		(3) Argillite		(4) Cellular Bioclastic Limestone	(5) Cross-bedded Bioclastic Limestone	(6) Lithic Sandstone
	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range		
Quartz	...	...	0–Tr.	...	0–Tr.	Tr.	...	...	...	...	...	...	5
Plagioclase	3–10	6.5	10–33	23	15–22	20	2–3	2.5	5–20	15	1–25	1	25
Rock fragments	Tr.–5	2.5	5–45	30	60–70	67.5	Tr.–2	Tr.	18–50	37	Tr.–40	0.5	60
Calcite fragments	15–40	30.0	0–70	27.5	...	...	...	...	10–70	20	25–95	90	...
Spherules	Tr.–10	3	0	0	...	...	20±	20	Tr.–20	5	...	...	...
Opaque grains	2–7	4	2–10	4	5–10	7	5–12	9	7–15	9	0–3	8.5	2
Matrix	50–60	55	5–25	7.5	5	5	60–73	67	Tr.–30	15	10	...	8

either chert or zeolites, or on recrystallization a coarser mosaic of quartz or zeolites separated by planes of geothite. Calcareous and cherty or zeolitic spherules may be found in the same section. These rocks contain a high biogenic component of pelagic macrofossils, and in all probability these spherules represent original planktonic microfossils of undetermined kind.

The minor types in the flaggy argillite member generally occur in thicker beds than the main types already described. Typical mineral compositions are shown in Table III for these minor types, and it can be seen they are closely similar to the main types. They include lithic sandstone, cellular-weathering bioclastic limestone, and cross-bedded bioclastic limestone.

The cellular-weathering bioclastic limestone (4) is composed of sand-sized clasts of calcite, volcanic rock fragments, and plagioclase. The calcite fragments are highly variable in shape and texture and many are recognizable fossil fragments. The subangular fine-grained basic volcanic rock fragments and plagioclase form as little as 10 to as much as 60 per cent of the rock, and the quantity varies gradationally in a fairly random way. The cellular-weathering texture seems related to this variation. Cherty sponge spicules are always present and may form up to 5 per cent of the rock. Other quartz minerals are virtually absent. The spicules show a marked preferred orientation that is the only indication of bedding.

The cross-bedded bioclastic limestone (5) is composed mostly of sand-sized calcite fragments with but minor basalt fragments or plagioclase, carbonaceous opaque matter, and pyrite. Sorting is fairly good, but shape varies from rounded to angular. Recognizable fossil fragments are fairly few, but the great variety of texture and shape of the calcite clasts indicates a biogenic origin. In most localities these rocks have been recrystallized, and neither their cross-bedding nor their characteristic texture is evident.

The lithic sandstone (6) has a composition similar to the graded beds but is generally a coarser, fairly well-sorted sandstone, but is not graded. Clasts are rounded to angular. Quartz is present but never forms more than 5 per cent of the rock. Carbonate is minor and mostly interstitial. Some disrupted and folded argillite fragments are occasionally observed in hand specimens.

Figure 16 is a triangular diagram on which quartz, total feldspar, and rock fragments are plotted for arenaceous rocks of all sedimentary units. Notable contrasts and sequential development are evident.

Thermal metamorphism converts black Kunga rocks into light-green, mauve, or white rocks by eliminating or concentrating much of the dispersed carbon. Graded beds are recrystallized to clinozoisite, and the fine-grained rocks to a mixture of fine plagioclase, diopside, sphene, and minor quartz. Dynamic metamorphism along shear zones readily converts the flaggy members into carbonaceous schists.

Stratigraphy.—The stratigraphy of the Kunga Formation is relatively constant where it is well exposed in simple structural situations. The three members are universally present and of the same order of thickness. The lowest unit, massive grey limestone, seems to vary most from just less than 100 to 600 feet or possibly more. Very commonly the Kunga Formation is in highly complicated structural situations because of its physical nature (thin bedded and carbonaceous). Faults of all sizes tend to follow it, in fact major steep (wrench?) faults repeatedly have lenses of sheared Kunga Formation strung out along their traces. Also the formation readily folds and quite commonly forms non-stratiform fold piles between massive blocks of volcanic rocks.

TYPE SECTION OF KUNGA FORMATION ON THE NORTH SHORE OF KUNGA ISLAND

Member	Unit	Thickness in Feet	Cumulative Thickness above Karmutsen Formation	Member thickness
	Top of exposure.			
	Yakoun Formation andesite sills and flows?	200	—	
Black argillite member	Flaggy black argillite and some green calcareous argillite	172	3,135	1,630 feet
	Black calcareous lithic sandstone	3	2,963	
	Flaggy black argillite with *Arietites?* sensu lato	95	2,960	
	Flaggy black argillite with dark lithic sandstone and 6-inch beds of cross-bedded grey limestone	15	2,865	
	Flaggy black argillite, poorly exposed	30	2,850	
	Flaggy black argillite with about 30 per cent dark-green calcareous argillite and containing poor arietitid ammonites	65	2,820	
	Flaggy black argillite with some sheared dark-green calcareous shale	190	2,755	
	Flaggy black argillite with some large (4 by 8 feet) limestone concretions	50	2,565	
	Flaggy black argillite with some grey limestone beds up to 9 inches thick and green calcareous shale	130	2,515	
	Covered	50	2,385	
	Disturbed belt in which duplication is assumed but not proven	—	—	
	Flaggy black laminated argillite, rare limestone, and arietitid ammonites	30	2,335	
	Flaggy black laminated argillite, 10 per cent calcareous argillite to limestone	80	2,305	
	Dyke	20	—	
	Flaggy black laminated argillite with calcareous argillite beds about 4 inches thick every 3 to 4 feet; arietitid ammonites	110	2,225	
	Flaggy black laminated argillite with 10 per cent 1- to 3-inch dark limestone beds	60	2,115	
	Flaggy black laminated argillite poorly exposed	30	2,055	
	Greenstone dyke	20	—	
	Flaggy black laminated argillite, contorted and poorly exposed	60	2,025	
	Flaggy black laminated argillite with about 20 per cent grey limestone beds up to 6 inches thick; *Arietites* sensu lato	140	1,965	
	Greenstone dyke	10	—	
	Flaggy black argillite calcareous concretion and a few cross-bedded limestone beds and dark flaggy limestone; arietitid ammonites	136	1,825	
	Cross-bedded grey clastic limestone	4	1,689	
	Flaggy black argillite with some 1-foot black lithic sandstone beds	30	1,685	
	Flaggy black argillite with a few 6-inch grey limestone beds	80	1,655	
	Flaggy black argillite with 20 per cent 1-foot-thick grey clastic limestone beds	65	1,575	
	Cellular-weathering bioclastic limestone	5	1,510	
Black limestone member	Flaggy black laminated limestone with *Monotis subcircularis*	70	1,505	905 feet
	Strike fault and disturbed strata adjacent	10	—	
	Flaggy black calcareous argillite	15	1,435	
	Flaggy black limestone and argillite with *Halobia* sp.	20	1,420	
	Dyke	—	—	
	Flaggy black limestone; minor thin clastic limestone beds	140	1,400	
	Disturbed by minor folds	—	—	
	Flaggy black limestone with some 6-inch to 1-foot grey clastic limestone beds	65	1,260	
	Covered	230	1,195	
	Flaggy black limestone	4	965	
	Dark-grey clastic limestone	6	961	
	Flaggy black limestone	17	955	
	Sharpstone limestone conglomerate	1	938	
	Flaggy black limestone	14	937	
	Grey clastic limestone	8	923	
	Flaggy black limestone	20	915	
	Dyke	15	—	
	Flaggy black laminated limestone	15	895	
	Covered	140	880	
	Dark-grey massive clastic limestone	15	740	
	Flaggy black limestone	15	725	
	Dark-grey clastic limestone and pebbly granule limestone conglomerate poorly exposed	50	710	
	Flaggy black limestone (slightly schistose)	20	660	
	Covered	40	640	
	Fault and dyke parallel strike	6	—	
Grey limestone member	Massive grey limestone	400	600	600 feet
	Greenstone flow? or sill?	75	—	
	Massive grey limestone	200	200	
	Karmutsen Formation.			

TYPE SECTION OF KUNGA FORMATION ON THE NORTH SHORE OF KUNGA ISLAND

Member		Thickness in Feet	Cumulative Thickness above Karmutsen Formation	Member thickness
	Top of exposure.			
	Yakoun Formation andesite sills and flows?	200	—	
Black argillite member	Flaggy black argillite and some green calcareous argillite	172	3,135	1,630 feet
	Black calcareous lithic sandstone	3	2,963	
	Flaggy black argillite with *Arietites?* sensu lato	95	2,960	
	Flaggy black argillite with dark lithic sandstone and 6-inch beds of cross-bedded grey limestone	15	2,865	
	Flaggy black argillite, poorly exposed	30	2,850	
	Flaggy black argillite with about 30 per cent dark-green calcareous argillite and containing poor arietitid ammonites	65	2,820	
	Flaggy black argillite with some sheared dark-green calcareous shale	190	2,755	
	Flaggy black argillite with some large (4 by 8 feet) limestone concretions	50	2,565	
	Flaggy black argillite with some grey limestone beds up to 9 inches thick and green calcareous shale	130	2,515	
	Covered	50	2,385	
	Disturbed belt in which duplication is assumed but not proven	—	—	
	Flaggy black laminated argillite, rare limestone, and arietitid ammonites	30	2,335	
	Flaggy black laminated argillite, 10 per cent calcareous argillite to limestone	80	2,305	
	Dyke	20	—	
	Flaggy black laminated argillite with calcareous argillite beds about 4 inches thick every 3 to 4 feet; arietitid ammonites	110	2,225	
	Flaggy black laminated argillite with 10 per cent 1- to 3-inch dark limestone beds	60	2,115	
	Flaggy black laminated argillite poorly exposed	30	2,055	
	Greenstone dyke	20	—	
	Flaggy black laminated argillite, contorted and poorly exposed	60	2,025	
	Flaggy black laminated argillite with about 20 per cent grey limestone beds up to 6 inches thick; *Arietites* sensu lato	140	1,965	
	Greenstone dyke	10	—	
	Flaggy black argillite calcareous concretion and a few cross-bedded limestone beds and dark flaggy limestone; arietitid ammonites	136	1,825	
	Cross-bedded grey clastic limestone	4	1,689	
	Flaggy black argillite with some 1-foot black lithic sandstone beds	30	1,685	
	Flaggy black argillite with a few 6-inch grey limestone beds	80	1,655	
	Flaggy black argillite with 20 per cent 1-foot-thick grey clastic limestone beds	65	1,575	
	Cellular-weathering bioclastic limestone	5	1,510	
Black limestone member	Flaggy black laminated limestone with *Monotis subcircularis*	70	1,505	905 feet
	Strike fault and disturbed strata adjacent	10	—	
	Flaggy black calcareous argillite	15	1,435	
	Flaggy black limestone and argillite with *Halobia* sp.	20	1,420	
	Dyke	—	—	
	Flaggy black limestone; minor thin clastic limestone beds	140	1,400	
	Disturbed by minor folds	—	—	
	Flaggy black limestone with some 6-inch to 1-foot grey clastic limestone beds	65	1,260	
	Covered	230	1,195	
	Flaggy black limestone	4	965	
	Dark-grey clastic limestone	6	961	
	Flaggy black limestone	17	955	
	Sharpstone limestone conglomerate	1	938	
	Flaggy black limestone	14	937	
	Grey clastic limestone	8	923	
	Flaggy black limestone	20	915	
	Dyke	15	—	
	Flaggy black laminated limestone	15	895	
	Covered	140	880	
	Dark-grey massive clastic limestone	15	740	
	Flaggy black limestone	15	725	
	Dark-grey clastic limestone and pebbly granule limestone conglomerate poorly exposed	50	710	
	Flaggy black limestone (slightly schistose)	20	660	
	Covered	40	640	
	Fault and dyke parallel strike	6	—	
Grey limestone member.	Massive grey limestone	400	600	600 feet.
	Greenstone flow? or sill?	75	—	
	Massive grey limestone	200	200	
	Karmutsen Formation.			

SECTION OF KUNGA FORMATION EAST OF SECTION COVE, BURNABY ISLAND

Member	Strata	Thickness in Feet	Cumulative Thickness above Karmutsen Formation	
Black argillite member.	End of exposure.			355 feet.
	Dyke.			
	Flaggy black argillite	73	1,050	
	Grey clastic limestone	1	977	
	Flaggy black argillite with some grey limestone beds	66	976	
	Basalt composite dyke	30	......	
	Flaggy black argillite with grey limestone beds	20	910	
	Flaggy black argillite	38	890	
	Grey cross-bedded clastic limestone	2	852	
	Flaggy black laminated argillite and some cross-bedded clastic limestone	97	850	
	Blocky black limestone	4	753	
	Flaggy black argillite; some thin limestone beds	23	749	
	Grey limestone	2	726	
	Flaggy black argillite	29	724	
Black limestone member.	Flaggy black limestone and laminated limestone with *Monotis subcircularis*	15	695	610 feet.
	Small strike fault	......	......	
	Flaggy and laminated black limestone and black shaly limestone with *Monotis subcircularis*	61	680	
	Flaggy to blocky black limestone	29	819	
	Flaggy black limestone and argillite	13	790	
	Grey limestone with some flaggy black argillite	4	777	
	Flaggy black limestone and argillite	43	773	
	Flaggy black limestone with 6-inch to 1-foot grey limestone beds about every 10 feet	55	730	
	Flaggy black limestone with 30 per cent intercalated cross-bedded clastic limestone	105	675	
	Small fault	......	......	
	Flaggy black limestone with 20 per cent intercalated cross-bedded clastic limestone	75	570	
	Clastic grey limestone with flaggy black limestone	10	495	
	Small fault	......	......	
	Dark-grey calcareous lithic sandstone	10	485	
	Flaggy black limestone and some cross-bedded clastic limestone	20	475	
	Small fault	......	......	
	Flaggy black limestone and massive grey limestone	35	455	
	Flaggy black laminated limestone with calcareous argillite with *Halobia?* sp.	30	420	
	Flaggy black laminated limestone with 20 per cent clastic limestone	40	390	
	Fault and disturbed flaggy strata	25	350	
	Dark calcareous lithic sandstone	3	325	
	Flaggy black limestone	2	322	
	Fault	......	......	
	Flaggy black limestone with 50 per cent blocky clastic limestone	35	320	
	Poor exposure, flaggy black limestone	25	285	
	Flaggy black limestone	30	260	
	Pebbly limestone granule bed	1	230	
	Flaggy black limestone	17	229	
	Dark-green granule limestone bed	2	212	
	Blocky grey limestone and flaggy black limestone interbedded	18	210	
	Fault	2	......	
	Flaggy black argillite and limestone with some 6-inch-thick clastic limestone beds	52	192	
	Fault	......	......	
	Flaggy black limestone	55	140	
Grey limestone member.	Blocky grey limestone with intercalated flaggy black limestone	20	85	85 feet.
	Massive grey limestone beds mostly 2 feet thick	65	65	
	Karmutsen amygdaloidal greenstone	400	......	
	Major fault.			

Two reconnaissance-measured sections are given on pages 57 and 58. The type section on the north shore of Kunga Island is the most complete, but it is cut by some strike faults of unknown movement and possibly includes unrecognized duplications. Unfortunately this section is not overlain by the Maude Formation but by 200 feet of andesite sills and possibly flows that are probably part of the Yakoun Formation. The other section is on the north shore of Burnaby Island immediately east of Section Cove toward Alder Island. The rocks on the shore of Section Cove where Dawson measured a section (1880, pp. 55–56) currently are not well exposed. The measured section is well exposed but not complete as only a few hundred feet of the black argillite member is exposed. Furthermore, the massive grey limestone member is inordinately thin (85 feet), partly as a result of structural complications. This member has a more normal thickness on Section Cove, where it is 350 feet thick.

Origin.—The Kunga Formation was deposited during a period of quiescence within an otherwise highly volcanic time. Its character and fauna show that the formation is marine and was most likely deposited in a basin more or less remote from shore.

The massive limestone member because of its recrystallization contains few clues as to origin other than the remnants of a benthonic fauna in some localities and a low content of non-carbonate detritus. Kania (1929) has shown submarine fumaroles and lava flows are capable of precipitating large quantities of calcium carbonate from sea water and also concentrating the resulting limestone in depressions. Continued fumarole activity after the cessation of Karmutsen volcanism could well have produced the massive limestone member and could explain its large variation in thickness. However, clastic and bioclastic limestones are important in the superimposed members and a benthonic fauna existed in the basal member, so the origin is unlikely to be entirely chemical.

The upper two members have features in common which contrast with those of the lower member; for example, thin persistent beds, high carbonaceous content, admixture of lithic silt and sand, and cross-laminated non-carbonaceous clastic limestones. Furthermore, the fauna of the upper member is almost entirely pelagic: in the black limestone member the thin-shelled pelecypods *Halobia* and *Monotis* occur to the near exclusion of all other forms and in some beds to the near exclusion of all other rock matter; in the black argillite member, arietitid ammonites occur in fair abundance. The black, organic, and pyritic nature of these units together with the lack of benthonic fauna almost certainly indicate deposition in a barred basin or euxinic environment.

A strong contrast exists between the component interlaminated types of these members. The very fine-grained rocks are highly carbonaceous and contain abundant spherules, whereas the graded beds are very slightly carbonaceous and contain no spherules. The spherules were probably also a pelagic microfauna of phytoplankton, *Radiolaria,* or *Foraminifera.* Two entirely different modes of deposition are indicated: the one a slow rain of very fine detritus and coarser organic matter from the surface; the other pulses of lithic sands from a more distant basic volcanic source, probably distributed by turbidity currents. The cross-bedded bioclastic calcarenites indicate another mode that is difficult to rationalize with the type of environment indicated by the other two. Evidently a source of shell detritus was present on the perimeter of the basin, which must have been swept by vagrant currents that carried shell detritus in small dunes over the bottom.

In summary the Kunga Formation is a flysch deposit that was laid down in a marine basin which at first was free of terrigenous matter and possibly of relatively shallow depth. With advancing time the basin became barred, the environment of the bottom became toxic, and the depth may have increased. Into this at first minor terrigenous detritus from a basic volcanic source was flushed. Eventually the detritus was brought in by turbidity currents and the pace of basin filling became more rapid. The ubiquitous *Monotis* beds mark the transition from dominantly very fine calcareous deposits to dominantly fine detrital deposits.

Age and Correlation.—The Kunga Formation ranges in age from Karnian (early Upper Triassic) to Sinemurian (mid Lower Jurassic). The formation abounds in fossils but preservation is generally poor, so that the age is not known as well as it might be. Characteristic fossils are the pelecypods *Halobia* and *Monotis subcircularis* and arietitid ammonites. Collections were sent to the Geological Survey of Canada and identified by Drs. Frebold and Tozer.

Table IV (in pocket) summarizes their identifications, except for a few critical localities listed below. All localities are shown on Figure 8, but the geological maps, Figure 5, also show localities at which fossils were collected and indeterminate, or observed but not collected.

The relation of the collections to the stratigraphy is apparent in the table. Very little was collected in the massive grey limestone member except unidentifiable corals. The only useful collection (Locality No. 1, 59AB28) is from Kaisun, and included *Aulacoceras* sp., *Arcestes?* sp., and *Halobia* sp. taken in the uppermost part of the member. Twenty feet above the base of the flaggy black limestone member at Bluejay Cove on Burnaby Island (Locality No. 95, 65AB2 and 65AB5) the following were collected:—

Field No. 65AB2, G.S.C. Locality 69188—

Discotropites? sp. (venter not preserved).
Arcestes sp.

Field No. 65AB5, G.S.C. Locality 69190—

Juvavites sp.
Arcestes sp.
Homerites cf. *semiglobosus* Hauer.
Halobia cf. *superba* Mojsisovics.

Halobia sp. can be collected over the whole thickness of the flaggy black limestone member below *Monotis subcircularis* Gabb, which occurs only at the top of the member. As a result of recent re-examination, Tozer now identifies two *Halobia* species: *Halobia alaskana* Smith of the early Lower Norian (Locality No. 28, 58AB104, and Locality No. 43, 61AB38), and *Halobia* cf. *rugosa* Guembel (Locality No. 24, 58AB17) of the late Lower Karnian. The latter age is the oldest known from the flaggy black limestone member. Additional interesting specimens collected within the member at complex structural locations in which precise stratigraphic relations are unknown include one *Discophyllites* cf. *ebneri* Mojsisovics from Huston Inlet (Locality No. 6, 59AB195) and *Monotis salinaria* Bronn from Lockeport (Locality No. 19, 61AB336) and probably from Inskip Channel (Locality No. 58, 59AB49). In the flaggy black argillite member compressed ammonites of the family Arietitidæ are common. The genera identified is mostly *Arniotites,* and all are Sinemurian or possibly Sinemurian. No fossils representative of the Rhætian or Hettangian stages have been identified, although sedimentation appears to be continuous between the Norian and Sinemurian.

Tozer remarks in regard to the 1958 and 1959 collections: "Virtually all the specimens of *Halobia* are poorly preserved. Some could represent specimens of *Daonella* and be as old as Middle Triassic, but I think this unlikely. The collections with *Halobia* almost certainly come from a level lower than the *Monotis* beds, and they are probably Karnian or Norian. Collection 59AB28 (Locality No. 1) is certainly Karnian, and 59AB195 (Locality No. 6) is probably also Karnian." In regard to the 1965 collection (Locality No. 95), Tozer says that "the age is mid Upper Karnian, and the beds are to be correlated with the *Tropites welleri* Zone." Tozer elsewhere says *Monotis subcircularis* and *Monotis salinaria* are Late Norian, and Frebold that *Arniotites (Melanhippites) harbledownensis, Arniotites* sp., and (or) *Arietites* sensu lato are Sinemurian.

The Kunga Formation is correlative with the whole of the Quatsino Formation and with the lower part of the Bonanza Formation of northern Vancouver Island. Hoadley (1953, pp. 20, 21, and 22) leaves some doubt about what he considers the top of the Quatsino Formation. Surdam, Susuki, and Carlisle (1963) tentatively place the boundary at a lithologic change from flaggy carbonaceous limestones to slabby argillites that occur above the *Monotis subcircularis* beds. Hence the two limestone members of the Kunga Formation are the correlative of the Quatsino Formation and the argillite member probably the partial correlative of the lower Bonanza Formation on the Iron River, Vancouver Island. The Kunga Formation is also the correlative of the combined Parsons Bay and Harbledown Formations of islands at the north end of Vancouver Island (Crickmay, 1928).

In summary, the massive limestone is Karnian, older than the *Tropites welleri* zone; the flaggy black limestone extends from this zone to the lower Suessi Zone of the Upper Norian, and the flaggy black argillite member extends presumably from the Suessi Zone through to nearly the end of the Sinemurian, although no definite Rhætian nor Hettangian are recognized.

Maude Formation

The Maude Formation is a thin sedimentary unit composed of argillite, shale, calcareous shale, and lithic sandstone. Where present it rests conformably on the top of the Kunga Formation and is overlain by the Yakoun Formation with conformity in some localities at least. The contact with the Kunga Formation is gradational over a few tens of feet and with the Yakoun Formation is abrupt. It is similar enough to the Kunga Formation so that the two can only be distinguished with certainty where well exposed or fossils can be collected. Nevertheless it is certain that it is not present everywhere between Yakoun and Kunga Formations even where these are seemingly conformable. Figure 9 shows its distribution. The Maude Formation is a relatively thin unit considering the length of time represented during its deposition. Its maximum thickness is of the order of 600 to 700 feet, and it is Pliensbachian and Toarcian in age. Hence the Maude Formation is a thin and impersistent unit which locally marks the close of the time of volcanic quiet.

The Maude Formation was first named by MacKenzie (1916, pp. 39–47), who said it was typically exposed on the south shore of Maude Island and South Bay. The exposures on Maude Island are mostly Maude Formation as herein used but includes some of the upper part of the Kunga Formation (black argillite

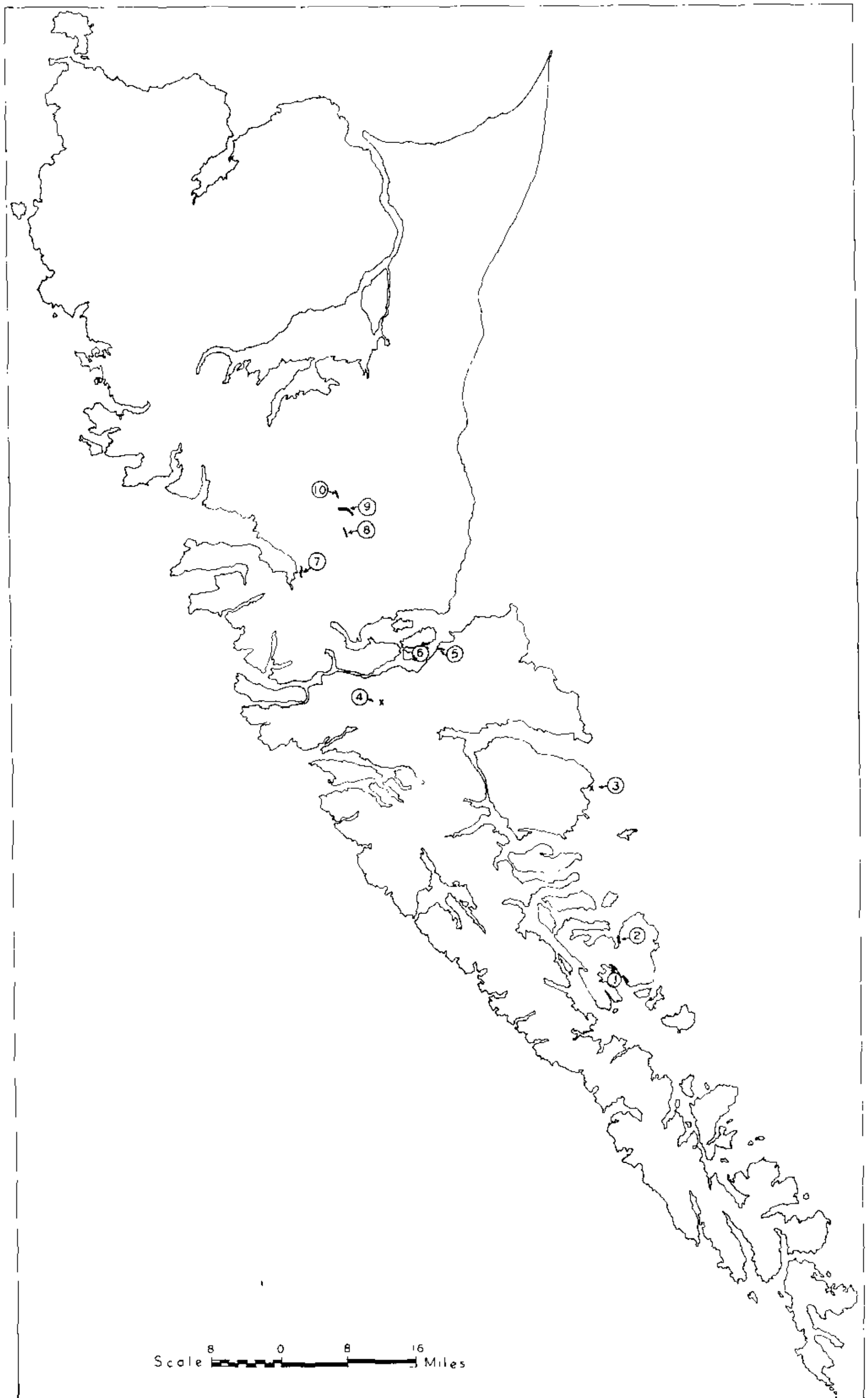


Fig. 9. Maude Formation: Distribution and fossil localities.

member). MacKenzie included in his Maude Formation at other localities all the Kunga Formation, the Longarm Formation, and some of the Queen Charlotte Group, notably the Honna conglomerates at Pillar Bay. Clearly the Maude Formation as used by MacKenzie is nearly meaningless. McLearn (1949, pp. 6–9) carefully studied the type locality and its faunal succession. However, he included at the top in his Maude Formation 600 to 800 feet of calcareous cemented lapilli tuff that the writer has found characteristic in many localities of the base of the Yakoun Formation. Hence the Maude Formation as used by the writer is very much restricted.

Lithology.—The Maude Formation is composed of shale, argillite, siltstone, and lithic sandstone, most of which are calcareous, and very minor limestone. Colour of the fine rocks varies from dark to light grey and of the sandstones from grey to grey-green. Bedding is slabby to blocky where pronounced, but in the shales is not very noticeable except where there are intercalations of other rock types. The proportions of the various rocks vary from locality to locality. All these features contrast with the Kunga Formation.

The type locality is composed of interbedded dark-grey lustreless calcareous shale, light-grey shale, blocky dense dark-grey argillite with some intercalated blocky grey calcareous sandstone and light-grey to buff carbonate beds (*see* Plate VIc). On the Yakoun River the arenaceous beds are more prominent. Grey-green sandstone occurs in thick sets of beds and intercalated with grey shale and calcareous siltstone. In a number of localities small septarian nodules are present in the shales. Belemnites are very common in certain beds.

Individual rock types of the Maude Formation resemble rocks of other units; for example, the shales and some sandstones are similar to Haida rocks and the blocky argillites resemble Longarm argillites. In aggregate, however, the Maude Formation is unique.

Microscopy.—Microscopically and macroscopically the Maude rocks resemble the Kunga rocks but with characteristic differences. Table V gives a summary of six representative specimens and Figure 16 shows quartz, total feldspar, and rock fragments plotted for arenaceous rocks from all sedimentary units.

TABLE V.—MINERAL COMPOSITION, MAUDE FORMATION

	Maude Island				King Creek	Ghost Creek
	Silty Argillite	Silty Carbonaceous Shale	Lithic Calcareous Argillite	Silty Bioclastic Limestone	Belemnitic Sandstone	Lithic Sandstone
Clasts—						
Plagioclase	27	15	20	6.5	10	20
Quartz	Tr.	0.5	Tr.	Tr.	5	....
Opaques	5	5	5	8	2.5	1
Rock fragments	12.5	5	10	3	17.5	69
Calcite fragments	....	10	60	} 50	50	....
Matrix	52.5	60	5	}	10	10
Spherules	3	5	....	32.5	5	....

In the fine-grained rocks the matrix is normally composed of very fine sericite or chlorite and only rarely of calcite. In some specimens not noticeably metamorphosed the matrix has been partially recrystallized with poikilitic amœboid chlorite crystals of large size. The lithic sandstones also have a significant chloritic matrix commonly well crystallized. Calcite fragments, many recognizably organic, are common in many types except the dense argillites and lithic sandstones. Volcanic rock fragments and plagioclase are abundant in all specimens, with plagioclase exceeding the rock fragments in the finer rocks. The volcanic rocks of clasts include fine basalt-like rocks, but porphyritic andesite similar to the Yakoun rocks predominate in the lithic sandstones, a precursor of things to come. Plagioclase is predominantly andesine. Quartz is very rare but present in trace amounts. The 5 per cent shown in the belemnitic sandstone is really mostly chert of microfossils. All the fine rocks contain spherules, mostly spherical, of 0.05 to 0.2 millimetre in diameter. Most are calcite filled, but some contain a mosaic of very fine chert or zeolite. Rarely, as in the belemnitic wacke or silty bioclastic limestone, they contain a rude internal structure. Most of the rocks contain a moderate amount of opaque minerals, both fine organic matter and pyrite, but never equal to the quantities shown for the most organic or pyritic specimen from the Kunga.

Stratigraphy. — The stratigraphy of the Maude Formation is more variable, both locally and areally, than that of the Kunga Formation. The type section on southeastern Maude Island is only partly well exposed, and the one across the inlet on Moresby Island is less well exposed. The section on the Yakoun River south of Ghost Creek is the best and thickest exposure.

TYPE SECTION OF MAUDE FORMATION ON SOUTHEASTERN MAUDE ISLAND

Yakoun Formation calcareous lapilli tuff.	Thickness in Feet	Feet above Kunga Formation
Dense grey blocky argillite (6-inch to 1-foot beds) with some buff-weathering light-grey calcareous siltstone and concretionary limestone with some septarian nodules (minor faulting, poor exposure)	49	450
Buff-weathering light-grey limestone with collection 61AB283 (*Harpoceras propinquum*)	1	401
Grey shale with calcareous concretions and septarian nodules and some blocky argillite	20	400
Covered	150±	380
Dense dark-grey blocky argillite and calcareous greywacke (6-inch to 3-foot beds)	49	230
Light-grey-weathering sandy limestone with collection 61AB282 (*Fanninoceras* cf. *kunæ*)	1	181
Dense dark-grey blocky argillite (1- to 3-foot beds)	30	180
Light-grey to buff-weathering grey calcareous sandstone to concretionary limestone with collection 61AB280 (*Tropidoceras actæon* and *Eoderoceras* cf. *armatum*)	1	150
Dark-grey shale (2- to 3-foot beds) with dense dark-grey blocky argillite (2- to 3-foot beds) with minor light-grey to buff-weathering grey calcareous shale to concretionary limestone (2- to 8-inch beds)	149	149

Kunga Formation (black argillite member).

SECTION OF MAUDE FORMATION ON YAKOUN RIVER ABOVE GHOST CREEK

End of exposure—Yakoun Formation exposed not far above.	Thickness in Feet	Cumulative Thickness above Kunga Formation
Greenish-grey sandstone and grey siltstone in 6-inch to 1-foot beds, with some buff-weathering light-grey carbonate beds, collection 62AB55 and many belemnites	100	600
Grey siltstone and shale with greenish-grey sandstone; poorly exposed	150	500
Greenish-grey fine to medium sandstone, collection 62AB56	50	350
Grey shale with grey calcareous siltstone (around 6 inches thick) every 2 to 6 feet and greenish-grey fine sandstone (around 9 inches thick) every 10± feet; some small septarian nodules near top; collection 62AB57, mostly from talus over entire thickness	200	300
Greenish-grey lithic (volcanic) sandstone with belemnites; poorly exposed along strike	100	100

Kunga Formation.

Origin.—The Maude Formation is entirely marine and contains benthonic as well as pelagic faunas. The nature of the formation indicates a gradational but marked change from the conditions of the Kunga Formation, but thickness and lithology vary widely. The rocks are no longer highly carbonaceous nor are they thinly bedded. Graded beds are absent, but arenaceous rocks of abundant volcanic detritus are common. Belemnites abound in some volcanic sandstones, and in several localities (for example, lower King Creek) have preferred orientations, indicating currents moving from the east. In summary the basin of deposition may have been becoming fragmented and shoal whilst volcanism similar to Yakoun began on the fringes of the area.

Age and Correlation.—The Maude Formation is of late Lower Jurassic age and is now known to include parts of the Late Sinemurian, Pliensbachian, and Toarcian stages in the type section. McLearn (1949, pp. 6–9) concluded from less complete collections that the Maude Formation was Toarcian. Frebold studied the writer's collections and in a recent paper (1967, pp. 1145–1149) has revised the age assigned to the *Fanninoceras* fauna to the Pliensbachian from the Toarcian on palæontological and stratigraphic grounds. In addition, he identified a group of ammonites that were collected from a 1-foot bed 30 feet stratigraphically below the *Fanninoceras* fauna that appears to include two faunas. Frebold (1967, p. 1147) states: "From this bed, in which two faunas of different age seem to be concentrated, the author has determined: *Eoderoceras* cf. *E. armatum* (Sowerby), *Acanthopleuroceras?* sp. nov., *Platypleuroceras* spp., and *Tropidoceras* spp. *Eoderoceras* is probably of late Sinemurian (Lotharingian) age; the other ammonites are of early Pliensbachian (Carixian) age." The *Harpoceras* fauna which occurs within 50 feet of the top of the formation is Toarcian (*see* Type Section, p. 64).

FOSSIL LOCALITIES, MAUDE FORMATION

Map No.	Locality	G.S.C. No.	Field No.	Fossils
1	Sedgwick Bay	36981	58AB362	*Weyla* aff. *bodenbenderi.*
		40942	59AB278	
		52362	62AB133	Ammonite species indeterminate ?*Arniotites.*
2	Atli Inlet	36986	58AB412	Sonniniid ammonite?
		40988	59AB295	*Mortoniceras* (=*Pervinquieria*) cf. *tehamænsis* Reagan? *Prohysteroceras?*
3	Skedans Bay	48591	61AB323	Fragments of Arietitids?
4	Deena Creek	———	———	
5A	Whiteaves Bay	48584	61AB301	*Harpoceras propinquum* McLearn.
5B	Whiteaves Bay	45564	61AB302	*Nodicœloceras.* *Harpoceras* sp.
6A	Maude Island	48603	61AB280	*Eoderoceras* cf. *armatum* (Sowerby). *Acanthopleuroceras?* sp. nov. *Platypleuroceras* spp. *Tropidoceras actæon* (d'Orbigny).
6B	Maude Island	48573	61AB282	*Fanninoceras* cf. *kunæ* McLearn. Pelecypod fragments.
6C	Maude Island	48563	61AB283	*Harpoceras propinquum* McLearn.
7	Rennell Sound	———	———	
8	Yakoun River near Phantom Creek	52339	62AB 65	Fragments of large ammonites.
		52340	62AB 66	Hildoceratid ammonite fragment.
9	Yakoun River near Ghost Creek	52334	62AB 55	Fragments of ammonites of sub-family Grammoceratinæ Buckman?; others similar to large ammonite at locality 52339.
		52335	62AB 56	Fragment of large ammonite similar to (3) at locality 52336.
		52336	62AB 57	(1) *Harpoceras* ex gr. *H. falcifer* (Sowerby). (2) Medium-sized ammonite, sub-family Grammoceratinæ. (3) Large fragment, possibly of same species as (2).
10	King Creek	48565	61AB247	*Vela* sp. indet. Belemnites.

Collections from across the inlet from Whiteaves Bay on Moresby Island are not very complete and add little to the information. Collections from the section on the Yakoun River have not been fully identified, but 62AB57 in the middle of the section contains *Harpoceras* ex gr. *Harpoceras falcifer* (Sowerby). All other collections from the Queen Charlotte Islands are either indeterminate or non-diagnostic. In particular, collections from locality 2 (G.S.C. 36986 and 40988) on Atli Inlet are determined as possibly Cretaceous or mid-Jurassic, but the writer believes the rocks to be Maude Formation.

The Maude Formation, therefore, is the correlative of the lower part of the Hall Formation and probably of the upper part of the Elise Formation of the Salmo area, of south central British Columbia. It is also the correlative of the lowest part of the Fernie Group of the southern Rockies, and probably of the lower part of the Taylor Group of the southeastern flank of the Coast Range. However, the best correlation is with sandstones in the upper part of the Bonanza Group (?) in the Kyuquot-Esperanza area of Vancouver Island, which also contains *Harpoceras* and *Fanninoceras* (Jeletzky, 1954, p. 13).

Yakoun Formation

The Yakoun Formation is primarily a volcanic unit dominated by pyroclastic rocks, many of which are formed largely of porphyritic andesite. In addition, the formation includes much volcanic sandstone, some conglomerate, shale, siltstone, and minor coal. Many of the sedimentary rocks are marine but some are non-marine, and it is likely that the vents from which the volcanic rocks were erupted built cones out of the marine basin. This is the youngest formation of the Vancouver Group, and its age is Middle Jurassic (Bajocian and Bathonian) and earliest Upper Jurassic (Callovian).

The distribution of the Yakoun Formation is shown on Figure 10. Most exposures are in the central part of the islands.

The history of nomenclature for rocks now called Yakoun Formation is complicated, and a statement of all the various revisions and alternative mappings would be lengthy. McLearn (1949, pp. 2–5) gave a good detailed review of the situation up to the present mapping, which has made minor revisions. In essence, the volcanic rocks of the formation were recognized by Dawson (1880, pp. 63–64 and 69–70) as subdivision D, agglomerates, and included in his Cretaceous Series, because of errors in correlation. In this he was misled by the near identity in appearance of Haida and Yakoun sandstones and by their previously having been mapped together by Richardson (1873). Billings (1873) had reported these (combined) sandstones were of Jurassic and Cretaceous age, but Whiteaves insisted (1876, 1883, 1884, and 1900) there was only one fauna and that it was early Lower Cretaceous because of Jurassic affinities of some of the fossils. These errors were corrected successively by Ells (1906) and more particularly by Clapp (1914) and MacKenzie (1916). Cretaceous and Jurassic sandstones were mapped separately, and the latter included with the volcanic rocks, to which they are related. MacKenzie named this Jurassic formation, and said it was well exposed on Skidegate Inlet and Yakoun Lake, getting its name from the latter. He recorded three localities at which the Cretaceous Haida Formation unconformably overlay the Jurassic Yakoun Formation. McLearn studied in detail the Skidegate Inlet localities of

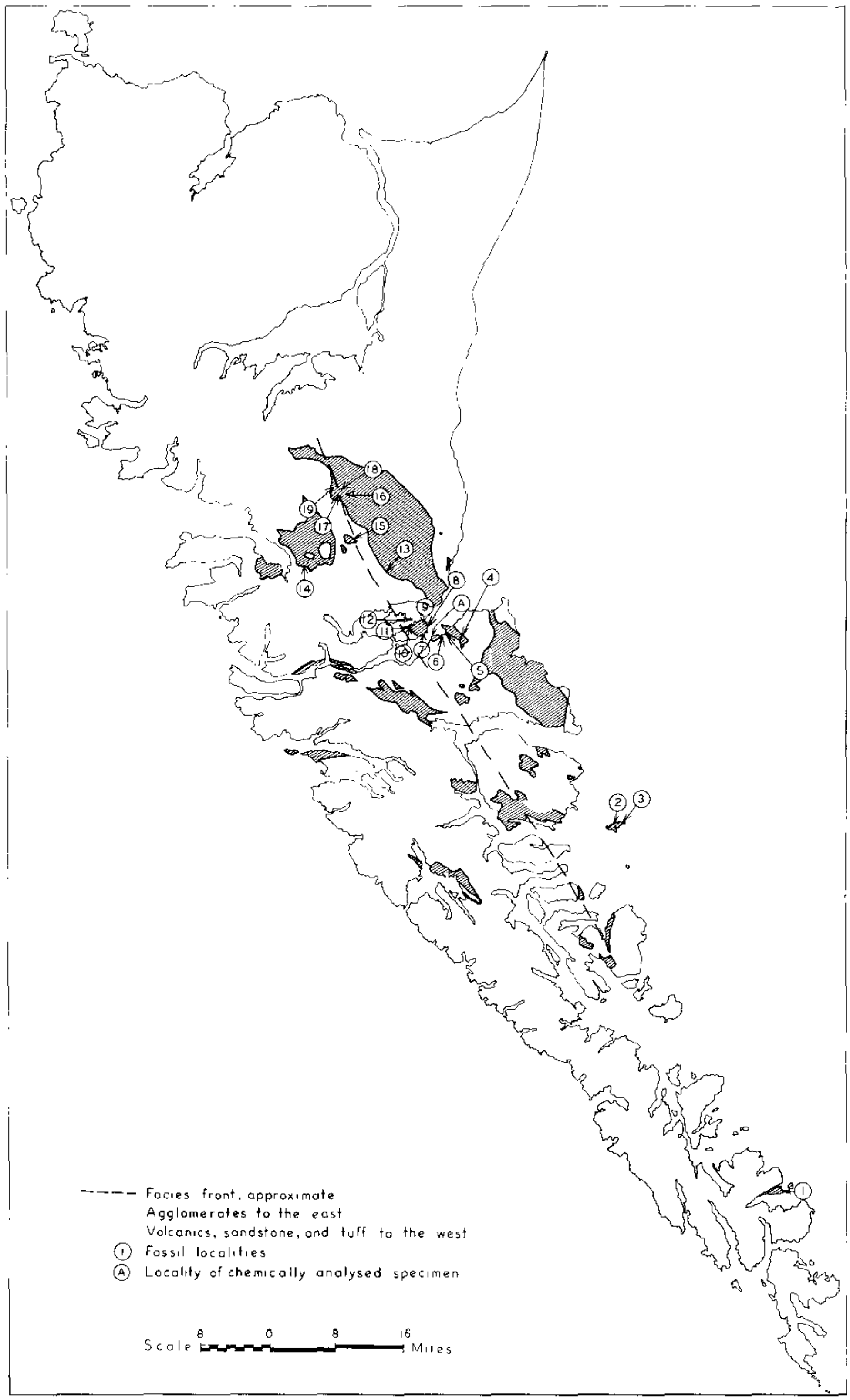


Fig. 10. Yakoun Formation: Distribution and fossil localities.

Maude Island and Alliford Bay. These localities are actually much better for study than the Yakoun Lake localities, and the writer considers the one on southeastern Maude Island the type locality. Changes resulting from the present mapping in eastern Skidegate Inlet are minor; however, in western Skidegate Inlet the situation is complicated: Masset volcanic rocks (Tertiary) were mistaken for Yakoun and Lower Cretaceous Longarm Formation for Maude Formation (Lower Jurassic).

The Yakoun Formation conformably overlies the Maude Formation and may be disconformable or somewhat unconformable on the Kunga Formation and includes small intrusive bodies into these units. The contact relations with the Longarm Formation are not well known and may not everywhere be the same. Simple unfaulted well-exposed relations are almost unknown. East of Rennell Sound it is difficult to find a break between the two, but elsewhere such as at Lyell Island the relations are indicative of unconformity. Relations between Haida and Yakoun Formations are definitely angularly unconformable.

Lithology.—The Yakoun Formation is dominated by pyroclastic rocks and characterized by porphyritic andesite agglomerate and tuffs. In addition, it contains much sedimentary rock, most of which is directly derived from the volcanic rocks. Volcanic flows are apparently quite rare; dykes and sills are relatively common in older rocks but difficult to discern within the formation. The type section on southeastern Maude Island described on page 73 may be considered typical but is in no way a standard as the unit is highly variable.

The most abundant and the characteristic rock type of the Yakoun Formation is agglomerate formed of porphyritic andesite fragments. Commonly this agglomerate is found in massive outcrops in which the fragmental character is only noticed on close observation. At other localities, however, the fragments weather in relief and its fragmental character is obvious (*see* Plates VIIA and VIIB). Colour varies widely but weathered outcrops are generally slightly mottled light to middle brown. Fresh rocks are most commonly dark grey to purplish grey or greenish grey with prominent cream plagioclase phenocrysts. Fragments range from angular to subrounded and in size from 2 to 3 feet in diameter to lapilli, with blocks greater than 8 inches relatively rare. They are only crudely sorted, but the maximum size of fragments in any locale is fairly consistent. The agglomerate is very dense with a compact matrix of comminuted matter identical to the larger fragments. Rarely the matrix may be partly or wholly calcareous, and at most of the localities where the fragments weather in relief, the matrix is lighter coloured and calcareous. The size and percentage of phenocrysts in adjacent fragments vary widely and colour may vary, but normally quite subtly. Obviously vesicular fragments and accidental fragments are rare. Non-porphyritic fragments are moderately common in some areas. Phenocrysts are predominantly feldspar, but pyroxene and amphibole are common. With reduced grade size, agglomerates pass into similar lapilli tuff and to crystal lithic tuffs in which feldspar crystals are very prominent. The agglomerates may grade imperceptibly into volcanic conglomerates, and lapilli tuffs into volcanic sandstones.

Associated with the porphyritic andesite pyroclastics in some localities are water-lain tuffs that are well bedded and moderately well sorted. They commonly contain much carbonate and weather light buff. Large fragments are angular and may or may not be porphyritic. Crystal debris is normally prominent in the matrix. Within these tuff members there are commonly channels or sets of beds of rock similar in appearance but showing better-sorted cross-laminæ and other sedimentary features showing they are volcanic sandstone resulting from reworking of the tuffs.

Another pyroclastic rock that forms a characteristic part of the formation is a lapilli tuff or tuff of finely scoriaceous fragments with a calcareous matrix. This rock normally forms the basal member of the formation and as such is widely distributed from George Bay to Rennell Sound. Similar tuffs or admixtures of similar material in the porphyritic andesite tuffs occur in small amount sporadically throughout the formation. This rock weathers a finely mottled buff and brown, but when fresh the fragments are uniform olive-grey with white matrix. The largest fragments are rarely greater than 5 centimetres and more commonly are less than 2 centimetres. Sorting is fairly good, and bedding may be quite marked by variation in the amount of carbonate matrix. Particles are angular to subangular; larger ones are normally finely vesicular to scoriaceous, and all or almost all are aphanitic.

Other volcanic rocks including definite flow rocks occur sparingly within the formation.

Sedimentary rocks form a considerable part of the unit, the percentage varying from locale to locale. Naturally many rocks are difficult to classify definitely as tuffs or volcanic sandstones. Nevertheless it is quite clear that large quantities of volcanic sandstone are part of the formation. In addition, true conglomerates and shales are found, and some coal beds. The sandstones normally are dense, poorly bedded, rather featureless rocks that weather dark brown but are dark greenish grey when fresh. They are mostly medium to coarse grained with abundant feldspar grains. Sedimentary features are rare and fossils fairly uncommon, apart from scattered belemnites and carbonized wood. Exceptionally such rocks contain abundant ammonites or pelecypods.

Conglomerates are most common as marginal deposits to agglomerates, and in such cases are nearly identical to the agglomerates, except for much greater rounding and slightly better sorting. Some pebble beds, or exceptionally thick beds with some cobbles, occur within sandstone sequences. These conglomerates are composed entirely of volcanic fragments, and granitic debris such as is conspicuous in Honna conglomerates is absent.

Dark-grey shales and siltstones form a small part of the formation but are particularly important because they contain most of the good fossils. Shales seldom occur in sets thicker than 10 to 20 feet and are generally well bedded as a result of intercalations of tuff or sandstone laminæ or beds. Some of the shales contain scattered crystal or lithic debris that is probably of air-fall origin. Carbonized or carbonatized wood is fairly common, leaves and fruits of plants are common at some localities, and coal is common in shales and sandstones of the Yakoun River valley.

Microscopy.—The Yakoun Formation is composed almost wholly of rocks of various textures and origins, but formed from one magma type that normally crystallizes to a porphyritic andesite. All but one of the four categories used in this study are formed from porphyritic andesites; the exception is a chemically similar if texturally different type. The categories are (1) porphyritic andesite agglomerates, (2) porphyritic andesite crystal lithic tuffs, (3) calcite-cemented scoriaceous lapilli tuff (the exception), and (4) volcanic sandstones and conglomerates. Modes for these types are shown on Table VI, together with the mode of one chemically analysed specimen of porphyritic andesite.

The porphyritic andesite contains about 40 per cent plagioclase phenocrysts of An_{60-30} composition with marked oscillatory zoning over a small range. These have a stubby shape, some 1 to 4 millimetres long, with common parallel combined crystals. Carlsbad twins are very common, and originally glassy inclusions are evident. Partial alteration to chlorite, carbonate, and, rarely, stilbite is normal. Mafic minerals include augite, hornblende, and rare pigeonite, but all are normally altered to chlorite and serpentine with an opaque iron-rich periphery on the hornblende. The matrix may be entirely a cryptocrystalline felsic and chloritic mass with iron ores or may contain distinguishable plagioclase and granular pyroxene with a finely felted or trachytic texture. Some carbonate alteration of the matrix is common. Irregular to spherical amygdules containing chlorite are inconspicuous but fairly common.

(1) The agglomerates are normally composed entirely of porphyritic andesite fragments in a more finely comminuted matrix of the same. Variation in crystallinity, opaqueness of the matrix, and vesicularity in adjacent fragments indicate that the rocks are not flow breccias. Specimens from certain areas and beds show considerable calcareous replacement of the comminuted matrix.

(2) The porphyritic andesite tuffs and lapilli tuffs are the finer equivalents of the agglomerates. They, too, are derived almost entirely from the porphyritic andesite magma but show slightly more variation in the texture of the fragments than do the blocks in the agglomerates. Almost all are lithic tuffs with 20 to 30 per cent crystal fragments and about 20 per cent finely comminuted matrix. A few, mostly fine tuffs, are crystal tuffs. Table VI shows the range and average of 13 specimens. Although the range is wide, most are close to the average.

The rock fragments vary in size of phenocrysts, crystallinity of the matrix, and vesicularity more than the porphyritic andesite of the agglomerate. Very few accidental fragments are present. The shape of the fragments varies widely, with angular, irregular, blocky, subangular, and rounded fragments being common in the same specimen. Fragments with mainly chlorite-filled amygdules are common. Most of the tuffs examined are lapilli tuffs, with largest fragments in the range of 2 millimetres to 1 centimetre. Most specimens and particularly the matrixes are highly altered—chloritized, sericitized, and carbonatized. Other specimens have been subjected to thermal metamorphism. Plagioclase, where fresh enough to determine, is commonly oscillatorily zoned in the range An_{58-50}. Antiperthite is evident in about one-quarter of the specimens examined.

(3) *The calcite-cemented scoriaceous lapilli tuff differs from the normal tuff* (2) in several respects. Normal porphyritic andesite fragments are virtually absent; finer trachytic varieties are present in minor amount, except in one specimen in which it formed the bulk. Most fragments are scoriaceous to pumiceous, chloritic, very fine-grained rocks with microphenocrysts of plagioclase ($An_{40\pm}$) and augite. The matrix is chemical, not clastic; it was carbonate and may now be calcite, dolomite, or zeolite, or some mixture of these. Mesolite is the most common zeolite, but heulandite and chabazite were noted.

The lapilli are irregular in shape, and in only a couple of the most pumiceous specimens show any compaction. As with the porphyritic andesite tuffs, alteration is intense, chloritization is general, and in many specimens the plagioclase is altered to zeolite.

(4) Volcanic sandstones are composed dominantly of subangular fragments of porphyritic andesite with a minor amount of other rock fragments and about 40 per cent of angular crystal fragments compactly arranged in a scant chloritic matrix (*see* Table VI). Plagioclase grains greatly outnumber quartz grains, on the average 4 or 5 to 1. Much of the plagioclase shows oscillatory zoning and ranges from An_{54-24}. Other crystal fragments include pyroxene, hornblende, chlorite

pseudomorphs, and magnetite. Calcareous shell fragments are moderately common in certain specimens. Most specimens show no indication of bedding in thin-section, but the sorting is fair. Most examined specimens are coarse sandstones. Figure 16 shows quartz, total feldspar, and rock fragments plotted for arenaceous rocks of all sedimentary units.

Chemistry.—One specimen of fresher than normal porphyritic andesite from a large block in an agglomerate was chemically analysed. This is shown on Table VI along with the mode. It differs from normal andesites in being lower in magnesia and lime and higher in soda. The high soda is a regional characteristic; the low calcium is related to this. The low magnesia is related to the excess phenocrystic plagioclase.

As an approach to understanding the origin of the Yakoun porphyritic andesite, the table also shows an analysis calculated to represent a mix of 65 per cent Karmutsen pillow lava with 35 per cent plagioclase of An_{35} composition and also an average of two hornblende quartz diorites from the San Christoval Batholith. A Karmutsen-type lava may have evolved to produce the porphyritic andesite by addition of floated plagioclase. If 35 per cent of An_{35} crystals are added to Karmutsen liquid (that is, average pillow lava, Table II), the result is not greatly different from the andesite. Alternatively the syntectonic batholiths which seem also to have been generated from Karmutsen rocks (or magma) may have been a possible source of the porphyritic andesite. The hornblende quartz diorites shown in Table VI represent evolved, truly intrusive phases of these batholiths. With the exception of the alkalis, these two analyses bracket the one analysis of porphyritic andesite.

On the data at present available, no more than a crude suggestion can be made on the origin and evolution of the magma that produced the porphyritic andesite. The extensive oscillatory zoning of the andesine and the abnormally large quantity of these phenocrysts throughout the bulk of the volcanic deposits of the Yakoun Formation indicate a prolonged and selective evolution. Some crystal accumulation, possibly by gravitative floating to cupolas in the magma chamber, is likely. The addition of 35 per cent andesine to the pillow basalt liquid would not be greatly different from the porphyritic andesite. The hornblende quartz diorites represent relatively highly evolved phases of the syntectonic plutonic rocks thought to have had a similar origin (*see* p. 144). Excess alkalis would be expected at a cupola beneath volcanic vents.

TABLE VI.—CHEMICAL ANALYSES AND MODES, YAKOUN FORMATION

PORPHYRITIC ANDESITE

Phenocrysts—	Range	Average of 7	61AB298*
Plagioclase	20–55	42.6	35.9
Pyroxene	Tr.–10	6.6	8.4
Hornblende	0–10	1.6	1.0
Iron ores	3–10	4.6	6.0
Matrix	30–49	44.6	48.8
		100.0	100.1
Plagioclase	An_{60-30}		$An_{35\pm}$
Pyroxene	Augite+(pigeonite)		Augite+(pigeonite)

PORPHYRITIC ANDESITE TUFFS

	Average of 13	Range
Rock fragment	49.6	Tr.–70
Crystal fragment	29.8	5–75
Comminuted matrix	20.6	5–40
	100.0	

CALCITE-CEMENTED SCORIACEOUS LAPILLI TUFF

	Average of 7	Range
Scoriaceous rock fragment	55.8	60–80
Non-vesicular andesite	16.4	0–80
Crystal fragments	0.7	0– 5
Matrix, carbonate or zeolite	27.1	20–40
	100.0	

VOLCANIC SANDSTONE

	Average of 10	Range
Rock fragments—		
Porphyritic andesite	49.1	40–70
Other	5.2	0–15
Crystal fragments—		
Plagioclase	30.3	20–50
Quartz	7.0	Tr.–22
Other	1.4	Tr.– 9
Matrix	7.0	Tr.–30
	100.0	

CHEMICAL ANALYSES, PORPHYRITIC ANDESITE

	1*	2	3
SiO_2	56.90	53.60	60.32
TiO_2	0.69	1.26	0.70
Al_2O_3	17.53	17.30	17.39
Fe_2O_3	4.62	2.30	2.14
FeO	2.55	6.20	3.89
MnO	0.15	0.10	0.12
MgO	2.08	3.60	2.25
CaO	5.66	8.80	5.89
Na_2O	6.01	4 70	3.99
K_2O	2.29	0.20	1.41
H_2O+	0.73	....	1.46
H_2O-	0.49	....	0.16
CO_2	0.15	....	0.04
P_2O_5	0.15	....	0.14
SO_3	0.002	....	0.003

*1=61AB298, porphyritic andesite from Transit Island, Skidegate Inlet. Analysis by S. Metcalfe, Analytical and Assay Branch, Department of Mines and Petroleum Resources.

2=Mix of average Karmutsen pillow lava (Table II, p. 47) with 35 per cent An_{35} plagioclase.

3=Average hornblende quartz diorite, San Christoval Batholith (Table XVIII, p. 134).

Stratigraphy.—The stratigraphic sections of the Yakoun Formation differ greatly from locale to locale, as might be expected from a dominantly pyroclastic unit. The same rock types are generally present in any considerable section. The most constant relation is that the calcite-cemented finely scoriaceous lapilli tuff forms the basal unit at nearly all localities where the base is well exposed. The thickness of this member, however, varies widely and is nowhere known to be thicker than at the type locality on Maude Island. McLearn included this member in the Maude Formation, but from regional considerations it must be included with the Yakoun. For the rest of the formation there is an approximate inverse relationship between the porphyritic andesite pyroclastic rocks and the volcanic sandstones. Figure 10 shows a line from Atli Bay on Lyell Island to the bend of the Yakoun River that is called the facies front. It represents the centre of a zone of transition from predominantly agglomerates on the east to predominantly tuffs and volcanic sandstones on the west.

The type section which follows is on the southeastern shore of Maude Island. It is representative because it is from the zone of transition and both facies and most rock types are present in quantity.

A small fault separates the Haida sandstone from the top of the Yakoun Formation so that the unconformity is not actually visible, but its presence is quite evident. Other faults cut the type section, but they are all judged to be relatively small except for the one between B and C members, which might be sizeable. C member is considerably thicker at Alliford Bay, less than 1 mile south, which may indicate that this fault is one of considerable movement.

TYPE SECTION, YAKOUN FORMATION, SOUTHEASTERN SHORE OF MAUDE ISLAND

Haida Formation sandstone with *Douvilleiceras spiniferum*.

Member		Thickness in Feet	Cumulative Thickness above Maude Formation	
E member	Dark-green volcanic sandstone, poorly bedded, some pebble beds, rare large pelecypods	150	2,955	455 feet
	Covered, with loose blocks of volcanic sandstone	50	2,805	
	Grey shale with collection 61AB294 and McLearn's Y6 (*Chondroceras* sp., *Pleuromya* sp., *Trigonia* spp., and other pelecypods)	35	2,755	
	Covered	30	2,720	
	Greenish volcanic sandstone with shale and rare pebbly sandstone; 6-inch thick beds of corals *Montastrea* sp.? in situ near top	50	2,690	
	Poorly exposed volcanic sandstone and shale	50	2,640	
	Dark purplish-grey siltstone and fine volcanic sandstone with some shale and calcareous siltstone, 2- to 3-foot-diameter concretions near top	90	2,590	
D member	Poorly exposed crystal lithic tuff and lapilli tuff and(?) volcanic sandstone	370	2,500	800 feet
	Volcanic sandstone and minor conglomerate and pebbly sandstone	50	2,130	
	Fine crystal lithic tuff	100	2,080	
	Cross-bedded volcanic sandstone	50	1,980	
	Tuff and lapilli tuff	100	1,930	
	Lapilli tuff	20	1,830	
	Cross-bedded volcanic sandstone, a few brachiopods 62AB290, McLearn's Y4	50	1,810	
	Fine porphyritic andesite agglomerate grading to crystal lithic tuff at top	60	1,760	
C member	Porphyritic andesite agglomerate, mostly massive with blocks to 3 feet in diameter but most large ones 6 inches to 1 foot	950+	1,700	950+ feet
	Fault with horizontal movement, fairly important.			
B member	Interbedded shale, tuffaceous shale, tuffaceous sandstone and tuff; sharply folded and attenuated near fault; collections 62AB288, McLearn's Y3 (*Chondroceras* spp., *Stephanoceras* sp., belemnites, *Phalodomya*, and other pelecypods, gastropods); mostly from lowest shales; much calcitized wood	100±	750	100± feet
A member	Fine porphyritic andesite agglomerate	20	650	650 feet
	Green tuff with some exotic blocks	30	630	
	Lapilli tuff and tuff, buff-weathering, olive, finely scoriaceous, aphanitic fragments in white calcareous cement, becoming less calcareous toward top	600	600	

Maude Formation.

The bed of corals in E member is identical to the one in Newcombe Bay, three-quarters of a mile to the west, and relates the collection there, 61AB258, to 61AB294. At Newcombe Bay *Kepplerites* sp. and *Cadoceras?* sp. were collected, as well as belemnites, pelecypods, gastropods, and corals.

FOSSIL LOCALITIES, YAKOUN FORMATION

Map No.	Locality	G.S.C. No.	Field No.	Fossils
1	Iron Point	40978	59AB137	*Pachyteuthis* cf. *densus* Meek, 1867. *Pachyteuthis cuneata* Gustomessov, 1960. *Pachyteuthis* sp. indet.
2	Reef Island	40985	59AB297	*Stephanoceras* cf. *yakounense* McLearn. *Belemnites* sp. *Pleuromya* sp. *Trigonarca tumida* Whiteaves. Other pelecypods.
3	Reef Island	40946	59AB298	*Chondroceras (Defonticeras)* sp.
4	Road south of Alliford Bay	44738	60AB232	Ammonite indet. *Ostrea* sp. *Trigonia* aff. *dawsoni* Whiteaves.
5	Alliford Bay	44707	60AB317	Ammonite indet. *Trigonia dawsoni* Whiteaves. Other pelecypods.
6	Fossil Point, Alliford Bay	44708	60AB318	*Trigonia* aff. *dawsoni* Whiteaves. Pelecypods.
7	Richardson Bay, Maude Island	48594	61AB288	*Chondroceras* spp. *Stephanoceras* sp. Belemnites. *Phalodomya* sp. Other pelecypods and gastropods.
8	Robber Point, Maude Island	48605	61AB294	*Chondroceras* sp. *Pleuromya* sp. *Trigonia* spp. Other pelecypods.
9	Newcombe Bay, Maude Island	48602	61AB258	*Kepplerites* sp. *Cadoceras?* sp. Belemnites. Pelecypods. Gastropods. Corals.
10	Clapp Bay, Maude Island	48598	61AB227	*Teloceras?* sp.
11	MacKenzie Bay, Maude Island	48593	61AB196	*Teloceras itinsæ* McLearn. *Teloceras* sp. *Zemistephanus?* sp.
12	South Balch Island	44711	60AB160	*Stephanoceras* sp. Pelecypods.
		5856	61AB 1	*Cycadeocarpus columbianus* Dawson. *Cycadeocarpus* new sp.?
		48601	61AB 1	*Stephanoceras skidegatense* McLearn. *Stephanoceras* sp. *Chondroceras* sp. *Nautilus* sp. *Trigonia* sp.
13	Skowkona Creek	52329	62AB 34	Ammonite indet. Belemnites. *Weyla?* sp.
14	Rockrun Creek	52356	62AB101	*Chondroceras* sp. Pelecypods.
15	Near Brent Creek	52351 52354	62AB 85 62AB 88	*Chondroceras* sp. *Normannites* sp.
16	Camp Wilson		62AB 52	Coal with the following Jurassic microflora:— *Eucommiidites troedsconii.* *Vitreisporites* sp. *Sphagnum* sp. *Cyathidites* sp. *Microreticulatisporites* sp. *Classopollis classoides* *Cycadopites* and other cycad-*Ginkgo* pollen. *Tsugaepollenites* sp.
17	Yakoun River at Ghost Creek	52331	62AB 48	?Stephanoceratid ammonite.
18	Wilson Creek	52332 52333	62AB 50 62AB 51	*Inoceramus* cf. *I. obliquiformis* (McLearn). Belemnite.
19	Hill near King Creek	52344	62AB 71	*Normannites* sp.

As McLearn (1949) has shown, the section at Alliford Bay is similar to the type section although not identical. At other localities considerable differences exist. Near Skidegate, only a few miles north, there is a good exposure of at least 5,000 feet of agglomerates similar to C member but without significant sedimentary rocks, except some volcanic conglomerates near the top of the exposure. In the vicinity of the Copper River and the upper Tlell, similar great thicknesses of pyroclastic rocks are exposed. In contrast, along the Yakoun River north of Ghost Creek and between Yakoun Lake and Rennell Sound considerable thicknesses of volcanic sandstones occur. Along the Yakoun River above the Maude Formation there is a covered interval and then an exposure of 200 feet of volcanic conglomerate with some volcanic sandstone, and above this sporadic outcrops of volcanic sandstone, shale, and some tuff for several thousand feet stratigraphically. Within this section occur the coal beds of Wilson Creek. Above these rocks are the porphyritic andesite agglomerates and other volcanic rocks. Near Rennell Sound above a considerable thickness of normal pyroclastic rocks and intercalated volcanic sandstones is a great thickness of massive volcanic sandstone without obvious break. From near the top of the exposure fossils of Longarm age were collected.

MacKenzie (1916, pp. 54–58) thought the Wilson Creek coal and associated measures were Haida Formation, the Yakoun Basin of the Haida Formation, and consequently overlying agglomerates were Masset Formation. Fossils from a number of localities (16 to 19) establish that these rocks are definitely Yakoun Formation. The writer did not visit Camp Robertson but now suspects that " the lower member of the Haida Formation " mentioned by MacKenzie (1916, pp. 56–57) is in fact also Yakoun Formation and is overlain by the Haida Formation; however, the area north to Brent Creek is all shown as Haida Formation on the areal map, Figure 5.

Little Yakoun Formation is now found south of Lyell Island, except dykes and sills that might be related. On George Bay a thin remnant of A member, calcite-cemented lapilli tuff, is exposed overlying the Kunga Formation. At Iron Point (Locality 1, Fig. 10) sandstone and pebbly and gritty sandstone occur, in which abundant belemnites are found. The rocks closely resemble Longarm Formation; however, Dr. Jeletzky suggests a Bathonian to Callovian age likely, in which case these rocks are Yakoun Formation. Definite Longarm Formation unconformably overlies Kunga and Karmutsen Formations in numerous localities in the southern islands, and hence it appears that the Yakoun Formation was largely eroded by Early Cretaceous time if it were deposited in any thickness here.

Origin.—The Yakoun Formation, even as known at present, indicates fairly clearly the general setting and sequence of events during its formation. The Middle Jurassic started with widespread emission of fine scoria of intermediate composition which settled into a calcareous marine environment. In places this phase was followed by quiet marine sedimentation interrupted by pulses of lapilli and ash. Then a series of vents opened up along a line subparallel and west of the later Sandspit fault and erupted slightly vesicular blocky porphyritic agglomerate and tuffs which built cones above sea-level. At the same time, erosive processes distributed volcanic detritus and possibly ash in the shoal seaway beyond the volcanic structures. Leaves, fruit, and abundant wood indicate the local cones were probably repeatedly clothed in lush Jurassic forests, and coal beds within the flanking sandstones indicate non-marine conditions alternated with marine, probably due to changes in elevation associated with intumescence related to the volcanic processes. And so the Middle Jurassic proceeded with renewed eruptions of block agglomerate followed by erosion and distribution with possibly marine planation and resulting intercalation of marine deposits of reworked volcanic detritus. There is no real record of the close of this period; no (Upper Jurassic) deposits younger than Callovian are known, unless in the featureless volcanic sandstones near Rennell Sound underlying similar rocks containing a Longarm fauna. It is, however, fairly clear that the volcanic episode was brought to a close with intense deformation and the evolution and emplacement of the syntectonic batholiths.

Age and Correlation.—The age of the Yakoun Formation was established precisely as a result of McLearn's work (1927, 1949). The collections from B member on the south shore are Middle Bajocian (Humphriesianum Zone), whereas those on the north shore in seemingly identical rocks are slightly older (Sauzei Zone) (Arkell, 1956, p. 542). Collections from E member correlate with Calloviense Zone (Arkell, 1956, pp. 527, 536, and 541) or with the adjacent Koenigi Zone (McLearn, 1949, p. 17) of the Middle to Lower Callovian Stage. No fossils of the Bathonian Stage are found, but these have not been found on the Pacific border from California to Alaska, so that their absence is not strange. This stage was highly volcanic. Hence the dated part of the Yakoun Formation embraces all the Middle Jurassic and part of the earliest stage of the Late Jurassic. The writer's collections add little to what was known from all the previous work, except collections were made at a number of new localities remote from Skidegate Inlet. Professor Rouse commented regarding the microfauna in the Wilson Creek coal as follows: " The age of this assemblage is considered Jurassic rather than Cretaceous, although an early Cretaceous age cannot be completely ruled out. However, several diagnostic Lower Cretaceous forms such as *Trilobosporites* are completely absent, and the abundance of microfossils such as the cycadophyte—*Ginkgo,* and *Classopollis* suggest a Jurassic age."

The Yakoun Formation is the correlative of the middle part of the Fernie Group (Frebold, 1953, p. 1246) in the Rocky Mountains. It is the correlative of the Thompson Group and much of the Ashcroft Group of the Ashcroft area (Crickmay, 1930B), and the upper part is partly correlative with the Mysterious Creek Formation of the Harrison Lake area (Crickmay, 1930A) of the interior and coastal areas of British Columbia respectively. The Yakoun Formation is also at least partly correlative with a number of largely volcanic units of coastal and interior British Columbia, although the dearth of fossils in these make correlations very general. Such units are the Lower Hazelton Group, Upper Takla Group, and most likely part of the Bonanza Group.

Longarm Formation

The Longarm Formation, described here for the first time, is a sedimentary unit that in certain localities contains some volcanic rocks. The lithology, age, and structural relations of this unit are known fairly well, but the stratigraphy is not known adequately. The formation is characterized by massive dark calcareous siltstone containing prisms of *Inoceramus* shells but also contains distinctive granule conglomerates, buff to green volcanic sandstones, and some volcanic rocks akin to those of the Yakoun Formation. The age of the Longarm Formation spans much of the early and middle Lower Cretaceous, for it includes latest Valanginian and Hauterivian and Barremian fossils. The Longarm Formation overlies the Kunga Formation, with great angular unconformity at a number of locations (*see* Plate

XIIA), but its relation with the Yakoun Formation is less well displayed. Near Rennell Sound it is difficult to distinguish a break between them. On Lyell Island there appears to be a slight unconformity. The relation to the Haida Formation is even more of a problem as the two rarely appear to be in contact except across large faults. The Honna Formation appears to be conformable on both Haida and Longarm, but there is reason to suspect unconformity (*see* pp. 97–98). The stratigraphy of the Longarm Formation is not well known because the sections that appear to be thickest are all contained within the wide fault zone from Rennell Sound to Louise Island. In this zone neither the top nor bottom is normally seen and subsidiary faults are numerous. Furthermore, much of the formation is composed of similar dark calcareous siltstones and fine greywackes in which there seem to be no markers. Beyond the fault zone the base of the formation and up to a thousand feet of strata may be seen, but not more. In the fault zone it is believed there could be as much as 4,000 feet of Longarm strata. In effect the formation consists of two facies: a trough facies dominated by dark calcareous siltstones and greywacke, and a shoreline facies dominated by conglomerates and sandstone. The type locality is Long Arm, recently renamed Long Inlet. At the head of this inlet the formation is well displayed, and future studies in this vicinity may outline the detailed stratigraphy. Figure 11 shows the distribution, fossil localities, and facies distribution of the formation.

Lithology.—The Longarm Formation is composed primarily of dark-grey calcareous siltstones and lithic fine greywackes. It also contains granule conglomerates and buff, greenish to light-grey coarse greywackes. Minor volcanic rocks similar to the Yakoun Formation occur within the thicker section.

The dark siltstones and fine lithic greywackes are massive to thick-bedded rocks of great toughness, which weathered or fresh are coloured dark grey (*see* Plate VIIIB). Bedding is indistinct, and beds range from 1 to 10 feet or more thick. The most distinctive feature of these rocks is the abundance of *Inoceramus* shell debris of all sizes. United valves are very rare and whole valves uncommon, but prisms of fibrous calcite from broken shells are very abundant. Silt-sized fragments are abundant enough to make the rock as a whole calcareous, although calcareous cement is rare. Recognizable shells are almost all a very large *Inoceramus;* other fossils are uncommon. These rocks compose most of the formation in the type area, and they also occur as a part of the section in other locales.

A second distinctive rock type that occurs in fair abundance is a conglomerate composed of granules or rarely fine pebbles with an over-all black and white appearance not unlike terrazzo in section. At least half of the granules are composed of black argillite, and the rest are light-coloured largely aphanitic volcanic rocks with some carbonate fragments. Sorting is only fair and the fragments range from subangular to subrounded. Sphericity of argillite fragments may be low. The rock is compact and indistinctly bedded. This conglomerate is found at the base of the formation at most exposures beyond the fault zone, but because the base has not been seen in the vicinity of Long Inlet it is not known in the type area except as float. Within the conglomerates at the very base in certain localities such as Arichika Island, there may be a layer containing a few large to immense boulders in a matrix of granule conglomerate.

In addition to these two rock types which are distinctive of the Longarm Formation, there are medium- and coarse-grained sandstones and conglomerates composed dominantly of volcanic rock fragments. The sandstones are not greatly different in hand specimen from those of other formations. These rocks are buff, brown, or light-green weathered, but are normally mid-grey when fresh. Bedding is

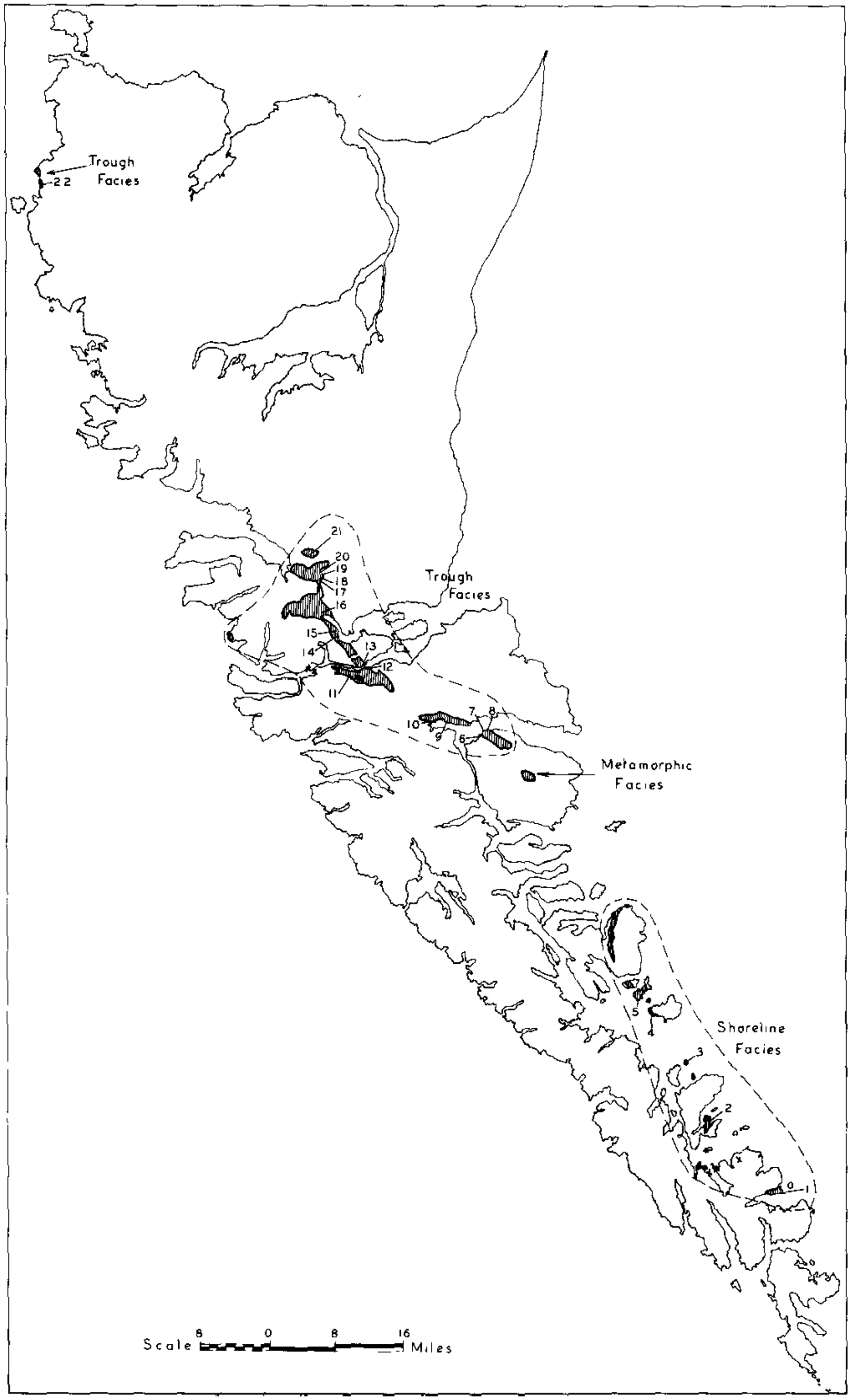


Fig. 11. Longarm Formation: Distribution and fossil localities.

not pronounced, although indistinct lamination and cross-bedding are evident in some localities. Most of these volcanic sandstones are somewhat calcareous, and rarely they grade into rocks that look similar but are actually calcarenites. The sandstones, like the conglomerates, are comparatively less important near Long Inlet but occur in small volume at the head of Lagins Creek and east of Rennell Sound. The formation on Lyell Island is chiefly formed of conglomerate, which here overlies Yakoun Formation in all probability with moderate unconformity.

Minor volcanic rocks occur within the formation at scattered localities from Cumshewa Inlet to Rennell Sound. These include fine agglomerates and finely porphyritic flows similar in most respects to those of the Yakoun Formation. Minor fine tuff and agglomerate occur near the base on both sides of Cumshewa Inlet.

Microscopy.—The Longarm rocks are seen microscopically to be composed principally of clasts of volcanic rocks, sedimentary rocks, and *Inoceramus* shells, in widely varying proportions. Table VII lists the range and averages for fairly distinct types, and Figure 16 shows quartz, total feldspar, and rock fragments for arenaceous rocks of all sedimentary units.

The black and white granule conglomerate (1) is characteristic of the base of the formation. It is composed of clasts of volcanic rocks and Kunga argillite commonly in subequal amounts but with volcanic clasts dominant. However, it is the presence of the black Kunga clasts that gives the rock its distinctive appearance. The volcanic rock types are numerous but include Yakoun-like porphyritic andesites with lesser amounts of trachytic feldspathic rocks, felsite, and basalt. *Inoceramus* shell fragments may form from 0 to 30 per cent of the rock. Amongst the finer clasts, plagioclase and quartz are both present and commonly plagioclase is dominant. Epidote and clinozoisite are invariably present as clasts and may form almost 1 per cent of the rock. Opaque minerals are not prominent. Matrix is relatively minor and may be formed of calcite or chlorite, or both, or more rarely of chert or very fine sandstone. Sorting and shape of fragments are as variable as the composition. The sphericity of clasts is very low but rounding is good. Kunga fragments in particular tend to be elliptical or rounded, rectangular, or triangular shaped. A bimodal or trimodal size distribution is common. The granule conglomerate (1 to 4 millimetres diameter) commonly fills in around large, widely spaced boulders, and fine sandstone similar to that which may be intercalated with the granule conglomerate may form a distinct population within the granules.

Similar conglomerates (2) occur in small volume above the base of the unit, and in such cases they are composed almost wholly of volcanic rock clasts with only minor Kunga chips, plagioclase, or quartz grains. Some of these volcanic conglomerates are much stained by ferruginous materials.

The sandstones (3) of the formation are more distinctive in thin-section than in hand specimen. They are characterized by a variable but not uncommonly a significant amount of *Inoceramus* shell debris and by slightly less quartz than plagioclase in an essentially lithic sandstone. Rock fragments are dominantly volcanic, but carbonaceous siltstones are commonly present and may be important. In general the siltstones seem to be locally derived Longarm fragments. Epidote or clinozoisite clasts are present in many specimens. Opaque minerals, both pyrite and carbonaceous material, are commoner than in the conglomerates. The amount of matrix is variable from only a trace to 15 per cent and is commonly well-crystallized chlorite or calcite. Rarely rocks that look similar to these sandstones are found to be almost entirely composed of rods, plates, and grains of calcite that are separated from the prismatic layer of the large *Inoceramus*. Sorting in all sandstones is fair to good, rounding is slight.

The most abundant rock type is the dark-grey siltstone (4). This name is a misnomer, for truly the rock is composed of a heterogeneous assortment of chips, shreds, balls, and irregular clasts of siltstone which can be distinguished in thin-section by their slight variations in opaqueness and grain size but which do not show in hand specimen. *Inoceramus* shell debris of all sizes is characteristic. About 15 to 20 per cent of this is in the coarse silt size. Concentrations of larger fragments vary widely but are common. Some granule-size fragments are seen to be deformed along the planes of the prisms. Bedding is crudely indicated by planar shell debris and the more opaque shred-like siltstone clasts. The constituent siltstones are composed of plagioclase, fine volcanic rock fragments, calcite, and quartz clasts with considerable fine pyrite and organic matter in a very fine chloritic matrix. Most of the primary clasts are in the range 0.02 to 0.08 millimetre. The larger secondary clasts are variable, but many are 2 to 5 millimetres in long dimension (*see* Plate XVIB).

TABLE VII.—MINERAL COMPOSITION, LONGARM FORMATION

	1		2		3		4	
	Black and White Granule Conglomerate		Volcanic Conglomerate		Sandstones		Siltstones	
	Range	Average	Range	Average	Range	Average	Range	Average
Rock fragments—								
Volcanic	30–45	38.5	60–90	78.2	1–55	29.8	15–35	25.0
Sedimentary	2–49	27.0	Tr.–10	3.3	Tr.–15	5.6	....	......
Fossil fragments	0–30	7.9	....	......	Tr.–90	27.0	15–20	18.3
Mineral grains—								
Plagioclase	Tr.–16	6.6	Tr.–19	8.0	4–30	18.8	20–30	26.6
Quartz	Tr.–10.5	4.9	Tr.– 1	0.5	Tr.–20	8.2	5–25	11.7
Epidote	Tr.– 1	0.5	Tr.	Tr.	Tr.	Tr.	....	......
Opaque	Tr.	Tr.	....	......	1–20	5.6	2–7	4.7
Matrix	5–35	14.5	Tr.–20	10.0	Tr.–15	5.0	8–20	13.7

Stratigraphy.—The thickest mass of Longarm Formation at Long Inlet and the head of Lagins Creek has not been studied in sufficient detail to provide a type section. This area is complicated by numerous subparallel faults and by discontinuous exposure. Even casual study indicates it is the area of greatest accumulation, and further work, possibly on the mountain on Rennell Sound south of Rockrun Creek, might provide an adequately exposed complete section. Near Long Inlet there are several thousand feet, possibly 4,000, of very similar dark siltstones and fine lithic greywackes. On Skidegate Channel the Longarm Formation is not well exposed and is again cut by numerous faults. Exposures on Gillatt Arm and Cumshewa Inlet are similar in lithology to the type area but also are sliced by many faults and are haphazardly exposed.

Sections of the Longarm Formation away from the Rennell Sound-Cumshewa Inlet section are more readily studied. The exposure on Arichika Island is typical, except no siltstones are exposed.

SECTION OF LONGARM FORMATION, ARICHIKA ISLAND

	Thickness in Feet	Cumulative Thickness above Kunga Formation
End of exposure.		
Coarse to fine thickly bedded buff-weathering mid-grey lithic sandstone with poorly preserved brachiopods	350	610
Interbedded black and white fine granule conglomerate and buff-weathering cross-stratified coarse lithic sandstone and pebbly sandstone	240	260
Conglomerate of cobbles and small boulders with occasional very large boulders	20–5	20

Large angular unconformity underlain by *Monotis*-bearing Kunga Formation.

The basal boulder conglomerate rests on truncated folds of the *Monotis* beds of the Kunga Formation, and much of the cobbly material and most of the granular matrix are Kunga black argillite and limestones scarcely rounded at all. The large boulders are all well-rounded volcanic rocks of general andesitic nature similar to dykes occurring within the Kunga. The largest is some 20 by 30 feet, but most are only a few feet in diameter. The fine granule conglomerate above is essentially similar but much finer. It is intercalated with the coarse lithic sandstone in complicated broadly braided sets of beds, which in detail show finer cross-stratifications.

Other exposures in the south are similar, except the conglomerates are mostly fine pebble or granule conglomerates and generally are thinner. However, on northeast Lyell Island conglomerates of Yakoun-like clasts form most of the section. On Poole Inlet and Murchison Island and vicinity, the dark *Inoceramus* prism-bearing siltstones are present in addition to the sandstones and conglomerates.

Origin.—The Longarm Formation is entirely marine, for marine shells and clasts from them are a characteristic part of most of the formation. A common feature of all rock types is their immaturity. Obviously the time between exposure, erosion, and final deposition of raw materials of this unit was short, and any reworking was not a sorting process but only rearrangement. The main distribution of the unit along the Rennell Sound-Louscoone fault linkage, with the thickest part of the succession within the wide zone north of Louise Island, is probably not accidental. The siltstones are not identical to typical turbidites and lack many of the sedimentary structures attributed to them. Nevertheless the disaggregation and comminution of the abundant large shells taken with the microscopic nature of the siltstones indicates a highly unstable environment. The writer tentatively concludes that submarine slumping and redistribution must have been important.

The facies deposited outside the main fault zone (trough) shows evidence of other types of environment. Current bedding is common in the lithic sandstones and associated granule conglomerates. Pre-Longarm erosion, presumably subaerial, had stripped the Yakoun Formation from this area. The distribution of very large boulders along the unconformity together with the nature of these boulders suggest that they are lag deposits of dyke rocks within the Kunga slightly worked by advancing seas. The common presence of small amounts of epidote or clinozoisite clasts indicates metamorphic rocks were being eroded for the first time. Greater abundance of quartz clasts may indicate granitoid rocks were also exposed. Volcanism was rare in Longarm time, mostly confined to the north, and generally of pyroclastic nature. Near Cumshewa Inlet minor fine agglomerate occurs near the base.

In summary then, if our view is correct, we may picture the Longarm Formation as laid down in a lineal graben-like trough and lapping out of this onto eroded margins of Yakoun volcanic structures to the east. Fault movement, slumping, and turbidity redistribution rapidly built up a thick prism of sediments, while on the trough margins metamorphic and possibly granitoid rocks were exposed for the first time.

Age and Correlation.—The age of the Longarm Formation is early to mid Lower Cretaceous, for it contains fossils of Late Valanginian, Hauterivian, and Barremian ages. The fossils that have been identified specifically or generically are rare compared with the abundant very large *Inocerami* which have not been specifically identified.

The Longarm Formation is correlative in part with a large number of units in British Columbia, many of which have had only meagre faunas collected from them. On the coast, the lower part of the Longarm Formation correlates with the sandstone-shell limestone uppermost member of Lower Cretaceous rocks in the Kyuquot-Esperanza area (Jeletzky, 1950, pp. 43–44). There is probably a fuller correlation with rocks of Quatsino Sound (Jeletzky, in preparation). At Harrison Lake the Broken Back Hill Formation is correlative in large part (Crickmay, 1930A). In the southwestern interior it is correlative with parts of the Dewdney Creek Group of the Princeton map-area (Rice, 1947, pp. 18–19), and the Brew, Lillooet, and Jackass Mountain Groups of the Ashcroft area (Duffell and McTaggart, 1952, pp. 34–52), and the Fraser River valley between Lillooet and Big Bar Creek (Trettin, 1961, pp. 34–58).

FOSSIL LOCALITIES, LONGARM FORMATION

Map No.	Locality	G.S.C. No.	Field No.	Fossils
1[1]	Iron Point	40978	59AB137	Belemnoids (*see* Yakoun Formation).
2	Poole Inlet	40948	59AB208	*Inoceramus colonicus* Anderson, 1938.
3	Arichika Island	40970	59AB244	*Pecten* sp.
4	Ramsay Island	40943	59AB271	*Belemnites* sp. indet.
5	Southwest Murchison Island	52361	62AB126	*Acroteuthis*-like belemnoid; large *Inoceramus*.
6	Northwest Louise Island	40952	59AB310	Large pelecypod fragments.
7	Northwest Louise Island	41004	59AB311	Ammonite indet.; pelecypods.
8	Northwest Louise Island	41005	59AB313	*Inoceramus* sp.
9	Near Aero, Cumshewa Inlet	44671	60AB265	*Inoceramus* n. sp.?
10	Island west of Aero	....	59AB323	*Inoceramus*.
11	South of east Skidegate Narrows	....	63AB9	*Inoceramus?*
12	Skidegate Channel	48574	61AB191	*Buchia crassicollis*.
13	Skidegate Channel	48592	61AB190	*Simbirskites?*; *Buchia crassicollis;* *Inoceramus* sp.
14	Southwest Long Inlet	48566	61AB200	*Simbirskites?* sp.; *Inoceramus?*
15	Southwest Long Inlet	44717	60AB145	*Pleuromya?* sp.
16	Creek head of Long Inlet	52366	62AB181	*Inoceramus* sp. indet.
17	Creek southwest Yakoun Lake	52350	62AB81	*Heteroceras* (in broad sense) sp.; *Inoceramus* cf. *quatsinoensis* Whiteaves.
18	Creek southwest Yakoun Lake	52349	62AB80	*Inoceramus* cf. *quatsinoensis* Whiteaves.
19	Creek southwest Yakoun Lake	52348	62AB79	*Simbirskites* (in broad sense) (=*Hollisites* Imlay) sp.
20	Creek southwest Yakoun Lake	52347	62AB78	*Inoceramus* sp.
21	Ridge north of Shields Creek	52358	62AB104	*Dichotomites* (in broad sense) or *Craspedodiscus* sp. *Inoceramus* sp.
22	North of Haines Creek	48570	61AB132	*Buchia crassicollis*.

[1] Also shown in Yakoun Formation localities. Lithology indicates these rocks are Longarm Formation, but identification of the belemnites favours a Jurassic age.

Queen Charlotte Group

The Queen Charlotte Group includes three formations: at the base the Haida Formation of sandstone and shale, overlain by the Honna Formation of conglomerate and coarse sandstone, with the Skidegate Formation of siltstone, shale, and sandstone at the top. The Haida Formation is of Albian, Cenomanian, and possibly Turonian age (latest Lower and earliest Upper Cretaceous). The Honna and Skidegate Formations contain few fossils, and their age is not defined closer than Upper Cretaceous.

The group is best exposed on Skidegate Inlet and vicinity and the type sections are along the north shore. No exposure of the group south of Logan Inlet is known. The group is well exposed at the northwestern part of Graham Island from Beresford Bay to Pillar Bay.

The history of nomenclature of the Queen Charlotte Group is as complicated as that of the Yakoun and for the same reason, lumped collections and mistaken correlation of Yakoun and Haida sandstones. The discussion on page 66 covers the history from the viewpoint of the Yakoun Formation; what follows is a brief review from the viewpoint of the Queen Charlotte Group.

The earliest geological work on the islands (Richardson, 1873) divided the rocks of Skidegate Inlet into three units: (3) upper shales and sandstones; (2) coarse conglomerates; (1) lower shales with coal and iron ores. Of these, units (2) and (3) are in fact the Honna and Skidegate Formations, but (1) bears a complicated relation to present stratigraphy, except on Bearskin Bay, where it included only the upper shales of the Haida Formation.

Dawson (1880) augmented the section by adding the sandstone member of the present Haida Formation to (1) above and by adding two lower units — (D) agglomerates, (E) lower sandstones—which are now the Jurassic Yakoun and Maude Formations. Dawson's section was very nearly correct, but he was misled by Whiteaves' insistence on one fauna (*see* McLearn, 1949, pp. 2–5) which was of Cretaceous age and by the difficulty of distinguishing between Haida and Yakoun sandstones. He correctly separated " Triassic " argillites and limestone (Kunga Formation) from (E) lower sandstones (Maude Formation).

Whiteaves (1883) first used the name Queen Charlotte Island Group for the lower three of Dawson's units, and later Dawson (1889) used Queen Charlotte Island Formation for the same units. The Queen Charlotte Group (Series) of Clapp and subsequent geologists refers to the upper three units of Dawson. Two papers written about stratigraphy of other parts of the Cordillera were the first to overtly challenge Whiteaves' and Dawson's interpretation (Stanton, T. W., and Martin, G. C., 1905; Dowling, D. B., 1906). Ells (1906), in a brief reconnaissance in 1905, did not include the agglomerates with his Cretaceous rocks. The names of the units currently used were proposed by Clapp (1914), except he called them members of the Queen Charlotte Series and included a basal conglomeratic unit which he repudiated in a footnote as a result of MacKenzie's further work. MacKenzie (1916) first described the units of the Queen Charlotte Group in detail and as they are now known.

The thickness of the group varies rapidly. Maximum thickness is of the order of 7,000 to 9,000 feet.

Haida Formation

The Haida Formation is the oldest of the Queen Charlotte Group. It is the oldest unit in the area not fully involved in the deformations and in which there is any significant granitic debris. It overlies, commonly with considerable unconformity, all older formations with the exception of the Longarm (*see* Plate XIIB). In turn it is overlain by conglomerates and coarse sandstones of the Honna Formation with seeming conformity in outcrop but in reality with either considerable unconformity or interfingering (*see* pp. 93, 98). The formation is exposed from Logan Inlet to Parry Passage (*see* Fig. 12) but is best known from Cumshewa Inlet to near Yakoun Lake. It is well exposed in eastern Skidegate Inlet and the type section extends from Haida Point, after which it was presumably named by Clapp, to Lina Narrows. Comparatively little is known about the formation as exposed from Beresford Bay to Parry Passage. The formation is generally divisible into two distinct members—a lower sandstone member and an upper shale member. The type section is the thickest known, and here the sandstone member is about 2,700 feet thick and the shale member about 1,075 feet thick. Major changes in thickness occur over short distances.

On Skidegate Inlet the age of the formation ranges from late Early Albian to Turonian (?) and on Beresford Bay includes Early Albian, so that as a whole it ranges from late Early Cretaceous to early Late Cretaceous.

Lithology.—Most of the Haida Formation is composed of a small range of sandstone types and silty shales, but near the base and at rare intervals there occur variants. The sandstone member is composed almost wholly of sandstone, more than half of which is dark to mid grey, but the most characteristic is grey-green. The latter is normally medium or coarse grained, massive looking, but actually finely bedded or cross-bedded (*see* Plate VIIIA). It weathers a brown colour with spheroidal form inland, but on the shore generally remains green with large rounded slabby forms showing isolated vertical faces having a fine cellular texture in the spray zone. Cross-bed sets may be 2 to 3 feet thick, commonly separated by massive or regularly bedded green or grey sandstone several feet thick. Large buff-weathering concretions are fairly common, generally in massive or regularly bedded sandstone rather than cross-bedded. Coquina beds of large *Trigonia* are relatively common near the base of the formation. A feature commonest in the green sandstones and in the lower part of the formation is scattered coal pebbles. Carbonized and carbonatized wood fragments are also common throughout the member, many showing teredo holes, etc.

The grey sandstones are finer and less massive than the green. They are fine- to medium-grained rocks that weather in a shaly manner. Bedding is not pronounced, except by intercalations of slightly differing lithology. Cross-bedding is rare. The colour is a medium to dark grey when fresh, but weathered may be light grey to brown. Calcareous concretions, concretionary beds, and, more rarely, buff-weathering calcareous mudstone to fine sandstone are moderately common.

The grey and green sandstones may be interstratified on all scales. Interlaminated grey and green fine sandstones are particularly common at localities away from Skidegate Inlet. Green sandstones are most common in the lower part of the member and are virtually absent in the upper part of the type section. Conversely the calcareous beds and a few shales or siltstones are only found in the upper part of the member.

In the sandstone member at or within 100 feet or so of the base there may be some pebbly sandstones, pebbly granule beds, and fine pebble conglomerate (*see* Plate XIIB). These rocks are most common right at the basal unconformity but may be up to 200 feet above it. They are intercalated with green sandstones and are generally poorly bedded but may be cross-bedded or bear a cut-and-fill relation to the green sandstones. These pebbly rocks are generally light coloured over all but speckled black and white in detail. The light-coloured particles are quartz, feldspar, and some volcanic rocks, and the dark are principally Kunga argillite chips. A small but significant number are granitic rocks. Sorting and rounding are fair, but sphericity is variable, mostly poor. The largest pebbles are about 3 inches in

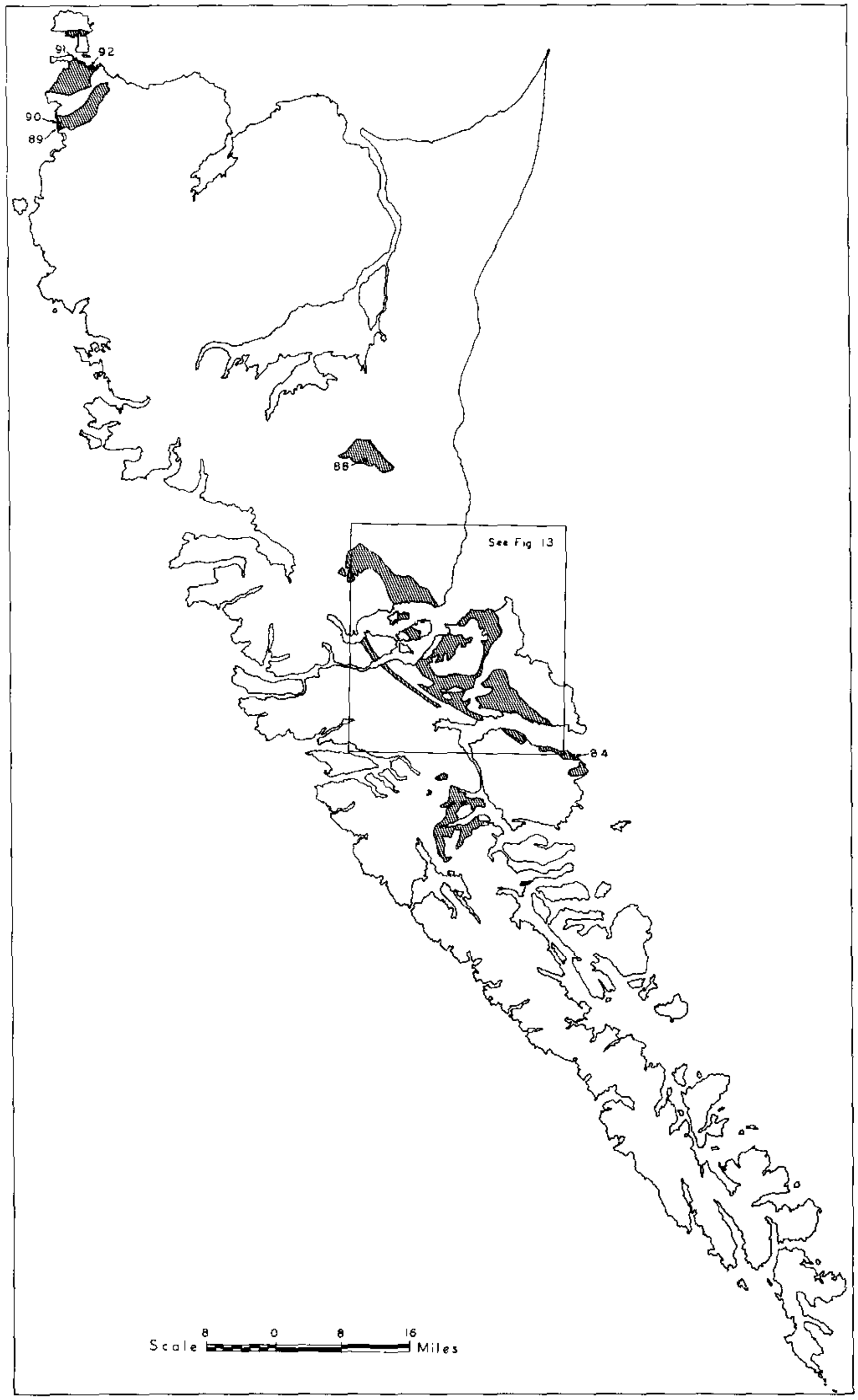


Fig. 12. Haida Formation: Distribution and fossil localities.

diameter (8 centimetres), but more commonly the largest size is 1 to 2 centimetres. These rocks resemble the basal ones of the Longarm Formation, except they are generally lighter coloured, more quartzose, and somewhat better sorted and rounded. Rarely pebble beds and pebbly sandstones may be found higher in the section, and in several localities some pebbly sandstone and interformational shale sharpstone beds are found at the top of the member. Commonly these rocks contain some bright-green chloritic fragments in addition to the calcareous shale chips and rounded exotic pebbles.

The shale member is composed primarily of grey silty shales and very fine siltstones. When completely fresh these are massive dark-grey rocks that are well bedded to laminated, but nevertheless are dense, conchoidal fracturing rocks that are only fissile where bedding planes have abundant carbonized twigs. On weathered surfaces these rocks take on a lighter-grey colour and become shaly, split moderately well, and are relatively soft (*see* Plate VIIIc). Buff to light-grey calcareous shale and siltstone beds are moderately common and fairly continuous; for example, beds 6 to 8 inches thick extend laterally for more than 200 feet and occur every 5 to 10 feet stratigraphically. Some concretionary beds occur, and these may grade into uniform calcareous beds. Also some laminated calcareous beds occur, and these show convolutions similar to ripple load convolutions. Fossils other than the carbonized twigs and flattened *Inocerami* and worm tubes seemingly are absent.

A minor group of variable coarser fragmental rocks occurs within the member. They vary from shale with minor flake-like shale sharpstones, the most common type, to thin beds full of angular intensely green chloritic fragments, to granule beds composed of rounded calcareous shale and chloritic fragments. The latter type is rare, but the fine sharpstones and the laminæ with chloritic fragments (devitrified ash?) are widely distributed if not volumentrically important. The lowest chloritic fragmentary bed occurs at the contact with the sandstone member.

Minor grey fine to medium sandstone occurs within the member, particularly in the uppermost part.

Microscopy.—Sandstones of the Haida Formation are seen microscopically to be composed of subequal amounts of quartz, feldspar, and rock fragments with a variable array of accessory constituents that give the various types their character. Most are compact rocks formed of angular fragments with fair sorting and little true matrix. Such matrix as there is largely appears to be chloritic, micaceous, or soft rock fragments squeezed into interstices. In general the rocks are immature and the constituent feldspar and rock fragments fresh. Most plagioclase is andesine and most potash feldspar is orthoclase with rare perthite. Table VIII gives ranges and averages for sandstones of the various types and comparison of averages of the type section with other localities. The three types described macroscopically are distinct types microscopically—the basal black and white pebbly sandstone, the green sandstone, and the grey sandstone. Figure 16 shows quartz, total feldspar, and rock fragments plotted for arenaceous rocks of all formations.

In the characteristic green sandstone, feldspar is more abundant than quartz, volcanic rock fragments are generally as common as feldspar, and plagioclase exceeds potash feldspar by about 4 to 1. The rock contains a significant component of calcite grains and glauconite, the latter giving it its colour. Some of the glauconite grains contain vestiges of microfossils (*see* Plate XIVA). Opaque minerals, pyrite, leucoxene, and carbonaceous matter together form about 5 per cent and are rather evenly distributed. Matrix is generally minor and may be chlorite or calcite. Sorting is generally fair. Heavy minerals include epidote, clinozoisite, and sphene.

TABLE VIII.—MINERAL COMPOSITION, HAIDA FORMATION

	Sandstone Member							Shale Member	
	Green Sandstone	Grey Sandstone	Black and White Sandstone	Sandstones Type Section		Sandstones Other Localities			
	Average	Average	Average	Range	Average	Range	Average	Range	Average
Mineral grains—									
Quartz	17.5	21.2	43.4	15–35	25.8	15–65	25.7		
Plagioclase	20.0	23.4	15.0	5–30	18.8	10–35	21.7	10–42	17.4
Potash feldspar	5.0		2.3	2–12	4.0	....			
Calcite	12.5	3.1	0.7	Tr.–10	3.7	Tr.–15	4.3	Tr.–27	16.4
Mica	Tr.	3.2	.....	0–3	1.0	Tr–10	2.9	....	.....
Glauconite	17.5	1.8	.....	0–15	4.0	0–20	3.6	....	.....
Opaque	5.0	5.4	2.0	3–10	5.7	Tr.–10	3.6	Tr.–3	2.0
Rock fragments—									
Volcanic	12.5	32.6	18.3	10–40	22.2	Tr.–53	29.7		
Sedimentary	Tr.	3.4	14.0	0–20	7.3	Tr.–20	3.6	0–5	2.4
Matrix	10.0	5.8	4.3	Tr.–15	7.5	Tr.–10	5.0	25–80	62.0

The grey sandstone is slightly more heterogeneous, poorer sorted, more carbonaceous and micaceous, slightly more quartzose, and less calcareous and glauconitic, but equally devoid of true matrix. Shreds of organic matter, detrital biotite, and chips and clasts of siltstone are common. Pyrite preferentially replaces the organic matter. Heavy minerals are similar to those in the green sandstone.

In comparison with the main sandstones, the basal black and white sandstones are much more quartzose, better sorted, and of higher sphericity and rounding. Vein quartz, combined quartz and feldspar grains, perthite, and Kunga argillite clasts are all present in very much greater than normal concentration. Volcanic rock fragments are reciprocally less. Altogether these sandstones are exceptional in being relatively mature and winnowed and the grains more abraded.

The shale member is chiefly formed of silty shales and siltstones, most of which are significantly calcareous. Table VIII shows the range of composition and average. They normally contain at least 10 per cent silt of quartz and plagioclase in about equal proportions. Silt-sized grains of calcite are normally present, and replaced structureless calcareous microfossils may be present. Some specimens contain a small amount of angular clasts of clear green chlorite, possibly devitrified glass, and some contain silt-sized clasts of recognizable fine volcanic rocks. Sand- or granule-sized chips or lenses of calcareous siltstone or shale recognizable by differing opaqueness are common and filled burrows not rare. The matrix may be a very fine semi-opaque mass of clay, chlorite, and (or) calcite, but in some specimens the matrix appears to be dominated by scarcely recognizable silt-sized rock fragments.

Within the shale member there are minor sandstones in most ways similar to those of the sandstone member. In addition, some granule-size rocks occur, formed principally of rounded chips of calcareous siltstone and silty shale with lesser bright-green chlorite clasts in a matrix of fairly normal sandstone.

Stratigraphy.—The type section of Haida Formation extends from near Haida Point to Lina Narrows on the north shore of Bearskin Bay in Skidegate Inlet. The basal few hundred feet are repeated in remnant panels unconformably overlying the Yakoun Formation from Haida Point to 3,000 feet west, where the section proper begins. The type section is typical of the formation and the thickest section that has been noted. The separation into two members is distinct, as it appears to be in most areas studied. Exposure is relatively good even in the shale member. However, the upper part of this member is much duplicated in very gently warped folds and a certain amount of extrapolation is necessary. In particular, near the mouth of the Honna River the interpretation rests on a few scattered outcrops (indicated by 0? in the footage). The biostratigraphic zones are indicated on the column and are discussed later.

TYPE SECTION OF HAIDA FORMATION, BEARSKIN BAY

	Locality on Figs. 12 and 13	Thickness in Feet	Cumulative Thickness above Yakoun Formation
Honna Formation—seemingly conformable.			
Shale member.			
Grey siltstone	....	5	3,775
Covered and poorly exposed grey siltstone with some flaggy grey medium sandstone	....	155	3,770
Grey siltstone, some calcareous shale and minor shale and chlorite granule beds	....	145	3,615
Covered interval with minor outcrop—projected structurally and correlated by granule beds	....	0?	3,470
Grey siltstone well bedded, 2- to 3-inch beds, minor shale and chlorite granule beds	....	50	3,470
Grey siltstone and minor fine sandstone, well-bedded 2- to 6-inch beds, calcareous shale lenses, some convolute beds, worm tubes—*Inoceramus* sp. A	29	59	3,420
Covered	....	9	3,361
Shale member. *Inoceramus labiatus* zone.			
Grey silty shale and siltstone beds 2 to 6 inches thick, calcareous shale and siltstone beds every 10± feet rarely with convoluted bedding, minor laminæ with chloritic fragments every 10± feet	...	172	3,352
Covered	..	10	3,180
Grey silty shale, beds 3 to 6 inches, some calcareous siltstone—*Inoceramus* sp. A, *Inoceramus* sp. B	28	37	3,170
Covered	....	10	3,133
Desmoceras (Ps.) japonicum zone.			
Grey shale and siltstone with some calcareous shale and worm tubes	....	43	3,123
Covered	....	22	3,080
Grey shale and siltstone, beds 2 to 6 inches	....	13	3,058
Covered	....	30	3,045
Interbedded grey shale and siltstone, bed 2 to 3 inches, 6- to 9-inch buff-weathering calcareous shale, beds every 5± feet	....	125	3,015
Covered	....	105	2,890
Grey shale	....	25	2,785
Grey siltstone with calcareous concretions	....	35	2,760
Grey shale—poorly bedded	....	25	2,725
Pebbly grey fine sandstone, large concretions and scattered roundstones and coal pebbles—*Hypophylloceras* aff. *californicum*, "*Scalaria*," *Desmoceras (Ps.) dawsoni*	27	8	2,700
Grey fine sandstone	....	22	2,692
Covered	....	15	2,670
Grey medium to coarse sandstone with concretions—*Desmoceras (Ps.)* n. sp., *Mortoniceras* sp., *Inoceramus subsulcatus*, *Hypophylloceras* aff. *californicum*	25, 26	60	2,655

Zone (Sandstone member)		Locality on Figs. 12 and 13	Thickness in Feet	Cumulative Thickness above Yakoun Formation
Mortoniceras and *Desmoceras (Ps.) dawsoni* zones	Covered	....	10	2,595
	Grey medium to fine sandstone with small numerous concretions—*Inoceramus subsulcatus*	24	120	2,585
	Covered	....	15	2,465
	Grey medium sandstone, beds or small concretions	....	50	2,450
	Covered	....	84	2,400
	Poor exposure of grey medium to fine sandstone—*Trigonia (Heterotrigonia)* sp.	....	182	2,316
	Small fault.			
	Grey medium sandstone—*Puzosia?, Desmoceras (Ps.)* aff. *dawsoni*	22, 23	5	2,130
	Grey fine sandstone	....	15	2,125
	Grey medium sandstone with some concretionary beds and rare dense buff-weathering calcareous shale beds—*Desmoceras (Ps.)* n. sp. cf. *alamoense, Anagaudryceras sacya, Marshallites* n. sp.	21	72	2,110
	Covered	....	78	2,038
	Grey medium sandstone poorly exposed	....	15	1,960
	Covered	....	20	1,945
	Grey medium sandstone poorly exposed	....	30	1,925
	Covered	....	15	1,895
	Grey to grey-green medium sandstone with calcareous concretionary beds every 3 to 4 feet—*Mortoniceras* sp., *Inoceramus subsulcatus*	20	70	1,880
	Green coarse sandstone, fairly massive—*Inoceramus subsulcatus*	19	103	1,810
	Covered	....	62	1,707
	Grey medium sandstone	....	30	1,645
	Covered	....	30	1,615
	Grey medium sandstone	....	35	1,585
	Grey medium sandstone interbedded with 1- to 2-foot sets of cross-bedded green coarse sandstone	....	15	1,550
	Grey medium sandstone	....	18	1,535
	Covered	....	22	1,517
Cleoniceras (Grycia) zone	Grey medium sandstone, fairly massive—*Cleoniceras perezianum, Trigonia (Apiotrigonia) newcombei, Trigonia (Heterotrigonia)* sp., *Thetis affinis*	17, 18	30	1,495
	Covered	....	30	1,465
	Grey medium sandstone, poorly exposed	....	15	1,435
	Grey medium sandstone, some siltstone interbeds	....	30	1,420
	Grey medium sandstone with some concretions—*Anagaudryceras sacya, Inoceramus* cf. *moresbyensis*	15, 16	75	1,390
	Grey fine to medium sandstone with concretionary beds	....	65	1,315
	Grey medium sandstone	....	25	1,250
	Covered	....	25	1,225
	Grey medium sandstone with concretions, small transverse fault	....	62	1,200
	Grey medium sandstone with concretions with interbedded laminated green sandstone	....	118	1,138
	Green medium sandstone—*Cleoniceras perezianum, Inoceramus concentricus, "Trigonarca"* sp.	12, 13, 14	95	1,030
	Grey medium to fine sandstone with concretions—*Desmoceras (Ps.)* n. sp. cf. *alamoense, Trigonia (Apiotrigonia?)* sp., *"Trigonarca"* sp.	11	20	935
	Green coarse to medium sandstone, with cross-bedded sets and rare concretionary beds	....	47	915
	Poorly exposed grey medium to fine sandstone	....	43	868
	Green massive medium sandstone—*Cleoniceras perezianum*	10	10	825
	Green medium sandstone, some concretions, many dumbbell shaped—*Cleoniceras perezianum, Inoceramus concentricus, Trigonia (Apiotrigonia)* cf. *newcombei, Trigonia (Heterotrigonia)* sp.	8, 9	95	815
	Grey medium sandstone with some coal pebbles and some fine cross-bedding and concretions—*Cleoniceras perezianum, Trigonia (Apiotrigonia) maudensis*	6, 7	107	720
	Poorly exposed green fine sandstone—Pelecypods	....	113	613
	Covered	....	95	500
	Green medium to fine sandstone with some *Trigonia* beds—*Trigonia* sp., *Thetis affinis*	....	55	405
	Covered	....	22	350
	Green medium to fine sandstone, with some cross-bedding, and a few concretions—*Pecten* sp.	5	58	328
	Covered	....	70	270
Brewericeras zone	Grey medium-grained sandstone with small calcareous concretions—*Brewericeras hulenense*	4	40	200
	Green coarse sandstone with scattered coal and argillite pebbles and abundant *Trigonia* shells—*Trigonia (Pterotrigonia?)* sp.	3	70	160
	Black and white pebbly very coarse sandstone with interbedded coarse green sandstone beds 1 to 5 feet thick	....	70	90
	Covered	....	20	20
	Yakoun Formation—unconformable.			

Although the lithology remains similar, changes in section are important even short distances from Bearskin Bay. These changes include total thickness, development of the shale member, the time stratigraphic position of the base, and possibly the non-deposition or erosion of certain zones. Figures 12 and 13 show the distribution of the members and faunal zones as they are known.

On the upper Honna River only 4 miles north, the total thickness is only 2,800 feet. The shale member is much the same, but the sandstone member is only 1,700 feet thick. However, the lowest zone is represented because *Brewericeras hulenense* was collected near the base. On the northwest shore of Maude Island the section again includes about 1,100 feet of shale member but only about 2,200 feet of sandstone, from which the writer collected few distinctive fossils. Although the formation is poorly exposed on the south shore, the shale member again appears to be about 1,000 feet thick but the sandstone member only about 1,200 feet thick. However, faults near the base complicate any interpretation. On Sandilands Island the base is involved in a zone of large east-west faulting. Sandstones of the *Cleoniceras (Grycia) perezianum* zone outcrop over much of the exposure of the sandstone member, and the shale member is represented by at most 400 feet of strata. The total thickness of the formation here is about 1,200 feet.

East of Alliford Bay, exposure on the shore is too intermittent to reconstruct an accurate section. The sandstone member seems particularly massive and composed dominantly of coarse green sandstones, whereas the shale member is relatively thin (500± feet). Most of the fossils collected were long ranging or poorly preserved, but McLearn collected *Desmoceras (Pseudouhligella) japonicum* in the shale member here. South of Skidegate Inlet the formation, and particularly the shale member, becomes thin.

In western Skidegate Inlet the formation becomes involved in intense folding and faulting of the Rennell fault zone, but it is apparent the formation is much thinner.

Between Skidegate Inlet and Cumshewa Inlet exposure is poor. About the east end of Skidegate Lake much of the sandstone member is composed of grey siltstones similar to those of the shale member but with intercalated sandstones. On the Copper River north of the lake, *Brewericeras hulenense* occurs in the basal sandstone. On the hills to the east, *Desmoceras (Pseudouhligella)* n. sp. occurs to within 600 feet of the base. West of central Skidegate Lake the formation appears generally coarser but thinner than to the east. *Brewericeras hulenense* is found on the road to Aero south of the lake.

On Cumshewa Inlet relations are variable. At Dawson Cove about 700 feet of sandstone member is exposed, containing *Brewericeras hulenense* in the lower part, the base is not seen, and the sandstones are overlain directly by the Honna Formation. Two miles east at Conglomerate Point, sandstones with *Desmoceras (Pseudouhligella)* n. sp. are unconformably draped over an island of Kunga Formation. From the upper part of this unconformity to the base of the Honna Formation there are about 500 feet of sandstones and then 200 feet of shale with *Inoceramus?*, but small faults complicate the section. From Conglomerate Point to beyond McLellan Island the Haida Formation is intermittenly exposed, mostly striking subparallel to the shore. Seemingly some 1,500 to 2,000 feet are exposed with sandstone in the lower part and grey siltstone and shale in the upper, but the division into members is not distinct. *Desmoceras (Pseudouhligella) japonicum* (at Locality 80) and *Desmoceras (Pseudouhligella) dawsoni* (at Locality 79) were both collected at separate localities west of McLellan Island near the top of the presumed sandstone member.

Relatively little is known about the formation at localities remote from Skidegate to Cumshewa Inlets. Only a few exposures of the formation were seen near the lower Yakoun Valley. East of Yakoun Lake the writer now suspects that some of the sandstone mapped as Haida Formation following MacKenzie are actually Yakoun Formation, and that the coal of Camp Robertson, etc., was in the Yakoun Formation as it is on Wilson Creek, which MacKenzie also believed was in the Haida Formation.

The formation as seen from Beresford Bay to Parry Passage in northwestern Graham Island is lithologically very similar to that of the type area, and thickness is of the same order. Furthermore, it would seem to be divided into a lower sandstone and an upper shale member. Lower Albian fossils of the *Leconteites lecontei* zone were collected from coarse green sandstones near the base and *Desmoceras (Pseudouhligella)* sp. from laminated grey and green fine sandstone near the top of the sandstone member.

Another extensive area of Queen Charlotte Group occurs from Lagoon Inlet south to Logan Inlet and west nearly to Tasu Sound. Much of the area is covered by younger rocks of the Masset Formation. In this area the group can be divided into a lower shale and sandstone unit tentatively called the Haida Formation and an overlying conglomerate identical in lithology to the Honna Formation. Unfortunately both units are unfossiliferous so that no certainty exists. Grey shales and fine grey sandstone predominate in the Haida Formation, but coarse green sandstones are present.

Origin.—The Haida Formation was deposited in a marine basin with considerable submarine topography swept by moderate currents and with adjacent land supplying abundant detritus. The marine nature is shown because marine fossils and glauconite are found throughout. The proximity of land is shown by abundance of wood, including some large logs within the sandstone member and much plant debris intercalated in the shale member. In addition, the fragile coal pebbles could not have been transported far from their probable source in the Yakoun sandstones. The relief of basin bottom is evident by the draped unconformity on Conglomerate Point, the remnant sill extending from the upper Copper River through to the cuestas of Kunga limestone south of Skidegate Lake, and the remnants of basal Haida on the Balch Islands. That the older rocks extending across Skidegate Lake formed a sill is shown by the disparity in thickness and lithology on the opposite sides.

Much of the detritus that forms the Haida rocks was of volcanic origin, particularly from Yakoun agglomerates (and sandstones) but with a significant amount of granitic debris. Hence the margins of the basin were most likely elevated and subject to erosion. No special study of cross-beds was made, but on Bearskin Bay small slumps indicate the initial slope was toward the southwest and current direction to the west or northwest preferentially in the eastern part of the Skidegate Basin. The sudden change from sandstone to shale deposition indicates a sudden change in environment. A general subsidence of the region, including margins and basin, might be an explanation.

The palæogeography cannot be accurately reconstructed on the basis of present information, but a crude appraisal can be made. A large elevated island probably existed in the west with a margin along the Rennell-Louscoone fault. It exposed

Karmutsen and Kunga and syntectonic plutonic rocks. Yakoun volcanics may have largely been eroded during the exposure. A channel to the Pacific in the vicinity of Sewell Inlet probably separated this highland into two islands. Farther east the main mass of Yakoun agglomerates from Yakoun River to Reef Island, the remnants of old Yakoun volcanoes, may well have formed a chain of islands and peninsulas separating the main Skidegate Basin from a probable basin still farther east (presently under Hecate Strait). What the connection is between exposures north of Skidegate in the lower Yakoun Valley and northwest Graham Island is problematic. However, the distribution of units and zones as presently known suggests a shoreline extended from near Skidegate village to Beresford Bay with the depositional basin to the northeast.

Age, Biostratigraphy, and Correlation. — The age of the Haida Formation embraces all of the Albian stage of the Early Cretaceous period and also the Cenomanian and possibly part of the Turonian stage of the Late Cretaceous. The type section, however, does not have the earliest Albian zone.

In British Columbia west of the Rockies few areas of marine Albian and Cenomanian rocks are known, except about Tahtsa Lake (Duffell, 1959, pp. 64–67). Extensive continental deposits of probable Albian age are known in the interior plateau (for example, Kingsvale Group, Duffell and McTaggart, 1952, p. 58) and in the Rocky Mountains (for example, Upper Blairmore Group, Bell, 1956, pp. 12–15). In northern California and Oregon and in Alaska, marine rocks of Albian, Cenomanian, and Turonian age are well known (Murphy, 1956; Imlay, 1960; Matsumoto, 1959).

Zonation of the writer's collection of ammonites and pelecypods *Trigonia* and *Inoceramus* from the Haida Formation is evident in Table IX (in pocket). Most of the fossils were identified by Dr. F. H. McLearn, who had earlier made extensive collections in Skidegate Inlet and who at the time of his death was preparing a monograph of Haida ammonites. Dr. David Jones, of the United States Geological Survey, visited Skidegate Inlet in 1963. He also identified the collections from Beresford Bay. The faunal zones used are those recommended by Jones in a personal communication with the concurrence of McLearn.

Turonian	*Inoceramus labiatus?*
Cenomanian	*Desmoceras (Pseudouhligella) japonicum.*
Late Albian	*Desmoceras (Pseudouhligella) dawsoni; Mortoniceras.*
Mid Albian	*Cleoniceras (Grycia) perezianum.*
Late Early Albian	*Brewericeras hulenense.*
Early Albian	*Leconteites lecontei.*

Characteristic fossils in the Haida for these zones are:—

Leconteites lecontei:

- *Leconteites lecontei whiteavesi.*
- *Phyllopachyceras* cf. *chitinanum* Imlay.
- *Aucellina* sp.

Brewericeras hulenense:

- *Brewericeras hulenense* (Anderson).
- *Douvilleiceras spiniferum* (Whiteaves).
- *Trigonia (yaadia) leana* var. *whiteavesi* (Packard).
- *Trigonia (Pterotrigonia)* cf. *columbiana* (Packard).

Cleoniceras (Grycia) perezianum:

Cleoniceras (Grycia) perezianum (Whiteaves).

Inoceramus concentricus Parkinson.

Trigonia (Apiotrigonia) maudensis (Whiteaves).

Trigonia (Apiotrigonia) newcombei (Packard).

Mortoniceras:

Mortoniceras (Deiradoceras).

Inoceramus subsulcatus Whiteaves.

Desmoceras (Pseudouhligella) dawsoni:

Desmoceras (Pseudouhligella) dawsoni (Whiteaves).

Inoceramus subsulcatus Whiteaves.

Desmoceras (Pseudouhligella) japonicum:

Desmoceras (Pseudouhligella) japonicum (Yabe).

Fossils of the *Leconteites lecontei* zone are only identified on Beresford Bay; all the others are present in the type section. Both McLearn and Jones point out that the *Oxytropidoceras packardi* zone (Murphy, 1956, pp. 2114–2119), which should occur between the *Brewericeras hulenense* and *Mortoniceras* zones, is not represented in the type section, nor is it identified elsewhere in the Queen Charlotte Islands, but the *Cleoniceras perezianum* zone, which occurs nowhere else, is apparently equivalent.

Honna Formation

The Honna Formation is the middle unit of the Queen Charlotte Group, between the Haida and Skidegate Formations. The contact with the Haida Formation seems structurally conformable in outcrop, with only minor indications of scour in detail. However, several lines of evidence indicate either major erosional truncation of beds and (or) major interfingering of Haida and Honna Formations. The Skidegate Formation overlies the Honna Formation conformably with gradation over a small interval.

The Honna Formation is found from Logan Inlet to Langara Island (*see* Fig. 14). The type locality is on the north side of Lina Narrows, near the mouth of the Honna River, after which it is named. It commonly outcrops boldly. In lowlands, in which it dips steeply, it forms knobby hills. In parts of the Skidegate Plateau, where it is flat lying, as south of Alliford Bay, it tends to accentuate the mesa-like nature of hills. Thickness varies greatly; in the type locality it is 1,300 feet, but on Maude Island, only 3 miles south, is about 2,500 feet, and on Skidegate Channel is about 4,000 feet.

The Honna Formation contains few fossils, and no diagnostic ones have been collected, hence the age of the conglomerate is known only as post-Cenomanian or Turonian and pre-Paleocene. Most likely it is early Late Cretaceous.

Lithology.—The Honna Formation is composed of conglomerate and coarse arkosic sandstone with minor shale or siltstone. The formation is characterized by the conglomerate, but the relative percentage of conglomerate to coarse sandstone varies widely from place to place, and conglomerate may even form a relatively small percentage of the whole. Shale or siltstone are always minor, commonly forming rare thin interbeds or sets of beds at most 30 to 40 feet thick. Other rocks, including fine sandstones, are virtually absent.

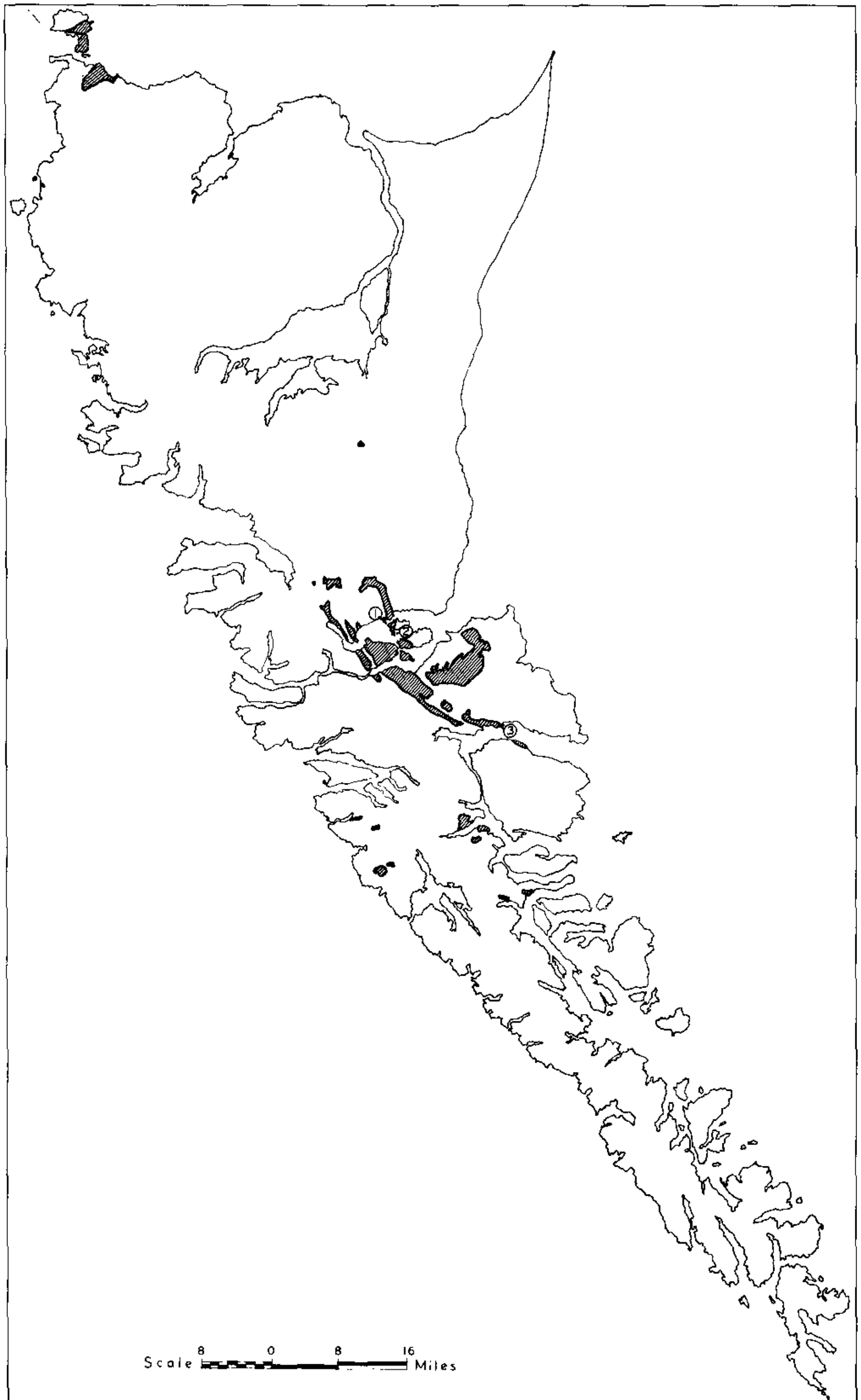


Fig. 14. Honna Formation: Distribution and fossil localities.

The conglomerate weathers dark shades of grey or brown, but is middle grey when fresh. Most conglomerate is formed of well-rounded coarse pebbles (>16 millimetres) to small cobbles (<128 millimetres) with about 20 per cent coarse sand matrix. Rarely some large cobbles occur in small number. A bimodal frequency distribution of particles is the rule, and sorting within the coarse and the fine admixtures is relatively good. Although most fragments are well rounded, sphericity may be low and sharpstones of shale form a small but relatively constant component. In general, bedding is quite good, evident by variation in average pebble size or by intercalation of sandstone beds (*see* Plate VIIc). Overt cut-and-fill structures are rare, bedding is relatively planar, and imbrication is absent or slight.

Variation in percentages of rock types occurring as pebbles is not great. The following summarizes pebble counts from small areas in four localities, Lina Narrows (the type locality), Pillar Rock, Deena River, and southwest of Skidegate Lake:—

	Volume (Per Cent)
Granite	8–21
Argillite and shale	18–25
Yakoun porphyries	15–28
Karmutsen greenstone	7–23
Other including indeterminate volcanic	0–20
Matrix (sandstone)	15–20

A constant and characteristic feature is a significant component of granitoid pebbles. Some are similar to hornblende quartz diorites of the syntectonic plutons, some to granites of post-tectonic aspect, and some not similar to any mapped bodies. Apart from some of the few pebble beds within the Haida Formation, this is the oldest conglomerate with granitic debris. Shale sharpstones from the Haida Formation and (or) interbeds within the Honna are common, but argillite recognizable as Kunga Formation is as common or commoner. The bulk of the pebbles are volcanic, with porphyries similar to Yakoun rocks slightly more numerous than greenstones similar to Karmutsen. Some volcanic rocks are not readily identified as either. Other pebbles include limestone, quartz, chert, sandstone, and pyroclastic rocks, but these are all rare. Secondary pyrite is common but minor.

Sandstones of Honna Formation are akin to the matrix of the conglomerates; they are generally coarse-grained (>0.5 millimetre) rocks composed of feldspar, quartz, and rock fragments in subequal amounts. They might be called grits and would be classified as arkoses by most sandstone classifications (*see* Table X). In colour they weather buff, light red-brown, or dark grey, but where fresh are light grey with a slight greenish cast. Large (3 to 6 feet in diameter) oblate spheroid calcareous-cemented concretions are moderately common, and an irregular platy cleavage subparallel to bedding is common on shore exposures. Every gradation occurs between sandstone and conglomerate both by general increase in grain size or by advent and increase in percentage of coarse fragments.

Grey well-bedded shale or siltstone forms a small but normal part of the unit. These intercalations are the obvious source of most of the sharpstones within the sandstone and conglomerate, although some of the rounded chips and calcareous shale chips may have originated from erosion of the shale member of the Haida Formation.

Microscopy.—The sandstones and interstitial sands in the conglomerates are virtually identical and are treated together here. They are coarse, compact, poorly sorted rocks of angular clasts and little matrix. Table X shows the mineral composition of eight specimens from the type section. Volcanic rock fragments are generally the most abundant clasts, followed by feldspar, quartz, and sedimentary rock. The plagioclase is normally in the range An_{30-40}. Granitic fragments are common in trace amounts, and potash feldspar (orthoclase, rarely perthite) forms about one-eighth of the total feldspar. Calcite clasts, including recognizable shell fragments, are common in a few specimens and biotite is present in most. Matrix is scant, some is calcareous, but more commonly it is composed of soft micaceous rock fragments and biotite and chlorite clasts that appear to be squeezed into interstices. Opaque minerals, ores, and carbonaceous materials are commonly minor. Specimen 100 is atypical, being composed dominantly of rounded plates of calcareous siltstone of the Haida shale member, which it immediately overlies.

In comparison with Haida sandstones, the Honna are coarser, less well sorted, and contain a higher percentage of rock fragments, but no glauconite. In addition, feldspar exceeds quartz in most Honna sandstones instead of the reverse. This is shown in the general diagram in which quartz, feldspar, and rock fragments are plotted for arenaceous rocks of all sedimentary units (Fig. 16).

TABLE X.—MINERAL COMPOSITION, HONNA SANDSTONES, TYPE SECTION

	100	101	102	103	104	106	107	108	Average
Mineral grains—									
Quartz	10	20	20	20	28	25	18	15	19.5
Plagioclase } Potash feldspar }	10					35	12		27.1
Plagioclase		15	35	35	37			20	
Potash feldspar		2	5	5	1			5	
Calcite	9	......	......	--	3	......	......	......	1.5
Mica	1	1	1	2	5	......	......	......	1.2
Opaques	2	2	......	1	1	10	......	......	2.0
Rock fragments—									
Volcanic	3	22	33	32	20	20	65	30	28.1
Sedimentary	60	20	1	1	......	......	......	5	10.9
Granitic	......	Tr.	1	......	Tr.	Tr.	Tr.	......	.1
Matrix	5	18	4	4	5	10	5	25	9.5

Stratigraphy.—The type section of the Honna Formation at Lina Narrows, between Kagan and Bearskin Bays, is one of the thinner sections of the Honna Formation. In other respects it is typical. Great facies variation is illustrated at Lina Narrows, for the percentage of conglomerate and the amount of cobble conglomerate markedly decrease between the type section and the north shore of Lina Island and again to the west shore. At the latter locality even pebble conglomerate is rare, and coarse sandstone and some pebbly sandstone constitute the bulk of the formation.

The Honna Formation at other localities is very similar to the type at Lina Narrows. However, the exposed thickness increases markedly toward the south and west, with about 2,400 feet at Maude Island, 3,000 to 4,000 from Long Inlet west of Kagan Bay and Skidegate Channel, and 2,000 to 3,000 south and west of Skidegate Lake. On Cumshewa Inlet about 1,500 feet is exposed, and about the same or slightly less between Skidegate Lake and Alliford Bay. At other localities more remote from Skidegate Inlet and not in outcrop continuity, the lithology is very nearly identical and the stratigraphic succession no more varied than on Skidegate Inlet. At the southernmost locality on Logan and Crescent Inlets, some 300 to 500 feet is found, on Sewell Inlet about 1,700, and near Kootenay Inlet, an isolated southwesternmost occurrence, about 800 feet. On northern Graham and on Langara Islands the formation is some 3,000 to 4,000 feet thick again, but at the locality north of Frederick Island it is only a few hundred feet thick.

TYPE SECTION OF HONNA FORMATION, NORTH OF LINA NARROWS

65 feet covered then Skidegate Formation seemingly conformable.	Thickness in Feet	Cumulative Thickness above Haida Formation
Reddish-brown weathering grey coarse sandstone with shale sharpstones and some pebbly beds	30	1,365
Red-brown weathering grey shaly siltstone with some coarse sandstone with shale sharpstones	16	1,335
Red-brown weathering pebble conglomerate with numerous angular blocks of grey shale or siltstone at top	64	1,319
Red-brown weathering coarse sandstone	10	1,255
Covered	20	1,245
Pebble conglomerate interfingering with coarse sandstone	15	1,225
Grey well-bedded siltstone, shale, and fine sandstone; 60AB105 ammonoid fragment	40	1,210
Cobble conglomerate with some small boulders grading upward to pebble conglomerate; large shale sharpstones prominent	100	1,170
Very coarse sandstone	40	1,070
Pebble conglomerate with some coarse sandstone	12	1,030
Coarse sandstone	5	1,018
Fine pebble conglomerate	5	1,013
Coarse sandstone with some pebbles	30	1,008
Covered	109	978
Cobble conglomerate with scattered coarse cobbles, rare large blocks of shale, and intercalated sandstone lenses, becoming one-half sandstone near top	54	869
Brown-weathering coarse pebbly sandstone with scattered pebble beds and shale sharpstones	55	815
Covered—probably mostly coarse sandstone	340	760
Coarse pebble, sandy conglomerate with rare cobble beds	327	420
Coarse sandstone	2	93
Pebble conglomerate with some cobbles	12	91
Coarse pebble conglomerate	5	79
Pebble conglomerate	5	74
Coarse sandstone	1	69
Fine cobble conglomerate	4	68
Coarse sandstone	2	64
Pebble conglomerate	7	62
Coarse cobble conglomerate grading upward to pebble conglomerate with scattered cobbles	10	55
Grey pebbly sandstone with numerous discoid calcareous pebbles	10	45
Brown-weathering medium-grained well-bedded sandstone with scattered pebbles	30	35
Andesite dyke	55	- ....
Brown-weathering medium-grained sandstone with scattered pebbles	5	5

Shale member of Haida Formation—seemingly conformable.

In the thicker sections the formation rests with seeming conformity on Haida Formation in most instances recognizably the upper shale member. Thinner sections commonly rest on diverse units from Kunga Formation to Longarm Formation, with either marked or slight unconformity. In some of the sections of intermediate thickness (that is, Dawson Cove, Cumshewa Inlet, and Sandilands Island) the Honna rests on either the Haida sandstone member or on a very thin section of the shale member.

Origin.—The setting and mechanics of deposition of widespread marine polymictic conglomerates remain something of a problem. Duffell and McTaggart (1952, p. 74), in considering the origin of the similar conglomerates of the Jackass Mountain Group, rejected a marine origin and suggested instead a subareal, fluviatile origin along a narrow foreland to a mountain front with intermittent intercalations of marine shales.

Features of the Honna Formation which bear on the problem are listed below. The Honna conglomerates are overlain, underlain, and intercalated with rocks of proven marine origin. Imbrication is a relatively minor feature, cut-and-fill structures and lensoid beds very rare but scour of fine beds is common. Rounding of pebbles ranges from good to poor, but sphericity is generally low. Distinct bimodal particle distribution with sharp peaks in coarse pebble and coarse sand-size grades is characteristic, but coarse sand also occurs without pebbles. The structural attitude of the basal conglomerate and the underlying Haida beds are similar, but the conglomerate " rests " on different lithologic and biostratigraphic parts of the formation, and indeed on older rocks. Clear indications of major interfingering of conglomerates with the Haida Formation have not been seen but have been suspected. The Honna apparently overlies the whole of the basins filled with Haida Formation but laps onto its margins. In spite of imbrication not being marked and hence not trustworthy, a majority of indications on Skidegate Inlet suggests a western to southwestern source. And, finally, the thickness of the formation greatly increases toward the Rennell Sound fault line.

In conclusion, the nature of the Honna Formation would seem to indicate extensive fault movements on the margins of the Haida basins. Sheets of conglomerate were rapidly deposited in the sinking basins under marine conditions. In all probability the northern segment of the Rennell Sound-Louscoone fault zone was an active element during this period, but a connection to the Pacific was maintained in the vicinity of Sewell Inlet to Kootenay Inlet.

Age and Correlation.—The age of the Honna Formation is known only within wide limits, for, by its nature, it is not a fossiliferous unit, nor is the Skidegate Formation which overlies it. The Honna is clearly younger than the Cenomanian and possibly the Turonian, for it overlies the shale member of the Haida Formation. However, it is possible the Honna Formation might in part interfinger with the Haida Formation. A period of erosion clearly antedates the effusion of the Masset Formation of Paleocene and younger(?) age. Hence the Honna Formation is largely Late Cretaceous, probably immediately post-Turonian. Indirect evidence from the age of ultramafic intrusions in southeastern Alaska points to the Turonian as a time of major deformation (Lanphere and Eberlein, 1965). The nearest serpentine is at Duke Island, just north of Dixon Entrance.

Fossils are rarely found in the Honna, and those found are of little diagnostic value. Such as there are, have been found in shale interbeds, proving these at least are marine. The following three localities are all that are known.

FOSSIL LOCALITIES, HONNA FORMATION

Map No.	Locality	G.S.C. No.	Field No.	Position	Fossils
1	Lina Narrows	44733	60AB105	1,200 feet above base of formation	Indeterminate ammonoid fragment.
2	Western Lina Island	44737	60AB125	Bottom of formation	*Inoceramus* sp.
3	Conglomerate Point, Cumshewa Inlet	44672	60AB270	Bottom of formation	*Inoceramus* sp.

Because the age is so poorly defined, the Honna Formation cannot be correlated with other formations. The Benson Formation, a conglomerate at the base of the Nanaimo Group on Vancouver Island, is probably Santonian, so that it might possibly be a correlative. Units of Coniacian age are seemingly unknown in southeastern Alaska and western British Columbia regions, although they are well known in California (lower part of the lower Asuncion Group; F. M. Anderson, 1958).

The Honna Formation does resemble lithologically the Jackass Mountain Formation, Division B, of the Ashcroft area (Duffell and McTaggart, 1952), although this unit is the time equivalent of the Longarm Formation.

Skidegate Formation

The Skidegate Formation is the uppermost unit of the Queen Charlotte Group. It is only known on Skidegate Inlet, after which it is named. The only outcrop not contiguous to the type locality is a small area near Leonide Point of similar rocks that may be Skidegate Formation. The type locality extends in continuity with those of the Haida and Honna Formations along the north shore of the inlet, on Kagan Bay from Lina Narrows. The Skidegate Formation occupies the core of the main syncline of the Queen Charlotte Group and is overlain with considerable unconformity by volcanic rocks of the Masset Formation.

The formation is composed of grey silty shale, siltstone, and fine to medium sandstone and buff-weathering calcareous shale. These rocks are not greatly different from Haida rocks or even intercalations within the Honna conglomerate, so that it would be difficult to positively identify small isolated outcrops. Nevertheless no considerable quantity of such rocks has been found elsewhere above the Honna Formation, so it is believed to have been deposited or preserved only locally. It may indeed interfinger with the Honna conglomerate.

The age is not well known as the unit is sparsely fossiliferous. It must, however, be mid Late Cretaceous, for the Haida Formation ranges up to the Cenomanian or Turonian and the unconformably overlying Masset Formation is Paleocene.

The thickness at the type locality is about 3,000 feet; about 2,000 feet is well exposed on the shore, but the upper part, about 1,000 to 1,500 feet, is poorly exposed on the lower slopes of Slatechuck Mountain.

Lithology.—The Skidegate Formation is composed of a group of detrital rocks of relatively fine grain: silty shale, siltstone, and fine sandstone with lesser medium sandstone, calcareous shale and sandstone, and rare coarse sandstone. The most abundant rock type is grey silty shale to siltstone. The general proportions of siltstone to sandstones to all others (chiefly calcareous shale) are about 6:3:1. Characteristic colours are mid to light grey, but some dark-grey to light-brown rocks occur. Most of the calcareous rocks weather buff, the others some shade of grey. The formation is well bedded throughout, much finely bedded to laminated. Many rocks cleave readily along bedding. Characteristically there is an alternation of the rocks, resulting in a flaggy, fissile nature. The fissility of some sandstones results from abundance of shale wisps and chips, and more rarely mica. These descriptions are based on the lower 2,000 feet of the formation; the upper 1,000 to 1,500 feet is poorly exposed but apparently similar.

The rocks along Slatechuck and Kagan Creeks below the Masset Formation are mapped as Skidegate Formation, although whether they are Skidegate or Haida Formations is not clear. Structurally they appear to overlie an overturned anticline

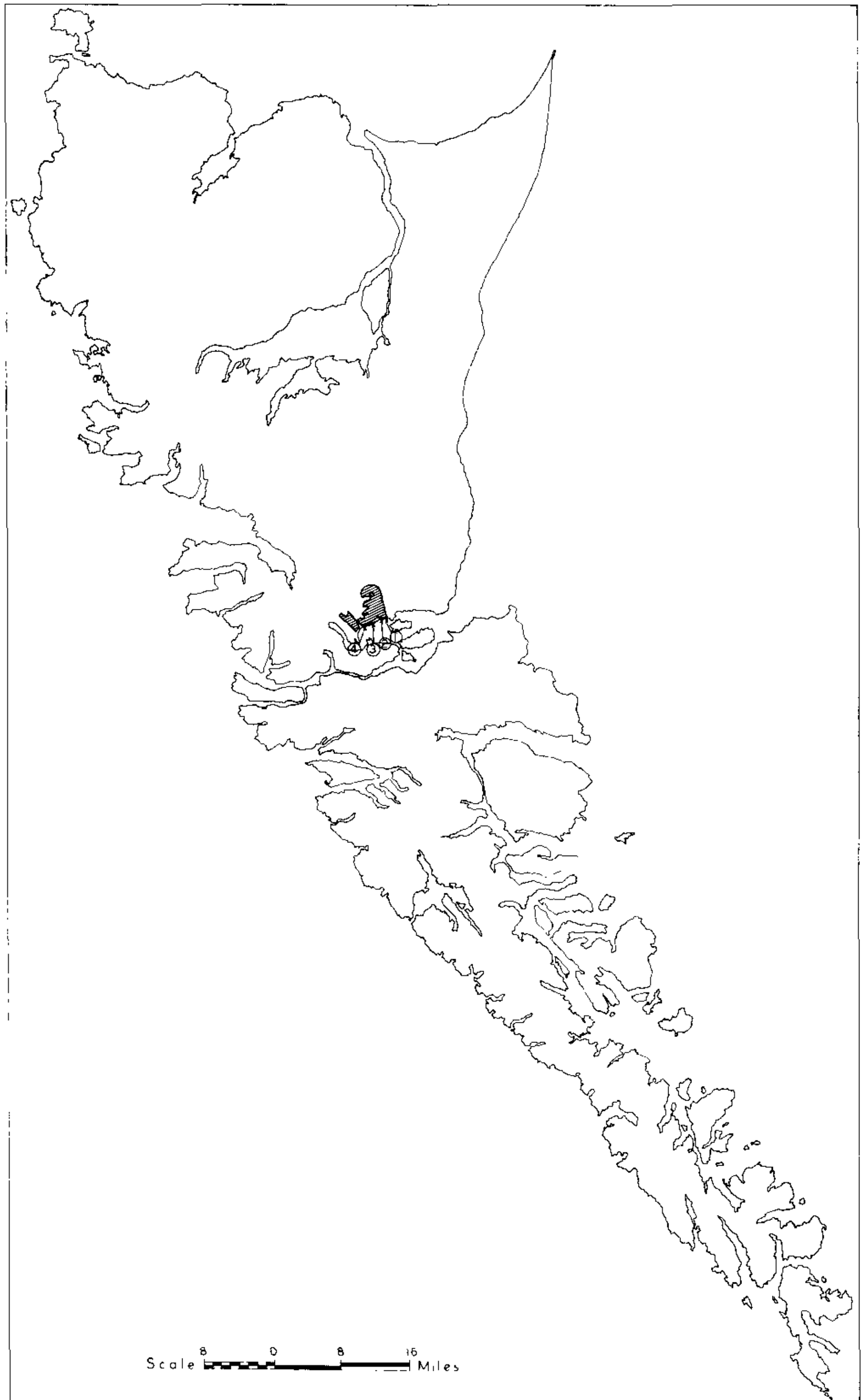


Fig. 15. Skidegate Formation: Distribution and fossil localities.

of Honna Formation. The amount of outcrop is relatively small and discontinuous, but the rocks exposed are mostly grey siltstone and fine sandstones, slightly metamorphosed. The stone used by the Haidas for carving, a black carbonaceous slate, is part of this sequence of rocks. This rock is not identical to any rocks in either Skidegate or Haida Formations. The difference partly results from the metamorphism but not entirely. Further details about this rock type are included on page 176.

Sedimentary structures present other than bedding include a few slump folds, rare cross-bed sets, convolute bedding, and cone in cone structures generally in the calcareous shales and sandstones. The axes of folds in one interpretable slump west of the synclinal axis are oriented north 20 degrees west and movement was directed eastward.

The Skidegate and Haida Formations are similar but differ in many details. The Skidegate Formation is characterized by (1) very good bedding, (2) rapidly alternating rock types, (3) flaggy fissility, (4) colour (light to mid grey in contrast to green to dark grey), (5) dearth of fossils, (6) fewer coarse sandstones, (7) no general tendency from coarse to fine rocks, (8) less wood and coal, and (9) more calcareous rocks.

Microscopy.—The Skidegate sandstones are similar to Haida and Honna sandstones but, as Figure 16 shows, are more feldspathic. The Skidegate sandstones are compact rocks composed of angular clasts of feldspar, rock fragments, and quartz, in that order of abundance. Plagioclase (mostly andesine) exceeds potash feldspar by about 7 to 1. Rock fragments are almost entirely volcanic and predominantly a fine trachytic porphyry. Accessory clasts include biotite, calcite, and opaque minerals, chiefly leucoxene, carbonaceous matter, and pyrite in that order. Detrital heavy minerals include epidote, sphene, and rare apatite and zircon. Little matrix is present, except in the few calcareous sandstones. In the normal sandstones, much of the apparent matrix is compressed fine chloritic rock fragments or mica, and in the calcareous ones probably represents rearrangement by solution and redeposition. Partial replacement of plagioclase by calcite is fairly common.

Sorting is fair, with many sandstones having a range in maximum and minimum diameter of clasts from 0.5 to 0.07 millimetre. Lamination by intercalation of siltstone or by leucoxene and pyrite-rich bands is common.

TABLE XI.—MINERAL COMPOSITION, SKIDEGATE FORMATION

	Sandstone									Siltstones and Shales	
	109	113	116	118	119	120	121	137	Av.	Range	Av.
Mineral grains—											
Quartz	15	24	28	15	10	10	25	10	17.1	} 20–30 (Quartz, Plagioclase, Potash feldspar)	25.0
Plagioclase	22	} 36	} 23	} 60	60	} 50	45	} 15	} 40.1		
Potash feldspar	3				8						
Calcite	30	......	3	5	5	10	5	10	8.5	5–65	21.2
Mica	2	3	5	Tr.	Tr.	......	9	5	3.0	5–35	12.5
Opaque	5	7	1	5	2	5	1	10	4.5	5–10	6.2
Rock fragments—											
Volcanic	Tr.	30	30	5	10	20	15	50	20.6	} 15–60 (Volcanic, Sedimentary, Matrix)	37.5
Sedimentary	......	......	5	......	......	......	..	..	......		
Matrix	23	Tr.	5	10	5	5	Tr.	Tr.	6.0		

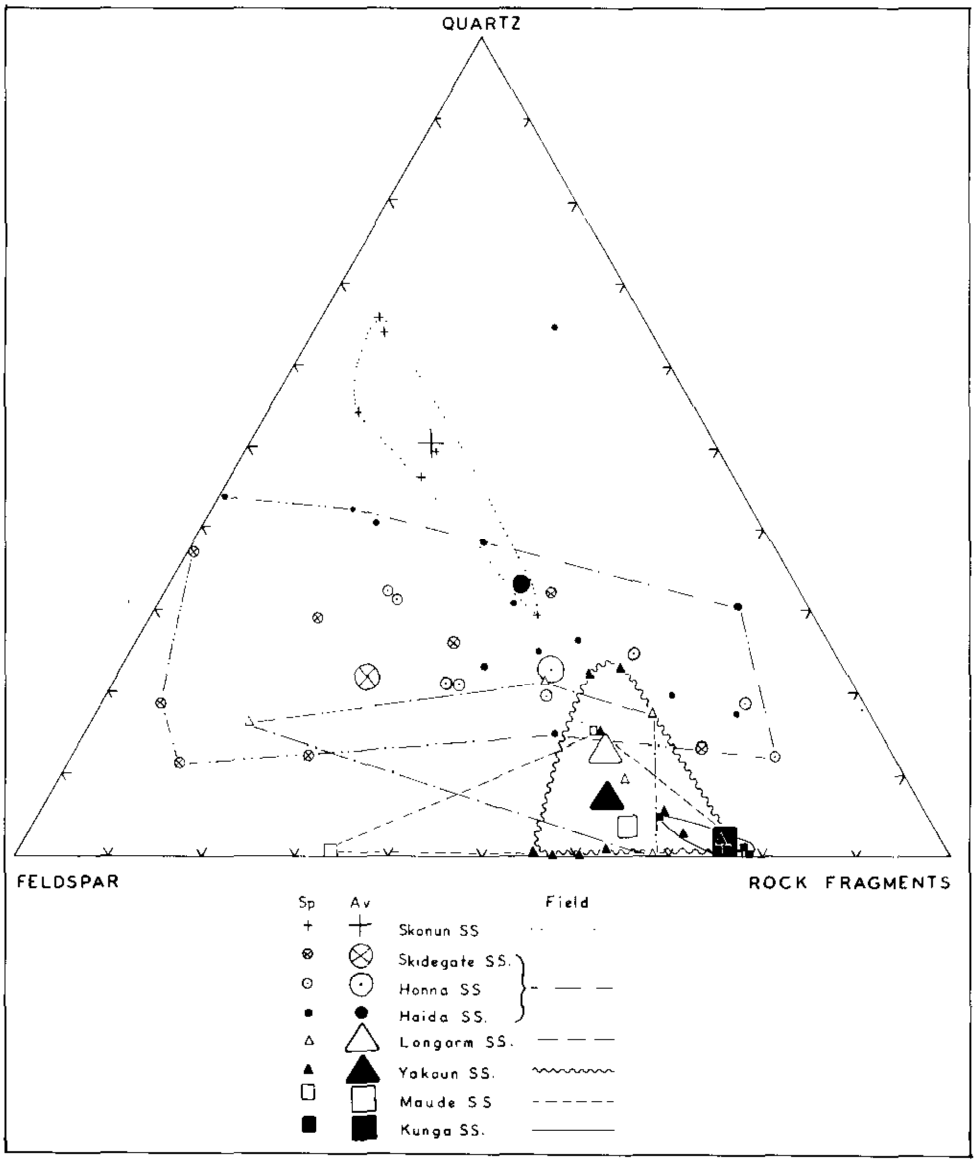


Fig. 16. Mineral composition of arenaceous rocks, all formations.

The siltstones and silty shales and calcareous varieties range widely in ratio of silt to very fine matrix to carbonate. The silt rarely forms less than 20 per cent of the rock and is composed of feldspar in excess of quartz. Mica is present in all examined specimens, and opaque minerals form a constant 5 to 10 per cent. In non-calcareous siltstones, fine silt-sized volcanic rock fragments are abundant, and matrix is scant if present. Distinguishing matrix from rock fragments in the finer rocks is virtually impossible. Finely interlaminated siltstone and calcareous siltstone are fairly common. Table XI shows the average composition of the specimens examined.

Stratigraphy.—The lower 2,000 feet of the Skidegate Formation is well exposed on Kagan Bay on both sides of the main syncline. The type is taken adjacent to the type section of the Honna Formation east of the syncline. The two exposures are similar but not identical. One difference is that in the western exposure the degree of alternation of rock types is less. Thicknesses are both of the order of 2,000 feet. Estimates of covered intervals on the type section are therefore judged to be approximately correct. Comparison of the covered intervals shows they most probably are underlain by rocks similar to those adjacent.

MEASURED SECTION, SKIDEGATE FORMATION, NORTHEAST KAGAN BAY

	Thickness in Feet	Cumulative Thickness above Honna Formation
Good exposure on shore terminates at main synclinal axis; poor exposure continues on lower slopes of Slatechuck Mountain where an additional 1,000 to 1,500 feet of similar rocks dominantly well-bedded siltstones is overlain with angular unconformity by the Masset Formation.		
Covered, centre of main syncline	20	2,075
Fissile, grey, fine sandstone; rare calcareous beds	15	2,055
Covered	85	2,040
Fissile, grey shaly siltstone and very fine sandstone. Well bedded; rare concretionary beds	50	1,955
Interbedded light greenish-grey medium sandstone with buff calcareous sandstone and shaly siltstone; 1- to 4-inch beds; abundant worm tubes, etc.	50	1,905
Light buff to grey calcareous micaceous sandstone with buff shaly sandstone and shale	15	1,855
Grey shaly siltstone; beds 1 to 2 inches thick. Buff calcareous shale bed every 10 feet, more or less	65	1,840
Covered	20	1,775
Grey shaly siltstone with buff and greenish-grey medium sandstone and one 3-foot granule bed; beds mostly 1 to 4 inches	130	1,755
Covered	155±	1,625
Flaggy laminated buff and dark-grey medium sandstone with some interbeds of grey siltstone, beds 1 to 4 inches; worm tubes	105	1,470
Interbedded flaggy medium sandstone and shaly siltstone in beds about 2 feet thick	22	1,365
Grey siltstone with medium sandstone and some calcareous concretionary siltstone	113	1,343
Light- to dark-grey calcareous to medium flaggy sandstone with shale interbeds	55	1,230
Interbedded brownish-grey weathering medium to calcareous sandstone and grey siltstone	50	1,175
Covered and folded so interval assumed	50±	1,125
Coarse platy sandstone with carbonized laminæ of twigs	5	1,075
Interbedded fissile grey silty shale (70 per cent) in 6- to 9-inch beds with dark brownish-grey weathering medium sandstone in 1-inch to 1-foot beds; rare calcareous concretionary beds	45	1,070
Covered	32	1,025
Interbedded grey siltstone with fine to coarse sandstone. Rare calcareous shale	18	993
Interbedded grey siltstone and medium to coarse sandstone	15	975
Interbedded grey siltstone with fine to coarse sandstone. Rare calcareous shale	60	960
Interbedded grey shaly siltstone and fine sandstone; 6-inch beds; cream-weathering calcareous shale bed every 5 feet, more or less	35	900
Interbedded grey shaly siltstone, with lesser light-grey fine to medium sandstone and buff-weathering grey calcareous shale with convolute bedding and cone in cone beds ½ to 6 inches; 60AB114 *Inoceramus* sp.; worm tubes	145	865
Covered	600?	720
Poorly exposed laminated siltstone, fine sandstone and calcareous siltstone	32	120
Laminated grey fine siltstone and sandstone, buff-weathering calcareous siltstone and cross-bedded medium-grained sandstone; 60AB110, an ammonoid impression	23	88
Covered	65	65

Honna Formation—structurally concordant.

Origin.—The Skidegate Formation appears to have originated in a shallow marine basin swept by variable currents. The relief of the basin margins must have been very much less than during Honna time. The increase in feldspar in relation to rock fragments may indicate somewhat more extensive time lapse between erosion and final deposition, but the absence of significant increase in rounding and sorting suggests that reworking had not increased.

Age and Correlation.—The age of the Skidegate Formation is known only to be Late Cretaceous. The formation is not very fossiliferous. Scattered *Inocerami* of one or more unidentified species occur throughout the well-exposed section, but only one ammonoid, again unidentified, was found. Unfortunately also the shales (silty shales) appear to contain few microfossils. The only abundant fossil remains are worm tubes.

The following lists localities from which fossils were collected. Poor *Inocerami* were seen at a number of other localities but not collected. Figure 15 shows the distribution of the formation and the fossil localities.

FOSSIL LOCALITIES, SKIDEGATE FORMATION

Map No.	Locality	G.S.C. No.	Field No.	Fossils
1	East of Kagan Bay adjacent to Honna Formation	44734	60AB110	Poor ammonoid impression.
2	East of Kagan Bay	44735	60AB114	*Inoceramus* sp.
3	Kagan Bay, centre of syncline	44715	60AB138	*Inoceramus* sp.
4	West of Kagan Bay near Honna Formation	44716	60AB141	*Inoceramus* sp. with prominent concentric ribs.

Without more accurate dating, correlations are impossible; however, the Skidegate Formation might be the correlative of some of the lower(?) part of the Nanaimo Group.

Masset Formation

The Masset Formation is a very thick accumulation of volcanic flows and pyroclastic rocks of differing aspect in various parts of the islands but primarily composed of alkali basalt and sodic rhyolite. The basic lavas for simplicity are all called basalts here, but some are basaltic andesites. Characteristic units are thin flows of columnar basalt, basalt breccias, thick sodic rhyolite ash flow tuffs, and welded tuff breccias and breccias of mixed basalt and rhyolite clasts. In addition, certain basic and acidic hypabyssal intrusions are intimately connected with the flow rocks and are included in the formation.

The Masset Formation was named by MacKenzie (1916, p. 76) from exposures about Masset Inlet. He stated that the Masset Formation overlay the Skonun Formation. " The writer has not seen the contact between the overlying Masset and the Skonun Formations, but from the general areal distribution of the Tertiary rocks, it is thought that the Masset Formation overlies the Skonun with overlap or unconformable relations " (1916, p. 74). Dawson (1880, pp. 84–89) treated the Tertiary volcanic and sedimentary rocks together and made no general

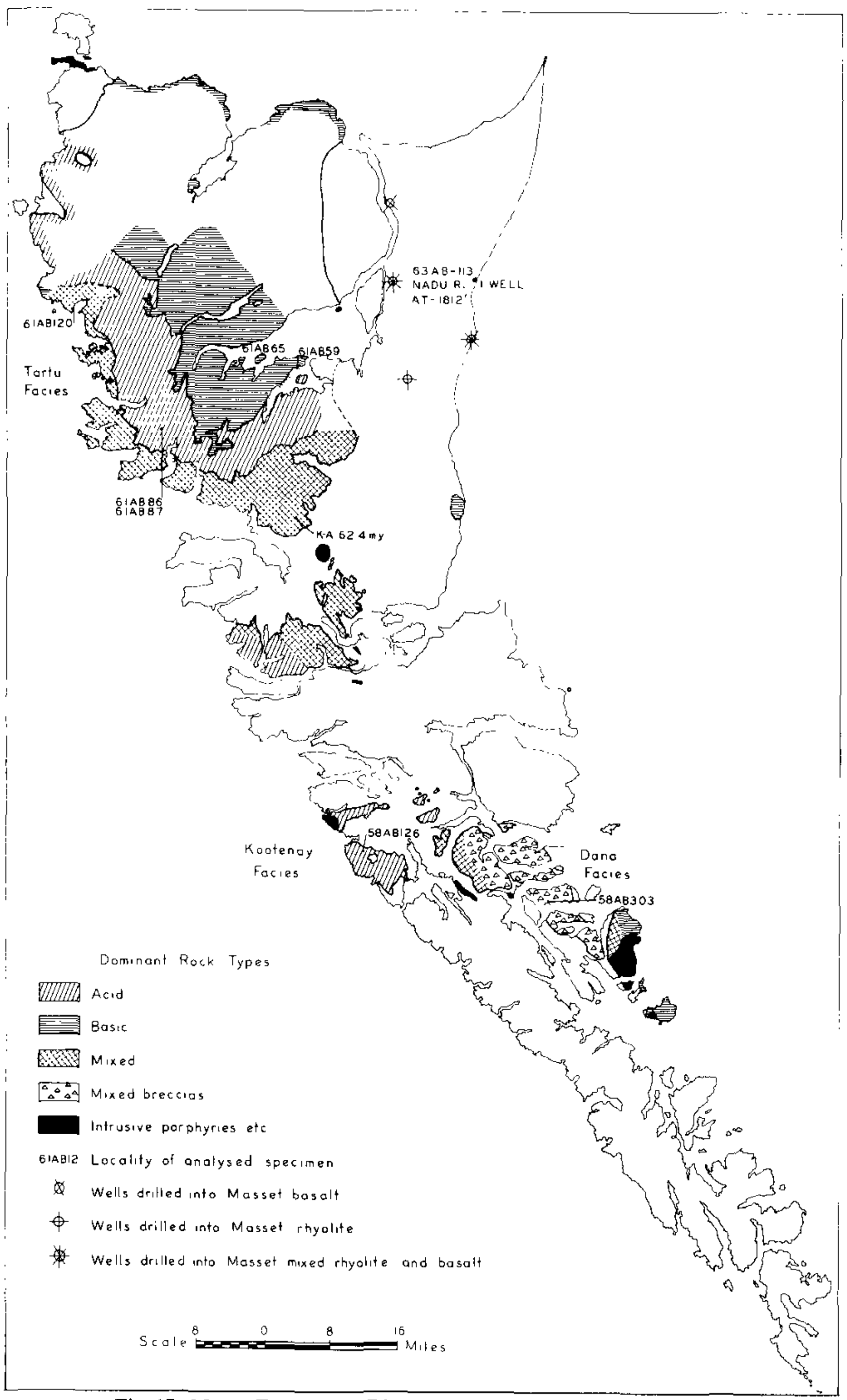


Fig. 17. Masset Formation: Distribution, facies, and special localities.

comment about relative stratigraphic positions, except that at Tow Hill and Lawn Point basalts overlay sedimentary rocks. Ells (1906, pp. 23–26, 46) and Clapp (1914, pp. 25–29) discussed Tertiary sedimentary and volcanic rocks separately, did not name them, and confused other units with Masset, so that their discussions are of only incidental interest. The Yakoun volcanic and sedimentary rocks were mistaken for Haida and Masset at Wilson Creek, and Tow Hill basalt for Masset. The correlation of Tow Hill basalt with Masset Formation basalts is understandable but has probably been the main cause of much of the error. Drilling by Richfield Oil Company proved beyond doubt that the Skonun overlies the Masset Formation and that the Tow Hill basalt is a sill within the Skonun Formation. Tertiary hypabyssal rocks of Graham Island were called the Ethaline Formation by MacKenzie (1916, pp. 66–73) and were thought to be older than the Masset Formation but are not separately named in this study because they are believed to be directly related to the Masset flows.

For convenience of reference the writer has separated the Masset Formation into three different facies named after Tartu Inlet, Kootenay Inlet, and Dana Inlet (*see* Fig. 17). The Tartu facies underlies most of Graham Island north of Rennell Sound and west of the Yakoun River and Masset Sound. It also occurs beneath the Skonun Formation on northeastern Graham Island. Similar rocks occur in smaller amounts at localities on southern Graham and Moresby Islands. The Tartu facies is composed of a plateau sequence of columnar basalts, basalt breccias, and rhyolitic ash flows and has an aggregate thickness of some 18,000 feet. It, or more particularly the basalts, forms the unit formerly thought of and referred to as the Masset Formation. The Kootenay facies is typified by welded rhyolite tuff breccias and spherulitic rhyolites. It occurs primarily on the west coast near Kootenay and Bottle Inlets but also near Dawson Inlet. The Dana facies is formed principally of pyroclastic breccias of mixed basalt and rhyolite clasts and occurs on the east coast from Selwyn Inlet to Sedgwick Bay. Both Dana and Kootenay facies, or what remains of them, are very much thinner than the Tartu, being about 4,000 to 5,000 feet thick respectively.

The Masset Formation and, generally speaking, each of the facies overlies with angular unconformity all older units from Karmutsen Formation to Queen Charlotte Group, with degree approximately corresponding to the difference in age. The Masset Formation in turn is overlain with considerable unconformity by the late Cenozoic Skonun Formation. The Masset is intruded and locally metamorphosed by some of the post-tectonic plutons.

The age is known approximately from one potassium-argon age on a biotitic sill(?) near the base of the Tartu facies as Paleocene and younger and as pre-Miocene from the relationship with the Skonun Formation.

Lithology.—The most abundant rock type of the Masset Formation is dark-brown to black aphanitic basalt that has a subvitreous lustre and commonly weathers to some middle shade of grey-brown. The weathered skin is only 2 to 5 millimetres thick. Most of the basalt has pronounced columnar joints (*see* Plate IXB) and in addition a fine platy cleavage and slight discoloration parallel to stratification and to a microscopic trachytic flow texture. Microphenocrysts and phenocrysts rarely comprise as much as 10 to 15 per cent of the rock. Such dark, microporphyritic, aphanitic columnar basalts form probably half of the formation.

Also abundant are basaltic breccias that most likely originated in diverse manner. The commonest variety is a varicoloured rock in dark shades of red, brown, or purple with some green. The basalt fragments of these rocks vary widely in vesicularity and granularity as well as colour. These units occur as beds of varying thickness but rarely more than 50 feet and commonly much thinner. Some beds, however, are several hundred feet thick locally. Fragments greater than 2 feet (60 centimetres) in diameter are very rare, and maximum sizes about 2 to 3 inches (5 to 8 centimetres) are more usual. True tuffs (that is, composed dominantly of fragments less than 4 millimetres) are very rare. Some of the basalt breccias may have an admixture of acid fragments. Less commonly they may contain some roundstones. Another type of breccia is composed of irregular homogeneous fragments of variable size but with many large fragments. The origin of these various basalt breccias would seem to range from true pyroclastic breccias for the commonest type to flow breccias and scoriaceous tops for the last described.

Sodic rhyolites of variable aspect form the second most abundant rock type in the formation. These rocks commonly weather some light shade of buff to grey or purplish grey, but are dark to light grey when fresh. They are commonly streaky banded rocks with irregular open or drusy vesicles. Some are extremely well banded with sharply varying laminæ of black to buff. The rhyolites are variably porphyritic, many with no visible phenocrysts but others with up to 15 per cent. Most phenocrysts are feldspar, some are pyroxene, but quartz is very rare. However, silica minerals with some zeolites partially fill vesicles. The groundmass of the rock is commonly stony aphanitic but may be glassy. These obviously acid volcanic rocks were called felsites, trachytes, pitchstones, and vitrophyres in the field, but microscopic and chemical analysis shows they are all sodic rhyolites.

Associated with the sodic rhyolites are a few rocks of palpable fragmental nature which vary from white, buff, or light-grey ashy tuffs to purply grey wispy or eutaxitic lapilli tuff, to purplish brown or buff, very angular lapilli-sized breccia of non-vesicular homogenous fragments with chalcedony filling or partially filling the small amount of original voids.

All the foregoing lithological types are primarily found in the Tartu facies, but occur in some degree elsewhere. The following types occur primarily in Kootenay or Dana facies.

The Kootenay facies is characterized by light-grey or light-brown weathering, dark-grey to black acid pyroclastic rock with well-developed eutaxitic structure and assorted fragments, many of which are wispy collapsed pumice. On fresh surfaces the clastic nature of these rocks is not readily apparent, and they look like vitrophyres. Fragment size varies; most of the rocks are lapilli tuffs, but some have many particles in 2- to 3-inch (5 to 8 centimetres) size range and some as large as 10 inches (25 centimetres). These larger fragments generally form a relatively small percentage of the rock. Almost all matrix and fragments appear to be cognate. Much was originally glassy and fluid before eruption, but many of the larger fragments were consolidated banded rhyolites. Both fragments and matrix contain 5 to 15 per cent of well-formed acid plagioclase laths. Accidental fragments such as basalt occur in small amount. The shape of fragments varies greatly from wispy sub-planar collapsed pumice fragments to angular feldspar crystals and banded rhyolite fragments to well-rounded accidental fragments. A crude large-scale (3-foot centres) columnar jointing is common. Beds range from 20 feet to several hundred feet, possibly 400 feet, thick. An excellent foliation is common—much is formed by eutaxitic structure but some, as in Plate IXA, is a through-going foliation. The microscopic nature confirms the macroscopic evidence that these pyroclastic rocks are welded tuff breccias; that is, ignimbrites. The size grades range from tuff to agglomerate, being commonly lapilli, so that they might also be called welded lapilli ash flows. The chemical composition is essentially identical to the sodic rhyolites of different aspect that form such a large part of the Tartu facies (*see* Table XIV).

Associated with the welded tuff breccias are white- to buff-weathering greenish-white spherulitic aphanitic rhyolites. These rocks are not as certainly welded ash flows but most likely are. Spherules and drusy lithophysae may form 50 per cent of the rock but normally considerably less. They range up to 5 centimetres in diameter but commonly are about 5 millimetres. The rhyolite commonly has an excellent foliation, and this traverses the spherules. If the foliation parallels bedding as it seems to, these rhyolites are only gently folded but yet contain small recumbent folds of flow origin, indicating some movement during welding (*see* Plate IXA). Some of the foliation is formed of thin discontinuous planes of quartz minerals. The spherulitic rhyolites in part are interbedded with the lapilli ignimbrites. Field relations are not clear but are suggestive of a general gradational relationship between the two rhyolitic rock types. Although different macroscopically, these rhyolites are similar microscopically and chemically to those of the Tartu facies.

The characteristic rock of the Dana facies is a fine tuff breccia of heterogeneous fragments in which the colour varies from light grey to a clear light green. In general these rocks are unbedded but some contain perceptible graded beds, although bedding planes are rarely marked. Sorting in the normal tuff breccia is extremely poor. The majority of the rock is composed of about 70 per cent angular fragments of lapilli size (4 to 32 millimetres diameter) in a finely comminuted matrix. However, fairly randomly distributed although not everywhere present are large blocks from 1 foot (30 centimetres) to 20 feet (6½ metres) in diameter, commonly angular or irregular but some in some localities rounded. The fragments are dominantly basaltic, but 20 to 40 per cent are finely banded rhyolite. Rarer are fine purplish feldspar porphyry fragments. A few specimens were found which contained charred wood fragments. The graded bedded tuffs appear to be reworked material similar to the main breccia, but rounding of fragments does not appear to be significantly greater.

Intercalated with these mixed clast tuff breccias are purplish-grey feldspar porphyries with 10 to 20 per cent plagioclase phenocrysts, 1 to 2 millimetres long, and buff- and rusty-weathering light-grey rhyolites, some of which are finely banded. These rocks occur as common dykes and some tabular bodies that may be either sills or flows.

Breccias similar but not identical to the Dana facies breccias occur with Kootenay facies near Portland Bay and near Slatechuck Mountain and Dawson Harbour localities. These breccias are on the whole coarser and better sorted, and though containing mixed clasts, they are dominantly acidic. Average particle size is 2 to 3 inches with maximum about 9 inches. Fragments are highly angular. These breccias occur in beds 1 foot to many hundreds of feet or more thick(?). The fragments are devitrified sodic rhyolite to dacite with some admixture of basaltic or andesitic fragments. Many fragments have feldspar phenocrysts.

Variations of these general types of effusive rocks are known but are minor. The variations commonest are aphanitic grey-green dacite to andesite flows and tuffs which occur in minor amount at Slatechuck Mountain, Dawson Harbour, and Portland Bay localities, particularly at the former two.

A group of intrusive hypabyssal rocks, feldspar porphyries and gabbros, intimately associated areally with the Masset effusive rocks and cutting them at a number of localities, are described with the Masset Formation. In part they may represent consolidated plug-like and dyke-like orifices or upper magma chambers within older rocks, but some are sill-like bodies within the Masset effusions. The feldspar porphyries are white to light-grey or brownish-grey rocks with stubby plagioclase phenocrysts (2 to 4 millimetres long), hornblende, and hexagonal biotite plates in a dominant (60 to 80 per cent) aphanitic matrix. Examples include the large elongate pluton from Cape Knox to Parry Passage, plug-like mass west of Yakoun Lake, a large complex mass on southeast Lyell Island, and many smaller bodies, including sills such as the one on the peak west of Ghost Creek and near Klashwun Point on the north coast. The gabbros are typically coarse grained but grade to fine diabase. They are all mafic-rich dark rocks but are otherwise quite variable. Examples include the large dyke-like body west of Barrier Bay on Tasu Sound, sill-like bodies south of Skidegate Narrows, and pipe-like bodies east of Moresby Lake.

Microscopy.—The basalts of the Masset Formation are relatively uniform microscopically as they are in hand specimen. The mode of 25 specimens was estimated, some specimens were checked against point count analyses, and the total is as follows:—

TABLE XII.—MINERAL COMPOSITION, MASSET BASALTS

	Percentage	Range	Composition
Phenocrysts—			
Plagioclase	7¼	0–30	An_{80}–An_{60}.
Olivine	1	0– 5	Iddingsite±.
Pyroxene	1	0– 2	Augite or hypersthene.
Matrix—			
Plagioclase	44	30–55	An_{70}–An_{40}.
Olivine	2	0–30	
Pyroxene	27½	20–35	Augite.
Iron oxides	5	5–10	Magnetite(?).
Mesostasis	12¼	10–25	Glassy to cryptocrystalline.

Three-quarters of the analysed specimens have a fair to good trachytic texture of flow-oriented plagioclase laths and the remainder an intergranular to intersertal texture. All but one contained microphenocrysts or phenocrysts of plagioclase, and most had some olivine, augite, or, rarely, hypersthene phenocrysts. Plagioclase of phenocryst and matrix is zoned, and some phenocrysts have oscillatory zones with three cycles of narrow compositional range. Large phenocrysts in some specimens are broken and partly resorbed and look accidental. Olivine is always altered to iddingsite, antigorite, or other secondary minerals, but most of the other minerals are fresh. Phenocrystic pyroxene is commonly augite, rarely hypersthene; matrix pyroxene is augite. The iron ore appears to be magnetite.

Some specimens coarse enough to be called diabase were collected. The mineralogy of these is nearly identical to the basalts.

	Percentage
Plagioclase (An_{80-60})	37½
Augite	30
Olivine	7½
Potash feldspar	1
Iron ore	5
Zeolite (thompsonite)	15
Chlorite	4

The texture is diabasic to subophitic with random discrete olivine grains and thompsonite, potash feldspar, and chlorite in interstices.

Pyroclastic basaltic rocks (hence excluding flow breccias, flow tops, and collapse breccias) are commonly composed of two contrasting types of basalt fragments closely packed with little matrix. The fragments are angular to irregular and the matrix is formed of comminuted crystals, basaltic dust, and opaline silica. Fragments tend to be either holocrystalline basalt of widely differing nature or originally quite glassy basalt with a considerable percentage of generally irregular vesicles now filled with bright-green chlorite. Gradations occur between the two types and either may show trachytic or flow structures. They most likely were originally cognate accessory and essential materials respectively. A minor amount of rhyolitic clasts may be included.

The rhyolites show more variety microscopically than the basalts, as indeed they do in hand specimen. Most of the differences are inconsequential and result only from minor variation in the form of devitrification. Although most of the rocks are devitrified, many appear glassy in hand specimen and a few are truly glassy when seen in thin-section.

Particles found in the matrix of these rocks include phenocrysts, xenocrysts, rock fragments, vesicle fillings, veinlets and segregations, and carbon. About three-quarters of the rhyolite specimens contain crystals of plagioclase, and some contain pyroxene and iron ore. Plagioclase crystals form up to 20 per cent of some rocks but more commonly about 5 per cent or less. They are generally recognizable as belonging to one of two suites: the one of rounded, resorbed, zoned basic plagioclase (An_{60-40}), and the other of lath-like to rounded acid plagioclase (An_{30-20}) fairly commonly with glassy inclusions. Either type may look broken or glomerated. Clearly the basic plagioclase is xenocrystic, whereas the other is truly phenocrystic. Pyroxene, present in about one-fifth of the specimens, is commonly altered, and may be hypersthene or augite. Iron ore, probably magnetite, and apatite needles are relatively common. Many rocks have irregular amygdules and partially filled vesicles, segregations or veinlets of silica minerals, and, more rarely, zeolites. However, quartz phenocrysts are almost unknown. Silica minerals include quartz, tridymite, chalcedony, and opal, any three of which may be found in the same vesicle. Chabazite is the commonest zeolite. Calcite and goethite are present in vesicles of some specimens. Rock fragments are common in perhaps a quarter of the specimens. Most fragments are of similar rhyolites or vitrophyres, but some are basalt, argillite, or carbon.

Textures resulting from devitrification range from uniform extremely finely felted texture, to spherulitic, to one formed of crudely equidimensional areas about 1 millimetre in diameter of one crystal orientation containing a dense mass of randomly oriented to swirly microlites. The mineralogy of these felsitic devitrified glasses is not known certainly but seems to involve mainly quartz or cristobalite and sodic plagioclase.

Most rocks have a fine foliation or banding which may take many forms, from slightly curving discontinuous foliated streaks to discrete and fairly regular laminæ. The latter cases generally represent differential devitrification of alternating bands. The former cases are believed to represent all that remains of original compressed welded shard eutaxitic structures in most of these rocks. Fortunately some of the glassy rocks preserve enough of these structures so there is little doubt that at least some of these rhyolites were welded ash flow tuffs. Plate XIIIA shows the compressed and distorted pumice and platy shards and some Y-shaped shards that are so characteristic of welded ash flows. Other specimens, such as ones from Kennecott Point to Beresford Bay, are glassy ash flow tuffs, but they are only slightly welded and compressed. Rocks exhibiting these textures have been collected in both mixed and rhyolite members and from near Otard Bay, Skelu Bay, and Tartu Inlet and the hills east of Port Louis and Port Chanal.

Some of the glassy welded tuffs have a significant content of lithic and welded tuff fragments. As most of these are cognate, they are difficult to recognize in devitrified specimens but are definitely present in some. Perlitic cracks are common in some of the glassy rocks, a few of which are slightly expansible. The refractive index of fused specimens is $1.490\pm$.

Rhyolitic tuff breccias of the Kootenay facies are obviously welded tuffs or ignimbrites in hand specimen. In thin-section some are very like some of the compressed welded ash flow tuffs with rock fragments described above, but in general contain a greater percentage of cognate and accidental rock fragments and broken crystal fragments. Most specimens are quite highly devitrified, so that in thin-section little of the original textures can be seen. The spherulitic rhyolites of this facies are similar to the rhyolites of the Tartu facies but are more highly devitrified with large spherules. However, they may contain scattered partly resorbed phenocrysts of quartz and perthitic soda anorthoclase. Lamination is relatively poorly defined microscopically.

Rhyolites from other localities such as Dawson Harbour may have been similar initially to those described from the Tartu facies but generally have been so completely devitrified by slight metamorphism that none of the original texture remains.

Volcanic tuff breccias of the Dana facies have a characteristic appearance in thin-section as in hand specimen but vary considerably in details of composition, size, and sorting. All are composed of mixtures of angular clasts of basalt and rhyolite. All are dense compact rocks with little matrix and normally no original voids. Size of particle ranges from rare large blocks to about 1 millimetre. Sorting is normally very poor. Relative proportions of basalt to rhyolite in specimens examined is as 9 is to 7 but it varies from 1:1 to 4:1. An estimate for the whole of the facies is impossible at present but might be more basaltic than the 9:7 recorded above. Fragments not assignable to either basalt or rhyolite are rare and include argillite and carbonized wood. The basalt and rhyolite clasts themselves vary greatly in vesicularity and crystallinity. Some basalts are holocrystalline and moderately coarse grained; most are fine amygdaloids with chlorite-filled and rarely quartz-rimmed amygdules. Vesicularity up to 50 per cent is common. Most fragments show trachytic orientation of feldspar laths and some planar orientation of vesicles. The irregularity and angularity of highly vesicular fragments is notable. Rhyolites are all devitrified with felsitic textures, many are banded, some quite porphyritic with resorbed sodic plagioclase, and a few show remnant perlitic cracks. The average size of rhyolite fragments is greater than that of the basalts. Very angular shard-like shapes are common. Matrix finer than 1 millimetre is relatively minor (rarely 10 per cent), is formed of comminuted matter similar to the clasts plus feldspar crystals, and fills the minor spaces between the closely compacted clasts. What were originally voids were only seen in one specimen where they were filled with chalcedony.

Much of the area occupied by the Dana facies has been metamorphosed by young intrusive bodies so resulting chloritization and lesser epidotization has somewhat obscured relations.

The hypabyssal rocks associated with the Masset Formation are also sharply divided into two groups, feldspar porphyry and gabbro.

Feldspar porphyries are composed of about 30 per cent phenocrysts dominated by plagioclase laths averaging 2 to 3 millimetres long, but containing hornblende and biotite or, more rarely, pyroxene or quartz. The matrix is a fine lathy mixture of plagioclase and orthoclase with quartz, biotite or chlorite, magnetite, calcite, and minor apatite. Estimated modes of eight specimens are as follows:—

TABLE XIII.—MINERAL COMPOSITION, MASSET FELDSPAR PORPHYRIES

	Percentage	Range	Composition
Phenocrysts—			
Plagioclase	19.2	5–27	An_{30-40}.
Hornblende	4.8	0–10	
Biotite	2.0	0– 5	
Quartz	1.0	0–10	
Pyroxene	2.0	0–10	Hypersthene.
Matrix—			
Plagioclase	27.0	25–35	$An_{30}\pm$.
Potash feldspar	19.0	15–30	
Quartz	11.0	0–35	
Biotite or chlorite	6.5	0–10	
Iron ore	3.3	2– 5	Magnetite.
Calcite	1.2	0– 8	
Other	3.0	———	Apatite, semiopaques.

Plagioclase phenocrysts are oscillatory zoned over a narrow compositional range, are partly resorbed, and may be broken. Hornblende or pyroxene are altered to biotite or chlorite, calcite, and magnetite. Some of the quartz of the matrix was chalcedony and occurs in fibrous rosettes. The composition of these porphyries is between a granite and quartz monzonite and so is close to the rhyolites of the formation.

The gabbros and diabases are variable in crystal size and mineralogy, ranging from coarse to fine with ophitic, poikilitic, or intersertal textures. Plagioclase is commonly labradorite, about An_{50}, but ranges from An_{60-40} and forms 30 to 50 per cent of the rock. Mafic minerals may include olivine and two pyroxenes (hypersthene and augite), fine chlorite, and iron oxides. Olivine, hypersthene, or augite may be the dominant mineral, so that the rocks may be olivine gabbro, norite, or gabbro, or their diabasic equivalents. All minerals are commonly quite altered.

Chemistry.—The chemical composition of eight characteristic Masset volcanic rocks is shown in Tables XIV and XV and includes four rhyolites, three basalts, and one Dana facies tuff breccia. Amongst the rhyolites are: Column 1 (61AB86), an obsidian without xenocrysts or vitroclastic structure; Column 2 (61AB87), a devitrified rhyolite without xenocrysts; Column 3 (61AB120), an obsidian with welded vitroclastic structure and some rock fragments; Column 4 (58AB126), a welded tuff breccia of Kootenay facies with some accidental fragments. The modes of these rocks are also shown in Table XIV. The analyses are all averaged in Column 5 and the first two only in Column 6, which probably represents uncontaminated rhyolite. These analyses are compared with Nockolds' average peralkaline rhyolite and obsidian (Column 7), with which they are most nearly akin, but higher in CaO and MgO and considerably lower in K_2O. Probably the best name for these rocks is sodic rhyolite.

The chemical compositions of basalts and Dana tuff breccia with their modes are listed in Table XV. Columns 1 to 3 are basalt, and Column 4 the average of 1 to 3. These analyses are compared to Nockolds' average tholeiite (Column 5) and Waters' (1961) average Yakima basalt (Column 6). The Masset basalts analysed show considerable variation considering how similar they are in hand specimen and mineralogy (*see* Table XV, Modes). Specimen 61AB59 is a basaltic andesite, but the plagioclase phenocrysts are zoned from An_{75-60} and the matrix plagioclase is about An_{60}. Considering this, the average analysis, the appearance and mineralogy of all the flows, they are best considered as basalts. Comparison with Nockolds' and Waters' averages shows the Masset average is very close to Waters' but contains more Al_2O_3 and Na_2O and less total iron and CaO than Nockolds'. The Masset basalts are even more sodic than the Yakima basalts and about the same as the Karmutsen basalts. However, the lime-alkali ratio of the Masset basalts is less extreme than that of the Karmutsen, the K_2O content higher, and the Na/K ratio very much less (*see* Table II). In summary the Masset basalts are moderately high alumina, alkali basalt.

TABLE XIV.—CHEMICAL ANALYSES AND MODES, MASSET RHYOLITES

	1* (61AB86)	2* (61AB87)	3* (61AB120)	4* (58AB126)	5 Average 1–4	6 Average 1–2	7 Nockolds' Average
SiO_2	72.48	72.72	67.64	70.98	70.95	72.60	72.31
TiO_2	0.26	0.31	0.47	0.49	0.38	0.29	0.42
Al_2O_3	12.88	13.04	13.56	13.15	13.16	12.96	10.88
Fe_2O_3	1.14	2.95	0.89	2.31	1.82	2.04	2.92
FeO	1.96	0.34	3.09	2.24	1.91	1.15	2.42
MnO	0.10	0.07	0.11	0.11	0.10	0.08	0.14
CaO	1.03	0.43	1.67	1.96	1.27	0.73	0.68
MgO	0.36	0.35	0.61	0.35	0.42	0.36	0.16
K_2O	2.70	2.98	2.12	1.94	2.43	2.84	4.42
Na_2O	5.74	5.42	5.76	4.68	5.40	5.58	5.17
H_2O-	0.37	0.28	0.43	0.21	0.32	0.32	——
H_2O+	0.67	0.76	3.49	1.41	1.58	0.72	0.45
CO_2	0.21	0.20	0.07	0.09	0.14	0.20	....
P_2O_5	0.04	0.04	0.08	0.05	0.05	0.04	0.03
SO_3	0.005	0.007	0.002	0.009	0.006	0.006	....
Totals	99.945	99.897	99.992	99.979	99.936	99.916	100.00

MODES OF ANALYSED MASSET RHYOLITES

	1 (61AB86)		2 (61AB87)		3 (61AB120)		4 (58AB126)
	Volume (Per Cent)	Composition	Volume (Per Cent)	Composition	Volume (Per Cent)	Composition	
Plagioclase crystals	3.65	$An_{30}\pm_2$	4.70	$An_{25}\pm$	4.53	$An_{25}\pm$	15.40
Pyroxene crystals	0.60	Augite	....	....	1.19	Augite	5.02
Quartz	....	....	....	....	....	....	Tr.
Iron oxide	0.03	Magnetite?	0.86	Magnetite?	0.21	Magnetite?	0.23
Rock fragments	....	....	....	....	7.56	Mostly cognate	19.01
Matrix	95.72	Felsophyric	94.44	Felsitic	86.51	Vitroclastic	60.34

1—61AB86, obsidian from hills northwest of Seal Inlet (*see* Fig. 17 for localities). } Tartu facies.
2—61AB87, devitrified rhyolite, hills northwest of Seal Inlet. } Tartu facies.
3—61AB120, obsidian with welded vitroclastic structure, west entrance point of Otard Bay. } Tartu facies.
4—58AB126, welded tuff breccia, Kootenay facies, north spur of mountain south of Kootenay Inlet.
5—Average of 1 to 4.
6—Average of 1 and 2, uncontaminated rhyolite.
7—Average of 39 superior analyses of peralkaline rhyolite and obsidian (Nockolds, 1954).
* By Analytical and Assay Branch, Department of Mines and Petroleum Resources, Victoria, B.C.; analysts, S. W. Metcalfe and R. S. Young.

The specimen of Dana tuff breccia analysed (Column 7) is a typical specimen, but with such a unit a very great many analyses would be necessary to secure a truly representative average. It should be compared to the average rhyolite (Column 4, Table XIV) and average basalt (Column 4). It should be noted the silica percentage is almost exactly half-way between that of the rhyolite and basalt averages; that the Na_2O and P_2O_5 percentages also are half-way between; but the CaO, MgO, and MnO are less than corresponds with this ratio of mixing; and that the Al_2O_3, total iron, TiO_2, and K_2O are more. All components, however, fall between the limits of the two types and on either side of a 1:1 mixture, with the farthest departure on either side being 3:1. The mode of the analysed specimen is about 1:1. The mode of all examined specimens was 9 basalt to 7 rhyolite. But it was stated the true average might be even more basaltic. In conclusion there is no doubt from considering the mineralogy or chemistry that the Dana tuff breccia represents a mechanical mixture of the two fundamental types of rocks in relatively equal proportions.

TABLE XV.—CHEMICAL ANALYSES AND MODES, MASSET BASALTS

	1* (61AB65)	2* (63AB113)	3* (61AB59)	4 Average 1–3	5	6	7 (58AB303)
SiO_2	54.10	48.34	59.12	52.31	53.8	50.83	61.84
TiO_2	1.95	1.77	1.37	1.70	2.0	2.03	1.36
Al_2O_3	16.46	17.27	16.18	16.64	13.9	14.07	15.95
Fe_2O_3	5.03	7.78	2.54	5.12	2.6	2.88	2.21
FeO	5.90	2.61	5.05	4.52	9.3	9.00	5.76
MnO	0.17	0.18	0.11	0.15	0.2	0.18	0.11
CaO	7.48	8.27	6.07	7.24	7.9	10.42	2.39
MgO	4.25	7.06	1.53	4.28	4.1	6.34	1.54
K_2O	0.71	1.04	1.71	1.15	1.5	0.82	1.66
Na_2O	2.06	4.25	4.80	3.70	3.0	2.23	4.56
H_2O-	1.44	1.02	0.49	0.98	} 1.2	} 0.91	0.46
H_2O+	0.15	0.12	0.69	0.32			1.80
CO_2	0.01	0.08	0.06	0.05	....	....	0.05
P_2O_5	0.42	0.37	0.26	0.35	0.4	0.23	0.17
SO_3	0.014	0.010	0.001	0.008	....	....	0.009
Totals	100.144	100.170	99.981	98.518	99.9	99.94	99.869
Fe_2O_3/FeO	0.85	2.98	0.50	1.13	0.28	0.32	....
Na/K	2.9	4.10	2.80	3.22	2.0	2.72	....

MODES OF ANALYSED MASSET BASALTS

	1 (61AB65)		2 (63AB113)		3 (61AB59)	
	Volume (Per Cent)	Composition	Volume (Per Cent)	Composition	Volume (Per Cent)	Composition
Plagioclase	46.23	An_{80-45}	42.50	$An_{68}\pm$	48.47	An_{75-60}
Pyroxene	26.23	Augite	3.59	Augite	19.32	Augite
Iron ore	6.62	Magnetite?	....	....	2.81	Magnetite?
Glassy mesostasis	20.92	....	53.91	Very fine pyroxene, plagioclase, magnetite	29.40	....

1—61AB65, basalt, north shore of Dinan Bay, Masset Inlet (*see* Fig. 17 for localities).
2—63AB113, porphyritic basalt, from core Nadu River No. 1 well at 1,812 feet.
3—61AB59, basaltic andesite, northwest shore of Juskatla Inlet.
4—Average of 1 to 3.
5—Average Yakima basalt, eight analyses (Waters, 1961).
6—Average normal tholeiitic basalt, 137 superior analyses (Nockolds, 1954).
7—58AB303, tuff breccia of mixed clasts, Dana facies, south shore Tanu Island.
*By Analytical and Assay Branch, Department of Mines and Petroleum Resources, Victoria, B.C.; analysts, S. W. Metcalfe and R. S. Young.

Stratigraphy.—The stratigraphy of the Masset Formation has not been studied in detail. Most of the mapping of the Tartu facies was done rapidly by helicopter. Other areas, such as that of the Dana facies, are not readily studied because of a dearth of indications of bedding and because of the discontinuities resulting from major faults and the island nature of the area. Nevertheless the general features of the stratigraphy are readily apparent.

The main area of Masset Formation, embracing most of the area north of Rennell Sound and west of Masset Sound, is underlain by rocks that form the Tartu facies. On the east coast of Graham Island these underlie the Skonun Formation, as is shown by core from Richfield wells and the outcrop area of Lawn Hill. This facies is formed almost entirely by columnar basalt flows, basalt breccias, and sodic rhyolite ash flows. In the area of good exposure from Tartu Inlet up the coast to Otard Bay and across to Masset Inlet, the formation is divided into three distinct members: a basal mixed member, an overlying rhyolite member, and a topmost basalt member. The type section would better be selected after detailed work, but a preliminary choice would be on a line from the entrance of Tartu Inlet to McClinton Bay on Masset Inlet and on to the outlet of Ian Lake. The following table of gross stratigraphy applies to the type section and the whole of the area of good exposure. Structural cross-sections N, M, and O (Fig. 6) show some details of stratigraphic sequence, but the thickness of some of the flow units is exaggerated.

RECONNAISSANCE SECTION, MASSET FORMATION, TARTU FACIES

Unit	Lithology	Approximate Thickness in Feet
	Overlain unconformably by Skonun Formation.	
Basalt member	Columnar basalt flows, minor basaltic and rhyolitic pyroclastic rocks	5,000+
Rhyolite member	Rhyolite ash flow tuffs and minor columnar basalt flows	5,500–7,500
Mixed member	Basalt breccias and columnar flows, rhyolite ash flow tuffs	6,000–6,500
	Unconformably overlying Kano quartz diorite syntectonic batholith, and also Karmutsen, Kunga, Haida, and Honna Formations.	

The mixed member is composed of columnar flows a few tens of feet to perhaps 200 feet thick, basalt breccias a few feet to, more rarely, 300 or 400 feet thick, and rhyolitic ash flows 100 feet or more thick. Perhaps one-third of the mixed member is rhyolitic. The basal unit differs from place to place. Generally in the southwest the basal unit is basaltic, but from Kennecott Point to Beresford Bay is unwelded rhyolitic ash flow. At the entrance to Tartu Inlet the basal unit is a columnar flow and the lowest rhyolite is more than 500 feet above the base. The base near Hippa Island and north Skelu Bay is formed by coarse basalt breccias, but on south Skelu Bay it is formed by columnar basalts. The coarse breccias may be vent opening breccias. The thick rhyolitic ash that forms the basal unit from Kennecott Point to the north seems to be traceable south to Ingraham Bay, where it clearly overlies a good many hundreds of feet of basalt breccias and columnar flows. It is possible that this thick basal rhyolite, which forms the base north of Kennecott Point, actually is the base of the rhyolite member and that the mixed member is absent by overlap or non-deposition. The basal unit at Pillar Bay and outcrops along the north coast are overwhelmingly basalt.

The rhyolite member is composed of very thick units 100 to as much as 400 feet thick. Most are the typical buff and grey fluidal banded aphanitic rhyolite, but some or parts of some are vitrophyre, perlite, or obsidian. Columnar basalt is rare.

The thickness of this unit appears to increase measurably toward Port Louis, and as described above it may form the basal unit on the northwest coast, but not on the north coast.

The basalt member is composed of thin flow units of columnar basalt with some scoriaceous flow tops, rare basalt breccias, and rarer rhyolite ash flows or breccias. The top of the exposed unit may well have been approximately the top of the formation.

Four of six exploratory holes drilled by Richfield *et al.* in the Skonun Formation penetrated the Masset Formation, Tartu facies at depth. Core from these wells is in all respects similar to typical Tartu facies. The uppermost 10 to 20 feet appear weathered, but whether this is subaerial weathering to groundwater was not determined. The Masset well penetrated 1,200 feet of mostly massive basalt with minor basaltic breccia. The Nadu River well penetrated 3,000 feet, three-quarters of which were massive basalt, with the remainder rhyolite, basalt breccia, and a basalt conglomerate. The Gold Creek well penetrated only 60 feet, all of which was rhyolite or rhyolite breccia. The Cape Ball well penetrated 1,880 feet of Masset Formation, of which the upper 900 feet was all massive basalt, but the lower 980 feet contained much basalt breccia and some rhyolite. Figure 20 is a diagram showing the lithology encountered in the wells. The distribution of facies indicated by the wells fits projection of the contacts shown on Figure 17.

The section along the northernmost spur of Mount Russ is designated the type section of the Kootenay facies. The whole section is formed of crudely columnar jointed flows of sodic rhyolite, welded tuff breccia, or ignimbrite of varying thickness and fragment size. Several miles farther south the section is composed primarily of fine spherulitic rhyolites, so that it appears the tuff breccias grade into or interfinger with the former. Some columnar basalts occur, particularly on the fringe of the outcrop area. The Kootenay facies overlies, with varying angular discordance, Karmutsen, Kunga, and Honna Formations but is not overlain by any younger rocks.

The Dana facies is fairly well exposed on the shores of Selwyn, Dana, Logan, Richardson, and Atli Inlets, and is named after the second. It is impossible at present to suggest a meaningful type section. All inlets present similar aspects of outcrops of massive mixed clast breccias cut by dykes of finely banded rhyolite and purplish-grey feldspar porphyry and with intercalated flows or sills of the same rocks. The graded beds of breccia are too rare to do more than just indicate pervasive gentle dips (20 degrees, more or less). The minimum stratigraphic thickness of such rocks necessary to explain the distribution is 5,000 feet. No superincumbent rocks are known.

The outcrop areas from Slatechuck Mountain to Gudal Bay are composed of rocks having some similarities to all facies, but dacites are more common than elsewhere. Whole areas, such as near Tana Bay, are composed of aphanitic rhyolites and fine blocky rhyolite breccias, whereas near Slatechuck Mountain basalt and basalt breccias with some dacites or andesites form the bulk of the succession with some acidic breccias near the top. South of Lagins Creek, basalt and light-green porphyritic dacite are dominant, with overlying breccia of mixed clasts in which rhyolite is most abundant.

Origin.—The Masset Formation, with the exception of the Dana facies, was erupted subaerially. This is substantially shown by the ubiquitous columnar jointing in the basalt flows, by the welding of rhyolite ash flows and Kootenay tuff breccias, and by the lack of pillow lavas and intercalated sedimentary rocks.

The evidence that the rhyolites originated as ash flows is based on a few specimens in which welded vitroclastic structures can be recognized (*see* Plate XIIIA) because commonly spherulitic devitrification has proceeded to a point where such structures are not evident. Additional evidence is provided by the chemically similar welded columnar jointed tuff breccias of the Kootenay facies. Finally, thick but continuous tabular deposits of acid flow rocks are now generally thought to have such an origin.

The Dana facies, composed of unsorted breccias of mixed clasts with intercalated graded beds of similar material, greatly resembles the Ohanapecosh Formation of Washington, interpreted by Fiske (1963, pp. 391–405) as formed by subaqueous pyroclastic flows. In particular the unsorted nature and the restricted area of outcrop fit the Fiske and Matsuda (1964, p. 104) postulate for eruption into shallow water. They may have originated largely by subaqueous slumps.

The mode of origin of the basalt breccias is probably multiple, but most seem to be truly pyroclastic, for they are formed of semi-angular fragments of differing crystallinity and vesicularity and of wide distribution. One such pyroclastic basalt unit near the base of the Tartu facies at the entrance to Seal Inlet was not far removed by erosion from a dyke of similar composition, which suggests some erupted as pyroclastic flows. Some of the thick units at the base may have been vent opening breccias. Other breccias composed of homogeneous fragments are flow breccias and collapse breccias and are fairly uncommon.

Not enough evidence was gathered of distribution, form, and other relationships of the lapilli-sized blocky rhyolites to suggest a mode of origin.

Vents for the eruption of the Masset Formation take a number of forms as dykes and plugs. Probably most of the columnar basalts and many or most of the rhyolite ash flows were erupted via long lineal vents, now dykes. Large dykes of basalt and, to a lesser extent, of rhyolite are a common feature of the areas underlain by older rocks fringing the Masset Formation. Several dyke-like connections to flows were noticed, with good fans of columns changing in orientation from subhorizontal in the feeder to sub-vertical in the flow. The best examples are in basalt at the east entrance to Tartu Inlet on Skaga Island of the Tar Islands, and in rhyolites at Ells Point. A dyke connection to a perlitic rhyolite flow containing cognate rounded blocks occurs on the ridge north of Skelu Bay. A coarse basalt breccia of unknown plan but with steep walls occurs at Lawn Point and is most likely a vent throat, possibly a rootless one. A body of coarse breccia of cognate rhyolitic clasts and very coarse accidental blocks occurs south of Bottle Point in the Kootenay facies and may well represent a filled vent.

Many porphyry bodies of various plans are associated with the Masset Formation. Biotitic feldspar porphyry bodies at Cape Knox, Yakoun Lake, Lyell Island, and possibly Lomgon Bay are of this sort. The Lyell Island body is large and complex, for it appears to consist of porphyry cut by a sequence of abundant large dykes of almost identical composition. Coarse diabase to gabbro bodies occur east of Barrier Bay on Tasu Sound, near Moresby Lake, and on Ramsay Island. Some of the dyke-like bodies grade laterally to basalt. Both the porphyry and gabbro bodies are thought to represent consolidated vents or upper magma chambers related to Masset flows.

The origin of the basaltic and rhyolitic lavas is considered briefly in the section on petrogenesis (p. 161). It is concluded the basalts may be upper mantle material slightly modified by contamination and differentiation. The origin of the rhyolites is more of a problem. They may be early melting material remobilized from the syntectonic quartz diorites or from deeply buried Palæozoic plutons. The minor amount of dacite and andesite is probably mixed lavas or hybrids.

Age and Correlation.—The age of the Masset Formation is not well defined for a number of reasons. It is largely a subareal volcanic formation with almost no intercalations of marine sedimentary rocks and none of fossiliferous nature. Silicified and charred wood fragments are relatively common within the acidic ash flows, but none of any diagnostic value was collected. None of the flow rocks is biotitic, and all are generally low potassium rocks. One specimen was collected from a tabular biotitic feldspar porphyry body, presumably a sill, near the base of the formation. This locality is shown on the geological maps and distribution map, Figure 17. The specimen was submitted to Dr. W. H. Mathews, and the analysis was performed at the University of Alberta. The age is 62 ± 3 million years B.P. or Paleocene (Mathews, 1964, pp. 465–468). This is a minimum age for the start of volcanism. Eruption of Masset flows may have continued for some while, possibly into the Middle Eocene, which Mathews (1964) shows was a time of extensive volcanism in British Columbia. Certainly extensive faulting, tilting, and erosion occurred prior to the deposition of the Skonun Formation in the Mio-Pliocene.

Correlations must await better dating of the Masset Formation and its possible correlatives. The Eocene Metchosin pillow basalts of southern Vancouver Island are a likely correlative in part, as are some units of northern Washington, such as the Chuckanut Group and Early Tertiary continental sandstones and overlying andesitic basalts of the Admiralty Trough of southeast Alaska (Brew, Loney, and Muffler, 1964; Lathram *et al.*, 1965).

Correlation within the Queen Charlotte Islands of all the isolated localities assigned to the Masset Formation is based on similar stratigraphic relationships, generally overlying proven Cretaceous rocks, and on similar lithology, mineralogy, and chemical compositions.

Skonun Formation

The Skonun Formation is composed of marine and non-marine sands, sandstone, shale, lignite stringers, and conglomerate of Late Tertiary (Mio-Pliocene) age. It overlies Masset Formation with unconformity where it laps onto this formation. It is intruded by the Tow Hill sills and overlain unconformably to conformably by thick to thin Pleistocene drift and outwash. The Skonun rocks are in general friable and do not outcrop well, so that exposures are limited, as shown on Figure 18. Exploratory wells by Richfield *et al.*, however, confirm the earlier belief that a large area of eastern Graham Island is underlain by this unit. The thickest sections revealed in the wells are: Cape Ball No. 1, 6,000 feet, and Tow Hill No. 1, 6,000 feet, still in the formation. Although the precise age of the complete formation has not been determined, pollen found at 3,470 feet in the Tlell well is essentially identical to that from outcrops. In general, opinion based on invertebrates and pollen suggests that rocks of both Miocene and Pliocene age are included.

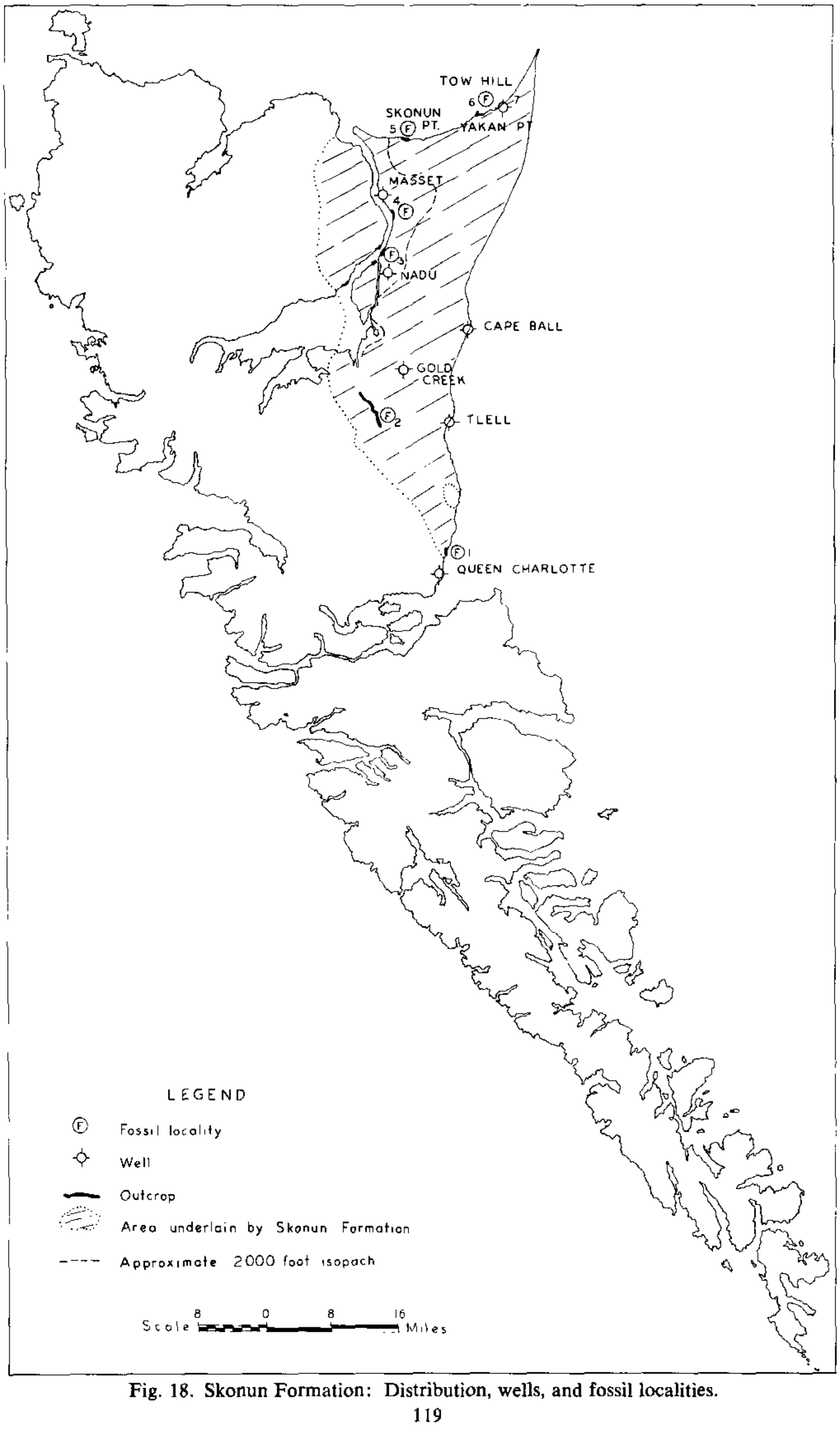


Fig. 18. Skonun Formation: Distribution, wells, and fossil localities.

The Skonun Formation was named by MacKenzie (1916, pp. 73–76) after the exposure at Skonun Point, and believed by him to underlie the Masset Formation. The Skonun was discussed by Dawson under the heading " Tertiary Rocks " with the volcanic rocks that are now called the Masset Formation. He made many observations on the sedimentary rocks and collected an extensive fauna at Skonun Point (1889, pp. 85B–87B). Richfield Oil Corporation has studied the unit in some detail (Cox, 1959) and drilled six exploratory wells. More recently Shell Canada has been investigating this unit.

Lithology.—The Skonun Formation is composed of sands to sandstone, siltstone, and shale with less conglomerate, lignite, and marl. Seventy to eighty per cent of the formation is composed of arenaceous deposits, and these characteristically are clean, friable, poorly lithified rocks. The most common colour is light grey speckled by fairly abundant hornblende and biotite. Light olive-grey sandstones are also common. Biotite increases markedly in some beds, and laminæ and the rocks then become much darker, more foliated, and fissile. Quartz is the dominant mineral in all these rocks; feldspar commonly forms about 30 per cent; biotite and hornblende commonly form 10 to 15 per cent but may form up to 50 per cent in certain laminæ; and rock fragments commonly form 10 to 20 per cent. Most grains are subangular. Shelly and pebbly sandstones are characteristic of the type locality (*see* Plates XA and XB) and are present in some degree at most localities.

Bedding type varies widely, with massive poorly defined bedding being commonest, but well-defined thick and thin beds, laminated sandstone, and intercalated sandstone and shale beds are all common. Certain laminæ and some well-defined bedding planes are normally well plastered with biotite, carbonaceous debris, or both. Cross-bedding is also common and variable from festoon to simple type. In addition, slump and truncated slump structures are prominently shown in core of the Tow Hill well.

Shales and siltstones form a lesser part of the formation. True shales are virtually absent, all are silty. Most are fairly compact, but some at shallow depth are claystone or even clay. Light- to middle-grey slightly fissile silty micaceous shales are the commonest variety. Most carry some carbonaceous matter and the percentage may increase, to a degree where the rock is a carbonaceous shale to lignite. Quite commonly carbonaceous matter is concentrated on bedding planes giving a laminated shale. Some shales are slightly to moderately calcareous or marly and a few are slightly bentonitic.

Conglomerate is rare, except in the lower part of the Tow Hill well, where it is completely dominant. Elsewhere some pebbly sandstones and granule conglomerates are not uncommon, but true conglomerates are relatively rare. In the uppermost part of all wells, stony clays and tills of Pleistocene age occur. The conglomerates of the Tow Hill well are dominantly composed of slightly chloritized basalt fragments, but pink and grey granitic rocks and shale are common, and rhyolites, porphyries, and metamorphic rocks occur. The matrix is light-grey to olive-grey quartzose, biotitic sandstone. Cobbles and cobble conglomerates are rare; pebbles of 1 to 2 inches in diameter are commonly the largest fragments. Rounding is poor to fair at best and discoid shapes common.

Carbonaceous deposits are common and vary from a tough fibrous or woody lignite, such as in the outcrop stringers at Skonun Point, to black shiny coal with conchoidal fracture, such as occurs in the Tlell and Gold Creek wells at a depth of about 3,000 feet.

Microscopy.—The rocks examined microscopically are not entirely representative because they are all fairly well lithified by calcareous cement in contrast to the normal friable sands. Otherwise the compositions of sands and sandstone seem similar.

The Skonun sandstones are composed mostly of angular sand with some rounded or subrounded clasts. They vary greatly in compactness; most have an abundant calcareous matrix and some calcite clasts or recognizable shell fragments. Table XVI shows the mineral compositions. Quartz exceeds feldspar, which in turn normally exceeds rock fragments. Most of the feldspar is andesine, but some is potash feldspar. Rock fragments are dominated by Masset-like rhyolite, basalt, and Cape Knox type porphyry, but granitic fragments of many types are common. Metamorphic rocks, quartz-muscovite schists, and micaceous quartzites form a small but consistent component. Mica, mostly biotite, forms an important minor mineral and in some laminæ forms 50 per cent of the rock. Heavy minerals are also important, particularly in the micaceous laminæ. A wide range is present dominated by hornblende but including clinozoisite, epidote, sphene, garnet, tourmaline, apatite, and zircon.

The siltstones are similar to the sandstones, except that they contain much less feldspar and much more mica in a generally calcareous and not rarely carbonaceous matrix.

In summary the Skonun Formation continues the trend set in the arenites of the Queen Charlotte Islands of becoming successively more quartzose and less lithic with succeeding units (*see* Fig. 16 and p. 163).

TABLE XVI.—MINERAL COMPOSITION, SKONUN FORMATION

	Nadu River Well, 1,405 Ft.	Skonun Point	Tow Hill Well				Average
			614 Ft.	1,475 Ft.	2,545 Ft.	3,625 Ft.	
	110	119	121	125	130	134	
Mineral grains—							
Quartz	35	45	30	35	25	25	32.5
Plagioclase } Potash feldspar	15	18	20	25	10	20	19.2
Potash feldspar		2				5	
Calcite	20	Tr.	10	2	....	2	5.7
Mica	2	2	20	5	5	8	7.0
Opaques	Tr.	Tr.	Tr.	1	2	Tr.	3.5
Heavy minerals	5	3	5	2	3	Tr.	
Rock fragments	3	5	5	15	15	35	13.0
Matrix	20	25	10	5	40	5	19.1

Stratigraphy.—The Skonun Formation is named after Skonun (originally Chown) Point, where it outcrops more boldly and displays a greater thickness than at any other natural exposure. However, it leaves much to be desired for a type section, especially when compared to the subsurface sections of the wells. It is these rather than the Skonun Point exposure that should form the standard.

At Skonun Point the exposure can only be viewed adequately at very low tide, and even then outcrop is scattered sparsely over 4,000 feet of beach. The outcrops form part of an east-west anticline that plunges gently to the west and is slightly arcuate in plan, concave to the north. Dips on the north limb are uniformly about 20 degrees north and on the south range from about 50 degrees south near the axis to about 25 degrees 500 feet farther south. To reconcile the differing stratigraphy of either flank, a fault is necessary and must roughly parallel the axis and drop the north side.

The largest outcrop, at the point itself on the north flank of the fold, exposes about 75 feet of compact, light-grey, buff-weathering, shelly, calcareous sandstone with rare pebbles and very rare cobbles in beds mostly 6 inches to 2 feet thick. Some beds contain planar cross-strata with foresets all dipping more steeply to the north than the main bedding planes. On strike and about 400 feet west, similar sandstone is irregularly cut and filled by and intercalated with pebble conglomerate that contains some cobbles. Masset basalt, hornblende diorite, and Skonun sandstone are all prominent in the clasts. About 1,000 feet east of the Point on the intertidal beach, about 50 feet of sandstone is exposed, which appears to underlie the shelly sandstone of the Point by about 75 feet. South and east of the 50 feet of sandstone and wrapping partially around the plunging nose is a sequence of interbedded lignite and silty shale some 230 feet thick. These are overlain by 90 feet composed of thick beds of calcareous sandstone with some carbonaceous laminæ separated by intervals of no exposure which are probably underlain by shales or non-calcareous sandstone. The tough fibrous lignite weathers in relief and is well exposed, but the intercalated shales are scarcely exposed at all. MacKenzie (1916, p. 179) quotes a fragmentary report of a diamond-drill hole in which 13 beds of lignite separated by clay are described. Currently nine lignite beds are exposed, of which the thickest is 3 feet (6 feet in the drill hole) and the aggregate about 20 feet. The sandstones of the southernmost exposure are similar to those of the north limb east of the Point. If they are correlative, then fault movement not less than 200 feet is indicated, and the total section at Skonun Point is about 470 feet thick, of which the upper 75 feet are definitely marine deposits of shallow water to shoreline nature, and the lower 230 feet are definitely non-marine. Hence, although the type locality is inadequate in most ways, it is in fact moderately representative.

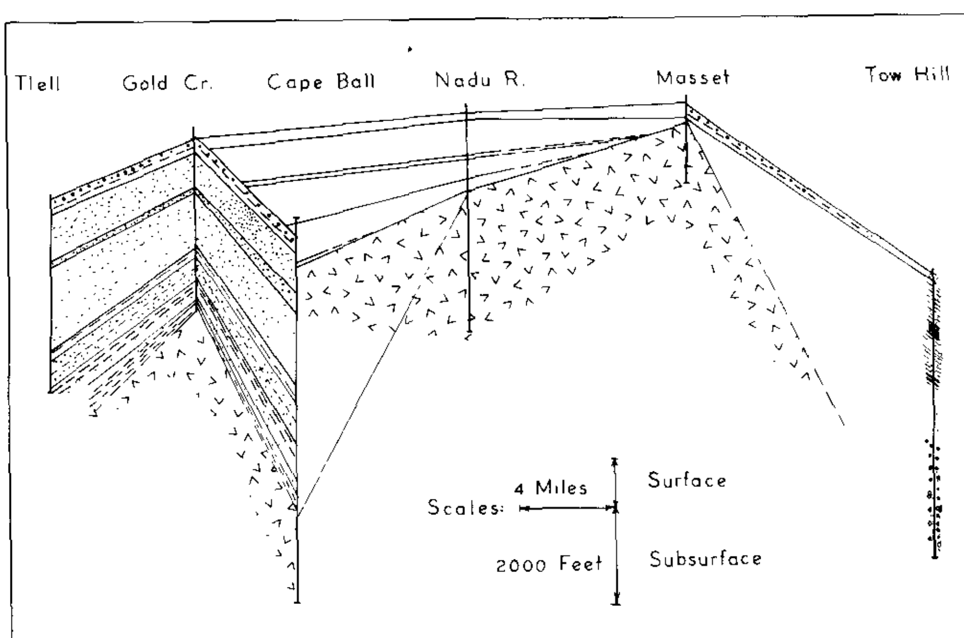


Fig. 19. Fence diagram, Skonun Formation.

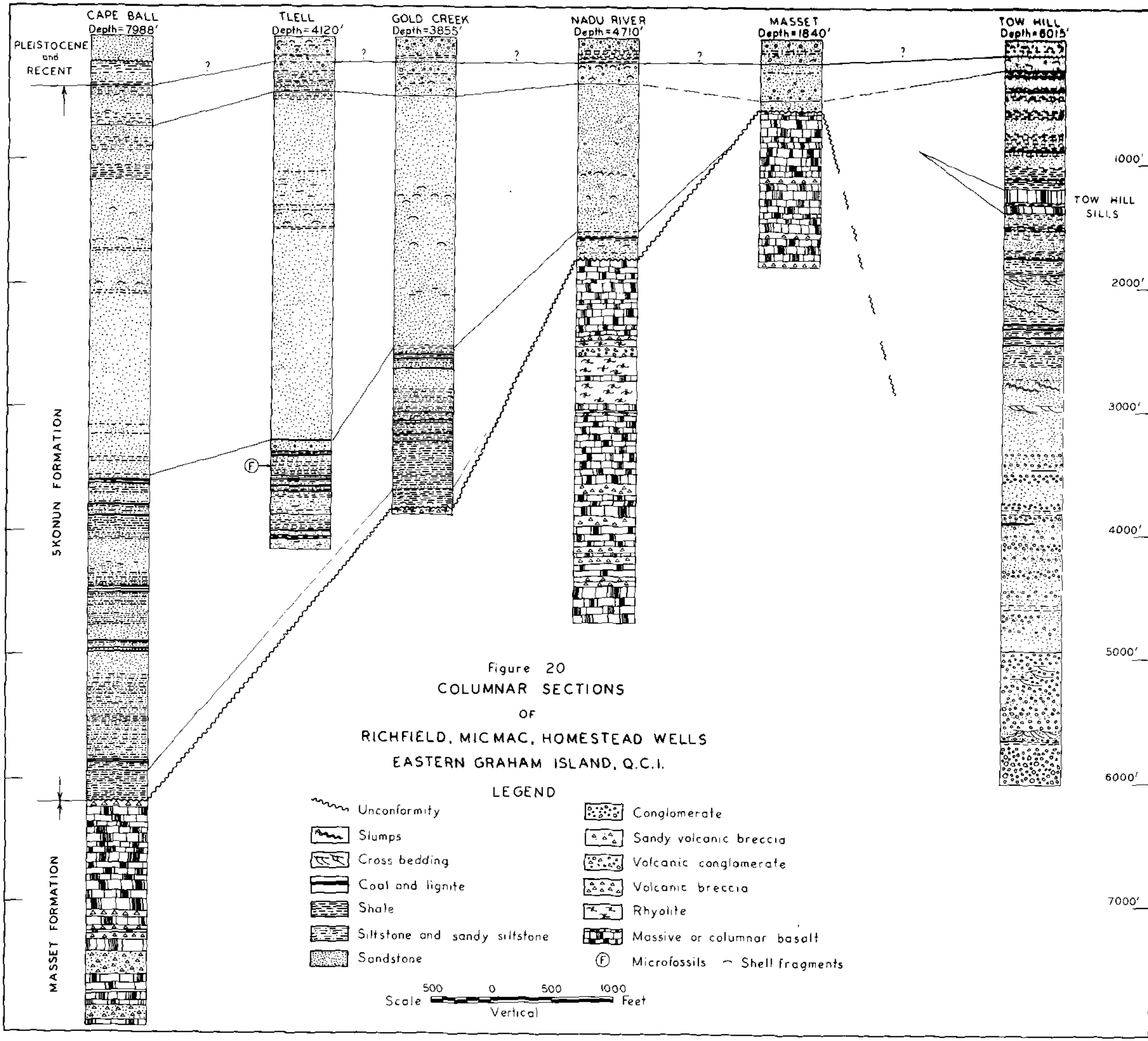


Figure 20
COLUMNAR SECTIONS
OF
RICHFIELD, MICMAC, HOMESTEAD WELLS
EASTERN GRAHAM ISLAND, Q.C.I.

Other surface exposures are scattered from the mouth of Chinukundl (Miller) Creek, along the lower Yakoun River, along Masset Sound from Collison Point to the Watun Creek, at Yakan Point, and at Tow Hill. None contains as thick a section as at Skonun Point. The first three localities are primarily poorly lithified sands with minor shale or clay and some pebbly or shelly sandstones. At Chinukundl Creek several stringers up to a foot thick of woody lignite are exposed and coarse planar cross-bed sets of coarse sands with foreset beds dipping about 20 degrees east and top sets less than 10 degrees in various orientations. Along the Yakoun River some diatomaceous clays up to 12 inches thick occur interbedded with the festoon cross-bedded sands, which indicate a general current orientation to the north-northwest. The exposures at low tide along Masset Sound yield fossils that may be Late Pliocene or Early Pleistocene, and these sandstones grade upward into pebbly claystones that may be glacial marine drift. There is some doubt about the precise relation to the Skonun Formation. At Yakan Point light-grey calcareous sandstone in coarse planar cross-bedded sets with some marine shells and pebbles overlie fine olive sandstone and claystone with carbonaceous debris and leaves on bedding planes. Under the main sill at Tow Hill, slightly baked claystone and silty shale occur.

The stratigraphy of the Skonun Formation is best shown by the wells. The columnar sections (Fig. 20) were prepared from examination of core and cuttings and logs prepared by Richfield Oil Corporation and Shell Canada Limited. Figure 19 is a fence diagram based on the same data and shows the salient features.

The sections of the Tlell, Gold Creek, Nadu River, and Cape Ball wells are very similar and rather unlike that of the Tow Hill well. Only a few hundred feet of Skonun occur in the Masset well. In all wells the precise definition of the boundary between Skonun Formation and Pleistocene deposits is problematic and those indicated are tentative. The base of the Skonun is reached in all but the Tlell and Tow Hill wells and is everywhere weathered Masset Formation basalt, basalt breccia, or rhyolite. The four southern wells have the following characteristics in common:—

SKONUN SECTIONS IN DRILLED WELLS

	Nadu River	Gold Creek	Tlell	Cape Ball
	Thickness in Feet			
Pleistocene and Recent till, stony clay, outwash sands, and some shelly equivalents	200	200	190	400?
Pliocene marine shelly sands and interbedded sands and shale	160	270	260	320
A thick section of sands, some calcareous sandstone and very minor shale; included are some shelly sands of marine origin but much may be non-marine; the shelly sands seem correlatable as is a zone with prominent garnet	1,205	2,030	2,800	2,830
A thick non-marine or mainly non-marine section of interbedded sand (and sandstone), shale, and lignite with some marly shales	225	1,160	870+	2,380
A marine(?) shale and interbedded sandstone and shale	Masset	150		240
		Masset		Masset

At the Masset well there is 550 feet of unconsolidated sands, pebbly sands, and some silty clay, of which probably about the upper 200 feet is till, marine drift, etc., and the correlation of the remainder unsure. The section at the Tow Hill well is as follows:—

SKONUN SECTION IN TOW HILL WELL

	Thickness in Feet	Cumulative Thickness
Pleistocene and Recent till, marine drift, and sand	70	70
Pliocene marine pebbly sands	165	235
Interbedded sands and alternating sands or siltstone and shale or claystone with some lignite, interrupted at 1,200 to 1,380 feet by Tow Hill basalt sill with minor sills above and below and baking of adjacent shales; sands become compact calcareous sandstone by 2,080 feet; prominent cross-bedding and truncated slump structures from 1,900 feet	2,400	2,635
Calcareous sandstone and some pebbly sandstone with some interbeds of siltstone or shale; prominent slump structures; cross-beds	695	3,330
Interbedded pebbly conglomerate and calcareous sandstone with pebbly sandstone and some cobble conglomerate and siltstone; fair amount of carbonaceous debris and some minor coal beds; conglomerates not well sorted nor are the pebbles well rounded	2,715	6,015 Total depth

It is apparent from Figures 19 and 20 (columns and fence diagram) that the members evident in the southern wells thin and overlap toward the north and east, and that there was a subsurface ridge of Masset Formation separating the southern from the northern part of the basin. The rocks in both basins are generally similar, except for the abundance of conglomerates in the northern one, and they are of similar age, but they clearly are not correlatable as members, etc.

Origin.—The Skonun Formation accumulated during the Late Tertiary in a fairly large basin subjected, at least on its margin, to alternating marine and non-marine conditions. The formation underlies all northeastern Graham Island, probably much or most of Hecate Strait, and possibly a significant part of Dixon Entrance (*see* Shor, 1962, which could be interpreted to indicate the latter). The formation is part of Late Tertiary onlap of marine sediments on the western continental margin but differs from most in being separated from the Pacific Ocean by an island barrier and sediment source and by a larger percentage of non-marine rocks.

The part of the basin underlying the Queen Charlotte Islands is separated into two sub-basins by a ridge extending eastward from the vicinity of the Masset well. The facies and tectonics evident on either side of the ridge differ. In the southern part, sediments accumulated under a fairly stable regimen and now have gentle basinward dips increasing with depth, which probably result largely from compaction. In the northern part the tectonic regimen was more active. In the Tow Hill well, dips are steeper, about 25 degrees, partly from subsequent fault and fold deformation but also from high initial dips indicated by truncated slump structures.

Much of the detritus can or must have been derived from the Queen Charlotte Islands, but some is unlikely to have been. The coarse clasts are dominated by Masset-like basalt, rhyolite, and porphyry, and they are unlikely to have had any other source. The siltstone and shale sharpstones that are found have an intraformational source. Granitic rocks—hornblende diorite, quartz diorite, and pink granite—are all common, and all but the pink granite could have been derived from the islands. The metamorphic rocks that occur in small amount, however, are unknown in the Queen Charlotte Islands and must have originated from the mainland or southeastern Alaska. In contrast to earlier sedimentary units, the sand-sized material is dominated by quartz with feldspar, rock fragments, and lesser biotite and hornblende. The particles are generally angular so relatively unworked. Excessive quantities of quartz and biotite could not be derived from the Masset Formation, but although they could have been derived from adjacent exposed areas of older rocks in the islands, they likely came from a mainland or Alaskan source, as did the metamorphic component.

The environment of deposition alternated between marine and non-marine. In general, Skonun time was an interval of pulsing onlap. Units thicken and successively overlap onto the basin margin. There is a possibility that some of the thickening of marine units in the eastern wells may result from interfingering facies change basinward. The last deposition was a marine onlap in the Late(?) Pliocene, which extended over a wide platform previously exposed or but thinly covered. Nevertheless, the percentage of the formation that is definitely marine is considerably less than either that which is definitely non-marine or that which is not definitely known. The marine environment is all shallow water, near shore, and the non-marine is all near sea-level and may include swamp, lagoon, lacustrine, and delta. Martin and Rouse (1966), considering the palæoecology of pollen from the Skonun Formation, concluded as follows:—

" The topography probably was similar to that of today: low, relatively flat, close to the sea, swampy, or marshy. This is supported by the occurrence of gently dipping and interbedded marine and non-marine beds, together with interbedded lignite stringers. Swampy or marshy conditions probably prevailed over at least part of the area, as indicated by the presence of particular species. For example, *Taxodium*, the swamp cypress, and its Asiatic equivalent, *Glyptostrobus*, are well represented in Millar Creek lignites; and both *Myrica* (cf. *Myrica gale*) and *Carpinus* (cf. *Carpinus caroliniana*), which normally inhabit swampy areas and stream borders in extant floras, are present in the Skonun Point lignites. Dinoflagellates occurring in the Skonun Point shales, Tow Hill No. 2, and Yakan Point shales indicate a brackish water environment at the time of deposition. The beds of lignite are mostly allochthonous, approximately 30 cm thick, and are interbedded with coarse marine and fine marine and brackish water deposits that are often thin-bedded. This suggests an oscillating shoreline which at intervals flooded coastal swamps or marshes. Swamp and drier-habitat species are always found mixed together in the same deposits. This suggests that the swamp or peat areas were flanked by flat forest lands, with streams draining from inland areas into the swamps, probably much as at present in the region immediately back from the coast on northeastern Graham Island.

" Not far inland from the coastal swamps or marshes, where drainage was adequate, the forest likely consisted predominantly of *Quercus* spp. and *Alnus* spp., together with many other anthophytes. Although conifer pollen grains are present, they never occur in numbers comparable to those of anthophytes. This contrasts markedly with the extant forest of the Queen Charlottes, where conifers are the main tree elements of the forest, and anthophyte trees are few in both numbers of species and individuals. In general the Skonun flora appears to represent three phases of coastal community: (1) a true forest-swamp type similar to that now found on the Gulf Coast in Louisiana (*see* Penfound and Hathaway 1938), with Taxodiacae, *Alnus, Quercus,* Polypodiaceae-Dennstaedtiaceae; exemplified by the assemblage in the Millar Creek lignites (Table II); (2) an Everglades or more open water type, characterized by three anemophilous genera (*Quercus, Alnus, Pinus*) and spores of Polypodiaceae-Dennstaedtiaceae, exemplified in the Millar Creek and Collison Point shales; and (3) a more coastal, brackish water environment, with *Alnus, Corylus, Betula,* and *Pinus,* and containing dinoflagellates. This type is exemplified in shales from Skonun Pt., Yakan Pt., and Tow Hill.

" The climatic conditions appear to have been relatively humid, and probably somewhat more temperate than those of the region today. The mean annual temperature was likely higher than that of today, with virtually no frost during the year. This conclusion is suggested by the presence of plants such as *Sequoia, Taxodium, Metasequoia, Glyptostrobus,* and a significant population of ferns, all of which thrive in moderately warm and moist climatic conditions."

In summary, it appears that a moderately rapidly sinking basin, possibly fault controlled at its eastern and northern margins, was filled to capacity with detritus from the proto-Queen Charlotte Islands and probably the mainland. Alternating marine and non-marine conditions resulted from either interrupted connection of the estuarine-like basin with the sea or irregular sinking of the basin or uplift of the source areas.

Age and Correlation.—The Skonun Formation includes rocks fairly definitely of Miocene and Pliocene age. More precise dating must await further work both on the Skonun and elsewhere on north Pacific Coast Late Tertiary rocks.

The writer's collections are fairly sparse but are amplified by collections of many others. The following fauna was identified by F. J. E. Wagner, of the Geological Survey of Canada, and the plant microfossil assemblages by H. A. Martin and G. E. Rouse, of the University of British Columbia (Martin and Rouse, 1966).

FOSSIL LOCALITIES, SKONUN FORMATION

Map No.	Locality	G.S.C. No.	Field No.	Fossils
3	Masset Sound	48567	61AB253	*Laqueus vancouveriensis* (Davidson); *?Neptunea* sp.
4	Watun Creek	48562	61AB252	*Hemithyris psittacea* (Gmelin); *?Hiatella arctica* (Linné); unidentified Pelecypoda; unidentified Echinoidea.
		44746	60AB331	
5	Skonun Point	44745	60AB332	*?Cardium* sp.; *?Serripes* sp., *Chione securis* (Shumard); *Tagelus* sp.
6	Yakan Point	....	60AB333	Leaves: *Pterocarya* sp. cf. *oregoniana* Chaney; *Alnus* sp.; *Juglans* sp. Spores: *Reticuloidosporites* spp.; *Lævigatosporites ovatus* Wilson and Webster; *Deltoidospora diaphana* Wilson and Webster. Pollen: *Alnus* sp.; *Corylus* sp.; *Carpinus* sp.; *Pterocarya* sp.; *Betula* sp.; *Salix* sp.; *Rhamnus* sp.; *Ilex* sp.; *Tsuga* sp.; *Picea* spp.; *Pinus* sp.

Miss Martin and Dr. Rouse comment regarding the flora as follows: "The microflora is generally similar to that obtained from the Sooke Formation on the west coast of Vancouver Island, which is most probably early Miocene. The abundance of *Pterocarya* sp. cf. *oregoniana* strongly suggests a late Miocene or early Pliocene age, and this range of age is all that can be confidently offered from the evidence available." Their results have been published (Martin and Rouse, 1966) with no other suggestions regarding age of the Skonun Formation.

Dr. Wagner suggests a Miocene age for the sparse fauna. Localities 3 and 4, however, may not actually belong to the Skonun Formation but may be part of a Pleistocene unit. Locality 4 is described by Dawson (1880, p. 86B) under glacial deposits. However, at both 3 and 4 the fossiliferous sands are overlain by pebbly sands and gravel, sands and compact siltstones totalling from 50 to 100 feet before a bona fide till occurs. The following comment regarding megafossils collected by Shell Canada at locality 3 was received from S. Davidson: "These megafossils consist of a boreal fauna with some North Atlantic and Arctic forms which indicate that this sample was deposited some time after the Bering Strait connection of the North Pacific Ocean with the Arctic Ocean was established in the latest Pliocene or earliest Pleistocene. Age Pleistocene (probably early Pleistocene)."

An extensive collection from Skonun Point by Dawson (1880, p. 87B) was identified by Whiteaves with comments on state of preservation and range of species. A Pliocene or Miocene age was inferred.

Collections by Richfield Oil Corporation indicate a probable Pliocene age for the Skonun Point fauna. The uppermost marine member of the Skonun Formation was called the Cape Ball Formation and regarded from marine microfossils as probably Late Pliocene.

Obviously correlation of the Skonun Formation cannot be made precisely at present. Its tectonic equivalent units on Vancouver Island, the Carmanah and Sooke Formations, range from Late Oligocene to Early Miocene so are probably mostly older. In the vicinity of Lituya Bay, southeastern Alaska, some 12,000 feet of rocks very similar to the Skonun Formation range from Late Miocene to Pliocene in age.

Tow Hill Sills

The Tow Hill sills are composed of olivine basalt. They are, as far as known, volumetrically insignificant compared with earlier volcanic units. They occur as outcrop only at Tow Hill and subsurface only in the Tow Hill well. In the past they have generally been correlated with basalt flows of the Masset Formation, from which some confusion regarding the relative ages of units has arisen. At low tide below the main basalt body, silty shale and sandstone of the Skonun Formation can be seen to be intruded and baked by small sills of related lithology. Core from the Tow Hill well shows shales above and below the main basalt are also baked, so that there is no longer any doubt about the intrusive and sill-like nature of these basalts. The form of Tow Hill suggests it was shaped by glacial erosion. Hence these sills were emplaced after the main part of the Skonun Formation was deposited and prior to the end of glaciation, most likely in the Late Pliocene or Earliest Pleistocene.

The main sill at Tow Hill is some 350 feet thick and in the well the aggregate thickness is over 200 feet.

Lithology.—The Tow Hill sills are composed of olivine basalt that, weathered or fresh, is a dark shade of brownish grey. The grain size varies from that of an aphanitic porphyry in the chill zone or in minor sills to a medium-grained diabase in the interior of the main sill. Columnar jointing is marked generally with pentagonal columns about 4 feet in diameter extending from near sea-level continuously for 250 feet to the top of the cliff face. In addition, a very marked lamination that is normal to the columns weathers in relief in the tidal and splash zone. The resulting differentially weathering bands are continuous over 50 feet or more and are about 6 inches apart. They do not appear to result from mineral concentrations but may reflect minor differences in deuteric alteration related to a cross-joint set.

Microscopy.—The chilled basalt of minor sills is an aphanitic glomeroporphyry with randomly oriented groups of phenocrysts of plagioclase and olivine forming 10 to 20 per cent of the rock. The fresh bytownite-labradorite laths average about 1 millimetre long. The olivine is altered to a rim of chlorite with a core completely replaced by calcite, but the crystal shapes show the grains but little resorbed. The matrix is formed of plagioclase microlites with small chloritized olivine and iron-ore grains in a chloritic matrix in which incipient crystals of pyroxene can be identified.

The coarser specimens from outcrop and well core are good ophitic textured diabase composed of fresh zoned plagioclase and augite with fresh to highly altered magnesian olivine and minor vugs or interstices filled with chlorite and in some cases chalcedony. The modes estimated visually for three specimens are as follows:—

	Volume (Per Cent)	Composition
Plagioclase	42.5	An_{88-65}
Pyroxene	17	Augite
Olivine	11	Magnesian
Chlorite, etc.	24	
Iron ores	4	Magnetite?
Chalcedony	1.5	

Age, Correlation, and Origin.—The age as previously stated is most likely Late Pliocene to Early Pleistocene. Scattered along the Pacific Coast from Sitka to the Goose Islands north of Vancouver Island are a small number of Pleistocene to Recent volcanic structures. Those east of Hecate Strait centred about Milbanke and Laredo Sounds are predominantly soda-rich riebeckite-bearing basalts. It is possible that Tow Hill olivine basalts are crudely correlative with the ones east of Hecate Strait.

The general difference from the Masset basalts should be noted, particularly the much larger olivine content of the Tow Hill sills and the lack of the characteristic trachytic texture of plagioclase of the Masset basalts. Any doubts about the affiliation of the basalts of Lawn Point can be settled by these points alone for the latter are olivine poor and trachytic textured.

PLUTONIC AND METAMORPHIC ROCKS

Plutonic and metamorphic rocks underlie a significant part of the Queen Charlotte Islands, but in comparison to the area underlain by stratified volcanic and sedimentary rocks it is minor. About one-eighth of the islands (480± square miles) is underlain by plutonic rocks and much less by metamorphic rocks.

The plutonic bodies are of two general types—syntectonic and post-tectonic. These differ significantly in most of their features, but both are abnormally sodic in comparison with normal calc-alkaline rocks. Within the group designated as post-tectonic there may be some that more properly should be called late-tectonic, but these are not readily distinguished.

Contrasts between syntectonic and post-tectonic plutons occur in almost all aspects, including the appearance, fabric, and composition of individual specimens; bulk composition and range; amount and nature of inclusions; nature of contacts; type and width of metamorphic aureole. Syntectonic plutons are composed almost entirely of medium- to coarse-grained foliated hornblende diorite to quartz diorite containing oriented planar inclusions (*see* Plate XIB). The bodies may be large and are mostly elongated northwestward in a partly concordant manner. Border zones may be migmatitic and nearly everywhere contain abundant oriented inclusions. The border rocks are in most places Karmutsen basalts that have been dynamothermally metamorphosed to fine black amphibolites for a width of about a mile adjacent to steeply dipping contacts. In contrast post-tectonic plutons have a greater range of composition covering the complete spectrum of normal types from diorite to granite but on the average more acidic, and in particular mafic poor and alkali feldspar rich in contrast to quartzose syntectonic rocks (compare Figs. 22 and 23). Most post-tectonic bodies are composed of fine-grained equigranular rocks, but some are porphyritic and a few coarse grained. Miarolitic cavities are common in some bodies. Inclusions are relatively few and are commonly angular and may be recognizable as to origin. The average size of post-tectonic plutons is smaller and the shape more varied in plan and section. Migmatites and foliation are absent. Border rocks, which are more varied in original type, have been thermally metamorphosed in aureoles a few hundred to thousands of feet wide adjacent to steep contacts. However, some broad areas of hornfels have resulted from the interplay of topography with pluton shape, in which case plutonic rocks occur in the deeper valleys or at shallow depth. Photographs of hand specimens of syntectonic and post-tectonic types showing the characteristic textures form Plates XIVB and XV A and B.

From these briefly described characteristics it can be seen that the syntectonic bodies are mesozonal, whereas the post-tectonic are epizonal (Buddington, 1959, pp. 676–680, 695–697). It is also apparent from the descriptions to follow that the syntectonic bodies were emplaced during a period of stress and a time at least roughly coincident with major deformation, whereas the post-tectonic intrusions, where dated, are younger than all significant deformation.

Syntectonic Plutons

The distribution of the syntectonic plutons is not random, for they are concentrated along the west coast (*see* Fig. 21). The two largest are the San Christoval Batholith and the West Kano Batholith, both along the west coast. In addition, there are smaller bodies at the following localities: Kunghit Island, Luxana Bay, Bischoff Islands, Sedgwick Bay, Buck Channel.

The syntectonic bodies tend to be elongate and oriented parallel to the west coast of Moresby Island. The San Christoval Batholith is about 50 miles long, 3 to 6 miles wide, and oriented about north 40 degrees west. This orientation conforms closely with that of the dominant northwesterly faults and also with the general strike of the enclosing rocks. The details of contact type and relationship vary widely from sharp discrete intrusive contacts to multiple dykes separating screens of amphibolized country rocks, igneous breccias, and migmatitic zones to vague gradational borders. In spite of this diversity a valid generalization is that the western contact everywhere seems to dip steeply eastward ($65\pm$ degrees) and to conform with the strike but truncate the dip of the wallrocks. The latter, however, have a second foliation roughly parallel to the contact. Relationships on the east are somewhat more diverse, but the contact also generally dips steeply eastward. Foliation within the batholith conforms fairly closely to the attitude of the walls adjacent to them, and toward the centre normally strikes subparallel to the long axis of the batholith and dips at various steep angles.

In contrast to the San Christoval Batholith, which is well exposed, most of the West Kano Batholith is covered by water or younger rocks, or intruded by younger rocks (central Kano Batholith). Only some 44 square miles is exposed, but the actual size must be three times as large. Migmatitic zones at Kindakun and Hunter Points and Marble Island indicate the western border is likely along this line, and judging by the foliation of the migmatites and the faulted contact on Marble Island it probably dips steeply eastward.

The form and contact relations of the Kunghit pluton are similar to those of the San Christoval. However, water covers much of the former body, so that it is less well known, but it is judged to extend at least to Anthony Island because exposures there share a slightly distinctive petrology. The remaining plutons are small lens-shaped bodies that commonly are inhomogeneous and have gradational to migmatitic border zones. The lens-like bodies on Buck Channel are the largest representative of a swarm of small plutonic bodies within a large metamorphosed area of Karmutsen basalts between Skidegate and Inskip Channels. The Luxana Bay pluton is entirely composed of layered migmatites that have a uniform steep northeast dip.

Particular significance is attributed to the relationship between metamorphosed Karmutsen Formation, migmatites, and plutonic rocks revealed in the area between Skidegate and Inskip Channels. Here dynamothermally metamorphosed rocks are widely developed, but definite plutonic rocks are minor. A great variety of rocks of fairly similar mineralogical composition but very diverse texture occur. The origin of some of these is obvious; for example, much of the area is composed of fine amphibolites that are clearly metabasalts because they grade perceptibly outward through rocks with vague quartz clots to pillow basalts with quartz-rich interstices. Other rocks are just as clearly intrusive dykes of quartz diorite. On the other hand, considerable areas occur in which the origin of the rocks is not clear and contacts are gradational, vague, or irregular networks. The rocks concerned grade from fine amphibolites to fine amphibolitic gneiss, to porphyroblastic gneiss, to medium-grained gneiss and foliated quartz diorite. Locally, especially in the areas of gneiss, there will be irregular clots and veins of aplite and basic pegmatite, or coarse quartz diorite. These mottled and migmatitic areas may grade into foliated diorite or quartz diorite indistinguishable from that of normal syntectonic plutons, or into diorites of highly irregular poikilitic grain.

Petrology

The syntectonic plutons are composed primarily of medium- to coarse-grained hornblende diorite to quartz diorite that is uniform in appearance but ranges either side of the quartz diorite boundary. In hand specimen these are generally good fresh black and white rocks, visibly foliated, with obvious hornblende, plagioclase, and quartz, with or without minor biotite (*see* Plate XIVB). In outcrop, inclusions form a significant part, rarely less than 5 per cent. Every sort of gradation occurs from this percentage of inclusions to amphibolites with a few veinlets of quartz diorite or to fine amphibolitic gneiss with porphyroblastic augen and lenses of quartz dioritic material. Migmatites of varied appearance but with subequal amounts of medium-grained diorite to quartz diorite and fine amphibolite are common. Prominent amongst the variety of migmatitic types are:—

(1) Regularly layered quartz diorite and amphibolitic gneiss (venite; example, Luxana pluton).
(2) Regularly oriented flattened oblate spheroids of fine amphibolite in a coarser dioritic matrix (example, north shore Gowgaia Bay).
(3) Regularly oriented, elongate, slightly wavy, fish-like inclusions of fine amphibolite in a coarser dioritic matrix (nebulite, very common; examples, south shore of Gowgaia Bay and Cadman Island).
(4) Irregular but vaguely planar amphibolitic gneiss inclusions in a ramifying dioritic matrix (agmatite; examples, north shore of Gowgaia Bay and Kindakun Point).
(5) Mixed rocks of obvious metasomatic origin (example, roof pendants of the West Kano Batholith; these areas are composed of heterogeneous rocks of widely varying appearance in detail with generally vague gradational boundaries, common amongst them being fine-grained amphibolites with randomly distributed but irregularly spaced feldspar porphyroblasts).

The mineralogy of the diorite and quartz diorite is simple and constant, and the composition varies only within certain limits. The principal constituents are plagioclase, hornblende, and quartz with or without some biotite and rarely minor potash feldspar (*see* Plate XIVB). Constant accessories include iron ore, sphene, and apatite. The mineral composition of specimens that were examined microscopically from all important syntectonic plutons is shown on Table XVII, together with the range of composition for specimens from the San Christoval and West Kano Batholiths. The figures shown are visual estimates controlled by comparison with charts and checked in several instances by modal analyses. Modes for specimens examined microscopically are considered to be a representative sample of a much larger suite examined carefully by hand-lens. Not represented in these figures and tables is the contribution of the amphibolitic inclusions.

TABLE XVII.—MINERAL COMPOSITION, SYNTECTONIC PLUTONS

	San Christoval		West Kano		Kunghit (2)	Luxana (2)	Bischoff (3)	Total (25)
	Average (13)	Range	Average (5)	Range				
Plagioclase	50.5	25–70	56	50–65	47	41	49	50
Plagioclase composition	$An_{38 \cdot 5}$	An_{30-60}	$An_{46 \cdot 5}$	An_{42-55}	An_{50}	An_{26}	An_{33}	$An_{39 \cdot 5}$
Hornblende	24.5	17–38	26.5	17–35	27.5	42.5	17	25.5
Quartz	15	7–27.5	11	5–15	15	6.5	5	12.5
Potash feldspar	1.5	0–12	1	0–4	0	5	0	1.5
Biotite and chlorite	6	0–23	3	0–10	10	0	27	8
Accessories	2	0–5	3	1–5	1	5	2	2.5

Two specimens from the San Christoval Batholith have been chemically analysed. Both are quartz diorites of rather similar composition and are considered fairly typical of the San Christoval rocks but more quartzose than the average. The analyses and modes are shown on Table XVIII together with those of post-tectonic analysed specimens.

In most syntectonic rocks, plagioclase is the dominant mineral and is unzoned or at most weakly zoned andesine. Bent twin lamellæ are common, as is a fair preferred orientation with C-axes in the foliation plane. Hornblende forms about a quarter of the rock and occurs in poikilitic euhedral crystals and groups of crystals with small included plagioclase, magnetite, and sphene crystals. It has a good to fair preferred orientation with C-axes in foliation plane. Quartz varies in amount and habit. It may form 5 to 25 per cent of a rock and may occur in a variety of modes, including the following: Scattered small interstitial grains, trains of small grains in layers with hornblende, large irregular but generally lenticular grains, ophitic interstitial grains with extensive optical continuity. All these modes may show strain, shattering, granulation, or polygonal mosaic recrystallization. Potash feldspar is rarely present, and then a minor constituent as small interstitial grains. Biotite occurs as large grains that seem in some cases to replace earlier hornblende. Cleavage commonly is not oriented in the foliation. Accessories include iron oxides, sphene, apatite, and zircon in order of abundance. All are most commonly associated with hornblende. Iron ores may form nearly 2 per cent and sphene may form nearly 1 per cent of a rock.

The alteration of these rocks is normally slight. Most specimens are fresh but in some plagioclase is extensively sericitized, hornblende may be partly altered to biotite or chlorite, and biotite may be interleaved by chlorite. Rarely more intense alteration occurs with plagioclase saussuritized, hornblende partly changed to clinozoisite, and biotite changed to an interleaved mixture of chlorite and clinozoisite.

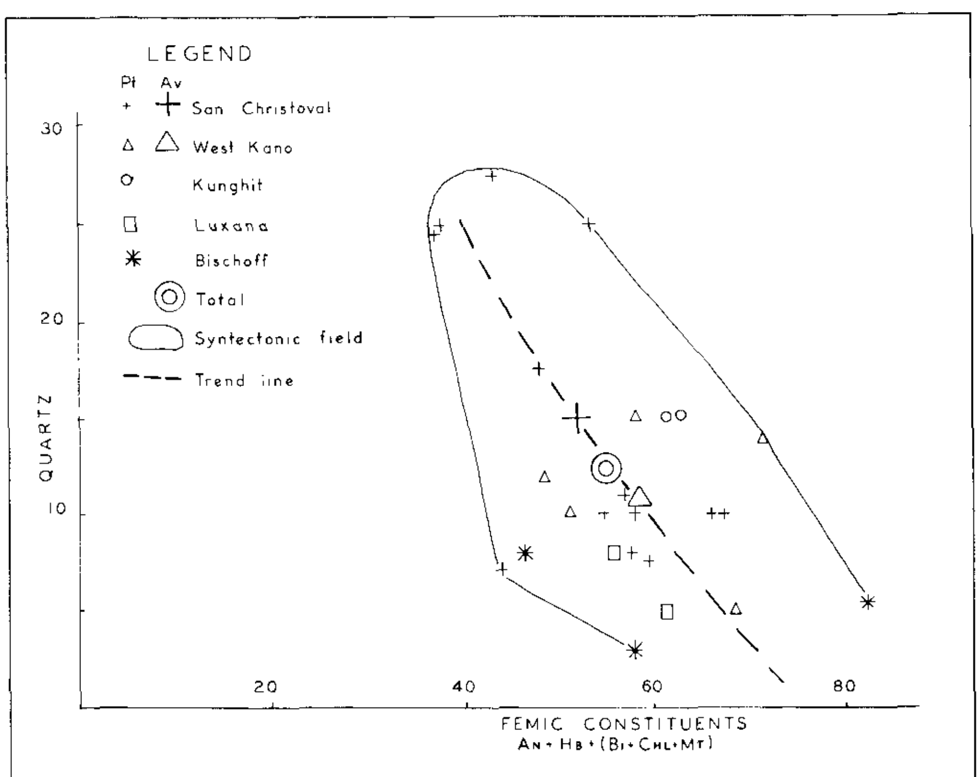


Fig. 22. Compositional diagram, syntectonic plutons.

Figure 22 shows the mineral composition data in a plot of quartz against total femic constituents, this latter including the anorthite content of the plagioclase. The only significant felsic constituent other than quartz is the albite content of the plagioclase as the potash feldspar contribution is negligible. The figure shows the high femic content of all these rocks, which together with the wide range of quartz content (from 3 to 27.5 per cent with a concentration about 10 per cent) is characteristic. Figure 25 shows, against the same ordinate and abscissa, the averages and extremes for all plutonic groups, post-tectonic as well as syntectonic. The tie lines connect points representing maximum quartz and maximum femic, not in the same specimen, with minimum quartz and femic for the whole group. The averages should and do fall close to the tie lines. For the syntectonic plutons the averages fall along a line that is the same as the trough if the data of Figure 22 is contoured. This may be taken to represent the syntectonic trend.

Microscopic foliation in syntectonic rock is normally apparent and results not only from fair to good preferred orientation of the hornblende and less obvious preferred orientation of the plagioclase laths, but also from slight mineral banding of hornblende and quartz-rich layers in contrast with plagioclase-rich layers. The foliation on all scales, the planar nature of inclusions, the slight gneissic mineral layering, and preferred orientations, the nature of the plagioclase and quartz, and the late granulation of the latter all indicate relative movement during crystallization and to a lesser extent after crystallization was essentially complete. In one pluton, penetrative movements have been far more drastic. The Luxana pluton is formed entirely of very regularly banded migmatites that can be seen microscopically to be extremely cataclastic in both the coarser dioritic bands and finer amphibolitic gneiss bands. Mineral layering occurs on a fine as well as coarse scale, hornblende and sphene preferred orientation is excellent, plagioclase occurs as lenticular grains with few twin lamellæ and these bent or erratic, and quartz is reduced to a milled-out sequence of very small grains. Evidently movement continued from protoclastic stage almost to the mylonitic.

Described examples of similar plutons are relatively rare. Buddington (1959, p. 712) only mentions one that is in many respects similar, and this is the Pinckneyville Batholith of Alabama (Gault, 1945, pp. 181–246), which is similar in composition and structure but occurs within a schistose metamorphic terrain that does not seem to be derived from basic volcanic rocks. Similar plutons are also known on the west coast of Vancouver Island.

Age

The age of the syntectonic plutons is not known very accurately from field relations. They all cut Karmutsen Formation and many intrude Kunga Formation, but none are in contact with rocks unequivocally of the Yakoun Formation. The syntectonic bodies are intruded by post-tectonic bodies, are overlain by the Masset Formation, and provided detritus to the Honna Formation and probably the Haida Formation. Therefore, from the field relations these bodies are younger than Early Jurassic and older than Late Cretaceous. Their age may well be closely similar to that of the Yakoun Formation with final emplacement somewhat younger; that is, Late Jurassic. It is hoped a potassium-argon age will be available soon so that doubt will be removed.

	Syntectonic		Post-tectonic		
	San Christoval		Jedway	Central Kano	Pocket Inlet
	58AB299	59AB68	61AB363	61AB29	58AB36
	1	2	3	4	5
SiO_2	59.30	61.34	54.74	61.24	74.04
TiO_2	0.75	0.66	0.85	0.94	0.33
Al_2O_3	16.91	17.88	18.26	16.61	13.95
Fe_2O_3	2.29	2.00	3.63	2.31	0.58
FeO	4.27	3.52	5.26	4.23	1.84
MnO	0.13	0.11	0.18	0.10	0.05
MgO	2.46	2.04	3.25	2.36	0.52
CaO	6.75	5.04	8.02	5.31	1.81
Na_2O	3.22	4.76	2.90	3.79	4.01
K_2O	1.37	1.45	1.01	2.02	2.08
H_2O-	0.09	0.22	0.16	0.25	0.09
H_2O+	2.17	0.74	1.55	0.51	0.47
CO_2	0.03	0.05	0.10	0.08	0.05
P_2O_5	0.13	0.16	0.18	0.15	0.09
SO_3	0.003	0.003	0.002	0.005	0.009
Totals	99.873	99.973	100.092	99.905	99.919

MODES

	Volume Percentage				
	1	2	3	4	5
Quartz	21.40	27.60	12.88	15.52	24.87
Plagioclase	52.47	58.94	55.21	54.23	7.10
Plagioclase composition	An_{38}	An_{32}	$An_{45}\pm_{17}$	$An_{46}\pm_{20}$	$An_{33}\pm_{5}$
Microperthite	....	....	....	7.40	21.30
Myrmekite	....	....	....	....	43.70
Hornblende	16.48	5.52	23.35	17.82	0.72
Biotite	0.25	0.91	....	....	1.01
Chlorite	7.05	6.55	3.98	2.83	1.30
Accessories	2.35	0.48	4.58	2.20	Tr.

1—58AB299, quartz diorite, from the San Christoval Batholith at the head of Bigsby Inlet (*see* Fig. 21 for localities).

2—59AB68, quartz diorite from the San Christoval Batholith on Gowgaia Bay.

3—61AB363, quartz diorite, from southern margin of Jedway stock, southern plutons.

4—61AB29, quartz diorite, from central phase of the Kano Batholith, southeast of Givenchy Anchorage.

5—58AB36, granite, from Pocket Batholith on Barry Inlet.

Analyses by Analytical and Assay Branch, Department of Mines and Petroleum Resources, Victoria, B.C.; analyst, S. W. Metcalfe.

Post-tectonic Plutons

The post-tectonic plutons are distributed more widely than the syntectonic, and occur from coast to coast, many being on the east (*see* Fig. 21). They occur in groups that have in most instances common characteristics that appear to relate them, adding weight to spatial association. There are some 20 plutons divided into five groups and several single bodies. The total exposed area of these plutons (210 square miles) is less than that of the syntectonic, and none are nearly as large; few are in fact batholiths. The groups that will be discussed are, from north to south, as follows:—

Group	Number	Localities	Size	
			Miles	Square Miles
Langara	3	Langara Island	4 × 2	6
		Sialun River	1 × ½	½
		Pivot Mountain	2 × 2	3
Kano (post-tectonic phases)	2	Van Inlet (central)	13 × 7	50
		Shields Bay (eastern)	4 × 4	10
Sandspit	3+	Chinukundl Creek	6 × 2	12
		Sandspit	1 × 1	1
		Cumshewa Head	2 × 2	2
Skidegate Channel	1	Skidegate Channel	2½ × 1	2½
Louise	4	Louise Island	11 × 4	40
		Talunkwan Island	6 × 1½	9
		Atli Inlet	1 × 1	1
		East Sedgwick Bay	1 × ½	½
Lagoon	1	Lagoon Inlet	4 × 3	8
Pocket	1	Pocket Inlet	13 × 3	40
Southern plutons	5	Burnaby Island	6+ × 3+	10–20
		Jedway	2 × 1	2
		Collison Bay	2½ × 1	2½
		Carpenter Bay	2 × 1	2
		Langford Point	2 × 2	4

In addition there are some minor bodies, in effect large dykes and some small plutons on northeastern Louise Island that may belong to the Sandspit Group. Several of the bodies listed above are divided on the map by water, but continuity is reasonably assured.

The form of individual plutons varies widely, but many are irregular in plan, partly as a result of the interaction of roof elevation and topography. The groups form linear assemblages, and some of these are definitely related to major northwesterly fault lines in a manner unlikely to be accidental. For example, the Louise plutons are like beads along the Louscoone-Rennell Sound fault and the Sandspit plutons along the Sandspit fault. Several of the minor bodies are also along major fault lines. The Langara and southern plutons form linear associations but are not associated with any known major faults.

Contacts of these plutons are generally sharp and truncate structures in the wallrocks. Certain contacts, such as the western one of the Pocket Batholith, have a gross " exploded " breccia of country rock in a plutonic matrix (*see* Plate XIa), the whole being several hundred yards wide. The same pluton and several others, such as the Lagoon and Louise, have well-defined sharply intruded roofs. Some, such as Louise and Talunkwan plutons, are called separate plutons but certainly are joined by a saddle lower than the topography judged by aeromagnetic patterns and the extent of hornfels. All sizeable bodies have a hornfelsic metamorphic aureole, the volume of which bears some relation to that of the pluton, although the surface area is related more to accidents of juxtaposition of topography and roof areas.

Petrology

The post-tectonic plutons show more range in composition collectively and individually than do the syntectonic; nevertheless post-tectonic ones over all have a similar mineralogy, texture, and structural features which unite them and distinguish them from the syntectonic plutons. The post-tectonic rocks are commonly fine to

TABLE XIX.—MINERAL COMPOSITION, POST-TECTONIC PLUTONS

	Southern Plutons		Pocket		Louise		Sandspit		Kano Central		Kano East		Langara		Lagoon	Skidegate Channel	Total
	Average (11)	Range	Average (7)	Range	Average (7)	Range	Average (5)	Range	Average (4)	Range	Average (3)	Range	Average (4)	Range	Average (1)	Average (1)	Average (43)
Plagioclase	47½	65–35	37	45–30	43	75–22	48½	55–45	60	75–40	45½	60–20	61	78–48	26	31	46½
Plagioclase comp.	An_{39}	An_{62-25}	$An_{30.5}$	An_{41-24}	An_{34}	An_{40-26}	An_{42}	An_{54-20}	An_{45}	An_{52-38}	An_{34}	An_{46-2}	$An_{38}\pm$	An_{31-45}	An_{26}	An_{37}	An_{37}
Potash feldspar	13	40–Tr.	29	35–20	24½	45–Tr.	8	15–5	7	20–2	24	48–5	8	15–0	40	30	17½
Quartz	15	22–5	23	32½–18	18	30–6	19	38–8	12	22½–7	20	30–15	14	22½–0	30	12½	17½
Hornblende and pyroxene	12½	30–5	3	10–Tr.	8	22–Tr.	16	27–3	17½	31½–10	3	5–0	9	14–7	2	4	9½
Biotite and chlorite	9½	20–5	7	10–1½	3	10–0	5½	10–3	.....	.....	9	13–1	7	13–Tr.	....	22½	6½
Accessories	2½	8–Tr.	1	2–Tr.	3½	7–1	2	3–2	2	4–1	1½	2–1	1	1½–Tr.	2	....	2

medium grained but may be coarsely porphyritic (*see* Plates XVA and B). On the average they are lighter coloured with less mafic minerals and more quartz than the syntectonic. Microscopically they are characterized by highly but normally zoned euhedral plagioclase, significant potash feldspar, hornblende, and biotite in subequal amounts, and myrmekite in the acidic specimens. Miarolitic cavities are common in some bodies. Foliation is seemingly absent and inclusions are normally sparse, equant in shape, and unoriented.

A large number of specimens from all plutons was examined in hand specimen, and a representative suite of 43 specimens was examined microscopically. The composition of these specimens was estimated visually by comparison with charts, and some were checked by modal analyses. The data of average mineral composition and range of composition of the distinct groups of plutons is shown on Table XIX. Three specimens from diverse plutons were chemically analysed: a very basic quartz diorite from the Jedway stock, an acidic quartz diorite from the central phase of the Kano Batholith, and a sodic granite porphyry from the Pocket Batholith. The analyses and modes are shown on Table XVIII. In Figure 23 for all specimens examined microscopically quartz content is plotted against total femic constituents, this latter including the anorthite content of the plagioclase. By examining these tables and figures and comparing them with Table XVII and Figure 22, it can be seen the post-tectonic plutons range in composition from diorite nearly as mafic as the syntectonic ones to leucogranites considerably more quartzose and mafic poor than the syntectonic quartz diorites. The average of examined

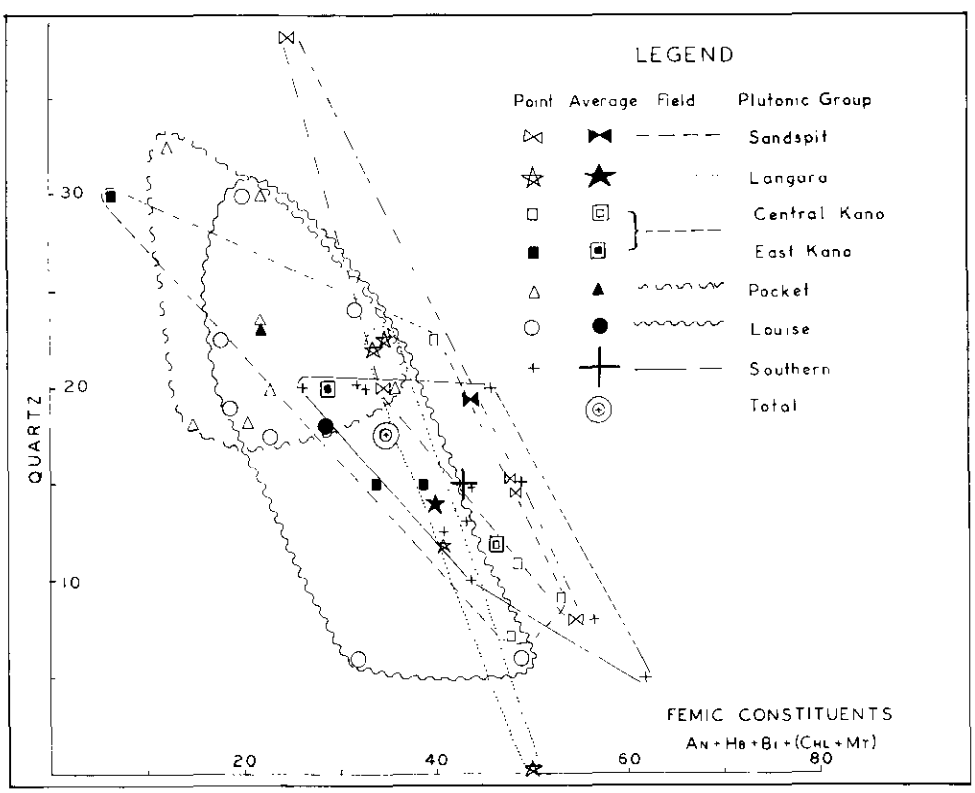


Fig. 23. Compositional diagram, post-tectonic plutons.

post-tectonic specimens is a granodiorite near the quartz monzonite boundary. A great majority of specimens fall close on either side of a straight-line trend from 0 quartz and 70 femic to 35 quartz and 0 femic, and the averages for the post-tectonic plutonic groups with one exception are also right along this trend line (*see* Fig. 25), which may be considered the post-tectonic trend line.

Although the percentage compositions vary, the bulk of specimens have fairly similar mineralogy and texture. Normally these rocks are formed of dominant plagioclase in well-zoned euhedral laths in some cases with irregular or incomplete albitic or potassic outer rims. The core is generally andesine but may be labradorite and the rims andesine to oligoclase. Quartz and potash feldspar occur in subequal amounts in an anhedral mosaic interstitial to the plagioclase and hornblende crystals. The potash feldspar is normally microperthite, but in a few specimens is microcline; however, in the Sandspit and Langara associations it is orthoclase. In acidic specimens, myrmekitic and micrographic textures, are common either as matrix or fretted borders to feldspars. In porphyritic plutons such as Pocket Inlet and Skidegate Channel, euhedral to resorbed quartz phenocrysts and subhedral microperthite phenocrysts are the rule. Hornblende is normally the most abundant primary mafic mineral and is euhedral but may occur in knots with or without biotite. Biotite is only the dominant primary mafic mineral in the more acidic specimens or plutons and occurs as large subhedral grains and aggregates. Pyroxene is virtually absent, except in the Langara plutons, where hypersthene or, more rarely, augite are common and amphibole rare. Accessory minerals are rarely more than a few per cent of the rock and are dominated by iron oxides with some apatite, sphene, and zircon in most specimens. Alteration is generally slight, potash feldspar is clouded, plagioclase may be sericitized or partially replaced by late albite, and the mafic minerals may be altered to chlorite wholly or partially. Rarely new fibrous amphibole replaces primary hornblende.

The plutonic associations and the individual plutons do have some distinct characteristics and variations from the normal petrology. These are listed below:—

Group	Pluton	Characteristics
Langara		The only association in which pyroxene is the common primary mafic mineral in addition to biotite, and one of two groups in which the potash feldspar is orthoclase. Plagioclase is greatly zoned.
	Langara	Uniform quartz monzonite commonly with hypersthene.
	S.alun	Fine pyroxene-bearing quartz diorite.
	Pivot	Hypersthene diorite with minor feldspathoids?
Kano (post-tectonic phase)	Central	Similar in composition to syntectonic phase but of medium grain without foliation or abundant inclusions but with everywhere some microperthite.
	Eastern	Fine-grained leucocratic quartz monzonite and granite in which biotite exceeds hornblende.
Sandspit		Potash feldspar is orthoclase.
	Chinukundl	Fairly uniform medium-grained biotite hornblende granodiorite to quartz diorite.
	Sandspit	Uniform diorite to quartz diorite.
	Cumshewa Head	Mostly acidic quartzose quartz monzonite, but some more basic border phases.
Skidegate Channel		Porphyritic quartz monzonite but contaminated and variable.
Louise		Generally uniform medium-fine perthitic quartz monzonite, miarolitic in places.
	Louise	Medium-fine to finely porphyritic quartz monzonite, miarolitic in part.
	Talunkwan	Mainly quartz monzonite but becomes contaminated mafic and inclusion rich near parts of its border.
	Atli	Fine miarolitic quartz monzonite.
	East Sedgwick	Fine monzonite with accicular amphibole in feathery groups.

Group	Pluton	Characteristics
Lagoon		Fine leucogranite to quartz monzonite, miarolitic in part.
Pocket		Very white-weathering coarsely porphyritic granite to quartz monzonite. Mild cataclasis. Much micrographic to myrmekitic matrix.
Southern		Quite variable from pluton to pluton but more basic and mafic rich than average post-tectonic. The overly large suite from the Jedway pluton emphasizes this effect in the mineral composition table.
	Burnaby	Uniform medium-grained mafic-rich quartz monzonite. Most of pluton shattered and seamed by kaolinite veinlets.
	Jedway	Diorite to quartz diorite.
	Collison	Variable from diorite to granite.
	Carpenter	More acid than most southern plutons, granite to quartz monzonite.
	Point Langford	Quartz monzonite.

Age

Although most seem to be relatively young, the post-tectonic plutons may not be all of one age. Certainly many intrude or metamorphose Cretaceous and Early Tertiary rocks. Critical relations have not been seen at some of the most important plutons. The following list summarizes the known relations:—

Pluton	Intrudes	Metamorphoses	Is Overlain by—
Langara	Honna Formation	Honna Formation.	
Sialun	?	?	?
Pivot Mountain	Either intrudes Masset Formation or is a monadnock surrounded by flows.		
Kano Central	Masset Formation	Masset Formation.	
Kano West	Kano Central?, Longarm Formation	Masset Formation.	
Chinukundl	Yakoun Formation, possibly Haida Formation.		Unmetamorphosed faulted contact with Skonun Formation.
Sandspit	Yakoun Formation		Haida Formation?
Cumshewa Head			Haida Formation?
Skidegate Channel	Longarm Formation.		
Louise Island	Longarm Formation	Possibly Masset Formation Dana facies.	
Talunkwan	Masset Formation, Dana facies.		
Atli	Masset Formation, Dana facies.		
East Sedgwick	Yakoun Formation.		
Lagoon	Longarm Formation, Masset Formation.		
Pocket	San Christoval Batholith.		
Burnaby	Longarm Formation.		
Jedway	Kunga Formation.		
Collison	Kunga Formation.		
Carpenter	Kunga Formation.	Longarm Formation?	
Point Langford	Kunga Formation.		

If all are of one age, they likely are of Late Eocene age. If some are pre-Masset or even pre-Haida, then they are Early or Late Cretaceous and Eocene age.

Metamorphism has not been so widespread nor so intense that there are many areas where there is doubt about the original nature of any rocks nor the stratigraphic unit to which they belong. Metamorphic rocks are, for the most part, directly associated with plutonic bodies and, as with these, are chiefly of two kinds: amphibolites associated with syntectonic plutons and hornfels associated with post-tectonic. The typical amphibolites are fine-grained gneisses of amphibole, plagioclase, quartz, and iron ores. The hornfels are more variable but generally are non-foliated rocks containing fine new pyroxene, and (or) epidote, zoisite, or clinozoisite, and biotite or chlorite. Two groups of metamorphic rocks occur in lesser amounts: chloritic schists and schistose plutonic rocks associated with certain fault zones, and metasomatic skarns.

Figure 24 shows the distribution of metamorphic rocks and their close relation to plutonic bodies and to certain faults. In general, the amphibolitic facies adjacent to the syntectonic plutons are more intensely developed than the hornfelsic aureoles of the post-tectonic plutons, and the former may have true widths of about a mile, whereas any broad area of hornfels is either certainly or suspectedly underlain at no great depth by plutonic rocks. One broad area of amphibolite, about 60 square miles, occurs with but minor plutonic rocks exposed and several broad areas of mild hornfelsic metamorphism occur with no evidence of plutons.

The *amphibolites* form aureoles about the syntectonic batholiths that are broad with respect to the average width about post-tectonic plutons but are nevertheless rather narrow. Generally they are less than a mile wide, and only in the area between Skidegate and Inskip Channels do they occur in a broad zone of some 60 square miles with but minor plutonic rocks. The syntectonic batholiths are emplaced within the large masses of the Karmutsen Formation, and except for minor contact with the Kunga Formation all other rocks in contact with them are younger. The small amount of Kunga limestone in contact with the syntectonic pluton is marbleized or locally metasomatized. Hence the amphibolites are formed essentially from one general rock type, sodic basalt. The basalt originally contained no amphibole, and it is the principal characteristic of the metamorphic rocks that they now contain abundant green hornblende.

The amphibolites typically are fine-grained, foliated, very dark green to greenish-black rocks that on intensive weathering take on a characteristic fine mottling of white and dark grey-green. They do, however, vary considerably from very coarse rocks of similar nature to very fine essentially unfoliated rocks that are difficult to distinguish from unaltered basalts in the field. These latter, of course, grade into slightly altered basalts and greenstones, and the typical fine-foliated amphibolites grade into similar rocks of more felsic nature and into migmatites of mixed amphibolite and diorite or quartz diorite.

Microscopically the amphibolites are seen to be composed of subequal amounts of an amphibole, generally green hornblende, but in some cases cummingtonite and plagioclase, generally andesine, with lesser quartz and iron ores and in some cases chlorite, biotite, or clinozoisite. The texture varies considerably, but most commonly is one of well-oriented fine euhedral amphibole prisms that may be raggedly terminated between which plagioclase and secondary quartz occur. Palimpsest plagioclase phenocrysts may be recognized, and large poikilitic porphyroblasts of hornblende are fairly common. Some of the coarsest amphibolites occur

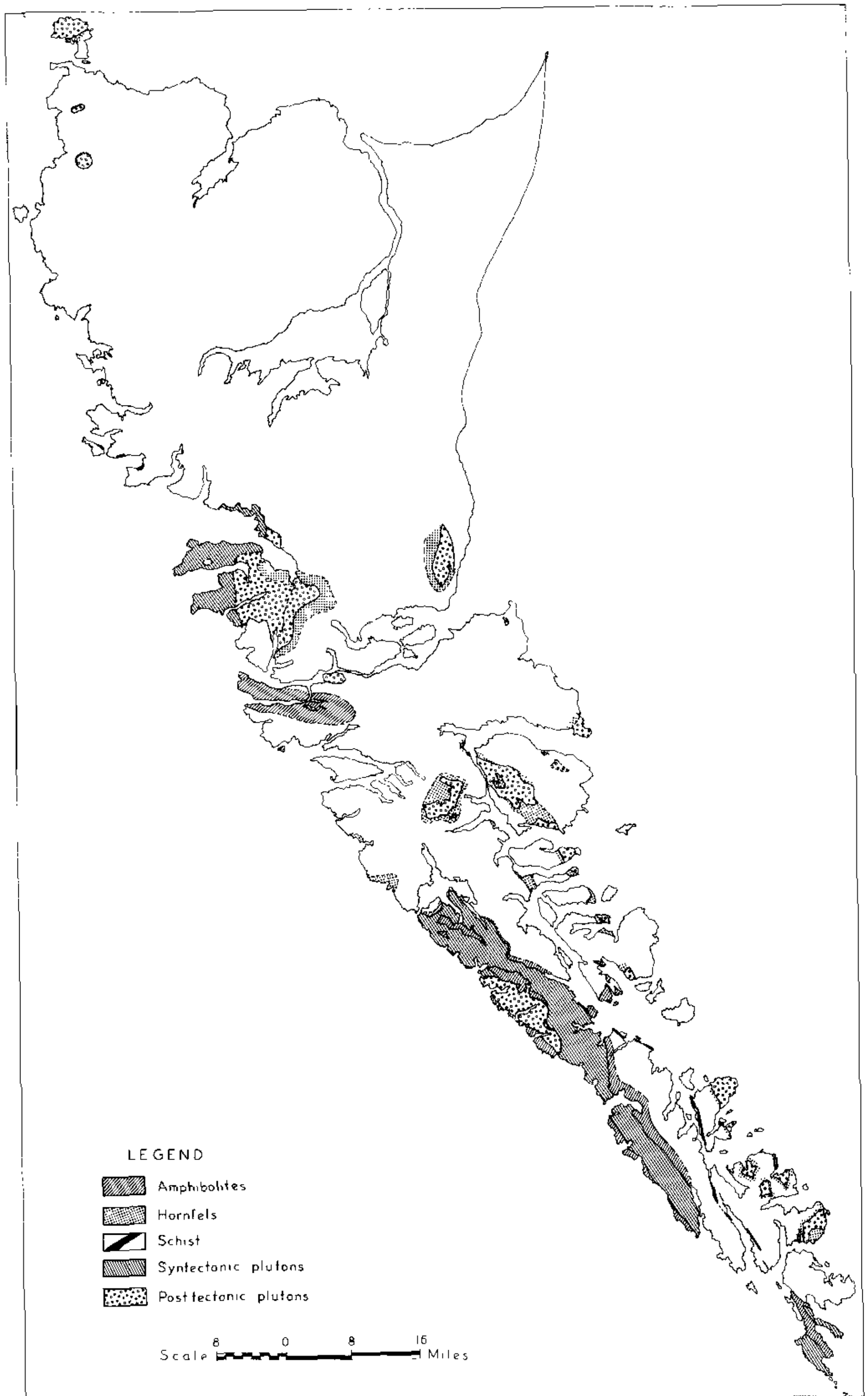


Fig. 24. Distribution of metamorphic and plutonic rocks.

in the screens between the San Christoval and Pocket Batholiths, and in many instances these do not have a good foliated fabric.

The typical amphibolites grade outward through fine amphibolites which are scarcely discernible as such in the field to altered basalts and greenstones in which fine new clinozoisite, albite, and chlorite partially replace previous pyroxene, plagioclase, and original matrix. Amygdules may contain coarse quartz, clinozoisite, chlorite, pumpellyite, or prehnite. Minor fine fibrous actinolite may also occur, and olivine phenocrysts are entirely altered in some instances to talc.

These mineralogical assemblages correspond well with those of Abukuma-type facies series (Winkler, 1965, pp. 98–107) or those developed at relatively low pressures in comparison with the temperatures reached. Because only basic volcanic rocks are involved in the metamorphism, it is difficult to precisely identify the subfacies involved. In the main inner part of the aureole the sillimanite-cordierite-muscovite-almandine (A 2.2) or sillimanite-cordierite-orthoclase-almandine (A 2.3) subfacies of the cordierite-amphibolite facies would seem to be involved because of the green colour of the hornblende or the abundant presence of cummingtonite. In the peripheral zone the quartz-albite-muscovite-biotite-chlorite subfacies (A 1.1) of the greenschist facies is identified by absence of actinolite.

Two post-tectonic bodies have amphibolitic aureoles, one of which is inherited and one which appears to have formed during post-tectonic intrusion. Pocket Batholith has a fringe of amphibolites on its western contact as well as in the screen partially separating it from the San Christoval Batholith. Without doubt the amphibolites owe their origin to the thermal and tectonic conditions existing during the emplacement of the syntectonic pluton with subsequent recrystallization during emplacement of the post-tectonic pluton. The coarseness and general lack of foliation of the amphibolites of the screens support this conclusion. The Jedway stock also has a partially amphibolitic aureole. These amphibolites are developed in only part of the Karmutsen Formation where it is in contact with the stock and differ from the normal amphibolites in being very chloritic, containing new diopside in addition to amphibole, and generally lacking foliation. Much of the remainder of the aureole is fairly typical hornfels. The amphibolites of the Jedway stock border probably result from the combination of higher average temperature of emplacement of the Jedway diorite in contrast to that of the more acidic remainder of the southern plutons and the accidental result of its emplacement into the Karmutsen Formation.

The *hornfelsic rocks* form aureoles about the post-tectonic plutons of quite variable width, but except in roof areas are narrow, and the intensity of metamorphism commonly grades rapidly to relatively unaltered rocks. The aureole of some plutons at steeply dipping contacts may be limited to a few tens of feet but may be several thousand feet. In general, broader aureoles indicate gently dipping to flat contacts. Areas of mild hornfels over fairly broad areas between Bottle Harbour and Tasu Sound in the Masset Formation may indicate a post-tectonic pluton at shallow depth, possibly related to magma chambers for the later flows. The hornfelsic area between the western end of Dana and Logan Inlets is related indirectly to the fault and may indicate a small covered pluton similar to ones that occur elsewhere along the same fault line.

The post-tectonic plutons intrude the whole range of rock types and most formations on the islands. As would be expected, they are thus fairly diverse in appearance but are surprisingly uniform in mineralogy. Most hornfelsic rocks have lighter colours than their original counterparts and more commonly have intense rusty-weathered surfaces. Common colours of fresh hornfels are light greyed greens and browns. The original dark colour of many of the sedimentary rocks results from dispersed carbonaceous matter which is driven off and (or) combined on mild metamorphism. In particular, the Kunga black argillites are changed to rusty-weathering light-greenish to mauve to light-grey rocks. Dark-grey and greenish-grey sandstones of many units are changed to mid-brown dense isotropic rocks. Similarly, many dark-green volcanic rocks have become rusty-weathering light-green rocks.

The new minerals formed in hornfelsic rock are diopside; clinozoisite, epidote, or zoisite; actinolite, biotite, chlorite, albite, and sphene. Fine diopside is present in the higher-grade hornfels formed from the fine-grained sedimentary rocks. Either clinozoisite, epidote, or zoisite is present in all hornfels, and may be a major constituent and of coarse grain in the higher-grade rocks or just minor fine porphyroblasts within original grains in the lower-grade rocks. Fine fibrous actinolite is present chiefly in the rocks of volcanic or volcanoclastic origin, but also in the arenaceous rocks. Porphyroblastic chlorite and new albite are common in lower-grade rocks and fine brown biotite is common throughout, particularly the arenaceous rocks. Ragged sphene porphyroblasts are common in the metasedimentary rocks. In summary, the hornfelsic aureoles range from hornblende hornfels facies at the contact to albite-epidote facies at the periphery. The latter facies is found at the border of a few plutons.

The fabric of hornfels is granoblastic to porphyroblastic, the degree depending roughly on proximity to the contact. In very rare instances some rocks within the hornfelsic aureole may have an oriented fabric usually only apparent microscopically. Some of the marginal rocks of sedimentary origin on the eastern contact of the Louise Batholith have a cataclastic overlay and an oriented hornfelsic recrystallization.

Schists are rare and local in the Queen Charlotte Islands. Most are parts of fault zones, and all sizeable schist zones are related to large faults. Within some of the schist zones there are schistose to massive variably contaminated granitoid rocks, and lesser amount of massive metamorphic to metasomatic rocks of uncertain origin. Many of the schists have clearly been derived from basalts of the Karmutsen Formation, and many black carbonaceous schists from flaggy Kunga argillites. Along the Louscoone fault zone the width of schist along lower George Bay is greater than several hundred feet and has within it horses of less schistose material. The foliation results from abundant growth of chlorite.

Metasomatic skarns are economically important and widely distributed but volumetrically insignificant. The main mineral deposits of the islands are of metasomatic origin and are described in greater detail in Chapter V, particularly on pages 169 to 172. Skarns are associated with both syntectonic and post-tectonic plutons; however, the mineralogy of rocks mildly metasomatized is really not very different than that produced by hornfelsic alteration. The rocks affected are more commonly greenstones adjacent to limestone than limestone itself. In the greenstones and dyke rocks of metasomatic areas the widest halo is an intense chloritization. More restrictedly dense porphyroblastic growth of epidote and actinolite occurs, or, more rarely, epidote and anthophyllite. Even more restricted is mineralization of garnet, with or without magnetite and sulphides. In adjacent limestone the widest alteration involves bleaching and variably coarse recrystallization, and the most intense alteration replacement by garnet and tremolite, with or without magnetite, and sulphides. A rare instance of boron metasomatism is indicated by Yakoun-like lapilli tuffs that have been changed to a patchy aggregate of dumortierite, tremolite, and epidote. These rocks were discovered as float on the shore north of Skidegate near the Chinukundl pluton.

Origin

The origins of plutonic and metamorphic rocks of the Queen Charlotte Islands are clearly interrelated, judged by their spatial association and chemical and mineralogical nature. The post-tectonic plutons are ringed by hornfelsic aureoles which clearly resulted from the emplacement of the plutons. Similarly, the syntectonic plutons are ringed with aureoles that, though bigger and of dynamothermal type, just as clearly are related to the thermal event that includes the emplacement and probable generation of the syntectonic batholiths. The amphibolites and syntectonic plutons are mesozonal, whereas the hornfels and post-tectonic plutons are epizonal, and this is in keeping with their relative ages and the possibilities for extensive erosion. Figures 22 and 23 emphasize the difference between the two types of plutons, but the consanguinity of them is shown by their chemical nature. In comparison with normal calc-alkaline rocks and in relation to their silica content, all are sodium, iron, magnesium, and calcium rich and potassium poor.

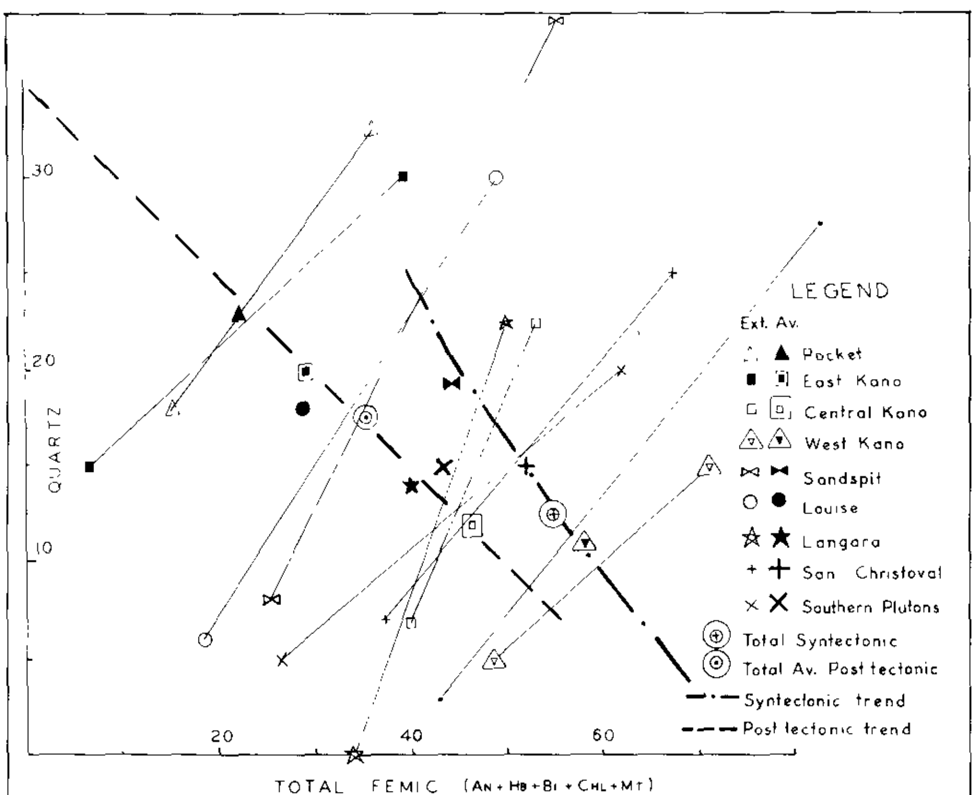


Fig. 25. Diagram of average and extreme composition, all plutons.

The evidence of internal and external structure indicates the syntectonic batholiths moved upward and slightly westward within or into the great layer of the Karmutsen sodic basalts. The field relations in the large area of amphibolites, amphibolitic gneisses, and minor plutonic rocks within a mass of Karmutsen basalts south of Skidegate Channel suggest that the metamorphic and plutonic rocks may all have been generated from the basalts, the amphibolites by recrystallization and the plutonic rocks by differential melting and mobilization of migmatized rocks. In and about the other syntectonic bodies the origin of the migmatites is not always obvious, but at least some seem to have been generated by partial melting and recrystallization or similar processes in a stressed medium. The lack of zoning in the plagioclase could be a result of such a process. The chemical difference of the average syntectonic rock and the basalts is not very great (compare the averages of Tables II and XVIII). A projection of the trough of average syntectonic composition (Fig. 22) or trend line (Fig. 25) reaches the femic abscissa at about 75 per cent total femic minerals including anorthite. This is approximately the composition of basalt which would contain only 10 to 13 per cent less quartz and 20 per cent more femic constituents than the average syntectonic rock. The quantity of basalt needed to produce the syntectonic batholiths is only a small fraction more than that of the basalts replaced. The structural, petrological, and chemical evidence all tend to favour hypothesis of generation of the syntectonic batholiths by partial melting and upward mobilization of the Karmutsen basalts, at moderate depths. An estimate of the depths and temperatures involved can be made from the facies series of the amphibolites and a knowledge of the stratigraphy. Abukuma-type amphibolite of subfacies A 2.3 is estimated to be formed at about 700 degrees centrigrade and 2,000 to 3,000 bars pressure or 20,000 to 35,000 feet depth (Winkler, 1965, p. 105). This grade just may have been reached in the highest-grade amphibolites. The stratigraphic pile at the end of the mid-Jurassic would have involved at least 15,000 feet of Karmutsen, 3,000± feet of Kunga, and, say, 6,000 feet of Yakoun Formation. The heat flow during Yakoun volcanism must have been high. Winkler (1965, pp. 201–203) shows experimental anatexis of greywackes at 685 to 715 degrees centigrade and 2,000 bars.

The linearity and orientation of syntectonic plutons suggest they may have been generated by heat flow channeled along major northwest fault lines now scarcely perceptible. This suggestion is supported by the nature of the migmatitic veined gneiss of the Luxana pluton, which appears to have been subject to major differential planar shear during crystallization and is located along a strand of a major fault line.

The differences in petrological and structural type between the syn- and post-tectonic plutons cannot disguise their chemical relationship. The post-tectonic bodies differ from normal calc-alkaline series in their proportionately high content of mafic minerals and high soda and low potash compared to their silica content (*see* Table XVIII and Figs. 23 and 25). The more mafic post-tectonic specimens are similar to average syntectonic specimens in mineral composition if not in texture. However, the averages and trends on Figure 25 show that there is a distinct and separate trend for the post-tectonic plutons (excepting the Sandspit group), although both trends project backward to similar (basaltic) composition. The orientation of the tie lines is also distinct for the two types of plutons, steeper for the post-tectonic except for the southern plutons, which are overly influenced by the large representation from the basic Jedway stock.

The field evidence such as the hornfelsic aureoles, gross igneous dilation breccia borders, truncation of structures, and location along fault lines that are both older and younger than emplacement, and petrological evidence such as miarolitic cavities, highly zoned plagioclase, etc., all indicate the post-tectonic plutons were mobile, largely fluid, and truly intrusive. The writer favours a hypothesis that they represent either a partial remelting of syntectonic plutons or a second generation by partial melting of the original basalt followed by normal evolution from this magma. The later phases of the Kano Batholith and the Pocket Batholith may represent remelting of syntectonic plutons. The others may have been generated along fundamental fault lines and moved upward along them to chill at various upper levels of the volcano-sedimentary pile, where they now resemble beads along these fault lines. These ideas are shown in Figure 32, a diagram of the hypothetical evolution of the igneous rocks.

CHAPTER 4

Structural Geology

Major crustal fracture appears to have dominated the tectonics of the region of the Queen Charlotte Islands throughout known geological history. Fault movements in the past appear to have controlled the distribution of volcanic and plutonic rocks and the distribution and nature of some sedimentary rocks, and they form the major structural features of the present islands. Faulting is still active in this region, which is the most active seismic area in Canada. Folds are of lesser importance and the origin of some may be related to fault tectonics.

The structure of the islands is illustrated by a number of maps and diagrams: Figure 5, the areal maps; Figure 6, structural cross-sections normal to the west coast of Moresby Island at 10-mile intervals; Figure 26, faults and linears; Figure 27, statistical summaries of faults and linears; Figure 30, folds; Figure 31, the tectonic record; and Figure 32, a diagram of petrogenesis.

FAULTS

Faults are one of the most prominent geological features of the islands. The geological maps (Fig. 5), and, on a smaller scale, text Figure 26 show the distribution and strike of the abundant faults and linears. The most obvious feature on the maps is the continuous linkage of the northwestward-trending faults. These form three subparallel systems—the Sandspit fault zone in the east, the Rennell Sound-Louscoone Inlet fault zone in the centre, and the Queen Charlotte fault in the west. In addition to other less continuous faults of similar northwest orientation, there are prominent faults in the following approximate orientations: north, north 60 degrees east, and east. Linears of uncertain origin are shown separately and are most common in the extensive areas of Graham Island, underlain by Masset Formation where most linears are oriented in the northeast quadrant. All these features are emphasized on Figure 27, which is a statistical summary of faults and linears by 15-minute quadrangles. The figure shows the orientation of strike in line miles per 15-degree sectors with faults in the northern semicircle and linears in the southern. All major known faults are steep and dips are not plotted.

Rennell Sound-Louscoone Inlet Fault Zone

This fault zone will be described in some detail as not only is it the largest and most complicated structure about which much is known, but also it has many general features common to faults on the Queen Charlottee Islands.

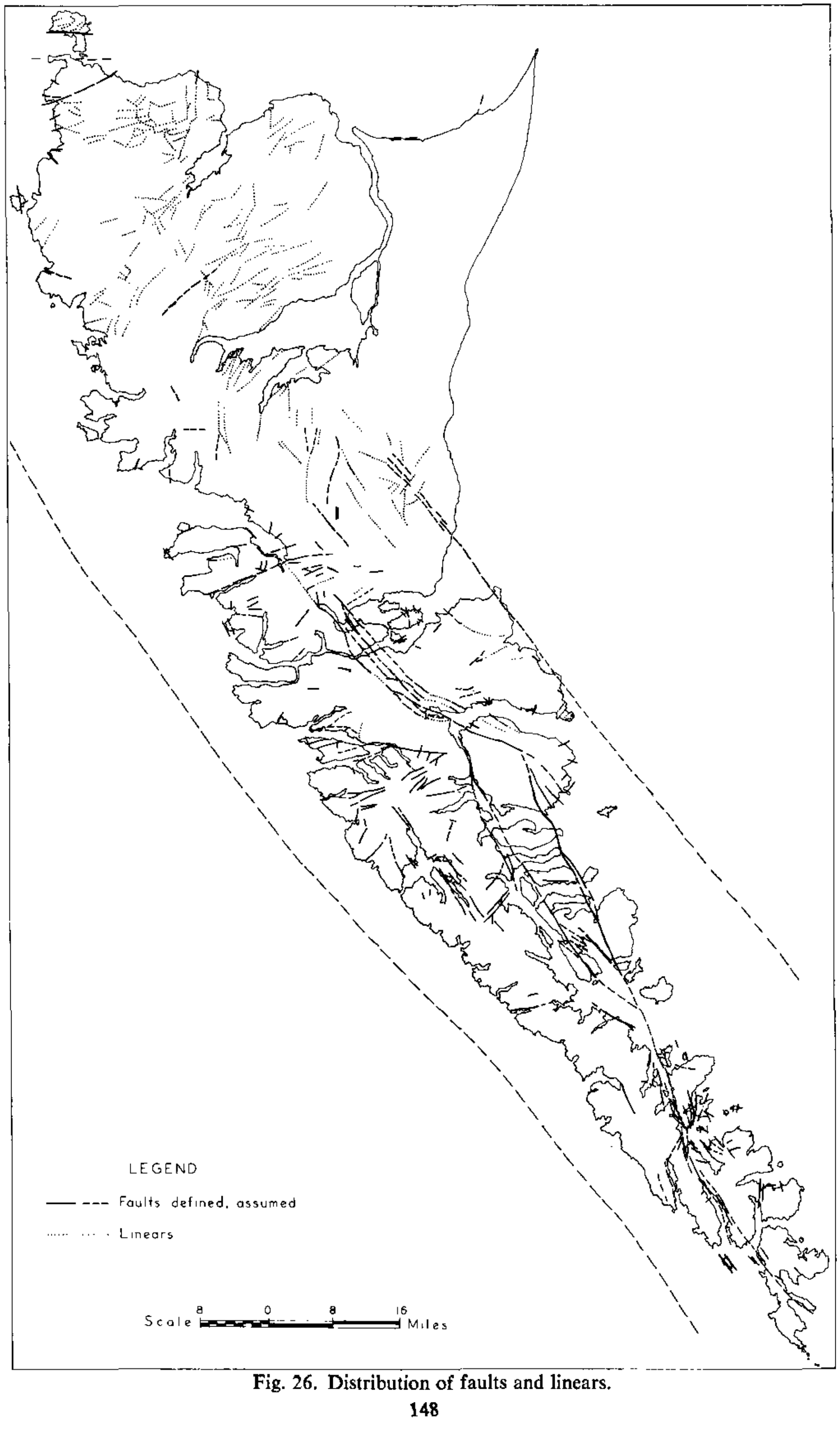


Fig. 26. Distribution of faults and linears.

The main fault zone can be traced with varying degrees of certainty from Howe Bay on Kunghit Island 120 miles northwest to Rennell Sound. Most of the fault strands have some topographic expression, which in many cases is quite marked. Topographic expression can also be recognized on the sea floor, in particular in Laskeek Bay and part of Juan Perez Sound, thus connecting areas where it can be traced on land. The fault has a slightly arcuate over-all trace; south of Louise Island the strike of the main strand averages about north 25 degrees west (Louscoone Inlet fault), whereas north of the island it is about north 50 degrees west (Rennell Sound fault). Main and subsidiary strands are all steeply dipping, most commonly between vertical and 75 degrees northeastward, rarely southwestward.

The trace of the zone is highly braided on a fine and coarse scale with many major and minor parallel subsidiary faults, splay faults, and large horses, such as the one between the Beresford splay and the main strand. The main splay and subsidiary faults are (1) south along Louscoone Inlet, (2) Burnaby Island, (3) along Juan Perez Sound from Werner Point to Hoskins Point, (4) Beresford fault, (5) Darwin Sound, possibly same as (3), (6) southeast Louise Island, and (7) Cumshewa Inlet to Long Inlet. There is a notable deflection in the main strand at Louise Island that may be explained partially if the present faults are peripheral to the Louise Batholith, which occupies the site of the early fault. Between Louise Island and Long Inlet the zone is an imbrication of four or more faults with an over-all width of 3 to 4 miles. North of Long Inlet the faults in the Masset Formation and the eastern phase of the Kano Batholith appear to have minor offset and expression, but in older rocks of Rennell Sound are again large faults of considerable offset.

The physical natures of the faults and their wallrocks vary widely. The most intensely deformed rocks are cataclastic to sub-mylonitic migmatites of the Luxana pluton. Of similar intensity are the chlorite schists formed from Karmutsen basalts and basaltic tuffs. These form belts several hundred to a thousand feet wide that may contain horses of less deformed rocks. The schists are prominent along George Bay, part of Luxana Inlet, and the south shore of Juan Perez Sound. Of the same order are carbonaceous schists that result from the shearing of thinly bedded upper Kunga carbonaceous limestone and argillite. These may contain boudins of massive limestone, greywacke, or dykes. Many faults tend to follow the bedding in these rocks, and a gradation exists between such occurrences and ones where the carbonaceous schists formed from them are pulled out along fault planes so that they occupy positions between blocks of massive volcanic rocks. In some cases moderate-sized lenses of the Kunga Formation occur like beads on a string along an otherwise tight fault line with just a small carbonaceous smear of gouge. In some localities the walls are fairly massive, and the fault tight. In still others, especially near Burnaby Strait, faults are filled by iron- and magnesium-bearing carbonate rocks which may be up to 150 feet wide. Other fault fillings include dykes of the Masset Formation in the north, lenses and dykes of schistose contaminated plutonic rocks, and small plutonic lenses at Louscoone Inlet, George Bay, Burnaby Island, Juan Perez Sound, Tanu Island, Dana Inlet, and Selwyn Inlet. In addition, wallrocks are commonly slightly metamorphosed—in some cases only thermally.

It is reasonably assured that the faults have controlled the emplacement of many plutons. The Louise, Talunkwan, Atli, and East Sedgwick bodies are aligned along the main fault, and the East Kano body is astride the northern strands. All these were emplaced at shallow depths. The Luxana migmatitic pluton is aligned along the southern extension and shows evidence of strong protoclastic deformation parallel to its elongation during generation at a much deeper level.

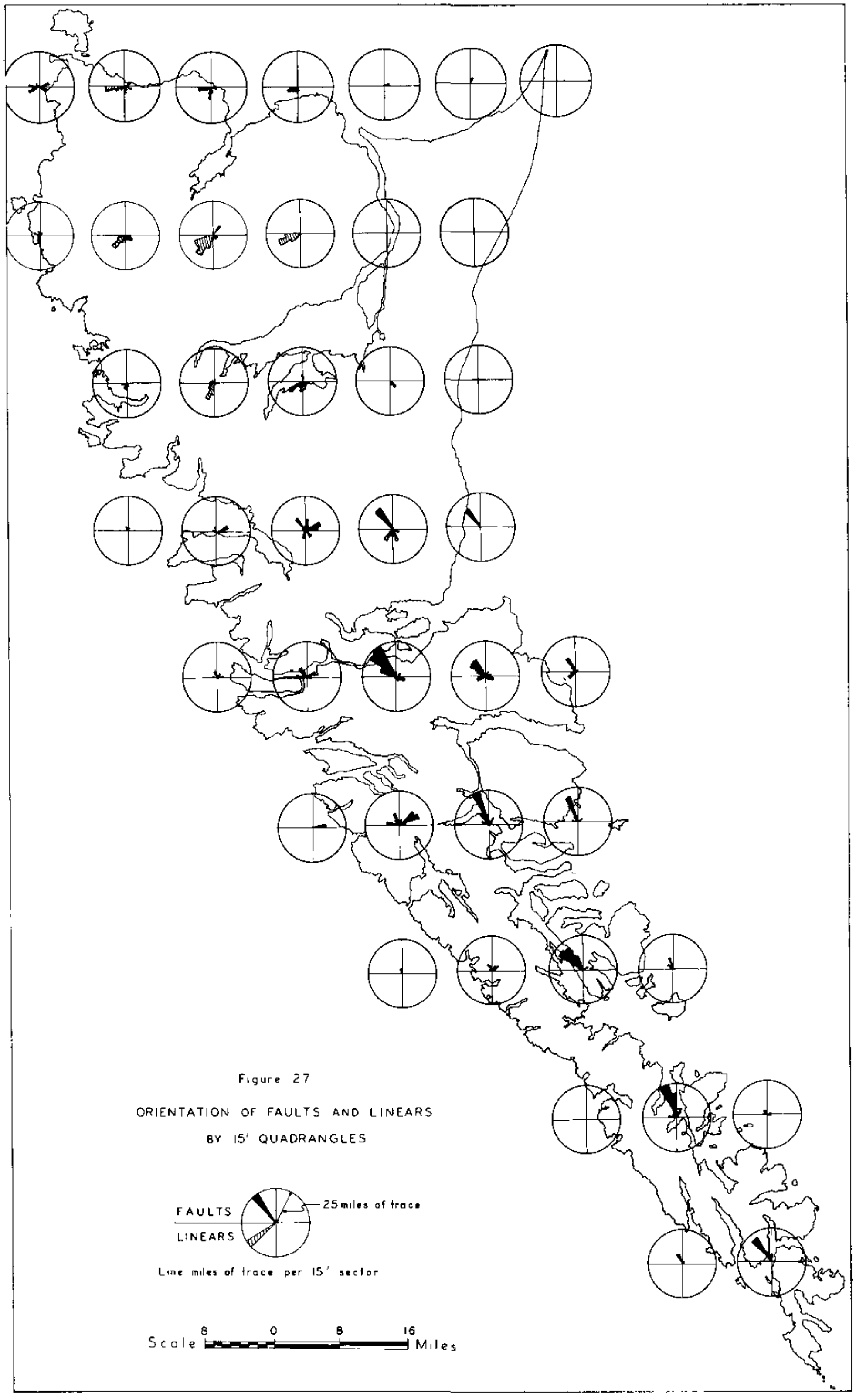


Fig. 27. Faults and linears, orientation by 15-minute quadrangles.

Also there are a number of dyke-like plutons and narrow bands of thermal metamorphism aligned along the fault as previously described. Thus the faults have acted as conduits for heat, and plutons appear to have been generated and moved upward along these planes.

The Rennell-Louscoone fault zone appears to have been active during deposition of the Longarm and Honna Formations and to have influenced their nature and distribution. The Longarm Formation is very much thicker within the imbricate fault zone from Rennell Sound to Louise Island. This unit is composed primarily of greywacke and siltstone, which are full of shelly clasts. The writer concluded the formation was laid down in a narrow graben-like trough in which slumping and turbidity current distribution were probably important. The Honna conglomerates and grits appear to have originated from the area west of the fault zone, probably as this block rose relative to the marine basin of the Queen Charlotte Group in the east.

The fold systems of the southern Queen Charlotte Islands (*see* Fig. 30) bear a complicated relation to the faults in general and the Rennell-Louscoone linkage in particular. Further discussion occurs on page 156, but the simple pattern of folds in the Queen Charlotte Group near Skidegate Inlet will be outlined here. The trend of fold axes in these rocks parallels the trace of the fault zone. The intensity of folding is generally low but increases toward the fault zone, where vertical dips and slightly overturned limbs occur.

Movement along this fault system was obviously complicated; however, the net movement has combined large right lateral separation with significant relative subsidence of the eastern block. Even though most strands dip steeply to the east, it is doubtful if this subsidence should be called normal movement. The compression of the Queen Charlotte Group against the fault renders this term unsuitable. Slickensides showing latest movements are all subhorizontal. No data from this study indicate with any certainty the amount of fault movement, but rough estimates can be made. If one assumes the mid-points of the outcrop belts of Dana facies of the Masset Formation were initially opposed across the fault lines, then right lateral movement of about 12 miles occurred across the two faults (approximately 7 miles on the main strand and 5 on the Beresford). However, as much of the fault movement must have pre-dated deposition of the Dana facies, the possibility of a larger separation must be considered. Fold trends across the fault in the Vancouver Group would be fairly compatible if movement of the order of 16 miles were restored. A much larger restoration would align the two major anticlines and ill-defined syncline from Skidegate Channel to Kootenay Inlet with the similar fold system from Skincuttle Inlet to Luxana Bay. If this restoration is valid, 58 miles of right lateral movement would have occurred.

From the preceding evidence, activity on the Rennell Sound-Louscoone Inlet fault system lasted from before the Late Jurassic or Early Cretaceous to after the Eocene. Some recent activity is not unlikely.

Vertical movement could be measured with precision if one knew certainly what the horizontal separation was. In the Long Inlet to Cumshewa Inlet area, relative movement of the order of 5,000 to 10,000 feet appears likely. From Louise Island to Juan Perez Sound, total vertical displacement across the Beresford fault and the main strand appears to be only a few thousand feet, but the bounded block appears to be a graben. From Juan Perez Sound to Kunghit Island, relative displacement of a few thousand to 5,000 feet appears likely.

In summary, the east block has been vertically displaced 2,000 to 10,000 feet downward and possibly 12 to 58 miles southward relative to the west block.

Age: The Rennell Sound-Louscoone Inlet fault zone has had a long complicated history. Much of the movement may have occurred in the Cretaceous, possibly some in the Late Jurassic. In the Masset Formation and East Kano Batholith in the north and the Louise Batholith in the south, faults are much less prominent than in immediately adjacent older rocks. Thus these areas of young rocks have been subject to lesser movement that must have occurred in Late Tertiary. There are a few certain indications of contemporary activity.

The Sandspit Fault System

This system can be traced with relative certainty from Cumshewa Head to the northward bend of the Yakoun River some 37 miles. The fault almost certainly continues southward in Hecate Strait for an additional 50 miles, and it or parallel faults may continue northwestward across Graham Island to Dixon Entrance.

Much less is known about the Sandspit fault than the Rennell Sound-Louscoone Inlet fault system. The only exposures are of parallel subsidiary faults between Sandspit and Copper Bay. The strike of the main fault is uniformly about north 37 degrees west. The fault position at the entrance to Skidegate Inlet was clearly indicated by a sparker survey run for Richfield Oil Corporation. On Graham Island the trace of fault strands is readily apparent on air photographs and on maps by offset drainage on most creeks. On the ground small eroded scarplets and breached sag ponds can also be recognized. A southerly trending splay fault at the mouth of Chinukundl Creek has pyritized and shattered granitic rocks on the west wall and slickensided semi-consolidated sands and gravels of the Skonun Formation on the east wall. This fault dips about 65 degrees westward. On Moresby Island from Sandspit to Gray Bay, dead sea cliffs mark the fault line. Along these cliffs, hornfelsic and pyritized Yakoun agglomerates are cut by a large number of subparallel subsidiary faults that mostly strike north 30 to 40 degrees west and dip 60 to 80 degrees northeast. On one fault exposed mullions indicate largely vertical movement. Till rests undisturbed on top of a number of faults. However, recent seismic activity is indicated by the small topographic features of southern Graham Island and the reported disappearance of the beach at Sandspit and fissuring of the beach at Skidegate (Milne, 1956, p. 134) during a 1929 earthquake that had an epicentre in Hecate Strait.

The belief that the fault continues southward from Cumshewa Head for at least 50 miles is based on the submarine topography. Along a line on strike with the fault the topography changes markedly. A submarine plain lies at shallow depth to the east of the line and complex topography with relief up to 1,000 feet lies to the west.

Rocks exposed in the west block are invariably older than those exposed in the east—Yakoun Formation and Sandspit plutons in the west, Masset and Skonun Formations in the east. The Sandspit plutons are apparently aligned along the fault trace but are cut by the faults and seem to have supplied detritus to the Skonun Formation.

One can only guess the amount of movement on the Sandspit fault because exposure, particularly of the eastern block, is so scant. Certainly the eastern block

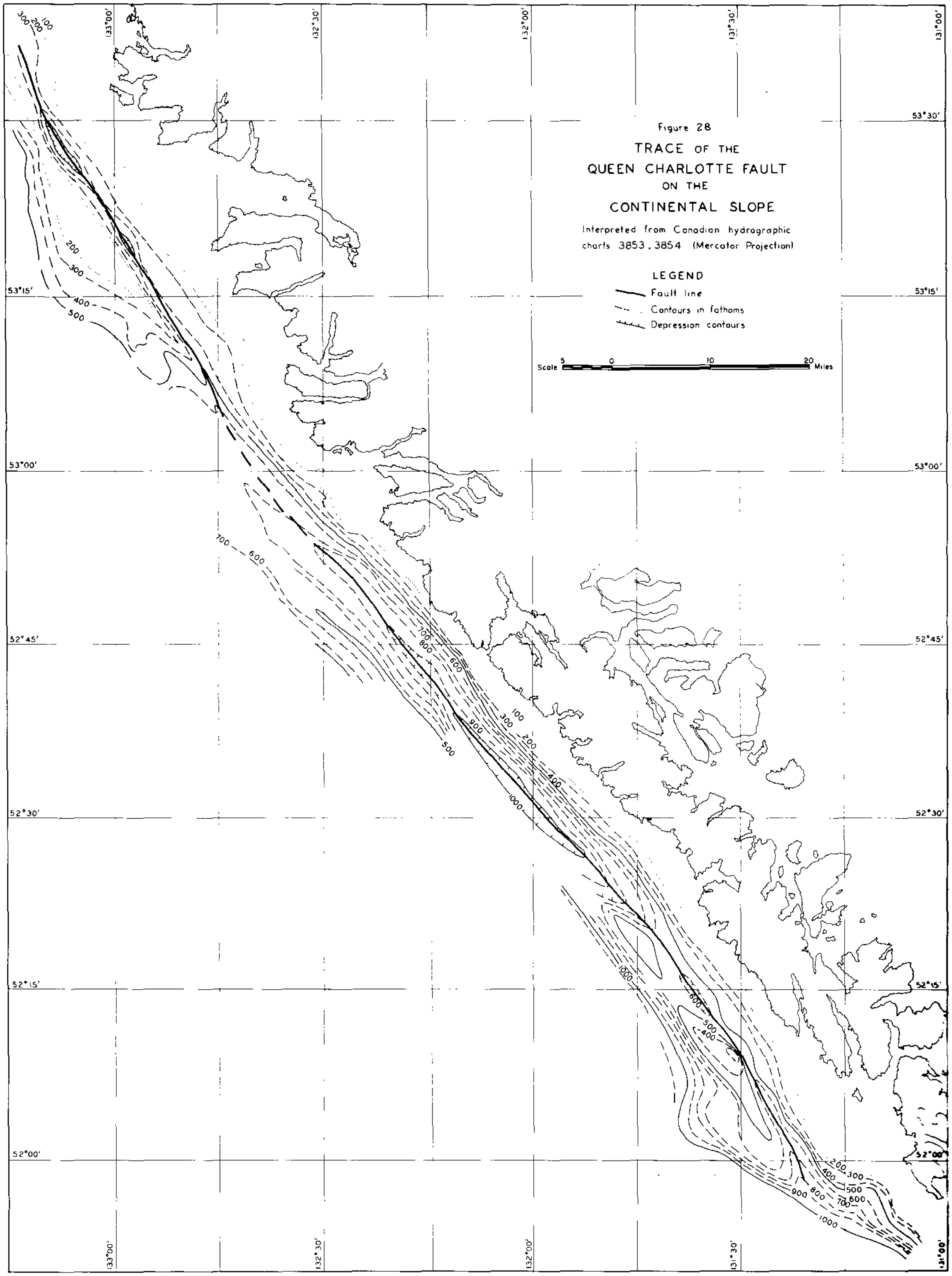


Figure 28
TRACE OF THE
QUEEN CHARLOTTE FAULT
ON THE
CONTINENTAL SLOPE
Interpreted from Canadian hydrographic
charts 3853, 3854 (Mercator Projection)
LEGEND
Fault line
Contours in fathoms
Depression contours
Scale 5 0 10 20 Miles
133°00'
132°30'
132°00'
131°30'
131°00'
53°30'
53°15'
53°00'
52°45'
52°30'
52°15'
52°00'

has been dropped many thousands of feet relative to the west; however, latest movement as indicated by the scarplets appears to have been east block up. The horizontal component of movement is completely unknown, but with such a long straight fault it is probably significant.

Age: If the emplacement of the Sandspit plutons was controlled by the Sandspit fault, then this structure was most likely active in the Cretaceous, and although some strands have not been active since the Pleistocene, others most certainly have.

Queen Charlotte Fault

Off the west coast of the Queen Charlotte Islands is a great fault, the Queen Charlotte fault, that has a different order of magnitude to the ones previously described, for it is part of the circum-Pacific, continental margin fault linkage (St. Amand, 1957). Observations regarding this fault are also of a different nature and consist solely of submarine topography, seismic activity, continuity with other such faults, and theoretical considerations.

The bathymetry of the west coast of the Queen Charlotte Islands is outlined in a reconnaissance manner on Canadian Hydrographic Service Charts (3844, 3853, 3854), but when contoured it is sufficient to indicate the surface trace of the fault (*see* Fig. 28). This is in fact a connected series of canoe-shaped depressions on the continental slope oriented about north 43 degrees west in the southern part and curving smoothly to north 30 degrees west in the north along the whole length of the Queen Charlotte Islands (200 miles) and undoubtedly beyond. All we know of the geology of the Queen Charlotte Islands leads us to believe that the geology of the slope will be complicated and that massive volcanic rocks will most likely be the commonest rocks. These considerations of alignment and probably geology make an alternative explanation of the unusual topography unlikely—that is, that it represents the back edge of a massive slumped block.

The Queen Charlotte Islands and vicinity probably form the most highly seismic area in Canada. Figure 29 shows the plotted epicentres of major recorded shocks from 1921 to 1961. Because of the geometry of seismograph stations, the recorded positions of most epicentres are not very accurate. However, the epicentre of a great earthquake like the Queen Charlotte earthquake of August 22, 1949 (54.2 degrees north, 133.5 degrees west), is probably fairly accurately located, is close to the Queen Charlotte fault, and undoubtedly represents movement on this fault. Hodgson and Milne (1951, pp. 231–232), in a study of direction of faulting in the north Pacific, conclude this shock was caused by a fault striking north 29 degrees west and dipping 77 degrees northeastward and that motion was almost purely right-hand transcurrent, with minor movement of the west block downward. Many of the other epicentres may result from movement on this fault. Milne (1964) shows total strain release concentrated along the Queen Charlotte fault line. No estimate of the initial age of this fault can be made other than to suggest that it is probably similar to the Denali fault of Alaska and is active currently.

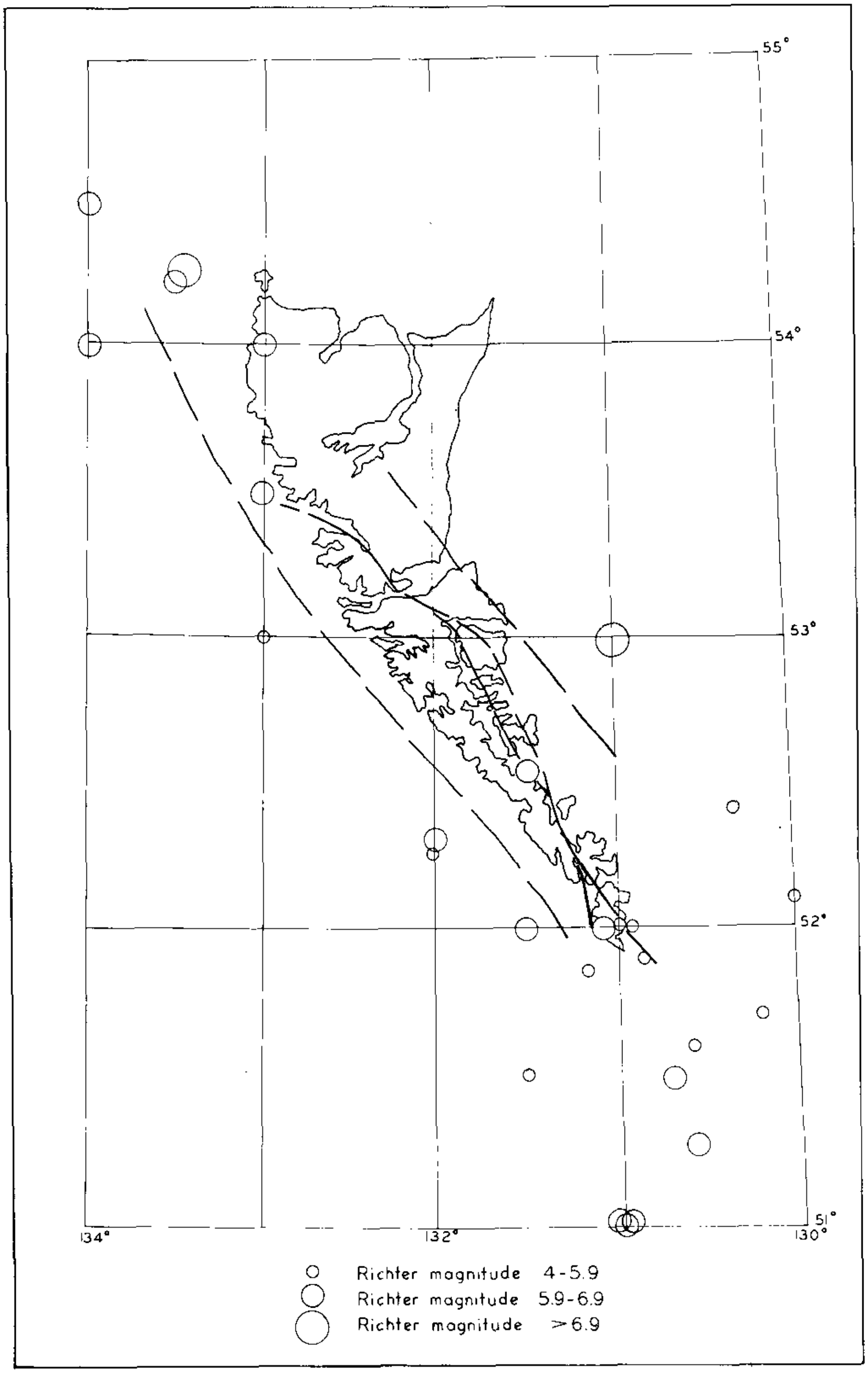


Fig. 29. Distribution of earthquake epicentres greater than magnitude 4.

Other Northwest Faults

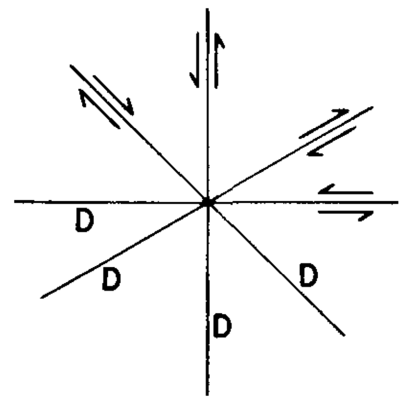
Many other faults are oriented northwesterly, but none are known to be of the same order as those previously described. Faults that appear important occur at Gowgaia Bay, Botany Bay, Newcombe Inlet, Tana Point, Kindakun Point, Kwana Bay, Ghost and Phantom Creeks, and west of the Yakoun River. Most of these are shear zones with evident right lateral displacement.

Faults Other than Northwest

Faults in other orientations have not been traced for much more than 10 miles, but some have the appearance of being large. Significant northerly striking faults occur at Rose Inlet, Burnaby Island, north of Rennell Sound, and at Frederick Island. Many of these are left lateral shears with some relative downthrow of the east block. Significant faults oriented approximately north 60 degrees east are widely distributed, particularly near Lockeport and Moore Channels, Van Inlet, and Sialun Bay. Linears of this orientation are the most common throughout Graham Island. North and west of Masset Inlet most of the faults of this orientation have a vertical component of movement that drops the south block, but many may have a significant horizontal component, which in the south is right lateral but in the north is left lateral. If the linears and the faults have the same origin, these structures are relatively young. Another orientation of many faults is approximately east. These are prominent near Skincuttle Inlet, Mike Inlet, Bottle Inlet, and Langara Island. Linears of this orientation are common on northern Graham Island. Some of these faults are definitely left lateral, such as that at Langara, and a probable fault at Parry Passage, along which the Cape Knox porphyry has been emplaced. Others seem to be normal faults on which the south block has dropped.

It is not clear whether the linears belong either entirely or partially to the systems just described. In a few instances linears can be traced into faults, and it is likely that all linears represent fractures of some displacement. Most of the linears plotted are in northern and central Graham Island, areas of meagre outcrop and gentle relief. In this area most linears are oriented in the northeast quadrant, but there is a swing in average orientation from northerly in the south to easterly in the north. If this pattern is compared with the fold pattern of the Masset Formation the same area (*see* Fig. 30), a tendency to an orthogonal net related to bedding can be detected. This leaves some doubt about the kinship of the main mass of linears to the main fault systems.

The pattern of faults includes four main orientations which rotate slightly anticlockwise from the south to the centre and then clockwise to the north. The northwesterly shears are the dominant faults by an order of magnitude. The northerly, north 60 degrees west, and easterly faults are smaller and fewer but still important. Most faults seem to combine wrench and normal movement with down-dropped sides on the east or south block, and wrench movement as shown below.



It seems unlikely that such a fracture pattern results from only one stress pattern, and yet in general all fault systems appear to have been active over a long and overlapping period. A preliminary synthesis that appeals to the writer is that great clockwise shear stress built up to be periodically released by sufficient large rupture so that the general cordilleran east-west compression became dominant in between.

FOLDS

Folds are important structural features on the Queen Charlotte Islands, but are of lesser importance than the faults and may largely be secondary features. The intensity of folding is low. Characteristically great monoclinial or warped panels of volcanic rock dip less than 30 degrees. Only locally are sedimentary rocks compressed into steep or overturned folds. Folds appear to have originated in part from regional stress systems together with a conjugate fault system, in part as local adjustments to fault block movement, and in part without obvious relation to faults. The fold systems are shown on Figure 30, where they are distinguished according to the rocks involved into four classes—Triassic and Jurassic, Cretaceous, Early Tertiary, and Late Tertiary. Trend lines in monoclinal panels are shown in addition to fold axes. The fold systems of the respective classes are so different they will be treated separately.

Folds in Triassic and Jurassic Rocks

Triassic and Jurassic rocks are folded in two distinct orientations—west and northwest. Axes of both orientation are distributed throughout the islands where rocks of these ages are exposed. Westerly axes are prominent along the east coast from Juan Perez Sound to Luxana Bay, along the west coast from Kootenay Inlet to Chaatl Island, at Frederick Island, at South Bay, and north of Yakoun Lake. In the first-order folds, anticlines are better defined than synclines. Major anticlines include one south of Buck Channel, one at Kootenay Inlet, one at Ikeda Cove, and one north of Kunghit Island. These have half wave lengths of 5 to 8 miles and amplitudes of 2 to 3 miles, or less than the total thickness of Karmutsen lavas.

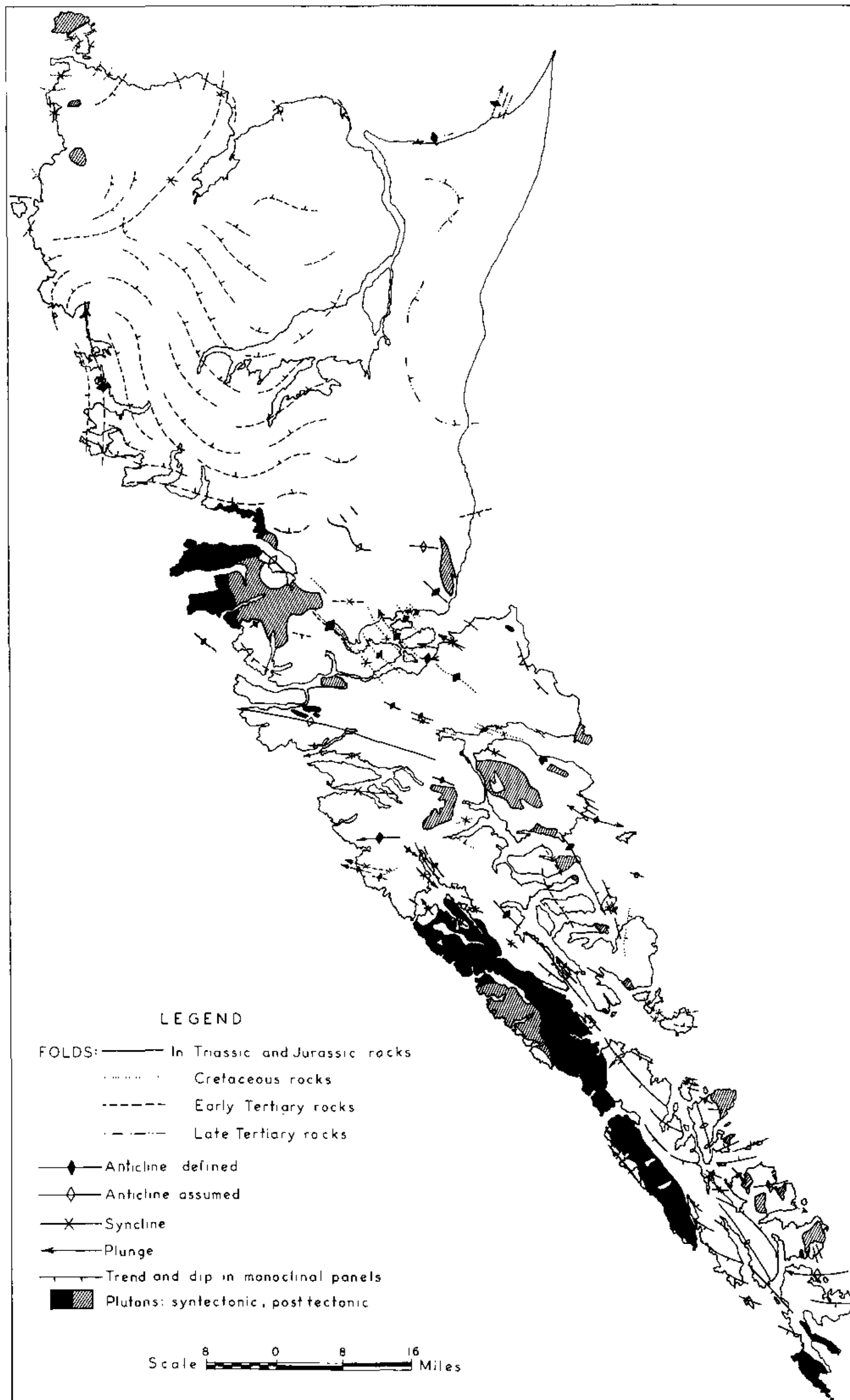


Fig. 30. Fold systems.

Northwesterly trends are prominent along the course of the Louscoone fault, Darwin Strait, Tasu Sound, Copper River, Rennell Sound, and Sialun Bay. Many of these trends are in fact monoclinal panels, but others are complete folds (Crescent Inlet), some of which are tightly compressed and faulted (Newcombe Inlet).

Interference effects between folds in the two orientations may be present, as for example in the area between Tasu Sound and Inskip Channel, but such effects may be obscured by younger rocks not involved in these foldings. At many localities westerly fold axes on approach to major transverse faults either lose their identity or appear to bend toward the trend of the fault and/or the northwest folds. The swing of axes into the major dislocations and alignment of northwest fold axes along the faults probably indicate that the easterly folding was the earlier and that the northwest folding is related to compression across these primarily tangential shears. The faulted folds at the north end of Newcombe Inlet impressed on a first-order easterly plunging anticline of Kootenay Inlet are good examples of the interaction of these two fold systems and of the lack of clear definition of critical relationships on a large scale.

Second-order folds are inclined to be more compressed, and third-order folds may be isoclinal and very complex. In general, massive or pillowed Karmutsen lavas are not subject to intense minor folding, except tuffaceous limestones and shales near the base (for example, at Shuttle Island). In contrast the flaggy and carbonaceous Kunga rocks are particularly subject to minor folding. Chevron-type folds of a few tens of feet are very common. Complex folds of two generations are also common (for example, south shore of Maude Island). No particular study was made of these complex minor folds, but the indications from reconnaissance observations was that easterly folding pre-dated northwesterly.

Folds in Cretaceous Rocks

The main mass of Cretaceous rocks is exposed from northern Louise Island to Yakoun Lake, where there is a northwesterly trending fold system with axes entirely parallel with the Rennell fault system. In the northeast these folds are gentle, dips rarely exceed 30 degrees, but on approach to the Rennell fault zone intensity increases markedly so that minor folds are compressed, and vertical or slightly overturned attitudes are the rule. Again compression normal to the northwest shears seems to be an essential explanation, but in this instance the gradient of intensity toward the Rennell fault seems fairly conclusive evidence of this stress orientation and strain release.

In contrast to the overt and uniform fold pattern about Skidegate Inlet, Cretaceous rocks elsewhere have a rather random array of fold axes in which northwesterly, easterly, and northeasterly ones are all common.

Folds in Early Tertiary Rocks

Early Tertiary rocks, the Masset Formation, are chiefly warped into broad gentle non-axial folds that are not likely to be of compressional origin. Most prominent is the broad basin of central Graham Island. However, linear structures do occur; for example, the " anticline " from Hippa Island north to Otard Bay and the broad very gentle warped syncline between Cape Naden and Omega Mountain. Other distinct folds occur south of Kootenay Inlet, Long Inlet, and north of Slatechuck Mountain. Monoclinal volcanic panels occur about Dawson Harbour, Selwyn to Atli Inlets, Ramsay Island, and Lawn Hill. There is little unity to these various trends. Some undoubtedly reflect initial dip and others tilting of fault blocks. Few are compressional folds, except those south of Kootenay Inlet and possibly the anticline north of Hippa Island. The origin of the basin of Graham Island and the Hippa anticline is not clear, but the former may represent sag over an evacuated magma chamber. The anticline may be a remnant of a linear volcanic structure of accumulation, although the fact the " basement " also appears to be elevated along this trend makes this unlikely. Along the northeast shore of Rennell Sound the southern edge of the basin is turned up sharply, and this is most likely related to movement on the Rennell fault.

Folds in Late Tertiary Rocks

Late Tertiary rocks are generally undeformed, except north of the " basement " sill that divides the main basin from the one along Dixon Entrance (*see* Fig. 19 and p. 124). In the main basin, beds at the surface are essentially flat, but with increasing depth in the exploratory wells, dip increases toward the basin probably as a result of compaction. In contrast to the southern basin, along Dixon Entrance there is evidence of intense tectonic activity during deposition (*see* pp. 120, 124), and this activity continued after deposition, for the surface exposures reveal faulted anticlinal folds which at Skonun Point are oriented east and plunge gently westward, and at Tow Hill are oriented about north 20 degrees east and plunge northward.

TECTONICS

Any synthesis of the tectonics based on our present knowledge is speculative, but certain relationships limit the possible interpretations. The dominance of major faulting in the tectonic regimen is scarcely in doubt, nor is the relative importance of the northwesterly faults. These faults in particular have had a long history, not yet completed. They and similar fundamental fractures have controlled

(1) the distribution of pillow lava and massive lava facies of the Karmutsen Formation (*see* pp. 41, 49);
(2) the probable location of volcanic vents of Yakoun Formation reflected in the west by the facies front (*see* pp. 72, 75);
(3) the probable location and genesis of syntectonic plutons (*see* p. 145);
(4) sedimentation and distribution of the Longarm Formation (*see* pp. 77–81);
(5) sedimentation and deformation of the Queen Charlotte Groups (*see* pp. 91–98, 151);
(6) the location and possible genesis of the post-tectonic plutons (*see* pp. 135, 146);
(7) the distribution of recent seismic shocks (*see* p. 153.)

These fracture systems have thus been active from Triassic times to the present.

The relations between faulting and folding are known with less certainty. Easterly folding appears to have been the earliest followed by northwesterly. Whether the folding of pre-Cretaceous and Cretaceous rocks in the northwestern trend was synchronous, separate, or reinforcing is not known. The compressional features normal to the northwest faults in both assemblages are similar but are more exactly parallel to the faults in the Cretaceous relationship. Also there is evidence of repeated development of easterly and northwesterly folds throughout the remaining history. In general, compression appears minor in the Tertiary tectonic regimen.

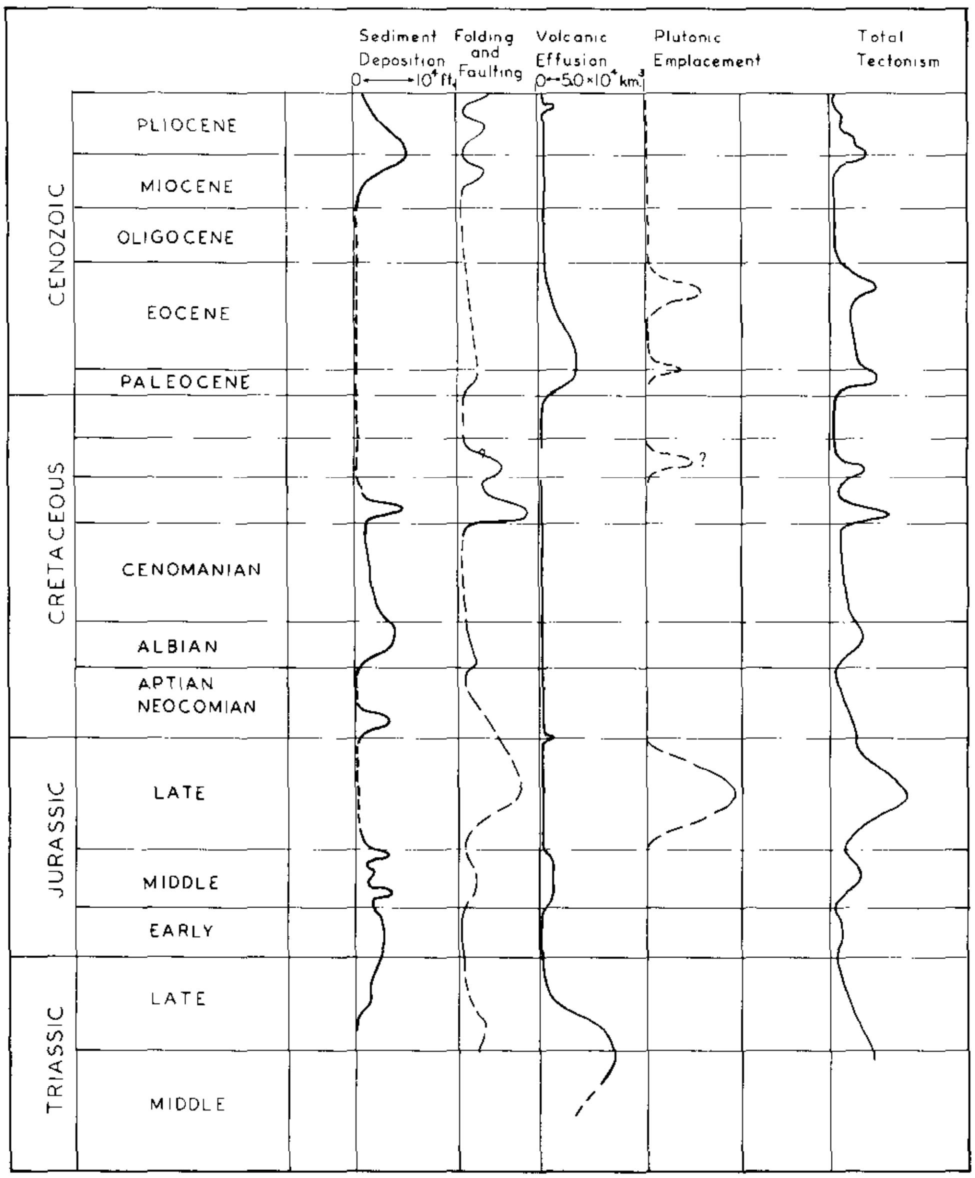


Fig. 31. Tectonic record.

Some speculations on the stress systems of the past can be made. The present system for the Queen Charlotte Islands and most of coastal North America, according to Lensen (1960, p. 392), involves principal horizontal stress in a north direction with both direct and indirect evidence that major faults are clockwise, transcurrent, and strike roughly parallel to the Pacific margin. Such a system in the past could explain the main northwest shears, the lesser conjugate north shears, and also possibly the easterly folds. In addition, the northwest folds and north 60 degrees east, and easterly shears must be explained. These may all result from east-northeast compression, a normal cordilleran orientation. The fold orientations appear to be controlled by the northwest fault orientation, possibly by compression against these faults. The shears would be oriented at an acute angle to the main compression. An alternation of clockwise shear and east-northwest compression could explain the features present and may result by periodic release of clockwise shear by major rupture with the principal horizontal stress then being east-northeast.

The region of the Queen Charlotte Islands has been tectonically active since the first records available in the Triassic, and activity has continued to the present. The tectonism is indicated indirectly by a number of parameters which are known with varying accuracy. None are free of subjective elements, estimations, or projections. Nevertheless, Figure 31 is an attempt to plot these parameters against time and to add them to form a curve crudely representing the tectonic history. The curves representing sedimentary deposition and volcanic effusion are ones freest of subjective elements. When the plutonic rocks are dated by isotope methods, this curve will be the most accurate. The curve of folding and faulting depends on structural information and on the curve of sedimentation.

It can be observed that plutonism and volcanism are only partly related in time. Their fundamental relation has been questioned repeatedly. As is fairly common, major volcanism seems to immediately pre-date plutonic emplacement. In the Queen Charlotte Islands there is a certain kinship in all igneous rocks apparent in their relative high soda-low potash content throughout the spectrum of igneous types. These range from oceanic tholeiitic basalts of the Karmutsen Formation through sodic porphyritic andesites of the Yakoun Formation to alkali basalts and sodic rhyolite ash flows of the Masset Formation, and in plutonic rocks from mafic-rich hornblende diorite to quartz diorite syntectonic plutons to diorite, quartz diorite, granodiorite, sodic granite post-tectonic plutons. The evidence suggests the Karmutsen lavas represent truly oceanic tholeiites and thus most likely represent a relatively unmodified tap of mantle materials. Their geographic and temporal relationships to the East Pacific Rise remains to be fully examined, but the rise appears to be too young to be a source. The writer has also concluded that the evidence favours a hypothesis (p. 145) that the syntectonic plutons were generated by anatexis of the Karmutsen basalts, along linear zones during periods of extraordinary high heat flow. Likewise the post-tectonic plutons were generated in a similar manner from similar materials and moved upward along the same planes in which heat flow was concentrated to become emplaced high in the crust. Post-tectonic plutons may have been generated by selective remelting of Karmutsen and other units or rheomorphism of syntectonic plutons. The total volume of Yakoun andesites is small in comparison to Karmutsen basalts or syntectonic plutons. It is possible they represent the evolved products of Karmutsen volcanism with addition of floated andesine phenocrysts and added alkalis in extensive cupolas along their vent line. The evolution may have occurred as part of the syntectonic plutonism; this would not be contradicted by Yakoun mineralogy, chemistry, or the timing of their eruption. The Masset volcanism is characteristic of post-tectonic volcanic

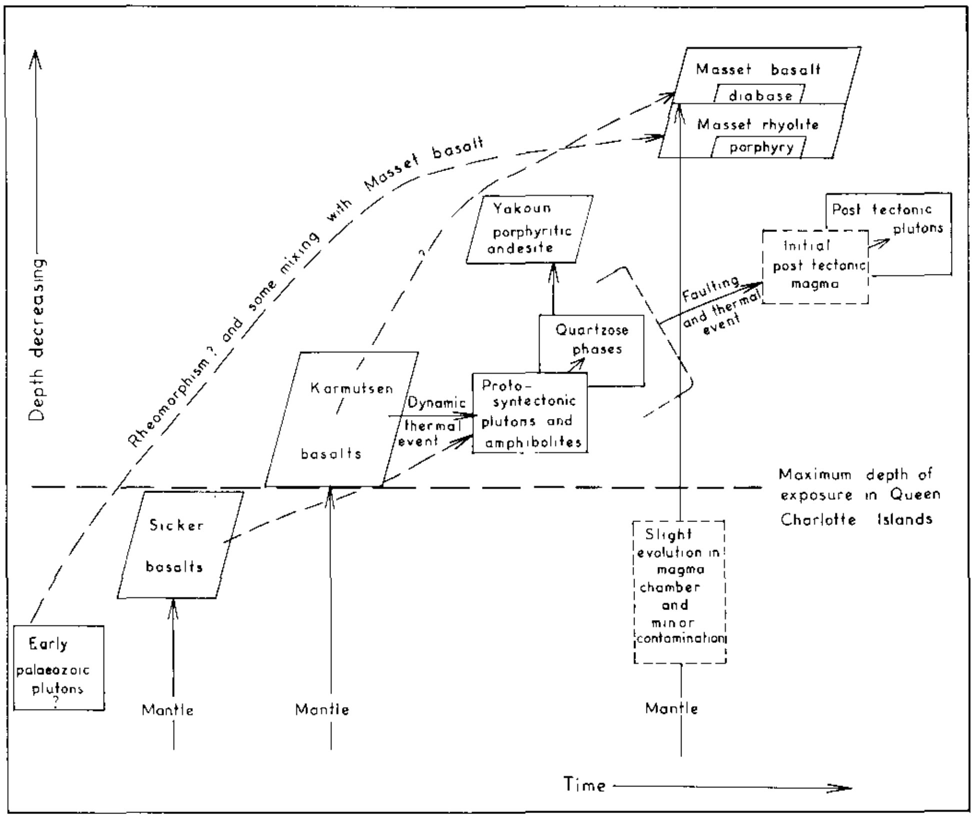


Fig. 32. Hypothetical evolution of the igneous rocks.

cycles in that it combines columnar plateau basalts with rhyolitic ash flows—in this case both sodic. The basalts are more aluminous, more alkali-rich, and more oxidized than the Karmutsen, hence these basalts may represent either a nearly complete remelting of Karmutsen lavas or a new tap of mantle materials somewhat contaminated by sial or slightly modified by differentiation. The origin of the large volume of Masset rhyolites presents the most difficult problem as their volume is so great. They were erupted with the basalts and in part slightly contaminated by basalt phenocrysts and magma, but must presumably have been generated at a level below that of any of the known geology, including by extrapolation that of Vancouver Island (Late Palæozoic Sicker Group basalts, etc.). One must look to southeastern Alaska with its Early Palæozoic plutonic rocks (Brew *et al.*, 1966) for a possibly buried source that could be sufficiently deep to have been mobilized and of suitable petrology. Figure 6–13 (Sutherland Brown, 1966, p. 100) shows in a section to the mantle a layer with intermediate seismic velocities similar to that of granite at about 10 kilometres that could be a source for the rhyolites. Figure 32 illustrates diagrammatically the present speculations on origin and lineage of the igneous rocks of the Queen Charlotte Islands.

The evolution of the sedimentary rocks is related to the whole tectonic process. The trend is indicated by Figure 33, which shows a ternary diagram of quartz, total feldspar, and rock fragments in sandstones from all sedimentary units. From the almost quartzless lithic sandstones of the Kunga Formation there is a fairly smooth trend of average composition toward the quartz-rich feldspathic sandstones of the Skonun Formation which are relatively poor in rock fragments. The Queen Charlotte Group presents a minor interruption in the trend as shown because the basal Haida sandstones which are relatively quartz-rich are proportionally too well represented, and also the Skidegate Formation as a whole is very much more feldspathic than the other sandstones of the group. Over-all feldspar increased sharply from Kunga to Maude but thereafter remained about 30 per cent, except in the Skidegate. Potash feldspar remained rare until the Haida deposition, thereafter the ratio to plagioclase remained in the range 1:5 to 1:10. Prior to the Skonun deposition, substantially all sediment appears to have been derived within the general region of the Queen Charlotte Islands. The Skonun, however, appears to have a minor admixture from distant and disparate sources. Nevertheless the trend is clearly set that from a low quartz basaltic " basement " all evolution, in igneous source rocks and sedimentary processes, have tended toward increasing quartz at the expense of rock fragments.

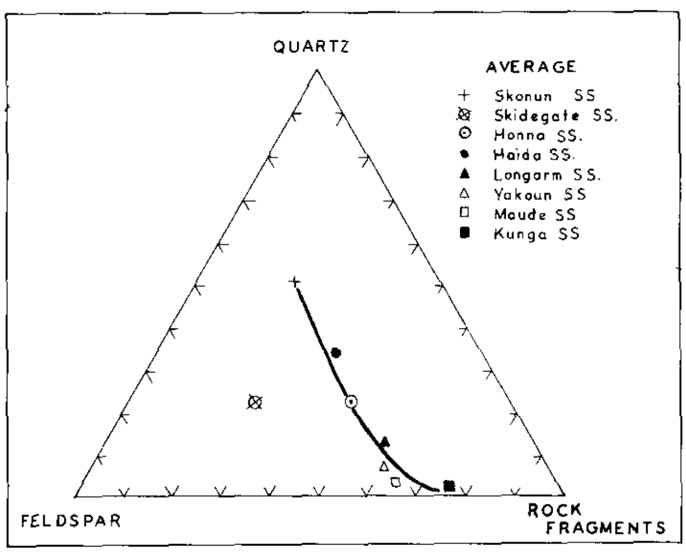


Fig. 33. Evolution of the sedimentary rocks.

CHAPTER 5

Mineral Resources

INTRODUCTION

The known mineral resources of the Queen Charlotte Islands are important because of their total quantity, their relationship to the development of the islands, and their position in the British Columbia economy. Vague and optimistic statements about the mineral wealth of the islands have been made at intervals for a century, but even preliminary realization has been delayed to the present. In 1966 iron concentrates to the value of approximately $5 million were shipped, and this may be expected to increase sharply and to be joined by copper concentrates when Tasu comes into production. Present reserves are sufficient for more than 20 years' production. In the future one may expect also some diversification in mineral products produced. Hydrocarbons may be found in economic amounts, and probably industrial rocks and minerals and possibly manganese will some day be exported. Shipments of peat moss, which could be considered a hydrocarbon, started in 1967.

Some idea of the importance of the known mineral wealth can be gained from the following information. The value of ores shipped prior to 1962 was not much more than one-half million dollars at today's metal prices. The value of iron concentrates shipped from the start of operations at Jedway until the end of 1966 was approximately $17 million. The value of reasonably assured ore at Tasu, Jedway, and Burnaby Island is estimated to be of the order of $200 million and an estimate of ultimate potential is about $400 million.

The following discussion and property descriptions were completed in 1965. Only minor revisions have been added since.

HISTORY

Mineral deposits in the Queen Charlotte Islands were first explored more than 110 years ago. Since then repeated cycles of boom and bust with accompanying initial optimism, unreal expectation, and quiet subsidence have followed one another until the recent past. The incomplete and even fanciful record of the early period together with the remote setting and occasional hostility of some of the Haida communities lend that period an exotic and legendary character. The earliest development at Mitchell Inlet in 1852 led directly to the establishment of the Queen Charlotte Islands as a Crown colony the following year. This venture, the first lode-mining in British Columbia, was variously reputed to have yielded $5,000 to $75,000 in gold, which was lost in transit in a wreck near Cape Flattery. The mining on Mitchell Inlet, then called Kuper or Gold Harbour, was under the direction of Captain Mitchell of the brig " Una " of the Hudson's Bay Company, and the vein was reportedly mined out in the short operation. A certain excitement was created by the news of this venture, which led to succeeding expeditions. These did not recover any quantity of gold, but one, led by a Major William Downie, discovered coal on Skidegate Inlet in 1859. In 1862–63 Francis Poole explored the vicinity of Skincuttle Inlet and discovered the chalcopyrite and magnetite showings near the present mill-site at Jedway and the cupriferous skarns on the Copper Islands and near the orebodies of the Jib (Burnaby Iron Mines Limited). He sank small shafts on chalcopyrite-rich skarn and on a vein both on the present Jib group, but is remembered chiefly for his fanciful account of his adventures (Poole, 1872). About the same time a shaft was sunk by a Mr. Waddington exploring for copper ore on the north side of Copper Bay. Coal exploration started about 1865, and full-scale preparation for mining was made at the Cowgitz " mine " between Kagan Bay and Long Inlet without adequate preliminary exploration or study. This venture closed in 1872 after the waste of much capital, but it did lead to the early investigations of the Geological Survey by Richardson, Billings, and Dawson. After the coal exploration tapered off, activity in general was slight until the beginning of this century.

Beginning in 1900 but particularly during the years 1906 to 1914, prospecting and development were intense and a large percentage of the showings known today were found. About 1900 A. Heino started once again the exploration of the cupriferous skarns of Skincuttle Inlet, which he continued for more than 30 years. Copper exploration was most active about Skincuttle Inlet, Lockeport, and Tasu Sound and led to the successful production from two significant mines and trial shipments from numerous other prospects. Direct shipments from the Lily mine, Ikeda Cove, began in 1907 and continued fairly regularly until 1920, and from the Warwick, now part of Tasu, Tasu Sound, in 1914 with a small production thereafter. Coal exploration was centred on Graham Island about the upper Honna and Yakoun Rivers and at Skonun Point. Once again large sums were invested and optimism was high. Exploration found coal but no significant mineable reserves. Foreclosure by a major investor in one of the companies combined with the start of the Great War finished coal exploration for the time. Once again, however, geological studies by Ells, Clapp, and MacKenzie were successively initiated primarily to aid coal exploration. Oil exploration was centred at Tian Bay on the west coast of Graham Island, where the logistic problems must have been formidable, and yet a 1,600-foot exploratory well was drilled by a standard rig. The exploration philosophy is baffling, for the hole was spudded in volcanic rocks of the Masset Formation remote from any sedimentary rocks. The venture started in 1913 and was abandoned in 1915.

Between 1918 and 1939 exploration was rarely intense, but some exploration and development of lode-gold prospects and beach placers occurred throughout the period, with effort concentrated on the Blue Mule at Kootenay Inlet; Homestake, Cumshewa Inlet; Early Bird, Mitchell Harbour; Southeaster, Skidegate; and placer at Shuttle Island and the northeastern beaches and Bluejacket Creek of Graham Island. Some work was also performed on copper prospects at Harriet Harbour and Louise Island.

Exploration was again at a very low level until the recent developments, which might be said to have started with the acquisition during the mid-1940's of the Crown-granted Ikeda claims by St. Eugene Mining Company (now Falconbridge Nickel Mines Limited). Interest in the skarn deposits of Tasu Sound was shown in 1953 by the purchase of St. Eugene of the key Crown-granted claims of Tasu at a Sheriff's auction and by prospecting by The Consolidated Mining and Smelting Company of Canada, Limited (now Cominco Ltd.). In 1954 Tasu was examined by Alex Smith of Falconbridge, the Garnet group on Tasu Sound explored by the Consolidated company, and the McMillin (Copper Queen) on Harriet Harbour by R. E. Legg. In 1955 St. Eugene purchased and located more claims at Tasu and continued exploration there and elsewhere. In 1956 activity reached a preliminary peak with drilling at Tasu by a newly formed St. Eugene company subsidiary, Wesfrob, and at the Copper Queen by Silver Standard; by prospecting of the Swede group at Lockeport by New Jersey Zinc, and the Ikeda claims by St. Eugene; and by the acquisition and preliminary investigation of the key claims of Jedway by Dr. J. M. Black and Western Canada Steel. The new *Mineral Act* in 1957 resulted in uncertainty and a cessation of most activity for the next two years. Meanwhile in 1958 the Department of Mines started geological mapping of Moresby Island as an aid to iron exploration, and in 1959 sponsored an aeromagnetic survey of a 15-minute strip south of 53 degrees. In 1959 and 1960 Silver Standard proceeded with the drilling of a number of properties on Harriet Harbour and had most success on the Jessie Crown-granted mineral claim, which was to become the heart of Jedway. 1961 was another active year, the highlights of which included the purchase by the Granby company of the Jedway property from Silver Standard and the decision to proceed to production, renewal of drilling and engineering studies at Tasu by Falconbridge, and the aeromagnetic survey for Dennison Exploration of a strip of the southeast coast of Moresby in which the Kunga Formation and a number of plutons were outlined on the preliminary geological map. This survey discovered a significant anomaly just off Burnaby Island, the site of the present Jib group. In 1962 Canex and Silver Standard drilled the Iron Duke on Louise Island, and in October Jedway Iron Ore Limited began shipments of iron concentrates to Japan. In 1963 Highland Bell drilled the anomaly off Burnaby Island and proved the existence of a major magnetite body, and Falconbridge completed drilling and exploration and early in 1964 announced sales contracts with Mitsubishi for Tasu iron and copper concentrates with production to start in late 1966.

Oil exploration has been intermittent and as yet unsuccessful. Royalite drilled an exploratory well near Skidegate in the winter of 1949–50. The hole was spudded in the Haida Formation but near a plutonic body which was reached by the drill at 3,300 feet. Little further occurred until Richfield Oil Corporation acquired considerable acreage on northeastern Graham Island and Hecate Strait and drilled five exploratory holes in 1958. After further study in 1961, a 6,000-foot hole was drilled and abandoned at Cape Ball. Exploration in Hecate Strait was continued by Shell Canada in 1963–65 without announced decisions.

CLASSIFICATION

The mineral resources of the Queen Charlotte Islands will be classified in the following discussion and description of properties as follows:—

A. Metallic minerals.
  1. Pyrometasomatic iron-copper deposits.
  2. Massive to disseminated sulphide deposits.
  3. Gold veins.
  4. Manganese veins.
  5. Placer deposits.

B. Industrial minerals and rocks.
   1. Limestone.
   2. Perlite.
   3. Bentonite.
   4. Diatomaceous clay.
   5. Carving slate.

C. Hydrocarbons.
   1. Coal.
   2. Lignite.
   3. Peat moss.
   4. Oil and gas.

DISTRIBUTION

Figure 34 shows the locations, types, and relative sizes of the mineral deposits of the Queen Charlotte Islands. The deposits are numbered from north to south and listed on the margin of the map. Certain geological features of importance are indicated, such as the distribution of plutonic rocks, the Kunga limestone, Masset Formation, and Skonun Formation. The importance of these features in the distribution of the various resources will become increasingly evident in the following discussion.

GENERAL APPRAISAL

Pyrometasomatic iron-copper deposits are by several orders of magnitude the most important mineral deposits now known in the Queen Charlotte Islands. Mineable reserves have a gross value approaching $200 million, and the ultimate potential of known economic deposits has a gross value of about $400 million. Not only are these deposits the most valuable, but they are the most numerous. There is really no distinct break between these deposits and those of the second category, massive and disseminated sulphide deposits. For the purposes of the report, the pyrometasomatic deposits are those with significant skarn minerals, magnetite, or both, whereas the others do not have these features. Massive to disseminated sulphide deposits have not been important to date but offer a distinct possibility in the future, for they are known to be present but are considerably harder to find. Gold-bearing veins are not rare, some have good values locally, but no property has yet developed enough tonnage and grade to provide a continuing operation. Only one important manganese " vein " is known, but others, if they exist, probably occur in a relatively unprospected part of the islands where outcrop is minimal. The importance of the known deposit has not been adequately tested. It is possible bedded manganese deposits could occur related to this or other sources. Deposits of placer gold and heavy minerals are found along the northeastern beaches where they are formed by storm action on glacial sands of adjacent sea cliffs. The parent sands are not rich in these minerals, and the concentrations have not proved large enough to support a continuing operation. The industrial minerals and rocks may not be exploited in the near future, but considerable volumes of high-calcium limestone occur near tidewater in sheltered locations, and eventually they may be utilized. Perlite exists on Graham Island, and suitably expansible material might be found by exploration. Little is known of the diatomaceous clay or bentonite, except of their existence. No mineable reserves of coal are known, and the possibility of developing them at today's economics is not great. Large volumes of lignite occur but not in thick beds near the surface, so that the possibility of exploitation is slight. Peat moss of excellent quality exists in large volume, and production started at a new plant in 1967. No bona fide oil or gas shows are known on the islands, and the results of the Richfield drilling was not encouraging. Nevertheless the considerable Late Tertiary section holds some promise of future discovery.

GENERAL DISCUSSION

A. Metallic Mineral Deposits

1. *Pyrometasomatic Iron-Copper Deposits*

Nature.—Pyrometasomatic iron-copper deposits are composed of magnetite and chalcopyrite in a range of relative proportions, usually with pyrite or pyrrhotite, and associated with a partial or complete envelope of skarn. They form a distinct type, characteristic of Vancouver, Texada, and Queen Charlotte Islands, which are united by similar stratigraphic setting, structure, form, and mineralogy. The description that follows is based on Queen Charlotte Islands occurrences but might with few changes be applied to them all. Many of the common features have been noted from the earliest studies, McConnell (1909) and Young and Uglow (1926), but recent studies have noted these features with increasing precision as a result of much greater detailed knowledge of the deposits gained from extensive drilling and development and of the regional geology (Bacon, 1952).

The significant deposits and the great majority of the lesser deposits have the following features:—

(1) At or within a few hundred feet of the contact of the massive limestone member of the Kunga Formation with altered basalts of the Karmutsen Formation.
(2) Near (within 500 feet) a plutonic body.
(3) Pre-ore diorite porphyry bodies present.
(4) Post-ore dykes abundant.
(5) Skarn envelope or partial envelope present—composed of garnet, epidote, tremolite, pyroxene, and chlorite.
(6) Pre-ore faulting present.
(7) Evidence of brecciation common.
(8) Massive bodies of magnetite or magnetite, chalcopyrite, pyrite, and pyrrhotite in variable proportions with variably sharp to gradational boundaries.
(9) Shape of the orebodies an interplay of a number of forms concordant or discordant to bedding.
    (*a*) Tabular-lensoid or lensoid swarm conformable with bedding.
    (*b*) Tabular discordant to bedding.
    (*c*) Pipe-like discordant to bedding.

    Orebodies may combine these shapes in varying degrees but concordant lensoid shapes are commonest.

TABLE XX.—CHARACTERISTICS OF PYROMETASOMATIC DEPOSITS

Deposit	Map No.														
	15	36	30	11	38	37	29	44	39	51	45	18	16	17	32
	Mineral Claim														
	Tasu	Jedway	Jib	Iron Duke	Lily	Adonis	Mac	Magnet	Rose	Thunder	Copper Queen	Apex	Garnet	Tasu, Old Townsite	Copper Island
Replaces—															
Limestone	×	?	×	×	?	×	×	?	?	×	?	×	×	×	×
Karmutsen	×	×	×	×	×	×	?	×	×	×	×	?	×	×	
Plutonic rocks	?	×	?	×	?				×			×			
Porphyry	×	×	?	?		?			×						
Plutonic rocks—															
Close	×	×	×	×	×	×	×	×	×	×	×	×	×	×	?
Type—															
Syntectonic	×											×	×	×	
Post-tectonic		×	×	×	×	×	×	×	×	×	×				
Pre-ore porphyry—															
Present	×	×	×	?		×		?	×	?		?	×	×	
Important	×					×			×						
Post-ore dykes, important	×	×	×		×	×				×	×	×		×	
Pre-ore faults, important	×	×	×	?	×	×		?		×					?
Breccias, important	×	?	?												
Orebodies, massive	×	×	×	×	×	×	×	×	×	×	×	×	×	×	
Form—															
Tabular, concordant	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Tabular, discordant	×	×	?			×	?			×			×		×
Pipe-like			?							×					
Oxide	×	×	×			×	×	×	×	×				×	
Oxide-sulphide	×			×						×	×	×	×		
Sulphide oxide					×								×		×
Metal-content—															
Iron—															
Large ($>10^6$ tons)	×	×	×												
Medium ($>10^5$ tons)				×		×	×	×	×	×		×	×	×	
Small ($<10^5$ tons)					×						×				
Copper—															
Large ($>10^6$ pounds)	×				×							×	×		×
Small ($<10^6$ pounds)										×	×				
Skarn—															
Important	×	×	×	×		×			×	×		×	×	×	×
Minor					×		×	×			×				

These features are shown on Table XX, which is a check list for all the important deposits and selected others. The locations of the deposits are shown on Figure 34, the mineral resource map. Inspection of the table will show how relatively uniform this group of deposits is. Some small massive magnetite bodies or larger disseminated bodies occur in the Karmutsen Formation basalts or minor limestones in this formation, or may occur remote from plutonic rocks. Pragmatic prospectors have considered none of these sufficiently large to be worthy of continuing ownership. All the significant deposits are in the preferred setting. In addition, the larger deposits all seem to have indications of pre-ore porphyry, faulting, brecciation, and normally abundant post-ore dykes. The skarn envelope is commonly better developed in the basalts or diorite porphyry than in limestone, both in regard to completeness and size. In a few deposits in limestone, skarn minerals are limited to the immediate vicinity of the magnetite, or even to the interstices of the magnetite grains.

The mineralogy of skarn and ore is also relatively uniform. Skarn formed from limestone is commonly composed of fairly coarse mid-brown garnet of the andradite-grossularite series. In other rocks, garnet is commonly developed only in the most intense skarns and is either fine or of irregular grain of more variable colour. Skarns formed from Karmutsen rocks are dominantly green rocks of chlorite, actinolite, epidote, and minor anthopyllite and orthoclase. Skarns formed of porphyries are lighter green, epidote, garnet, actinolite rocks. In both Karmutsen rocks and porphyries, remnants of the original texture are common. Minor quartz, calcite, and magnetite are present in almost all skarns. The ore itself is formed of a low titanium magnetite with scattered chalcopyrite, pyrite, or pyrrhotite, and rare high iron black sphalerite. The proportions of sulphide to oxide may be reversed; normally in such a case the ore is replacing limestone. Magnetite may be fine to coarse grained and is commonly coarser where replacing limestone. Replacement of volcanic rocks, porphyry, or diorite is, on the average, not as complete as of limestone, for inclusions of skarn or partly skarned rock of all sizes occur and the boundaries are generally gradational. Ore replacing limestone also commonly has small areas of coarse calcite, the boundaries of which invariably have the coarsest well-crystallized magnetite so that the calcite appears like a vug filling. Scattered or massive garnet may occur within ore in limestone but rarely chlorite, epidote, or amphibole. Sulphides occur as smooth blebs or streaks, as irregular filling of interstices, or as veinlets with clear quartz. Copper and zinc sulphides are commonest in limestone or orebodies replacing limestone and pyrite or pyrrhotite in orebodies replacing igneous rocks.

Origin.—The origin of the pyrometasomatic iron-copper deposits of the coastal islands has received considerable attention but mostly through detailed field and microscopic study (Swanson, 1925; Jeffery, 1961; Stevenson and Jeffery, 1964; Sutherland Brown, 1963; Eastwood, 1966). Geochemical, thermodynamic, and theoretical aspects have had less attention and are still needed (Sangster, 1964; Eastwood, 1965). A consensus has been reached about the ultimate source of iron, although the mechanisms of concentration, conduction, and introduction are not outlined with detail nor confidence.

The nature of the deposits limits the possible origins. A glance at the mineral resources map is enough to reaffirm that the basic setting is not accidental. These deposits are all close to plutons which intrude the Karmutsen Formation, and deposition has generally occurred at or near the basalt-limestone contact. The Karmutsen basalts are abnormally high in iron as well as soda, with total iron oxides content about 13 per cent (*see* pp. 46–47). The plutons not only intruded the Karmutsen Formation, offering an opportunity for assimilation, but also seemingly originated by differential melting and mobilization of the Karmutsen Formation (*see* pp. 145, 161). Therefore, there is an available source of iron that spatial data suggest is the actual source.

The physical conduit system for the metallization is believed to be more nearly akin to hydrothermal processes than was believed in early studies concerned with skarns developed exclusively at intrusive contacts. Most significant deposits are definitely associated with either mineralized pre-ore faults or breccia pipes. Most of the larger deposits are also associated with pre-ore irregular diorite porphyry bodies which are more or less confined to their vicinity. The porphyry bodies provide a great contrast in physical properties to either the limestone or chloritic basalts and behave brittly. Brecciation results in deformation and a permeable, reactive environment. Recent underground development at Texada Mines Ltd., Texada Island, reveals the lower conduit system and the structural relations of porphyry, limestone, volcanics, breccia, intrusive rocks, and skarn orebodies. The orebodies form an upward branching system that follows a zone at the contact of the intrusive rocks in which irregular porphyry bodies and breccia are important. Where the system reaches the gently dipping limestone, both porphyry and orebodies blossom out. The whole system appears to have been a breccia pipe before it was largely replaced by skarn and magnetite (Sutherland Brown, 1964, pp. 146–151). Similarly, the Kingfisher orebodies at Empire mine on Vancouver Island are pipes of circular cross-section which bifurcate upward and are localized along a pre-ore fault (Jeffery, 1960).

The chemical mechanism for the transfer of the iron, alumina, and silica into, and other materials out of, the ore zone is not as obvious. The actual transfer of materials in a pyrometasomatic deposit is large and in replacement of limestone is very obvious. Replacement of basalt and porphyry involves more complicated transfers, such as the net increase in CaO in the skarn zone in contrast to a decrease in limestone skarns. This was suggested by the writer (1962) and demonstrated for the Prescott orebody of Texada Mines Ltd. by Sangster (1964, p. 173). On considering the origin of colloform magnetite from the Kingfisher ore pipes replacing limestone, Stevenson and Jeffery (1964) conclude that rapid deposition occurred from a gel that approximates the chlorite solutions proposed by Holser and Schneer (1961). A complete review of these aspects is beyond the scope of this bulletin and has recently been well done by Sangster, who concludes (1964, p. 134):—

"Skarnification, which took place in the temperature range 700–550° C., generally preceded the main stage of magnetite deposition. Conformity to Gibbs Phase Rule and non-appearance of incompatible phases is strong evidence that equilibrium was attained during skarnification. Neutralization of iron chlorite solutions by calcite resulted in precipitation of magnetite in the temperature range 400–550° C. Ore fluids, originally one phase, probably developed into a two-phase system at lower temperatures. These fluids increased in pH by reaction with calcite until they reached at least 7.8, the minimum stability pH of calcite. Magnetite first filled cavities in skarn and brecciated volcanic rocks, then diffusion into, and replacement of, volcanic rocks took place. Where the volume of host rock dissolved exceeded the volume of metasome deposited, cavities were formed, some of which were later filled by magnetite or by post-ore calcite and/or quartz."

2. *Massive to Disseminated Sulphide Deposits*

These deposits are arbitrarily distinguished from the pyrometasomatic deposits by their lack of magnetite or skarn minerals. It seems clear there is a gradation in character from massive magnetite deposits without significant sulphide, through sulphide-rich deposits with magnetite and skarn, to massive sulphide deposits without these accessories, to disseminated sulphide deposits also without skarn or magnetite. Known massive and disseminated sulphide deposits are not as common as the pyrometasomatic deposits, but are harder to find so may be more abundant than they appear. Whether their relative scarcity is real or apparent, they are not well enough known to treat adequately. The Swede group of disseminated chalcopyrite in Karmutsen basalts with occasional small veins of chalcopyrite forms one type representative of this group, and the Johnson Nickel property of massive sulphides—chalcopyrite and pyrrhotite, with minor bravoite and pentlandite—is representative of the more massive deposits. An additional type common in plutonic and some volcanic rocks is pyritic shear zones which may contain traces of chalcopyrite.

3. *Gold Veins*

Gold-bearing veins are not rare in the Queen Charlotte Islands, but none have proved large enough to support a continuing operation. Five properties have fairly extensive workings—Early Bird on Mitchell Inlet, Blue Mule on Kootenay Inlet, Cumshewa on Cumshewa Inlet, Southeaster near Skidegate, and Ellen on Shuttle Island. The setting of these deposits is varied, but they are normally in volcanic rocks, either Karmutsen basalts or Yakoun agglomerates or volcanic sandstones. The veins are not distributed in any obvious relation to plutons of either type nor to major fault or fold structures. However, all are stringer vein systems associated with steeply dipping minor faults. In several the amount of quartz present is small, and carbonate, vein breccia, and gouge are as prominent. They are sparsely mineralized with pyrite, traces of chalcopyrite, and some fine free gold. Wallrocks are slightly chloritized and silicified. The Southeaster is in many ways the largest, with a quartz-filled vein 2 to 20 feet wide and about 1,000 feet long which contains lenses of sulphides. In contrast the Early Bird has explored over 200 feet of a ramifying narrow stringer vein system with little quartz or sulphide but occasional concentrations of free gold. No new development has occurred since World War II, so that access to workings on these properties is not generally good.

4. *Manganese Veins*

Manganese " veins " are represented by one known example, the Shag Rock property near Klashwun Point on the north coast of Graham Island. This is a breccia-filled fault cemented by manganese oxides within the Masset Formation. It is exposed naturally on the tidal zone in an area with few other exposures in a region that is little prospected. The indications are that the fault is a significant structure with continuity over distances much greater than the exposure. The breccia of volcanic fragments is very nearly sealed by the manganese oxides, and ramifying veinlets extend into the fault walls. The mineralogy of the oxides—manganite with lesser pyrolusite and traces of hausmannite and jacobsite, together with banded textures with open drusy vugs filled with minute crystals of dolomite and adularia(?)—indicate a primary hypogene origin (Hewett, 1964). The setting within layered basalt (and rhyolite) supports this conclusion, and the presence of Cape Knox type porphyry may be an added factor.

5. *Placer Deposits*

Investigation of placer deposits on the Queen Charlotte Islands has occurred intermittently for a hundred years. Most activity has been on the beaches of the north and east coasts of Graham Island from Tlell to Masset, but one endeavour was on Shuttle Island in Darwin Sound. Until recently all the efforts were to recover gold in heavy mineral concentrates, but in 1957 the iron or titanium content was the chief concern. "Black sand" and gold concentrations were mentioned by Dawson (1878, p. 33B) and were known before. The heavy mineral concentrates on the east coast result from reworking during southeast gales of Pleistocene and, possibly at some stages, Skonun sands exposed in cliffs along the coast. On the north coast the situation is similar, but the shore is not currently being eroded and concentrations are smaller. The parent materials are in all respects quite average without abnormal amounts of heavy minerals, and it is only secondary concentration by storms of beach sands that creates local deposits worthy of economic consideration. These sands were studied by Holland and Nasmith (1958) at a time when they were being drilled by Mogul Mining Corporation and investigated by two other companies. Holland and Nasmith state (1958, p. 6):—

"Numerous unsuccessful attempts have been made to mine the beach sands for their gold content. Placer-mining took place at Cape Fife, along a 3-mile stretch of beach 5 miles south of Cape Fife, along a stretch south of the mouth of Oeanda River, and in a small area at the mouth of Blue Jacket Creek a mile south of Masset. These are areas where there has been a concentration of magnetite in the normal sand into lenses possibly a few inches thick (from 1 to 8 inches normally), a few tens of feet wide, and possibly 500 or more feet long. The lenses might possibly average 50 per cent magnetite, and consequently represent a fairly high ratio of concentration of the normal beach sand. The small amount of placer gold the lenses contained was never sufficient to support a profitable operation other than for a few individuals."

On Shuttle Island a small gravel beach has been worked for placer gold on several occasions. Local small gold-bearing veinlets appear to have been eroded with gold concentrated quite locally.

B. Industrial Minerals and Rocks

No industrial minerals or rocks have been exploited nor even much studied, yet with the advantage of proximity to the ocean that applies to most of the islands it will be surprising if some are not utilized within the coming few decades. The only exceptions are slate used for carving by the Haida Indians, which has been quarried in a small way for at least 150 years, and suitable rocks quarried for road construction. A brief discussion follows about limestone, perlite, and diatomaceous clay and carving slate. There is no description of properties, but localities are marked on the mineral map (Fig. 34).

1. *Limestone*

The lower two members of the Kunga Formation represent the main limestone resource of the Queen Charlotte Islands, particularly the basal massive grey limestone member. This unit is the correlative of the main Quatsino or Marble Bay limestone that has been so extensively utilized on Vancouver and Texada Islands. It comformably overlies the Karmutsen Formation and is widely distributed on the Queen Charlotte Islands. It is rarely cherty or dolomitic, but may contain abundant dykes and sills. Its thickness varies from less than 100 feet to more than 600 feet.

Analyses were made of samples from two localities of the normal basal massive grey limestone member. They were not collected to represent either especially good or even average limestone. At Kunga Island, J. W. McCammon collected chips every 20 feet over 500 stratigraphic feet along the south shore. At Limestone Island the writer collected three samples across separate repetitions representing about 200 stratigraphic feet.

ANALYSES

	Limestone Island[1]	Kunga Island
Insoluble	2.37	4.29
R_2O_3	0.33	0.21
Fe_2O_3	0.25	0.17
MnO	0.03	0.07
MgO	0.06	0.11
CaO	54.45	53.20
P_2O_5	Under 0.001	0.21
S	0.006	0.004
Ignition loss	42.74	42.03
H_2O, 105° C.	0.01	0.06

[1] Average of three.
Analysis by Analytical and Assay Branch.

Thicker than normal sections occur at the following localities: Tasu mine, Kunga Island, southeast Burnaby and Copper Islands, Sandilands Island, Gillatt Arm. Bleached white limestone to marble occurs at Tasu mine, Lockeport, southeast Burnaby Island, and other localities. Good outcrop on sheltered tidewater occurs at Sandilands Island, upper Newcombe Inlet, Tasu mine, Gillatt Arm, Lockeport, Crescent Inlet, and near tidewater at Skidegate and Mosquito Lakes.

2. *Perlite*

Perlite occurs in dykes and flow-like masses in rhyolitic units of the Masset Formation. Expansible glass in the Queen Charlotte Islands was first reported by Mathews (1949, p. 7) from a locality, Lunch Island, in Juskatla Inlet. This was a vitrophyre, as are many rhyolites of the Masset Formation, but it was not perlitic. True perlites were found at a number of localities by the writer, but none of the samples tested were exceptionally expansible. Better material could likely be found with search. The map shows localities in which perlitic rhyolite was observed. These include localities above Skelu Bay, near Port Louis on Ironside Mountain, the head of Coates Creek, on Blackwater Creek, and at the junction of Gold Creek with the Yakoun River.

3. *Bentonite*

During the road construction from Juskatla Camp, a quarry was opened on a seemingly solid Masset volcanic rock on Blackwater Creek. It turned out to be a very poor road material, and some was sent to the writer for examination. It was found to be bentonite.

4. *Diatomaceous Clay*

Diatomaceous clay is exposed in some cutbanks along the lower Yakoun River between Black Bear and Canoe Creeks. These diatomaceous clays are part of the Upper Skonun Formation, presumably uppermost marine Pliocene unit. They are thus the only known marine diatomaceous rocks of British Columbia. One bed is about 10 to 12 feet thick. Sandy Davidson, of Shell Canada Ltd., described them to the writer, who has not seen them.

5. *Slate for Carvings*

The slate or argillite used for carving by the Haidas is a fairly unique rock composed of silt-sized fragments of kaolinite and less montmorillonite in a macerated very fine carbonaceous clay matrix that forms some 40 to 75 per cent of the rock. There is no detrital quartz, and any detrital feldspar appears to be altered to kaolinite. In addition, crudely barrel-shaped grains of kaolinite with a different texture appear to be porphyroblasts that have grow out of the fine matrix. The rock has a well-developed fine foliation but is compact unless sharply hit. The Haidas have a Crown-granted mineral claim centred on the site of their small quarry near Slatechuck Creek, 1½ miles from Kagan Bay. The quarry is not far from a faulted contact of Masset Formation. Some doubt remains regarding the precise stratigraphic location within the Queen Charlotte Group. It has always been said to be in the Haida Formation and could be in the upper shale member, but the interpretation shown on the map (Fig. 34) places it in the Skidegate Formation. Only detailed work in this region of abundant faults, complex folding, and relatively poor exposure in tangled logging slash could resolve the problem. There is a considerable tonnage of the rock on the claim, although not all is of good quality (that is, some contains detrital minerals). A similar rock without the low-grade metamorphism induced by the folding and metamorphism by the adjacent eruption of the Masset Formation would be unlikely to have the same subtle characteristics that make the rock desirable for carving.

C. Hydrocarbons

No fossil fuels are currently being exploited, and the potentiality to produce coal or oil and gas remains to be proven. Abundant lignite exists, but economically mineable reserves are not known. Production of peat moss started in 1967.

1. *Coal*

At various times in the past the coal resources have been stated to be important, but proven reserves are meagre. Clapp (1914, p. 38) calculated the proven reserves as 6,900,000 tons and estimated the probable reserves as large. The writer believes the geological basis on which probable reserves were projected was faulty, so that only a new full-scale exploration programme could produce realistic figures. No significant exploration has occurred since 1914, and developments in the years immediately previous are fully reported by Clapp (1914, pp. 29–39) and MacKenzie (1916, pp. 119–158), both of whom saw workings which are now inaccessible. Hence this account will be concerned primarily with the geological premises on which reserves were projected.

Exploration was concentrated near Slatechuck Creek (Cowgitz and Slatechuck), of the headwaters of Brent Creek (Camp Anthracite and Camp Robertson), on Baddeck Creek near Yakoun Lake (Camp Trilby), and near the Yakoun River on Wilson Creek (Camp Wilson). The quality of the coals evidenced by the analyses (Clapp, 1914, pp. 31–36; MacKenzie, 1916, pp. 125–157) is good for some localities or specimens, but on the average the coals are rather high in ash. They range from low volatile bituminous to sub-anthracite. Unfortunately all except Camp Wilson are from relatively thin seams or aggregates of seams with much intercalated shale. No seam is much more than 2 feet thick. At Camp Wilson a lenticular seam varies from 4 to 18 feet thick within about 50 feet in the workings, and the writer believes pinches out entirely in a few hundred feet. The greatest apparent continuity exists between Camp Robertson and Camp Anthracite; in the former 2½ to 4 feet of coal occurs within 8 feet of beds and at the latter 4½ feet of coal occurs within 9 feet of beds.

The difficulty of correctly distinguishing between sandstones of the Haida and Yakoun Formations has perplexed all geologists concerned, from Dawson to the writer, and this problem is fundamental to the discussion of coal reserves. With experience most individual outcrops can be assigned with confidence to one unit or the other but other outcrops cannot. Fortunately fossils are abundant in the Haida Formation and not rare in the Yakoun. Otherwise, considering the facies changes in the Yakoun, the faults, and the abundant cover everywhere, the problem would be much more difficult. The question is of considerable importance because the coals have been thought to be in the Cretaceous Haida Formation, whereas at least those of Wilson Creek can be proven to be Middle Jurassic Yakoun Formation. By abundant plant microfossils in the coal and by ammonites and other invertebrate in the sandstones, the whole of the "Yakoun Basin" of MacKenzie is apparently Yakoun Formation, not Haida (*see* p. 75). The writer has not seen the area surrounding Camp Robertson, and it is mapped as Haida Formation following MacKenzie, but the possibility of it being Yakoun Formation overlain by Haida is now considered likely. The Haida Formation is believed to be entirely marine where it is well exposed, but characteristically it contains in its lower part not only carbonized logs, branches, and twigs, but also rounded coal pebbles, which the writer now believes represent eroded Yakoun coal. On the other hand, the writer also has no confidence that the coal of Slatechuck and Cowgitz is within the Haida Formation, and although it is within the Queen Charlotte Group, the structural complexity of this area precludes certainty as to the formation. Whatever the unit, it is apparently non-marine, and this may be explained by being adjacent to the active fault line from which detritus was shed into the basin. The Cowgitz coal is apparently adjacent to the very large dyke of Masset Formation in the centre of the peninsula, and the contact has been the locus of later faulting.

In conclusion, it looks as if instead of a simple situation of coal existing at about one horizon of the Haida Formation which can be expected to exist over a major part of the basin with attendant large possible reserves, one is actually dealing with coal of at least two periods, in one of which coal was deposited on the flanks of volcanoes in a medium of rapid facies change and in the other in another environment in which not much continuity should be expected.

2. *Lignite*

There is an abundance of lignite in the Queen Charlotte Islands, but again there is no known economic reserve. Within the Skonun Formation there is much lignite, as shown by surface outcrops of the type locality and by the Richfield wells. In the southern basin, lignites occur in quantity only in the lower non-marine member, which at Cape Ball occurs at 3,500 to 5,000 feet depth, and at Tlell from 3,250 feet to the total depth of 4,120 feet, and at Gold Creek 2,500 feet to the base of the formation at 3,810 feet (*see* Fig. 20 and pp. 120–124). This member becomes thinner and appears to be overlapped by younger members as it approaches the basin edge, so that there would be no significant lignites at open-pit mining depths. However, some beds about 1 foot thick outcrop at the mouth of Chinukundl Creek. In the northern basin, lignites appear to occur throughout the section but primarily in the upper non-conglomeratic portion (*see* Tow Hill well, Fig. 20). The northern basin is disturbed by faults and folds but is really only known from the Tow Hill well and outcrops and the outcrops at Skonun and Yakan Points. The outcrop at Skonun Point is described in some detail on page 121. Thirteen beds of woody lignite occur, of which nine are exposed, with an aggregate thickness of about 20 feet in some 200 feet of shale. The thickest bed exposed is but some 3 feet thick (in an old drill-hole the thickest is 6 feet thick). The beds occur in a faulted west-plunging moderately compressed anticline. An exploration programme might find significant deposits of lignite at relatively shallow depth in the northern basin, although the Skonun locality is not in itself overly interesting. Analyses of lignites from Skonun Point are quoted by Clapp (1914, pp. 38–39) and MacKenzie (1916, p. 157).

3. *Peat and Peat Moss*

Very large reserves of post-glacial peat and peat moss occur on the Queen Charlotte Lowland, which is in large part organic terrain. The problems of exploitation are not those of reserves but of handling and marketing. The quality of the Queen Charlotte peat moss is reported to be excellent. An operation to mine the peat moss by hydraulic methods started production in 1967.

4. *Oil and Gas*

The possibility of producing petroleum and natural gas on the Queen Charlotte Islands has received some attention since 1913, when the first exploration hole was drilled near Tian Head. Not until Richfield Oil Corporation conducted their programme from 1958 to 1961 had there been any intensive exploration. Richfield conducted a geological survey in the summer of 1958, drilled five holes, and ran marine seismic and sparker surveys in Hecate Strait in the winter of 1959, ran further helicopter-supported seismic surveys ashore in 1960, and drilled a 6,000-foot well at Cape Ball in 1961. In 1963 Shell Canada started geological mapping on the islands and offshore studies in Hecate Strait as part of a general offshore programme in British Columbia.

The character of the various units is treated at some length in Chapter II. The older units have not been the target of recent exploration because they are considered too deformed, metamorphosed, and faulted, and most of the arenaceous rocks do not have suitable permeabilities. Perhaps the flaggy carbonaceous upper members of the Kunga Formation and the Haida sandstone-shale interface deserve more study and consideration, the former as an oil shale. MacKenzie (1916, pp. 161–166) treated the tar contained in vesicles in volcanic rocks of the Masset Formation in detail. The writer observed other localities with tar-filled vesicles, including one in the Yakoun Formation. The common denominator of most of these occurrences is that the flows concerned immediately overlie sandstones or shales that contain much woody matter. Hence the tar would seem to be a wood distillate.

Recent search has been concentrated on the Mio-Pliocene Skonun Formation, the correlatives of which have proven productive in California and Alaska. The thick sand member of this formation in the southern basin (*see* Fig. 20) is very porous and permeable. Unfortunately being almost unconsolidated, it is not well represented in the cores. The underlying member of equivalent thickness contains much lignite and appears to be largely non-marine. Only one slight area of stain was noticed in all the core, in the Tow Hill well at 1,730 to 1,735 feet not far below the sills. The Richfield cores and cuttings are stored at Charlie Lake, British Columbia, and logs are available at the Petroleum and Natural Gas Branch in Victoria. The character of the formation as represented by the cores may be expected to change both basinward and north of the north coast. Only an elaborate and expensive programme can test whether this considerable basin of young sediments has a real possibility of petroleum production.

DESCRIPTION OF PROPERTIES

A1. Pyrometasomatic Iron-Copper Deposits

Northwester (4)

The Northwester showings are found at an elevation of about 2,200 feet on the steep south slope at the head of Van Harbour. They were discovered in 1928 by George McRae and Archie Dewall and have been held intermittently by located claims, most recently by Mastodon-Highland Bell Mines Limited with 11 claims of the Magnet group. In 1962 this company carried out geological, magnetometer, and E.M. surveys to explore the area of mineralization.

The Northwest is a pyrometasomatic replacement deposit in the typical setting. The showings occur in the southwest corner of a large pendant that includes Karmutsen to Yakoun and possibly Masset Formations; the pendant is essentially surrounded by various phases of the Kano massif. The showings are at the contact of Karmutsen greenstones and a band of Kunga grey limestone, and some flaggy black limestone which outcrops along the steep slopes at about 2,100 to 2,400 feet elevation. The Kunga Formation is overlain by Yakoun andesites and volcanic sandstones. Near the showings the sequence strikes about north 60 degrees east, dips steeply to the northwest, and is cut by many andesite and basalt dykes. Faults are numerous nearby but are not definitely identified at the showings. Kano diorite outcrops below the showings to an elevation of about 1,000 feet.

The showings consist of pods of actinolite garnet skarn, and magnetite with chalcopyrite at or near the Kunga-Karmutsen contact and distributed over 1,400 feet along strike. Judged by the surface geology and magnetometer survey, there is no large body of magnetite at or near the surface. Some small lenses contain up to 1 per cent copper, and large float blocks of high-grade chalcopyrite occur down the slope from the showings. A few showings are on inaccessible cliff faces, but none of the accessible ones are of such a size or grade to be copper ore.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1928, p. C 64; 1962, p. 10; Assessment Report No. 495.]

Iron Duke
(11)

This property consists of 10 Crown-granted claims and fractions and has included a varying number of located claims. The Crown-granted claims are Lots 2331 to 2340. The ownership is dispersed, but Campbell M. Robertson, of New Westminster, one of the owners, has had an agreement with the others that enabled him to explore the property or negotiate regarding it.

The property is on the slope north of Waste Creek, about 2½ miles west of Girard Point on the northeast coast of Louise Island. The elevation of the creek is about 850 feet, the main showings between 1,000 and 1,400 feet, and the ridge-top about 1,500 feet. Most of the known ore and the magnetic anomaly are on Iron Duke No. 2 claim, Lot 2333, but both extend uphill onto the southwest corner of Iron Duke No. 1, Lot 2332. The property can be reached by an indifferent trail that climbs steeply from the beach, 4,000 feet west of Girard Point. Much of the servicing of the property during recent exploration was by helicopter.

The property was discovered in 1911 and surveyed and Crown granted in 1921. Most of the physical work on the property other than the recent diamond drilling was done about 1918. The early work included an 80-foot adit and a minor amount of test-pitting. Recent work started with an examination and magnetometer survey by Silver Standard Mines Limited in 1959. During 1961 exploration initiated by Campbell Robertson included a geological examination and an attempt to build a road to the property from the shore near Mathers Creek. In the autumn the property was optioned by Magnum Consolidated Mining Co. Ltd., who made a magnetometer survey of the property and a geological map of the vicinity. Two diamond drills were moved to the Iron Duke late in 1961, and in January and February, 1962, 15 AX holes were drilled totalling 3,054 feet. Later in the year Silver Standard optioned the property and drilled 33 EX holes totalling 4,805 feet.

The claims and area surrounding are largely covered by glacial till and heavily forested, hence outcrop is relatively rare. On the showings, till is generally 10 to 30 feet thick. However, nearly 8,000 feet of short-hole diamond drilling and magnetometer surveys enable one to draw a diagrammatic geological map (Fig. 35) and sections (Fig. 36).

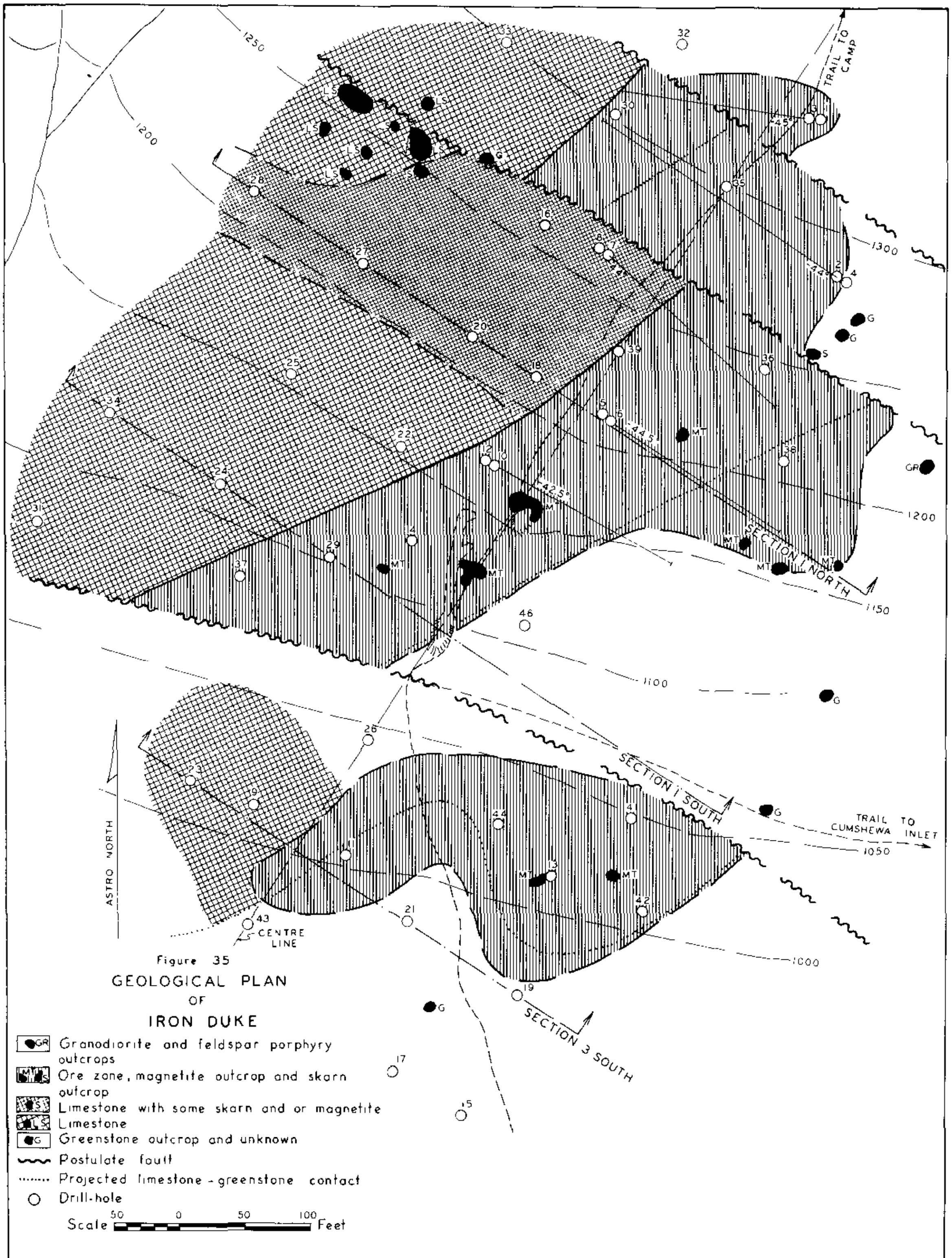


Figure 35
GEOLOGICAL PLAN
OF
IRON DUKE

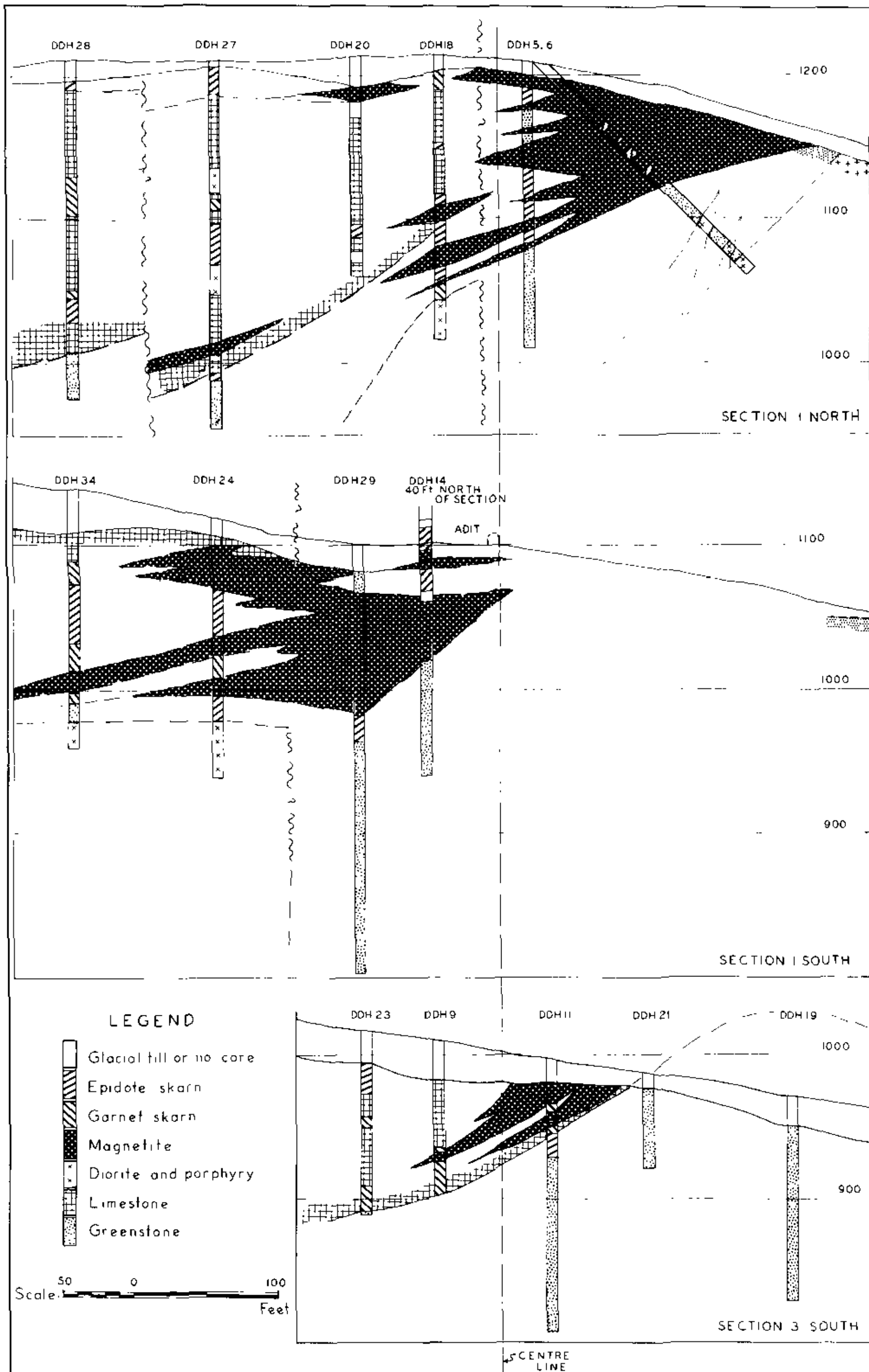


Fig. 36. Iron Duke, cross-sections.

The Iron Duke is a normal pyrometasomatic iron deposit in the typical stratigraphic setting. A thick grey limestone that undoubtedly is the Kunga grey limestone member overlies chloritized basaltic rocks, certainly Karmutsen Formation. These are intruded by contaminated and altered diorite to granodiorite and some diorite to dacite porphyries. The limestone and adjacent Karmutsen greenstones are extensively skarnified and replaced by magnetite and minor iron sulphides. The diorite and porphyry appear kaolinized, chloritized, silicified, pyritized, and even epidotized in varying degree, but they have not been observed highly skarnified or replaced by significant magnetite.

The structure of the host rocks is shown by the plan and sections, Figures 35 and 36. The Kunga limestone overlying the Karmutsen greenstones strikes north to north-eastward and dips gently westward. A minor anticline and syncline are evident at the south, but the orientation of the axes is not. Diorite to dacite porphyry dykes cut the bedded rocks, and diorite to granodiorite intrude the greenstones at relatively shallow depth and outcrop sporadically to the east for one-half mile. The magnetite ore indicated by magnetic anomalies, drill core, and exposure occurs in a dislocated northeast-trending zone that lies adjacent to the limestone along a band that is coincident with the projected limestone-greenstone contact. Judged by position alone, the ore appears chiefly to replace the basal part of the limestone, but other considerations suggest this may not be entirely correct. An alternative explanation that the ore zone is located along a northeast pre-ore fault situated approximately along the western trace of the ore zone has the following to recommend it: (1) There is a major discontinuity in rock types below the ore zone along this line with intrusive rocks appearing at a high level west of the line and volcanic rocks east; (2) minor volcanic rocks occur within the ore zone. If the correct interpretation is a pre-ore fault, then the majority of the ore replaces greenstone that is adjacent to the limestone. In any case the host rocks and the ore zone are cut by three steep post-ore faults trending about north 60 degrees west, with offsets of from 50 to 300 feet. These faults were not encountered in drill-holes but are evident from the plan and from the company magnetometer maps.

The shape of the ore zone is fairly regular in plan, assuming offset by the post-ore faults. It is then about 960 feet long, trending northeastward and up to 200 feet or more wide. In normal cross-sections it is a wedge-like mass with highly digitated margins. The ore consists principally of magnetite and may be quite pure, but commonly has some disseminated skarn minerals and much pyrite. Chalcopyrite is relatively rare. Intercalated within the ore are sections that are formed principally of skarn minerals. Skarn also envelopes the ore zone, has a similar digitated wedge-like form, but extends much farther as wing-like sheets from the ore zone. These appear to follow particular bands in the limestone. The skarn may be characterized as either garnet skarn or epidote skarn. Tan garnet skarn most commonly replaces limestone and may be quite pure garnetite or contain minor amounts of magnetite, epidote, and calcite. Epidote skarn is commonly bright green, less pure, and contains significant garnet, magnetite, and chlorite, and most commonly replaces greenstone.

Reserves calculated by Silver Standard and its consultant geologist, D. D. Campbell, from all drilling are 546,000 tons proven and probable ore of 46 per cent iron as magnetite with an additional possible 36,000 tons. Sulphur may average 2 per cent.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1918, pp. 43–44; 1961, p. 17; 1962, p. 13; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, 1926, pp. 27–30.]

Tasu (15)

The Tasu mine is located on Tasu Sound, west of the entrance to Fairfax Inlet (*see* Plate XVIIA). The property consists of 21 Crown-granted claims and 50 recorded claims that stretch from Tasu Peak to Lomgon Islets. The property is held by Wesfrob Mines Limited, a wholly owned subsidiary of Falconbridge Nickel Mines Limited.

The history of the property began in 1908, when the Elliott Mining Company located 20 claims, the Warwick group, on the cupriferous magnetite showings of what is now called No. 3 zone. Over the next six years several options were taken on the property. Exploration and development work included driving a 300-foot-long adit at 1,180 feet elevation on the Tassoo claim, Lot 604, and sinking a 40-foot-deep winze. Over the following four years, mainly in 1914, the property produced 5,180 tons of ore yielding 94 ounces of gold, 1,408 ounces of silver, and 165,566 pounds of copper, from two stopes on the adit. During this period a lower adit at 1,060 feet elevation was driven 200 feet, but not far enough to encounter the ore. The property was thereafter inactive until the two key claims, Tassoo and Warwick, Lot 615, were acquired in 1953 at a tax sale by St. Eugene Mining Corporation, a subsidiary of Falconbridge. Adjacent recorded claims located in 1952 by Albert Jones, of Skidegate village, were purchased in 1955, and in 1956 a new wholly owned company, Wesfrob Mines Limited, was formed to explore and develop the property. In 1956 and 1957 exploration included 22,285 feet of packsack, EX, and AX diamond drilling. No further work was then done until 1961. Exploration and development thereafter have been continuous, leading to the decision early in 1964 to prepare for production. A total of 132,162 feet of core of all sorts had been drilled to the end of 1964 (*see* Plate XVIIIA). An expenditure of $25 to $30 million was estimated to be required to bring the property into production at a planned rate of 8,500 tons of ore per day. The mine was officially opened in June, 1967.

The plant produces both sinter- and pellet-feed iron concentrates and a copper concentrate. Production of 855,000 to 1,045,000 metric tons of concentrate per year is contracted to Mitsubishi Shoji Kaisha.

Reserves were stated in December, 1965, to be as follows:—

REASONABLY ASSURED

Zone	Million Short Dry Tons	Iron	Copper
1	11.66	40	....
2	8.37	38	0.14
3	7.50	48	0.66
Sub-totals	27.53	41	......
INDICATED			
4		Not drilled off.	
5	15.65	45	0.20
Totals	43.18	43	......

More recent recalculation by computer has not significantly changed these. The various zones referred to above are shown on the plan, Figure 37. Of the known ore, about 20 million tons is expected to be produced by open-pit mining.

Geology

Tasu, like the Jessie, is one of the standards by which other coastal pyrometasomatic iron-copper deposits must be judged. Extensive drilling together with moderately good exposure, considering the forested nature of the area, have led to a fairly detailed knowledge of the deposit. Complete stripping during mining may be expected to revise and clarify concepts to some degree.

The Tasu deposit seems unique in two ways: its great size in comparison to others and the abundance and importance of pre-ore porphyry. A third feature that may be distinctive is its association with a syntectonic batholith rather than post-tectonic stock.

Figure 37 is a general plan of Tasu, showing the surface geology and the numbered ore zones. The essential structure is a folded and tilted panel of stratified rocks surrounded and underlain in part by the northern termination of the San Christoval Batholith. The stratified succession includes the upper part of the Karmutsen Formation and the three members of the Kunga Formation. Only the two limestone members are closely involved in the ore zones. The stratified panel was repeatedly intruded by igneous rocks from its initial formation to late in the geological history of the area. First, Karmutsen basalts were cut by minor related sills. Next, a complex laccolith of diorite porphyry of considerable importance was emplaced principally between the Karmutsen and the Kunga Formations. Then the San Christoval Batholith was emplaced, followed by skarnification and mineralization. Finally two volumetrically important post-ore dyke swarms, the earlier andesitic and the later basaltic, were intruded. The magnetite ore and associated skarn very largely are found in a stratiform zone some 200 feet thick above the top of the Karmutsen Formation, replacing massive limestone and diorite porphyry.

Petrology

The Karmutsen Formation is largely composed of massive amygdaloidal greenstones that have been subjected to varying degrees of metamorphism or metasomatism. Minor occurrences of what appear to be aquagene tuffs were noted in drill core. The only other rock type is lathy star porphyry greenstone that occurs as a sill about 100 feet below the top of the unit. Where fresh this is composed of 30 per cent labradorite laths up to 2.5 centimetres long and agglomerated laths in a fine sub-ophitic matrix of augite and plagioclase with magnetite and sphene. The Kunga Formation is in all respects normal. However, the basal massive grey limestone member approaches its maximum thickness, about 600 feet, in No. 3 zone, must have been thin in No. 1 zone, and is only about 150 feet thick in a drill-hole at the northwest of No. 5 zone. The massive limestone is largely bleached and slightly recrystallized in outcrop. The flaggy black limestone is of normal thickness and mostly is not very bleached or recrystallized, but in some localities it is transformed into a banded garnet tremolite rock. Flaggy argillite is seen in outcrops or in core in a few localities in the west of No. 5 zone, but similar rocks may occur within the flaggy limestone in small amount so there is no assurance that the upper member truly occurs within the ore zones. All suspected occurrences are quite bleached and hornfelsic.

The pre-ore porphyry is highly variable, partly because of minor original differences in phenocryst content or size but mainly because of great variation in alteration. The least altered specimens are normally composed of about 45 per cent zoned plagioclase phenocrysts ($An_{35\pm5}$), 5 to 10 per cent hornblende phenocrysts, and rare quartz and pigeonite phenocrysts in a finely lathy quartzofeldspathic matrix. In general these rocks seem to contain less than 10 per cent total quartz, so that the name diorite porphyry seems most applicable. An ill-defined clastic texture that pre-dates skarnification is a common feature. The mode of the intrusion of the porphyries has not been fully determined, but it seems as if the emplacement may have taken place in a number of pulses. Minor original differences in phenocryst content and size would be a likely result from multiple intrusion. However, much of the apparent difference in relatively unaltered specimens is only the result of differing colour contrast between phenocrysts and matrix, both of which separately may vary from dark green to white. In addition, the hornblende may be black or light green. These variations may be found in separate localities, in patchy masses, or within hand specimens in a patchy or reticulate form. Even the least altered specimens are far from fresh; the plagioclase is almost completely sericitized and the rock may contain variable amounts of carbonate, chlorite, serpophite, kaolinite, epidote, actinolite, and pyrite. Quite commonly the porphyry is converted to skarn with progressive development of epidote, actinolite, and finally garnet.

The San Christoval Batholith is formed principally of foliated hornblende diorite and quartz diorite (*see* pp. 129–134). In the vicinity of the mine, exposures are mostly contaminated and/or altered, but are medium-grained rocks originally composed of dominantly unzoned plagioclase ($An_{32\pm}$) with 15 to 25 per cent hornblende, 5 to 10 per cent quartz, and minor potash feldspar, magnetite, and sphene. Exposures other than those along Fairfax Inlet include a skarnified west-trending dyke near the causeway to Gowing Island and within the conveyor adit below No. 1 zone. Some reported occurrences in drill core No. 5 zone are regarded by the writer as diorite porphyry.

The two main post-ore dyke swarms have definite family characteristics, although individual dykes vary in phenocryst content and crystallinity and hence in superficial appearance. The earlier, andesitic, swarm is characteristically porphyritic greenish-grey rock with phenocryst content varying from 1 to 20 per cent and crystallinity from stony aphanitic to fine grained, yet with few exceptions the rocks belonging to the suite are immediately recognizable. The more porphyritic specimens resemble the diorite porphyries to some degree, and the fine stony specimens which come from small dykes resemble some late basalts superficially. Microscopically all this swarm is very similar with identical alteration. The average composition of eight analysed specimens is as follows:—

	Average (Per Cent)	Range (Per Cent)	Composition
Phenocrysts—			
Plagioclase	8.3	1–20	$An_{30\pm2}$
Pyroxene	1.0	0– 3	?
Matrix—			
Plagioclase	46.0	40–55	$An_{28\pm2}$
Quartz	6.6	2–15	
Pyroxene	5.7	0–13	
Iron ores plus sphene	4.5	2.5–10	
Carbonate, chlorite, and sericite	23.1	15–35	
Epidote	4.4	1–20	

The plagioclase phenocrysts are zoned, commonly agglomerated, and may be slightly epidotized. They range from 1 to 4 millimetres long. The pyroxene phenocrysts are completely chloritized. Iron ores include sphene and leucoxene. The carbonate, chlorite, and sericite in part probably represent altered glass but, as with the epidote, in part replace original minerals.

The late basalt swarm also varies in phenocryst content and crystallinity. Coarse labradorite phenocrysts may form as much as 25 per cent of the rock, but most dykes are not porphyritic. Crystallinity definitely is closely correlated with the size of dyke. These rocks have been called gabbros, gabbro porphyry, diabase, and basalt. Most actually are fresh diabases with the characteristic ophitic texture, and composed of sub-equal amounts of slightly zoned labradorite and augite with as much as 5 per cent magnetite. The plagioclase is invariably fresh, but pyroxene may be locally altered to chlorite, serpophite, and kaolinite. This swarm is almost certainly related to Early Tertiary Masset volcanism.

A few small dykes seem to be younger than the main basalt swarm. These include small dark-green fine basalt dykes and rare sugary-textured trachytic light-green felsite.

Structure

The structure of the Tasu mine area is shown by the regional map (Fig. 5) and the local plan and structural sections (Fig. 37). The plan and sections are compiled from surveys by company geologists augmented by those of the writer. The accuracy is variable, being good in ore zones Nos. 1, 2, and 3, but elsewhere mostly only fair. Only the largest of the great number of dykes are shown. A considerable amount of interpretation is necessary to draw sections through the widely spaced drill-holes of No. 5 zone; therefore, the plan and sections should be regarded as somewhat diagrammatic.

The panel of Karmutsen and Kunga Formations that forms the locus of the ore deposits has been moderately compressed into a synclinorium with two subsidiary anticlines, all with axes striking north 30 degrees west and plunging about 25 degrees northwest. The Tasu ore zones occur along the crest of the eastern subsidiary anticline and extend down the west limb toward the synclinal axis. The diorite porphyry has essentially the same general distribution as the ore. It forms a complex body of dykes and sills which have the over-all form of a flat Christmas tree laccolith with the base along the Karmutsen-Kunga contact. The upper " limbs " actually extend farther into the enclosing strata than do the basal, so that the term " Christmas tree " is not entirely suitable. Extensive alteration and skarn and ore replacement make it difficult to distinguish whether the body was built up with a great number of similar dykes and sills or whether it resulted from a single or a few intrusions.

The San Christoval Batholith surrounds the folded panel of stratified rocks on three sides and underlies it at least in part. The porphyries have a similar composition to the San Christoval and probably represent an early intrusive phase. The folding of the panel was essentially complete before it was engulfed, but the high plunge may result from simple synkinematic tilting. The semiclastic textures in the porphyries may indicate that they were intruded before folding was complete and, being brittler than the limestone or even the greenstone, were extensively ruptured. Minor sharp folds in the thin-bedded limestone in the southwest part of No. 5 zone strike south 50 degrees west, hence nearly normal to the regional folds. These plunge southwestward toward the synclinorium axis. These folds are paralleled by a steep south-dipping fault. The origin of these cross-folds is obscure but may relate to thrusting during emplacement of the San Christoval Batholith, the contact of which is on Mount Tasu (Moody) and is parallel to this orientation.

The structural attitude of dykes of each swarm show a preferred orientation, which rotates with time of intrusion from northwest for diorite porphyry to north for the basalt swarm. More precisely, the majority of dykes of the three swarms have the following orientations:—

Swarm	Strike	Dip
(1) Diorite porphyry	North 45 to 60 degrees west	Steeply west.
(2) Andesite	North 35 to 45 degrees west	65 degrees± east.
(3) Basalt	North to north 25 degrees east	Vertical—steeply east.

The ore zones are traversed by a large number of faults in many orientations and of many ages. Most are small and of slight importance, but some are moderate sized with movements of several hundred feet and fundamental importance in regard to metallization. Some important faults are not adequately defined by present exposure and drilling. The most important faults strike north 55 to 85 degrees west and dip more than 75 degrees either north or south. Slightly arcuate traces are common but are partly the result of the interplay of topography. These faults include the important central faults in Nos. 2 and 3 zones and by projection in No. 5 zone. Other only slightly less important faults, such as the central fault in No. 1 zone, strike north 20 to 35 degrees east and dip nearly vertically. The movement of no fault has been determined precisely, but in general the main northwest and northeast faults in effect drop their south blocks 100 to 200 feet. Some horizontal movement is indicated, and the total horizontal movement may exceed vertical. All these faults pre-date the mineralization, but some have been subjected to later movement as brecciated ore is common along them, a primary breccia of skarn cemented by magnetite is evident along some, and the distribution of ore and skarn bears a close spatial relation to them. Thus there is little doubt they were part of the conduit system of the ore-bearing fluids.

In general neither post-ore dyke swarm is cut by the main faults. However, the dykes are cut by a few small northwesterly steep faults.

Metasomatism

Skarn is more widespread than magnetite ore and in general forms an envelope that surrounds individual orebodies and may extend well beyond them. The skarn is somewhat selective, affecting massive limestone less than greenstone or flaggy limestone, and these less than porphyry. This is well illustrated in the vicinity of No. 3 zone, where porphyry dykes or sills cutting limestone may be quite highly skarnified, but the limestone is only bleached and recrystallized or apparently unaffected. In contrast, the flaggy limestone is not readily bleached but may be converted into a banded fine garnet-tremolite rock that on weathering may resemble a garnet sandstone. With diorite porphyry and greenstone, the least intense and earliest stage of metasomatism is a thorough chloritization, followed by growth of epidote, actinolite-tremolite, and less commonly orthoclase and anthophyllite. Anthophyllite has only been observed in some greenstone skarns. Minor magnetite, quartz, and carbonate occur in most intense skarns. Garnet replaces the earlier minerals and commonly shows zonal growth. The first formed or the most remote from intense skarn is commonly pale-cream coloured. The latest, the largest, and the exterior of crystals are a rich cinnamon-brown colour.

The oxide and sulphide minerals have distribution and textures indicating they are the latest in the metasomatic sequence. Magnetite replaces all earlier minerals and is found principally in the core of the skarn areas and as central bands in skarn replacement veinlets. Still younger are the sulphide minerals, pyrite, pyrrhotite, chalcopyrite, and rare sphalerite. Sulphur content of orebodies is fairly uniform at 2 to 3 per cent, regardless whether chalcopyrite is the main sulphide, as in No. 3 zone, or pyrite and pyrrhotite, as in No. 1 and No. 2 zones. The sulphide minerals generally occur as blebs and small masses in magnetite but are also common as veinlets. Some blebs clearly replace interstitial calcite between magnetite crystals. Bladed intergrowths of sulphides and oxides are not rare but are accompanied normally by fine veinlets, so that selective replacement of a bladed actinolite skarn is a more likely explanation of this texture than eutectic crystallization. Bladed textures also occur in essentially pure magnetite that is normally lodestone and generally a replacement of limestone. Quartz veinlets transecting sulphide veinlets occur in selected locales in very minor quantity. A black, very high iron sphalerite occurs in small veinlets in very small amount on the fringes of the skarn area.

Transition from ore to skarn or skarn to country rock may be sharp and commonly is in limestone but not in greenstone and porphyries. The transitional zone includes an outer zone of intense chloritization and minor porphyroblastic growth of epidote or less commonly orthoclase. This zone on approach to intense skarn becomes traversed by an increasing number of joints, commonly in a semi-reticulate pattern, from which skarn minerals have " spread." Commonly the replacement adjacent to the joints shows the order of zoning outward, brown garnet, cream fine garnet, epidote, and finally scattered epidote. Magnetite may occur at the centre of the replacement veinlet, and this is commonest near magnetite orebodies in the core of skarn areas.

Dykes of the andesitic swarm cut skarn and ore but are slightly chloritized and epidotized themselves. As previously described, the basalts may be slightly chloritized but normally are fresh.

Orebodies

The Tasu orebodies and their skarn envelope form a tabular panel some 100 to 400 feet thick which conforms to the bedding attitude of the top of the Karmutsen Formation, although it replaces diorite porphyry sills as well as Kunga limestone. This panel extends over a horizontal area at least 3,500 by 4,000 feet. Within the panel there are areas of greater and lesser development of skarn and magnetite, but no area is entirely free from some metasomatism. In effect the major orebodies form linear lenses in plan within the over-all panel. From these ore " build-ups " planar sheets of skarn and ore extend into the less intensely replaced areas. The linear ore " build-ups " occur along pre-ore fault lines. Stratiform lenses and crosscutting sheets or pipes of ore also occur within the Karmutsen Formation, but although these have not been fully investigated, they seem of minor economic importance. The sections illustrate these concepts substantially.

The various ore zones 1 to 5, used for convenient reference, each largely represent one central " build-up " and fringe area. This is true of all but No. 5 zone, which is a conglomeration of all the areas to the west in which reconnaissance drilling only has been done. The orebodies of No. 3 zone replace limestone, are relatively free of skarn, are copper-rich, and are concentrated just above the contact of the Karmutsen Formation. The orebodies of No. 1 zone replace porphyry, are skarny and on the average less pure, are copper-poor, extend through a greater thickness, and are less concentrated at the Karmutsen contact. No. 2 zone is intermediate in space and characteristics, between No. 1 and No. 3 zones. No. 4 zone is undrilled and is, as far as known, a small zone south of No. 3 with characteristics similar to it. No. 5 zone is not adequately explored but seems to include the continuations of No. 3 and No. 2 zones. No. 2 and No. 3 zones trend about north 65 degrees west, whereas No. 1 zone trends north 20 degrees east.

The ore zones are transected by a very large number of post-ore dykes of the two swarms, and this seriously diluted the grade. In some areas as much as 30 per cent of the ore zones are occupied by post-ore dykes.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1908, p. 62; 1910, pp. 78–79; 1913, pp. 96–97; 1956, pp. 125–127; 1961, pp. 11–13; 1963, pp. 13–16; *Western Miner,* Oct. 1959, pp. 38–44; Oct., 1965, pp. 87–96; Polk, G. K., 1964, unpublished private report for Falconbridge Nickel Mines Limited; Smith, A., and Wade, E. J., Dec., 1965, unpublished abstract of talk given to Northwest Mining Association, Spokane, Wash.; Wade, E. J., 1967, *Can. Min. Jour.,* Vol. 88, No. 3, pp. 65–71.]

Garnet
(16)

The Garnet group of nine located claims is situated on the northwestern end of the peninsula between Fairfax and Botany Inlets, Tasu Sound. The property is held under option by Moresby Mines Limited, a company formed in 1965. The property was discovered in 1908 by Messrs. Chapman, Kitson, and Husband and originally called the Ajax. A 70-foot adit dating from this period (the Tommy adit) is on the southern boundary of the claims adjacent to the Tommy claim, which was originally staked by Albert Jones. Five claims, Garnet 1 and 2 and Ruby 1, 2, and 3, were located in 1953 by R. E. Wolverton for Cominco, and explored by trenching by that company over the next few years. The claims were retained by Wolverton after Cominco's interest terminated. In the winter of 1962 Silver Standard Mines Limited drilled 213 feet of packsack diamond-drill holes, cleaned out some trenches, and conducted a magnetometer survey. An option was taken in 1964 by Bardale Mining & Development Company and transferred to Moresby Mines Limited when that company was formed.

Geology

The Garnet property is a pyrometasomatic replacement deposit in which iron, copper, and also zinc are important. The surface geology is shown on Figure 38. The setting is the normal one of the metasomatic deposits even though there are some differences in detail. A pad of the Kunga grey limestone member overlies Karmutsen greenstone. These rocks are enveloped to the south and east by hornblende quartz diorite of the San Christoval Batholith, dykes of which cut the older rocks in the area of the showings. The limestone appears to form a synclinal keel and to trend north 35 degrees west. Along the shore at the northwest point is another outcrop of limestone that dips steeply northeast. If this is Kunga limestone, as seems probable, there is an anticline overturned to the west between the main limestone pad and the shore. Small faults oriented north to north 30 degrees east are moderately common.

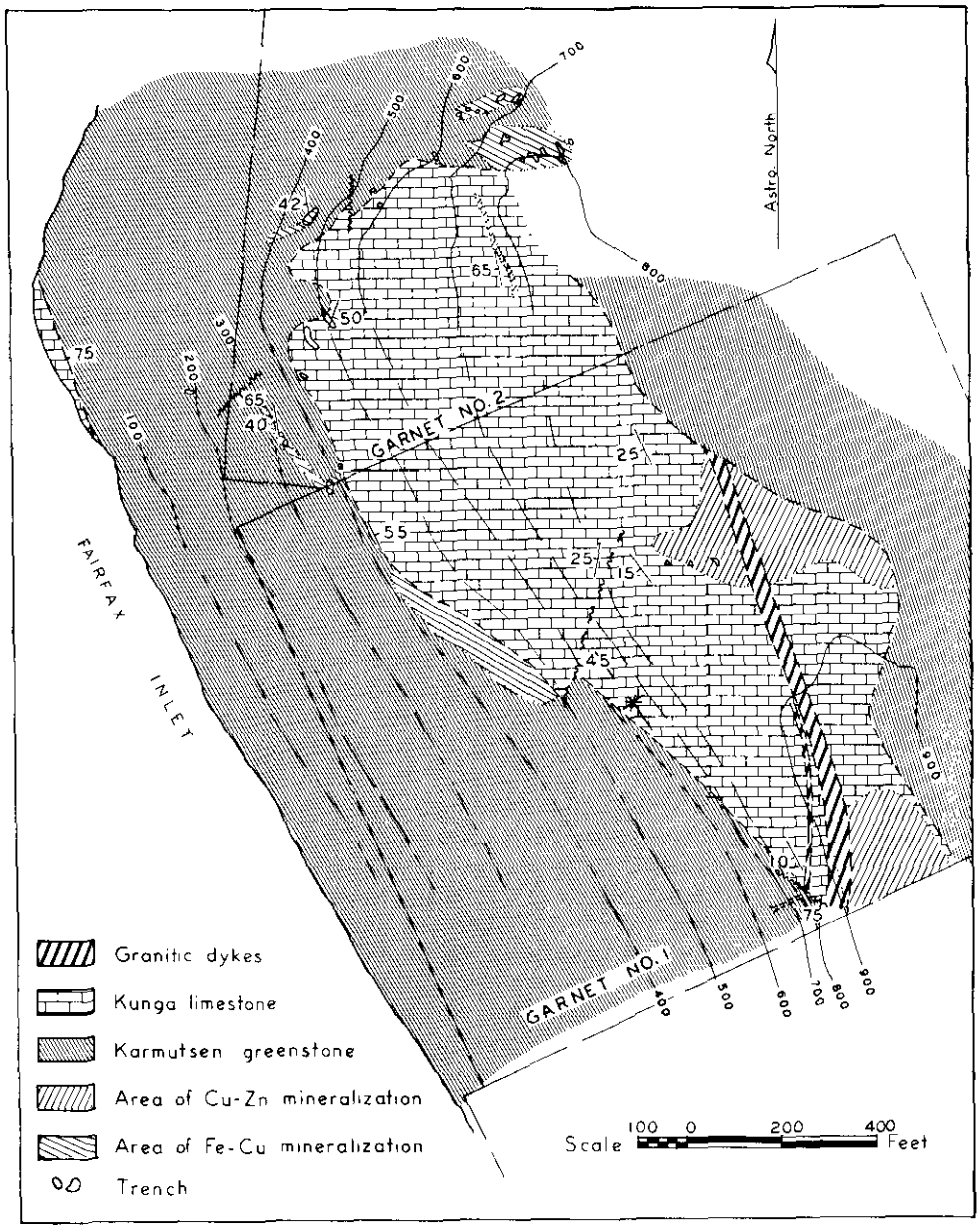


Fig. 38. Garnet group, geological plan.

The showings are dispersed over much of the Garnet No. 1 and No. 2 claims. Exposure is poor, but considerable hand trenching done by Cominco reveals bedrock. Mineralization consists of two types: magnetite skarn with chalcopyrite, found chiefly in the upper part of the Karmutsen Formation, and sphalerite, pyrite, and chalcopyrite, found as vein-like and irregular masses in the limestone. The magnetite ore is found around much of the western and northern periphery of the limestone keel and generally 50 to 100 feet below the contact. Continuous bands up to 500 feet long by 20 feet thick are known. Much is banded with intercalated layers of magnetite and tan garnet, and some is in effect laminated. Pyrite and chalcopyrite may be disseminated in the more massive ore but also occur as vein-like bodies in transecting small faults. The main sulphide mineralization consists of vein-like masses cutting limestone. These may partly be fine fissure fillings along small faults with disseminated replacement of the walls. High-grade masses of sphalerite with pyrite and chalcopyrite are known from the northern nose of the limestone to the southern claim boundary. One " vein " at the northern end with an average mineralized width of 4 feet is continuous for 250 feet. Other areas are known, with rather random masses of sulphides replacing limestone. Float of high-grade sphalerite-chalcopyrite is also widely distributed.

At the time of the writer's study the property had not received intensive enough exploration to estimate reserves.

[Reference: *Minister of Mines, B.C.,* Ann. Rept., 1962, p. 10.]

Old Townsite, Tasu (17)

These showings are on the old Tasu townsite, on Hunger Harbour, Fairfax Inlet. They are on located claims held by Wesfrob Mines Limited as part of the large block of the Tasu mine but are separate from the main Tasu orebodies. Signs of old work indicate the mineralization was probably known about 1910. In 1954 Cominco located the showings and did some stripping and pitting. In the summer of 1964 Wesfrob drilled nine AX holes totalling 2,346 feet at the property.

Geology

These magnetite showings are contained in a synclinal pendant of Kunga limestone with a thin skin of skarn or Karmutsen greenstone engulfed in diorite of the San Christoval Batholith. The west limb is shown by drilling to continue at a steep attitude to at least 500 feet below sea-level. The core and east limb are irregularly penetrated by a tongue of quartz diorite. The sheath of greenstone and skarn on the west limb varies from 150 to as little as 20 feet thick, and trends north 50 degrees west from the head of the bay south of Hunger Harbour. Within the greenstone and skarny greenstone in the southern 400 feet there are a number of outcrop pits and natural exposures that show scattered magnetite mineralization with some pyrite and chalcopyrite disseminated in skarn. The southernmost exposure shows 35 feet across strike of fairly pure magnetite. Farther north the skarn band is narrow and not well exposed. Wesfrob drilled two fans of diamond-drill holes from set-ups near the southern bay and 400 feet from Hunger Harbour in the north. In some of the drill-holes, diorite porphyry is prominent, although it is not well exposed on the surface. Of the ore encountered, much replaces limestone near the skarn sheath. Proven reserves developed from the limited drilling totalled less than 100,000 tons of relatively low-grade ore.

Apex (18)

This property consists of two located claims, Alpine No. 1 and No. 2, held by Wesfrob Mines Limited. The showings are on the ridge between Botany Inlet of Tasu Sound and Anna Lake at an elevation of 2,700 to 2,800 feet. They may be reached by an old trail from the head of Anna Inlet. The showings, originally called the Star, were discovered by Messrs. Davis, Bell, and Harris in 1907.

The mineralization consists of a chalcopyrite-bearing magnetite skarn zone at the base of a small roof pendant in the San Christoval Batholith near its eastern margin. The pendant consists primarily of grey limestone and skarn but includes some skarnified volcanic rock and is cut by late dykes of basalt, granite, and feldspar porphyry. It is oriented northwestward parallel to the nearby margin of the batholith and is about 400 feet long at the somewhat irregular base about 100 to 150 feet below the ridge-top. The walls are fairly planar and steep, and about 200 feet apart. Bedding possibly strikes north 20 degrees west and dips about 70 degrees east. It is not known whether this limestone is a remnant of the Kunga Formation or a member of the Karmutsen Formation. Skarn and magnetite replace limestone and a small amount of volcanic rocks and quartz diorite at the base of the pendant. The profile of the skarny magnetite at the north face is quite irregular but up to 50 feet thick. At the south face it is wedge shaped, about 75 feet thick on the east and a few tens of feet thick on the west. Most of the replacement consists of magnetite, but patches of garnetite and coarse calcite are fairly common and epidote skarn is present, some of the latter clearly replacing original volcanic rocks. Weathered exposure of skarn is stained by malachite, and chalcopyrite is common as blebs in the magnetite and in small vuggy quartz veinlets at the base.

During the early exploration an adit was driven from the south side 50 feet below the pendant and entirely within the quartz diorite. The adit and its ramifying branches include about 200 feet of workings. Recent exploration has included sampling, and in 1963 three packsack holes totalling 320 feet were drilled to confirm the continuity between the two exposures. Assuming this continuity, Young and Uglow calculated the reserves as about 300,000 tons of ore. Calculations based on the drilling indicate somewhat less ore with a grade of close to 50 per cent iron and possibly 1 per cent copper.

[References: McConnell, R. G., *Geol. Surv., Canada,* Sum. Rept., 1909, pp. 79–80; *Minister of Mines, B.C.,* Ann. Rept., 1913, p. 99; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, pp. 30–31.]

Lobstalk (23)

This property is on Lyell Bay on the west side of Lyell Island. It is presently held by the Marven group of 10 located claims. The showing is less than 100 feet from the shore. It consists of pyritic magnetite replacing metamorphosed Karmutsen greenstones, adjacent to minor limestone beds striking north 30 degrees west and dipping on the average 50 degrees east. About 150 square feet of surface area is magnetically anomalous or contains exposures of magnetite, and the principal exposure is in a large trench. In 1956 two short packsack holes were drilled by Frobisher (Falconbridge) immediately east of the trench. One bottomed in skarny magnetite at 90 feet; the other ended in greenstone at 74 feet. In 1964 a detailed magnetometer survey was run on the property for Placid Oil Company Limited.

Alder Island (27)

This property on Alder Island, which is just north of Burnaby Island, is held by two recorded claims. The showings are of interest partly because they differ from the normal metasomatic deposits in situation and mineralogy. Alder Island is only a small island but is underlain by complex geology, including folded Kunga Formation, Yakoun volcanic rocks, granitoid dykes related to the Burnaby Batholith, Longarm sandstones, and Masset basalts. The eastern side of the island is a northerly striking fault zone. Adjacent to this, skarn is variably developed in Longarm sandstones. The skarn varies from a pyroxene to garnet skarn to skarny sandstone. Magnetite, pyrrhotite, and chalcopyrite form minor but constant accessories. Some small masses of pyrrhotite occur, and these apparently are nickeliferous. In addition, the skarn contains some late calcite veinlets that carry arsenical allemontite.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1922, pp. 41–42.]

Mac (29)

The Mac property is 3¼ miles southwest of Scudder Point on Burnaby Island and may be reached by a 1½-mile trail along a large creek from an exposed bay 2½ miles south of the point. The property includes a large number of located claims covering much of northeastern Burnaby Island that are held by Merrican International Mines Ltd.

The showings are on the Mac No. 1 claim, north of the creek between 200 and 400 feet elevation. They were discovered by A. Heino about 1906 and are described under the heading " Burnaby Island " by Young and Uglow. Little was done in prospecting other than examination and dip-needle surveys until 1962, when Merrican started a programme that over the next two years included a magnetometer survey, trenching, 11 X-ray drill holes totalling 1,193 feet, and 16 EX drill holes totalling 5,507 feet.

Geology

The Mac magnetite showings are in the normal pyrometasomatic setting at the contact between Karmutsen greenstone and Kunga limestone near the Burnaby Batholith. Alluvium and glacial drift cover much of the area of the showings, although above 400 feet elevation exposure is fair. Moreover, the diamond drilling has been very largely at an acute angle to the stratification, so that there is no certainty about details of the geology. In particular it is difficult to be sure whether the known ore is replacing limestone adjacent to the contact of the Karmutsen Formation or to similar greenstone sills within the Kunga Formation. Such sills are common on Burnaby Island and Copper Island. Below the lowest exposure of magnetite (200 feet), the few outcrops that exist are mostly basaltic greenstone similar to the Karmutsen Formation but include minor limestone. No doubt exists that the main limestone that outcrops on the hill between 200 and 450 feet is the basal member of the Kunga Formation, for *Halobia* was found in the overlying flaggy limestone member. The stratified rocks generally strike north 45 to 60 degrees east subparallel with the contours of the hill and dip 35 to 55 degrees northwestward into the slope. Fine-grained basic dykes and sills cut the massive and also the flaggy limestone, but with the dearth of outcrop their orientation and continuity are in doubt. No diorite porphyries were observed. Quartz monzonite of the Burnaby Batholith outcrops east of a gully about 350 feet northeast of the main showing. The gully appears to follow a breccia zone along the contact. Post-ore faults are believed to occur and to be oriented northwestward.

The surface showings consist of four magnetite outcrops, two of which are significant. The largest is a sill-like body that outcrops at an elevation of about 275 feet along the hillside. It is about 110 feet long and of variable thickness, 25 feet at the east, where it abuts against a greenstone dyke, and 5 feet at the west. The body appears to replace limestone and to dip parallel to it at about 35 degrees northeast. Some 75 feet northeast of this showing at about the same elevation, a small outcrop of magnetite replaces limestone. The second important showing occurs parallel to the first, with the east end 70 feet southeast of the west end of the main showing. From the east end it is exposed intermittently for 120 feet and is generally 5 feet or less wide. It replaces limestone and appears to dip rather steeply. Quite possibly the two main showings were continuous but are separated by a steep northwesterly trending post-ore fault. If so, the first three showings may represent only one bed. The fourth showing is a minor one in a large basic dyke adjacent to limestone and about 75 feet above and to the west of the western end of the main showing. The large showings consist of almost pure magnetite with rare garnet crystals. Other skarn minerals or sulphides are seemingly absent in the ore, and neither the limestone nor the greenstone show any significant skarnification other than the ore band.

The writer has not had access to the drill results. The company has stated possible reserves of 1,500,000 tons, grading between 40 and 50 per cent iron (George Cross Newsletter No. 102, 1964). Considering the drilling pattern which was largely enforced by topography, and the resulting acute intersections of strata and ore, the results would require caution in interpretation.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1962, p. 14; 1964, pp. 46–47; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, pp. 32–33; George Cross Newsletter No. 102, 1964.]

Jib
(30)

The Jib iron-ore deposit is situated at Bluejay Cove on southeastern Burnaby Island (*see* Plate XVIIB). The major part of the deposit is just offshore. The property is held by Burnaby Iron Mines Limited, a company formed in 1963 and owned jointly by Mastodon-Highland Bell Mines Limited and Leitch Gold Mines Limited. It consists of 47 located claims which cover much of the southeastern peninsula of Burnaby Island south of Poole Point and extends across Skincuttle Inlet to Skincuttle Island of the Copper Islands.

The Jib iron-ore deposit does not outcrop, but cupriferous skarns related to it were first investigated in 1862–63 by Francis Poole. The small adit and shaft near tidewater dating from this period can be seen on the bay south of the main deposit. Some further work was carried out on these copper-rich skarns on the present property both at Poole's original showing and farther to the southeast during the period 1910 to 1916. The history of the discovery of the iron deposit is as follows: In 1961 Denison Mines Limited had an aeromagnetic survey flown of the area from Burnaby Island to Kunghit Island in which the requisite geology was known to occur. A significant magnetic anomaly was discovered over the present deposit and claims located. However, these were allowed to lapse without much further testing, and in the fall of 1962 were relocated by Highland Bell. Drilling started in January, 1963, and continued to September. Eighteen AX holes totalling 12,208 feet were drilled in fans from the shore, the lengths of the longest being nearly 1,000 feet. This preliminary drilling established 2.5 million tons of 50 per cent iron ore and an additional 1.5 million tons of probable ore. In 1965 drilling recommenced in May and continued until September; five new holes were drilled and six deepened for a total of 6,735 feet.

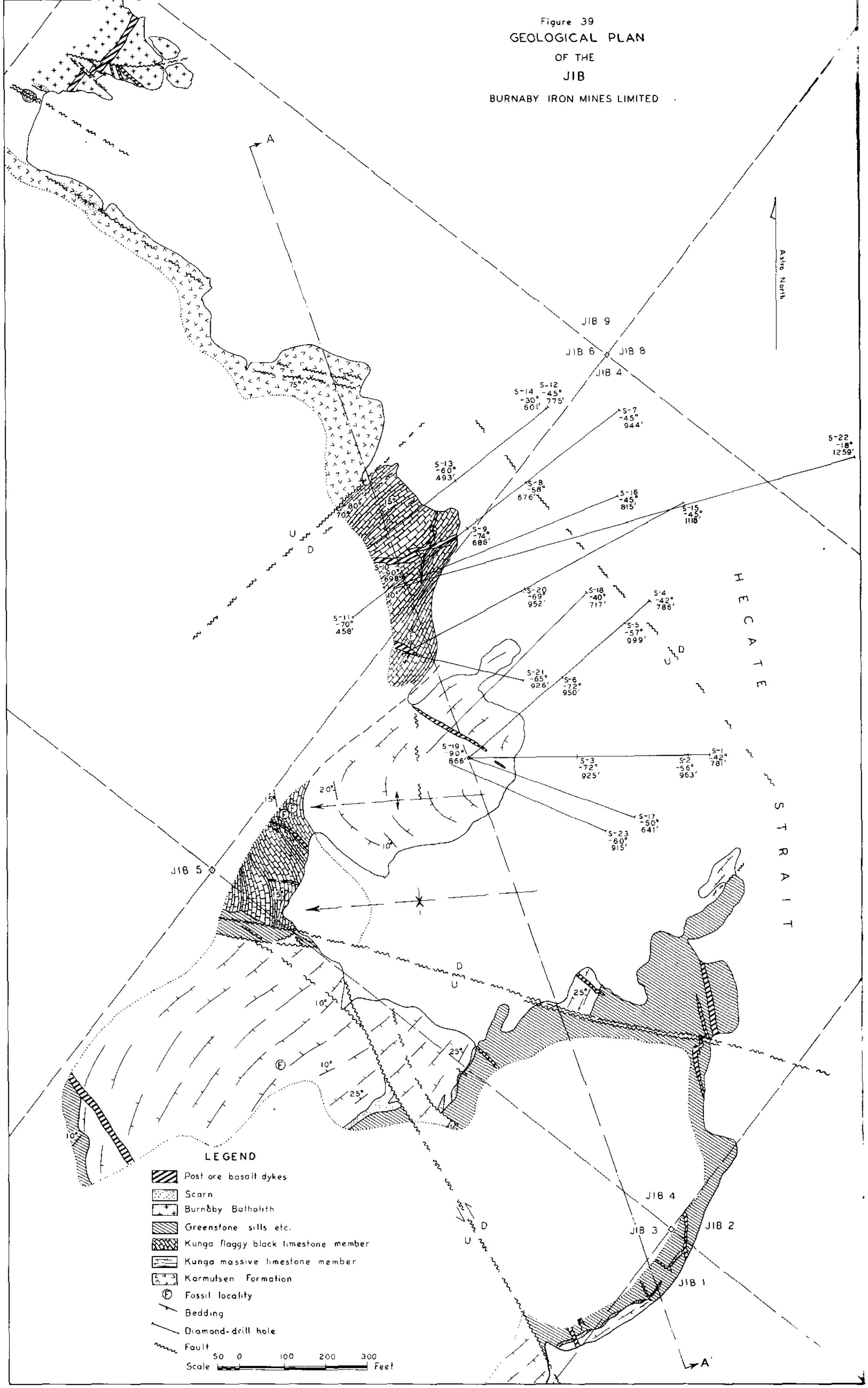


Figure 39
GEOLOGICAL PLAN OF THE JIB
BURNABY IRON MINES LIMITED

The Jib is a typical pyrometasomatic magnetite deposit in the typical setting. The geology is illustrated by Figure 39, a plan of the shoreline, and Figure 41, which is a longitudinal vertical section on the western fringes of the orebodies, and by Figure 40, two vertical cross-sections. The stratified succession includes Karmutsen Formation and Kunga Formation massive grey limestone and flaggy black limestone members. All these rocks have characteristics normal for the units as described on pages 50 to 61. The Karmutsen Formation is formed of massive amygdaloidal basalt flows that are fairly well chloritized. Since sills found within the limestone are very similar to these basalts, doubt may occur regarding correlation of specific areas of this type of rock. The grey limestone is shown by the drilling to have a total thickness of about 775 feet. Only the basal 100 feet of the flaggy black limestone is encountered on the showings or in the drill-holes. Although collections from the massive limestone are indeterminate, the palæontological control of one horizon of these rocks is precise, for collections on the property from two localities 20 feet above the base of the flaggy black limestone indicate an Upper Karnian age probably correlatable with the *Tropites welleri* zone (*see* p. 60). Both limestone units are bleached and recrystallized in part. The massive grey limestone has a pronounced bedding cleavage in the main bay, whereas the flaggy limestone exhibits boudinage of the more massive beds at the northern outcrop area. The stratified rocks are intruded by dykes and sills and by the Burnaby Batholith. This latter body is composed chiefly of melanocratic quartz monzonite. A sheared, skarnified contact of Karmutsen greenstone and the batholith is exposed in the little bay north of the showings. Highly altered granitoid rock that was penetrated in diamond-drill hole S-7 at 871 feet may be the main body or possibly a dyke from it. The dykes and sills consist of three groups. The earliest are basaltic greenstones, in all respects very similar to the Karmutsen flows. These rocks also occur within the Kunga massive limestone throughout the area surrounding Skincuttle Inlet. They resemble the Karmutsen flows lithologically, and structurally are mostly quite conformable, but they also occur as dykes, can be seen to have a minor crosscutting relationship with beds, and occur in varying stratigraphic positions in different areas. They probably are penecontemporaneous with deposition of the limestone and represent the last pulse of Karmutsen volcanism. The volcanic area south of the main bay is such a sill as can be seen best in section (Fig. 41). The second group of dykes are diorite porphyries similar to ones at other major metasomatic deposits. Their relationships at the Jib are not well known, for they do not occur on the surface. They are skarnified and may be replaced by magnetite. At other properties they pre-date the main plutonic body and probably represent an early phase. The third group are late basalts to andesites that are post-ore and have a complicated relationship to the faulting, seeming largely to post-date major faulting but may pre-date late movement. Many are completely undeformed and have crudely developed columnar jointing normal to the walls. None are very large.

The structure of Skincuttle Inlet is relatively simple. Gently dipping panels which trend east to northeast and dip northward are cut into a mosaic pattern by steep block faults. The structure near the Jib is similar with some complications. Beds generally strike north 45 degrees east and dip from 10 degrees to at most 25 degrees northwestward. There is, however, a gentle minor anticline-syncline pair in the vicinity of the main bay with axes trending west and plunging west 10 to 20 degrees (*see* Fig. 39). Additional complexities are the cleavage in the grey limestone and boudinage and small recumbent folds in the flaggy limestone. The axes of recumbent folds and boudins are oriented north 65 degrees east and indicate a net movement of the upper beds southward. The bedding cleavage may well result from the intrusion of the subjacent greenstone sill. The boudinage and recumbent folds might also result from dilation pressures on the intrusion of greenstone sills, but the orientation of axes is nearly normal to the contact of the Burnaby Batholith, so that it may well result from an outward thrust at a high level during emplacement of this body.

Three well-defined block faults near the Jib are oriented north 45 degrees east, north 75 degrees west, and north 30 degrees west. The largest is the fault oriented north 45 degrees east which apparently dropped the southeast block 1,100 feet, assuming the greenstone on the west is truly Karmutsen Formation. The other two definite faults have some striæ indicating late horizontal movement, but the main stratigraphic indications are of normal movement of 50 to 150 feet with the north and the northeast blocks down. Two other important faults are believed to exist but are relatively poorly known or defined. One parallels the contact with the batholith, (around north 60 degrees west) which is highly sheared and slightly skarned on the shore. Parallel to this, minor shears occur in the greenstone. The other fault is known only from drill holes and has a similar orientation (north 55 degrees west) and may in fact be the same fault. It appears to be a steep fault that drops the northeast block 100 to 150 feet. Precise information on the relative ages of faulting is lacking. Most faults appear to be pre-ore in part (because skarn and magnetite are emplaced along the fault lines), but most have also been subject to post-ore movement, offsetting even some of the late basalt dykes.

Orebodies

Exploration has not yet fully tested the magnetic anomalies on the Jib group. Some anomalies offshore have not been drilled at all, and one of the more important has been penetrated by only one hole. Hence analysis and conclusions regarding the orebodies are preliminary.

The mineralogy of the ore and skarn is typical of the Queen Charlotte Islands pyrometasomatic deposits, with slight variations. On the whole the ore is fairly pure magnetite, but every gradation occurs to skarn with trace amounts of magnetite. Hematite occurs in some skarns in preference to magnetite. Sulphides are quite erratic and are chiefly pyrite, rarely chalcopyrite or pyrrhotite, and very rarely sphalerite. The average tenor of sulphur in ore is only 0.2 per cent; of Cu, 0.02 per cent; TiO_2, 0.08 per cent; and of P, 0.05 per cent. Skarn minerals are variably developed. Some skarns are nearly pure light-brown garnetite, and in others epidote, actinolite, pyroxene, or chlorite may be dominant but seldom without much of the other skarn minerals. Quartz and calcite are common accessory minerals but are never dominant.

The Jib has two distinct groups of orebodies—one at the base of the limestone called the underlime orebody and the other within the massive limestone but concentrated about greenstone sills. The underlime deposit is on the whole a conformable body replacing the uppermost part of the Karmutsen Formation and to a lesser extent the basal Kunga limestone. It has a crest more than 40 feet thick elongated in a north 10 degrees west orientation. At the southern part in diamond-drill hole S-23, the body is very much thicker and penetrates well up into the limestone. This may represent a vertical pipe or conduit and may connect the underlime with the upper bodies. Nearly everywhere the lower magnetite orebody is separated from

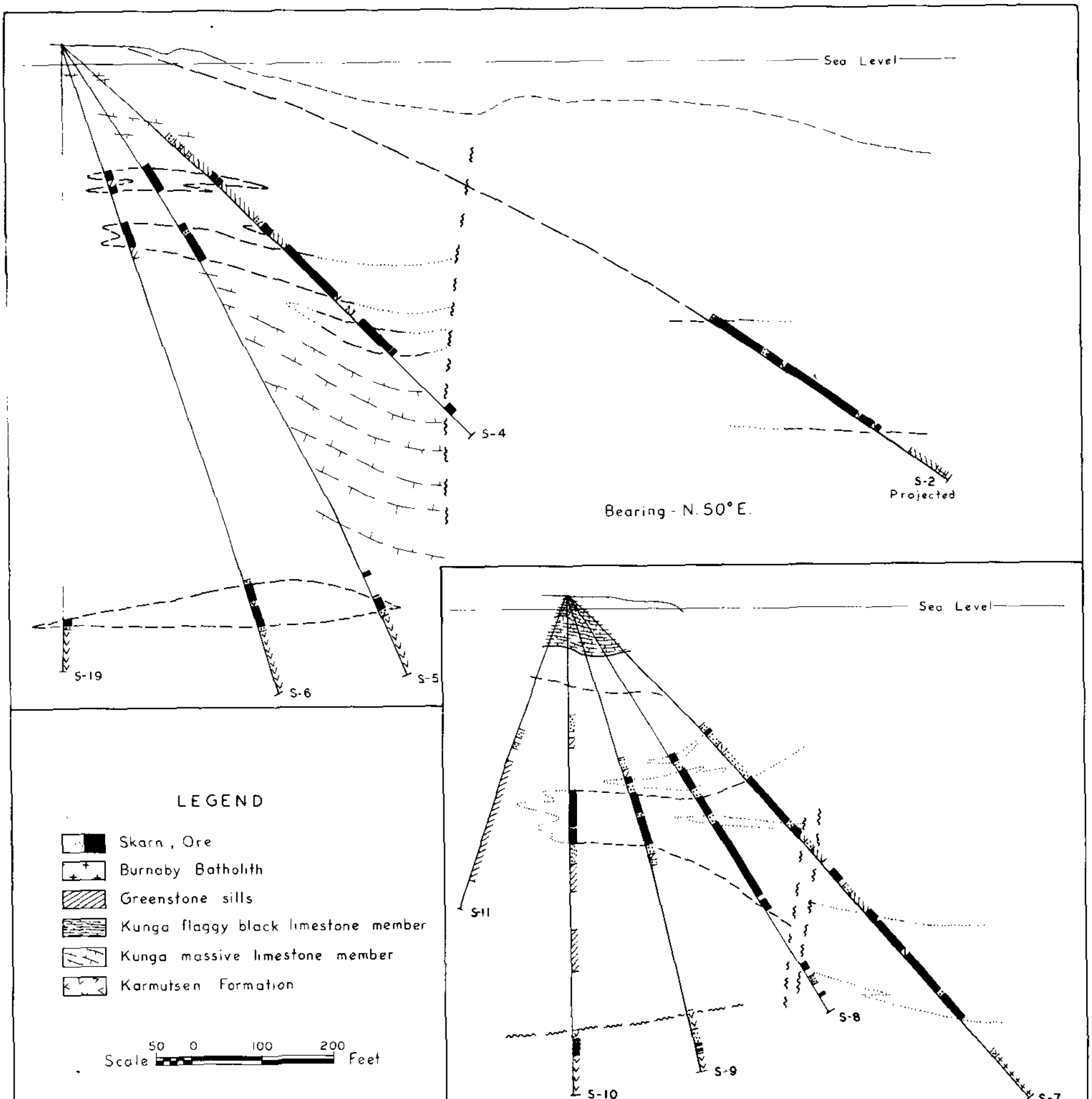


Figure 40: JIB. Vertical Sections

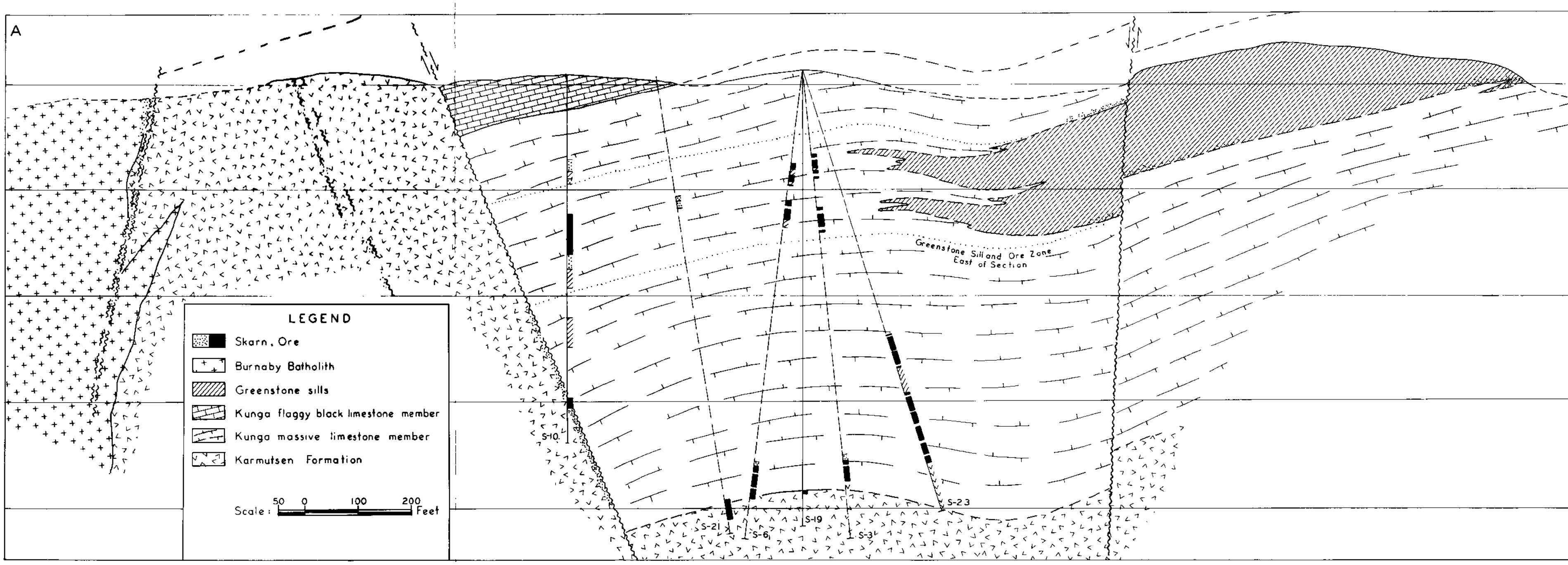


Figure 41 : JIB. Longitudinal Section A-A'. Bearing N 19½° W.

adjacent greenstone or limestone by a thin sheath of skarn, and in general the underlime deposit is slightly less pure than the upper bodies, containing more skarn minerals.

The upper orebodies are less regular than the underlime but are generally higher grade and commonly considerably thicker. The sections show that only the thickest sections are in continuous ore; toward the fringes they tend to fray out into two or more bodies separated by skarn, greenstone, or limestone. Skarn is a common transitional rock between ore and greenstone or limestone, but it does not form such a continuous sheath or envelope as it does in the underlime deposit. It is clear from the sections that the orebodies replace the greenstone sills, particularly the contacts of the sills. Essentially one can say, no greenstone sill, no ore. Other factors must also be important but not all are clear. The thicker sections seem to be related areally to some of the faults, particularly the main fault through the ore zone (north 55 degrees west).

Reserves

As a result of the 1693 drilling, the company announced reserves of 2.5 million tons of reasonably assured ore and 1.5 million tons of possible ore. Total reserves were estimated in a short article by the engineering staff of the company after the 1965 drilling (Western Miner, p. 97) to be 8,200,000 tons of ore grading 49.45 per cent soluble iron.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1962, pp. 13–14; 1963, pp. 18–21; Western Miner, October, 1965, p. 97.]

Copper Islands (31, 32)

Cupriferous skarn showings occur on most of the Copper Islands but particularly on Skincuttle and East Copper Islands. These showings have been held by located claims, sometimes as a group by one owner, sometimes separately. At present they are held as follows: Skincuttle Island, part of Jib " B " group; George Island, Sandy Nos. 1 to 4; East Copper Island, Elma group—five claims. These showings were discovered first by Francis Poole in 1862–63 and rediscovered by A. Heino in 1900. The Skincuttle Island showings were held in 1902–07 by Law, Hamilton, and Raper but were located later by Heino, who worked at times on all these showings and others on Burnaby Island for more than 30 years. Most of the work was on the East Copper Island showings, which were variously called the Red Raven, Quinitsa, or Skincuttle Entrance. Workings include a 150-foot adit essentially at sea-level and two shafts, one reportedly 100 feet deep with a 180-foot crosscut. By means of his own boat, Heino made many small shipments to Tacoma, of which there is little record, but in 1916–17 he is recorded as having shipped 55 tons of sorted ore which contained: Silver, 23 ounces; copper, 15,725 pounds. In recent years the showings have been repeatedly examined and a minor amount of packsack drilling has been done on East Copper Island, but nothing further. On Skincuttle Island there are two small shafts, one reportedly sunk by Poole. Recent work includes a magnetometer survey at sea off the island by Burnaby Iron Mines Limited in 1964.

The Copper Island showings are formed entirely of the Kunga grey limestone member and intrusive sills of amygdaloidal andesite to basalt not greatly different from the Karmutsen flows. These rocks strike east, dip 10 to 30 degrees north, and are cut by small steep block faults oriented chiefly either north, northwest, or westerly. Granitic rocks do not outcrop on the islands but most likely occur at no great distance to the north, judging by the projected contact of the Burnaby Batholith. The showings are mainly garnet-rich skarns carrying some disseminated chalcopyrites and minor magnetite and pyrite. Bornite, tennantite, and cuprite are said to occur in minute amounts, and malachite stain is common. The skarn zones follow the bedding attitudes at contacts with the sills and principally replace the volcanic rocks. Some of the disseminated chalcopyrite extends into adjacent unskarnified limestone. The skarn zones can be traced hundreds of feet horizontally along strike but are rarely as thick as 10 feet. In addition to the disseminated mineralization in the bedded garnet skarn, there are small chalcopyrite veinlets transecting the bedding in and near skarns and quartz veins with traces of chalcopyrite in some of the block faults.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1900, p. 788; 1907, pp. 68–69; 1913, pp. 101–102.]

Lucky Seven (34)

This property is on the lower part of the creek just east of Harriet Harbour that is the main source of water for the Jedway mill. It is held by Jedway Iron Ore Limited by the located claim Pipe No. 6. The Lucky Seven, also called the Dorathkalon and Producer groups, was a small shipper of hand-cobbed copper ore. This showing was probably located in 1915 by H. E. Bodine. The next year a 50-foot inclined shaft and 60-foot drift were developed and 42 tons of ore shipped, which contained: Gold, 60 ounces; silver, 218 ounces; copper, 8,336 pounds. In 1917–18 a 375-foot adit was driven and a 100-foot raise developed to the drift.

The Lucky Seven showing is a sulphide vein that in the drift averaged 18 inches wide, composed largely of the sulphides, chalcopyrite, pyrite, and pyrrhotite with traces of sphalerite. The vein is contained in Kunga black limestone member. The developments in 1917–18 did not prove up much new ore. This vein is representative of what might be called leakage-type deposits associated areally with metasomatic deposits.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1916, p. 87; 1918, p. 38; 1919, p. 39.]

Jessie (Jedway Iron Ore Limited) (35, 36)

The Jessie mine is the main source of ore for Jedway Iron Ore Limited and was the only producing property for Jedway until the small Adonis pit started production in September, 1964. It is situated on the ridge between Harriet Harbour and Ikeda Cove, about 1½ miles from the mill, concentrate storage, and dock at the entrance to Harriet Harbour. The Jessie property is held by Jedway Iron Ore Limited, a subsidiary of The Granby Mining Company Limited. Ownership is complicated. Jedway holds 61 claims by record, has three mineral leases that include four reverted Crown-granted claims (Mineral Lease 2, Adonis, Lot 1865; Mineral Lease 37, Hot Punch, Lot 1976, and Iron Duke, Lot 1977; and Mineral Lease 105, Jessie, Lot 1861), and 10 Crown-granted claims as follows: Moresby Island, Lot 78; Magnet, Lot 79; Blue Belle, Lot 80; Ajax, Lot 81; Sandwich Fraction, Lot 92; Emma, Lot 854; Della, Lot 2597; Lizzie B, Lot 2604; Cypress Queen, Lot 2607; Mattie H. Fraction, Lot 2608. In addition, Granby holds 64 recorded claims in the vicinity. Thus the property now includes a number of showings that were originally explored separately. Some of these are described separately in this report, including the Adonis (37), Magnet (44), Plunger (56), Producer (34), Reco (42), Moresby Island (46), Dingo (Blue Belle) (43), and Eagle Tree (47).

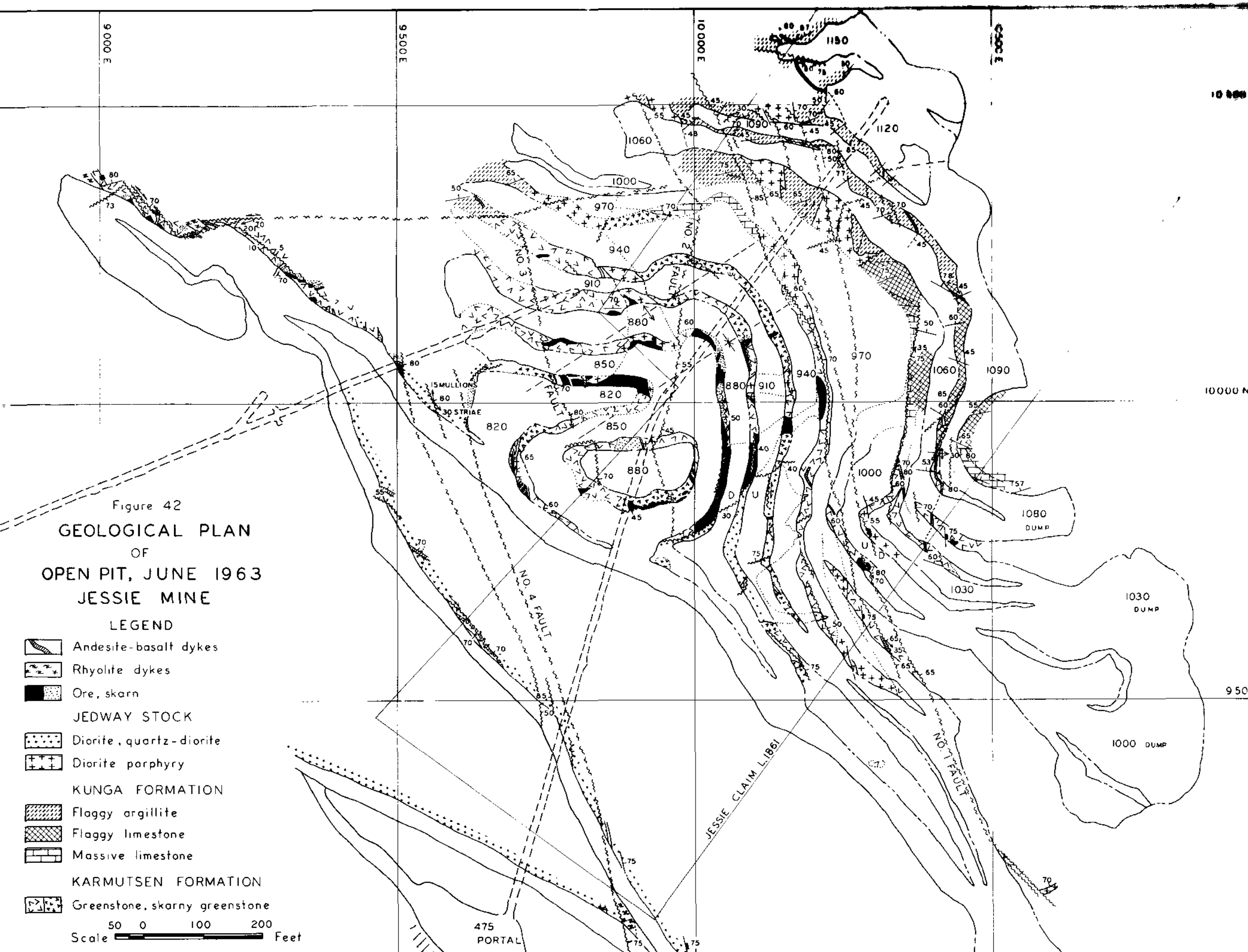


Figure 42
GEOLOGICAL PLAN OF OPEN PIT, JUNE 1963 JESSIE MINE

The first exploration on the property was in 1863 by Francis Poole, at a showing of magnetite, skarn, and minor sulphides on the shore just south of the dock. This is presently on the Tip No. 1 claim. It was described by Dawson (1880, pp. 54B–55B) in some detail. The Jessie claim was first mentioned with one called the Harriet in the 1908 Annual Report and was described as having had considerable work done, presumably trenching and surveying. The Jessie showings are not rich in chalcopyrite, so that interest lapsed. Young and Uglow (1926, pp. 39–42) described the magnetite showing in some detail. Little further work was done until 1956, when Dr. J. M. Black, for Western Canada Steel Limited, explored the area and conducted a magnetometer survey over the showings. In 1959 Silver Standard Mines Limited acquired options on the key claims and started a drill programme which by 1960 had outlined some 2,500,000 tons of ore. In January, 1961, The Granby Mining Company Limited optioned the property, and after some additional drilling purchased it and formed Jedway Iron Ore Limited to operate the property. Production started in late summer, 1962, and the first concentrates were shipped in October, 1962. The reserves at the start of production were stated to be 4,700,000 tons, which would produce 2,570,000 tons of concentrate. The company had a contract with Sumitomo Shoji Kaisha for 2,000,000 tons of concentrate to be supplied over five years. At the start of production it was anticipated only 2,000,000 tons of ore would be mined by open-pit methods, but this was revised and a larger ultimate pit with higher stripping ratios was planned in 1964 (*see* Plate XVIIIB). In the same year some ore was contributed by the nearby Adonis (37) orebody, and in 1966 from the Rose (39). Preparation for underground mining was started during 1965 with production in 1966.

Production from the Jessie pit has been as follows:—

Year	Tonnage Mined[1]	Concentrate		
		Produced	Shipped	Grade Iron (Per Cent)
1962	166,430	87,385	53,515	62.81
1963	700.553	357,297	339,008	61.86
1964[2]	587,233	351,822	363.136	62.21
	(693,907)	(415,866)	(429,239)	
1965	852,011	403,731	395,442	61.70
Totals	2,412,901	1,264,279	1,217,204	—

[1] Short dry tons.
[2] Figures in parentheses include Adonis production.

Some 12,371,600 tons of waste was removed to the end of 1965, with an overall stripping ratio of 5:1.

Recoverable reserves as of January 1, 1966, were calculated to be 369,100 tons in the pit and 569,500 tons in one underground stope, for a total of 938,600 tons grading 35 per cent magnetic iron. An additional 962,800 tons of the same grade exists underground but is judged to be presently uneconomic.

Geology

The Jessie orebody is one of the standards by which other pyrometasomatic deposits in the Queen Charlotte Islands are judged. It is better known than all others because not only has it been extensively explored by drilling, but also it is the only one to have been extensively exposed by mining.

The geology is illustrated by a plan (Fig. 42) showing an early stage in the life of the pit (June, 1963) and also the 150 and 450 adits, and by a representative vertical section (Fig. 43). The stratified succession includes altered basalts of the upper part of the Karmutsen Formation and the lower part of the Kunga Formation, including all of the lower and middle limestone member and several hundred feet of the argillite member. These rocks are cut by a sequence of intrusive bodies, large and small, which, from oldest to youngest, are:—

(1) Greenstones and glomeroporphyry greenstones related in nature and age to the Karmutsen flows.

(2) Diorite porphyry dykes, sills, and small irregular bodies.

(3) Diorite to quartz diorite of the Jedway stock.

(4) Rhyolite dykes.

(5) Small andesitic to basaltic dykes.

The period of skarnification and mineralization separates the intrusion of the dykes, (4) and (5), from the earlier bodies.

The Karmutsen Formation is composed of greenstones that may be amygdaloidal or finely glomeroporphyritic but otherwise are fairly textureless. It is likely that the glomeroporphyritic greenstones are actually sills of related age and lithology rather than flows. Some limestone lenses are definitely present in the upper part of the greenstones. The two limestone members of the Kunga Formation are inordinately thin at the Jessie mine in comparison with nearby localities and particularly with the thicknesses present on the Copper Islands, Jib group, and southern Burnaby Island. The basal massive grey limestone member is only about 50 to 100 feet thick and the flaggy black limestone member only about 250 feet thick. In contrast, the argillite member is of normal thickness.

The diorite porphyries vary considerably in appearance because of differing colours and contrast between plagioclase phenocrysts and matrix. These differences are entirely superficial and result from slight differences in alteration and metamorphism. Most commonly the porphyries are formed of 40 to 50 per cent prominent white phenocrysts of plagioclase (zoned $An_{40\pm}$, 1 to 3 millimetres long) with about 5 per cent chloritized amphibole in a light- to dark-green matrix formed mainly of very fine andesine and chlorite, and minor quartz, magnetite, and sphene. The diorite porphyry dykes are truncated by the Jedway stock and do not occur in the adits below the pit. The Jedway stock is composed of fairly uniform medium-grained diorite to quartz diorite that on the average is composed of about 50 per cent of zoned andesine with sub-equal amounts of hornblende, quartz, and orthoclase (10 to 15 per cent), and some biotite and magnetite. The rocks exposed in the Jessie pit or nearby are visibly bleached in comparison with the normal quartz diorite.

Post-ore dykes in the pit are small and insignificant, but in the nearby area and in the adits below they are relatively common. Buff-coloured aphanitic rhyolites form the largest ones. These may carry 2 to 5 per cent quartz phenocrysts in a very fine spherulitic quartz and feldspar matrix. Commonly they are flow banded and may have a parallel platy cleavage. They occur near the coarse crusher and in the adits below, but are not exposed in the pit. The smaller basic dykes are either andesites or basalts, and are dark-green to grey brown-weathering finely spherulitic rocks composed of fine andesine, augite, and chlorite with sphene or leucoxene. Both dyke types are undeformed and follow large faults without being sheared but may be offset by small amounts. They appear to be of roughly equivalent age,

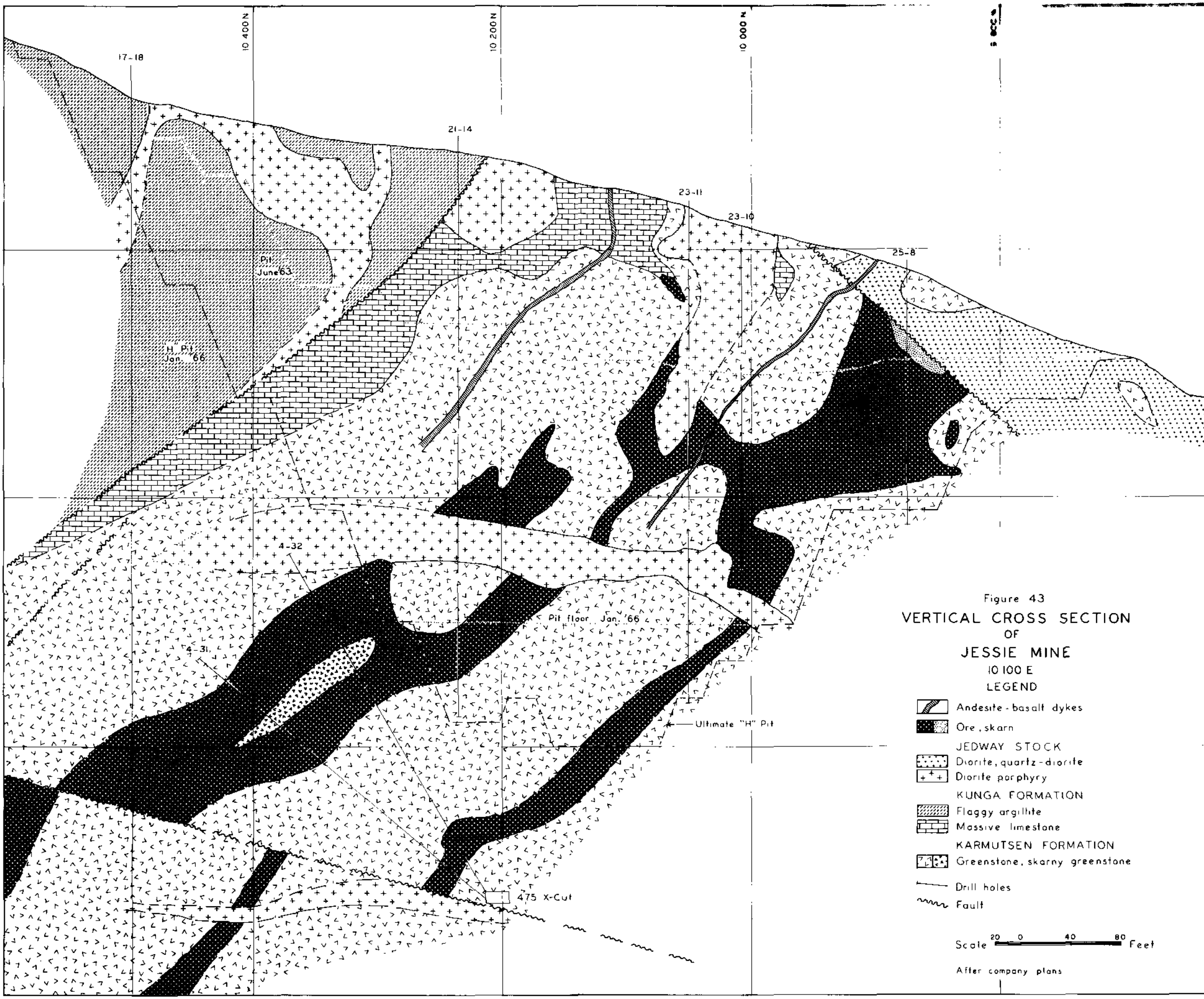


Figure 43
VERTICAL CROSS SECTION
OF
JESSIE MINE
10 100 E
LEGEND

although in one locality basalt was observed cutting rhyolite. By the nature and relative age it appears likely that they are part of the Masset dyke swarm.

Alteration including metamorphism and metasomatism has affected all but the post-ore dykes to a considerable degree. Karmutsen flows and related sills have been subjected to complicated overlapping periods of alteration with resulting variety in effects. These rocks appear to have been subjected to an early chloritization which was followed or graded into a partial amphibolitization and then to a related sequence of skarnification and ore replacement. This, depending on intensity, ranged from complete or partial replacement by garnet, epidote, or magnetite with new actinolite, and chlorite. The fringe areas of this alteration are intensely chloritized. In addition, adjacent to the quartz diorite contact are patchy areas of contaminated diorite to granitized greenstone and nearby much calcite filled fracturing. In comparison with the greenstones, the limestones have not been much altered, although somewhat bleached and recrystallized. Very little skarn or ore replaces the limestone. On the other hand, the flaggy argillites overlying the limestones have been subjected to patchy bleaching and slight hornfelsing. In these areas, pyritic-coated fractures and replacement of laminæ are relatively common. The diorite porphyry resists alteration, skarnification, and ore replacement, but all these processes have affected selected locales. The commonest alteration to the porphyries is variable chloritization of mafic minerals and matrix and intense sericitization of the feldspars. This may be accompanied by reddish fine ferro-dolomitic replacement of the matrix. Replacement by garnet, epidote, or magnetite is less common than in adjacent greenstone, and as a result some dykes appear to cut the ore, although all are pre-ore. The Jedway diorite to quartz diorite below the contact has apparently been depleted in mafic minerals, and those present are intensely chloritized. A faulted tongue of diorite within the ore zone is more highly altered to a bleached talcose rock with remnant granitoid texture. A minor part of this tongue is replaced by skarn minerals and magnetite.

Structure

The Jessie orebodies are on the northern flank of a westward-trending domal anticline near its intersection by a north 40 degrees west fold and fault structure of presumably younger age. This intersection may well have been a main reason for this localization of the intrusion of the Jedway stock. The ore is primarily in the Karmutsen greenstones adjacent to and above the contact with the stock, and most of the ore lenses are conformable with bedding. The stratified rocks at the Jessie, except immediately adjacent to faults, strike within 10 degrees of east and west and dip 45 to 75 degrees north, with the average dip probably about 50 to 55 degrees. In the upper part of the pit a sharp anticline-syncline pair was exposed. These folds either were non-stratiform or minor greenstone bodies penetrated and disrupted them in part. An irregular body of diorite porphyry partially followed the warped limestone-greenstone contact, forming a small irregular basin beneath the syncline with a stem-like conduit below. The section used (Fig. 43) does not illustrate these upper structures well.

Faults of moderate and small size are numerous in the pit area, with two major orientations: northerly with an eastward dip of 45 to 75 degrees, and north 60 to 80 degrees east with a similar range of southward dips. The northerly faults are apparently the larger and in some instances offset the easterly faults. Four important northerly faults occur in the pit zone, numbered from east to west. No. 1 and No. 4 are the largest fault zones. Nos. 1, 3, and 4 strike north 20 degrees, 0 degrees, and 15 degrees west respectively, whereas No. 2 cuts from No. 3 to No. 4 striking about north 5 degrees east. Nos. 3 and 4 are steeper than Nos. 1 and 2, averaging about 75 degrees east in contrast to 60 degrees. Of the easterly faults, two are important—one at the north and one at the south of the pit. Judging by the variety of orientations of striæ on fault planes, fault movement is complicated. No. 1 fault zone has an apparent total of 400 feet right-hand offset. Actual movement probably combines right hand with normal movement, both of the order of 200 feet. No. 4 fault may have been subjected to movement of about the same amount, but No. 2, No. 3, and the easterly faults have likely been subjected to less movement.

Orebodies

The orebodies occur in a zone essentially concordant with bedding that includes several bands of magnetite ore separated by skarn, chloritic greenstone, or diorite porphyry. In general there are three bands of ore—the upper one about 100 to 120 feet below the Kunga contact and about 20 feet thick, the main or intermediate band about 20 to 40 feet below and about 40 to 80 feet thick, and a lower band some 80 to 100 feet below the main band and 20 to 25 feet thick. The bands maintain their character over 800 feet of dip and strike length but tend to coalesce at the upper elevations in the vicinity of the basin-like mass of diorite porphyry and limestone. Skarn does not form a complete sheath about the individual bands but is common as a transition from magnetite ore to chloritic greenstone. The ore bands as they reach a major fault zone, No. 1 or the southern east-west fault in particular, follow up the fault zones. Indeed, the uppermost exposures of ore all resembled dykes following the faults. As stripping progressed, these enlarged downward and then diverged into the bedding attitudes. There is little evidence to suggest that the ore replaces limestone beds in the Upper Karmutsen, although some limestone beds do exist. The ore and skarn in general contain many remnants that in all respects resemble altered greenstone.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1908, p. 60; 1959, pp. 11–14; 1960, pp. 11–12; 1961, pp. 13–15; 1962, pp. 11–13; 1963, p. 16; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Econ. Geol. Ser. No. 3, 1926, pp. 39–42; Gilleland, H. B., *Western Miner,* October, 1959, pp. 110–113; Staff, *Western Miner,* January, 1962, pp. 14–17.]

Adonis (37)

The Adonis orebody is on the Adonis Crown-granted claim, Lot 1865, and extends onto the Sweet Pea Crown-granted claim, Lot 68. The showings are between Harriet Harbour and Ikeda Cove from about 500 to 600 feet elevation on the Ikeda side of the ridge. They are about half-way between the Jessie and Lily mines. The Adonis claim is held by mineral lease by Jedway Iron Ore Limited, but the Sweet Pea is held by Falconbridge Nickel Mines Limited, and any ore mined on it will be on a royalty basis to that company.

The Adonis magnetite showing was probably discovered about 1906–08, although there is little record of the early history. Silver Standard Mines Limited in 1959 and 1960 carried out the first extensive prospecting by reconnaissance magnetometer survey and then drilled 13 EX holes totalling 1,081 feet on it. Later

Jedway mapped it in detail in 1964 and drilled nine AX holes totalling 1,668 feet. This work proved the presence of a small orebody. A mile of road was built to connect with the Jessie system, and a pit prepared for production which began in September, 1964. In that year 106,674 tons of ore was produced. In 1965 additional drilling totalling 1,094 feet in five AX holes in line across the extension of the ore showing in the pit face proved up another 137,000 tons of ore that has a reasonable stripping ratio. It occurs in a westerly trending zone that extends onto the Sweet Pea claim.

Geology

The Adonis deposit is another pyrometasomatic magnetite deposit that occurs in the normal setting. The ore lies at the lower contact of limestone and Karmutsen greenstones. The limestone may be a lens in the top of the Karmutsen Formation rather than the Kunga Formation, because it is apparently overlain by some greenstones and is structurally below the Kunga limestone at the adjacent Jessie pit. Alternatively it may be a down-faulted repetition of the Kunga-Karmutsen contact. The limestone is about 100 feet thick and strikes about north 75 degrees east and dips 45 degrees north through most of the drilled section but flattens to the north. The lower contact is complicated by a sill-like body of diorite porphyry and minor diorite, and the orebody. The ore appears largely to replace greenstone but also definitely replaces some limestone and may replace diorite porphyry. The latter is in part altered to skarn. Post-ore sugary-textured green andesite sills are common. The ore is contained in a small block bounded by steep faults about 180 feet apart trending about north 65 degrees east. Fault movement appears to have been chiefly horizontal but may also have dropped the contained block. The faults are pre-ore, for narrow ore lenses occur along them. Two linear magnetic anomalies with orientations similar to these faults occur on the Adonis claim—one on the projection of the southern of the two faults and the other 500 feet to the south near the boundary of the claim.

[Reference: Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Econ. Geol. Ser. No. 3, 1926, p. 48.]

Lily (38) The Lily copper mine is located three-quarters of a mile west of the head of Ikeda Cove and has four portals between 264 and 594 feet elevation. The Lily claim, Lot 66, is the centre of a large group of claims including 20 Crown-granted claims, 3 mineral leases of former Crown-granted claims, and 10 located claims, all held by Falconbridge Nickel Mines Limited. This group includes the Rose, Lot 1871 (*see* p. 206), Sweet Pea, Lot 68 (*see* p. 202), Sadie, Lot 2610, and Spade Flush, Lot 2612 (*see* Thunder, p. 211).

The Lily showings were discovered about 1900 by A. Ikeda or members of his fishing company, who prospected the area as a result of finding chalcopyrite float on the beach. The fishing company developed and shipped the easily mined ore, with production starting in 1906. By 1909 the easy mining was finished, and grade and tonnage dropped. A new company, Ikeda Mines Limited, was formed in Vancouver, and a programme of exploration and development started which included 2,520 feet of diamond drilling. Claims were surveyed in 1911 and Crown granted in 1912. Mining was renewed in 1915 and continued until 1920. The production figures are as follows:—

Year	Tonnage Mined	Gold (Oz.)	Silver (Oz.)	Copper (Lb.)
1906	4	2	26	1,353
1907	671	165	2,291	119,982
1908	6,928	693	14,079	489,859
1909	4,260	261	4,216	133,360
1915	355	101	1,529	112,788
1916	1,060	135	1,977	132,345
1917	1,000	153	1,792	152,883
1918	210	58	795	62,933
1919	151	51	722	38,990
1920	141	27	305	21,088
Totals	14,780	1,646	27,732	1,265,581

There was little interest in the mine or the area from 1920 until 1943, when St. Eugene Mining Corporation bought the Crown-granted claims still valid and later obtained mineral leases on the others or staked located claims so that most of the original block was again held. Exploration of the Lily property was delayed until 1956, when it was examined and sampled in detail. Work in the succeeding years was generally minor, except in 1964, when seven AX holes totalling 1,774 feet were drilled.

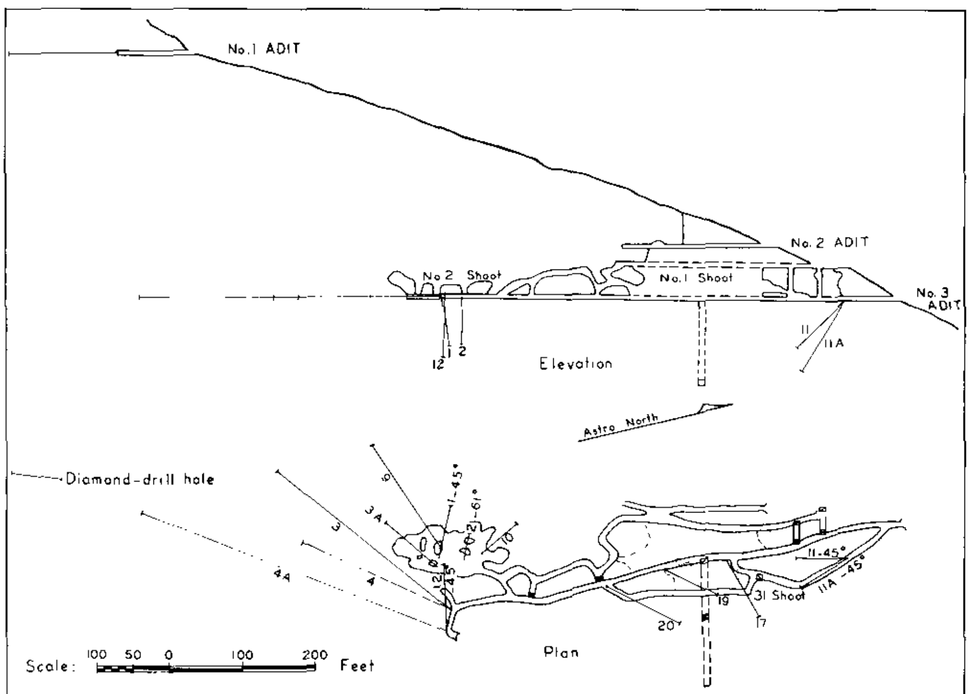


Fig. 44. Plan and elevation, Lily mine.

Mine development consists of four adits; three are close together with portals at 264, 308, and 324 feet elevation respectively, and the No. 1 or upper adit is at 594 feet (*see* Fig. 44). The main entry is the lowest or No. 3 adit. It is 660 feet long, and two stopes, a winze, and sublevel are developed from it. One stope on No. 1 shoot is near the portal, connects with the other lower levels, and opens to the surface. The other stope starts about 550 feet from the portal and extends a maximum of 50 feet up dip. A 110-foot winze inclined at 45 degrees with a 138-foot sublevel crosscut to the east is developed 260 feet from the portal. All adits are blocked and entry can only be gained through the open stopes, and the writer has not done this so that the following account of the geology is dependent almost entirely on the references.

Geology

The Lily mine is in the top of the Karmutsen Formation. Limestone exposed in the main workings is most likely one of the lenses in the top of this formation rather than Kunga limestone, although the limestone at the No. 1 adit is clearly Kunga Formation. The rocks locally strike about north 50 degrees east and dip about 35 degrees east, which is somewhat discordant to the expected attitude related to the domal anticline from Harriet Harbour to Ikeda Cove. Outcrop is rare in the area and the significance of this discordance is not known. The greenstone and limestone are flanked on the west by a sill-like body of fine diorite. Three subparallel " veins " occur, of which one has produced most of the ore from two shoots. The two veins of the main workings are in effect mineralized shear zones parallel or subparallel with bedding. with widths up to 25 feet between usually well-defined walls. These veins consist apparently of highly altered, sheared, and replaced greenstone and now are composed of chlorite, actinolite, quartz, and calcite with pyrite, chalcopyrite, magnetite, pyrrhotite, and traces of sphalerite. The sulphides occur as streaks and bands, especially at the walls, as disseminated blebs, and as larger irregular masses. Late diabase to basalt dykes cut the shears and ore without offset. The " vein " of the No. 1 adit differs in being a thin planar magnetite-rich skarn lens at the contact of Kunga and Karmutsen Formations. The drilling in 1964 shows this body continues south of the adit to the claim boundary and is responsible for a magnetic anomaly there present. The widths are all less than 10 feet and the body is copper-poor.

The main Lily orebodies are not typical copper-rich metasomatic deposits but represent an extreme variant that belongs to this group. The Lily ore is found in the typical stratigraphic locale, but the structural setting differs from surrounding typical pyrometasomatic iron-copper deposits including the No. 1 adit " vein." The Lily ore clearly replaces volcanic rocks but in a bedded shear zone and without the full array of skarn minerals, containing only actinolite, chlorite, magnetite, and pyrrhotite.

The main vein has been followed continuously in No. 3 adit for 670 feet, and in this distance two shoots of economic grade and width were mined—No. 1 shoot for about 250 feet of length and No. 2 for 140 feet. No. 1 shoot was mined over 110 feet of dip length and was developed by the winze over another 110 feet. No. 2 shoot was only partially mined up dip for 50 feet. This vein shear strikes on the average north 10 degrees east and dips east 35 degrees in No. 2 shoot and 45 degrees in No. 1 shoot. No. 31 shoot is a separate subparallel vein about 40 feet in the hangingwall of No. 1 shoot. It was narrow (1 to 3 feet) but high grade and

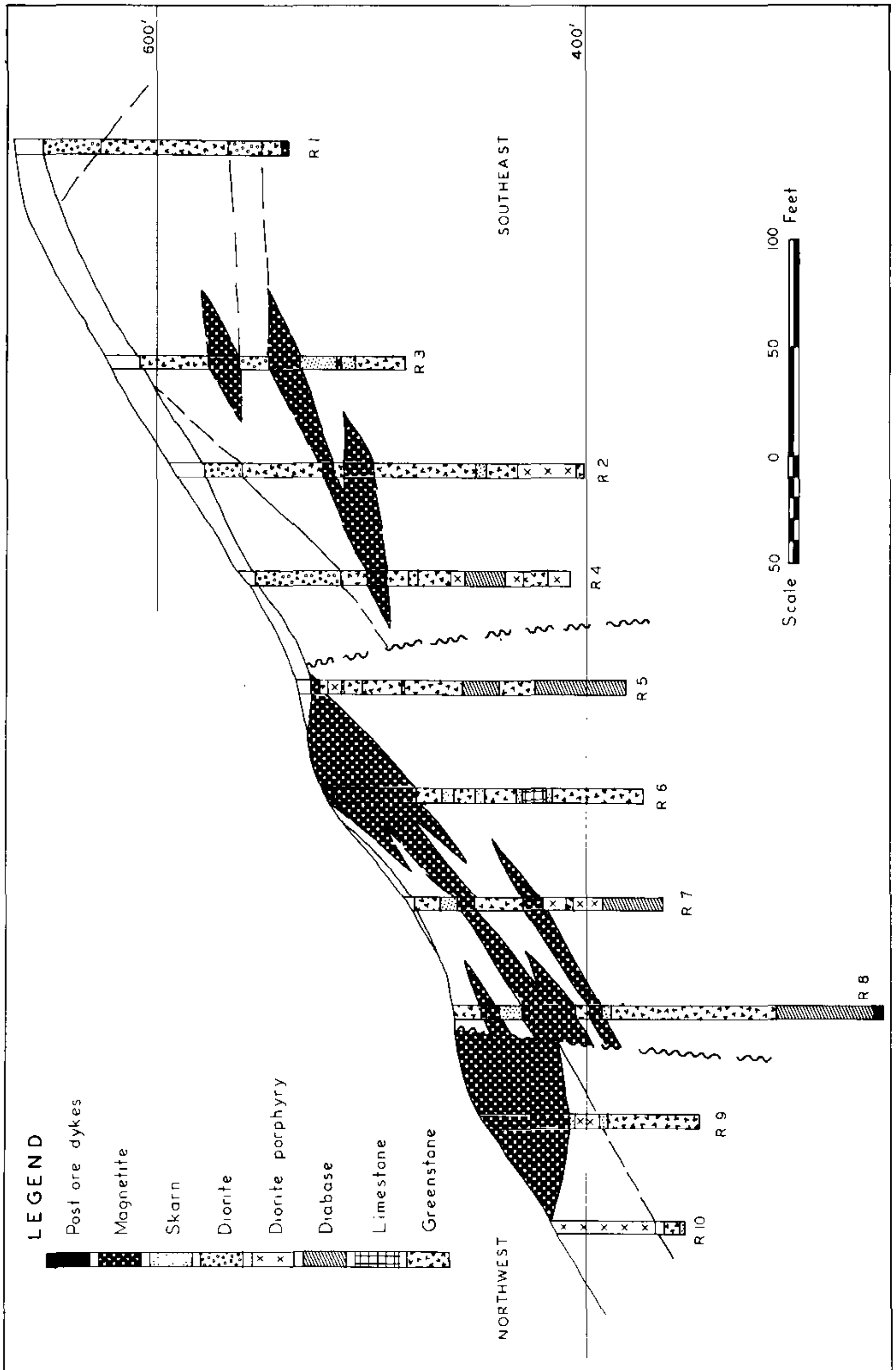


Fig. 45. Rose, vertical section.

was stoped over 140 feet of length. The "vein" in No. 1 adit is most likely a separate structure, although its attitude is similar.

Developed reserves are small, about 25,000 tons of 1.5 to 2 per cent copper with some gold and silver.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, pp. 63–64; 1913, p. 100; 1918, pp. 38–39; McDougall, J. J., 1956, private report to St. Eugene Mining Corporation.]

Rose
(39)

The Rose, a Crown-granted claim, Lot 1871, is on the ridge between Ikeda Cove and Collison Bay. The showings extend from near the ridge-top down the northwestern slope and just over the boundary onto the adjacent claims, Elva Nos. 3 and 4 and Maple. All claims are part of a large block held by Falconbridge Nickel Mines Limited, but the showings were drilled in 1965 by Jedway Iron Ore Limited and will be mined by them on a royalty basis. A road will be built to connect with the one to the Adonis, and the ore will be trucked 2½ miles to the coarse crusher at the bottom of the Jessie pit.

The showings were discovered by A. Ikeda and Company some time during the period 1901–06 when they were prospecting in the vicinity of their Lily showings. Some stripping and prospecting ensued, but the magnetite bodies found were copper-poor and so were largely ignored. The Rose showings were described by Roberston and Young and Uglow as the Chrysanthemum Group. Falconbridge (St. Eugene Mining Corporation) acquired the Lily and other claims in the mid-40's and did some packsack drilling in 1956 on the Rose. Silver Standard Mines Limited carried out a magnetometer survey in 1959. The Granby Mining Company Limited mapped the showings in detail in 1962, and Jedway Iron Ore Limited drilled 37 short holes totalling 4,610 feet in 1965.

Geology

The Rose is situated at the eastern end of a domal anticline adjacent to the Collison Bay stock. Outcrop in the vicinity is relatively scarce and much of what exists is of magnetite ore. The showings are contained in greenstones, with minor limestone lenses at the top of the Karmutsen Formation. The main Kunga limestone outcrops along the ridge to the northeast and southwest within about 500 feet of the showings, and should have occurred at only slight additional elevation above the present slope. The normal Karmutsen basaltic greenstones are cut by a sequence of small intrusions, most of which appear to be sills: firstly, diabase and glomeroporphyritic diabase most likely related to the flows; secondly, fine diorite porphyry; and, thirdly, medium-grained diorite. All the foregoing rocks may be skarnified and replaced by magnetite and in addition are highly chloritized. The metamorphism and metasomatism have obscured original lithologies and relationships to a considerable degree, so that distinguishing between diabase and diorite porphyry in particular is difficult. Post-ore intrusives are insignificant but include small andesite and felsite dykes.

The structure is not fully revealed, but apparently bedding strikes about north 35 degrees east and dips about 20 to 30 degrees northwestward, so that beds are essentially parallel with the slope. Pre-ore intrusive bodies, skarn bands, and orebodies generally have the same attitude. Faulting does not appear important and may be limited to small steep faults parallel to the strike, judging by the continuity of the magnetic anomalies described below.

Surface mapping (as shown by Young and Uglow and by Granby) reveals three parallel bands of scattered outcrops of magnetite over an area some 550 by 400 feet. Magnetometer anomalies connect the scatter outcrop into rather continuous bands. The sections (Fig. 45) show these anomaly bands do not result from dyke-like orebodies but from gently dipping lenses. Anomalies occur at the thicker sections and at outcrop areas. The ore and the skarn can replace any of the units except the small andesite and felsite dykes. Quite clearly porphyry and diorite are chloritized and skarned, and it is reasonably certain some of the ore replaces these rocks. Remnants of limestone on the fringes of some ore indicate this too may be replaced; however, most of the ore replaces greenstone, judged by its envelope and remnants within.

The ore varies widely in grade and sulphide content, but copper is generally quite low. Drill holes by Falconbridge adjacent to R9N13 (section N, Fig. 45) assayed over 35 feet: Iron, 66 per cent; sulphur, 0.34 per cent. A second hole drilled into the hill at 45 degrees from the same location over 37 feet assayed: Iron, 61.9 per cent; sulphur, 2.8 per cent. The average grade of magnetic iron is probably over 40 per cent and sulphur content about 1 per cent. Sufficient reserves have been outlined to warrant development, so that the drilling programme was not completed. Thus reserves are not accurately known. Drilling on rows J, L, N, and P have developed about 561,000 tons of 40 per cent magnetite iron ore with a low stripping ratio. Total reserves of twice this amount may be recoverable at a much higher stripping ratio.

[References: *Minister of Mines, B.C.*, Ann. Rept., 1907, pp. 64–65; Young and Uglow, *Geol. Surv., Canada*, Iron Ores of Canada, Vol. 1, Ec. Geol. Ser. No. 3, 1926, pp. 48–51.]

Reco
(42)

The property consists of one Crown-granted claim, Lot 82, held by McMillin interests. The showings are one-quarter mile southwest of the south end of Harriet Harbour. It was discovered about 1906 and explored by a small inclined shaft and several hundred feet of diamond drilling in 1908. Since then the only significant work was done in 1956, when Silver Standard Mines Limited drilled several short packsack holes totalling about 400 feet. The deposit is a pyrometasomatic replacement of fractured Karmutsen greenstone at the contact of the Jedway stock. A small body of magnetite with some garnet and containing pyrite and chalcopyrite as veinlets trends westward from the contact and dips north about 40 degrees. The body is some 80 feet long and 4 to 8 feet wide on the surface and runs about 1.5 per cent copper.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1907, p. 67; 1929, p. 60.]

Blue Belle
(43)

The property consists of one Crown-granted claim, Lot 80, held by Jedway Iron Ore Limited. It has commonly been called the Dingo (*see* Young and Uglow), although this is actually a separate showing and claim. The showing is south of Harriet Harbour at about 800 feet elevation and between the Magnet and the Moresby Island. The showing is a small pipe-like lens of magnetite with minor garnet striking northwest and dipping nearly vertically at a contact between limestone, possibly the Kunga, and Karmutsen greenstone. The main lens on the surface is about 40 feet long and 5 to 15 feet wide. In 1960 Silver Standard drilled seven EX holes totalling 554 feet and estimated reserves of 15,000 tons.

Magnet (44) The Magnet showing is about three-quarters of a mile south of Harriet Harbour at about 1,450 to 1,600 feet elevation. The magnetite outcrop was discovered about 1906 by or for J. S. McMillin and originally called Iron Mountain. Some stripping was carried out and a 22-foot adit driven about 1908, otherwise little further work was done until Silver Standard Mines Limited optioned the property in 1956. In the fall of 1959, 22 EX holes, totalling 1,531 feet, were drilled. The Magnet claim is Crown-granted Lot 79, and is currently held by Jedway Iron Ore Limited as a result of part of the agreement between The Granby Mining Company Limited and Silver Standard Mines Limited.

Geology

The Magnet is a fairly typical example of one variety of pyrometasomatic magnetite deposit in the normal setting in which little skarn is developed beyond the ore. It is a lensoid body of magnetite and garnetite that appears to replace volcanic rocks and possibly limestone at the top of the Karmutsen Formation near the Jedway stock. The enveloping rocks are greenstones and pillowed greenstones, but a lens of limestone occurs near the showings and the main Kunga grey limestone member outcrops within a few hundred feet to the north. The pillow greenstones locally strike north and dip 20 to 35 degrees westward, and the flaggy Kunga limestone to the north has a similar attitude. Fine diorite porphyry dykes are common in the Kunga flaggy limestone member, and the Jedway diorite and quartz diorite outcrop within 600 feet to the east. A moderately small-sized regional fault striking about north 55 degrees west projects to the vicinity of the Magnet orebody and may either cut it off down dip or, if pre-ore, may have been the locus of mineralization.

The surface showing is a continuous body 360 feet long and 40 to 80 feet wide with an average true thickness of about 20 feet. Drilling shows the greatest dip length to be 180 feet. The outcrop traces northwestward down the hill from the highest outcrop at about 1,600 feet. The small adit is at 1,450 feet elevation at the bottom of the natural exposure. The body is composed of massive magnetite with included pods of garnetite and some remnants of slightly epidotized volcanic rocks.

Sulphide minerals are fairly rare, are concentrated along the western margin, and include pyrite, chalcopyrite, and traces of sphalerite. Some of the magnetite is reported to be lodestone. The grade of much of the exposed body is about 60 per cent iron (soluble iron) as magnetite. The diamond drilling established reserves of about 160,000 tons.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, p. 67; 1929, p. 60; McConnell, R. G., *Geol. Surv., Canada,* Sum. Rept., 1909, p. 78; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, pp. 37–39; Gilleland, H. B., *Western Miner,* October, 1959, p. 112.]

Copper Queen (45) The Copper Queen showings are nearly a mile south of Harriet Harbour on either side of a small steep creek at about 950 feet elevation. The Crown-granted claim, Lot 77, is a key claim of a group including the Dingo, Lot 187, Eagle Tree, Lot 2600, Reco, Lot 82, and Modoc, Lot 83, that has been called the McMillin group. The Copper Queen has been held continuously since about 1906 by J. S. McMillin or his family. This claim was one of the first of the group to be located and has received a major share of the exploration. In 1907 and 1908 stripping, several small adits, and one long adit were started and a tram-line was cut out to the beach. In 1909 the long adit reached its target, but the results were disappointing, and the property received little more attention until 1954, when R. E. Legg drilled some short holes. The latest exploration was in 1956, when Silver Standard Mines Limited drilled nine EX holes totalling 1,222 feet.

The Copper Queen is a copper-rich pyrometasomatic deposit in the top of the Karmutsen Formation at the contact of the Jedway stock. The Karmutsen is metamorphosed to a partially amphibolitized greenstone. It appears to strike north 50 degrees east and dip about 30 degrees northward. Limestone is exposed in the creek above the showings. The Jedway stock is locally a mafic-rich quartz diorite, and has a fairly regular roof just below an elevation of 900 feet.

The workings consist of a 375-foot adit driven due south in the quartz diorite at an elevation of about 850 feet, three short adits in the surface showings, and two open cuts. Two adits are in the west bank of the creek and one in the east. Only the lowest on the west is open to the face. One open cut is at the quartz diorite contact in the west bank, the other above the adit in the east bank.

The showings are minor lenses of magnetite with chalcopyrite at the contact and a more important bedded horizon of lenses some 50 feet above the contact in the surface exposures. The main lens exposed is in the west bank and is continuous for about 40 feet on dip and 25 feet along strike in the adits and up to 10 feet thick. The margin of this lens appears to be exposed in the east bank. The long adit reaches under these showings and is almost entirely in quartz diorite, although there is some amphibolitized greenstone with disseminated magnetite near the face. The surface showing consists of massive magnetite with much chalcopyrite as streaks, blebs, and discrete veinlets cutting magnetite, and locally averages from 1 to 4 per cent copper. Pyrite, garnet, and actinolite are locally important, and malachite is present. At the fringes of the ore lens, vuggy quartz-pyrite-magnetite veinlets occur. The showings are cut by unaltered green pyritic andesite dykes trending north-south.

Diamond drilling results are not known in detail to the writer. Holes were drilled from two main positions, both near the creek, one below the showings and one just above. The holes were drilled to the south and west chiefly at angles from −20 to −60 degrees. The rocks encountered were mostly amphibolitized greenstone and quartz diorite with some feldspar porphyry and felsite dykes. Little additional ore was found.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, p. 66; 1929, p. 60; McConnell, R. G., *Geol. Surv., Canada,* Sum. Rept., 1909, p. 77.]

Moresby Island (46)

This property, Crown-granted claim Lot 78, is held by Jedway Iron Ore Limited as one of its large group of claims. It was originally discovered by J. S. McMillin or associates about 1905–06. The showings are 1 mile south of Harriet Harbour at about 750 feet elevation northeast of the Copper Queen. They consist of a small compact body of magnetite and a zone of disseminated chalcopyrite in a lightly skarned flat-lying lens of limestone at the southern contact of the Jedway stock. The lens occurs on a spur with quartz diorite below and greenstone above, so it seems to be part of the Karmutsen Formation. The limestone is variably altered, ranging from slightly recrystallized to marbleized to skarnified with replacement by garnet, epidote, and actinolite. Disseminated chalcopyrite occurs on the surface in an area about 190 feet long and up to 30 feet wide exposed by old pits and trenches. In 1956 Silver Standard Mines Limited drilled two packsack holes totalling 100 feet through this zone. One hole dipping east at −52 degrees ended in diorite at 75 feet. Chip samples of surface showings averaged slightly over 1 per cent copper with about 1 ounce of silver per ton.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, p. 67; 1929, p. 60.]

Eagle Tree
(47)

This property consists of one Crown-granted claim, Lot 2600, about a mile south of Harriet Harbour. It is held by the McMillin interests. The showing, at 1,000 to 1,100 feet elevation, is a linear zone over 300 feet long and as much as 20 feet wide at the contact of the Jedway quartz diorite and Karmutsen volcanics. The contact trends about north 65 degrees east and dips steeply south. At this contact, magnetite, pyrite, and chalcopyrite occur in massive and disseminated bodies. Late rhyolite dykes are common in the area. The showings exposed by six trenches on the surface are of interest only for their copper content, which runs more than 2 per cent in some trenches. An adit crosscut 90 feet below the central trench has been driven about 220 feet to and beyond the contact but shows little mineralization. In 1956 Silver Standard Mines Limited drilled 12 EX holes totalling 1,864 feet.

[Reference: *Minister of Mines, B.C.,* Ann. Rept., 1929, p. 60.]

Ida
(48)

This property is part of the Jim group of recorded claims held by Jedway Iron Ore Limited, about a mile east of the southeast end of Huston Inlet and about 1,000 feet west of the Hercules. The showing, at an elevation of about 800 feet, is a vertical dyke-like body of magnetite-rich skarn striking north 10 degrees east. The magnetite contains green garnet and calcite in variable amounts and minor sulphides. The body can be traced for nearly 200 feet and is up to 25 feet wide.

[References: *Minister of Mines, B.C.,* Ann. Rept., 1907, p. 68; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, p. 43.]

Hercules
(49)

This property is part of the Jim group of recorded claims held by Jedway Iron Ore Limited. The showing is 1¼ miles east of the southeast end of Huston Inlet at an elevation of about 1,100 feet. It was discovered about 1906 by McMillin, Watson, and McEachern. The showing consists of the irregular metasomatic replacement of the contact of the Karmutsen Formation with the Carpenter quartz monzonite stock, near the base of the Kunga limestone and is up to 100 feet thick. The purity of the skarn varies widely, much being quite garnetiferous. Some cuts and two small adits expose the ore on the steep but covered slope.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, p. 68; 1913, p. 101; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, pp. 43–44.]

Lotus
(50)

This property is part of the large block of claims held by Falconbridge Nickel Mines Limited centred on the Lily mine. It was originally the Lotus Crown-granted claim, Lot 1860, but is now held by recorded claims Ikeda Nos. 7 and 8. The showings were discovered in the period 1901–06 by prospectors of A. Ikeda & Company. They are at an elevation of about 500 feet, about three-quarters of a mile south of Ikeda Cove near the Thunder. Mineralization consists of a sulphide-rich massive replacement body at the contact of Kunga and Karmutsen Formations. The mass is composed of pyrrhotite with pyrite, chalcopyrite, and arsenopyrite. It is developed by a 75-foot-long open cut and a 120-foot-long adit at 480 feet elevation. On the surface a body of some 35 by 20 feet is exposed, and in the adit about 50 feet below a thickness of 45 feet is exposed. The grade of copper is about 0.75 per cent.

[Reference: *Minister of Mines, B.C.,* Ann. Rept., 1907, p. 65.]

Thunder (51)

The Thunder is a Crown-granted claim, Lot 2611, one-half interest held by Mrs. Sadie Thompson, of Vancouver, and the other half by the McMillin estate, of Seattle. The Thunder adit is about one-half mile southwest of Collison Bay on the ridge between this bay and Ikeda Cove. The Thunder in the past was commonly grouped with the adjacent claims, Sadie, Lot 2610, and the Spade Flush, Lot 2612, both of which are now held by Falconbridge Nickel Mines Limited, by mineral lease. One of the Thunder showings projects onto the Sadie claim. These showings were discovered in 1907 by Ike Thompson and C. T. Daykin. A 300-foot adit was driven in 1913–14 to intersect one of the showings and some surface stripping was done. Recent exploration has mainly involved examination and magnetometer surveying, first by Falconbridge Nickel Mines Limited and then by The Granby Mining Company Limited and Jedway Iron Ore Limited.

Geology

The geology of the Thunder, Sadie, and Spade Flush was rather fully described by Young and Uglow, 1926, pages 44 to 47, and relatively little new work has been done and will not be described as fully here. However, the showings described as being on the Sadie or Spade Flush are almost entirely on the Thunder, although one of the ore zones does project onto the Sadie.

The claim is heavily mantled with overburden and timber. The isolated outcrops include numerous rock types, many of which are dykes. It is clear, however, that the country rock over most of the Thunder claim is Karmutsen greenstone, and this is true in the adit. On the Sadie claim across a gully to the south and on the ridge-top along the western part of the Thunder claim, Kunga grey limestone outcrops. Intrusive rocks on the surface and in the adit include diorite and post-ore banded felsite or rhyolite and basalt dykes. The limestone strikes about north 30 degrees east and dips gently westward. Most of the dykes, including the diorite, have a similar strike (north 10 to 50 degrees east) but dip 60 to 80 degrees eastward.

The adit has its portal near the east corner of the claim at 620 feet elevation and is driven north 62 degrees west for 320 feet. At 250 feet an irregular 70-foot drift follows a shear and orebody to the north, and at 270 feet an irregular crosscut bears to the west for 100 feet. The adit is entirely in greenstones, except for the diorite, felsite, and basalt dykes, which occur at fairly regular intervals of about 30 feet. Besides the main north-northeasterly shear, followed by the drift, there are two northerly shears (north 10 degrees west and north 25 degrees west — both dip 65 degrees eastward). A 25-foot banded rhyolite dyke striking north 30 degrees east on reaching one of the northerly shears turns and follows it north. The ore zone of magnetite, calcite, and chalcopyrite is about 12 feet wide in the drift and is followed for 80 feet. At the south end it grades sharply into garnet skarn. The shear on the east or hangingwall carried much pyrite and chalcopyrite.

Three general ore zones occur on the Thunder and extend slightly onto the neighbouring claims. Near the southwest corner at about 1,000 feet elevation a zone 500 feet long by up to 100 feet wide contains scattered exposures of magnetite, garnetite, or a mixture. A general magnetic anomaly surrounds the scattered exposures. Skarn and magnetite appear to replace Kunga limestone at the Karmutsen contact, to strike parallel to the rocks (north 30 degrees east), and to dip gently westward. The ores' true thickness is not known. Above the adit at about 800 feet elevation a lens of skarn and magnetite occurs, striking north 35 degrees east, that is 210 feet long and up to 20 feet wide. This projects downward to the ore lens in the adit and thus dips 64 degrees west. The third zone is at about 1,000 feet elevation on the upper slopes and about 500 feet northwest of the adit showing and near the northwest boundary of the Thunder. Within this zone there are two distinct bodies, one an equant-shaped body up to 100 feet long, and nearby a dyke-like body at least 200 feet long and 10 to 20 feet wide is oriented north 35 degrees east.

The Thunder orebodies include two general types, tabular bodies conformable with stratification and dyke-like to pipe-like bodies nearly normal to stratification. All of the zones and bodies are composed of mixtures in varying degree of magnetite and garnet-rich skarn. In certain localities, pyrite and chalcopyrite form significant concentrations. Much additional work would need to be done to properly assess the possible iron-ore reserves of the Thunder and the value of the chalcopyrite. High garnet and sulphide content makes doubtful the possible recovery of a magnetite concentrate of sufficiently high grade and purity to satisfy present-day contracts.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1908, p. 59; 1913, pp. 102–103; 1926, pp. 67–68; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, pp. 44–47.]

Meal Ticket and Maple Leaf
(52) (53)

These two separate properties are similar and adjacent, about one-half mile south of Collison Bay. Although they have been covered by recorded claims in recent years, they have received little new work. Both were discovered about 1906. They both consist of dyke-like sulphide-rich masses of magnetite, pyrrhotite, pyrite, and chalcopyrite that are of interest for their copper content. They appear to be metasomatic replacements along steep northerly striking fault or fracture zones within the Karmutsen Formation. The Meal Ticket has been followed about 200 feet on the surface, is up to 8 feet wide, and is intersected by a 33-foot adit. The Maple Leaf had considerable development by the Collison Bay Mining Company. Three adits were driven; the upper at 500 feet is 15 feet long, the central at 350 feet elevation has a 100-foot crosscut, 100-foot drift, and 80-foot winze; and the lower is 50 feet long but did not reach the ore. Both bodies had copper contents of the order of 1 to 2 per cent.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, p. 65; 1909, p. 81; 1918, pp. 44–45; 1923, p. 44.]

Oceanic and Wireless
(54) (55)

These two properties are similar and adjacent or possibly even the same. They are on the shore at the west entrance to Collison Bay. Discovery occurred about 1906 by the Daykin brothers. The ore is copper-rich bedded replacement of a thin interlava limestone in the Karmutsen Formation. The bed strikes north 25 degrees east and dips 45 to 50 degrees northwest and is up to 4 feet thick. A 50-foot adit was driven chiefly in 1911 on the Wireless at sea-level. Sorted chalcopyrite ore, totalling 15 tons and containing 1,178 pounds of copper and 7 ounces of silver, was shipped from the Oceanic in 1913. In 1916, 17 tons was shipped from the Wireless, containing 795 pounds of copper, 14 ounces of gold, and 12 ounces of silver.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1910, p. 84; 1911, p. 74; 1913, p. 103; 1918, p. 44.]

Plunger (56)

This property is part of the large group of claims held by Jedway Iron Ore Limited and The Granby Mining Company Limited, specifically the Plunger 1 to 4 held by Granby. It seems likely these showings were originally called the Ivan in 1913. They are 1 mile east of the southeast end of Huston Inlet and scattered on the south side of the valley from about 300 to 850 feet. There are two principal showings: one at about 550 feet elevation is a blob-like body some 50 by 30 feet on the surface, composed of magnetite and garnet; the other, between 700 and 825 feet elevation, is a planar deposit some 500 feet long and 25 feet or less wide, composed of skarn with magnetite, pyrite, and chalcopyrite. The upper deposit apparently is a replacement of a northwest-trending shear zone and is of interest primarily for copper content. A number of pits dating from the early exploration expose the mineralization. A small adit of similar age below the showings fails to reach the mineralization.

The showings are all very near the contact of the Carpenter quartz monzonite stock, and the lower magnetite deposit is actually a local flatish contact. Most of the replacement is of metamorphosed Karmutsen greenstones, some of granitic rock. Post-ore rhyolite and basalt dykes are common in the area. In 1962 Jedway did 150 feet of packsack drilling on the property.

[References: *Minister of Mines, B.C.*, Ann. Rept., 1913, p. 101; Young and Uglow, *Geol. Surv., Canada,* Iron Ores of Canada, Vol. I, Ec. Geol. Ser. No. 3, 1926, pp. 42–43.]

Flo (62)

This property is close to the shore at the east entrance to Poole Inlet on Burnaby Island. It consists of a group of 29 recorded claims, the Flo group, held by Merrican International Mines Ltd. The showings consist of an area reportedly 150 by 100 feet of magnetite replacing Kunga limestone near a large north-trending fault and several small areas nearby that are chalcopyrite-rich. During 1964 the company drilled 500 feet of EX holes in the vicinity.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1964, pp. 46–47.]

Hope (64)

This property is part of a group of located claims held by The Granby Mining Company Limited. The showings are about 1 mile east of the southeast end of Huston Inlet at about 300 feet elevation. The showings consist of a dyke-like replacement body of sulphide-rich skarn, of interest primarily for its copper content. The body is exposed for about 80 feet and is up to 20 feet wide, although the copper-rich portion is narrower. Grades of the order of 2.7 per cent copper across 10 feet are reported (Ann. Rept., 1918). It strikes north 60 degrees west and dips steeply east. A similar showing occurs several hundred feet to the south along strike. The body occurs near the contact of the Carpenter quartz monzonite but is seemingly entirely within that body. Silver Standard Mines Limited drilled one short packsack hole in February, 1960, which intersected 20 feet of magnetite with 5 feet containing 0.85 per cent copper.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1913, p. 101; 1918, pp. 39–40; 1929, p. 61.]

Courte Antimony
(3)

This property, which is held by 18 recorded claims, is on Riley Creek, which flows into Rennell Sound. It reportedly was known during World War I but received no more attention until staked by V. Courte in 1942, after which it received some examinations but little work. The showings are at about 500 feet elevation in the bottom of a steep south-flowing tributary. The country rocks are either highly altered porphyritic andesites of the Yakoun Formation or altered diorites, or the former cut by dykes of the latter. The main creek follows an east-west crush zone, and by the showings a short way up the side creek there is a stockwork of quartz stringers with occasional veinlets up to 8 inches wide. Stibnite with some chalcopyrite and galena and some precious metals is erratically distributed in the quartz veinlets.

Swede
(19)

This property includes the whole of the Swede Peninsula near Lockeport. It is held by 20 recorded claims, the D group, in the name of King Stevenson Gas & Oil Company. The showings were discovered about 1907 by Larsen, Pearson, and Rodgers. In the next few years many open cuts were dug and three small adits were driven. Since then only extensive examinations and minor packsack diamond drilling have been done. Nearby properties, originally separate, the Last Chance and Jones group, are now included with the Swede.

The Swede Peninsula is formed of massive amygdaloidal greenstones of the upper part of the Karmutsen Formation overlain by massive and thin-bedded members of the Kunga Formation. The limestone forms an irregular syncline plunging northwestward at about 25 degrees and faulted off at the west (*see* geological map). The peninsula appears to be bounded by block faults. The northeast fault parallel with Anna Inlet is a large one, with either the south block dropped relative to the north or a large right-hand component of movement.

There are three small adits on the northwest side of the peninsula and an old open cut on the southeast near the outlet of the main creek. Two adits are about 80 feet above sea-level and the same distance apart. The western is about 150 feet long, and the other 80 feet. The third adit is at about 450 feet elevation and is 55 feet long. All are driven southeastward. In addition, there are a number of open cuts. The rocks exposed are similar Karmutsen amygdaloidal greenstones with some coarser diabasic dykes. All have been chloritized and slightly epidotized and contain minor prehnite and pumpellyite.

Traces of mineralization in the form of chalcopyrite in amygdules and hairline fractures can be found at many localities throughout the peninsula, but only near the adits on the northwest and to a lesser degree near the old open cut on the southeast side has there been found any concentration of even submarginal economic interest. The mineralization is highly erratic and no obvious control is apparent, with the possible excepiton that highly vesicular flows seem to contain better than normal concentrations. Most of the rocks are fairly highly fractured, but only in certain areas do these fractures contain films of chalcopyrite. In the northwestern adit a chip sample in the south wall from 15 to 25 feet from the portal of the best grade observed ran copper, 2.49 per cent; silver, 0.3 ounce per ton. Ten feet near the face of the southwest adit ran copper, 1.32 per cent; silver, trace. These assays are about 10 times those of two taken to indicate average grade in this vicinity.

Much additional work would need to be done to find if there are any economic concentrations at the Swede group.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1907, pp. 69–71; 1908, p. 61; 1909, p. 82; 1913, p. 99; 1918, p. 40; McConnell, R. G., *Geol. Surv., Canada,* Sum. Rept., 1909, pp. 78–79.]

Johnson Nickel (26)

This property consisted of a large number of recorded claims, most of which have been allowed to lapse. The original two claims are on the cove west of Section Cove on northwestern Burnaby Island. They are held by Mr. Johnson and associates, of Sandspit, and were optioned by Silver Standard Mines Limited and Jedway Iron Ore Limited jointly, who carried out an extensive exploration programme from January to May in 1963. Geological, magnetometer, electromagnetic, and soil surveys were conducted, as well as 1,857 feet of packsack drilling.

The area is geologically complex because it is within the belt of braided faults of the Louscoone Inlet-Rennell Sound fault zone. Argillites of the Kunga Formation have been intruded by small heterogeneous diorite stocks and later gabbro dykes and plugs and cut by the north-northwesterly faults. The initial showing is in the bottom of the westernmost north-flowing creek about 600 feet from the shore in an area of few exposures. An outcrop about 18 feet in diameter consists of gabbro mineralized with pyrrhotite, chalcopyrite, and bravoite with minor nickeliferous minerals. The showings contained about 1 per cent nickel and 1 per cent copper. The mineralization proved to be very local, although another mineralized gabbro body was found several hundred feet south.

[Reference: *Minister of Mines, B.C.,* Ann. Rept., 1963, p. 18.]

A3. Gold Veins

Southeaster (6)

This property is covered by two Crown-granted claims, the Southeaster, Lot 1302, and the Beaconsfield, Lot 1303, registered in the name of Emil Valley. The property was first recorded in 1910 and most extensively explored from 1919 to 1936, during which period it had a small production. It has also been called the Skidegate and Skidegate-Sunrise. The showings are about 1 mile north of Skidegate village, just beyond the reserve. Workings include a 100-foot shaft, from which there are two drift levels, one 125 feet long at 50 feet and another 350 feet long at 100 feet. A stope extends from just below the upper level to the surface. Another 65-foot shaft occurs to the southeast on the Skidegate reservation. Production from 1919 to 1936 is recorded as 505 tons containing 41 ounces of gold, 27 ounces of silver, 259 pounds of copper, and 665 pounds of lead. The country rocks are slightly hornfelsed andesitic agglomerates of the Yakoun Formation. The showings consist of one principal quartz vein some 1,000 feet long and 2 to 20 feet wide which contained sparse sulphide minerals with some concentrations of galena, pyrite, sphalerite, and chalcopyrite. The vein follows a fault zone which strikes northwest and dips steeply southwest.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1910, p. 85; 1915, p. 75; 1918, pp. 37–38; 1926, p. 66; 1929, pp. 55–56; 1930, pp. 62–63; 1931, pp. 34–35; 1932, pp. 39–40; MacKenzie, J. D., *Geol. Surv., Canada,* Mem. 88, 1916, pp. 174–175.]

Cumshewa (10)

This property is held by three Crown-granted claims, Lots 1222, 1223, and 1224, owned by the Stevens brothers, of Skidegate. The showings were discovered in 1907, underground development started in 1910, and by 1913 some 1,800 feet of drift and crosscut and 280 feet of winze and shaft had been completed. This development is mainly from a portal at about 300 feet above sea-level and one-half mile from the bay east of McLellan Island in Cumshewa Inlet. The main adit bears north 75 degrees east for 365 feet where it branches. The southern branch (Go East) continues on a similar bearing for some 190 feet to a winze and raise, beyond which it is caved. The northern branch (Homestake) continues on a bearing of north 40 degrees east for 85 feet, where it is caved. Many hundreds of feet of workings lay beyond the cave on the Go East drift. A 117-foot drift on the Homestake vein is 65 feet above the main workings.

The workings are in hornfelsic argillite and greywacke and some agglomerates of the Yakoun Formation cut by basic and acidic dykes. The workings essentially follow steep fault zones that have stringer systems and silicified breccias at intervals along them. Whatever may have been the case, sulphide minerals are sparse in the available workings. Original descriptions mention much galena and sphalerite in addition to pyrite and good gold values in the galena. Three samples of better-looking vein material taken by the writer ran only trace in gold and less than an ounce per ton in silver.

[References: *Minister of Mines, B.C.*, Ann. Repts., 1908, p. 62; 1909, p. 72; 1913, p. 98; 1932, pp. 46–48.]

Early Bird (12)

This property was the first lode mine in British Columbia, being the site of the exploration in 1852 by Captain Mitchell for the Hudson's Bay Company. It is on the west side of Una Point, named after the Hudson's Bay Company's brig. The value of the original production is in doubt, variously being reported as $5,000 to $75,000. Since then investigation and exploitation have been attempted many times. Between 1907 and 1933, under John McLellan, 172 tons of ore containing 154 ounces of gold and 30 ounces of silver was mined. Production in 1939 under D. F. Kidd is not recorded but was reportedly 15 tons, which contained 150 ounces of gold.

The workings include three adits and a shaft from the surface to the lower adit. The lower adit, which has a portal just above high sea-level, is a 200-foot-long drift slightly curved with an average strike of north 35 degrees east. The middle adit has a 25-foot crosscut that strikes north 50 degrees west to a 60-foot drift. The upper adit is a 40-foot drift. The shaft is 35 feet from surface to lower adit and reportedly continues for 38 feet below to a 10-foot crosscut and 70-foot drift. An open stope exists from the lower to the upper adit levels. The mine is contained in pillow lava facies of the Karmutsen Formation. There is minor silicification and chloritization of the walls with some growth of pumpellyite. The mine development follows a minor fault zone containing a frayed stringer vein system that strikes on the average north 37 degrees east at the top and below splits into two systems north 45 degrees east and north 27 degrees east. Dips are either side of vertical. The veinlets themselves are only a few inches wide but may be contained in a crush zone up to 3 feet wide with numerous strands. The veinlets are composed of quartz and calcite with minor pyrite and apparently fine free gold. At present no ore is visible. The best assay obtained from stringers in the lower adit was as follows: Gold, 0.25

ounce per ton; silver, 0.1 ounce per ton, over 2 feet near the south end of the open stope.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1909, pp. 76–77; 1918, pp. 41–44; 1932, pp. 41–44.]

Blue Mule (13)

This property has been held by recorded claims much of the time by the Stevens family, of Skidegate. It has also been called the Kootenay, Rupert, and Haida gold mines. It is three-quarters of a mile north of the east end of the south arm of Kootenay Inlet. It was discovered in 1919 by Jones, Wiggs, and McRae, of Queen Charlotte and Skidegate, and received most exploration about 1931 and 1932. The workings consist of a series of open cuts. Massive greenstones of the Upper Karmutsen Formation which strike easterly and dip about 40 degrees south form the country rock. In these rocks a reticulate quartz vein system is developed, which strikes northeast and dips steeply southeast. Individual veins have been traced 100 to 400 feet and are 6 inches to 5 feet wide. Five veins occur within 350 feet across strike. The vein walls are slightly silicified and chloritized but otherwise unaltered. The veins are composed mostly of quartz with sparse sulphides, pyrite, and chalcopyrite with some fine free gold. Values reported by Mandy (Ann. Rept., 1932) range from 0.2 to 0.6 ounce per ton.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1920, p. 43; 1923, pp. 41–42; 1932, pp. 38-40.]

Ellen (22)

This property has been held by recorded claims and recently was included in a large group, the Bud group, covering much of Shuttle Island. The property is near sea-level on the northern part of Shuttle Island in Darwin Sound. It was discovered about 1918 and developed over the next three years. Workings include a 100-foot crosscut and 25-foot drift with but 30 feet of backs. In 1919, 50 tons was produced, yielding 18 ounces of gold. The country rocks are greenstone and intercalated limestone and argillites of the Lower Karmutsen Formation. Two small intersecting veins, 8 inches wide or less, were the source of the ore. These or other small veins are considered the probable source of the placer gold recovered on the shores of Shuttle Island.

[References: *Minister of Mines, B.C.,* Ann. Repts., 1918, p. 41; 1919, p. 40; 1921, p. 39.]

A4. Manganese Veins

Shag Rock (1)

This property of 17 recorded claims is 25 miles west of Masset on the east side of Klashwun Point near Shag Rock. It was discovered by J. Pauloski in 1955 and is now held by Naden Harbour Manganese Ltd.

Rock is exposed in the area only along the wide tidal zone, and the showings are on the shore. Basaltic lavas of the Masset Formation and porphyritic andesite sills of Cape Knox type here strike north to northeast and dip 15 to 20 degrees eastward. The lavas are cut by a north-trending fault, on the east of which the lavas are underlain by dark-grey shale and buff calcareous shale to sandstone of about 75 feet thickness. The affiliation of these rocks is unknown, but they resemble Skidegate Formation to some degree. The fault strikes north 15 degrees east, subparallel to the shore, and dips about 80 degrees eastward. It is filled with 5 to 15 feet of volcanic fault breccia that is cemented by variable amounts of manganite. Fragments in the breccia are angular and as much as 2 feet across, although commonly the large fragments are only 6 to 8 inches across. Fragments range downward in size from these dimensions to a few millimetres; still smaller sizes were not seen. Veinlets of manganite also extend into the volcanic rocks of the west wall of the fault.

The fault and the showings are exposed along the shore for about 550 feet from the beach near the Indian reservation northward to where the shore trends sharply to the west. The fault is a large regional structure, but the breccia filling is quite lensoid. The best showings appear to be in the northern third of the exposure. Large hand specimens may be taken that contain as much as 50 per cent manganese. At the northern end, where the breccia outcrops boldly like a dyke, one of the higher-grade lenses, about 8 feet high by 50 feet long by 5 feet wide, is estimated to contain between 20 and 30 per cent manganese. Falconbridge Nickel Mines Limited, during May, 1965, took out bulk samples of the order of 150 to 200 tons of fresh material and drilled 254 feet in two packsack diamond-drill holes. The positions of the holes did not provide conclusive results. One hole may have penetrated the fault zone; the other hole intersected it at a narrow locality, although the breccia lens adjacent on the surface is large.

[References : *Minister of Mines, B.C.*, Ann. Repts., 1960, p. 11; 1965, p. 68.]

TABLE XXI.—MINERAL DEPOSITS LOCATED ON MAP WHICH ARE EITHER OF MINOR IMPORTANCE OR ABOUT WHICH LITTLE IS KNOWN

Map No.	Name	Location	Metal	Type	Host	Reference
14	Hawks Nest	East Talunkwan Island	Copper, zinc	Vein?	Karmutsen?	Ann. Rept., 1908, p. 62.
25		Yakulanas Bay	Copper, molybdenum	Quartz vein	Karmutsen?	
28	Nick's	Burnaby Island, south of Alder Island	Copper (nickel)	Replacement	Longarm?	
33	Gigger	Southeast Burnaby Island	Copper, iron	Replacement	Kunga limestone	
58		West of north end of Louscoone Inlet	Copper	Native	Karmutsen	
59	Sakai	Moore Head, Kunghit Island	Copper	Shear zone	Karmutsen	Ann. Rept., 1913, p. 102.
60	Copper Coin	East side of High Island	Copper	Replacement	Karmutsen	Ann. Rept., 1913, p. 102.
61		Treat Bay	Copper	Replacement	Karmutsen-Kunga	
63		Ridge north of Carpenter Bay	Iron	Replacement	Karmutsen	
57	Ivan	Southeast of Huston Inlet	Copper, iron	Replacement	Karmutsen	Ann. Rept., 1911, p. 76.
65		Raspberry Cove, Houston Stewart Channel	Copper, zinc	Veins?	Karmutsen and Point Langford stock	
40	Togo	West of Harriet Harbour	Copper, iron	Replacement	Kunga	Ann. Repts., 1908, p. 60; 1914, p. 163; Young and Uglow, 1926, pp. 34–35.
41	Modoc	Southwest Harriet Harbour	Copper, iron	Dyke-like replacement	Karmutsen	Ann. Repts., 1907, p. 67; 1929, p. 60; Young and Uglow, 1926, p. 35.
5	Dall	Gudal Bay	Copper, iron	Metasomatic replacement	Kunga	Ann. Rept., 1962, p. 10.
7		Southeast of Downie Island	Copper	Metasomatic replacement	Kunga	
2		Point north of Gospel Point	Antimony, iron	Metasomatic replacement	Gneiss	
9	Copper Bay	200 feet north of fisheries cabin	Copper	Disseminations and calcite cemented breccia vein	Yakoun agglomerate	Ann. Repts., 1905, p. 81; 1907, p. 71.
8		Mackenzie Cove	Copper, zinc			

APPENDIX

LIST OF AVERAGE DENSITIES FOR A REPRESENTATIVE SUITE OF ROCKS FOR EACH FORMATION

Unit	Average	Number of Specimens	Standard Deviations
Karmutsen	2.872	24	.098
Kunga	2.637	11	.101
Maude	2.644	5	.034
Yakoun	2.668	10	.044
Longarm	2.686	11	.066
Haida	2.669	12	.054
Honna	2.689	10	.062
Skidegate	2.688	6	.052
Masset basalts	2.731	10	.105
Rhyolites	2.496	10	.070
All	2.615	22	.142
Skonun sandstone*	2.561	5	.088
Shale	2.405	1	.....
All	2.483	6	.101
Syntecton'c plutons—			
San Christoval	2.783	12	.055
All	2.788	15	.061
Post-tectonic plutons—			
Pocket	2.633	7	.010
All	2.675	22	.071

* Lithified specimens rare except some calcareous sandstones. Average for the unit is taken as the average of the average sandstone and the one shale.

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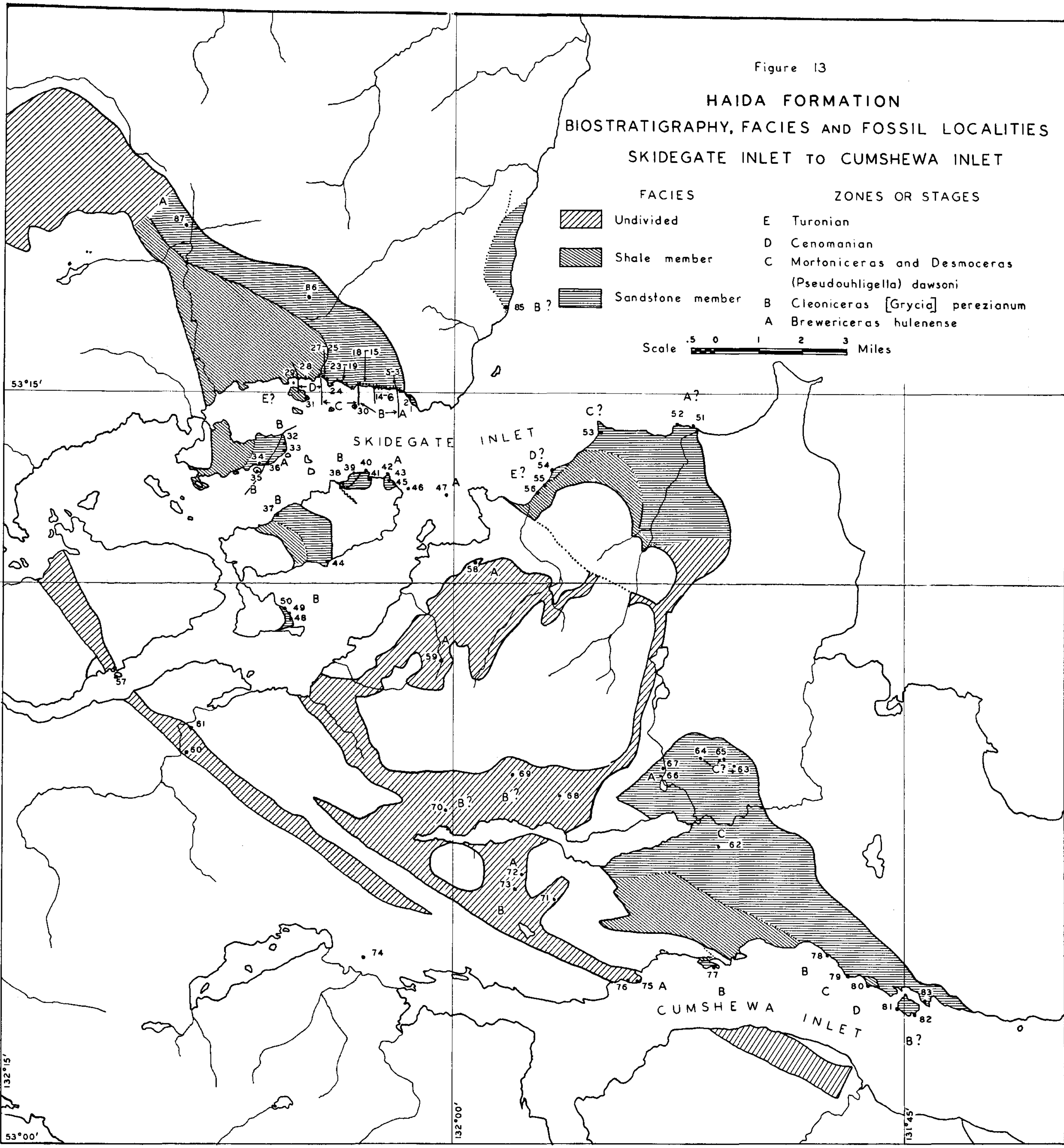
Figure 13
HAIDA FORMATION
BIOSTRATIGRAPHY, FACIES AND FOSSIL LOCALITIES
SKIDEGATE INLET TO CUMSHEWA INLET
FACIES
Undivided
Shale member
Sandstone member
ZONES OR STAGES
E Turonian
D Cenomanian
C Mortoniceras and Desmoceras (Pseudouhligella) dawsoni
B Cleoniceras [Grycia] perezianum
A Brewericeras hulenense
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SKIDEGATE INLET
CUMSHEWA INLET
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132°00′
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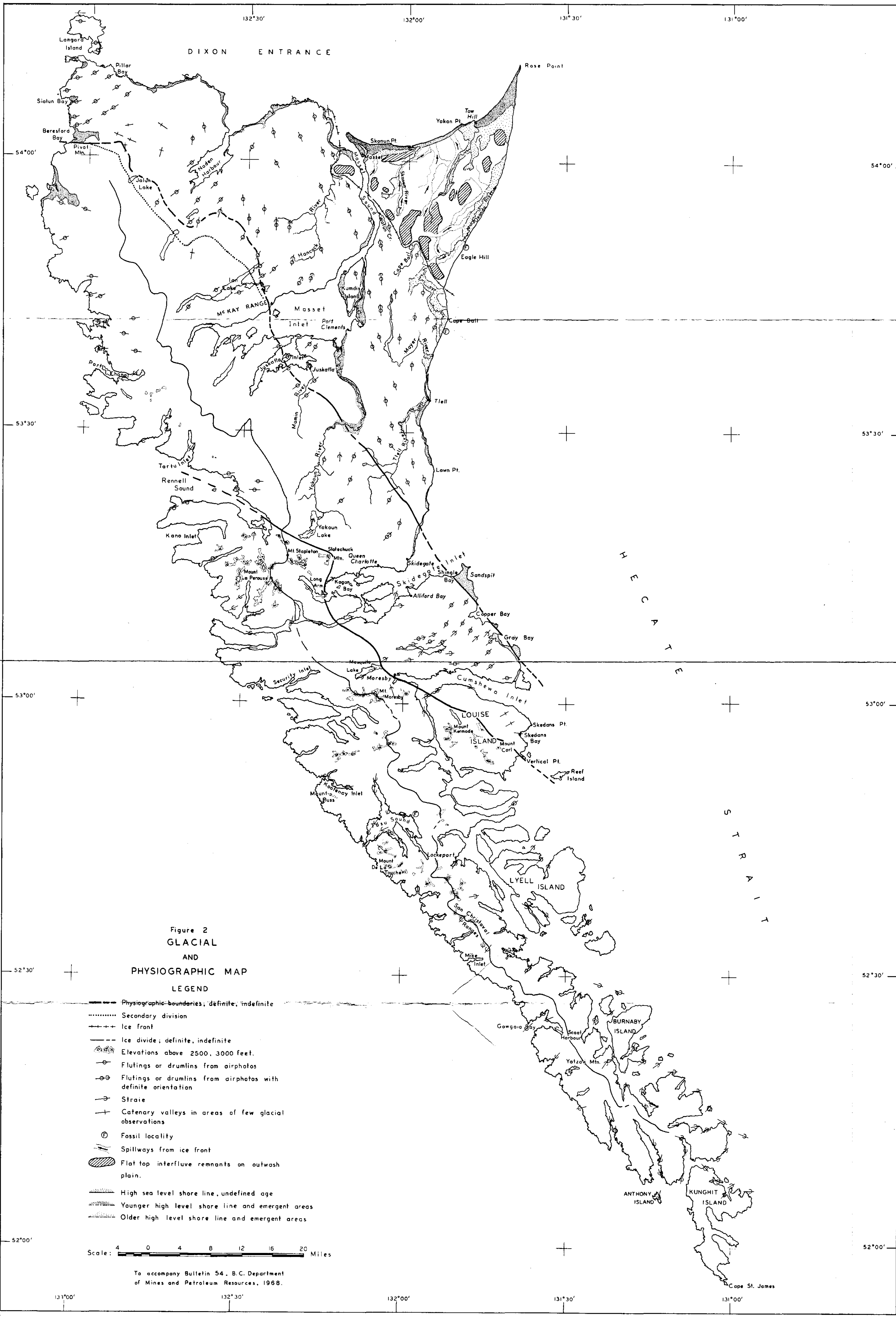

Figure 2
GLACIAL AND PHYSIOGRAPHIC MAP

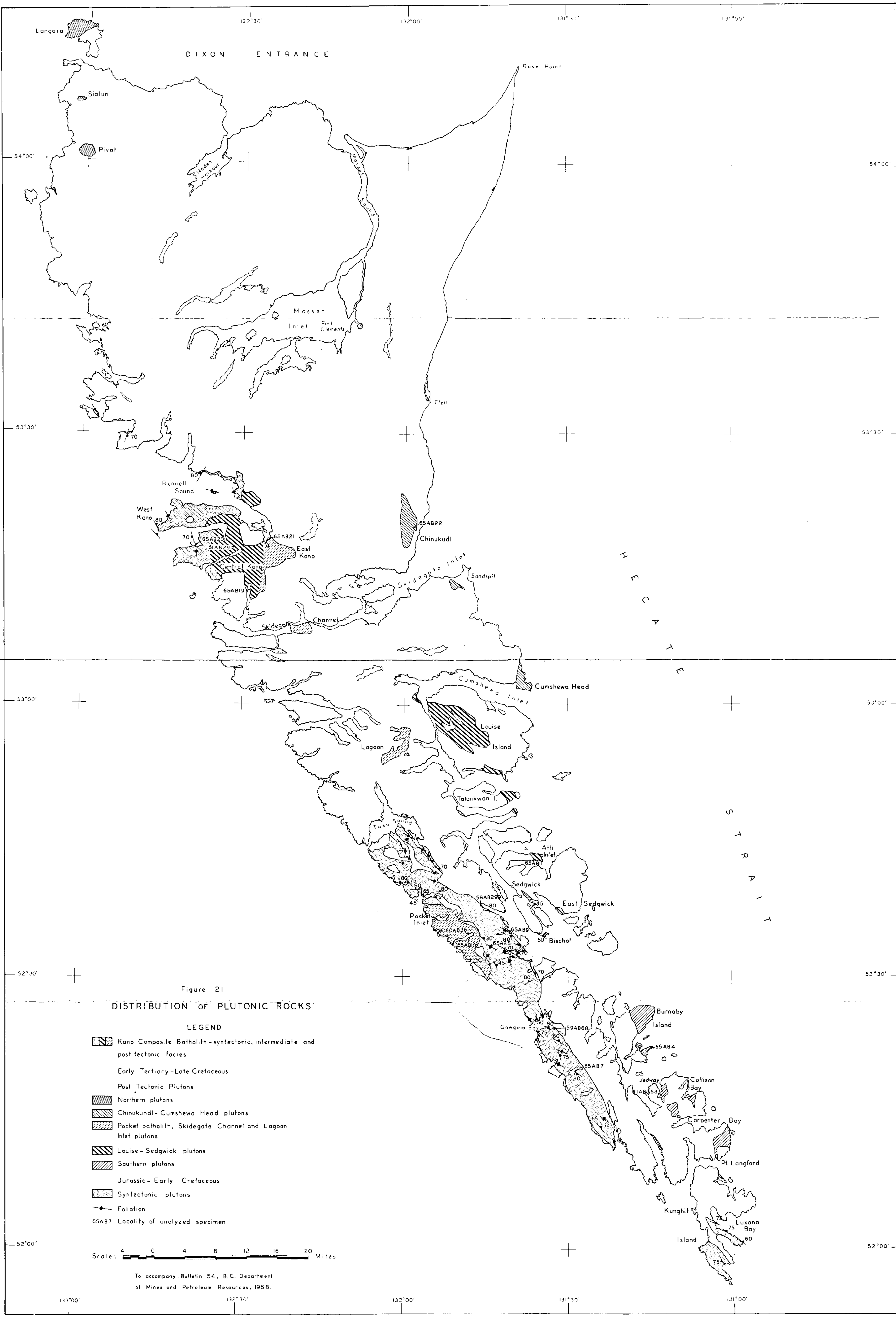

Figure 21

DISTRIBUTION OF PLUTONIC ROCKS

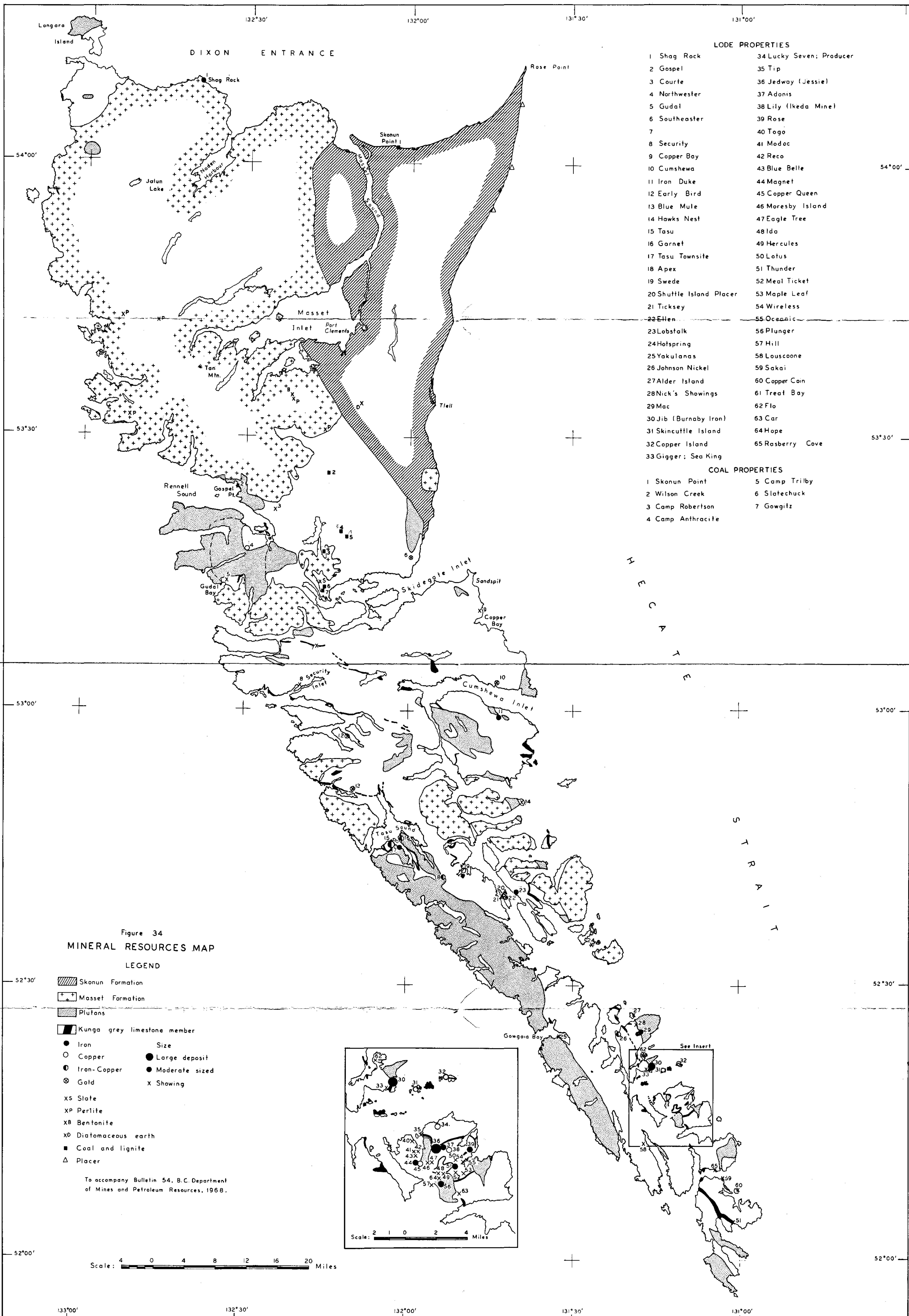

Figure 34

MINERAL RESOURCES MAP

To accompany Bulletin 54, B.C. Department of Mines and Petroleum Resources, 1968.

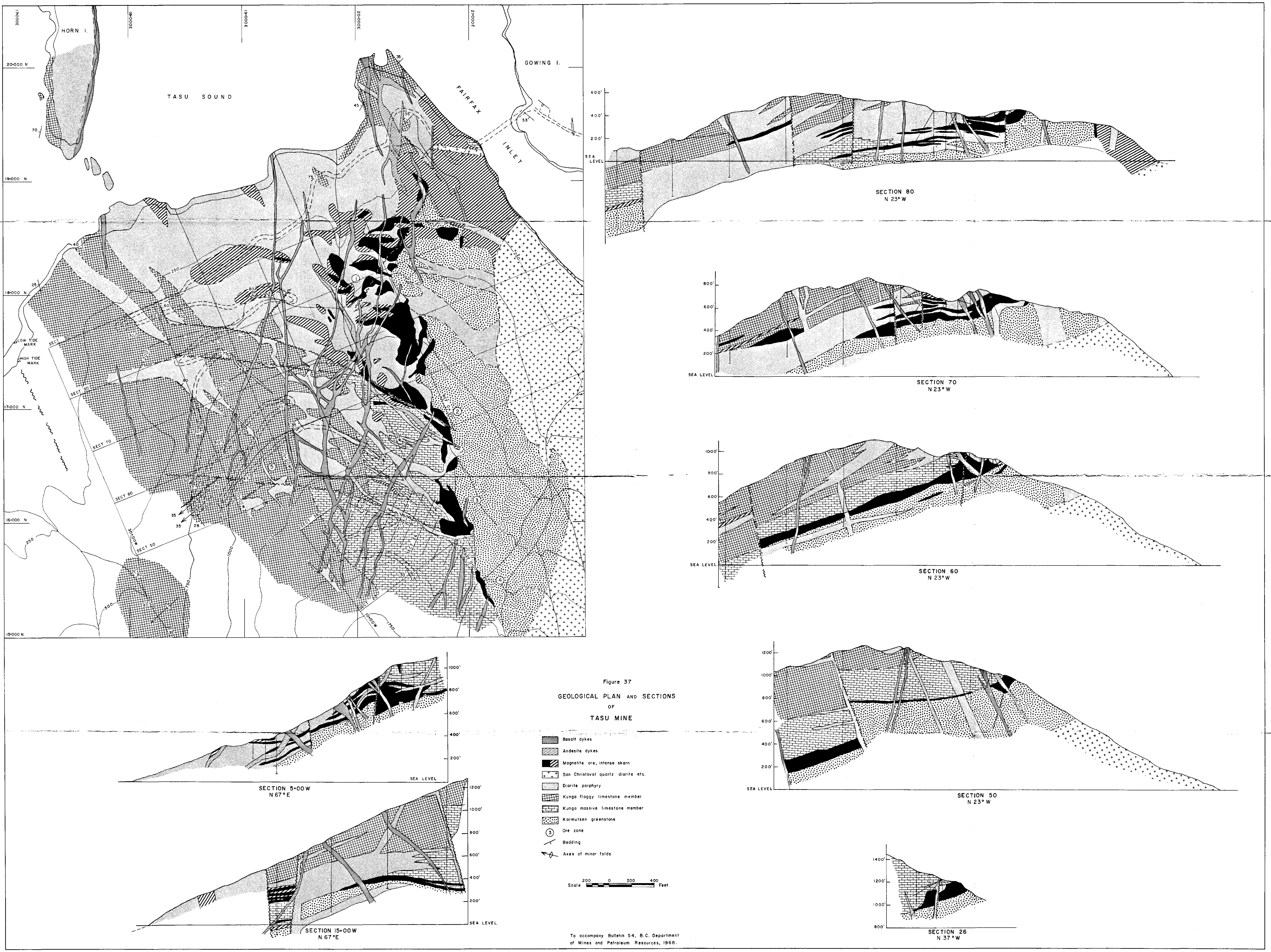

Figure 37

GEOLOGICAL PLAN AND SECTIONS OF TASU MINE

To accompany Bulletin 54, B.C. Department of Mines and Petroleum Resources, 1968.

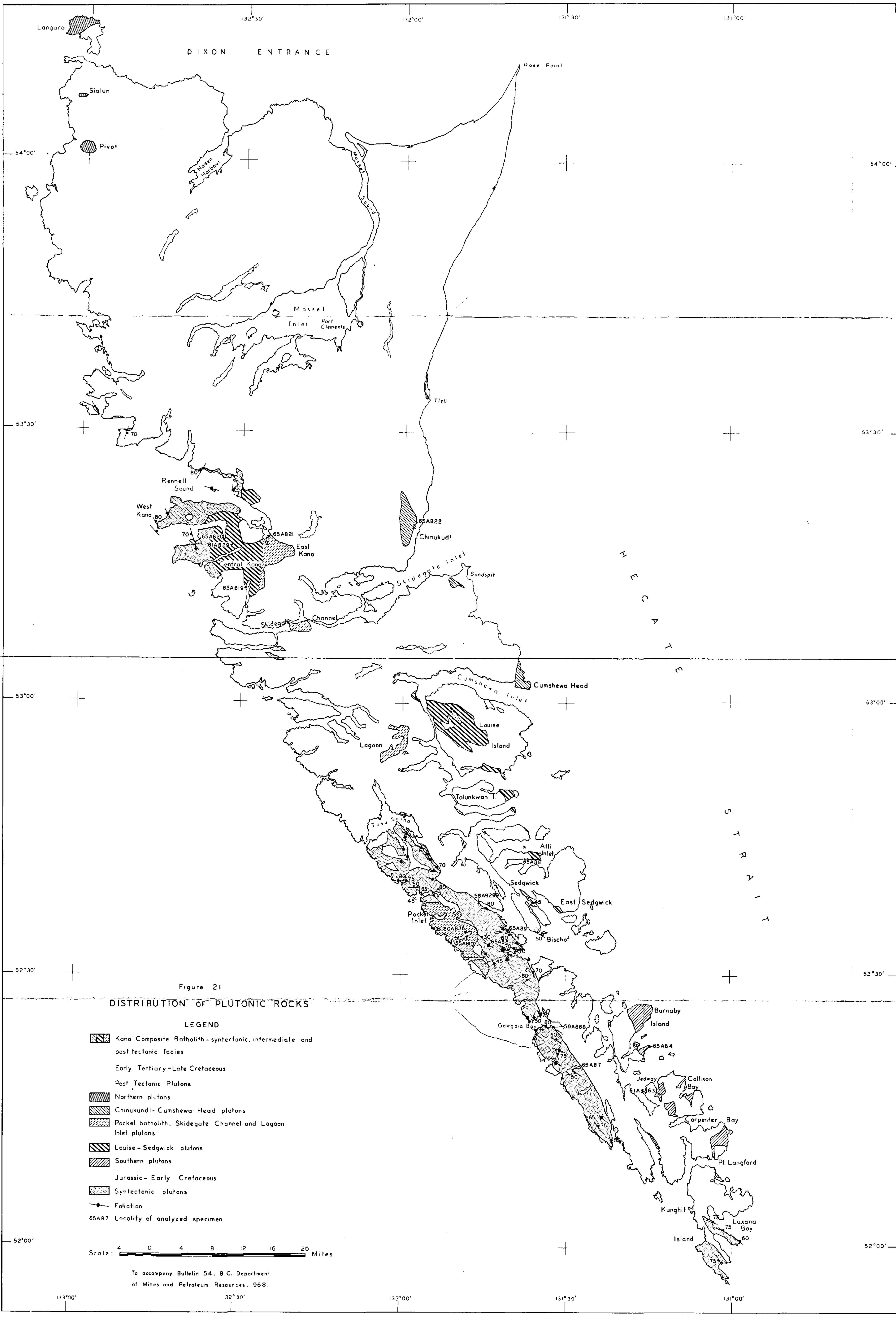

Figure 21

DISTRIBUTION OF PLUTONIC ROCKS

TABLE IV.--FAUNAL LIST, KUNGA FORMATION

Map No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Locality	Kaisun	Houston Stewart Channel	Houston Stewart Channel	Houston Stewart Channel	Carpenter Bay	Huston Inlet	Saltery Cove	Deluge Point	Kingfisher Cove	Kingfisher Cove	Poole Inlet	Poole Inlet	Poole Inlet	Section Cove	Alder Island	N.E. Huxley Island	N.W. Huxley Island	Anna Inlet	Lockeport	Lockeport	Crescent Inlet	Crescent Inlet	Crescent Inlet	Fairfax Inlet
Field No.	59AB 28	59AB106	59AB107	59AB109	59GJ 63	59AB195	59AB172	59AB163	59AB205	59AB219	59AB211	59GJ 90	59GJ 92	59AB256	59AB232	59AB241	59GJ100	61AB334	61AB336	61AB335	58AB306	58AB307	58AB308	58AB 17
Loc. No.	40962	40956	40972	40961	41014	40982	40981	40980	40957	40967	40969	41016	41018	40987	40960	40944	41019	48837	48839	48838	37002	37003	37004	36991
Aulacoceras sp.; Arcestes ? sp.	x																							
Halobia sp.	x	x	x	x	x	x	x	x	x	x	x	x	x	?	?	?	x	?		?	x	x	x	x
Discophyllites cf. ebneri (Mojsisovics)						x																		
Monotis salinaria Bronn																			x					
Monotis subcircularis Gabb																	x							
Other (Triassic)											?													
Arniotites (Melanhippites) harbledawnensis Crickmay																								
Arniotites sp.																								
Arietites sensu lato																								
Arietitid ammonite																								
Other (Jurassic)																								
MEMBER	GREY LIMESTONE	BLACK LIMESTONE																						

Map No.	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Locality	Tasu	Kunga Island	Newcombe Inlet	Newcombe Inlet	Limestone Island	Skedans Bay	Kuper Island	Kuper Island	Inskip Channel	Inskip Channel	Boomchain Bay	Boomchain Bay	Beattie Anchorage	Beattie Anchorage	Mosquito Lake	Mosquito Lake	South Deena River	Log Point	Shields Island	Point Langford	Rose Inlet	S.W. Burnaby Island	Kingfisher Cove	Section Cove
Field No.	59AB 65 61AB396	59AB288	58AB163	58AB104	59AB305	58AB431	59AB 44	59AB 48	59AB 36	59AB 32	59AB 24	59AB 25	59AB308	59AB309	61AB309	60AB260	61AB266	59AB 3	61AB 38	59AB118	59GJ 50	59AB204	59AB220	59AB255
Loc. No.	40968 48843	40974	36997	36992	41000	37008	40953	40963	41010	40976	41008	40992	40989	40995	48558	44650	48621	41009	48606	40955	41012	40975	40950	40984
Aulacoceras sp.; Arcestes ? sp.																								
Halobia sp.	?	x	x	x	x	x	x	x	?	?	x	x	x	x		x	x	?	x					
Discophyllites cf. ebneri (Mojsisovics)																								
Monotis salinaria Bronn																								
Monotis subcircularis Gabb																x				x	x	x	?	x
Other (Triassic)											?				x	x								
Arniotites (Melanhippites) harbledawnensis Crickmay																								
Arniotites sp.																								
Arietites sensu lato																								
Arietitid ammonite																								
Other (Jurassic)																								
MEMBER	BLACK LIMESTONE																							

Map No.	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Locality	Arichika Island	Darwin Sound	Kunga Island	Newcombe Inlet	Kootenay Inlet	Kootenay Inlet	Kootenay Inlet	Near Breaker Bay	Leopold Islet	Inskip Channel	Hibben Island	Kaisun	Mosquito Lake	Mosquito Lake	Log Point	Rennell Sound	Frederick Island	Fleurieu Point	Sedgwick Bay	Klunkwoi Bay	Crescent Point	S. Kunga Island	S. Kunga Island	S. Kunga Island
Field No.	50AB246	58AB295	59AB289	58AB105	58AB121	58AB124	58AB136	58AB428	59AB 51	59AB 49	59AB 52	59AB 29	61AB311	61AB310	59AB 4	62AB 95	61AB129	61AB144	58AB362	58AB311	58AB302	58AB402	58AB404	58AB406
Loc. No.	40986	37000	40990	36993	36994	36995	36996	37007	40965	40979	40964	40993	48582	48604	40991	52355	48610	48607	36981	37005	36980	36982	36983	37006
Aulacoceras sp.; Arcestes ? sp.																								
Halobia sp.																								
Discophyllites cf. ebneri (Mojsisovics)																								
Monotis salinaria Bronn																								
Monotis subcircularis Gabb	x	x	x	x	x	x	x	x	?	x	x	x	x	x	x	x	x	x						
Other (Triassic)												?												
Arniotites (Melanhippites) harbledawnensis Crickmay																				x	x		x	
Arniotites sp.																						x		
Arietites sensu lato																								
Arietitid ammonite																								?
Other (Jurassic)																			x					
MEMBER	BLACK LIMESTONE																	BLACK ARGILLITE						

Map No.	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Locality	S. Kunga Island	N. Kunga Island	N. Kunga Island	N. Kunga Island	Lamgon Bay	Lamgon Bay	Breaker Bay	Near Vertical Point	Near Vertical Point	Near Moresby Lake	Near Moresby Lake	Leopold Islet	N. Mosquito Lake	Sandilands Island	Maude Island	Yakoun River	Yakoun River	Ghost Creek	Ghost Creek	King Creek	Kennicott Point	Two Mountain Bay	Blue Jay Cove	Braveman Creek
Field No.	58AB409	59AB291	59AB292	59AB294	58AB 13 59AB 66 61AB382	58AB 19	58AB423	58AB429	58AB430	60AB192	60AB199	58AB198	60AB252	60AB305	61AB279	62AB 67	62AB 58	62AB 61	62AB 64	61AB251	61AB128	62AB142	65AB 2 65AB 5	60AB 37
Loc. No.	36985	40998	40945	40977	36977 40941 48841	36978	36987	36988	36989	44658	44656	36979	44648	44647	48619	52341	52337	52338	52342	48580	48611	52364	69188 69190	44651
Aulacoceras sp.; Arcestes ? sp.																								
Halobia sp.																							x	x
Discophyllites cf. ebneri (Mojsisovics)																								
Monotis salinaria Bronn																								
Monotis subcircularis Gabb																								
Other (Triassic)																							x	
Arniotites (Melanhippites) harbledawnensis Crickmay																								
Arniotites sp.										?	?		?	x	?				x	?	?	x		
Arietites sensu lato		x	?	?	x																			
Arietitid ammonite					?	?	?	?	?			?				?	?	?						
Other (Jurassic)	x				x																			
MEMBER	BLACK ARGILLITE																						BLACK LIMESTONE	

TABLE IX.--FAUNAL LIST, HAIDA FORMATION

Map No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Geographic Location	North Shore - Skidegate Inlet																												
	Type Section - Bearskin Bay																												
Field No.	60-52	60-56	60-59	60-60	60-61	60-65	60-66	60-67	60-68	60-69	60-71	60-72	60-73	60-74	60-75	60-76, 60-77, 60-78, 63-14, 60-79, 60-80					60-82	60-84	63-12	63-15	60-86	63-36, 37	63-38, 65	60-90	60-92
G.S.C. Loc. No.	44698	44700	44701	44697	44702	44685	44686	44690	44687	44719	44720	44721	44722	44723	44724	44725	44726	44727	44728	44659	44660	44646		44729				44731	44739
SPECIES — AMMONOIDEA																													
Phyllopachyceras cf. chitinanum Imlay																													
Phyllopachyceras sp. juv.																													
Hypophylloceras aff. californicum (Anderson)																										x	x		
Anagaudryceras sacya (Forbes)															x	x					x								
Anagaudryceras sp.																													
Tetragonites aff. subtimotheanus (Wiedmann)																					x								
Pseudhelicoceras carlottense (Whiteaves)																													
Pseudhelicoceras sp.																													
Puzosia n. sp.																													
Puzosia sp.																													
Puzosia ? sp.																						x							
Pachydesmoceras ? sp.																													
Beudanticeras ? sp.																													
Leconteites lecontei whiteavesi Jones, Murphy, and Packard																													
Brewericeras hulenense (Anderson)		x		x																									
Desmoceras (Pseudouhligella) dawsoni (Whiteaves)																											x		
Desmoceras (Pseudouhligella) aff. dawsoni (Whiteaves)																							x						
Desmoceras (Pseudouhligella) n. sp. ? cf. alamoense (Anderson)											x										x								
Desmoceras (Pseudouhligella) n. sp.																							x			x			
Desmoceras (Pseudouhligella) n. sp. A ?																													
Desmoceras (Pseudouhligella) japonicum (Yabe)																													
Desmoceras (Pseudouhligella) sp.																													
Marshallites n. sp.																					x								
Douvilleiceras spiniferum (Whiteaves)																													
Douvilleiceras sp.																													
Cleoniceras (Grycia) perezianum (Whiteaves)						x			x	x		x	x	x				x											
Cleoniceras var. ?																													
Arcthoplites sp.																													
Mortoniceras (Deiradoceras) sp.																				x					x				
PELECYPODA																													
Inoceramus concentricus Parkinson									x			x																	
Inoceramus cf. moresbyensis Whiteaves																x													
Inoceramus subsulcatus Whiteaves																			x	x				x	x	x			
Inoceramus sp. A																												x	x
Inoceramus sp. B																												x	
Inoceramus sp.																													
Trigonia (Yaadia sensu lato) leana var. whiteavesi (Packard)	x																												
Trigonia (Yaadia ?) sp.																													
Trigonia (Pterotrigonia) cf. columbiana (Packard)																													
Trigonia (Pterotrigonia) sp.																													
Trigonia (Pterotrigonia ?)			x																										
Trigonia (Apiotrigonia) maudensis (Whiteaves)							x																						
Trigonia (Apiotrigonia) newcombei (Packard)																	x												
Trigonia (Apiotrigonia) cf. newcombei (Packard)									x																				
Trigonia (Apiotrigonia ?)								x			x																		
Trigonia (Heterotrigonia) sp.									x								x						x						
Trigonia (Myophorella) sp.																													
Other					x	x	x	x	x		x		x					x					x				x		

Map No.	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Geographic Location	Islands in Skidegate Inlet																				
	Maple Island	Robertson Island	Lina Island					Maude Island									Robber Island	Bare Rock	Sandilands Island		
Field No.	60-153	60-149	60-98	60-99	60-128	60-129	60-131	61-195	61-228	61-229	61-255	61-257	61-259	61-260	61-276	61-295	61-296	61-297	62-1	62-2	62-3
G.S.C. Loc. No.	44675	44684	44694	44695	44696	44713	44714	48613	48589	48623	48609, 68, 69	48617	48612	48622	48555	48572	48559	48560	52324	52325	52326
SPECIES — AMMONOIDEA																					
Phyllopachyceras cf. chitinanum Imlay																					
Phyllopachyceras sp. juv.																					
Hypophylloceras aff. californicum (Anderson)	x												x				x				
Anagaudryceras sacya (Forbes)					x								x							x	
Anagaudryceras sp.																					
Tetragonites aff. subtimotheanus (Wiedmann)								x					x								x
Pseudhelicoceras carlottense (Whiteaves)	x																				
Pseudhelicoceras sp.																					
Puzosia n. sp.	x																				
Puzosia sp.											x	x			x						
Puzosia ? sp.																					
Pachydesmoceras ? sp.																					
Beudanticeras ? sp.											x										
Leconteites lecontei whiteavesi Jones, Murphy, and Packard																					
Brewericeras hulenense (Anderson)			x	x								x	x				x	x			
Desmoceras (Pseudouhligella) dawsoni (Whiteaves)																					
Desmoceras (Pseudouhligella) aff. dawsoni (Whiteaves)																					
Desmoceras (Pseudouhligella) n. sp. ? cf. alamoense (Anderson)						x				x		x									
Desmoceras (Pseudouhligella) n. sp.																					
Desmoceras (Pseudouhligella) n. sp. A ?																					
Desmoceras (Pseudouhligella) japonicum (Yabe)																					
Desmoceras (Pseudouhligella) sp.																					
Marshallites n. sp.																					
Douvilleiceras spiniferum (Whiteaves)				x									x	x		x	x				
Douvilleiceras sp.												x									
Cleoniceras (Grycia) perezianum (Whiteaves)						x				x									x		x
Cleoniceras var. ?													x								
Arcthoplites sp.																					
Mortoniceras (Deiradoceras) sp.																					
PELECYPODA																					
Inoceramus concentricus Parkinson						x		x													
Inoceramus cf. moresbyensis Whiteaves																					
Inoceramus subsulcatus Whiteaves																					
Inoceramus sp. A		x																			
Inoceramus sp. B		x																			
Inoceramus sp.									x												
Trigonia (Yaadia sensu lato) leana var. whiteavesi (Packard)							x				x										
Trigonia (Yaadia ?) sp.																					
Trigonia (Pterotrigonia) cf. columbiana (Packard)							x														
Trigonia (Pterotrigonia) sp.								x													
Trigonia (Pterotrigonia ?)									x												
Trigonia (Apiotrigonia) maudensis (Whiteaves)																					
Trigonia (Apiotrigonia) newcombei (Packard)																					
Trigonia (Apiotrigonia) cf. newcombei (Packard)																					
Trigonia (Apiotrigonia ?)																					
Trigonia (Heterotrigonia) sp.																					
Trigonia (Myophorella) sp.																					
Other						x	x			x											

Map No.	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
Geographic Location	Skidegate to Cumshewa Inlets																						
	Shingle Bay		Onward Point	East of Alliford Bay			E. Skidegate Narrows	South of Alliford Bay	South Bay	Deena River Road		Skidegate Lake and Vicinity											
Field No.	60-161	60-162	60-165	60-169	60-170	60-171	61-188	60-177	60-322	60-236	61-261	60-209	60-210	60-224	60-226	61-285	61-286	60-299	60-315	60-239	60-319	60-231	60-268
G.S.C. Loc. No.	44676	44683	44678	44662	44661	44682	48557	44655	44743	44653	48561	44680	44681	44691	44718	48614	48581	44742	44742	44654	44679	44657	44673
SPECIES — AMMONOIDEA																							
Phyllopachyceras cf. chitinanum Imlay																							
Phyllopachyceras sp. juv.																							
Hypophylloceras aff. californicum (Anderson)		x				x																	
Anagaudryceras sacya (Forbes)		x			x	x																	
Anagaudryceras sp.																							
Tetragonites aff. subtimotheanus (Wiedmann)						x																	
Pseudhelicoceras carlottense (Whiteaves)																							
Pseudhelicoceras sp.																							
Puzosia n. sp.																							
Puzosia sp.																							
Puzosia ? sp.																							
Pachydesmoceras ? sp.		x																					
Beudanticeras ? sp.																							
Leconteites lecontei whiteavesi Jones, Murphy, and Packard																							
Brewericeras hulenense (Anderson)								x									x					x	
Desmoceras (Pseudouhligella) dawsoni (Whiteaves)																							
Desmoceras (Pseudouhligella) aff. dawsoni (Whiteaves)																							
Desmoceras (Pseudouhligella) n. sp. ? cf. alamoense (Anderson)																							
Desmoceras (Pseudouhligella) n. sp.																							
Desmoceras (Pseudouhligella) n. sp. A ?													x	x			x						
Desmoceras (Pseudouhligella) japonicum (Yabe)																							
Desmoceras (Pseudouhligella) sp.			x									x											
Marshallites n. sp.																							
Douvilleiceras spiniferum (Whiteaves)								x															
Douvilleiceras sp.																							
Cleoniceras (Grycia) perezianum (Whiteaves)																							
Cleoniceras var. ?																							
Arcthoplites sp.																							
Mortoniceras (Deiradoceras) sp.																							
PELECYPODA																							
Inoceramus concentricus Parkinson										x	x								x				
Inoceramus cf. moresbyensis Whiteaves																							
Inoceramus subsulcatus Whiteaves																							
Inoceramus sp. A																							
Inoceramus sp. B																							
Inoceramus sp.																					x		
Trigonia (Yaadia sensu lato) leana var. whiteavesi (Packard)																							
Trigonia (Yaadia ?) sp.	x																						
Trigonia (Pterotrigonia) cf. columbiana (Packard)																							
Trigonia (Pterotrigonia) sp.																							
Trigonia (Pterotrigonia ?)							x											x					
Trigonia (Apiotrigonia) maudensis (Whiteaves)																							
Trigonia (Apiotrigonia) newcombei (Packard)																				x			x
Trigonia (Apiotrigonia) cf. newcombei (Packard)																							
Trigonia (Apiotrigonia ?)																							
Trigonia (Heterotrigonia) sp.																							
Trigonia (Myophorella) sp.	x																						
Other	x			x					x						x	x							

Map No.	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Geographic Location	Cumshewa Inlet											Graham Island							
	Pallant Creek	Dawson Cove		Conglomerate Point	Near Cumshewa						Near Skedans	N. Skidegate Village	N. Queen Charlotte City	Honna River	Yakoun River	Beresford Bay		Parry Passage	
Field No.	61-313	60-275	60-276	60-271	60-279	60-281	60-282	60-283	60-285	60-286	61-318	60-324	62- 9, 10	62- 35	62- 73	61-134	61-143	61-111	61-109
G.S.C. Loc. No.	48577	44670	44667	44674	44668	44693	44665	44666	44664	44669	48590	44689	52327, 8	52330	52345	48616	48615	48583	48587
SPECIES — AMMONOIDEA																			
Phyllopachyceras cf. chitinanum Imlay																	x		
Phyllopachyceras sp. juv.																x			
Hypophylloceras aff. californicum (Anderson)																			
Anagaudryceras sacya (Forbes)		x	x		x	x		x	x	x					x				
Anagaudryceras sp.																	x		
Tetragonites aff. subtimotheanus (Wiedmann)			x		x														
Pseudhelicoceras carlottense (Whiteaves)																			
Pseudhelicoceras sp.						x													
Puzosia n. sp.																			
Puzosia sp.																			
Puzosia ? sp.																			
Pachydesmoceras ? sp.																			
Beudanticeras ? sp.																			
Leconteites lecontei whiteavesi Jones, Murphy, and Packard																x	x		
Brewericeras hulenense (Anderson)		x												x					
Desmoceras (Pseudouhligella) dawsoni (Whiteaves)						x													
Desmoceras (Pseudouhligella) aff. dawsoni (Whiteaves)																			
Desmoceras (Pseudouhligella) n. sp. ? cf. alamoense (Anderson)				x								x							
Desmoceras (Pseudouhligella) n. sp.																			
Desmoceras (Pseudouhligella) n. sp. A ?																			
Desmoceras (Pseudouhligella) japonicum (Yabe)							x												
Desmoceras (Pseudouhligella) sp.																			x
Marshallites n. sp.	x					x													
Douvilleiceras spiniferum (Whiteaves)																			
Douvilleiceras sp.																			
Cleoniceras (Grycia) perezianum (Whiteaves)																			
Cleoniceras var. ?																			
Arcthoplites sp.		x																	
Mortoniceras (Deiradoceras) sp.																			
PELECYPODA																			
Inoceramus concentricus Parkinson												x							
Inoceramus cf. moresbyensis Whiteaves					x														
Inoceramus subsulcatus Whiteaves																			
Inoceramus sp. A																			
Inoceramus sp. B																			
Inoceramus sp.		x			x								x					x	
Trigonia (Yaadia sensu lato) leana var. whiteavesi (Packard)																			
Trigonia (Yaadia ?) sp.																			
Trigonia (Pterotrigonia) cf. columbiana (Packard)											x								
Trigonia (Pterotrigonia) sp.																			
Trigonia (Pterotrigonia ?)																			
Trigonia (Apiotrigonia) maudensis (Whiteaves)																			
Trigonia (Apiotrigonia) newcombei (Packard)																			
Trigonia (Apiotrigonia) cf. newcombei (Packard)																			
Trigonia (Apiotrigonia ?)																			
Trigonia (Heterotrigonia) sp.																			
Trigonia (Myophorella) sp.																			
Other			x									x	x		x	x	x		

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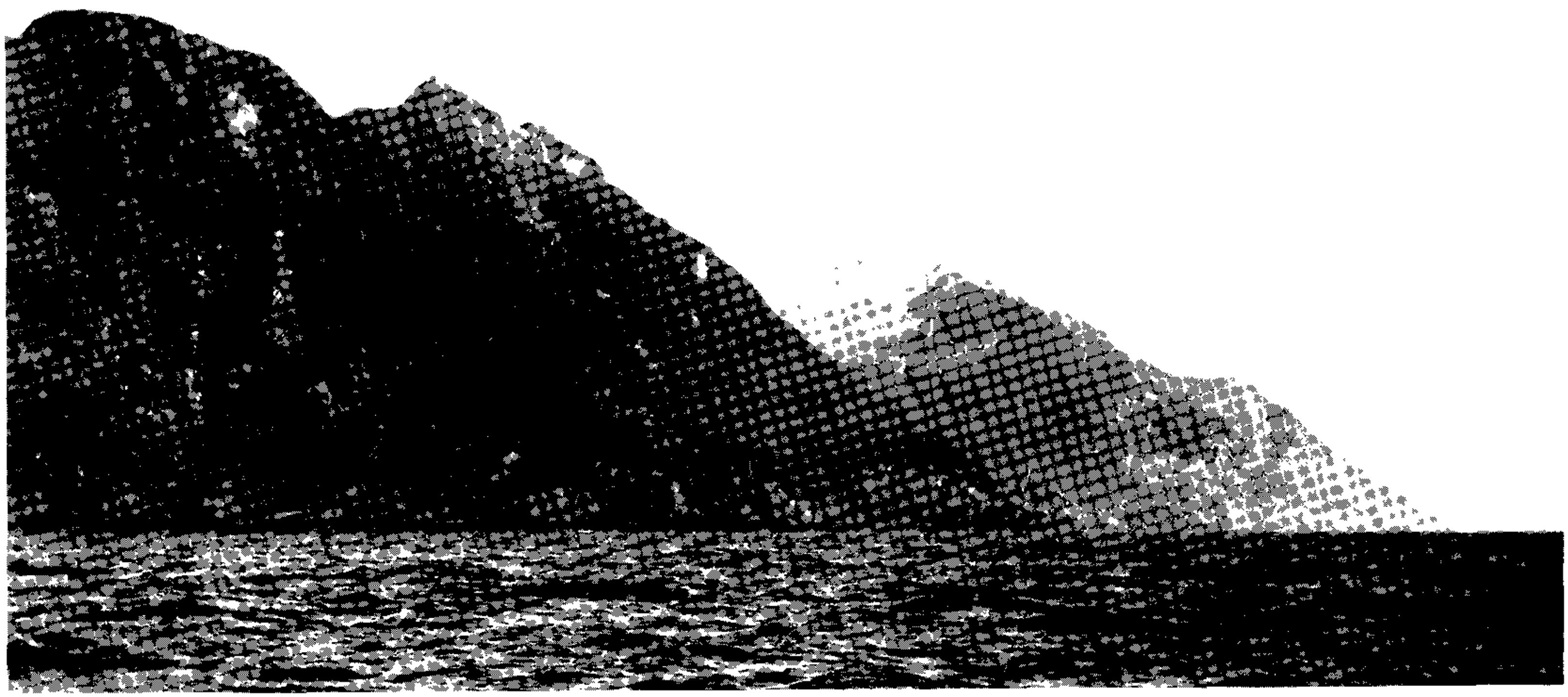


Plate I. San Christoval Range from opposite Tasu Head. Mount De la Touche in the distance.

Plate II. Security Inlet, a typical west coast fiord.

Plate IIIA. Panorama of Skidegate Inlet from Slatechuck Mountain, showing Lowland, Skidegate Plateau, and Queen Charlotte Ranges.

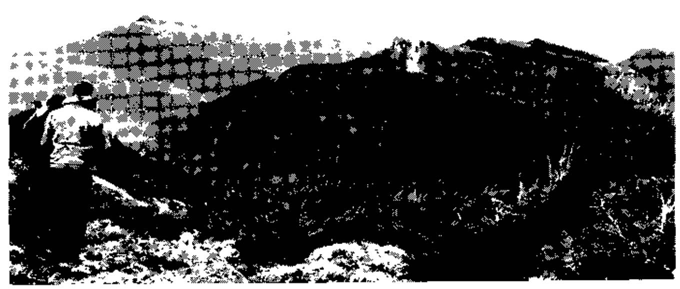


Plate IIIB. Skidegate Plateau looking northwest from west of Tartu Inlet. Plateau surface truncates Masset flows.

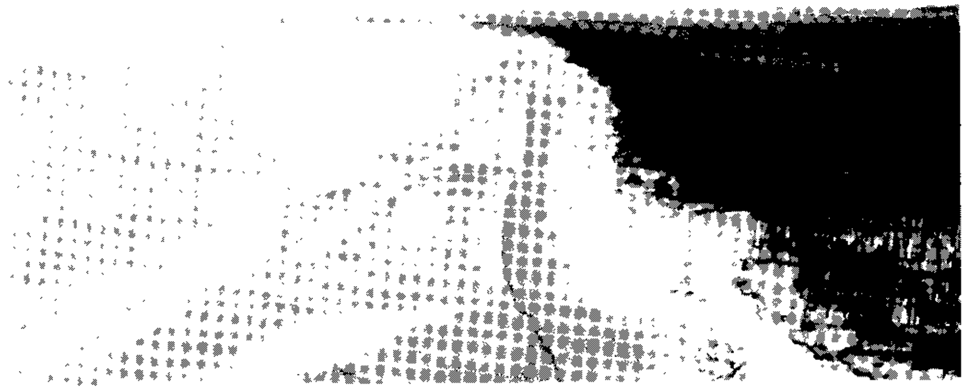
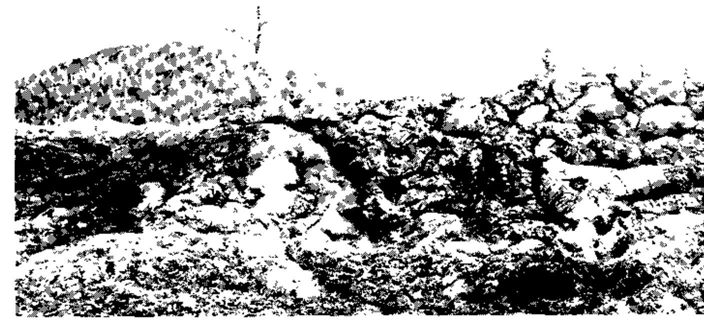


Plate IVA. Argonaut Plain, Queen Charlotte Lowland, looking south from near mouth of Oeanda River.

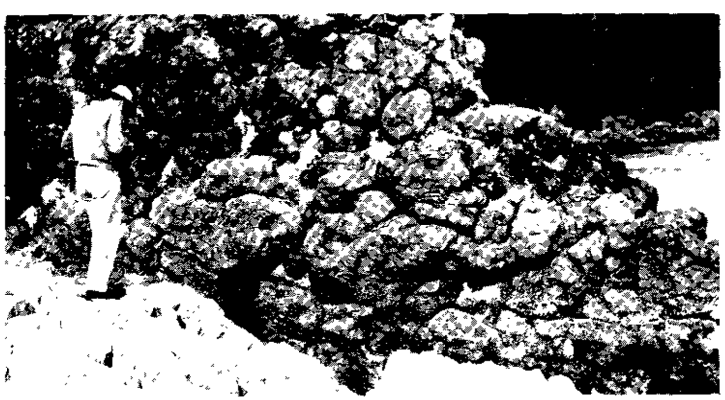
Plate IVB. Tow Hill and Yakan Point—view of Lowland to west.

Plate V. Karmutsen Formation.

(*c*) General view of well-bedded pillow lava facies on Yatza Mountain.



(*a*) Complex pillows, bolsters, and lava tubes, Louscoone Inlet.



(*d*) Separated pillows with calcareous interstices on a limestone lens, upper part of formation, near Vertical Point, Louise Island.

(*b*) Aquagene tuff with inverted grading and reworked tuff, Gordon Islands.

Plate VIA. Kunga flaggy argillite, Kunga Island, view to Titul Island where whole of massive limestone member is exposed. Note wave-cut bench.

Plate VIB. Kunga massive limestone, with solution pits and Masset basalt dyke showing amount of post-glacial solution, Bolkus Islands.

Plate VIC. Maude blocky argillite, calcareous and noncalcareous shale. Note contrast with Kunga flaggy argillite, Maude Island.

Plate VIIA. Yakoun blocky agglomerate, Alliford Bay.

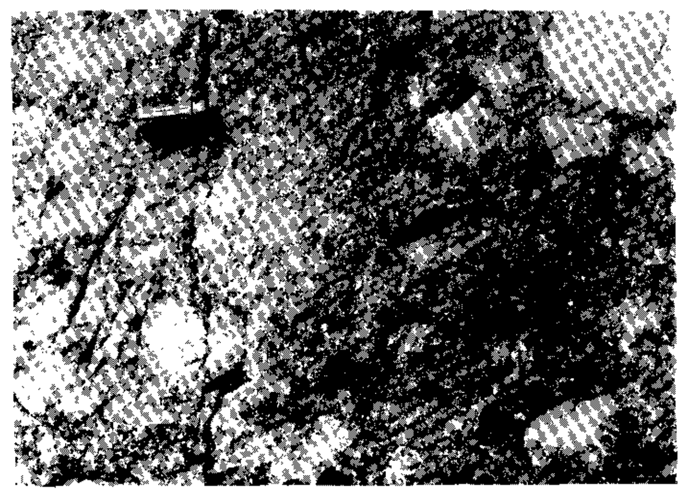


Plate VIIB. Detail of Yakoun porphyritic andesite agglomerate, near Skidegate Village.

Plate VIIC. Honna conglomerate and coarse feldspathic sandstone. Note granitic and Kunga argillite cobbles, and shale sharpstones; near Mosquito Lake.

Plate VIIIA. Haida coarse green sandstone with *Trigonia* coquina bed by figure, northeastern Maude Island.

Plate VIIIB. Longarm dense calcareous siltstone, Murchison Island.

Plate VIIIC. Haida silty shale with laminated calcareous shale by pick, Queen Charlotte.

Plate IXA. Masset foliated spherulitic rhyolite with recumbent flow fold, Kootenay facies, Mount Russ.

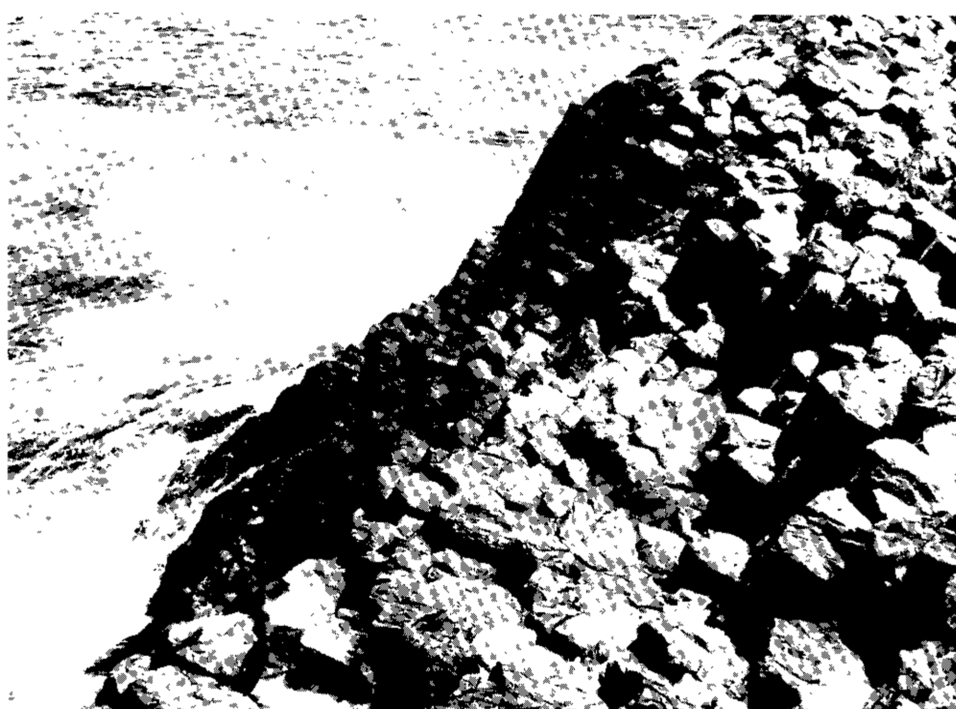


Plate IXB. Masset columnar basalt of the basal member of the Tartu facies (TMa), Joseph rocks near Tian Head.

Plate XA. Skonun shelly and pebbly calcareous sandstone at the type locality, Skonun Point, looking west.

Plate XB. Detail.

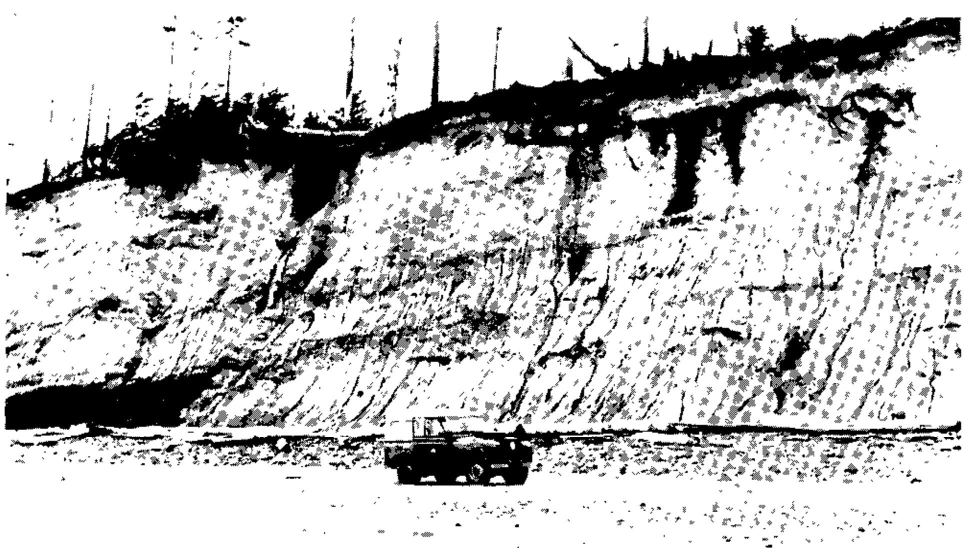


Plate XC. Sea cliff of Pleistocene deposits, north of Mayer River, showing 17 feet of stony clay at the base, overlain by 10 feet of sands and 20 feet of till.

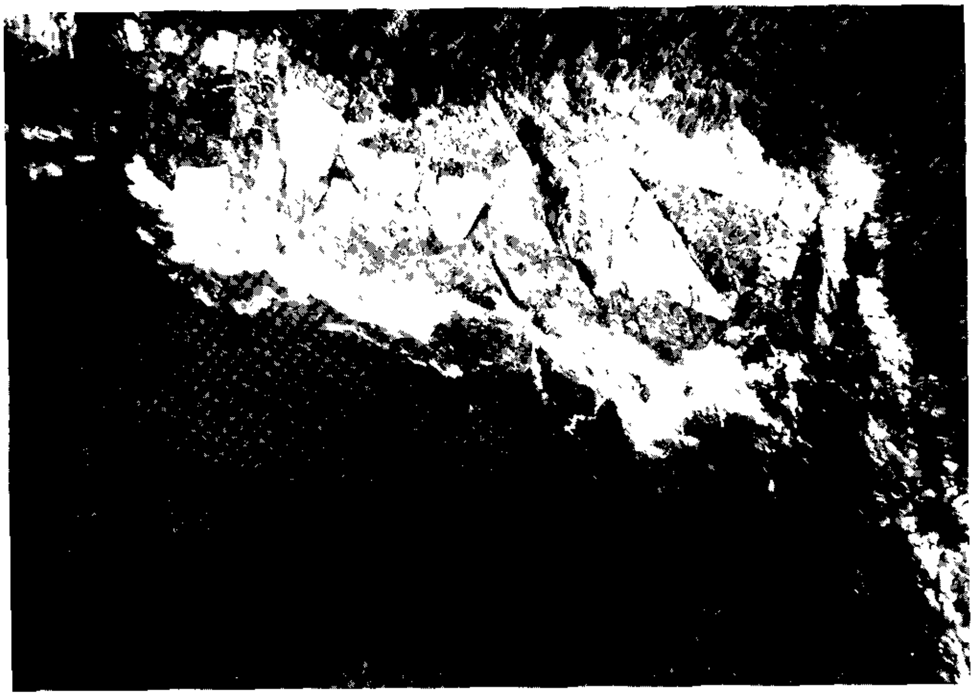


Plate XIA. Gross contact breccia of post-tectonic Pocket granite and Karmutsen meta-basalt cut by minor Masset basalt dykes, near Barry Inlet.

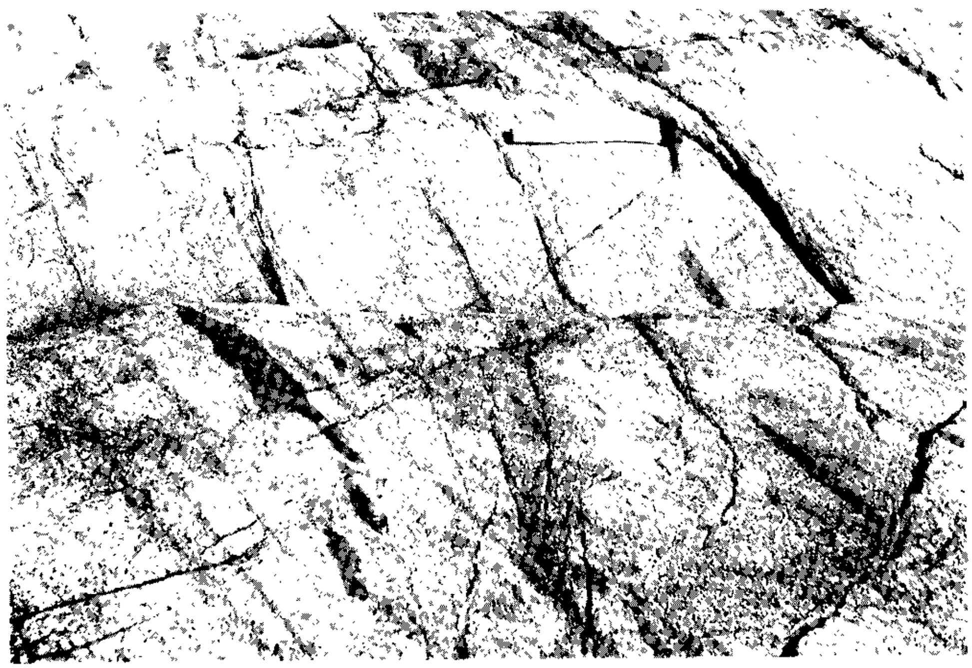


Plate XIB. Foliated syntectonic hornblende quartz diorite with characteristic mafic inclusions, Nangwai Rock at entrance to Gowgaia Bay.

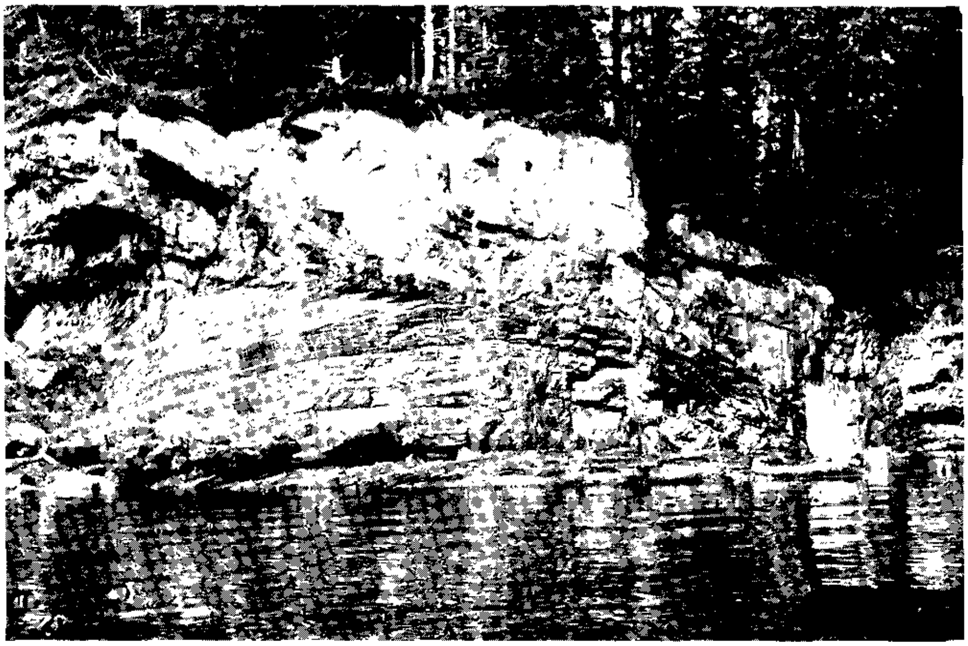


Plate XIIA. Bouldery sandstone of shoreline facies of Longarm Formation unconformably overlying flaggy *Monotis*-bearing black limestone of Kunga Formation, Arichika Island.

Plate XIIB. Pebbly black and white basal sandstone of Haida Formation unconformably overlying conglomeratic Yakoun andesite, Haida Point.

Plate XIIIA. Photomicrograph of Masset rhyolite welded ash flow (TMa) from Otard Bay. Note welded glass shards, clasts of porphyritic basalt, acid plagioclase, and earlier welded tuff. Plain light ×50.

Plate XIIIB. Negative projection of a thin-section of Karmutsen fine broken pillow breccia (opaque shows white and vice versa). Note angular fragments of microporphyritic basalt and shard-like amygdaloidal sideromelane with reaction rims. Locality, Mitchell Inlet. Plain light ×6.2.

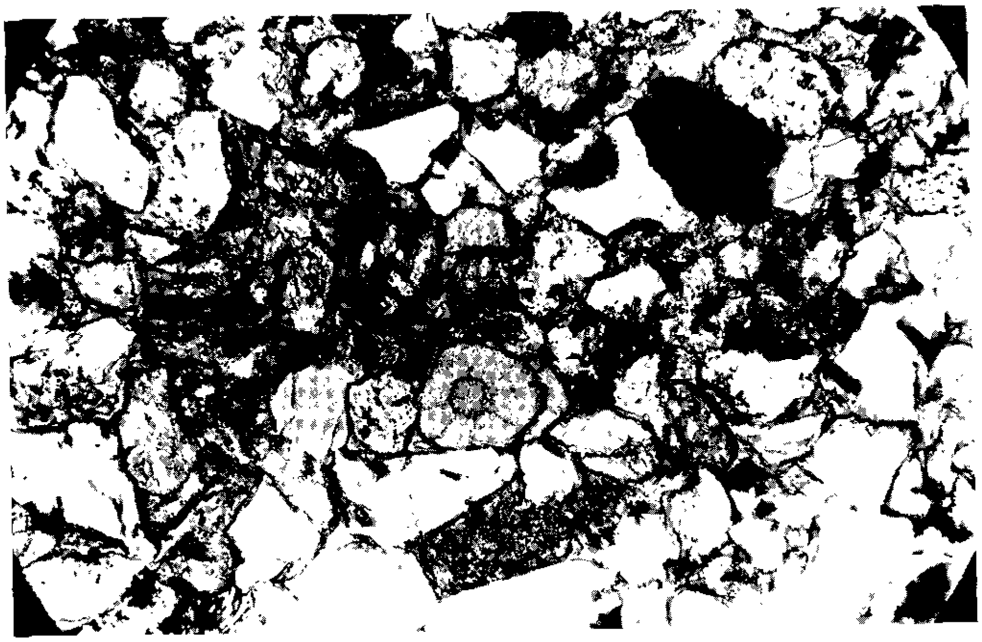


Plate XIVA. Photomicrograph of Haida glauconitic sandstone. Note microfossil in glauconite grain, and compact arrangement of angular feldspar, quartz, and rock fragments. Locality, Bearskin Bay. Plain light ×60.

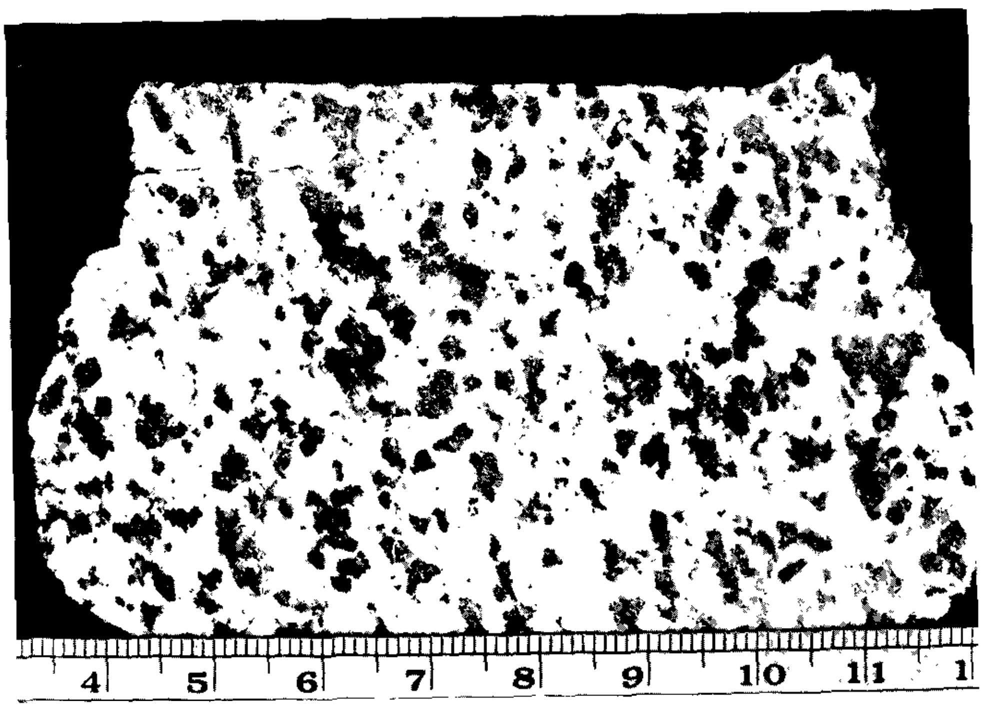


Plate XIVB. Hand specimen of syntectonic hornblende quartz diorite of San Christoval batholith, foliation at a minimum. Locality, upper Victoria Lake. Scale in millimetres. ×1.5.

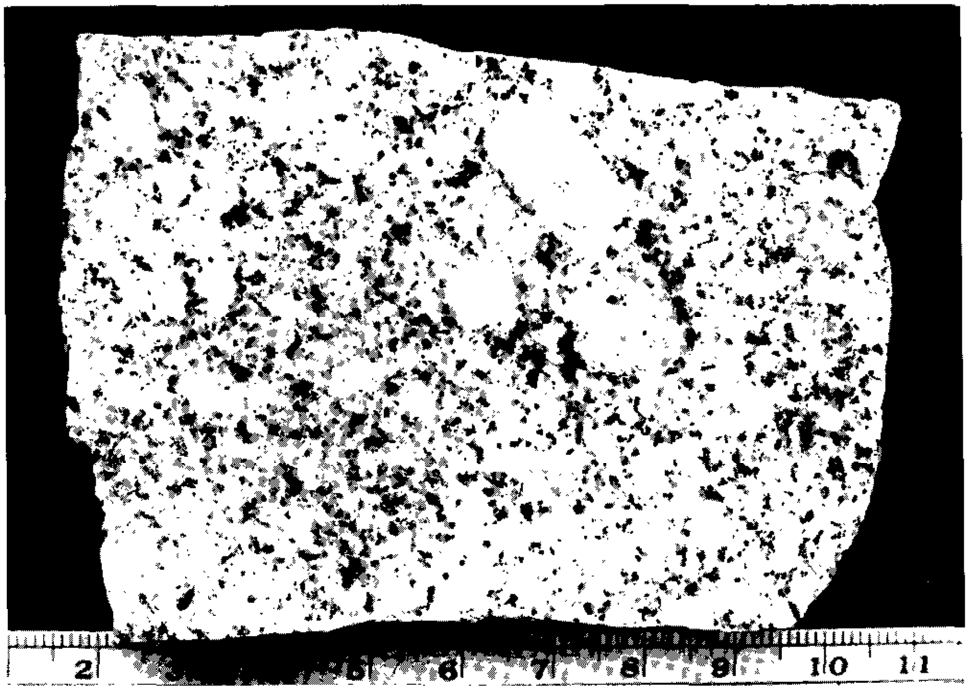


Plate XVA. Hand specimen of post-tectonic porphyritic granite of Pocket batholith from Barry Inlet. Scale in millimetres, ×1.3.

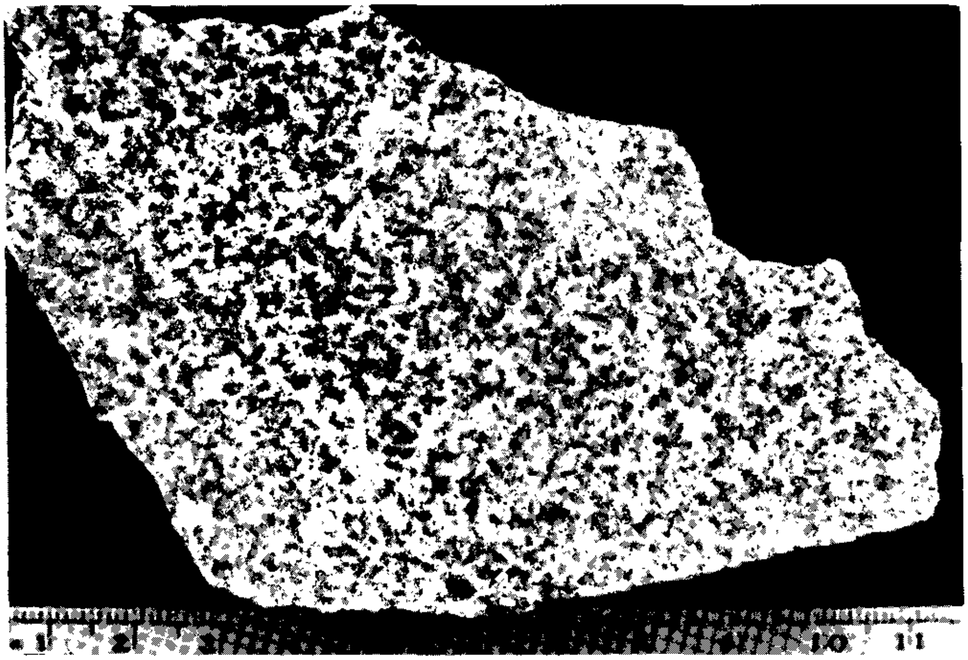


Plate XVB. Hand specimen of post-tectonic fine quartz monzonite of East Kano batholith from Shields Bay. Scale in millimetres, ×1.2.

Plate XVIA. Negative projection of a thin-section of Kunga argillite showing the three types of laminæ—graded lithic siltstone, laminated carbonaceous calcareous shale, and carbonaceous argillite. The numerous microspherules in the centre laminæ do not show well. Grinding scratches and bubbles in cement show in lower laminæ. Locality, Kennecott Point. Plain light, ×9.5.

Plate XVIB. Negative projection of a thin-section of Longarm calcareous siltstone showing heterogeneous agglomeration of siltstone clasts of slightly varying nature. Locality, Rockrun Creek. Plain light, ×9.5.

Plate XVIIA. Tasu before development (1963), Horn Island, foreground; Gowing Island and Fairfax Inlet beyond.

Plate XVIIB. Drill on Jib Group, Bluejay Cove, Burnaby Island, looking toward Jedway.

Plate XVIIIA. Diamond drill in hemlock forest at Tasu (1961).

Plate XVIIIB. Jessie open pit at Jedway (1964), looking west to Skincuttle Inlet.

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1968

Figure 6

GEOLOGICAL CROSS SECTIONS OF THE QUEEN CHARLOTTE ISLANDS

SECTIONS 'A' TO 'Q' AT 10 MILE INTERVALS

Scale: 3 2 1 0 2 4 6 8 10 12 14 16 Miles

1:125,000

To accompany Bulletin 54, B.C. Department of Mines and Petroleum Resources, 1968.

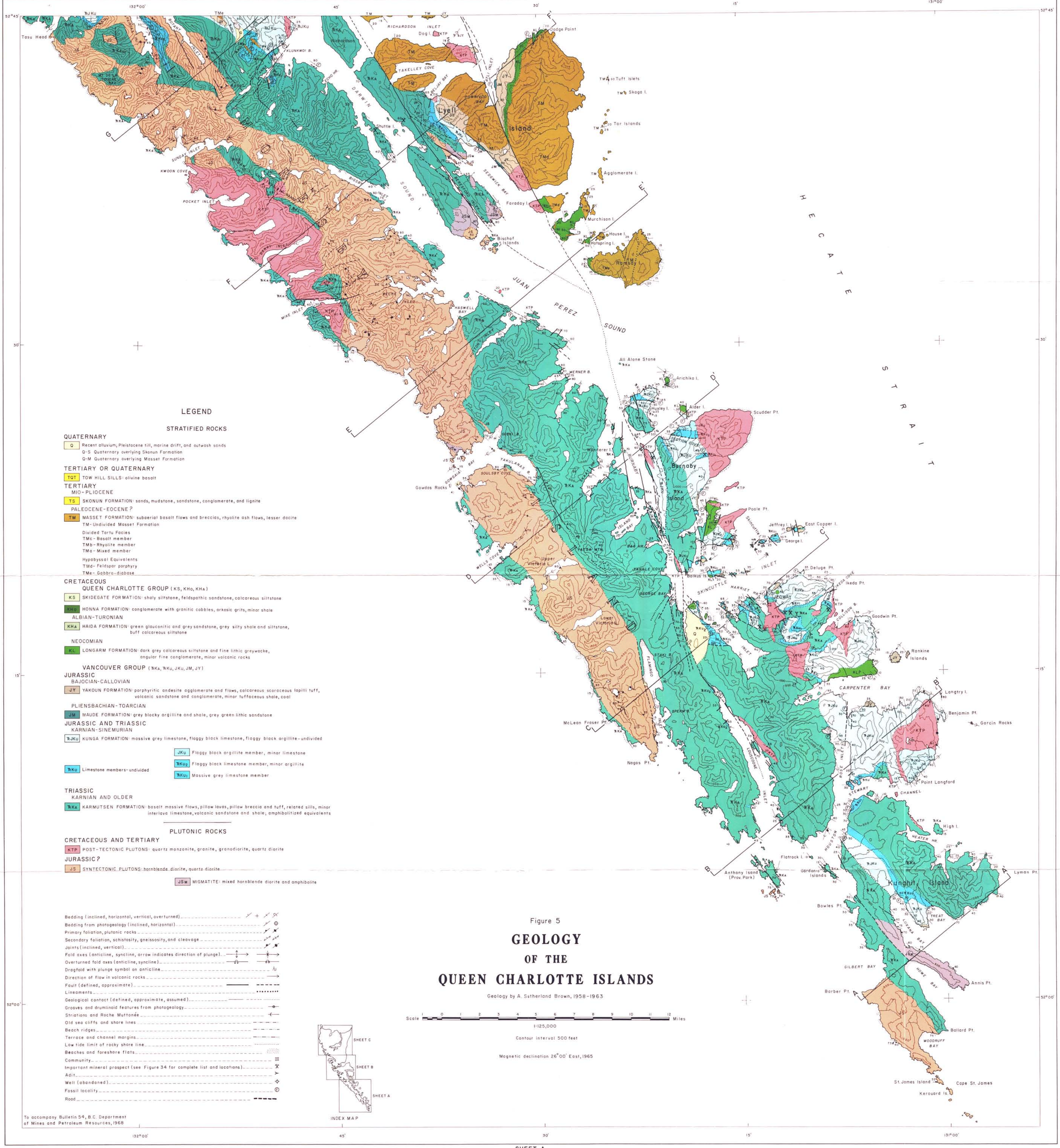
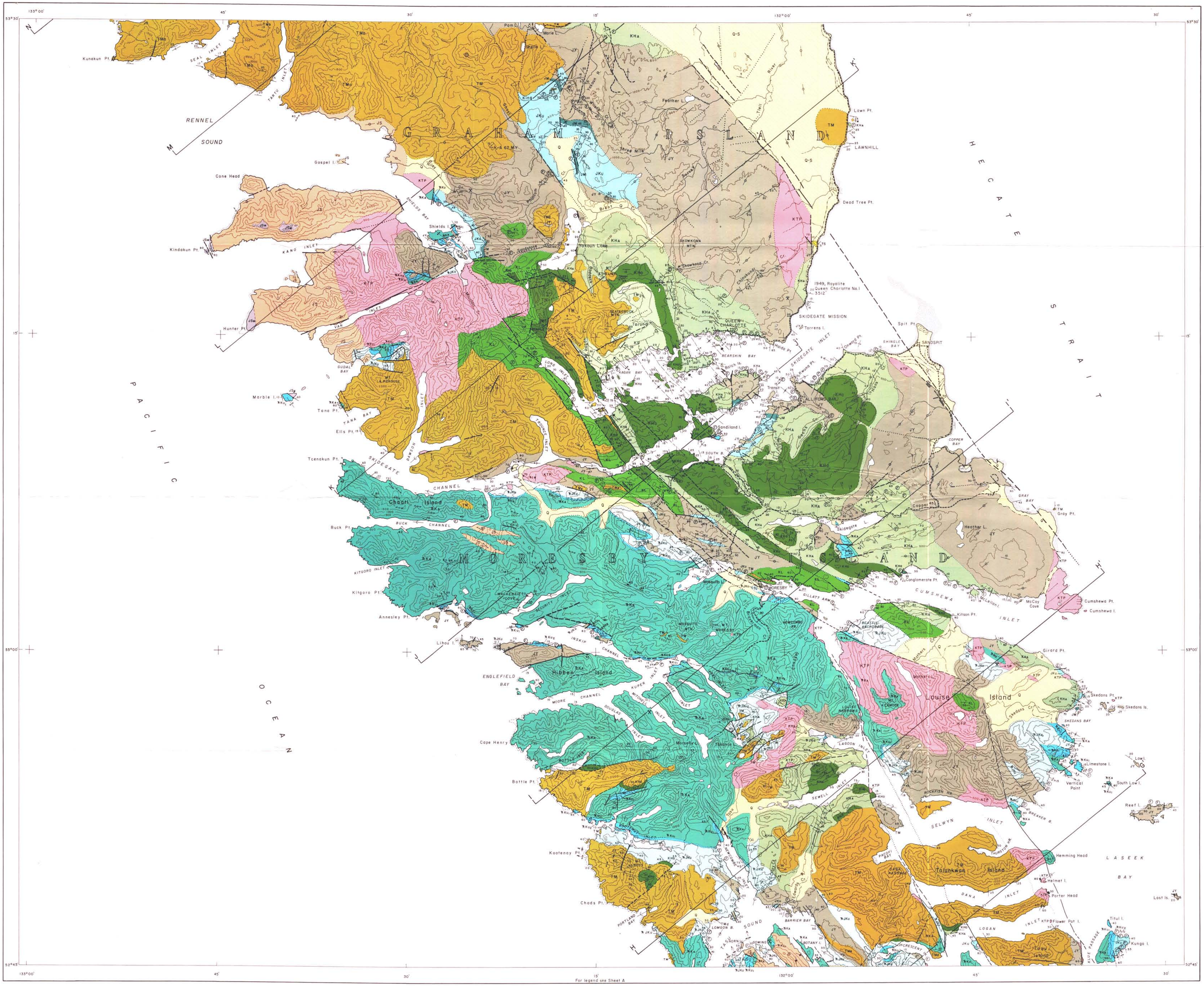


Figure 5

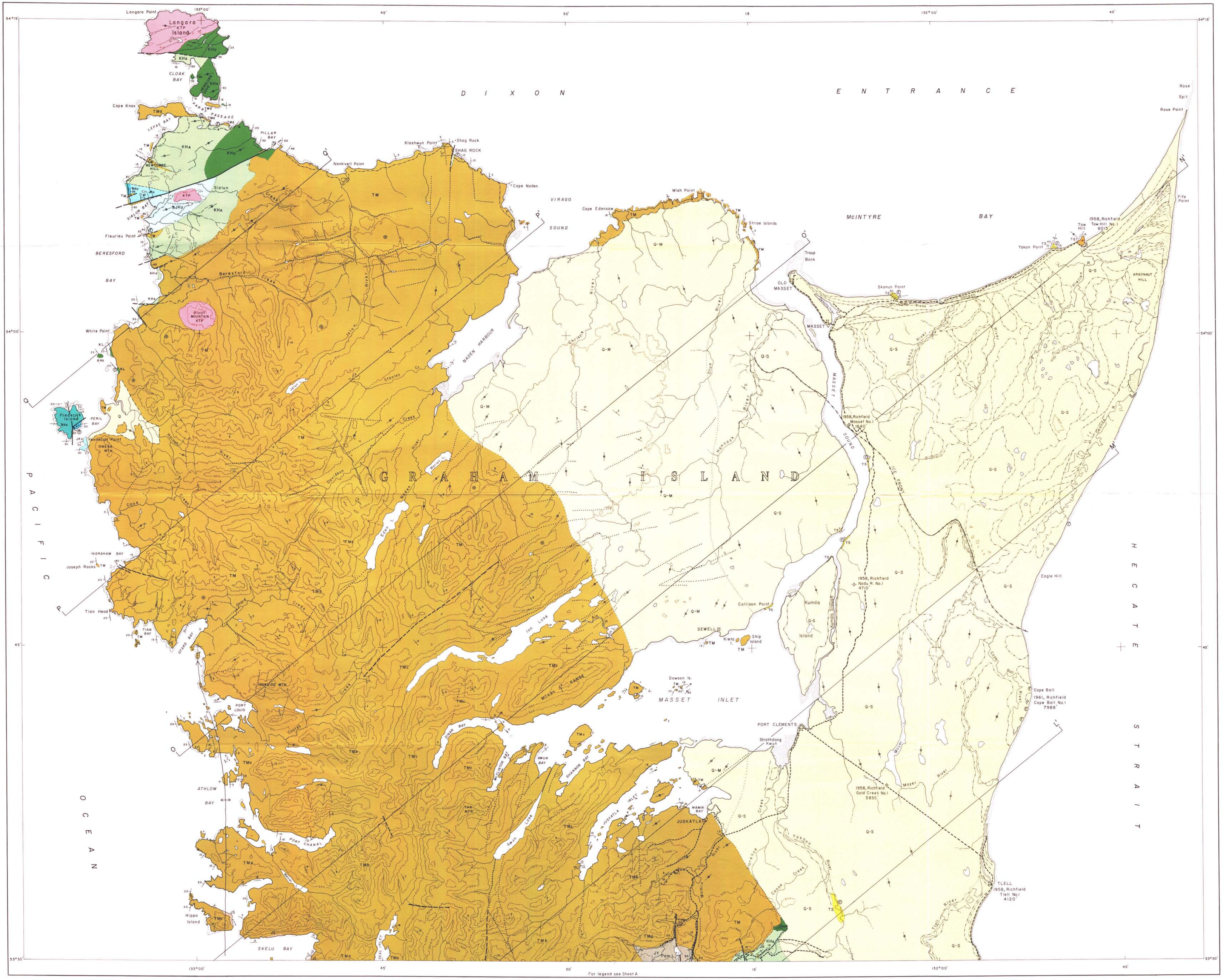
GEOLOGY OF THE QUEEN CHARLOTTE ISLANDS

SHEET A



For legend see Sheet A

Figure 5, SHEET B



For legend see Sheet A

Figure 5, SHEET C