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GEOLOGY AND MINERAL DEPOSITS OF NOOTKA SOUND MAP AREA, VANCOUVER ISLAND, BRITISH COLUMBIA

Abstract

The map area encompasses glacially sculptured mountains bordering Nootka Sound and adjacent inlets on the west coast of Vancouver Island, the principal part of the Insular Belt of the Canadian Cordillera. It is underlain by mainly volcanic and crystalline rocks and by minor sedimentary rocks. The Sicker Group includes volcanics and clastic and carbonate sediments of low metamorphic grade; the few fossils found indicate a late Paleozoic age.

The Vancouver Group (redefined) is composed of three formations: a thick sequence of pillowed to layered basalts (Karmutsen), overlain by Upper Triassic, Karnian to Norian carbonates (Quatsino) and carbonate-clastic sediments (Parson Bay). North of the map area pelites with Ladinian fossils, intruded by diabase sills, form the base of the group. The relationship suggests that a Paleozoic volcanic arc was rifted, engulfed and covered by oceanic basalt, whereon in Late Triassic time carbonate-clastic shelf deposits were laid down.

The Bonanza Group (redefined) consists of Lower Jurassic intermediate volcanic rocks and Pliensbachian clastic sediments. The Westcoast Complex is composed of basic gneiss, agmatite and amphibolite, probably derived from the pre-Jurassic rocks. Island Intrusions are Early Jurassic batholiths which range in composition from quartz diorite to granite (new IUGS definition). The three groups of Jurassic plutonic and volcanic rocks are considered to be successive stages and products of the same plutonic-volcanic process.

The Upper Jurassic – lowermost Cretaceous Kyuquot Group (new) includes three formations: Kapoose (new), Callovian to Portlandian; One Tree, Berriasian to lower Valanginian; and Longarm, Valanginian to Barremian (only in Alert Bay map area). The group represents an eastward transgressive clastic wedge, deposited in shelf seas that invaded the eroded Early Jurassic plutonic-volcanic complex. The Pacific Rim Complex is approximately coeval and represents off-shelf clastic, cherty and volcanic rocks, commonly deformed into melange, probably as a result of underthrusting of the Pacific Plate beneath the North American Plate.

Catface Intrusions (new name) are small, early Tertiary stocks and sills of fine-grained, K-feldspar poor, granitoid rocks and porphyries. The Carmanah Group (redefined) of Tertiary clastic sediments is composed of a basal conglomerate, the Escalante Formation, Narizian; the main component Hesquiat Formation (redefined), Refugian to early Zemorrian, or late Eocene to early Oligocene; and the Sooke Formation, late Zemorrian? or late Oligocene? (mainly in Victoria map area). The beds were laid down mainly in deep water on the continental slope (?), partly in quiet water and partly in turbulent submarine channels.

The structure of the region is generally a southwest dipping homocline of early Mesozoic rocks, disrupted by Jurassic batholiths. Steep to vertical major faults dominate the structural pattern. They are broadly categorized in sets of northerly and westerly faults of probable early Mesozoic origin, and late Mesozoic to Tertiary northwesterly and northeasterly faults.

Résumé

Le secteur cartographié englobe les monts modelés par les glaces qui bordent la baie Nootka, et les détroits adjacents situés sur la côte ouest de l'île de Vancouver, principale partie de la zone insulaire de la Cordillère canadienne. Le sous-sol est principalement composé de roches volcaniques et cristallines et de quelques couches sédimentaires. Le groupe de Sicker comprend des sédiments volcaniques, clastiques et carbonatés de degré de métamorphisme modéré; les quelques fossiles trouvés indiquent que ce groupe date de la fin du Paléozoique.

Le groupe de Vancouver (redéfini) est constitué de trois formations: une épaisse succession de laves basaltiques que passent de la forme en coussins à stratifiée (Karmutsen), recouverte de sédiments des étages Karnien à Norien du Trias supérieur, carbonatés (Quatsino) ou carbonatés clastiques (Parson Bay). Au nord du secteur cartographié, des pélites contenant des fossiles de l'étage Ladinien, et pénétrées par des sills de diabase, forment la base du groupe. Ceci semble indiquer qu'un arc volcanique formé au Paléozoique a été fracturé, puis recouvert d'épaisses couches de basalte océanique, sur lesquelles se sont déposés au Trias supérieur des dépôts clastiques carbonatés, de plate-forme.

Le groupe de Bonanza (redéfini) consiste en roches volcaniques intermédiaires du Jurassique inférieur et en sédiments clastiques du Pliensbachien. Le "Westcoast Complex" est composé de gneiss basiques, agmatites et amphibolites, probablement dérivés des roches pré-jurassiques. Les "Island Intrusions" sont des batholithes formés au Jurassique inférieur, dont la composition varie de la diorite quartzique au granite (nouvelle définition de l'IUGS). On considère que les trois groupes de roches plutoniques et volcaniques du système jurassique représentent les produits et étapes successifs de la même phase d'activité plutonique et volcanique.

Le groupe de Kyuquot (nouveau groupe), d'age Jurassique supérieur et debut du Crétacé, comprend trois formations: la formation de Kapoose (nouvelle formation), du Callovien au Portlandien; la formation de One Tree, du Berriasien au début du Valanginien; et la formation de Longarm, du Valanginien au Barrémien (seulement dans le secteur de Alert Bay). Ce groupe correspond à un ensemble disposé en biseau, transgressif vers l'est, de roches clastiques déposées dans des mers peu profondes, qui ont progressivement submergé le complexe érodé, plutonique et volcanique, formé au Jurassique inférieur. Le complexe de Pacific Rim (bordure du Pacifique) est à peu près contemporain, et représente des roches clastiques, cherteuses et volcaniques, déposées en eau profonde, et généralement déformées au point de constituer un mélange, probablement par suite du charriage de la plaque pacifique au-dessous de la plaque nord-américaine.

Les intrusions de Catface (nouvelle désignation) sont de petits amas et sills formés au début du Tertiaire, et composés de roches granitoïdes à grain fin, appauvries en K-feldspath, et de porphyres. Le groupe de Carmanah (reféfini), constitué de sédiments clastiques tertiaires, contient: un conglomérat basal, la formation d'Escalante du Narizien; la plus importante, la formation d'Hesquiat (redéfinie), du Refugien au début du Zemorrien, soit de la fin de l'Eocène au début de l'Oligocène; et la formation de Sooke, du de la fin du Zemorrien? ou de la fin de l'Oligocène? (principalement dans le secteur de Victoria). Les couches se sont généralement déposées en eau profonde, sur la pente continentale (?), tantôt en eau calme, tantôt dans les eaux turbulentes de chenaux sous-marins.

Du point de vue structural, la région est en général représentée par un homoclinal de pendage sud-ouest, composé de roches du début du Mésozoïque, et fragmenté par des batholithes jurassiques. D'importantes failles, fortement inclinées ou verticales, caractérisent toute la structure. On peut grosso modo les classer en un système de failles de direction nord et de direction ouest, probablement formé au début du Mésozoïque, et en un système de failles de direction nord-ouest et de direction nord-est, formé à la fin du Mésozoïque au Tertiaire.

INTRODUCTION

Location and Access

Nootka Sound map area (92 E) occupies a triangular part of the middle west side of Vancouver Island, bounded by the Pacific Ocean, longitude 126 degrees west and latitude 50 degrees north. Along its much indented coastline, Clayoquot Sound, Nootka Sound and Kyuquot Sound form broad re-entrants, separated by Flores Island, Hesquiat Peninsula, and Nootka Island. From the sounds many wide channels, flanked by forest-covered islands of relatively low relief, lead northwestward to narrow, steep-sided, fiord-like inlets, generally less than 3 km wide. Muchalat Inlet nearly reaches the east border of the map area while Tahsis, Zeballos and Espinoza inlets lead close to the north border. Highest peaks are between the heads of these inlets in the northeast corner of the map area.

The inlets and connecting main valleys provide natural travel routes that are more or less perpendicular to the general northwest direction of the coastline. A paved road leads across Vancouver Island from Campbell River on the east coast to Gold River in the northeast corner of the map area. From this town, built by Tahsis Company Ltd. about 1966 for the workers in its new pulpmill, three roads now give access to various parts of the area. A paved road leads along Gold River to the mill at the head of Muchalat Inlet. A restricted logging company gravel road leads via Muchalat Lake to the Oktwanch Valley and thence along Nimpkish Valley to Port McNeill and Port Hardy in Alert Bay map area. Another recently constructed, restricted, rough road leads from Gold River via Tlupana Inlet to the town of Tahsis, at the head of Tahsis Inlet. Zeballos, at the head of Zeballos Inlet, is now reached by logging road via Vernon in Nimpkish Valley.

Logging roads have been built through much of the northeast corner of the area and afford relatively easy access as well as good exposures in roadcuts and quarries. Such roads are scarce to nonexistent in the coastal part of the region where transportation and access is mainly by water and by air. A small passenger carrying freighter plies regularly between Gold River, Friendly Cove and Tahsis and logging camps between. Small floatplanes are readily available in these settlements for regular and chartered flights.

For geological reconnaissance work the writers used four wheel-drive vehicles on the logging roads, powered rubber rafts along the coastlines where exposures are excellent on the outer tidal flats and fair to good along the steep-sided inlets. About 200 helicopter landings above timberline and on lakes and swamps below timberline provided additional outcrop information.

Field Work and Acknowledgments

Field work in the area was started in 1968 by J.E. Muller when most of the marine shorelines were investigated using **M.V. Invader** as a moving base and rubber rafts as traversing and landing craft. The survey was almost completed during the 1971 field season with road, creek, and helicopter traverses and additional seaborne work. A few additional days were spent in the area in 1969, 1973 and 1974.

B.E.B. Cameron began his field work and related laboratory work on Tertiary stratigraphy and micropaleontology in 1969 on Nootka Island and in 1971, 1972 and 1974 made detailed investigations of Hesquiat Peninsula and Flores Island. The completion of his field work on Tertiary sediments of Vancouver Island northwest of Barkley Sound coincided with that of Muller's work on the older rocks of the map area.

Since 1968 K.E. Northcote of the British Columbia Department of Mines and Petroleum Resources has been engaged in investigations of mineral deposits of Vancouver Island. The principal writer is pleased that these two colleagues, after pleasant co-operation and exchange of ideas in the field and office, were willing to join him in preparation of this report. Cameron and Northcote are mainly responsible for sections on the Carmanah Group and on Economic Geology, respectively, Muller is the author of the remainder of the report.

Thanks for the able assistance in the field to J.E. Muller are due to J.F. Childs, C.J. Dodds, and D.A. Bridge in 1968, and to T. Schroeter, T.W. Neufeldt and L.G. Rogers in 1971. B.E.B. Cameron was likewise ably assisted in the field by the late M.E. Atchison in 1969, C. Rodriques in 1971 and 1974 and B. Griffith in 1972. Mrs. S. Banninger provided valuable laboratory assistance.

Special acknowledgment is due to J.A. Jeletzky of the Geological Survey who pioneered the study of Mesozoic and Tertiary sediments and their contained macrofauna on the west coast of Vancouver Island and supplied the writers with unpublished data. His contributions have aided in the preparation of the present report even though in several instances the writer's interpretations differ materially from those of Jeletzky. Acknowledgment is also due to D. Carlisle of the University of California at Los Angeles for his collaboration in the study of lower Mesozoic stratigraphy.

Finally the writers are grateful for discussions with many mining exploration geologists in the field and in the office and for contributions of many data obtained in their detailed work. Co-operation from logging companies who permitted the use of company roads and occasionally afforded lodging and meals in company camps is also gratefully acknowledged.

Historical Notes

The importance of Nootka Sound in the early history of the Pacific coast should be mentioned briefly. These events have been recorded in considerable detail in the journals of the Spanish, British and American explorers and traders, and by recent historical monographs (e.g. Ormsby, 1958, Anderson, 1960, Akrigg and Akrigg, 1975).

The Spanish colonized Mexico in the early 15th century and considered the Pacific Ocean as their private domain. The Russians moved into the northern Pacific following the 1741 Bering expedition to the Gulf of Alaska. Perez, the first Spanish explorer in northern latitudes briefly entered Nootka Sound in 1774 on his return from Alaska. The first British ships to arrive there in 1778 were **H.M.S. Resolution** and **H.M.S. Discovery**, in the course of Captain James Cook's third voyage of exploration – the bicentennial of that event was celebrated in 1978. Before sailing north in search of the Northwest Passage the ships spent four weeks for repairs and refitting in "Resolution Cove", on the southeast coast of "Bligh Island". Cook named the cove and island after the ship and its master, of later **Bounty** renown. The career of this outstanding maritime explorer ended prematurely with his murder less than a year later in the Sandwich Islands (Hawaii).

The publication of Cook's journals and charts after the return of his ships aroused much interest with British entrepreneurs. Of special note was the fortuitous discovery that sea otter pelts, obtained from Nootka Indians, could be traded with great profit in China. British and American trading ships, some carrying other flags of convenience as they had no Spanish nor British licence, began to arrive in Nootka Sound. Rivalries between traders and their dealings with the local Indians, ranging from benevolent to bizarre and unscrupulous, are well documented in numerous journals. John Meares, a trader unencumbered with honesty, acquired land from Chief Maquinna at Friendly Cove (= Nootka) and there built a storehouse and a small ship. In 1789 his land, cargoes and ships were confiscated by Spanish Captain Esteban Martinez (commemorated in Estevan Point), who had arrived from Mexico to take possession of Nootka. That seizure eventually sparked the Nootka Controversy between Britain and Spain that almost resulted in war. Spain later agreed to return land and ships to the British under the Nootka Convention, but in the meantime they established a fort at Nootka.

Captain George Vancouver was commissioned in 1791 to explore the North-American west coast between latitudes 30° and 60° north, and to look for any sea-arm that might connect east and west coasts of the continent. After charting a reconnaissance of the Oregon-Washington coast, Strait of Juan de Fuca, Puget Sound and the inside passage north of these, he arrived at Nootka in August of 1792. There the Spanish Captain Quadra had been waiting for Vancouver and was expected to formally return Nootka to British possession. Protracted negotiations, accompanied by ceremonial dinners and festivities, ensued between the Spanish and British officers. However, neither had sufficiently precise instructions from their governments to definitely claim or cede the disputed territory. Quadra, while waiting at Nootka, had obtained statements from captains of American trading ships that Meares' claims to landownership at Nootka were false. By a letter to Vancouver he partly reneged on the Nootka Convention by denying the right of British ships to enter ports between Nootka and San Francisco. Notwithstanding the diplomatic impasse Vancouver and Quadra apparently maintained courteous relationships and in recognition Vancouver named the large island he had circumnavigated "Quadra and Vancouvers Island".

Vancouver's ships remained in the Pacific surveying the entire northern coast in the summers and wintering in Hawaii, meanwhile waiting for definite instructions regarding the transfer of Nootka. He arrived there for the last time in September of 1794, after having surveyed the entire coast between California and Bering Strait without finding a northwest passage. Unbeknownst to the British or local Spanish officials a "Convention for the Mutual Abandonment of Nootka" had been signed in Madrid January 1794. A ceremonial hoisting of the British flag followed by evacuation by both nations of Nootka occurred in March 1795 while Vancouver was homeward bound.

Previous Geological Work

Recorded geological investigations in the map area were made mainly by the Geological Survey of Canada, beginning in 1902. Arthur Webster and Ernest Haycock conducted this survey mainly from a 19-foot sealing boat. Their separate narratives (Haycock, 1903; Webster, 1903) described the general nature of the granitic, volcanic and minor sedimentary rocks exposed along the coast.

The coastline was again surveyed in 1920 by V.A. Dolmage who gave a general account of the geological formations, largely based on previous work by Dawson (1887) and Clapp (1912) in adjacent coastal areas. With the help of a few fossil collections he established the presence of Triassic, Jurassic and Cretaceous sediments, but erroneously included the Tertiary rocks of Nootka and Flores islands and of Hesquiat Peninsula in the Cretaceous. The report also discussed the known mineral deposits of the area. The "Vancouver Sheet", a geological map of Vancouver Island and the southwest Mainland, issued in 1928, incorporates these early surveys and divides the coastline into areas of Triassic and Jurassic rocks, Cretaceous rocks (i.e. Tertiary rocks) and granitic rocks.

In 1935 the west coast of the area was the subject of geological reconnaissance by M.F. Bancroft (1937). Working from a 55-foot boat he concentrated his investigation on the mineral deposits, especially the gold veins economically of much importance in "the thirties". His account of the general geology draws heavily on the work of Gunning (1931, 1932, 1933) in Nimpkish and Buttle Lake areas but he first recognized Tertiary sediments on Hesquiat Peninsula from which he collected a gastropod fauna as well as an archeocete vertebra indicating upper Eocene or lower Oligocene age.

The last geological investigations preceding the present one were carried out by Hoadley (1953) who spent the summers 1947 to 1950 in Zeballos map area and by Jeletzky (1950, 1954) who during the summers 1949 to 1952 made a detailed examination of the Mesozoic and Tertiary sediments of the coastal area between Hesquiat Peninsula and Kyuquot

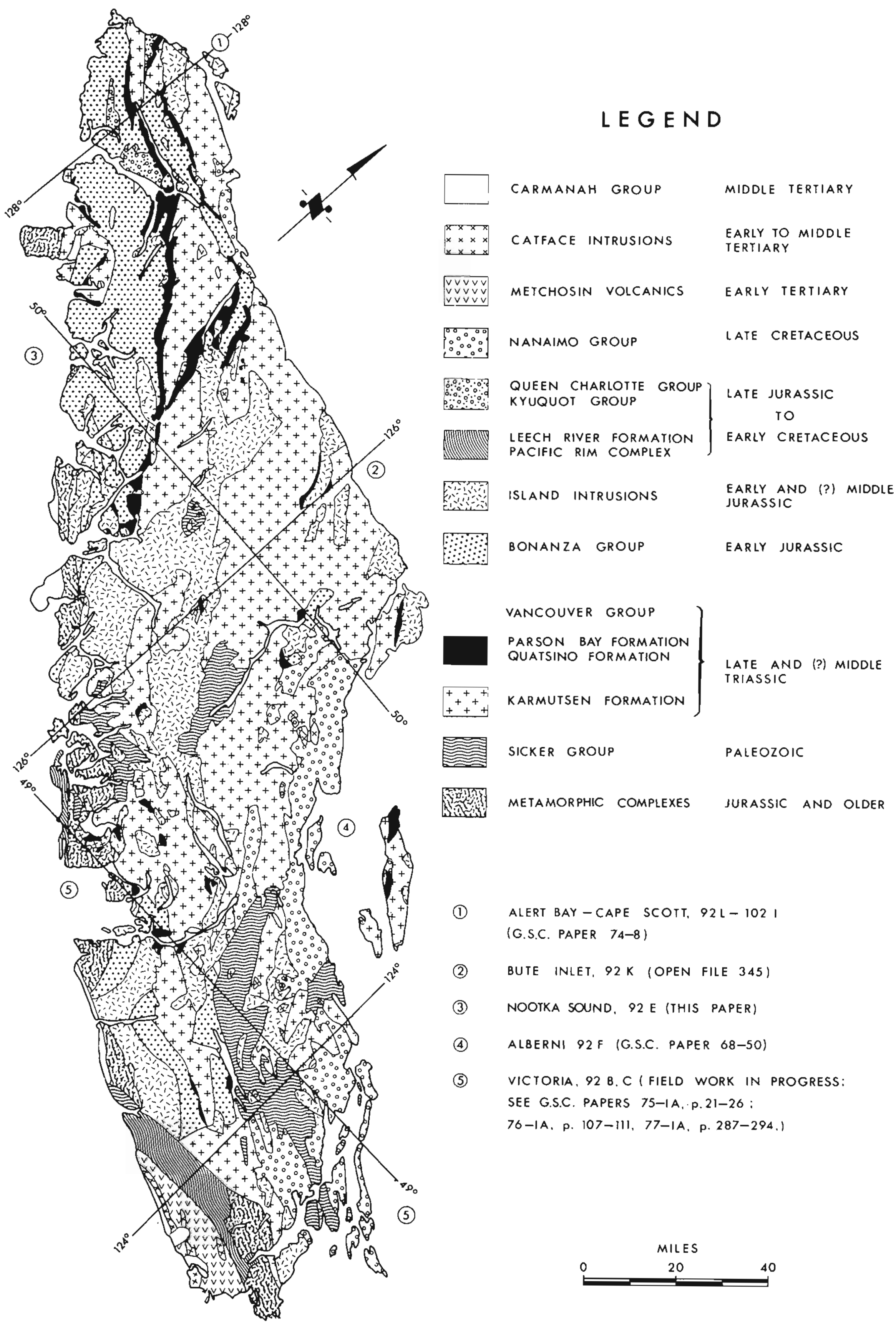


Figure 1. Geological sketch map and index to geological mapping on Vancouver Island.

Sound. Hoadley's published work combined the work of H.C. Gunning in Nimpkish area with his own in Zeballos area. Jeletzky's stratigraphic and paleontological investigations established a stratigraphic framework for the region and his Mesozoic stratigraphy has been incorporated with little change in the present report.

Investigations of mineral deposits in the region have been made regularly by officers of the British Columbia Department of Mines and are recorded in that department's published annual reports. J.S. Stevenson spent parts of several field seasons between 1935 and 1949 in the Zeballos Camp, at the north border of the map area and the results are recorded in a departmental bulletin (1950).

Physiography and Glaciation

The map area lies mainly within the western part of the Insular Mountains but contains also a large part of the Estevan Coastal Plain (Holland, 1964). Most of the larger valleys are fiords and only in the northeast corner are there valleys with floors to about 1 km (0.6 mile) wide and to about 450 m (1500 ft) elevation. The mountains are relatively subdued, most reach barely 1500 m (5000 ft) elevation; the highest is Trio Mountain (1732 m; 5683 ft) in the northeast corner.

The physiography is the result of a complex history of multiple glaciation and fluvial erosion. No detailed studies of Pleistocene deposits have been made in the map area or adjacent areas and the most recent published work dealing with southeastern Vancouver Island is by Fyles (1963) and Halstead (1968). The senior writer has made preliminary morphological studies using air photographs of all parts of Vancouver Island and has been able to distinguish two clearly defined levels of glaciation. The highest and clearly oldest ice sheet was continuous from the mainland across the Strait of Georgia and Vancouver Island to the Pacific Ocean. This "Mountain Glaciation" covered Beaufort Range and Forbidden Plateau and northern ranges bordering Georgia and Johnstone Strait up to about 1525 to 1675 m (5000 to 5500 ft). The writer believes that this ice level was attained prior to the Olympia non-glacial interval and possibly relates to the Dashwood Drift, of unknown age, but older than 37 000 years B.P. (Armstrong et al., 1965; Clague, 1977). The younger, but still extensive glaciation followed deposition of Quadra Sediments representing the Olympia non-glacial interval. The ice sheet occupied Georgia Strait and covered Nanaimo Lowlands to a height of about 450 to 600 m (1500 to 2000 ft) and abutted against Beaufort Range, Forbidden Plateau and the ranges bordering Johnstone Strait. It entered the major valleys within these mountains and coalesced with ice streams issuing from the higher Vancouver Island mountain ranges. This "Valley Glaciation" ice sheet was clearly the Fraser Glaciation, with its maximum Vachon Stade at about 15 000 years B.P.

It is possible to infer the general flow of the ice sheets from the grain of the mountain ranges and from individual directional features examined in the field and on air photographs. The Mountain Ice Sheet entered Nootka Sound map area in a westward flow centring over Muchalat Inlet and in a southward flow centring over Gold River Valley, Tahsis and Espinoza inlets. At the head of Muchalat Inlet it stood at about 1200 m (4000 ft), above Tahsis at about 900 m (3000 ft). The Tahsis and Muchalat ice streams coalesced over Bligh Island and surrounding channels and there the ice surface was at about the 600 m (2000 ft) level. Another ice stream flowed westward across Nootka Island and joined a southward flow over Espinoza Inlet in the depression of Esperanza and Nuchatlitz inlets. All other southwestward directed valleys and the coastal plains facing the ocean were filled and covered up to about 450 to 600 m (1500 to 2000 ft) elevation and a continuous wall of ice presumably bordered the ocean.

During the Valley (= Fraser ?) Glaciation the ice stood at about 600 m in Georgia and Johnstone straits and pushed southwestward into the major valleys. It probably merged in many places with ice issuing from the central Island Mountain Ranges. There were three major centres of glaciation: one in Sutton Range north of Nootka Sound map area (including the highest peak on Vancouver Island, Victoria Peak, 2163 m (7095 ft), one in Strathcona Park to the east, and one farther south in the Nitinat-Cowichan area. From the northern centre ice flowed south via Muchalat, Oktwanch and Gold River valleys, coalesced over the plain now occupied by the Gold River townsite, and ended just south of the confluence of Heber and Gold rivers. The canyon of lower Gold River was cut by meltwater from that glacier and Muchalat Inlet appears to have been free of ice. During retreat a lake was dammed in Gold River and Muchalat valleys and its varved silts are exposed in several places. There is no morphological evidence of other glacier tongues entering the area. However, alpine valley glaciers issued from mountain masses with substantial nivation areas above the present 750 m (2500 ft) level and these glaciers terminated at the 150 m (500 ft) level. These glaciers retreated in three or four stages each of which is documented by more or less distinct end moraines and meltwater channels in the valley floor below. The highest and latest stages are tarn lakes above 1000 m (3000 ft) elevation.

GENERAL GEOLOGY

About one half of the exposed surface of the map area is underlain by granitoid terrane. It is composed partly of heterogeneous agmatitic and gneissic rocks of the general composition of hornblende quartz diorite (Westcoast Complex) and partly of relatively homogeneous rocks varying in composition from hornblende quartz diorite to biotite quartz monzonite (Island Intrusions). They apparently crystallized in Jurassic time but may have been formed by migmatization of Paleozoic and lower Mesozoic volcanics and sediments.

Formations of the Vancouver and Bonanza groups are equally widespread. The former consists of a thick pile of Upper Triassic basaltic volcanics (Karmutsen Formation), overlain by Upper Triassic carbonate, pelitic and volcaniclastic sediments (Quatsino and Parson Bay formations). The latter consists of a Lower Jurassic sequence of basaltic to dacitic effusive and pyroclastic volcanics with minor intercalated sediments.

There are minor occurrences of silicified clastic sediments, limestone and metavolcanics of probable late Paleozoic age (Sicker Group) and of Upper Jurassic, Lower Cretaceous and lower Tertiary clastic sediments (Kyuquot and Carmanah groups). Finally there is a highly tectonized assemblage of greywacke, argillite, chert and volcanics of probable Jurassic to Cretaceous age (Pacific Rim Complex) and there are some small early Tertiary plutons (Catface intrusions). The relationships of these formations are shown on the Table of Formations (Table 1) and on Figure 2.

Sicker Group

Nomenclature

The name Sicker Group, originally Sicker Series, was introduced by Clapp (1912) for an assemblage of low-grade metamorphic, volcanic and sedimentary rocks, exposed on southern Vancouver Island and specifically on Mount Sicker west of Duncan. Clapp considered the rocks to be part of the Vancouver Group, with a probable Triassic or Jurassic age. Fyles (1955) changed the name to Sicker Group and recognized a lower part of cherty tuffs, clastic sediments and basaltic flows, and an upper part of limestone and minor chert. On the basis of fossils in the limestone he assigned a

Table 1. Table of Formations

Period	Series	Identified Stages	Group	Formation		Map unit	lithology	Thickness Metres (Feet)
TERTIARY	OLIGOCENE	JUANIAN	CARMANAH	Sooke		Ts	conglomerate, sandstone	15 (50)
				contact faulted, probably disconformable				
TERTIARY	OLIGOCENE / EOCENE	ZEMORRIAN, MATLOCKIAN, REFUGIAN, GALVINIAN	CARMANAH	Hesquiat		lTH	siltstone, shale, sandstone, conglomerate	1200 (3600)
				contact gradational				
TERTIARY	EOCENE	NARIZIAN	CARMANAH	Escalante		TE	sandstone, conglomerate	140 (420)
				no contact: may be partly coeval				
TERTIARY	EOCENE			Catface Intrusions		Tg	tonalite, granodiorite, hornblende–plagioclase porphyry	N A
				contact with Pacific Rim Complex is intrusive				
CRET.	LOWER	VALANGINIAN, BERRIASIAN	KYUQUOT	One Tree		lKOT	siltstone, calcareous grit—sandstone	200? (600?)
				contact probably conformable				
JURASSIC	MIDDLE–UPPER	PORTLANDIAN, KIMMERIDGIAN, OXFORDIAN, CALLOVIAN	KYUQUOT	Kapoose		JK	siltstone, shale, greywacke, conglomerate	500 (1500)
				no contact; rocks are in part coeval				
JURASSIC	MIDDLE–UPPER			Pacific Rim Complex		JKP	greywacke, siltstone, conglomerate, ribbon chert, pillow lava	N A
				Fault contacts only				
JURASSIC	LOWER	PLIENSBACHIAN	BONANZA	sediments volcanics		lJB	basaltic to rhyodacitic lava, tuff, breccia; greywacke, siltstone	2000? (6000?)
				contact	↑	intrusive		
JURASSIC	LOWER			Island Intrusions	PLUTONISM	Jg	granodiorite, quartzdiorite, granite	N A
				contact	PLUTONISM	gradational		
JURASSIC	LOWER			West Coast Complex	PLUTONISM	PM	sv: actinoliteschist, amphibolite meta-sediments. din: quartzodiorite, tonalite, agmatite, gneiss, amphibolite.	N A
				contact	↑	intrusive or migmatic		
TRIASSIC	UPPER	NORIAN	VANCOUVER	Parson Bay	MIGMATIZATION	uTrPB	calcareous siltstone, shale, limestone greywacke, breccia	400 (1200)
				contact	MIGMATIZATION	gradational		
TRIASSIC	UPPER	KARNIAN	VANCOUVER	Quatsino	MIGMATIZATION	uTrQ	limestone	750 (2500)
				contact	MIGMATIZATION	disconformable or conformable		
TRIASSIC	MID?		VANCOUVER	Karmutsen	MIGMATIZATION	uTrK	pillowed and layered basalt, aquagene tuff, breccia	7,000 (20,000)
				contact	MIGMATIZATION	disconformable or unconformable		
PALEOZOIC			SICKER	sediments (volcanics)		CPs	greywacke, argillite, limestone, includes metadiabase sills	600 (2,000)

"Permian or older" age to the group. Permian (?) limestone of Buttle Lake was tentatively called "Buttle Lake Formation" by Gunning (1931) and was later included as the upper part of the Sicker Group by Yole (1969) and Muller and Carson (1969).

Distribution and Thickness

In Nootka Sound map area the Sicker Group is represented mainly by metamorphosed clastic sediments which outcrop in areas of a few km^2 in roof pendants and along the margin of Muchalat Batholith. Almost everywhere they are underlain by the batholith and overlain by Karmutsen volcanics. One area of outcrops is within 16 km of Muchalat Lake, another area lies along the shores of inlets east and west of Bligh Island.

Sequences of Sicker Group sediments generally form bold cliffs and are exposed in steep gullies such as those tributary to Swah Creek (east of Vernon Lake), Oktwanch River and Magee Creek. As they are generally in intrusive contact with granitoid rock no total thickness can be given but the estimated exposed thickness is between 300 and 600 m (1000 and 2000 ft). The sediments are commonly interleaved with metabasaltic rocks. The latter, although in places almost concordant, appear to be sills that were emplaced later, possibly in conjunction with the eruption of Karmutsen lavas.

Lithology of Sediments

A fairly well exposed section of Sicker sediments lies in a gully on the east side of Magee Creek, above Tahsis Company logging spur H 10, about 1.5 km south of Upana Road. The lowest part of this section is exposed on the road and consists of silty limestone, a few metres thick, with irregular wavy beds, 2 to 10 cm thick. It contains coquina layers with corals, poorly preserved brachiopods and silicified foraminifera. A few other limestone lenses are exposed higher in the section, but most of the sediments are brownish grey, well banded, silicified siltstone and argillite, in places with layers of somewhat coarser, fine grained meta-greywacke. In thin section the siltstones show an assemblage of mainly quartz, as interlocking grains 0.01 to 0.05 mm in diameter, with minor irregular flakes and grains of calcite and epidote. Laminated argillite comprises quartz, chert, albite and chlorite grains in a matrix of indeterminate opaque material. A breccia, exposed on the west side of McGee Creek, probably underlies the sediments. It contains locally angular fragments up to 15 cm long of fine grained, black cherty rock and white feldspar, a few mm long. Thin sections show angular fragments of quartz, altered sodic plagioclase and minor K-feldspar, chert fragments with interlocking quartz grains and a few grains of doubtful volcanic texture in a matrix of quartz, albite, and chlorite with some albite-prehnite veinlets. The chlorite is in part light brown pleochroic and is possibly manganiferous clinochlore. Similar sediments also outcrop in the other roof-pendants of Sicker Group rocks.

In the range between Sebalhall Creek and Oktwanch River, steep, east trending canyons expose metasiltstone and argillite, interbedded with some marble. The carbonate rocks are thin and irregularly laminated and exhibit cherty nodules to about one cm in size that may have been coral or other fossil fragments. Irregular dykes of granitoid rocks intrude these sediments and at the contacts the siliceous rocks are fragmented and the carbonate rocks deformed into flow-folds. The carbonate rocks are in part marble and in part hard silicified rocks that in thin section show mainly fine grained prehnite, diopside, calcite and minor sphene.

Lithology of Metadiabase and Amphibolite

Sicker Group sediments are intimately interlayered with sills of metadiabase that in many places, as for instance in the exposed sequence east of McGee Creek, far exceed the sediments in thickness. Although these mafic rocks generally appear to be concordant with bedding of the sediments they are probably entirely intrusive. Extrusive megascopic features such as pillows, amygdules or flow layering are lacking and no volcanic relict textures are visible in thin sections.

The sills in the roof pendant areas of Muchalat Batholith are massive, untextured, greenish black, fine- to medium-grained amphibolites. Thin sections commonly show relict diabasic texture. Plagioclase may occur as phenocrysts 2 to 4 mm in size, of almost clear, unaltered labradorite, but more commonly it is converted to albite enclosing grains of epidote and actinolite fibres. Pyroxene has been converted totally to amphibole; light green actinolite and a light blue – bright green – pink pleochroic hornblende are also

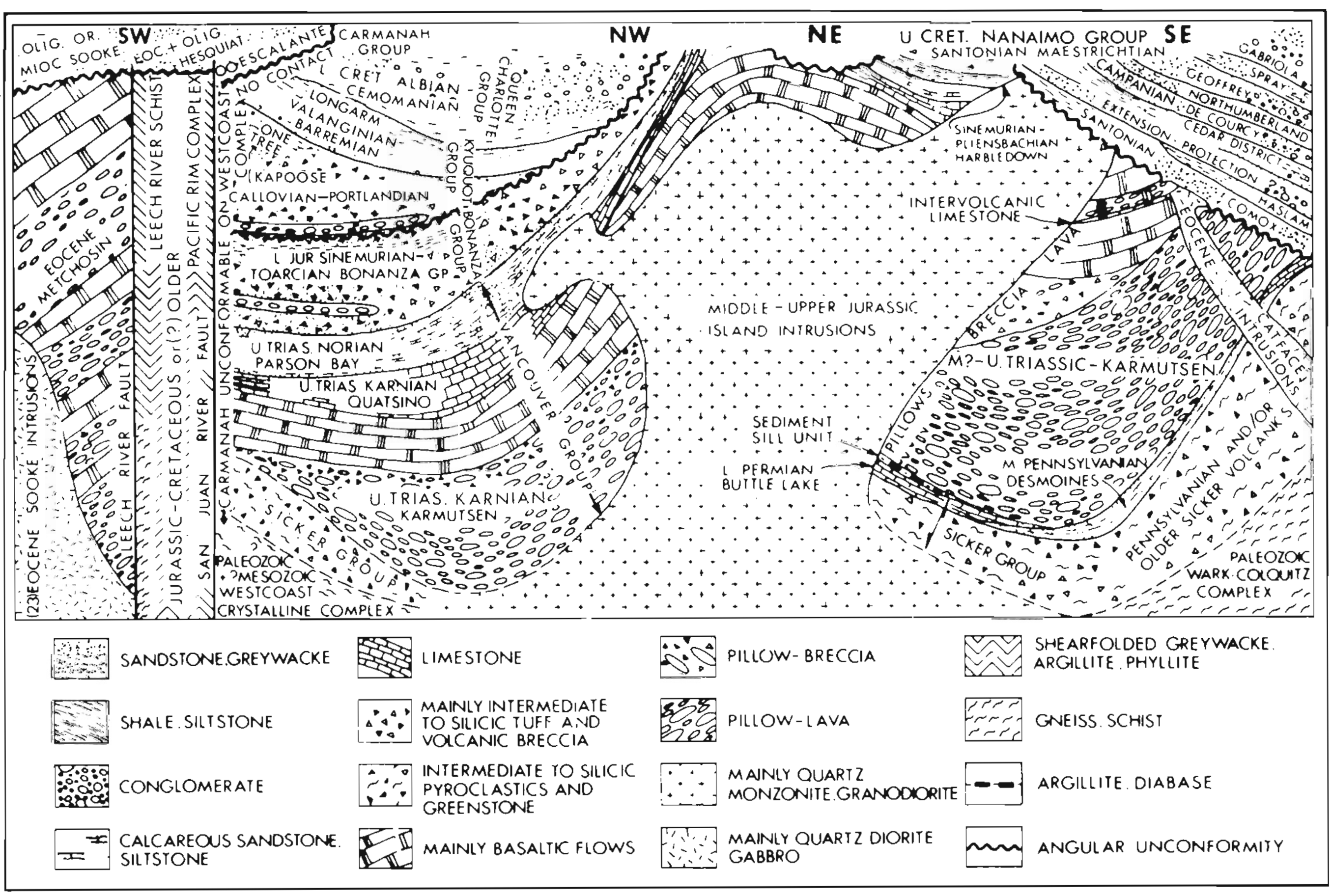


Figure 2. *Relationships of formations of Vancouver Island.*

present. The matrix is composed of epidote, albite, actinolite and some quartz and about 5 per cent of opaque material, locally with triangular ilmenite skeletons.

Origin and Metamorphism

Sicker Group sediments were probably transported and deposited as turbidites on or off an insular slope. The fairly abundant quartz and plagioclase and occasional K-feldspar in thin sections of greywacke suggest that granitoid rocks were subject to erosion, whereas detrital carbonate beds indicate the presence of carbonate reefs(?) on the immediate shelf. According to current interpretation, Sicker volcanic rocks, as known in Buttle Lake and Cowichan Lake areas, southeast of Nootka Sound map area, were formed in an island arc environment. Subsequent erosion of the basaltic to rhyolitic volcanic rocks yielded the succeeding upper Paleozoic turbidite sequences.

In Late Triassic time the sediments were intruded by diabase sills, comagmatic with basaltic Karmutsen volcanics and minor thermal metamorphism doubtlessly occurred. During Early to Middle Jurassic time pre-Jurassic rocks were subjected to high temperature-pressure conditions with ensuing metamorphism ranging from lowest grade to migmatization. The more intense transformations yielded the Westcoast Complex and Island Intrusions but less severe thermal metamorphism at structurally higher levels resulted in well preserved metasediments and enclosed diabase sills of prehnite-pumpellyite to greenschist facies. The lowest grade rocks are characterized by quartz, albite, chlorite, prehnite, minor carbonate and relict plagioclase and locally K-feldspar, the greenschists exhibit epidote, actinolite, albite, light bluish green amphibole and relict plagioclase. Some metacarbonates contain diopside.

Age

The limestone on the east side of McGee Creek yielded silicified foraminifera, extracted and identified by B.E.B. Cameron. Only generic identification was possible, as follows:

Lugtonia	Range: Carboniferous (Visean to Namurian)
Earlandinita	Late Mississippian to Pennsylvanian
Calcitornella	Pennsylvanian to Jurassic
Ammodiscus?	(possibly **monotaxinoides**)

Cameron concluded that the assemblage suggested a probable Early Pennsylvanian age.

Rocks directly on trend with Sicker sediments in the northeast part of Nootka Sound map area have also been described from the southwest part of Alert Bay map area (Muller et al., 1974). There Cameron identified a microfauna of ostracods, foraminifera and conodonts for which a tentative Middle to Late Pennsylvanian age was suggested.

Some macrofossils were also discovered by J. Lund in limestone in the range between Sebalhall Creek and Oktwanch River. These were examined by E.W. Bamber of the Geological Survey and described as follows:

GSC Loc. 79150

Locality:	5 miles SSW of Vernon Camp; 49°58'10"N, 126°19'00"W.
Identification:	fenestellid bryozoans poorly preserved, unidentifiable brachiopods.
Age:	range from Ordovician to Permian. Too poorlypreserved for further age determination.

The sediments are correlative with turbidite sequences containing minor detrital limestone lenses, exposed southeast and northeast of Cowichan Lake and on Ballenas Islands (Muller and Carson, 1969; Yole, 1969). They may be slightly older than the Buttle Lake Formation, a limestone formation up to 300 m thick, exposed west of Buttle Lake and north of Horne Lake in Alberni map area. That limestone is either Early Permian or Pennsylvanian and is considered to form the top part of the Sicker Group.

Vancouver Group

The Vancouver Group is by far the most extensive unit on Vancouver Island and underlies about one third of Nootka Sound map area. Dawson (1887, p. 10B) introduced the name Vancouver Series for all volcanic and sedimentary rocks unconformably underlying the Cretaceous of Vancouver Island and Queen Charlotte Islands. He suggested that "If this great mass of rocks should eventually prove separable into Triassic and Carboniferous portions, I would suggest the name of Vancouver Series for the former". The Vancouver Group is now established as a sequence of Upper Triassic volcanic and sedimentary formations of the entire Insular Belt, including Vancouver Island, Queen Charlotte Islands and neighbouring smaller islands. The group is divided into Karmutsen, Quatsino and Parson Bay formations. The Bonanza Group (Subgroup), included in the Vancouver Group by Hoadley (1953) and Muller et al. (1969, 1974) is now considered as a separate group.

Karmutsen Formation

Nomenclature

The Karmutsen Formation is the thickest and most extensive formation on Vancouver Island. The name was introduced by Gunning (1932, p. 23A) for the volcanic rocks underlying Upper Triassic limestone of the Quatsino Formation and exposed in Karmutsen Range west of Nimpkish Lake. Muller and Carson (1969) proposed that other local names such as Valdez Group, Texada Formation, Vancouver Volcanics and Franklin Creek Formation be abolished in favour of Karmutsen Formation. In the last decade the formation has received considerable attention in geological literature because it comprises a thick pile of tholeiitic basalts, that have yet to be unequivocally explained in the framework of global tectonics.

Distribution and Thickness

Several blocks of Karmutsen rocks, each occupying most of a mountain range, are present within the map area and form all the high peaks near or over 1500 m (5000 ft) elevation. The largest area of Karmutsen volcanics is in the range east of Tahsis, and includes Mount McKelvie (1631 m; 5350 ft) and Malaspina Peak (1573 m; 5160 ft). It extends northward into Alert Bay map area in Karmutsen Range and beyond. The ranges east and west of Gold River are also composed of Karmutsen Formation, separated by granitoid rocks exposed in the deep valleys of Gold, Muchalat and Upana rivers.

In addition several peaks forming roof pendants within Muchalat Batholith, including the conspicuous Matterhorn-like Conuma Peak, are composed of Karmutsen rocks. The total thickness of the formation, exposed between the base that overlies Sicker sediments on Sebalhall Creek and the overlying Quatsino limestone east of Tahsis Inlet is calculated at between 4500 and 6000 m (15 000 and 20 000 ft). Similar thicknesses of about 6000 m were reported in Buttle Lake area (Muller and Carson, 1969) and in Alert Bay map area (Muller et al., 1974). It is apparent that the formation reaches its greatest thickness in the central part of Vancouver Island and is reduced to a few thousand feet in the northwestern and southeastern parts.

Subdivisions

The Karmutsen Formation, as recently reviewed by Carlisle and Susuki (1974), is divisible into a lower part of pillow lavas 2450 to 2750 m (8000 to 9000 ft) thick, a middle part of pillow breccias and aquagene tuffs, 600 to 900 m (2000 to 3000 ft) thick, and an upper part of basaltic flows with minor sedimentary intercalations (9000 to 10 000 ft) thick. These subdivisions have been mapped in some other areas (Carlisle, 1976) but have not been distinguished in the present reconnaissance survey. In general the areas of Karmutsen volcanics in the west part of the map area are composed mainly of pillow lavas of the lower part of the formation. In the range east of Tahsis the high peaks on the west side are composed of lava flows; pillow breccia is exposed on a ridge one mile east of Mount Leiner and extends southeastward; and pillow lavas are exposed on the ridges directly west of Sebalhall Creek and the head of Conuma River.

Lithology of Pillow Lavas

No detailed petrographic study of Karmutsen volcanics has been made in the map area and the following description is based on observations of Carlisle (1963), Carlisle and Susuki (1974), Kuniyoshi (1972) and the writer (Muller et al., 1969, 1974) and applies almost uniformly to all Karmutsen rocks on Vancouver Island.

Close-packed pillows of the lower subdivision vary in shape from rough spheres, 15 to 30 cm in diameter, to irregular ellipsoids up to 1.5 m wide and 0.5 m high. Kuniyoshi (1972) measured "pillows" 6 m long and even one 18 m long (perhaps more properly called "flow-tongue"). Many pillows have chilled rims of dark green or brown aphanitic rock, 1 to 2 cm thick, enveloping reddish brown weathering, fine grained, commonly porphyritic or amygdaloidal basalt. Roughly tetrahedral spaces between pillows are typically filled mainly with quartz and less epidote, prehnite and pumpellyite. Such quartz nests are, in places, the best indicators of pillow structure in otherwise massive-looking basaltic rock. Thin sections of pillows show plagioclase phenocrysts, not uncommonly clustered, whose composition in fresh rocks is about An_{65}-An_{80}, but which are commonly in part or entirely sericitized and albitized. Subophitic augite occurs between plagioclase crystals or as single subhedral grains that are colourless or uralitized to green actinolitic hornblende. Opaque minerals, about ten per cent of the rock, occur as small interstitial masses of Fe-Ti oxides, commonly replaced by sphene. Thin sections of the outside of pillow rims show translucent, pale green to brown, almost isotropic sideromelane, recrystallized into spherulites of chlorite and on the inside, darker coloured tachylite, recrystallized to spherules of brown, highly refractive and birefringent goethite. The "glass" contains microlites of plagioclase and augite.

Lithology of Pillow Breccias

Pillow breccia of the middle subdivision consists of pillows, broken into angular fragments a few centimetres to about 20 centimetres in size, some showing parts of chilled rims. Their petrography is similar to that of pillow lavas but according to Kuniyoshi (1972) they are generally more glassy. They are embedded in a matrix of aquagene tuff (hyaloclastite) containing many green, white-rimmed globules, up to 1 cm in diameter but generally only visible with a hand lens, and angular shards. The thin section shows these to be mainly chlorite, they occur together with broken plagioclase and augite crystallites. The composition of this subdivision varies from rather closely packed pillow fragments to aquagene tuff with few or no large fragments.

Lithology of Lava Flows

Lavas of the upper subdivision are layered and the flows, where clearly discernible, vary in thickness from about 2 m to about 20 m. Amygdules are concentrated near the tops of flows and to a lesser extent near the bottoms. In roadcuts and quarries jointing, roughly perpendicular to the layering, is commonly more conspicuous than layering itself, and provides an indirect guide to the attitude of the rocks. Columnar jointing is rare. Some massive, well-jointed layers of basalt may represent sills rather than flows. Thin sections of flows show diabasic to plagiophyric assemblages of calcic plagioclase, up to An_{85}, or albite, and augite, minor Fe-Ti ore, interstitial tachylite and amygdules filled with quartz, carbonate, chlorite and in many instances prehnite and pumpellyite.

Intervolcanic Limestone

The upper part of the Karmutsen Formation locally contains one or more thin layers of limestone and argillite, commonly a few centimetres to a few metres thick and of limited extent. They have been studied and described in some detail by Carlisle and Susuki (1974). Generally the sediments overlie lava flows but are themselves overlain by a thin sequence of pillow lava and breccia, succeeded by flows. One such occurrence was reported by Hoadley (1953) "at elevation 2000 feet, on the northeasterly trending ridge leading from the head of Tahsis Inlet to Mount Leiner". According to him "black to dark brown argillite with some fossils, about 25 feet (8 m) thick is exposed for 100 feet along the east side of a small gully in the ridge". The writer found on the same ridge a lenticular mass, about 1.2 m thick, of black micritic limestone with a few shale interlaminae.

Chemistry

Chemical analyses are available mainly from Bute Inlet map area (Kunyioshi, 1972) and from Alberni map area (Muller, 1971 and unpublished) and average analyses are given in Table 2. They have all been done by X-ray fluorescence. Kunyioshi analyzed 193 samples of Karmutsen volcanic rocks including massive flows, rims and cores of pillows, and matrix material of tuff and breccia. His samples were taken from three metamorphic zones ranging from prehnite-pumpellyite to albite-epidote-actinolite and to hornblende-plagioclase rock. Norms and rock classifications according to Irvine and Baragar (1971) were determined by computer for Kunyioshi's 193 samples with the following results:

	no. of samples	per cent
Tholeiitic basalt series		
Picrite basalt	5	2.5
Tholeiite	157	81.5
Andesite	4	2.0
	166	86.0
Calc-alkali series		
High alumina basalt	4	2.0
Dacite	1	0.5
Rhyolite	9	4.5
	13	7
Alkali - olivine basalt, sodic series		
Alkalic picrite basalt	3	1.5
Ankaramite	2	1.0
Alkali basalt	8	4.0
	13	6.5

Clearly, the tholeiitic basalt series and specifically tholeiite are the predominant rock type, forming more than 80 per cent of all samples. The calc alkaline and alkaline rocks are mainly, and in the case of rhyolite and dacite exclusively, from pillow cores, breccia and tuff. In these rocks a certain amount of differentiation, diagenesis and silicification is to be expected and is known to occur. In view of the great uniformity of Karmutsen volcanic rocks it is highly probable that those of the map area are of similar composition.

Metamorphism

Except for small areas where they overlie Paleozoic rocks, Karmutsen volcanics form the roof and walls of Muchalat Batholith. The contact commonly includes a zone of agmatite composed of quartz diorite with sharply outlined inclusions of dioritized volcanic rock, a few centimetres to about 50 centimetres in diameter, and a zone of dioritized volcanic rock, shattered and criss-crossed by veinlets and veins, to about 10 cm wide, of hornblende quartz diorite and granodiorite. The contact metamorphic rock grades from plagioclase amphibolite to albite-epidote-actinolite hornfels that generally has preserved original pillowed, fragmental, or amygdaloidal textures. Spaces between pillows and vesicles are filled with epidote and quartz. The amphibolite and hornfels zones are one thousand to a few thousand metres thick and grade into rocks of the prehnite-pumpellyite zone where original plagioclase and pyroxenes are at least partly preserved. Metamorphism of Karmutsen volcanic rocks is discussed in considerable detail by Surdam (1973) and Kunyioshi and Liou (1976).

Origin

The great thickness of up to about 6000 m of tholeiitic basalt, of which the lower part is clearly submarine, combined with considerable aereal extent, indicate an oceanic (i.e. noncontinental) origin for the Karmutsen volcanics. They are predominantly tholeiitic basalt, but in detail the tholeiite is chemically more akin to that of the midoceanic spreading ridges than that of the Hawaii-type seamounts (Kunyioshi, 1972). However, the fact that the formation locally overlies the Sicker Group volcanic arc sequence clearly precludes an analogy with those open ocean settings. As a possible alternative it has recently been suggested by Muller (1977) that the Karmutsen was formed in a rifting basin at the continental margin, similar to the present Gulf of California. That setting would account for the occurrence of remnant blocks of the Paleozoic volcanic arc terrane, separated and overlain by Triassic oceanic basalt.

Age

The age of Karmutsen volcanics is now well established on the basis of fossil-bearing sediments underlying, interbedded with, and overlying the sequence. The only known locality is near Schoen Lake in Alert Bay map area (Muller et al., 1974) where **Daonella** in argillite underlying the formation indicates probable early Late Ladinian age. Clastic-carbonate sediments, interbedded in the upper part of the Karmutsen Formation, on Texada Island, east of Buttle Lake, and on Hisnit Island in Ououkinsh Inlet contain faunas indicating the **Dilleri** Zone of the Upper Karnian stage (Muller and Carson, 1969; Carlisle and Susuki, 1974). E.T. Tozer in 1977 reidentified fossils from Nootka Sound map area, collected by J.W. Hoadley in 1949:

Field no.: F-1-H-49
GSC Loc.: 17123
Location: "At elevation of 2000 feet on the northeasterly trending ridge leading from the head of Tahsis Inlet to Mount Leiner". (See Hoadley, 1953, p. 17 and GSC Map 1027A.) 49°55'40", 126°38'05"W.

Clydonites? n. sp. (As at GSC loc. 79255, south of Crescent Beach, Texada Island)
Tropidit? fragment.

Age: Probably Upper Karnian, possibly **Dilleri** Zone.

Table 2. Average chemical compositions of Karmutsen volcanic rocks

	Kelsey Bay area Analyst: S. Kunyioshi (Kunyioshi, 1972) Method: X-ray fluorescence		Buttle Lake area Analyst: S. Courville Method: X-ray fluorescence, supplemented by rapid chemical analysis for Fe, Na_2O, P_2O_5, CO_2 and total H_2O
	Pillows (25 samples)	Flows (36 samples)	flows (14 samples)
SiO_2	48.02	47.30	47.5
Al_2O_3	15.24	14.70	14.3
CaO	11.23	10.52	11.0
Na_2O	2.33	2.43	2.7
K_2O	0.19	0.22	0.36
FeO			7.2
Fe_2O_3			4.2
"Fe_2O_3	13.18	12.54	
MgO	6.22	7.38	6.3
TiO_2	1.85	1.73	1.68
MnO	0.20	0.20	0.17
H_2O	1.30	3.20	3.2
Total	99.9	100.35	99.7

Finally, fossils collected by Jeletzky (1970, p. 2-3; 1976, p. 13-14; and by Muller et al., 1974, and this report) in the Quatsino Formation indicate the **Welleri** Zone of Upper Karnian age. However, Carlisle and Susuki (1974) also have found fossils of the preceding **Dilleri** Zone in Quatsino limestone. These facts indicate that extrusion of the thick succession of Karmutsen volcanics occurred and terminated in early Karnian time. As they rest in one place at least on Ladinian sediments, a late Ladinian inception of this volcanism cannot be ruled out.

Quatsino Formation

Nomenclature

The name "Quatsino Limestone" was first used by Dolmage (1919) and later by Gunning (1932) for the limestone extensively exposed in Quatsino Sound area. The limestone commonly grades upward into calcareous clastic sediments which Gunning included in the Bonanza Group. The "Bonanza sediments", now called Parson Bay Formation form, with the Quatsino Formation, essentially one coherent assemblage of Upper Triassic sediments.

Distribution and Thickness

The medial belt of upper Triassic sediments of Alert Bay – Cape Scott map area (Muller et al., 1974) enters Nootka Sound map area at the head of Tahsis Inlet and continues southwestward towards Head Bay at the head of Tlupana Inlet. Beyond that point it is terminated by Muchalat Batholith. It is exposed in a monoclinal, southwest dipping succession between underlying Karmutsen and overlying Parson Bay rocks. The maximum thickness in this belt, not measured in detail, is probably similar to that in Alert Bay map area or about 750 m (2500 ft) although a thickness of 1050 m (3500 ft) estimated by Hoadley (1953) could be accommodated in the mountains east of Tahsis.

A small capping of Quatsino limestone, overlying Karmutsen volcanics, is present east of Muchalat Batholith, at the head of Jacklah River. In the complex western belt of Upper Triassic sediments on the west coast of Alert Bay map area the Quatsino Formation is less than 30 m thick and probably pinches out in Nootka Sound area. There, neither Quatsino nor Karmutsen formations are exposed underlying Parson Bay beds in the scattered exposures on the west coast. Recrystallized limestone, apparently overlying amphibolite on the coast of Nootka Island, northwest of Maquinna Point, was interpreted by Jeletzky (1954) as Quatsino limestone. No fossils have been found and the rocks also could be correlative with the Buttle Lake Formation.

Lithology

In its lower part the Quatsino Formation consists of thick bedded to massive, brown-grey to light grey, grey to white weathering, fine to microcrystalline, commonly stylolithic limestone. In its upper part it is thin- to thick-bedded, darker brown and grey, with fairly common layers of shell debris. The formation is in gradational contact with the overlying Parson Bay Formation by an increase in layers of calcareous pelites.

Origin

The limestone was apparently deposited in a shelf area on the submerged shield of Karmutsen volcanics. The sedimentary sources perhaps were carbonate reefs subject to wave-erosion, shedding lime debris and minor other organic material on broad submarine aprons.

Age

Most of the Quatsino Formation, although composed mainly of organogenic limestone, contains very few fossil remains suitable for dating. Most fossils are found in the upper part where thin beds of grey limestone are interbedded with black calcareous shale and siltstone. The beds are transitional to those of Parson Bay Formation, composed mainly of fine clastic material with a minor carbonate component. In an earlier publication (Muller et al., 1974) the transitional mainly carbonate beds were included in the Quatsino Formation and this practice is followed in this report. However, Carlisle and Susuki (1974, p. 265) have placed these fossil bearing beds at the base of Parson Bay Formation.

Extensive fossil collections were made from the Quatsino Formation of Union Island by J.A. Jeletzky in 1949 and 1950. The following collections were made within the map area, from the west coast of Union Island at the headland 0.7 km northwest of Raccoon Point (tidal flats); 49°59'25"N, 127°18'25"W. All are from a stratigraphic interval of about 35 m. They are listed in ascending stratigraphic sequence. Fossil and age determinations are by E.T. Tozer of the Geological Survey.

T_RQ 1a. GSC loc. 20524 (Jeletzky field no. 149/1)
Arcestid indet.
Trachysagenites sp. indet.
Sympolycyclus sp. indet.
Age: Upper Karnian

T_RQ 1b. GSC loc. no. 20233 (Jeletzky field no. 149/1A)
Halobia cf. **H. superba** Mojsisovics
Age: Upper Karnian

T_RQ 1c. GSC loc. 20537 (Jeletzky field no. 149/1B)
Halobia sp. **H. superba** Mojsisovics
Age: Upper Karnian

T_RQ 1d. GSC loc. 20526 (Jeletzky field no. 149/2)
Sympolycyclus sp. indet.
Discotropites sp. indet.
Tropites sp. indet.
Age: Upper Karnian

T_RQ 1e. GSC loc. 20532 (Jeletzky field no. 149/2A)
Sympolycyclus sp. indet.
Age: Upper Karnian

T_RQ 1f. GSC loc. 20534 (Jeletzky field no. 149/2C)
Trachysagenites sp. indet.
Projuvavites sp. indet.
Age: Upper Karnian, **Welleri** Zone

T_RQ 1g. GSC loc. 20234, 20678 (Jeletzky field no. 149/3)
Arcestid indet.
Pamphagosirenites sp. indet.
Tardeceras parvum Hyatt and Smith
Bacchites hyatti (Smith)
Projuvavites brockensis (Smith)
Age: Upper Karnian, **Welleri** Zone

T_RQ 1h. GSC loc. 20232 (Jeletzky field no. 149/3A)
Halobia sp. indet.
Age: Probably Upper Karnian

Thus fossils from the Quatsino Formation of Union Island, in the western belt of Triassic sediments, generally indicate late Karnian age and those in the highest beds are diagnostic in particular of the **Welleri** Zone. No fossils have been collected in Nootka Sound map area in the central belt of Quatsino limestone, but to the north in Alert Bay map area the limestone of this belt has also yielded late Karnian **Welleri** Zone fossils and possibly also younger Norian fossils (Muller et al., 1974).

Parson Bay Formation

Nomenclature

The name Parson Bay Group was introduced by Bancroft (1913) for shales, limestone and minor volcanic rocks exposed at Parson Bay, Harbledown Island, just northeast of northern Vancouver Island and containing the Upper Triassic fossils **Pseudomonotis** (now **Monotis**) **subcircularis** and **Halobia**, and also **Celtites vancouverensis.** Crickmay (1928) identified the latter fossil as **Melanhippites harbledownensis** sp. nov and considered it to indicate an Early Jurassic age. On that basis he divided the beds at Parson Bay into an Upper Triassic Parson Bay Formation and a lower Jurassic Harbledown Formation. Gunning (1932) named sedimentary and volcanic rocks overlying the Quatsino Formation in Nimpkish area "Bonanza Group". His suggestion that "if the group be later subdivided, the term Bonanza should be retained for that division lying directly above the Quatsino Formation" has never been fully implemented by later workers. Jeletzky (1950) did not name the Upper Triassic sediments in his paper or on his map of the coast south of Kyuquot Sound, but Hoadley (1953) called them the Sedimentary Division of the Bonanza Group in Zeballos-Nimpkish area. The same term is also used in later papers of Jeletzky (1970, 1976) and by Muller and Carson (1969). Carlisle and Susuki (1974) and Muller et al. (1974) have now reinstated the name Parson Bay Formation for Upper Triassic post-Quatsino carbonate-clastic sediments of Vancouver Island and this name is now well established. The most complete section is that north of Klaskino Inlet (Klaskino Section of Muller et al., 1974); it is also referred to by Carlisle and Susuki (1974) and Jeletzky (1976).

Distribution

In the middle belt of Triassic sediments that extends from Alert Bay map area into the Tahsis Inlet region of Nootka Sound map area the Parson Bay Formation generally overlies the Quatsino Formation with gradational contact. In the western, coastal belt the formation is exposed in several small isolated fault blocks, together with a narrow section of Quatsino limestone, or without any exposure of that formation. Several of the fault blocks with typical varied Parson Bay lithology contain abundant Upper Triassic fossils but south of Esperanza Inlet more highly metamorphosed sediments of the coastal area have not yielded any fossils and could equally well be part of the Sicker Group.

Lithology

Upper Triassic sediments of the map area were first studied in detail by J.A. Jeletzky in 1949-1953. In an early paper he (1950) divided the beds here referred to as the Parson Bay Formation into a lower "Thinly Bedded Member" with **Monotis subcircularis** Gabb, a middle "Arenaceous Member" and an upper "Limestone Member". In later papers he (1970, 1976) correlated the "Limestone Member" with the "Sutton Limestone" of southern Vancouver Island on the basis of similar late Norian faunas. He also considered the Sutton limestone to be coeval with the Arenaceous Member (Jeletzky, 1976, Table of Formations).

The lithology of Parson Bay sediments was studied in some detail by Carlisle and the writer in 1971. The reconstructed sequence of the west coast of Union Island and of the isolated fault blocks south of Kyuquot Sound is similar to the better exposed Klaskino Section (Muller et al., 1974) and is broadly as follows:

A. The lower part of the formation consists of thinly bedded (10 cm) dark grey to black, very fine grained, laminated silty limestone and calcareous lithic sandstone interbedded with nonlaminated impure oolitic and micritic limestone. This part, about 150 m thick, commonly contains **Halobia.**

B. The next part is composed of alternating beds of medium grey nonlaminated limestone and dark grey, crudely laminated silty limestone and is about 60 m thick. A and B appear to be the "Thinly Bedded Member".

C. This part consists of brown coarse grained sandy, feldspathic limestone and calcareous lithic sandstone with prominent grading and crossbedding alternating with fine grained, dark coloured laminated siltstone locally containing **Monotis.** The thickness is about 175 m. Unit C appears to be the "Arenaceous Member" of Jeletzky even though he states (1976, p. 18) that **Monotis subcircularis** only occurs in the upper part of the "Thinly Bedded Member" and not in the "Arenaceous Member" of the Kyuquot sections.

D. On Amos and Walters Island (just north of Nootka Sound map area) and north of Mushroom Point these beds are apparently overlain by massive coralline reefoid limestone and thinly bedded fragmental limestone less than 30 m thick. Contacts between C and D are commonly sheared but a gradual progression from interbedded and mixed clastic-carbonate rocks of C to interbedded reefold and calcarenite rocks of D appears to be indicated. This unit is clearly the "Limestone Member" or "Sutton Formation (limestone)" of Jeletzky (1950). He (1976, p. 20, 21) carried the name "Sutton Formation" from its original locality on Cowichan Lake in southern Vancouver Island on the basis of similar lithology and similar late Norian faunal content. As in earlier papers (Muller et al., 1974; Carlisle and Susuki, 1974) the Sutton Limestone is here considered as a member of the Parson Bay Formation. The member is defined by the carbonate facies that contains the "Sutton Fauna" and may include some beds called "Arenaceous Member" by Jeletzky.

The stratigraphy of the middle belt of Upper Triassic sediments that crosses the north end of Tahsis Inlet was not examined in detail. Judging from the Alice Lake section in Alert Bay map area (Muller et al., 1974) and observations of scattered outcrops within Nootka Sound map area, the section is considerably thicker and the clastic component of the rocks is finer than in the sections in the west coast belt; the formation consists mainly of black, brown weathering siltstone and shale with minor tuffaceous beds. The Sutton Limestone, though present in the Alice Lake section, was not identified within the map area.

Near intrusive contacts such as that with the Tahsis Mountain pluton, Parson Bay beds have been converted to fine grained, commonly well banded hornfels.

Origin

According to Carlisle and Susuki (1974) the gradual change from carbonate to clastic sedimentation at the Quatsino – Parson Bay transitional boundary was a result of change in the Late Triassic depositional basin from a shallow turbulent shelf to a deeper nonturbulent anaerobic environment. They showed in sedimentary interlayers within Karmutsen volcanics a similar sequence of basalt flows (subaerial), overlain by coarse bioclastic limestone, in turn succeeded by black siliceous shale with **Halobia** and finally pillow lava (submarine). Clearly the small "submergent sequence mimics the transition from Quatsino limestone to Parson Bay shale". The appearance of tuffaceous feldspathic material in the upper part of the western sedimentary belt presumably reflects the onset of Bonanza volcanism and one may conclude that the volcanic source lay to the west. Carlisle and Susuki (1974) also noted that whereas the Karmutsen and Quatsino formations occupy only one ammonite zone, possibly as many as eight such zones are represented in Parson Bay Formation. Assuming similar time spans (about 1 Ma) per zone they calculated that the rate of deposition of Parson Bay beds was about one twentieth that of the Quatsino limestone.

Age

The age of Parson Bay Formation within the map area has been determined almost entirely from fossils obtained by J.A. Jeletzky on the west coast between 1949 and 1953, supplemented with collections from east of Tahsis Inlet by J.W. Hoadley in 1950 and by the writer in 1971. The collections from Union Island were obtained about 1 km north of the map area in Alert Bay area. Fossil and age determinations are by E.T. Tozer of the Geological Survey, who for the purpose of this paper reviewed in 1977 his earlier determinations (Tozer, 1967) (See map of locations, Fig. 5B). Locations and co-ordinates were determined by the writer from the collector's notes.

T_RPB 1)
Field no. 147/5A, "Thinly Bedded Member"
GSC loc. 20237
Locality: West side of Union Island, in a small bay at 50°00'05", 127°19'00"W. The shale beds are west of a wide fault zone that separates them from Karmutsen volcanics to the northeast.

Halobia alaskana Smith
<u>Age</u>: Probably Lower Norian, Kerri Zone (Tozer, 1967, p. 36)

T_RPB A) (not on Fig. 5B)
Field no. (J.W. Hoadley, 1950) F-1-H-50
GSC loc. 17338
Locality: East shore Tahsis Inlet about half a mile north of Tsowin River. 49°47'05", 126°38'25"W.

Halobia sp. indet.
Placites cf. **P. symmetricus** Mojsisovics
"Arcestes" sp. indet.
Acanthinites cf. **A. silveri** Diener
Didymites sp. indet.
Discophyllites sp.

Belemnoids, identified by J.A. Jeletzky:
Aulacoceras sulcatum (v. Hauer, 1860)
Aulacoceras sulcatum (v. Hauer, 1860) var. **elliptica**
Bulow Trummer 1915
(both forms indistinguishable from their Timor Island representatives)
<u>Age</u>: (from evidence of ammonoids): Middle Norian, Rutherfordi Zone

T_RPB 2)
Field no. 147/5F, "Thinly Bedded Member"
GSC loc. 20255
Location: West coast of Union Island, tidal flats southwest of a sill of feldspar porphyry that forms headland, at 50°00'03"N, 127°19'10"W.

Placites sp. indet.
Clydonites n. sp. aff. **C. decoratus** (Hauer) (= "Sandlingites" cf. **"S." striatissimus** Diener of Tozer, 1967, p. 81).
<u>Age</u>: Middle Norian, probably Columbianus Zone.

T_RPB 3)
Field no. 84/1, 84/1a, 84/1b, 84/1c, (Thinly Bedded Member)
GSC loc. 19275, 19667, 19678, 19709
Location: Shore of Rolling Roadstead and small island, 1.3 km east of east end of Peculiar Point. 49°51'25"W, 127°03'50"W.

Monotis sp. indet.
Pinacoceras parma Mojsisovics
Steinmannites n. sp.
Himavatites multiauritus McLearn
Distichites canadensis McLearn
Episculites n. sp.
Episculites teres (McLearn)
Racophyllites debilis (Hauer)
<u>Age</u>: Middle Norian, Columbianus Zone

T_RPB 4)
Field no. 147/4
GSC loc. 20674
Location: as in T_RPB 2); from bed stratigraphically above GSC loc. 20255

Monotis subcircularis Gabb
<u>Age</u>: Upper Norian, Lower Suessi Zone

T_RPB 5)
Field no. 19 (Thinly Bedded Member)
GSC loc. 18482
Location: Kapoose Rocks (opposite mouth of Kapoose Creek), 49°56'55"N, 127°14'00"W, from beds just below conglomerate at base of Upper Jurassic sediments

Monotis subcircularis Gabb
<u>Age</u>: Upper Norian, Lower Suessi Zone

T_RPB 6)
Field no. 90/1 (Thinly Bedded Member)
GSC loc. 19020
Location: Small cove about 500 m south of Brecciated Point, 49°56'00"N, 127°13'05"W.

Monotis subcircularis Gabb
<u>Age</u>: Upper Norian, Suessi Zone

T_RPB 7)
Field no. 23/1 (Thinly Bedded Member)
GSC loc. 19321
Location: Point halfway between the mouth of Porritt Creek and southeast end of Mushroom Point; 49°55'30"N, 127°12'25"W. From beds 4 m below contact with Bonanza volcanics

Monotis subcircularis Gabb
<u>Age</u>: Upper Norian, Lower Suessi Zone

T_RPB 8)
Field no. 136/10 (Thinly Bedded Member)
GSC loc. 19672
Location: Same approximate locality as T_RPB 3), from main shore, 49°51'25"N, 127°03'50"W

Monotis subcircularis Gabb
Rhabdoceras suessi Hauer
<u>Age</u>: Upper Norian, Lower Suessi Zone

T_RPB 9)
Field no. 90/2 (Arenaceous Member)
GSC loc. 19015
Location: Bay north of Mushroom Point and about 0.5 km southeast of T_RPB 6; 49°55'50"N, 127°12'55"W

Spondylospira lewesensis (Lees)
Propeamussium yukonense (Lees)
Chlamys tyaughtonae (McLearn)
Plicatula perimbricata Gabb
Plagiostoma sp. indet.
Minetrigonia suttonensis (Clapp and Shimer)
Myophorigonia n. sp.
Tutcheria cf. **T. densestriata** (Körner)
"Astarte" sp.
other bivalve species, undetermined
<u>Age</u>: Upper Norian, Upper Suessi Zone

T_RPB 9b)
Field no. 66 (Arenaceous Member)
GSC loc. 18411
Location: As T_RPB 9a), about 13 m higher in section
Minetrigonia cf. **M. cairnesi** (McLearn)
Age: Upper Norian, Upper Suessi Zone

T_RPB 9c)
Field no. 90/3 (Arenaceous Member)
GSC loc. 19032
Location: As T_RPB 9b), but higher in section
Placites sp. indet.
Rhabdoceras suessi Hauer
Age: Upper Norian, Upper Suessi Zone

T_RPB 9d) (Jeletzky, 1950) (Jeletzky, 1976)
Field no. 67/3, 67/3a (Limestone Member; Sutton Formation)
GSC loc. 18347, 19019
Location: As T_RPB 9c), but higher in section
Myophorigonia sp.
Peripleurites roemeri Mojsisovics
Age: Upper Norian, Upper Suessi Zone
Triassic

As stated earlier, all collections from the west coast area, shown on Figure 5B, were made by J.A. Jeletzky in 1949-1953. The following collections were made near Tahsis Inlet by the writer in 1971.

T_RPB B)
Field no. 71-3M
GSC loc. 88615
Location: East side of Tahsis Inlet, across Mozino Point and just south of a small creek, 49°51'40"N, 126°39'00"W
Monotis salinaria Brohn
Age: Upper Norian, Lower Suessi Zone

T_RPB C
Field no. 71-18F3
GSC loc. 88616
Location: Upper logging road, west side of Tahsis Mountain, 49°51'25"N, 126°37'30"W
Monotis salinaria Brohn
Age: Upper Norian, Lower Suessi Zone

In T_RPB B) the fossils occur in black, poorly bedded argillite, in beds 5-50 cm thick, interbedded with calcarenite in beds 10-30 cm thick. These are directly overlain by agglomeratic, amygdaloidal lava of the Bonanza Group. In T_RPB C) the fossils are in black, well bedded argillite overlying bedded silty limestone and overlain by a feldspar porphyry sill and more argillite. Both locations are clearly in the upper part of the Parson Bay Formation.

In summary the Parson Bay Formation occupies the entire Norian stage of Late Triassic time. The lower part (lithological subdivisions A and B), composed of pelagic, mainly pelitic beds, contains the Kerri and Columbianus Zones (collections 1 to 3). The intervening Dawsoni and Magnus Zones (Tozer, 1967) have not been identified in Nootka Sound map area and the Rutherfordi Zone only in one collection (T_RPB A) from east of Tahsis Sound. The upper part (subdivisions C and D), composed of shallow water, coarser grained clastic and reefold beds, contains the lower and upper parts of the Suessi Zone (collections 4-11).

Bonanza Group

Nomenclature

The name Bonanza Group was introduced by Gunning (1932, p. 23A) for the assemblage of sedimentary and volcanic rocks exposed above the Quatsino Formation on the upper slopes west of Bonanza Lake. Hoadley (1953) and Jeletzky (1954) divided this group into a lower Sedimentary Division and considered it as the upper part of the Vancouver Group. In an attempt to adjust the terminology to the code of stratigraphic nomenclature the senior author first changed the name to "Bonanza Subgroup" (Muller and Carson, 1969) and later to "Bonanza Volcanics" (Muller et al., 1974). In the latter paper the name Parson Bay Formation was applied to the Triassic part of the Sedimentary Division and it was removed from the Bonanza. As a last step in these nomenclatural changes the Bonanza is now taken out of the Vancouver Group and reinstated as the Bonanza Group, which directly overlies the Vancouver Group. The lower Jurassic Harbledown Formation of northeastern Vancouver Island is part of the Bonanza Group.

This nomenclature, setting apart the essentially different Triassic tholeiite-carbonate-clastic sequence of the Vancouver Group and the Jurassic basalt-andesite-dacite-rhyolite-sediments assemblage of the Bonanza Group seems to be practical and will, it is hoped, be adhered to in following papers by the writer and other workers.

Distribution

Bonanza volcanics and subordinate sediments underlie most of the northwestern land area of Nootka Sound map area, north of Esperanza Inlet and west of Tahsis Inlet. Smaller areas of Bonanza volcanics, some of dubious identity, occur farther southwest as small fault blocks and roof pendants on the Nootka, Ehatisat and Sydney batholiths.

Lithology

The Bonanza Group exhibits, as might be expected from a succession built in a volcanic island arc environment, great vertical and lateral variation in lithology, which is further complicated by severe faulting. A general succession of interdigitating volcanic and sedimentary subunits as shown by Jeletzky (1970, 1976) is probably broadly correct, but in detail units are much less persistent than shown by that author and there is no evidence that 10 separate and distinct lithological and time-stratigraphic units can be distinguished. At Cape Parkins in Alert Bay – Cape Scott map area (Muller et al., 1974) a reasonably undisturbed section of about 2000 m was measured in Bonanza volcanic and sedimentary rock but the composite section exposed along the coast south of Kyuquot Sound is thinner, and younger in its upper part. Fossils in the Cape Parkins section indicate Sinemurian age, those in Nootka Sound map area are typical of the next younger Pliensbachian stage of Early Jurassic time.

At a point between the south end of Mushroom Point and the mouth of Porritt Creek dark green massive lava and minor volcanic breccia disconformably overlie thin bedded argillite with **Monotis subcircularis** (GSC loc. 19321). The basal breccia is only locally developed and contains limestone fragments presumably derived from Upper Triassic sediments. Similar volcaniclastic sequences, including layers of sandy and silty limestone, are present at the Triassic-Jurassic boundary in Alert Bay map area and have been called "Hecate Cove Formation" by Jeletzky (1976) or "waterlain Breccia" (Jeletzky, 1970) and he considers them to be basal Bonanza beds. In view of the presence of considerable amounts of bedded silty limestone in the Hecate Cove section, eastern Quatsino Sound, these beds were correlated with the upper part of Parson Bay Formation by Muller et al. (1974). In the vicinity of Mushroom Point either the breccia or the "Arenaceous Beds" or the "Sutton Limestone" overlie argillite with **Monotis** and are apparently overlain by Bonanza volcanics; thus they may well be correlative to one another. Only a small thickness of volcanic rocks succeeding the breccia is exposed near Mushroom Point.

At Rugged Point, some 5.5 km to the northwest, a sequence about 500 m of southeastward dipping Bonanza volcanic rocks is partly exposed. They are maroon and green coloured amygdaloidal lava, volcanic breccia, crystal tuff and tuffaceous siltstone. Possibly greater thicknesses of similar rocks are exposed along the coast of Kyuquot Channel and the mountains to the east along the northern border of the map area. The shorelines of Espinoza, Esperanza, Zeballos and Tahsis inlets and Hecate Channel also abound with exposures of dark green and maroon, massive to agglomeratic lava, commonly with pink plagioclase phenocrysts, plagioclase-pyroxene crystal tuff, breccia, and more rarely ignimbrite.

No detailed petrographic studies were made in Nootka Sound map area, but the rocks are assumed with confidence to be petrographically and chemically like those at Cape Parkins. There chemical analyses have yielded a great variety of compositions. Classified according to the system of Baragar and Irvine (1971) they are for a large part basalt, andesite, dacite and rhyolite of the tholeiite series. However, sodic, potassic and high alumina basalts are also present. Tholeiitic andesite and hawaiite (= alkaline andesite) are the predominant rock types.

The volcanic rocks are overlain by clastic sediments, fairly well exposed in a northwest dipping sedimentary sequence about halfway between Gregoire Point and the mouth of Tatchu Creek. The sequence begins with a basal layer of gritty lithic sandstone and pebble conglomerate and continues with lithic, locally calcareous sandstone and platy shale, some banded layers of tuffaceous siltstone and minor coaly beds. Marine fossils include ammonites and trigoniid bivalves. The section was examined in detail by Jeletzky, who estimated a thickness of 600 m (Poulton, 1976). This figure may be excessive because of faulting.

Origin

As noted above the Bonanza Group is a sequence of interbedded lava, breccia and tuff with compositions ranging from basalt through andesite and dacite to rhyolite. Clearly its setting was a volcanic island arc and in that environment great lateral variations in lithological sequence must be expected. The lower part of the Bonanza sequence, containing Sinemurian fossils in the marine clastic sediments and well exposed in Quatsino Sound area, cannot be identified in Nootka Sound area but may well be represented by the basal volcanic sequence. Conversely the overlying Pliensbachian sediments exposed south of Kyuquot Sound have not been found in Quatsino Sound area. If all rocks are part of one volcanic centre of eruption the Quatsino Sound sequence should represent the central and oldest part of the volcano, whereas Nootka Sound rocks represent the flanks with overlying (postvolcanic?) clastic sequence.

The typical red colour of Bonanza volcanics, due to finely disseminated hematite, was discussed earlier by Hoadley (1953, p. 28), who concluded that the mineral was formed during consolidation (apparently subaerially) of the lava by precipitation from volatile constituents. Tipper and Richards (1976, p. 46) cite red coloration as a distinctive mark of subaerial volcanics, but according to them such rocks may be interbedded with nearshore marine clastic sediments.

Age

In the Bonanza Group of Nootka Sound map area no fossiliferous sedimentary beds similar to those in Alert Bay – Cape Scott map area (Muller et al., 1974) have been found within the volcanic rocks. However, the overlying clastic sequence, studied in some detail by Jeletzky (1954, p. 13), yielded ammonites and trigoniid bivalves that he originally thought to be of Toarcian age. The ammonites were recently re-examined by H. Frebold and the bivalves, especially Trigoniids were studied by T.P. Poulton (see also Poulton, 1976). The many collections made by Jeletzky in 1949 and 1950 have been grouped together in newly numbered lots and their collective location and co-ordinates have been determined from the collector's descriptions as accurately as possible by the present writer. A number of Jeletzky's collections from almost identical localities and with the same fauna have been omitted.

JB1
Field no. 100/9, 100/10, 100/14, 100/19
GSC loc. 19040, 19039, 18998, 19028
Locality: 0.7 to 0.8 km north of mouth of Tatchu Creek, in sandstone member, probably the one shown at 150 m above the base of the sedimentary unit by Poulton (1976); 49°53'35"N, 127°10'35"W.

Bivalves:
- **Astarte** (?) sp.
- **Cercomya** (?) sp.
- **Gervillea** (?) sp.
- **Hippodium** (?) sp.
- **Lima** (?) sp.
- **Meleagrinella** sp.
- **Parallelodon** (?) sp.
- **Perna** (?) sp.
- **Psilotrigonia canadensis** Poulton
- **Thracia** (?) sp.
- **Weyla** (?) sp.
- ostreiids (?) indet.
- pectinids, indet.

Gastropods: several poorly preserved forms.

Age: probably Pliensbachian, on the basis of the occurrence of **Fanninoceras** McLearn in equivalent beds in the same area.

JB2
Field no. 100/36, 100/42, 100/42a, 100/44b, 100/46
GSC loc. 19374, 19411, 19383, 19389, 19292
Locality: 10 to 50 m south of the tip of "Seal Point" (point halfway between Gregoire and Jurassic Points). 49°53'45"N, 127°10'50"N. Shown in Jeletzky's section 100 (Poulton, 1976) at about 400 m above base of sedimentary section.

- **Corbula** (?)
- **Cucullaea** (?) sp.
- **Goniomya** (?) sp.
- **Meleagrinella** (?) sp.
- **"Ostrea"** sp.: abundant in 100/42
- **Protocardia** (?) sp.
- **Trigonia** sp.
- **Vaugonia** sp. aff. **V. vancouverensis** Poulton

Age: The only diagnostic form, **Vaugonia** is represented by a specifically indeterminable fragment that resembles Pliensbachian forms from Oregon and southern Alaska and other localities in the same area (see JB3). A similar age is suggested.

JB3a
Field no. 100/52
GSC loc. 19387
Locality: About 50 to 55 m west of the tip of "Seal Point" (point halfway between Gregoire and Jurassic Points). Taken from the rocky fringe round this point below high tide mark; 49°53'50"N, 127°11'00"W.

Bivalves:
- ostreiids, indet.
- **Pleuromya** (?) sp.
- **Meleagrinella** (?) sp.
- **Entolium** (?) sp.
- **Vaugonia** sp. aff. **V. vancouverensis** Poulton
- **Astarte** (?) sp.
- **Lima** (?) sp.

Rhynchonellid brachiopod

Age: probably Pliensbachian.

JB3b
Field no. 100/56a, 100/56b, 100/56c
GSC loc. 19303, 19415, 19395
Locality: 60 to 75 m west of the tip of "Seal Point" (point halfway between Gregoire and Jurassic Points). From east shore of channel between point and rocky islet. Apparently these lots are the ones with "? **Grammoceras**" shown at 480 m above base of section 100 of Jeletzky, in Poulton, 1976. Co-ordinates as JB3a.

Ammonites: **Protogrammoceras** sp. indet.
Fuciniceras spp. indet.
Poorly preserved small ammonites

Bivalves: **Entolium** (?) sp.
Meleagrinella (?) sp.
Posidonomya (?) sp.
Weyla (?) sp., small fragment

Crustacean fragments
Gastropod

Age: on basis of ammonites, Late Pliensbachian.

JB4
Field no. 100/65
GSC loc. 19393
Locality: About 60 m northeast of the northeast end of rocky islet off "Seal Point" (point halfway between Gregoire and Jurassic Points). NB In Poulton's paper it is 200 feet southeast of northwestern end of rocky islet. In section 100 shown about 600 m above base of sedimentary section (which includes a fault).

Ammonites: **Protogrammoceras** or **Fuciniceras** (one fragment)

Age: Late Pliensbachian

Bivalves: **Astarte** (?) sp.
Bositra (?) sp.
Cercomya (?) sp.
Corbula (?) sp.
Entolium (?) sp.
Meleagrinella (?) sp.
Modiolus sp.
Ostrea (?) sp.
Protocardia (?) sp.
Vaughonia vancouverensis Poulton
Vaughonia jeletzkyi Poulton (?)

other bivalves indet., including a poorly preserved pectinid with some similarity to **Weyla.**

other fossil plant fragments.

Age: Late Pliensbachian, as based on ammonites.

JB5
Field no. 115/6, 115/7, 115/8, 115/9
GSC loc. 19373, 19376, 19378, 19386
Locality: Point about 0.5 km southeast of Gregoire Point and reef south of it. 49°54'05"N, 127°11'20"W. Impure, coarse tuffaceous, limy sandstone and grit (probably high in the sedimentary section).

Ammonites: Poorly preserved small ammonites:

Protogrammoceras? sp. indet.

Age: Late Pliensbachian

Bivalves: **Anomia** (?) sp.
Corbula (?) sp.
Entolium sp.
Gervillia (?) sp.
Mytilus (?) sp.
Pholadomya sp.
Trigonia (?) sp.
Weyla (?) sp.

JB6
Field no. 116/1
GSC loc. 19380
Locality: Reef 0.25 km east of Gregoire Point; 49°54'05"N, 127°11'20"W.

Ammonite: Referred to but not reported by H. Frebold.

Bivalves: **Corbula** (?) sp.
Meleagrinella (?) sp.
Thracia (?) sp.
other bivalves, indet.

JB7
Field no. 120/1, 120/3, 120/4, 120/5
GSC loc. 19377, 19400, 19370, 19379
Locality: Sandstone and siltstone north, up to 300 m distance, of small creek north of Gregoire Point.

Bivalves: **Corbula** (?) sp.
Entolium sp.
Gervillia (?) sp.
Mytilus (?) sp.
Pholadomya sp.
"Ostrea" sp.
Vaugonia jeletzkyi Poulton
Weyla sp.

Age: probably Pliensbachian

JB8
Field no. 120/8
GSC loc. 19404
Locality: 50 m west of cave at end of beach, 0.8 km north of Gregoire Point.

Bivalves: **Gervillia** (?) sp.
Vaugonia vancouverensis Poulton

Age: probably Pliensbachian

JB9
Field no. 121/1, 121/2
GSC loc. 19409, 19413
Locality: Limestone reef and black shales west of it, running south from "Badluck Point" (0.8 long. north-northwest of Gregoire Point); 49°54'35"N, 127°11'45"W.

Ammonites: Very small and poorly preserved, probably **Protogrammoceras** sp. indet.

Age: Late Pliensbachian

Bivalves: **Entolium** (?) sp. indet.
Posidonomya (?) sp. indet.
Vaugonia vancouverensis Poulton
other bivalves, indet.
Crustacean (?) fragments

JB10
Field no. 122/4, 122/4a
GSC loc. 19398, 19394
Locality: Southeast end of Mushroom Point, at north end of bay south of that point; 49°55'35"N, 127°12'55"W.

Bivalves: **Corbula** (?) sp.
Entolium (?) sp.
Gervillia (?) sp.
Meleagrinella sp.
Thracia (?) sp.
Vaugonia sp.

Age: probably Lower Jurassic

Frebold commented as follows (internal report J-10-1977):

"Previously the writer has given an opinion on the ammonites dealt with in this report (see Hans Frebold in J.A. Jeletzky, Geological Survey of Canada, Paper 69-14, 1970, p. 15).

"The restudy of the very unsatisfactorily preserved ammonites shows that they belong to the genera **Protogrammoceras** Spath and the closely related **Fuciniceras** Haas respectively. These two genera are characteristic of the lower part of the Upper Pliensbachian (Domerian). A few species are also known from the upper part of the Lower Pliensbachian (Carixian) (See R. Fischer, Palaeontographica, vol. 151, 1975, p. 92).

"The two genera are now also known from other parts of British Columbia, eastern Oregon and California."

Poulton (1976, p. 42) also concluded a Pliensbachian age, on the basis of **Vaugonia** sp., similar or conspecific to his **V. vancouverensis,** occurring in upper Sinemurian and Pliensbachian beds of Oregon and central British Columbia. Jeletzky (1954, p. 13) earlier tentatively identified ammonites from the same sequence and collections and based a Toarcian age on these. The reidentification by Frebold is taken to supersede the determinations of Jeletzky and thus beds of Toarcian age have not been identified on the west coast of Vancouver Island. Furthermore it must be questioned whether or not Jurassic beds near Sproat Lake, in the Alberni map area, that were reported to contain "Trigonia (s. lato) ex gr. **costata** Sowerby" (Jeletzky in Muller and Carson, 1969) are not also Pliensbachian instead of Toarcian in age.

Westcoast Complex

Definition and Distribution

The name "Westcoast Crystalline Complex" was first used in a report on Alberni map area (Muller and Carson, 1969) for a heterogeneous assemblage of amphibolite and basic migmatite with minor metasedimentary and metavolcanic rocks of greenschist metamorphic grade that outcrop in an irregular belt along or close to the west coast of Vancouver Island. In Nootka Sound map area it extends from Nuchatlitz Inlet south across Bligh and Flores islands and intervening parts of Vancouver Island to Millar Channel.

The rocks are considered to be derivatives of pre-Jurassic volcanic and sedimentary rocks and exhibit various degrees of recrystallization or migmatization, related to the Jurassic plutonic event. On the geological map the complex is subdivided into two units. The Amphibolite Unit includes metavolcanics and metasediments of mainly low amphibolite grade of metamorphism. The migmatite unit includes basic granitoid rocks, mainly quartz diorite and tonalite, and various kinds of migmatite. There are no well defined contacts between these units. It is difficult to make a clear separation between Amphibolite Unit and metamorphosed Sicker Group and Vancouver Group rocks, except on the basis of metamorphic grade. Likewise there is a gradual transition between heterogeneous and bimodal migmatite, quartz diorite and tonalite of Westcoast Complex, and granodiorite of Island Intrusions.

Lithology of Amphibolite Unit

The Amphibolite Unit is well exposed on Nuchatlitz Inlet east of Ferrer Point, near Maquinna Point west of Friendly Cove, and intermittently from Hesquiat Lake to Hot Springs Cove. It consists of massive to foliated metavolcanic rocks and includes also metasediments. They appear to be mainly low-grade amphibolites and exhibit local isoclinal folding and well defined, generally northwest directed fold axes. The metavolcanics are partly flows, as indicated by epidote-filled relict amygdules, but in part also metabasaltic dykes and sills. Metasedimentary rocks are mainly bedded to massive, partly or entirely silicified carbonate and pelitic rocks.

Thin sections show hornblende as the predominant mineral in metavolcanic rocks. In many the hornblende occurs in irregular fibrous masses, less than 0.3 mm long, pleochroic from yellow green to bluish green and with extinction angles up to 30 degrees. In some thin sections actinolite occurs as weakly pleochroic, pale green, with extinction angles of less than 16 degrees. Epidote is commonly present as small granules, either scattered or in solid patches. Relict (?) laths of plagioclase in one sample contain 45 to 55 per cent An determined on albite and albite-Carlsbad twins, but in most samples cloudy, not distinctly twinned, low-refractive plagioclase is probably more sodic. Some samples contain patches of quartz mosaic and all are clouded with finely disseminated opaque material. Strong cataclastic texture of several specimens indicates a period of deformation after amphibolite metamorphism.

Metasedimentary rocks of the complex are metamorphosed pelitic and carbonate rocks. Many of these exhibit distinct bedding with complex isoclinal folding. One thin section of metasiltstone shows very fine grained (± 0.05 mm) quartz, calcite and diopside with minor grossularite, but others are of lower metamorphic grade and contain quartz, albitic relict plagioclase and very fine chlorite with veinlets of epidote-zoisite-calcite.

Lithology of Migmatite Unit

The general character of the Migmatite Unit corresponds well with the definition of such rocks by Mehnert (1968). It is a "megascopically composite rock consisting of two or more petrographically different parts; one is the country rock in a more or less metamorphic stage, the other is of pegmatitic, aplitic, granitic, or generally plutonic appearance". Typically the rocks are composed of distinct dark and light coloured bodies, called leucosome and melanosome by Mehnert which may exhibit diffuse or sharp contacts. Their complex structures are best seen in wave-washed, or clean glaciated exposures or in fresh roadcuts. The melanosomes form irregular layers, a few centimetres to several metres thick or sharp angular blocks of great variety of shape and dimension. More intense migmatization leads to more diffuse contact and to reshaping of the melanosomes into more or less well aligned ellipsoidal bodies indicating direction of plastic flow of the migmatite. The leucosomes vary from assemblages of dykes and veins criss-crossing amphibolitic masses to more or less gneissic tonalite and quartz diorite that include sharply delineated to ghost-like masses of melanosome. Within the Migmatite Unit all transitions can be seen between amphibolite with minor granitoid dykes to tonalite with clearly outlined included bodies of melanosome and to almost homogeneous granitoid rock with ghost-like inclusions. These thoroughly mixed, almost homogeneous rocks were called "diatexite" by Mehnert (1968).

Although the diversity of rock types within most outcrops of Westcoast Complex cannot be overlooked; lithologies sampled are those that appeared to be the most common within any outcrop. Twenty modal analyses made on thin sections of widely scattered samples include several, published earlier by Carson (1973), with 500 or more points counted per section. The modes were arranged by IUGS classification and maxima, minima and averages of mineral percentages together with specific gravities are given in Table 3. They were also plotted on triangular percentage plots that combine the most commonly used K-Feldspar – Plagioclase – Quartz diagram on the right with the Mafics – Feldspars – Quartz diagram of Mehnert on the left.

Table 3. Modal compositions of Westcoast Complex

Number of Samples		Quartz	Plagioclase	Potash Feldspar	Biotite	Hornblende	Pyroxene	Chlorite	Epidote and Prehnite	Opaque	Accessory minerals		Specific gravity	Number of samples for Specific gravity
						LEUCOGRANITE								
1	Ave.	32.9	41.0	21.6	2.4	-	-	1.3	-	0.6	0.2			0
	Min.	20.8	36.0											
						GRANODIORITE								
4	Ave.	33.3	50.5	6.7	3.6	1.6	-	2.6	-	0.5	1.4	Sericite	2.66	3
	Min.	20.8	36.0	5.0	-	-	-	0.6	-	0.2	-	Carbonate	2.61	
	Max.	46.8	59.8	8.4	7.0	6.2	-	4.9	-	0.8	4.0	Apatite Sphene	2.69	
						LEUCOTONALITE								
1		37.3	54.2	4.0	3.8	-	-	0.4	-	-	-		2.66	1
						TONALITE								
6	Ave.	18.3	52.9	0.8	8.7	12.7	1.8	2.0	-	0.6	1.5	Sericite	2.79	4
	Min.	14.4	49.8	-	2.0	-	-	-	-	-	-	Apatite	2.79	
	Max.	22.0	55.1	2.4	14.8	17.9	9.8	7.0	1.4	1.6	3.8		2.79	
						QUARTZ DIORITE								
7	Ave.	7.7	53.9	-	1.3	27.4	0.9	5.2	1.3	1.7	0.4	Sericite	2.88	5
	Min.	2.8	46.2	-	-	11.4	-	-	-	-	-	Apatite	2.81	
	Max.	13.4	62.2	-	5.4	43.8	6.4	11.6	3.8	3.0	2.2	Sphene	2.99	
						DIORITE								
2	Ave.	0.4	65.1	0.3	-	13.9	-	11.7	6.4	2.1	-		2.81	2
	Min.	-	60.0	-	-	2.8	-	1.0	0.4	1.4	-		2.75	
	Max.	0.8	70.2	0.6	-	25.0	-	22.5	2.4	2.8			2.87	
						AGMATITES: (1 = Melanosome; 2 = Leucosome)								
						LEUCOGRANITE AND QUARTZ DIORITE								
	1	11.8	60.8	0.8	10.4	13.2	-	-	-	1.4	1.6	Apatite Sphene	2.86	
	2	41.2	30.2	27.0	-	-	-	1.6	-	-	-	Hematite	2.62	
						QUARTZDIORITE AND GRANODIORITE								
	1	6.6	52.4	-	3.8	30.4	-	5.2	-	1.2	0.4	Sphene	2.87	
	2	46.8	36.0	5.0	7.0	-	-	4.0	-	0.8	0.4	Apatite Sphene	2.69	
						GABBRO AND TONALITE								
	1	-	44.0	-	-	48.6	1.2	2.6	0.6	3.0	-		3.08	
	2	29.4	60.0	0.6	4.4	0.6	-	-	0.6	1.2	-		2.81	

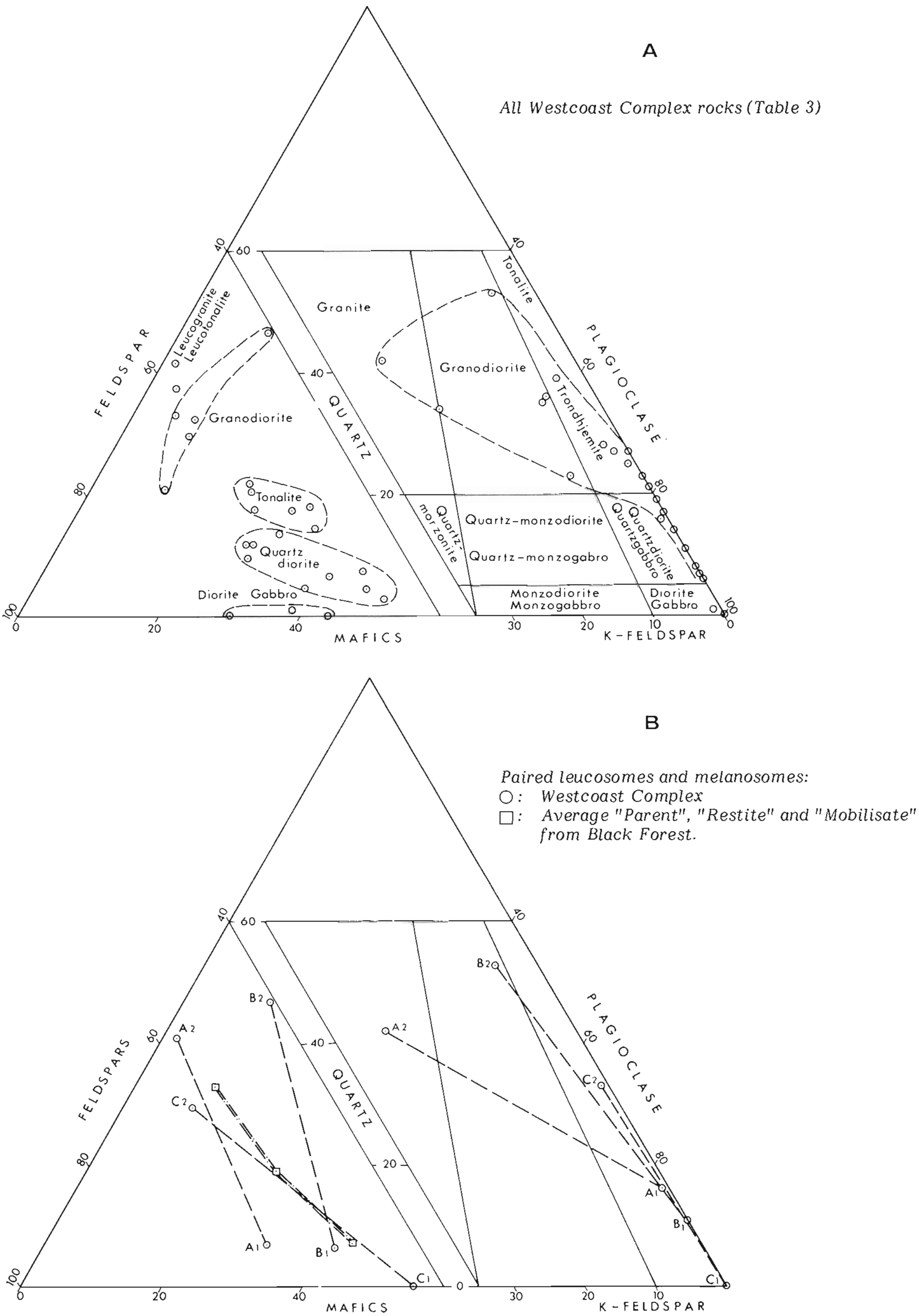


Figure 3. *Modal plots of Westcoast Complex rocks.*

"QUARTZ" separates the two partial diagrams, each of which show all modes of Table 3 in Figure 3A, and three leucosome-melanosome pairs, compared to Mehnert's Black Forest agmatites, in Figure 3B.

Most samples are leucosomes, commonly with compositions of biotite-hornblende quartz diorite, tonalite, and granodiorite, but including a few of leucotonalite and leucogranite. The melanosomes, represented by a few samples, are essentially plagioclase amphibolites with granoblastic texture and compositions of diorite, gabbro, quartz diorite and quartz gabbro. Leucosome-melanosome pairs (Table 3, Fig. 3B) range from gabbro with tonalite to quartz diorite with leucogranite. They appear similar to the mobilizate-restite pairs of Mehnert.

Biotite hornblende quartz diorite is medium to dark coloured (colour index 30 to 50) and fine- to medium-grained (plagioclase and hornblende 1 to 4 mm). Plagioclase, the predominant mineral (average 54%) is subhedral, in places weakly zoned and with a composition An_{36-48} according to maximum extinction on albite twins. Alteration to sericite, epidote and prehnite is common. Quartz occurs in small interstitial spaces and potash feldspar appears to be totally lacking. Hornblende is generally in irregular anhedral masses with green to yellow pleochroism. It may enclose plagioclase and in some instances contains relict cores of colourless pyroxene. Biotite is a minor component and generally altered to chlorite. Accessory minerals are opaque constituents and occasionally sphene and zircon.

Biotite hornblende tonalite and biotite tonalite is light to medium coloured (colour index 5 to 30) and fine- to medium-grained (plagioclase 1 to 4 mm). Plagioclase, as in quartz diorite, is the largest and predominant mineral (average 60%). It is more commonly zoned and varies, like quartz diorite, between 37 and 48 per cent in anorthite content, according to maximum extinction on albite twins and combined albite-Carlsbad twins. Quartz occurs as irregular grains with serrated edges and is commonly strained. It also may invade plagioclase in veinlets and irregular pockets. A few per cent of potash feldspar occur in irregular patches. Hornblende, in places with pyroxene relict cores, and biotite, are similar in character to the mafic minerals of quartz diorites but considerably less abundant. Alteration minerals are chlorite, epidote, prehnite and sericite, and opaque minerals, sphene and apatite are accessories. Quartz diorite leucosomes differ from tonalite mainly in containing less quartz and biotite and more hornblende.

The most quartz-rich end-members of the rock suite are fine- to medium-grained, light coloured granodiorite (colour index less than 10), also with a high plagioclase content (almost 50%), but with about 30% quartz and 5 to 20% potash feldspar. Subhedral plagioclase, up to 5 mm, where not altered to sericite contains 22 to 28% anorthite; quartz and potash feldspar occur in anhedral masses up to 3 mm. Only a few per cent of biotite and little or no hornblende are present.

Melanosomes are granoblastic, quartz-poor quartz diorite, diorite and gabbro with 50 to 70 per cent plagioclase, 25 to 50 per cent hornblende, little or no biotite and commonly apatite and sphene.

Origin

The Westcoast Complex is considered to have been formed by migmatization of pre-existing volcanic and sedimentary rocks of Sicker and Vancouver groups. The genetic relationship between Westcoast migmatites, amphibolites and metasediments is well documented in exposures along the Pacific coast in Nootka Sound map area and also along the coast and islands of Barkley Sound. However, the metavolcanic and metasedimentary rocks have not been traced into well-dated unmetamorphosed formations.

The process of migmatization has been examined and studied by many workers since it was first recognized and described by Sederholm (1913). The work of Mehnert (1968) and coworkers (Busch, 1966) is of special relevance to the petrology of Westcoast rocks. Migmatites are the product of anatexis, or partial remelting of rocks under the required conditions of temperature, load, and water pressure. Depending on these conditions and the composition of the parent rock a quartz-feldspar leucocratic "mobilizate" is formed. Initially the "leucosome" is concentrated in pores and minute veinlets, but with progressive mobilization it is concentrated in a criss-crossing network of veins and dykes. In a further stage blocks of the parent rock become isolated and enclosed in lighter coloured leucosome. Subsequently the amount of darker parent rock is diminished, plastically deformed and assimilated by the leucosome. Thus while in the initial stages of migmatization there is differentiation into leucocratic and melanocratic parts these two components are assimilated again in a later stage into a "diatexite". Mass movement of leucosome or diatexite into higher parts of the crust is now considered by many petrologists to be the source of granitoid plutonism and Westcoast Complex appears to be a rather convincing example of the process.

Mehnert (1968) distinguished many different types of "mobilizates". The dioritic mobilizate quartz-plagioclase-hornblende is clearly applicable to Westcoast Complex rocks. In the Black Forest studies he showed that leucosome compositions derived from widely divergent parent rocks tend towards an apparently cotectic, 35:65 quartz-feldspar ratio (95% plagioclase, An_{25-35}; 5% potash feldspar). Modes of a group of basic migmatites from the Black Forest (Hirschbachtal), recorded by Busch (1966) and Mehnert (1968) are closely similar to Westcoast Complex rocks, when plotted on Q – P – K and Q – F – M triangular plots. Both show the trend towards a similar quartz-feldspar ratio, but the mafic minerals show different trends. The biotite-hornblende ratio decreases significantly towards the leucocratic rocks in the Black Forest while it increases in the Westcoast Complex. In the Black Forest example hornblende-biotite gneiss of tonalitic composition is considered to be the parent rock that generated a more felsic tonalitic, and in other instances granodioritic mobilizate, leaving a residual more mafic quartz dioritic or dioritic "restite" (Fig. 3B). The genesis of Westcoast Complex migmatites appears to be based on similar petrological processes but there are differences in details of petrology that merit more detailed investigations.

Contact Relations and Age

The age of crystalline rocks is generally ascertained from contact relations and available isotopic age determinations. For the Westcoast Complex the former are not yet well understood and the latter are only available from adjacent areas. Contacts are gradational in the sense that metamorphism increases from greenschist or lower grade in metavolcanics and metasediments to amphibolite grade and migmatite in Westcoast rocks. Unfortunately no direct link has been established between metasediments of the complex and unmetamorphosed fossiliferous sediments elsewhere. Highly folded and recrystallized, bedded to massive limestone northwest of Maquinna Point is in contact with amphibolite, apparently representing a recrystallized basic sill. The rocks were tentatively identified by Jeletzky (1954) as Quatsino and Karmutsen formations, but the limestone could also be Paleozoic in age. Likewise the amphibolite of the complex may be derived from Paleozoic Sicker Group volcanics or from Mesozoic Vancouver Group volcanics or from both.

A possible unconformity between dioritized volcanics of Westcoast Complex and a volcanic-sedimentary formation is exposed in rocky promontories and small islands, about 2 to 3 km north-northwest of Dagger Point on the west coast of Flores Island. There, altered, dioritized volcanics, apparently part of Westcoast Complex, are overlain unconformably by a sequence of rhyodacitic (?) altered volcanic tuff and fine breccia, together with reddish tuffaceous argillite and well bedded black silty argillite. The rocks are tentatively mapped as Late Jurassic to Early Cretaceous Pacific Rim Complex, but on the basis of lithology they could equally well be part of the Early Jurassic Bonanza Volcanics. The unconformity is therefore assumed to represent Middle Jurassic late to post plutonic uplift and erosion, following Early Jurassic plutonism and preceding Late Jurassic subsidence and deposition.

A few isotopic age determinations, though not within the map area, are relevant to the age of the complex. Firstly zircons were concentrated by R.K. Wanless from biotite gneiss of Westcoast Complex near Tofino and yielded almost concordant Pb/U ages of 264 ± 7 Ma (Muller et al., 1974). A basic dyke cutting the outcrop is metamorphosed to amphibolite and its hornblende yielded a K-Ar age of 192 ± 9 Ma. It was concluded that the gneiss was derived from late Paleozoic primary volcanic material, was intruded by the dyke in Triassic time, concurrent with Karmutsen volcanism, and was subsequently metamorphosed to amphibolite grade in earliest Jurassic time. Two K-Ar datings (Wanless, 1978, p. 7) of the complex in Barkley Sound are also relevant. One, of a hornfelsic basic dyke in the complex on Spilling Island yielded 163 ± 7 Ma from hornblende. Another, an amphibolite grading laterally into carbonate sediment on Howell Island was dated at 115 ± 5 Ma on hornblende. The early Middle Jurassic date of Spilling Island is compatible with Early to Middle Jurassic metamorphism of the complex. The mid-Cretaceous date of Howell Island can only be explained by burial at deeper crustal levels until that time or reheating at a later time.

In summary the available data generally support the concept that the Westcoast Complex consists of Sicker and Vancouver groups, late Paleozoic to Early Mesozoic rocks, metamorphosed and migmatized during Early to Middle Jurassic plutonism.

Island Intrusions

Name and Distribution

Granitoid batholiths and stocks of Jurassic age underlying large parts of Vancouver Island have been termed "Island Intrusions" by Eastwood (1965) and the name has since been used generally (e.g. Carson, 1973; Muller et al., 1974). They are batholiths of granodiorite and granite (K-feldspar >1/3 of total feldspar; quartz >20% of total light coloured constituents) that, together with migmatite, quartz diorite and tonalite of the Westcoast Complex form the granitoid bodies outcropping in about half of the land area of Nootka Sound map area. The largest body is Muchalat Batholith in the northeast, about 750 km^2 in extent and up to almost 20 km in width. It is transected by Muchalat River and Muchalat Lake in the north and by Muchalat Inlet in the south. This batholith connects with Vernon Batholith in Alert Bay area and with Bedwell Batholith in Alberni map area.

Nootka and Ehatisaht batholiths (named by Hoadley, 1953) are smaller batholiths, about 5 km wide and dissected by Esperanza, Nuchatlitz and Tahsis inlets. These north-westerly trending plutonic belts, each about 100 km^2 in area, are separated by equally wide belts of Bonanza volcanics. Sydney Batholith is a north-northwesterly elongated body underlying an area of about 200 km^2 between Sydney Inlet and Mooyah Bay.

Petrography of Muchalat Batholith

The granitoid rocks include compositions ranging from quartz diorite and tonalite to leucogranite. The dioritic members of the series grade into basic migmatite of the Westcoast Complex and are marginal facies in the contact zones with the Vancouver and Bonanza groups. They are commonly heterogeneous in outcrop, exhibiting inclusions, agmatitic and schlieren structure similar to those of the Westcoast Complex, but show no gneissic foliation. The more granitic members, lacking distinctive material and with fewer, more fully assimilated inclusions are, or appear to be more homogeneous. Modal compositions of sixteen samples of the batholith are given in Table 4 and Figure 4. They are based on point counts (at least 500) of Muller's and Carson's (1973) thin sections. The rocks appear to be predominantly hornblende < biotite granite and hornblende < biotite granodiorite with minor leucogranite, tonalite, leuco-quartz monzodiorite and quartz diorite. Classifications are according to the newly proposed IUGS Classification (Anonymous, 1973). Rocks classed as granite in this paper were classed quartz monzonite in the report on Alert Bay – Cape Scott map area (Muller et al., 1974).

The granites range from medium grained (quartz and feldspar slightly over 5 mm) to aplitic and are light coloured (colour index generally <10). Quartz is commonly dull grey or "smoky" and feldspars white or rarely light pink. Biotite occurs in small, commonly partly chloritized flakes and hornblende occurs in indistinct patches. Thin sections show granitoid textures with subhedral plagioclase, biotite, hornblende and minor apatite. Spaces between these minerals are filled with anhedral quartz and potash feldspar. A fine grained granitic rock from the south shore of Muchalat Inlet contains garnet and hypersthene and is probably of metamorphic origin. Chlorite and epidote, sericite, and less commonly prehnite, pumpellyite, and zoisite are alteration products of feldspars and mafics indicating postplutonic, low-grade metamorphism.

Granodiorite is megascopically little different from granite. The rocks are also medium grained and light coloured but lack the distinct smoky quartz grains of the granite. Thin sections show granitoid assemblages similar to those of granite. The colour index is less than 10 and biotite, commonly converted to chlorite, is predominant.

A limited sampling of modal analyses only encountered one example each of leucotonalite, leuco-quartz monzodiorite and quartz diorite. The tonalites are light coloured rocks, similar to granite and granodiorite, but with only a few per cent interstitial potash feldspar. The dioritic rocks occur in contact areas and commonly contain mafic inclusions. They are darker (colour index >15) and finer grained than the granite-granodiorite-tonalite group of rocks. Thin sections show strongly predominating plagioclase, 2 to 3 mm long and with 35 to 40 per cent anorthite; hornblende, in yellow to green pleochroic prisms, to 4 mm long, is more abundant than biotite. Some sphene and the usual alteration products chlorite, epidote and prehnite are commonly present.

Petrography of Nootka, Ehatisaht and Sydney Batholiths

The three southwestern batholithic intrusions are considerably narrower than Muchalat Batholith and whereas the latter intrudes Vancouver Group and Sicker Group rocks, they invade and are in contact with the Bonanza Group and Westcoast Complex. However, their petrography is only slightly different, as shown in Table 5 and Figure 4B. The most notable difference is their generally lower quartz and potash feldspar content and higher plagioclase content in every class of rocks.

Table 4. Modal compositions of Muchalat Batholith (see plot, Figure 4A)

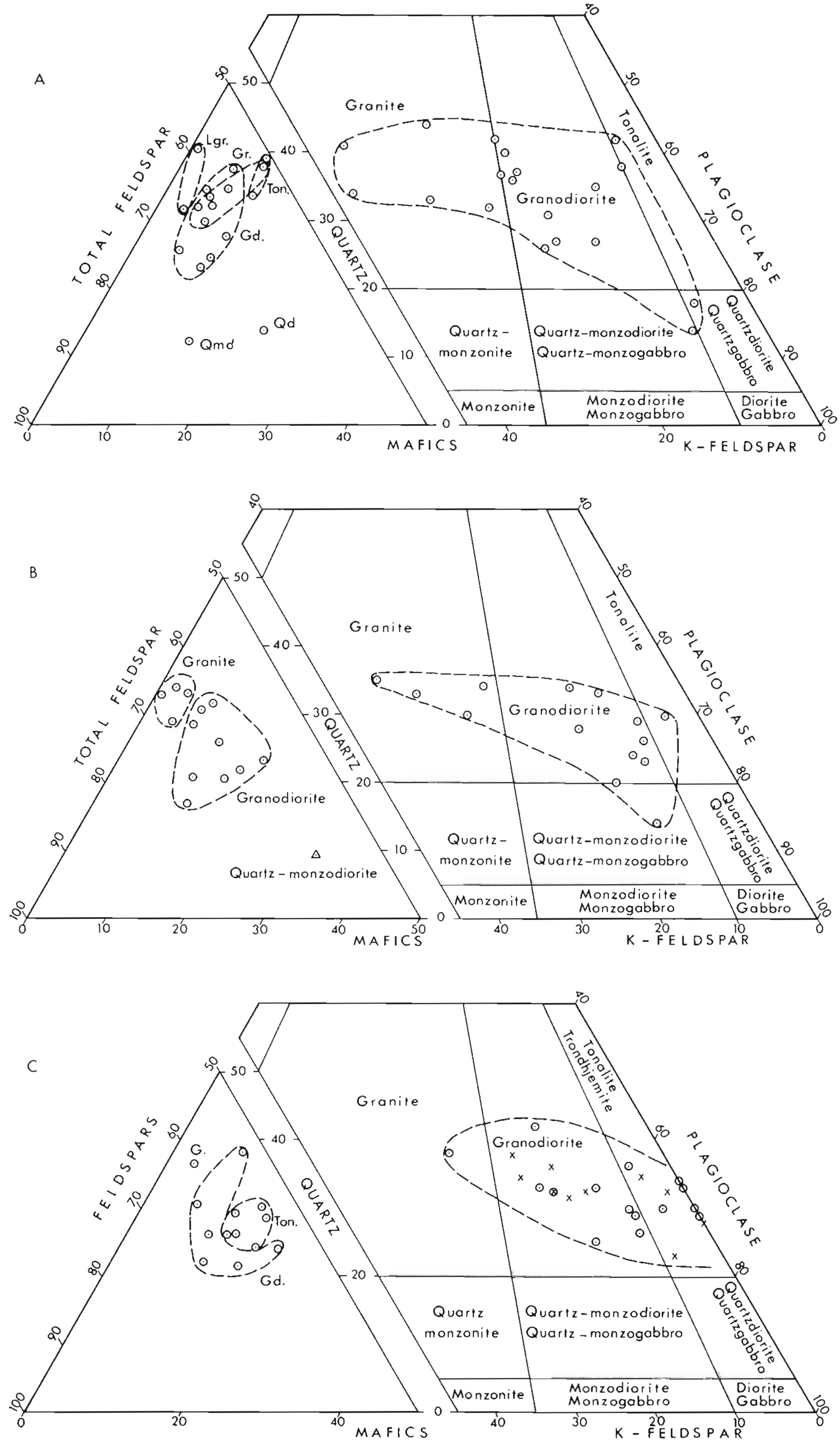
Number of Samples		Quartz	Plagioclase	Potash Feldspar	Biotite	Hornblende	Pyroxene	Chlorite	Epidote and Prehnite	Opaque	Accessory minerals		Specific gravity	Number of samples for Specific gravity
							LEUCOGRANITE							
2	Ave.	35.9	25.5	36.1	1.8	-	-	0.2	-	0.4	0.1	Apatite	2.62	2
	Min.	31.4	18.4	32.2	0.6	-	-	-	-	0.2	-		2.61	
	Max.	40.4	32.6	40.0	3.8	-	-	0.4	-	0.6	0.2		2.64	
							GRANITE							
5	Ave.	35.0	31.7	25.7	2.3	0.2	1.2	2.8	0.2	0.1	0.4	Muscovite	2.63	5
	Min.	32.0	22.4	18.2	-	-	-	-	-	-	-	Garnet	2.61	
	Max.	40.8	39.2	40.4	4.8	0.8	6.2	9.0	0.7	0.4	1.2		2.69	
							GRANODIORITE							
8	Ave.	29.7	45.1	17.2	2.2	0.5	-	3.3	0.9	0.6	0.1	Apatite	2.66	8
	Min.	25.4	37.2	10.7	-	-	-	0.1	-	-	-	Muscovite	2.64	
	Max.	37.2	49.8	19.9	5.5	2.6	-	7.6	4.2	1.2	0.2		2.69	
							LEUCOTONALITE							
1		38.8	49.6	4.4	5.2	0.2	-	1.2	0.2	0.4	-		2.67	1
							TONALITE							
1		33.8	49.8	5.2	0.2	3.0	-	6.6	1.4	-	-		2.69	1
							LEUCO QUARTZ MONZODIORITE							
1		12.1	65.9	8.0	6.6	5.8	-	-	0.5	1.1	-		2.74	1
							QUARTZ DIORITE							
1		13.8	57.6	5.8	-	12.2	-	5.0	3.8	2.8	-		2.73	1

Granite, mainly from samples north of Esperanza Inlet, is light coloured (c.i. <5), medium grained (2-4 mm) with distinct granular texture commonly exhibiting dull grey quartz, white plagioclase, pink potash feldspar and minor biotite flakes. Thin sections show subhedral and zoned plagioclase with anorthite content ranging from about 5 to 28 per cent. Both feldspars are generally cloudy and K-feldspar is finely perthitic.

Granodiorite is also light to medium coloured (c.i. <15), medium grained (2-5 mm), and with conspicuous smoky quartz grains. In thin sections textures are hypidiomorphic granular. Plagioclase, the major component, is in general regularly zoned, varying from 45 to 20% anorthite in unaltered crystals. Potash feldspar is perthitic and occurs interstitially, quartz is in irregular, optically strained, and broken masses. Biotite, mostly chloritized, or yellow to green hornblende may be the predominant mafic mineral. The single examples of tonalite and monzodiorite are fine- to medium-grained, light coloured, much altered rocks composed chiefly of saussuritized plagioclase, hornblende, and interstitial, locally granophyric, quartz and potash feldspar.

Contact Relations

Muchalat Batholith is mainly in contact with Vancouver Group and to a lesser extent with Sicker Group rocks. An intrusive contact with Karmutsen volcanics, well exposed on the road from Gold River townsite to the pulp mill on Muchalat Inlet, is probably representative. There "clean" biotite granodiorite, almost without inclusions, is exposed in a large cut at the crossing of the main logging road and the paved highway. One and one-half km farther south, at a sharp bend, a hybrid granitoid rock is exposed. It consists mainly of greenish grey, medium- to coarse-grained tonalite with about 50 per cent white, distinct, almost phenocrystic plagioclase and about 15 per cent dull grey quartz, both up to about 5 mm in size, together with smaller hornblende and diffuse fine grained hornblende-plagioclase clots. The rock contains some vertical septa of amphibolite. About 0.5 km farther southwest the rock is agmatitic and varies from quartz diorite with sharply defined inclusions of amphibolite, a few centimetres to one metre in size, to brecciated amphibolite with criss-crossing veinlets, to fine grained tonalite about 10 cm wide. About 0.5 km farther south again



A Muchalat Batholith (Table 4)
B Nootka, Ehatishat and Sydney Batholiths (Table 5)
C Catface Intrusions (Table 6)

Figure 4. *Combined Qu-Pc-Kf and Qu-Fs-Maf modal plots.*

hornfelsic volcanics are exposed with quartz-epidote nests indicating low grade metamorphism. Similar contact zones, one or more kilometres in width, are exposed in rock cuts along other roads, as for instance the road from Gold River to Tahsis or cliffs along Muchalat Inlet.

The smaller Nootka, Ehatisaht and Sydney batholiths are narrower than the Muchalat Batholith. Hoadley (1953) described migmatitic zones varying considerably in magnitude from place to place, depending largely on the dip of the contact, but with a true width probably not more than 50 to 100 feet (15 to 30 m). He also observed that the number and angularity of inclusions increase regularly towards the contact, ranging from a few vague patches or schlieren of dark minerals to well defined, angular fragments constituting about 75 per cent of the rock separated by small dykes and veinlets of intrusive rock.

Age

The age of Island Intrusions has been fairly well established in the areas east and north of Nootka Sound map area. The presently known geological constraints are intrusive relationships with Upper Triassic Vancouver Group and Lower Jurassic Bonanza Group rocks and unconformity with overlying Upper Cretaceous Nanaimo Group sediments. Hoadley (1953) concluded on that basis a Late Jurassic to Early Cretaceous time of emplacement. Jeletzky (1954, 1976, p. 68) believed to have additional evidence in "pebbles of acidic intrusive rocks closely resembling those of the Coast (Island) Intrusions ... in the conglomerate beds of Callovian rocks at Tatchu Point" and he suggested a "? Bathonian" (mid-Middle Jurassic) age (1976, p. 5). Carson (1973) did not find the presumed plutonic clasts, and, like the present writers found in the Callovian conglomerates only clasts of fine grained volcanics and of feldspar porphyry, more probably derived from Bonanza flows or dykes. He inferred, on the basis of K-Argon dates, a "late Lower to middle Upper Jurassic age". The total available isotopic datings, mainly by R.K. Wanless of the Geological Survey (e.g. Muller, 1977) ranges from 181 to 141 Ma with a median value of about 155 Ma, or earliest late Jurassic. The writer believes that the younger of these dates do not represent intrusive ages and are due either to slow cooling or argon loss. An Early Jurassic age is supported by recent Rb-Sr isotope studies at the University of British Columbia by R.L. Armstrong (personal communication, 1976). Six samples supplied by Muller from Nimpkish and Vernon batholiths, all taken within a radius of about 10 km of Woss Camp in Alert Bay map area, gave an isochron of 174 ± 10 Ma, with initial ratio about 0.7035. A total of 15 samples of Island Intrusions from Alert Bay and Nootka Sound map areas gave a similar line with slightly higher intercept.

Northcote and Muller (1972) earlier suggested that Island Intrusions and Bonanza volcanics are cogenetic. Possibly cooling of the batholith lagged somewhat after extrusion of the volcanics. On the basis of all available data the writers now conclude that Bonanza volcanism and plutonism of Island Intrusions occurred and ceased within Early Jurassic time.

Origin

Gradational contact relations and similar age ranges of Westcoast Complex and Island Intrusions are indications of their cogenetic origin. The hypothesis that the Westcoast

Table 5. Modal compositions of Nootka, Ehatishat and Sydney batholiths (see plot, Figure 4B)

Number of Samples		Quartz	Plagioclase	Potash Feldspar	Biotite	Hornblende	Pyroxene	Chlorite	Epidote and Prehnite	Opaque	Accessory minerals		Specific gravity	Number of samples for Specific gravity
						LEUCOGRANITE								
4	Ave.	32.2	34.3	30.6	1.0	0.1	-	1.2	0.1	0.3	0.1	Muscovite	2.62	4
	Min.	28.8	26.7	23.9	0.1	-	-	0.2	-	-	-	Sphene	2.60	
	Max.	34.4	39.4	37.1	2.9	0.4	-	2.4	0.4	0.6	0.3		2.63	
						GRANODIORITE								
8	Ave.	23.9	53.6	10.2	4.2	3.7	-	2.3	1.2	1.3	0.2	Apatite	2.68	7
	Min.	17.2	45.2	7.2	0.2	-	-	-	-	-	-	Calcite	2.65	
	Max.	31.4	57.6	13.4	6.6	8.0	-	9.6	5.6	2.6	0.7		2.70	
						LEUCOTONALITE								
1		28.2	61.2	3.2	6.2	-	-	-	-	0.2	-		2.74	1
						MONZODIORITE								
1		9.4	50.0	8.8	-	17.6	-	12.2	0.2	1.8	-		2.78	1

migmatites were derived from Sicker and Vancouver Group rocks has been presented in a preceding section and it is suggested that the granitic material of Island Intrusions was derived by mobilization of granodioritic material produced by partial melting of the pre-existing rocks. The formation of granitoid migma as the ultimate stage of metamorphism has been discussed by many authors since its initial formulation by Sederholm (1913). Mehnert (1968) discussed at length the formation of anatectic granitoid rocks and showed that a parent rock such as amphibolite could generate quartz dioritic "mobilizates" and mafic-rich "restites". The formation of a suite of rocks in the Coast Plutonic Complex, proceeding from hornblende diorite via quartz diorite and granodiorite to granite has also been discussed by Roddick (1965). He also believed that large volumes of plutonic rock might have evolved from pre-existing rocks and moved by plastic flowage without being extensively molten. Insufficient quantitative data are available to prove that Island Intrusions may be migmatic derivatives of older volcanic and sedimentary rocks. The writer believes, however, that such an origin could be demonstrated with more detailed work.

A further genetic relationship probably exists between Island Intrusions and Bonanza volcanics, as first suggested by Northcote and Muller (1972). Cogenetic origin of volcanic rocks of the andesite-rhyolite series and plutonic rocks of the quartz diorite – granite series is inferred now in many orogenic belts (Carmichael et al., 1974, p. 566). On Vancouver Island detailed mapping of the Jurassic volcanic and plutonic rocks of an area adjacent to Kyuquot Sound indicated to D.G. Leighton (personal communication, 1974) that such a relationship is demonstrable. "Facies changes" (of Bonanza volcanic rocks) "are roughly concentric to the margins of the presently exposed plutonic rocks. Coarse pyroclastics (vent or cone complex facies) and more acid (hence viscose) flows are restricted to the immediate vicinity of the stock ... and volcaniclastic sediments (alluvial or epiclastic facies) tend to occur at greater distance from the intrusive".

Kyuquot Group

The coastal region south of Kyuquot Sound is the only area where Middle and Upper Jurassic sediments are known. They were discovered and studied by Jeletzky (1950) and many fossil collections were made between 1949 and 1951. The beds are the lowest part of a composite clastic wedge that unconformably overlies the Lower Jurassic Bonanza Group. Within this wedge a complex stratigraphy of overlapping units, Middle Jurassic to mid-Cretaceous in age, has been outlined broadly (Muller et al., 1974; Jeletzky, 1976) but requires more detailed work. The middle (Valanginian to Barremian) part of the wedge, which overlaps Bonanza rocks in the western Quatsino Sound region, has been named Longarm Formation after coeval rocks in Queen Charlotte Islands. The upper (Aptian to Cenomanian) part of the wedge, unconformable on the middle part and overlapping on Bonanza and older rocks in eastern Quatsino Sound area, has been named after the correlative Queen Charlotte Group of Queen Charlotte Islands. The lower part of the wedge, exposed along the coast and on the islands just south of Kyuquot Channel, is late Middle Jurassic, Callovian, to Early Cretaceous, middle Valanginian in age, and its base lies with major unconformity on Bonanza or Vancouver Group rocks.

It is now proposed to incorporate the entire sequence of rocks, lying unconformably on the Early Jurassic volcanic-plutonic complex, and overlain by the Queen Charlotte Group, into a new Kyuquot Group, named after Kyuquot Sound where most of the group is exposed. The group comprises three formations of clastic sediments: a lower, newly named Kapoose Formation, the One Tree Formation, and the Longarm Formation (in Alert Bay map area).

Kapoose Formation

Name and Distribution

Exposures of clastic, largely pelitic, sediments of Callovian to Kimmeridgian age are scattered along a few kilometres of coastline from Jurassic Point to McLean Cove (see Fig. 5). For these strata, called informally "Division A"* and "Division B" by Jeletzky (1950) the name Kapoose Formation is proposed, after Kapoose Creek and Kapoose Rocks. The combined sections of Jurassic Point, Kapoose Point and Gross Point, although faulted and not yet worked out in detail, must serve as type sections. They were discovered and studied by Jeletzky (1950) and later examined by Muller and Cameron.

Lithology

Jurassic Point Section. Kapoose Formation sediments lie unconformably on Bonanza Group or Vancouver Group. The unconformity is seen on Kapoose Rocks where Parson Bay sediments, composed of black to brown calcareous siltstone and shale in beds 1-15 cm thick with **Monotis subcircularis** and some calcareous sandstone layers, are overlain with minor angular unconformity by up to 30 cm of conglomerate with pebbles, up to 3 cm in size, of fine grained volcanic rocks. The conglomerate is overlain by lithic sandstone and grit; in other places the sandstone lies directly on the unconformity surface. These beds contain abundant Cadoceratinae of Callovian age, thus the entire Bonanza Group is missing at this locality.

The section exposed south of Tatchu Creek at Jurassic Point (section 71-S2, Fig. 5) contains the lower two members of Division A. The base of the section is truncated by a fault and several other faults repeat parts of the section, rendering the true succession somewhat uncertain. The lower 35 m consist of soft, nonlaminated siltstone and fine grained lithic sandstone with minor lenticular limestone. This part contains ammonites (Cadoceratinae), belemnites, and **Inoceramus.** The succeeding 25 m consists of laminated to crossbedded sandy limestone, calcareous siltstone, and sandstone and contains similar fossils. The succeeding beds are exposed south of Jurassic Point and also south of Kapoose Point. At the former locality (71-S2) the top is missing, but it is present in the latter (71-S3). The maximum thickness at Jurassic Point is 125 m. There the base is taken as the base of the prominent conglomerate which is about 20 cm thick and composed of well rounded pebbles, 1 to 10 cm in diameter, of grey green and red volcanic rocks and feldspar porphyry derived from dykes. Jeletzky (1950, p. 24) noted that the conglomerate is broken by faults into many segments and it is possible that there is only one conglomerate bed. The conglomerate is overlain by about 30 m of fine grained lithic sandstone containing several beds with Cadoceratinae, succeeded by about 100 m of calcareous siltstone with small concretions in the lower part.

Kapoose Point Section. The top of the same succession is exposed southwest of Kapoose Point and consists of about 65 m of siltstone, locally with large concretions, up to 1 m in diameter and locally containing **Phylloceras.** There may be a disconformity between the siltstone ("Lower Shale Member") and the overlying sandstone ("Sandstone Member"), exposed in shoreline cliffs of Kapoose Point. They are respectively of Middle and Upper Jurassic age, but upper Callovian to lower Oxfordian beds appear to be missing. Above the apparent hiatus basal Upper Jurassic beds consist of limestone, about 30 cm thick, with fine current bedding at the top. It is overlain by medium grey, massive, fine grained lithic sandstone in beds 0.5 to 1.5 m thick. Those beds form the top of the Kapoose Point Section and contain ammonites (**Cardioceras**), belemnites and pelecypods of early Oxfordian age.

Gross Point Section. The beds exposed at Gross Point, 1 km north of Kapoose Creek, represent the "Upper Shale Member" of Division A of Jeletzky (1950). They comprise about 40 m of poorly, unevenly bedded calcareous siltstone with locally ellipsoid calcareous concretions, containing **Buchia** and **Cylindroteuthis** of late Oxfordian to Kimmeridgian age.

Grassy Islands Section. The Jurassic part of the Jurassic-Cretaceous sequence of the Grassy Islands group is exposed on the northeast side of Grassy Island. Jeletzky (1950; 1965, p. 65) called it "Division B" and noted a disconformity with the overlying lowermost Cretaceous rocks of the One Tree Formation. He divided this unit into three lithological members, but differences between these members appear to be slight and contacts gradational. They are mainly composed of medium grey calcareous siltstone with fine laminations and bedding planes about 30 cm apart. They contain layers with calcareous nodules and many lenses with abundant **Buchia's.**

Age and Correlation

The age of the Kapoose Formation is based mainly on the many fossil collections made by J.A. Jeletzky, between 1949 and 1951 and on additional collections made by the

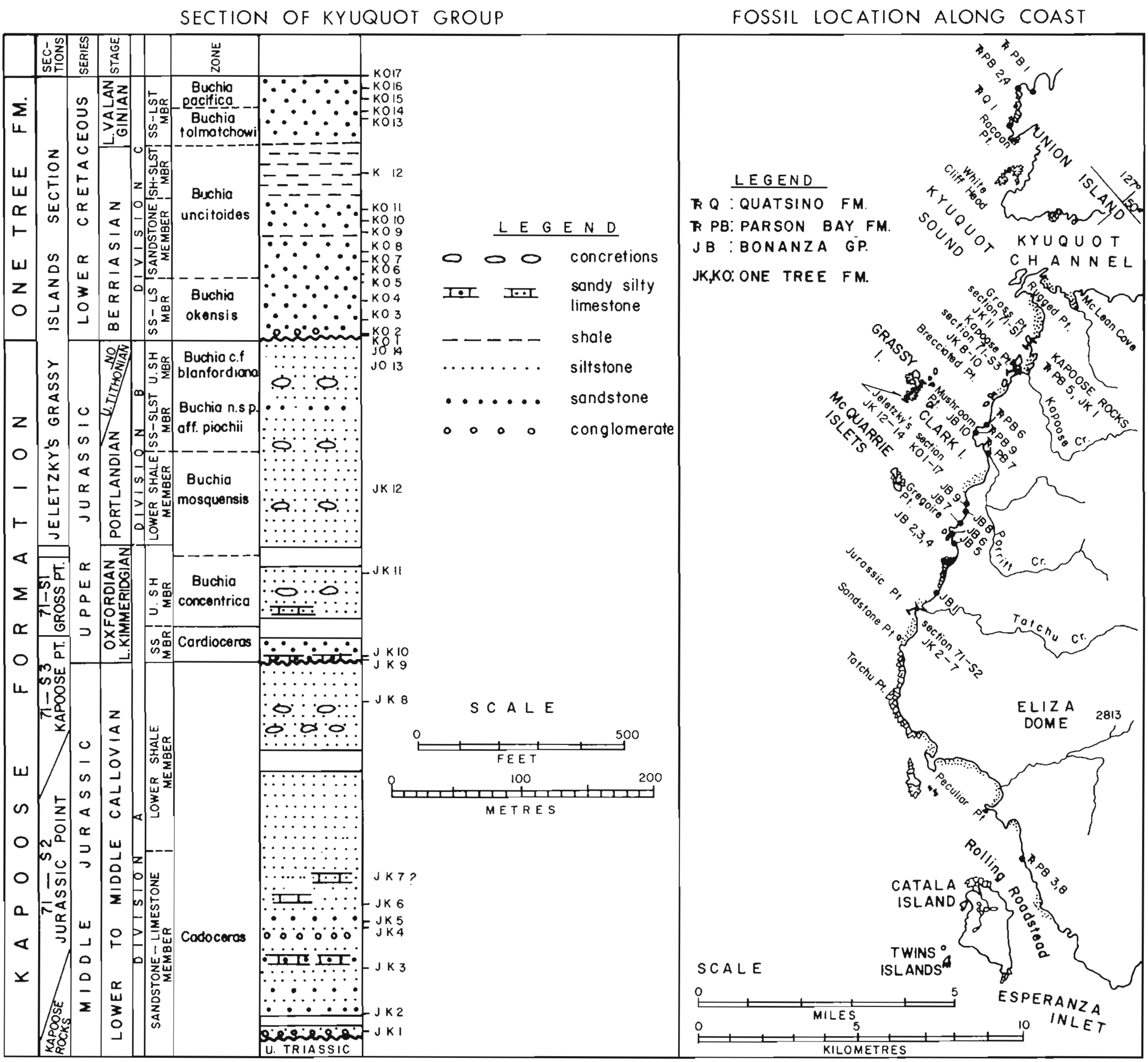


Figure 5. *Section of Kyuquot Group and fossil locations in coastal strip, Union Island to Esperanza Inlet.*

writer between 1969 and 1971. Jeletzky studied the **Buchia's** and belemnites, H. Frebold identified the ammonites, and T.P. Poulton assembled all fossil material for the purpose of this report and studied the bivalve collections. The writer has endeavoured to establish locations and co-ordinates for the earlier collections on the basis of the collector's descriptions. Some closely spaced localities without specific stratigraphic information have been grouped together and the grouped collections are numbered and prefixed by JK. Geographic and stratigraphic locations are shown on Figure 5. Localities JK1 to JK11 are in Jeletzky's (1950) Division A, localities JK12 to JK14 in Division B.

JK1

Field no. 10/1a 24 } (Jeletzky) 71-30C } (Muller)
GSC loc. 18327 18335 } 88619 }

Locality: Kapoose Rocks (opposite mouth of Kapoose Creek), 10 to 20 feet (3.5 to 7 m) above Triassic-Jurassic unconformity; 49°56'55"N, 127°13'55"W.

Ammonites: **Cadoceras doroschini** (Eichwald)
Cadoceras cf. **C. wosnessenskii** (Grewingk)
Cadoceras (Stenocadoceras) cf. **C. (S). striatum** Imlay
Cadoceras (Stenocadoceras) aff. **C. (S). iniskinense** Imlay
Cadoceras (Stenocadoceras) sp. indet.
Pseudocadoceras crassicostatum Imlay
Pseudocadoceras grewingki (Pompeckj)
Pseudocadoceras cf. **P. schmidti** (Pompeckj)
Phylloceras (Calliphylloceras) sp.

Age: Callovian (late Middle Jurassic)

JK2

Field no. 71-S2-F1A 71-S2-F1B } (Muller)
GSC loc. 88622 88626 }

Locality: South side of Tatchu Creek, near base of section 71-S2; 49°52'55"N, 127°10'30"W.
Cadoceras? sp. indet.: one small fragment of a young whorl
Nautilus sp.
Belemnoid fragment
Inoceramus (Retroceramus) spp. indet.

Age: Probably Callovian

JK2A

Field no. 27/1, 27/1, 27/1A, 27/2, 27/2a, 27/2a } (Jeletzky)
GSC loc. 19299, 20609, 20559, 20058, 20060, 20560 }

Locality: 50 to 70 feet (15 to 21 m) south of the mouth of Tatchu Creek, about same locality as JK2.

Ammonites: **Cadoceras** cf. **C. comma** Imlay and **C. glabrum** Imlay
Cadoceras (Stenocadoceras) cf. **C. (S). multicostatum** Imlay
Cadoceras (Stenocadoceras?) sp. indet.
Pseudocadoceras cf. **P. grewingki** (Pompeckj)
Pseudocadoceras sp.
Phylloceras sp. indet.

Bivalves: **Entolium** sp.
Corbula (?) sp.
Inoceramus (Retroceramus) sp.

Gastropods ? indet.

Age: Callovian

JK3

Field no. 27/3c 27/3f } (Jeletzky)
GSC loc. 20637 20686 }

Locality: About 50 m (150 feet) south of the mouth of Tatchu Creek, in sandstone bed and faultzone, immediately above a prominent conglomerate bed (Jeletzky's description of "6' conglomerate bed" is taken to mean a 6-inch bed). The conglomerate bed is offset by faults and indicates repetition of the stratigraphic section exposed in the tidal flats; 49°52'55"N, 127°10'35"W.

Bivalves: **Anomia** (?) sp.
Astarte (?) sp.
Gervillia (?) sp.
Inoceramus (Retroceramus) spp.

Belemnites: poorly preserved

Age: Probably Callovian

Remarks by T.P. Poulton: "The **Inoceramus** specimens are regularly and relatively finely ribbed. In some there is a marked change at about 3 to 5 cm from the umbo, from very fine dense ribbing to somewhat coarser ribbing; and in some specimens a constriction occurs at the locus of change. These features characterize some specimens from the Callovian upper part of the Bowser Formation of Alaska (specimens seen with permission of E.G. Kauffman) and with those from other localities of NW Vancouver Island, and a Callovian age is therefore indicated. It is unwise to apply specific names to the species in view of their current complex nomenclature, which will require considerable study to clarify but the affinities are most strongly with **Retroceramus retrorsus** (Keyserling) and **R. vagt** Kosckelkina."

JK4

Field no. 27/3i, 27/3j, 27/3k, 27/3m

GSC loc. 20062, 20635, 20682, 20688

Locality: 27 to 34 feet (8 to 10 m) "above the 6' conglomerate bed which is 150' south of the mouth of Tatchu Creek" (see note for JK3). Co-ordinates approximately as for JK3.

Ammonites: Cosmoceratid? poorly preserved fragment
Cadoceras (Stenocadoceras) cf. **C. (S). striatum** Imlay
Pseudocadoceras?

Belemnites: poorly preserved

Bivalves: **Anomia** (?) sp.
Brachidonites (?) sp.
Astarte sp.
Camptonects sp.
Corbula (?) sp.
Entolium sp.
Gresslya (?) sp.
Inoceramus (Retroceramus) sp.
Myophorella sp. aff. **M. montanaensis** (Meek)
Ostrea (?) sp.
Pinna sp.
Pleuromya spp.
Protocardia sp.
ostreiids indet.
pectinid indet.

Gastropods: indet.

Scaphopods: indet.

Age: Callovian, on basis of ammonites. The bivalve fauna is closely similar to that of Callovian rocks of the Hazelton Group.

JK5

Field no. 27/3P, 27/3Q

GSC loc. 20544, 20542

Locality: 50 to 52 feet (15 to 16 m) above conglomerate (see JK3).

Ammonites: **Cadoceras** ? fragments of young specimens

Age: Probably Callovian

JK6

Field no. 27/5, 27/7

GSC loc. 20545, 20546

Locality: 84 to 94 feet (26 to 29 m) above conglomerate (see JK3).

Ammonites: **Phylloceras** sensu lato ?

Bivalves: **Inoceramus (Retroceramus)** sp.
Corbula (?) sp.
Myophorella sp.

Age: Probably Callovian

JK7

Field no. 76/6b, 76/6c, 76/7

GSC loc. 20549, 20550, 20243

Locality: "On a fault block, approx. 30 feet (10 m) southwest of the tip of no. 2 bluff, which lies approx. 600' (180 m) south of the mouth of Tatchu Creek." (Probably similar, perhaps somewhat higher, stratigraphic position as JK6: J.E.M.)

Ammonites: **Cadoceras** sp.
Cadoceras (Stenocadoceras) cf. **C. (S). stenoloboide** Pompeckj
Cadoceras (Stenocadoceras) spp. indet.
Pseudocadoceras sp.
Phylloceras bakeri Imlay

Belemnites: poorly preserved

Bivalves: **Entolium** (?) sp.
Meleagrinella (?) sp.

Gastropods: small, indet.

Age: Callovian

JK8

Field no. 71-S3-F1 } (J.E. Muller)
GSC loc. 88624 }

Locality: South of Kapoose Creek, Section 71-S3, near base of seastack, 120 feet (37 m) above base of section; 49°56'40"N, 127°13'30"W.

Ammonite: Phylloceras sp. "This specimen is only preserved in fragments. The ribs seem to be as fine as for instance in **Phylloceras bakeri** Imlay from the Alaskan Callovian but the imperfect state of preservation does not permit detailed comparison."

Age: Uncertain, Callovian?

JK9

Field no. 71-S3-F2A

GSC loc. 88613

Locality: Bluff on third point immediately south of Kapoose Creek, 217 feet (66 m) above base of section 71-S3; 49°56'40"N, 127°13'30"W.

Ammonite: **Cardioceras (Scarburgiceras)** cf. **S. wyomingense** Reeside (impressions and fragments)

Bivalves: fragments of various genera

Age: Early Oxfordian, Early Cordatum Zone

JK10

Field no. 71-S3-F2B

GSC loc. 88611

Locality: Same locality as JK9, 225 feet (69 m) above base of section 71-S3.

Ammonites: **Cardioceras** aff. **C. distans** (Whitfield)
Cardioceras mountjoyi Frebold (fragments)

Bivalves: **Oxytoma** aff. **O. wyomingensis** Stanton
Pecten sp. indet.
fragments of other pelecypods

Age: Early Oxfordian

JK10A

Field no. 5/1, 5/1a, 33, 34, 35

GSC loc. 18465, 19011, 18355, 18356, 18391

Locality: Second rocky bluff south of Kapoose River, various localities in about 15 feet (5 m) of section. (These collections by Jeletzky are believed to be from the same bluff as JK9 and JK10.)

Ammonites: **Cardioceras** spp. indet.
Cardioceras (Scarburgiceras) cf. **C. (S.) cordiforme** (Meek and Hayden)
Cardioceras (Scarburgiceras ?) sp. aff. **C. (S.?) leckenbyi** Arkell
Phylloceratids indet. (very small specimens and fragments)
Phylloceras (Partschiceras?) sp. indet. (small fragment)

Age: Early Oxfordian. Cordatum Zone

JK11

Field no. 71-S1-F1 } (J.E. Muller)
GSC loc. 88614 }

Locality: Gross Point, about 110 feet (34 m) above base of measured section 71-S1; 49°57'10"N, 127°13'35"W.

Ammonites: **Phylloceras** sp. A large not too well preserved specimen with constrictions, fine lines of growth or very fine ribs. Belongs to **Calliphylloceras** Spath or **Holocophylloceras** Spath.

Lytoceras sp. Secondarily compressed specimen of about 113 mm diameter, rather fine straight ribs (H. Frebold).

Age: Late Jurassic

Belemnites: **Pachyteuthis (Pachyteuthis)** n. sp. (undescribed) **Cylindroteuthis (Cylindroteuthis)** ex. aff. **C. (C.) septentrionalis** Bodylevski 1960. So far as known, **Pachyteuthis (Pachyteuthis)** n. sp. (to be described and figured shortly) is restricted to the late Oxfordian to Kimmeridgian Upper Shale Member of Jeletzky (GSC Paper 50-37, p. 31-32). **Cylindroteuthis (Cylindroteuthis)** ex aff. **C. (C.) septentrionalis** Bodylevski 1960 appears to range through the lower Oxfordian Sandstone Member (ibid., p. 27) and into the Upper Shale Member (J.A. Jeletzky).

Bivalves: **Buchia** sp. No report on the **Buchia's** collected by J.E. Muller is available, but Jeletzky made numerous collections from the same section, as follows:

Field no. 45/1, 45/2, 46/2, 46/3, 46/4, 47/1, 47/1b, 47/2

GSC loc. 18407, 18503, 18504, 18506, 18481, 18473, 18339, 18375

Ammonites: **Lytoceras** sp. indet.
Phylloceras cf. **P. apenninicum** Canavari
Phylloceras cf. P. apenninicum Canavari from these localities is probably the same ammonite mentioned by Jeletzky (1950, GSC Paper 50-37, p. 6, 28) as "**Phylloceras** ex. gr. **glennense** Anderson". **P. glennense** Anderson and **P. apenninicum** Canavari are similar to each other and belong to the same group. **P. glennense** Anderson was found in the Knoxville Series of California and placed in the Tithonian (Anderson, 1945, Bull. GSC, vol. 56, p. 940), **P. apenninicum** Canavari occurs in Italy in beds with Aspidoceras (Canavari, 1897, p. 32), in Mexico in the Portlandian (Burkhard, 1906, Faune Jurassique de Mazapil, p. 106, pl. 28, figs. 1-5). (H. Frebold)

Age: Oxfordian-Kimmeridgian

Bivalves: **Buchia concentrica** s. lato (= ? **B. bronni** Rouillier) (J.A. Jeletzky, in GSC Bull. 103 and personal communication, 1968)

Age: Oxfordian to Kimmeridgian

The following collections were made from a section of Jurassic to Cretaceous sediments, measured in roughly north-south direction over the tidal flats bounding the small island between Grassy Island and Clark Island, from 49°55'30"N, 127°14'45"W to 49°55'10"N, 127°14'4"W (Jeletzky, personal communication, 1969). The fossil lists are taken from Jeletzky, 1950, p. 33-34; 1965, p. 17 and 65 and are from his Division B. The upper part (lowermost Cretaceous) forms the type section of the One Tree Formation.

JK12

Field and GSC loc. numbers not available

Locality: Grassy Islands sections, northeast part, lower about 120 m (400 ft) of Jeletzky's Division B.

Ammonites: **Phylloceras** sp. closely related to
P. reticulatum
Burghard and **P. subplicatum** Burghard

Belemnites: **Cylindroteuthis** sp.

Bivalves: **Buchia mosquensis** (Buch) sensu lato
Buchia piochii var. **russiensis** Pavlow

JK13

Locality: Same as JK12, upper about 15 m (50 ft) of Division B.

Ammonites: **Phylloceras** sp.

Belemnites: **Cylindroteuthis** sp.

Bivalves: **Buchia** cf. **blanfordiana** (Stoliczka)

Age of JK12 and JK13: Portlandian

JK14

GSC loc. 16577, -78, -80, -84, -85

Locality: 30 cm to 1.5 m (1-5 ft) below Jurassic-Cretaceous unconformity; 152.5 to 154 m (501-506 ft) above base of Grassy Islands section. From: Jeletzky, 1965, plate II.

Ammonites: **Gymnodiscoceras** Spath, 1925
oppelioid ammonite resembling
Gymnodiscoceras Spath, 1925
ammonite resembling **Substeueroceras stantoni** Anderson, 1945

Belemnites: **Cylindroteuthis** aff. **obeliscoides** Pawlow and Lamplugh, 1892

Bivalves: **Buchia** cf. **blanfordiana** (Stoliczka, 1866)

Age: upper Portlandian

The fossil collections JK1 to JK14 indicate that the Kapoose Formation ranges in age from late Middle Jurassic, Callovian to Late Jurassic Portlandian. Its oldest part is correlative to the youngest part of the Yakoun Formation of Queen Charlotte Islands (Sutherland Brown, 1968), but its younger part does not seem to be represented there. The Relay Mountain Group of southwestern mainland British Columbia is coeval with the Kyuquot Group and its lower part correlates to the Kapoose Formation.

One Tree Formation

Name and Occurrence

The name "One Tree Formation" seems to have been used first by Jeletzky (1965, Fig. 4 and captions for plates) but the formation does not appear to have been defined in the text of his report. Jeletzky apparently derived the name from the earlier collections by Dolmage (1921, p. 17A) of fossils of lowermost Cretaceous age from One Tree Island. Bancroft (1937, p. 8) referred these beds to the "Cowichan Group", but as no rocks of the same age are present in Cowichan area that name is inappropriate.

Judging by his Figure 4 (1965, p. 65) Jeletzky included in the One Tree Formation all clastic sediments above the Jurassic-Cretaceous unconformity, as exposed in the Grassy Island Group (of which Clark Island, formerly One Tree Island, is the easterly one). The formation is also exposed on McQuarry Islets (Jeletzky, 1950, geological map), but is not known elsewhere on Vancouver Island. It ranges from the **Buchia Okensis** to **Buchia pacifica** faunal zones. The Longarm Formation with **Buchia crassicolis** succeeds and presumably overlaps the One Tree Formation to the east but the two have not been found in superposition.

Lithology and Thickness

The sequence is exposed on the southwest side of the Grassy Island group and is about 200 m thick. Jeletzky (1950, p. 38) noted a marked lithological distinction between the siltstones of Division B and the predominant calcareous sandstones of the Lower Cretaceous beds. The sandstone contains locally a pronounced basal shale-pebble conglomerate, locally 2 to 3 m thick, but elsewhere it is a thin bed of calcareous grit and the disconformity is only "apparent on close scrutiny" (Jeletzky, 1950, p. 39). The total exposed section of Cretaceous rocks is according to Jeletzky (1950, p. 6; 1965, p. 65) at least 200 m (650 ft) thick. B.E.B. Cameron briefly explored the section in 1972 and measured 130 m (430 ft) of mainly calcareous sandstone above a conspicuous siltstone-sandstone contact that is probably Jeletzky's disconformity. The formation is largely composed of greenish grey, thick bedded calcareous sandstone with minor calcareous grit and siltstone. It has a middle member, about 30 m thick, of hard siltstone. Shell beds with abundant **Buchia** occur in many parts of the section.

Age and Correlation

Jeletzky made numerous fossil collections from the One Tree Formation and these were recorded and figured extensively (1965). The following localities KO1 to KO17 were compiled by Muller from the information contained in the captions to the plates of Jeletzky's publication (1965). All are from his measured section across the small island and surrounding tidal flats between Grassy Island and Clark Island, from 49°55'30"N, 127°14'45"W to 49°55'10"N, 127°14'04"W. The height above the Jurassic-Cretaceous unconformity, as measured or estimated by Jeletzky, is also shown.

KO1 GSC loc. 17436, -40, -41, -45, -46, -47, -51, -53

0 to 4 inches (0 to 10 cm) above Jurassic-Cretaceous unconformity

Buchia okensis (Pavlov, 1907) f. typ.
Buchia okensis (Pavlov, 1907) var. **subokensis** (Pavlov, 1907)
Buchia uncitoides (Pavlov, 1907) s. lato
Buchia aff. **fischeriana** (d'Orbigny, 1845)

KO2 GSC loc. 17435, -37, -38, -43, -49, 16589, 16594

6 to 10 feet (1.8 to 3 m) above Jurassic-Cretaceous unconformity

Buchia okensis (Pavlov, 1907) f. typ.
Buchia okensis (Pavlov, 1907) var. **canadiana** (Crickmay, 1930)
Buchia okensis (Pavlov, 1907) var. **subokensis** (Pavlov, 1907)

KO3 GSC loc. 16459, 16597, 17461, -65, -66

45 to 47 feet (13.5 to 14.5 m) above unconformity
Buchia okensis (Pavlov, 1907) f. typ.
Buchia okensis (Pavlov, 1907) var. **subokensis** (Pavlov, 1907)
Buchia uncitoides (Pavlov, 1907) var. **catamorpha** (Crickmay, 1930)

KO4 GSC loc. 17468, -69, -70, -71, -74, -78, -79, -81

94 to 101 feet (28.5 to 31 m) above Jurassic-Cretaceous unconformity

Buchia okensis (Pavlov, 1907) var. **subokensis** (Pavlov, 1907)
Buchia aff. **uncitoides** (Pavlov, 1907) s. lato
Buchia uncitoides (Pavlov, 1907) var. **spasskensoides** (Crickmay, 1930)

Age, assemblages KO1-KO4: **Buchia okensis** zone, early Berriasian

KO5 GSC loc. 17482 to 17516 inclusive

155 feet (47 m) above Jurassic-Cretaceous unconformity

Buchia okensis (Pavlov, 1907) s. lato
Buchia uncitoides (Pavlov, 1907) var. **spasskensoides** (Crickmay, 1930)
Buchia uncitoides (Pavlov, 1907) var. **acutistriata** (Crickmay, 1930)
Buchia uncitoides (Pavlov, 1907) var. **catamorpha** (Crickmay, 1930)

KO6 GSC loc. 16600, 16609

172 to 176 feet (52.5 to 53.5 m) above Jurassic-Cretaceous unconformity

Buchia uncitoides (Pavlov, 1907) var. **spasskensoides** (Crickmay, 1930)
Spiticeras (Spiticeras) sp. indet. juven. (possibly young representative of **S. (S.) scriptus** Strachey 1865)

KO7 GSC loc. 16608

193 to 196 feet (59 to 60 m) above Jurassic-Cretaceous unconformity
Spiticeras (Spiticeras) sp. indet. juven.

KO8 GSC loc. 16619
218 to 219 feet above Jurassic-Cretaceous unconformity

Spiticeras (Spiticeras) cf. **mojsvari** Uhlig, 1903

KO9 GSC loc. 16604, 16606

259 to 267 feet (79 to 81.5 m) above Jurassic-Cretaceous unconformity

Buchia uncitoides (Pavlov, 1907) s. lato
Spiticeras spp.

KO10 GSC loc. 16612, -13, -14

283 to 289 feet (86 to 88 m) above Jurassic-Cretaceous unconformity

Buchia uncitoides (Pavlov, 1907) var. **Catamorpha** (Crickmay, 1930)
Neocomites s. lato n. sp. indet.
Spiticeras (Groebericeras) n. sp. indet. ?

KO11 GSC loc. 16603, 16610, 16615

322 to 326 feet (98 to 99.5 m) above Jurassic-Cretaceous unconformity

Buchia keyserlingi (Lahusen, 1888) var. **visigensis** (Sokolov, 1908)
Buchia uncitoides (Pavlov, 1907) var. **acutistriata** (Crickmay, 1930)
Berriasella (Protacanthodiscus) n. sp. aff. **B. (P.) micheicus** (Bogoslovsky, 1897)

KO12 GSC loc. 16599, 16611

413 to 414 feet (126 m) above Jurassic-Cretaceous unconformity

Buchia keyserlingi (Lahusen, 1888) var. **visigensis** (Sokolov, 1908)
Buchia keyserlingi (Lahusen, 1888) var. **sibirica** (Sokolov, 1908)

Age, assemblages KK5 to KK12: **Buchia uncitoides** zone, late Berriasian

KO13 GSC loc. 16635, -36, -37, -39, -40

540 to 544 feet (164.5 to 166 m) above Jurassic-Cretaceous unconformity

Tollia (Tollia) mutabilis (Stanton, 1895) s. lato
Tollia (Tollia) mutabilis (Stanton, 1895) var. **tehamaensis** (Anderson, 1938)
Tollia (Tollia) mutabilis (Stanton, 1895) var. **burgeri** (Anderson, 1938)
Buchia tolmatchowi (Sokolov, 1908) var. **americana** (Sokolov, 1908)
Buchia tolmatchowi (Sokolov, 1908) f. typ.

Age: **Buchia tolmatchowi** zone, earliest Valanginian

KO14 GSC loc. 16646

551 to 553 feet (168 m) above Jurassic-Cretaceous unconformity

Neocomites (Parandiceras) cf. **rota** (Spath, 1925)

KO15 GSC loc. 16643, 16644

597 to 607 feet (182 to 185 m) above Jurassic-Cretaceous unconformity

Buchia pacifica n. sp. (Jeletzky, 1965)

KO16 GSC loc. 16654

623 to 627 feet (190 to 191 m) above Jurassic-Cretaceous unconformity

Buchia pacifica n. sp. (Jeletzky, 1965)

KO17 GSC loc. 16649

640 to 642 feet (195 to 196 m) above Jurassic-Cretaceous unconformity

Buchia pacifica n. sp. (Jeletzky, 1965)

Age, assemblages KK14-KK17: **Buchia pacifica** zone, middle Valanginian

In summary, the One Tree Formation contains four successive **Buchia** faunal zones: the **B. okensis** s. lato; the **B. uncitoides** s. lato; the **B. tolmatschowi** s. lato and the **B. pacifica** zones. They indicate the Berriasian and the lower part of the Valanginian standard stages.

The youngest **Buchia pacifica** zones also is represented in the Pacific Rim Complex, offshore equivalent of Kyuquot and Queen Charlotte groups. Thus far no fossils are known indicating the presence of sediments coeval to the One Tree Formation on Queen Charlotte Islands. However, all its **Buchia** zones are represented in the Relay Mountain Group of the Tyaughton Trough of the southwest British Columbia mainland.

Depositional Environment of the Kyuquot Group

The lithology of the sediments, together with the character of the fauna, suggest that the Kyuquot Group was deposited on the continental shelf in a neritic environment, i.e. between wave base and 200 m depth. The sediments were laid down unconformably as a clastic wedge on the eroded surface of the Early Jurassic volcanic-plutonic terrane. Their clastic material was derived from these emergent rocks and transported oceanward. Beyond the shelf area, at bathyal depth, sediments of the Pacific Rim Complex may have formed simultaneously, possibly from the same detrital material.

Pacific Rim Complex

Name and Distribution

A highly disturbed assemblage of sedimentary and volcanic rocks of Late Jurassic to Early Cretaceous age is exposed in a narrow coastal strip in Alberni map area and extends northeast into Nootka Sound map area. In an earlier report these rocks were called "Tofino Area Greywacke Unit" (Muller and Carson, 1969) and later they were named "Pacific Rim Sequence" (Muller et al., 1974) and more recently (Muller, 1977) "Pacific Rim Complex". The term "complex" appears to be most appropriate according to the definition of the International Stratigraphic Guide: "a lithostratigraphic unit composed of diverse types of...rock (sedimentary, igneous, metamorphic), characterized by highly complicated structure to the extent that the original sequence of the component rocks may be obscured" (Hedberg, 1976). Most of the complex is exposed in the coastal strip between Barkley Sound and Clayoquot Sound and underlies Vargas, Blunden and Bartlett islands and surrounding islets and reefs in the southeast corner of Nootka Sound map area.

Lithology

The complex is composed of several typical rock assemblages that are believed to have been successive members of the original stratigraphic sequence. The presumed upper member is composed of argillite, greywacke siltstone and sandstone, and some grit units. Predominantly pelitic rocks are generally highly deformed and converted to either schistose rocks or to melanges, but massive, medium- to coarse-grained rocks have, in many places, well preserved bedding and exhibit grading and other textures common to turbidites. Some greywackes contain scattered boulders of sedimentary, plutonic and volcanic rocks, apparently derived from earlier Mesozoic and ?Paleozoic rocks.

Another "member" is composed of grey, green or (rarely) red ribbon chert, in distinct layers 1 to 5 cm thick, parted by argillite laminae and commonly irregularly folded. Chert and limestone pods also occur as minor components in argillite and that lithology invariably displays melange structure. The inferred lower member of the complex contains basaltic pillow lavas with lenses of chert and bedded tuffs and, less commonly, limestone. Considering the limited known exposed width of the complex it is likely that its volume is relatively small, as compared to the similar Franciscan Terrane of California.

Age

Red radiolarian cherts are commonly unmetamorphosed, whereas those with grey, green and black colours are more or less recrystallized and lack well preserved radiolarians. Radiolarian maroon coloured cherts were found on a point of land just east of Ucluelet Inlet (Cape Flattery map area), opposite Food Islets, at 48°55'10"N, 125°29'55"W. They were collected, processed and determined by E.A. Pessagno Jr. of the University of Texas, as follows:

Eucrytidium (?) **ptyctum** Riedel and Sanfilippo
Praceonocaryomma mamillaria (Rust)
Praeconocaryomma magnimamma (Rust)
Hsuium maxwelli Pessagno
Hsuium cuestaensis Pessagno
Hsuium obispoensis Pessagno
Pantanellium riedeli Pessagno
Archaeodictyomitra rigida Pessagno
Parvacingula turrita (Rust)
Paronaella sp.
Spongocapsula palmerae Pessagno
Parvacingula sp.
Emiluvia sp.

According to Pessagno this fauna indicates Subzone 2A (late Kimmeridgian to early Tithonian Stages of the Upper Jurassic) of his radiolarian zonation of the California Coast Ranges (Pessagno, 1977).

In the greywacke-argillite member a few beds composed mainly of **Buchia** shells were found in two locations southwest of Ucluelet and determined by J.A. Jeletzky.

GSC loc. 89780

Field no. 72-11A

Location: Bay on southwest coast of Ucluth Peninsula at foot trail from Ucluelet, lat. 48°56'12"N, long. 125°33'10"W.

GSC loc. 89781

Field no. 72-261

Location: Bay on southwest coast of Ucluth Peninsula, near new residential homes, 0.75 km due south of Ucluelet, 48°56'00"N, 125°32'40"W.

In both locations: **Buchia pacifica** Jeletzky 1965

(a coquina-like accumulation of single valves commonly squeezed into one another)

Age and Correlation. Mid-Valanginian stage, **Buchia pacifica** zone (Jeletzky, 1965, p. 43-49). "The apparent absence of closed or gaping, complete (i.e. double valved) shells could be interpreted as suggestive of re-deposition of fauna either by wave action or by turbidity currents" (Jeletzky's comments).

Thus the paleontological dating indicates a latest Jurassic and earliest Cretaceous age for the middle and upper members of the complex. In addition plutonic cobbles in the greywacke member are most probably derived from Jurassic Island Intrusions. Such clasts appear first in Albian (?) conglomerate of the Queen Charlotte Group, the nearshore sedimentary assemblage that is coeval with the Pacific Rim Complex. On that basis the upper part of the complex may be as young as mid-Cretaceous. On the other hand the lower volcanic part of the complex, in places containing limestone lenses, has lithological similarity to the Vancouver and Bonanza groups and could therefore be Upper Triassic or Jurassic in age.

Origin

Pacific Rim Complex has several aspects in common with the Franciscan complex of California and is inferred to have the same origin. Its lithological categories are very similar although apart from some pillow lavas no bodies of ophiolite have been found. Neither has blueschist metamorphism been noted. The highly deformed or melange structure also is held in common with the Franciscan and the rare **Buchia's** and radiolarians indicate similar age. Thus the writer has in several earlier papers (e.g. Muller, 1977) suggested that the complex is like the Franciscan a slope-trench-ocean deposit that up to early Tertiary time formed part of the subduction zone on the western margin of North America.

Catface Intrusions

Name and Distribution

Small intrusive stocks of early Tertiary age and of general quartz dioritic composition are known in many parts of Vancouver Island. They have been described from Alberni map area (e.g. Mount Washington; Muller and Carson, 1969) and from Alert Bay map area (Zeballos stock; Muller et al., 1974). A few intrude Eocene Metchosin Volcanics of southern Vancouver Island and have been called Sooke Intrusions (Clapp and Cooke, 1917). However, that name is apt to be confused with the Sooke Formation and should be modified. Furthermore the name is also in use for Sooke Gabbro, the plutonic substratum to the Metchosin Volcanics. It is herein proposed to name these intrusions Catface Intrusions, after Catface Range, at and beyond the east border of Nootka Sound map area, just north of Vargas Island.

Only in a few places is it possible to distinguish Catface Intrusions from Island Intrusions on the basis of field relationships. Such is the case at Mount Washington and on Forbidden Plateau in Alberni map area. There a pluton and related sills of quartz diorite and plagioclase porphyry intrude and overlie Upper Cretaceous Nanaimo Group sediments. Elsewhere, including all occurrences in Nootka Sound map area, Catface Intrusions cut Jurassic and older rocks and have to be identified by K-Ar age determinations. The lithology of intrusions of known Tertiary age is somewhat different from that of Island Intrusions and some plutons have tentatively been mapped as Catface Intrusions on the basis of lithology without K-Ar identification. With more detailed work it is probable that several more stocks and sills of Catface Intrusions will be recognized on Vancouver Island.

Tertiary intrusions mapped in Nootka Sound map area are aligned more or less in southwest-northeast direction between the Catface stock, just east of the map area, and the Zeballos stock on its middle northern border. They are:

1. the Flores Island Intrusions, forming a 1.5 km wide belt through the middle of Flores Island (identified at one point by K-Ar age);
2. the Hot Springs Stock, an irregularly shaped body around Hot Springs Cove (confirmed by one K-Ar age);
3. a small body south of the head of Shelter Inlet (not confirmed by K-Ar age);
4. the Hisnit Stock, north of the junction of Tlupana and Hisnit inlets (not identified by K-Ar age);
5. the Perry Lake Stock, southwest of that lake (identified by K-Ar age);
6. the Santiago Creek Stock (not identified by K-Ar age);
7. the Zeballos Stock, shown by Carson (1973, Fig. 2) as extending from southwest of Zeballos River (north of the border of Nootka Sound map area) to Tahsis Valley, but now inferred on the basis of field identification to extend only about half that distance westward.

Lithology and Petrography

The rocks of Catface Intrusions are generally massive, light coloured, fine- to medium-grained equigranular to locally porphyritic granitoid rocks. Commonly they are regularly and closely jointed. Megascopically most are unaltered and show about 10 per cent of small shiny biotite flakes and patches of hornblende, less than 2 mm across in a granular quartz-feldspar aggregate, varying from 2 to 4 mm in size.

The modal compositions, shown in Figure 4C and Table 6, are mainly granodiorite and tonalite, but there also are examples of granite. In most samples plagioclase forms more than one half of the rock. It is subhedral and, as noted by Carson (1973) shows complex oscillatory zoning, varying about 20-55 per cent an., averaging 35 per cent anorthite and with maximum size 2 to 5 mm. Aggregates of finer grained anhedral quartz, with or without K-feldspar, fill the space between plagioclase. K-feldspar is commonly perthitic and cloudy but plagioclase and quartz are mostly clear. Graphic quartz-feldspar intergrowth is not uncommon. Biotite, a few millimetres long, is fresh and little chloritized, green hornblende occurs in small anhedral patches and apatite is a common accessory.

The modes tabulated and figured represent rocks from Nootka Sound map area and include some from Zeballos and Catface stocks, just beyond its border. They seem to be similar to those of Muchalat Batholith, but rocks of the latter extend farther into the granitic field.

Catface Intrusions probably include many dykes of hornblende-feldspar (-quartz) porphyry that intrude pre-Tertiary rocks. However, these cannot, as a rule, be distinguished from similar porphyry dykes associated with Jurassic Bonanza volcanics or Paleozoic Sicker volcanics on the basis of field relationships or lithology. One dyke of porphyry, exposed near the portal of the old Tidewater (Indian Chief)

Mine at Stewarton Inlet was identified by K-Ar determination. It is a light coloured rock, composed of plagioclase to about 2 mm in size and conspicuous dark green hornblende tablets and needles, also to about 2 mm in length. The thin section shows about 30% plagioclase, An_{35-55}, about 1% rounded quartz, and 5% hornblende in a very fine grained matrix (<0.02 mm) of probably plagioclase, quartz and hornblende. There is a considerable alteration to chlorite, epidote and saussurite.

The Zeballos and Catface stocks are related to gold and to copper deposits and have accordingly been examined in more detail than other Tertiary plutons in the area. The Zeballos pluton according to Stevenson (1950) is quartz diorite, a "speckled black and white massive rock" with conspicuous jointing. Exfoliation tends to round sharp joint-angles and gives the rock an easily recognizable hummocky appearance. It is an even, medium grained rock composed of quartz, sodic plagioclase and biotite. Stevenson, although not aware of the considerable age difference between Island and Catface intrusions, had no difficulty in distinguishing the latter from granodiorite of the Jurassic intrusions and was able to map their contact. He noted a lack of "any sign of granulation and recrystallization" in the younger intrusions. At contacts with older rocks quartz diorite exhibits zones of contact breccia consisting of fragments of volcanics and diorite (= dioritized volcanics ?) in a matrix of quartz diorite. Dykes of feldspar porphyry younger than the other intrusive rocks consist of conspicuous phenocrysts of andesine, 3-6 mm long, in a matrix of feldspar, with minor brown hornblende, biotite and quartz. In the Central Zeballos Mine light coloured, fine grained granitic dykes with about equal amounts of andesine and orthoclase with "moderate" quartz are common and locally form the matrix of intrusive breccia. Aplites, composed of quartz and orthoclase, and lamprophyre of andesine, hornblende, biotite and minor quartz, are also mentioned.

At Catface Mountain Northcote (1971) and McDougall (1976) distinguished an early quartz monzonite that is probably part of Jurassic Island Intrusions, intruded by several phases of Catface Intrusions. The "Hecate Bay Quartz Diorite" (tonalite in the classification used in this report) cuts Westcoast Diorite, Sicker volcanics and the quartz monzonite. It is a light coloured, equigranular, medium grained rock with 55 to 65% plagioclase, An_{34-40}, and showing oscillatory zoning, about 10% K-feldspar, about 10 to 15% biotite and hornblende and 20 to 25% quartz. Biotite occurs as well formed small flakes and as interstitial aggregates, perhaps of secondary origin. This rock was dated 48 ± 12 Ma (see below). The "Porphyritic Granodiorite" cuts the same rocks as the quartz diorite and is probably comagmatic with it. It is divided into a "Cliff" and a "Grey" phase, but both have mineral abundances similar to the Hecate Bay quartz diorite and the differences are mainly based on texture. Modal plots of all Catface rocks, as shown by Northcote (1971) coincide closely with those plotted for the present report. Porphyritic dacite of Catface Mountain is similar to that of Indian Chief Mine and probably to that of the Zeballos stock, with a predominant very fine grained ?plagioclase-quartz matrix. It is most highly altered and cross-sections based on drillholes show it to cut all other phases. All rocks of Catface Mountain are characterized by strong oscillatory zoning of plagioclase.

Age and Correlation

The age of Catface Intrusions in Nootka Sound map area was determined by a small number of K-Ar determinations, all by R.K. Wanless and staff of the Geological Survey Geochronological laboratories. The following list of determinations (Table 7) includes two from Catface and Zeballos plutons that were made for and published by Carson (1973); the others are referred to in age determination reports 12 and 13 of the Geological Survey (Wanless et al., 1974, 1978).

Table 6. Modal compositions of Catface Intrusions

Number of Samples		Quartz	Plagioclase	Potash Feldspar	Biotite	Hornblende	Pyroxene	Chlorite	Epidote and Prehnite	Opaque	Accessory minerals	
						GRANITE						
1	Ave.	36.5	33.9	26.1	2.5	0.5	-	-	0.5	-	-	
						GRANODIORITE						
6	Ave.	27.1	50.8	9.6	6.2	4.2	-	1.1	0.5	0.4	0.1	Apatite
	Min.	21.6	40.8	6.3	4.6	1.1	-	-	-	-	-	
	Max.	38.3	56.0	12.9	7.7	7.9	-	3.2	2.5	1.2	0.4	
						TONALITE						
6	Ave.	27.3	56.7	1.2	10.2	3.0	-	0.9	-	0.3	0.4	Apatite
	Min.	24.0	54.8	-	7.2	-	-	-	-	-	-	
	Max.	30.1	60.0	4.2	12.2	5.0	-	1.8	-	0.4	0.7	

Table 7. Potassium-argon age determinations of Catface Intrusions

Sample No.	Mineral	Location	%K	%Ar	Rock type	Age
GSC 65-12	Biotite	Central Zeballos Mine 50°02'07"N 126°47'04"W	4.28	56	Quartz diorite	38 ± 14
GSC 76-15	Biotite	1/2 mile NW of Malaspina Lake 49°51'45"N 126°34'25"W	7.35	69.9	Quartz diorite	33.8 ± 2.1
GSC 76-16	Hornblende	As above	0.517	40.1	Quartz diorite	38.0 ± 2.8
GSC 73-4	Hornblende	Near Portal, Indian Chief Mine 49°26'50"N 126°18'35"W	0.204	17.4	Hornblende-plagioclase porphyry	42.1 ± 7.0
GSC 73-6	Biotite	Sydney Inlet, west side, small cove 49°24'25"N 126°16'25"W	6.92	70.0	Granodiorite	36.6 ± 2.1
GSC 73-5	Hornblende	As above	0.480	30.1	Granodiorite	32.5 ± 3.9
GSC 73-7	Biotite	Flores Island, west coast 49°22'25"N 126°13'50"W	4.98	54.5	Granite	35.1 ± 2.1
GSC 65-11	Biotite	Catface Peninsula 49°14'35"N 125°57'00"W	7.35	73	Quartz diorite	48 ± 12

The table includes two hornblende-biotite pairs. Within the 95% confidence level the Malaspina Lake age is slightly discordant and the Sydney Inlet age is concordant. In general, the spread between 38 and 48 Ma appears to represent at least in part a real difference of cooling ages that according to present standards would encompass late Eocene to early Oligocene age. It should be noted that late Eocene to Oligocene Carmanah Group sediments have nowhere been found in intrusive contact with Catface Intrusions. If the Oligocene age (<40 Ma) of most of the determinations is indeed the same as that of the sediments, intrusive activity occurred simultaneously with uplift, erosion and deposition of Carmanah sediments. Furthermore, in that case the intrusions apparently did not reach the surface to produce any volcanic activity.

Mode of Origin and Emplacement

Whereas the origin of Jurassic Island Intrusions can be credibly related to the process of migmatization of pre-Jurassic rocks into the Westcoast Complex and to Bonanza volcanism, such fairly obvious relationships are lacking for Catface Intrusions. Carson (1973, Figure 4) showed that Tertiary intrusions on Vancouver Island are aligned in three belts, radiating southeast, northeast and northwestward from the Tofino to Catface Range area. No major fault zones or other structural lineaments can be identified at the surface to explain these belts, but perhaps they represent major fractures of the lower lithosphere. In the Sooke region of southern Vancouver Island no pre-Tertiary crustal rocks are present. There it is inferred that small plutons of quartz diorite were generated by differentiation of late phases of basaltic magma, the source of Eocene Metchosin basalts and Sooke Gabbro. It is here suggested that quartz diorite magma was generated in a similar manner in or below the deeper pre-Tertiary crust and forced up through crustal zones of weakness to form the relatively small cupolas, dykes and sills of Catface Intrusions. It would seem probable that they manifested themselves locally as volcanic cones but it must be admitted that evidence for this is lacking in presently known Eocene and Oligocene deposits.

Carmanah Group

Nomenclature

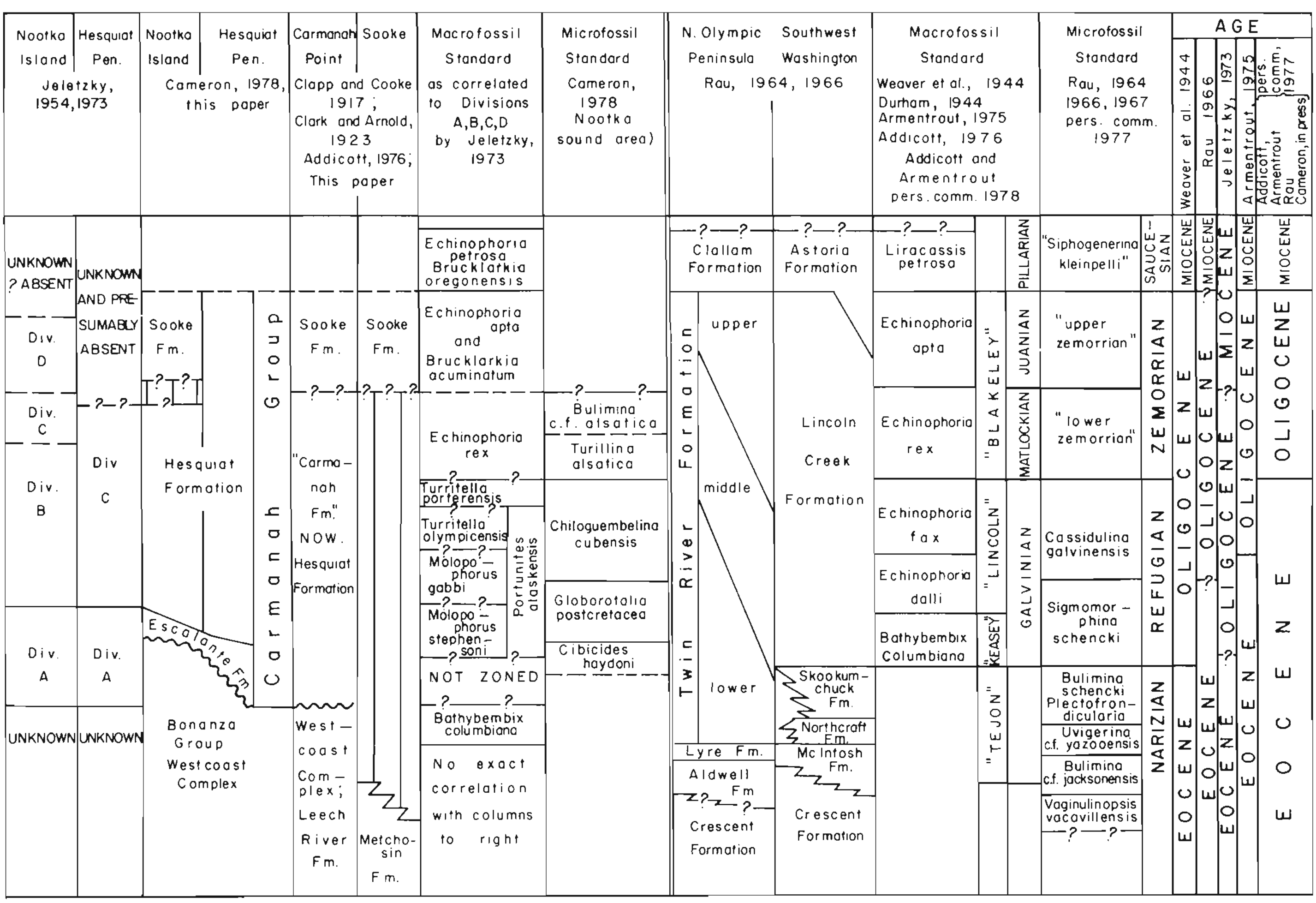
Tertiary sediments have been known on the southwest coast of Vancouver Island since macrofossils, collected by Dr. F.C. Newcombe of Victoria, were described by Merriam (1896). Merriam recognized an older fauna in a collection from Carmanah Point and a younger one from the Sooke District, but considered both to be Miocene. Since then the Tertiary strata of the Carmanah and Sooke areas of southern Vancouver Island have been studied several times and the names Carmanah Formation and Sooke Formation have been used in many publications. Only the Sooke Formation however was defined by type section (Clark and Arnold, 1923, p. 129).

The Tertiary formations of the Nootka Sound map area have been studied more recently by J.A. Jeletzky and B.E.B. Cameron of the Geological Survey and the names Escalante Formation, Hesquiat Formation and "Division D" (=Sooke Formation) have been employed. Unfortunately these latter detailed studies did not include Tertiary rocks of the "classical" Sooke and Carmanah areas although almost complete time equivalence is apparent (Table 8). In this report the existing formational names are used in a slightly modified and generalized sense that should be useful and adaptable to further work.

Clapp (1912) mapped "Carmanah and Sooke Formations" as one map unit of Oligocene-Miocene marine sediments, exposed along the southwest coast of Vancouver Island. Later he collected fossils at many localities "from the Sooke Formation and from the so-called Carmanah Formation" (1917, p. 336-339). These were identified by C.E. Weaver (in Clapp, 1917), who concluded that they indicated a Miocene age and that "the Carmanah Point beds could be slightly older than those from Sooke". Clark and Arnold (1923), in their detailed study of the fauna of the Sooke Formation, observed the following: "The most conclusive evidence of the stratigraphic position of the Sooke Formation was obtained from the Oligocene beds in the vicinity of Carmanah Point ... to the south of Carmanah Point lighthouse. A typical Lincoln fauna was found in the lower part of the section, while the Blakeley fauna was found throughout the upper portion. Heavy conglomerates separate the beds containing the faunas. Two localities near the top of the section are of special interest because of the interfingering of the typical Blakeley and Sooke faunas". Weaver (1937, 1942) mentioned the Carmanah beds briefly in text and a chart, but the Carmanah Formation is not shown in the "Correlation of the Marine Cenozoic Formations of Western North America" (Weaver et al., 1944). Jeletzky (1954), in the first more detailed study of Tertiary stratigraphy of Vancouver Island, stated that "the Carmanah Formation apparently corresponds with all the Tertiary division of the Hesquiat-Nootka area with the sole exception of Division D of Nootka Island". In a later paper (1973, p. 343) he used "Carmanah Group" overlain by "Sooke Formation" for the south Vancouver Island Tertiary beds (Table 8).

In 1973 P.D. Snavely Jr., N.L. McLeod and J.E. Muller made collections of macrofossils and samples for microfaunal analysis at Carmanah Point below and within the above-mentioned conglomerate noted by Clark and Arnold. Identifications by W.W. Rau (personal communication to P.D. Snavely Jr., 1973) and one of the authors (B.E.B. Cameron) indicate Refugian to Zemorrian age for siltstone below the conglomerate and a siltstone-clast within it. Macrofossils from the conglomerate are, according to W.O. Addicott (personal communication, 1978) like those of the Sooke Formation and of "latest Oligocene age". Thus it appears that both middle and late Paleogene strata, perhaps separated by a minor unconformity with mixed and partly reworked fossils, are present at Carmanah Point. Accordingly it seems reasonable to use "Carmanah Group" to represent the entire sequence of Tertiary strata of south and west Vancouver Island. The Escalante, Hesquiat and Sooke formations are considered to be upward successive formations of the Carmanah Group and will be dealt with consecutively in the following sections.

Table 8. Correlation of Tertiary formations of Vancouver Island and Western Washington



Escalante Formation

Name

Bancroft (1937) first mentioned "the oldest Tertiary sediments thus far found on Vancouver Island" as "coarse conglomerates with rounded pebbles of the Vancouver Group" outcropping at Escalante Point, on the northwest coast of Hesquiat Peninsula. His table of formations identified the conglomerate as "Escalante". Jeletzky (1954) described the basal beds of the Tertiary succession as Division A or (Table of Formations) Escalante Formation. Subsequently Cameron (1971) used the name informally and Jeletzky (1975b, p. 10) substituted Escalante Formation for this Division A. Cameron (in press) called the Escalante Formation the basal unit of the Tertiary succession and in this paper it is further identified as the basal unit of the Carmanah Group. It unconformably overlies pre-Tertiary rocks, is composed of sandstone with minor conglomerate lenses, and is in gradational contact with the overlying Hesquiat Formation. The type section is at Escalante Point (Jeletzky, 1975b) and is about 140 m thick.

Distribution and Lithology

The Escalante Formation is present in all exposed Tertiary sections of Nootka Sound map area from Flores Island in the southeast to Tatchu Point in the northwest. It consists mainly of sandstone and relatively minor conglomerate, the latter concentrated mainly at the base. Just northeast of Escalante Point a basal conglomerate, about 1 m thick, lies on dioritized metavolcanic rock of the Westcoast Crystalline Complex; the surface of the unconformity exhibits a relief of more than one metre. The conglomerate contains pebbles and locally boulders, up to about 50 cm in size, of dioritic and metavolcanic rock. This basal conglomerate is exposed in three places: one in the reef at the southwest end of the sandy beach south of Escalante River, again by fault repetition, in the cliffs that terminate westward in Escalante Point, and finally repeated once more on the eastern edge of Escalante Island. The conglomerate of Escalante Point is overlain by 7.5 m of medium- to coarse-grained pebbly grit, overlain in turn by another 2 m bed of conglomerate with boulders up to about 15 cm in size. The succeeding beds, about 130 m in thickness, are fine grained to gritty, grey-green, light brownish grey weathering partly calcareous sandstone, in beds 10 cm to 1 m thick. The sandstone locally contains lenticular beds of shelly pebble conglomerate and also abundant calcareous nodules and spherical concretions, about 10 cm in size and commonly containing plant debris.

On the east side of Hesquiat Peninsula the basal Tertiary unit is exposed in two places north of LeClaire Point, due to a fault repetition. There, about 30 m of conglomerate, overlain by about 60 m of slightly calcareous sandstone are in evidence. The conglomerate contains some boulders of biotite granodiorite together with preponderant dioritized metavolcanics. Further southeast the Escalante Formation is poorly exposed in the vicinity of Hesquiat Point and may be in fault contact with the basement rocks. The coastal stretch south of Kanim Lake however exposes about 30 m of lenticular conglomerate and sandstone overlain by 60 m of calcareous sandstone. Escalante rocks are discontinuously exposed on Flores Island between Dagger Point and Siwash Cove and typically contain little or no conglomerate in approximately 50 m of sandstone.

On Nootka Island the Escalante Formation rests unconformably on amphibolite of the Westcoast Crystalline Complex. There, approximately 150 m of slightly calcareous sandstone and grit with interbedded silty and shaly sandstone and rare pebble conglomerate is exposed. At Tatchu Point about 50 m of calcareous, shelly sandstone with minor basal conglomerate is exposed above the unconformity.

Age and Correlation

Fossil collections from the Escalante Formation have been assigned either an Eocene or Oligocene age by various workers since Bancroft first examined the sequence. Kellog (in Bancroft, 1937) suggested a late Eocene or possibly an early Oligocene age for the formation on the basis of a fossil whale vertebra. Subsequent datings of these rocks by Jeletzky (1954, 1973, 1975b) using fossil mulluscs and crabs and Cameron (1971, 1972, in press) using foraminifers have resulted in assignments to the west coast Lincoln molluscan "stage" and the Refugian (possibly Narizian in type section Escalante Formation only) foraminiferal stage respectively. These age assignments are in essential agreement in west coast terms but their correlation with international standards (Eocene and Oligocene) has been a subject of controversy (Table 8). Traditionally, the Lincoln molluscan faunas have been assigned to the Oligocene (Weaver, 1937, 1942; Weaver et al., 1944, and others). Accordingly, Jeletzky (1975b) dated the Escalante Formation as early to middle Oligocene. The Californian Refugian foraminiferal stage (Schenck and Kleinpell, 1936) has been assigned by various authors (see Cameron, in press) to the late Eocene or early Oligocene. Cameron (op. cit.) recognized an early Refugian equivalence in the Escalante foraminifers and consequently assigned a late Eocene age.

More recent research in the northwestern United States both on the basis of molluscs (Addicott, 1976; Armentrout, 1975, 1977) and foraminifers (Rau, 1958, 1966, 1967) favours placing the Eocene/Oligocene boundary at the top of the Refugian foraminiferal stage and at the top of the Lincoln molluscan "stage" (=middle and upper Galvinian molluscan stage of Armentrout, 1975).

The suggestion by Cameron that the type section of the Escalante Formation may be older than in other areas is based on his recognition of the **Cibicides haydoni** zone only in the type area (Cameron, in press). Foraminifers collected from all other Escalante rocks are somewhat younger. On the other hand, Jeletzky's molluscan collections and subsequent age determinations are from rocks other than the type section (i.e. east side of Hesquiat Peninsula (Jeletzky, 1975b) and Nootka Island (Jeletzky, 1973)). The diachroneity suggested by Cameron (1973) for the Escalante Formation is apparently not evident from the molluscan faunas but has been challenged on the basis of lithostratigraphy and superpositional relationships (Jeletzky, 1975b, p. 15).

Depositional Environment

Various opinions have been expressed by Jeletzky (1973, 1975b) and Cameron (1971, 1980) concerning the environment and depth of deposition of the Escalante Formation. Cameron (op. cit.) interprets the faunas of the upper part of the type Escalante Formation to be indicative of outer neritic to upper bathyal water depths. Foraminiferal assemblages from other localities however (e.g. Nootka Island, Cameron, 1971) are suggestive of entirely bathyal water deposition. Jeletzky on the other hand (1973, 1975b) interprets the molluscan faunas from the Escalante Formation of both Nootka Island and Hesquiat Peninsula to be littoral to supratidal and inner neritic at the base and inner neritic or outer littoral in upper parts of the formation. Thick-shelled, shallow water pelecypods are preferentially concentrated in lenticular pebble conglomerate in the basal beds of the type Escalante Formation and in other localities. Their reliability as indicators of original depositional environment is therefore questionable as at least some degree of transport is suggested. A more detailed discussion of palaeoenvironment is given by Cameron (1980) to which the reader is referred.

Hesquiat Formation

Name

In his first report on the Tertiary sediments of Nootka Sound map area Jeletzky (1954) distinguished Divisions A, B, C and D as provisional map units. Division A was the basal conglomerate-sandstone unit of all sections (=Escalante Formation). The thick units overlying Division A he called Division B on Nootka Island and Division C on Hesquiat Peninsula. His reason for erecting two separate but roughly coeval units only 25 km apart was their highly contrasting lithology: the Hesquiat section contained several resistant sandstone-conglomerate members, alternating with shale, whereas the Nootka section was composed almost entirely of shale. On the basis of similar mollusc and fossil crab faunas Jeletzky (1954, p. 58) concluded that all the beds of Division B of Nootka Island were contemporary with the lower and middle part of Division C of Hesquiat Peninsula. He recognized a thin Division C lithology on Nootka Island, overlying Division B. Correlation between Division C rocks of Nootka Island and Hesquiat Peninsula was based on their being "lithologically indistinguishable" (1954, p. 25) for no fossils were found in the former. Division C of Nootka Island, exposed on the tidal flats and reefs near Bajo Point, is composed of much faulted shale and sandstone and is in fault-contact with Division B. Its correlation with Division C of Hesquiat Peninsula was questioned by Cameron (1971, p. 92) who identified a Miocene microfauna at Bajo Point contrasting with the Eocene-Oligocene age of Hesquiat Peninsula beds.

The definition of Division C was transferred in 1975 to a newly named Hesquiat Formation as follows (Jeletzky, 1975a, p. 2): "The formal name Hesquiat Formation is proposed here for the sequence of rocks previously described informally by Jeletzky (1954, p. 19-21, 25-27) as Division C. The name is derived from the Hesquiat Peninsula where the typical facies of the formation is best exposed and reaches maximum thickness. The known geographical extent of Hesquiat Formation (i.e. of Division C) on the west coast of Vancouver Island has been discussed previously by Jeletzky (1954) and is represented graphically on two geological maps." Reference to the 1954 publication shows that the Hesquiat Formation would be limited to the Tertiary shale-sandstone-conglomerate formations of Hesquiat Peninsula, Hesquiat Point, Flores Island and the small reef-area off Bajo Point. Coeval strata on Nootka Island and Tatchu Point would presumably be excluded but no new formational name was proposed for these rocks. Cameron (1980) has included both the Nootka Island and Hesquiat Peninsula lithofacies in the Hesquiat Formation. A redefinition of the Hesquiat Formation is as follows:

"The Hesquiat Formation is the thickest part of the Carmanah Group of Tertiary sediments presently known on Vancouver Island. It includes all sequences of clastic rocks (composed either of mainly shale, or of alternating shale, and sandstone-conglomerate units) that lie on the Escalante Formation or on the pre-Tertiary unconformity, and at Bajo Point is inferred to be unconformably overlain by the Sooke Formation." The age of the formation as presently known ranges from late Eocene to early or middle Oligocene (Cameron, 1980). Coeval strata on the west coast of the United States contain fossils correlated with the provincial Refugian and early Zemorrian foraminiferal stages and the Galvinian and Matlockian molluscan stages.

Distribution, Lithology and Thickness

The Hesquiat Formation is exposed throughout the Nootka Sound map area. It underlies the coast and lowlands of Flores Island, almost all of Hesquiat Peninsula, the southwest coast and lowlands of Nootka Island and, in the northwest Tatchu Point. Two contrasting lithofacies are readily recognizable within the Hesquiat Formation. The distal facies (Cameron, 1980) is best exposed on Nootka Island (Division B of Jeletzky, 1954). The proximal facies is represented in the type section of the Hesquiat Formation on the west side of Hesquiat Peninsula.

On Nootka Island, the Hesquiat Formation conformably overlies the sandstone, shale and conglomerate of the Escalante Formation. The sequence there consists of a monotonous sequence of grey, thinly bedded, fissile to blocky, calcareous silty shale. The shale is sparsely interlayered with thin beds, a few centimetres thick, of rusty weathering, undulatory claystone and rare siltstone, and fine grained sandstone, and with rows of siltstone concretions especially near the base. Pyrite or marcasite nodules are common throughout. A thickness of some 600 m of shale in a section north of Calvin Creek (Skuna Bay and adjacent tidal flat) and 1200 m in a section from Beano Creek to Bajo Point is reported by Cameron (1980).

The type section of the Hesquiat Formation was described in detail by Jeletzky (1954, 1975a), who distinguished seven "shale-clayey sandstone members", alternating with seven "resistant sandstone-conglomerate members". The total thickness was estimated to be close to 3050 m (Jeletzky, 1975a). Cameron however (1980) suggests a thickness closer to 1100 m for the type Hesquiat Formation and on the basis of foraminiferal zones and lithologic sequence was able to show extensive fault repetition throughout the section to explain this thickness discrepancy.

Lithology of the shale-siltstone units of the type Hesquiat Formation is similar to that of the Nootka Island section but generally they contain a greater proportion of fine grained sandstone. These beds consist of interbedded grey shale, sandy shale, and light brown to buff, laminated sandstone. The shale, about 2 to 20 cm thick, forms the bulk of these units and the sandstone, commonly lenticular and varying from a few centimetres to about 1 metre, do not collectively exceed one quarter of the entire thickness of the section. The shales contain irregularly aligned calcareous ironstone nodules, scattered marcasite nodules, wood fragments and carbonaceous material. The resistant sandstone-conglomerate units are composed mainly of fine grained to gritty sandstone with lenses of conglomerate containing in some instances small pebbles but in other places well rounded cobbles of plutonic and volcanic rock and reworked sandstone, up to about 10 cm in diameter. Large load-casts and rip-up shale clasts are common at the base of the conglomerate but features like coarse crossbedding and festoon-bedding are absent. Pebbly mudstones occur throughout the section and are usually represented in highly churned and contorted areas. The implications of these sedimentary structures as pertaining to depositional environment is discussed in more detail by Cameron (1980).

Age and Correlation

The age of the Hesquiat Formation is well documented by the contained faunas of foraminifers, molluscs, crabs, and a few vertebrate fragments (Cameron, 1980; Jeletzky, 1954, 1973, 1975a). As with the Escalante Formation, these authors do not disagree substantially on the correlation with west coast provincial molluscan and foraminiferal stages but interpret the equivalence to European standards (i.e. Eocene and Oligocene) differently. Thus Jeletzky's (1975a) age assignment of "Lincoln" and Lower "Blakeley" for the Hesquiat Formation do not differ greatly from Cameron's (1971, 1980) Refugian and early Zemorrian correlations. Cameron places the Eocene/Oligocene boundary at the top of the Refugian foraminiferal stage (i.e. top of the Lincoln molluscan "stage" or top of the Galvinian molluscan stage of Armentrout, 1975). Jeletzky (op. cit.) followed the older interpretations (Durham, 1944; Weaver et al., 1944, and others) and placed the Eocene/Oligocene boundary below the base of the Lincoln "stage".

Depositional Environment

Like the Escalante Formation, the depositional environment of the Hesquiat Formation has been interpreted in different ways by Jeletzky (1954, 1973, 1975a) and Cameron (1971, 1972, 1975, 1980). Jeletzky interpreted his molluscan fossils to be indicative of predominantly neritic water depths while Cameron assigned the whole sequence to bathyal water depths on the basis of foraminifers, sedimentary relationships and sedimentary structures. Cameron (1980) further suggests that at least some of the molluscs listed by Jeletzky have been reported from substantial water depths. Modern molluscan distribution as a basis for molluscan paleobathymetric interpretation is not well known (Armentrout, personal communication, 1978). It is perhaps significant to note that both foraminiferal and molluscan faunas analogous to the Hesquiat Formation (Lincoln Creek Formation of southwest Washington) are currently being interpreted by other west coast workers as wholly bathyal water assemblages (Armentrout, 1975).

Sooke Formation

Name and Definition

The name Sooke Formation appears to have been used first by Clapp (1910). Referring to the Tertiary formations of the west coast of Vancouver Island he credited Merriam (1896) for subdividing them into Carmanah and Sooke formations on paleontological evidence. Merriam only referred to "Sooke fauna" and "Sooke beds", which he considered to be of "middle Neocene age". Clapp and Cooke (1917) described the Sooke Formation and included a detailed section, measured along Kirby Creek and the shoreline to the east of its mouth. Subsequently Clark and Arnold (1923) gave a detailed account of the Sooke fauna and named Clapp's published section as its type section. Since then the formation has been referred to in many other papers (e.g. Weaver et al., 1944; Russell, 1968; Jeletzky, 1973).

Distribution and Lithology

In the type area the Sooke Formation lies directly on early Eocene Metchosin Volcanics. In the Nootka Sound map area the formation has been identified only in tidal flats and reefs off Bajo Point, Nootka Island (=Division D of Jeletzky, 1954).

The Sooke Formation at Bajo Point is composed of one (or more?) units of pebble conglomerate and coarse gritty sandstone, and includes volcanic, intrusive, shale and sandstone pebbles. The upper 10 m of the exposure consists of light grey to green, calcareous, fine- to medium-grained sandstone. The upper sandstone beds are crossbedded, partly laminated, and carbonaceous; fossil molluscs are abundant. The section is severely faulted but the total stratigraphic thickness of the formation at Bajo Point appears to be approximately 20 m. Contact relationships with the underlying Hesquiat Formation are uncertain but there is some evidence of an unconformity within a low weathering, 1 m thick shale unit below the Sooke.

Age and Correlation

Samples of the rich fossil molluscan fauna were collected and identified by Jeletzky (1954, 1973) who remarked on their close similarity to faunas of the type Sooke Formation. His suggested correlation with rocks of northwestern Washington was to units carrying the Upper Blakeley "stage" molluscs and specifically the **Echinophoria apta** zone (Durham, 1944). At the time this zone was referred to the lower Miocene internationally. More recent work (Armentrout, 1975; Addicott, pers. comm., 1977) favours the placement of the Upper Blakeley molluscan faunas in the late Oligocene.

Meagre foraminiferal collections from the Sooke rocks at Bajo Point enabled Cameron (1971) to suggest a Miocene or Pliocene age for these deposits. It is now concluded that these assemblages are facies-bound shallow water forms and their stratigraphic position is somewhat uncertain. Accordingly, the Bajo Point foraminifers are presently under review along with a detailed study of the type Sooke faunas.

Depositional Environment

Well-sorted conglomerate and sandstone of the Sooke Formation, unlike the unsorted slump-conglomerates of the Hesquiat Formation, suggest shallow water and possibly wave-action. Jeletzky (1973, p. 358) cites prevalence of burrowing pelecypods and abundance of ornamented gastropods as indicating littoral environment. Shells occur in coquina-like beds but are well preserved, indicating only slight wave action. Cameron also (1971, p. 93) found shallow water foraminifera in the Nootka Island Sooke Formation. A similar nearshore facies also characterizes the type Sooke Formation of southern Vancouver Island.

Boulder Conglomerate of Flores Island

An unusual conglomerate is exposed at one place on a small islet just off the west coast of Flores Island, 2.1 km north of Dagger Point. The conglomerate unconformably overlies red volcanic breccia and tuff and laminated silty argillite of the Bonanza Group. It is composed of tightly packed fairly well rounded boulders, up to about 25 cm in size, of altered light green volcanic rocks of intermediate composition. Although it does not resemble any other known Tertiary rocks the conglomerate is tentatively assigned a Tertiary age.

Regional Correlations

Rocks assigned to the Carmanah Group are discontinuously exposed in outcrops along the west coast of Vancouver Island from Tatchu Point in the north to the Sooke area to the south. Beds of similar age are present offshore in the Tofino Basin but have not been reported north of Brooks Peninsula (Tiffin et al., 1972).

Late Eocene and Oligocene (Refugian and Zemorrian) beds are widely distributed along the coasts of Washington and Oregon. Partial or complete time equivalents of the Carmanah Group are the Twin River Formation of the northern Olympic Peninsula of Washington (Rau, 1964) and the Lincoln Creek Formation of southwestern Washington (Beikman et al., 1967). The Refugian part of the Carmanah Group is coeval with the Quimper Sandstone and Marrowstone Shale of Puget Sound area, Washington (Armentrout and Berta, 1977). To the south, Refugian and Zemorrian rocks are represented in the Alsea Formation (Snavely et al., 1975), the Eugene Formation and the Keasy Formation of Oregon. In Washington and Oregon the formations consist predominantly of tuffaceous siltstone, massive or concretionary mudstones and sandstones. They are most similar to the Carmanah Group beds of Nootka Island but do not appear to contain the conglomeratic proximal facies of the Hesquiat Formation on Hesquiat Peninsula. The type Hesquiat Formation therefore represents a relatively uncommon facies along the west coast of North America as far as is presently known.

STRUCTURE

General Statement

The geological structure of Nootka Sound map area is mainly the result of block faulting. Paleozoic Sicker Group bedded volcanic and sedimentary rocks, less metamorphosed and better exposed in other parts of Vancouver Island, are deformed into asymmetric and locally isoclinal shear folds. However, the folding apparently did not affect Mesozoic formations and appears to have preceded deposition of the late Paleozoic Buttle Lake Formation. Apart from local syndepositional folding and the intense deformation of the Pacific Rim Complex, Mesozoic and Tertiary formations are mainly block-faulted. The synclines and anticlines reported by some authors are generally shallow troughs and domes that reflect slight warping of the underlying crystalline crust.

An essentially monoclinal, southwest dipping succession of Vancouver and Bonanza Group rocks, in places on a base of Sicker Group rocks in the northeast is exhibited in the Karmutsen Block of Alert Bay map area (Muller et al., 1974). This structure, obscured by faults and intrusions, extends into the northern part of Nootka Sound map area. On its east side the monocline is cut off obliquely by the north-northwest trending Muchalat Batholith and in the west the Bonanza Group rocks are intruded by Ehatisaht and Sydney batholiths, which strike northwesterly, more or less parallel with the volcanic rocks. Vancouver Group, Bonanza Group and Island Intrusion rocks occupy the larger, inland, northeastern part of the map area and are affected mainly by northerly and westerly trending faults. Formations in the coastal area are cut mainly by northwesterly, and less importantly by northeasterly trending faults.

The faults are invariably steep and may have vertical as well as transcurrent offsets that in most instances cannot be determined due to a lack of marker beds. Flat intertidal and a few stream exposures are the only places where faults, marked by zones of shattered rocks tens to a few hundred metres wide, can be observed. Jeletzky (1954) and Cameron show on their detailed maps a multitude of small faults in Tertiary sediments, exposed on the tidal flats of Hesquiat Peninsula and Nootka Island. The abundance of visible faults in these good exposures of the youngest rocks in the area indicates that faulting is widespread throughout the entire region.

Because faults are narrow linear belts of shattered rocks they have a major influence on groundwater circulation, erosion and the topography. Thus major steeply dipping faults are generally occupied by prominent valleys, inlets and lakes and by conspicuous gullies where they intersect mountain ranges. As a consequence, most faults are covered by superficial deposits or water. Faults shown on the accompanying geological map are largely based on interpretation of aerial photographs and available topographic maps. It is the principal writer's experience that wherever bedrock is exposed faults inferred from topographic lineaments can commonly be observed in the field. He has therefore chosen to show a fairly dense fracture pattern of probable faults rather than to mark only those fragmentary fault traces that have actually been identified by shear zones, a method adopted by many other workers.

The network of faults displayed in the Nootka Sound area map, like that of other parts of Vancouver Island, is chaotic at first sight. It can perhaps be explained as the superposition of two or more fracture patterns, each with characteristic directions and of different age and origin.

North-trending Faults

Most prominent are the north to north-northwest trending faults. The Tahsis fault can be traced from the Pacific coast near Nootka along Tahsis Inlet to the north border of the map area and continues as Woss and Bonanza faults (Muller et al., 1974) to Johnson Strait. Just west of, and apparently branching off the Tahsis fault, the Hecate Channel fault trends north-northwesterly to northerly up Friend Creek, the north tributary of Little Zeballos River. It is probably cut off by the Tertiary Zeballos pluton but appears to continue north of the intrusion in Alert Bay map area as the North Zeballos River fault, described in some detail by Gunning (1933, p. 35, 36), Stevenson (1950, p. 38) and Hoadley (1953, p. 42). The Zeballos fault continues into the Nimpkish fault to Broughton Strait. Another pair of subparallel northerly faults are the Espinoza and Port Eliza faults. They probably join in Nuchatlitz Inlet and continue south via the tidal inlet one kilometre east of Ferrer Point. Northward in Alert Bay map area they seem to be cut off or offset by easterly trending faults, but perhaps their continuation is the Tahsis – Benson River fault system. Finally, the Saunders Creek fault, in the northeast corner of the map area east of Gold River, continues north in the White River fault system.

The northerly set of faults may well be early Mesozoic. It affects Sicker and Vancouver groups but is entirely lacking wherever these rocks are intruded by Jurassic batholiths. The Hecate Channel – Zeballos – Nimpkish fault system is clearly interrupted by the Zeballos pluton. It is here suggested that this fault system was the result of a stress condition that prevailed during and/or directly after deposition of the Vancouver Group in Late Triassic to Early Jurassic time and was disrupted by Early Jurassic plutonism. The sense of these faults has not been established and may be a combination of strike- and dip-slip movement.

East-trending Faults

Easterly, east-northeasterly and west-northwesterly faults are prominent throughout the central Jurassic batholith of Vancouver Island, composed of the Bedwell Batholith in Alberni map area, the Muchalat Batholith in Nootka Sound map area and the Vernon and Bonanza-Nimpkish batholiths in Alert Bay map area. In Nootka Sound map area the most notable are the Muchalat River and Muchalat Inlet faults. These are clearly structures inherent to the Island Intrusions and may have formed as major fractures related to the cooling of the batholith in Jurassic time. Again, sense of movement on these faults is unknown.

Northwesterly Faults

One or more northwesterly faults follow the main Pacific coast line and locally exhibit a wide zone of crushed and shattered rocks. The fault zone consists of two or more parallel strands and has been named Westcoast fault (Muller et al., 1974; Muller, 1977). It passes from the head of Brooks Peninsula through Kyuquot to the southwest side of Union Island where it disrupts Triassic strata. South of Kyuquot Channel it forms the brecciated rocks of Brecciated Point and Mushroom Point (see Figure 5 and Jeletzky, 1950), and probably passes inland up Porritt Creek. Other strands form the brecciated zones in the bay south of Tatchu Point, at Yellow Bluff and at Peculiar Point and the north and south sides of Catala Island. South of Tatchu Point the brecciated zone is overlain unconformably by undisturbed conglomerate and sandstone of the Carmanah Group with a late Eocene foraminiferal assemblage. The faulting affects late Jurassic sediments and can thus be dated as late Jurassic to possibly early Eocene. South of Ferrer Point the main fault zone may run west of the coastline or could be covered by Carmanah beds at Bajo Point. A shear zone is exposed in the pre-Tertiary rocks south of Bajo Point and some northwesterly faults also cut the Tertiary sandstones. Several parallel faults are present farther northeast on Nootka Island. On Hesquiat Peninsula several northwesterly faults offset mainly southwest dipping Carmanah beds. Repetition of exposed sections indicate uplift on the southwest side of the faults. Faults also cut through the southwest side of Flores Island and from there the fault zone appears to continue along the north coast of Vargas Island. In Alberni map area it leads into the Westcoast fault zone that separates the Pacific Rim Complex to the southwest from the Westcoast Complex to the northeast. It should be noted that the northeastern limit

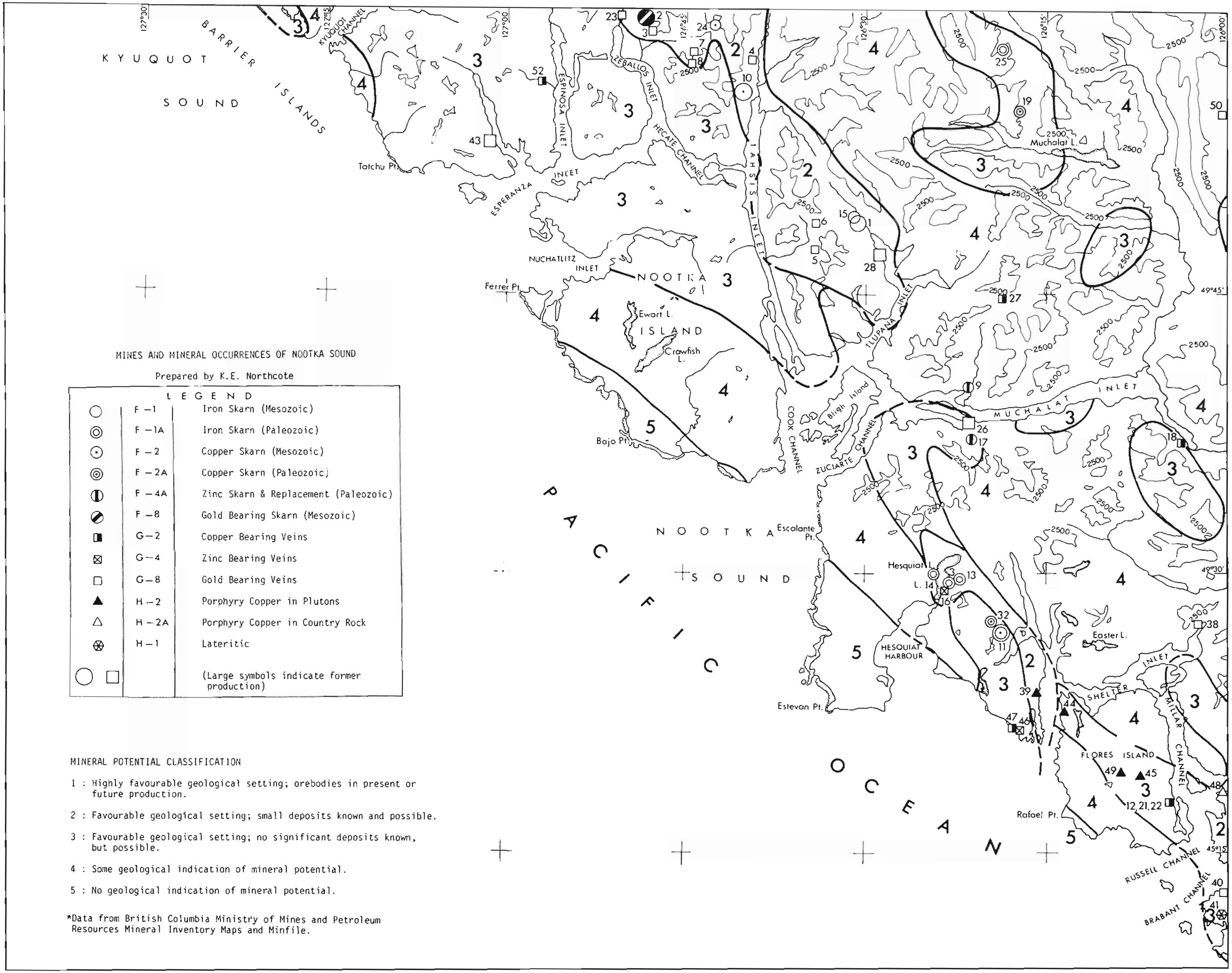


Figure 6. *Map of metalliferous deposits and showings and mineral potential map.*

of Tertiary sediments, although commonly close to the Westcoast fault, does not generally coincide with it. For instance at Escalante Point the Escalante Formation lies unconformably on Westcoast Complex rocks. Some 600 m to the southwest of the unconformity a narrow strip of pre-Tertiary rocks is uplifted along a northwesterly fault that is probably a strand of the Westcoast fault. The repeated Westcoast rocks are overlain by Escalante conglomerate a short distance to the southwest.

It has earlier been suggested (Muller, 1977) that the Westcoast fault zone is the locus along which, in late Mesozoic to early Tertiary time, the Pacific Rim Complex was thrust beneath the early Mesozoic to Paleozoic crust of Vancouver Island. That underthrusting may have occurred in an oblique right-lateral direction, as the Pacific Plate moved north with respect to the North American Plate. In late Eocene time the subduction zone is believed to have shifted westward but subsequently parts of the fault system may have been reactivated as normal faults. Possibly some north trending faults were reactivated as well, offsetting the Westcoast system.

Northeast-trending Faults

Northeast trending faults are generally short and are mainly confined to the coastal areas. The Brooks Peninsula Fault Zone of Alert Bay map area is the most extensive northeasterly fault system. It is apparently related to minor late Tertiary volcanism. In Nootka Sound map area many small faults offsetting Tertiary sediments belong to the northeasterly set and these are therefore of Tertiary age. A few other northeasterly faults cutting pre-Tertiary rocks and some northwesterly faults in the coastal areas may have formed in the same period.

ECONOMIC GEOLOGY

Introduction

Metalliferous deposits within Nootka Sound map area include most of the types of mineral deposits known on Vancouver Island, as classified by Carson (in Muller and Carson, 1969). A few of these have been producers but at present there are no producing mines. Two abandoned mines and one potential mine (Zeballos, Privateer, and Catface) are just outside the map area.

Data for mineral showings are taken mainly from "BCDM Minfile", a computerized mineral deposit inventory, operated by British Columbia Systems Corporation. Other sources of data are publications by the British Columbia Department of Mines and Petroleum Resources, by the Geological Survey of Canada, and to a small extent field data. "Minfile" is being updated continuously and this report summarizes information available up to May 1978. For abbreviations used in text see bottom of Table 10. Numbers in the text (e.g. 92F-15) are original "BCDM Minfile" numbers and are shown, without the "92E" prefix, on Figure 6.

The report summarizes the various types of deposits in the map area, describes the best known representatives of each type, and their probable genesis. The geological parameters favourable for mineralization are discussed briefly and areas of greater and lesser mineral potential are shown tentatively on Figure 6.

Metalliferous Deposits

The mineral deposits can be divided into three major groups and one minor group: (F) Contact metasomatic (skarn) deposits; (G) Veins and shear zones; (H) Porphyry deposits; and (M) Lateritic deposits. Massive sulphide deposits, important in other parts of Vancouver Island, are not known in the map area. The locations of known mineral deposits and occurrences are shown on Figure 6 and listed on Table 10. They are represented by symbols similar or identical to those used in earlier papers on the Alberni map area (Muller and Carson, 1969, Fig. 3) and Alert Bay – Cape Scott map area (Muller et al., 1974, Fig. 15). Table 9, is modified from Table 10 in Muller et al., 1974. Unlike the earlier table contact metasomatic deposits associated with rocks of the Sicker Group and Westcoast Complex are distinguished from those associated with rocks of the Vancouver Group. It also provides a more orderly Type-Commodity notation. Most deposits are readily identified as one certain type of deposit. Several, however, have characteristics of two or more classes or types. This is indicated on Table 10 by placing the subordinate classification in brackets below the main type.

Classes F and FA: Contact Metasomatic and Replacement Deposits

Skarn deposits have been divided into Class F: deposits associated with Quatsino limestone or (rarely) other carbonate rocks of the Vancouver Group, and Class FA: deposits associated with Sicker Group rocks and metamorphic rocks of the Westcoast Complex. In both classes the rocks are in intrusive contact with Jurassic Island Intrusions.

Class F deposits have generally well developed skarn zones in which epidote, garnet, ilvaite, diopside, actinolite, hedenbergite, wollastonite, chlorite and calcite are the most common minerals. Associated metallic minerals are magnetite, chalcopyrite, pyrrhotite, pyrite and sphalerite. The class is subdivided according to the predominant metal present; in type F-1 it is mainly iron; in type F-2 mainly copper, and in F-4 mainly zinc. Gold and sivler values are generally low in the skarn deposits but one example of a gold-bearing pyrrhotite deposit, the Beano, is considered to be a skarn. F-1 and F-2 are represented by several major past producers of Vancouver Island and Queen Charlotte Islands.

Class F-A deposits exhibit in many instances more complexity of form and mineralogy then Class F deposits. Skarn zones may be less well developed and contain quartz, calcite, diopside, epidote and garnet. Metallic minerals include various amounts of chalcopyrite, bornite, chalcocite, pyrite, pyrrhotite, magnetite, hematite and sphalerite. Significant gold and/or silver values are commonly present. Like Class F this class is subdivided according to the predominant metal: Class F-1A, mainly iron; Class F-2A, mainly copper; and Class F-4A, mainly zinc.

F-1: Contact Metasomatic Iron Deposits in Vancouver Group Rocks

Glengarry (Head Bay, Stormont) (92E-1) and Rob Roy (Fido) (92E-15) are examples of iron-skarns in Quatsino limestone. They are located about one mile northwest of the end of Head Bay, Upper end of Tlupana Arm, Nootka Sound. Crystalline Quatsino limestone and metavolcanics are cut by Island Intrusions, mainly sills and dykes of diorite and granodiorite. Magnetite-bearing skarn lenses, elongated in three parallel northwesterly trending belts, occur within limestone, at limestone-metavolcanic or limestone-intrusive contacts. The magnetite bodies are associated with garnet and lesser amounts of epidote gangue and are considered to be disconnected replacements of inclined limestone beds.

Available assays from Glengarry range from 56.8 to 66.4% Fe with 0.17 to 0.26% S, Tr. to 0.16% P and 1.6 to 6.1% Si. The magnetite, with exceptions, is notably free of pyrite. A total of 62 500 tons of ore was milled from the Glengarry property, producing 25 000 tons of magnetite concentrate. Reserves at Glengarry are estimated at approximately 297 500 tons of about 43% Fe and at Rob Roy they are 50 000 tons probable and 200 000 tons possible ore.

Table 9. Types of metallic mineral deposits of Nootka Sound map area

Class	Symbol	Main Metals	Example	Mineralogy	Host Rocks	Structural Control	Associated Alteration	Age
SKARN, REPLACEMENT DEPOSITS	F-1	Fe > Cu	Glengarry (1)	Mag, Po, Hem.	Vancouver Group; mainly Quatsino Formation	Intrusive and stratigraphic contacts, folds, fractures, breccia zones	Skarn: epidote, garnet, wollastonite, diopside, actinolite, hedenbergite, ilvaite	F-, G-, and H- deposits are all believed to be related to the emplacement of either Jurassic Island Intrusions or early Tertiary Catface Intrusions
	F-2	Cu > Fe	Geo (10)	Cpy, Bo, Mag.				
	F-8	Au, Ag, (Cu)	Beano (2)	Po, Cpy.	Bonanza Group		Actinolite	
	F-1A	Fe > Cu	Satchie (13)	More complex than F-1, F-2: Po, Py, Mag, Hem, Cpy, Bo, Cc, Sl; Au and Ag values.	Sicker Group, Westcoast Complex, mainly in carbonate metasediments		Gangue of quartz, calcite, diopside, epidote, garnet	
	F-2A	Cu, Au, Ag	Indian Chief (11)					
	F-4A	Zn, Cu, Pb, (Au, Ag)	Silverado (17)					
VEIN DEPOSITS	G-2	Cu > Pb, Zn	June (18)	Cpy, Cc, Py, Po, Mo.	In all rock-groups; mainly in Paleozoic and Mesozoic volcanic rocks	Shear zones, shattered zones, faults, fractures	Silicification, carbonatization, sericitization; G-8 also chloritization	
	G-4	Zn > Cu, Pb	Brown Jug (16)	Sl, Py, Cpy, Ga, Po, Apy.				
	G-8	Au, Ag (Pb, Zn, Cu, As)	Baltic (26)	Py, Sl, Ga, Cpy, Apy, NG.				
PORPHYRY DEPOSITS	H-2	Cu > Mo	Sydney (39) (Catface)	Cpy, Py, Bo, Po, Mo.	Island- and Catface Intrusions and their envelopes	Fracture zones in intrusives	Commonly argillic to propylitic alteration; here insufficient data on alteration	
	H-2A	Cu > Mo	"JB", "PW", "RW" (48)			Fracture zones in country rock		
LATERITIC	M-1	Fe, Mn	"MN" (41)	Lim, Pl.	Pacific Rim Complex	Formed by recent (?) weathering of Fe- and Mn-rich cherty sediments		

Abbreviations: Apy: Arsenopyrite; Bo: Bornite; Cc: Chalcocite; Cpy: Chalcopyrite; Ga: Galena; Hem: Hematite; Lim: Limonite; Mag: Magnetite; Mo: Molybdenite; NG: Native Gold; Pl: Pyrolusite; Po: Pyrrhotite; Py: Pyrite; Sl: Sphalerite.

F-2: Contact Metasomatic Copper Deposits in Vancouver Group Rocks

Geo (Star of the West) (92E-10) is an example of an F-2 copper skarn deposit but contains some zinc and has associated copper-bearing quartz veins. It is located about 1.5 km west of the head of Tahsis Inlet and is in a northwesterly trending belt of Quatsino limestone, flanked on the northeast by Karmutsen basalts and on the southwest by Parson Bay sediments. The succession is cut by granodiorite.

Quartz veins mineralized by chalcopyrite, pyrite and sphalerite are described in early reports. More recent reports indicate that the deposits are copper and zinc bearing skarn zones that, unlike most F-2 type deposits, carry gold and silver values. The skarn zones, consisting mainly of recrystallized limestone, garnet and epidote, are 2 to 60 m wide and up to at least 200 feet in length. The mineral assemblage is chalcopyrite with some arsenopyrite, pyrrhotite, magnetite, galena and bornite.

Assays from Star of the West and Hakadate claims range from 0.2% to 16% Cu; nil to 15% Zn; Tr. to 0.7 oz/ton Au and Tr. to 4 oz/ton Ag. A test sample of 700 kg or ore contained 5.2% Cu, 0.135 oz/ton Au and 0.30 oz/ton Ag.

F-4: Contact Metasomatic Zinc Deposits in Vancouver Group Rocks

Although there are no known examples of typical type F-4 deposits in Nootka Sound map area, Geo (Star of the West) (92E-10), described with type F-2 deposits also has some of the characteristics of the F-4 type.

F-8: Contact Metasomatic Gold-bearing Deposits

Type F-8 deposits are pyrrhotite-rich actinolitic skarn deposits containing high gold values. Beano (92E-2) is the only known example of this type. It also has characteristics of type G-8, gold bearing pyrrhotite-quartz-carbonate veins.

The Beano property is located on Beano Creek, 5.6 km south of Little Zeballos River at 800 m (2600 ft) elevation. The rocks are tuffs and flows of the Bonanza Group and about 10 m of interbedded limestone, intruded by diorite. Two types of mineralization are present in the deposit. In one type bodies of fibrous actinolite together with dioritic rock occur as replacements in limestone and in tuffaceous rocks. The actinolite skarn is mineralized by lenses and disseminations of pyrrhotite, commonly accompanied by some chalcopyrite. In the other type veins of quartz and carbonate contain lenses of gold-bearing pyrrhotite. Assays indicate that the gold is associated with pyrrhotite. Fine grained and coarse grained actinolite samples yielded 0.01 oz/ton gold and no silver, nickel or platinum; pyrrhotite samples varied from nil to 0.2 oz/ton gold; nil to 3.04 oz/ton silver and no nickel or platinum. Reported production is 23 tons of ore with 106 ounces of gold, 45 ounces of silver and 75 pounds of copper.

F-1A: Contact Metasomatic Iron Deposits in Sicker Group Rocks

Satchie (92E-13) and Hesquiat (92E-31) are examples of F-1A contact metasomatic iron mineralization in Sicker Group rocks. These properties and variously named other related claims, are located about midway along the east side of Hesquiat Lake, about 1 km inland.

According to R.E. Chaplin's description of the area (BCDM AR 464) the properties are underlain by granodiorite and a sequence of Sicker tuff and minor intercalated limestone. Skarn, consisting of garnet and lesser amounts of epidote and quartz, is mineralized by magnetite and chalcopyrite. At Satchie magnetite bands have an average thickness of about 50 cm and occur in three small exposures, the largest of which is approximately 100 m^2 (1000 sq ft). At Hesquiat magnetite in concentrations of about 20% occurs in erratically distributed masses and disseminations in skarn and the largest mineralized area is a few hundred square metres. At Satchie assays range from 25 to 40% Fe with 0.02 to 1.35% S and 0.02 to 0.06% P.

F-2A: Contact Metasomatic Copper Deposits in Sicker Group Rocks

Indian Chief (Dewdney) (92E-11) and adjacent Prince (Blackbird) (92E-32) are examples of F-2A copper mineralization in Sicker Group limestone and volcanic rocks, intruded by granodiorite and by basic dykes. K-Ar dating of a porphyry dyke, sampled near the entrance of the mine, yielded an age of 42 Ma (see Table 7). Thus this deposit may be a result of Tertiary rather than of Jurassic plutonism. Mineralization occurs at limestone-granodiorite contacts where the limestone is recrystallized and skarnified. Two principal orebodies are about 500 m apart. The south orebody forms irregular swells or enlargements from 1.5 m to 12 m wide within recrystallized limestone. The north orebody consists of two distinct ore zones also within recrystallized limestone near the granodiorite contact. Ore minerals include chalcopyrite, bornite and magnetite, and are found mainly in fissures and shear zones in the silicified limestone. The Prince deposit is probably a continuation of the mineral-bearing zone of the Indian Chief. Indian Chief deposit has produced 81 139 tons of ore from which 2 430 310 pounds of copper, 722 ounces of gold and 54 895 ounces of silver were recovered.

F-4A: Contact Metasomatic Zinc Deposits in Sicker Group and Westcoast Complex Rocks

Silverado (92E-17) represents type F-4A zinc deposits in rocks within the Westcoast Complex. The property was located on Silverado Creek, about 1 km south of the south shore of Muchalat Arm. According to Stevenson (MMAR, 1949) the property is underlain by hornblende hornfels which contains two limestone bands. Mineralization has partly replaced a 3 m thick limestone bed along its contact with greenstone, forming a series of disconnected lenses. The lenses are several centimetres to about 2 m thick and 7 to 30 m long. The zone of lenses was traced over the surface for 115 m. Mineral assemblages consist of sphalerite with small amounts of chalcopyrite, pyrrhotite and magnetite associated with a gangue of quartz, calcite, diopside, epidote and garnet. Assays over measured widths up to 2 m range from Tr. to 0.1 oz/ton gold; Tr. to 6.5 oz/ton silver; <0.3 to 11.1% copper; <0.3 to 0.32% lead and <0.3 to 55.8% zinc.

Class G: Veins and Shear Zones

Class G deposits include mineralized quartz and quartz-carbonate veins and shear zones; in some instances the gangue is subordinate to the metallic minerals. This type of deposit is generally known or inferred to be genetically related to intrusive rocks. The predominant metallic mineral determines the subdivisions of this class: G-2 for copper, G-3 for lead, G-4 for zinc and G-8 for gold. They commonly are composed of chalcopyrite and pyrite and include one or more of other copper sulphides, sphalerite, molybdenite, arsenopyrite and native gold. They are not limited to any formation but are probably more common in volcanic rocks.

Table 10. List of known metalliferous deposits and showings of Nootka Sound map area

No.	Name	NTS 92E	Location	Class	Minerals	Assays Maximum (%; oz/ton for Au, Ag)	Assays Average	Production	References
1	Glengarry Head Bay Stormont Rob Roy	15E	W side of Sucwoa R., ±3 km NW of Head Bay	F-1	Mag	Fe: 66.4	66.1 (3 G S)	62,500 tons; 25,000 tons of mag concentrate	MMAR 1902-208; 1903-193; 1906-185; 1909-278; 1916-293; 1951-198; 1952-231; 1956-131; 1959-134; 1960-106; BCDM B 3-1917-27; GSC EG3-1-231, 235
2	Beano	15W	Beano Crk, ±3 km N of Little Zeballos R., el. 2,600 ft	F-8 (G-8)	Po, Cp.	Au: 9.4 Ag: 3.0	1.3 0.07 (C S 88")	23 tons 106 oz Au; 45 oz Ag; 75 lbs Cu	MMAR 1938-F-42; 1947-181; GEM 1974-171; BCDM Bull. 27-135; GSC Paper 40-12-38; GSC Mem. 272-50; BCDM AR 5079
3	Friend	15W	Friend Crk, ±2 km N of Little Zeballos River	G-8	Apy, Py,Po, Cpy,NG	Au: 8.3 Ag: 0.7	0.1 0.2 (C S 184")		MMAR 1938-F-45; 1946-179; BCDM Bull. 27-138; GEM 1974-171; GSC Mem. 272-52; GSC Paper 40-12-37; BCDM AR 5079
4	Independence, Harlow	15E	Tahsis River Valley, west side; ±3 km from Tahsis Inlet	G-8	Py, Cpy, Sl.	Au: 1.2 Ag: 0.4	0.02 0.07 (2 veins)		GSC Mem. 272-55
5	Mohawk	15E	S side Tsowwin R., ±5 km from Tahsis Inlet	G-8	Py.				GSC Mem. 272-54
6	Vivian	15E	Head, Tsowwin R., ±6 km from Tahsis Inlet	G-8	None seen	Au: 2			GSC Mem. 272-54
7	Ubell Creek	15E	Ubell Crk, ±0.5 km S of Little Zeballos River, el. 1000 ft.	G-8	Apy, Cpy	Au: 0.4 Ag: 0.2	0.3 0.1 (3 G S)		GSC Mem. 272-56
8	Ubell	15E	Tributary E of Ubell Crk and ±2 km S of Little Zeballos R.	G-8	Py.	Au: Ag:	0.005 0.035 (1 G S)		GSC Mem. 272-55
9	Shannon	9W	N side Muchalat Arm, opposite Gore Island	F-4A	Sl, Ga, Cpy	(1GS)	Au:Tr. Ag:6.6 Pb:8 Zn:13		MMAR 1927-345; 1928-372; 1933-252
10	Geo, Star of the West	15E	±1.5 km NW of Tahsis Inlet	F-2 (F-4)	Cpy, Py, Sl.	Cu:16.0 Zn:15.0 Au:0.24 Ag:4.0	7.2 3.4 0.1 1.1 (15 G S)	1500 lbs. ore with (1962) Au:.18oz Ag:.40 Ton Cu:5.2%	MMAR 1922-231; 1923-247; 1924-224; 1925-269; 1926-300; 1928-373; 1931-168; 1933-252; 1955-78; 1956-119; 1962-104; GEM 1970-284; 1971-232; GSC Mem. 204-20

11	Indian Chief, Dewdney, Prince Blackbird	8W	W side of Stewardson Inlet; el. ±1400 ft	F-2A (G-2)	Mag, Cpy, Bo.		Cu:1.5 Au:0.009 Ag:0.68	81,139 tons Cu:2,430,310 lbs.; Au: 722 oz; Ag: 54,895 oz	MMAR 1899-791; 1900-923; 1901-1098; 1902-232; 1903-192; 1904-27; 1906-185; 1908-143; 1916-336; 1917-248; 1918-266; 1919-199; 1920-196; 1922-229; 1923-248; 1925-272; 1928-372; 1929-375; 1931-168; 1938-F-68; 1965-119; 1963-101; GEM 1973-229; GSC SR 1918-B-37; 1920-A-20; BCDM AR 462
12	Ormond, Contact, Iron King, Pete, Copper King	8E	E side of Flores Island ±1 km from W side of Matilda Arm, el. 1000 ft	G-2 (F-1A)	Po, Py, Cpy, Mag, Sl.	Cu:8.8 Ag:4.2 Fe:53.5	6.0 3.5 (12 G S) 53.5	100 sacks of iron ore from Ormond	MMAR 1906-186; 1915-287; 1916-334; 1929-375; 1931-168; 1932-204; 1966-74; 1967-74; GEM 1969-216; 1972-262; 1974-170; BCDM AR 465
13	Satchie, Hesquiat, Vi, Paco, Agnes	8W	At Hesquiat Lake, ±1.5 km inland from SE side of S of Satchie Crk	F-1A	Mag, Cpy.	Cu:1.2 Fe:41	0.4 27 (C S 74 ft)		MMAR 1902-209; 1903-193; 1940-27; 1961-101; 1967-74; GEM 1969-216; 1972-262; 1973-229; GSC EG 3-1-230; BCDM AR 464
14	Paco, Violet	8W	NW side Hesquiat Lake, small gulch ±1200 ft from shore; el. 350 ft	F-1A	Mag.	Fe:59.8 Cu:0.03	56.7 0.01 (3 G S)		MMAR 1902-209; 1916-291; GSC EG 3-1-230; BCDM AR 464
									MMAR 1916-294; CSC EG-3-1-235
16	Brown Jug	8W	Hesquiat Lake, ±0.8 km from S shore, el. 300 ft	G-4 (G-2)	Sl, Cpy, Ga, Py.	Au:0.6 Ag:8.0 Cu:3.5 Zn:12.0	0.1 5.4 1.7 6.0 (C S 5 ft)		MMAR 1899-793; 1902-233; 1903-193; 1906-185; 1909-147; 1910-152; 1916-337; 1925-272; GEM 1969-216; 1972-262 1973-229; BCDM AR 464
17	Silverado (Danzig)	9W	Silverado Crk, W side, ±1 km S of Muchalat Inlet	F-4A	Sl, Cpy, Po, Mag.	Zn:55.8 Cu:11.1 Pb:0.7 Au:0.04 Ag:6.5	18.1 <0.3 <0.3 0.01 0.7 (C S 39 ft)		MMAR 1948-157; 1949-219; 1951-197; 1952-210; GSC Mem. 204-18
18	June (Jade)	9E	June Crk, W side of Matchlee Bay, head of Muchalat Inlet	G-2	Cpy, Mag, Apy, Po,Sl, Py,Ga	Au:16.7 Ag:26.9 Cu:22.0 Pb:9.4 Zn:17.2	0.3 2.7 1.6 0.3 0.7 (C S 30 ft)		MMAR 1946-179; GEM 1971-232
19	Oktwanch	16W	S fork of Oktwanch R, west side of head	F-2A (F-1A)	Mag, Py, Cpy,Po				MMAR 1965-233; BCDM AR 743
23	Answer	15W	Main road to Zeballos, ±1.5 km N of townsite	G-8	Py	Au:1.2 Ag:0.6	0.2 0.1 (C S 27 in)		MMAR 1938-F-41; BCDM Bull. 27-49

Table 10 (cont.)

No.	Name	NTS 92E	Location	Class	Minerals	Assays Maximum (%; oz/ton for Au, Ag)	Assays Average	Production	References
24	Nomash	15E	Mntn W of head Nomash R., North trending ridge	F-2	Cpy				GSC Mem. 272-56; Paper 40-12-33; SR 1932-AII-44
25	Nimpkish Copper (H.K.)	16W	On Tolnai Crk, 10 km NW of Muchalat Lake, 4.5 km W of head Oktwanch R.	F-2A	Cpy, Bo,Cc Mag				BCDM AR 4102
26	Baltic	9W	S shore of Muchalat Inlet, opposite E end of Gore Island	G-8	Py,Cpy, Sl, > Ga,Po	Au:6.9 Ag:7.1		143 tons with Au 179 oz; A Ag 321 oz	MMAR 1949-219; 1951-197; GSC Mem. 204-18
27	Lady Grace	9W	Nesook R, ±4 km E of Nesook Bay, Tlupana Inl	G-2 (G-8)	?	Au:0.4 Ag:2.2 Cu:22.0	0.2 1.1 9.2 (3 G S)		MMAR 1924-224
28	Zeballos	16W	Head Bay, Tlupana Arm, W shore	G-8				5 tons with Au: 7 oz; Ag: 3 oz; Cu: 7 lbs	
38	High Boy	8E	Head, Shelter Inlet, NW side	G-8	Py	Au:0.2			GSC Mem. 204-25
39	Sydney Syd, Access	8W	Sydney Inlet, W side, ±6 km N of Sharp Point	H-2 (G-2)	Cpy,Py, Bo,Mo	Cu:0.64 Mo:0.01	0.45 0.01 (C S 12 ft)		MMAR 1968-102; GEM 1971-231; 1972-262; 1973-228; BCDM AR 1592
40	MN	1E	Vargas Island, North central part, ±3 km from shore	M-1	Lim, Pl.	Mn:<15			GEM 1969-217; BCDM AR 1696; GSC SR 1920A-22
43	Rustand, Sunrise, Sundown, Port Eliza Goldmine	14E	W side of Port Eliza Inlet ±6 km S of head	G-8	Py	Au:4.2 Ag:0.1	0.3 0.08 (C S 96 in)	14 tons with Au 14 oz; Ag 3 oz; Cu: 22 lbs.	BCDM Rept. by J.S. Stevenson, Jan 25, 1945
44	Bay	8E	NW corner of Flores Island at bay ±2 km S of Starling Point	H-2	Cpy, Py, Cc	Cu:0.30 Mo:0.003 Au:0.02 Ag:0.1	0.3 Tr. 0.007 0.06	(12 G S)	GEM 1971-231; BCDM AR 3240

45	"JR"	8E	Flores Island, head, E fork Cow Crk, el. 1030 ft	H-2	Cpy, Py, Cc	Cu:0.08 Mo:Tr.			GEM 1972-263; BCDM AR 3689
46	"K-15"	8W	W side of Refuge Cove	G-4	Sl	Zn:10.3 Ag:0.02	5.0 0.01 (C S 5 ft)		GEM 1972-261; BCDM AR 3750
47	"K-18"	8W	NW side of Refuge Cove	G-2	Cpy	Cu: Au:	0.6 0.02 (1 G S)		GEM 1972-261; BCDM AR 3750
48	"JB", "PW", "RW"	8E	Catface Peninsula, just N of Falcon-bridge claims	H-2A	Py, Cpy				GEM 1969-216; BCDM AR 2116, 2454
49	Flow	8E	Flores Island, ±7 km NW of Ahousat, el. 1000-2400 ft (= Trio)	H-2	Cpy, Py.				BCDM AR 2317, 4956
50	Vanhall, "DV"	16E	Horseshoe Mntn, ± 15 km N of Gold River townsite	G-2	Py, Mag.	Cu:1.7 Ag:0.9	0.5 0.2 (7 G S)		GEM 1972-263; BCDM AR 2436, 3953
51	Beach (Acme)	15W	Zeballos Arm, W shore, ±4 km S of Zeballos	G-8?	?				BCDM Rept. by J. Warwick, 1938
52	"ESP"	15W	± 1 km W of Espinoza Inlet, 5 m N of Esperanza Inlet, el. 500 ft.	G-2	Cpy, Py, Mo?	Cu:0.75			GEM 1973-230; BCDM AR 4280

Numbers and names of properties and showings are taken in condensed form from the "REVISED MINERAL INVENTORY MAP", released by the British Columbia Department of Mines and Petroleum Resources; the quoted locations are condensed from that Department's Annual Reports and "GEM".

For abbreviations see Table 9.

Assays quoted from references. Maximum: highest assay shown. Average: for grab samples, e.g. (3 G S) average of 3 given assays; for channel samples, e.g. (C S 21 in) weighted average of total width of veins as quoted:

Example: width of vein Au, oz/ton

width of vein	Au, oz/ton
3"	1.4
6"	0.4
12"	0.2

$$\text{Ave: } \frac{3 \times 1.4 + 6 \times 0.4 + 12 \times 0.2}{3 + 6 + 12} = 0.4$$

MMAR 1902-208 = British Columbia, Minister of Mines (and Petroleum Resources), Annual Report for 1902, page 208. BCDM Bull. 3-1917-27 = British Columbia Department of Mines, Bulletin No. 3,1917, page 27; BCDM AR 5079 = British Columbia Department of Mines, Assessment Report No. 5079; GEM 1974-171 = Geology, Exploration and Mining in British Columbia, 1974, page 171; GSC EG3-1-231 = Geological Survey of Canada, Econ. Geol. Series 3, Vol. 1, p. 231; GSC Paper 40-12-38 = Geol. Surv. Can., Paper 40-12, p. 38; GSC Mem. 272-50 = Geol. Surv. Can., Memoir 272, p. 50.

Underlined items contain geological data.

G-2: Copper-bearing Quartz Veins and Shear Zones

Although there are many type G-2 copper-bearing veins in Nootka Sound map area none have so far proven to be of economic significance. The June (Jade) showing (92E-18) is an example of copper-bearing quartz veins that locally also contain values in gold. The claims are on the west side and 500 m from the head of Muchalat Inlet. They are underlain by Karmutsen volcanics which are cut by felsic dykes. The mineralized veins are thought to be related to these plutonic rocks.

At least four veins occur on the property; the main vein follows a shear zone varying in width from several centimetres to 2 m and had been exposed during development work in 1946 for about 40 m. At its western end the shear zone was intensely silicified over widths of about 30 cm to 2 m and it now consists mainly of fine grained, dark grey quartz. Metallic minerals are chalcopyrite with smaller amounts of arsenopyrite, pyrrhotite, pyrite, sphalerite and galena. A few representative assays from Stevenson (1946) are shown below.

G-4: Zinc-bearing Quartz Veins and Shear Zones

"K" (92E-46) is a zinc vein deposit. The property is on the northwest side of Refuge Cove, about 32 km northwest of Tofino. The rocks are Sicker Group metavolcanics that at a small distance from the showing are in contact with quartz diorite of Tertiary Catface Intrusions. Mineralization occurs in a 7 m wide epidotized shear zone that contains a 1.5 m interval that is well mineralized with sphalerite. Assays from this interval contained 5% Zn and 0.3 g/tonne Ag. A selected sample contained 10.3% Zn and 0.6 g/tonne Ag.

G-8: Gold-bearing Quartz Veins and Shear Zones

Gold deposits in quartz veins are rather abundant but generally small. Bancroft (1937) examined and described many of them and Carson (1969, 1973) first noted the relationship of many to intrusions of early Tertiary age. Zeballos Camp just north of Nootka Sound map area at the head of Zeballos Inlet is quoted as an example, following Stevenson's (1950) description.

The gold-quartz veins of the Zeballos Camp are quartz-sulphide fillings in well defined fracture systems in the Zeballos Stock (see Catface Intrusions). They are generally less than 30 cm wide but some sheeted zones attain 120 cm; attitudes are fairly uniform for considerable distances. According to Stevenson northeasterly trending tension fractures have been most favourable for gold mineralization. Sulphide and gold occur in layered veins of quartz, carbonate and sulphide. The sulphides are pyrite, sphalerite, arsenopyrite, chalcopyrite, galena, pyrrhotite and a little marcasite. Sulphides may total up to one half of the vein matter and the amount of gold is generally proportional to sulphide content. It is most abundant in the presence of sphalerite and galena.

Total production from the camp until its final closure in 1948 was 287 811 ounces (8159.44 kg) of gold and 124 700 ounces (3535.24 kg) of silver. The Privateer Mine, largest producer of the camp, contributed more than half of that amount.

Baltic (Danzig) (92E-26) is another example of gold-quartz deposits, located on the south side of Muchalat Inlet opposite the east end of Gore Island. The showings are Island Intrusions granodiorite, cut by dykes of felsite and feldspar porphyry and mineralized quartz veins. Bancroft (1937) reports the main vein to be 10 to 30 cm wide, with a known length of more than 300 m, traced by open cuts. Vein minerals include pyrite, sphalerite, chalcopyrite, some galena, pyrrhotite, and probably free gold and tellurides, too fine to be identified with certainty, in quartz gangue. Assays were as follows:

	Au oz/ton	Ag oz/ton	Cu %	Pb %	Zn %
2.25 kg sample	6.95	7.06	-	-	-
10 cm band sphalerite in No. 1 vein	0.03	3.37	tr	2.55	21.19
smelter sample, 7.7 tonnes	5.64	8.8	-	-	-

In addition the Baltic produced 130 tonnes of ore which contained 179 oz (5 kg) of gold, 321 oz (9 kg) of silver and 192 lbs (87 kg) of copper.

From table of assays of June showing
(Stevenson, MMAR, 1946, p. A180-181)

		Width (Inches)	Au oz/ton	Ag oz/ton	Cu %	Pb %	Zn %
3.	Diagonal quartz vein in shear	30	0.06	3.10	1.60	-	-
5.	Across 10 cm of quartz and 10 cm of chalcopyrite	20	1.78	6.50	2.80	0.68	0.70
7.	2 m from floor of adit; microscope shows abundant chalcopyrite, arsenopyrite, pyrrhotite, and magnetite; no galena seen	5	16.68	22.90	20.00	1.13	-
	Samples from ore pile near portal:						
18.	Mixed sulphides in quartz	-	0.85	17.60	4.40	2.39	-
21.	Mainly chalcopyrite, no quartz	-	0.72	13.58	22.00	0.40	4.95
27.	Open cut on beach at mouth of June Creek, main shear, strongly oxidized	15	nil	0.50	-	-	0.53

Class H: Porphyry Deposits

Some porphyry deposits have been discovered in Nootka Sound map area, but none have yet been found that warrant economic development. For Class H-2 Catface property, just outside the southeast corner of Nootka Sound map area, is the outstanding example. There metallic mineralization occurs mainly within a zone of alteration that includes late-stage differentiates within the margin of plutons. Some of the mineralization may extend outward into the altered country rock. In class H-2A porphyry-type mineralization occurs mainly within an envelope of alteration in the country rock surrounding a differentiated pluton. The Island Copper Mine in Alert Bay map area is the most prominent example of this type (designated as H-1 in Muller et al., 1974). One or more stages of fracturing and/or brecciation are evident and probably prerequisite features of these porphyry deposits.

H-2: Porphyry Copper (Molybdenum) Deposits

Catface porphyry copper (molybdenum) deposit represents type H-2 and is located on Catface Peninsula, just east of the map area at the entrance of Clayoquot Sound and was described by Northcote (1972) and McDougall (1976). At Catface rocks of Sicker Group and Westcoast Complex, together with granodiorite (quartz monzonite) believed to be part of Jurassic Island Intrusions, are intruded by quartz diorite and associated porphyries of Tertiary Catface Intrusions. The Sicker Group volcanic rocks have been metamorphosed to hornblende-actinolite hornfels. Weathered surfaces show the well preserved agglomeratic texture with amygdaloidal and fine grained volcanic fragments in similar matrix. The rock is prominently foliated by flattening and alignment of the fragments. The Westcoast diorite is in fault contact and migmatic contact with Sicker rocks. Although it is uniform in mineralogy it shows a wide range of texture, grain size and relative amount of minerals. The older Jurassic (?) granodiorite (called Catface Quartz monzonite in the reports of Northcote, 1972 and McDougall, 1976) was emplaced as a large sill-like body along the contact between Westcoast diorite and Sicker volcanic rocks. The Tertiary Catface Intrusions, with associated copper and molybdenum mineralization, intrude all older rock units. In the detailed studies of Northcote and McDougall they are subdivided into Hecate Bay quartz diorite, porphyritic diorite, Cliff porphyritic granodiorite, Grey porphyritic granodiorite and porphyritic dacite. Intrusion breccias associated with the younger intrusive units suggest high level emplacement into a roof of Sicker volcanics, Westcoast diorite and older granodiorite, only slightly above the present erosion surface. The multitongued outline of the porphyritic phases of the Tertiary intrusions, exposed on the upper levels of Catface Peninsula, suggests fracture controlled emplacement. Although intrusion breccias are present there is no widespread brecciation of either older or younger intrusive rocks to suggest explosive brecciation in a subvolcanic environment. Dykes of porphyritic dacite, the youngest intrusive phase, contain patches of epidote, calcite, and chloritized mafic minerals and appear to be the most extensively altered intrusive rocks.

In the adit the best mineralized zones are in Sicker volcanic rocks and in the porphyritic phases of Catface Intrusions, but the latter are not consistently well mineralized. The distribution of better grades of mineralization suggests that the top part of the section, which is presumably near the top of the magma chamber or cupolas leading from it, contains the best grades. That level is about at the present erosion surface. Copper mineralization occurs as coatings in fractures and as disseminations in the rock matrix where it is commonly associated with mafic minerals. The copper minerals are mainly chalcopyrite and bornite with some chalcocite. A significant amount of copper is in secondary minerals like covellite, cuprite and tenorite which occur in fracture zones. Molybdenum is closely associated with quartz in fractures and occurs as coatings and as small, crystal clusters in quartz veins. Catface Intrusions and associated minor H-2 copper deposits reappear to the west of Catface Peninsula on Flores Island and in the Hotsprings (Refuge) Cove area and the deposits are listed on Table 10.

H-2A: Porphyry Copper in Country Rock Envelope

The most prominent example of this type of porphyry copper is Island Copper Mine near Port Hardy in Alert Bay map area. It has been described in detail by Northcote (Northcote and Robinson, 1972; Muller et al., 1974) and by Cargill et al. (1976). The designation H-2A is here used for a porphyry deposit in country rock enveloping the pluton; "2" stands for copper, as in previously discussed types of deposits. "JB", "PW" and "RW" (92E-48) are possible examples of H-2A deposits in Nootka Sound map area. They are located on Catface Peninsula immediately north and adjacent to the Falconbridge Catface property described in the foregoing section. The eastern part of the claims, largely in Alberni map area, is underlain by Sicker Group rocks composed of a tightly folded sequence of limestone, siliceous tuff and chert and a few thin flows. Westward these rocks grade into migmatitic rocks of the Westcoast Crystalline Complex. The southern part of the property is underlain by massive pyroclastic rocks and flows. There are no major intrusive bodies but small dykes, sills and irregular masses of feldspar porphyry are common. Minor disseminations and widespread fracture fillings of pyrite and pyrrhotite occur in metadiorite and migmatite and more abundant disseminated pyrite is found in the metasediments. Chalcopyrite occurs only as traces in the diorite.

Class M: Lateritic Deposits

"MN"9 and 10 (92E-41) are the only representative of this type of lateritic-manganese iron deposit and are located on north central Vargas Island, about 3 km from the north shore. The showing is in a swampy area underlain by a band of cherty ferruginous sheared sediments of the Pacific Rim Complex, weathered to a depth of 3 to 4 m and containing much limonite and some pyrolusite. Assays have indicated less than 15% Mn.

Mineral Potential

Known metalliferous deposits of any consequence in Nootka Sound map area are of three main types: (F) Contact metasomatic (skarn) deposits; (G) Veins and shear zones and (H) Porphyry deposits. Massive sulphide deposits have not been found, perhaps because the rhyolitic suite of Sicker volcanic rocks, associated with such deposits at Western Mines, central Vancouver Island, is not present. Thus it seems likely that any future mineral discovery would be of the skarn, shear zone, or porphyry type. The British Columbia Department of Mines and Petroleum Resources has for some years issued mineral inventory maps and mineral deposit-land use maps on scale 1:250 000. Figure 6 is a modified and reduced version of these maps for Nootka Sound (NTS 92E) map sheet. Figure 6 shows areas of high to moderate mineral potential, approximately coinciding with areas where Quatsino, Bonanza and Sicker rocks are cut by Island Intrusions. Moderate mineral potential corresponds to areas underlain by Bonanza volcanics and Catface Tertiary Intrusions. Areas of lower mineral potential are underlain by Karmutsen volcanics and the lowest potential corresponds to areas of Tertiary sediments.

The most promising mineral potential for Nootka Sound map area appears to be for iron and copper metasomatic deposits in areas where Island Intrusions invade Vancouver

Group rocks, or in the roof pendants of Sicker Group metasediments, surrounded by Island Intrusions and Westcoast Complex rocks. There has been limited production from two such properties. Glengarry (-Stormont-Rob Roy) at the head of Head Bay milled 62 500 tons of ore producing 25 000 tons of magnetite concentrate. The Indian Chief on Stewartson Inlet shipped 81 139 tons yielding 2 430 310 lb of copper, 722 oz of gold and 54 895 oz of silver.

Porphyry copper and molybdenum occurrences associated with Tertiary plutons north of Refuge Cove and on Flores Island have yielded only low copper and molybdenum assays but otherwise have many similarities to the Catface deposit on Catface Peninsula a few kilometres to the east. There is also a possibility of encountering as yet undiscovered high-level porphyry intrusions into Bonanza volcanics similar to the shallow subvolcanic geological setting of the Island Copper Mine copper-molybdenum deposit. In addition the possibility of massive sulphide deposits, related to submarine rhyolitic volcanic centres in Bonanza volcanics, cannot be ruled out even though at the present time no such deposit is known from the Bonanza Group.

There is also a potential of gold production from small operations on some of the numerous gold-bearing quartz veins (type G-8) and a lesser probability of economic recovery of copper from veins. Clearly profitable recovery from small deposits is not possible under present economic conditions.

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