Bulletin

MESOZOIC AND ?TERTIARY ROCKS OF QUATSINO SOUND VANCOUVER ISLAND, BRITISH COLUMBIA

by

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ABSTRACT

The report-area is underlain largely by the more than 25,000-foot-thick succession of Triassic and Lower Jurassic volcanic and sedimentary rocks of the Vancouver Group. The base of the group is not exposed. The Vancouver Group is subdivided into the Karmutsen Subgroup below and the Bonanza Subgroup above with the Quatsino Limestone included in the latter.

The broad Karnian (i.e. Karmutsen and early Quatsino time) marine basin, which extended well to the west and east of the report-area, was transformed into a relatively narrow, north-trending depositional trough in the early Norian and then fragmented by source areas (?islands) in the late Norian. The resulting complex facies pattern of clastic and calcareous sediments (Thinly bedded member, Arenaceous member, Sutton limestone) was terminated by the latest Triassic (?early Rhaetian) orogenic phase which flexed the Triassic rocks and faulted them judging by the concurrent outburst of volcanism. The crests of at least two north-trending anticlines (i.e. Port Alice - Coal Harbour and Southwestern tectonic lands) became source areas supplying pyroclastics, lavas and coarse volcanic clastics to the intervening Neroutsos and West Coast residual marine troughs.

The latest Triassic orogenic phase and the accompanying volcanism did not affect the northeastern side of Vancouver Island, the Queen Charlotte Strait, and the Queen Charlotte Islandswhere the deposition of marine argillites and limestones (upper parts of Parson Bay and Quatsino formations) continued into the Jurassic. This resulted in the subdivision of the Insular Tectonic Belt into two zones. The southwestern tectonically and volcanically active zone included all of the report-area and the adjacent parts of northwestern Vancouver Island. The tectonically and

volcanically quiescent zone comprised areas to the southeast, east, northeast, and north of the report-area. This depositional-structural pattern persisted to the end of Early Jurassic time.

Some 10,000 to 20,000 feet of mainly andesitic volcanics and sediments of the Volcanic division of the Bonanza Subgroup were deposited during the latest Triassic and Early Jurassic in the report-area and adjacent parts of the tectonically and volcanically active zone. The Volcanic division is subdivided, in ascending order as follows: Hecate Cove Formation (new), Lower Jurassic volcanic unit, Cherty limestone unit, Grey volcanic unit, Matthews Island Formation (new), Uppermost Sinemurian volcanic unit, Uppermost Sinemurian argillite unit, ?Dark grey volcanic unit, and ?Pliensbachian-Toarcian greywacke unit. Only 2,000 to 3,500 feet of argillites and limestones (Harbledown and Maude formations) were simultaneously deposited in the quiescent zone which obviously was sediment-starved. The sedimentary interbeds of the Volcanic division appear to be the tongues of the Harbledown and Maude formations of the quiescent zone.

The Early Jurassic depositional-structural pattern was annihilated by the Middle Jurassic orogeny and accompanying batholithic Coast Intrusions. The Vancouver Group of the report-area was flexed into an open, north-trending and west-dipping homocline apparently comprising the western limb of the anticlinorium of Vancouver Island. This basically simple Mid-Jurassic tectonic pattern was strongly complicated locally by the influence of largely syntectonic Coast Intrusions. The Mid-Jurassic orogeny transformed all of the Insular Tectonic Belt into a tectonic land and caused the "migration" of volcanism (Yakoun volcanics) from the Early Jurassic active zone into the Early Jurassic quiescent zone.

The Coast Intrusions of the report-area are small to large dykes, plugs, and rarely small stocks characterized by fine to coarse porphyritic, amygdaloidal, or felsitic textures. These dioritic to gabbroic plutons appear to be extremely shallow to hypabyssal apophyses and cupolas of larger hypocrystalline intrusive bodies still hidden at depth. These hidden intrusives are believed to be intimately connected with or to represent a direct continuation of the principal Coast Intrusion bodies of the Coast Mountains.

The stratigraphical-paleontological data indicate the occurrence of only one, geologically brief (?Bathonian) major epoch of the Mesozoic Coast Intrusions in the report-area and elsewhere on the Vancouver Island. This contradicts the now fashionable hypothesis of a more or less continuous igneous activity in the Western Cordillera.

No Late Jurassic or Berriasian to mid-Valanginian rocks were found in the report-area. This part of Vancouver Island apparently remained above sea level and was undergoing erosion throughout this time interval following a regional uplift of the Insular Tectonic Belt in the wake of the Mid-Jurassic Orogeny.

The Vancouver Group and the Coast Intrusions are overlapped unconformably by more than 10,000 feet of Cretaceous strata. These exclusively sedimentary, partly marine rocks apparently covered originally most or all of the report-area but were removed by the post-Cretaceous erosion, except for a few outliers preserved within downfaulted blocks or synclinal structures.

An unnamed late Valanginian to late Barremian group, equivalent to the Longarm Formation of Queen Charlotte Islands and the Cretaceous part of Relay Mountain Group of the Tyaughton Trough, forms the basal part of the Cretaceous

sequence. This 3,000-foot to 3,500-foot thickness of rocks is subdivided into (ascending order): Buchia crassicollis greywacke, Hauterivian siltstone unit, Upper Valanginian to ?Hauterivian greywacke-conglomerate unit, Inoceramus colonicus calcarenites, Barremian fine-grained greywacke unit, and Barremian variegated clastic unit. These Neocomian rocks were deposited in a relatively shallow marine embayment confined between the Brooks Peninsula Landmass in the southeast and the Northeast Coast Landmass in the northeast. The pulsating late Valanginian to late Barremian transgression gradually advanced eastward and southeastward over the worn down northwestern part of the Mid-Jurassic tectonic land. The transgression culminated in the late Barremian when all of the report-area was flooded and the flanking source areas essentially peneplaned.

The Neocomian rocks are overlain, apparently conformably, by a succession of predominantly coarse-grained, almost exclusively nonmarine clastics, as much as ?8,000 feet thick, named the Coal Harbour Group (new). These Aptian to Albian rocks are subdivided into a Coarse arenite unit below, ?800 to ?5,390 feet thick, and the overlying Blumberg Formation (new), at least 3,000 feet thick.

The nonmarine Coal Harbour Group is equivalent to the Jackass Mountain Group of the Tyaughton Trough. It registers the occurrence of the interregional Aptian (?late Aptian) orogeny which strongly uplifted the previously peneplaned Mid-Jurassic tectonic land and represents piedmont deposits laid down in an embayment-like subsiding basin on its northwestern side. The bulk of coarse clastics was apparently supplied by the strongly elevated Brooks Peninsula Landmass to the southeast of the report-area. Some coarse clastics were, however, derived from the less elevated

tectonic land occupying the northeastern side of Vancouver Island. Unlike the Tyaughton Trough, the report-area apparently was not flooded by the Albian sea.

At least 680 feet of Cenomanian and Turonian marine shale with minor amounts of coarser clastics occur locally in the report-area. This Upper shale unit is a small erosional remnant of the southeastward onlap of the late Haida Sea of Queen Charlotte Islands onto the subsiding northwestern part of the Aptian-Albian tectonic land of Vancouver Island. The areal extent of this early Upper Cretaceous transgression is uncertain.

The Nanaimo Group is represented by a unique, small outlier ?unconformably overlapping the Barremian rocks on the eastern side of Neroutsos Inlet. Its arkosic sandstones, more than 280 feet thick (top faulted), are equivalent only to the late Campanian Cedar District Formation of the Nanaimo-Comox area. The Neroutsos outlier represents the central part of the northern embayment of the late Nanaimo Sea. This sea advanced from the northwest or ?west, did not extend southward beyond the line defined by Suquash River, head of Neroutsos Inlet, and Kwakiutl Point. Its eastern limit was presumably situated somewhere beneath the Queen Charlotte Strait.

A few small to medium-size dyke- and plug-like plutons invade the Cretaceous rocks of the report-area. Because of their post-Nanaimo (i.e. post-Campanian) age and the localization along the planes of the presumably early Tertiary faults, these plutons are tentatively correlated with the Sooke Intrusions of southeastern Vancouver Island and assigned an early Oligocene age.

The mineralogical composition of the ?Sooke Intrusions ranges from granitic to gabbroic. The small size of the plutons, the prevalence of fine to coarse porphyritic, amygdaloidal, and felsitic texture, and the abundance of metasomatically altered Cretaceous sediments (thermal halos) in their vicinity indicate their being

extremely shallow to hypabyssal apophyses and cupolas of larger plutons still hidden at depth.

No outcrops of Tertiary sedimentary rocks were seen in the report-area. The allegedly ?late Tertiary volcanics outcropping on the northern shore of Holberg Inlet appear to be a strongly indurated and silicified facies of the Volcanic division of the Bonanza Subgroup.

Several principal faults trending northwest or west-northwest and delineating four or ?five structurally discontinuous large to medium fault blocks dominate the present day structure of the report-area. A multitude of closely spaced major and minor faults striking in several directions dissect all of the principal fault blocks. Normal and ?strike-slip faults predominate whereas high angle thrust faults are rare. With one exception, all observed faults transect indiscriminately all Mesozoic rocks, including those of the Nanaimo Group. However, they do not seem to disrupt the presumably early Oligocene ?Sooke Intrusions. The age of these faults is more likely early Tertiary than latest Cretaceous. However, they may be younger since all major faults on the west coast of Vancouver Island are known to transect the Tertiary (Oligocene and early Miocene) strata.

The predominant fault block tectonic style of the report-area and other parts of the Insular Tectonic Belt is caused by a somewhat peculiar basement control. The ubiquitous presence of a thick and rigid "shield" of Karmutsen volcanics must have prevented the development of tight to overturned folds by Late Triassic and Early Jurassic time. Before the end of Middle Jurassic time this "volcanic basement" was further strengthened by the invasion of numerous small and large Coast Intrusions and the accompanying induration or metamorphism of the sediments and volcanics of the Vancouver Group. The resulting "magmatic basement" determined the subsequent tectonic

style of the report-area and other parts of the Insular Tectonic Belt by yielding to the stresses of all post-Middle Jurassic tectonic movements by large and small scale faulting only. The relatively thin post-Middle Jurassic sediments were protected to a large extent from compressive stresses and could not be even moderately folded, except in the proximity of major or principal faults. This predominant block fault tectonic style seems to be out of place in an otherwise typical geosynclinal (= orthogeosynclinal or eugeosynclinal) region. However, other examples of a similar tectonic style are becoming known elsewhere in the Circumpacific Orogenic Belt.

MESOZOIC AND ?TERTIARY ROCKS OF QUATSINO SOUND, VANCOUVER ISLAND, BRITISH COLUMBIA

INTRODUCTION AND ACKNOWLEDGMENTS

This report is based on the results of a detailed survey of Mesozoic and ?Tertiary rocks of parts of Quatsino Sound which took place during parts of the 1953 and 1954 seasons and also includes results obtained from work during a supplementary survey of some parts of the area in 1968 and 1969.

The work, largely confined to the generally well-exposed shoreline, was carried on by means of a locally chartered 40-foot boat and dinghy. A panel truck was used to survey sections along logging roads at the headwaters of Lippy Creek, east of Neroutsos Inlet, and the channels of some larger streams were traversed on foot. Attempts to survey inland parts of the area at a distance from major stream channels and logging roads were found to be unrewarding because of luxuriant vegetation which covers all of the lowlands and most of the steeper slopes above the high tide mark.

The parts of the shoreline occupied by fossiliferous sedimentary rocks were studied in much greater detail than those occupied by volcanic or intrusive rocks. Previous geological reconnaissance work of Dawson (1887), Dolmage (1921), and Gunning (1930), including some unpublished reconnaissance geological maps by Dolmage, was utilized for general orientation and as a guide to the major sedimentary outliers of the area. The geological mapping of these early explorers, and the recent mapping of Jeffery (1962), Northcote (1969) and Muller (1967, 1969,

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1970) is, for the most part, too generalized to be used to fill in the gaps between those parts of the area mapped by the writer on the scale of one-half inch to one mile, or a still larger scale. Geological maps and profiles accompanying this report were compiled primarily to elucidate the stratigraphic, paleontological, paleogeographical and structural conclusions and thus facilitate their use by mapping and economic geologists.

The field work was greatly facilitated by the assistance and co-operation of the residents of the area. Thanks are due to Messrs. Norman Van Dine and Albert P. Schmidt for able assistance in the field during the 1953 season, to Mr. D.D. McIntyre during the 1954 season, to Mr. R.A. Farley during the 1968 season, and to Mr. B.D. Stewart during the 1969 season.

Triassic invertebrate fossils and, except where otherwise indicated, Jurassic invertebrate fossils listed in this report were identified and dated by E.T. Tozer and H. Frebold, respectively, of the Geological Survey of Canada. All Cretaceous invertebrate fossils listed were identified and dated by the writer. W.S. Hopkins, also of the Geological Survey of Canada, identified an important collection of spores and pollen from the Blumberg Formation.

STRATIGRAPHY

VANCOUVER GROUP

The investigated part of Quatsino Sound is underlain mainly by a very thick succession of Triassic and Lower Jurassic volcanic, pyroclastic, and sedimentary rocks. These rocks, which are older than the Coast Intrusions, have been referred to as the Vancouver Group (originally proposed as Vancouver Series by Dawson, 1887).

TABLE OF FORMATIONS

Time-rock units					
System and series	Stage	Regional Zone	Group and Formation		Lithology and thickness
Tertiary	Unknown and probably absent				
	Lower Oligocene? or younger?		?Sooke Intrusions		Granite porphyry, diorite porphyry, and gabbro; minor rhyolite, dacite, andesite, and diabase
	Intrusive contact with Cretaceous strata				
	Unknown and probably absent				
Upper Cretaceous	Unknown and probably absent				
	Early upper Campanian	Baculites cf. chicoensis Pterotrigonia evansana	Nanaimo Group (Cedar District equivalent)		Arkoses and arkosic sandstones; 280'+
	Unknown and probably absent by non-deposition (a major period of orogeny[1])				
	Cenomanian and ?younger		Upper shale unit (= Upper shale of Dawson, 1887)		Siltstone, shale and some fine-grained greywacke; minor limestone; 680'+
Lower Cretaceous	Albian		Coal Harbour Group (new)	Blumberg Formation (new)	Pebble to boulder conglomerate; some grit and coarse to fine-grained subgreywacke; minor sandy siltstone and shale; locally coaly and with coal layers; 3,000'+
	Aptian			Coarse arenite unit	Coarse to medium grained, common gritty subgreywacke and greywacke; some fine-grained greywacke, arenaceous siltstone and shale; minor limestone, pebble conglomerate and coal; ?800' to ?5,390'+

[1] As interpreted by the writer, an "orogenic phase" or "orogeny" implies a demonstrable or probable occurrence of folding of the rocks occurring beneath the unconformity in addition to their uplift and erosion. Batholithic intrusions of granitic rocks may or may not accompany an "orogeny".

Time-rock units			Group and Formation			Lithology an' thick...
stem nd ries	Stage	Regional Zone		Forward Inlet to Kewquodie Creek area and Quatsino village	Rupert Inlet and Holberg Inlet; east of Neroutsos Inlet	
Lower Cretaceous	Upper and middle Barremian	Heteroceras (Heteroceras) cf. heliceroides ?Hemihoplites sp. indet.	Longarm Formation equivalents (unnamed group)	Barremian fine-grained greywacke unit	Barremian variegated clastic unit 200'± to 1,000'±	See text details litholo and thickne of individ units
		?				
		Eulytoceras aff. phestum				
	Lower Barremian ?and/or latest Hauterivian	Shasticrioceras cf. poniente		Inoceramus colonicus calcarenites		See te details litholo and thickne of indivi units
	Hauterivian	Simbirskites (Simbirskites) broadi		West Hauterivian siltstone unit / East Upper Valanginian and(?) Hauterivian greywacke-conglomerate unit	Unknown and apparently completely absent because of non-deposition	See tex details litholo and thickn of individ units
		?				
		Homolsomites oregonensis				
		?				
	Upper Valanginian	Buchia crassicollis s. str.		Buchia crassicollis greywacke ? Hiatus		

Time-rock units					Group and Formation	Lithology and thickness
stem and ries	Stage	Regional Zone				
and basal Cretaceous	Unknown and probably totally absent by non-deposition (a major interval of erosion)					
Middle Jurassic	?Bathonian				Coast Intrusions	Quartz diorite, diorite and gabbro; various dacitic to ?andesitic minor hypabyssa intrusions
	Intrusive contact with rocks of Vancouver Group					
Lower Jurassic	?Toarcian	?Grammoceras sp.	Vancouver Group	Volcanic division of Bonanza Subgroup	?Pliensbachian-Toarcian greywacke unit 1,000'+ (both contacts covered)	
	Pliensbachian	Fanninoceras sp.				
		Acanthopleuroceras sutherlandbrowni			?Dark grey volcanic unit Thickness uncertain	
	Sinemurian	Echioceras (Melanhippites) harbledownensis			Uppermost Sinemurian argillite unit	Dark grey, tuffaceous argillites; some fine to medium grained greywacke and calcareous grit; minor impure limestone; 150'+
					Uppermost Sinemurian volcanic unit	Various waterlain pyroclastics and amygdaloidal to porphyritic lava flows; 300' to 600'+
		Asteroceras aff. obtusum			Matthews Island Formation (new)	Black to dark grey, mostly tuffaceous and/or arenaceous argillites; some waterlain volcanic tuff and breccia; some tuffaceous, fine to coarse grained greywacke; minor mostly impure limestone; 1,300'+
		Arnioceras (Arniotites) kwakiutlanus				
	? — ?					

Time-rock units			Group and Formation			Lithology and thickness
rstem and eries	Stage	Regional Zone				
Lower Jurassic	?Upper Hettangian		Vancouver Group	Volcanic division of Bonanza Subgroup	Grey volcanic unit	Dull- to bluish grey, amygdaloidal, porphyritic or felsitic, intermediate lavas and similarly coloured volcanic breccias and tuffs; 2,000'+
	?				?	?
	?Middle Hettangian				Cherty limestone unit	Thinly bedded to laminated cherty limestone and black to dark grey chert; minor interbeds of various calcarenites, limy greywacke and grit, and waterlain calcareous pyroclastics; 350'+
	?				?	?
	?Lower Hettangian				Basal Jurassic volcanic unit	Predominantly red to maroon intermediate to ?acidic, commonly porphyritic unsorted and poorly to non-stratified volcanic breccia and tuff; considerably similarly coloured, amygdaloidal to porphyritic, acidic? to basic? lavas; 5,000 - ?7,000'
?	?				?	

Time-rock units			Group and Formation			Lithology and thickness
System and Series	Stage	Regional Zone				
Upper Triassic	?Rhaetian		Vancouver Group	Volcanic division of Bonanza Subgroup	Hecate Cove Formation (new)	Green-grey to light grey, coarse to very coarse, waterlain volcanic breccia with calcareous, argillaceous and tuffaceous matrix; some poorly rounded volcanic conglomerate; finer grained, waterlain volcanic breccia and waterlain volcanic tuff; predominantly limestone, sedimentary breccia and/or conglomerate at the base; some porphyritic lavas and massive crystal tuffs (especially near the top): ?500 - 2,500'±
		?				
		Mostly (except in residual ?Rhaetian depositional troughs; see Fig. 5) an unconformity and hiatus of variable magnitude (early Rhaetian orogeny)				
	?					
	Upper Norian	Upper subzone of Suessi Zone	Vancouver Group	Sedimentary division of Bonanza Subgroup	West / Middle / East Arenaceous Member Arenaceous Member Sutton Formation (Limestone)	See text for details of lithology and thickness

Time-rock units			Group and Formation			Lithology and thickness
System and Series	Stage	Regional Zone			West / East	
Upper Triassic	Upper Norian	Lower subzone of Suessi Zone	Vancouver Group	Sedimentary division of Bonanza Subgroup	Thinly Bedded member	Black, mostly more or less tuffaceous and/or arenaceous argillite; minor impure limestone; 300'+ (or? more west of Neroutsos Inlet)
	Middle Norian	Columbianus Zone				Massive to indistinctly bedded, cryptocrystalline often cherty limestone (predominantly in the lower unit); thinly to medium bedded, often cherty limestone (predominantly in the upper part of unit); minor chert, pyroclastic and calcareous argillite interbeds; 600' - 2,500'+
		?				
		Rutherfordi Zone				
		? ?				
		Magnus Zone				
		? ?				
	Lower Norian	Dawsoni Zone			Quatsino Formation	
		Kerri Zone				
Upper Triassic and (?) older	Upper Karnian and(?) older	Macrolobus Zone				
		Welleri Zone				
		Dilleri Zone and (?) older		Karmutsen Subgroup (upper part)	Amygdaloidal flows unit (upper part only?)	Dark green to dark bluish grey, basic, mostly amygdaloidal and well banded lavas; minor waterlain pyroclastics and minor limestone; ±3,000'; base not exposed

The sedimentary rocks, which occur at several levels within the Vancouver Group, are especially prominent at about its middle part, where they predominate almost to the exclusion of the lavas and pyroclastic rocks. Several other less prominent sedimentary zones occur in the upper part of the Group. All sedimentary zones of the Vancouver Group are relatively thin when compared with the thicknesses of the adjacent volcanic to pyroclastic rock units and tend to form relatively narrow belts within much larger areas occupied by the latter types. These sedimentary belts appear, however, to be rather extensive in their areal distribution and to retain their stratigraphic position throughout, except where missing as a result of faults or where obliterated by bodies of Coast Intrusions.

The fundamental importance of the sedimentary zones for the subdivision of the Vancouver Group and mapping of its structure was recognized by Dawson (1887, p. 9B, etc.). Dolmage (1919, p. 32A), in the course of his investigations of Quatsino Sound, used a thick limestone formation as a horizon marker and named it the Quatsino Limestone. However, Gunning (1930, pp. 102A-104A; 1931, 1932, pp. 23A-25A; 1933, 33AII-35AII) was the first to propose a generalized but workable scheme of subdivision of the rocks of the Group. At the onset of his work, Gunning (1930, p. 103A) insisted that: "Before the structure of the Vancouver Group can be worked out the sediments will have to be mapped carefully and their succession established". Later, Gunning (1932, p. 23A) proposed a subdivision of the rocks of the Vancouver Group of the Nimpkish map-area into the Karmutsen volcanics below, Quatsino Formation in the middle, and the Bonanza Group above. This threefold division was found to be fully valid by Hoadley (1953) for Zeballos map-area, and by Jeletzky (1950, 1954a, 1954b, 1970b, and unpublished) for the west coast of Vancouver

Island between Brooks Peninsula and Clayoquot Sound and was found also to be valid for the investigated part of Quatsino Sound. Accordingly, they are used with minor adjustments in the body of this report as well as on the geological maps and profiles accompanying it.

The term Vancouver Group in the sense of Dawson (1887) and subsequent workers lost its practical usefulness as a map unit after the recognition of the regional validity of its threefold subdivision as proposed by Gunning (1932). The restriction of the Vancouver Group to one of Gunning's (1932) subdivisions appears to be impractical. At the same time, the term is valuable for the designation of all intensely faulted and sheared, more or less altered or metamorphosed, pre-batholitic Mesozoic rocks of Vancouver Island. Therefore, it was decided to retain the Vancouver Group and to treat Karmutsen and Bonanza Groups as its subgroups. Where used in the text, the term Vancouver Group is meant to embrace all three divisions of Gunning (1932), to the exclusion of all Paleozoic rocks tentatively included in the Vancouver Group in its original definition (Dawson, 1887, p. 10B).

Karmutsen Subgroup

The Karmutsen volcanics are accorded a subgroup status as Surdam's (1968, pp. 17-18, Figs. 3-5) work in Buttle Lake area has demonstrated the feasibility of their subdivision into several informally named lithological units of formational rank. Surdam's (1968) subdivisions of the Karmutsen Subgroup appear to be valid for the investigated part of Quatsino Sound.

Amygdaloidal Flows Unit

Distribution and stratigraphy. The oldest rocks exposed in the report area are dark bluish grey to dark green, mainly amygdaloidal or porphyritic basic lavas of the Karmutsen Subgroup. These lavas appear to be lithologically similar and stratigraphically equivalent to the Amygdaloidal Flows unit of Surdam (1968, p. 18, Fig. 5) and are accordingly correlated with this informal unit. The basic lavas are confined to a small area around the confluence of Holberg Inlet, Rupert Inlet and Quatsino Narrows where as much as 3,000 feet of lavas, locally with minor interbeds of basic pyroclastic rocks and tuffaceous sediments (see below) are exposed. Their base is nowhere exposed and is believed to be faulted in all sections studied. The top is invariably faulted, except possibly in one section on the eastern shore of Quatsino Narrows where the massive limestone of the lower member of the Quatsino Formation seems to overlie, conformably and gradationally, the bluish green, fine-grained (?)lavas of the Karmutsen Subgroup. It is possible, however, that these rocks at this locality comprise a 5- to 6-foot thick intrusive sill. The nature of the poorly exposed contacts with adjacent beds of the Quatsino Formation and Karmutsen Subgroup remains uncertain.

The lithology and observed thickness of Karmutsen rocks suggest that only the upper part of the Amygdaloidal Flows unit of Surdam (1968, p. 18, Fig. 5) is exposed within the report area.

Studied sections of the Karmutsen Subgroup are characterized by the extreme lithological monotony of their commonly well-banded lavas, and an almost complete absence of pillow structures. No sedimentary or pyroclastic interbeds were found in most sections investigated but two isolated sections at the mouth of Marble River are

characterized by a more variable lithology. The section on the west bank exposes 250 to 300 feet of very dark green to almost black, abundantly and coarsely porphyritic lavas interbedded with some similarly coloured amygdaloidal lavas and dark brown to dark brown-grey pyroclastic rocks. Both contacts are covered. The adjacent, apparently underlying section on the east bank, exposes 120 to 150 feet of well-banded, dark green to almost black porphyritic and amygdaloidal lavas. At the visible base, and especially at the visible top of the section, these lavas are interbedded with dark brown to almost black pyroclastic? rocks (volcanic tuffs?). They grade stratigraphically upward imperceptibly into a 20- to 25-foot thick sedimentary unit consisting of black to dark grey, tuffaceous, concretionary shale interbedded with similarly coloured coarse grit and impure, partly gritty limestone and waterlain volcanic rocks [spilitic lavas or (?)volcanic tuffs].

These peculiar rock units appear to represent one of several, partly sedimentary, marine interbeds within the upper part of the Karmutsen Subgroup, such as were observed locally well below its top at Ououkinsh Inlet and elsewhere on the west coast of Vancouver Island by the writer (Jeletzky, unpublished), and by Surdam (1968, p. 18, Fig. 5) in Buttle Lake map-area.

Age and correlation. No fossils were found in the Karmutsen Subgroup of Quatsino Sound. The subgroup is dated, however, as early Late Triassic (Karnian) and (?)older Triassic because of its apparently gradational contact with the overlying Karnian Quatsino Limestone and because of the writer's discovery of ammonites of the Dilleri Zone in its topmost beds in the Kyuquot area, west coast of Vancouver Island (GSC loc. 24033; see Tozer, 1967, p. 82).

Bonanza Subgroup

The Karmutsen Subgroup is overlain by a thick and lithologically diversified sequence of volcanic and sedimentary rocks customarily referred to as the Quatsino Formation and the Bonanza Group as in adjacent areas of Vancouver Island (e.g. Gunning, 1930, 1932, 1933; Hoadley, 1953; Jeletzky, 1950, 1954a, 1954b, 1969, 1970a, 1970b; Muller, 1967, 1969, 1970; Muller and Carson, 1969).

The name "Bonanza Group", as originally defined by Gunning (1932, p. 23A), was applied to all volcanic and sedimentary rocks of the Nimpkish map-area that are older than the Coast Intrusions and younger than the Quatsino Formation. It was realized that this group consisted of a lower, predominantly Sedimentary division and an upper, predominantly Volcanic division, but the evidence then available was not considered to be sufficient for formal naming of these divisions. Gunning (1932, p. 23A) stated, however, that: "if this group be later subdivided, the term Bonanza should be retained for that division lying directly above the Quatsino Formation".

Subsequent workers, including the writer, have found the divisions of the Bonanza Group proposed by Gunning (1932) to be valid at least throughout the north-western part of Vancouver Island including the surveyed parts of Quatsino Sound. However, none of these workers has elected to name them formally or to restrict the term "Bonanza Group" in accordance with Gunning's (1932, p. 23A) suggestions.

In principle, the writer favours treating both divisions of the Bonanza Subgroup as independent subgroups of rocks and restricting the "Bonanza Subgroup" to the Sedimentary division only. It is commonly difficult, however, to map their subordinate volcanic and sedimentary rock units on lithology alone because of the rarity or absence of reliable lithological horizon markers, extreme lateral lithological

variability of most units within short distances, and the common reappearance of the same lithological types at different levels. In practice, one must rely, for the most part, on direct or indirect use of index fossils for mapping these units (Jeletzky, 1961a, pp. 3-4; Jeletzky and Tipper, 1968, pp. 5-6) and the units commonly are lithostratigraphic units in name only. The final decision on the subject is deferred, therefore, pending the completion of other reports on the Mesozoic and Tertiary rocks of northwestern Vancouver Island. The informal terms "Sedimentary" and "Volcanic" divisions of the Bonanza Subgroup are used accordingly in this report and on the accompanying maps and geological profiles. Wherever practicable, the fossiliferous sedimentary subunits of each division have been mapped separately and named informally or, in some cases, formally (e.g. Sutton Formation). The Quatsino Limestone thins drastically northeastward and southwestward of the Quatsino Narrows - Victoria Lake belt and its upper part is laterally replaced by fine to coarse clastic rocks of the Sedimentary division of the Bonanza Subgroup (Jeletzky, 1954a, p. 1269, 1970b, p. 3, Figs. 1, 2, 5, and in the following sections of this report). This circumstance and the presence of other prominent limestone lenses (e.g. Sutton Limestone) higher in the Sedimentary division necessitates the inclusion of Quatsino Limestone as one of the formations of the Sedimentary division of the Bonanza Subgroup.

Sedimentary Division

The outcrops of the Sedimentary division of the Bonanza Subgroup including Quatsino Limestone) are confined almost exclusively to that part of Quatsino Sound east of Klotchlimmis and Hawisnakwi Creeks. The rocks of the division always are considerably faulted and locally contorted because of the incompetence of its argillite units. The Sedimentary division (including the Quatsino Limestone) appears to be subdivisible into the same rock units as its equivalents on the west coast of Vancouver Island (Jeletzky, 1950, pp. 7-12; 1954a, p. 1269; 1970b, pp. 3-5, Figs. 1, 2; McLearn, 1953, p. 1210). However, most units of this subdivision become unrecognizable on the eastern side of Vancouver Island and the islands of Queen Charlotte Strait (Jeletzky, 1970b, pp. 3-4, Figs. 1, 2) where a different formational nomenclature must be used for its equivalents (e.g. Parson Bay Formation; see Fig. 5). Three different facies of the Sedimentary division were recognized in the investigated part of Quatsino Sound (see Table of Formations). The eastern facies is characterized by an extremely thick development of Quatsino Limestone, a thick development of greywacke in the overlying clastic units, the apparently complete absence of the Sutton Limestone and the presence of an unconformity between the Sedimentary and Volcanic divisions. The intermediate facies is characterized by a decrease of greywacke and an increase of argillite and limestone in the clastic units, appearance of the Sutton Limestone in the uppermost part of the division and the apparent disappearance of the unconformity between the Sedimentary and Volcanic divisions. Judging by its only exposure-area in Koprino Harbour, the western facies is lithologically identical with the eastern facies. No exposures of Quatsino Limestone are known in the intermediate and western sections but its thickness is believed to be greatly reduced in this part of the area because of its well-established regional thinning toward the southwest (Jeletzky, 1954a, p. 1269; 1970b, pp. 3-4, Figs. 1, 2).

Quatsino Formation

Distribution and stratigraphy. The Quatsino Formation outcrops extensively in the same part of the area as the underlying Karmutsen Subgroup. Also, it outcrops extensively inside Varney Bay, on lower Marble River, throughout Quatsino Narrows, and along the northeastern shore of Neroutsos Inlet. The unexplored eastern half of Drake Island possibly is built of Quatsino Limestone in part at least.

Dolmage (1919, p. 32B), the author of the formational name Quatsino Limestone, defines it as follows:

> The limestone occurs chiefly in one large bed, which outcrops continuously along the east shore of the Southeast arm, through the narrows, and as far west as Marble creek in Rupert arm. It also appears on the west shore of the Southeast arm, and on the West arm. It has been mapped separately and named provisionally the Quatsino Limestone. Above and below it, interbedded with the thin flows and beds of tuff, are numerous thin beds of similar limestone, in places slightly argillaceous. The limestone contains all the copper deposits of the district, which are invariably situated at the contact of the intrusive diorites and related rocks.

Dolmage did not designate any type section, nor has this been done by any later worker to the best of the writer's knowledge. After investigating most of the Quatsino Limestone sections between Neroutsos Inlet (Southeast arm) and the eastern part of Rupert Inlet, the writer declines to select any of them as the type section of the formation. All of these sections are incomplete with neither base nor the top of the formation exposed, repeated by faulting, more or less sheared and irregularly folded. It seems best to postpone the selection until the discovery of a more satisfactory section within the general type-area designated by Dolmage (1919, p. 32B).

Lower member. The formation appears to be divisible, based on lithology, into the informal Lower and Upper members. The Lower member is at least 1,300 feet thick. It consists predominantly of massive to indistinctly bedded (Pl. I; Pl. II, Fig. B), light grey, rose-grey or medium grey, cryptocrystalline (except where transformed into marble in the proximity of larger bodies of Coast Intrusions), pure to cherty limestone, weathering whitish grey to dirty white. Upper Karnian (Welleri Zone) ammonites (Discotropites, Hoplotropites and Juvavites s. lato were found at one place in beds believed to represent the topmost part of the member some 1,500 feet south of Stewart Point, Holberg Inlet (GSC loc. 24335). The underlying, invariably unfossiliferous beds of the member probably represent the lower part of the Welleri Zone since diagnostic ammonites of the Dilleri Zone have not been found so low in the Quatsino Formation. These have been found only in the topmost beds of the underlying Karmutsen Subgroup of the Kyuquot area, west coast of Vancouver Island (Tozer, 1967, p. 82) and in its intraformational limestone member (Tozer, 1967, p. 82; Jeletzky, 1970b, p. 2).

About 1,300 feet of the Lower member are exposed in the best available, apparently almost continuous section of the Quatsino Formation measured along the southwestern shore of Rupert Inlet just northeast of Kenny Point (Fig. 1). However, the base of the member is missing in this section due to faulting and it is not possible to estimate the thickness of its missing basal part. The predominantly massive to thickly and indistinctly bedded, rose-grey to light grey, cryptocrystalline limestones of the Lower member commonly contain numerous inclusions of dark grey to brown-grey chert at many levels. Several intercalated beds (up to 30 feet thick) of thin to thick and distinctly bedded, dark grey to brown-grey limestone interrupt the monotony of the Lower member in this section.

Other sections of the Lower member exposed on the shores of Quatsino Narrows (Pl. II, Fig. A), Varney Bay, Kokwina Cove, on the northeastern side of Hecate Cove, on Lakken Point, and along the northeastern shore of Neroutsos Inlet are entirely similar lithologically to that of Kenny Point. Some of these sections seem to be more than 1,300 feet thick. However, they are invariably too intensely faulted and crumpled to admit even a rough estimate of the thicknesses involved. Contacts with the Upper member are invariably faulted in these sections.

Upper member. The Upper member is at least 1,200 feet thick. It consists predominantly of medium to thinly and distinctly bedded, medium grey to brown-grey or dark grey to black, in places more or less argillaceous limestones (especially near the top). Limestones of the Upper member are commonly cherty and include numerous inclusions, thin interbeds, layers and lamellae of brown-grey, dark grey or black chert. The unit is sparsely fossiliferous throughout and locally includes lenses and thick beds of coquina, coralline and stromatoporoid limestone. Its top is invariably faulted.

In the best available section just northeast of Kenny Point (Fig. 1), the Lower member is conformably and gradationally overlain by some 250 feet of 6-inch to 2-foot thick and well-bedded, dark grey to blackish grey, locally argillaceous limestones referred to the lower part of the Upper member. These limestones include abundant nodules, irregularly shaped lenses and laminae of black to dark grey chert. Near the base (GSC loc. 23259) it has yielded the basal Norian (Kerri Zone) *Halobia alaskana* Smith, *Dictyoconites* sp. indet. and indeterminate arcestid ammonites. The late Karnian *Hoplotropites* fauna of GSC loc. 24335 was found apparently in beds equivalent

to the uppermost part of the Lower member of the Kenny Point section (Fig. 1) that are lithologically transitional to the Upper member and only 100 to 150 feet stratigraphically below the Halobia alaskana bed of GSC locality 23259.

The thinly bedded limestone unit of the Upper member is gradationally and conformably overlain by a unit, at least 850 feet thick, of medium to thickly and distinctly bedded (well-defined beds 2 to 5 feet thick), pinkish grey or white, brownish grey weathering limestone rich in irregular nodules, lenses and layers of dark grey to brownish grey chert. Numerous interbeds of dark grey, often argillaceous limestone, as in the underlying unit, occur at several levels, but are more common near the visible top of the unit. Several thick interbeds of coralline and stromatoporoid limestone, as much as 10 feet thick, and several 2- to 5-foot thick beds of coquina-like limestone occur in the upper part of the unit. This upper part of the Upper member is, furthermore, moderately to abundantly fossiliferous throughout. The middle part of the unit has yielded the basal Norian Mojsisovicsites kerri fauna (GSC locs. 23266, 23269). The upper part did not yield any short-ranging fossils but is believed to be early Norian to early middle Norian (older than the Columbianus Zone) in age because of the presence of specifically indeterminate Halobia (GSC loc. 23270) and the apparent total absence of Monotis (Tozer, 1967, p. 38).

The top of the unit is covered and appears to be faulted against the Karmutsen lavas at the point about 1,000 feet east of the tip of Kenny Point (Fig. 1). Rocks of the Upper member are flexed into several open folds, locally are faulted considerably and may be repeated. The estimated minimum thickness of 850 feet is based on

measurements of the uniformly tilted, continuously exposed and rarely to moderately faulted westernmost part of the section (Fig. 1) where GSC localities 23269, 23270 and 23257 are situated.

Poor, severely faulted and badly contorted outcrops of dark grey, well-bedded limestones, apparently referable to the Upper member were observed south of Stewart Point in the proximity of GSC locality 24335.

Medium- to thin- and well-bedded, dark grey to grey, whitish grey weathered, mostly fossiliferous (GSC locs. 24326, 24328) limestones outcropping for some 250 feet across the strike around the sharp rocky point immediately north of the mouth of Marble River are tentatively referred to the Upper member in spite of the apparent absence of well-preserved, diagnostic fossils. Their top and base are covered and are believed to be faulted against the Lower member of the Quatsino Limestone and Karmutsen lavas, respectively.

Age and correlation. As pointed out by Jeletzky (1954a, p. 1269), the Quatsino Limestone of Quatsino Sound, at least 2,500 feet thick, represents a considerably longer time interval than the Quatsino Limestone of the west coast of Vancouver Island (i.e. between Brooks Peninsula and Esperanza Inlet), which is normally only 100 to 550 feet thick. It definitely includes the Kerri Zone and probably includes the Dawsoni, Magnus and Rutherfordi Zones. The Quatsino Limestone of the west coast has, in contrast, yielded only late Karnian ammonites of the Welleri Zone (see Tozer, 1967, p. 82; Jeletzky, 1970b, pp. 2-3). The occurrence of *Mojsisovicsites kerri* and *Halobia alaskana* in the overlying argillites of the Bonanza Subgroup in Nimpkish map-area and that of *Halobia alaskana* in the basal part of the Thinly Bedded member on Union Island (see Tozer, 1967, p. 81) effectively rule out the presence of

any younger faunas in the Quatsino Limestone of the west coast of Vancouver Island. The Quatsino-Bonanza contact is, therefore, markedly diachronic in the northeast-southwest direction. Most or all of the more than 1,200-foot thick Upper member of the Quatsino Formation of the report-area appears to be laterally replaced by the lower part of the Thinly Bedded member of the Bonanza Subgroup described by Jeletzky (1950, p. 8, Fig. 1; compare this report Fig. 5) somewhere between the eastern shore of Varney Bay and Ououkinsh Inlet.

The Quatsino-Thinly Bedded member contact appears to be similarly diachronic eastward of the investigated part of Quatsino Sound. Like that of the Thinly bedded member of the west coast of Vancouver Island, the calcareous, black argillite of the Parson Bay Formation of Harbledown Island area comprises all of the Norian stage including the Kerri Zone. This is indicated clearly by the occurrence of Halobia alaskana Smith in the lowermost exposed beds (Crickmay, 1928, pp. 54, 59; Tozer, 1967, p. 81). The concealed (or faulted out?) Quatsino Formation of Parson Bay area (Crickmay, 1928, p. 59) can only include, therefore, the late Karnian Welleri and Dilleri Zones.

The lateral replacement of most or all of the Upper member of Quatsino Formation of Quatsino Sound by the argillites of Parson Bay Formation in the east, and by those of the Thinly Bedded member of the Sedimentary division in the west, indicates a gradual narrowing of the extremely broad late Karnian depositional trough of northern Vancouver Island during the early and middle Norian. This gradual narrowing of the essentially clastic-free central part of the trough (Figs. 2, 5) apparently reflects some uplifts along its western and eastern margins, which were supplying the gradually increasing amounts of fine clastic material to the early and

middle Norian trough. The apparently complete absence of arenaceous or psammitic material in the Parson Bay Formation, its absence or scarcity in the Thinly Bedded member, and the exclusively open sea character of the fauna of these formations indicate that they were deposited far from shore. The eastern shore of the early to mid-Norian depositional trough probably was situated well within the present day Coast Range whereas its western shore probably was situated beneath the Pacific Ocean some distance to the west of the present day west coast of Vancouver Island (Jeletzky, 1970b, pp. 4-5; this report, Fig. 2).

In contrast, there is no evidence favouring the diachronic nature of the Quatsino-Karmutsen contact either within the surveyed area or between Quatsino Sound and the west coast of Vancouver Island. The discovery of ammonites of the Dilleri Zone in the "Interlava Sediments" in the Campbell River area (Givens and Susuki, 1964; see Tozer, 1967, p. 82) suggests that the contact is more or less isochronous in terms of ammonite zones between Union Island and the east coast of Vancouver Island and elsewhere within the Insular tectonic belt as already suggested by Sutherland-Brown (1966, p. 84) and Jeletzky (1970b, p. 2, Fig. 1).

Thinly Bedded member

At least 300 feet of black to dark grey, commonly thinly bedded to laminated but locally thick-bedded to massive and indistinctly bedded, tuffaceous and calcareous argillites overlie the upper member of the Quatsino Formation at the headwaters of Lippy Creek. The lower contact of the Thinly Bedded member appears to be gradational and numerous intercalated beds of thin- to medium- and well-bedded, black to dark grey, impure limestone occur in the lower part of the unit. In some

sections (see Sec. 1, of the Appendix) a large number of such limestone beds persist to the very top of the unit. Several interbeds of greywacke and calcareous grit were noted locally in the upper part of the Thinly Bedded member.

At least 200 feet of the lithologically similar argillite outcrops between the massive limestone of the Lower member of the Quatsino Formation and the greenish grey to maroon, waterlain pyroclastics and lavas of the Hecate Cove Formation immediately northwest of Ohlsen Point at the west end of Quatsino Narrows. Contacts with adjacent units appear to be faulted and the argillite itself is more or less contorted throughout and often is completely crushed. No fossils were found in this argillite unit which is tentatively correlated with the Thinly Bedded member rather than with the argillite beds of the Arenaceous member of the Lippy Creek sections.

Other outcrops of lithologically similar argillite occur on the northeastern shore of Neroutsos Inlet north of Atkinson Cove. These outcrops were not studied in any detail and are referred to the Thinly Bedded member on their lithology alone.

The Thinly Bedded member grades upward into the greywackes of the Arenaceous member (see Sec. 1 of the Appendix).

No outcrops of the Thinly Bedded member have been seen in the investigated parts of Rupert and Holberg Inlets either because of the lack of outcrops or because it is missing due to faulting in all sections of the Sedimentary division studied in this part of the area.

No outcrops of the Thinly Bedded member were observed anywhere to the west of its Atkinson Cove exposures. However, the member is believed to persist throughout the western part of Quatsino Sound and to thicken gradually southwestward at the expense of the Upper member of the Quatsino Formation until it reappears in Klaskino Sound (see p. 27 and Fig. 5). It is assumed, accordingly, that the Thinly Bedded member has plunged deep enough beneath sea level throughout this interval to prevent its reappearance even on the relatively upthrown sides of the largest faults.

Poorly preserved fossils found in the uppermost 10 feet of the Thinly Bedded member (see Sec. 1) suggest a late Norian age for this part of the unit at least. Because of the probable presence of the early middle Norian fossils in the upper part of the Upper member of the Quatsino Formation in the same general area, the older, so far unfossiliferous beds of the Thinly Bedded member probably are not older than the Columbianus Zone of late middle Norian age (see Table of Formations) in any of its exposed sections. The Thinly Bedded member of Quatsino Sound, therefore, can be correlated only with the upper part of the Sedimentary division of the Bonanza Subgroup described by Jeletzky (1950, p. 8; 1970b, pp. 3-4, Fig. 1) in the Esperanza-Kyuquot area and elsewhere on the west coast of Vancouver Island (cf. pp. 19-20).

Arenaceous member

The Thinly Bedded member is conformably and probably gradationally overlain by at least 400 feet of predominantly arenaceous rocks in all sections studied at the headwaters of Lippy Creek on the northeastern side of Neroutsos Inlet. This Arenaceous member of the Sedimentary division consists of dark grey to dark green, predominantly fine-grained, in places tuffaceous, greywacke interbedded with lesser dark grey to dark brown or black, mainly arenaceous and tuffaceous argillite. Minor amounts of interbedded fine- to coarse-grained, well-bedded,

waterlain volcanic tuff, grit and fine pebble conglomerate occur in some sections. The member is overlain disconformably and apparently discordantly by the volcanic conglomerates or waterlain volcanic breccia of the Hecate Cove Formation.

All measured sections of the Arenaceous member are incomplete, disturbed by faulting, and locally contorted. The estimate of the thickness of the Arenaceous member and its tentative subdivision proposed below are based on a somewhat arbitrary combination of several incomplete sections. The best of these sections are 1, 5, 6 and 7 described in the Appendix.

The Arenaceous member of the Lippy Creek area is subdivided tentatively into a lower unit, about 250 feet thick, consisting mainly of greywacke and an upper unit, about 150 feet thick, which apparently includes more than 50 per cent of arenaceous and tuffaceous argillite. Judging by the isolated outcrops of the member studied at Stewart Point and in Koprino Harbour, this subdivision may be valid throughout the investigated part of Quatsino Sound.

The greywacke unit comprises beds 8 to 15 of section 1. Only 127 feet of this unit are exposed in this section. However, the basal part of the section is not exposed, nor are the upper beds which are believed to be at least 125 feet thick judging by some other incomplete and only cursorily studied sections of the unit.

The greywacke unit of the Arenaceous member is represented predominantly (more than 75% of the thickness) by dull grey to dull green, predominantly fine-grained, commonly more or less tuffaceous greywacke with some interbeds and lenses of medium- to coarse-grained greywacke and grit. Furthermore, this unit includes some intercalated beds of dark grey mudstone, similarly coloured argillite and laminated cherty shale. Interbeds and lenses of calcareous coquinoid grit and light grey cryptocrystalline limestone were observed in place only in one exceptional section of the unit described below.

About 200 feet of intensely contorted dark grey, fine- to coarse-grained commonly tuffaceous greywacke with some interbeds and lenses of calcareous coquinoid grit, light grey cryptocrystalline limestone and blackish grey, and calcareous argillite outcrops between the Cretaceous coarse arenite unit and the lower member of the Quatsino Formation in the interval 350 to 700 yards southwest of Stewart Point in Holberg Inlet (see geol. map 1). This unit did not yield any diagnostic fossils and both of its contacts appear to be faults. However, it is correlated tentatively with the greywacke unit of the Arenaceous member at the headwaters of Lippy Creek because of the lithological similarity. This section of the Arenaceous member contains some littoral rock types which were seen only in the consedimentary slump breccias (see Sec. 1, Units 4, 14) of the Arenaceous and Argillite units of the Lippy Creek sections. Therefore, and because it is situated east of the Lippy Creek sections, the Stewart Point section of the Arenaceous member is interpreted tentatively as its extreme littoral facies, situated next to the northeastern source area which provided clastic debris to the marine trough on the eastern side of which the sediments of the Arenaceous member have been deposited (Fig. 3).

The argillite unit of the Arenaceous member comprises beds 3 to 5 of section 1. Only 54 feet of this unit are actually exposed in this section. However, at least 80 feet of this unit are exposed in section 7 (see Appendix) and the covered interval between beds 5 and 8 of section 1 is believed to conceal at least 90 to 100 feet of the argillite unit. The coarser grained interbeds of the argillite unit include some lavender coloured, well-bedded and obviously waterlain volcanic tuff in addition to rock types identical with those occurring in the underlying Greywacke unit. This waterlain volcanic tuff is lithologically similar to that characteristic of the more fine-grained

facies of the overlying Hecate Cove Formation in Julian Cove (see p. 43) and on the west coast of Vancouver Island (Jeletzky, 1950, pp. 12-13). Some limestone pods and interbeds were noted in the Koprino Harbour section (see Unit 7, Sec. 5) of the argillite unit.

The ratio of argillite and coarser clastics varies greatly from one section of the argillite unit to another. However, the argillite comprises more than 60 per cent of the exposed thickness in all its sections studied. A geographically isolated outcrop, about 70 feet thick and 900 feet long, consisting of apparently overturned, greatly sheared to almost milonitized, predominantly argillaceous sediments closely resembling those of the argillite beds of the Arenaceous member, occupies the front (i.e. the eastern) side of the nameless point between Spencer and Robson Coves in Koprino Harbour (see Unit 7 of Sec. 5 for details). These sediments have yielded only indeterminate pectenid pelecypods (GSC loc. 24327). However, they are correlated tentatively with the argillite unit of the Arenaceous member because of the close lithological similarity and the association with limestone breccias, amygdaloidal lavas and volcanic breccias referable to the Hecate Cove Formation (see Sec. 5). This outcrop of the Arenaceous member is extremely important paleogeographically (see section on the late Norian paleogeography) because of its geographic position a considerable distance to the west of the Lippy Creek-Stewart Point outcrop-area of the unit.

Age and correlation. The Lippy Creek sections of the Arenaceous member commonly contain abundant *Monotis salinaria* (Schlotheim), *M.* cf. *salinaria* (Schlotheim), *M.* cf. *ochotica* var. *densistriata* (Teller) and *Heterastridium* sp. indet. (see Secs. 1, 6, 7) indicating a late Norian (Suessi Zone) age for the member (Tozer, 1967, pp. 38-41).

The fauna of the Arenaceous member of Quatsino Sound is unlike that occurring in the Arenaceous member of the west coast of Vancouver Island (Tozer, 1967, pp. 79-80) which appears to lack completely all of the above-mentioned forms. Only Monotis forms belonging to, or comparable with Monotis subcircularis (Gabb) were found in the numerous late Norian sections studied within the Esperanza-Ououkinsh segment of the west coast and they are restricted to the upper part of the Thinly Bedded member. No Monotis forms were found either in the Arenaceous member or in the Sutton Limestone (= Limestone member of Jeletzky, 1959, pp. 9-10) in any of these sections.

The lithology and fauna of the late Norian sections of Klaskino Inlet studied together with J.E. Muller in 1968 are, in contrast, very similar to those of the late Norian sections at the headwaters of Lippy Creek. The upper beds of the typically developed Thinly Bedded member of Klaskino Inlet sections contain Monotis subcircularis (Gabb) (e.g. GSC locs. 82939 and 82941). This member grades upward into the Arenaceous member which, at that locality, is 250 feet thick, commonly gritty and tuffaceous, and locally conglomeratic, and in which Monotis salinaria (Schlotheim) and Monotis cf. ochotica var. densistriata (Teller) were found by J.E. Muller (personal communication of E.T. Tozer, of April 10, 1970). The Arenaceous member is disconformably and apparently discordantly overlain by pyroclastic rocks of the Hecate Cover Formation which seems to overstep the Arenaceous and Thinly Bedded members. The Sutton Limestone is absent in all sections of eastern Quatsino Sound and Klaskino Inlet studied by the writer in 1968.

The local variations of stratigraphic ranges of Monotis species complicate the more exact dating and correlation of the Arenaceous member of eastern Quatsino Sound. The abundant presence of Monotis salinaria (Schlotheim) and apparent absence of Monotis

subcircularis (Gabb) in this member suggest, according to Silberling (in Silberling and Tozer, 1968, p. 33), that it is largely or entirely younger than the Lower Suessi Zone (i.e. Monotis subcircularis subzone) and represents at least the basal part of the Upper Suessi Zone. Therefore, and because of the similar stratigraphic position of all units concerned, the Arenaceous member of eastern Quatsino Sound is believed to be correlative with part or all of the Arenaceous member of the Sedimentary division of the Esperanza-Ououkinsh segment of the west coast (Jeletzky, 1950, pp. 9-11) and the equivalents of the Upper Limestone member of the Sutton Formation of the Buchholz Channel sections (see below) are believed to be absent in the Lippy Creek sections (see Secs. 1, 6, 7). The same is believed to be true of the Klaskino Inlet sections (Fig. 5).

Sutton Formation (Limestone)

Distribution and stratigraphy. The rocks of the Sutton Formation were studied in detail only on the southern shore of Buchholz Channel between the eastern side of Smith Cove and the western side of Julian Cove, and on the northeastern side of Banter Point. However, the formation also outcrops on the southwestern shore of Neroutsos Inlet northeast of the Yreka Mine pier and on the southwestern part of Drake Island.

The Sutton Formation was not observed on the northeastern side of Neroutsos Inlet between Evenson Point and Jeune Landing. Nor was it observed in any of the sections studied farther northeast at the headwaters of Lippy Creek. The absence of Sutton Formation in these areas appears to be due to the lateral replacement of the Lower Limestone member by the Arenaceous member of the Sedimentary division and the non-deposition of the Upper Limestone member there because of the effects of the early Rhaetian orogenic phase (see below).

Sutton Formation is believed to be absent throughout the western part of Quatsino Sound because of its lateral replacement by the Arenaceous member in this direction. However, the apparently gradational nature of the contact between the Hecate Cove Formation and the argillite unit of the Arenaceous member in its Koprino Harbour section (see Units 6, 7, of Sec. 5) suggests that the Arenaceous member of western Quatsino Sound continues to include equivalents of the Upper Limestone member of the Sutton Formation, at least that far southwest. The hiatus between the Arenaceous member and the Hecate Cove Formation is believed to be restricted to yet more westerly parts of Quatsino Sound.

On the southern shore of Buchholz Channel, the Sutton Formation outcrops on the relatively upthrown sides of several northwest-trending fault blocks (see Figure 17). All sections studied are intensely faulted, crumpled, commonly contorted, and invariably invated by dykes and small plug-like bodies of the Coast Intrusions.

Section 2 of the Appendix is the best known section of Sutton Formation in Quatsino Sound. It represents the relatively clastic-free facies of Sutton Formation which also outcrops along the western shore of Julian Cove and in places along its eastern shore.

East of section 2, the equivalent but lithologically more variegated, apparently more shallow water beds of the Sutton Formation are exposed on the rocky seashore between the western side of Smith Cove and the eastern side of Julian Cove. Those intensely disturbed sections exhibit the following general sequence of beds in descending order:

1. Upper Limestone member. A unit, about 150 feet thick, consisting predominantly of relatively pure, grey, thin- to medium- and well-bedded limestone. The unit contains subordinate lenses and interbeds of light grey to dirty white, massive cryptocrystalline limestone, coralline and stromatoporoid limestone, various arenaceous rocks, and argillite lithologically similar to those of unit 2 of section 2. This unit, locally containing abundant fossils, has yielded Paracochloceras sp. indet. in an outcrop (GSC loc. 24333) situated at the eastern entrance to Julian Cove. Elsewhere it has yielded only some non-diagnostic marine fossils. Like the equivalent unit 2 of section 2, this upper unit of the Sutton Formation appears to be conformably (?paraconformably) overlain by the basal beds of the Hecate Cove Formation of the Volcanic division (see Sec. 3, Unit 6).

2. Lower Limestone member. This unit, which gradationally underlies the Upper Limestone member, is 150 to 200 feet thick, and consists of black, often limy to very limy, thin-bedded tuffaceous and/or arenaceous argillite somewhat cyclically alternating with almost equal amounts of calcarenitic to cryptocrystalline, somewhat arenaceous or tuffaceous limestone and lesser amounts or brownish grey, very limy sandstone and grit locally grading into arenaceous and gritty calcarenite. Some intercalated beds of consedimentary limestone breccia occur locally. All rocks form more or less lenticular beds, lenses and inclusions. The limestones are normally lithologically similar to those of the Lower and Upper members of Quatsino Formation but they also include numerous lenses and interbeds of dark grey limestone replete with angular inclusions of cherty, black limestone. Poorly preserved fossils, including corals and stromatoporoids, are common at several levels but no diagnostic forms were found. The base of the unit is covered or cut off by faults in all sections studied.

Age and correlation. The presence of Paracochloceras sp. indet. in the Upper Limestone member (GSC loc. 24333) indicates an Upper Suessi age (Tozer, 1967, pp. 38-41) at least for the upper part of the Sutton Formation of Quatsino Sound.

Because of the gradational contact of the Lower Limestone member with the Upper Limestone member and its assumed superposition on the western continuation of the Thinly Bedded member (see Table of Formations, Fig. 5), an Upper Suessi age is proposed for the former.

The presence of Paracochloceras sp. indet. in the Upper Limestone member and the presence of an apparently Late Triassic fauna (i.e. ?Rhaetian) in the topmost beds of the overlying Hecate Cove Formation (see pp. 50-51) suggest the absence of any post-high upper Norian rocks in the Sutton Limestone of Quatsino Sound.

The correlation of the Sutton Formation with the Quatsino Formation (e.g. Bostock, Mulligan and Douglas in Stockwell et al., 1957, p. 302, Table XIX) is untenable as already pointed out by McLearn (1953), Tozer (1954, 1967) and Jeletzky (1954a, 1970b and in this report), except where the two appear to merge into a single, very thick limestone unit (e.g. in Buttle Lake area and in Queen Charlotte Islands; see Jeletzky, 1970b, pp. 5, 9). The apparently complete absence of the Quatsino Formation beneath the Sutton Formation in the Duncan-Sooke area of Vancouver Island must be due either to faulting (Tozer, 1967, pp. 78-79) or possibly to the lateral replacement of Quatsino Limestone by the Karmutsen volcanics (= Franklin Creek volcanics of Fyles, 1955, p. 19).

Because of the presence of Paracochloceras sp. indet., the Upper Limestone member of the Sutton Formation of eastern Quatsino Sound is correlative with the type Sutton Formation of Cowichan Lake (Tozer, 1967, pp. 78-79) in part at least. Furthermore, the two units are similar lithologically and in stratigraphic position. These circumstances and the apparent continuity of these high upper Norian limestones throughout Vancouver Island justifies the extension of the name Sutton Formation to the Quatsino Sound sections.

The Sutton Formation of eastern Quatsino Sound contains elements of the abundant late late Norian (Upper Suessi Zone) fauna occurring in the Arenaceous and Limestone (= Sutton Formation) members of the Sedimentary division of the Esperanza-Ououkinsh segment of the west coast of Vancouver Island (Jeletzky, 1950, pp. 8-9; Tozer, 1967, p. 80). Therefore, the Arenaceous and Limestone members of that area taken together are correlative with the Sutton Formation of eastern Quatsino Sound.

The disconformable, and apparently regionally unconformable nature of the contact between the Arenaceous member of eastern Quatsino Sound and Klaskino Inlet and the largely nonmarine facies of the overlying Hecate Cove Formation (see p. 28) suggest the non-deposition (or less likely a subsequent erosion) of the Upper Limestone member of the Sutton Formation in these two areas. This conclusion is supported by the apparently conformable to ?paraconformable nature of the contact between the Upper Limestone member of the Sutton Formation and the prevailingly marine facies of the overlying Hecate Cove Formation in all sections where the Sutton Formation is present. Furthermore, it agrees well with the following lateral facies changes observed in the Sutton Formation of

Quatsino Sound. In the sections situated between the western side of Smith Cove and the eastern side of Julian Cove, its Lower Limestone member is a considerably more arenaceous and argillaceous deposit than the equivalent unit 3 of its section 2 situated farther west. This eastern (or Smith Cove) facies of the Lower Limestone member is more lithologically similar to the Arenaceous member than is its western facies represented by the unit 3 of section 2. This facies contains a much greater ratio of black, extremely calcareous argillites than the Arenaceous member and many interbeds of various limestones which are absent in the latter unit while being at the same time a more argillaceous and arenaceous unit than the equivalent unit 3 of the Banter Point section (see Sec. 2 of the Appendix).

The eastern facies of the Sutton Formation appears to be transitional between the neritic to littoral, almost exclusively clastic facies of the Arenaceous member and the largely clastic-free, offshore (or western) facies of the formation outcropping on Banter Point and the western side of Julian Cove. Both facies of the Lower Limestone member are considered to be shallow water deposits because of the abundance of colonial corals and stromatoporoids and the local presence of coquina layers built of thick-shelled pelecypods.

Similar lateral facies changes occur also in the Upper Limestone member of the Sutton Formation. In the sections situated between the western side of Smith Cove and the eastern entrance to Julian Cove, this unit (see Sec. 3, Unit 6 and earlier in this section) is considerably more argillaceous, arenaceous and calcarenitic than the thickly and indistinctly bedded to massive, more or less clastic-free and often cherty limestones of the equivalent unit 2 of the Banter Point section (see Sec. 2 of the Appendix). The eastern and western facies of the Upper Limestone member are believed to be younger than any parts of the Arenaceous member of the Lippy Creek and Klaskino Inlet areas.

Though an offshore deposit, the relatively pure limestone of the western (or Banter Point) facies of the Upper Limestone member is a relatively shallow water deposit because of the presence of colonial corals and stromatoporoids. The corals include numerous delicate (not-rolled) fragments of branching forms while stromatoporoids locally form crust- to bud-like colonies oriented along the bedding planes. These fossils were therefore buried either in close proximity of their habitat (corals) or in their living position (stromatoporoids).

Late Norian Paleogeography

As recognized by Jeletzky (1970b, p. 5), the presence of extensive areas of the late late Norian (Upper Suessi Zone) arenaceous sediments to the east (i.e. at the headwaters of Lippy Creek and at Stewart Point) and to the west (i.e. in Koprino Harbour and Klaskino Inlet) of that part of Quatsino Sound occupied by the late late Norian limestones is one of the clearest indications of the ensuing tectonic fragmentation of the previously continuous, clastic-free central zone of the early to middle Norian depositional trough of the Insular Tectonic Belt. This facies pattern indicates the emergence of sizable late Norian tectonic lands within the investigated part of Quatsino Sound which provided argillaceous, arenaceous, and some coarser clastics to the marginal parts of the intervening, residual marine troughs. The inferred paleogeographical pattern (Fig. 3) contrasts with the earlier pattern which characterized the same area during the times of deposition of the Quatsino Formation and the lower part of the Thinly Bedded member (Fig. 2).

The complex facies pattern which emerged at the onset of Suessi Time in Quatsino Sound and adjacent parts of northwestern Vancouver Island (Jeletzky, 1970b, p. 5) was apparently limited to this part of the Insular Tectonic Belt and did not extend into its southeastern (Buttle Lake area) and northwestern (Queen Charlotte Islands) parts.

The scarcity of outcrops of the Thinly Bedded member within the investigated part of Quatsino Sound precludes a detailed description of facies and paleogeographic pattern of the early late Norian (i.e. Lower Suessi or Monotis subcircularis) time. The previously mentioned lithological diversity of the upper part of the Thinly Bedded member within and beyond the investigated part of Quatsino Sound and the clearly recognizable, southwestern direction of paleoslope (see p. 32) in the outcrops of the Thinly Bedded member of Klaskino Sound suggest the existence of a facies pattern similar to that of the late late Norian time (Fig. 3). The writer (see also Jeletzky, 1970b, p. 5) believes, accordingly, that at least the nuclei of the late late Norian tectonic lands and residual marine troughs discussed below arose in early late Norian time and that their locations coincided mainly with those of the late late Norian and latest Triassic (Rhaetian?) tectonic lands.

The late late Norian (i.e. Upper Suessi time) facies pattern indicates the existence of at least two northwest-trending tectonic lands within the investigated parts of Quatsino Sound. The first, or Coal Harbour-Alice Lake tectonic land, apparently occupied the eastern shore of Holberg Inlet in the vicinity of Coal Harbour and extended southeastwards therefrom at least to the eastern side of Alice Lake (Fig. 3). The apparent prevalence of dark grey, impure limestones of Suessi Zone in the Buttle Lake area (Jeletzky, 1970b, p. 5) suggests the

termination of this tectonic land somewhere in the vicinity of Woss Lake (Fig. 3). The data available is, however, too scarce and too localized for any definitive conclusion on this subject.

The prevalence of dark grey, impure limestones of the Suessi Zone in Queen Charlotte Islands (Jeletzky, 1970b, p. 5) suggests the termination of the Coal Harbour-Alice Lake tectonic land either somewhere within the northwestern part of Vancouver Island or beneath the waters of Queen Charlotte Sound. There is, however, no evidence available at present for any closer estimate of the extent of this tectonic island to the northwest of the Coal Harbour area and no attempt was made to delimit its northwestern part in Figure 3.

The latest Triassic orogenic phase (see p. 52) and the concurrent volcanic outburst did not affect the eastern side of Vancouver Island as the Late Norian argillites or impure limestones appear to grade imperceptibly into the lithologically similar low Lower Jurassic sediments throughout the tectonically and volcanically quiescent zone of the Insular Tectonic Belt (Jeletzky, 1970b, p. 9, Figs. 1, 2; this report Figs. 5, 6). This indicates that the Coal Harbour-Alice Lake tectonic island was only a narrow, presumably cordillera-like welt which probably did not extend northeastwards beyond the line: Quatse Lake-Waukwass Creek - southern end of Bonanza Lake (Fig. 3). However, the Sedimentary division of this area was not studied in any detail by the writer and it is impossible to define the northeastern margin of the Coal Harbour-Alice Lake tectonic land with any degree of precision until some outcrops of the arenaceous to psammitic facies of the Upper Suessi Zone are found to the east of Holberg and Rupert Inlets.

The residual late late Norian marine trough flanking the Coal Harbour-Alice Lake tectonic land from the southwest is named herein the Neroutsos Trough (Fig. 3). In the Quatsino Sound area, the northeastern margin and the northeastern flank of Neroutsos Trough are fairly well defined by the previously discussed lateral facies changes of the Arenaceous member and Sutton Limestone. This trough apparently opened up into the southeastern (i.e. Buttle Lake area) and northwestern (i.e. Queen Charlotte Islands) parts of the Insular Tectonic Belt that were characterized by the predominantly calcareous facies of Suessi Zone (see p. 30 under the discussion of the Coal Harbour-Alice Lake tectonic land).

No outcrops of the high upper Norian (i.e. Upper Suessi Zone) rocks are known anywhere between Banter Point and Koprino Harbour where its arenaceous facies, apparently representing the southwestern flank of Neroutsos Trough, reappears at the southern tip of an upthrown fault block (see Figure 18). Therefore, the eastern (or Smith Cove) and western (or Banter Point) facies of Sutton Limestone are assumed to reappear in a reversed order within the interval between Banter Point and Koprino Harbour devoid of Sutton outcrops. Then the eastern facies is believed to be replaced by the Arenaceous member east of Koprino Harbour (Fig. 3).

The Koprino Harbour section (see Unit 7 of Sec. 5) of the Arenaceous member includes numerous pods, lenses and interbeds of impure limestone and seems to grade upward into the waterlain pyroclastics and marine sedimentary rocks of the second facies of the Hecate Cove Formation. Therefore, it appears to be lithologically transitional to the marginal (i.e. eastern) facies of the Sutton Limestone. This suggests, in turn, that the calcareous facies of the Upper Suessi Zone of Neroutsos Trough may have extended southwestward almost to Koprino Harbour.

No outcrops of the high upper Norian (i.e. Upper Suessi Zone) rocks are known anywhere between Koprino Harbour and Klaskino Inlet. A southwestern direction of paleoslope is indicated, however, by the direction of slump folds in the limestone breccias, argillites, and greywacke in the studied outcrops of Sedimentary division of Klaskino Sound and by the persistent southwestward thinning and/or disappearance of coarser clastic interbeds observed in the Thinly Bedded member of the same sections. A late late Norian tectonic land - the Southwestern Tectonic Land - must, therefore, have been situated in the interval between Koprino Harbour and the Klaskino Sound. This northwest-trending tectonic land apparently flanked the residual Neroutsos Trough from the southwest and extended along the west coast of Vancouver Island at least in the interval between Esperanza and Klaskino Inlets (Jeletzky, 1970b, pp. 7-8). The existence of this Southwestern Tectonic Land southeast of Brooks Peninsula (Fig. 3) is indicated by the restriction of outcrops of Sutton Limestone to the outer coast and offshore islands (Jeletzky, 1970b, pp. 7-8). The equivalent high upper Norian clastic rocks are conversely concentrated farther inland (e.g. in the inner parts of Malksope and Ououkinsh Inlets and in Klaskino Inlet) throughout the surveyed parts of the Esperanza-Klaskino segment of the west coast.

Because of the apparent lack of outcrops of the upper Norian rocks between Koprino Harbour and Klaskino Inlet, very little is known about the width and orographic character of the here discussed Southwestern Tectonic Land. Nor was it possible to cull any pertinent information from the scarce literature concerned with inland parts of Vancouver Island flanking this section of Quatsino Sound.

The partly calcareous lithology of the Arenaceous member in Koprino Harbour and its apparently gradational contact with the overlying Hecate Cove Formation suggest that the northeastern shore of the Southwestern Tectonic Land was situated at least a few miles farther west. It seems likely that it may have approximated the line Galato Creek-Nordstrom Cove-Mabott Island - a point west of O'Connell Lake - headwaters of Klaskish River and the entrance to Kashutl Inlet (Fig. 3). Nothing is known about the extension of the northeastern shoreline of this tectonic land farther to the southeast and northwest.

The late late Norian residual marine trough flanking the Southwestern Tectonic Land from the southwest is herewith designated the West Coast Trough. This trough occupied the outer parts of the west coast of Vancouver Island and the offshore islands in the interval between the Esperanza and Klaskino Inlets. The Sutton Formation is prominent in this zone in the interval between Esperanza Inlet and the southern side of Brooks Peninsula (Jeletzky, 1950, pp. 9-11; 1970b, pp. 7-8; and unpublished). However, the Sutton Formation is completely absent in all Klaskino Inlet sections studied (i.e. replaced laterally by the Arenaceous member), therefore it is believed to occur beneath the sea off the entrance to the inlet. Furthermore, the Sutton Formation becomes more arenaceous and argillaceous northeastwards until it is replaced laterally by the prevailingly arenaceous, commonly tuffaceous and partly nonmarine rocks of the Arenaceous member near the heads of Malksope and Ououkinsh Inlets. Because of these shoreward facies changes, the northeastern margin of the West Coast Trough apparently was situated in the proximity of the line: Cape Parkins - Gooding Cove - Sieward Hill - head of Klaskino Inlet - Hisnit Islets in Ououkinsh Inlet - head of Malksope Inlet, Hohoae Point in Kyuquot Sound and Queens Cove in Esperanza Inlet.

Southeast of the Esperanza Inlet, the West Coast Trough is believed to extend at least to the Cowichan Lake area. It seems likely that the trough disappears completely beneath the Pacific Ocean off Cape Parkins and Lippy Point northwest of the entrance to Quatsino Sound.

Like the Coal Harbour-Alice Lake Tectonic Land, the Southwestern Tectonic Land apparently was a more or less continuous but narrow, cordillera-like welt (Fig. 3). The central part of the West Coast Trough apparently is concealed everywhere beneath the Pacific Ocean off the west coast.

Volcanic Division

Throughout the investigated part of Quatsino Sound, the Sedimentary division of the Bonanza Subgroup is overlain unconformably to apparently conformably (?paraconformably) by a very thick succession of andesitic, dacitic and ?rhyolitic, mainly lavender- to maroon-coloured lavas and pyroclastic rocks. These volcanics correspond to the Volcanic division of the Bonanza Group as defined by Gunning (1932, p. 23A) and subsequent workers. Volcanic tuffs and breccias predominate in most sections studied, but felsitic, prophyritic and amygdaloidal lavas may be prominent, and even predominant locally. The relatively brightly coloured pyroclastic rocks and lavas of the Volcanic division are normally easily distinguishable from the monotonous, dark lavas of the Karmutsen Subgroup. However, fairly thick units of ?basic, dark bluish grey to dark green, amygdaloidal lavas lithologically indistinguishable from those of the Karmutsen Subgroup may occur locally in the division. These lavas are especially common in its basal part.

No complete sections of the Volcanic division of the Bonanza Group were observed anywhere in the surveyed part of Quatsino Sound. Structural complexity of most of the partial sections studied and the lithological monotony of the volcanic and pyroclastic rocks of the unit have, furthermore, made it difficult either to work out a composite section or to estimate closely its total thickness. The previously proposed tentative estimates of the total thickness of the Volcanic division (e.g. Jeletzky, 1954a, p. 1270; 1970b, p. 19, Fig. 2) range between 10,000 and 20,000 feet and cannot be refined reliably without an additional detailed paleontological-stratigraphic study of the area.

The 8,500-foot-thick section of the Volcanic division measured by Muller (1970, p. 47) along the Pacific coast of Vancouver Island north of Quatsino Sound is almost certainly incomplete in the upper part since it is overlapped unconformably by the Lower Cretaceous rocks (pers. com. of J.E. Muller, 1969).

The Volcanic division outcrops extensively on the shores of Quatsino Sound between the western entrance to Quatsino Narrows and the mouth of Forward Inlet. It is even more widespread inside of Forward and Browning Inlets. East of Quatsino Narrows, the Volcanic division outcrops extensively on the northern shore of Holberg Inlet between Apple Bay and Coal Harbour, in the upper course of Nuknimish Creek, in the northeastern corner of Rupert Inlet, and in the mouth of Waukwass Creek in its southeastern corner.

In that part of the report-area situated west of Quatsino village, the predominantly andesitic to dacitic, grey-, lavender- or maroon-coloured pyroclastic rocks and lavas of the division are interbedded with three or (?)more units of fossiliferous, marine sediments each several hundred feet to more than

1,300 feet thick. In this part of the area, furthermore, the pyroclastic rocks of the division are, in places, markedly waterlain and may grade locally to tuffaceous sediments.

In spite of the well established northeastward thinning out of volcanic units of the Volcanic division and their lateral replacement by the fine clastics of the Harbledown Formation (Jeletzky, 1970b, pp. 17-19, Figs. 1, 2; this paper Fig. 5) no sedimentary interbeds were observed in its outcrops east of Ouatsino Narrows. This appears to be due to the almost complete or ? complete absence of the younger part of the division to which these sedimentary interbeds are confined. So far only the Hecate Cove Formation and the Basal Jurassic volcanic unit have been observed in this relatively tectonically positive part of the report-area.

The writer has attempted to map separately each of the volcanic and sedimentary units of the Volcanic division discussed in the following sections of this report (see Figures 17-18). This task, however, was difficult because of far-reaching lithological similarity of the volcanic units of the division and their obscure (faulted or covered contacts) structural and stratigraphic relationships with the adjacent biochronologically datable sedimentary units. Consequently, some of the mapped outcrops of the Volcanic division had to be left unassigned beyond their placement in this division and the specific assignments of some other outcrops must be considered as tentative only.

Hecate Cove Formation

The basal unit of the Volcanic division was originally designated the Upper Triassic or Jurassic pyroclastic and tuffaceous unit (Jeletzky, 1950, p. 12) and later renamed informally the Waterlain breccia unit (Jeletzky, 1969, p. 126; 1970b, pp. 5-8, Fig. 1) because of the characteristically waterlain nature of its principal pyroclastic rock types. This name is replaced here by a formal formational name,

the Hecate Cove Formation, which is derived from Hecate Cove on the northern shore of the main Quatsino Channel immediately east of Quatsino Village. The designated type section is that occurring on the northwestern side of Hecate Cove between Jesdal Islet and the sharp nameless point opposite Kitten Islet where the best known section of the formation is exposed. This section (see Sec. 4 of the Appendix) locally contains abundant marine fossils of a probable Late Triassic age and leaves little doubt as to its sequential relationships with the overlying basal Jurassic volcanic unit. The base of the Hecate Cove Formation is covered and probably faulted at its type section but is well exposed in section 2. The latter section, which accordingly can serve as a parastratotype of the Hecate Cove Formation, shows its stratigraphic relationship with and its direct superposition on the Sutton Formation of the Sedimentary division.

The Hecate Cove Formation is best characterized by the predominantly layered and sorted, more or less distinctly rounded, waterlain character of its pyroclastic fragments and by the argillaceous and calcareous nature of the commonly dark to bluish grey matrix. Another characteristic feature is the presence of greater or lesser numbers of interbeds of various (mostly psammitic), commonly marine clastics and limestones either in the basal part of the unit or throughout its thickness. The limestones commonly are represented by consedimentary slump breccias; otherwise their fragments form part of the mixed sedimentary-volcanic breccias. The colours of the lavas are mainly green-grey to blue-green. They tend to lack the pink to orange plagioclase phenocrysts characteristic of the overlying Basal Jurassic volcanic division, except at some places in the upper part of the formation. Similar somber (grey, green or blue) colours are characterisitc

of the volcanic and mixed sedimentary volcanic breccias. The distinctly and thinly bedded, waterlain volcanic tuffs of the formation tend, in contrast, to be coloured buff, orange or lavender. The extreme lithological diversity of the Hecate Cove Formation is another characteristic feature.

Some of the above-mentioned distinctive lithological features may be absent in the individual sections of the Hecate Cove Formation. However, even its most extreme, predominantly or ?entirely nonmarine facies (see Secs. 1, 6, 7) is usually sufficiently distinctive lithologically to be recognized without reference to the stratigraphic relationships with the adjacent sedimentary units. The Hecate Cove Formation is the most distinctive unit of the Volcanic division of the Bonanza Subgroup and is a valuable lithological horizon marker in the investigated part of Quatsino Sound. Also, it is distinctive lithologically and stratigraphically valuable in other parts of the tectonically and volcanically active zone of the Insular Tectonic Belt (Jeletzky, 1970b, pp. 5-9, Figs. 1, 2).

Muller (1970, p. 45) proposed to include the "Waterlain breccia" (i.e. the Hecate Cove Formation of this report) with the Bonanza sediments and to treat these two units as a "volcanic-clastic-carbonate melange deposited in a time of local volcanic quiescence". This interpretation is incompatible with the results of the writer's field and office work (Jeletzky, 1954a, 1954b, 1969, 1970a, 1970b, pp. 8-9) and is not followed in this report. The predominantly volcanic Hecate Cove Formation is sharply and commonly unconformably delimited from the units of the Sedimentary division in all sections studied by the writer (see below) and overlies them throughout the tectonically and volcanically active zone. Because of the stratigraphic position, structural relationships, characteristic lithology, and the inferred younger (?Rhaetian) age, the formation forms part of the Volcanic division. Only insignificant interbeds of well-bedded, waterlain volcanic tuffs and

breccias, unrelated to the Hecate Cove Formation, have been observed locally in the Thinly Bedded and Arenaceous members of the underlying Sedimentary division.

The latest Karnian to Norian (i.e. Quatsino-sedimentary Bonanza) period of quiescence appears to be a regional phenomenon within the Insular Tectonic Belt (Jeletzky, 1970b, pp. 3-5, Figs. 1, 2; and in the preceding pages of this report) and there does not seem to be any justification for treating the almost exclusively sedimentary rocks of that time as a "volcanic-clastic-carbonate melange" or to amalgamate them with regionally deposited, younger syntectonic Hecate Cove volcanics.

Distribution and stratigraphy. The known exposures of the Hecate Cove are confined almost entirely to the eastern part of Quatsino Sound. In this part of the report area, the formation was observed on the northern side of the main channel of Quatsino Sound between Jesdal Islet and the inner basin of Hecate Cove, on the southern shore of Buchholz Channel between Pender Point and the western side of Julian Cove, on Banter Point, around a nameless point immediately west of Ohlsen Point on the eastern side of Hecate Cove, on the eastern shore of Holberg Inlet between Coal Harbour and Apple Bay, and at the headwaters of Lippy Creek on the eastern side of Neroutsos Inlet. Except for one restricted area of exposure in the northwestern corner of Koprino Harbour, the Hecate Cove Formation is not known to outcrop anywhere between Kultus Cove and Klaskino Inlet.

Outside of the report-area, the Hecate Cove Formation is widespread on the west coast of Vancouver Island, on Cowichan Lake (unpublished personal observations) and between the Esperanza and Klaskino Inlets (Jeletzky, 1950, pp. 12-13; 1970b, pp. 5-9). The Hecate Cove Formation is essentially a syntectonic product of the latest Triassic (Rhaetian?) orogenic phase. Consequently,

it is restricted to the tectonically and volcanically active zone produced within the Insular Tectonic Belt by these movements and is completely unknown on the east side of Vancouver Island and in Queen Charlotte Islands because of the lateral replacement of its waterlain pyroclastics and coarse to fine clastics by impure limestones and calcareous argillites of the upper Quatsino and ?upper Parson Bay Formations (Jeletzky, 1970b, pp. 5-9, Figs. 1, 2; this report Fig. 5).

The lithology and thickness of the Hecate Cove Formation is even more variable than that of the underlying sedimentary rocks of the Upper Suessi Zone. In some sections, herein designated as the first facies of the formation, its lower beds are represented by a complex interfingering of marine limestone breccia, waterlain mixed sedimentary-volcanic breccia, various intermediate (?andesitic) volcanics including pillow lava and pillow breccia, various (volcanic, mixed sedimentary-volcanic, predominantly limestone) conglomerates composed of poorly rounded pebbles, well-bedded, waterlain volcanic tuffs, and various clastic and calcareous sedimentary rocks lithologically similar to those of the Upper Suessi Zone. Waterlain volcanic breccia and tuff, and locally ?andesitic lavas, predominate over the other rock types in the middle and upper part of the sections of this facies.

The first facies of the Hecate Cove Formation is exemplified by the sections measured on the southern side of Buchholz Channel of Quatsino Sound between Pender Point and the western side of Julian Cove, and on Banter Point (Sec. 2). In this part of the area, the basal part of the Hecate Cove Formation is exposed in several sections. It is represented either by a 15- to 20-foot-thick bed of fine to coarse limestone breccia, which also includes some dispersed, more or less rounded limestone pebbles (as on the west side of Smith Cove; see below) or by a

150-foot-thick unit of rusty to tawny coloured, coarse volcanic breccia with fragments and pods of grey limestone or calcareous, waterlain volcanic tuff (see Secs. 2, 3).

On the western side of Smith Cove, where the basal part of the formation consists of limestone breccia, its matrix is very calcareous but locally rich in tuff- and breccia-size fragments and imperfectly rounded pebbles of volcanic rocks similar to those occurring in the overlying beds of the unit. The amount of volcanic fragments and pebbles increases upward in the limestone breccia bed. This results in its gradual transformation into an overlying limy and argillaceous conglomerate composed of imperfectly rounded volcanic pebbles to boulders. This volcanic conglomerate, as much as 25 feet thick, in turn grades upward into, or is locally replaced laterally by green-grey to light grey, coarse to very coarse, waterlain volcanic breccia with an abundant dark grey to greenish grey, calcareous, argillaceous and tuffaceous matrix. Judging by its complete absence in adjacent sections, the basal limestone breccia interfingers with and becomes replaced by the above-described volcanic conglomerate and coarse, waterlain volcanic breccia westward (Sec. 3) and ?eastward.

The next younger beds of the formation outcropping on the northeastern shore of Smith Cove consist of similar conglomerate and volcanic breccia including some interbeds of finer grained waterlain volcanic breccia and volcanic tuff, as well as those of dark green porphyritic lava with rust- to pink-coloured phenocrysts of ?sodic plagioclase. The breccia fragments and pebbles mainly are of the above-mentioned lava or of the lithologically similar crystal tuff. The estimated thickness of these waterlain pyroclastic rocks and lavas outcropping on the northeastern shore of Smith Cove is

between 900 and 1,000 feet. Near the head of the cove, these rocks are overlain, apparently conformably, by some 150 feet (top is concealed) of dark green, porphyritic lavas with phenocrysts of rust to pink ?sodic plagioclase and some similarly coloured crystal tuffs rich in phenocrysts of the same feldspar. These rocks may represent the basal part of the Basal Jurassic volcanic unit of the division (cf. Unit 1 of Sec. 4).

The adjacent, apparently continuous section 3 (see Appendix) represents a lithologically different facies of the lower part of Hecate Cove Formation in which the waterlain volcanic breccia predominates throughout.

Numerous exposures of considerably faulted basal beds of the Hecate Cove Formation occur about one-half mile southwest of section 3 in the southwestern corner of Julian Cove. In these exposures, the coarse to medium, waterlain, volcanic and limestone breccias include some interbeds of thinly bedded and well-sorted conglomerates. They contain, furthermore, irregularly interbedded in about equal amounts, fine-grained, distinctly and mainly thin-bedded, often crossbedded, more or less calcareous volcanic tuffs grading into tuffaceous greywacke. These waterlain rocks are coloured tuscan-red to dark grey and are similar lithologically to the fine-grained varieties of the Upper Triassic or Jurassic pyroclastic and tuffaceous rock units that are widespread on the west coast of Vancouver Island (Jeletzky, 1950, pp. 12-15; and unpublished). The dips of forest beds seem to indicate a northwestern or western source area for the better rounded, well-bedded varieties of these rocks.

Outcrops of the lower part of the Hecate Cove Formation occurring on the northeastern side of Banter Point do not seem to differ materially from equivalent beds outcropping between Pender Point and the eastern side of Julian Cove. The same beds exposed at the tip of Banter Point (see Unit 1 of Sec. 2) are similar to equivalent beds of section 3.

The southwestern side of Banter Point is built of well-bedded, fine volcanic breccia interbedded with the mainly fine-grained, distinctly and mostly thinly bedded, commonly calcareous volcanic tuffs locally grading into tuffaceous greywacke. These waterlain pyroclastics are maroon to dark lavender in colour. The rocks strike at 345° and dip westwards at 60° but are not much disturbed otherwise. This finer grained phase of the Hecate Cove Formation is believed to overlie unit 1 of section 2. The top of these waterlain breccias and tuffs is covered and probably cut off by a major northwest-trending fault in the southeastern corner of Kultus Cove.

The facies of Hecate Cove Formation exposed in the western corner of Julian Cove and on the southwestern side of Banter Point is transitional between that of the sections farther east and that of the type section of the formation.

The section of the Hecate Cove Formation exposed west of Ohlsen Point appears to belong to the same facies as the sections on the southern shore of Buchholz Channel. This section consists largely of greenish grey to maroon, partly waterlain volcanic tuffs and fine to coarse volcanic breccias interbedded with some tuffaceous grits and coarse, volcanic conglomerates with imperfectly rounded pebbles. Numerous interbeds of similarly coloured medium- to coarse-grained porphyritic lavas occur in this section of the Hecate Cove Formation. Some of the lavas contain abundant reddish grey to orange phenocrysts of ?sodic plagioclase. The stratigraphically lower beds of the unit exposed near the western end of Indian village are much better rounded and sorted, and more regularly and distinctly bedded; they are, in part, rich in inclusions and lenses of calcareous waterlain pyroclastic rocks and tuffaceous clastics. The base of this section, about 600 feet thick, of the middle part of the unit was not reached and its top is faulted.

The second facies of the Hecate Cove Formation is characterized by a marked decrease in the amount of the coarse waterlain breccias and volcanic conglomerates and a corresponding increase in the number and thickness of interbeds of fossiliferous marine greywacke, grit, impure limestone and calcareous argillite as compared with its Buchholz Channel facies. The sediments are mainly tuffaceous. The second facies also contains numerous interbeds of fine-grained, waterlain volcanic tuff. The tuffaceous clastics, tuffaceous limestones, and finer grained waterlain pyroclastics occur at intervals throughout the thickness of the second facies of the Hecate Cove Formation. This relatively fine-grained and predominantly marine facies is best exemplified by the type section of the Hecate Cove Formation (see Sec. 4 of the Appendix).

The type section of Hecate Cove Formation is about 1,899 feet thick. It is considerably thicker than any other section of the formation studied, in spite of the fact that its basal beds, corresponding to units 1-3, 5 of section 3, to unit 1 of section 2, and to units 4-6 of section 5, are believed to be concealed beneath the visible base of bed 13. Another 150 feet of the formation may be concealed in the covered interval above its visible top. If this interpretation is correct, the total thickness of the second facies of the Hecate Cove Formation would be in order of 2,500 feet.

The only section (see Sec. 5 of the Appendix) of the Hecate Cove Formation observed in the western part of Quatsino Sound represents its second facies. This intensely sheared and often contorted section exposes only the basal ?450 feet of the formation which is largely or ?entirely absent in the type section.

The third facies of the Hecate Cove Formation is characterized by the scarcity or complete absence of the limestone breccia and interbeds of marine sedimentary rocks. Furthermore, it includes numerous interbeds of basic porphyritic lavas (mostly augite porphyry) and their conglomerates. In the studied sections of this facies (see Secs. 1, 6, 7), the predominantly coarse and poorly sorted, mixed sedimentary-volcanic or purely volcanic breccias, lavas, and volcanic conglomerates overlie disconformably to regionally unconformably the deeply eroded surface of the Sedimentary division of the Bonanza Subgroup. In the report-area, the underlying Sedimentary division is represented exclusively by the Arenaceous member (see Secs. 1, 6, 7). In the west coast sections, however, this facies of the Hecate Cove Formation apparently overlies unconformably the Arenaceous and Thinly Bedded members. The third facies of the Hecate Cove Formation tends to be considerably thinner than either of the other two known facies. So far as is known, its thickness in Quatsino Sound does not exceed 500 feet and, locally, may be less.

The apparent complete absence of marine shells in the third facies of the Hecate Cove Formation and the almost complete absence of the calcareous and argillaceous matrix in the pyroclastics and psammites suggests that the facies is predominantly or ?exclusively of nonmarine origin. The absence of any pillow lavas or pillow breccias in all studied sections in Quatsino Sound supports this conclusion.

The prominent ?augite porphyry unit of section 6 appears to be only a local feature of the third facies of the Hecate Cover Formation. Similar basic lavas have been seen at the base of the formation in the section of the third facies measured by J.E. Muller at the headwaters of Yogtook Creek, east of Victoria Lake and visited by the writer in 1969. However, such lavas are absent at the same level in section 7 situated in close proximity to sections 1 and 6.

What appears to be another outcrop-area of the third facies of Hecate Bay Formation occupies the northern shore of Holberg Inlet between the western entrance to Coal Harbour and the eastern side of Apple Bay. Orr Islet apparently is built of these intensely altered volcanic rocks which appear to be, for the most part, fine to coarse volcanic breccia, buff to rust coloured, strongly jointed and locally sheared; the surface is honeycombed and the matrix appears to be calcareous. The volcanic breccia is interbedded with some light grey (?discoloured) porphyritic ?lava rich in rectangular to lath-like phenocrysts of whitish grey to buff feldspar. No definite attitude was observed. A rocky islet in a shallow embayment of the shoreline at the point about 2 miles west of Coal Harbour's wharf exposes the following section of these rocks:

1. Diabase-like volcanic rock (?tuff), dark grey to almost black, hard, resistant, massive-looking; contains some dark red, coarse fragments; northern contact covered on north side of the islet; southern contact poorly exposed but appears to be abrupt; visible up to 60 feet.

2. Fine volcanic breccia, purple, massive-looking, southern contact concealed beneath the water; visible up to 40 feet. The rocks strike about east-west and dip about vertically. It was not possible to infer the direction of the top and the base of this section.

These volcanic rocks of the Hecate Cove Formation extend inland only from 300 to 600 feet before they are cut off by Holberg Fault (see Figure 17).

Origin and environmental significance of some peculiar rock types. The Hecate Cove Formation includes a number of very peculiar lithological types which are either rare or absent in other units of the Vancouver Group. The foremost of these rocks are the almost unique marine limestone breccia embedded in the argillaceous and/or limy, tuffaceous matrix and the marine, volcanic breccia embedded in a similar matrix (Jeletzky, 1950, pp. 12-13). The latter breccia was subsequently renamed the "Agglomerate" Limestone by Hoadley (1953, p. 24, Pl. IIA, B; Pl. III). All transitions exist between these two breccia types and either of them may grade imperceptibly into sedimentary, volcanic or mixed conglomerates.

The writer agrees with J.E. Muller's suggestion (pers. com. in July, 1968) that much of the limestone breccia occurring in basal beds of Hecate Cove Formation and elsewhere was caused by the areally restricted consedimentary slumping of limestone interbeds commonly occurring in the first and second facies of the Hecate Cove Formation. The fragmentation and downslope sliding of the almost unconsolidated to feebly consolidated sediments was accompanied by an extensive penetration of calcareous or argillaceous ooze between the fragments.

The common presence of more or less rounded sedimentary and volcanic fragments and pebbles in some of the limestone breccias may reflect more widespread slumping which also involved the littoral and beach parts of the basin where the coarse clastic sediments have been deposited. Some other limestone breccias must have been reworked in situ by waves and currents after the formation and partial hardening of their fragments. This is indicated by a high percentage of distinctly waterworn but nevertheless angular limestone clasts occurring in them, and by the lateral gradation of these "reworked" limestone breccias and limestone conglomerates to completely angular slump breccias.

The marine volcanic breccias (= "Agglomerate" Limestone) of the Hecate Cove Formation have been interpreted (Hoadley, 1953, p. 24, Pl. IIA, B; Pl. III) to be the result of burial of airborne pyroclastic products (ejectamenta of volcanic explosions) in the limy mud or marl accumulating on the adjacent parts of sea floor at that time. This explanation appears to be entirely satisfactory to the writer, where pure types of such marine volcanic breccias are concerned. However, the common gradation of such marine volcanic breccias to mixed sedimentary-volcanic breccias (including typical limestone breccias) apparently necessitates a concurrence of strong volcanic explosions with the more or less extensive slumping of calcareous or argillaceous sediments on adjacent parts of sea floor where the volcanic ejectamenta were falling.

The commonly observed lateral or vertical intergradation of waterlain pyroclastics with volcanic or mixed sedimentary-volcanic conglomerates appears to be the result of the intermixing of volcanic ejectamenta with the typical piedmont clastic facies which formed at the base of adjacent ?Rhaetian (i.e. Hecate Cove time) mountain ranges under nonmarine or littoral conditions. The widespread occurrence of these peculiar breccias in the Hecate Cove Formation and their almost complete absence in the underlying and overlying units of the Vancouver Group was effected by the latest Triassic (?Rhaetian) orogenic phase (Jeletzky, 1970b, p. 8). These tectonic movements produced a strongly diversified relief characterized by the existence of apparently shallow, residual marine troughs in close proximity to rapidly rising tectonic highlands. This relief, in concurrence with a strong outburst of latest Triassic (?Rhaetian) explosive volcanism created a favourable environment for

the formation of marine pyroclastic breccias. The rapid and extensive vertical movements within the report-area and the tremors accompanying the late Triassic (?Rhaetian) tectonic movements must have been affecting strongly the residual marine troughs in which the bulk of the Hecate Cove sediments were being deposited and were causing the widespread slumping of these sediments wherever the sea bottom had sufficient slope.

Age and correlation. An abundant but indifferently preserved probably Upper Triassic marine fauna was found in 1968 in the uppermost bed of the type section of the Hecate Cove Formation (Jeletzky, 1969, p. 126 and bed 3, Sec. 4). Muller and Rahmani (1970, p. 17) found Plicatula? sp. and indeterminate pectenids about 500 feet below the top of the formation (GSC loc. 84008) in a section on the southwestern part of Drake Island (Lat. 50°30'40"; Long. 127°39'14"). This section was not studied by the writer. A questionable late Norian age was assigned to this Plicatula? fauna. Indeterminate marine fossils occur locally in other sections of the first and second facies of the Hecate Cove Formation.

The combined evidence of the superposition of the Hecate Cove Formation on the late upper Norian (Upper Suessi Zone) Sutton Formation and the Arenaceous member (Jeletzky, 1970b, pp. 8-9 and earlier in this report) and the occurrence of the probably Upper Triassic and questionably late Norian marine faunas in the upper to uppermost beds of the second facies of the formation indicates that it is latest Triassic, either the latest Norian and/or Rhaetian. The lower part of first and second facies of the Hecate Cove Formation may well be late Late Norian in age because of the apparently conformable and possibly gradational relationship of these facies with the underlying Upper Limestone member of the Sutton Formation.

It does not seem likely, however, that the bulk of the type section (at least 1,899 feet thick) of the Hecate Cove Formation would represent only the upper part of the Upper Suessi Zone. The entire formation, therefore, is placed tentatively in the Rhaetian stage.

The disconformable and probably regionally unconformable relationship of the third, largely or entirely nonmarine facies of the Hecate Cove Formation with the underlying high upper Norian Arenaceous member probably rules out the latest Norian age of this particular facies (Jeletzky, 1970b, pp. 8-9).

The inferred Rhaetian age of the Hecate Cove Formation agrees well with its occurrence stratigraphically far below the oldest dated low Lower Jurassic (early Sinemurian) rocks. The formation is apparently conformably overlain by the Basal Jurassic volcanic unit which is from 5,000 to ?7,000 feet thick. This unfossiliferous unit appears to be overlain by the ?Hettangian Cherty Limestone and Grey Volcanic units which are, in turn, overlain by the Sinemurian Matthews Island Formation. The presence of these three thick units between the Hecate Cove Formation and the early Sinemurian basal beds of the Matthews Island Formation suggests the possibility that the Basal Jurassic volcanic unit may be also, in part at least, of latest Triassic (Rhaetian) age. This possibility is ignored for the time being, however, and the Triassic-Jurassic boundary is tentatively placed at the base of the Basal Jurassic volcanic unit for the sake of convenience in description and mapping.

Latest Triassic (?Rhaetian) orogenic phase and the resulting facies and paleogeographic pattern

Throughout the investigated part of Quatsino Sound and in Klaskino Inlet, the lithologically variegated but mainly coarse to very coarse, syntectonic rocks of the Hecate Cove Formation overlie the arenaceous and argillaceous or calcareous marine rocks of the Upper Suessi Zone. The same is true of the entire extent of the tectonically and volcanically active zone of the Insular Tectonic Belt (Jeletzky, 1970b, pp. 5-7, Figs. 1-2).

This drastic change of the sedimentary regime indicates the occurrence of geologically abrupt and strong uplifts within the Quatsino Sound area following the deposition of the Sutton Formation and the Arenaceous member. Because of the predominantly volcanic lithology of the Hecate Cove Formation, these uplifts must have been accompanied by a strong outburst of mixed explosive-effusive volcanic activity. These tectonic events formed part of the latest Triassic (Early Rhaetian or ?latest Norian) orogenic phase which was felt throughout the tectonically active zone of the Insular Tectonic Belt (Jeletzky, 1970b, pp. 5-9, Figs. 1, 2).

In spite of the intensity of the latest Triassic orogenic phase which is reflected in the predominantly coarse to very coarse, poorly sorted piedmont lithology and synorogenic nature of the Hecate Cove Formation, this phase apparently did not change drastically the paleogeographic facies pattern characteristics of the partly flysch-like pre-orogenic rocks of the Upper Suessi Zone (Figs. 3, 4).

The Coal Harbour-Alice Lake tectonic land evidently continued to exist in a much more elevated, volcanically activated, and apparently somewhat enlarged state. The southwestern side of this land is roughly defined by the previously discussed zone of outcrops of the relatively thin (?500 feet or less), nonmarine third facies of the Hecate Cove Formation extending at least from Apple Bay on the northern shore of Holberg Inlet to the headwaters of Yogtook Creek east of Victoria Lake (Fig. 4).

For reasons stated by Jeletzky (1970b, pp. 5-7, Figs. 1, 2) and recapitulated in the section of this report dealing with the late late Norian paleogeography of Quatsino Sound area, the latest Triassic (?Rhaetian) Coal Harbour-Alice Lake tectonic land could hardly have extended northeastward, northward, northwestward and southeastward much beyond the suggested margins of its late late Norian predecessor (compare Figs. 3 and 4). The volcanically and tectonically quiescent zone of the latest Triassic (?Rhaetian) time had apparently about the same extent as the late late Norian quiescent zone (Jeletzky, 1970b, pp. 5-7, Figs. 1, 2).

The northwest-trending Neroutsos Trough also continued to exist. Its eastern and western limits are believed to be roughly defined by the extent of those sections (i.e. between Smith Cove and Koprino Harbour) in which the contact between the variegated but mainly coarse clastics of the Hecate Cove Formation and the underlying neritic Sutton limestone or the calcareous facies of the Arenaceous member (in Koprino Harbour) is either not accompanied by an obvious erosional disconformity or is clearly transitional. The Hecate Cove Formation of Neroutsos Trough, furthermore, is represented by the partly or entirely marine first or second facies.

Because of the presence of an isolated outcrop of the second facies of the Hecate Cove Formation in Koprino Harbour (see Sec. 5), the Quatsino Sound part of the latest Triassic Neroutsos Trough may have extended about as far west as did its late late Norian predecessor (Figs. 3 and 4). As in the eastern part of the trough, a drastic but apparently gradational change of facies occurred at the base of the Hecate Cove Formation.

No outcrops of the Hecate Cove Formation are known between Koprino Harbour and Klaskino Inlet and the outcrops of the formation studied in Klaskino Inlet belong to the first, partly marine facies. However, the formation overlies disconformably the eroded surface of an unusually coarse-grained, partly conglomeratic and tuffaceous facies of the Arenaceous member. Equivalents of the Sutton Formation appear to be absent by non-deposition as on the southwestern side of the Coal Harbour-Alice Lake tectonic land. Furthermore, the formation seems to lap onto the deeply eroded surface of the upper part (i.e. Lower Suessi Zone) of the Thinly Bedded member in one other, intensely disturbed (contact complicated by faulting) section.

As recognized by Jeletzky (1970b, pp. 7-8, Fig. 1), the Klaskino Inlet outcrops of the Hecate Cove Formation formed part of a residual trough different from the Neroutsos Trough. This West Coast Trough was the successor to the previously described late late Norian West Coast Trough. The existence of a northwest-trending tectonic land which separated the latest Triassic West Coast Trough from the contemporary Neroutsos Trough is indicated first of all by the northeastward facies changes of the Hecate Cove Formation in the Esperanza-Ououkinsh Inlets segment of the west coast described by Jeletzky (1970b, pp. 5-9,

Figs. 1, 2). It is indicated also by the clearly recognizable southwest- or west-directed paleoslope in the studied Klaskino Inlet sections of the Thinly Bedded and Arenaceous members of the Sedimentary Division. Like the Coal Harbour-Alice Lake latest Triassic tectonic land, this Southwestern Tectonic Land must have been a much more elevated, volcanically activated version of its late late Norian predecessor. However, there is no reason to think that the Quatsino Sound segment of this latest Triassic land was appreciably wider than its late late Norian counterpart. Judging by the facies of the Hecate Cove Formation in the Koprino Harbour section (see Sec. 5), the northeastern margin of this land must have been situated at least a few miles farther to the west. The Hecate Cove Formation of Klaskino Inlet is likewise represented by the relatively fine-grained and mostly marine second facies. This suggests that the southwestern boundary of the Southwestern Tectonic Land was situated at least a few miles farther to the east.

The paleogeographic data suggest that the latest Triassic uplifts in the Quatsino Sound and Klaskino Inlet areas were largely or entirely restricted to the Coal Harbour-Alice Lake tectonic land on the northeastern side of the residual Neroutsos Trough and to the Southwestern Tectonic Land separating this trough from the West Coast Trough. If this was so, most or all of the coarse to very coarse, synorogenic clastics of the Hecate Cove Formation must have been derived from these two fast rising, presumably cordillera-like tectonic lands. These sediments spread basinwards for a considerable distance, rapidly filling the two residual, presumably subsiding marine troughs.

The apparent restriction of the generally coarser, less sedimentary and less marine first facies of the Hecate Cove Formation to the southern side of Quatsino Sound (see pp. 41, 44) and the apparent restriction of the second facies to the northern side of the Sound may well be paleogeographically significant. It may reflect a gradual northwestward retreat of the largely marine facies of the formation within the Neroutsos Trough. Unfortunately, the data now available are too sparse for a definitive solution of this problem.

Sandy to conglomeratic clastic rocks and waterlain volcanic breccias occur abundantly in all outcrop-areas of the Hecate Cove Formation known within the Neroutsos Trough. This seems to contradict the tentative conclusion that the width of the latest Triassic (?Rhaetian) Neroutsos Trough was closely comparable to that of the preceding late late Norian trough. In view of the absence of any known outcrops of the Hecate Cove Formation between Kultus Cove and Koprino Harbour, some presently unrecognizable additional tectonic lands may have existed in this region and served as additional source areas of coarse synorogenic clastics and waterlain volcanic breccias. The presence of these clastics and volcanic breccias in the inner parts of Neroutsos Trough may be explained, however, by the strongly pulsating character of the latest Triassic tectonic movements which resulted in temporary uplifts of considerable parts of the trough and corresponding inward shifts of the coarse clastic and volcanic breccia facies. This hypothesis, which is preferred by the writer, also accounts for the widespread occurrence of the largely consedimentary limestone breccias throughout the width of Neroutsos Trough. These limestone breccias and related coarse clastic types of the Hecate Cove Formation must have been connected intimately with the latest Triassic tectonic pulses and tremors which accompanied them (see pp. 52-55).

The effects of the latest Triassic orogenic movements were felt strongly across the whole width of the Neroutsos Trough. This is indicated by the ubiquitous, abrupt or at any rate rapid upward replacement of the shallow water limestones or argillites by the limestone breccias, marine volcanic breccias, various other pyroclastics and conglomerates.

Tectonically and volcanically quiescent zone of the latest Triassic

The latest Triassic orogenic phase and the concurrent volcanic outburst apparently did not affect the eastern side of Vancouver Island and Queen Charlotte Islands (Figs. 5, 6). The late Triassic rocks of this northeastern part of the Insular Tectonic Belt appear to be represented either by black, commonly tuffaceous argillite of the upper Parson Bay Formation (Crickmay, 1928, pp. 56, 59) or by black carbonaceous limestone of the upper Quatsino Formation with interbeds of tuffaceous argillite (Sutherland-Brown, 1966, p. 98, Figs. 6-11; 1968, pp. 57, 58; Surdam et al., 1964, p. 226; Surdam, 1968, p. 20, Fig. 6).

The late Upper Triassic sediments appear to grade imperceptibly into early Lower Jurassic (Sinemurian) black argillites or limy argillites and very fine grained volcanic tuffs in all better known parts of the northeastern zone of the Insular Tectonic Belt (Sutherland-Brown, 1966, p. 98, Figs. 6-11; Surdam, 1968, p. 20, Fig. 6).

Crickmay (1928, pp. 56, 59) inferred a disconformity and a hiatus embracing most or all of the Rhaetian and Hettangian stages between the Parson Bay and Harbledown Formations. This conclusion appears to be untenable, however, since it is based solely on the absence of faunas concerned within an apparently continuous sequence of beds separating the fossiliferous upper Norian calcareous argillites from the fossiliferous siliceous Sinemurian argillites.

The evidence available indicates that during latest Triassic time (late upper Norian and Rhaetian) the tectonically and volcanically quiescent zone became restricted to the Queen Charlotte Islands and most or all of the eastern side of Vancouver Island and Queen Charlotte Strait (at least as far southeast as the Buttle Lake map-area) of the Insular Tectonic Belt (Figs. 5, 6). The limited distribution of the latest Triassic orogenic phase and the accompanying outburst of volcanic activity resulted in subdivision of the Insular Tectonic Belt into an active zone and a quiescent zone. The active zone included all of the report-area and apparently all adjacent areas of northwestern Vancouver Island. The quiescent zone is represented by the sections of easternmost Vancouver Island adjacent to the report-area, the islands in Queen Charlotte Strait, and Queen Charlotte Islands.

Basal Jurassic volcanic unit

The Hecate Cove Formation is considered to be conformably and gradationally overlain by a thick succession of lithologically distinctive (see p. 58) pyroclastic rocks and lavas which appear to be devoid of any sizable interbeds of sedimentary rocks except in its topmost beds. This unit was tentatively placed in the basal Jurassic (Hettangian) and designated the Basal Jurassic volcanic unit.

Distribution. In the stratigraphic section and on the geological maps accompanying this report, the writer has attempted to indicate the principal outcrop-areas of the Basal Jurassic volcanic unit on the basis of its distinctive lithology, known or assumed stratigraphic relationships with adjacent sedimentary units, and inferred structural relationships. Because of the commonly slender nature of the evidence available and the structural complexity of most parts of the mapped area, considerable thicknesses of the younger volcanic units of the Volcanic division could conceivably have been lumped together with the Basal Jurassic volcanic unit in some of the outcrop-areas listed below.

No outcrops of the Basal Jurassic volcanic unit have been observed west of Koskimo Islets and northeastern shore of Ahwhichaolto Inlet. They appear to be overlain by the younger units of the Volcanic division in this direction and to be situated well below sea level even along the anticlinal axes and on the relatively upthrown limbs of major faults throughout this part of the report-area.

Stratigraphy. The lower part of the Basal Jurassic volcanic unit is composed predominantly of maroon, brick-red, tawny- and lavender-coloured intermediate (andesitic?) to more rarely acidic (dacitic to ?rhyolitic) pyroclastics and lavas. The more acidic phases of the unit contain abundant phenocrysts of pink to orange feldspar (Jeletzky, 1950, pp. 16-19; 1969, p. 26; 1970b, p. 10). This feldspar is a sodic plagioclase (J.E. Muller, pers. com., 1968). The lavas are normally less common than the pyroclastic rocks but may comprise as much as 50 per cent of the unit's thickness in some sections. The red lavas are mainly amygdaloidal but fine to coarse porphyritic varieties may be common locally. In some sections, red to maroon, amygdaloidal lavas may be replaced partly or even entirely by dark green, blackish green or dark blue, amygdaloidal or porphyritic ?basic lavas indistinguishable from those of the Karmutsen Subgroup. The red pyroclastic rocks also may be replaced locally by greenish grey, light grey or dark grey pyroclastic rocks (e.g., between Klotchlimmis and Kewquodie Creeks on the southern shore of Quatsino Sound).

Pyroclastic rocks are characteristically unsorted to poorly sorted. As a rule, they lack the well-defined bedding of the underlying Hecate Cove Formation. The argillaceous and calcareous matrix, as well as interbeds, appear to be absent. It is inferred from this that the pyroclastics of the lower part of the Basal Jurassic volcanic unit were deposited predominantly above sea level and were not subjected to prolonged water action. The characteristically purple to red lavas appear to lack pillow structures and sedimentary, waterlain interbeds. These features permit a fairly reliable recognition of the lower part of the unit based on lithology alone whenever its thick and well-exposed sections are available.

Volcanic breccias predominate among the pyroclastic rocks. They are commonly coarse to very coarse. More or less rounded (volcanic bombs) fragments are most common in coarse breccias and are composed mainly of crystal tuff rich in phenocrysts of pink to orange sodic plagioclase.

Section 8 (see Appendix), exposed along the water front of Quatsino village, is the best section of the lower part of Basal Jurassic volcanic unit seen by the writer.

About 600 feet of pyroclastic rocks and lavas lithologically identical with those of section 8 outcrop on the northern shore of Rupert Inlet behind Narrow Island. These rocks are assumed to extend eastward to the western side of a stock-like granitic intrusion in the northeastern corner of the inlet. Similar rocks reappear, commonly more or less metamorphosed and strongly sheared on Red Island and on the northern shore of the inlet northeast from Red Island. An isolated, small exposure of maroon to speckled (red, blue and green), coarse, virtually unsorted, massive volcanic breccia and similarly coloured, amygdaloidal to massive lavas occur within the tidal flat area in southeastern corner of Ruptert Inlet and the completely covered southern shore of Rupert Inlet is believed to be underlain by the Basal Jurassic volcanic unit for about 3 miles westward therefrom to the inferred position of the trace of Holberg Fault (see Figure 17). All these exposures are referred to the lower part of the Basal Jurassic volcanic unit.

A thin and considerably disturbed section of the Basal Jurassic volcanic unit observed on the main Gibson Road at the headwaters of Lippy Creek (see Units 7, 8, of Sec. 29, and Pl. V, Fig. B) is noteworthy because of the acidic, apparently rhyolitic composition of its topmost bed. Except for the deep, spheroidal weathering seen underneath the apparently disconformable contact with the Barremian variegated clastic unit, bed 7 would have been regarded as a sill of Early ?Tertiary intrusive rocks similar to unit 3 of section 39.

The apparently west-dipping?, blackish green to blackish grey, massive, aphanitic to fine-grained, ?basic lavas outcrop at the point some 1,400 yards west of the mouth of Klotchlimmis Creek and for some 350 yards farther westward along the southern shore of Quatsino Sound. This unit is followed (overlain?) by green-grey, fine to medium, unsorted volcanic breccia with interbeds of similarly coloured volcanic tuff and ?basaltic lavas (see Units 9, 10 of Sec. 23). These pyroclastic rocks outcrop for 200 yards along the shore and become tawny to reddish grey in the westernmost part of their outcrop where they are capped unconformably by the Upper Valanginian and ?Hauterivian greywacke-conglomerate unit. This volcanic unit is correlated tentatively with the lower part of the Basal Jurassic volcanic unit exposed in section 8.

The extremely monotonous, dull grey to reddish grey or maroon, massive, porphyritic lavas rich in phenocrysts of meat-red, sodic plagioclase occupy all of the northeastern shore of Ahwhichaolto Inlet and appear to extend northwestward into the headwaters of Denad River. Their attitude and thickness are unknown and both contacts are covered. These lavas are similar lithologically to the porphyritic lavas occurring in the lower part of the Basal Jurassic volcanic unit of the Volcanic division. Therefore, and because of their apparent superposition on the typical waterlain volcanics and limestone breccias of the Hecate Cove Formation outcropping on the shores of Spencer and Robson Coves (see Sec. 5), these lavas are tentatively correlated with the lower part of the Basal Jurassic volcanic unit exposed in its Quatsino village section (see Sec. 8). The top of these lavas appears to be cut off by the Mahatta Fault Zone beneath the waters of Ahwhichaolto Inlet.

That part of the shoreline west of Brockton Island, about 1 mile long, was not traversed for the most part. This interval is believed to represent a relatively upthrown fault block of the westward dipping lower part of the Basal Jurassic volcanic unit because the lavender to maroon, coarse to very coarse, almost unsorted, massive, extremely porphyritic volcanic breccia apparently striking N40°-50°E and dipping steeply to the west outcrops for a few hundred feet at its western end. This volcanic breccia is identical with that commonly occurring in section 8. It appears to be faulted against the relatively downthrown sediments of the Matthews Island Formation (see Sec. 16). On the major, nameless point, situated about one-half mile east of the eastern end of the outcrops of Matthews Island Formation, this breccia is underlain by at least several hundred feet of medium- to coarse-grained, purple-green speckled volcanic tuffs locally containing abundant lath-like phenocrysts of pink to rust-coloured sodic plagioclase. These tuffs are mostly massive but include some interbeds of thinly bedded tuff striking about 315° and dipping about 50° west.

A unit of westerly dipping tawny, dull red, or speckled (red, blue and green), coarse to fine volcanic breccia, about 2,000 feet thick, with interbeds of similarly coloured volcanic tuff, outcrops on the west side of the Kewquodie Creek Cretaceous outlier. These pyroclastic rocks are overlain conformably by several hundred feet of lavender to speckled blue and red, coarse to fine amygdaloidal lavas flexed into several, minor, open folds. These lavas extend to the mouth of Cleagh Creek where their top is believed to be cut off by a major northwest-trending fault. Because of their prevalent attitude and the inferred structural relationships with the previously described section of the lower part of the Basal Jurassic volcanic unit exposed on the eastern side of the Kewquodie Creek Cretaceous outlier, the base of these volcanic rocks is believed to be at least 1,000 feet stratigraphically above the top of the Quatsino village section (see Unit 2 of Sec. 8) of the unit.

The lithology of the upper part of the Basal Jurassic volcanic unit exposed between Kewquodie and Cleagh creeks is similar to that of the volcanic rocks outcropping on the southern shore of Quatsino Sound opposite the largest Koskimo Islet (see Units 3-6 of Sec. 9) and on the easternmost tip of the latter (see Units 20, 21 of Sec. 10). From this it is concluded that the lower part of the volcanic unit conformably underlying the Hettangian? cherty limestone unit in the above sections is equivalent to the volcanic rocks of the Kewquodie Creek-Cleagh Creek section and represents the uppermost part of the Basal Jurassic volcanic unit. The uppermost beds of the Basal Jurassic volcanic unit of these sections (i.e. beds 2 and 3 of Sec. 9 and beds 17-19 of Sec. 10) are believed to be only slightly younger than the youngest beds exposed in the Kewquodie Creek-Cleagh Creek section. They are probably either concealed or faulted out in the valley of Cleagh Creek.

Section 9, described in the Appendix, is the thickest and best exposed section of the uppermost part of the Basal Jurassic volcanic unit. Judging by this section (see Unit 2 of Sec. 9) and by the lithologically similar but thinner section exposed on the eastern tip of the largest Koskimo Islet (see Units 17-19 of Sec. 10), the uppermost part of the Basal Jurassic volcanic unit consists predominantly of grey to dark grey, ?basic, somewhat amygdaloidal lavas resembling those of the basal part of the unit and those of younger units of the Volcanic division. The less common pyroclastic rocks are mostly waterlain, well bedded, and intercalated with a considerable number of limestone beds. These pyroclastics are somewhat similar lithologically to those of the Hecate Cove Formation or to those of the older parts of the Basal Jurassic volcanic unit. The uppermost part of the Basal Jurassic volcanic unit discussed here would, therefore, be difficult or impossible to recognize whenever it is not in contact with the adjacent, lithologically more distinctive units, such as the units 4 to 6 of section 9 or those of the lower parts of the Basal Jurassic volcanic unit or the distinctive sediments of the Hettangian? cherty limestone unit.

Small exposures of light grey to speckled purple, more or less strongly altered volcanic breccia and dark grey to maroon, mainly porphyritic lava occur in beds of two tributaries of Nuknimish Creek at the point about 1,000 feet upstream from its first fork (see Unit 7 of Sec. 30). These very strongly sheared and jointed volcanic rocks are lithologically similar to those of the upper part of the Basal Jurassic volcanic unit such as are exposed on the southern shore of Quatsino Sound between Kewquodie and Cleagh Creeks.

Estimated thickness. Accurate measurement of the Basal Jurassic volcanic unit is not possible. A minimum thickness of between 4,000 and 5,000 feet is estimated by combining the section between Kewquodie and Cleagh Creeks with that at Quatsino village. However, the writer believes that about 1,000 feet of strata are present, though not exposed, between the two sections and that another few hundred feet should be added for the topmost beds of sections 9 and 10. Thus, a figure of between 5,000 and 7,000 feet is estimated for the unit in the central part of Quatsino Sound. No estimates of thickness of the unit are possible for any other parts of the Quatsino Sound area but there are some indications that it thins considerably toward the east.

Age and correlation. For reasons stated by Jeletzky (1970b, p. 11, Fig. 1) and recapitulated in the section of this report dealing with the age and correlation of the Hecate Cove Formation, the Basal Jurassic volcanic unit was tentatively placed in the basal Jurassic and provisionally dated as ?Hettangian.

Cherty limestone unit

Distribution and stratigraphy. A unit of dark grey to black, thinly bedded to laminated, cherty limestone with numerous laminae, thin layers, inclusions and lenses of black to dark grey chert and minor interbeds of calcarenites, calcareous clastics and calcareous pyroclastics was observed only in one small outcrop in the middle of the southwestern shore of Ahwhichaolto Inlet, on the eastern end of the largest Koskimo Islet (see Sec. 10), and on the mainland opposite the latter section (see Secs. 9 and 11). All known sections of this limestone unit, including the immediately overlying and underlying volcanic rocks, are separated from the biochronologically dated sedimentary units of the Volcanic division by major faults.

For reasons explained in the previous section of this report, the Cherty limestone unit appears to overlie conformably and gradationally the Basal Jurassic volcanic unit of the division. The Cherty limestone unit appears to be older than the Grey volcanic unit and the overlying sediments of Matthews Island Formation because of its inferred conformable and gradational superposition on the Basal Jurassic volcanic unit which is known to overlie conformably the latest Triassic Hecate Cove Formation. Furthermore, all known sections of the Cherty limestone unit are situated downdip from those of the Grey volcanic unit and the volcanic rocks overlying the Cherty limestone unit are similar to those of the Grey volcanic unit. Because of these stratigraphic relationships and as it has no lithological similarities with the other sedimentary units of the Volcanic division, the Cherty limestone unit cannot be correlated with any of them. Therefore, it is inferred to be a separate sedimentary unit within the Volcanic division of the Bonanza Subgroup.

The best known section of the Cherty limestone unit is the lower part of section 10 described in the Appendix. Another strongly disturbed section (see Sec. 11 of the Appendix) nearby supplements section 10. This section exposes a sequence of waterlain pyroclastics, tuffaceous limestones, and amygdaloidal lavas which appears to be transitional between the Cherty limestone unit and Grey volcanic unit. This sequence is believed to fill out part or all of the faulted out interval between units 4 and 6 of section 10.

Section 11 suggests the intergradation of the Cherty limestone unit with overlying pyroclastics and lavas lithologically similar and apparently referable to the lower part of the Grey volcanic unit. Like the sequence of waterlain pyroclastics and tuffaceous sediments connecting the Cherty limestone unit with the underlying Basal Jurassic volcanic unit, these transitional beds resemble some of the rock types of the Hecate Cove Formation. They may be confused with the latter formation in small sections which do not expose contacts with adjacent lithologically more distinctive units of the Volcanic division. However, the apparently complete absence of limestone breccia and marine volcanic breccia with limestone matrix in these transitional beds seems to provide a reliable distinguishing feature.

Small exposures of extremely contorted, cherty limestones occur in the middle part of the southwestern shore of Ahwhichaolto Inlet. These limestones are lithologically identical with those of beds 11 to 13 of the Koskimo Islets section 10. Neither top nor bottom of the Cherty limestone unit was observed in this section. However, the limestones dip underneath the thick succession of predominantly grey lavas and pyroclastic rocks similar lithologically to those conformably overlying the Cherty limestone unit in the Koskimo Islet sections.

Thickness. The minimum measured thickness of the Cherty limestone unit is 350 feet as measured in section 10. The complete thickness is probably greater but could neither be determined nor estimated because of the intense faulting and/or contortion of the unit in any other section known to date.

Age and correlation. In spite of its apparently marine origin, the Cherty limestone unit did not yield any diagnostic fossils. It was tentatively placed in the Hettangian (Jeletzky, 1954a, p. 1269; 1970b, p. 11) because of its inferred stratigraphic position between the uppermost Triassic (?Rhaetian) Hecate Cove Formation and the early to late Sinemurian Matthews Island argillites.

Grey volcanic unit

Distribution. As far as is known, the outcrops of Grey volcanic unit are confined to the western part of Quatsino Sound southwest of the trace of the Mahatta Fault Zone. In this part of the area, the unit underlies most or all of the southern shore of Quatsino Sound between the point opposite the eastern side of the largest Koskimo Islet and the area around the mouth of Mahatta River (Pl. IV, Fig. B) and all of Koskimo Islets with the exception of the easternmost part of the largest islet. On the northern side of Quatsino Sound, the unit underlies the southwestern shore of Spencer Cove and extends for an unknown distance westwards towards Nordstrom Cove. To the northwest of Spencer Cove, the unit occupies the downthrown southwestern side of Mahatta Fault to the northwestern end of Ahwhichaolto Inlet and extends for an unknown distance farther northwest. The unit outcrops locally on the western shore of Forward Inlet between Greenwood Point and Kains Peninsula (see Figure 18).

Stratigraphy. The basal beds of the Grey volcanic unit were observed only in section 11 on the southern shore of Quatsino Sound opposite Koskimo Islets where they are at least 335 feet thick. Their lithology and environmental interpretation have been described previously in connection with the discussion of the contact relationships of the Cherty limestone unit. In this section and in section 10, these transitional beds appear to be overlain conformably (contacts are covered or faulted) by 350 to 830 feet of characteristically grey to dull purple or reddish grey pyroclastics interbedded with dull to bluish grey, massive and amygdaloidal lavas.

Several hundred (at least 600) feet of dull grey, bluish grey or dull lavender, massive volcanic rocks (lavas?) closely comparable and apparently correlative with those of the upper part of Koskimo Islets section outcrop on the southwestern shore of Spencer Cove and along the southwestern shore of Ahwhichaolto Inlet. At one point on the shore of the inlet they overlie the Cherty limestone unit but the contact between the two units is covered. On the southwestern side of Spencer Cove and in Ahwhichaolto Inlet, these lavas(?) are interbedded with some dull to bluish grey, maroon, or speckled blue and purple volcanic breccia, similarly coloured volcanic tuff, and grey to lavender-grey amygdaloidal lavas. No waterlain, well-bedded pyroclastic rocks or tuffaceous, sedimentary interbeds are known to occur in these rocks.

The predominantly lavender, maroon or red, amygdaloidal to porphyritic lavas with interbeds of lavender to dull green, partly well-bedded, waterlain pyroclastic rocks and similarly coloured volcanic conglomerates (Pl. IV, Fig. B) are exposed in the banks of Mahatta Creek for some 500 yards upstream from its mouth (i.e. to the first waterfall). Neither top nor bottom of these rocks is exposed but they seem to be referable to the lower part of the Grey volcanic unit.

The top of these rocks was not observed but, because of the prevalent attitude and localization (see Figures 17, 18), they are believed to grade upwards into similarly coloured lavas and associated pyroclastics that conformably underlie the Matthews Island Formation on the eastern part of Matthews Island and farther north on the western shore of Forward Inlet. They consist of as much as 1,000 feet of predominantly light grey to bluish grey, mostly distinctly banded amygdaloidal lavas, commonly with pronounced pillow-like structures. A large number of intercalated beds of similarly coloured, coarsely porphyritic lavas and those of similarly coloured, coarse volcanic breccia (? pillow breccia), which is composed mainly of the above-mentioned amygdaloidal lavas, occur in this part of the unit. The base was nowhere observed. The contact with the overlying argillites of Matthews Island Formation is definitely gradational in some sections (see Sec. 12 of the Appendix). However, in some other sections, such as that measured on the eastern side of Matthews Island (see Units 3, 4 of Sec. 17), this contact appears to be somewhat more abrupt, although still conformable.

The proposed informal name – Grey volcanic unit – reflects the unit's characteristic light grey colour. This unit appears to be distinguishable lithologically from all other volcanic units of the Volcanic division described in this report because of the predominance of light grey to bluish grey, amygdaloidal, felsitic, and porphyritic lavas and volcanic breccias, the rarity of brightly coloured pyroclastic rocks and the common occurrence of pillow-structures in lavas of the upper part.

Thickness. The combination of the two thickest sections of the Grey volcanic unit, which represent respectively its lower (Sec. 11) and upper (Sec. 12) parts with no apparent overlap, indicates that the unit is at least 2,000 feet thick. The total thickness may well be greater, but there are no means to infer, let alone to estimate, the order of the magnitude of this thickness.

Age and correlation. No fossils were found in the Grey volcanic unit. However, the unit underlies conformably and probably gradationally the reliably dated lower but not basal Sinemurian *Arnioceras kwakiutlanus* zone (Jeletzky, 1970b, p. 12, Fig. 1; this report p. 77, Fig. 5), and overlies apparently conformably and gradationally (see Sec. 11) the probable Hettangian Cherty limestone unit. It could, therefore, be either of the upper Hettangian? or of the basal Sinemurian (i.e. *Arietites bucklandi* zone; Frebold, 1951, pp. 13-14; Arkell, 1956, p. 37) age. The former age is proposed tentatively in this report for the Grey volcanic unit as determinable ammonites of *Arnioceras* fauna were not found in the basal 100 feet of the overlying Matthews Island Formation (see Unit 2, Sec. 7).

Matthews Island Formation

A unit, between 755 and 1,300 feet thick, of predominantly argillaceous rocks separating the Grey volcanic unit or its lavender to maroon-coloured equivalents (as in Kyuquot Sound; Jeletzky, 1970b, p. 12) from the uppermost Sinemurian volcanic unit is widespread in the western part of Quatsino Sound and also outcrops in Kyuquot Sound. This unit was informally named Sinemurian argillites by Jeletzky (1970b, p. 12, Fig. 1) but is now formally named the Matthews Island Formation after Matthews Island situated at the junction of Forward and Browning Inlets where the best known sections are

situated. The relatively little disturbed and fossiliferous sections 14 and 17 combined are herewith designated as the type-section of the Matthews Island Formation. The middle part of the formation, assumed to be about 290 feet thick, is not exposed in any of these sections and its upper contact in section 14 may possibly be complicated by faulting. However, the chances of finding a better type-section seem to be remote indeed as all known sections of the formation are invariably faulted, more or less contorted and invaded by numerous dykes and sills of the Coast Intrusions.

Historical remarks. Some of the exposures of the predominantly argillaceous, sedimentary rocks referred to the Matthews Island Formation in this report originally were discovered by Dawson (1887, p. 83B). However, they were erroneously dated as of Triassic age for reasons discussed below.

Distribution. The outcrops of Matthews Island Formation appear to be restricted to the western part of Quatsino Sound west of Lind Islet. Unlike the underlying Cherty limestone and Grey volcanic units, the outcrops of Matthews Island Formation occur to the southwest as well as to the northeast of the trace of Mahatta Fault. Within the general outcrop-area of the formation, its outcrops are most widespread on both shores of Forward Inlet including Matthews Island (= Robson Island of Dawson, 1887, p. 83B) and on both shores of Browning Inlet. It is almost equally widespread on both shores of Winter Harbour between Greenwood Point and the mouth of Galato Creek. Throughout this part of the area, the Matthews Island Formation is flexed in a number of open, medium-size , northwest-trending and plunging folds (see Figure 18). Commonly, these folds are intensely faulted and invaded by sills, dykes and larger irregular bodies of Coast Intrusions.

On the southern shore of Quatsino Sound, east of Mahatta logging camp, the formation outcrops almost continuously for about 1/2 mile east of an unnamed rocky point opposite the eastern end of Salmon Island and also in the bed of Monkey Creek between about 3/4 and 7/8 of a mile above its mouth.

An apparently isolated, intensely disturbed but generally anticlinally folded outcrop-area of the Matthews Island Formation was first discovered by J.E. Muller in 1968 on the west side of Nordstrom Cove; this was subsequently studied by the writer.

Other exposures of the Matthews Island Formation may occur in the unexplored parts of the northern and southern shores of Quatsino Sound between Montgomery Point and Nordstrom Cove and between Cliffe Point and Koskimo Inlet. The writer was shown a moderately well preserved specimen of an arietitid ammonite by Mr. H. Eldridge of Quatsino village which was said to have been collected near the mouth of Mahatta Creek. However, when traversing Mahatta Creek, no sedimentary rocks were found at this locality for about 500 yards upstream from its mouth. The volcanic rocks occupying this interval were discussed above in connection with the description of the Grey volcanic unit.

Stratigraphy and facies. The Matthews Island Formation was provisionally subdivided by Jeletzky (1970b, p. 12) into: "a Lower argillite member at least 500 feet thick; an Intermediate waterlain tuff member 100 to 150 feet thick; and an Upper argillite member 120 to at least 700 feet thick". This subdivision appears to be valid for all sections of the Matthews Island Formation studied in Forward Inlet, Browning Inlet and Winter Harbour but not for the easternmost known section 16 immediately east of Mahatta logging camp. The recently studied vertical distribution of diagnostic

ammonites in this section (see Units 6 and 11 of Sec. 16) suggests that the Intermediate waterlain tuff member of the more westerly sections (see Sec. 13, 14) is lithologically unrecognizable in this section as it is replaced laterally by partly tuffaceous or arenaceous argillites of unit 9. The stratigraphically lowest, largely pyroclastic units of section 16 (i.e. Units 13 to 21 inclusive) were found to be lithologically distinctive enough to be treated as the fourth member of the formation - the ?Basal variegated member.

In Forward Inlet, Browning Inlet and Winter Harbour, the Matthews Island Formation appears to be subdivisible into the following 3 members, in ascending order, as follows:

1. Lower argillite member consisting of at least 500 feet of dark grey, black, brown-grey, or maroon, thinly to thickly bedded to laminated, pure to arenaceous and/or tuffaceous argillite. The argillite is interbedded with variable, but minor amounts of thin beds, layers and lamellae of grey to brown or maroon, fine- to medium-grained greywacke, pure to arenaceous, grey limestone and pebble conglomerate.

2. Intermediate waterlain tuff member (abbreviated to Waterlain tuff member in the following text) consisting of between 50 and 150 feet of greenish to brownish grey, distinctly bedded, waterlain volcanic tuffs, with intercalated beds of other rock types. The latter include green to brown-grey, mostly fine to medium, waterlain volcanic breccia; similarly coloured, fine- to coarse-grained greywacke and grit; dark grey, brown, or maroon, arenaceous to tuffaceous argillite; and locally grey to lavender amygdaloidal lava.

3. Upper argillite member consisting of 86 to 120 feet of argillite similar to that of the Lower argillite member. In the westernmost known section (see below), the argillite may be interbedded with, and partly to almost wholly replaced by various clastic rocks including some pebble conglomerate and grit, tuffaceous and pure limestone, various sedimentary breccias, and various waterlain pyroclastic rocks.

Both the lithology and thickness of these three members of the Matthews Island Formation change drastically eastwards from Winter Harbour-Forward Inlet area.

The argillites of the Upper argillite member become less arenaceous and tuffaceous in more easterly sections of the formation. Furthermore, they appear to lose all of the conglomeratic and waterlain volcanic breccia interbeds and most of the waterlain volcanic tuff interbeds in this direction (see Unit 4 of Sec. 15 and Units 3-7 inclusive of Sec. 16).

These facies changes indicate the lateral eastward replacement of the greater part of the coarse clastics and coarse waterlain pyroclastics of the Uppermost Sinemurian volcanic unit by the Upper argillite member. This conclusion finds further support in the marked eastward decrease in total thickness of the Uppermost Sinemurian volcanic unit discussed in the next section.

Outcrops of the Upper argillite member of the Matthews Island Formation, which appear to be equivalent and lithologically similar to those exposed in Section 16, were observed in the bed of Monkey Creek about 3/4 of a mile above its mouth. Echioceras (Melanhippites) harbledownensis Crickmay of late Sinemurian age was found on the south shore of Quatsino Sound 900 yards up Monkey Creek (GSC loc. 24303).

Unless the succession of the Upper argillite member is repeated by faulting, which is possible, the eastern facies of this member is more than 1,000 feet thick in section 16. At any rate, the member is more than 500 feet thick in this section in contrast to the much smaller (86 - 120 feet) thickness of its western facies (see Secs. 13, 14).

The Waterlain tuff member appears to be restricted to the western part of the area comprising Forward Inlet, Browning Inlet and Winter Harbour. In this part of the area, the member was observed to thicken considerably in some sections, especially those occurring on the western shore of Forward inlet and in Winter Harbour, as compared with its thickness in section 14. In these faulted and contorted sections this member appears to replace laterally parts of the shales of the Lower and Upper shale members. The latter may become restricted locally to units 30 to 70 feet thick alternating with units 50 to 100 feet thick composed of very thick-bedded or massive, green-grey to dull grey or brown, arenaceous to tuffaceous argillites, similarly coloured, fine- to coarse-grained greywacke and waterlain volcanic tuff. Some beds

of crystal tuff rich in phenocrysts of red sodic plagioclase, and of variously coloured amygdaloidal lavas may occur locally in these interbeds. The proposed subdivision of the western facies of Matthews Island Formation into three members may not be applicable in these abnormal sections, all of which are either too faulted and contorted or too poorly exposed to be definitively compared with the better sections of Matthews Island Formation measured in the same general area.

The Lower argillite member does not show any drastic facies changes comparable to those of the younger members anywhere in Forward Inlet and Winter Harbour areas compared with its typical development in the type section of the formation. Units 14 to 17 of section 14 are representative of the upper part of the member.

The basal beds of the Lower argillite member and its contact with the Grey volcanic unit are well exposed on the northwestern shore of Forward Inlet in section 12 (see Units 1, 2) and on Matthews Island in section 17 (see Appendix).

In the eastern part of the outcrop-area of the Matthews Island Formation, the Lower argillite member is exposed only in section 16. Although somewhat faulted, locally metamorphosed and invaded by a plug-like body of the Coast Intrusions, much of the thickness of this member (see Unit 11, Sec. 16) appears to be preserved there between the lithologically unrecognizable argillaceous facies of the Waterlain tuff member above and the ?Basal variegated member below. Judging by its preserved part, the Lower argillite member may be at least 820 feet thick in the eastern sections as against its apparent thickness of 640 feet in the western sections. Furthermore, it seems to lack conglomeratic interbeds such as are known to occur in its western facies (see Unit 1 of Sec. 17) or, for that matter, any arenaceous interbeds common in this facies.

The presence of a relatively thick (at least 378 feet) unit of waterlain volcanics and various clastics of the so far unique ?Basal variegated member stratigraphically below the offshore facies of the Lower argillite member (see Units 13 to 21 inclusive of Sec. 16) is puzzling. The presence of generically indeterminate arietitid ammonites (GSC loc. 24313) indicates a general Sinemurian age for this unit and prohibits its exclusion from the Matthews Island Formation. The ?Basal variegated member is tentatively assumed to be a local, predominantly pyroclastic phase of the basal beds of the Lower argillite member related to an areally restricted short-lived volcanic vent on the bottom of the Sinemurian basin of Quatsino Sound.

The presence of numerous intercalated beds of pure or arenaceous to tuffaceous limestone in some faulted and contorted or very poorly exposed sections of the Matthews Island Formation suggests local and short-lived paucity of clastic sediments within the Sinemurian basin of Quatsino Sound.

Facies and source area. The above discussed east-west facies changes of the Matthews Island Formation indicate that the shoreline of the Sinemurian (i.e. Matthews Island time) basin was situated to the west of the report-area and that the eastern part of the outcrop-area of Matthews Island Formation (i.e. between Nordstrom Cove and Mahatta logging camp) represented its offshore part. This problem will be discussed in greater detail in the section dealing with the Lower Jurassic depositional environments and paleogeography of the Quatsino Sound area.

Thickness. No complete sections of the Matthews Island Formation were seen. However, the western facies of the formation appears to be about 755 feet thick in its type section (i.e. Secs. 14 and 17 combined) provided that no major faults occur in the covered interval between sections 14 and 17.

The eastern facies of the formation is at least 1,300 feet thick if one assumes that the Upper and Lower argillite members of section 16 are repeated by faulting. If this is not the case, the Matthews Island Formation would be at least 1,850 feet thick in this section. Either of these estimates may be close to the total thickness of the eastern facies of the formation if the writer's interpretation of the ?Basal variegated member of section 16 is correct.

Age and correlation. The formation was for a long time believed to be Triassic in age because the poorly preserved ammonites, collected from its type section by Dawson (1887, p. 83B), were described as Celtites(?) vancouverensis by Whiteaves (in Dawson, 1887, pp. 110B-111B). These ammonites were later redetermined to be low Lower Jurassic arietitids closely allied to the early Sinemurian genus Arniotites (Crickmay, 1928, p. 60; Frebold, 1959, pp. 5-6). All the better preserved of the ammonites collected by the writer in the Lower argillite member of the formation have been determined recently by Dr. Hans Frebold (unpublished intradepartmental fossil reports, 1968 and pers. com., 1969) as Arniotites kwakiutlanus Crickmay, Arniotites sp. indet., Arnioceras sensu lato sp. indet., or Arnioceras? sp. indet. (see bed 15 of Sec. 14; Unit 11 of Sec. 16; and Unit 2 of Sec. 17). The Arniotites (or Arnioceras) fauna is diagnostic of the late early Sinemurian Arnioceras semicostatum zone of International Standard (Frebold, 1951, pp. 13-14; Arkell, 1956, p. 37). The basal Sinemurian Arietites bucklandi zone is not represented by fossils in Quatsino

Sound area. However, there is room for it in the so far unfossiliferous basal 100 feet of the Lower argillite member and in the ? Basal variegated member which is at least 378 feet thick. The latter unit is fossiliferous but it has yielded only Weyla sp. and indeterminate arietitid ammonites (see Unit 15 of Sec. 16).

All the better preserved of the ammonites collected by J. E. Muller and the writer from the Upper argillite member have been determined recently by Dr. Hans Frebold as Echioceras (Melanhippites) harbledownensis Crickmay and ? Echioceras sp. indet. (see Unit 6 of Sec. 16; Unit 4 of Sec. 15; and GSC loc. 24303, 3/4 of a mile up Monkey Creek). According to Frebold, the Echioceras (Melanhippites) harbledownensis fauna corresponds to the uppermost Sinemurian Echioceras raricostatum zone of International Standard (compare Arkell, 1956, p. 37).

J.E. Muller's fossil collections from the outcrops of Matthews Island Formation situated outside of this report-area (GSC loc. 82892; identification by Dr. Hans Frebold in an unpublished intradepartmental fossil report, 1969) also contain the intervening Asteroceras aff. A. obtusum fauna which so far has not been found in Quatsino Sound area.

The presence of Echioceras (Melanhippites) harbledownensis and Crucilobicera spp. fauna in the overlying Uppermost Sinemurian argillite unit (see in the next two sections) indicates that the Upper Argillite member of Matthews Island Formation includes only the lower part of the Uppermost Sinemurian Echioceras raricostatum zone (abbreviated to Raricostatum Zone in the following sections). The Matthews Island Formation, therefore, spans most of the Sinemurian stage (Fig. 5; Table of Formations).

The so far invariable restriction of the Arniotites kwakiutlanus fauna to the Lower argillite member and of the Echioceras (Melanhippites) harbledownensis

fauna to the Upper argillite member has facilitated greatly the interpretation of incomplete, extremely faulted and/or contorted, and lithologically aberrant sections of the Matthews Island Formation. It has, in particular, made it possible to infer the approximate stratigraphic position of the equivalent of the Waterlain tuff member in section 16 (see Units 6, 9 and 11) and to rule out the lithologically more plausible interpretation of its ? Basal variegated member as an unusually thick equivalent of the Waterlain tuff member.

The Matthews Island Formation is the only unit of the Volcanic division that yields fairly numerous, readily identifiable, diagnostic fossils in practically every outcrop in the report-area. The common occurrence of generically indeterminate arietitid ammonites represents the best distinguishing feature of this unit in the field since its argillite members are commonly lithologically indistinguishable from some phases of the Thinly Bedded and Arenaceous members of the Sedimentary division of the Bonanza Subgroup. Similarly the waterlain pyroclastic rocks, sedimentary (especially limestone breccia) and mixed waterlain breccias of the Waterlain tuff and ? Basal variegated members may be lithologically indistinguishable from the equivalent rocks of the Hecate Cove Formation of the Volcanic division.

Southeast of Quatsino Sound in the Buttle Lake map-area, the formation is correlative with that part of an unnamed, 750-foot-thick unit of grey, tuffaceous argillite occurring between the Quatsino limestones and the presumably middle Jurassic (Yakoun equivalents) volcanics and containing Sinemurian ammonites (Surdam et al., 1963; Sutherland-Brown, 1966, p. 98, Figs. 6-11; and Surdam, 1968, p. 20, Fig. 6).

East of Quatsino Sound, the Matthews Island Formation is correlative with the fossiliferous beds of the (at least 1,600 feet thick) Harbledown Formation of Parson Bay area (Crickmay, 1928, pp. 56-57, 59). The Harbledown Formation yielded the same late early Sinemurian and latest Sinemurian ammonite faunas as the Matthews Island Formation of Quatsino Sound (Frebold and Tipper, 1970, p. 4).

Northwest of Quatsino Sound, Arietites beds are correlative with the early Sinemurian part of the Harbledown Formation (formerly upper member of Kunga Formation; see Jeletzky, 1970b, p. 2, Footnote) of Queen Charlotte Islands. The Harbledown Formation of Queen Charlotte Islands also has yielded Arniotites and Echioceras (Melanhippites) faunas (Sutherland-Brown, 1966, pp. 84, 98, Figs. 6-11; 1968, p. 61; Frebold and Tipper, 1970, p. 4).

Uppermost Sinemurian volcanic unit

A predominantly volcanic, unfossiliferous unit occurring between the Matthews Island Formation and the Uppermost Sinemurian argillite unit was tentatively named the Basal Pliensbachian volcanic unit by Jeletzky (1970b, p. 13, Fig. 1) because of its inferred post-late Sinemurian age. This working hypothesis was, however, discredited by the more recent discovery of definitively identifed latest Sinemurian ammonites in the early Pliensbachian argillite unit (which see for further details).

Distribution. Like the underlying Matthews Island Formation, the Uppermost Sinemurian volcanic unit is widespread along the shores of Winter Harbour and along those of Forward and Browning Inlets (see Secs. 13 and 14). It also outcrops on the western side of Nordstrom Cove (see Units 1, 2 of Sec. 15), on the southern shore of Quatsino Sound east of Mahatta logging camp (see Units 1, 2 of Secs. 16 and 18) and in the bed of Monkey Creek in the interval 500 to 800 yards above its mouth.

Stratigraphy and facies. The unit consists of green-grey to grey, mainly waterlain pyroclastics (mostly coarse to medium volcanic breccia); grey, green or speckled lavender, amygdaloidal to porphyritic lava flows of intermediate composition; coarse volcanic conglomerates and grits and some limestone breccia. The lavas of this unit commonly show well-developed pillow structure and many volcanic breccias appear to be pillow breccias.

The conglomerates and breccias comprising the basal beds of the Uppermost Sinemurian volcanic unit locally contain an abundance of locally derived argillite and limestone pebbles and boulders. However, all observed contacts with the underlying Matthews Island Formation and overlying Uppermost Sinemurian argillite unit appear to be conformable and gradational. These pebbles are therefore believed to have been derived from a latest Sinemurian source-area (a volcanic land) situated closely to the west of the report-area (see below).

The somewhat scanty data available suggest that the Uppermost Sinemurian volcanic unit may be subdivided into the following lithological members traceable throughout the western part of Quatsino Sound.

Lower waterlain pyroclastic member consisting of 100 (in the east) to at least 400 (in the west) feet of various waterlain pyroclastics. Light to dull grey or green-grey pillow breccias are prominent in most sections. Other prominent types are similarly coloured, coarse to fine, normally distinctly bedded, waterlain volcanic to mixed volcanic-sedimentary breccias, the fragments of which are somewhat rounded. These breccias are interbedded with variable amounts of volcanic pebble conglomerates (pebbles poorly rounded), fine- to coarse-grained, waterlain volcanic tuffs, tuffaceous greywackes and grits. Peculiar sedimentary breccias consisting largely (with greater or lesser admixtures of shale and greywacke fragments) or entirely of limestone fragments, apparently derived from the erosion of underlying units of the Bonanza Subgroup, occur locally in the basal part of the member. The lower contact seems to be conformable and gradational throughout the investigated part of Quatsino Sound.

Intermediate amygdaloidal lava member consisting of at least 200 to 300 feet of purple, red, blue, green (mostly speckled) or grey, rarely to abundantly amygdaloidal, ?andesitic lavas, which are commonly well banded and exhibit well-developed pillow-like structures. Some interbeds of similarly coloured porphyritic lavas and rare, thin interbeds of volcanic breccia and tuff occur locally. No sedimentary interbeds were seen in any of the surveyed sections of the member. The lower contact is conformable and the upper contact is invariably faulted.

Upper waterlain pyroclastic member consisting of at least 106 feet of dark to light grey, mostly fine, well-bedded and waterlain volcanic, and mixed volcanic-sedimentary breccia. Some interbeds of similarly coloured fine- to course-grained, waterlain volcanic tuff and tuffaceous greywacke occur locally. Both contacts appear to be conformable in the few known sections of this member.

Most of the studied sections of the Uppermost Sinemurian volcanic unit expose only its basal few hundred feet. Of these, sections 13, 14 and 15 are the most valuable as they expose the normal unfaulted and apparently conformable lower contacts of this unit

Sections 16 and 18 of the Uppermost Sinemurian volcanic unit are strongly sheared and disturbed but are most important because they expose the normal unfaulted contacts of the unit with both the underlying Matthews Island Formation and the overlying Uppermost Sinemurian argillites. The lower part of the Uppermost Sinemurain volcanic unit (see Units 1-2 of Sec. 16) adjoins from the east the covered interval 6 of section 18. It is represented by 200 feet of amygdaloidal lavas (Unit 1) underlain conformably by about 100 feet of waterlain pyroclastic rocks (Unit 2) grading downward into the Upper argillite member of Matthews Island Formation. All these rocks have about the same attitude as unit 5 of section 18 (strike N10° -20° E, dip 45° -50° W) and dip under it. There is, therefore, no reason to assume major structural complications and the disappearance of considerable thicknesses of beds by faulting between the upper and lower parts of Uppermost Sinemurian volcanic unit exposed in these two sections occurring east of Monkey Creek.

The only other representative section of the Uppermost Sinemurian volcanic unit known to the writer is section 14 on the northwestern side of Matthews Island in Forward Inlet which exposes the equivalents of the amygdaloidal lavas and lower waterlain pyroclastic rocks of sections 16 and 18. The top of the section is cut off by a major fault. Both of the exposed units differ from their equivalents farther east in being considerably

thicker. The breccia fragments and psammitic clasts of the lower waterlain pyroclastic unit of section 14 are, furthermore, invariably much coarser than those in its Monkey Creek equivalent. The volcanic breccias are mostly represented by coarse to very coarse pillow breccias. The same appears to be true of the other sections of this unit observed in the Forward and Browning Inlets.

The upper waterlain pyroclastic units of section 18 is not exposed on Matthews Island. However, it appears to be present locally in some shorter, exceedingly contorted sections of the Uppermost Sinemurian volcanic unit elsewhere in Forward Inlet and to consist of coarser waterlain pyroclastics than farther east.

Since it is at least 600 feet thick on the Matthews Island (see Units 1-7 of Sec. 14) and only about 400 feet thick in the sections 16 and 18 east of Mahata logging camp, the Uppermost Sinemurian volcanic unit thins out markedly eastward between Forward Inlet and Koprino Harbour. Furthermore, the eastern facies of the unit contains a considerably greater ratio of waterlain pyroclastics and sedimentary clastics and is characterized by generally smaller and better rounded clasts. These eastward facies changes suggest that the Uppermost Sinemurian volcanic unit pinches out completely somewhere between Koprino Harbour and Rupert Inlet and is replaced laterally by predominantly argillaceous sediments of the Matthews Island Formation and Uppermost Sinemurian argillite unit (Fig. 5).

The somewhat scanty data about the westward thickening and coarsening of the waterlain pyroclastic rocks and sedimentary clastics of the Uppermost Sinemurian volcanic unit suggest that, like the rocks of the Matthews Island Formation, the rocks of this unit were derived from a western source area (Fig. 5). The lithology of the rocks and the apparently conformable and gradational contact between the Matthews Island Formation and the Uppermost Sinemurian volcanic unit within the

report-area suggests that the uplift, which must have occurred at the time of the end of deposition of the Matthews Island Formation did not end the marine regime within the investigated part of Quatsino Sound. It is suggested accordingly that the source area (a volcanically active tectonic highland or a volcanic archipelago; see Jeletzky, 1970b, p. 22) established by this uplift was a northwest-southwest trending welt situated immediately west of the area now occupied by the Forward and Browning Inlets. The coarse volcanic and clastic fragments derived from this rapidly rising tectonic land began to pour into that rapidly shallowing part of Quatsino Sound at the end of Sinemurian time.

Age and correlation. No fossils were found in the Uppermost Sinemurian volcanic unit. However, its Lower waterlain pyroclastic member overlies gradationally the Upper Argillite member of the Matthews Island Formation containing the early late Sinemurian *Echioceras* (*Melanhippites*) *harbledownensis* fauna devoid of *Crucilobiceras*. The Upper waterlain pyroclastic member of the unit is conformably and apparently gradationally overlain by the Latest Sinemurian (Upper Raricostatum Zone) argillite unit characterized by the association of *E.* (*M.*) *harbledownensis* and *Crucilobiceras* spp. The volcanic unit concerned can therefore only represent the middle part of the Raricostatum Zone (see Fig. 5 and in the next section).

The waterlain volcanic breccias (including pillow breccias) and tuffs of the Lower and Upper waterlain pyroclastic members of the Uppermost Sinemurian volcanic unit are similar lithologically to those of the Hecate Cove Formation. Furthermore, the basal part of the Lower waterlain pyroclastic member of the unit locally contains sedimentary or mixed sedimentary-volcanic breccias, limestone

breccias, and volcanic conglomerates with poorly rounded pebbles lithologically indistinguishable from those of the Hecate Cove Formation.

The waterlain pyroclastics and the associated clastic rocks of the Uppermost Sinemurian volcanic unit apparently differ from those of the Hecate Cove Formation only in the somewhat lighter colour of their grey to green-grey phases. From pyroclastic rocks of the Basal Jurassic volcanic unit they differ in the same lithological features as the pyroclastic rocks of the Hecate Cove Formation.

The predominantly amygdaloidal lavas of the Intermediate member appear to be the same as those of the Basal Jurassic volcanic unit. However, they are distinguishable from the amygdaloidal lavas of Hecate Cove Formation and the amygdaloidal lavas of the Grey volcanic unit because of the prevalence of lavender, red, maroon and blue colour phases. Consequently, the Uppermost Sinemurian volcanic unit can be recognized with certainty only in those sections where its stratigraphic relationships with adjacent sedimentary units of the division are either obvious or at least decipherable.

Uppermost Sinemurian argillite unit

On the southern shore of Quatsino Sound opposite Koprino Harbour (i.e. on both sides of Mahatta logging camp), the Uppermost Sinemurian volcanic unit is locally overlain, apparently conformably, by a unit of dark grey argillite interbedded with some arenaceous limestone, greywacke, and calcareous grit. This unit was named Lower Pliensbachian argillites by Jeletzky (1970b, p. 13) because of a discovery of poorly preserved ammonites which according to Dr. Hans Frebold could be either of a late Sinemurian or of an early Pliensbachian age. At that time the writer choose to assign these argillites to the early Pliensbachian because of their occurrence in the same section with but stratigraphically well above the topmost beds of Matthews Island Formation containing the Echioceras (Melanhippites) harbledownensis fauna

representing the latest Sinemurian Raricostatum Zone. Later, however, these "Early Pliensbachian" argillites have yielded definitively identified diagnostic ammonites representing the upper part of the Raricostatum Zone of the international standard. Because of this discovery these argillites are here renamed the Uppermost Sinemurian argillite unit.

Uppermost Sinemurian)

Distribution. The Uppermost Sinemurian argillite unit is exposed only in scattered, greatly disturbed and locally contorted outcrops on the shore 300 yards northwest of the mouth of Monkey Creek, east of its mouth at the base and at the front of a nameless major rocky point 1/3 of a mile east of Mahatta logging camp, and in the bed of Monkey Creek in the interval between 1/2 and 3/5 of a mile above its mouth. Small outcrops of lithologically similar, unfossiliferous argillites observed at the head of Browning Inlet just northeast of the mouth of Kwatleo Creek are placed in this unit only tentatively.

Stratigraphy. The thickest observed section of the unit outcrops in the intertidal zone about 300 yards west of the mouth of Monkey Creek. It consists of strongly sheared and locally contorted brownish grey to blackish grey or black, mostly pure, indistinctly bedded to massive argillites resembling the more thickly bedded argillite types of the Matthews Island Formation. These argillites are interbedded with relatively rare beds, as much as 1 foot thick, of dull grey, calcareous grit, similarly coloured, fine- to medium-grained greywacke, and bluish grey, arenaceous limestone. Neither the top nor the base of the unit is exposed in this section and the visible thickness of exposed rocks does not exceed 120 feet.

(Uppermost Sinemurian)

The basal 27 feet (and possibly as much as 42 feet) of the Uppermost Sinemurian argillite unit are exposed in section 18 on the eastern side of Monkey Creek. In this section, the unit appears to overlie conformably the Upper waterlain pyroclastic member of the Uppermost Sinemurian volcanic unit although the contact is not exposed.

(Uppermost Sinemurian)

Except in the vicinity of Monkey Creek on the southern shore of Quatsino Sound, rocks lithologically similar to the Uppermost Sinemurian argillites were observed only at the head of Browning Inlet just northeast of the mouth of Kwatleo Creek. There, about 150 feet of grey to light grey, thin- to medium-bedded, fissile, soft (except in the proximity of intrusive rock) shales striking N10°-20°W and dipping 80° to 85° east (overturned?) are unconformably overlapped by the upper Valanginian Buchia crassicollis greywacke which conceals their stratigraphical base. The stratigraphical top of these shales is cut off by an irregularly shaped, large body of light to whitish grey, rusty-weathering, felsitic intrusive rock belonging to the hypabyssal phase of Coast Intrusions.

These unfossiliferous shales contain intercalated beds (6 inches to 1 1/2 feet thick) of similarly coloured laminated cherty limestone and dull to light green, hard, cherty, fine-grained, waterlain volcanic tuff.

The shales concerned are somewhat similar lithologically to some of the lighter coloured phases of the Uppermost Sinemurian argillite unit and do not resemble the rocks of any other sedimentary unit of the Volcanic division known to the writer. They are, therefore, correlated tentatively with the former unit (see Figure 18). However, because of their obscure stratigraphic relationships and unfossiliferous nature, the shales concerned could possibly belong elsewhere (e.g., to represent a peculiar phase of the Cherty limestone unit) or even represent an entirely different, perhaps Toarcian, sedimentary unit of the Volcanic division.

The top part of the Uppermost Sinemurian argillite unit and its contact with the younger high Lower Jurassic rocks of the Bonanza Subgroup were not observed in any of the studied sections. The unit is at least 150 feet thick and the rather arbitrary combination of its several partial sections suggests that it may be up to 500 feet thick.

Age and correlation. A poorly preserved ammonite, possibly belonging to the family Eoderoceratidae Spath and the genus ? Microderoceras or ? Crucilobiceras, was found 115 feet above the visible base of the section measured 300 yards to the northwest of the mouth of Monkey Creek (GSC loc. 24311). The presence of this ammonite suggests a late Sinemurian or early Pliensbachian age for the Uppermost Sinemurian argillite unit. Entolium balteanum Crickmay and an indeterminate fragmentary imprint of an ammonite (GSC locs. 24304 and 24308) were found a few feet stratigraphically lower in the section. The discovery of these fossils prompted a tentative assignment of the Uppermost Sinemurian argillite unit to the early Pliensbachian stage in a preliminary report (Jeletzky, 1970b, p. 13, Fig. 1).

Subsequent collecting in the here discussed argillites by J.E. Muller (in 1971) yielded the following more diagnostic fossils:

1. Field No. 71-47A (GSC loc. 88621) in Roadcut at old log-dump, Mahatta River. Lat. 49° 27'45"; Long. 127° 48'00". Aug. 30, 1971. According to Dr. Hans Frebold this collection contains: "Echioceras (Melanhippites) harbledownensis (Crickmay), Crucilobiceras spp. indet. One specimen with one outer row of spines, but only on last whorl, the other specimen (impression of part of whorl) has an inner and an outer row of spines (as for instance in C. crucilobatum). The unsatisfactory preservation of the two specimens does not warrant identification of species. Age: Early Jurassic. Late Sinemurian. Upper part of Raricostatum Zone".

2. Field No. 71-47B (GSC loc. 88620). Beach outcrop slightly west of Mahatta Camp. Near hydrographic beachmark. Lat. 49° 27'30"N; Long. 127° 40'45"W

According to Dr. Hans Frebold this collection contains: "Ammonoids Crucilobiceras sp. indet. Pelecypods Entolium balteanum Crickmay. Age: Early Jurassic. Late Sinemurian. Upper part of Raricostatum Zone."

The GSC loc. 88620 of J.E. Muller was collected from the same topmost beds of the unit which yielded the previously discussed GSC localities 24311, 24304 and 24308. The locality 88621 represents beds intermediate in stratigraphic position between the former beds and the basal beds of the unit exposed in Section 18.

The Uppermost Sinemurian argillite unit is correlated tentatively with lithologically identical dark grey, marine argillites outcropping on Catala Island and in the bed of Tatchu Creek in the Kyuoquot-Esperanza area, west coast of Vancouver Island (Jeletzky, 1970b, p. 13). These argillites, several hundred feet thick, form a unit in the dark grey, intermediate volcanic rocks of the Volcanic division. No diagnostic fossils have been found in these argillites but their occurrence in close proximity to and apparently stratigraphically below the Pliensbachian-Toarcian greywacke unit equivalent to the Maude Formation of Queen Charlotte Islands (Jeletzky, 1954b, p. 13) supports their suggested lithologic correlation with the Uppermost Sinemurian argillite unit of Quatsino Sound.

The Harbledown Formation of the tectonically and volcanically quiescent zone of the Insular Tectonic Belt includes fossiliferous Sinemurian beds apparently equivalent to the Uppermost Sinemurian argillite unit of Quatsino Sound.

?Dark Grey Volcanic Unit

Distribution and stratigraphy. An isolated section (see Sec. 19 of the Appendix) of dark grey porphyritic to extremely amygdaloidal, ?andesitic lavas outcrops at the head of Browning Inlet (see Fig. 18). These lithologically distinctive lavas were tentatively correlated with the Dark grey volcanic unit of the Kyuquot-Esperanza area of the west coast by Jeletzky (1970b, p. 14) because of a far-reaching lithological similarity and the inferred stratigraphic relationships with other units of the Volcanic division. These lavas outcrop in a downfaulted block on the southwestern side of extensive outcrops of the Matthews Island Formation which seems to dip under them. On the other hand, these lavas appear to overlie outcrops of ?Uppermost Sinemurian argillite unit on the northwestern side of the lagoon.

Age and correlation. In the Esperanza-Kyuquot area, the Dark grey volcanic unit grades upward into the reliably dated Pliensbachian-Toarcian greywacke unit and appears to overlie conformably and gradationally the argillites apparently equivalent to the Uppermost Sinemurian argillite unit (Jeletzky, 1970b, p. 14). The Dark grey volcanic unit represents, therefore, some part of the early Pliensbachian stage. The same age is suggested tentatively for its apparent equivalents exposed in Browning Inlet (Fig. 5).

?Pliensbachian-Toarcian Greywacke Unit

Distribution and stratigraphy. At least 1,000 feet of moderately hard to soft, dark to light bluish-grey, fine to very fine pebble conglomerate, coarse-grained greywacke and coarse grit outcrop on the west side of the lagoon at the head of Browning Inlet in the bed of Kwatleo Creek between the points 300 and 850 yards above its mouth (see Fig. 18). This unit contains variable but normally minor amounts of similarly coloured, mostly well-bedded and sorted, definitely waterlain volcanic tuffs and breccia. Some of these volcanic rocks could be classified almost as well as poorly rounded and sorted sedimentary clastics. All clastic rocks seen appear to be composed of sedimentary and volcanic particles and clasts and lack completely any grains and pebbles of intrusive origin.

The uppermost 150 - 200 feet of the unit are composed mainly of bluish grey to light blue, extremely well and thinly bedded, fine to coarse tuffaceous greywacke, grit and very fine pebble conglomerate with dispersed larger (1/2 - to 2-inch) pebbles. In the lowermost 300 to 350 feet of the unit, the waterlain pyroclastic rocks comprise 50 to 60 per cent and the intercalated tuffaceous clastic rocks consist almost exclusively of fine to very fine pebble conglomerate and coarse grit with tuffaceous matrix.

The rocks strike N40°-50°E and dip 35°-40°W. Their basal beds are faulted against the upper Valanginian *Buchia crassicollis* greywackes and in the west their top is concealed beneath the Pleistocene gravels.

Age and correlation. No fossils were found but the rocks are similar lithologically to those of the Pliensbachian-Toarcian greywacke unit of the Kyuquot-Esperanza area of the west coast of Vancouver Island (Jeletzky, 1954a, p. 1269; 1954b, p. 13; 1970b, pp. 14-16). Furthermore, they occur within a downfaulted block to the west of the possibly overturned shale outcrops tentatively assigned to the Lower Pliensbachian argillite unit. The apparent complete absence of granitic grains and clasts and the presence of pyroclastics in this unit suggests that they form part of the Volcanic division of the Bonanza Subgroup. The upper Valinginian *Buchia crassicollis* greywacke that outcrops in the vicinity is lithologically dissimilar to the sedimentary-clastic to pyroclastic unit discussed here and the two appear to be in fault contact. Because of the above considerations, the sedimentary clastic-pyroclastic unit is correlated tentatively with the Pliensbachian-Toarcian greywacke unit of the Kyuquot-Esperanza area and assigned a general Pliensbachian to Toarcian age (Fig. 5).

Lower Jurassic Tectonic and Depositional Pattern of Insular Tectonic Belt

The tectonic and depositional pattern produced by the latest Triassic orogenic phase (see previous sections of this report) apparently persisted essentially unchanged during Early Jurassic time since all Lower Jurassic units of the Volcanic division discussed appear to be restricted to the latest Triassic tectonically and volcanically active zone of the Insular Tectonic Belt (Fig. 5).

Depositional Area of the Lower Jurassic Part of Volcanic Division

As pointed out by Jeletzky (1970b, p. 10), the Lower Jurassic part of the Volcanic division is well developed and was deposited everywhere in the northwestern part of Vancouver Island west of longitude 126° west. East of this meridian outcrops are few (on Cowichan Lake, Fyles, 1955, p. 23; in Sproat Lake area, Muller and Carson, 1969, p. 16; in Kennedy Lake area, Eastwood, 1968, pp. 26, 27) but those known appear to be readily assignable to the individual sedimentary or volcanic units of the division recognized on the northwestern part of Vancouver Island on the basis of their stratigraphic position and lithology. Thus, it is assumed that the Lower Jurassic part of the Volcanic division was originally deposited in the same, or at least basically similar facies over most or all of the western half of southeastern Vancouver Island but was either subsequently eroded or has been sufficiently metamorphosed to be now unrecognizable in most areas.

Sedimentary Sequence of the Lower Jurassic Tectonically and Volcanically Quiescent Zone

As in latest Triassic time, the periodic Lower Jurassic volcanic outbursts recorded by the volcanic units of the Volcanic division of the Bonanza Subgroup (Figs. 5, 6) apparently did not affect the eastern side of Vancouver Island, the islands of Queen Charlotte Strait, and Queen Charlotte Islands. The Lower Jurassic rocks of this northeastern part of the Insular Tectonic Belt appear to be represented either exclusively or almost exclusively by more or less tuffaceous argillites and impure limestones interbedded with varying amounts of fine-grained (argillite-like) waterlain volcanic tuffs (Crickmay, 1928; Dawson, 1887, pp. 72B-74B; Surdam _et al._, 1964, p. 226; Surdam, 1968, p. 20, Fig. 6; Sutherland-Brown, 1966, 1968; Jeletzky, 1970b, pp. 16-21, Figs. 1, 2; Muller, 1970, p. 47).

Tuffaceous argillites of Buttle Lake Area

Lower Jurassic limy, tuffaceous argillites ("limy tuffs" of Surdam, 1968, p. 20), conformably overlying Norian limestones of the Quatsino Formation at Iron River east of Buttle Lake, contain Sinemurian fossils 200 feet above their base (Surdam, 1968, p. 20, Fig. 6). Because of an extremely fine grain size, apparent absence of any erosional intervals, and stratigraphic-lithologic similarity with the more fossiliferous Harbledown (i.e. Black argillite member of the Kunga Formation; see Jeletzky, 1970b, p. 2, footnote 1) and Maude Formation of Queen Charlotte Islands (Frebold, 1967, p. 1148; Sutherland-Brown, 1968; Frebold and Tipper, 1970, p. 4), these Tuffaceous argillites of the Iron River area are believed also to include Rhaetian, Hettangian, Pliensbachian, and Toarcian sediments. The total thickness of the tuffaceous argillites does not exceed 750 feet (Surdam, 1968, p. 20, Fig. 6).

Harbledown Formation of Queen Charlotte Strait

The exposed thickness of black, noncalcareous argillite of the Harbledown Formation does not exceed 1,600 feet in its type section (Crickmay, 1928, p. 59). The top is cut off by granitic Coast Intrusions (Crickmay, 1928, p. 52) and the contact with the underlying calcareous argillites of the Parson Bay Formation appears to be gradational.

According to Dr. Hans Frebold (unpublished fossil reports and personal communication, 1968), the type Harbledown Formation contains the same Sinemurian ammonite faunas as the Matthews Island Formation of Quatsino Sound.

Because of a probable gradational contact with calcareous argillites of Parson Bay Formation, which extends upward at least into the Lower Suessi Zone (Crickmay, 1928, pp. 55, 56; Tozer, 1967, pp. 39, 71, 81), the unfossiliferous argillites underlying the Sinemurian beds of the Harbledown Formation are believed to represent the late late Norian, Rhaetian, and Hettangian stages.

The uppermost 560 feet of the type Harbledown Formation did not yield any diagnostic fossils (Crickmay, 1928, p. 59) and so cannot be dated. The presence of Acanthopleuroceras cf. sutherlandbrowni Frebold in the Harbledown argillites of Balaklava Island (see below) suggests, however, that the uppermost part of the type Harbledown Formation may include some lower Pliensbachian beds correlative with the Maude Formation of Queen Charlotte Islands.

According to Dawson (1887, pp. 72B-74B), the Hope-Galiano (now Nigei) Island group on the south side of Queen Charlotte Strait is underlain mostly by dark flaggy argillites and quartzites invaded by extensive Coast Intrusions. Volcanic rocks referable to the Volcanic division of the Bonanza Subgroup seem to be scarce or absent throughout this group of islands. This conclusion, originally reached by Jeletzky (MS, 1968 and 1970b, p. 17), was subsequently confirmed by Muller's (1970, p. 47) mapping of these islands.

Ammonites comparable with lower Sinemurian Arniotites vancouverensis (Whiteaves) have been recorded from these argillites near Port Alexander on Nigei Island (Dawson, 1887, p. 73B) and lower Pliensbachian Acanthopleuroceras cf. A. sutherlandbrowni Frebold has been identified by Dr. Hans Frebold (unpublished intradepartmental fossil report, 1968) in fossil collections recently obtained by J.E. Muller from similar argillites on Balaklava Island.

The Lower Jurassic argillites and quartzites of the Hope-Nigei Island group appear to represent the marginal southwestern part of the tectonically and volcanically quiescent zone of the Insular Tectonic Belt and are referred tentatively to the Harbledown Formation rather than to the Matthews Island Formation of the Volcanic division of the Bonanza Subgroup (Fig. 6). No information is available about their relationships with underlying and overlying rock units but they are believed to be essentially similar to those of the type Harbledown Formation and its equivalents on Queen Charlotte Islands (see Fig. 5: Crickmay, 1928; Sutherland-Brown, 1968).

Harbledown and Maude Formations of Queen Charlotte Islands

The Harbledown Formation (= Black argillite member of Kunga Formation of Sutherland-Brown, 1968; see Jeletzky, 1970b, p. 2, footnote 1), as much as 1,900 feet thick, grades downward into the black carbonaceous limestone member of the Quatsino Formation and is conformably overlain by shales, argillites and lithic sandstones of the Maude Formation (Sutherland-Brown, 1968, p. 39). It contains Arniotites (lower Sinemurian) and Echioceras (Melanhippites) harbledownensis Crickmay (upper Sinemurian) faunas (Sutherland-Brown, 1968, p. 61; Frebold and Tipper, 1970, p. 4). Because of its stratigraphic position and conformable relationships with adjacent rock units this "flaggy black argillite member extends presumably from the Suessi Zone through to nearly the end of the Sinemurian, although no definite Rhaetian nor Hettangian are recognized" (Sutherland-Brown, 1968, p. 61).

Because of the similar stratigraphic position and lithologic identity with the type Harbledown Formation, the Harbledown equivalent of Queen Charlotte Islands is believed to have been continuous with the latter. The complete absence or rarity of arenaceous to psammitic material in the Harbledown Formation and lower part of the Maude Formation and the almost exclusively open sea character of the fauna

(ammonites, aulacocerids and Posidonia-like pelecypods) strongly suggest their origin as being offshore deposits.

The Maude Formation, comprising as much as 600 feet of interbedded grey shale, blocky dark grey argillite, light grey calcareous shale, and greenish grey lithic sandstone is thought to be unconformably overlain by pyroclastics of the Yakoun Formation (Sutherland-Brown, 1968, pp. 39, 61-66).

The faunas of the Maude Formation have been revised recently by Dr. Hans Frebold (Frebold, 1967; Frebold and Tipper, 1970; Sutherland-Brown, 1968, p. 64). Frebold recognized three faunas: the lowest, 150 feet above the base, has Tropidoceras and Acanthopleuroceras and is of early Pliensbachian age; the middle fauna, with Fanninoceras, is also early Pliensbachian; and the upper assemblage, which occurs within 50 feet of the top of the formation (Sutherland-Brown, 1968, p. 65) is the Toarcian fauna with Harpoceras and Dactylioceras originally described by F.H. McLearn. The only comparable fauna known elsewhere in the tectonically and volcanically quiescent zone of the Insular Tectonic Belt is the early Pliensbachian fauna with Acanthopleuroceras cf. sutherlandbrowni Frebold from the Harbledown argillites on Balaklava Island. It is not known whether the apparent absence of younger Maude faunas within this zone outside of Queen Charlotte Islands is due to the erosional or igneous destruction of the corresponding rocks, collection failure, or lateral facies changes.

Relationships of Sedimentary Lower Jurassic Sequences to the Volcanic Division of Bonanza Subgroup

The lithology of the exclusively or prevailingly sedimentary Lower Jurassic rocks of the quiescent zone described above contrasts strongly with that of the previously discussed, predominantly volcanic and much thicker rocks of the Volcanic division of

Bonanza Subgroup (Figs. 5, 6). Their diagnostic faunas are, however, identical with those occurring in the sedimentary interbeds of the Volcanic division. This indicates the essential contemporaneity of these two lithologically dissimilar rock sequences, and to their being but different Lower Jurassic facies deposited side by side within the Insular Tectonic Belt.

The entirely or prevailingly sedimentary sequences of the northeastern side of Vancouver Island, the islands of Queen Charlotte Strait, and Queen Charlotte Islands formed part of a continuous (at least from Queen Charlotte Islands to Buttle Lake map-area) tectonically and volcanically quiescent zone which existed in this part of the Insular Tectonic Belt from the end of the late Karnian and (?)earlier Karmutsen volcanic outburst until Toarcian time. This quiescent zone apparently was not affected to any extent by the recurrent outbreaks of volcanic activity, the latest Triassic orogenic phase, and the Sinemurian and early Pliensbachian uplifts (Figs. 5, 6). The only obvious influence of these volcanic outbreaks within the early Jurassic quiescent zone of the Insular Tectonic Belt is the greater or lesser admixture of fine (argillite-like), airborne volcanic tuffs in its marine sediments. This is remarkable, considering that the volcanic-rich type area of the Bonanza Subgroup in Nimpkish Lake map-area is situated only 15 to 16 miles south of the exclusively sedimentary and essentially contemporary type sections of the Parson Bay and Harbledown formations. The writer prefers to disregard for the time being the admittedly possible but as yet unsubstantiated tectonic juxtaposition of these sections by a major strike-slip fault concealed beneath Johnstone Strait. He assumes, therefore, that this close proximity of Lower Jurassic volcanic and sedimentary facies is a natural phenomenon and that neither pyroclastic fragments (except for the previously mentioned very fine volcanic dust) nor lava flows of the Volcanic division were spreading for more than a few miles away from their sources.

Scarcity of Sediment in Tectonically and Volcanically Quiescent Zone

The tectonically and volcanically quiescent zone of the Insular Tectonic Belt (Fig. 6) accumulated only between 2,000 and 3,500 feet of predominantly fine-grained clastic and calcareous sediments during its rather prolonged existence (from late upper Karnian to Toarcian inclusive). This thin sedimentary column contrasts with the many thousands of feet (at least 10,000 to 20,000 feet) of predominantly volcanic rocks that accumulated during the same time in the adjacent tectonically and volcanically active zone of the belt (Figs. 5, 6). The quiescent zone was thus relatively "sediment starved" in spite of its occurrence inside the extremely mobile Early Mesozoic orogenic belt of western British Columbia.

The "sediment-starved" character of the quiescent zone of the Insular Tectonic Belt apparently indicates:

1. The absence of any nearby large source areas to the east (i.e. within the western part of the present Coast Mountains) throughout late Triassic and early Jurassic time.

2. Apparent absence of any larger, strongly elevated nearby source areas to the west (i.e. near northeastern boundary of the tectonically and volcanically active zone of the Insular Tectonic Belt) throughout late Triassic and early Jurassic time; and

3. That the lava flows and most of the pyroclastic fragments of the Volcanic division of the Bonanza Subgroup apparently spread only a few miles (see in previous section) beyond the easternmost vents and fissures of the active zone.

Thus, it would appear that a low relief characterizing the eastern part of the Early Jurassic active belt hindered any extensive spread of lava flows into the quiescent zone.

For reasons indicated by Jeletzky (1970b, pp. 11-16, Figs. 1, 2 and in the previous sections of this report) the Cherty limestone unit, Matthews Island Formation, Uppermost Sinemurian argillite unit, and Pliensbachian-Toarcian greywacke unit of the Volcanic division appear to be but sedimentary tongues of the Harbledown and Maude Formations (Figs. 5, 6). These tongues appear to expand gradually (in their time spans but not in thicknesses; compare Fig. 5) eastward, northeastward, and northwestward at the expense of the intervening volcanic units of the Volcanic division until they merge into a much thinner continuous sedimentary sequence (Harbledown and Maude Formations) somewhere near the eastern, northeastern and northern coasts of Vancouver Island.

Volcanic Cycles of the Volcanic Division

The stratigraphic sequence of predominantly volcanic rocks of the Volcanic division reveals the cyclical character of the uppermost Triassic and Lower Jurassic volcanism in all better known areas of the tectonically and volcanically active zone.

The more or less widespread occurrence of four volcanic units separated from each other by equally widespread sedimentary units suggests the occurrence of at least four regionally valid (i.e. within the tectonically and volcanically active zone of the belt) volcanic cycles in the Volcanic division of the Bonanza Subgroup. Each of these cycles begins with accumulation of considerable thicknesses of subaerially and/or subaqueously deposited lavas and pyroclastics and ends with deposition of fine clastic (mainly argillites) and/or calcareous (mainly impure limestone), predominantly or entirely marine sediments. The suggested sequence of these cycles is:

1. Hecate Cove Formation - Basal Jurassic volcanic unit - Cherty limestone unit.

2. Grey volcanic unit - Sinemurian Matthews Island Formation.

3. Uppermost Sinemurian volcanic unit - Uppermost Sinemurian argillite unit; and

4. Dark grey volcanic unit - Pliensbachian-Toarcian greywacke unit.

Judged by the thicknesses of extruded volcanic rocks, these four volcanic episodes of the Volcanic division were of unequal energy. The first (i.e. the apparently Rhaetian-Hettangian) volcanic episode must have been by far the strongest. The second (i.e. the ?Hettangian or Grey volcanic unit event) must have been considerably more intense than the later two events which apparently resulted in accumulation of no more than a few hundred feet of lavas and/or pyroclastics each. This suggests that a gradually declining trend was superimposed on the generally cyclical character of the Lower Jurassic volcanic activity within the tectonically and volcanically active zone of the Insular Tectonic Belt. The Bonanza outburst of volcanism appears, therefore, to have been connected with the latest Triassic orogenic phase, reached its peak soon after its end (i.e. during the time of deposition of the Basal Jurassic volcanic unit), and was on the decline during the late Hettangian to ?? Pliensbachian and ? Toarcian time.

Lower Jurassic Depositional Environments and Tectonic Movements of Tectonically and Volcanically Active Zone

Basal Jurassic Environments

As pointed out by Jeletzky (1970b, pp. 10, 11, 21), the facies of the Basal Jurassic volcanic unit apparently remained essentially the same throughout most (or all?) of the tectonically and volcanically active zone of the Insular Tectonic Belt.

The constituents of its pyroclastic rocks appear to be largely or completely angular and unsorted throughout the investigated parts of the zone. To the best of the writer's knowledge, marine interbeds and pillow structures are unknown except near the unit's top, suggesting a largely or entirely subaerial deposition. These data, together with the ensuing, widespread transgression of the Cherty limestone sea (see below), suggest that the volcanics of the Basal Jurassic volcanic unit were deposited on a relatively flat lowland which subsided as fast as, or faster than, the volcanic piles were accumulating. If so, the strongly diversified relief created within the active zone by the latest Triassic (early Rhaetian or ?latest Norian) orogenic phase (see Jeletzky, 1970b, pp. 8, 9 and in previous sections of this report) must have been essentially bevelled prior to the deposition of the ?early Hettangian Basal Jurassic volcanic unit. This inference finds additional support in the "sediment starved" nature of the adjacent tectonically and volcanically quiescent zone.

The predominantly fine-grained, calcareous rocks of the ?Hettangian Cherty limestone unit in all its known sections suggest that the sea that covered the active zone at this time transgressed over a relatively flat lowland and that any adjacent western and southern source areas of that time were of low relief.

Pillow lavas and pillow breccias abound in most studied sections of the Grey volcanic unit in Quatsino Sound, being particularly prominent in its westernmost outcrops in Forward Inlet. This, and the apparently complete absence of erosionally reworked, more or less rounded and sorted pyroclastics, suggests a largely or entirely subaqueous mode of deposition for rocks of the Grey volcanic unit.

Sinemurian Environments and Tectonic Movements

The predominantly fine-grained (argillaceous to calcareous) strata of the Sinemurian Matthews Island Formation in most of its known outcrops indicate that most of the active zone was subjected to essentially the same depositional environment as prevailed during the time of deposition of the Cherty limestone unit. Some coarse clastics (including limestone breccia and conglomerate) appear, however, in the westernmost studied sections of Matthews Island Formation in Forward and Browning Inlets. The intervening Waterlain tuff member of the Sinemurian argillites appears, furthermore, to thicken westward in Quatsino Sound. In contrast, the Upper argillite and Lower argillite members of this unit become thinner westward, the former member becoming replaced laterally largely by the poorly rounded conglomerates and coarse to fine volcanic breccias of the lower part of the Uppermost Sinemurian volcanic unit in the westernmost sections studied. This suggests the occurrence of an uplift (or uplifts?) during Sinemurian time and the resulting emergence of a sizable, sufficiently elevated and volcanically active western Sinemurian source area in close proximity to the present west coast of northern Vancouver Island. The exact location and extent of this source area are uncertain but it seems likely that is was situated just off the west coast and extended at least from Cape Scott to Esperanza Inlet.

The Sinemurian western source area apparently remained active in latest Sinemurian time judged by the considerable amounts of poorly sorted coarse clastics and somewhat rounded waterlain pyroclastics deposited in the Quatsino Sound area during the time of deposition of the Uppermost Sinemurian volcanic unit. The latter area itself probably remained a lowland or a shallow sea. A largely subaqueous mode of deposition for the poorly sorted coarse clastics and more or less reworked

pyroclastics of the Uppermost Sinemurian volcanic unit is suggested by their intercalation with considerable amounts of pillow lavas and pillow breccias in several sections.

The latest Sinemurian depositional environment may have extended along the west coast of Vancouver Island at least as far south as Esperanza Inlet.

In the western part of Quatsino Sound, coarse clastics and waterlain pyroclastics of the Uppermost Sinemurian volcanic unit grade upward into the Uppermost Sinemurian argillite unit. The same seems to be true, furthermore, of the Kyuquot-Esperanza area. The resumption of deposition of fine-grained sediments in the western part of northern Vancouver Island suggests a bevelling of most or all of the Sinemurian western source area and the temporary cessation of the volcanism within it.

Pliensbachian-Toarcian Environments and early Pliensbachian Uplift

Too little is known about the areal extent and the lithology of the Dark grey volcanic unit to attempt an environmental-structural evaluation of this "moment" of ? early Pliensbachian time.

The predominantly coarse clastic rocks of the lower part of the Pliensbachian-Toarcian greywacke unit contrast strongly with the predominantly argillaceous strata of earlier sedimentary units of the Volcanic division, including the Uppermost Sinemurian argillites. The deposition of these coarse clastics near the southwestern margin of the tectonically and volcanically active zone of the Insular Tectonic Belt in the Kyuquot-Esperanza area and probably in the western part of Quatsino Sound, and the apparent presence of a major erosional interval underneath the Pliensbachian-Toarcian greywacke unit in the Sproat Lake area(Fig. 6),suggest the occurrence of an early(but not the earliest)Pliensbachian uplift in these parts of the zone at least. The coarse,nearsho

to nonmarine sediments of the Pliensbachian-Toarcian greywacke unit apparently passed laterally eastward, northward and northwestward into argillites and limestones of the Maude and Harbledown Formations (Fig. 5) but the latter rocks are, so far, unknown outside of the Lower Jurassic quiescent zone.

The facies relationships of the Lower Jurassic rocks of the active zone suggest that, like the coarse clastics and erosionally reworked volcanics of the latest Sinemurian time, the coarse clastics of the Pliensbachian-Toarcian greywacke unit were derived from a western source area (a tectonic land) that probably represented a northwest-trending, narrow cordillera which was situated immediately seaward of the present west coast of Vancouver Island and extended at least from Cape Scott to Barkley Sound.

The apparent absence of folding or faulting attributable to Sinemurian and early Pliensbachian tectonic movements suggests their non-orogenic nature. Furthermore, no angular discordances were observed either within the Matthews Island Formation or at the base of the Pliensbachian-Toarcian greywacke unit.

MIDDLE JURASSIC INTRUSIONS

Coast Intrusions

A considerable number of the intrusive bodies of the report-area, varying widely in their size, texture and mineralogical composition, are united under the heading of "Coast Intrusions" as they appear to be of the same, or at least approximately the same (i.e. general Middle Jurassic) geological age. The term "Island Intrusions" used by Eastwood (1965, p. 126) and adopted by Muller and Carson (1969, p. 17) for the Coast Intrusions of Vancouver Island is not accepted in this report. In the writer's opinion, this term is rather unfortunate in obscuring the long-recognized (Dawson,

1887, p. 11B) intimate connection existing between the Coast Intrusions of Vancouver Island and those of the adjacent parts of the Coast Mountains on the mainland of western British Columbia. The dykes, sills and larger plug- to boss-size bodies of northwestern Vancouver Island are interpreted as very shallow to hypabyssal apophyses and cupolas of larger intrusive bodies still hidden at depth and either intimately connected with or representing a direct continuation of the principal intrusive bodies of Coast Intrusions of the Coast Mountains. This relationship is suggested by the structurally depressed nature of the northwestern part of Vancouver Island in particular and of Vancouver Island in general as compared to the Coast Mountains of the mainland of western British Columbia (see below for details). The retention of true isotopic ages (i.e. those confirmed by biochronology) by the Middle Jurassic intrusive bodies of northwestern Vancouver Island and the prevalence of the reset Cretaceous isotopic ages in the closely related intrusions of the Coast Mountains proper may well have been caused by the deep-seated nature of the latter.

This report is concerned primarily with the stratigraphic and structural relationships of Coast Intrusions of Quatsino Sound and with their relative (i.e. paleontological) age. Relatively little attention is paid to the radioactive ages of Coast Intrusions as the writer is extremely sceptical about the validity of generally assumed degree of precision, and even about the general reliability of all now existing methods of radioactive age determination of igneous and sedimentary rocks within ancient orogenic belts at least.

The microscopic petrography of the Coast Intrusions is beyond the scope of this report and the tentative petrographic assignment attempted below of some of the intrusives is based solely on the macroscopical and hand lens study of their specimens.

Previous Investigations

Dawson (1887) apparently did not recognize the presence of any granitoid Coast Intrusion bodies within Quatsino Sound as he neither mentioned their presence in the text of the report nor showed them on the attached geological maps. The mention of an intrusive rock cutting the Lower Cretaceous sediments in Koprino Harbour (Dawson, 1887, p. 88B) refers not to the Coast Intrusions but to the presumably Tertiary ?Sooke Intrusions.

Dolmage (1919, pp. 32B-33B) was the first to recognize the rare presence of granitoid Coast Intrusions in Quatsino Sound and to differentiate them from the post-Cretaceous diabase dykes. He mentions specifically a true granite body occurring at the west end of Rupert Inlet, a large quartz diorite mass occurring at the head of Ingersoll River and near the Yreka Copper mine, and a true diorite body at Old Sport mine. Gunning (1930, pp. 106A-108A) confirmed Dolmage's observations and discovered a few additional bodies of granitoid Coast Intrusions mainly outside of the investigated part of Quatsino Sound.

Distribution and Composition

The paucity of Coast Intrusions in the investigated part of Quatsino Sound (Dolmage, 1919, p. 32B) is striking when compared with their abundance in other investigated parts of the west coast of Vancouver Island (Jeletzky, 1950, 1954b, and unpublished) and Zeballos-Nimpkish map-area (Hoadley, 1953). Most of the Quatsino Sound intrusives are, furthermore, sills, dykes, and irregularly shaped minor bodies, the thickness of which fluctuates from a few inches to about 100 feet. It is, therefore, impossible either to show all of these minor Coast Intrusions on the attached geological maps and profiles or to discuss all of them in the text of this report. The rather

rare, larger bodies of Coast Intrusions are, likewise, considerably smaller than the larger Coast Intrusions of the west coast of Vancouver Island and of the Zeballos-Nimpkish map-area. They are all plug- or boss-like, or irregularly shaped bodies, the observed maximum width of which (i.e. along the shoreline) does not exceed 1 1/3 miles. In most cases, the maximum observed width of the larger Coast Intrusions of the report-area fluctuates between 100 feet and 1/2 mile. There are some indications that larger bodies of Coast Intrusions may be concealed in dense forests covering the tops of the mountains farther inland. However, it is not expected that any of these bodies would be comparable in size with the large stock- to batholith-like Coast Intrusions of the west coast of Vancouver Island and Zeballos-Nimpkish map-area.

Only the following nine newly discovered larger intrusive bodies are mentioned specifically:

1. An intrusion, about 1,000 feet wide, occurs at the southern base of Greenwood Point on the western shore of Forward Inlet (see Fig. 18). This body is largely composed of fine- to medium-grained, rose-grey to orange ?dacite porphyry containing abundant phenocrysts of orange to meat-red ?sodic feldspar. The groundmass is felsitic. The marginal parts of the body are composed of similarly coloured felsitic rock.

2. A gabbroic intrusion, about 800 feet wide, occurs on the southeastern shore of Winter Harbour (see Unit 9 of Sec. 21 for further details).

3. An intrusive body, about 3/4 of a mile wide, occurs on the southwestern shore of North Harbour in Forward Inlet. Near its margins and along the shore, this body is composed mainly of light grey, rusty-weathering, sheared and metamorphosed felsitic, somewhat porphyritic or coarsely amygdaloidal rock, which is probably dacitic in composition. However, in the central part of the body the rock becomes coarsely

prophyritic. This ?dacite exhibits excellent intrusive contacts with the surrounding rocks of the Matthews Island Formation and Uppermost Sinemurian volcanic unit and locally contains abundant xenoliths and large inclusions of these rock units. The intrusive body appears to widen rapidly inland and probably occupies most or all of Flat Top Mountain (see Fig. 18).

4. An intrusive body, about 700 feet wide, occupies the tidal platform at the head of Browning Inlet north of the mouth of Kwatleo Creek. This body consists of whitish grey, reddish brown weathering, felsitic to porphyritic, probably dacitic hypabyssal rock which is considerably sheared and cut by quartz and calcite veinlets and stringers. The intrusive rock invades sediments of the Vancouver Group correlated tentatively with the Uppermost Sinemurian argillite unit. The latter are intensely baked, sheared, contorted, and locally "granitized" in the proximity of the well-developed intrusive contact. The intrusive rock locally contains numerous large inclusions and xenoliths of the shale near the same contact.

The adjacent upper Valanginian Buchia crassicollis greywacke does not exhibit any thermal effects of this intrusive body and is not in any way disturbed in its proximity. Therefore, the greywacke is believed to be younger than the intrusive, even though both units were not seen in contact. Dawson (1887, p. 83B) observed the unconformable overlap of this intrusive body by the Buchia crassicollis greywacke but referred it to the Vancouver Group (see p. 123).

5. An irregularly shaped intrusive body, at least 1,000 feet long and 150 to 200 feet wide, occupies the northern side of a pronounced rocky point opposite the mouth of Kwatleo Creek and about 2/5 of a mile east of it, closing the lagoon of Browning Inlet from the southeast. This intrusive body consists of finely porphyritic,

massive, fresh ?dioritic rock which is dull grey to greenish grey near the western limit of its outcrop and light grey to whitish grey and essentially similar to that of intrusive body (3) farther east along the shore. The eastern margin of this body was not reached.

6. An intrusive body, about 250 to 300 feet wide, occupies the tidal platform on the eastern shore of Forward Inlet at the southern base of Hazard Point. This body consists of light grey, more or less porphyritic, probably dacitic hypabyssal rock similar to that of most other adjacent intrusions. This relatively small intrusive body appears to widen rapidly inland and could well be only the tip of a major intrusive body concealed in the forest above high tide boundary.

7. A dioritic to ?gabbroic intrusive body, as much as 800 feet wide, occupies the southern shore of Quatsino Sound at a point about 3/5 of a mile east of Salmon Island (see Unit 12 of Sec. 16 for details).

8. An apparently intrusive body, possibly up to 700 feet wide, is poorly and locally exposed in the bed of Monkey Creek in the interval 450 to ?700 yards above its mouth. The light to bluish grey, massive-looking, felsitic to feebly porphyritic rock of this body is probably a dacite invading the Latest Sinemurian and/or earlier Sinemurian argillites. However, its apparently intrusive contacts with the latter rocks are very poorly exposed, which makes the true nature of this ? dacitic body uncertain.

9. A number of intrusive, dyke-like, irregularly shaped bodies, up to 350 feet thick, invade and distort the rocks of the Sutton Formation and those of the Hecate Cove Formation on the southern shore of Quatsino Sound inside Julian Cove and between Julian and Smith Coves (see Fig. 17). The largest intrusive bodies of this swarm are dark grey, dark green, greenish grey or whitish grey coloured, medium to coarsely porphyritic (with white to light green feldspar phenocrysts), and apparently are dioritic to ?gabbroic in composition.

The medium to small intrusive bodies of this swarm may exhibit the same colour phases as the largest intrusives or be black, maroon, or rose-grey. Their texture varies from felsitic to fine or coarsely amygdaloidal or fine to coarsely porphyritic. All three types of texture may commonly occur in one and the same intrusive body, the felsitic and amygdaloidal textures being usually restricted to its marginal parts and the porphyritic texture being almost invariably restricted to its central parts. Judging by the hand specimens, the composition of the small to intermediate intrusive bodies of the swarm varies from dacitic to basaltic (diabase). Quartz was not observed in any of them.

The intermediate to basic composition and the predominantly felsitic, amygdaloidal, or finely to coarsely porphyritic texture of the Coast Intrusives of the western and northwestern parts of Quatsino Sound suggests their being largely or even exclusively shallow-seated to hypabyssal apophyses and cupolas of the larger, possibly batholitic Coast Intrusions which are still concealed at depth in this part of Vancouver Island. This suggests a close parallelism between the regional changes in the relief and the geomorphology of different parts of Vancouver Island, which was noted by Haycock (1906, p. 78A), and the amount of their structural uplift during the late Mesozoic (i.e. post Middle Jurassic) and Cenozoic times. It would seem that the marked but gradual decrease in height of the mountains in Quatsino Sound as compared with the more southerly parts of Vancouver Island reflects the considerably lesser uplift of the axes of major tectonic structures of the former area as compared with the more southerly areas.

There was no opportunity to study the large intrusive body occurring at the head of Rupert Inlet. The outlines and lithology of this body shown on the attached Figure 17 were taken from the geological maps of Gunning (1930) and Northcote (1969).

Gunning (1930, p. 106A) states that this intrusive body is: "a true granite, pinkish brown to grey in colour, and consists almost entirely of quartz, orthoclase, and a small amount of albite oligoclase. The rock is extensively carbonated and slightly chloritized". The writer also was unable to study other bodies of Coast Intrusions mapped by Dolmage (1919, p. 37B) and Gunning (1930, pp. 106A-107A) occurring east of Holberg Inlet, and inside of Neroutsos Inlet. According to Gunning's (1930, pp. 106A-107A) descriptions, all these Coast Intrusions have a true granitic, granodioritic or quartz dioritic composition. This is in contrast with the quartz dioritic, dioritic, or gabbroic composition of the intrusive bodies discovered in the more westerly and northwesterly parts of Quatsino Sound. This consistent petrographic distinction of the Coast Intrusions within the report-area could be due to the fact that the intrusive bodies mapped by the writer represent extremely shallow to hypabyssal phases of Coast Intrusions which are still preserved in the relatively depressed, western and northwestern parts of Quatsino Sound but which have been completely eroded in its more strongly uplifted eastern and southeastern parts. However, it is possible also that the more acidic plutons of the eastern part of Quatsino Sound belong not to the Coast Intrusions but to the ?Sooke Intrusions to which they seem to be lithologically similar.

Age and correlation. In the past, the Coast Intrusions of Vancouver Island have been variously assigned a general Jurassic age (Dolmage, 1919, p. 32B), a questionable Late Jurassic age (Gunning, 1930, pp. 99A, 106A; Bancroft, 1937, pp. 4, 8); a Late Jurassic or Early Cretaceous age (Gunning, 1932, p. 23A); a Late Jurassic or Cretaceous age (Jeletzky, 1950, pp. 36-38); a Late Jurassic and/or Early Cretaceous age (Hoadley, 1953, pp. 9, 37); a Middle Jurassic age (Jeletzky, 1954a, p. 66; 1954b, p. 14);

an Early Cretaceous age (Beveridge and Folinsbee, 1956); a Bajocian or Middle Jurassic to general pre-Nanaimo (Late Cretaceous) age (Sutherland-Brown, 1966, p. 85); and a Jurassic-Cretaceous age (Surdam, 1968, p. 21).

The biochronological evidence favouring the Late Jurassic to Early Cretaceous (or later) age of the Vancouver Island Coast Intrusions is unreliable because it is indirect and inferential. One of the principal arguments appears to be the old observation of Mackenzie (1916, pp. 53-54) that on Graham Island, Queen Charlotte Islands, the granitic intrusions invade the fossiliferous, reliably dated latest Middle Jurassic (Callovian) sediments of the Upper Yakoun Formation and are unconformably overlapped by the fossiliferous, equally reliably dated late Early Cretaceous (Albian) sediments of the Haida Formation.

The occurrence of granodioritic pebbles of the Coast Intrusions in the Lower Cretaceous conglomerates of Quatsino Sound noted by Dolmage (1919, p. 33B) and Gunning (1930, p. 108A) did not contradict Mackenzie's (1916) data, as these conglomerates were not more precisely dated at that time. In itself this observation is still roughly compatible with Mackenzie's (1916) data, since the conglomerates concerned were recently found to overlie the mid-Neocomian (Barremian) fossiliferous rocks and to contain late Early Cretaceous (Albian) pollen and spores (Jeletzky, 1954a, p. 1269 and in this report). However, the writer has found granitic, dioritic and gabbroic pebbles of the Coast Intrusions type in basal beds of the Lower Cretaceous sequence in several parts of Quatsino Sound. He has, furthermore, observed these early Lower Cretaceous rocks (upper Valanginian; Buchia crassicollis zone) to overlap unconformably at least one gabbroic body of Coast Intrusions on the east side of Winter Harbour opposite the mouth of Galato Creek (see units 8, 9 of Sec. 21 in the Appendix) and one ?dacitic

body at the head of Browning Inlet (see p. 123). This leaves very little room for the Coast Intrusions in the Early Cretaceous since they could be only of a basal Early Cretaceous (Berriasian to mid-Valanginian) age. Even this dating is next to impossible, considering the great length of biochronologically measurable time necessary to unroof the Coast Intrusions after their injection and uplift above sea level.

The Coast Intrusions of Quatsino Sound are, thus, definitely pre-upper Valanginian and almost certainly pre-Early Cretaceous in age. The Coast Intrusions are definitely post-Sinemurian in age, as they invade the reliably dated Matthews Island Formation and the Uppermost Sinemurian argillite unit.

It is impossible to date the Coast Intrusions of Quatsino Sound any closer since Upper Jurassic and basal Cretaceous rocks are unknown there. However, it is possible to date them much closer using the biochronological evidence available on the northwestern part of the west coast of Vancouver Island.

In the Esperanza-Kyuquot area on the west coast of Vancouver Island, the writer (Jeletzky, unpublished) has found rare dioritic to granodioritic pebbles of the Coast Intrusion type in the reliably dated, fossiliferous, basal Cretaceous (Berriasian to mid-Valanginian) conglomerates of One Tree Formation on Grassy Island. This evidence alone narrows the room left for the Coast Intrusions in the basal Lower Cretaceous time to practically nothing. Considering the duration of biochronologically measurable geological time needed for the uplift of the Coast Intrusions and their subsequent unroofing, this evidence is considered to be sufficient to rule out their Cretaceous age in this area and, by inference, in the Quatsino Sound area.

Jeletzky (1954b, pp. 13-14) has found, furthermore, that in the Kyuquot-Esperanza area, Coast Intrusions of the same type as those of Quatsino Sound invade the reliably dated, fossiliferous Pliensbachian-Toarcian greywacke unit (Jeletzky, 1970b, p. 15) but were nowhere observed to invade the widespread, fossiliferous, latest Middle Jurassic (Callovian) strata. In the same area, pebbles of acidic intrusive rocks closely resembling those of the Coast Intrusions have been found in the conglomerate beds of the Callovian rocks at Tatchu Point and in McLean Cove. A Middle Jurassic age is, therefore, indicated for the Coast Intrusions of the Kyuquot-Esperanza area, and the same age can be accepted as most probable for the Coast Intrusions of Quatsino Sound.

Another reason for the Cretaceous dating of Coast Intrusions of Vancouver Island appears to be the recent energetic advocation of this point of view by Beveridge and Folinsbee (1956, p. 20). These workers have emphatically rejected the Middle Jurassic age of the Vancouver Island Coast Intrusions proposed by Jeletzky (1954a, p. 1269) as being inconsistent with the radioactive ages obtained for the allegedly contemporary granitic intrusions in some other areas of British Columbia. The biochronological data presented above are, however, quite sufficient to invalidate Beverdige and Follinsbee's (1956, p. 20) conclusions. They are, furthermore, contradicted by the early Middle Jurassic (Bajocian) radioactive ages of about 167 m.y. obtained more recently on a body of Coast Intrusions situated on the west coast of Vancouver Island in the proximity of Kennedy Lake (Sutherland-Brown, 1966, pp. 85, 97, Figs. 6-10).

Like Carson (1968, p. 19), the writer was unable to obtain any evidence favouring the occurrence of more than one, geologically brief, major epoch of Mesozoic Coast Intrusions within the investigated part of Quatsino Sound. All conglomeratic beds of the Bonanza Subgroup observed in the area appear to be completely devoid of any coarse-grained, equigranular intrusive pebbles. This suggests that only extrusive igneous activity occurred within the area prior to the end of deposition of the Vancouver Group. Nor are there any definite indications of the post-Middle Jurassic Mesozoic intrusions within the investigated part of Quatsino Sound, as it will be pointed out in the section devoted to the ?Sooke Intrusions. The above conclusion appears to be valid for all other areas of Vancouver Island studied by the writer (Jeletzky, unpublished), and agrees well with the results of earlier workers such as Dawson (1887), Clapp (1912), Dolmage (1919, 1921), Gunning (1930, 1931, 1932, 1933), Bancroft (1937) and Hoadley (1953). Thus, the Mesozoic intrusive history of Vancouver Island obviously does not conform to the generalized scheme recently promulgated by Sutherland-Brown (1966, p. 83) for the whole of the Insular Tectonic Belt of western British Columbia. Nor does it give any support to the hypothesis of more or less continuous intrusive activity favoured by many recent workers (e.g. Sutherland-Brown, 1966, p. 83; Roddick, 1965).

RESULTS OF MIDDLE JURASSIC OROGENY

In Queen Charlotte Islands, the Pliensbachian-Toarcian argillites and limestones of the Maude Formation are overlain by the Bajocian pyroclastics and, to a lesser extent, by arenaceous to psammitic clastics of the lower Yakoun Formation (Sutherland-Brown, 1968, pp. 61, 68; Jeletzky, 1970b, Fig. 2). Although apparently conformable locally, the contact between the Maude and Yakoun Formations is regionally unconformable in the writer's opinion because the latter laps onto the older formations (Sutherland-Brown, 1968, p. 68).

In the Buttle Lake map-area, the Lower Jurassic tuffaceous argillites, which on lithologic and stratigraphic grounds are assumed to include beds equivalent to the Maude Formation, are overlain by at least 2,000 feet of andesitic lava flows and pyroclastics (Surdam, 1968, p. 20, Fig. 6; Jeletzky, 1970b, Fig. 2). This volcanic unit was correlated with the Volcanic division of the Bonanza Subgroup by Surdam (1968, p. 20). In the writer's opinion, however, the lithology and stratigraphic relationships of this unit suggest its equivalence with the Yakoun Formation of Queen Charlotte Islands.

In the Alberni map-area, about 1,000 feet of light coloured lava, tuff, and breccia of intermediate (latitic to andesitic) composition was recently discovered by J.E. Muller (Muller and Carson, 1969, p. 17). This unit also is believed to be correlative with the Yakoun Formation of Queen Charlotte Islands rather than with any part of the Volcanic division because it overlies sedimentary rocks apparently equivalent to the Pliensbachian-Toarcian greywacke unit of Kyuquot-Esperanza area. Muller and Carson (1969, p. 16) have tentatively referred this unit to the Volcanic division of the Bonanza Subgroup but have suggested that: "the volcanic rocks of Sproat Lake are younger than those occurring on the west coast".

Middle Jurassic volcanic and sedimentary rocks are unknown in the northwestern part of Vancouver Island (Jeletzky, 1954a, p. 1269) where nearly all known outcrop-areas of the Volcanic division are concentrated. The only known outcrop-area of Yakoun volcanics within the Lower Jurassic tectonically and volcanically active zone of the Insular Tectonic Belt is that of the Alberni map-area, well outside this part of Vancouver Island.

In the best known parts of the Early Jurassic quiescent zone, namely the Buttle Lake area and the Queen Charlotte Islands, deposition of the presumably offshore (see pp. 95-96) predominantly argillaceous clastics and limy oozes of the Harbledown and Maude Formations was abruptly terminated in or shortly after the Toarcian. This regime was replaced abruptly by one of volcanism, as testified by the appearance of the Yakoun Formation.

Most of the Middle Jurassic Yakoun volcanics and subordinate volcanic clastics within the Insular Tectonic Belt appear to be nonmarine deposits. Even in the Queen Charlotte Islands where the volcanics of the Yakoun Formation are largely marine and contain Bajocian and Callovian ammonite faunas, the rocks commonly include coal beds and fossil wood (Sutherland-Brown, 1968, pp. 68, 69). This suggests that the Insular Tectonic Belt was largely transformed into a tectonic land by the Middle Jurassic orogeny. Judging by the apparently complete absence of Middle Jurassic rocks in the northwestern part of Vancouver Island (Jeletzky, 1954a, p. 1269; 1970b, pp. 23-25), this part of the belt underwent the greatest uplift and was a source area throughout Bajocian and Bathonian time. It would appear that volcanic activity either became greatly weakened or ceased in the Early Jurassic active zone at essentially the same time as it was initiated in the zone that was quiescent in the Early Jurassic. The volcanism, therefore, migrated east and northwest at the onset of Middle Jurassic orogeny.

It seems likely that most or all of the Lower Jurassic quiescent zone of the Insular Tectonic Belt was tectonically and volcanically activated by the Middle Jurassic orogeny which began early in Bajocian time, judging by the Middle Bajocian fossils collected low in the Yakoun Formation of Queen Charlotte Islands (McLearn, 1949; Sutherland-Brown, 1968, p. 76).

The tectonic land formed by the Middle Jurassic orogeny within the Insular Tectonic Belt apparently occupied the place of the present Georgia and Queen Charlotte Straits and extended northwestward at least as far as Queen Charlotte Islands where the Yakoun Formation is composed largely of marine waterlain pyroclastics and tuffaceous clastics. Southward, this tectonic land extended at least into the Sproat Lake area and eastward almost to the Tatlayoko Lake and Harrison Lake areas (Jeletzky, 1965b, p. 72; Tipper, 1969, p. 85). It may have extended southwestward beyond the present day west coasts of Vancouver Island and Queen Charlotte Islands. So far as is known, only the early to mid-Callovian seas began to encroach upon the marginal parts of this tectonic land (Jeletzky, 1950, pp. 19-32; McLearn, 1949; Sutherland-Brown, 1968, p. 76; Tipper, 1969, p. 85). The Callovian and Late Jurassic marine troughs, however, had an entirely different configuration, surrounding rather than penetrating the Middle Jurassic tectonic land (Jeletzky and Tipper, 1968, pp. 74-77, Fig. 7). These residual Late Jurassic marine troughs formed part of the late Mesozoic phase of geological history of the Insular Belt which will be discussed in the following parts of this report.

The data now available about the Middle Jurassic history of the Insular Tectonic Belt suggests that the Middle Jurassic orogeny and the accompanying batholithic Coast Intrusions (Jeletzky, 1954a, p. 1269; 1970b, pp. 23-25 and above in the Coast Intrusions chapter of this report) have annihilated the previously described Lower Jurassic tectonic pattern produced there by the latest Triassic orogenic phase (Fig. 6). The Middle Jurassic orogeny represents, therefore, the veritable turning point in the geological history of the Insular Tectonic Belt in general and of the Quatsino Sound area in particular.

LATE JURASSIC AND BASAL CRETACEOUS TIME

No traces of the Upper Jurassic and basal Cretaceous (Berriasian to mid-Valanginian) sedimentary or volcanic rocks, such as occur in the Kyuquot-Esperanza area on the west coast of Vancouver Island (Jeletzky, 1950; 1954a, p. 1269) and in Queen Charlotte Islands (Mackenzie, 1916; McLearn, 1949; Sutherland-Brown, 1966, 1968), have been observed either within the investigated part of Quatsino Sound or anywhere else on northwestern part of Vancouver Island north of Brooks Peninsula. Therefore, it is concluded tentatively that this part of Vancouver Island remained well above sea level throughout the late Jurassic and earliest Cretaceous following strong regional uplift of the Insular Tectonic Belt caused by the Middle Jurassic orogeny and the penecontemporaneous invasion of the Coast Intrusions (Jeletzky, 1970b, pp. 23-25 and in the previous sections of this report). This tectonic highland apparently remained high and was undergoing intensive erosion until the early Early Cretaceous (late Valanginian) time and provided fine- and coarse-grained clastic debris to the late Jurassic and earliest Cretaceous marine depositional troughs situated just to the west and northwest of it (Jeletzky, 1965b, p. 72; 1970b, pp. 23-25; Sutherland-Brown, 1966, 1968; Jeletzky and Tipper, 1968).

LOWER CRETACEOUS STRATA

The rocks of the Vancouver Group and those of the Coast Intrusions locally are overlapped unconformably by a thick succession of Lower Cretaceous strata. These exclusively sedimentary, partly marine rocks are thought to have covered originally most or all of the investigated part of Quatsino Sound. However, this Lower Cretaceous cover was largely destroyed by subsequent erosion and only several outliers were preserved within the post-Lower Cretaceous downfaulted blocks (grabens) or synclinal structures.

The Lower Cretaceous rocks of Quatsino Sound were investigated in some detail by Dawson (1887, pp. 83B-99B) because of the reported occurrence of coal measures in some of their outliers. The results of this pioneer work were of a great value to the writer because Dawson located all of the Lower Cretaceous outliers now known to occur within the investigated part of Quatsino Sound and accurately mapped most of them. The generalized description of the stratigraphical succession and lithology of these rocks provided by Dawson (1887) is, for the most part, remarkably accurate.

The westernmost of the Lower Cretaceous outliers occurs at the head of Browning Inlet. This small outlier occupies the middle part of the western shore of the inlet around the mouth of Kwatleo Creek and extends up this stream for about 600 feet (see Fig. 18).

The second, much larger Lower Cretaceous outlier occupies both shores of the northern part of Winter Harbour between the mouth of Galato Creek and the northwestern end of Ahwhichaolto Inlet, and extends for an unknown distance inland. The existence of a strip of Lower Cretaceous rocks connecting the Forward Inlet and Koprino Harbour outliers on the northeastern side of Ahwhichaolto Inlet postulated by Dawson (1887, p. 85B and geological map) appears to be improbable on structural grounds and, therefore, is not shown on the attached geological map until such time as the area concerned is studied.

The third, small outlier of Lower Cretaceous rocks occupies the tidal flat at the southwestern end of Ahwhichaolto Inlet, most or all of the broad flat-bottomed valley connecting the latter with the head of Spencer Cove, and the eastern shore of the latter. It appears to be only a series of intensely distorted to mylonitized

tectonic slices between the individual splays of a major strike slip fault (the Mahatta Fault zone).

The fourth, very large Lower Cretaceous outlier occurs on the shores of Koprino Harbour between the eastern side of Robson Cove and Prideaux Point and the northern shore of Quatsino Sound between Prideaux Point and the point about 1,300 feet northeast of the mouth of Aweisha Creek near the western end of Quatsino village. The Koprino Harbour outlier apparently underlies most or all of the bottom of Quatsino Sound in this interval as the Lower Cretaceous outcrops on Salmon Island just north of the mouth of Monkey Creek almost certainly are part of its southern margin. Furthermore, the same appears to be true of the large outlier occupying the southern shore of Quatsino Sound between the point about one mile west of the mouth of Klotchlimmis Creek and that about 1/2 mile east of the mouth of Cleagh Creek and extending inland for an unknown but probably considerable distance.

The fifth, and the last investigated Lower Cretaceous outlier occupies the northern shore of Rupert Inlet for about 2 1/4 miles north of a nameless, deeply incised cove behind Narrow Island. Thence, it continues north behind Hankin Point to the southern base of Stewart Point and across Coal Harbour to the western side of Apple Bay. Its southern boundary throughout this interval is a major strike slip fault - the Holberg Fault. Northward the rocks of the Coal Harbour outlier wedge out within 2 miles northward of the fault forming its western boundary (Dawson, 1887, p. 91B, Fig. 2) or are limited by other major faults (as for example in Rupert Inlet; see Fig. 17 and profile).

Longarm Formation Equivalents

The late Valanginian to late Barremian sedimentary rocks discussed below are equivalent to the Lower Cretaceous part of the Relay Mountain Group of the Tyaughton Trough (Jeletzky and Tipper, 1968, p. 81, Fig. 8) and the Longarm Formation recently discovered by Sutherland-Brown on Queen Charlotte Islands (see Jeletzky and Tipper, 1968, p. 83, Fig. 8; Sutherland-Brown, 1968, pp. 76-81). The Longarm Formation was deposited in the same structural trough as the upper Valanginian to upper Barremian sedimentary rocks of Quatsino Sound and the two units were probably contiguous. The name Longarm Formation cannot, however, be applied to the contemporary rocks of the Quatsino Sound because of their rather different lithology. The upper Valanginian to upper Barremian rocks of Quatsino Sound are, furthermore, subdivisible into several mappable units of formational rank. They should accordingly have group status. The formal naming of the Longarm equivalents as a whole and that of their component mappable units was postponed in the hope of finding better sections of the units concerned which would be more suitable as their type sections. Therefore, all mappable component units of Longarm Formation equivalents have been named informally in this report. The descriptive informal names applied to them are of the same type as those used by Jeletzky and Tipper (1968, p. 12) for the component units of the Relay Mountain Group in the Taseko Lakes map-area.

Buchia crassicollis greywacke

Distribution and stratigraphy. In Forward and Browning Inlets, the basal beds of the Lower Cretaceous sequence are considered to be represented by the 500-foot-thick unit of green-grey to dark grey, somewhat calcareous, fine- to medium-grained

greywacke with minor intercalated beds, lenses and rows of concretions of similarly coloured, exceedingly calcareous greywacke or arenaceous (bioclastic) limestone. A bed of coarse-grained, pebbly grit, locally grading into fine to very fine, well-rounded pebble conglomerate, only a few feet thick, forms the base of this greywacke unit. This basal bed unconformably overlaps both the Vancouver Group and the Coast Intrusions (see above: p. 108).

Upward this Buchia crassicollis greywacke grades into unfossiliferous, dark grey arenaceous siltstones and similarly coloured fine to very fine, clayey greywacke which form the base of the Hauterivian siltstone unit. Section 20 is representative of the upper part of the unit while its lower part is well exposed in section 21 (see Appendix).

It is reasonable to conclude that the basal 50 feet of unit 8 of section 20 correspond to some (?upper) part of unit 2 of section 21. This lithological correlation suggests that the complete thickness of the Buchia crassicollis greywacke is in the order of 500 feet.

The sections, at least 80 feet thick, of Buchia crassicollis greywacke occurring immediately north of the mouth of Kwatleo Creek near the head of Browning Inlet are lithologically identical with the rocks of units 4 to 8 inclusive of section 21. The equivalence of the beds concerned is proven by their stratigraphic position in the basal part of the Buchia crassicollis greywacke. This was established by Dawson (1887, p. 83B) who observed the Browning Inlet section to: "rest on reddish-weathering hard felspathic rocks of the Vancouver series, of which they include rounded pebbles". The writer was unable to confirm this observation as the base of the Buchia crassicollis

greywacke unit concerned was covered everywhere by beach deposits during his visit. However, the interval between its base and the visible stratigraphic base of adjacent ? uppermost Sinemurian argillites locally does not exceed 20 feet. Only pebbly grit and conglomerate of the basal units 6 to 8 of the Forward Inlet section could, therefore, be concealed within this covered interval.

So far as known, the Buchia crassicollis greywacke outcrops encountered in the bed of Kwatleo Creek represent the same basal part of the unit as its exposures north of Kwatleo Creek. The top and base of these exposures are covered and almost certainly faulted.

Aucella piochii, recorded by Dawson (1887, p. 83B) from the Browning Inlet section of Buchia crassicollis greywacke, belongs actually to Buchia crassicollis (Keyserling, 1846) s. str. and its variants. This was confirmed by additional collections made by the writer (GSC loc. 24345) and by the re-examination of the original specimens collected by Dawson (1887, p. 83B) at this locality.

The only other known exposure of Buchia crassicollis greywacke occurs on the northeastern shore of the narrows connecting Winter Harbour with Ahwhichaolto Inlet near the entrance to the latter. A succession, about 150 feet thick, of strongly sheared, hardened, and rose-orange-coloured (metasomatically altered?) Buchia crassicollis greywackes striking north to N10° E and dipping at 30° to 35° west is exposed there. Both contacts of these rocks are covered and almost certainly faulted. The beds locally contain abundant Buchia crassicollis and its variants (GSC loc. 24277) and presumably comprise the middle or upper calcareous part of the unit.

Age and correlation. The Buchia crassicollis greywacke is more or less fossiliferous throughout (including its basal gritty to conglomeratic bed). This marine, neritic to littoral fauna is dominated by Buchia crassicollis (Keyserling, 1846) and its variants described and figured by Jeletzky (1965a, pp. 49-55, Pl. XX, Figs. 1, 9, 11, 12). In the middle part of the unit, B. crassicollis commonly occurs in great numbers and, locally, beds and lenses, from 1 to 5 feet thick, may be composed almost entirely of this fossil. Other rare to very rare fossils present include the following: Homolsomites quatsinoensis (Whiteaves) and closely allied Homolsomites forms described and figured by Jeletzky (1965a, pp. 38-39, 52-54; Pl. XX, Figs. 3-4, 14), indeterminate lytoceratid ammonites, Acroteuthis (Acroteuthis) sp. indet., Inoceramus sp. indet. and various other pelecypods. Homolsomites quatsinoensis and allies have been found only in the middle part of the unit. However, Buchia crassicollis and its variants range throughout all strata and permit an easy recognition. The unit is, therefore, named Buchia crassicollis greywacke.

As already pointed out (Jeletzky, 1965a, pp. 64-65, Fig. 4), all the Buchia crassicollis greywacke of Quatsino Sound is of late Valanginian age. The apparently complete absence of older Cretaceous rocks, which are so well developed on the west coast of Vancouver Island in the Kyuquot-Esperanza area (Jeletzky, 1950, pp. 38-44, geol. map; 1965a, pp. 64-65, Fig. 4), is probably due to their non-deposition in the investigated parts of Quatsino Sound. This reflects the extreme marginal position of the area concerned on the eastern flank of the Insular (= Vancouver Island-Queen Charlotte Islands) Lower Cretaceous Trough (Jeletzky, 1965a; Sutherland-Brown, 1966, p. 84, Fig. 6-6; Jeletzky and Tipper, 1968, p. 81, Fig. 8).

Facies and Paleogeography. The localities where Buchia crassicollis was found by Dawson (1887, p. 111B; under the name of Aucella piochii Gabb) and J.E. Muller (unpublished fossil identifications of the writer; GSC locs. 82857, 82861, 82869, 82884) suggest that the late Valanginian rocks are restricted to the west coast of Vancouver Island between Cape Scott and Lawn Point. No outcrops of Buchia crassicollis greywacke were observed east of Forward Inlet and the southwestern entrance to Ahwhichaolto Inlet and no Valanginian or Hauterivian rocks were found in the Cretaceous sections studied by the writer (Jeletzky, 1969, pp. 129-130) in the vicinity of Christensen Point on the northern side of Vancouver Island where the Barremian rocks overlap the eroded surface of the Thinly Bedded member of the Sedimentary division. Finally, Buchia crassicollis greywacke appears to pass laterally into the lower part of the apparently largely nonmarine upper Valanginian and ?Hauterivian greywacke-conglomerate unit somewhere between Forward Inlet and Salmon Island (see below and Fig. 7). It is concluded, accordingly, that the late Valanginian transgression did not penetrate eastwards beyond the line defined approximately by Fisherman Bay-headwaters of Macjack River-Ahwhichaolto Inlet-Salmon Island.

Buchia crassicollis greywacke, and for that matter any Cretaceous rocks, appear to be completely absent and probably were not deposited anywhere between Kwakiutl Point and Esperanza-Kyuquot area. This circumstance and the apparently complete absence of late Valanginian rocks in the Esperanza-Kyuquot area (Jeletzky, 1965a, pp. 64-66, Fig. 4) suggests that the late Valanginian embayment of Cape Scott-Quatsino Sound area resulted from an eastward and/or southeastward onlap of the late Valanginian sea onto a worn down Middle Jurassic tectonic land (Jeletzky,

1970b, pp. 23-25) and was situated updip of its Callovian to mid-Valanginian deposition-area. The alternative hypothesis of a total subsequent (i.e. prior to the late Valanginian transgression) destruction of the Callovian to mid-Valanginian marine rocks within the western part of Quatsino Sound is discounted as improbable. This late Valanginian sea probably did not penetrate southeastward much beyond Keith River in Brooks Bay (Fig. 7). As far as it is possible to judge, the area of Brooks Peninsula remained well above sea level in the late Valanginian time and limited the Cape Scott-Quatsino Sound embayment from the southeast. If the mid-Callovian to mid-Valanginian Esperanza-Kyuquot embayment continued to exist in the late Valanginian (i.e. Buchia crassicollis) time, it would have been separated from the contemporary Cape Scott-Quatsino Sound embayment by an extensive landmass centered in the positive fault block of Brooks Peninsula. The recent suggestion of a northeastern onlap of the early Cretaceous sea of Quatsino Sound (Muller, 1970b, p. 47) is therefore unacceptable to the writer.

Hauterivian siltstone unit

Distribution and stratigraphy. The Buchia crassicollis greywacke in the northeastern part of Winter Harbour is overlain conformably by at least 1,260 feet of bluish grey to dark grey, brownish to blackish grey weathering, massive-looking siltstone containing varying amounts of sand and locally (especially in basal 100 feet) grading into similarly coloured, fine- to very fine-grained, very clayey greywacke. This unit, named herewith the Hauterivian siltstone unit, contains numerous concretions 6 inches to 4 feet long and as much as 3 feet thick. The concretions are loaf-like to rounded, locally fossiliferous, and consist of bluish grey to dark grey,

dirty yellow to light brown weathering, slightly calcareous siltstone; fine-grained, very calcareous greywacke; or impure limestone. They are common throughout the thickness of the unit and are normally arranged in rows. A few, 1- to 4-foot-thick, persistent beds of similarly coloured impure limestone occur in the middle part of the unit.

The upper contact of the Hauterivian siltstone unit was not observed and apparently is a fault in all sections studied. The minimum value of the unit's thickness, given above, was obtained by a somewhat arbitrary combination of several intensely faulted and locally contorted partial sections. It must, therefore, be considered a rough estimate only.

Except for the basal 100 feet, the siltstones of the Hauterivian siltstone unit are fossiliferous at a number of levels. The exclusively marine fauna consists predominantly of ammonites. The relatively rare pelecypods and gastropods tend to be small and thin shelled indicating that the siltstones of the unit were deposited in relatively deep water, well offshore and beyond the reach of most winnowing agents.

The only known section of the basal part of the Hauterivian siltstone unit and its contact with the underlying Buchia crassicollis greywacke adjoins the upper part of Buchia crassicollis greywacke in section 20 (see Appendix).

Section 22 is the only known representative section of the unit. It is nearly complete (lacks the basal beds) but is structurally complex.

Poor, isolated exposures of totally sheared and badly contorted dark grey, fine-grained greywacke and similarly coloured arenaceous siltstone, lithologically identical with the basal beds of the Hauterivian siltstone unit, occur around the top of a nameless point situated immediately southeast of the mouth of Galato Creek. These unfossiliferous rocks are thought to be tectonic slices of basal beds of the unit within a major northeast-trending fault zone.

The only other known section of the Hauterivian siltstone unit occurs on the northeastern shore of the narrows connecting Winter Harbour with Ahwhichaolto Inlet near the entrance to the latter (see Fig. 18). This section exposes some 400 feet of sheared and locally contorted, almost certainly overturned, dark grey, notably rusty-weathering, arenaceous siltstones with some loaf-like concretions of similarly coloured, yellow-weathering impure limestone. These unfossiliferous siltstones apparently correspond to some part of unit 5 of section 22 of the Hauterivian siltstone unit. On the northeast side, this slice of the Hauterivian siltstone unit is faulted against the volcanic rocks of the Grey volcanic unit of the Volcanic division of Bonanza Subgroup, whereas on the southeastern side it is faulted against the metasomatically altered Buchia crassicollis greywacke.

Age and correlation. The lighter coloured and coarser greywackes of Buchia crassicollis greywacke unit grade imperceptibly into the dark to blackish grey, arenaceous siltstone of the Hauterivian siltstone unit in the only section where their contact is exposed (see Units 1, 2 of Sec. 20). Therefore, the lower boundary of the Hauterivian siltstone unit is drawn at the top of Buchia crassicollis zone i.e. at the level of a sudden disappearance of Buchia crassicollis (Keyserling) and other representatives of the genus Buchia (= Aucella). However, this regional zonal boundary may be situated somewhat beneath the Valanginian-Hauterivian boundary as defined by interregional ammonite zones. This was originally suggested by Jeletzky (1965a, p. 55, Fig. 4) and his suggestion is supported by the more recent discovery of Valanginites n. sp. ex aff. V. nucleus (Roemer) in the Taseko Lakes map area (Jeletzky and Tipper, 1968, p. 203, Addendum) in beds apparently equivalent to the basal 100 feet of the Hauterivian siltstone unit. In Western and Arctic North America the biochronological boundary between the Valanginian and Hauterivian stages of the international standard probably coincides with the first appearance of Homolsomites oregonensis (Anderson) rather than with the disappearance of Buchia crassicollis (Keyserling) and other representatives of the genus Buchia.

Lower Hauterivian index fossils, Homolsomites oregonensis (Anderson) and H. aff. oregonensis (Anderson) range through an approximately 590-foot thick succession of beds which are believed to overlie immediately (or almost immediately?) the

nonfossiliferous basal 100 feet of the Hauterivian siltstone unit. This part of the unit represents the Homolsomites oregonensis zone of Taseko Lakes and Mount Waddington map-areas (Jeletzky, 1967, p. 65; 1968, p. 105; Jeletzky and Tipper, 1968). The immediately following unfossiliferous interval of the unit, about 310 feet thick,could correspond to part or all of the following Hauterivian zones: 1. Homolsomites oregonensis zone; 2. Homolsomites packardi zone, the validity of which for the western part of the Canadian Cordillera was confirmed by the still unpublished results of the recent field work of the writer in Taseko Lakes and Mount Waddington map-areas; and 3. Speetoniceras-Simbirskites (Hollisites) zone.

The late Hauterivian Simbirskites (Simbirskites) broadi Anderson occurs first about 21 feet above the visible base of the 260-foot-thick upper part of the Hauterivian siltstone unit. This late Hauterivian fauna ranges up a further 220 feet and the uppermost 20 feet of this unit did not yield any diagnostic fossils but are assumed to form part of the zone.

A considerable thickness of beds appears to be missing due to faulting between the unfossiliferous interval, about 310 feet thick, of the Hauterivian siltstone unit and the Simbirskites (Simbirskites) broadi-bearing beds. This could explain the total absence of fossils attributable to the middle Hauterivian Speetoniceras-Simbirskites (Hollisites) zone which should normally occur between the Homolsomites packardi and Simbirskites (Simbirskites) broadi zones (e.g., in Taseko Lakes and Mount Waddington map-areas; Jeletzky, 1967, p. 65; 1968, p. 105; Jeletzky and Tipper, 1968).

The Simbirskites (Simbirskites) broadi- and S. (S.) lecontei-bearing beds of the Hauterivian siltstone unit are of a general late Hauterivian age. The possibly accidental absence of Craspedodiscus (= Hertleinites) in the writer's collections

precludes the more exact correlation of these beds. Judging by Imlay's (1960, pp. 178-180) comments, Simbirskites (Simbirskites) broadi is not restricted to the zone of Hertleinites aguila (≃ the uppermost Hauterivian Craspedodiscus cf. discofalcatus-Simbirskites (Simbirskites) cf. broadi zone of the Taseko Lakes map-area; Jeletzky and Tipper, 1968) but ranges into the next older, still late Hauterivian Hamlin-Broad zone of Anderson (1938, pp. 47, 48). In Taseko Lakes map-area, the beds immediately underlying the Craspedodiscus cf. discofalcatus-Simbirskites (Simbirskites) cf. broadi zone and presumably equivalent to the Hamlin-Broad zone are unfossiliferous. The Simbirskites (Simbirskites) broadi- and S. (S.) lecontei-bearing beds of the Hauterivian siltstone unit may, therefore, correspond either to this unfossiliferous interval and to the Hamlin-Broad zone of northern California or to the Craspedodiscus cf. discofalcatus-Simbirskites (Simbirskites) cf. broadi zone (= Hertleinites aguila zone).

The probable total absence of Inoceramus colonicus Anderson in the Hauterivian siltstone unit is a peculiar phenomenon (see below pp. 138-139) as this species abounds in all other known sections of the middle to late Hauterivian rocks of the Canadian western Cordillera regardless of their facies.

Facies and paleogeography. The offshore lithology and fauna of the Hauterivian siltstone unit reflects considerable deepening of the Lower Cretaceous sea that occupied Browning and Forward Inlets area at the end of Valanginian time. However, the deeper Hauterivian sea apparently did not extend any farther east than the much shallower late Valanginian sea (cf. Figs. 7 and 8). The absence of outcrops of the Hauterivian siltstone unit east of Browning and Forward Inlets and east of the southwestern entrance to Ahwhichaolto Inlet does not seem to be attributable to its subsequent erosion. For

reasons given below, it appears much more probable that the Hauterivian siltstones pass laterally into the upper part of the largely nonmarine upper Valanginian and? Hauterivian greywacke unit somewhere between the Forward Inlet and Salmon Islets. It is possible also, although admittedly less probable, that no Hauterivian rocks of any kind were deposited in the eastern part of Quatsino Sound area because of its strong uplift at the end of Valanginian time.

Hauterivian rocks are completely unknown either in that segment of the west coast situated between Quatsino Sound and Cape Scott or within the Christensen Point Cretaceous outlier (Jeletzky, 1969; 1970a) on the northern side of Vancouver Island. It is suggested tentatively that, in this part of the west coast, the Hauterivian sea did not penetrate any farther than did the late Valanginian sea (Fig. 8).

Hauterivian rocks are unknown south of Forward Inlet and Salmon Island. Therefore, there is no reason to assume that the Cape Scott-Quatsino Sound embayment entended any farther southeastward in Hauterivian time than it did in late Valanginian (cf. Figs. 7 and 8). The Hauterivian Brooks Peninsula landmass may have been more extensive than its late Valanginian predecessor if the probable absence of the Hauterivian rocks in the Esperenza-Kyuquot low Lower Cretaceous outcrop-area (Jeletzky, 1950; 1954a; 1965a) reflects their non-deposition rather than subsequent erosion there.

Upper Valangian and Hauterivian greywacke conglomerate unit

Distribution and stratigraphy. As discussed previously, the fossiliferous, entirely marine *Buchia crassicollis* greywacke and Hauterivian siltstone units were not observed east of Forward and Browning Inlets. In this part of the investigated area, the basal beds of the Lower Cretaceous sequence are represented by a relatively thin

unit of coarser clastic rocks. This lithologically variable unit, at least 330 feet thick, consists largely or entirely of unfossiliferous, mostly coarse- to medium-grained, gritty greywackes and poorly rounded pebble to boulder conglomerates. This unit appears to be a predominantly nonmarine facies of the Buchia crassicollis greywacke and Hauterivian siltstone units combined because of the similar stratigraphic position and the observed interfingering of the lower part of the unit with marine upper Valanginian rocks in its westernmost (i.e. Salmon Islets; see Secs. 25, 26) sections. It is named accordingly the Upper Valanginian and? Hauterivian greywacke-conglomerate unit.

In spite of the scarcity of well-exposed, representative sections, the Upper Valanginian and? Hauterivian greywacke-conglomerate unit seems to show rather regular and meaningful facies changes in the east-west direction.

The easternmost known sections of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit occur on the northern shore of Quatsino Sound east of the mouth of Aweisha Creek (see Unit 1 of Sec. 8) and on the southern shore of the Sound, 1 mile west of the mouth of Klotchlimmis Creek. The latter, more representative section is described in the Appendix (see Sec. 23).

The topmost bed of section 23 is separated from the visible base of the Barremian fine-grained greywacke unit only by a covered interval, about 200 yards wide, which is possibly underlain, in part at least, by the Inoceramus colonicus calcarenites. It is concluded accordingly that most of the thickness of the conglomeratic facies of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit is exposed in this section.

West of the Aweisha and Klotchlimmis Creek sections, the rocks of the Upper Valanginian and? Hauterivian unit are largely composed of coarse- to medium-grained, gritty and pebbly greywacke with only minor interbeds of grit and pebble conglomerate (see Sec. 24 in the Appendix). Furthermore, numerous interbeds of the presumably marine black to grey siltstone and shale appear in the basal parts of these sections.

Although thin, section 24 illustrates well the gradual replacement of pebble conglomerates and grits of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit by finer grained rocks away from its inferred easterr and? southeastern source area. This westward change of facies of the unit is even better illustrated by other much more extensive sections (see Secs. 25 and 26 of the Appendix) occurring about 3 miles farther west on Salmon Islets.

Section 25 (see Appendix) is important in being the only one containing well-preserved and diagnostic fossils of Buchia crassicollis zone. Another quite similar section of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit (see Units 12 to 17 of Sec. 26) was measured on the same islet at the point about 600 feet west of the base of section 25.

The basal part of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit is not exposed on Salmon Islets. It seems possible, however, that the black-grey siltstone forming the visible base of section 25 corresponds to the shale unit (1) of section 24 occurring about 3 miles farther east. This somewhat arbitrary combination of sections would suggest a total thickness of only 315 feet for the western facies of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit.

Age and correlation. As the name Upper Valanginian and? Hauterivian greywacke-conglomerate indicates, it is by no means certain that this unit includes any Hauterivian beds. So far only upper Valanginian fossils have been found in the unit and the contact of the unit with the overlying, presumably early Barremian *Inoceramus colonicus* calcarenites is erosionally disconformable, and possibly regionally unconformable, in the Salmon Islets sections. The known thickness of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit is small as compared with the combined minimum thickness of the *Buchia crassicollis* greywacke and Hauterivian siltstone units, in spite of the fact that one would expect a shoreward (i.e. eastward) thickening of the units concerned. These relationships could be interpreted as suggestive of an erosional removal of the time equivalents of the Hauterivian siltstone unit in the Salmon Islets sections prior to the deposition of the *I. colonicus* calcarenites. The probable restriction of the upper Valanginian marine interbeds to the lower part of the Salmon Islets' sections is, however, against this interpretation. The upper, unfossiliferous beds of the Upper Valanginian and? Hauterivian unit, which are about 120 feet thick in the Salmon Islets' sections, are therefore assumed tentatively to be of general Hauterivian age.

Finally, it is possible that the upper Valanginian and Hauterivian rocks pinch out completely just east of the longitude of Salmon Islets and that the conglomeratic facies of the Upper Valanginian and? Hauterivian unit outcropping between Cleagh Creek and the mouth of Neroutsos Inlet represents the basal conglomerates of the Barremian fine greywacke unit. However, this possibility is considered improbable

because of the lithological similarity of the shale member (bed 2) occurring in the Cleagh Creek section 24 to the Buchia crassicollis-bearing shales and siltstones of the Salmon Islets' sections.

Facies and paleogeography. The lithology of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit indicates that these beds were deposited mainly on the beaches fringing from the east and southeast the upper Valanginian and? Hauterivian seas of Quatsino Sound (see Figs. 7 and 8). However, they could have been partly (especially the eastern facies) deposited by fast moving streams draining the tectonic highland which is thought to have been situated to the east and southeast of the investigated part of Quatsino Sound (Jeletzky, 1965b, p. 72; Sutherland-Brown, 1966, p. 84, Fig. 6-6; Jeletzky and Tipper, 1968, p. 82, Fig. 8) and transported into the upper Valanginian and? Hauterivian seas.

This paleogeographical interpretation of the Aweisha and Klotchlimmis Creek sections (see Secs. 8 and 23) of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit agrees well with the apparent absence of equivalent rocks farther east.

The basal beds of Cretaceous outcrops of the Coal Harbour outlier were not studied but Dawson's work (1887, pp. 90B-99B) suggests that equivalents of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit were not deposited in this easternmost part of Quatsino Sound. Data supporting this are as follows: (1) no basal conglomeratic units lithologically similar to those of Aweisha Creek and Klotchlimmis Creek sections of this unit occur in any of the sections and borehole logs cited by Dawson (1887, pp. 90B-99B); (2) the presumably Barremian Quoiecchia aliciae fauna discussed later in in this report occurs closely above the base of the Lower Cretaceous sequence in the Nookneemish Creek section (see below) and elsewhere in the vicinity of Apple Bay

(Dawson, 1887, p. 94; J.E. Muller's unpublished collections; GSC locs. 24292, 24293); (3) the presumably Aptian coal-bearing beds and the immediately overlying Aptian to Albian conglomerate unit occur much closer to the base of the Lower Cretaceous sequence in the Coal Harbour outlier than in the more westerly areas of Quatsino Sound; (4) the Barremian Acroteuthis cf. pseudopanderi (Sintsov) has been found in the basal beds of the sections of Barremian variegated clastic unit measured at the headwaters of Lippy Creek east of Neroutsos Inlet (see Unit 2 of Sec. 29); and (5) the sections measured on the eastern side of Christensen Point Cretaceous outlier (Jeletzky, 1969, pp. 129, 130) appear to lack any pre-Barremian rocks.

Accordingly, it is suggested that the area of Rupert Inlet and that of the adjacent southern part of Holberg Inlet (at least as far north as Apple Bay) represented a tectonic highland throughout the late Valanginian and most or all of Hauterivian time. This inferred tectonic highland apparently was the source area for the rocks of the Aweisha and Klotchlimmis Creek sections of the predominantly conglomeratic eastern facies of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit. This highland likely became peneplaned only toward the end of the early Barremian. Soon thereafter it was flooded by the late Barremian transgression which apparently covered the whole northwestern end of Vancouver Island.

Inoceramus colonicus calcarenites

In Lower Cretaceous sections studied on Salmon Islets, the Upper Valanginian and? Hauterivian greywacke-conglomerate unit is overlain disconformably and possibly regionally unconformably by a unit, at least 208 feet thick, of bioclastic limestones with numerous interbeds of limy to very limy clastic rocks.

The fauna of the Inoceramus colonicus calcarenites consists almost solely of the name fossil which occurs throughout the thickness of the unit, commonly occurs in great numbers, and may be, locally, the dominant constituent of beds, lenses and pods, 1 foot to 5 feet thick, in any type of its rocks, not excluding the sedimentary breccia. Inoceramus colonicus is unknown in the underlying and overlying Lower Cretaceous rocks of Quatsino Sound. The calcarenitic unit discussed here was named, therefore, the Inoceramus colonicus calcarenites.

Distribution and stratigraphy. Inoceramus colonicus calcarenites are considerably more widespread than any of the previously described, older Lower Cretaceous marine units of Quatsino Sound. On the northern shore of Quatsino Sound, these beds extend eastward at least to Koprino Harbour where a small outcrop (fault slice) occurs on the eastern shore of Spencer Cove. On the southern shore of Quatsino Sound, I. colonicus calcarenites extend eastward at least to Salmon Islets and may extend still farther east to the eastern side of the Kewquodie Creek Cretaceous outlier.

Inoceramus colonicus calcarenites are fine to coarse grained, medium to dark grey, invariably arenaceous and argillaceous, and commonly more or less gritty and pebbly. These limestones in places grade laterally into and contain considerable pods, lenses and beds of Inoceramus coquina composed mainly of complete and well-preserved shells of I. colonicus Anderson. Numerous interbeds of dull grey, dark grey or almost black, limy to very limy shale and sandstone, as well as some intercalated beds of limy pebble conglomerate and sedimentary breccia are scattered throughout the succession of Inoceramus colonicus calcarenites.

The bulk of the information now available on the lithology, thickness and fauna of the Inoceramus colonicus calcarenites was obtained from their Salmon Islets sections. None of these sections exposes the complete succession of the unit but the combination of sections 25 and 26 (see Appendix) permits a reasonably close estimate of the total thickness and provides data regarding its lithology and contact relationships.

Because of the lithological monotony and pronouncedly lenticular nature of all observed beds of the Inoceramus colonicus calcarenite unit, it was not possible to recognize the individual beds described in section 27 in the adjacent section 26. However, it seems likely that at least the units 6 to 11 inclusive of the latter section do not occur in section 27 and that the total thickness of Inoceramus colonicus calcarenites on Salmon Islets is either close to or exceeds 225 feet.

Present information indicates that the poorly exposed and structurally complex outcrops of Inoceramus colonicus calcarenites occurring in Winter Harbour (see Unit 1 of Sec. 22) do not differ in their lithology from the Salmon Islets sections of the unit. The Winter Harbour outcrops are interesting, however, because they indicate that the apparently neritic Inoceramus colonicus calcarenites overlap both the nonmarine to littoral Upper Valanginian and? Hauterivian greywacke-conglomerate unit and the offshore Hauterivian siltstone unit.

The only other known section of Inoceramus colonicus calcarenites occurs on the eastern shore of Spencer Cove in Koprino Harbour. This section consists of 50 to 60 feet of drab grey to greenish grey, more or less arenaceous limestone commonly containing abundant small and large fragments of Inoceramus resembling I. colonicus Anderson (none collected). An almost complete guard of Acroteuthis (Boreioteuthis) aff. impressa (Gabb) was collected at about the middle of the unit (GSC loc. 24300). Some interbeds of mottled green to mottled grey, fine- to medium-grained greywacke

occur in the middle part of limestone member, which is underlain (seemingly conformably) by 2 to 3 feet ov very limy, brownish grey, fine-grained sandstone (calcarenite?). The base of this sandstone is concealed below the water level. The upper contact is a fault contact. Inoceramus colonicus calcarenites are mainly jointed and sheared and locally completely crushed and contorted. Their general strike varies from north 30° west to north-south and dips vary from more or less vertical to 25° east.

Age and correlation. As already mentioned by Popenoe et al. (1960), Imlay (1960), Jeletzky (1970c, p. 221), Jeletzky and Tipper (1968, p. 9, Table I), I. colonicus ranges through most or all of the Hauterivian stage as well as through part or ?all of the Barremian stage (Shasticrioceras poniente zone). Therefore, and because of a considerable local variation of its stratigraphic ranges in western British Columbia, the species does not permit a close dating of Inoceramus colonicus calcarenites of Quatsino Sound. These calcarenites cannot, however, be any older than the latest Hauterivian Craspedodiscus cf. discofalcatus and Simbirskites cf. (Simbirskites) broadi zone of Taseko Lakes map-area (Jeletzky and Tipper, 1968) or the approximately contemporary Hertleinites aguila zone of northern California (Imlay, 1960, pp. 180-181) as:

1. In Winter Harbour the Inoceramus colonicus calcarenites appear to overlie late Hauterivian siltstone containing Simbirskites (Simbirskites) broadi (see Units 1 and 3 of Sec. 22) which cannot be older than the early late Hauterivian and may be as late as the uppermost Hauterivian Craspedodiscus cf. discofalcatus and Simbirskites (Simbirskites) cf. broadi zone.

2. The latest Hauterivian to early Barremian index fossil Shasticrioceras cf. poniente Anderson was found 145 to 147 feet stratigraphically below the top of Inoceramus colonicus calcarenites in their Salmon Islets sections (see Unit 7 of Sec. 27). The genus

Shasticrioceras is not known to range below the uppermost Hauterivian Hertleinites aguila zone in California and Oregon (Imlay, 1960, pp. 180-181) and the same appears to be true of the Western Canadian Cordillera (Jeletzky, 1968, pp. 103-104). The genus Shasticrioceras in general and its S. poniente-like forms in particular ore, furthermore, rare to very rare in the uppermost Hauterivian beds while much more common in the succeeding, early to ?late Barremian Shasticrioceras poniente zone of California, Oregon and Canadian Western Cordillera (Imlay, 1960, pp. 180, 198; Jeletzky, unpublished). This circumstance definitely favours the early Barremian age of at least the upper 150 feet of the Inoceramus colonicus calcarenites of Quatsino Sound. The probable middle to late Barremian age of the basal beds of the overlying Barremian fine-grained greywacke unit is compatible with this suggestion. The Inoceramus colonicus beds of Quatsino Sound are dated accordingly as of the early Barremian ?and/or latest Hauterivian age.

Facies and paleogeography. The calcarenitic lithology, the invariable, commonly large admixture of psammitic and psephytic fragments, and the expressly shallow water character of the marine fauna of the unit indicate the neritic nature of Inoceramus colonicus limestones. The same is true probably of the limy to very limy, fossiliferous sandstones and shales intercalated with these limestones. Because of the relatively extensive area of deposition of the Inoceramus colonicus calcarenites (Fig. 9) and their lateral replacement by the littoral, brackish water, and nonmarine clastics of the lower part of the Barremian variegated clastic unit in Holberg and Rupert Inlets and east of Neroutsos Inlet (see below and in the next two sections), it is thought that these calcarenites were not deposited in close proximity to the lower tidal boundary or on the intertidal platforms. It is inferred accordingly that most or all of the extensive Quatsino Sound embayment of

early Barremian ?and/or latest Hauterivian sea was shallow to very shallow (mostly a few fathoms only?). Inoceramus colonicus calcarenites must have been deposited in strongly agitated and well aerated, shallow waters of the central part of this embayment. The local interfingering of these calcarenites with more or less limy and arenaceous to pebbly shales, gritty to pebbly sandstones and obviously submarine, sedimentary breccia (e.g. Unit 6 of Sec. 26) suggests the presence of a more or less strongly diversified bottom relief and of at least some local source areas (?islands) within the central parts of this embayment. The sedimentary breccia and arenaceous to pebbly shales, in particular, appear to be the result of local slumping of only partly consolidated sediments deposited on relatively steep submarine slopes.

The known and assumed extent of the Inoceramus colonicus calcarenites and their nearshore to nonmarine equivalents (i.e. the lower part of the Barremian variegated clastic unit) reflects a considerable eastward and(?) southeastward transgression of the shallow to very shallow early Barremian ?and/or latest Hauterivian sea within the investigated part of Quatsino Sound. This sea flooded considerable areas on the northeastern flank of the Valanginian and Hauterivian tectonic land (compare Figs. 7 and 8 with Fig. 9) along the northern coast of Vancouver Island, in Holberg-Rupert Inlets and east of Neroutsos Inlet.

The predominantly coarse clastic character of and the paucity or absence of carbonaceous rocks in the lower part of the Barremian variegated clastic unit within the Christensen Point Cretaceous outlier and in the outcrops on the eastern side of Neroutsos Inlet suggest the existence of a reasonably high landmass close to the northeast, east and southeast of these two areas. The predominantly finer, in part carbonaceous to coaly lithology of the lower part of the Barremian variegated clastic unit on the

northern side of Holberg Inlet suggests that; (1) either the intervening part of the flanking landmass was relatively low or, (2) more likely an extensive eastward-protruding estuarine to lagoonal enclave of the early Barremian ?and/or latest Hauterivian sea existed between the two flanking headlands in Holberg Inlet area (Fig. 9). The continuing existence of an extensive Brooks Peninsula landmass is inferred because of the previously discussed probable late Valanginian-Hauterivian orographic conditions which probably continued into Barremian time. The complete absence of post-middle Valanginian Cretaceous marine rocks anywhere on the west coast of Vancouver Island southeast of Quatsino Sound area is particularly suggestive of the continuous existence of this landmass.

The erosionally disconformable, and possibly regionally unconformable character of the lower contact of the Inoceramus colonicus calcarenites observed in their Salmon Islets sections suggests that the early Barremian ?and/or latest Hauterivian transgression was preceded by tectonic movements of some kind.

Barremian fine-grained greywacke unit

A poorly exposed unit, at least a few hundred feet thick, of fine- to very fine-grained greywacke with numerous interbeds of sandy siltstone underlies all of the shoreline within the Kewquodie Creek Cretaceous outlier and forms a few scattered outcrops in the Salmon Islets and in Spencer Cove on northwestern side of Koprino Harbour. This unit is named herewith the Barremian fine-grained greywacke unit.

Stratigraphy. The Barremian fine-grained greywacke unit consists predominantly of dark grey to green-grey or bluish grey, massive to indistinctly bedded, almost exclusively fine- to very fine-grained and more or less silty greywacke. This greywacke, which weathers spheroidally and conchoidally, commonly grades

laterally into similarly coloured, more or less sandy, massive to slabby siltstone. Locally, the unit may include numerous interbeds of this siltstone and, in parts of the unit, numerous concretions, pods, lenses and interbeds, 6 inches to several feet thick, of lighter grey coloured, brownish grey to brown-weathering, calcareous greywacke are common. The rocks of the Barremian fine-grained greywacke unit are characterized by an extreme lithological monotony and by a complete absence of any horizon markers. All its rock types appear to be of marine origin.

The upper contact of the Barremian fine-grained greywacke unit is not exposed in any of the studied sections and appears to be faulted at all localities. The contact with the underlying Inoceramus colonicus calcarenites is very abrupt but uneven wherever it was seen (e.g. Units 2, 3, of Sec. 27). A bed of fine to medium pebble conglomerate or coarse- to medium-grained, gritty and pebbly greywacke, 1/2 to 1 1/2 feet thick, forms the base of the Barremian fine-grained greywacke unit so that its lower contact is at least erosionally disconformable and possibly regionally unconformable in the Salmon Islets sections. This contact was not observed in any other studied section of the Barremian fine-grained greywacke.

All observed sections of the Barremian fine-grained greywacke unit are thin, poorly exposed and incomplete. The rocks of the unit have few distinctive lithological characteristics which would facilitate their reliable differentiation from the lithologically similar but mainly more finely grained rock types of the Hauterivian siltstone unit or of the generally more coarse-grained rock types of the Barremian variegated clastic unit, Diagnostic fossils are therefore critical for the recognition of the Barremian fine-grained greywacke unit and the sequential arrangement of its short and incomplete individual sections.

The basal beds of the Barremian fine-grained greywacke are satisfactorily exposed in units 1 and 2 of section 27 on the largest Salmon Islet and what are considered to be the next younger beds of the lower part of the unit are exposed in section 28 nearby.

Poor and intermittent outcrops of dull grey to bluish grey, or dark grey, almost exclusively fine- to very fine-grained, somewhat clayey and commonly shale-like, slabby, conchoidally to spheroidally weathering greywacke of the Barremian fine-grained greywacke unit occur on the southern shore of Quatsino Sound on a broad tidal shelf east of Kewquodie Creek. Ellipsoidal to round concretions, 6 to 10 inches in diameter, of limy, unfossiliferous greywacke are common in the middle part of the unit. The base and top of the unit are covered and almost certainly faulted. These beds contain fragments of Eulytoceras aff. phestum (GSC loc. 23279) and lack Heteroceras (Heteroceras) cf. heliceroides; they are accordingly placed in the lower part of the unit. They correspond mainly to the greywackes exposed in section 28 but may include younger beds not exposed in this section.

The greywackes outcropping around the mouth of Kewquodie Creek and in its bed are somewhat different lithologically from the greywackes comprising the basal part of the Barremian fine-grained greywacke unit on the eastern side of Kewquodie Creek outlier and in the previously described Salmon Islets sections. They overlie these greywackes conformably and contain a different, younger ammonite fauna (GSC locs. 23274, 23276, 23278, 23280 and 23282) characterized by a common occurrence of Heteroceras (Heteroceras) cf. heliceroides (Karsten), ?Hemihoplites sp. indet. and Eulytoceras n. sp. aff. inequalicostatum (d'Orbigny). These rocks are the youngest beds of the Barremian fine-grained greywacke unit seen by the writer.

The Kewquodie Creek outcrops of the Barremian fine-grained greywacke unit extend for about 1 mile across its predominant strike of north 30° to 40° west. The dips fluctuate between 5° and 25° west. Barring the possible repetition of beds by faulting, some 1,300 feet of Barremian fine-grained greywacke unit should be represented within this Lower Cretaceous outlier. This inferred thickness is believed to include most of the sections, as much as 100 feet thick, of its basal part exposed on Salmon Islets.

Some 35 to 40 feet of dark to brownish grey, sandy siltstone outcropping at the tip of the eastern shore of Spencer Cove in Koprino Harbour (see Fig. 17) did not yield any fossils. These rocks are correlated tentatively with the Barremian fine-grained greywacke unit because of their stratigraphic position and distinctive lithology. These sandy siltstones include numerous pods and lenses of fine- to coarse-grained, dark grey greywacke, grit, and fine pebble conglomerate in their basal 10 to 15 feet. They appear to overlie the *Inoceramus colonicus* calcarenites but the contact is obscure because of faulting and contortion of the beds concerned. The top of these basal beds of the Barremian fine-grained greywacke unit is cut off by a major fault.

Age and correlation. The fauna of the Barremian fine-grained greywacke unit includes diagnostic elements such as: *Partschiceras infundibulum* (d'Orbigny), *Eulytoceras* aff. *phestum* (Matheron), *E.* n. sp. aff. *inequalicostatum* (d'Orbigny), and *Heteroceras* (*Heteroceras*) cf. *heliceroides* (Karsten) which indicate its Barremian and partly or entirely mid to late Barremian age in terms of the international standard. The occurrence of *H.* (*H.*) cf. *heliceroides* clearly indicates the late Barremian age of the fauna and that of *A.* aff. *argonautarum* could even be interpreted as suggestive of an Aptian age. The tim

range of Argonauticeras is, however, but poorly known and its evidence is, therefore, discounted. Other taxa in the fauna include Partschiceras infundibulum (d'Orbigny) s. str., Hypophylloceras cf. onoense Stanton, some other indeterminate phylloceratids, Eulytoceras ex gr. subfimbriatum (d'Orbigny), ?Hemihoplites sp. indet., Acroteuthis (Boreioteuthis) ex aff. impressa (Gabb), Inoceramus aff. quatsinoensis Whiteaves, Pleuromya vancouverensis Whiteaves, indeterminate pectenids, several other generically indeterminate pelecypods, "Pterocera" sp. indet. and several other generically indeterminate gastropods.

At least two Barremian faunas are represented in the Barremian fine-grained greywacke unit. Eulytoceras aff. phestum (Matheron) and Argonauticeras aff. argonautarum Anderson were found only in the lower part of the unit presumably not higher than 150 feet stratigraphically above its base. Heteroceras (Heteroceras) cf. heliceroides (Karsten), ?Hemihoplites sp. indet., ?Shasticrioceras ex gr. poniente Anderson and ?Eulytoceras n. sp. aff. inequalicostatum (d'Orbigny) were found, in contrast, only in other outcrops of the unit centered around Kewquodie Creek, apparently its youngest exposed part, and lacking completely E. aff. phestum and Argonauticeras aff. argonautarum. Partschiceras infundibulum (d'Orbigny) s. str. occurs throughout the exposed parts of the unit. These two ammonite faunas correspond to two well-defined Barremian faunas occurring in the Jackass Mountain Group of Manning Park area in the Northern Cascade Mountains of British Columbia (Jeletzky, 1970c, pp. 216, 217, Fig. 1). The lower of these Manning Park area faunas contains Eulytoceras ex aff. phestum (Matheron) apparently conspecific with E. aff. phestum of the Barremian fine-grained greywacke unit. The upper fauna of Manning Park area contains well-preserved Hemihoplites n. sp. aff. H. soulieri (Matheron) possibly conspecific with the less satisfactorily preserved ?Hemihoplites sp. indet. of the Barremian fine-grained greywacke unit.

The presence of Heteroceras (Heteroceras) cf. heliceroides (Karsten) in the upper fauna of the Barremian fine-grained greywacke unit is most important in permitting its confident correlation with the Heteroceras zone of the late Barremian substage of the international standard (Busnardo, 1965, p. 165, Table II). It confirms, furthermore, the previously somewhat doubtful (because of the presence of Eotetragonites ex gr. wintunius) late Barremian dating of the Hemihoplites n. sp. aff. soulieri fauna of the Manning Park area proposed by Jeletzky (1970c, pp. 216, 217, Fig. 1).

The basal beds of Barremian fine-grained greywacke and the equivalent older Barremian fauna of Manning Park area can be tentatively placed in the middle part of the Barremian stage on grounds stated by Jeletzky (1970c, p. 216).

The Heteroceras (Heteroceras) cf. heliceroides fauna is present in the Longarm Formation of Queen Charlotte Islands because a further study of Heteroceras in broad sense) sp. previously identified by the writer from this formation (Sutherland-Brown, 1968, p. 82) indicates its being conspecific with Heteroceras (Heteroceras) cf. heliceroides (Karsten) of the Barremian fine-grained greywacke unit.

Barremian variegated clastic unit

The basal part of the Cretaceous sequence occurs on the eastern side of Neroutsos Inlet, on the northern shore of Coal Harbour, farther west on the northern shore of Holberg Inlet, and on the northern side of Vancouver Island on both sides of Christensen Point. At these localities it consists of a unit, 140 feet to more than 1,000 feet thick, of poorly exposed, variegated marine to nonmarine clastic strata locally containing some thin seams of inferior coal. These rocks were named informally "Barremian variegated clastic unit" (Jeletzky, 1969, p. 127) because of their age and their extremely variable, clastic lithology.

The lithology and facies of these clastic beds are unlike those of the marine Barremian rocks (i.e. Barremian fine-grained greywacke unit and Inoceramus colonicus calcarenites) outcropping in more westerly parts of Quatsino Sound. However, the fossil content of these rocks suggests that their lower part is equivalent to the Inoceramus colonicus calcarenites and that their upper part is correlative with the next younger Barremian fine-grained greywacke unit.

Stratigraphy. Perhaps the most distinctive feature of the Barremian variegated clastic unit is the great variability of its rock types and their facies. The marine clastics range from dark to dull grey, orange- to rusty-weathering, more or less arenaceous siltstone with small and large, rounded limy concretions, through dull grey to green-grey, fine- to coarse-grained, often gritty and pebbly greywacke and arkoses to similarly coloured, fine to coarse pebble and boulder conglomerates. The nonmarine clastics include carbonaceous to coaly siltstones, greywackes, arkoses and conglomerates devoid of marine fossils but commonly rich in carbonized wood fragments and plant remains. The ratios of different clastic types and those of marine and nonmarine facies vary considerably within short distances across and along the strike. However, the ratio of marine facies appears to be the greatest in the southeasternmost known outcrops at the headwaters of Lippy Creek on the northeastern side of Neroutsos Inlet (Jeletzky, 1969, pp. 127, 128) and in the northwesternmost outcrops near the western end of Holberg Inlet. The nonmarine facies and the bulk of coaly rocks including one or more thin (3 inches to 8 inches) seams of impure coal seem to be concentrated between these two outcrop-areas on the northern shore of Holberg Inlet (Dawson, 1887, pp. 90B-99B, Fig. 2).

The westernmost outcrops in Holberg Inlet appear to be transitional in their lithology and prevalence of marine facies to the almost entirely marine and non-carbonaceous facies of Barremian variegated clastic unit that is characteristic of the Christensen Point Cretaceous outlier on the northern side of Vancouver Island (Jeletzky, 1969, pp. 131, 132; 1970a, p. 211). The Barremian variegated clastic unit of Christensen Point outlier is, in turn, transitional to the Barremian fine-grained greywacke unit in the more or less calcareous composition and predominantly fine to medium grain size of its greywackes.

Throughout its outcrop-area, the Barremian variegated clastic unit can be subdivided into two members: 1. Basal coarse clastic member comprising the basal part of the unit and; 2. Siltstone-greywacke member comprising its thicker upper part.

The Basal coarse clastic member consists predominantly of pebble to boulder conglomerate and grit with greater or lesser numbers of interbeds and pods of coarse- to medium-grained, commonly distinctly crossbedded greywacke and, locally, with intercalated beds of coaly greywacke and some coal. Interbeds of waterlain mixed sedimentary-volcanic breccia or? very coarse waterlain volcanic tuff appear to be present in one section of the member. The rocks of the Basal coarse clastic member seldom contain marine fossils and appear to be largely piedmont or beach deposits. The Basal coarse clastic member is about 100 feet thick in the best known section (i.e. Sec. 29) of the unit. However, it seems to be considerably thinner locally (e.g. in borehole C; Dawson, 1887, p. 98B) and may be absent altogether in some poorly exposed sections in Coal Harbour and Apple Bay.

The Siltstone-greywacke member consists mainly of interfingering marine and nonmarine siltstones and sandstones. The sandstones may be either greywackes or arkoses but do not seem to include any quartzose types. More or less calcareous and concretionary marine to brackish water siltstones and sandstones are common to prevalent in the Siltstone-greywacke member. However, locally it includes considerable amounts of nonmarine, carbonaceous to coaly, plant- and wood-bearing siltstone and sandstone. Some pods, layers, and thin, 3- to 8-inch lenticular beds of impure coal may be present also. Small amounts of interbedded coarse-grained gritty greywacke, fine to coarse grit and fine pebble conglomerate were noted locally. These coarse clastics seem to be restricted to the topmost part of the unit transitional with the overlying coarse arenite unit the Coal Harbour-Apple Bay area. In some other sections, notably within the Christensen Point outlier on the northern side of Vancouver Island, the member consists predominantly of light grey to green-grey, more or less calcareous, marine fine- to medium-grained greywacke with minor interbeds of black arenaceous siltstone in the upper part (Jeletzky, 1969, pp. 129, 130; 1970a, p. 211).

The Siltstone-greywacke member does not seem to exceed 200 feet in any section but one. In some of the sections (see Unit 2 of Sec.29) its thickness appears to be reduced by pre-Nanaimo erosion. Other studied sections (e.g. Sec. 30) are poorly exposed and probably faulted. The log of the borehole C drilled in the vicinity of Coal Harbour (Dawson, 1887, pp. 97B-98B) tends, however, to support these estimates of the thickness of the Siltstone-greywacke member. This borehole apparently penetrated the complete thickness of the Siltstone-greywacke member.

The only known exception is the section of the Christensen Point Cretaceous outlier where the marine greywacke facies of the Siltstone-greywacke member was estimated to be at least 900 feet thick with the top destroyed by the ?Sooke Intrusion (Jeletzky, 1970a, p. 211). This anomalous section is, however, almost unfossiliferous in its upper 300 feet and may include some post-Barremian marine equivalents of the Coal Harbour Group.

The Barremian variegated clastic unit overlies erosionally, disconformably and probably regionally unconformably the rocks of the Vancouver Group in all sections where the contact is known. Nowhere does it seem to be underlain by any older Lower Cretaceous rocks. The upper contact with the coal-bearing facies of the coarse arenite unit seems to be conformable and gradational in the few sections where it was seen and in boreholes (e.g. borehole C; Dawson, 1887, pp. 97B-98B).

The best measured section of Barremian variegated clastic unit is section 29 on the northern side of Lippy Creek. This section is extremely important because of the presence of presumably Barremian Acroteuthis-like belemnites in the basal beds of the Barremian variegated clastic unit (see Unit 8). A diagnostic Barremian (presumably middle to late Barremian; see Jeletzky, 1964, pp. 60, 64, Pl. XVI, Figs. 2A-2E, 3A-3B, Pl. XVIII, Figs. 2A-2C) Acroteuthis (Acroteuthis) cf. pseudopanderi (Sintsov) was, furthermore, found at approximately the same level in an adjacent section of this unit (Jeletzky, 1969, p. 128).

The poorly exposed section 30 (see Appendix) measured in the banks of Nuknimish Creek represents the Quoiecchia aliciae-bearing facies of the unit.

Dawson (1887, p. 94B) recognized that the Quoiecchia aliciae-bearing rocks of Nuknimish Creek section occurred "not far above the lowest of the Cretaceous beds" of the Coal Harbour outlier. The invariably low dips of these rocks and the width of the covered interval separating them from those of the Basal Jurassic volcanic unit suggest that these presumably upper Barremian rocks occur only some 300 feet stratigraphically above the base of the Lower Cretaceous sequence. This suggestion finds some support in the inferred low stratigraphic position of the apparently equivalent shell-bearing "slate" in the log of borehole C recorded by Dawson (1887, p. 97B, Fig. 2). This borehole was drilled in the vicinity of Coal Harbour village about 3/4 of a mile northward from deep boring near "The Settlement" (A). The shell-bearing "slates" occur in the interval between 203 feet 10 inches and 215 feet 3 inches above the bottom of the borehole concerned. Unfortunately, this hole did not reach the base of the Lower Cretaceous sequence.

The thin section 31 in the proximity of section 30 is stratigraphically important. Judging by the east-west strike and northerly dip of its beds, section 31 represents some part of the covered interval between the base of Quoiecchia-bearing beds and the outcrops of the Basal Jurassic volcanic unit of section 30. It may be close to the base of the siltstone-greywacke member.

Age and correlation. The Basal coarse clastic member of the Barremian variegated clastic unit is lithologically similar to the eastern facies of the Upper Valanginian and? Hauterivian greywacke-conglomerate unit and would be correlated with the latter unit except for its Barremian fossil content. The Siltstone-greywacke member is commonly very similar lithologically to the overlying coal-bearing facies of the Coarse arenite unit and can be distinguished from the latter only because of its Barremian marine fauna.

Diagnostic Barremian fossils, including such belemnites as Acroteuthis (Acroteuthis) cf. pseudopanderi (Sintsov) (GSC loc. 55100) and Acroteuthis (Boreioteuthis) ex gr. impressa (Gabb) (see Unit 2 of Sec. 29) have been found in the lower part of the Barremian variegated clastic unit, including the lower part of its basal coarse clastic member. Elsewhere the lower part of the unit, including the upper beds of the basal coarse clastic member (Jeletzky, 1969, p. 130, and unpublished), has yielded Inoceramus colonicus Anderson which in Quatsino Sound area at least was found only in the lower Barremian ?and/or uppermost Hauterivian Inoceramus colonicus calcarenites (see pp. 139-140). These biochronological data indicate an early Barremian ?and/or latest Hauterivian age for the lower part of the Barremian variegated clastic unit and their being a marginal, partly nonmarine (mainly beach, alluvial and lagoonal) facies of the Inoceramus colonicus calcarenites (see Table of Formations and Fig. 9). There is no reason to think that the basal, so far unfossiliferous beds of the basal coarse clastic member are older than the rest because these beds grade upwards into the fossiliferous part of the member.

Quoiecchia aliciae Crickmay, Aucellina? sp. indet. and other non-diagnostic marine to brackish water pelecypods, including bank-like accumulations of Ostrea (s. lato) sp. indet. have been found in the younger beds of the Barremian variegated clastic unit which comprise exclusively its Siltstone-greywacke member (see Secs. 30, 31). In itself, this fauna is hardly diagnostic of the Barremian stage as Q. ex gr. aliciae is known to range down into the Hauterivian rocks elsewhere in western British Columbia. However, it provides the upper age limit for the Barremian variegated clastic unit since the genus Quoiecchia is unknown in the post-Barremian rocks of western British Columbia and probably does not reach the upper boundary of this stage (Jeletzky, 1970c,

p. 218). The close stratigraphical association of Q. aliciae with ?Aucellina sp. indet. in section 30, of the Siltstone-greywacke member is, therefore, the only paleontological indication of the mid- to late Barremian age (Jeletzky, 1958, pp. 13-14; 1964, pp. 64-68, Pls. XVIII, XX, XXII, corr. chart) as the genus Aucellina is not known to range down into the lower Barremian or Hauterivian. However, on the northern side of Vancouver Island in the Christensen Point Cretaceous outlier Q. aliciae is associated with Acroteuthis (Boreioteuthis) aff. impressa (Gabb) (GSC loc. 83925) conspecific with that occurring in the Barremian fine-grained greywacke unit of western Quatsino Sound. Similar A. (B.) ex gr. impressa were found also in unit 2 of section 29. In combination with the stratigraphic position (i.e. above the Barremian Basal coarse clastic member and Siltstone-greywacke member) and its previously discussed facies relationships, these scanty paleontological data are deemed to be sufficient to correlate it tentatively with the Barremian fine-grained greywacke unit, in part at least.

The lower part of the Siltstone-greywacke member may correspond to the Inoceramus colonicus calcarenites as I. colonicus ranges almost to the top of the member in the Christensen Point section. It is associated with Q. aliciae and A. (B.) aff. impressa in a bed of calcareous greywacke 150 feet stratigraphically below the visible top of the unit (GSC loc. 83925). Furthermore, Inoceramus colonicus-bearing greywacke and arenaceous limestone appear to replace laterally the Quoiecchia aliciae-bearing greywacke of sections 30 and 31 toward the northwest in some hastily studied sections within Holberg Inlet (e.g. in sections represented by fossil localities GSC locs. 82863 and 82867 collected by J.E. Muller; unpublished intradepartmental fossil report, 1968). It is, therefore, impossible even to suggest the division line between the equivalents of the Inoceramus colonicus calcarenites and Barremian fine-grained greywacke unit within the Siltstone-greywacke member.

Middle to late Barremian facies and paleogeography

The greywacke and siltstone of the Barremian fine-grained greywacke unit are locally moderately to abundantly fossiliferous. The fossils occur in rows of small pods, lenses or thin, lenticular interbeds within the otherwise rarely fossiliferous to unfossiliferous rock. The bulk of the fossils consists of extremely crowded small to very small, immature (often spat only) thin shelled pelecypods. Only a few medium to large, presumably adult pelecypods occur in these fossil clusters. No thick-shelled, obviously inner neritic to littoral pelecypods have been observed in any part of the unit. Other rarer fossils include free moving benthonic forms such as gastropods and purely nectonic animals such as ammonites and belemnites. The ammonite fauna is, furthermore, completely dominated by such open sea forms as lytoceratids, phylloceratids and heteromorphs. Therefore, it seems likely that the failure of most sessile benthonic forms (pelecypods) of the biocoenose to reach maturity was caused by unusually rapid sedimentation and by an almost complete absence of hard, more or less elevated substratum in this facies of the Barremian sea of Quatsino Sound. The sediments of the Barremian fine-grained greywacke unit must have been deposited in relatively deep and quiet water, well offshore, and beyond the reach of most winnowing agencies.

This offshore lithology and fauna of the principal outcrops of the Barremian fine-grained greywacke unit reflects a considerable deepening of the central part of Lower Cretaceous embayment of Quatsino Sound after the end of deposition of the *Inoceramus colonicus* calcarenites (?outer neritic environment).

The apparent absence of the Barremian fine-grained greywacke unit in the eastern part of Quatsino Sound is caused by its lateral replacement by various fine- to coarse-grained marine to nonmarine clastics of the equivalent upper part of the Barremian variegated clastic unit (Fig. 10). This conclusion agrees with the previously discussed offshore character of the Barremian fine-grained greywacke unit.

The upper part of the Barremian variegated clastic unit is characterized by a generally finer grain size and by the presence of a greater ratio of marine rocks as compared with the lower part of the unit. This appears to be true of its sections at the headwaters of Lippy Creek, east of Neroutsos Inlet (see Jeletzky, 1969, pp. 127, 128, Units 5-7; Units 2-4 of Sec. 29 in this report), of that in the Christensen Point Cretaceous outlier on the northern shore of Vancouver Island (Jeletzky, 1969, pp. 129, 130), and of those on the northern shore of Holberg Inlet (see Units 1-5 of Sec. 30). This suggests that along the northeastern, eastern and southeastern margins of the Quatsino Sound Cretaceous embayment, the middle to late Barremian transgression was more extensive than all previous Lower Cretaceous transgressions, including that of the early Barremian ?and/or latest Hauterivian time (cf. Figs. 9 and 10).

The wide extent of the middle to late Barremian sea in the Quatsino Sound Cretaceous embayment and the predominantly fine-grained, in places carbonaceous to coal-bearing character of its marginal facies suggest an extensive peneplanation of the northeastern part of the tectonic highland which flanked the embayment to the northeast, east and southeast from late Valaginian to early Barremian time (Fig. 10).

The middle to late Barremian transgression was not a simple culmination of the preceding, presumably early Barremian transgression of the Inoceramus colonicus time. This is shown clearly by the previously discussed erosionally disconformable

character of the lower contact of the Barremian fine-grained greywacke unit; this erosional interval indicates that, like the early Barremian ?and/or latest Hauterivian transgression, the middle to late Barremian transgression was preceded by an uplift, which was accompanied by an interruption of sedimentation and some erosion of the older rocks. It is not yet certain how much of the investigated part of the Quatsino Sound was raised above sea level. Nor is it possible to decide to what, if any, extent these erosionally disconformable relationships are attributable to submarine erosion supplemented by an influx of coarse clastic particles from the landmass situated somewhere to the east of Holberg and Rupert Inlets.

The progressive expansion of the late Valanginian to late Barremian seas in the Quatsino Sound embayment was a pulsating transgression interrupted at intervals by several shortlived uplifts until the onset of the Aptian orogeny discussed below.

The facies pattern of the Barremian rocks within the Quatsino Sound area (Figs. 9, 10) indicates that, like all older Lower Cretaceous transgressions, the middle to late Barremian transgression advanced eastward and southeastward. The northeastern Barremian onlap of the sea proposed by Muller (1970, p. 47) is unfounded in the writer's opinion.

The apparently complete absence of cephalopods and local abundance of oysters in the Quoiecchia aliciae fauna of the Coal Harbour Cretaceous outlier suggests the somewhat lowered salinity of the possibly lagoonal or estuarine part of the Barremian sea situated in the easternmost parts of Quatsino Sound. The presence of belemnites in the approximately contemporary rocks on the northern shore of Vancouver Island and at the headwaters of Lippy Creek east of Neroutsos Inlet suggest a more or less normal salinity of the Barremian sea in these two flanking areas. A major west-flowing river probably emptied into the mid- to late Barremian sea in the proximity of Coal Harbour.

Coal Harbour Group

Throughout the investigated part of Quatsino Sound, the upper Valanginian to upper Barremian sedimentary rocks (Longarm Formation equivalents) are overlain, apparently conformably, by a thick succession of predominantly conglomeratic to coarsely arenaceous, almost exclusively nonmarine rocks. Jeletzky (1961b, p. 543) and Jeletzky and Tipper (1968, pp. 88, 89) recognized the general facies, stratigraphical and structural equivalence of these rocks to those of the Jackass Mountain Group of the Tyaughton Trough. As interpreted by Jeletzky and Tipper (1968, pp. 88, 89), these nonmarine rocks of Quatsino Sound area record the occurrence of the same Aptian tectonic movements as the Jackass Mountain Group and represent piedmont deposits formed along the southwestern base of the tectonic highland that separated the Insular Trough (this name is substituted for the much longer, unwieldy name Vancouver Island-Queen Charlotte Islands Trough proposed by Jeletzky and Tipper, 1968, p. 75) from Tyaughton Trough during the Oxfordian to Aptian interval (Jeletzky and Tipper, 1968, Figs. 7-9).

The recent discovery of a marine Cenomanian fauna in the basal beds of "Upper Shale" unit overlying the post-Barremian nonmarine rocks in Quatsino Sound (Jeletzky, 1970a, pp. 210-211) and the presence of Albian pollen and spores in their upper conglomeratic unit (i.e. Blumberg Formation) indicates that these rocks span most or all of Aptian and Albian time. In contrast to the Tyaughton Trough, the sea apparently did not re-invade the northern part of Vancouver Island until Cenomanian time.

The Aptian-Albian nonmarine clastic rocks of Quatsino Sound must be treated as a group because they are subdivisible into at least two mappable units of formational rank. The name Jackass Mountain Group is not applicable as the Aptian-Albian coarse clastics of Quatsino Sound have been deposited in a different depositional trough. The latter rocks are, therefore, named herewith the Coal Harbour Group. The name is derived from Coal Harbour in Holberg Inlet where the rocks of the Coal Harbour Group are widespread, most typically developed, and represented by both formations occurring in superposition. During the last quarter of the 19th century, the rocks of the Coal Harbour Group were extensively trenched and drilled in the vicinity of Coal Harbour because of their coal-bearing character. The summary of these early prospecting activities given by Dawson (1887, pp. 90B-99B) provides invaluable information about the lithology and thickness of the group within the Coal Harbour Cretaceous outlier; such information is not available for any of the other outcrop areas of these strata.

Coarse arenite unit

The lower part of Aptian-Albian nonmarine rocks consists of a thick mappable unit of predominantly coarse- to medium-grained, locally gritty and pebbly arenaceous rocks. Because of the lack of a suitable type section exposing both contacts of the unit and some uncertainty concerning the stratigraphic position and age of its non-carbonaceous facies, the unit is tentatively named informally the "Coarse arenite unit".

Distribution. The rocks of the Coarse arenite unit are much more widespread than those of the underlying Barremian fine-grained greywacke unit and its equivalents (see Figs. 17 and 18 and in the stratigraphic section).

Stratigraphy. Most of the observed sections of the Coarse arenite unit are poorly exposed and discontinuous. Many of them are thin and expose only the uppermost part of the unit and its contact with the much more resistant, cliff-forming Blumberg Formation.

The coarse- to medium-grained, locally gritty and pebbly arenaceous rocks of the Coarse arenite unit are commonly somewhat more mature than those of the underlying Lower Cretaceous sedimentary units. Locally, they are composed largely of light coloured subgreywacke with some interbeds of subquartzose or subfeldspathic sandstone. Elsewhere they are darker and mainly carbonaceous greywacke.

The coarse- to medium-grained arenites appear to form from 70 to 80 per cent of the unit's thickness, with the darker, fine-grained, more or less silty greywacke, dark grey, arenaceous siltstone and shale, grit, and pebble conglomerate accounting for the rest. Minor intercalated beds, lenses and pods of impure limestone and coal occur locally but are estimated to comprise less than 2 per cent of the total thickness of the unit.

The Coarse arenite unit is estimated to be from ?800 to at least 5,390 feet thick. The lower contact of the unit is concealed and apparently faulted in all sections studied by the writer. However, the description of the borehole C provided by Dawson (1887, p. 97B) suggests that the basal, coaly sandstone of the unit overlies conformably the shell-bearing "slate" (i.e. shale) referable to the Quoiecchia aliciae-bearing facies of the Barremian variegated clastic unit.

The upper contact of the Coarse arenite unit is invariably sharp, uneven and erosionally disconformable (see Pl. IX, Fig. A). The basal conglomerate beds of the Blumberg Formation fill deep depressions in the upper surface of the unit and contain an abundance of subgreywacke, siltstone and limestone pebbles and particles obviously derived through the erosion of the latter. No angular discordance was observed at this contact but it may well be regionally unconformable, since the basal conglomerate beds of the Blumberg Formation appear to overlie lithologically different beds of the Coarse arenite unit in different parts of the area studied.

In spite of the scarcity of sufficiently well exposed, extensive sections of the Coarse arenite unit, it seems to show rather regular and meaningful facies changes in the east-west direction. At present, it is possible to distinguish the following two distinctive lithofacies of the unit:

1. A very thick non-carbonaceous facies apparently confined to the western part of Quatsino Sound (i.e. to the Winter Harbour area but possibly reappearing on the northern shore of the main channel of Quatsino Sound west of Quatsino village); and

2. A much thinner, coal-bearing facies mainly restricted to the remaining eastern part of Quatsino Sound but present locally in its western part (i.e. in Ahwhichaolto Inlet and in Spencer Cove).

The shores of the inner (northeastern) basin of Winter Harbour, those of Wedel Island, and those of several adjacent nameless islets offer numerous but discontinuous and poorly exposed outcrops of the non-carbonaceous facies of the Coarse arenite unit (see Fig. 18).

Sections 32 and 33 (see Appendix) are the two best exposed and thickest available. These sections of the non-carbonaceous facies, which are incomplete, structurally complex and locally severely faulted, occur on the northern shore of the inner basin of Winter Harbour between its head and the mouth of Galato Creek. So far as it is possible to tell, there is no repetition of beds in these two sections which together form the reference section of the non-carbonaceous facies of the Coarse arenite unit. Because of poor exposures, structural complexity of these sections, and the presence of numerous partly to wholly covered intervals within them, all measurements are approximate only.

Section 32 is of the upper part of this facies and exposes its contact with Blumberg Formation, whereas section 33 exposes the older, middle and ?lower parts of the non-carbonaceous facies. Judging by their different lithology, these two sections do not overlap.

The reference section of the non-carbonaceous facies of the Coarse arenite unit (i.e. Secs. 32 and 33 combined) exposes the total measured thickness of about 3,970 feet. When the presumably unfaulted but covered intervals within the section 33 (about 1,420 feet of strata) are added, a total thickness of about 5,390 feet is inferred for the westernmost known section of the Coarse arenite unit. The complete thickness of the unit should be still greater since its basal part is neither represented in these sections nor was observed elsewhere in Winter Harbour.

The exposed measured thickness of about 3,075 feet in section 33 includes approximately 2,210 feet, or some 71 per cent, of coarse- to medium-grained, partly gritty and pebbly sandstone. The remainder consists of about 685 feet, or some 24 per cent, of fine-grained, mostly silty sandstone and about 129 feet, or some 4 per cent, of various sandy siltstones and shales. Limestone, fine pebble conglomerate, and grit comprise the remaining 1 per cent of the exposed thickness of the unit.

These ratios of fine-grained sandstones, siltstones and shales are almost certainly underestimations because the presumably unfaulted covered intervals within the reference section seem to be underlain predominantly by these softer rock types.

The predominantly coarse-grained and commonly gritty arenites of the Winter Harbour sections of the Coarse arenite unit are typical of its non-carbonaceous facies. They are mainly light grey, light green-grey, buff- or rust-coloured and somewhat more mature than either those of its coal-bearing facies or those of other Lower Cretaceous formations of Quatsino Sound. These medium- to coarse-grained arenites are subgreywackes rather than true greywackes and include numerous interbeds of subquartzose and subfeldspathic sandstones. They are commonly more or less calcareous and, in some places, contain rows of concretions and lenses of impure limestone.

The finer grained arenites of the non-carbonaceous facies are generally darker (grey to dark grey) and more greywacke-like. These fine-grained arenites as well as the dark grey to brown, arenaceous siltstones and shales commonly contain rows of concretions or interbeds of impure grey limestone. Only a few beds, 1 foot to 2 feet thick, of pebbly grit and fine pebble conglomerate have been seen in the non-carbonaceous facies of the Coarse arenite unit. Carbonaceous or coaly rocks and coal are characteristically absent and even plant remains are rare in the non-carbonaceous facies.

In the remaining larger part of Quatsino Sound extending from the head of Ahwhichaolto Inlet (Dawson, 1887, p. 84B) to Apple Bay, Coal Harbour, and the northern shore of Rupert Inlet, the non-carbonaceous facies of the Coarse arenite unit is replaced laterally (except for Sec. 34) by an attenuated (only 800 to 900 feet

thick if one accepts the estimate of total thickness of the Lower Cretaceous rocks within Coal Harbour outlier of only 1,300 to 1,500 feet as suggested by Dawson, 1887, p. 91B) succession of predominantly carbonaceous to coaly clastics containing a variable amount of thin and lenticular, apparently non-commercial coal seams (Dawson, 1887, pp. 92B-94B).

The most common rock type of the coal-bearing facies is dark grey to brown-grey, coarse- to medium-grained, often gritty and pebbly greywacke. Unlike the light coloured subgreywackes of Winter Harbour area, these greywackes are commonly carbonaceous to coaly and contain numerous intercalated beds and members of dark grey to black, fine-grained, silty greywackes and similarly coloured, sandy siltstones. Lesser interbeds and members of pure shale, limestone, grit and pebble conglomerate occur in the coal-bearing facies of the Coarse arenite unit. Grit and pebble conglomerate interbeds appear to increase markedly in numbers eastward within the coal-bearing facies of the unit as illustrated by the Lind Islet section (see Sec. 35), the section at Stewart Point in Coal Harbour (see p. 186), and the borehole logs described by Dawson (1887, pp. 92B-99B) within the Coal Harbour outlier.

The coal-bearing facies of the Coarse arenite unit should probably be treated as an independent formation because of its distinctive lithology and geographic localization. However, it does not seem advisable to map these poorly understood, coal-bearing clastic rocks separately and to name them formally at present. None of the sections of the coal-bearing facies studied by the writer is sufficiently well exposed and extensive to serve adequately as its type section. These coal-bearing arenites are, therefore, provisionally mapped together with the non-carbonaceous facies of the Coarse arenite unit pending a more detailed study of their lithology, stratigraphy, and especially of the areal distribution.

The westernmost known outcrops of the coal-bearing facies of the Coarse arenite unit occur at the head of Ahwhichaolto Inlet. According to Dawson (1887, p. 84B), these intensely disturbed and small exposures consist of partly carbonaceous shale interbedded with impure and good coal in beds from 1 foot to 3 feet thick. The writer did not succeed in finding these important outcrops.

Small, poor outcrops of dark grey, carbonaceous greywacke and siltstone occur locally on the slopes of a narrow, logged off valley connecting the head of Ahwhichaolto Inlet with Spencer Cove in Koprino Harbour. These strongly disturbed exposures appear to represent a number of tectonic slices within the Ahwhichaolto fault zone; they were not studied in any detail.

Extensive outcrops of the Coarse arenite unit composed of sheared and contorted, dark green, coarse-grained greywacke interbedded with some brownish grey, gritty limestone and similarly coloured calcareous shale occur in the northwestern corner of Spencer Cove. These greywackes are underlain(?) by dark grey to black, carbonaceous to coaly shales with interbeds, 2 mm to 1 foot thick, of brownish grey, grey to dark grey, coarse-grained greywacke and grit and with pods and lenses of impure (clayey) limestone. All rocks strike northerly to northwesterly with irregularly alternating steep easterly and westerly dips. No estimate of thickness was possible and these rocks appear to occur as several fault slices within the Mahatta Fault Zone.

The exposures of the uppermost beds of the Coarse arenite unit occurring on the tidal shelf of the eastern shore of Robson Cove underneath 20- to 25-foot high bluffs of the Blumberg Formation duplicate the more easterly parts of Lind Islet exposures (see Sec. 35 and Pl. IX, Fig. A) in every detail including the disconformable character of the contact.

Section 35 of the uppermost part of the Coarse arenite unit and the basal part of the Blumberg Formation is important in exposing the erosionally disconformable contact of these units (Pl. IX, Fig. A). This section is separated from basal beds of the type section of Blumberg Formation (see Sec. 36) by a covered interval, 35 to 40 yards wide, possibly containing a fault. The upper part of unit 1 of section 35 apparently corresponds to unit 19 of the type section of the Blumberg Formation.

The Coarse arenite unit appears to be either almost completely faulted out or mostly covered on the eastern side of Koprino Harbour and farther east to the mouth of Aweisha Creek. The only possible exception is the extremely disturbed and thin (see Sec. 34) greywacke-siltstone section occupying the westernmost part of the above interval. This section is tentatively referred to the non-carbonaceous facies of the Coarse arenite unit as it lacks carbonaceous and coal-bearing rocks but it could possibly be some part of the Barremian variegated clastic unit.

The thin section 35a measured on the eastern side of Apple Bay probably is low in the succession of coal-bearing facies of the Coarse arenite unit because of its proximity to the underlying Quoiecchia aliciae-bearing facies of the Barremian variegated clastics (see Sec. 31). The contact between these two units is concealed everywhere in this part of the area.

Extensive exposures of brownish grey, coarse-grained, gritty sandstones grading into grit and containing pods and interbeds of coarse grit and pebble conglomerate outcrop on the tidal shelf of Coal Harbour for at least 400 yards south of the tip of Stewart Point. Their northern limit was not reached and in the south they are cut off by the Holberg fault (Fig. 16). Outcrops are poor and intermittent and the rocks are faulted and flexed into several drag folds. It was impossible, therefore, either to

work out the succession of beds or to give an estimate of their thickness. These coarse-grained sandstones and subordinate coarser clastics are tentatively referred to the upper part of the coal-bearing facies of the Coarse arenite unit. They may include, however, some undifferentiated beds of the Blumberg Formation.

In Rupert Inlet a section, some 37 feet thick, (see Units 13-18 of Sec. 37) of light to dark grey, fine- to medium-grained, mainly carbonaceous to coaly greywacke interbedded with an almost equal amount of dark to brownish grey, mostly arenaceous and coaly siltstone and shale outcrops on the southeastern shore of a nameless cove behind Narrow Island.

There was no opportunity to visit any other sections of the Coarse arenite unit within the Coal Harbour Lower Cretaceous outlier. The reader is referred to Dawson's (1887, pp. 90B-99B, Fig. 2) memoir for this information and to the logs of boreholes drilled through the coal-bearing facies of the Coarse arenite unit in the vicinity of Winter Harbour.

Age and correlation. The plants identified so far from the coal-bearing beds of the Coarse arenite unit appear to be non-diagnostic (Dawson, 1887, pp. 94B-95B).

The unit did not yield any marine fossils, except for a few indeterminate shells found in one bed in unit 33 of section 33 in Winter Harbour. The Coarse arenite unit appears, therefore, to be entirely nonmarine, with the exception of its westernmost known outcrops, which contain at least some marine beds. The age of the Coarse arenite unit can be determined only indirectly using its stratigraphic relationships with adjacent paleontologically datable Cretaceous units.

Information from borehole logs (Dawson, 1887, p. 97B) indicates that the basal beds of the coal-bearing facies of the Coarse arenite unit conformably and gradationally overlie the Quoiecchia aliciae-bearing beds of the Barremian variegated clastic unit within the Coal Harbour Cretaceous outlier. The same stratigraphic relationships are assumed to exist between the Barremian fine-grained greywacke unit and the overlying non-carbonaceous facies of the Coarse arenite unit in the more westerly parts of Quatsino Sound. This hypothesis remains unconfirmed, however, as all these contacts are invariably concealed and apparently faulted. Therefore, the Coarse arenite unit is probably only slightly younger than the upper Barremian stage of the international standard and can be correlated tentatively with the Aptian stage.

The upper age limit of the Coarse arenite unit is provided by the recent discovery of probably (possibly middle) Albian spores and pollen in the lower third of the overlying Blumberg Formation (see Unit 5 of Sec. 37). Because of the erosionally disconformable and probably regionally unconformable structural relationships between the Coarse arenite unit and the Blumberg Formation, it seems logical to place all of the latter into the Albian stage and to draw the Albian-Aptian boundary at the disconformity beneath it. The Coarse arenite unit probably represents most or all of the Aptian stage of the international standard but does not seem to include any Albian rocks.

The Aptian dating of the Coarse arenite unit is based on stratigraphical and structural relationships observed in the eastern part of Quatsino Sound in rocks of the coal-bearing facies of the unit. It is, however, applicable to the non-carbonaceous facies of the unit in the western part of Quatsino Sound because of the erosionally disconformable and probably regionally unconformable superposition of the Blumberg Formation on the non-carbonaceous facies of the unit in sections 32 and 35.

The lower contact of the Coarse arenite unit was recorded only in the coal-bearing facies of one Coal Harbour borehole. However, it does not seem likely that the coal-bearing rocks exposed at the head of Ahwhichaolto Inlet (Dawson, 1887, p. 84B) and within the Coal Harbour outlier (Dawson, 1887, pp. 92B-94B, Fig. 2) represent the lower part of the Coarse arenite unit, which is either covered or faulted out in the non-carbonaceous facies of the Winter Harbour sections. According to Dawson (1887, pp. 92B-93B) the highest coal-bearing zone of the formation occurring within the Coal Harbour outlier is situated only 200 to 300 feet stratigraphically below the base of the massive conglomerate unit evidently representing the basal part of the Blumberg Formation. Furthermore, units 13-18 of section 37 on the northern shore of Rupert Inlet, which represent the topmost beds of the coaly facies of the Coarse arenite unit, are exceedingly carbonaceous to coaly almost throughout and contain a few thin beds of very low grade coal. This contrasts markedly with the non-carbonaceous to only slightly carbonaceous character of the uppermost beds of the Coarse arenite unit in the studied sections at Lind Cove, Koprino Harbour and Winter Harbour. These coal-bearing sandstones and shales of the eastern part of Quatsino Sound appear, therefore, to be essentially time-equivalent to the non-carbonaceous or only slightly carbonaceous sandstones and siltstones of Winter Harbour sections of the Coarse arenite unit.

The stratigraphic conclusions presented above may not be applicable to section 33 of the Coarse arenite unit exposed on the northwestern shore of Winter Harbour since its stratigraphic relationships with any of the adjacent, reliably dated Lower Cretaceous formations are unknown (faulted contacts). The placement of section 33 into the Coarse arenite unit is based solely on its overall lithological similarity with the adjacent section 32, the stratigraphic position of which is known.

Facies and paleogeography. The previously discussed lithology and geographical localization of the Coarse arenite unit suggest that its rocks have been deposited on the relatively less elevated, possibly more or less peneplaned part of the rejuvenated Aptian tectonic land. This less elevated area must have been relatively wide in the east-west direction, as it occupied most or all of the present day Quatsino Sound. It was apparently confined between the more strongly elevated part of the tectonic land in the east and the early Aptian sea in the west (Fig. 11). Judging from the known and assumed extent of the Coarse arenite unit, the western limit of the more strongly elevated part of tectonic land, which served as its source area, was situated along the east coast of Vancouver Island. The eastern shore of the early Aptian sea should have been situated just west of the present day Forward Inlet area and the sea had apparently penetrated into the latter area at times.

The coal-bearing facies of the Coarse arenite unit was probably deposited entirely within the less elevated part of the early Aptian tectonic land at some distance from the sea coast. The predominant rock types of the coal-bearing facies, such as coarse- to medium-grained, partly carbonaceous to coaly greywackes, alternate cyclically with subordinate rock types which include coal-bearing, fine-grained greywackes, siltstone and shale. This suggests that the rapid, westward flowing streams, which deposited the above mentioned coarser clastics, became more sluggish at certain times. This cyclical recurrence of finer grained, coal-bearing clastics in all known sections and boreholes of the coal-bearing facies suggests the alternation of low intensity uplifts with more short-lived and rare periods of tectonic quiescence or subsidence. The coal-bearing character of finer grained clastics, their irregular lateral alternation, and the local occurrence of presumably fresh water limestones in

shales, suggest that considerable areas of the less elevated part of the Aptian tectonic land became transformed into densely wooded lowlands dotted by swamps and freshwater lakes during each of the above-mentioned, short-lived periods of tectonic quiescence or subsidence.

The coarse- to medium-grained, often gritty subgreywackes and subquartzose to subfeldspathic sandstones predominant in the non-carbonaceous facies of the Coarse arenite unit appear to have been deposited in a different environment. These somewhat more mature, better sorted, in part calcareous arenites probably were deposited on sea beaches fringing the eastern shore of the early Aptian sea. The localization of these arenites to the west of the coal-bearing facies (Fig. 11), the almost complete absence of well-preserved plant remains, and the so far unique find of marine shells in them agree well with this hypothesis.

The subordinate fine-grained greywackes, sandy siltstones and shales interfingering with coarser clastic rock types in all known sections of the non-carbonaceous facies have probably been deposited either within the more protected parts of the shoreline or within estuaries, tidal lagoons or salt marshes just behind the beaches. The apparent absence of cyclical alternation of coarse and fine clastics in the non-carbonaceous facies of the Coarse arenite unit makes it uncertain whether or not the deposition of the latter has been confined to the above-mentioned short period of tectonic quiescence or subsidence.

The complete absence of outcrops of the Coarse arenite unit on the southern shore of Quatsino Sound appears to be the result of their subsequent (pre-Nanaimo) erosion. It is unknown how far they originally extended in this direction, but it is suggested tentatively that the northwestern margin of the rejuvenated Aptian Brooks Peninsula landmass was situated only a few miles to the south of Quatsino Sound (Fig. 11).

Blumberg Formation

A mappable Albian conglomerate unit, at least 3,000 feet thick, caps the Coarse arenite unit throughout the investigated part of Quatsino Sound. This conglomerate unit is herewith named the Blumberg Formation from Blumberg Creek cascading down the bluffy northern shore of Quatsino Sound at a point about 3 miles east of Prideaux Point. The high bluffs extending westward from the mouth of Blumberg Creek to the nameless point opposite Lind Islet and for about 1 1/2 miles east from its mouth offer the best known, essentially continuous section of the Blumberg Formation. This section (described as Sec. 36 in the Appendix) is selected herewith as the type section of the formation.

Stratigraphy and distribution. The Blumberg Formation consists almost exclusively of dark grey, green-grey or rust-coloured, generally poorly sorted and rounded coarse to fine pebble and boulder conglomerates. The conglomerates form from 75 to 90 per cent of the unit's thickness. The remainder of its thickness consists of fine to coarse, commonly pebbly grits and coarse- to medium-grained, commonly gritty and pebbly, green-grey to rust-coloured greywacke. The matrix between pebbles also consists of these finer clastics. Fine-grained greywacke, siltstone and shale are exceptionally rare. These finer clastics may be carbonaceous to coaly in the easternmost part of Quatsino Sound (apparently only within Coal Harbour outlier) and one coal-bearing zone was observed in the Rupert Inlet section 37 of the formation. Elsewhere no carbonaceous to coaly interbeds have been noted in the formation.

Clasts consisting of various volcanic rocks of the Vancouver Group and granitoid to gabbroic intrusive rocks evidently derived from Coast Intrusions are common to predominant in most of the studied sections of Blumberg Formation.

Clasts consisting of various sedimentary rocks are, however, common locally. Although they include some rock types peculiar to the Vancouver Group, the sedimentary clasts mainly are lithologically identical with those of the underlying Coarse arenite unit and were apparently derived through the erosion of the latter; such clasts are especially common, and locally predominant in the basal beds of the Blumberg Formation.

The common to prevalent occurrence of the Coast Intrusion clasts in conglomerates of the Blumberg Formation is the most distinctive lithological feature of the formation and contrasts sharply with their paucity in all older Cretaceous conglomerate units of Quatsino Sound.

This distinctive lithology, resistant cliff-forming character, and persistence across the investigated part of Quatsino Sound (i.e. in the east-west direction) make the Blumberg Formation the best known horizon marker within the Lower Cretaceous sequence of this area.

The character of the lower contact of the Blumberg Formation and its tectonic implications have been discussed in connection with the Coal Harbour Group and the Coarse arenite unit.

The upper contact of the Blumberg Formation was not observed. It is covered and presumably faulted in the only known outcrop which exposes the presumably uppermost beds of the Blumberg Formation and the overlying basal part of the next younger Upper shale unit (see below).

It is not known whether the thickness of the Blumberg Formation changes materially in the east-west direction because of a complete absence of reliable horizon markers within the formation and the incompleteness of all its known sections. Because it is thick throughout its known outcrop-area, it is assumed to be comparably thick everywhere.

The lithology of the Blumberg Formation is remarkably uniform throughout the investigated part of Quatsino Sound. The only lateral facies change noted consists of the presence of interbeds of carbonaceous to coaly siltstone and shale, and of a thin coal-bearing zone in the easternmost section of the formation (see Sec. 37). This contrasts with the completely non-carbonaceous character of all more westerly sections of the formation.

The rocks of the Blumberg Formation are just as widespread as those of the underlying Coarse arenite unit. In the extreme western part of Quatsino Sound, an isolated outcrop-area (a fault block) of Blumberg Formation occurs at the northwestern end of Ahwhichaolto Inlet. This outcrop exposes some 700 to 800 feet of characteristic pebble to boulder conglomerates. Both contacts are covered and almost certainly faulted.

Another adjacent outcrop-area of the Blumberg Formation is shown by the upper part of section 32. It may extend for several miles northwestward of the head of Winter Harbour as outcrops of conglomerates have been recorded to occur a short distance up Denad Creek (= Zenaad River) by Dawson (1887, p. 84B). However, the writer did not traverse the headwaters of Denad Creek. No outcrops of the Blumberg Formation were recorded by Dawson (1887, pp. 78B-81B) to occur on the west coast of Vancouver Island between Cape Scott and the mouth of Quatsino Sound, possibly because of the erosion of all but the basal beds of the Lower Cretaceous sequence in this part of the area.

No exposures of the Blumberg Formation have been seen anywhere between the head of Winter Harbour and the Schloss Island in Koprino Harbour. However, rocks of the formation reappear northeast of the Mahatta Fault Zone and occupy the shores of Koprino Harbour between the northeastern shore of Robson Cove and Prideaux Point.

All smaller islets occurring within Koprino Harbour are underlain by rocks of the Blumberg Formation and no outcrops of the Upper shale unit have been found on any of them. The writer disagrees with Dawson's (1887, pp. 88B) conclusion that: "grey, finely fissile, rather hard and very regularly bedded shales" outcropping on the largest of the Linthlop Islets within East Cove overlie conformably the conglomerates of the Blumberg Formation. A closer study of these exposures has shown that this unit, 120 to 130 feet, of metamorphosed to "granitized" shales and fine-grained sandstones dips under a 100- to 110-foot unit of pebble conglomerate of the usual Blumberg Formation type. This conglomerate occupies the axial part of the syncline exposed on Linthlop Islet. The shales concerned represent, therefore, one of the fine clastic interbeds locally occurring in the Blumberg Formation.

As stressed by Dawson (1887, p. 87B), the excellent and extensive exposures of the Blumberg Formation within Koprino Harbour are always structurally complex. Strong faulting of the monotonous pebble to boulder conglomerates of the formation and their flexing into several open, northwesterly trending folds prevented the writer from either establishing the succession of exposed beds or estimating their thickness. However, comparison of the Koprino Harbour sections with less complicated sections of the Blumberg Formation outcropping between Prideaux Point and the head of Shapland Cove (see Sec. 36) suggests that only the lower part of the formation, corresponding to units 12 to 19 of its type section, outcrops within Koprino Harbour. The overlying middle and upper parts of the Blumberg Formation probably are exposed farther northeast in the bed of Koprino River (= Ten-o-suh River of Dawson, 1887, p. 87B), only the lower course of which was traversed by the writer.

Between Prideaux Point and the nameless small point about 185 yards east of Lind Islet, the northern shore of Quatsino Sound is underlain by typical conglomerates of the lower part of the Blumberg Formation (Pl. IX, Fig. A). These conglomerates dip north to northwest at 15 to 25 degrees and are not nearly as intensely faulted as the equivalent beds inside Koprino Harbour. Closer to Prideaux Point the rocks strike about east-west. However, the strike changes gradually toward north-northeast closer to Lind Islet. This results in the appearance of older and older beds of the Blumberg Formation in this direction until its base appears above sea level at the point about 185 yards west of Lind Islet (see Sec. 35). It is estimated that only the basal 1,000 to 1,100 feet of the Blumberg Formation are exposed in the cliffs along the shore between Prideaux Point and Lind Islet.

Farther east, the approximately 3,000-foot thick type section (see Sec. 36 of the Appendix) of the Blumberg Formation does not seem to be repeated by faulting or folding. Together with the basal beds of the Blumberg Formation exposed immediately west of Lind Islet in section 35, the type section appears to comprise the bulk of the conglomeratic part of the formation.

The interval, about 180 yards wide, separating the visible top of section 36 from the predominantly arenaceous basal beds of the Upper shale unit, which outcrop farther east and occupy the shoreline for the next half a mile or so, almost certainly harbours a major north- or northeast-trending fault.

The intensely faulted and sheared and locally contorted, mainly steeply dipping conglomerates of the Blumberg Formation reappear on the eastern limb of the previously mentioned north-trending syncline. There, they outcrop almost uninterruptedly on the northern shore of Quatsino Sound from Ildstead Islets to the secondary point about

3/4 of a mile west of the mouth of Aweisha Creek. As far as is known, the conglomerates of these exposures are lithologically identical to those of the type section of the formation. Both contacts are covered and almost certainly faulted. Strong faulting of the extremely monotonous pebble to boulder conglomerates of these exposures, as well as their supplementary folding and the presence of several major covered intervals, have made it impossible either to work out the succession of exposed beds or estimate their thickness.

No exposures of the Blumberg Formation were observed between those occurring on the eastern side of the Koprino Harbour outlier and those described by Dawson (1887, pp. 85B, 92B, Fig. 2) on the western side of Coal Harbour and farther north in the central part of the Coal Harbour outlier. None of these sections of the Blumberg Formation was visited and the reader is referred to Dawson's (1887) descriptions of them.

Section 37 (see Appendix), exposed on the northern shore of Rupert Inlet west of Narrow Island, appears to expose the lower third of the Blumberg Formation. This fossiliferous section is the most representative section of the formation known in the eastern part of the report-area.

Dawson (1887, p. 93B) erroneously concluded that section 37 is near the base of the Cretaceous rocks; he states: "At the eastern extremity of the field (coal field is meant; writer's remark), about three miles northeastward from Hankin Point, on the shore, a considerable thickness of conglomerates occur in what here must be the lowest part of the series. These were not seen elsewhere in the same position and this occurrence is somewhat anomalous".

The characteristic lithology of the Blumberg conglomerates of this Rupert Inlet section and their erosionally disconformable contact with the underlying typically developed uppermost beds of the coal-bearing facies of the Coarse arenite unit indicate instead the presence of a major north-northwest trending fault within the completely covered interval separating the basal exposed beds of this unit from the adjacent exposures of the Basal Jurassic volcanic unit (see Fig. 17). The covered upper contact of this section probably is faulted also. Otherwise, it would be hard to understand the apparent absence of exposures of the Blumberg Formation on the eastern shore of Coal Harbour at Stewart Point and their reappearance on its western shore immediately north of the Winter Harbour fault (Dawson, 1887, pp. 92B, 93B, Fig. 2 and Fig. 17).

Age and correlation. As has been discussed in connection with the age of the Coarse arenite unit, all of the Blumberg conglomerates appear to be Albian in age. This conclusion is based in part on the following dating by W.S. Hopkins Jr of the palynomorph collection GSC-C-4309. This collection was made by the writer from unit 5 of section 37 near the top of the lower one-third of the formation.

Hopkins states:

> Most of the palynomorphs identified from this sample would be characteristic of either the Jurassic or the Cretaceous. Furthermore, most of the forms are ferns with minor representation from the Lycopods, seed ferns, and Coniferales. A poorly preserved and questionable tricolpate grain, indicative of the Dicotyledoneae was also encountered.
>
> Although most of the palynomorphs could be either Jurassic or Cretaceous, several indicate a Cretaceous age, especially Cicatricosisporites. Furthermore, the doubtful presence of dicotyledons would suggest we were dealing with Lower or Middle Cretaceous rocks. However, there are two spores, both present in considerable numbers, which suggest a more definitive age.

> The first is Cicatricosisporites perforatus which has been found to have a range restricted to Aptian to Turonian in Alberta and Siberia. The second is Appendicisporites perplexus which is, so far as I know, restricted to the Middle Albian of Alberta. The age restrictions indicated by these two spores would refine the age as already suggested by the other elements of the florule.
>
> As a result, on the basis of this florule, I would venture the opinion that these rocks are Albian, and probably lower to middle Albian.

This conclusion is supported by the recent discovery of a marine Cenomanian (probably early Cenomanian!) fauna in the basal, mainly arenaceous beds of the overlying "Upper shale unit" (Jeletzky, 1970a, pp. 210, 211) which is discussed below.

Because of the erosionally disconformable and possibly regionally unconformable character of the lower contact, it is assumed that the basal beds of the Blumberg Formation are approximately contemporary throughout the investigated part of Quatsino Sound, and that the formation does not become replaced laterally by the arenaceous rocks of the Coarse arenite unit toward the west.

No traces of Blumberg conglomerates were observed between the Upper shale unit and the underlying Barremian variegated clastic rocks within the Christensen Point Cretaceou outlier (Jeletzky, 1970a, p. 211). It is somewhat difficult to assume the wholesale des truction of such a prominent formation either through faulting or through assimilation by ?Sooke Intrusions, so it is inferred that the Blumberg conglomerates pinch out completely somewhere between the head of Holberg Inlet and the adjacent segment of the northern shore of Vancouver Island. It is not yet possible to say which, if any, of the exposed Cretaceous units of the Christensen Point outlier is equivalent to the Blumberg Formation of Quatsino Sound.

On Queen Charlotte Islands, equivalents of the Blumberg Formation are represented by marine sandstones of the Sandstone member of the Haida Formation (Sutherland-Brown, 1968, pp. 83-93, Fig. 12). This early Haida sea apparently did not reach the Quatsino Sound area.

Facies and paleogeography. The deposition of a thick blanket of pebble to boulder conglomerate (Blumberg Formation) over all the investigated part of Quatsino Sound registers the occurrence of the principal tectonic phase of the interregional Aptian (apparently late Aptian) orogeny (Jeletzky and Tipper, 1968, pp. 88-89). This tectonic phase must have caused significant uplift (i.e. in comparison with the earlier level characteristic of the time of deposition of the Coarse arenite unit) of the northeastern flank of the Aptian tectonic land situated north of Holberg and Rupert Inlets and of its southeastern flank inferred to exist just south of Quatsino Sound.

Coaly clastic strata and interbeds of coal appear to be restricted to the Rupert Inlet-Coal Harbour sections of the Blumberg Formation (e.g. Sec. 37). This restriction of low energy, palustrine sediments and the considerably greater east-west width (over 20 miles) of the outcrop-area of the Blumberg Formation as compared with its known north-south extent suggests that the bulk of the clasts was derived from the more elevated (in comparison with the northeastern flank) southeastern flank of the tectonic land. This source area apparently represented the northeastern margin of Brooks Peninsula landmass (Fig. 12). It must have been situated only a few miles south of Quatsino Sound since the pebbles and boulders of the Blumberg Formation could hardly travel any farther from their source area. This conclusion agrees well with the apparently complete absence of outcrops of the formation on the southern side of Quatsino Sound, a fact that is more reasonably ascribed to non-deposition than to subsequent erosion of this extremely resistant unit.

The strongly uplifted southeastern flank of the Albian tectonic land of the Quatsino Sound area must have been a rapidly rising, mountainous area to provide the bulk of Blumberg Formation conglomerates.

The late Aptian tectonic phase must have caused a widespread westward and/or northwestward retreat of the early Albian ?and latest Aptian sea, since even the westernmost known sections of the Blumberg Formation (e.g. those at the head of Winter Harbour and at the northwestern end of Ahwhichaolto Inlet) consist of typical piedmont deposits and do not include any rock types or fossils suggestive of the proximity of the sea shore. However, it seems likely that the depositional area of the Blumberg Formation proper was not appreciably uplifted during the principal tectonic phase. Instead, it must have been subsiding gradually since the thickness of

the conglomeratic deposits within it increased. Its surface must have maintained the same level in relation to the adjacent northeastern and southeastern source areas throughout the time of deposition. Otherwise, it would be hard to understand how this depositional area could have accumulated upward of 3,000 feet of Blumberg conglomerates in Albian time. All of the investigated part of Quatsino Sound is interpreted, therefore, as a regular piedmont depositional Albian trough. The surface of this depositional trough apparently represented a triangular-shaped alluvial plain confined between rapidly rising mountain ranges to the northeast, southeast and south (Fig. 13). This plain must have been seasonally overwhelmed by torrential floods depositing enormous volumes of psephitic debris derived through rapid erosion of these mountain ranges. The inferred paleogeographical relationships are illustrated by figure 12 and the block diagram of figure 13. The Albian (i.e. Blumberg time) subsiding depositional trough apparently spread eastward as compared with that of the Aptian time (i.e. time of deposition of the Coarse arenite unit). The strong contrast of thicknesses characteristic of the non-carbonaceous and coal-bearing facies of the Coarse arenite unit (Fig. 11) is, indeed, no longer apparent during the time of deposition of the Blumberg Formation (Figs. 12, 13).

UPPER CRETACEOUS STRATA

Upper shale unit

The axial part of a shallow, faulted, north-south trending and pronouncedly southward plunging syncline occupies the northern shore of Quatsino Sound between the point about 300 yards west of Ildstead Islets and that about 1,200 yards west of the mouth of Bish Creek. The core of this syncline contains a poorly exposed, recessive,

predominantly shale-siltstone unit which is definitely younger than the Blumberg Formation on structural grounds and because of the recent discovery of a Cenomanian (i.e. earliest Upper Cretaceous) marine fauna in its basal beds (Jeletzky, 1970a, pp. 210, 211). The informal name "Upper Shales" was used for this mappable unit by Jeletzky and Tipper (1968, p. 73) following the example of Dawson (1887, p. 88B). The lack of a suitable type section prevented the writer from naming this unit and the informal name - Upper shale unit - is perpetuated in this report.

Distribution and stratigraphy. The only other outcrop-area of the Upper shale unit within the investigated part of Quatsino Sound, is a small, strongly disturbed outcrop of lithologically identical shale (see unit 14 of section 32 in Appendix) in Winter Harbour. The previously made claims of the occurrence of the Upper shale unit in Koprino Harbour (Dawson, 1887, p. 88B) have been found to be erroneous as was pointed out in the section dealing with the Blumberg Formation (see p. 175).

Outside of the area proper, the Upper shale unit outcrops extensively on the northern coast of Vancouver Island in the central part of Christensen Point Cretaceous outlier (Jeletzky, 1969, pp. 130, 131; 1970a, pp. 211-212). There are reasons to think that this outcrop-area of the Upper shale unit extends southeastward to the headwaters of Strandby River and possibly to the vicinity of Holberg village.

Greywacke member. What appears to be the oldest part of the Upper shale unit outcrops on the tidal flats of the northern shore of Quatsino Sound between the exposed top of the type section of the Blumberg Formation and the point about 600 feet west of the mouth of Bish Creek. These predominantly arenaceous rocks are named herewith the Greywacke member of the Upper shale unit and interpreted as the initial phase of the basal Upper Cretaceous transgression of the Quatsino Sound area.

The Greywacke member appears to be stratigraphically transitional between the uppermost exposed beds of the Blumberg Formation (see Unit 1 of Sec. 36) and the lowermost beds of the Shale-siltstone member of the Upper shale unit exposed in the bed of Bish Creek. However, both contacts are covered and almost certainly faulted and the placement of these rocks into the basal part of the Upper shale unit depends on the inferred Albian age of the adjacent beds of the Blumberg Formation and the presence of the Cenomanian fauna in the greywacke member (see Bed 2, Sec. 38).

The youngest exposed beds of the Greywacke member of the Upper shale unit outcrop about 600 feet west of the mouth of Bish Creek. They appear to dip under the basal exposed beds of the Shale-siltstone member but a major north-trending fault is assumed to be present within the completely covered interval of the shoreline separating the visible top of this unit from the Shale-siltstone member of the Upper shale unit exposed in the bed of Bish Creek. The covered interval is about 150 yards wide. Immediately west of this covered interval, the Greywacke member consists predominantly of grey to green-grey, medium - to fine-grained, resistant, in places clayey greywacke, which is locally carbonaceous to coaly and contains much bark and fossil wood. The greywacke is interbedded with varying but locally large amounts of brownish grey, conchoidally to spheroidally weathering, considerably arenaceous, soft shale and siltstone. These shales and siltstones form beds 1/2 to 1 1/2 feet thick. Locally, however, the beds may be as much as 15 feet thick. They resemble closely the shale

and siltstone of the overlying Shale-siltstone member. The Greywacke member includes several thin (up to 4 feet?) interbeds of peculiar, fine to medium pebble conglomerate, which consists predominantly of 1/4- to 2-inch pebbles of grey shaly limestone and hard grey shale.

The thin but extremely important section 38 (see Pl. X, Fig. A) of the uppermost beds of the Greywacke member was measured 600 feet west of the mouth of Bish Creek. Farther west, the Greywacke member outcrops intermittently for about 1/2 mile along the shore before disappearing beneath beach deposits (see p. 177 and discussion of Unit 1 of Sec. 36). Throughout this interval, they are flexed in a number of minor, often canoe-shaped, mostly open, northerly to northwesterly trending folds and are faulted and contorted at most places. It was, therefore, impossible to work out the rock succession within the member or to determine its thickness. It appears likely, however, that the same 200- to 250-foot succession of beds is repeated several times by folding and/or faulting throughout this interval. This estimate agrees with the estimated minimum thickness of the member on the northern shore of Vancouver Island (Jeletzky, 1970a, p. 211).

The Greywacke member does not seem to outcrop on the eastern limb of the syncline and probably is missing there due to a fault or faults occurring in the covered interval, about 300 yards wide, separating the westernmost outcrops of the Blumberg Formation from the easternmost outcrops of the Shale-siltstone member west of Ildstead Islets.

Shale-siltstone member. These strata are believed to overlie the Greywacke member. Throughout its outcrop-area between the point about 300 yards west of Ildstead Islets and the bed of Bish Creek, the Shale-siltstone member of the Upper shale unit is

represented by dark grey, fissile, soft shales and siltstones which characteristically weather conchoidally to spheroidally. Thick loaf-like concretions, 4 to 5 inches thick, as well as pods, lenses, and intercalated lenticular beds, 3 to 12 inches thick, of similarly coloured, hard, calcareous shale or cryptocrystalline clayey limestone occur commonly in the unit. At several levels, siltstone and shale are interbedded with numerous 3- to 12-inch thick interbeds and lenses, and rows of concretions, 1 to 3 feet long and 2 to 6 inches thick, of brown to dark rust coloured, ferruginous, commonly quartzose, fine- to medium-grained sandstone.

Outcrops of the Shale-siltstone member are poor within the above-mentioned 1 3/4 miles of the shoreline. Both contacts are covered and the top of the unit is not reached.

On the eastern limb of the syncline, intermittent outcrops of the Shale-siltstone member extend for about 1 mile across its predominant strike of north 10 to 20 degrees west between its covered and evidently faulted eastern contact and the axis of the syncline. Within this interval, the unit dips between 5 and 10 degrees west, and the rocks are but little disturbed otherwise. At least 480 feet of the Shale-siltstone member should, therefore, be present within this interval.

A change in the attitude of the normally westerly dipping strata of the Shale-siltstone member takes place in the bed of Hawisnakwi Creek and around its mouth. There the strike becomes irregular and the dips become steeper. This fact, and the appearance of disturbed rocks of the Blumberg Formation, with steep easterly dips, just east of the mouth of Hawisnakwi Creek indicate that the two units are separated by a major, northerly trending fault.

On the west limb of the syncline, the last outcrops of the Shale-siltstone member occur in the bed of Bish Creek about 300 yards upstream from its mouth. The completely covered interval of the shore, about 200 yards wide, occurring west of the mouth of Bish Creek must contain a major fault since extensive outcrops of the lithologically different, intensely disturbed rocks of the Greywacke member occur on its western side.

Only the lower part of the Shale-siltstone member of the Upper shale unit seems to be exposed in the previously described syncline on the northern shore of Quatsino Sound since sections of the member, 1,000 to 1,500 feet or more, outcrop on both sides of Christensen Point on the northern shore of Vancouver Island (Jeletzky, 1969, p. 130; 1970a, p. 211).

A small outcrop-area of extremely strongly disturbed mostly pure shales, light grey to ash grey when fresh, lavender tinged when weathered occupies a large wooded point at the western end (on the north bank) of a nameless channel connecting Winter Harbour with Ahwhichaolto Inlet (see Fig. 18 and unit 14 of section 32 in the Appendix for further details). These shales did not yield any fossils with the exception of an indeterminate *Inoceramus*-like shell and some *Inoceramus* prisms and so cannot be dated biochronologically. They are, however, lithologically identical with the fossiliferous shales of the Cenomanian ?and Turonian part of the Upper shale member exposed west of Christensen Point and are tentatively assigned to this member. The presence of indeterminate *Inoceramus* fragments in the Winter Harbour outcrop-area gives some support to this correlation.

Age and correlation. The diagnostic ammonites of the marine fauna found in the uppermost exposed beds of the Greywacke member (see Unit 2 of Sec. 38) belong to the widespread North Pacific *Desmoceras* (*Pseudouhligella*) *japonicum* fauna. This fauna is of Cenomanian age according to Matsumoto (1959, p. 81) and is usually considered to be confined to the lower part of the Cenomanian stage (Jones, 1967, p. 4; Terekhova, 1969, pp. 163-196; Jeletzky, 1969). In western Canada, *D.* (*P.*) *japonicum* fauna was known previously only from the Cenomanian part of the Shale member of the Haida Formation in Queen Charlotte Islands (Sutherland-Brown, 1968, pp. 88, 90, 92). At least the upper part of the Greywacke member of Quatsino Sound Cretaceous outlier appears, therefore, to be a nearshore equivalent of the Shale member of the Haida Formation and ?the Shale-siltstone member of the Christensen Point outcrop-area. In the latter area the Greywacke member may be equivalent to part or ?all of the so far unfossiliferous basal 450 feet of the Shale-siltstone member.

In Quatsino Sound, the rocks of the overlying Shale-siltstone member are almost unfossiliferous, except for fossil wood and fragmentary, poorly preserved plant remains which occur locally. The predominantly marine origin of the member is, however, indicated by the common occurrence of limestone concretions, lenses and interbeds, and by the rare occurrence of small marine pelecypods and other indeterminate marine fossils. One locality (GSC loc. 24276) on the tidal platform about 300 yards west of Ildstead Islets (Pl. XI, Fig. A) has yielded Astarte? sp. indet. and an indeterminate irregular echinoid resembling Toxaster. These fossils are not diagnostic.

The Christensen Point sections of the Shale-siltstone member are more fossiliferous, probably because of their much larger outcrop-area. Puzosia (Puzosia) aff. dilleri Anderson, Tetragonites? sp. indet., indeterminate desmoceratid ammonite and Inoceramus aff. I. incelebratus Pergament found in the interval 450 to 1,000 feet above the member's base on the western limb of the syncline (Jeletzky, 1969, p. 131) are now believed to indicate a late Cenomanian or Turonian age. This conclusion is confirmed by the more recent discovery (Jeletzky, 1970a, p. 211) of Tetragonites ex aff. T. jacksonense Anderson (GSC locs. 83927, 83926) and ?Eucalycoceras ex aff. shastense Reagan (GSC loc. 83229) in the same interval on the eastern limb of the Christensen Point Cretaceous syncline. This fauna is most likely of late Cenomanian age even though its earliest Turonian age cannot yet be ruled out.

The topmost exposed (top of the Upper shale unit was not seen in any of its sections) 100 feet of the Shale-siltstone member were seen only on the eastern limb of Christensen point Cretaceous syncline where they contain specifically indeterminate, concentrically ribbed Inoceramus shells and fragments (Jeletzky, 1970a, p. 211). Because

of their stratigraphic position about 500 feet above the beds with presumably late Cenomanian ammonites, these *Inoceramus*-bearing siltstones are probably Turonian in age and equivalent to the uppermost beds of the Haida Formation containing *Inoceramus labiatus*? Schlotheim (Sutherland-Brown, 1968, pp. 88, 92).

Facies and paleogeography. The Quatsino Sound and Christensen Point outcrops of the Upper shale unit represent small erosional remnants of yet another Cretaceous marine transgression which apparently followed immediately the previously described strong Aptian-Albian uplift of the Quatsino Sound area. The areal extent of this early Cenomanian to early Turonian transgression is unknown. The almost exclusively shaly to silty lithology of known exposures of the Upper shale unit suggests, however, that most or all of the investigated part of Quatsino Sound was flooded by the Cenomanian-Turonian sea.

The early Cenomanian Greywacke member of Quatsino Sound is a more shallow water marine deposit (beach to intertidal) than the equivalent beds of the Shale member of Queen Charlotte Islands and the presumably equivalent basal part of the Shale-siltstone member of Christensen Point. This suggests the southeastward onlap of the early Cenomanian sea onto the subsiding northwestern part of the Albian landmass of Vancouver Island. No paleogeographic map has been drawn for the Cenomanian time because of the extreme scarcity of data available.

Nanaimo Group

Cedar District equivalents

No outcrops of Upper Cretaceous sedimentary rocks were known anywhere in Quatsino Sound until the recent discovery of a downfaulted block (a half graben) of marine fossiliferous Nanaimo Group greywacke at the headwaters of Lippy Creek on the eastern side of Neroutsos Inlet (Jeffery, 1962, geol. map). This Nanaimo outlier was studied in greater detail by the writer (Jeletzky, 1969, pp. 127-128; 1970a, p. 210) and the results obtained are presented below.

Location and stratigraphy. The half graben is about 2 1/3 miles long, inclined to the southwest, and occurs high on the northeastern slope of a nameless 2,500-foot high ridge situated between Alice Lake and the adjacent part of Neroutsos Inlet (see Fig. 17). Within this half graben, the Nanaimo arenites strike northerly to northwesterly and dip westerly at low to moderate angles. On the eastern side of the outlier, the Nanaimo rocks appear to be in normal contact with the underlying Barremian variegated clastic unit (see Sec. 29) but the contact is covered in all sections studied. Considering the great time interval (Aptian to early Campanian inclusive) separating the two rock units concerned, the contact must be at least erosionally disconformable. The occurrence of Aptian orogeny after the deposition of the Barremian variegated clastic unit suggests that this contact is regionally unconformable as well. It may well be that unit 5 of section 39 represents the upper part of the basal conglomerate of the Nanaimo Group in this outlier.

The western boundary of the Neroutsos Inlet outlier is a major fault which brings the Nanaimo Group arenites against the Quatsino limestone (see Fig. 17).

About 280 feet of dull brown, whitish grey or buff, mostly orange to dark brown weathering, fine- to rarely coarse-grained, locally gritty arenites, mainly arkoses or ?arkosic sandstones, outcrop in the longest and best exposed section of the Nanaimo Group within the Neroutsos Inlet outlier (see Units 1, 2 and 4-7 of Sec. 39). Some interbeds of richly fossiliferous arkose, greywacke, grit and ferruginous, fine-grained pebble conglomerate were observed near the visible base of the unit (see Unit 5 of Sec. 39). No shale or siltstone interbeds were seen.

Judging by the apparently complete absence of plant remains and carbonaceous to coaly interbeds, and the presence of rare marine shells irregularily scattered throughout the exposed thickness of the unit, most or all of the exposed part of the Nanaimo Group

consists of marine rocks. Except for the basal 40 to 50 feet of exposed strata, the arenites of the unit are massive to indistinctly bedded, fine to very fine grained with, in places, crossbedding and ripple-marks. Therefore, the arenites of the middle to upper part of the unit do not seem to be littoral types; it seems more probable that they were deposited in the deeper neritic zone, where there was little turbulence of waves and current.

Age and correlation. The presence of *Baculites* cf. *chicoensis* Gabb in unit 6 of section 29 near the visible base of the Nanaimo sequence suggests that the Upper Cretaceous sea flooded the Neroutsos Inlet area only in early Cedar District time (early late Campanian). The precise age of the middle and upper parts of the exposed sequence is obscure. However, the writer is inclined to believe that the Nanaimo sea had left the Neroutsos area of Quatsino Sound at the same time as it did the Suquash area on the east coast of Vancouver Island; i.e. before the end of *Metaplacenticeras* cf. *pacificum* time (Jeletzky, 1970a, p. 213).

Facies and paleogeography. As pointed out by Jeletzky (1969, pp. 130, 132-133; 1970a, pp. 210, 212-214), the isolated outliers of the Nanaimo arenites equivalent to the Cedar District Formation of the Nanaimo and Comox Basins occur on Hope Island, in Queen Charlotte Strait and in Suquash Basin on the northern coast of Vancouver Island. These small and widely scattered outliers of the Nanaimo Group on the northern part of Vancouver Island appear to be small erosional remnants of a widespread late Nanaimo transgression which covered most or all of the area in early late Campanian (Fig. 14).

Except for their basal, distinctly littoral beds, the arenites of the Neroutsos Inlet outlier appear to be a deeper water marine deposit (deeper part of neritic zone) than the much coarser grained, littoral to nonmarine arenites of Hope Island outlier and Suquash Basin. The latter outliers apparently were situated in the proximity of the eastern shoreline of the late Nanaimo (i.e. of the Cedar District time) sea whereas the Neroutsos Inlet outlier represents the offshore part of the same basin.

The writer (Jeletzky, 1970a, pp. 212-214) observed that marine interbeds decrease and then disappear southeastwards in the littoral to nonmarine Cedar District equivalents of the Suquash Basin until the unit becomes entirely nonmarine in the vicinity of Suquash River and in the upper course of Keogh River. This fact and the prevalence of northwest-dipping foreset beds in the Nanaimo rocks of Suquash Basin suggest that the sea advanced from the northwest or ?west and did not penetrate beyond Suquash River and the upper course of Keogh River, at least on the east coast of Vancouver Island (Fig. 14).

The above data, the apparently complete absence of the outliers of Nanaimo rocks south of Quatsino Sound and the inferred continuous presence of the elevated Brooks Peninsula land mass in this direction, suggest that the late Nanaimo sea did not penetrate southward beyond the line defined by the Suquash mine, head of Neroutsos Inlet, and Kwakiutl Point.

The position of the eastern shoreline of the Quatsino Sound embayment of the late Nanaimo sea is somewhat uncertain because of an apparent lack of Nanaimo outcrops east of the line: eastern side of Hope Island - Port Hardy - Port McNeill. However, the facies changes described above within these areas and the inferred northwestern and/or western origin of the early Cedar District transgression suggest

that the late Nanaimo sea did not penetrate much beyond its presently known easternmost and southeasternmost outcrops even beneath Queen Charlotte Strait. The eastern and southeastern shorelines of this embayment of the late Nanaimo sea shown in Figure 14 actually may have been placed too far east and southeast.

The above data supports Sutherland-Brown's (1966, Figs. 6-7) idea about the continuous presence of a wide isthmus separating the Quatsino Sound-Susquash Basin embayment of the late Nanaimo (i.e. Cedar District time) sea from its southeastern (Oyster River-Texada Island) embayment. The writer's interpretation of the Quatsino Sound-Suquash Basin embayment of the late Nanaimo sea (Fig. 14) differs only from that proposed by Sutherland-Brown (1966, Figs. 6-7) in assuming its westward extention beyond the west coast of Vancouver Island.

?EARLY TERTIARY INTRUSIONS

?Sooke Intrusions

A number of small- to medium-size bodies of intrusive rock varying widely in their size, texture, and mineralogical composition were found to invade the Lower Cretaceous sedimentary rocks and the high Upper Cretaceous Nanaimo Group in the investigated part of Quatsino Sound. As now known, they include medium- to coarse-grained leucocratic granite porphyry, diorite porphyry, holocrystalline gabbro and various finer grained dyke rocks ranging from ?rhyolite through ?dacite to diabase. These intrusive rocks are tentatively grouped in this report under the heading of "?Sooke Intrusions" as they are lithologically and stratigraphically-structurally similar to the Lower Oligocene intrusions of the Sooke and Buttle Lake map-areas (Gunning, 1931, p. 64A).

As with the Coast Intrusions, this report is concerned primarily with the stratigraphical and structural relationships of the ?Sooke Intrusions of Quatsino Sound. The microscopic petrography of these rocks is beyond its scope and the tentative petrographic assignment of some of the intrusive rocks is based solely on the macroscopic study of their hand specimens.

Previous Investigations. Dawson (1887, p. 84B) observed that the Lower Cretaceous sedimentary rocks of Quatsino Sound locally occur in contact with the intrusive rocks but he did not give any details. These observations were confirmed by Dolmage (1919, pp. 32B, 33B) who was apparently the first to clearly separate these post-Cretaceous intrusive rocks from the Jurassic Coast Intrusions. According to Dolmage (1919, p. 33B): "The only igneous rocks later than the Cretaceous are a few diabase dykes found cutting the sandstone in two places. These dykes are small in size and very few in number, but some of the numerous dykes of a similar composition found cutting the Vancouver formations where there is no Cretaceous exposed possibly belong to this period of intrusion". Gunning (1930, p. 107A) came to essentially the same conclusions as Dolmage (1919) in stressing the occurrence in the area of the pre-Coast Intrusion of diabase dykes lithologically indistinguishable from the post-Cretaceous ones; he states: "Also it should not be forgotten that diabase dykes, similar to those that occur cutting the rocks of the Vancouver group, have been found to intrude[1] the Lower Cretaceous rocks on Quatsino Sound. Although some of the diabases of the Vancouver Group may belong to this period of intrusion, all of them do not, for on Nimpkish Lake a medium-grained, greenish grey diabase is altered by garnet, epidote, and other contact metamorphic minerals and consequently antedated the mineralization which is related to the Coast Range intrusives".

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[1]Dolmage, V: Geol. Surv. Can., Sum. Rept. 1918, pt. B, p. 33.

Geographical Distribution and Composition. Most of the observed ?Sooke Intrusions of Quatsino Sound are dykes and sills not exceeding 10 feet in thickness. The rare plug-like to irregularly shaped bodies are somewhat larger but their maximum observed thickness along the shoreline does not exceed 150 feet. There are indications that some of these larger ?Sooke Intrusions widen inland and actually may be considerably larger than their observed parts. However, it is not expected that any possible inland extensions of these bodies would exceed a few hundred yards in diameter.

The easternmost group of ?Sooke Intrusions occurs on the northern shore of Quatsino Sound proper in the interval 1,000 to 1,450 yards west of the mouth of Aweisha Creek. This group consists of three small dykes and one dyke-like body at least 100 feet thick. The three small diabase to ?dacite dykes cutting the westerly dipping sedimentary rocks are described in connection with the description of the surrounding rocks of the Coarse arenite unit in section 34 (see Appendix).

The outcrop of the larger intrusive body which occurs in the middle of a completely covered stretch of the shoreline, about 350 yards wide, is about 100 feet wide (along the shoreline). It is followed by extensive outcrops of conglomerates of the Blumberg Formation that strike N20°W and dip 15°E. This intrusive body is, therefore, believed to occur either near or directly within a major northerly-trending fault zone and to be fault controlled. It consists of light brownish green to dull green-grey, extremely weathered ?diorite porphyry locally containing abundant large, well-developed phenocrysts both of a dark mineral and almost completely decomposed ?sodic feldspar. The fine-grained groundmass is composed largely of feldspar. The size of this ?dioritic body is unknown, but it could possibly underlie part of the 350-yard wide, beach-covered interval.

The second group of the ?Sooke Intrusives occurs on the northern shore of Quatsino Sound proper at the point about 1 mile west of the mouth of Bish Creek. It consists of three closely spaced, wedge-like bodies, 12 to 105 feet wide (along the shoreline), of medium- to coarse-grained, leucocratic granite porphyry (for further details see the description of Units 7-10 of Sec. 36). This granite porphyry is beige to whitish grey or light pinkish grey when fresh and weathers light brown; it includes some 20 to 25 per cent of visible quartz crystals. Numerous phenocrysts consist predominantly of rust- to orange-coloured potash feldspar (?orthoclase) and water transparent potash feldspar (?sanidine) and only very rarely of a dark mineral. All three wedge-like granite bodies narrow rapidly southward and the two smaller ones appear to pinch out completely within the tidal shelf in this direction. All three granitic bodies widen gradually northward (i.e. inland). There seems little doubt that they merge in this direction and are only the protuberances of a single much larger granitic intrusive body. This intrusive body apparently occupies the densely forested upper slopes of the coast in this area. The attached Figure 17 and profile reflect this interpretation. However, no time was available to check the validity of this hypothesis.

The granite protuberances are separated from each other by thin layers of bright rust- to maroon-coloured, metasomatically altered and partly "granitized" pebble to boulder conglomerate and are completely surrounded by a zone, at least 30 feet wide, of similarly altered conglomerate forming a well-defined thermal halo. Near the contacts with thermally altered Blumberg conglomerate, the granite contains large and small xenoliths of the latter.

Areas of thermally altered conglomerates of the Blumberg Formation are widespread in the Koprino Harbour outlier. They will be described in some detail because of the potential economic importance and inferred proximity to shallowly buried ?Sooke Intrusions. A zone of bright rust- to vermillion-coloured, metasomatically altered Blumberg conglomerate, at least 350 feet wide (along the shore) occupies the northern shore of Quatsino Sound immediately east of Lind Islet. This zone occupies both the tidal platform and the steep bluffs above it to a height of at least 120 feet above sea level (see Unit 17a of Sec. 36). A few small (less than 1 foot thick) patches of slightly "granitized" conglomerate and numerous calcitic veins occur within this zone but no significant intrusive bodies have been observed. This zone of metasomatically altered conglomerate apparently represents a thermal halo of a sizable ?Sooke Intrusive body concealed just beneath the surface within this part of the coast. Another zone, 120 to 130 feet wide (along the shore), of similarly coloured, thermally affected rocks of the Blumberg Formation occupies the tip and the southwestern side of a nameless rounded point next southwest toward Lind Islet.

The third zone, about 750 feet wide (along the shore), of similarly coloured, thermally affected Blumberg conglomerates occurs approximately 650 to 900 yards west of Lind Islet. It extends from the water's edge right to the top of a slope of the shoreline 60 to 90 feet high. This thermal halo is separated from the fourth zone, about 800 feet wide, of similarly coloured, thermally affected Blumberg conglomerate by about 450 feet of the unaltered grey to greenish grey coloured pebble conglomerate. For the next 400 yards along the shore only a few small (up to 60 feet wide) patches of rust- to maroon-coloured, metasomatically altered pebble conglomerate occur within its predominantly unaltered grey variety. Then, about 100 yards east of a deep,

lagoon-like embayment of the shoreline obviously representing a strong northeasterly trending fault zone, the conglomerate again turns intensely red and is cut by a number of hydrothermal calcite veinlets. This metasomatically affected rock extends for the next 300 yards along the shore on both sides of the above-mentioned embayment.

About 500 yards farther westward, a broadly rounded embayment of the northern shore of Quatsino Sound, about 450 feet wide and situated about 350 yards southeast of the tip of Prideaux Point, is occupied by yet another zone of metasomatically altered Blumberg conglomerate.

The last of these metasomatically altered zones, before reaching the eastern side of Koprino Harbour begins about 150 yards east of the base of Prideaux Point and continues across its entire width. Some unaltered, dark grey conglomerates occur within this zone.

No intrusive rocks or metasomatically altered Lower Cretaceous sediments have been observed on the east side of Koprino Harbour between the northern base of Prideaux Point and the head of East Cove.

The third group of ?Sooke intrusions occur on Lintlop Islet in the northeastern part of Koprino Harbour. This group consists of three irregularly shaped minor intrusions. Judging by the strong metasomatic alteration and local "granitization" of the adjacent clastics of the Blumberg Formation, these intrusions may be simply cupolas or protuberances of a single larger intrusion underlying most or all of the islet.

The southern tip of Lintlop Islet is occupied by an irregularly shaped intrusive body, about 75 feet long (in east-west direction) and 45 feet wide, consisting of an aphanitic to slightly porphyritic, dark grey, probably andesitic dyke rock. The intrusive rock disappears beneath the water on three sides but on the northern side it

invades indurated and metasomatically altered finer clastics of the Blumberg Formation. The latter are considerably altered metasomatically and possibly "granitized" within a zone, 18 to 35 feet wide, adjacent to the intrusive contact and then become progressively less strongly metasomatically altered ("bleached") and indurated within the next interval which is 150 feet wide. A covered interval, 15 to 25 feet wide, occurs next followed by the reappearance of ?andesitic intrusive rock on the western side of the islet. This rock extends for at least 150 feet farther northward forming a somewhat irregularly rounded, plug-like body. The maximum visible width of this body (in its middle part) is 160 to 170 feet but it may be considerably wider since its eastern contact is concealed in the forested central part of the islet and its western contact is concealed beneath the sea. Northward this intrusive body rapidly tapers into a protuberance, 10 to 15 feet wide, which disappears beneath the sea. Like the first ?andesitic intrusive, this body invades metasomatically altered sediments of the Blumberg Formation.

The third intrusive body, 320 to 340 feet long (in north-south direction) and 20 to 130 feet wide, occupies the northwestern tip of Lintlop Islet. It is separated from the northern end of the second intrusive body by a partly covered interval, 150 feet wide (in north-south direction). Numerous patches of altered Blumberg Formation clastic rocks outcrop within this interval. These sediments are intensely altered and partly metasomatically replaced by the intrusive rock (i.e. "granitized") within a zone 30 to 40 feet wide, adjacent to the southern part of the intrusive body. Farther north, the contact between the intrusive and the surrounding sediments is invariably concealed. The western and northern contacts of the body are everywhere concealed beneath the sea.

The southernmost part of the third intrusive body, 120 to 130 feet long and 20 to 80 feet wide, is composed of the same ?andesitic dyke rock as the other two bodies. Farther north, this marginal intrusive facies is rapidly replaced laterally by dark to blackish grey, medium- to coarse-grained, mainly equigranular gabbro, which rock type constitutes the remaining northern part of the body which is 200 to 214 feet long and up to 135 feet wide. The contact of both intrusive facies appears to be gradational. The gabbro is considerably contaminated by xenoliths of the surrounding Blumberg Conglomerate and locally contains numerous calcite amygdules. The apparently complete absence of the ?andesitic marginal intrusive facies at the western and northern margins of gabbro exposures suggests that this intrusive body extends for some distance beneath the sea in this direction. This assumption is supported by the fact that Diggs Islet, situated about 550 yards west of Lintlop Islet in the mouth of Koprino River, is underlain mainly by maroon, metasomatically altered Blumberg clastic rocks. Furthermore, the same is true of medium- to coarse-grained pebbly sandstones of the Blumberg Formation outcropping about 500 to 600 yards east of Lintlop Islet around the head of East Cove.

?Sooke Intrusives have not been observed anywhere else within Koprino Harbour. However, a zone about 300 yards wide (along the shore), of maroon, metasomatically altered Blumberg clastic strata occurs in the northwestern corner of Robson Cove. Another zone, 50 to 60 yards wide, of reddish orange to maroon, metasomatically altered (including a few calcitic veins) occurs at the northern entrance to Robson Cove on the southwestern flank of a shallow syncline, the axis of which is situated behind Dockyard Islet. A third zone of such metasomatically altered Blumberg clastics occupies all of the eastern side of Schloss Island. All these zones are believed

to be thermal haloes of one or more shallowly seated ?Sooke Intrusions, which have invaded the surfaces of several large, northerly to northwesterly trending faults auxiliary to the Mahatta Fault Zone.

The fourth and the last known occurrence of ?Sooke Intrusions consists of a single sill-like body of ?rhyolite, more than 10 feet thick, which invades the Nanaimo Group in the Neroutsos Inlet outlier (see Unit 3 of Sec. 39). This small intrusive body is rather important for the purposes of dating and correlation of ?Sooke Intrusions.

Structural relations and mode of emplacement. Most of the known bodies of ?Sooke Intrusives invade intensely faulted and locally drag-folded Lower Cretaceous rocks within the basin-like part of the Koprino Harbour outlier. The same is true of all the above described areas of metasomatically altered Lower Cretaceous rocks believed to represent thermal haloes of shallowly seated ?Sooke Intrusives.

All of these intrusive bodies and thermal haloes occur within or adjacent to defined or inferred major fault zones. Most of the observed dykes seem to follow well-defined fault surfaces.

No tightly compressed and overturned folds or pronounced shearing and crushing of the surrounding sedimentary rocks attributable to the forcible injection of ?Sooke Intrusions were observed. It is concluded from this that the ? Sooke Intrusions are younger than the major post-Lower Cretaceous (?Tertiary) faults of Quatsino Sound, and that these intrusions have invaded the zones of weakness caused by the faulting under the conditions of regional tension.

The extremely variable acidic to basic composition and the felsitic, amygdaloidal, or finely to coarsely porphyritic (in larger intrusive bodies only) texture of most known ?Sooke Intrusions of Quatsino Sound (except for the gabbro body of Lintlop Islet) suggests that they are exclusively shallow-seated to hypabyssal apophyses and cupolas of the larger, possibly batholithic Tertiary granitoid intrusions which are still concealed at depth in this structurally depressed part of Vancouver Island (cf. under Coast Intrusions, p. 110).

This hypothesis finds additional support in the widespread occurrence of previously described small to large areas of rust- to orange-coloured, metasomatically altered Lower Cretaceous sediments within the Koprino Cretaceous outlier. These areas of altered sediments are lithologically identical with the thermal haloes of rust- to orange-coloured, metasomatically altered to regularly "granitized" sedimentary rocks surrounding the larger granite-porphyry intrusions observed in the type section of the Blumberg Formation east of the mouth of Blumberg Creek. It is believed accordingly that most or all of the above-mentioned areas of metasomatically altered Lower Cretaceous sediments represent thermal haloes of granitic ?Sooke Intrusions which lie just beneath the surface in these areas of Koprino outlier but are not yet unroofed at any point of the available outcrop-areas.

The alternative hypothesis, that most or all of these areas of metasomatically altered Lower Cretaceous sediments have resulted only from the penetration of hydrothermal solutions from depth along the shattered rock zones, appears to be improbable because of the close association of several of these areas of metasomatically altered sediments with the known ?Sooke Intrusions and their lithological identity with the thermal haloes surrounding these.

Age and correlation. Because of the extreme rarity of late Upper Cretaceous sedimentary rocks within the investigated part of Quatsino Sound, most of the above ?Sooke Intrusions can be directly dated only as of post-Cenomanian age. However, in Buttle Lake map-area, similar intrusive rocks are known to invade the mid-Upper Cretaceous sediments of the Nanaimo Group (Clapp, 1912, p. 106; Gunning, 1931, p. 64A) and the same is true of at least one small sill-like body of ?Sooke Intrusions in the report-area (see Unit 3 of Sec. 39).

The post-Nanaimo intrusives of Buttle Lake map-area were originally dated as of Eocene age by Clapp (1912, p. 106). However, Clapp (1917, p. 304) subsequently suggested a lower Oligocene age for these intrusions and correlated them with the ?Sooke Intrusions of the southeastern part of Vancouver Island. The latter correlation was tentatively accepted by Gunning (1931, p. 64A). All of the post-Cenomanian intrusions of Quatsino Sound are accordingly dated as of Lower Tertiary age and correlated tentatively with the ?Sooke Intrusions. Their latest Late Cretaceous (Maestrichtian) age appears to be most unlikely but cannot be ruled out at present.

The previously stressed subordination of all known intrusive bodies of ?Sooke Intrusions to defined or inferred, presumably Tertiary faults supports the post-Cretaceous age of the ?Sooke Intrusions of Quatsino Sound. However, this circumstance could indicate also that these intrusions are of post-Oligocene age since most or all of the major faults of the west coast of Vancouver Island are known to cut the fossiliferous Oligocene and ?lower Miocene sedimentary rocks (Jeletzky, 1954b, geol. maps).

OLIGOCENE AND ?MIOCENE ROCKS

Carmanah Group

No outcrops of the Oligocene and ?Miocene sedimentary rocks, such as occur locally on the west coast of Vancouver Island (Jeletzky, 1954a, 1954b) have been encountered

within the investigated part of Quatsino Sound. There is no evidence suggestive of their presence anywhere around the mouth of Quatsino Sound or for that matter anywhere on the west coast of Vancouver Island between Brooks Peninsula and Cape Scott.

?Late Tertiary volcanic rocks

No outcrops of the ?late Tertiary volcanic rocks have been encountered within the investigated part of Quatsino Sound. These rocks, consisting of fresh basaltic flows and poorly consolidated brick-red and brown volcanic tuffs and breccia, were originally discovered by Dawson (1887, p. 61B) in the vicinity of Port McNeill well outside of the report-area.

Muller (1967, p. 81, Fig. 1) has mapped recently numerous outliers of the above-mentioned Tertiary volcanic rocks on Straggling Islands, on parts of the northern coast of Holberg Inlet, and as a cap on Twin Peaks.

As shown on Muller's (1967, p. 82, Fig. 1) geological sketch map, the outcrop-area of the ?late Tertiary volcanic rocks includes small exposures of light grey, intensely altered volcanic breccia and dark grey porphyritic lava encountered by the writer in the bed of Nuknimish Creek at the point about 1,000 feet upstream from its first fork (see Unit 7 of Sec. 30). These intensely sheared and jointed volcanic rocks are, however, lithologically similar to those of the upper part of the Basal Jurassic volcanic unit of the Bonanza Subgroup and are invaded by small bodies of the felsitic Coast Intrusions; they have been mapped accordingly in this report.

The completely shattered and strongly metamorphosed, light grey to whitish grey, rust-red volcanic ?breccia underlies the sharp point closing Apple Bay from the southeast and from there extends for some distance toward the southeast along the shore.

This volcanic ?breccia likewise forms part of the outcrop-area of Muller (1967, p. 82, Fig. 1). However, the lithology of this volcanic ?breccia is very similar to that of the third facies of the Hecate Cove Formation and it is invaded by two bodies of basic, porphyritic to amygdaloidal intrusive rock similar in lithology to that of the Karmutsen volcanics. One of these bodies, which are tentatively referred to the Coast Intrusions, is a west-trending dyke, from 6 to 12 feet wide, and the other is an irregular plug-like body, 60 to 100 feet wide. This volcanic ?breccia was included accordingly in the Hecate Cove Formation of the Bonanza Subgroup together with other rocks (see p. 47) exposed on the relatively upthrown southern limb of the Holberg Fault for about 2 miles east of Apple Bay. This procedure follows the conclusions of Dawson (1887, p. 91B and geol. map).

STRUCTURAL GEOLOGY

The report-area extends across the structural grain of the Insular Tectonic belt and this fact compensates somewhat for the limited region covered by the writer's investigation. It is hoped, therefore, that this survey will contribute to the understanding of several previously unsolved structural problems of northwestern Vancouver Island. The solution of these problems has been hindered by the almost complete lack of reliable lithological markers, erratic changes of facies within short distances across and along the strike, and the absence or extreme paucity of index fossils in most of the Mesozoic units within the report-area and the adjacent parts of northwestern Vancouver Island.

PREVIOUS INVESTIGATIONS

Dawson (1887) was the first to comment on the structural geology of Quatsino Sound. He recognized the prevalence of northwestern strikes and southwesterly dips of the altered volcanic and sedimentary rocks of the "Vancouver series" and pointed out that these rocks are probably repeated either by folding or by faulting and that their eroded surface is locally overlain unconformably by folded and faulted but essentially unaltered Cretaceous rocks. Dawson (1887, pp. 85B-86B) defined two of the principal faults (i.e. Holberg and Mahatta Faults of this report) cutting the "Vancouver series" and the Cretaceous rocks alike and correctly assessed their regional significance.

Dolmage (1919, p. 32B) observed that: "The rocks of the Vancouver Group are steeply folded along a northeast and southwest direction, and in the region examined the dips are very consistently to the west. Considerable faulting has also occurred, particularly in the region where the main channel of the sound branches out into the various arms".

The following entirely different tectonic style has been suggested by Gunning (1930, pp. 104A-105A) for rocks of the Vancouver Group of the Quatsino-Nimpkish map-area:

> There are important intrusions of granitic rocks and it is evident, in the field that the folding and contortion of the rocks of Vancouver group are directly connected with the intrusions. The general tendency seems to be a contortion and tightly compressed folding of the intruded rocks near the intrusive with a doming up of the former around the latter so that locally, near gigantic stocks and between adjacent ones, almost any attitude may be expected. There is not yet sufficient detailed information to reveal the structure across the strike, but it is presumed that the rocks of the Vancouver group are compressed into a series of parallel overturned folds with the prevailing dip to the southwest. If this is not so we would be forced to conclude that there is a continuous succession of volcanic and sedimentary beds from the east and the west side of the island and the resultant thickness of the group would be so enormous that one is forced to discredit the possibility. Also there is evidence in several places of repetition of beds due to tight folding and overturning.

The structural role of faulting was obviously minimized by Gunning (1930, pp. 104A-105A), even though he pointed out the existence of numerous minor faults and suggested the existence of major faults in the vicinity of Quatsino Narrows.

Among later workers, Sutherland-Brown (1966, p. 85) has stressed the prevalence of faulting over folding throughout the Insular Belt and pointed out that the compressed and overturned folds appear to be: "limited to special adjustments between fault blocks, between panels of volcanic rocks, or adjacent to intrusive plutons".

Muller (1967, p. 83) pointed out that the structure of the eastern part of Quatsino Sound "consists of tilted blocks separated by two or three sets of normal faults, trending northwest, north and northeast". More recently, Muller (1970, p. 48, sketch map of northern Vancouver Island) concluded that the Alert Bay and Cape Scott areas: "like other parts of the island exhibit a southwestward increasingly complex block-fault structure. The greater fragmentation of the southwestern belt is possibly related to the thinning of the rigid 'shield' of Karmutsen volcanic rocks. Two principal northwest-trending faults separate three major southwestward tilted fault blocks".

FOLDS

The oldest clearly discernible fold structures of the investigated part of Quatsino Sound appear to be the late Norian to latest Triassic (Rhaetian) tectonic lands and residual troughs resulting from the latest Triassic orogenic phase. For reasons explained by Jeletzky (1970b, pp. 5-9) and summarized in the late Triassic sections of this report, the latest Triassic tectonic movements apparently not only uplifted the rocks of the Sedimentary division of the Bonanza Subgroup but also faulted and flexed them into a number of northwest-trending folds. The previously discussed Coal

Harbour-Alice Lake Tectonic Land is interpreted as one of these latest Triassic anticlinal folds. Another such anticlinal fold is probably represented by the previously discussed Southwestern Tectonic Land. The intervening residual Neroutsos trough and the West Coast trough are believed to be synclinal folds of the latest Triassic time (see pp. 29-35, 52-57 and Figs. 3, 4).

The generally moderate to gentle folding of the late Triassic rocks in those parts of Quatsino Sound distant from the major faults and intrusive bodies indicates that these latest Triassic folds were wide open structures with gently to moderately dipping limbs.

Another pre-Upper Jurassic fold structure of the investigated part of Quatsino Sound is the regional, north-northwest- to almost north-trending homocline of the Vancouver Group. This homocline is clearly revealed in the arrangement of the belts of the individual units of the Vancouver Group in the attached Figures 17 and 18. In spite of numerous and commonly pronounced local irregularities caused by the invasion of Coast Intrusions and the post-Cretaceous faulting, the north-northwest to almost north-trending units of the Vancouver Group become progressively younger westward across the strike.

The pre-Upper Jurassic homocline of Quatsino Sound originally extended across the prevalent strike direction of the Vancouver Group at least from the head of Rupert Inlet to the head of Browning Inlet. This homocline appears to represent part of the southwestern limb of the so-called geanticlinal core of Vancouver Island (Sutherland-Brown, 1966, p. 85), which shall be referred to as the Vancouver Island anticlinorium in this report.

The pre-Late Jurassic age and the gently to moderately dipping, open nature of the Quatsino Sound homocline of the Vancouver Group is indicated by the fact (already noted by Gunning, 1930, pp. 104A-105A and p. 208 of this report) that within the report-area, rocks of the Vancouver Group dip steeply to vertically and are contorted only in the proximity of the Middle Jurassic Coast Intrusions and the numerous post-Lower Cretaceous major faults. Away from the plutons and faults, these rocks commonly become only moderately folded in spite of their marked to intense jointing, shearing, and minor faulting; locally their dips do not exceed 20 to 30 degrees. The homocline appears to be a post-Triassic structure since it affects similarly the late Triassic part of the Vancouver Group which had suffered the effects of the latest Triassic orogenic phase, and the early Jurassic part of the group which postdates this phase. The intense Early Jurassic volcanism that occurred at intervals within the tectonically and volcanically active zone of the Insular Tectonic Belt (Jeletzky, 1970b, pp. 18-23, Figs. 1, 2 and the earlier sections of this report) suggest that the Early Jurassic faulting had preceded ?and/or accompanied the formation of this regional homocline.

The previously discussed (Jeletzky, 1970b, pp. 21-23; and pp. 103-115 of this report) Lower Jurassic paleogeography confirms the conclusion that the homocline of Quatsino Sound, and consequently the anticlinorium of Vancouver Island, began to form after the deposition of the youngest sedimentary (i.e. Pliensbachian-Toarcian greywacke unit) unit of the Volcanic division of the Bonanza Subgroup.

The Middle Jurassic homocline of Quatsino Sound was more or less distorted by the invasion of the apparently penecontemporaneous to ?somewhat younger plutons of the Coast Intrusions. It was formed, therefore, before the end of Middle Jurassic time.

Contrary to Gunning's (1930, pp. 104A-105A) interpretation, all deformations of the Vancouver Group rocks by the Coast Intrusions, including their contortion and tight folding in the proximity of the Coast Intrusions, are regarded by the writer only as a subordinate, localized phenomenon of the Middle Jurassic orogeny.

A much greater distortion of the Middle Jurassic homocline resulted from closely spaced major faults striking in several directions and generated by several Cretaceous and Tertiary tectonic movements. These faults have split this homocline into several disconnected sections and locally have almost obliterated its original nature.

Except for the latest Triassic folds and the Middle Jurassic regional homocline of the Vancouver Group, no regional fold pattern is recognizable within the report-area.

The rocks of the Vancouver Group and the Lower Cretaceous sediments are flexed in a great number of variously oriented, small- to medium-size, commonly more or less contorted folds. These younger folds are always confined to the individual principal fault blocks and normally extend only over parts of the latter. The vast majority of these folds appear to be drag-folds or pressure ridges of one kind or another generated by the movements on the principal or major faults delimiting or dissecting the principal fault blocks.

FAULTS

As elsewhere in the Insular Tectonic Belt (Sutherland-Brown, 1966, p. 85; Muller, 1967, p. 83; 1970, p. 48), the structure of the report-area is dominated by several principal (as defined on p. 214) faults. These trend northwest to west-northwest and delineate four or five structurally disconnected, large to medium fault blocks (Fig. 15). These principal (see p. 230) fault blocks are either strongly upthrown or strongly down-

thrown relative to one another which clearly demonstrates the prevalence of dip-slip movements. The principal fault blocks are tilted in different directions. Consequently, they expose rock sequences which commonly differ considerably from each other. In spite of these contrasts in the stratigraphy of the individual principal fault blocks, the intensity, type, and scale of tectonic structures remain more or less uniform throughout the surveyed area.

The most outstanding and significant internal structural feature of all surveyed principal fault blocks is the presence of a multitude of closely spaced major and minor faults striking in several directions. North, northeast, northwest and nearly east-west directions appear to be predominant. Relatively few of these lesser faults could be shown on the attached Figures 17 and 18. These lesser faults split all principal fault blocks into innumberable smaller to minute (measured in square yards or even feet), irregularly shaped fault blocks. Extensive parts of the report-area are so intensely faulted, sheared and jointed as to resemble coarse tectonic breccia.

Regular, major scale, intermediate to high angle thrust faults are rare within the area and even high angle to near vertical reverse faults are uncommon. The vast majority of the observed or inferred principal, major and minor faults appear to be normal, high angle to near vertical faults. However, one of the most important northwest-trending fault zones of the area (i.e. Mahatta Fault Zone) is known to have a prevalent strike-slip component, and appears to be a regular right-hand (dextral) strike-slip fault. The same appears to be true of another principal, west-northwest trending fault (Holberg Fault) and major strike-slip faults may be considerably more common and structurally important than they now seem to be.

For reasons given by Jeletzky (1970b, pp. 5-9 and in preceding sections of this report) the report-area must have been transected by a number of large faults prior to the early Rhaetian (i.e. time of deposition of Hecate Cove Formation). However, no direct evidence of this latest Triassic faulting has been observed so far.

The conclusion (see previous section, p. 210) for the occurrence of large scale faulting during the tectonically and volcanically active early Jurassic time is so far only supported by the obvious concentration of Coast Intrusions along the downthrown southwestern side of the Browning Inlet Fault (see p. 217). Except for this isolated piece of evidence, there is no direct indication of any pre-Middle Jurassic faulting. All other observed or inferred faults appear to transect indiscriminately all layered rock units of the area including the Cenomanian Upper Shale unit and the high Upper Cretaceous (Campanian) Nanaimo rocks. However, they do not seem to disrupt the presumably early Oligocene ?Sooke Intrusions. It is concluded therefrom that all principal major and minor faults of the area have been active in the post-Campanian time. It is this latest Cretaceous (i.e. Maestrichtian) and/or Tertiary faulting that has molded the present day structural pattern of the investigated area and of the adjacent parts of northwestern Vancouver Island.

Most of the large scale faults of Vancouver Island are known to be Tertiary (i.e. post-Nanaimo) structures (see Jeletzky, 1950, 1954b, geol. maps; Sutherland-Brown, 1966, p. 85, Figs. 6-10). The post-Late Cretaceous faults of Quatsino Sound are therefore assumed to be largely or chiefly of Tertiary age.

The validity of the previously discussed evidence regarding the pre-early Oligocene (i.e. pre-Sooke Intrusions) age of post-Late Cretaceous normal and ?strike-slip faulting appears to be doubtful. First, the ?Sooke Intrusions are rather rare within the investigated

area and this has prevented the writer from firmly establishing their structural relationships with the principal and major faults. Second, the early Oligocene age of the ?Sooke Intrusions of Quatsino Sound is not firmly established. They could conceivably be younger (Miocene or even Pliocene). Third, and lastly, many large scale faults of northwestern Vancouver Island are known to cut Oligocene and ?lower Miocene sedimentary rocks (Jeletzky, 1950; 1954b; geol. maps). Some of the major faults of Quatsino Sound (e.g. Browning Inlet Fault; see below) appear to be direct extensions of these late Tertiary faults.

Only the principal faults delimiting the principal fault blocks of the report-area and major faults otherwise important for the understanding of its structural framework are discussed below and shown in Figure 15. A considerable number of other, less important, defined or assumed faults have been mentioned in the stratigraphical part of this report and/or shown on the attached geological maps and profiles.

Grant Bay Fault

The existence, orientation, and extent of this poorly understood but apparently important major fault at the western edge of the report-area is inferred from structural relationships observed in the northern corner of the lagoon occurring at the head of Browning Inlet and an obvious north-south alignment of several adjacent topographical features. The trace of the Grant Bay Fault is not exposed but its presence underneath a strip of beach deposits, about 200 yards wide, occurring in the northern corner of the lagoon is indicated by abrupt changes of attitude and of age of rocks of the Volcanic division at that point. On the east side are the basal beds of the Uppermost Sinemurian volcanic unit and Matthews Island Formation striking toward the northwest, and dipping

moderately to steeply toward the southwest. On the western, downthrown side of the covered interval outcrop are ?dacites of the Coast Intrusions possibly invading the fault surface. These ?dacites are followed by shales tentatively correlated with the Uppermost Sinemurian argillite unit which strikes toward the northwest and dips steeply (70°-80°) toward the east. These shales are overlain unconformably by synclinally bent Buchia crassicollis greywacke. If the suggested correlation of the above-mentioned shales with the Uppermost Sinemurian argillite unit is correct, some 500 to 600 feet of rocks of the Uppermost Sinemurian volcanic unit are missing due to the Grant Bay Fault. If these shales are younger and of Pliensbachian and/or Toarcian age, the thickness of faulted out rocks could be considerably greater. The stratigraphic throw of the Grant Bay Fault is not known. Farther south, the Grant Bay Fault appears to underlie the lagoon of Browning Inlet throughout its length. Then it appears to underlie the densely wooded neck of low ground separating the southern end of the lagoon from the inner part of Grant Bay and to disappear beneath the ocean. The nearly straight course and northern orientation of the middle course of Kwatleo Creek valley directly north of the northern corner of the lagoon and the alignment of several other topographic features farther north suggest the extension of the Grant Bay Fault for a considerable distance in this direction. However, it seems more likely that it merges with the Browning Inlet Fault (see below) in the northern corner of the lagoon and this interpretation is tentatively adopted in Figure 15.

The straightness of the above-described north-south topographic lineament apparently underlain by the Grant Bay Fault suggests its vertical or near vertical dip. There are no indications of strike-slip movements along the Grant Bay Fault; it is interpreted, therefore, as a normal fault possibly subsiduary to the Browning Inlet Fault.

Browning Inlet Fault

The presence of a strong northwest-trending fault beneath Browning Inlet and beneath the narrow channel separating Matthews (= Robson) Island from Flat Top Mountain massif is indicated by intense shearing and contortion of rocks on both sides of the inlet and by the repetition of the succession of the southwest-dipping Matthews Island Formation and the Uppermost Sinemurian volcanic unit on both sides of the channel. This repetition of beds indicates that the southwest side of Browning Inlet Fault is relatively downthrown and that at least 500 to 600 feet of rocks of the Uppermost Sinemurian volcanic unit are faulted out along its surface. There is no way to determine the stratigraphic throw and direction of dip of the Browning Inlet Fault but its essentially straight course suggests that it is a vertical or near vertical normal fault. As yet, there is no evidence of strike-slip movements along the Browning Inlet Fault but this possibility should not be discounted.

Browning Inlet Fault apparently either merges with the Grant Bay and Galato Faults or transects these two faults at or near the northern corner of the lagoon of Browning Inlet. The former hypothesis is favoured in this report because of the presence of an extremely well-defined northwest-trending topographic lineament connecting this corner with the sharp bend of Macjack River valley occurring about one and one-half miles above its mouth. This lineament extends farther northwest along the west coast of Vancouver Island and suggests a considerable extent and regional importance of the Browning Inlet Fault. This was already noted by Sutherland-Brown (1966, p. 91, Fig. 6-10) who has shown the Browning Inlet Fault as extending all the way from San Josef Bay to Esperanza Inlet.

An interesting peculiarity of the Browning Inlet Fault consists in the invasion of several, apparently related, small- to medium-size northwest-trending plutons of Coast Intrusions all along the known extent of its downthrown, southwestern side. This plutonic activity is accompanied by a widespread, strong contact metamorphism and, locally, by granitization of the surrounding rocks of the Volcanic division. The close association of Coast Intrusions with the Browning Inlet Fault suggests its being an ancient pre-Coast Intrusion fracture. This pre-existing regional fracture could have facilitated the upward movement of the Coast Intrusions and explain their obvious concentration along the fault plane. The above-mentioned offset of the rocks of the Volcanic division by the Browning Inlet Fault indicates that it was active (reactivation?) in post-late Late Cretaceous (Tertiary?) time.

The relatively insignificant vertical displacement along the Browning Inlet Fault and the fact that it does not terminate the structural continuity of the rocks of Forward Inlet Fault Block may well be a local feature caused by the distribution of the displacement among several major faults (e.g. Grant Bay and Galato Faults) within its studied section. Therefore, Browning Inlet Fault may well have to be treated as a principal fault when its northwestern extension beyond the assumed point of coalescense with Grant Bay and Galato Faults has been studied in sufficient detail.

Galato Creek Fault

As with Grant Bay and Browning Inlet Faults, the approximate position, orientation and extent of the Galato Creek Fault had to be inferred from structural relationships of Lower Cretaceous rocks observed in the northeastern basin of Winter Harbour between the northwestern end of Ahwhichaolto Inlet and the mouth of Galato Creek, and from the obvious west-southwest alignment of several topographic features between Galato Creek and the head of Browning Inlet.

The abrupt changes of attitude and age of strongly dislocated and partly overturned Lower Cretaceous and Lower Jurassic rocks across the northeastern part of the narrow channel connecting Ahwhichaolto Inlet with the northeastern basin of Winter Harbour clearly indicate that the west-southwest trending Galato Creek Fault underlies this part of the channel. The north-northwest side of the fault is downthrown throughout this interval.

Galato Creek Fault appears to cut into the southeastern shore of the channel at the point about 1/4 mile southwest of the entrance to Ahwhichaolto Inlet and thence the fault appears to continue on a general west-southwest course across the low, densely wooded stretch of land adjoining the basin from the southeast until it disappears beneath the water at the southern base of a nameless point situated about 1/4 mile east of the eastern tip of Wedel Island. Farther west-southwest, the Galato Creek Fault underlies the narrow channel between Wedel Island and the southeastern shore of the basin, then cuts obliquely across the latter and enters its northwestern shore at the mouth of Galato Creek. So far as known, the west-northwest side of the fault is downthrown throughout the interval and is composed mainly of moderately faulted, contorted, east-west to northwest striking and gently to moderately north- to northeast-dipping rocks of the Coarse arenite unit (see description of Sec. 33).

The rocks of the relatively upthrown east-southeast side of Galato Creek Fault appear to be composed of the older Lower Cretaceous Buchia crassicollis greywacke, Hauterivian siltstone unit, and Inoceramus colonicus calcarenites throughout this interval. These rocks have extremely variable strikes and dips and are locally vertical to overturned. They are strongly to very strongly faulted, jointed and sheared. Several supplementary, tight to disharmonic, north-trending folds and zones of contorted rocks, as much as several hundred feet wide, occur on this side of the fault (see description of corresponding sections of Buchia crassicollis greywacke and Hauterivian siltstone unit).

West-southwest of the mouth of Galato Creek, the fault appears to underlie a nearly straight, well-defined strip of low, partly swampy ground extending to the head of Leeson Lake and thence from the southwestern end of the lake to the point just northwest of the head of Browning Inlet. There was, however, no opportunity to check the validity of this working hypothesis on the ground.

Most of the trace of Galato Creek Fault is concealed beneath the water and it seems to be invariably covered wherever it crosses the shores of Winter Harbour. Therefore, no direct information is available about its attitude or exact course. So far as it is possible to judge, the trace of Galato Creek fault is distinctly sinuous (see Fig. 18), which suggests that its plane is not vertical or near vertical but dips at a steep angle.

Because of its occurrence between two major, respectively possible and known, strike-slip faults and because of its orientation, it is tempting to interpret the Galato Creek Fault as a subsiduary high angle thrust which was generated by horizontal movements along the former faults. However, the relatively much less contorted character of the downthrown west-northwest side of Galato Creek Fault is against this interpretation. One would, indeed, expect the lower plate of the thrust to be much more broken than the upper plate. Galato Creek Fault is, therefore, interpreted tentatively as a steeply west-northwest dipping normal fault. There is no evidence of any strike-slip movements along its trace.

It is impossible to estimate the thickness of rocks faulted out along the plane of Galato Creek Fault since the complete thicknesses of the Barremian fine-grained greywacke unit and the non-carbonaceous facies of the Coarse arenite unit are unknown. It seems safe to say, however, that more than 1,000 feet of rocks are missing there because of this fault, but there is no way to estimate the stratigraphic throw of the fault.

Galato Creek Fault apparently branches off the Mahatta Fault Zone and is one of its major subsiduaries. Its assumed structural relationships with the Browning Inlet and Grant Bay Faults have been discussed already.

The shores of the narrow channel connecting Ahwhichaolto Inlet with the northeastern basin of Winter Harbour as well as the shores of Winter Harbour are cut by a multitude of major and minor, mostly northwest- to north-northwest, and west-trending faults. These faults may be mere subsiduaries of the Galato Creek Fault as they are most numerous in the proximity of its inferred course and decrease in number and size away from the latter.

Mahatta Fault Zone

The principal fault zone named the Mahatta Fault by Muller (1970 p. 46, sketch map of northern Vancouver Island) was first recognized by Dawson (1887, pp. 84B-87B), who traced it across the investigated part of Quatsino Sound and fully recognized its regional importance. This second largest and very important fracture of the area trends N45° to 55°W within its investigated segment which extends for about 10 miles from the northwestern corner of Ahwhichaolto Inlet to the completely covered stretch of the southern shore of Quatsino Sound about halfway between Koskeemo and Salmon Islets.

The well-defined alignment of a number of prominent topographic features northwest of Ahwhichaolto Inlet indicates that the Mahatta Fault Zone continues in this direction at least to the sharp bend formed by the Macjack River at the point about 2 miles west-southwest of Mount Brandes. This was recognized also by Muller (1970, p. 46, sketch map) who extended the Mahatta Fault Zone to the vicinity of Fisherman Bay on the northern coast of Vancouver Island. In the northwestern corner of Ahwhichaolto

Inlet, the fault zone appears to underlie a covered interval, about 1/3 of a mile wide, of low, densely wooded shore around the mouth of a nameless creek. Siltstones and greywacke of the Coarse arenite unit appear to occupy the downthrown southwestern side of the Mahatta Fault Zone on the northwestern bank of the inlet's mouth. Scattered exposures of exceedingly disturbed conglomerates of the Blumberg Formation occurring farther northwest are believed to be but tectonic slices of Lower Cretaceous rocks dragged into the fault zone by the strike-slip movements (see below).

On the southwestern shore of the mouth of Ahwhichaolto Inlet, the main break of the Mahatta Fault Zone appears to bring intensely sheared and ?metasomatically altered Buchia crassicollis greywacke in contact with equally intensely sheared volcanic rocks referable to the Grey volcanic unit of the Volcanic division. This break is believed to cut across the rocky promontory and to disappear beneath the waters of Ahwhichaolto Inlet just northwest of the outcrops of the Cherty limestone unit shown on Fig. 18. A considerable thickness of rocks of the Volcanic division must be faulted out along the break of the Mahatta Fault Zone in this distance because of the appearance of rocks of the lower part of the Basal Jurassic volcanic unit on the opposite side of the inlet. However, it is impossible to estimate the thickness of strata missing. None of the faults of the Mahatta Fault Zone is exposed within the above-described interval.

Farther southeast, the Mahatta Fault Zone seems to disappear beneath the waters of Ahwhichaolto Inlet. It occupies most or all of the inlet's width, judging by its visible width farther southeast where it completely occupies a flat-bottomed valley, about 1/8 to 1/4 of a mile wide, connecting the head of Ahwhichaolto Inlet with that of Spencer Cove. Within this interval, the Mahatta Fault Zone appears to consist of a number of individual faults separated by tectonic slices of extremely disturbed to milonitized Lower Cretaceous rocks.

Southwest of the outcrops of the Cherty limestone unit on the southwestern shore of Ahwhichaolto Inlet, the relatively downthrown southwestern side of the Mahatta Fault Zone is occupied by strongly jointed and sheared rocks of the Grey volcanic unit. These rocks strike toward the northwest but their dips may be either toward the southwest or northeast.

The relatively upthrown northeastern side of the Mahatta Fault Zone is occupied by volcanic rocks of the Basal Jurassic volcanic unit everywhere between the northwestern end of Ahwhichaolto Inlet and the tip of the nameless point separating Spencer Cove from Robson Cove. The still older Hecate Cove Formation and the Arenaceous member of the Sedimentary division occupy the northeastern side of the fault on this nameless point. This indicates the faulting out of most or all of the 5,000-foot- to 7,000-foot thick Basal Jurassic volcanic unit along this segment of the Mahatta Fault Zone. The presence of the Mahatta Fault Zone beneath the waters of Spencer Cove is made obvious by juxtaposition of the rocks of the Grey volcanic unit occupying its western shore and those of the Blumberg Formation underlying Schloss Island. The reversal of throw of the Mahatta Fault Zone occurring at this point appears to be related to the relative upthrow of the western side of the subsiduary Robson Cove Fault by the strike-slip movement along the Mahatta Fault Zone. The north-northeast trending Robson Cove Fault branches off the Mahatta Fault Zone at about that point, cuts in between Schloss Island and the above-mentioned nameless point, and underlies Robson Cove.

As recognized by Dawson (1887, p. 87B), the Mahatta Fault Zone crosses Quatsino Sound on the course just described. The principal fault on the southern shore of

Quatsino Sound separates the generally downthrown and greatly disturbed younger Lower Jurassic (Matthews Island Formation, Uppermost Sinemurian volcanic unit and Uppermost Sinemurian argillite unit) and Lower Cretaceous rocks of the Monkey Creek Syncline from the crumpled and disturbed but generally upthrown older Lower Jurassic rocks (upper part of Basal Jurassic volcanic unit, Cherty limestone unit and Grey volcanic unit) of Koskimo Islets and the adjacent part of the southern shore of Quatsino Sound. This fault is aligned exactly with the Mahatta Fault Zone and obviously represents its southeastern extension (i.e. Mahatta Fault of Muller, 1970, p. 46, sketch map). As elsewhere, none of the splays of the fault zone is exposed within a completely covered interval of the shoreline, about one mile wide, separating these fault blocks from each other.

The obvious alignment of several prominent topographic features indicates that the Mahatta Fault Zone extends on the course described for at least a few more miles south along the valley of Monkey Creek. Muller (loc. cit.) traces it into his Brooks Peninsula Fault Zone.

The Mahatta Fault Zone is remarkably straight throughout its investigated part and maintains its direction regardless of the lithology and competence of the Mesozoic rocks that it crosses. This indicates that most or all of its splays are vertical to near vertical faults.

At least 5,000 to ?7,000 feet of rocks are faulted out along the Mahatta Fault Zone. This clearly indicates a major dip-slip displacement, the amount of which cannot be estimated since no structure is known to cross it. Also, a major right-hand (dextral), strike-slip component of movement is suggested by the quite aberrant

northeastern to north-northeastern orientation of typical drag-folds occurring on its upthrown southwestern side in the vicinity of Koskimo Islets (see Fig. 18). The same is probably true of the north-northwest trending Monkey Creek syncline occurring on the downthrown northwestern side of the fault zone and of several north- or northeast-trending drag-folds of the Blumberg Formation occurring in the western part of Koprino Harbour. The latter drag-folds may, however, be related instead to the dextral strike-slip movement along Robson Cove Fault.

The amount of right-hand, strike-slip post-Albian movement along the Mahatta Fault Zone can be estimated closely on the basis of the reasonable assumption that the Forward Inlet Cretaceous outlier once represented the direct southwestern extension of the Koprino Harbour Cretaceous outlier relatively displaced northwestward in post-Albian (?early Tertiary) time. According to this interpretation, the numerous, previously mentioned tectonic slices of Lower Cretaceous rocks occurring between the individual splays of the zone are small to minute fault blocks of the easternmost part of the Forward Inlet outlier dragged for variable distances northwestward by the right-hand, strike-slip movements. Because of different possibilities in reconstructing the Forward Inlet and Koprino Harbour (including Salmon Islets) Cretaceous outliers, a range of from 5 to 7 miles of horizontal post-Albian (?early Tertiary) offset along the Mahatta Fault Zone (Fig. 15) is indicated.

Robson Cove Fault

The orientation, known extent, and inferred nature of this little known but apparently important fault have already been discussed in connection with the description of the Mahatta Fault Zone. The orientation in relation to the Mahatta Fault Zone and other previously discussed characteristics of the Robson Cove Fault are strongly

suggestive of its being a second order, right-hand, strike-slip splay of the former. However, its dip-slip displacement is considerable and there is no way of telling whether it is smaller or greater than the assumed right-hand, strike-slip component.

Shapland Cove Fault

The major west-northwest trending fault disrupting the type section of the Blumberg Formation (see Unit 13 of Sec. 36) inside Shapland Cove is herewith named the Shapland Cove Fault. This little known fault appears to be important since it extends west-northwestward into Koprino Harbour and east-southeastward across Quatsino Sound and for an unknown distance up Cleogh Creek. On the southern side of Quatsino Sound, the fault disrupts the succession of the Basal Jurassic volcanic unit. The trace of the Shapland Cove Fault is concealed everywhere and there is no way to estimate either its stratigraphic throw or even the thickness of rocks faulted. The fault is believed to be a nearly vertical, normal fault, possibly merging with the Robson Cove Fault to the northwest and with the Ildstead Fault Zone to the southeast (Fig. 15).

Ildstead Fault Zone

A group of major, closely spaced, apparently vertical to near-vertical, approximately south-southwest to north-south trending faults disrupt, and probably repeat the succession of the Blumberg Formation immediately east of Hawisnakwi Creek on the northern shore of Quatsino Sound. This fault zone, which is about 1/4 of a mile wide, extends south into Ildstead Islets. The latter are underlain by more weathering-resistant (?indurated) parts of the individual tectonic slices of the fault zone.

Ildstead Fault Zone apparently crosses Quatsino Sound on the course just described. On the southern shore it disrupts the easternmost part of the Lower Cretaceous outlier surrounding Kewquodie Creek. Farther south, the Ildstead Fault Zone is believed to merge with the east-southeast extension of the Shapland Cove Fault (Fig. 15) and possibly to limit the Koprino Cretaceous outlier in this direction.

None of the individual faults comprising the Ildstead Fault Zone is exposed in any of the investigated sections. However, they all are believed to be vertical to nearly vertical, normal faults. As with the Shapland Cove Fault, it is impossible to estimate either the thickness of faulted out rocks or the stratigraphic throw of any of the Ildstead Fault Zone faults. However, there is every reason to think that they have considerably smaller displacements than those of any of the principal faults (e.g. Mahatta Fault Zone. Holberg Fault, Rupert Inlet Fault) described in this report.

Aweisha Creek Fault

A little known but apparently important fault appears to bring the considerably fractured and magmatically invaded rocks of the Coarse arenite unit against those of the Upper Valanginian and ?Hauterivian greywacke-conglomerate unit on the northern shore of Quatsino Sound in the proximity of Aweisha Creek. This fault is herewith named the Aweisha Creek Fault as it appears to extend up Aweisha Creek in a general north-northwest direction.

The Aweisha Creek Fault appears to cross Quatsino Sound in an east-southeast direction and to extend up Smith Cove on its southern shore. It seems to be responsible for a number of north-northeast to north-trending drag-folds mapped in the Upper Triassic rocks on its south-southwest side between Smith and Julian Coves. Aweisha Creek Fault is therefore believed to be a predominantly high angle or near

vertical, left-hand (sinistral), strike-slip fault rather than a predominantly normal fault (Fig. 15). The south-southwest side of Aweisha Creek Fault is relatively upthrown throughout its known length. However, it is impossible to estimate its undoubtedly large dip-slip displacement in any of the studied sections because of structural complications or wide covered intervals. Aweisha Creek Fault only disrupts but does not terminate the tectonic structures of the Quatsino Fault Block and accordingly is not considered to be a principal fault. Its relationships with the principal faults of the area are obscure.

Unnamed Major Faults between Neroutsos Inlet and the Eastern Shores of Holberg and Rupert Inlets

As has been noted by Gunning (1930, p. 105A), some faults dissect the rocks of the Vancouver Group outcropping on the shores of Quatsino Sound in the interval between Neroutsos Inlet and Quatsino village in the southwest, and the eastern shores of Holberg and Rupert Inlets in the northeast. Some of the faults observed or assumed to exist within this interval are shown on the attached Figure 17. However, no time was available either to study the nature and extent of any of these faults in detail or to investigate their structural relationships with the Holberg Fault, of which they seem to be subsiduaries. None of these faults is believed to be in the class of principal faults because they only disrupt the rock sequence within the Quatsino Formation or bring its rocks against those of adjacent units of the Vancouver Group.

Holberg Fault

This largest and apparently most important fracture of the investigated part of Quatsino Sound was discovered and mapped in considerable detail by Dawson (1887, pp. 90B-92B, Fig. 2, geol. maps) who descirbed it as follows (ibid. p. 91B):

> To the south the basin (i.e. Coal Harbour outlier of Lower Cretaceous rocks; writer's remark) is cut by a fault with an extensive downthrow to the north, and a course of about N89°W. The throw of this fault must exceed the whole exposed thickness of the Cretaceous of this basin, which is at least 1,500 feet. To the west it runs past the mouth of Coal Harbour, cutting into the shore near a small cove, a mile and a third beyond the west entrance point of the harbour. It then crosses the bay at the mouth of the Nookneemish River, again cutting the shore a mile beyond the mouth of that stream. Eastward, it must cut the west shore of Rupert Arm, about two miles from its head, and as the shore in the intervening stretch is all low, it is possible that the rocks of the Cretaceous series here re-appear, and continue for some distance eastward. .Still further in this direction, the fault appears to run completely across the island to Port McNeill and beyond, as explained on p. 64B. The rocks to the south of the fault, which form Hankin Point, are massive, greenish amygdaloids, overlain by a thick bed of limestone, which forms low cliffs near the east entrance point of Coal Harbour, and re-appears in the cove at the east side of Hankin Point. On both sides of the bay into which the Nookneemish River flows, the older rocks to the south of the fault are hard, shattered, rusty quartzites, and greenish and purplish felspathic materials, sometimes evidently altered agglomerates.

This principal fault was recently named the Holberg Fault by Muller (1970, p. 46, sketch map).

The writer has found Dawson's (1887, pp. 90B-92B, Fig. 2, geol. maps) interpretation of Holberg Fault quite correct with the sole exception of the general trend of the fault. The Holberg Fault appears to trend at N20°W throughout its investigated interval (see Fig. 15 and Fig. 17). Therefore, it could hardly head toward Port McNeill as suggested by Dawson (loc. cit., p. 91B) but is more likely to reach the lower third of Nimpkish Lake, provided that its general direction does not change appreciably east-southeast of the topographically identified point where it is believed to merge with the Rupert Inlet Fault.

A somewhat detailed survey of the Holberg Fault in the vicinity of Stewart Point has revealed (Fig. 16) the presence of several typical, asymmetrical drag-folds on its east-northeast side. These drag-folds invariably strike east-northeast to north-northeast and become much more gentle away fromthe approximately located trace of the Holberg Fault.

The character and orientation of these drag-folds indicate their being generated by strong right-lateral (dextral), strike-slip movements along the Holberg Fault. Because of these folds, the remarkable straightness of its fault trace, and the complete dissimilarity of rock sequences occurring on either side, the writer interprets it as a principal right-hand, strike-slip fault. The dip-slip component of the Holberg Fault is believed to be relatively minor.

The remarkable straightness of the trace of the Holberg Fault indicates its being a vertical or near vertical fracture. There is no evidence of the fault consisting of several closely spaced splays, but this possibility cannot be denied as its trace is completely covered in all sections studied. The horizontal displacement along the Holberg Fault should be large but so far has not been evaluated.

Rupert Inlet Fault

The presence of this principal, northwest-trending fault beneath the waters of a nameless narrow cove occurring on the northern shore of Rupert Inlet behind Narrow Island is indicated by juxtaposition of the northwest-striking and southwest-dipping topmost beds of the coal-bearing facies of the Coarse arenite unit with the moderately southwesterly inclined volcanic rocks representing the lower part of the Basal Jurassic volcanic unit. Close to 1,500 feet of Lower Cretaceous rocks and at

least 3,000 feet of rocks belonging to the upper part of the Volcanic division should, therefore, be faulted out as a result of the Rupert Inlet Fault. Because of the close correspondence of attitudes of rocks on both sides of Rupert Inlet Fault and the narrow interval separating them, the above estimate probably approaches closely its stratigraphic displacement.

Northeastwards, the Rupert Inlet Fault apparently continues at least to the narrow, fissure-like embayment of the east-southeastern shore of Quatse Lake. Southeastwards, the fault is assumed to cross Rupert Inlet and to cut into the low and densely wooded southern shore at the point about 1 1/2 miles west of the mouth of Coetkwaus Creek. There, the fault appears to bring the pyroclastics of the Basal Jurassic volcanic unit against Karmutsen volcanics. Southeast of Rupert Inlet, the Rupert Inlet Fault is believed to continue on a course striking about N40° to 50°W until it merges with the Holberg Fault (Fig. 15).

The Rupert Inlet Fault is believed to be steeply dipping to nearly vertical because of its inferred straight course. It seems to be a principal normal fault and it is not known whether any strike-slip movements have occurred along it. However, the assumed merger of the Rupert Inlet Fault with the Holberg Fault southeast of Rupert Inlet (see above and Fig. 15) is somewhat suggestive of its being a strike-slip fault, possibly a second order, left-hand (sinistral) splay of the Holberg Fault.

PRINCIPAL FAULT BLOCKS

For the purpose of this report, the term principal fault block is defined as a mappable fault block, the stratigraphy and tectonics of which differ markedly from those of adjacent principal fault blocks. In particular, principal tectonic blocks are characterized by having most or all of their subordinate fault and fold structures (i.e. the post-Middle Jurassic ones) restricted to them.

The following four principal fault blocks have been recognized in the west-east direction within the investigated part of Quatsino Sound. Three of them coincide with fault blocks independently proposed by Muller (1970, pp. 46, 48, sketch map) for the Alert Bay and Cape Scott areas of northern Vancouver Island.

Forward Inlet Fault Block

The Pacific Ocean covers the western part of the fault block and the trace of the northwest-trending Mahatta Fault Zone limits it to the northeast throughout the report-area. The northern and southern boundaries lie outside the investigated area.

As presently known, the Forward Inlet Fault Block includes rocks of the Grey volcanic unit, Matthews Island Formation, and the Uppermost Sinemurian volcanic unit flexed in a series of moderately open to tight northwest-trending and markedly northwest-plunging, medium to small, commonly disharmonic folds. These rocks are cut by lesser, northwest- to west-trending faults; they are commonly somewhat sheared, contorted, and invaded by a considerable number of small to medium (dyke- to plug-size) Coast Intrusions. These subordinate folds, which are restricted to the Forward Inlet Fault Block, appear to be superimposed on the previously mentioned, southwest-dipping and northwest-striking homoclinal structure of Quatsino Sound. Outcrops of the underlying Cherty limestone and Basal Jurassic volcanic units are limited to the northeastern margin of the Forward Inlet Fault Block and those of the Uppermost Sinemurian argillite and ?Pliensbachian-Toarcian greywacke units are limited to its southwestern margin. Outcrops of older rocks of the Vancouver Group are completely unknown within the investigated part of the fault block.

The apparently unrelated, approximately northerly to north-northeasterly trending pattern of minor folds was observed in rocks of the Volcanic division on Koskimo Islets and on the adjacent parts of the southern shore of Quatsino Sound. As discussed previously, these minor folds appear to be drag-folds caused by the strike-slip movements on the Mahatta Fault Zone.

Small to medium-size outliers of Lower Cretaceous sedimentary rocks, generally graben-like but commonly faulted on one side only (half grabens of Muller, 1970, p. 47) discordantly overlap the deeply eroded surface of the Vancouver Group. Lower Cretaceous rocks are gently to moderately tilted and are flexed into several wide open supplementary folds. They are, however, just as intensely faulted as those of the Vancouver Group and these strata tend to be steeply dipping, vertical, or even overturned, moderately to strongly sheared and commonly contorted to completely crushed in the proximity of major faults.

Judging by the distinct to pronounced northwest plunge of all known subsidiary folds of the Vancouver Group and the distribution of Lower Cretaceous sedimentary rocks, the Forward Inlet Fault Block is tilted to the northwest. It is upthrown relative to the adjacent Quatsino Fault Block, except in the northeasternmost corner of its investigated part. The probable reasons for this reversal have been discussed under the description of the Mahatta Fault Zone.

The structure of the westernmost corner of the investigated part of the Forward Inlet Fault Block comprising the western side of Browning Inlet's lagoon around the mouth of Kwatleo Creek is peculiar. It is cut off from the remaining part of the fault block by the major north-trending Grant Bay Fault and includes within it the possibly younger but poorly understood units of the Volcanic division of the Bonanza

Subgroup. These units may not be present elsewhere in the investigated part of Quatsino Sound. Should this be true, and should the shale unit of this outcrop-area, tentatively correlated with the Uppermost Sinemurian argillite unit, be a different and younger unit of the Volcanic division, there would be good reason to treat the area concerned as part of yet another principal fault block. It is impossible to reach any conclusion on the subject until the age and stratigraphy of the units concerned are better understood.

Quatsino Fault Block

This fault block, named after Quatsino village, is confined between the surface trace of the Mahatta Fault Zone on the southwest side and that of the Holberg Fault on the north side. Its northwestern and eastern limits are outside of the report-area and no attempt was made to elucidate their nature from the literature. In spite of its considerably larger size compared with other principal fault blocks of Quatsino Sound, the Quatsino Fault Block is characterized by a degree of structural unity which precludes its subdivision into two or more principal fault blocks until more data are available. All now known major faults occurring within the Quatsino Fault Block, such as the Robson Cove Fault, Shapland Cove Fault, Ildstead Islets Fault Zone, and a number of unnamed major faults in the vicinity of Quatsino Narrows, and Varney Bay (see Fig. 15 and Fig. 17) have lesser displacements than those of the principal faults limiting the fault block and do not terminate the continuity of its structure and stratigraphy in the same way as do the Mahatta Fault Zone and Holberg Fault. These major faults are assumed to be mere subsidiaries of one or the other of the last mentioned two principal faults (Fig. 15).

The eastern part of the Quatsino Fault Block includes rocks of the Karmutsen Subgroup, Quatsino Formation, Sedimentary division of the Bonanza Subgroup and the lower part of its volcanic division (including the lower part of the Basal Jurassic volcanic unit). This part of the Quatsino Fault Block is strongly upthrown relative to the adjacent Coal Harbour Fault Block. The only known outlier of the Nanaimo Group arenites occurs in this part of the fault block.

As in the Forward Inlet Fault Block, the rocks of the Vancouver Group outcropping in the eastern part of the Quatsino Fault Block appear to form a faulted section of the previously mentioned southwest-dipping and northwest-striking major homocline. However, they are flexed into a series of moderately open to tight, predominantly north- to north-northwest trending, medium- to small-size, commonly disharmonic folds superimposed on this homoclinal structure. These folds were apparently generated by movements along the adjacent major faults since they tend to become progressively more gentle, more open and fewer in number away from them. In the proximity of the Mahatta Fault Zone, the axes of these subsidiary folds tend to swing so as to strike approximately east-west. These bends in the fold axes appear to be consistent with the recognized right-hand, strike-slip movement of the Mahatta Fault Zone. Rocks of the Vancouver Group, furthermore, are cut by northwest-, west-, north- and northeast-trending major faults and are commonly sheared and contorted in their proximity. Small to medium (dyke- to stock-size) bodies of the Coast Intrusions locally invade the rocks of the Vancouver Group in the western part of the Quatsino Fault Block.

Rocks of the Vancouver Group disappear westward beneath the Lower Cretaceous sediments and the larger western part of the Quatsino Fault Block is occupied mainly by the generally gently flexed, basin-like Koprino outlier of Lower Cretaceous rocks. The synclinal axis of the Koprino outlier appears to trend approximately north-south and to plunge markedly northward in its least disturbed part situated between Hawisnakwi and Bish Creeks. It may be a pre-Tertiary tectonic feature. However, this fundamentally simple basin-like structure of the Koprino outlier was considerably modified by younger (?early Tertiary) faulting. The Lower Cretaceous rocks are flexed into a considerable number of supplementary, northeast-, northwest-, and north-trending, small to medium folds in the proximity of almost every known major fault (Pl. XI, Fig. A). Like the previously mentioned subsidiary folds of the Vancouver Group, these folds in the Cretaceous rocks apparently were generated by movements on the adjacent major faults. They are tight in the proximity of these faults but tend to become gentler, more open and fewer in number away from them.

Some of the subsidiary synclines of the Cretaceous rocks seem to be basin-like whereas most or all of the subsidiary anticlines are distinctly to markedly plunging in one or both directions.

The Koprino outlier of Lower Cretaceous rocks does not seem to interrupt the homoclinal structure of the rocks of the underlying Vancouver Group. The younger beds of the Basal Jurassic volcanic unit reappear on the western side of this outlier (west of the mouth of Kewquodie Creek) with the same prevalent southwestern dips. In spite of various structural complications essentially similar to those characteristic of

the eastern part of the fault block, the southwest-tilted homocline of the Vancouver Group apparently continues uninterruptedly to the western side of the Quatsino Fault Block. The rocks of the Basal Jurassic volcanic unit appear to dip underneath the Matthews Island Formation and the latter, in turn, dips underneath the rocks of the Uppermost Sinemurian volcanic unit and the Uppermost Sinemurian argillites on the southern shore of Quatsino Sound east of Monkey Creek.

The north-northwest trending and plunging, medium-size basin-like syncline of younger units of the Volcanic division, occurring in the vicinity of Monkey Creek, seems to be an unusually large drag-fold generated by the movements on the Mahatta Fault Zone. Its trend is consistent with the recognized right-hand, strike-slip movement of this fault.

The northward expanding wedge of extremely faulted and sheared, partly contorted rocks of the older part of the Volcanic division of the Bonanza Subgroup containing a slice of the Arenaceous member at the apex, occurs in the western corner of Koprino Harbour between Spencer Cove and Robson Cove. This insufficiently understood structure appears to be a small northerly tilted horst of older rocks confined between the Mahatta Fault Zone on the west and the Robson Cove Fault on the east.

The surface of the Vancouver Group "basement" of the Quatsino Fault Block appears to have a marked westward tilt, judging by its very large relative upthrow within the northern and eastern parts of the fault block, and its comparably large relative downthrow within its southwestern part. The Lower Cretaceous rocks of the Quatsino Fault Block appear to be tilted northward and to a lesser extent are inclined to the southwest.

Coal Harbour Fault Block

This block appears to be a wedge-like body of the predominantly younger Lower Cretaceous rocks confined between the Holberg Fault on the south and Rupert Inlet Fault on the northeast. The apex of the wedge is assumed to be concealed on the southern shore of Rupert Inlet just east of Coetkwaus Creek where the above-mentioned principal faults seem to merge (Fig. 15). The western and northern boundaries of the Coal Harbour Fault Block lie outside of the investigated area.

As presently known, the Coal Harbour Fault Block is a graben largely filled by the gently flexed and moderately to slightly faulted rocks of the Coal Harbour Group. Only in the close proximity of the Holberg Fault (Fig. 16) do these rocks become steeply dipping to vertical and moderately to strongly sheared.

The gentle folds of the Cretaceous rocks trend northwesterly or westerly, except in the proximity of the Holberg Fault where the tight asymmetrical drag-folds trend toward the southwest. This orientation of drag-folds is consistent with the inferred relative eastward (i.e. dextral) movement of the northern side of the Holberg Fault (Fig. 15). The rocks of the Vancouver Group and those of the Coast Intrusions are known to outcrop only in the northwestern and northern parts of the fault block which indicates its being tilted toward the southeast.

Rupert Inlet Fault Block

The Rupert Inlet Fault Block is limited on the southwest by the Rupert Inlet Fault (Fig. 15). Its northern, western and southern limits lie outside of the investigated area. According to Muller's (1967, Fig. 1) geological sketch map, the Rupert Inlet Fault Block is limited on the west by a northeast-trending fault and on the northeast by

a principal northwesterly-trending fault which runs from Port Hardy to the headwaters of Keogh Creek and brings the westward-dipping rocks of the Bonanza Subgroup against the sediments of the Nanaimo Group.

So far as is known, the Rupert Inlet Fault Block is a horst of the moderately southwesterly inclined Bonanza Subgroup volcanics and sediments invaded by the small- to medium-size bodies of Coast Intrusions. No information is available about supplementary faulting or folding of the Bonanza volcanics within Rupert Inlet Fault Block.

CONCLUDING REMARKS

As elsewhere in the Insular Tectonic Belt (Sutherland-Brown, 1966, p. 83; Muller, 1970), the Mesozoic and Tertiary structural style of the Quatsino Sound area is dominated by faulting. Folding, other than the numerous small- to medium-size local drag-folds or pressure ridges generated by movements on major faults, was restricted to the earliest phases of the Mesozoic structural history (latest Triassic and Middle Jurassic). Only a few large but wide open, gently to moderately dipping folds were apparently produced by the early Mesozoic orogenic movements within the investigated parts of the Quatsino Sound area.

The prevalence of faulting over folding was caused by "basement control" of one kind or another. In pre-Middle Jurassic time, the thick and ubiquitous rigid "shield" of Karmutsen volcanics (Jeletzky, 1970b, pp. 1-2; Muller, 1970, pp. 44, 48) must have prevented the development of compressed and overturned folds both within the area and elsewhere in the Insular Tectonic Belt. Before the end of Middle Jurassic time, this "rigid volcanic basement" was further strengthened by the invasion of numerous small and large Coast Intrusions and the accompanying induration or metamorphism of the

sediments and volcanics of the Bonanza Subgroup (including the Quatsino Formation). The ubiquitous presence of the resulting, completely rigid, so called magmatic basement (Jeletzky, 1963, p. 59) determined the subsequent tectonic style of the area as it yielded to the stresses of all post-Middle Jurassic tectonic movements by large and small scale faulting. The relatively thin Cretaceous sediments (probably not more than 10,000 to 11,000 feet thick) consequently were protected to a large extent from compressive stresses and could not be even moderately folded, except in the proximity of major or principal faults. The prevalence of faulting over folding and the apparent absence of any discernible regional pattern of Cretaceous and Tertiary folds can thus be fully explained.

It may seem remarkable that such an expressly fault block tectonic style, morphologically similar to the paratectonic or Saxonian tectonics of non-geosynclineal structural regions (cf. Stille, 1924; de Sitter, 1956) should arise within an otherwise typical geosynclinal (= orthogeosynclinal or eugeosynclinal; see Jeletzky, 1963, p. 59) belt of the Canadian Western Cordillera. However, it becomes more and more obvious that the actual tectonic styles of many mobile or orogenic belts do not conform at all to the classical concept of geosynclines (e.g. Jeletzky, 1963, pp. 58-61; Mitchell and Reading, 1969). The tectonic style of the Quatsino Sound area in particular, and of the Insular Tectonic Belt in general (Sutherland-Brown, 1966, p. 83; Jeletzky, 1970b) is not too different from that of the Island Arc- and Japan Sea-type of geosynclines of Mitchell and Reading (1969, pp. 633, 634) in which the orogenic movements have consisted largely of block faulting and uplift. The tectonic style of the Tertiary northeast Honshu Island arc of the Japanese Archipelago in particular appears to be similar to that of the Mesozoic and Tertiary phase of the Insular Tectonic Belt of British Columbia.

REFERENCES

Anderson, F.M.
1938: Lower Cretaceous deposits in California and Oregon; Geol. Soc. Am., Spec. Paper 16, 339 pp., 83 pls., 1 index map, 2 corr. tables, 3 figs.

Arkell, W.J.
1956: Jurassic geology of the world; Oliver and Boyd, Ltd., Edinburgh and London, 806 pp., 30 pls., 28 corr. charts, 102 figs.

Bancroft, M.F.
1937: Gold-bearing deposits on the west coast of Vancouver Island, between Esperanza Inlet and Alberni Canal; Geol. Surv. Can., Mem. 204, 34 pp., 1 fig.

Beveridge, A.J. and Folinsbee, R.E.
1956: Dating Cordilleran Orogenies; Trans. Roy. Soc. Can., Ser. 3, sec. 4, vol. 50, pp. 19-43, 10 pls., 1 table, 4 figs.

Busnardo, R.
1965: Rapport sur l'Etage Barrémien; Mem. Bureau de Recherches Geol. et Minières, Colloque sur le Crétacé inférieur, Lyons, 1963, pp. 161-169, 2 tables.

Carson, D.J.T.
1968: Metallogenic study of Vancouver Island with emphasis on the relationships of mineral deposits to plutonic rocks; Carleton Univ., Ph.D Thesis, 238 pp., 25 pls., 16 tables, 26 figs.

Clapp, C.H.
1912: Geology of Nanaimo Sheet, Nanaimo Coal-Field, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1911, pp. 91-107, 1 table.

1917: Sooke and Duncan map-areas, Vancouver Island; Geol. Surv. Can., Mem. 96, 445 pp., 12 pls., 6 maps, 2 figs.

Crickmay, C.H.
1928: The Stratigraphy of Parsons Bay, British Columbia; Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 18(2), pp. 51-70, 4 pls., 1 map, 3 figs.

Dawson, G.M.
1887: Report on a geological examination of the northern part of Vancouver Island and adjacent coasts; Geol. Surv. Can., Ann. Rept. 1886, Pt. B, 129 pp., 1 map.

Dolmage, V.

1919: Quatsino Sound and certain mineral deposits of the west coast of Vancouver Island, B.C.; Geol. Surv. Can., Sum. Rept. 1918, Pt. B, pp. 30B-38B, 1 fig.

1921: West Coast of Vancouver Island between Barkley and Quatsino Sounds; Geol. Surv. Can., Sum Rept., 1920, Pt. A, pp. 12A-22A.

Eastwood, G.E.P.

1965: Replacement magnetite on Vancouver Island; Ec. Geol., vol. 60, pp. 124-148.

1968: Geology of the Kennedy Lake area, Vancouver Island, British Columbia; Brit. Columbia Dep. Mines, Bull. 55, 63 pp., 12 pls., 2 tables, 7 figs.

Frebold, H.

1951: Contributions to the Palaeontology and Stratigraphy of the Jurassic System in Canada; Geol. Surv. Can., Bull. 18, 54 pp., 18 pls., 2 figs.

1959: Marine Jurassic rocks in Nelson and Salmo Areas, Southern British Columbia; Geol. Surv. Can., Bull. 49, 31 pp., 5 pls., 1 table, 2 figs.

1967: Position of the Lower Jurassic genus Fanninoceras McLearn and the age of the Maude Formation on Queen Charlotte Islands; Can. J. Earth Sci., vol. 4, pp. 1145-1149, 7 figs.

Frebold, H. and Tipper, H.W.

1970: Status of the Jurassic in the Canadian Cordillera of British Columbia, Alberta, and southern Yukon; Can. J. Earth Sci., vol. 7(1), pp. 1-21, 1 table, 9 figs.

Fyles, J.T.

1955: Geology of the Cowichan Lake area, Vancouver Island, British Columbia; Brit. Columbia Dep. Mines, Bull. 37, 72 pp., 14 pls., 9 figs.

Givens, C.R. and Susuki, T.

1964: Late Triassic fauna from interlava sediments of east-central Vancouver Island (abstract); Geol. Soc. Am., Special Paper 76 (Abstracts, 59th Annual Meetings, 1963, Cordilleran Section), p. 203.

Gunning, H.C.

1930: Geology and mineral deposits of Quatsino-Nimpkish area, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1929, Pt. A, pp. 94A-143A, pls. 2-3, 1 map, figs. 4-8.

Gunning, H.C.

1931: Buttle Lake map-area, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1930, Pt. A, pp. 56A-78A, 1 pl., figs. 5-6.

1932: Preliminary Report on the Nimpkish Lake Quadrangle, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1931, Pt. A, pp. 22-35, Fig. 3.

1933: Zeballos River area, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1932, Pt. A. II, pp. 29-50, Fig. 4.

Haycock, E.

1906: Geology of the west coast of Vancouver Island, British Columbia; Geol. Surv. Can., Ann. Rept., vol. XV, Pt. A (1902-3), pp. 76-92.

Hoadley, J.W.

1953: Geology and mineral deposits of the Zeballos-Nimpkish area, Vancouver Island, British Columbia; Geol. Surv. Can., Mem. 272, 82 pp., 5 pls., 3 tables, 3 maps, 2 figs.

Imlay, R.W.

1960: Ammonites of Early Cretaceous age (Valanginian and Hauterivian) from the Pacific Coast states; U.S. Geol. Surv., Prof. Paper 334-F, pp. 167-228, pls. 24-43, 4 tables, text-figs. 34-36.

Jeffery, W.G.

1962: Preliminary geological map, Alice Lake-Benson Lake area; Brit. Columbia Dep. Mines.

Jeletzky, J.A.

1950: Stratigraphy of the west coast of Vancouver Island between Kyuquot Sound and Esperanza Inlet, British Columbia; Geol. Surv. Can., Paper 50-37, 52 pp., 1 map, 1 fig.

1954a: Geological history of west coast of Vancouver Island and Quatsino Sound (abstract); Bull. Geol. Soc. Am., vol. 65 (12/2), pp. 1269-1270.

1954b: Tertiary rocks of the Hesquiat-Nootka area, west coast of Vancouver Island, British Columbia (with brief comments on adjacent Mesozoic formations); Geol. Surv. Can., Paper 53-17, 65 pp., 1 map.

1958: Uppermost Jurassic and Cretaceous rocks of Aklavik Range, Northeastern Richardson Mountains, Northwest Territories; Geol. Surv. Can., Paper 58-2, 84 pp., 1 map, 1 corr. chart.

Jeletzky, J.A.

1961a: Upper Jurassic and Lower Cretaceous rocks, west flank of Richardson Mountains between the headwaters of Blow River and Bell River, Yukon Territory; Geol. Surv. Can., Paper 61-9, 42 pp., 2 figs.

1961b: Eastern slope, Richardson Mountains: Cretaceous and Tertiary structural history and regional significance; Geology of the Arctic, vol. 1, G.O. Raasch, ed., Univ. Toronto Press, pp. 532-583, 24 figs.

1963: Pre-Cretaceous Richardson Mountains trough; its place in the tectonic framework of Arctic Canada and its bearing on some geosynclinal concepts; Trans. Roy. Soc. Can., vol. LVI (III), pp. 55-84, 6 text-figs.

1964: Illustrations of Canadian fossils. Lower Cretaceous marine index fossils of the sedimentary basins of Western and Arctic Canada; Geol. Surv. Can., Paper 64-11, 100 pp., 36 pls., 1 table.

1965a: Late Upper Jurassic and Early Lower Cretaceous fossil zones of the Canadian Western Cordillera, British Columbia; Geol. Surv. Can., Bull. 103, 70 pp., 22 pls., 4 text-figs.

1965b: Age and tectonic nature of the Strait of Georgia Seaway (abst.); Geol. Surv. Can., Paper 65-2, p. 72.

1967: Stratigraphy and Palaeontology of Lower Cretaceous and Upper Jurassic rocks of Taseko Lakes (92-O) and Pemberton (92-J) map-areas; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 65-68.

1968: Stratigraphy and Palaeontology of Lower Cretaceous and Upper Jurassic rocks of northeastern corner of Mount Waddington map-area, British Columbia (92-N); Geol. Surv. Can., Paper 68-1, Pt. A, pp. 103-106.

1969: Mesozoic and Tertiary stratigraphy of northern Vancouver Island (92-E, 92-L, 102-I); Geol. Surv. Can., Paper 69-1, Pt. A, pp. 126-134.

1970a: Mesozoic stratigraphy of northern and eastern parts of Vancouver Island, British Columbia (92-E, F, L, 102-I); Geol. Surv. Can., Paper 70-1, Pt. A, pp. 209-214.

1970b: Some salient features of early Mesozoic history of Insular Tectonic Belt, western British Columbia; Geol. Surv. Can., Paper 69-14, 26 pp., 2 figs.

1970c: Lower Cretaceous and late Upper Jurassic biochronology and facies of Manning Park Area, British Columbia; Geol. Surv. Can., Paper 70-1, Pt. A, pp. 214-223, 1 fig.

1971: Marine Cretaceous biotic provinces and palaeogeography of Western and Arctic Canada: Illustrated by a detailed study of ammonites; Geol. Surv. Can., Paper 70-22.

Jeletzky, J.A. and Tipper, H.W.
1968: Upper Jurassic and Cretaceous rocks of Taseko Lakes map-area and their bearing on the geological history of southwestern British Columbia; Geol. Surv. Can., Paper 67-54, 218 pp., 4 tables, 14 figs.

Jones, D.L.
1967: Cretaceous ammonites from the lower part of the Matanuska Formation, Southern Alaska; U.S. Geol. Surv., Prof. Paper 547, 49 pp., 10 pls., 2 tables, 23 figs.

Keyserling, A. von
1846: Wissenschaftliche Beobachtungen auf einer Reise in das Petschora-Land im Jahre 1843, 2. Reste der Jura-Periode., St. Petersburg, C. Kray, pp. 293-336, pls. 13-22, geol. map.

Mackenzie, J.D.
1916: Geology of Graham Island, British Columbia; Geol. Surv. Can., Mem. 88, 221 pp., 16 pls., 2 maps, 23 figs.

Matsumoto, T.
1959: Cretaceous ammonites from the upper Chitina Valley, Alaska; Kyushu Univ. Mem. Fac. Sci., ser. D, vol. 8(3), pp. 49-90, pls. 12-29, tables 1-2, text-figs. 1-16.

McLearn, F.H.
1949: Jurassic formations of Maude Island and Alliford Bay, Skidegate Inlet, Queen Charlotte Islands, British Columbia; Geol. Surv. Can., Bull. 12, 19 pp., 3 figs.

1953: Correlation of the Triassic formations of Canada; Bull. Geol. Soc. Am., vol. 64, pp. 1205-1228, 1 pl., 2 figs.

Mitchell, A.H. and Reading, H.G.
1969: Continental margins, geosynclines, and ocean floor spreading; J. Geol., vol. 77(6), pp. 629-646, 3 tables, 2 figs.

Muller, J.E.
1967: Port McNeill area and Nanaimo Basin, Vancouver Island; Geol. Surv. Can., Paper 67-1, Pt. A, pp. 81-83, 1 geol. map.

1969: Northern Vancouver Island (92-E, K, L, 102-I); Geol. Surv. Can., Paper 69-1, Pt. A, pp. 27-29.

1970: Northern Vancouver Island, British Columbia (92-E, K, L, 102-I); Geol. Surv. Can., Paper 70-1, Pt. A, pp. 44-49, 2 figs.

Muller, J.E. and Carson, D.J.T.
1969: Geology and mineral deposits of Alberni map-area, Vancouver Island and Gulf Islands, British Columbia; Geol. Surv. Can., Paper 68-50, 52 pp., 5 tables, 1 map, 3 figs.

Muller, J.E. and Jeletzky, J.A.
1967: Stratigraphy and biochronology of the Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia; Geol. Surv. Can., Paper 67-1, Pt. B, pp. 39-47, 2 tables, 2 figs.

Muller, J.E. and Rahmani, R.A.
1970: Upper Triassic sediments of northern Vancouver Island; Geol. Surv. Can., Paper 70-1, Pt. B, pp. 11-18.

Northcote, K.E.
1969: Geology of the Port Hardy-Coal Harbour area; in Rept. Minister of Mines, 1968, Brit. Columbia Dep. Mines, pp. 84-87, Figs. 13-14.

Popenoe, W.P., Imlay, R.W. and Murphy, M.A.
1960: Correlation of the Cretaceous formations of the Pacific Coast (United States and northwestern Mexico); Bull. Geol. Soc. Am., vol. 71, pp. 1491-1540, 1 pl., 5 figs.

Roddick, J.A.
1965: Vancouver north, Coquitlam, and Pitt Lake map-areas, British Columbia; Geol. Surv. Can., Mem. 335.

Silberling, N.J. and Tozer, E.T.
1968: Biostratigraphic classification of the Marine Triassic in North America; Geol. Soc. Am., Spec. Paper 110, 63 pp., 1 pl., 1 fig.

Sitter, L.U., de
1956: Structural Geology; 1st ed., McGraw Hill Book Co., New York, 552 pp.

Stille, H.
1924: Grundfragen der vergleichenden Tektonik; Gebr. Borntraeger Press, Berlin, pp. viii + 443, 14 text-figs.

Stockwell, C.H. et al.
1957: Geology and Economic Minerals of Canada; Geol. Surv. Can., Econ. Geol., No. 1 (4th ed.), 517 pp., illus.

Surdam, R.C.
1968: The stratigraphy and volcanic history of the Karmutsen Group, Vancouver Island, British Columbia, Contrib. to Geol., Univ. Wyoming, vol. 7, No. 1, pp. 15-26, 3 pls., 6 figs.

Surdam, R.C., Susuki, T. and Carlisle, D.
1964: Upper Triassic Section on Iron River, Vancouver Island, British Columbia (abstract); Geol. Soc. Am., Special Paper 76, p. 226.

Sutherland-Brown, A.

1966: Tectonic history of the Insular Belt of British Columbia; Can. Inst. Mining Met., Special vol. 8, pp. 83-100, Figs. 6-1 to 6-13.

1968: Geology of the Queen Charlotte Islands, British Columbia; Brit. Columbia Dep. Mines, Bull. 54, 226 pp., 18 pls., 21 tables, 45 figs.

Terekhova, G.P.

1969: O nizhnei zone senomana v Anadyrsko-Koriakskoi oblasti [The lower zone of the Cenomanian stage in the Anadyr-Koriak province]; Sibirskoye Otdelenie Akad. Nauk SSSR, Trudy Severo-Vostochnogo Kompleksnogo Nauchno-Issledovatel'skogo Instituta No. 32, Magadan, pp. 162-172, 5 pls. (in Russian).

Tipper, H.W.

1969: Mesozoic and Cenozoic geology of the northeast part of Mount Waddington map-area (92-N), Coast district, British Columbia; Geol. Surv. Can., Paper 68-33, 103 pp., 2 tables, 1 map, 8 figs.

Tozer, E.T.

1954: Late Norian (Triassic) fauna in southern Yukon and western British Columbia (abstract); Bull. Geol. Soc. Am., vol. 65(12), p. 1315.

1967: A Standard for Triassic Time; Geol. Surv. Can., Bull. 156, 103 pp., 10 pls., 2 tables, 23 figs.

Usher, J.L.

1952: Ammonite faunas of the Upper Cretaceous rocks of Vancouver Island, British Columbia; Geol. Surv. Can., Bull. 21, 182 pp., 31 pls., 4 figs.

Whiteaves, J.F.

1889: On some fossils from the Triassic rocks of British Columbia; in Contributions to Canadian Palaeontology, vol. I, Pt. 2; Geol. Surv. Can., pp. 127-149, pls. 17-19.

APPENDIX

Selected measured sections

(Units numbered from top to bottom of measured section)

Section No. 1. (Field Nos. JA-F69-5 and 6). Exposed in the bed of nameless left confluent of Lippy Creek between altitudes ± 1,900 and 2,100 feet and farther downstream in the walls of a small quarry on the southeastern side of an abandoned northwest-trending logging road where the latter intersects the bed of the confluent (see Pl. III, Figs. A and B). The section's top is at latitude 50°28'46"N; longitude 127°28'35"W and the base at latitude 50°28'43"N; longitude 127°28'45"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	RHAETIAN STAGE?		
	VOLCANIC DIVISION		
	Hecate Cove Formation		
1	Volcanic breccia, green grey, fine to coarse; fragments consist mainly of fine amygdaloidal lava enclosed in fairly abundant, black, calcareous and argillaceous matrix; no attitude observed; base and top covered and no outcrops were seen in the bed of the right branch of the confluent for at least 100 feet upstream from bed 1; visible	3	199
2	Covered across general strike of bed 3	3	

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LATE NORIAN STAGE		
	SEDIMENTARY DIVISION		
	Arenaceous Member		
	Argillite unit		
3	Argillite, dark to blackish brown when fresh, weathers ash grey with rust-coloured specks or patches; chunky; medium to thickly (6 inches to 2 feet) and indistinctly bedded, moderately hard, commonly more or less arenaceous and calcareous; contains irregular interbeds and 6-inch to 2-foot nodules of dull blue, hard, very calcareous argillite and impure limestone; strikes at 200° and dips at 26°W and is not otherwise disturbed; a 6-inch bed of the arenaceous and calcareous argillite replete with *Monotis*-like pelecypods (GSC loc. 83910) 5 1/2 to 6 feet below visible top of unit includes *Monotis* cf. *ochotica* var. *densistriata* (Teller); grades downward into unit 4; visible	30	196

Unit	Description	Thickness (feet)	Height Above Base (feet)
4	Irregular interbedding of pods and lenticular 2- to 6-inch thick beds of dull to dark grey, very fine, silty greywacke, dull to blue grey, hard, calcareous argillite (or silty and sandy limestone), lighter grey, calcareous, commonly pebbly, coarse-grained greywacke and grit; the whole succession appears to be a consedimentary slump breccia in part, as pods and lenticular beds of coarse greywacke, grit, and pebbly grit are commonly broken into 3-inch to 2-foot fragments which are either folded or twisted and wedged between similarly broken, bent, and twisted fragments of other rock types; 3- to 5-inch thick pods of fine to medium pebble conglomerate were noted locally; they contain grey limestone pebbles; pods and lenticular interbeds of gritty rocks contain fragments of large, thick pelecypods (megalodontids?), fragments of Monotis-like pelecypods, and some poor imprints of ammonites possibly derived from an adjacent (to the east?) littoral environment; fossils collected from the		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	upper 4 to 4 1/2 feet of the unit (GSC loc. 83911) include fragments of a probably late Norian *Monotis* sp.; grades downward into unit 5	11	166
5	Argillite, similar to that of unit 3 but with some pods and interbeds of impure limestone and very fine greywacke (as in unit 4) scattered irregularly throughout its thickness; no signs of consedimentary slumping noted; attitude as in bed 3; a 1-foot thick bed 8 1/2 to 9 1/2 feet below top (GSC loc. 83912) yielded *Monotis salinaria* (Schlotheim); base covered 16 feet above the bed of the right branch at the point about 60 feet upstream of the junction of right and left branches of the confluent; visible	13	155
6	Covered in the bed of right branch across the general strike of the beds to the junction point of right and left branches; about	60 (est.)	
7	Covered but probably underlain by argillite as in bed 5 judging by a few small patches of weathered rock in the bed of the confluent between the confluence point of its left and right branches and		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	the top of the wall of a small quarry situated on the southwest side of secondary road branching due northwest of the main Gibson Road at the altitude of ± 1,800 feet; about	150 (est.)	
	Greywacke unit		
8	Greywacke, dull grey when fresh, weathers dull brown and speckled, fine grained, friable, mainly massive but with a few interbeds, (3 inches to 10 inches) of very thinly bedded to laminated greywacke and very sandy, rust-coloured argillite; contains abundant Monotis-like shell fragments almost throughout; well-preserved shells rare except in a 6-inch bed 3 feet below the visible top (GSC loc. 83913) where the fauna includes Monotis cf. salinaria (Schlotheim); at the level 2 1/2 to 3 1/2 feet above the visible base (GSC loc. 83915) where the fauna includes Heterastridium sp.; and in another 4-inch bed at the unit's base (GSC loc. 83914) containing Monotis cf. salinaria (Schlotheim); strike 160° and dip 25°W; top concealed at the upper rim of the		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	quarry (Pl. III, Fig. A) on southeastern side of a small waterfall formed by the left confluent of Lippy Creek; grades downward into unit 9; visible	12	142
9	Greywacke, dull grey in fresh and weathered state, fine grained, dense, hard, massive; only upper 12 feet of the unit are exposed on the eastern side of the confluent's bed (i.e. of the waterfall; see Pl. III, Fig. A) above the floor of the quarry; a normal fault striking at 215° and dipping at 55°E cuts off the unit just east of confluent's bed; the unit is upthrown about 20 feet on its western side where its visible thickness reaches about 33 feet (strike 220° and dip 37°W); lower 22 feet of the unit contain several 6- to 18-inch interbeds of thinly bedded to laminated dull grey argillite which locally are condepositionally slumped forming small recumbent folds and crenulations overturned toward southeast; another normal fault striking at 315° and dipping at 50°-55°E cuts into quarry's wall about 50 feet northwest		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	of confluent's bed (Pl. III, Fig. B), its north-eastern side is relatively upthrown about 15 feet and exposes the basal 12 feet of the unit; on this side of fault the unit strikes at 355° and dips at 28°W; grades into unit 10	50 (approx.)	130
10	Irregular interbedding of dull to whitish grey, very thinly bedded (1/4 to 1 inch) to laminated cherty shale and chert alternating in beds 1 inch to 1 foot thick; in the southwestern corner of the quarry (i.e. 25 feet west of last mentioned fault), the bed is cut through by yet another normal fault striking 245° and dipping 28°W, its western side is upthrown about 6 feet and exposes the complete thickness of the bed which strikes 190° and dips 30°W; grades downward into unit 11	5	80
11	Greywacke as in unit 8 containing abundant Monotis-like shells throughout; the fauna collected from the middle 1 foot of the bed (GSC loc. 83916) includes fragmentary Monotis sp. probably belonging to M. salinaria (Schlotheim); grades into underlying bed	4 1/2	75

Unit	Description	Thickness (feet)	Height Above Base (feet)
12	Interbedded dark grey to dark brown, soft shale and very fine-grained, green-grey greywacke in 1/2- to 2-inch beds and lamellae; grades into underlying bed	3 1/2	70 1/2
13	Greywacke as in units 8 and 11 but with some 3- to 10-inch thick interbeds of shale and very fine grained greywacke as in unit 12; replete with Monotis-like shells at several levels; fauna collected 9 1/2 to 10 1/2 feet below top (GSC loc. 83917) includes Monotis salinaria Schlotheim; lower contact sharp	13	67
14	Mudstone, dull blue to medium grey or dark grey, massive, weathers blocky; contains 3- to 6-inch thick by 2- to 3-foot long pods and similarly thick lenticular beds of calcareous, very fine grained, laminated greywacke and some similarly thick interbeds and pods of gritty and pebbly greywacke with fragments of thick-shelled pelecypods; the unit resembles lithologically units 4 and 5 of the Argillite unit; fauna collected 10 to 11 feet below top (GSC loc. 83918) includes Monotis salinaria (Schlotheim); grades downward into unit 15	15	54

Unit	Description	Thickness (feet)	Height Above Base (feet)
15	Greywacke, bluish grey to dark blue when fresh, weathers dark grey with rust-coloured specks; massive, weathers blocky; contains numerous pods and lenticular beds (as in bed 14) of very calcareous fine-grained greywacke and mudstone; poor imprints of Monotis-like pelecypods occur locally but no collection was made; becomes strongly sheared and intensively rust-coloured in basal 10 to 12 feet exposed; strikes 360° and dips 47°W near the top but the attitude changes to a strike of 220° and a dip of 48°W near the visible base; base covered and apparently faulted; visible	14	39
16	Covered across the strike on the northwestern side of quarry and in the quarry's floor near the logging road; the covered interval probably conceals a normal strike fault of a magnitude comparable to those cutting younger units of the section	15	

Unit	Description	Thickness (feet)	Height Above Base (feet)
	Thinly bedded member (top part)		
17	Argillite, black to dark grey, more or less calcareous, thinly to medium bedded (2- to 12-inch beds) or laminated, hard; interbedded with numerous but always lesser number of similarly thick but nodular beds of medium to dark grey, light grey to buff-weathering, impure limestone; minor interbeds of calcareous, fine- to coarse-grained, brownish grey greywacke; strikes 360° and dips 50°W; rocks are somewhat sheared and locally contorted near the top but only jointed farther down section; an ammonite fragment collected about 5 feet below visible top (GSC loc. 82961) probably belongs to Sagenites sp. of a probable Norian age; abundant but poorly preserved molluskan fauna collected from 10 to 11 feet below top from a bed of grey, nodular limestone interbedded with black argillite and containing small pods and lenses of calcareous greywacke (GSC loc. 83919)		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	includes Monotis sp. [fragments of ?M. subcircularis (Gabb)] of a probable upper Norian age; top covered on the quarry's floor; base covered near the southwestern side of secondary road; visible	25 (approx.)	25

Section No. 2. (Field No. JA-F68-5). Measured on the northeastern side of Banter Point between its tip at latitude 50°29'42"N, longitude 127°36'53"W and the point about 1/2 mile farther southeast at latitude 50°29'26"N; longitude 127°36'53"W.

RHAETIAN STAGE?

VOLCANIC DIVISION

Hecate Cove Formation

1	Volcanic breccia, dull grey to greenish grey; fine to medium, waterlain; matrix between fragments is dark grey, argillaceous and extremely calcareous; the basal 10 to 12 feet contain a fair number of limestone fragments in addition to prevalent volcanic fragments; the following 18 to 20 feet include numerous beds of fine to medium poorly rounded pebble conglomerate composed of volcanic rocks; lower contact abrupt but apparently even (paraconformable); 30 feet above base the unit is cut by a minor left lateral fault (displacement of about 25 feet) striking 325° to 330° and dipping vertically; above this fault the above described volcanic breccia includes interbeds of fine to rarely coarse mixed breccia and limestone breccia; top cut off by a strong west-trending fault in the middle of northern face of Banter Point; limestone of unit 2 reappears on the southern side of this fault; visible	250 (est.)	475

Unit	Description	Thickness (feet)	Height Above Base (feet)
	NORIAN STAGE		
	SEDIMENTARY DIVISION		
	Sutton Formation		
2	Limestone, light to dull grey, dirty white weathering, cryptocrystalline, massive to poorly and thickly bedded; contains considerable number of siliceous lamellae and small, irregularly shaped inclusions some of which are fragments of colonial corals; contains some interbeds and pods of brownish grey coralline limestone; occupies the tip of Banter Point (Pl. IV, Fig. A) and extends for about 300 yards toward southeast on its northeastern side; locally sheared and cut by minor faults; lower contact appears to be conformable; thickness	150 (est.)	225
3	Limestone, dull to dark grey, well-bedded, thin (6 to 12 inches) to medium (2 to 3 feet), impure, cryptocrystalline; includes several 6- to 10-inch beds of light grey coralline limestone and similarly thick beds of black apparently carbonaceous and limy argillite; at the point about 700 yards SE of the tip of Banter Point some poor fossils including poor plant remains and an indeterminate pectenid bivalve were collected from one of the argillite interbeds in the middle of the unit (GSC loc. 82944); base covered (and probably faulted) in the middle part of the northeastern side of Banter Point at the point about one-half mile southeast of its tip; strike is N 5°E and dip is 40°-50°W; visible	75 (est.)	75

Section 3. (Field No. 252, 1954). Measured in the middle part of a broadly rounded embayment of the southern shore of Buchholz Channel about half way between Smith and Julian Coves at approximate latitude 50°29'12"N; longitude 127°35'52"W. The section occupies the east-northeast limb of a structurally disturbed and magmatically intruded syncline.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	RHAETIAN STAGE?		
	VOLCANIC DIVISION		
	Hecate Cove Formation		
1	Limestone breccia, fine to coarse, grey; commonly grades into poorly to well rounded, fine to coarse pebble conglomerate consisting almost exclusively of limestone pebbles; grey to dark grey matrix of breccia and conglomerate is calcareous and tuffaceous and may include fine to medium fragments of volcanic rocks as elsewhere; matrix becomes very argillaceous and dark grey to black in the topmost few feet of the unit exposed; top not reached in the axis of the syncline; visible up to	70	232
2	Volcanic breccia? coarse, dull grey, exceedingly calcareous and including numerous small pods of calcite; this rock could be a coarse amygdaloidal lava brecciated in the process of underwater effusion (pillow breccia?); numerous interbeds of green-grey to light grey, coarse volcanic breccia with matrix consisting of calcareous volcanic tuff or tuffaceous limestone; numerous interbeds of limestone breccia as in unit 1 and of fine- to coarse-grained, calcareous, waterlain volcanic tuff; contact with unit 1 apparently conformable	105 (est.)	162
3	Volcanic breccia, coarse, rust- to tawny-coloured, waterlain and with abundant grey- to rust-coloured impure limestone matrix between clasts; occurs in 6-inch to 1 1/2-foot thick beds alternating with similarly thick beds of grey tuffaceous limestone; grades upward into unit 2; the base is an intrusive contact with unit 4	30 (est.)	57

Unit	Description	Thickness (feet)	Height Above Base (feet)
	MIDDLE JURASSIC		
	Coast Intrusions		
4	?Diorite porphyry, dark grey, fine to medium grained and rich in medium-size calcitic amygdales; locally feebly to fairly strongly mineralized with pyrite and (?) chalcopyrite; the body appears to be sill-like and does not seem to destroy continuity of surrounding sedimentary section	48 (est.)	
	RHAETIAN STAGE?		
	VOLCANIC DIVISION		
	Hecate Cove Formation		
5	Volcanic breccia essentially as in unit 3 and has the same impure limestone matrix; contains fragments and pods of grey cryptocrystalline limestone and very calcareous volcanic tuff; forms an intrusive contact with unit 4; contact with unit 6 seems to be conformable; visible	7	27
	LATE NORIAN		
	SEDIMENTARY DIVISION		
	Sutton Formation		
6	Limestone, fine to coarse, clastic (calcarenite), strongly tuffaceous; general strike N40°-50°W, dips 10° to 55°E; base cut off by an intrusive body, about 90 feet wide, similar to that of unit 4 and probably faulted; visible up to	20	20

Section 4. (Field No. JA-F68-2). Measured along the northern shore of Quatsino Sound between Jesdal Islet (immediately east of Quatsino village), and the sharp nameless point opposite Kitten Islet (on the west side of Hecate Cove), latitude 50°32'00"N; longitude 127°36'46"W to 50°32'26"N latitude; 127°36'00"W longitude.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	HETTANGIAN STAGE?		
	VOLCANIC DIVISION		
	Basal Jurassic volcanic unit		
1	Lava, predominantly maroon to brick red coloured, exceedingly amygdaloidal, becomes blackish green and Karmutsen-like in basal 30 feet; some interbeds of similarly coloured fine to coarse volcanic breccia; contact with (3) not exposed; occupies the sharp rocky point behind Jesdal Inlet on which Quatsino Hotel and Post Office are situated; this is unit 9 of section 8 (see p. 274); visible	150 (est.)	2,049
	RHAETIAN STAGE?		
	Hecate Cove Formation (type section)		
2	Completely covered within a deep, square bay immediately east of Jesdal Islet; presumably underlain by the same rocks as in (3)	105 (est.)	2,004
3	Irregular, thin to medium (beds 3 to 8 inches thick) interbedding of poorly rounded to angular, brownish green to dark greenish grey, fine pebble conglomerate and coarse to fine, pebbly grit; both rock types are commonly calcareous and therefore weathered differentially to honeycombed on the surface; numerous inclusions of calcareous grit and conglomerate; pebble and grit clasts predominantly composed		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	of various volcanic rocks; a considerable percentage of clasts consist of bluish grey to dark grey, fine-grained to cryptocrystalline limestone, which include some angular fragments up to 4 inches in diameter, occurs in all beds; numerous interbeds of dull brown, lavender-tinged or dark lavender, fine- to coarse-grained, waterlain volcanic tuff and similarly coloured, fine waterlain volcanic breccia occur throughout the unit; numerous interbeds of fine- to coarse-grained, more or less calcareous, differentially weathered (honeycomb), in places somewhat fossiliferous (poorly preserved marine shells; no collection made), gritty and pebbly greywacke occur in the middle part and near the base of the unit; top concealed beneath the water on the western side of a nameless sharp rocky point just east of Jesdal Islet; lower contact gradational; strikes regularly 10° to 20°N and dips 40° to 50°W and is not disturbed otherwise; visible	150 (approx.)	1,899
4	Greywacke dark greenish grey to brownish grey, fine to coarse grained, massive to indistinctly bedded, more or less calcareous throughout and commonly differentially weathered to honeycombed on the surface; normally gritty to pebbly; more or less fossiliferous throughout and contains an abundant marine fauna in the interval 2 to 12 feet above visible base; according to E. T. Tozer this probably Upper Triassic fauna (GSC loc. 82932) includes: Neomegalodon sp., Palaeocardita sp., indeterminate bivalves and indeterminate colonial corals; base covered at the eastern base of the above mentioned sharp point; visible	20	1,749
5	Completely covered	15	

Unit	Description	Thickness (feet)	Heig Above (feet)
6	Limestone, dark grey, impure (mostly tuffaceous); contains abundant fragments and rounded (1/4 inch to 3 inches) inclusions of lighter grey, softer limestone and of more rare fragments and inclusions of other sedimentary and volcanic rocks; attitude as in overlying beds; lower contact gradational; occupies a secondary embayment of the shore about 300 feet wide and the western side of a rounded point on its eastern side; indeterminate marine pelecypods (GSC loc. 24332) were found in float of the lower part of the unit; thickness	210 (est.)	1,729
7	Volcanic (? andesitic) breccia, dull green-grey, coarse to fine, distinctly bedded and waterlain; upper 200 feet interbedded with an almost equal amount of a similarly coloured, mixed and sedimentary breccia and of invariably poorly rounded fine to coarse pebble conglomerate (conglobreccia); these interbeds become progressively fewer farther downsection where the volcanic breccia is predominantly indistinctly bedded and its fragments much less waterworn; attitude as in overlying beds; outcrops continuously for 800 feet (across general strike) across the rounded point and to the inner western corner of a deep, angular bay following the former; visible	560 (est.)	1,519
8	Mainly covered in the NW corner of above mentioned bay around the mouth of a nameless small creek but probably underlain by the volcanic breccia as in 7 judging by the minor scattered outcrops within the interval; strikes about 360° and dips are 30° to 35°W throughout so that no major fault appears to be indicated within this interval; thickness	210 (est.)	959
9	Volcanic breccia, green-grey or blue-green, similar to that of unit 7; strikes about N10°E, dips 45° to 50°W; occupies a small rocky point in the middle of the bay; visible	100 (approx.)	749

Unit	Description	Thickness (feet)	Height Above Base (feet)
10	Interbedded (mostly thin) brown-grey to dark grey, fine-grained, waterlain volcanic tuff or similarly coloured tuffaceous argillite with waterlain volcanic breccia as in unit 9; outcrops are poor and scattered and alternate with many covered intervals; attitude as above; thickness	52 (est.)	649
11	Limestone, dull grey, brownish grey weathering cryptocrystalline, impure; considerable interbeds of limestone breccia as in overlying beds (e.g. in unit 6); top concealed; lower contact gradational; strike N5°E and dips 55° to 60°W; visible	37 (approx.)	597
12	Interbedded brownish grey to dull grey, more or less calcareous waterlain volcanic tuff; fine- to very fine-grained, similarly coloured, more or less calcareous, ?tuffaceous siltstone and similarly coloured, silty, fine-grained greywacke; all three rock types are well bedded with most beds 6 inches to 3 feet thick; contain fairly common lenses and pods of impure, nodular to breccia-like limestone as in unit 11; also includes several interbeds (1 to 5 feet) of dull grey to brownish grey, medium- to coarse-grained waterlain volcanic tuff, fine to medium, poorly rounded volcanic pebble conglomerate (conglobreccia), and mixed, waterlain breccia; rocks are locally flexed in small auxiliary folds and even somewhat contorted but the overall continuity of the sequence does not seem to be lost anywhere; strike around N20°E and dips 50° to 60°W; lower contact appears to be gradational; thickness	410 (approx.)	560

Unit	Description	Thickness (feet)	Height Above Base (feet)
13	Volcanic breccia generally as in units 7 and 9 but includes numerous interbeds of poorly rounded, volcanic, fine to medium pebble conglomerate; rocks are broken by minor faults and locally somewhat contorted; general strike 340°, dips vary from 50° to 55°W; base not exposed in the axis of a north-northeast-trending anticline which extends for about one-eighth of a mile along the shore around a nameless, sharp point of the shoreline ending in a prominent dry rock shown in all marine charts; visible	150 (est.)	150

Section No. 5 (Field No. 253/2, 1954). Measured in the northwestern corner of Koprino Harbour, along the western side of Robson Cove and across the tip of nameless point separating it from Spencer Cove. The top of the section is at approximate latitude 50°30'20"N; longitude 127°52'00"W.

RHAETIAN STAGE?

VOLCANIC DIVISION

Hecate Cove Formation

1	Interbedded brownish green, fine- to coarse-grained volcanic tuffs and black, ?tuffaceous argillite; rocks are considerably jointed and sheared throughout but appear to strike 220° to 240°; dips range from about vertical to 75° east (?overturned); lower contact poorly exposed and strongly disturbed but appears to be conformable; top concealed at the fringe of the forest just before the delta of a small creek falling into the head part of Robson Cove; thickness assumed to be about	100?	640?

Unit	Description	Thickness (feet)	Height Above Base (feet)
2	Fine to coarse volcanic breccia, greenish grey to purplish grey, partly well bedded and with somewhat waterworn fragments more or less sorted according to the size; a rounded boulder (18-inch diameter) of pinkish grey limestone was found in the middle part; some interbeds of dark grey, finely amygdaloidal lava and similarly coloured coarse-grained volcanic tuff; rocks are very strongly sheared and partly contorted but strike about 300° wherever less disturbed; dips vary from 50°W (?normal) to 30-65°E (?overturned); base covered; visible thickness assumed to be in order of	200?	540?
3	A completely covered (along the shore) interval, about 100 feet wide, within a marked embayment on the southern side of Robson Cove; probably is underlain by a major east-west trending fault		
4	Lava, (?andesitic), brownish grey to maroon, moderately to strongly amygdaloidal; interbedded with similarly coloured, distinctly bedded, waterlain volcanic tuff; minor pods, lenses and interbeds of limestone as in unit (5) scattered throughout the succession; rocks are exceedingly disturbed and totally sheared throughout but the general attitude seems to be the same as in adjacent units; seems to grade downward into unit (5); thickness is assumed to be in order of	200?	340?
5	Waterlain volcanic breccia, mottled grey, consists of various, fine to coarse breccia-size volcanic fragments embedded in abundant matrix of dull grey, whitish grey weathering limestone; lenses 3 to 5 feet thick and irregularly lenticular beds of more or less pure, grey, whitish weathering limestone occur at irregular intervals; strongly sheared and jointed and partly contorted but the general attitude appears to be more or less as in unit 6; lower contact appears to be gradational	50 (approx.)	140

Unit	Description	Thickness (feet)	Height Above Base (feet)
6	Irregular interbedding of sedimentary rocks as in unit 7 with dark green to greenish grey, amygdaloidal lavas and brownish grey to maroon, calcareous, waterlain pyroclastics rich in pods and 3- to 5-foot thick lenticular beds of dull grey, more or less tuffaceous limestone; rocks are badly disturbed but tend to strike 230° to 250° and to dip 50° to 70° east (?overturned); grades downward into unit (7)	20 (est.)	90
	LATE LATE NORIAN STAGE		
	SEDIMENTARY DIVISION		
	Arenaceous Member		
	Argillite unit		
7	Argillite, dark grey to black, mainly thinly bedded, tuffaceous to arenaceous; numerous thin to medium beds and layers of fine- to coarse-grained, dull grey greywacke and some layers of similarly coloured grit are dispersed throughout the unit; irregular pods, lenses and several minor interbeds of pure to arenaceous, grey limestone; several thin to thick beds of waterlain pyroclastics; some indeterminate marine (pectenid?) pelecypods (GSC loc. 24327) were collected from a row of pods of impure limestone near the top of the unit; rocks are excessively sheared to almost milonitized and contorted in part; wherever less disturbed, they strike 250° to 290° and dip more or less vertically; however, the dips may become either westerly (?normal) to easterly (?overturned) at angles ranging from 60° to 80° within short distances along and across the strike; base concealed beneath the water off the eastern side of the point; visible up to	70 (est.)	70

Section 6 (Field No. JA-F69-5/2). Measured in the left (northwestern) bank of the right branch of unnamed left confluent of Lippy Creek at the point about 260 feet upstream from the small abandoned quarry where the lower part of Section 1 was measured and about 120 feet south-southeast of the top of this section across the divide between the branches. Approximate latitude 50°28'40"N; longitude 127°28'42"W (see Pl. III, Fig. A).

Unit	Description	Thickness (feet)	Height Above Base (feet)
	RHAETIAN STAGE?		
	VOLCANIC DIVISION		
	Hecate Cove Formation		
1	Basic lava, dark green to almost black, abundantly and coarsely porphyritic with many large and well-formed ?augite phenocrysts, ground mass felsitic to ?trachitic; massive-looking when fresh, weathers spheroidally and locally pillow-like; no attitude; upper contact covered and no rock outcrops seen for at least 100 feet farther upstream; lower contact poorly exposed but possibly disconformable; visible	50 (est.)	71
2	Coarse pebble to boulder (4- to 12-inch clasts predominate) conglomerate, dark grey to dark brown, tightly packed, most clasts poorly rounded; the bulk of pebbles are composed of ?augite porphyry similar to that of unit 1; pebbles of bluish grey, argillaceous, water-lain volcanic breccia prevalent in other sections of the Hecate Cove Formation occur but rarely; some pebbles of dark grey argillite and dark grey greywacke as in the late Norian beds of Section 1; lower contact is sharp, rather uneven and obviously disconformable; the volcanic conglomerate fills depressions and pockets, 1 to 2 feet deep, in the surface of rust-coloured (deeply weathered?) argillite of bed 3; attitude of volcanic conglomerate appears to be about the same as the underlying argillite but no exact measurements were possible; the basal conglomerate appears to thicken southeastward across the outcrop from 3 to 5 feet and the ratio		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	of 4- to 12-inch clasts composed of blue-grey, argillaceous volcanic breccia increases in this direction	5	21
	LATE LATE NORIAN		
	SEDIMENTARY DIVISION		
	Arenaceous Member		
	Argillite unit		
3	Argillite, dark to blackish brown, lithologically similar to and continuous with the unit 3 of section 1 (see p.249); contains poor fragments of Monotis-like pelecypods but no collection was made; strikes about 210° and dips about 27°W; base covered on the lower part of the slope; visible	16	16

Section No. 7 (Field No. JA-F69-12). Measured along the southwestern bank of the secondary logging road branching northwestward off the main Gibson Road at the altitude of ± 1,800 ft. The section is situated 400 to 500 feet northwest of the small abandoned quarry where the lower part of Section 1 was measured; (latitude 50°28'51"N; longitude 127°28'46"W; approximate).

	RHAETIAN STAGE?		
	VOLCANIC DIVISION		
	Hecate Cove Formation		
1	Volcanic breccia (agglomerate?), green-grey, ?andesitic, medium to coarse, almost unsorted; this volcanic breccia is lithologically similar to the green-grey waterlain breccia characteristic of more westerly sections of the unit but its fine to coarse tuffaceous matrix appears to be devoid of argillaceous particles and is non-calcareous;		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	fragments appear to lack any erosional rounding and sorting according to size; upper contact covered; lower contact appears to be conformable but abrupt; visible	80 (est.)	180
2	Boulder conglomerate, dark grey, lithologically similar to that of unit 2 of section 6; strikes 340°, dips about 40°W; lower contact covered; visible	20	100
3	Completely covered interval across the general strike of unit 4 and probably concealing a normal but disconformable contact between units 2 and 4	3	
	LATE LATE NORIAN		
	SEDIMENTARY DIVISION		
	Arenaceous Member		
	Argillite unit		
4	Argillite, dark to brown-grey, weathers dark brown or dark chocolate; mostly medium to thickly (6 inches to 2 feet) and indistinctly bedded but includes some interbeds of thinly bedded to laminated calcareous argillite; some interbeds (up to 3 feet thick) of dark brown, calcareous, fine- to coarse-grained tuffaceous greywacke and similarly thick interbeds of lavender-coloured, distinctly and thinly bedded, waterlain volcanic tuff lithologically similar to that outcropping on the western side of Julian Cove and on the southwestern side of Banter Point (see pp. 43-44); strike 350°, dip 42°W; fauna collected about 17 feet below visible top of the unit from a paper thin lamella in a 3- to 4-inch thick greywacke interbed (GSC loc. 83930) includes the late Norian Monotis cf. ochotica var. densicostata (Teller); the unit is believed to be the equivalent of bed 3 of section No. 6 and of beds 3 to 5 of section No. 1; outcrops poor and intermittent; lower contact covered; visible	80 (approx.)	80

Section 8 (Field No. 243, 1953, 1954). Measured on the northern shore of Quatsino Sound between the nameless little bay immediately west of Sherberg Islet (latitude 50°32'15"N, longitude 127°38'36"W) and the nameless point behind Jesdal Islet on which Quatsino Hotel stands (latitude 50°32'00"N, longitude 127°36'45"W). This section is an upward extension of Section 4 of the Hecate Cove Formation.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	Upper Valanginian and ?Hauterivian greywacke-conglomerate unit		
1	Pebble conglomerate, fine to medium grey; pebbles very poorly rounded and sorted; large and small boulders of volcanic rocks lithologically identical with those in the underlying beds and apparently locally derived occur scattered between smaller pebbles in the basal few feet; higher in the section the conglomerate is interfingered with numerous lenticular beds and layers of coarse, gritty, poorly sorted greywacke commonly grading into pebbly grits; contact with unit (2) uneven and very sharp with deep depressions in the surface of unit (2) filled with the conglomerate; top concealed underneath beach and alluvial deposits of Aweisha Creek; visible	up to 35 (est.)	2,240
	HETTANGIAN STAGE? (LOWER JURASSIC)		
	VOLCANIC DIVISION		
	Basal Jurassic volcanic unit		
2	Volcanic breccia, dark reddish grey to tawny, or maroon, coarse to medium, completely unsorted; a few interbeds of poorly sorted and indistinctly bedded lithologically similar volcanic breccia; just below contact with (1) the breccia is interbedded with dark green, ?basic, amygdaloidal lavas; contact with (3)		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	poorly exposed but probably conformable; cut by several dykes and irregular bodies of very porphyritic, medium- to coarse-grained ?dioritic intrusive rock	300 (est.)	2,215
3	Lava, bluish green to blackish green, ?basic, strongly amygdaloidal, massive to very indistinctly banded; locally interbedded with some dark green, coarsely porphyritic, ?basic lava; lower contact covered	460 (est.)	1,915
4	Mostly covered by beach deposits or overgrown but with some outcrops of green-grey, fine to coarse volcanic breccia and similarly coloured, porphyritic or strongly amygdaloidal ?basic lavas along the beach, in creek beds and in the road cuts; unit probably underlain by interbedding of these rocks throughout	700 (est.)	1,455
5	Volcanic breccia, coarse, dark red to brick red; some interbeds of similarly coloured porphyritic lavas; top covered, lower contact poorly exposed but apparently conformable ...	160 (est.)	755
6	Lava, reddish-grey to dull red, massive, abundant meat-red to pink phenocrysts of ?sodic plagioclase; matrix felsitic to very finely porphyritic; base covered; visible	225 (est.)	435
7	Covered across general strike	100 (est.)	310
8	Irregular (often lenticular) interbedding of maroon to lavender or reddish grey, mostly well bedded, fine to coarse volcanic breccia and similarly coloured, fine to coarse volcanic tuffs, volcanic tuffs predominate in the upper 25 feet of the unit while volcanic breccia predominates in its lower 35 feet; lower contact conformable; top covered; visible (across general strike, strike is 350° to 360°, dip is 30°-35°)	60 (est.)	210

Unit	Description	Thickness (feet)	Height Above Base (feet)
9	Lava, predominantly maroon to brick-red, very amygdaloidal; become blackish green and Karmutsen-like in the basal 30 feet or so; some interbeds of similarly coloured fine to coarse volcanic breccia; this is the unit (1) of section 4 (see p. 262); lower contact covered; visible	150 (est.)	150

Section 9 (Field No. 244/1-5, 1953). Measured on a nameless rocky point of the southern shore of Quatsino Sound opposite the eastern tip of the largest Koskimo Islet; (latitude 50°29'45"N; longitude 127°50'39"W).

HETTANGIAN STAGE? (LOWER JURASSIC)

VOLCANIC DIVISION

Cherty limestone unit

1	Limestone, grey to dark grey, cherty, thin-bedded to laminated (commonly paper-thin); numerous layers and lamellae of black and grey chert; some 2- to 3-foot thick interbeds of cherty rock and strongly concretionary limestone rich in cherty inclusions, lenses and thin interbeds; some similarly thick interbeds of strongly tuffaceous grey limestone, calcareous grey shale and calcareous, waterlain volcanic tuff; rocks flexed into several disharmonic folds and strongly faulted; top faulted; lower contact apparently conformable; visible	150 (est.)	1,195

Basal Jurassic volcanic unit

2	Lava, blackish green, ?basaltic, very coarsely amygdaloidal; occurs in beds and members, 5 to 35 feet thick, interbedded with similarly thick beds and members of limestone as in (1), lower contact conformable	200 (est.)	1,045

Unit	Description	Thickness (feet)	Height Above Base (feet)
3	Lava, grey, blackish-green and lavender-grey varieties alternate irregularly, ?basic, strongly amygdaloidal, pronouncedly banded; minor interbeds of tuffaceous limestone as in unit (1); lower contact conformable	300 (est.)	845
4	Lava, light grey to bluish grey, speckled, fine amygdaloidal, massive; interbedded with some lavender to dark reddish grey coloured porphyritic lava; lower contact conformable ..	20	545
5	Volcanic tuff, light grey to bluish grey, speckled, fine- to medium-grained, massive; interbedded with some amygdaloidal and porphyritic lavas as in (3); lower contact apparently conformable	275 (est.)	525
6	Volcanic breccia, mottled reddish grey, fine grained; locally grades into similarly coloured coarse-grained volcanic tuff containing irregularly shaped nodules of similarly coloured, coarse-grained, calcareous volcanic tuff; numerous interbeds of greenish grey, well-bedded, calcareous, waterlain, fine to medium volcanic breccia and coarse-grained volcanic tuff in the middle part; rocks flexed into several, minor open folds; base not reached in their axial parts ...	250 (est.)	250

Lavas of unit (3) with easterly dips reappear on the southeastern side of outcrops of unit (5). Farther south no outcrops seen for 1 1/2 miles along the shore which apparently harbours a major fault zone.

Section 10 (Field No. 262, 1954). Measured on the finger-like, easternmost point of the largest Koskimo Islet. Latitude 50°28'20"N, longitude 127°50'45"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LATE HETTANGIAN STAGE? (LOWER JURASSIC)		
	VOLCANIC DIVISION		
	Grey volcanic unit		
1	Volcanic tuff, dull rose to dull red coloured, fine to coarse, abundant volcanic fragments and numerous crystals of red ?sodic plagioclase; minor interbeds of lithologically similar volcanic breccia; top faulted and lower contact poorly exposed; visible	80 (est.)	879
2	Lava, grey, massive, aphanitic to fine grained; considerably disturbed by faults and sheared; lower contact poorly exposed and may be faulted	50 (est.)	799
3	Lava, purple-grey, banded, amygdaloidal; interbedded with 2- to 5-foot thick bands of grey, massive, aphanitic to fine-grained (?trachitic) lava; lower contact appears to be conformable	40 (est.)	749
4	Volcanic rock (?lava), dark grey, massive, aphanitic; base faulted; visible	180 (est.)	709
5	A major, fault zone, trending N50° to 60°W, consisting of contorted and sheared beds of above described volcanic rocks and underlying cherty limestones of units 6 to 13 inclusive; width of fault zone	75 (est.)	

Unit	Description	Thickness (feet)	Height Above Base (feet)
	Cherty limestone unit		
6	Limestone, grey, thinly bedded; interbedded with much thinly bedded black chert; top cut off by fault; lower contact conformable; visible	15	429
7	Volcanic tuff, grey, fine to coarse grained, well bedded and obviously waterlain, minor interbeds of lithologically similar, waterlain volcanic breccia; lower contact conformable...	55	414
8	Limestone, dark grey to light grey, mostly pure, thinly bedded (beds 1 to 6 inches thick) and layered (1/2 to 1 inch thick) with considerable number of similarly thick interbeds and layers of black chert; several beds 2 to 5 feet thick, of calcareous grit or tuffaceous grit; lower contact much disturbed by faults and intrusive dykes but appears to be conformable	50 (est.)	359
9	Limestone much as in (8) but with considerably greater ratio (almost 50%) of interbeds and layers of black chert; considerably disturbed by faults and numerous, green-grey, amygdaloidal to feebly porphyritic dykes, sills and stock-like bodies of Coast Intrusions and commonly coloured orange by hydrothermal solutions; base covered, visible	45	309
10	Completely covered interval apparently harbouring a major fault; width across general strike	90	
11	Limestone, black to dark grey, very thinly bedded to laminated (1/2- to 3-inch beds and layers); replete with laminae of black chert which mostly parallel the bedding planes; frilled and twisted chert lamellae rare; 1- to 2-inch layers and up to 2 1/2-foot thick beds of more or less pure grey, whitish weathered limestone, those of gritty and sandy limestone, and those of similarly coloured calcareous and tuffaceous grit occur at irregular intervals in upper 40 feet.		

stock-like

Unit	Description	Thickness (feet)	Height Above Base (feet)
	Twenty to 40 feet below top, the cherty lamellae largely replaced by 1- to 4-inch thick, irregularly limited, concretionary beds; 23 to 26 feet below top, rock is replete in small indeterminable Planorbis-like shells; lower contact partly faulted but apparently conformable	100 (est.)	264
12	Limestone, black to brownish grey, cherty, replete with greatly and irregularly twisted and frilled cherty inclusions and lamellae which commonly comprise over 50% of the rock; interfingered with 1/2- to 1-foot thick inclusions and lenses of more pure, grey limestone; poorly exposed and often contorted in upper 12 feet (a minor strike fault); lower contact conformable	20 (est.)	164
13	Limestone, dark grey to black, cherty, occurs in 1- to 3-inch thick layers and 1/2- to 1 1/2-foot thick beds; replete with laminae of black chert or very cherty limestone, 1/2 to 12 mm thick; these laminae are often twisted and frilled in a most irregular fashion with similarly thick laminae of grey limestone wedged between them; lower contact conformable	60 (est.)	144
14	Limestone, dark grey to black, thin bedded to laminated (beds and layers 1/2 to 2 inches thick) extremely tuffaceous and cherty; interbeds of more pure, light grey limestone; base covered; visible	7	84
15	Covered, across general strike	15 (est.)	
16	Limestone, as in 14; top covered; lower contact conformable; visible	2	77

Unit	Description	Thickness (feet)	Height Above Base (feet)
	HETTANGIAN STAGE ?		
	VOLCANIC DIVISION		
	Basal Jurassic volcanic unit		
17	Volcanic tuff, purplish grey, coarse, very porphyritic (crystal tuff); inclusions and lenses of lithologically similar, calcareous tuff; lower contact conformable	3	75
18	Lava, dull to dark grey, fine to coarse porphyritic	2	72
19	Volcanic tuff, dull grey to speckled (blue and purple), fine to coarse grained, more or less calcareous and containing inclusions and lenses of grey, tuffaceous limestone; both contacts conformable	9	70
20	Lava, grey, massive, feebly porphyritic; lower contact conformable and gradational	8	61
21	Lava, dull grey with minor interbeds of dull purple and blue lavas, strongly to feebly amygdaloidal, occurs in 3- to 5-foot bands; persistent strike N to N10°W with dips 40° to 45°W; base concealed beneath the sea on the east side of the point, visible	53	53

Section 11 (Field No. 244/1, 1953). Measured on the southern shore of Quatsino Sound at the point approximately due south of the western side of the largest Koskimo Islet. Base of the section is situated almost opposite (slightly to southwest of) the top of Section 10, (latitude 50°28'08"N; longitude 127°51'10"W; approximate).

HETTANGIAN STAGE ? (LOWER JURASSIC)

VOLCANIC DIVISION

Grey volcanic unit

1	Volcanic breccia, mottled green-grey with reddish specks, fine to coarse; interbeds of similarly coloured volcanic tuff; closely		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	jointed and commonly sheared but strikes at 330° and dips 35° to 40° west; top not reached on the mainland; lower contact conformable; apparently corresponds to unit 1 of section 10; visible	800 (est.)	1,135
2	Volcanic rock (lava or tuff), blackish green, massive, aphanitic; attitude appears to be as in unit 1; lower contact covered; apparently corresponds to units 2 and 3 of section 10; visible	30 (est.)	335
3	Completely covered by logging debris around the mouth of a small creek (across general strike)	50	
4	Mixed, sedimentary-volcanic to ?sedimentary breccia grading into and interbedded with conglomerate (poorly rounded pebbles), dark grey, coarse to fine, rich in fragments which appear to be those of grey shale; partly calcareous; thinly but irregularly bedded; some interbeds of bright green, very fine-grained, waterlain volcanic tuff lithologically similar to that occurring as fragments in assumed Uppermost Sinemurian argillites outcropping (see p.98) north of the mouth of Kwatleo Creek; strike 330° to 340°, dips 50° to 55° west; both contacts covered; forms a high bluff and a 20- to 30-foot high undercut bench at the water's edge; visible	50 (est.)	305
5	Completely covered by logging debris inside of an embayment of the shore (across the strike) ...	60 (approx.)	
6	Volcanic tuff, dark grey to green-grey, fine grained, thinly bedded; some interbeds of grey thinly bedded to laminated, apparently considerably tuffaceous limestone with intercalated laminae and 1/4- to 1-inch thick interbeds of similarly coloured calcareous volcanic tuff; top covered, lower contact conformable; visible	25 (est.)	255

Unit	Description	Thickness (feet)	Height Above Base (feet)
7	Interbedded waterlain sedimentary-volcanic breccia and poorly rounded conglomerate more or less as in unit 4 and including some interbeds of volcanic tuff	180 (est.)	230
8	Lava, dark greenish grey, containing abundant amygdules of dark-green and white calcite; upper contact conformable; base covered; visible	50 (est.)	50
9	A completely covered interval within an embayment of the shoreline; probably underlain by a major fault; along the shore	350 (approx.)	
	MIDDLE JURASSIC		
	Coast Intrusions		
10	Intrusive dyke rock, dull-grey, dark grey weathering; contains abundant large (1/4 to 1/2 inch) white quartz amygdules; massive; contains hardened and partly baked inclusions of thinly bedded limestone apparently derived from the Cherty limestone unit; top covered; intrusive contact with unit 11; visible	15-20	
	HETTANGIAN?		
	VOLCANIC DIVISION		
	Cherty limestone unit		
11	Limestone, dark grey to light grey, cherty to ?pure, thinly bedded (1- to 6-inch beds) to layered (1/2- to 1-inch layers) or laminated; considerable number of similarly thick interbeds and laminae of black chert and siliceous shale; badly disturbed by faults		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	or completely crushed; no estimate of thickness possible; exposures extend along the shore for about 400 feet and are in fault contact with the unit 1 of section 9		

Section 12 (Field No. 241, 1953). Measured across a pronounced, double-pronged rocky point on the northwestern shore of Forward Inlet at the point about three-fifths of a mile northeast of the mouth of Browning Inlet, (latitude 50°29'40"N; longitude 128°02'40"W approximate)

LOWER SINEMURIAN (LOWER JURASSIC)

VOLCANIC DIVISION

Matthews Island Formation

1	Argillites, mostly medium to dark grey, thin bedded to laminated, mostly arenaceous or ?tuffaceous; exceedingly calcareous in part; interbeds and layers of tawny to brick-red-weathered argillite; rocks considerably broken by faults and strongly sheared; top cut off by a major fault; lower contact gradational; visible	20	1,134
2	Interbedding of dark grey, pure argillite with tuffaceous, grey argillite similarly coloured argillaceous, waterlain volcanic tuff, and thin, 2-inch to 1-foot interbeds of dark grey to brownish grey, abundantly porphyritic or amygdaloidal lava; rocks strongly faulted and sheared; lower contact conformable	15	1,114

UPPER HETTANGIAN?

VOLCANIC DIVISION

Grey volcanic unit

3	Lava, grey, strongly amygdaloidal commonly with pronounced pillow structures; medium to thinly banded; strongly sheared	55	1,099

Unit	Description	Thickness (feet)	Height Above Base (feet)
4	Lava, grey to brownish grey, strongly porphyritic, with lenses and interbeds of tuffaceous grey shale or argillaceous, waterlain volcanic tuff; lower contact conformable and gradational	4	1,054
5	Volcanic breccia and ?pillow lava, green-grey, coarse porphyritic to abundantly amygdaloidal; thinly banded	100	1,050
6	Lava, bluish grey to dull grey, abundantly amygdaloidal, commonly with distinct pillow structures, massive to banded; some interbeds of similarly coloured, porphyritic lava; both contacts conformable	550 (est.)	950
7	Volcanic breccia (?pillow breccia), green-grey, coarse (fragments from 4 inches to 2 feet in diameter), composed predominantly of amygdaloidal lava; base not reached; visible	400 (est.)	400

diameter

Section 13 (Field No. 256, 1954). Measured in the northwestern corner of Browning Inlet at the mouth of a nameless small creek which enters the inlet about 300 yards west of Leeson Creek, (latitude 50°30'33"N; longitude 128°05'12"W approximate).

SINEMURIAN

SINEMURIAN

VOLCANIC DIVISION

(Uppermost Sinemurian)

Uppermost Sinemurian volcanic unit

1	Volcanic breccia, light grey to brownish grey, medium to fine, distinctly and thinly bedded, partly well sorted, fragments somewhat rounded; presumably corresponds to units 6 and 7 of section 14; top concealed beneath beach deposits; lower contact conformable and gradational; visible	200 (est.)	302

Unit	Description	Thickness (feet)	Height Above Base (feet)
	SINEMURIAN		
	VOLCANIC DIVISION		
	Matthews Island Formation		
	Upper argillite member		
2	Argillite, black to dark grey, locally arenacous, thinly to medium bedded; some lamellae, thin layers and 1- to 2-foot thick interbeds of dull grey, fine-grained calcareous greywacke and similarly coloured impure limestone; fragment of a probable arietitid ammonite, genus and species indetermined (GSC loc. 24313) was found 10 feet below the top of the unit; presumably corresponds to units 8 to 10 inclusive of section 14; lower contact apparently conformable and gradational	90 (est.)	102
	Waterlain tuff member		
3	Volcanic tuff, greenish grey, fine to coarse grained, distinctly bedded and waterlain; some interbeds of similarly coloured, fine, waterlain volcanic breccia; presumably corresponds to units 11 and 12 of section 14; base concealed underneath the beach deposits, visible	12 (est.)	12

Section 14 (Field No. 240/1-8, 1953). Measured on northwestern side of Matthews Island (=Robson Island of Dawson, 1887, p. 83D) at the point about 2 1/2 miles southwestward of section 13; (latitude 50°29'06"N, longitude 128°02'30"W approximate)

Unit	Description	Thickness (feet)	Height Above Base (feet)
	SINEMURIAN SINEMURIAN (LOWER JURASSIC)		
	VOLCANIC DIVISION Uppermost Sinemurian Uppermost Sinemurian volcanic unit		
1	Lava, green-grey, bluish green, reddish to dull grey, purple and brick-red to maroon; these colours replace each each other quite irregularly along and across the strike; predominantly finely to coarsely amygdaloidal and commonly well banded; numerous interbeds of similarly coloured, porphyritic lavas containing abundant lath-like phenocrysts of orange to pink sodic plagioclase and of ?hematite; pillow structures were noted in places; rocks intensely sheared, jointed and contorted in the uppermost 150 to 200 feet; top cut off by a strong fault running along the southwestern side of the island; lower contact appears to be conformable; visible	300 (est.)	1,468
2	Volcanic breccia (pillow breccia in part), bluish grey, coarse to very coarse; relatively poor in matrix consisting of waterlain volcanic tuff and fine to medium breccia fragments; indistinctly bedded; rocks intensely sheared and faulted; base covered and apparently cut off by a major fault; visible	15	1,168
3	Covered interval apparently harbouring a major northwest-trending fault; width across strike	180	

Unit	Description	Thickness (feet)	Height Above Base (feet)
4	Volcanic breccia (mostly pillow breccia), grey when fresh, weathers blackish grey, coarse to very coarse with very large (1 to 2 feet in diameter), somewhat rounded pillow fragments enclosed in a matrix of medium to fine breccia fragments; all fragments composed of the same light grey, abundantly amygdaloidal lava; strongly sheared and cut by minor faults in uppermost 10-15 feet; top covered; lower contact conformable; visible	50 (est.)	1,153
5	Volcanic breccia (mostly pillow breccia), greenish grey, coarse; consists of rounded pillow fragments normally 1 1/2 to 6 inches in diameter but locally as much as 5 to 10 inches in diameter composed of amygdaloidal and porphyritic volcanic rock embedded in matrix consisting of tuffaceous to fine breccia fragments; some interbeds of banded volcanic tuff; otherwise massive and completely unsorted; lower contact conformable	100 (est.)	1,103
6	Volcanic breccia, reddish grey, medium (fragments from 1/8 to 2 inches in diameter predominate); indistinctly bedded and almost unsorted	120 (est.)	1,003
7	Volcanic tuff, bluish grey, thickly bedded (3- to 6-foot beds), coarse grained, locally grades into fine reddish grey volcanic breccia; 5- to 6-foot thick beds of fine-grained, thinly bedded to laminated, waterlain, partly distinctly sorted and calcareous volcanic tuff occur at more or less regular intervals. In the middle part occurs a bed, 15 to 18 feet thick, of fine, poorly rounded volcanic conglomerate interbedded with the waterlain volcanic tuff which commonly grades into tuffaceous greywacke; the ratio of fine volcanic breccia increases to 30-40% in the upper 60 feet of the unit where some interbeds of medium to coarse volcanic breccia (partly pillow breccia) appear as well; lower contact poorly exposed and sheared but appears to be essentially conformable and normal	128 (est.)	883

Unit	Description	Thickness (feet)	Height Above Base (feet)
	SINEMURIAN		
	VOLCANIC DIVISION		
	Matthews Island Formation		
	Upper argillite member		
8	Argillite, dark grey, arenaceous or tuffaceous; outcrops poor and intermittent, covered intervals may conceal other rock types	50 (est.)	755
9	Volcanic tuff, grey, rose-grey weathering, coarse grained, waterlain; calcareous and argillaceous; locally grades into tuffaceous greywacke or into mixed sedimentary-volcanic fine breccia; upper contact gradational	14	705
10	Argillite, dark grey to brownish grey, stained tawny to tuscan-red, thinly bedded to laminated; whitish grey lamellae and layers of chert and cherty shale, 1/2 inch to 3 inches thick, occur commonly; mainly calcareous, considerably arenaceous and/or tuffaceous; indeterminate ammonite fragments occur commonly 6 to 8 feet above base (GSC loc. 23288); lower contact conformable and gradational	17	691
	Waterlain tuff member		
11	Volcanic tuff, brown-grey, fine grained, well bedded, waterlain; grades locally into tuffaceous greywacke; contains calcareous inclusions; lower contact conformable	3	674

Unit	Description	Thickness (feet)	Height Above Base (feet)
12	Volcanic tuff, light greenish grey, lilac tinged and speckled; fine grained, almost massive but nevertheless somewhat sorted; some medium- to coarse-grained fragments (some of feldspar crystals) scattered or segregated in small inclusions and lenses; lower contact conformable and gradational	18	671
13	Volcanic tuff, light grey, fine to medium grained, numerous plagioclase phenocrysts (crystal tuff); waterlain; may grade laterally into tuffaceous greywacke; contains inclusions and lenses of and is interbedded with lenticular layers and 2- to 6-inch thick beds of similarly coloured coarse-grained, calcareous, volcanic tuff, tuffaceous greywacke, grit, and fine volcanic breccia; lower contact gradational	13	653
	Lower argillite member		
14	Argillite, brownish grey to tawny, thinly bedded and banded, hard (flinty); somewhat arenaceous; contain numerous lamellae, layers and 2- to 5-inch thick interbeds of coarse-grained, partly gritty greywacke or waterlain, partly reworked volcanic tuff; lower contact gradational	30 (est.)	640
15	Argillite, brownish grey to dark grey; pure, mostly calcareous, occurs in beds 4 inches to 1 1/2 feet thick; lamellae and layers (as much as 2 inches in thickness) of light grey, fine- to coarse-grained, partly tuffaceous, often calcareous greywacke, similarly coloured, impure limestone and interbeds 1 to 6 inches thick, of softer, fissile shale occur at regular, intervals of from 1 to 5 feet thick; a 2 1/2-foot bed of grey, arenaceous limestone forms the top of the unit; immediately below this bed a shale interval, 1 foot thick, contains abundant specimens of the probably lower Sinemurian ?Arnioceras sp. indet.		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	and indeterminate pelecypods (GSC loc. 23290); indeterminate ammonites (GSC loc. 23289) were found about 35 feet farther down in the succession; rocks cut by several 1- to 4-foot thick sills and dykes of intrusive rock as in (17); the sediments are jointed and sheared, and commonly faulted and contorted; lower contact intrusive with some 12 feet of shale at the base hardened and discoloured (baked).....	115 (est.)	610
	COAST INTRUSIONS		
16	Intrusive ?dioritic dull grey, fine to medium grained, porphyritic?.....	40	
	Lower argillite member		
17	Argillite as in 15 and with similar interbeds but more massive and occurring in beds 1 to 2 feet thick; a 2-foot thick bed of dull grey, fine-grained, tuffaceous greywacke occurs 10 to 12 feet above visible base; indeterminate, arietitid ammonites (GSC loc. 23285) occur 20 to 23 feet above visible base; base covered; visible.....	55 (est.)	495
18	Completely covered interval; assumed to conceal about 290 feet of basal part of the formation; these covered beds are represented in part by units 1-2 of section 17.....	290 (est.)	440
	?UPPER HETTANGIAN		
	VOLCANIC DIVISION		
	Grey volcanic unit		
19	Lava (partly pillow lava), light grey, ?intermediate; mostly well banded and very amygdaloidal; base concealed beneath the sea on the northeastern side of the rocky point; visible.....	150 (est.)	150

Section 15 (No Field No., 1968). Measured on the northern shore of Quatsino Sound. The top is situated at a sharp, bluffy point some 1,000 feet west of Nordstrom Cove (latitude 50°28'58"N, longitude 128°55'38"W) and the section extends along the west side of the cove approximately to latitude 50°29'18"N, longitude 128°56'00"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	(SINEMURIAN)		
	SINEMURIAN STAGE		
	VOLCANIC DIVISION		
	(Uppermost Sinemurian)		
	Uppermost Sinemurian volcanic unit		
1	Pillow lava, dull grey to greenish grey, ?intermediate, amygdaloidal; resembles pillow lava of Grey volcanic unit but is less monotonous and its amygdaloidal texture is less pronounced; the beds strike northwest and dip southwest at moderate angles; top not reached, lower contact covered, visible	150 (est.)	
2	Completely covered interval apparently concealing normal contact between units 1 and 2 judging by a complete absence of shearing and contortion in adjacent rocks; width across general strike	20 (est.)	
3	Waterlain volcanic tuffs similar to that of unit 7, section 14 but generally finer grained and more argillaceous; some pods and interbeds of black sandy and tuffaceous argillites, upper contact covered; lower contact conformable and gradational; visible	15 (est.)	
	SINEMURIAN STAGE		
	VOLCANIC DIVISION		
	Matthews Island Formation		
	Upper argillite member		
4	Argillites, black to dark grey, weather same or rust- to orange-coloured, thinly to medium bedded; some lamellae; commonly somewhat		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	arenaceous and/or tuffaceous; some thin layers and 1- to 2-foot thick interbeds of dull grey, fine-grained calcareous greywacke and similarly coloured impure limestone; no interbeds of waterlain tuff or coarser pyroclastics noted; rocks closely jointed, locally sheared and invaded by numerous minor (1-20 feet thick) irregular bodies of Coast Intrusions which are particularly common in axis of anticline formed by unit 4 on the tidal shelf at the western entrance to Nordstrom Cove; argillites of unit 4 first appear at the point about 300 feet west of Nordstrom Cove and outcrop uninterruptedly with regular northwest strikes and moderate to steep southwesterly dips to its western entrance; at the latter point the dips become reversed; the southwestern side of Nordstrom Cove is underlain by the same argillites, but with northeasterly dips for several hundred feet but the end of their outcrops was not reached; nor was the top of the Waterlain tuff member seen anywhere; fragmentary imprints of ?Echioceras sp. indet. of a questionable late Sinemurian age have been found by J. E. Muller inside Nordstrom Cove (GSC loc. 82886); maximum visible thickness on the southwestern limb of the anticline	200 (est.)	200

Section 16 (Field No. 244/16-26, 1954). Measured on the southern shore of Quatsino Sound in an interval, about 1/2 mile long, of rocky coast just east of an unnamed bluffy point at the eastern side of Mahatta logging camp and opposite the eastern end of Salmon Islets. Top of section at latitude 50°27'48"N; longitude 127°47'56"W; base at latitude 50°28'08"N; longitude 127°47'00"W.

SINEMURIAN

SINEMURIAN STAGE (LOWER JURASSIC)

VOLCANIC DIVISION

Uppermost Sinemurian

Uppermost Sinemurian volcanic unit

1	Lava, light grey, abundantly and coarsely amygdaloidal; amygdules composed of grey		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	to brownish grey calcite, commonly vermiform and 1 to 2 inches or more in diameter; rocks are jointed, sheared, locally contorted and faulted; top covered and presumably faulted; lower contact appears to be conformable; visible	200 (est.)	1,820
2	Volcanic to mixed (i.e. volcanic-sedimentary) breccia, grey, fine to medium; for the most part contains considerable admixture of fragments of various sedimentary rocks; more or less bedded and sorted throughout, waterlain; mixed tuffaceous-arenaceous matrix occurs between breccia-sized fragments; minor interbeds of grey, waterlain volcanic tuff and similarly coloured, tuffaceous greywacke; rocks are exceedingly jointed, sheared and locally contorted; grades downward into unit 3	100 (est.)	1,620
	SINEMURIAN STAGE		
	VOLCANIC DIVISION		
	Matthews Island Formation		
	Upper argillite member		
3	Interbedding of bluish grey, silty, fine-grained greywacke and dark grey, arenaceous (and tuffaceous?) argillites; base covered; visible	12	1,520
4	Covered across general strike and presumably underlain by argillites of unit 5	50	1,508
5	Argillite, dark grey to bluish grey, arenaceous and tuffaceous, occurs in beds 1/2 to 2 feet thick; some similarly thick beds of dark grey, argillaceous, fine-grained greywacke; inclusions and lenses of this greywacke also occur in many of the argillite beds; 15 to 21		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	feet below top of the unit an argillite bed, about 6 feet thick, contains abundant generically indeterminate arietitid, possibly echioceratid, ammonites (GSC loc. 24305); lower contact conformable and gradational; top concealed; visible	25 (est.)	1,458
6	Argillite, dark to blackish grey, rust- to maroon-weathering, mostly pure, in beds 1 to 3 feet thick; indeterminate arietitid ammonites occur commonly throughout the upper 120 feet of the unit; a collection of these ammonites (GSC loc. 24318) made 50 to 52 feet below top from a bed of dark grey argillite contains Echioceras (Melanhippites) harbledownensis Crickmay of a late Sinemurian age; thin layers and 2- to 6-inch thick beds of very arenaceous argillite, argillaceous, fine-grained waterlain volcanic tuff (including crystal tuff) and tuffaceous fine-grained greywacke are interfingered with 1- to 2-foot thick beds of pure to arenaceous argillite at irregular intervals ranging from 2 inches to 1 1/2 feet; their number seems to increase downward in the unit; grades downward into unit 7	120	1,433
7	Argillite, similar to that of unit 6 but much harder (flinty?); locally light to whitish grey (discoloured) and somewhat schistose; much more arenaceous than the argillite of unit (6); commonly interbedded with 1- to 5-foot thick beds of maroon-coloured, fine-grained, tuffaceous greywacke; almost unfossiliferous; rocks are commonly nearly vertical, strongly sheared and somewhat contorted; base covered; visible	280 (est.)	1,313
8	Covered across general strike and probably underlain by argillites of unit 7	135 (est.)	1,033

Unit	Description	Thickness (feet)	Height Above Base (feet)
	Waterlain tuff member equivalent (argillaceous facies)		
9	Argillite, black to brownish grey, partly tuffaceous or arenaceous; thinly bedded; some loaf-like concretions, 1-3 feet in diameter, of dark grey impure limestone; numerous 1- to 6-inch thick layers and beds of fine-grained, tuffaceous greywacke and ?waterlain arenaceous volcanic tuff; a few beds, 1 to 6 inches thick, of grey, coarse amygdaloidal and porphyritic ?lava; rocks are commonly intensely disturbed; top and base covered; visible	120 (est.)	898
	Lower argillite member		
10	Almost completely covered across general strike; partly underlain by argillite similar to that of unit (9) but probably harbours at least one major north-south-trending fault	420	
11	Argillite, much as in unit (9) and with the same concretions of impure limestone; some early Sinemurian (GSC loc. 24307) ?Arnioceras sensu lato sp. indet. fossils were collected at the visible top of the unit; top concealed; above high tide boundary the argillite is at first strongly hardened and bleached and then strongly metamorphosed or transformed into bluish grey to dark green, medium- to coarse-grained and equigranular dioritic or? gabbroic intrusive rock. This intrusive body occupies most of the middle and upper wooded slopes above the tidal platform (south of the measured section) for the next 300 feet across the strike of the beds of Matthews Island Formation; it continues inland for an unknown distance; throughout this 300-foot wide interval the argillites occupying the tidal platform are warped around the northern margin of this intrusive body and locally contorted but apparently neither intensely folded		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	nor repeated by faulting; they become progressively more metamorphosed and partly transformed into intrusive rocks downdip (i.e. eastward along the shore); some sill-like intrusive bodies, 6 to 10 feet thick, invade the metamorphosed argillites within this interval; top covered; base cut off by the intrusive; visible	400 (est.)	778
	MIDDLE JURASSIC		
	Coast Intrusions		
12	Dioritic intrusive rock, light green, medium grained and essentially equigranular, massive-looking; 150 feet farther east along the shore becomes replaced by the bluish grey to grey-green dioritic intrusive rock (see in unit 11) in the central part of the intrusive body; seems to grade into the same dioritic intrusive rock inland; this light green, apparently more acidic marginal phase of the intrusive appears to grade into metamorphosed argillites on both sides and contains numerous "granitized" inclusions of the same; extends along the shore (i.e. across general strike of argillites) for	400 (est.)	
	SINEMURIAN STAGE (LOWER JURASSIC)		
	VOLCANIC DIVISION		
	Matthews Island Formation		
	?Basal variegated member		
13	Argillite, dark grey, strongly tuffaceous and/or arenaceous, forms beds, 2-3 feet thick, alternating with almost equal number of beds, 1-3 feet thick, of grey, fine- to coarse-grained, mostly strongly tuffaceous greywacke;		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	3-foot thick bed of greenish grey, coarse grit to fine sedimentary breccia occurs 3 to 6 feet below visible top of the unit; some interbeds, 5 to 6 feet thick, of irregularly contorted, laminated, arenaceous limestone; an indeterminate ammonite (GSC loc. 24316) was collected from a greywacke bed 3 to 4 feet below top of the unit; top cut off by the intrusive contact with unit (12) which is accompanied by a zone of strongly hardened, locally discoloured and metamorphosed shale 9 to 10 feet wide; the shale is slightly sheared, contorted and cut by calcitic veinlets and stringers; base covered; visible	60 (est.)	378
14	Covered across the general strike and probably contains a fault	100	
15	Volcanic tuff, green-grey, coarse grained; fragments are often markedly rounded and sorted according to the size; arenaceous, distinctly bedded and obviously waterlain, locally grades into coarse tuffaceous grit and greywacke; matrix of waterlain tuff is commonly argillaceous and very finely tuffaceous; contains numerous rounded or irregularly shaped concretions of calcareous grit and gritty limestone; indeterminate ammonites of a probable early Jurassic age were collected (GSC loc. 24317) from calcareous concretions 3 to 4 feet below visible top of the unit; 8-9 feet below top of unit a bed of limy, tuffaceous argillite, 2-3 feet thick, grading into waterlain limy volcanic tuff has yielded (GSC loc. 24313) Weyla sp. indet. and an indeterminate arietitid ammonite; some interbeds of dark grey tuffaceous and calcareous shale in lower 15 to 20 feet; top and base covered; visible	70 (est.)	318

Unit	Description	Thickness (feet)	Height Above Base (feet)
16	Covered across general strike and probably contains a strike fault	24	
17	Argillite, dark bluish grey, very tuffaceous to arenaceous; rich in inclusions of and locally grades into tuffaceous, fine-grained greywacke; some interbeds of orange-weathering, impure (dolomitic?) limestone 3 to 6 inches thick; rocks extremely sheared and contorted; both contacts covered and probably faulted	10	
18	Covered across general strike and probably harbours a minor fault	12	
19	Volcanic tuff, blue and purple (speckled), fine grained; contains small fossiliferous concretions of calcareous waterlain tuff; some indeterminable ammonites (GSC loc. 24315) were collected from these concretions; top concealed and probably faulted; lower contact apparently conformable; visible	3	
20	Grit or very fine pebble conglomerate, rust- to brownish yellow coloured, soft; grades laterally into similarly coloured, fine, distinctly bedded waterlain volcanic breccia; base covered; visible	6	
21	Covered across general strike and probably conceals a strike fault	20	
	East of the covered interval 21 the rocks of units 17 and 19 to 20 inclusive are repeated by faulting; their perfectly exposed, almost undisturbed, and complete downward succession is as follows:		
17 and 18	Interbedding of argillite and limestone as above; top concealed; lower contact gradational; visible	18	248

Unit	Description	Thickness (feet)	Height Above Base (feet)
19	Volcanic tuff, bluish green, waterlain, with the same concretions and ammonite fauna (none collected) as above; lower contact covered	9	230
20	Volcanic breccia, rust- to brownish grey coloured, fine to medium; very well and thinly bedded and strongly crossbedded, waterlain; numerous interbeds of similarly coloured fine to coarse, waterlain volcanic tuff, tuffaceous grit and poorly rounded fine pebble conglomerate; base concealed, visible.....	21	221
21	Covered along the shore (approx. across general strike of the rocks); possibly underlain by Grey volcanic unit but apparently harbours one or more major faults as well	380	
	HETTANGIAN STAGE ?		
	VOLCANIC DIVISION		
	Basal Jurassic volcanic unit		
22	Volcanic breccia, lavender to maroon-coloured, coarse to very coarse (with frequent fragments and large blocks from 3 to 6 feet in diameter), almost unsorted according to size and nearly lacking any traces of bedding; fragments consist mainly of very porphyritic, ?andesitic lava; top concealed, base not reached, visible in the western side of a high escarpment of a major point of the shoreline	200 (est.)	200

Section 17 (Field No. 240/14-15, 1953). Measured in the southern part of a broad embayment, about 300 yards long, occupying the middle part of the eastern side of Matthews Island (=Robson Island of Dawson, 1887, p. 83B) in Forward Inlet (Latitude 50°29'55"N, longitude 128°02'30"W).

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER SINEMURIAN (LOWER JURASSIC)		
	VOLCANIC DIVISION		
	Matthews Island Formation		
	Lower argillite member		
1	Fine pebble conglomerate, mottled grey, abundant poorly rounded pebbles and angular fragments of presumably locally derived argillite similar to that of unit 2, hard, tightly packed; lower contact erosionally disconformable; it is sharp and uneven with depressions and pockets, up to several feet deep, in the surface of unit 2 filled by the conglomerate; top concealed in the forest on top of a bluff, 20 feet high, fringing the tidal flat, visible	20 (est.)	440
2	Argillite, dark grey to black, commonly weathering brownish grey to brown, containing numerous thin layers and lamellae of brown shale, mostly pure but somewhat arenaceous or ?tuffaceous in some beds; thin bedded (2- to 10-inch beds) to laminated; invaded by a few dykes and sills, 1-6 feet thick, of grey to brown, aphanitic to feebly porphyritic intrusive rock and in places hardened and discoloured near the intrusive contacts; strongly jointed, sheared, and locally contorted; about 100 to 101 feet above base the shale contains abundant specimens of "Arniotites" sp. indet. (= Arniotites sp. Whiteaves 1889, p. 147, pl. 19, fig. 3 and "Celtites (?)" vancouverensis Whiteaves (pars). in Dawson, 1887, p. 110B) of an early Sinemurian age; contact with the underlying pillow lavas of unit (7) is uneven		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	and sharp but no accumulation of coarser particles, or any basal conglomerate	160 (est.)	420
	UPPER HETTANGIAN		
	VOLCANIC DIVISION		
	Grey volcanic unit		
3	Lava, grey to dull blue, mostly well banded, slightly to abundantly amygdaloidal; numerous pillow-like structures some of which reach 5 feet in diameter; locally appears to include some interbeds of volcanic breccia as in (4); in the uppermost 10 to 15 feet the pillows are commonly separated from each other or even completely surrounded by thin layers of arenaceous or ?tuffaceous shale as in (2); the lava may include some lenses and inclusions of this shale in the uppermost 1-2 feet; rocks are mostly strongly jointed, sheared, and contorted; lower contact appears to be conformable	120 (est.)	260
4	Volcanic breccia, coarse, composed of the same lava as in unit (3) and appears to be a pillow breccia; lower contact appears to be conformable	40 (est.)	140
5	Lava as in (3) but with numerous interbeds of volcanic breccia as in (4); pillow structures widespread in lavas; base concealed beneath the sea; visible	100 (est.)	100

Section 18 (Field No. 244/14a, 1954). Measured between the southeastern base and the front (i.e. northern end) of a major rocky point on the southern shore of Quatsino Sound overlooking Mahatta logging camp from the east and situated opposite the eastern end of Salmon Islets. Latitude 50°27'36"N, longitude 127°47'06"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	(SINEMURIAN)		
	SINEMURIAN STAGE (LOWER JURASSIC)		
	VOLCANIC DIVISION		
	(Uppermost Sinemurian)		
	Uppermost Sinemurian argillites		
1	Argillite, dark grey, arenaceous; interbeds of grey, fine-grained greywacke; top covered at the southeastern base of the rocky point; lower contact conformable and gradational; visible	2	148
2	Shale, dark grey, fissile, forms beds 1 to 2 feet thick; often arenaceous and contains dispersed large and small inclusions of fine- to coarse-grained, green-grey greywacke throughout the thickness; moderately jointed and faulted locally, otherwise undisturbed; persistent strike of N 10-20°W, dips 45 to 50°W; lower contact covered	25	146
3	Almost completely covered and presumably underlain by shale of unit 2	15	121
	(Uppermost Sinemurian)		
	Uppermost Sinemurian volcanic unit		
4	Breccia, mixed (i.e. volcanic-sedimentary) to sedimentary, dark grey, fine; interbedded with similarly coloured, strongly tuffaceous, fine- to coarse-grained greywacke which grades locally into arenaceous waterlain volcanic tuff; concretionary in part; top covered; lower contact apparently conformable but poorly exposed; visible	6	106

Unit	Description	Thickness (feet)	Height Above Base (feet)
5	Volcanic breccia, grey to dark grey, fine to rarely medium; volcanic fragments are mixed with various sedimentary fragments and embedded in a very argillaceous matrix; minor interbeds of similarly coloured coarse-grained, tuffaceous and argillaceous greywacke and waterlain, arenaceous volcanic tuff; base covered; visible.....	100 (est.)	100
6	Covered across the front of major rocky point of the shore situated opposite the eastern end of Salmon Islets and possibly harbours a minor north-northeast-trending fault.....	100	
	The covered unit 6 separates the base of section 18 from the top of section 16 (see unit 1 of that section)		

Section 19 (Field No. 274/6, 1954). Measured on the eastern side of the tidal lagoon at the head of Browning Inlet. Latitude 50°30'03"N, longitude 128°04'54"W.

?LOWER PLIENSBACHIAN (LOWER JURASSIC)

VOLCANIC DIVISION

?Dark grey volcanic unit

1	Lava, dark brownish grey, porphyritic to slightly amygdaloidal; contains dark-red (?hematitic) phenocrysts; numerous interbeds of similarly coloured, very amygdaloidal lavas; become intensively rust-coloured, cut by veinlets of red calcite, and locally metamorphosed or transformed into reddish weathered, whitish grey intrusive rock (?a dacite) near the stratigraphical top of the unit in proximity of ?dacitic intrusion occupying the southern side of the entrance to the lagoon; (see under Coast Intrusions): strike N 50-60°W, dips vary from 80°E (overturned?) to ±90°; top covered and an interval 150 to 175 yards wide separates the unit (1) from the southern margin of the ?dacitic body of Coast Intrusions, lower contact appears to be conformable; visible.....	230 (est.)	740

Unit	Description	Thickness (feet)	Height Above Base (feet)
2	Lava, very dark greenish grey, commonly stained tuscan red to blackish red, ?basic, often distinctly banded, strongly amygdaloidal and contains dark-red (?hematitic) amygdules; strike N 60-70°W, dip 75°E (overturned?); numerous irregularly distributed interbeds of lava identical with those of unit (1); contact with unit (3) covered; visible	180 (est.)	510
3	?Diabase, dark greenish-grey, massive-looking, hard, more or less porphyritic; no attitude; this unit could possibly be an intrusive body unrelated to adjacent lava of Volcanic division; both contacts covered; visible	330 (est.)	330?
4	Completely covered between the southern base of a nameless, large, rounded point and the southern end of the lagoon (a tidal flat)	3/4 mile	

Section 20 (Field No. 245/7-10, 1953). Measured across a nameless small rocky islet in Winter Harbour about 600 yards southeast of the mouth of Galato Creek. Latitude 50°31'35"N, longitude 128°01'00"W.

?HAUTERIVIAN (LOWER CRETACEOUS)

Hauterivian siltstone unit

(?Uppermost Valanginian part)

1	Greywacke, dark to blackish grey, massive-looking, fine to very fine grained, shaly and locally grades into very arenaceous shale; unfossiliferous; general strike N 70°E, dips from 50 to 60° west; extremely sheared and jointed throughout; faulted and contorted near the visible top; top concealed beneath the sea on the southwestern side of the islet; grades downward into unit (2); visible	100 (est.)	505

Unit	Description	Thickness (feet)	Height Above Base (feet)
	UPPER VALANGINIAN		
	Buchia crassicollis greywacke unit		
	(Buchia crassicollis zone)		
2	Greywacke similar to that of unit (1) but lighter grey coloured and less shaly; contains 6-inch to 2-foot thick concretionary interbeds of grey-purple coloured, brownish grey weathering, impure limestone and numerous small (1 to 6 inches) to large (2 to 3 feet) rounded concretions of grey, impure limestone arranged in rows; Buchia crassicollis (Keyserling) s. str. occurs scattered throughout the thickness of the unit (GSC loc. 23946); base covered; visible	30 (est.)	405
3	Almost covered across general strike; some small patches of greywacke as in (4) and presumably underlain by this greywacke throughout	40 (est.)	375
4	Greywacke, dark grey, rust-weathering, medium to fine grained, with numerous large (up to a few feet in diameter) irregularly rounded concretions of impure (arenaceous) limestone rich in Buchia crassicollis (Keyserling) s. str. and locally contains indeterminate lytoceratid ammonites (GSC loc. 23945); strongly sheared and jointed; general strike E to N 80° E, and dips from 55° to 60° north; base concealed; visible	20 (est.)	335
5	Almost completely covered across the strike, some patches of greywacke as in unit (6) and probably underlain by this rock throughout	20 (est.)	315
6	Greywacke as in unit (8) and with the same fauna; top and base concealed; visible	15 (est.)	295

Unit	Description	Thickness (feet)	Height Above Base (feet)
7	Completely covered across general strike; probably underlain by the same greywacke as in units (6) and (8)	110 (est.)	280
8	Greywacke, greenish grey to yellow-grey, fine to medium grained, partly clayey, resistant; surface differentially weathered to honeycombed; some interbeds and lenses of softer, strongly calcareous and clayey greywacke or those of pebbly and gritty, calcareous greywacke rich in fossils; numerous, irregularly nodular to loaf-like inclusions of strongly calcareous, brownish-grey weathering greywacke grading into sandy and gritty bioclastic limestone; rocks are extremely sheared and jointed throughout and cut by a number of small (only a few feet of displacement), high angle faults; general strike N 50°-60°E and dips 55 to 60° west; the basal 50 feet visible are massive-looking to indistinctly bedded and generally poor in fossils but scattered specimens of Buchia crassicollis (Keyserling) s. str. et var. occur throughout this part of the unit (GSC loc. 23977); the upper 120 feet are more calcareous and contain a much greater number of very calcareous to calcarenitic interbeds, lenses and inclusions rich in various fossils; Buchia crassicollis (Keyserling) et var. solida (Lahusen) occurs more or less commonly throughout this part of the unit (GSC loc. 23275 and 23281); Homolsomites quatsinoensis (Whiteaves), Acroteuthis (Acrotheuthis) sp. indet. and Inoceramus sp. indet. were found in the interval 50 to 100 feet above visible base of unit (8) (GSC loc. 23275); base concealed beneath the sea on the southeastern side of the islet and is possibly cut off by a fault; visible.....	170 (est.)	170

and Inoceramus sp. indet.

Section 21 (Field No. 241/12-13, 1954). Measured on the southeastern shore of Winter Harbour at the southwestern base of a major nameless point, the tip of which is situated almost exactly opposite the mouth of Galato Creek. Latitude 50°31'24"N, longitude 128°00'24"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
1	Southeast of an isolated, small outcrop of unfossiliferous greywacke tentatively referred to *Buchia crassicollis* greywacke unit (a fault block?) occurring near the tip of the point the shore is completely covered for (a fault zone?)	1,050 (est.)	
	UPPER VALANGINIAN (LOWER CRETACEOUS)		
	Buchia crassicollis greywacke unit		
	(*Buchia crassicollis* zone)		
2	Poor and intermittent outcrops of greywacke as in unit (3); rocks are more disturbed and jointed than farther down in the section but their general attitude remains about the same; top covered and probably cut off by a fault; visible	100 (est.)	271?
3	Greywacke, grey-green, mostly fine to medium grained but contains rare interbeds and inclusions of grit and fine pebble conglomerate; commonly calcareous and sparsely to abundantly fossiliferous (almost exclusively *Buchia crassicollis* (Keyserling) and its variants); this fauna (GSC loc. 24284) was collected 60 to 65 feet above base of the unit; attitude as in unit (4) but dips gradually steepen upward in the succession until they become 60° to 65° west near its visible top; top concealed; visible	80 (est.)	174

Unit	Description	Thickness (feet)	Height Above Base (feet)
4	Greywacke, dark green to bluish grey; mostly fine to medium grained but contains a number of irregularly distributed, lenticular interbeds and lenses, 2 to 8 inches thick, of coarse-grained, grey wacke, fine to coarse grit and fine pebble conglomerate; pebbles are mainly of ?Lower Jurassic chert and shale, and various volcanic rocks of the Vancouver Group; rare pebbles of gabbroic intrusive rock identical with that of unit (7); greywacke is only locally and sparsely fossiliferous (almost exclusively Buchia crassicollis (Keyserling) and its variants); a collection (GSC loc. 24283) was made 7-8 feet above the base; strike N 40-50°W, dip 30 to 35° east; both contacts are gradational	11	94
5	Grit, green-grey, very coarse, pebbly, grades into very fine pebble conglomerate; sparse 1/2- to 2-inch pebbles of the same lithology as in bed 4 are scattered throughout the rock or segregated into thin lenticular layers and lenses; lesser lenticular interbeds and thin layers of similarly coloured, coarse- to fine-grained greywacke; attitude as in bed (4).....	8	83
6	Greywacke, green-grey, massive-looking, medium grained, gritty and locally fine pebbly	3	75
7	Pebble conglomerate, mostly fine to very fine (1/8- to 1/2-inch pebbles predominate) but with some scattered pebbles as much as 2 inches across; pebbles composed mainly of dark grey argillite but include fairly common pebbles of volcanic and intrusive (including those of gabbroic rock) rocks; rich matrix consists of fine to coarse grit or greywacke as in bed 6	3 1/2	72

Unit	Description	Thickness (feet)	Height Above Base (feet)
8	Irregular interbedding of pebble conglomerate as in bed 7 with greywacke as in bed 6 and with fine- to coarse-grained and pebbly, bluish grey grit; the basal grit interbed overlaps erosionally disconformably and probably regionally unconformably the uneven surface of unit 9	3 1/2	68 1/2
	MIDDLE JURASSIC		
	Coast Intrusions		
9	Gabbro, dark green to dark bluish green, mostly medium to coarse grained and more or less equigranular; fine grained for the first 50 feet from the contact with the Cretaceous rocks (unit 8) and includes some coarse porphyritic and coarse amygdaloidal varieties closer to the margins of the intrusive body; width along the shore	800 (est.)	
	LOWER JURASSIC		
	VOLCANIC DIVISION		
	Matthews Island Formation		
10	Slate, whitish grey to rose-grey, ?chloritic; well-developed cleavage intersects the thin and well-developed bedding of these originally shaly to arenaceous rocks; general strike N 70° to 80°W and dips 35° to 40° northeast; base covered; top cut off by gabbro of unit (9); slate is invaded by numerous 6- to 10-foot thick dykes and irregularly shaped bodies of gabbroic rock essentially similar to the marginal phases of unit (9) and apparently representing its offshoots; base covered; visible	65 (est.)	65

Section 22 (Field No. 241/14-22, 1954). Measured on the southeastern shore of Winter Harbour. The base is on the nameless point opposite the mouth of Galato Creek (latitude 50°31'40"N, longitude 128°00'06"W). The top is opposite the southern end of Wedel Island (latitude 50°31'46"N; longitude 128°00'30"W).

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	LOWER BARREMIAN AND/OR (?) UPPER HAUTERIVIAN		
	Inoceramus colonicus calcarenites		
1	Sandstone, light grey to brownish grey, medium grained, very calcareous; mostly rich in fragments of *Inoceramus* (no collection made); commonly grades into arenaceous bioclastic limestone; fairly well jointed and locally contorted; appears to be cut by several minor faults; predominant strike about east-west with dips 15°-20° north, top covered and obviously cut off by a major fault zone trending N 30°-40°E; base covered; visible	100 (est.)	1,260
2	Covered and apparently harbours a strong strike fault	285	
	Hauterivian siltstone unit		
	Simbirskites (*Simbirskites*) *broadi* zone		
3	Siltstone, bluish grey when fresh, weathers brownish grey to blackish grey, and conchoidally to spheroidally, slightly to moderately sandy, contains numerous, loaf-like to spheroidal concretions, 1-3 feet long and 6 inches to 1 1/2 feet thick, of similarly coloured, brown-yellow weathering, hard, very calcareous siltstone or impure limestone; fossiliferous more or less throughout but well preserved fossils are exceedingly rare; well preserved *Simbirskites* (*Simbirskites*) *broadi* Anderson and some		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	indeterminate marine pelecypods have been collected (GSC loc. 24288) about 21 feet above visible base of the unit; numerous well-preserved representatives of Simbirskites (Simbirskites) broadi Anderson and indeterminate pelecypods have been collected (GSC loc. 24285) about 8 1/2 to 9 feet stratigraphically higher; another 1-foot thick siltstone layer replete with well-preserved Simbirskites (Simbirskites) broadi Anderson, S. (S.) cf. lecontei (Anderson) and indeterminate pelecypods and gastropods (GSC loc. 24294) occurs about 81 feet stratigraphically above the level of GSC loc. 24285; this layer also contains Dentalium (s. lato) sp. indet. and rare Acroteuthis (Boreioteuthis) ex gr. impressa (Gabb); yet another fossiliferous layer (GSC loc. 24298) containing Simbirskites (Simbirskites) cf. broadi Anderson and Protetragonites cf. quadrisulcatus (d'Orbigny) occurs about 67 feet stratigraphically above the bed containing GSC loc. 24294; some indeterminate marine pelecypods (GSC loc. 24282) have been collected about 17 feet stratigraphically above the last fossiliferous level (GSC loc. 24298); Trigonia (Pterotrigonia?) cf. kayana Anderson, ?Astarte sp. indet. and some indeterminate pelecypods and gastropods were collected (GSC loc. 24291) from the topmost 3-4 feet of the unit; rocks are invariably well jointed and sheared; locally strongly contorted and even completely crushed within minor fault and shear zones which have only a few feet of displacement; the continuity of section does not seem to be lost anywhere and the succession of fossil zones in units (3) and (5) shows that the unit is not overturned; predominant strikes vary between east-west and north 10-20° east, with the dips 40° to 55° west (true); base covered; visible	260 (est.)	1,160

Unit	Description	Thickness (feet)	Height Above Base (feet)
4	Completely covered along the shore and apparently contains a major fault zone	360 (est.)	
	Homolsomites oregonensis zone and ?younger		
5	Siltstone, dark grey when fresh, brownish grey to blackish-grey and conchoidally weathering, massive-looking, strongly arenaceous; commonly grades into similarly coloured, fine to very fine grained, very clayey greywacke; loaf-like to rounded, locally fossiliferous concretions, 6 inches to 4 feet long, of similarly coloured, hard, limy to very limy sandy siltstone, fine grained, very limy greywacke or impure limestone occur at irregular intervals; they are arranged in rows; a few persistent beds of impure dark grey limestone, 1 to 4 feet thick, occur above the 450-foot level; rocks invariably strongly to very strongly jointed and sheared, contorted and/or completely shattered within several fault or shear zones transecting the unit; so far as it is possible to judge, all of these faults and shear zones have only a few feet of displacement and do not cause the loss of continuity of the section or its repetition; predominant strikes vary from N 40-50°W to N 30-40°E, dips vary as a rule from 55° to 85° west but vertical dips and those 80° to 85° east (overturned) have been noted in the most disturbed parts of the unit (especially near its top); Homolsomites aff. oregonensis Anderson probably transitional between H. quatsinoensis (Whiteaves) and H. oregonensis (Anderson), Protetragonites sp. indet., indeterminate pelecypods and indeterminate gastropods occur locally about 5 feet above the visible base (GSC loc. 24289); well-		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	preserved typical representatives of Homolsomites oregonensis (Anderson), indeterminate phylloceratids, indeterminate gastropods, and indeterminate pelecypods have been collected from a row of large, loaf-like, concretions at about the 390-foot level (GSC loc. 24286). A few poorly preserved ammonites apparently belonging to H. oregonensis occur in a row of calcareous concretions at about the 490-foot level (none collected); these concretions occur at the top of a secondary rocky point where the dips of rocks are temporarily reversed (strike N 10° W and dip 70-75° east); another row of fossiliferous concretions containing Inoceramus sp. indet., poorly preserved pelecypods and poorly preserved ammonites occurs at about the 550-foot level (none collected); well-preserved typical representatives of Homolsomites oregonensis (Anderson), and Protetragonites sp. indet. have been collected (GSC loc. 24290) from a bed of impure limestone, 1 to 1 1/2 feet thick at about the 590-foot level; no identifiable fossils were seen above the 590-foot level; both contacts covered; visible (rough estimate only!)	900 (est.)	900
6	Completely covered along the shore to the isolated outcrop of Buchia crassicollis greywacke forming unit 1 of Section 21 (see there) (presumably harbours a major fault zone)	1,000 (est.)	

Section 23 (Field No. 242/1, 1953). Measured on the southern shore of Quatsino Sound on a nameless, sharp rocky point situated about 1 mile west of the mouth of Klotchlimmis Creek. Latitude 50°29'42"N, longitude 127°41'30"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	Upper Valanginian and (?) Hauterivian greywacke-conglomerate unit		
1	Conglomerate, fine pebble, grey; some interbeds of medium pebble conglomerate; some inclusions of fine to medium pebble conglomerate with abundant calcareous, arenaceous matrix; numerous interbeds of fine- to coarse-grained, commonly gritty, partly calcareous greywacke; general strike N 30°-40°E with dips 25° to 30° west; top covered and probably cut off by a major north-south trending fault; grades downward into unit (2); visible	25 (est.)	330
2	Irregular but frequent intercalation of 3- to 10-foot beds of dull-grey, fine to medium pebble conglomerate and grey-green, medium- to coarse-grained, often gritty and pebbly greywacke; this greywacke is nearly always calcareous, differentially weathered and locally honeycombed on the surface; attitude as in unit 1; both contacts gradational	50 (est.)	305
3	Greywacke, green-grey, to rust-grey, massive-looking; in the upper 20 to 25 feet appear 6-inch to 1-foot interbeds of fine pebble conglomerate and grit which gradually increase upward; strike N 70-80°E, dip 25° west	55 (est.)	255
4	Conglomerate, dull grey, fine pebble, pebbles mostly range from 1/8 to 1/2 inch in diameter and are very poorly rounded so that the conglomerate could be called a waterlain		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	sedimentary breccia (conglobreccia); pebbles of this and all underlying conglomeratic units are composed almost exclusively of the volcanic rocks of the Vancouver Group; only a few sedimentary pebbles and no undoubted Coast Intrusion pebbles have been noted; conglomerate commonly grades into and is interbedded with coarse, pebbly grits; strike north to N 10°W and dips 30-35° west; both contacts gradational	125 (est.)	200
5	Irregular but thick (3-8 feet) interbedding of green-grey, medium- to coarse-grained and distinctly crossbedded greywacke with foreset beds oriented as in unit (6) with fine to coarse grit and fine but very poorly rounded and sorted pebble conglomerate similar to that of unit (4); attitude as above; lower contact gradational	25 (est.)	75
6	Greywacke, rust-green, medium to coarse grained, distinctly crossbedded (deltaic type crossbedding) with foreset beds invariably dipping westward which indicates an eastern to southeastern source area; contains numerous lenses of coarse grit and fine pebble conglomerate as in surrounding beds; attitude as above; lower contact covered; visible	15 (est.)	50
7	Covered interval presumably underlain by rocks of unit (6) or unit (8)	30 (est.)	35
8	Pebble conglomerate, green-grey, fine; lithology and degree of rounding and sorting as in overlying conglomerate units; numerous interbeds and lenses of coarse grit; regular strike N 50°-60°W, dip 45°-50° west; top covered; lower contact unconformable the conglomerate filling deep crevices and hollows in the deeply eroded surface of unit (9); differences of elevation of the contact up to 5 feet were observed within a few feet along and across the strike; visible	5	5

Unit	Description	Thickness (feet)	Height Above Base (feet)
	HETTANGIAN STAGE ?		
	VOLCANIC DIVISION		
	Basal Jurassic volcanic unit		
9	Volcanic breccia, green-grey for the most part but becomes tawny to reddish grey coloured in the westernmost part of the outcrop (deep pre-Lower Cretaceous weathering ?); unsorted and massive-looking; interbeds of similarly coloured volcanic tuff and ?basaltic lavas; no attitude; outcrops along the shore for	600	
10	Lavas, blackish green to blackish grey, ?basic, aphanitic to fine grained, massive-looking; no definite attitude but presumably dips to the west; upper contact appears to be conformable; base not reached at the point of shoreline some 1,400 yards west of the mouth of Klotchlimmis Creek; outcrops along the shore for	1,050	

Section 24 (Field No. 242/8, 1954). Measured on the eastern side of a nameless, major, rocky point situated about 1/2 mile northeast of the mouth of Cleagh Creek on the southern shore of Quatsino Sound. Latitude 50°38'06"N; longitude 127°49'24"W.

	LOWER CRETACEOUS		
	Upper Valanginian and (?) Hauterivian greywacke-conglomerate unit		
1	Shale, dull grey, light grey or grey-green, fissile to somewhat slaty; laminated, normally slightly arenaceous; strike N 50° E and dip 25° to 30° west; both contacts are covered; exposures poor and intermittent; visible	25 (est.)	108

Unit	Description	Thickness (feet)	Height Above Base (feet)
2	Covered and presumably underlain by shale of unit (1)	10 (est.)	83
3	Conglomerate, grey, pebble, coarse to medium, locally includes some scattered cobbles and boulders up to 3 feet in diameter or some inclusions and interbeds of cobble to boulder conglomerate; large to medium pebbles, cobbles, and boulders are surrounded by abundant groundmass of fine- to medium-size, better rounded pebbles or coarse grit; strikes N 50°E and dips 30° to 35° west; overlaps the deeply eroded surface of unit (4) with an angular discordance; the latter exhibits several ravine-like depressions, 15 to 20 feet deep, alternating with similarly high ridge-like to cupola like elevations; the surface of unit (4) is commonly polished and contains potholes, which clearly indicates the beach nature of at least the basal part of the conglomerate; top covered; visible up to	18	73

LOWER JURASSIC

VOLCANIC DIVISION

Basal Jurassic volcanic unit

4	Volcanic breccia, speckled (blue, green, and red), fine, almost unsorted and only indistinctly bedded; strike N 20°-30°E, dip 60° east; base covered by beach deposits; visible	55	55

Section 25 (Field No. 255, 1954). Measured on the southern shore of largest Salmon Islet at the point about 600 feet east of the base of section 26. Latitude 50°27'48"N, longitude 127°48'14"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	Upper Valanginian and (?) Hauterivian greywacke-conglomerate unit		
1	Greywacke, bluish grey, coarse grained and gritty, massive-looking and concretionary weathering; numerous inclusions and interbeds of fine to coarse grit; corresponds to the unit (15) of section 26 (see p.322); attitude as for unit (2); no fossils seen; top covered and thought to be cut off by a north-trending fault; visible	15	52
2	Siltstone, dark bluish grey, hard, massive-looking, contains abundant 1-inch to 3-inch, irregularly rounded pyritic or? marcasitic concretions; strike N 60-70°W, dip 30-35°E; *Buchia crassicollis* (Keyserling) s. str., its variants, and *Buchia* n. sp. aff. *inflata* Jeletzky, 1964 occur sparingly in the upper 1 to 1 1/2 feet of the bed (GSC loc. 24339); the bed corresponds to bed (16) of section 26; upper contact appears to be gradational in spite of rapidity of lithological transition.....	7	37
3	Greywacke, rust-coloured, ferruginous, fine grained, concretionary weathering; contact with the overlying bed (2) is covered and may be complicated by faulting; attitude as in underlying bed (5); visible	3	30
4	Greywacke, grey, rust-weathering, partly crossbedded, medium grained	4	27

Unit	Description	Thickness (feet)	Height Above Base (feet)
5	Siltstone, blackish grey to almost black, strongly conchoidally weathering; slightly arenaceous, strike N 40°-50°E, dip 30-35°W; upper contact gradational, the siltstone becoming grey-green, arenaceous and interbedded with 2 beds of hard, fine-grained, grey greywacke, each 5 to 10 inches thick, in the topmost 2-3 feet; base concealed beneath the sea; visible	23 (est.)	23

Section 26 (Field No. 255/8-14, 1954). Measured across the largest Salmon Islet on the western side of a narrow "neck" of sandy beach (underlain by a major north-northeasterly-trending fault) occurring 400 feet east of the northwestern tip of the islet at latitude 50°27'48"N and longitude 127°48'22"W.

tip

LOWER CRETACEOUS

LOWER BARREMIAN? AND/OR UPPERMOST HAUTERIVIAN

Inoceramus colonicus calcarenites

1	Sandstone, light brownish grey and speckled, fine grained, silty and very calcareous; commonly grades into impure bioclastic limestone; some interbeds of *I. colonicus* coquina; GSC loc. 24279 collected from the 5- to 6-foot thick bed of coquina occurring 10 to 15 feet below visible top of the unit; strike N 50-60°W dip 50-55° east; top concealed beneath the sea on the northern side of the islet; visible	34	370
2	Siltstone, greenish to brownish grey, very calcareous and commonly sandy; grades locally into calcareous, fine-grained sandstone; some interbeds 3-10 inches thick of *I. colonicus* coquina (no collection made); grades upward into bed (1)	7	336

Unit	Description	Thickness (feet)	Height Above Base (feet)
3	Siltstone, dark olive-green to grey, commonly more or less sandy, spherically weathering; some I. colonicus seen locally; grades upward into unit (2)	9	329
4	Limestone, grey to brownish grey, laminated, partly bioclastic and with inclusions and interbeds of I. colonicus coquina; locally contains small and very rare lenses and inclusions of calcareous grit and fine pebble conglomerate; resistant and stands out as a hogback; uppermost 5-6 feet consist of brownish grey, very limy coquina sandstone replete with I. colonicus Anderson (GSC loc. 24343); upper contact conformable but abrupt	67	320
5	Interbedding of 6-inch to 2-foot thick beds of grey, very limy, mostly laminated, fine-grained, shaly sandstone, with 2- to 5-foot thick beds of blackish grey to brownish grey, conchoidally weathering, commonly laminated calcareous shale; attitude as in overlying beds; no fossils seen; lower contact abrupt and uneven, the shale filling out the hollows and depressions occurring in the upper surface of unit (6); upper contact conformable and probably gradational.....	23	253
6	Coarse sedimentary breccia (probably a submarine slide) of dark grey, brownish tinged shale and lighter grey limestone similar to that of beds (8)-(10); fragments embedded in light grey calcarenitic matrix locally grading into Inoceramus colonicus coquina; abundant inclusions and lenticular beds of fine to coarse pebble conglomerate in which pebbles of volcanic rocks of Vancouver Group and those of Coast Intrusions are mixed with 2-inch to 2-foot angular fragments of shale and sandstone of uncertain origin; lower contact gradational	18	230

Unit	Description	Thickness (feet)	Height Above Base (feet)
7	Pebble conglomerate; brownish grey; fine to coarse; pebbles are imbedded in calcareous and clayey matrix; abundant inclusions of brownish grey shale and impure pebbly limestone; lower contact sharp and uneven and in the nature of an erosional disconformity; thickness varies from 3 inches to 1 1/2 feet within short intervals along and across the strike	1 (approx.)	212
8	Limestone, light grey, brownish tinged, very thinly bedded to laminated, sandy to very sandy and grades locally into very limy coarse-grained sandstone (partly bioclastic); numerous interbeds and lenses, 1 to 3 inches thick, of similarly coloured coquina limestone and intercalated beds of fissile, brownish grey, very calcareous shale; Inoceramus colonicus Anderson and other indeterminate pelecypods occur throughout (none collected); lower contact conformable and gradational	24 (est.)	211
9	Limestone, much as that of bed (8) and similarly grading locally into very limy, coarse-grained sandstone; some interbeds of fine, calcareous grit; scattered fine pebbles occur locally; no calcareous shale interbeds noted; only indeterminate marine pelecypods seen; attitude as in underlying beds; lower contact conformable and gradational	10	187
10	Limestone, dark to light grey, mostly brownish tinged, fragmentary and arenaceous; numerous inclusions and lenses, 2 to 15 inches long and 1 to 3 inches thick, of dark grey, very calcareous, sandy shale, calcareous sandstone, and calcareous grit; scattered fine pebbles and inclusions of the same occur in the lower 3 to 4 feet; higher part of the bed is rich in layers and lenses of coquina limestone consisting almost exclusively of Inoceramus colonicus Anderson; fossil collection GSC loc. 24299 from a 1- to 1 1/2-foot thick interbed of such coquina about 3 feet below the top; attitude as in underlying beds; lower contact appears to be gradational	11	177

Unit	Description	Thickness (feet)	Height Above Base (feet)
11	Pebble conglomerate, medium to coarse, blackish to brownish grey, tightly packed; locally contains much calcareous, sandy matrix and interbedded with shaly and pebbly sandstone and calcareous, arenaceous shale; thickness varies within a few yards along the strike from a few inches to 4 feet; locally it is reduced to a 2-3 inch layer of very fine pebbles embedded in calcareous, sandy matrix	4	166
	HAUTERIVIAN		
	Upper Valanginian and (?) Hauterivian greywacke-conglomerate unit		
12	Greywacke, yellowish grey to yellowish green, medium to fine grained, strongly crossbedded; some inclusions of dark grey greywacke, 2 to 6 inches thick, and a few rust-coloured concretions of ferruginous greywacke; no fossils seen; this bed is poorly developed on the western end of the island; general strike N 50-60°W, dip 50 to 55° east; contact with bed (11) is not always sharp; bed contains locally scattered pebbles like those of bed (11)	12	162
13	Greywacke (or ?subgreywacke), dark green-grey, coarse grained, very gritty and often pebbly, massive-looking; commonly grades into more or less pebbly, fine to coarse grained grit; minor interbeds of similarly coloured, but somewhat calcareous, honeycombed greywacke or grit; no fossils seen; locally includes inclusions from 1 to 10 inches thick, lenses and lenticular beds of fine to medium pebble conglomerate; strike N 60-70°W, dip 40-45°E; base concealed beneath the sea on the southwestern end of the island; visible	55	150

Unit	Description	Thickness (feet)	Height Above Base (feet)
14	Covered by sea water within a narrow channel separating the southwestern end of largest Salmon Islet from a bare rock occurring immediately south of the latter; apparently underlain by the same greywacke as that of unit (13)	35 (est.)	95
	UPPER VALANGINIAN		
15	Greywacke, mainly light blue-grey but with interbeds of dark green to bluish green greywacke as in unit (17); predominantly medium grained, hard; numerous interbeds and lenses of similarly coloured fine to coarse grit; poor casts of Buchia cf. crassicollis (Keyserling) occur in basal 2-3 feet of the unit; lower contact conformable; strike N 70°-80°W, dip 45°-50°E; top covered; visible	38 (est.)	60
16	Shale, dark grey to black, fissile, hard; slightly sandy locally; contains common pyritic or ?marcasitic inclusions; B. crassicollis and its variants, other indeterminate pelecypods and plant fragments occur rarely throughout the thickness; collection GSC loc. 24338 from basal 2-3 feet; both contacts conformable	7	22
17	Greywacke, dark green to bluish grey, mostly medium grained, hard; some interbeds, 6 inches to 1 foot thick, of blackish grey, fine-grained, very clayey but sometimes pebbly sandstone; attitude as above; no fossils seen; base concealed beneath the sea; visible	15 (est.)	15

Section 27 (Field No. 255/3-7, 1954). Measured on the northern and eastern sides of the largest Salmon Islet. Latitude 50°27'48"N, longitude 127°48'10"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	BARREMIAN STAGE		
	Barremian fine grained greywacke		
1	Greywacke, green-grey, weathering dark grey, hard, fine to very fine grained and commonly very silty, massive looking; grades into and contains numerous interbeds of similarly coloured, sandy to very sandy siltstone; general strike east-west, dip 25° north; ?Eulytoceras sp. indet., Acroteuthis (?Boreioteuthis) sp. indet. and indeterminate conifer plants (GSC loc. 24340) collected about 22 feet above the base; top concealed beneath the sea; lower contact gradational; visible up to	35 (est.)	192 1/2
	The exposures of unit (1) occur only about 240 feet east of the "neck" of the islet on the western side of which was measured Section 26; however, the rocks of the unit (1) outcrop in a number of fault blocks for the next 1,000 feet eastward along the shore; at the end of this interval begins the following section of the basal beds of unit (1) and the underlying beds which continue along the eastern side of the islet.		
2	Pebble conglomerate, fine to medium, green-grey, hard; rich in greywacke matrix lithologically similar to the greywacke of unit (1); grades laterally into 3- to 5-foot-thick beds of crossbedded, green-grey, pebbly, medium- to coarse-grained greywacke; contact with unit (1) appears to be gradational but that with unit (3) is very sharp		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	and uneven and erosionally disconformable (Pl. V, Fig. A) or regionally unconformable; thickness varies from 1/2 to 1 1/2 feet within short distances	1 1/2	157 1/2
	LOWER BARREMIAN ?AND/OR UPPERMOST HAUTERIVIAN		
	Inoceramus colonicus calcarenites		
3	Limestone, dark grey to blackish grey, brownish grey weathering, very sandy and silty, commonly bioclastic; locally grades into calcareous sandstone; thinly bedded to laminated; some pods and interbeds of purer limestone; strike N 50°E, dip 30° to 35° west; Inoceramus colonicus Anderson occurs at intervals throughout the thickness of the unit and locally forms pods and thin interbeds; GSC loc. 24295 collected 10-12 feet below its top; lower contact gradational.....	75 (est.)	156
4	Intricate interfingering of: 1. Limestones like those in unit (3) with; 2. More pure and lighter coloured limestone; and 3. Dark to medium grey, very calcareous shale; attitude as above; Inoceramus colonicus Anderson occurs rarely throughout the bed and a 4- to 5-foot thick bank in which this fossil is abundant (GSC loc. 24299) occurs 12 to 16 feet above its visible base; lower contact covered; visible	35 (est.)	81
5	Covered but presumably underlain by rocks of unit (4)	9 (est.)	46
6	Limestone more or less as that of unit (7) but much more arenaceous and in places grading into very limy, fine-grained sandstone or very limy, sandy siltstone; numerous pods and lenses of fine pebble conglomerate with rich to very rich, limy, arenaceous matrix;		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	rare Inoceramus colonicus Anderson occur locally; the number of pods and interbeds of sandstone, limy shale and fine pebble conglomerate gradually increases upward within the bed; lower contact gradational; top covered, visible	18 (est.)	37
7	Limestone, dark grey, very sandy and clayey; fine grained but often bioclastic; interbeds and pods of light grey, more pure limestone; thinly bedded and crossbedded, and containing abundant fragments and well preserved shells of Inoceramus colonicus throughout; fauna collected from a 2- to 3-foot thick bed of impure limestone 9-11 feet above visible base of unit (GSC loc. 24296) includes numerous I. colonicus and a single juvenile specimen of Shasticrioceras cf. poniente Anderson; strike N 40-50°E, dip 25°-30° west; base concealed beneath the sea near the southeastern tip of the islet; visible	19 (est.)	19

Section 28 (Field No. 255/1-2, 1954). Measured across a small rocky islet situated about 200 yards to the northeast of the largest Salmon Islet. Latitude 50°28'00"N, longitude 127°48'06"W.

LOWER CRETACEOUS

Barremian fine grained greywacke unit

1	Greywacke, dark grey to greenish grey, fine grained, hard, massive-looking; numerous interbeds and lenses, 6 inches to 1 1/2 feet thick, and inclusions of similarly coloured, brownish-grey weathering, calcareous, locally fossiliferous greywacke; strike N 40-50°E, dip 20°-30° west; ?Argonauticeras aff. argonautarum Anderson, Eulytoceras aff. phestum (Matheron) and indeterminate pelecypods (GSC loc. 24297) collected 10 to 12 feet above the base of the unit; Partschiceras		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	infundibulum (d'Orbigny), Eulytoceras aff. phestum (Matheron), Acroteuthis (Boreioteuthis) ex. aff. impressa (Gabb), indeterminate belemnitid, Inoceramus aff. quatsinoensis Whiteaves, ?Aucellina sp. indet., Astarte? sp. indet., indeterminate pelecypods, and indeterminate gastropods (GSC loc. 24278) have been collected from a 2- to 3-foot bed of greywacke 30 to 33 feet above the base of the unit; similar but poorly preserved fauna occurs locally in the uppermost 15 feet of the unit; top concealed beneath the sea on the northern side of the islet; grades downward into unit (2); visible	50 (est.)	75
2	Greywacke, dark grey, very fine grained and silty, hard, massive-looking; attitude as above; no identifiable fossils seen, base concealed beneath the sea on the southern side of the islet; visible	25 (est.)	25

Section 29 (Field No. JA-F68-13/1-7, 1968). Measured on the northern side of Lippy Creek, 2 miles east of Neroutsos Inlet and 2 1/2 miles west of Alice Lake on the western side of a short, north-trending secondary logging road branching off Gibson Road of the Rayoneer Co. Ltd. at the altitude of 2,150 feet and on the north side of Gibson Road for about 200 feet below the junction. (Latitude 50°28'08"N; longitude 127°28'35"W).

1	A completely covered interval about 20 yards long along the secondary logging road (i.e. in about 350° direction). This interval is the same as unit 7 of section 39 and separates section 39 from the section of Barremian variegated clastic unit described below. Barring the most unlikely occurrence of a fault (rocks on both sides have concordant, very low dips, are neither sheared nor contorted and do not exhibit any calcitic veinlets or stringers), this covered interval conceals a normal but at least disconformable (more likely unconformable) contact between the Nanaimo Group and the underlying Barremian variegated clastic unit. Estimated thickness of covered rocks	8	179

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	Barremian variegated clastic unit		
2	?Arkosic sandstone, whitish grey, beige or dull green when fresh, weathers buff to dull yellow with dark grey spots; fine to more rarely medium grained, medium hard; includes some interbeds of siliceous, fine-grained, hard sandstone which may be more or less bentonitic in part; indistinctly but normally thinly bedded and locally laminated; commonly rich in or replete with small (1/2"-3") to large (up to 4' long), partly carbonized wood fragments and poor plant remains mostly aligned along bedding planes and oriented more or less along the strike; these wood fragments and plants occur throughout the unit's thickness; persistent strike 310° to 320° with dips about 10°W; single cast of Acroteuthis (Boreioteuthis) ex gr. impressa (Gabb), several Serpula-like worm tubes, and indeterminate pelecypod fragments (GSC loc. 82956) have been found in places 12 to 13 feet above visible base of the unit; otherwise no marine fossils seen; upper 25 (est.) feet of the unit outcrop poorly and intermittently for 180 yards along the partly eroded road-bed and in overgrown road cuts of secondary logging road; the lowermost visible 16 feet are excellently exposed in nearly vertical western bank of this road for about 70 yards northward from its junction with the main logging road; visible (total)	41 (est.)	171
3	Covered interval assumed to represent about	3 (est.)	130
4	Pebble conglomerate, mottled grey, fine to very fine (pebbles from 1/8" to 1/2" predominate); mostly very poorly rounded and commonly grades into a mixed (sedimentary-volcanic) very fine breecia or coarse to very coarse, waterlain volcanic (crystal?) tuff; matrix appears to be tuffaceous to arenaceous;		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	tightly packed, hard, massive; no definite attitude but seems to strike approximately along the previously mentioned N-trending secondary logging road for about 70 yards north from its junction with the main logging road; both contacts covered, visible	17 (est.)	127
5	Covered interval at the junction of the previously mentioned main and secondary logging roads; appears to represent.....	1 (est.)	110
6	Greywacke, bluish grey and massive-looking when fresh, weathers brownish grey to dull brown and chunky; medium grained, hard; outcrops only on the left side of main logging road just below its junction with the secondary logging road; outcrops poor in topmost 5-6' visible; attitude presumably as in the underlying beds, both contacts covered, visible	25 (approx.)	109
7	Covered interval occurring immediately east (i.e. down the main road) of the junction of the main and secondary logging roads	3 (est.)	84
8	Grit, greenish grey when fresh, weathers brownish grey, fine to coarse and often pebbly, hard to very hard and massive-looking, except in the uppermost 5-6 feet where it becomes slabby and medium to thinly but indistinctly bedded; numerous lenses, 3 to 18 inches thick and up to 25 feet long, of fine to coarse pebble conglomerate as in unit 9; some interbeds of mainly coarse-grained, gritty greywacke similar to that of unit 6 in the uppermost 6 to 8 feet; lithology of pebbles and coarser grit particles as in unit 9; strike ?020°, dip 18°W; cast of the alveolar part of a poorly preserved but unmistakably Acroteuthis-like belemnite was found in place 3 1/2 above base (GSC loc. 82955); top covered, visible	18	81

Unit	Description	Thickness (feet)	Height Above Base (feet)
9	Pebble conglomerate, coarse to fine, mottled greenish grey (see Pl. VI, Figs. A, B); fine pebble conglomerate is mostly restricted to the basal 2 feet where it predominates and to pods and lenses, 3 to 6 feet thick, in the higher parts of the unit; hard, tightly packed; poorly to moderately rounded pebbles in ranging from 2" to 6" in diameter predominate in middle and upper parts of the unit; the matrix between these pebbles is rich in fine to very fine (1/8" to 1/2") pebbles and grit particles; considerable number of 9" to 12" cobbles and 1' to 3' boulders occur locally; the pebbles consist predominantly of various red to lavender-coloured pyroclastics and lavas presumably derived from the Volcanic division of the Bonanza Subgroup; pebbles of various dark-grey to dark-green, ?basic porphyry (?dyke rock or ?Karmutsen lavas) are common; pebbles of limestone, greywacke and dark-grey argillite presumably derived from the Sedimentary division of the Bonanza Subgroup are relatively rare; no definite granitic pebbles of Coast Instrusions seen; upper contact gradational and rare scattered pebbles continue to occur in basal 6"-12" of unit 8; attitude as in underyling bed	26	63
10	Greywacke, ash-grey when fresh, weathers brown to dull brownish grey, mostly medium to coarse grained with interbeds of fine to very fine grained greywacke in basal 6 feet thinly but indistinctly bedded; some very indistinct crossbedding; an orange-weathering (limonitic) interbed, 5 to 6 inches thick of locally coaly and dark grey, sandy clay with scattered 1/4" to 1/2", well rounded pebbles of volcanic rocks forms the base of the unit; no fossils seen except for some small shell fragments near the top; contact with the uneven and deeply weathered surface of unit 11 very sharp and obviously erosionally disconformable; grades upward into unit 9 through about one foot of coarse-grained, pebbly and gritty greywacke with small pods and lenses, 2 to 3 feet long and 2 to 6 inches thick, of fine pebble con-		

1/8"

the type is erosional

Unit	Description	Thickness (feet)	Height Above Base (feet)
	glomerate; strike 335°, dip 18°W	13	37
	LOWER JURASSIC		
	Volcanic division of Bonanza Subgroup (undivided)		
11	Rhyolitic lava, light bluish grey to whitish grey when fresh, maroon to bright orange weathering, porphyritic and abundantly and coarsely amygdaloidal; mineralogically and texturally closely similar to the lava of unit 3 of section 39 except for an apparently larger ratio of quartz phenocrysts; weathers spheroidally and pillow-like; the almost perfectly rounded, pillow-like structures, (1 to 4 feet in diameter) do not seem to exhibit definite chilled rims and so appear to reflect a profound spheroidal exfoliation of the lavas during a prolonged period of subaerial erosion preceding the presumably Barremian marine transgression of unit 10; upper 2 to 2 1/2 feet are bright orange-coloured, partly limonitized and friable presumably because of pre-Barremian weathering	4	24
12	?Andesitic lava, dark to dull grey when fresh, weathering light to dull brown or rust coloured, fine to medium grained often with trachytic structure but becomes felsitic to finely amygdaloidal in uppermost 6 feet; distinctly and finely banded locally; interbedded with some similarly coloured, fine-grained volcanic tuff; apparent strike near the base 260° with dip 25° N but the beds appear to be contorted and invaded by at least one dyke, less than 6 feet thick, of dark green, medium-grained, porphyritic and amygdaloidal gabbroic rock striking 260° and dipping 80° to 85°E; a 1- to 3-foot thick sill of the same gabbroic rock seems to branch off the above dyke near the base		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	of the unit; apparent strike in the topmost 6 feet is N 15°E with dip of 10°W; contact with unit 11 appears to be conformable but abrupt; base covered at the point about 200 feet NE of junction of previously mentioned logging roads; visible in the left side of the main logging road	20?	20?

Section 30 (Field No. 259/1-4, 1954). Measured in the banks of Nuknimish Creek on the northern side of Holberg Inlet beginning with the point about 150 yards above creek's mouth. Latitude 50°36'18"N; longitude 127° 38'54"W.

LOWER CRETACEOUS

Barremian variegated clastic unit

Siltstone-greywacke member

1	Siltstone, greenish grey, rusty-weathering, concretionary, soft, slightly sandy; contains rare shells of ?*Mya* sp. indet., other indeterminate marine pelecypods, and some fragmentary plants (GSC loc. 24273); attitude seems to be the same as in unit 3; top and base covered; visible	25 (est.)
2	Covered and apparently underlain by siltstones of bed 1	5 (est.)
3	Siltstone as in bed 1; apparently strikes north 40°-50° east and dips 3°-5° west; the basal 2 to 3 feet of the bed have yielded (GSC loc. 24274): ?*Aucellina* sp. indet., ?*Pholadomya* sp. indet., ?*Mya* sp. indet., *Tancredia*? sp. indet., generically indeterminate pelecypods, generically indeterminate crab remains, indeterminate plant remains; top and base covered; visible	15 (est.)
4	Covered across the general strike of the rocks (roughly upstream)	450 (est.)

Unit	Description	Thickness (feet)	Height Above Base (feet)
5	Greywacke, dark to greenish grey, fine grained, moderately to very silty, massive-looking; some interbeds of similarly coloured, somewhat sandy siltstone; general strikes vary from north 60° west to north-south, dips vary from 5° to 10° west; the rocks are cut by numerous minor faults (displacement does not exceed few feet); the uppermost 2 to 3 feet exposed (GSC loc. 24293) have yielded Quoiecchia aliciae Crickmay and other indeterminate pelecypods: the lowermost 3 to 4 feet exposed (GSC loc. 24292) have yielded some Q. aliciae; top and base covered; visible	10 (est.)	
6	Covered upstream from the first fork shown on Figure 17 (approximately across the strike of overlying rocks) for	1,000 (est.)	

LOWER JURASSIC

VOLCANIC DIVISION

Basal Jurassic volcanic unit

7	Volcanic breccia, medium to coarse, light grey, weathers rust-yellow, moderately to intensively altered and apparently locally invaded by minor (2 to 3 feet thick?) bodies of light grey, felsitic intrusive rock; top and base covered; visible	15 (est.)	

Section 31 (Field No. JA-F68-1/3-5, 1968). Measured on the straight part of the northern shore of Apple Bay at a small embayment situated about 1,000 feet west-northwest of the mouth of Nuknimish Creek. Latitude 50°36'27"N; longitude 127°39'45"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS		
	BARREMIAN STAGE		
	Barremian variegated clastic unit		
	Siltstone-greywacke member		
1	Greywacke, dull grey, fine to medium grained, hard, rare pelecypod fragments seen; strikes almost east-west, dips 12° north; top covered, contact with bed 2 conformable and gradational; visible	1 (approx.)	4 1/2
2	Oyster bank consisting of Ostrea (s. lato) sp. indet. (GSC loc. 82929) in greywacke matrix as in bed 1; lower contact gradational	1/2	3 1/2
3	Greywacke as in bed 1	1	3
4	Greywacke similar to that of beds 1 and 3 but contains numerous rounded concretions, 2 to 6 inches in diameter, of calcareous greywacke containing Quoiecchia aliciae Crickmay (GSC loc. 82930)	1	2
5	Greywacke similar to that of beds 1 and 3 but softer and containing loaf-like concretions, 1 1/2 to 2 feet long, of calcareous greywacke rich in Q. aliciae (GSC loc. 82931) base covered and probably faulted at the fringe of the forest, visible	1	1

Section 32 (No Field No., 1954). Measured along the northern shore of the channel connecting the eastern end of Winter Harbour with Ahwhichaolto Inlet from latitude 50°32'27"N, longitude 127°58'15"W, to latitude 50°32'37"N, longitude 127°57'00"W.

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS (APTIAN)		
	COAL HARBOUR GROUP		
	Coarse arenite unit		
1	Interbedding of dark grey, friable, very thinly bedded to laminated, fine- to more rarely medium-grained, clayey greywacke and similarly coloured distinctly bedded but conchoidally weathering sandy to very sandy siltstone and shale; general strike N 30-40° W, dips 35 to 40°E; top covered at the northwestern base of a sharp rocky point overlooking the northwestern end of Ahwhichaolto Inlet from the south and presumed to be cut off by a major northwest-trending fault somewhere within a covered interval of the flat shoreline, about 400 yards wide, surrounding a nameless creek falling into Ahwhichaolto Inlet from northwest; lower contact conformable and gradational; visible	100 (est.)	485 2,485
2	(?)Subgreywacke similar to that of unit 3 but strongly rusty-weathering and thinly bedded (1- to 6-inch beds predominate); some interbeds and layers of friable, sandy, mostly thinly bedded to laminated, multi-coloured (with alternating grey, reddish, and tawny lamellae) sandy siltstone; strike N 40°W, dip 40°E; both contacts gradational ..	200 (est.)	385 2,385
3 Subgreywacke N	(?)Subgreywacke, brownish grey, rusty-weathering, coarse grained and more resistant than the subgreywackes of units 2 and 4; medium bedded; strike more or less east-west, dips 30 to 35°N; units 2 and 3 occupy the front part of the above-mentioned, sharp, rocky point; both contacts gradational	35 (est.)	185 2,185

Unit	Description	Thickness (feet)	Height Above Base (feet)
4	Interbedding of dark grey, rusty-weathering, fine- to more rarely medium-grained, thinly bedded to laminated, friable, clayey greywacke and similarly coloured, sandy, thinly bedded to laminated, often multicoloured siltstone; some interbeds, 1 to 2 feet thick of medium-grained, rusty-weathering, harder subgreywacke; strike about east-west, dips 30 to 35°N; base covered; visible	225 (est.)	150 2,150
5	Covered for about 120 feet across general strike within the inner part of a triangular-shaped embayment of the shore; presumably harbours a northwest-trending fault	120	
6	Interbedding of greywacke and siltstone as in unit 4; some 1- to 2-foot thick beds of rust-coloured, medium-grained, harder sandstone occur at irregular intervals; rocks are rather strongly jointed and sheared, cut by small faults, and in part contorted near the visible top and base of the unit; in the middle part the regular strike is N 50-60°W and the dips vary from 60 to 65°E; top and base covered and cut off by major northwest-trending faults, visible	330 (est.)	1,925 1,925
7	Completely covered for about 20 feet across general strike and thought to contain a major northwest-trending fault	20 (est.)	
	<u>Blumberg Formation</u>		
8	Irregular but thick (beds 3 to 7 feet thick) interbedding of green-grey, coarse-grained, gritty, resistant greywacke with similarly coloured or rust-green fine to coarse pebble conglomerate; conglomerate is softer than that of unit 9 and contains a greater amount of sandy and gritty matrix between pebbles; in the lower 80 to 100 feet of the unit the rocks		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	are intensely sheared and jointed and shattered by countless, normally minor, strike and cross faults forming a great number of small to large fault blocks; general strike N 30-40° E with dips ranging from nearly vertical to 80° W (overturned); the rocks are considerably less disturbed in the middle 180 feet of their thickness but become again shattered by numerous faults in the upper 30 to 40 feet where the dips become 60 to 85° E (normal); top covered and obviously cut off by a northwest-trending fault with the downthrow on its northeastern side in excess of several hundred feet; lower contact conformable and gradational; visible	320 (est.)	1,595
9	Pebble conglomerate, coarse to medium, green-yellow to rust-coloured, massive-looking, tightly packed, hard; the lower 1 to 3 feet contain numerous shale and greywacke pebbles similar to and apparently derived from the underlying beds of the Coarse arenite unit; higher up volcanic and igneous pebbles predominate; general strike N 40°-50° W and dip 75° to 80° E; the rocks are jointed, sheared, and cut by numerous minor strike faults; lower contact is abrupt but uneven with the lowermost, predominantly flat or obliquely lying pebbles filling out depressions in the deeply eroded surface of unit 10; no angular discordance was observed at this erosionally disconformable contact	130 (est.)	1,275
	<u>Coarse arenite unit</u>		
10	Greywacke, dark grey, fine grained, partly clayey; irregularly interbedded with about equal amount of dark grey to multicoloured (in thin layers or laminae), laminated, more or less arenaceous, locally somewhat carbonaceous siltstone; attitude as in overlying beds; lower contact conformable and gradational	45 (est.)	1,145

Unit	Description	Thickness (feet)	Height Above Base (feet)
11	Sandstone (subgreywacke ?) light grey to brownish grey, intensively yellow to rusty weathering, mainly coarse and gritty (see Pl. VIII, Figs. A, B); indistinctly bedded; locally rich in fragments of carbonized wood; rocks are strongly sheared and jointed throughout, and are commonly cut by minor strike and cross faults; strike varies from N 70°W to N 30°W and dips vary from 60°E in the lower part of the unit to 80°E in its upper part; both contacts conformable and gradational; at the lower contact the colour phases characteristic of units 11 and 12 alternate irregularly within an interval, 15 to 20 feet thick, until the bright rust colouration of unit 11 becomes established; the coarse-grained, gritty sandstone of this transitional zone contains numerous fragments and pebbles of presumably locally derived grey shale; this sandstone alternates with grey, fissile, sandy shale and similarly coloured, clayey sandstone rich in small, irregularly shaped to rounded, impure limestone concretions	600 (est.)	100 1,100
12	Sandstone (subgreywacke ?), brownish grey to greenish grey, mostly coarse grained and locally gritty; often massive-looking but is distinctly and thinly bedded elsewhere; moderately hard; some large, loaf-like concretions of harder, calcareous sandstone; rocks are normally sheared and jointed and locally disturbed by minor strike and cross faults; strikes vary from north-south to N 60°-70°W and dips vary from 30° to 60°E; base covered and evidently cut off by a major east-west trending fault; visible	500 (est.)	500 500
13	Covered interval across general strike probably containing one or more strong east-west or/ and northwest-trending faults; this fault zone occupies the eastern base of a pronounced large wooded point overlooking the western end of the channel connecting Winter Harbour with Ahwichaolto Inlet	120 (est.)	

Unit	Description	Thickness (feet)	Height Above Base (feet)
	UPPER CRETACEOUS		
	Cenomanian or ?Turonian stage		
	Upper shale unit		
	Shale-siltstone member		
14	Shale, light- to ash-grey when fresh, lavender-tinged when weathered, mostly pure, moderately hard, massive to fissile, weathers conchoidally; the lower (on the west side of the point) 100 feet mainly massive and contain numerous 3- to 10-inch, ellipsoidally shaped to irregularly rounded and 1 to 3 feet irregularly shaped concretions of hard dull grey, yellow to buff-weathering, impure (?dolomitic), aphanetic limestone; some 1/4-inch to 4-inch layers and interbeds of fine to medium-grained, dark green, dull rust-weathering greywacke occur in this part of the unit; upper (on the front and eastern side of the point) 150 feet commonly more or less fissile and much less concretionary; the middle beds of this part of the unit contain several layers and thin interbeds of greywacke lithologically similar to that occurring in the lower part of the unit; an indeterminate *Inoceramus*-like shell was found in a limestone concretion in the middle of the eastern side of the point and some *Inoceramus* prisms were found in another limestone concretion in the basal exposed beds on its west side; rocks are strongly to moderately jointed except in the proximity of their visible top and base where they are sheared, strongly disturbed (contorted) and cut by a number of minor faults; general strike N 50°-60°W, dips 30°-35°E; base concealed beneath the water on the western side of above-mentioned large point and presumably cut off by a major east-west trending fault; top is covered and obviously faulted (*see* under unit 13); visible.....	250 (est.)	

Unit	Description	Thickness (feet)	Height Above Base (feet)
	This exposure of the Upper shale unit is evidently a part of a downdropped fault block of the Upper Cretaceous rocks unrelated to the Section 32. This fault block disappears beneath the waters of the channel and possibly reappears on its unexplored southern bank.		
	Units 11, 12, and 13 reappear on the western side of the large wooded point occupied by the unit 14 and outcrop intermittently in the wooded northern shore of Winter Harbour to the point about 200 yards southeast of the mouth of Klayina Creek.		
	It is impossible to estimate the thickness of beds concealed within the covered interval between the visible base of unit 13 at the point closest to the mouth of Klayina Creek and the visible top of unit 1 of the following section 33 about 800 feet southwest therefrom, because of the inferred presence of several strong faults within this interval.		

Section 33 (Field No. 245, 1953-1954). Measured on the northwestern shore of Winter Harbour between the mouth of Klayina Creek (latitude 50°32'36"N, longitude 127° 58'51"W) and that of Galato Creek (latitude 50°31'54"N, longitude 128°00'18"W).

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS (APTIAN)		
	COAL HARBOUR GROUP		
	Coarse arenite unit		
1	Siltstone, dark grey, sandy, laminated; interbedded with three thin beds of grey, very arenaceous limestone grading into very limy sandstone; strike N 50°W, dip 30°E; base covered; top covered on the northern side of a low rounded point situated about 800 feet southwest of the mouth of Klayina Creek; visible	12 (est.)	4,496
2	Covered across general strike and presumably underlain by rocks as in bed (1) for 1,100 feet; assumed thickness of concealed sediments	350 (est.)	4,484
3	Greywacke, laminated, dark grey to multicoloured (alternation of grey, tawny and rusty laminae), fine to very fine grained, contains much clay; some interbeds of similarly coloured and laminated, strongly arenaceous siltstone; top covered; lower contact conformable and gradational; visible	60 (est.)	4,134
4	Interbedding of grey to dark grey, laminated to thinly bedded, fine-grained greywacke and similarly coloured, mostly silty and arenaceous shale with interbeds and rows of concretions of impure limestone (as in underlying beds); strike N 70°W, dips 25° to 30°E; lower contact poorly exposed but apparently conformable	90 (est.)	4,074

Unit	Description	Thickness (feet)	Height Above Base (feet)
5	Greywacke (or subgreywacke?), grey, medium grained, resistant and mostly massive looking; locally thinly bedded; strikes fluctuate from about east-west to N 60°E, dips 20° to 25°E; rocks are disturbed by faulting; lower contact conformable; this unit occupies the tip of a pronounced low point of the shore	20 (est.)	3,984
6	Interbedding of greywacke and siltstone with limestone beds and concretions as in bed 4; base covered; visible	120 (est.)	3,964
7	Greywacke, grey to dark grey, fine to medium grained, contains little to abundant clay; thinly bedded to laminated; 1 inch to 10-inch interbeds of dark grey, very arenaceous siltstone; strike N 60°W, dip 35°E; lower contact conformable and gradational; the rocks occupy a marked point of the shoreline	21 (est.)	3,844
8	Greywacke (or subgreywacke) as in bed 5 but interbedded with greywacke as in bed 7; in the upper 12 feet also occur interbeds of thinly bedded and crossbedded greywacke with numerous, large, loaf-like concretions of harder and somewhat calcareous? greywacke; strike N 60-70°W, dip 30° to 35°E; base covered; visible	32 (est.)	3,823
9	Covered across general strike for about 1,000 feet and presumably underlain by softer greywacke and siltstone as in units 4 and 6; assumed thickness of concealed rocks	500 (est.)	3,791
10	Greywacke (or subgreywacke?), light grey to buff, coarse grained, gritty, thickly bedded; pods and interbeds, 3 to 10 inches thick, of coarse to fine grit which decreases upward in the unit, rounded to loaf-like, pods of calcareous, rust-weathering grit and gritty greywacke 1 to 5 feet in diameter; in the lower part of unit strike is N 60-70°W and dips 10° to 15°E; the dips decrease to 3-5°E near the top of the unit; rocks are strongly		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	jointed, cut by minor cross- and strike faults and somewhat contorted; top and base covered; visible	50 (est.)	3,291
11	Covered across general strike within a broadly rounded embayment of the shore and presumably harbours a major northeast-trending fault for about	900	
12	Greywacke, brownish grey, coarse to fine grained, mostly strongly clayey, thin bedded to laminated; several 6-inch to 1-foot thick interbeds of grey, medium-grained, resistant, calcareous subgreywacke occur in the lower 50 feet but this rock type becomes predominant in upper 125 feet; strike N 70°W, dip 30° to 35°E and the rocks are undisturbed otherwise; the unit occupies the front part of the sharp wooded point covering the mouth of Denad Creek from northeast; top concealed and presumably cut off by a major fault; base covered; visible	175 (est.)	3,241
13	Covered around the mouth of Denad River across general strike of the rocks and presumably underlain by greywacke similar to that of units 12 or 14; about 600 feet; assumed thickness of covered rocks	300 (est.)	3,066
14	Greywacke as in the lower 50 feet of bed 12 but with minor interbeds of fine-grained, clayey, soft greywacke; regular attitude as in underlying rocks; top concealed; visible	35 (est.)	2,766
15	Subgreywacke, light to brownish grey, medium to coarse grained, mostly gritty, resistant, mostly heavily and indistinctly bedded; commonly more or less calcareous and honey-combed on the surface; numerous interbeds of rusty-weathering, stronger calcareous sandstones; shale and siltstone interbeds all but absent; outcrops locally poor in the upper 125 feet of the unit; strike N 60°W, dip 35°E; both contacts conformable and gradational; the unit outcrops around a		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	major wooded point covering the mouth of Denad River from the south	225 (est.)	2,731
16	Greywacke (or subgreywacke?), grey to brownish grey, medium to coarse grained, mostly thickly bedded (3-to 6-foot beds) but in places thin-bedded and crossbedded within thick beds; a few 3-inch to 3-foot thick interbeds of coarse grit and very fine pebble conglomerate locally with abundant fragments and poorly rounded pebbles of dark grey siltstone 2 to 6 inches; some 3-inch to 3-foot thick interbeds of dark grey to blackish grey, laminated, very sandy siltstone the number of which increases upward in the unit; irregularly shaped, pods and lenses of reddish grey weathering, calcareous subgreywacke, 3 to 5 feet long, with poor plant remains occurring in the upper part of the unit; rare, loaf-like lenses of impure grey limestone, 3 to 4 feet long, strike N 60°-70°W, dip 30° to 35°E; lower contact appears to be gradational	98 (est.)	2,506
17	Irregular interbedding of pebbly grit and pebbly and gritty greywacke containing abundant 2- to 6-inch fragments and poorly rounded pebbles of dark grey siltstone similar to that occurring in the underlying beds and presumably locally derived	1	2,408
18	Pebble conglomerate, fine, dull grey; rich in gritty and sandy matrix; larger pebbles (1/2 to 2 inches in diameter) are almost invariably composed of the apparently locally derived grey, impure limestone; upper contact apparently gradational; lower contact gradational but transition from one rock type to another is rapid	2	2,407

Unit	Description	Thickness (feet)	Height Above Base (feet)
19 interbeds	Siltstone dark grey, conchoidally fracturing, arenaceous; interbeds 1 to 6 inches thick, of brownish grey to dull grey, medium- to fine-grained, hard and resistant sandstones (subgreywacke ?); these interbeds gradually increase upward until they become the predominant rock type near the top; sandstones become gritty near the top; small concretions, pods, and lenses (commonly arranged in rows) of grey impure, unfossiliferous (? fresh water) limestone abound in lower 35 to 40 feet of the unit; strike N 70°W, dip 30°E	75 (est.)	2,405
20	Irregular interbedding of subgreywacke as in bed 22 with siltstones and shales as in adjacent units; upper contact conformable and apparently gradational; lower contact covered; visible	70 (est.)	2,330
21	Covered on both sides of a small creek for about 71 yards across general strike and presumably underlain by the same rocks as in unit 20; assumed thickness of concealed rocks	105 (est.)	2,260
22	Subgreywacke, brownish grey, medium to coarse grained, resistant; occurs in beds 3 inches to 2 feet thick interfingered with laminae, thin layers and 6- to 12-inch beds of siltstone as in bed 20, both contacts covered, visible	9 (est.)	2,155
23	Covered for about 18 yards across the general strike and presumably underlain by the same rocks as in unit 24; assumed thickness of concealed rocks	28 (est.)	2,146
24	Interbedding of dark grey, very arenaceous, thinly bedded to laminated, soft siltstone and similarly coloured shale; a number of rows of concretions of dark-grey, white weathering, impure limestone; some interbeds of subgreywacke as in bed 25; strike N 80°W, dip 30°N; top covered; lower contact gradational	42 (est.)	2,118

Unit	Description	Thickness (feet)	Height Above Base (feet)
25	Greywacke (or subgreywacke ?), dark grey, fine to medium (rarely) grained, much clay; interfingered with a number of laminae and interbeds of thin-bedded and multicoloured, extremely arenaceous, fissile siltstone; numerous irregularly shaped pods and lenses of similar but harder and more or less calcareous greywacke; some pods, lenses and thin interbeds of very impure, grey limestone; in the lower part of the unit strike is N 70°W and dips vary from 30° to 40°W, strike near the top is N 70° - 80°W, and the dips lessen to 25° to 30°E; base covered, visible	30 (est.)	2,076
26	Covered for about 20 yards across general strike at the mouth of a small, dry creek and probably harbours a strike fault	60 (est.)	
27	Greywacke, mottled dark grey to rust-coloured, medium to fine grained, moderately soft, commonly clayey; abundant irregularly shaped inclusions and lenses of harder, slightly calcareous, light grey (?) subgreywacke; a few interbeds, 2 to 8 inches thick, of grey, very impure, unfossiliferous limestone; the upper 30 to 32 feet of the unit are composed predominantly of dark grey, fine-grained and very argillaceous greywacke; strike N 60°-70°W, dips vary from 40° to 45°E, except near the top where they increase to 55°E; the rocks are more intensely sheared and locally faulted near the visible top of the unit; top covered and probably faulted; base covered; visible	84 (est.)	2,046
28	Covered for about 35 yards across the general strike at the northern base of a sharp rocky point of the shore and probably underlain by the same rocks as in unit 27; assumed thickness of covered rocks	73 (est.)	1,962

Unit	Description	Thickness (feet)	Height Above Base (feet)
29	Sandstone (subgreywacke ?), grey-green, coarse grained, gritty, resistant, heavily bedded; regularly tilted and not disturbed otherwise; strike N 80°W, dip 40°N; top covered; lower contact gradational, visible	210 (est.)	1,889
30	Thin interbedding (mostly in 1- to 6-inch beds) of grey, resistant, fine- to medium-grained subgreywacke with dark grey, fine-grained, clayey, thinly layered to almost laminated sandstone locally grading into similarly coloured arenaceous siltstone; attitude as in the underlying bed, lower contact conformable and gradational	75 (est.)	1,679
31	Covered for about 40 feet across the general strike and presumably underlain by the same rocks as those of unit 30; assumed thickness of covered rocks	28 (est.)	1,604
32	Greywacke, green-grey, fine to medium grained, medium to thickly and well bedded (4 to 5 feet or even thicker beds), resistant; these greywacke beds alternate regularly with beds, 2 to 3 feet thick, of tawny to dark green weathering, commonly fine grained, thin layered to laminated (alternation of multicoloured lamellae), friable greywacke with some concretions of similar but calcareous greywacke; some layers and interbeds, 2 to 3 feet thick of grey, arenaceous shale or very clayey, fine-grained greywacke; strike N 50-60°W; dips 30° to 35°E; top covered, visible	85 (est.)	1,576
33	Sandstone (subgreywacke ?) green-grey, predominantly coarse grained; gritty; some pods and layers of coarse grit and fine pebble conglomerate; numerous interbeds of brown- to rusty-weathering, coarse- to medium-grained, gritty, more or less calcareous sandstone with honeycombed weathering of the surface, a few fragments of indeterminate marine shells seen in one of the interbeds of this sandstone about 600 feet below top of the unit; otherwise no fossils seen; interbeds of		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	fine-grained, friable greywacke and arenaceous shale as in unit 32 are rare or absent; strike N 50°-60°W, dips 30° to 35°E; rocks are locally jointed, sheared, and cut by minor faults striking in several directions (especially near the top of the unit) but the continuity of section does not seem to be lost anywhere; both contacts are conformable and gradational	900 (est.)	1,491
34	Covered for 15 feet across general strike and presumably underlain by the same rocks as in unit 33; assumed thickness of covered rocks	8 (est.)	591
35	Sandstone (subgreywacke ?) similar to that of unit 33 but invariably coarse grained and gritty; pods and layers of coarse grit and fine pebble conglomerate are more common than in unit 33; base and top covered; visible	40 (est.)	583
36	Covered for about 55 feet across general strike and presumably underlain by the same rocks as in units 35 and 37; assumed thickness of covered rocks	28 (est.)	543
37	Sandstone (?subgreywacke) as in unit 35; interbeds and layers of fine to coarse grit, interbeds of thinly layered, friable, clayey greywacke as in unit 33 are rare, thin, and very indistinctly developed; attitude as in unit 38; top covered; lower contact gradational	35 (est.)	515
38	Sandstone (?subgreywacke) as in unit 32; interbeds of friable, clayey greywacke as in unit 32 locally become predominant and intercalated beds, 5 to 8 feet thick, of grey, arenaceous shale as in unit 32 also may be more prominent locally; strike N 50°-60°W, dips 35° to 40°E and the rocks are virtually undisturbed otherwise; both contacts conformable and gradational	255 (est.)	480

Unit	Description	Thickness (feet)	Height Above Base (feet)
39	Greywacke, green-grey, mostly fine to medium grained, locally coarse grained and gritty, massive-looking to thickly and indistinctly bedded in the lower 50 feet; higher up the greywacke becomes medium and well bedded (in beds 1 to 3 feet thick) and alternates regularly with beds, 2 to 3 feet thick, of tawny to dark green-weathering, thinly layered to laminated (alternation of multi-coloured lamellae), fine-grained, friable greywacke; no fossils of any kind; near the base the rocks strike N 50°-60°W, dip 25° to 30°E and are almost undisturbed otherwise; between the levels 50 to 150 feet above base dips increase to 75°-85°E and rocks become strongly jointed, locally sheared and cut by a few minor faults; in the upper 75 feet dips lessen again to 30°-35°E and the rocks are undisturbed otherwise; upper contact conformable and gradational; outcrops end at the point 600 feet northeast of the mouth of Galato Creek and the base of the unit is believed to be cut off by a major northeasterly to east-west trending fault somewhere within the covered interval, 600 feet wide, between this point and the creek's mouth; visible	225 (est.)	225

Section 34 (Field No. 239/3-5, 1954). Measured on the northern shore of Quatsino Sound in the interval, about three quarter mile wide, between the mouth of Aweisha Creek and the extensive exposures of Blumberg Formation west therefrom (latitude 50°32'00"N, longitude 127°39'39"W).

LOWER CRETACEOUS (APTIAN)

COAL HARBOUR GROUP

Coarse arenite unit

1	Interbedding of 1- to 3-foot thick beds of greenish grey, resistant, medium- to coarse-grained, partly gritty and pebbly greywacke with similarly thick beds of darker coloured, soft and friable, fine-grained, partly		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	laminated, clayey greywacke; strike N 30°E and dip 20°W; top covered and presumably is cut off by a major northerly-trending fault; lower contact conformable; visible	5 (est.)	165
2	Siltstone, dark grey, soft, spheroidally weathering, partly arenaceous; lower contact conformable	10 (est.)	160
3	Interbedding of fine- and medium- to coarse-grained greywacke as in bed 1; attitude as in bed (1); lower contact conformable	8 (est.)	150
4	Siltstone as in bed 2; base cut off by intrusive rock of unit 5	10 (est.)	142
	LOWER TERTIARY OR (?) HIGHEST UPPER CRETACEOUS		
	?SOOKE INTRUSIONS		
5	Diabase, dark greenish grey, fine grained, slightly porphyritic (trachytic), dense; this intrusive dyke strikes N 20°W and dips 75°W	3	
	LOWER CRETACEOUS (APTIAN)		
	COAL HARBOUR GROUP		
	Coarse arenite unit		
6	Siltstone as in beds 2 and 4; both contacts cut off by intrusive rocks	7 (est.)	132

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR (?) HIGHEST UPPER CRETACEOUS		
	?SOOKE INTRUSIONS		
7	?Dacite, light green-grey, felsitic to very finely porphyritic; phenocrysts consist of lath-like, white feldspar and of dark mineral (?hornblende); numberous large pyrite crystals; this intrusive dyke strikes N 50°W and dips 60° to 70°W; thickness fluctuates from 2 to 4 feet	4	
	LOWER CRETACEOUS (APTIAN)		
	COAL HARBOUR GROUP		
	Coarse arenite unit		
8	Siltstone as in beds 2, 4, and 6; strikes N 10°E, dips 40°W; both contacts cut off by intrusive rocks of dykes 7 and 9	45 (est.)	125
	LOWER TERTIARY OR (?) HIGHEST UPPER CRETACEOUS		
	?SOOKE INTRUSIONS		
9	Diabase, dark green-grey, felsitic to somewhat and finely porphyritic, locally slightly and finely amygdaloidal (white calcitic amygdules); very dense; this intrusve dyke strikes north-south and dips about 90°	2	

amygdules

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS (APTIAN)		
	COAL HARBOUR GROUP		
	Coarse arenite unit		
10	Siltstone, dark grey, spheroidally weathering, partly arenaceous; very similar to siltstone of beds 2, 6 and 8; strikes N 10°E, dips 40°W; base covered; upper contact intrusive; visible	30 (est.)	80
11	Covered along the shore for	225 (est.)	
12	Greywacke, grey, coarse grained, partly gritty and locally pebbly; thickly (3 to 6 feet) bedded; includes pods and lenses of similar but calcareous greywacke and grit; strike N 30° to 40°E, dip 20° to 25°W; base and top covered; visible	50 (est.)	50
13	Covered east of visible base of bed 12 (harbours a major fault?) to the mouth of Aweisha Creek for	3,000 (est.)	

Section 35 (No Field No., 1954). Measured on Lind Islet and in the bluffs of the northern shore of Quatsino Sound for about 185 yards west of the Islet. Latitude 50° 29'06"N, longitude 127°48'48"W.

	LOWER CRETACEOUS (APTIAN)		
	COAL HARBOUR GROUP		
	Blumberg Formation		
1	Pebble conglomerate, fine to coarse, green-yellow to rust-coloured, tightly packed, hard; lithology of pebbles generally as in the other sections of the formation; in the basal 3 to 6 inches the conglomerate contains abundant fragments and pebbles of greywacke and siltstone lithologically undistinguishable from those of the underlying beds; higher up		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	these pebbles become rare; strike N 70°E, dip 25° to 30°W; contact with bed 2 sharp, somewhat uneven and suggestive of an erosional disconformity (Pl. IX, Fig. A); top not reached in the shore bluffs; visible up to	100 (est.)	280
	Coarse arenite unit		
2	Greywacke, greenish grey, coarse grained, partly gritty; interbedded with beds, 2 to 3 feet thick, of green-grey, fine to medium pebble conglomerate as in overlying beds and dark grey, fine-grained, partly clayey, laminated greywacke; within the next 160 yards westward along the shore this unit seems to lose gradually all its congomeratic and gritty interbeds until it is composed almost exclusively of fine-grained greywacke irregularly interbedded with an equal amount of dark grey to multi-coloured (in thin layers or laminae), laminated, more or less arenaceous, locally somewhat carbonaceous siltstone (Pl. IX, Fig. B); attitude as in bed 1; lower contact poorly exposed but apparently conformable; upper contact is well exposed only at the western end of above mentioned interval	55 (est.)	180
3	Greywacke, mostly green-grey but locally intensively rust- to rose-coloured (?thermally altered); forms beds 1 to 3 feet thick; strike N 50°E, dip 20°W; well exposed only on the southern side of a rounded point situated behind Lind Islet; base concealed beneath the sea; visible	40 (est.)	125
4	Channel separating Lind Islet from the mainland is covered by sea water for 60 yards and probably underlain by rocks of unit 5	60 (est.)	85

Unit	Description	Thickness (feet)	Height Above Base (feet)
5	Sandstone (subgreywacke ?), dull grey, fine to medium grained; thin bedded to laminated; contains a number of lenticular lenses or loaf-like inclusions, 2 to 20 feet long and 1 to 1 1/2 feet thick, of similar but harder and very limy sandstone grading into impure limestone; these limy sandstones are locally rich in small plant fragments but are unfossiliferous otherwise; strike N 70° E, dip 20°W; top and base concealed beneath the sea; visible	25	25

Section 35a (Field No. 259/7, 1954). Measured on the eastern side of Apple Bay about 150 to 200 yards north of the base of a sharp point closing the bay from southeast (latitude 50°36'06"N, longitude 127°38'48"W).

LOWER CRETACEOUS (APTIAN)

COAL HARBOUR GROUP

Coarse arenite unit

1	Greywacke, green-grey, mostly medium grained; contains rounded concretions, 3 to 10 inches in diameter, of harder but otherwise similar greywacke; attitude varies from almost horizontal to strike N 40°-50°W and dips from 3° to 10° west; top and base concealed, visible	15 (est.)	29
2	Covered and presumably underlain by the same greywacke as in (1)	6 (est.)	14
3	Greywacke, greenish grey, fine grained, strongly micaceous and silty, rich in coaly plant fragments; strike north 40°-50° west, dip 5° to 10° west; top and base covered; visible	8 (est.)	8

Section 36 (Field No. 293/8-11, 1954). Measured on bluffy northern shore of Quatsino Sound between the point about 1,200 yards west of Bish Creek (latitude 50°30'54"N, longitude 127°43'00"W) and that opposite Lind Islet (latitude 50°29'06"N, longitude 127°48'48"W).

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS (ALBIAN)		
	COAL HARBOUR GROUP		
	Blumberg Formation		
1	Pebble conglomerate, coarse, massive-looking, contains considerable number of cobbles and boulders, dark grey, abundant dark grey, fine-grained greywacke matrix; pebbles, cobbles, and boulders vary in size from 1/2 inch to 4 feet in diameter but pebbles ranging between 3 and 8 inches predominate; clasts consisting of the volcanic rocks of Vancouver Group and of the intrusive rocks of the Coast Intrusions predominate; clasts consisting of the grey clayey limestone, grey shale and rust-green coloured pebble conglomerate probably derived from the underlying Lower Cretaceous rocks occur more rarely; the presence of pebbles of conglomerate lithologically identical with that characterizing the lower part of the Blumberg Formation (see Pl. X, Fig. B) is interesting in suggesting the occurrence of intraformational periods of uplift and erosion within the Blumberg Formation; attitude unknown; top concealed and a completely covered interval, about 180 yards wide, separates the bed from the predominantly arenaceous rocks referred to the basal part of Upper shale unit (see pp. 197); base covered; visible	18 (est.)	2,978
2	Completely covered along the shore but possibly underlain by the same conglomerate as that of bed 1.....	600 (est.)	

Unit	Description	Thickness (feet)	Height Above Base (feet)
3	Pebble conglomerate as in bed 1 but includes some pods and interbeds of dark grey, medium grained greywacke; includes large boulders of very gritty, blackish grey greywacke; outcrops poor; rocks are greatly disturbed by minor faults and apparently bent into a shallow anticlinal fold; top concealed; lower contact gradational; visible	80 (est. ?)	2,960
4	Greywacke, grey, medium to coarse grained, massive-looking, hard; strike N 10°-20°W, dip 20° to 25°E; lower contact conformable and gradational	15 (est.)	2,880
5	Pebble conglomerate, much as in bed 3 but with a grit rather than greywacke matrix in the upper 15 to 20 feet; lower 140 to 150 feet includes numerous pods and interbeds of greenish grey, coarse-grained greywacke and its matrix becomes lighter and brownish green coloured; this conglomerate phase is indistinguishable lithologically from the conglomerates of the lower part of Blumberg Formation; strike fluctuates from N 20°W to N 10°E with dips 20° to 30°E; lower contact gradational	200 (est.)	2,865
6	Greywacke, greenish grey, massive-looking; coarse to medium grained, hard; outcrops poor and intermittent; lower contact covered	50 (est.)	2,665
7	Conglomerate, dark grey, predominantly cobble to boulder; includes numerous large blocks, boulders and pebbles of dark grey, partly coaly shale and siltstone and those of rust-greenish coloured pebble conglomerate similar to that characteristic of the lower part of Blumberg Formation; large pods and lenses of whitish grey, coarse- to fine-grained ?arkose occur locally; outcrops poor and intermittent in the middle interval (60 feet wide) which apparently harbours a fault as the conglomerate is strongly disturbed, sheared and contorted in the proximity of		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	this interval; elsewhere it strikes north-south to N 10° E and dips 15° to 30° E; outcrops are again very poor for about 80 feet in the interval 35 to 115 feet above the base (intrusive contact) of the unit; the basal 30 to 35 feet are bright rust- to maroon-coloured and hardened due to the thermal effect (thermal halo) of the adjacent intrusive body 8; this colour change takes place abruptly some 100 yards east of the point where the shore becomes rugged and bluffy; grades into intrusive body 8 through a few feet of metasomatically altered to completely granitized, hard conglomerate.....	260 (est.)	2,615

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR (?) HIGHEST UPPER CRETACEOUS		
	?SOOKE INTRUSIONS		
8	Granite porphyry, beige to whitish grey or light pinkish grey when fresh, weathers light brown; medium to coarse grained; phenocrysts consist predominantly of rust- to orange-coloured potassic feldspar (?orthoclase) and water transparent potassic feldspar (?sanidine); visible quartz crystals fairly numerous (20 to 25%); phenocrysts of dark mineral rare to very rare (leucocratic granite); numerous xenoliths of pebble conglomerate occur near the contact with unit 7; a little sulfide mineralization noted locally; intrusive body appears to pinch out completely on the tidal shelf near the water's edge and to widen rapidly inland to	75 (est.)	
	LOWER CRETACEOUS (ALBIAN)		
	COAL HARBOUR GROUP		
	Blumberg Formation		
9	Pebble to boulder conglomerate, bright rust- to maroon-coloured due to thermal action of adjacent intrusive bodies; metasomatically altered and partly "granitized" near the contacts and high in the shore bluffs; includes at least one 12- to 18-foot wide protuberance of strongly contaminated granitic intrusive rock much as in units 8 and 10; attitude as in unit 7	50 (est.)	2,355

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR (?) HIGHEST UPPER CRETACEOUS		
	?SOOKE INTRUSIONS		
10	Leucocratic granite porphyry as in body 8 and surrounded by zones of "granitized" conglomerate, 3 to 4 feet thick, near the contacts with surrounding sediments; sharp intrusive contact with unit 9 strikes about north-south and dips about 90°; appears to pinch out to about 11 feet at the tip of a sharp rocky point and to widen gradually inland; there seems little doubt that intrusive bodies 8 and 10 are only protuberances of a much larger granitic intrusive body occupying the densely forested upper slopes of the coast in this interval; width along the eastern side of the point	105 (est.)	
	LOWER CRETACEOUS (ALBIAN)		
	COAL HARBOUR GROUP		
	Blumberg Formation		
11	Pebble conglomerate, coarse to fine, mostly dark grey but with some interbeds of rust-coloured to rust-green coloured pebble conglomerate; the rock is thermally altered and bright rust- to maroon-coloured as in bed (9) in a zone about 30 feet wide, fringing the intrusive body 10; mainly tightly packed and pebbles are fairly well sorted as to size in the individual beds; pebbles 1/2 inch to 6 inches in diameter predominate but a greater or lesser admixture of coarse (6 to 10 inches) pebbles, cobbles and small to large boulders occurs in some beds; pebbles consist predominantly of various volcanic rocks apparently derived from the Vancouver Group and of granitic rocks presumably derived from the Coast Intrusions; pebbles are mostly subrounded to well rounded; interbeds of greywacke and pebbly grit are rare; strikes		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	range from N 80°W to N 40°W with dips 10°-20°E; the rocks are cut by minor, NW-trending normal and reverse high angle faults but the continuity of the section does not seem to be lost anywhere; the conglomerate with above mentioned attitude outcrops in the high bluffs for about 4,500 feet across its general strike from the contact with the intrusive body 10; its true thickness is therefore in order of	1,110 (est.)	2,305
12	Irregular alternation of dark grey pebble conglomerate as in unit 11 with rust-coloured to green-yellow pebble conglomerate; both colour phases are about equally widespread; numerous irregularly scattered interbeds and lenses of mainly coarse-grained, locally bright salad-green coloured greywacke and grit gradually increasing downward in the section; general attitude as in unit 11 and the rocks are moderately to strongly cut by minor faults of the same trend; outcrops are commonly very poor along the sea shore inside of Shapland Cove but the bluffs above are built of the same pebble conglomerate thoughout this interval; upper contact gradational; lower contact covered at the mouth of a small creek entering the sea in the northern corner of Shapland Cove; the conglomerates of unit 12 outcrop uninterruptedly for about 1,100 yards across their general strike; its visible thickness is therefore in order of	800 (est.)	1,195
13	Completely covered across general strike of Blumberg Formation on the western side of above mentioned small creek and apparently contains the major west-northwest trending Shapland Cove Fault	300 (est.)	

Unit	Description	Thickness (feet)	Height Above Base (feet)
14	Interbedding of beds of coarse to fine pebble conglomerate, 5 to 8 feet thick, as in unit 12 with beds, 3 to 4 feet thick, of similarly coloured, coarse- to medium-grained, pebbly greywacke; strike about east-west, dips 55° to 60° north; top covered and presumably cut off by the above-mentioned, major fault; lower contact poorly exposed but apparently conformable	130 (est.)	395
15	Pebble conglomerate, fine to coarse, green-yellow to rust-coloured, tightly packed, hard; attitude as above, base covered; visible	100 (est.)	265
16	Greywacke, grey to dark grey, fine to medium grained, thin bedded to laminated; general strike N 40°-50°E dip 45°W; but the rocks seem to be strongly disturbed; outcrops very poor and patchy except in the middle 17 to 18 feet of the unit; top covered; visible	85 (est.)	165
17	Irregular interbedding of pebble conglomerate, grit, coarse-grained greywacke, and fine-grained, laminated sandstones (as in the overlying beds) with dark grey sandy siltstone; pebble conglomerate is more common than other rock types; all rocks are exceedingly contorted, shattered and obviously occur within a strong fault zone; no estimate of thickness is possible; width across two long and broad, low points and the intervening shallow embayment of the shoreline	1,000 (est.)	
18	Greywacke, greenish grey, coarse to medium grained; some interbeds of pebble conglomerate as in the overlying beds; regular strike N 20° E and dip 20°W; upper contact covered; lower contact appears to be conformable; visible	60 (est.)	80

Unit	Description	Thickness (feet)	Height Above Base (feet)
19	Pebble conglomerate as in overlying beds; strike N 10°W to north-south; dip 20° to 25°W; base covered beneath the water; visible	20 (est.)	20
	Units 18 and 19 disappear beneath the sea at the southern base of a marked rocky point about 1,000 feet northeast of Lind Islet. Unit 17a outcropping on and just behind the shore throughout this interval, conformably overlies unit 18 and represents either a conglomerate facies of unit 17 or a separate unit faulted out at the contact between units 17 and 18.		
17a	Pebble conglomerate, as in unit 15; attitude as in beds 18 and 19; at the point of the shoreline about 150 feet northeast of Lind Islet the conglomerate on the beach and in the bluffs above it becomes intensely rust-coloured and thermally altered as that of bed (9); some 60 to 70 feet farther southward this bright rust- to vermillion-coloured conglomerate becomes extremely metamorphosed and in places (small dykes or veins?) partly "granitized"; this metamorphosed conglomerate outcrops on the tidal platform and in the steep, bluffy slopes above it for the next 300 to 350 feet; no significant dyke or larger intrusive body has been seen within this interval; it is thought, however, that such a body occurs there just below the surface; southwest of Lind Islet the above described, thermally altered to "granitized" conglomerates become replaced by fresh, unaltered conglomerates as in bed 15; base covered; visible	120 (est.)	

partly

Section 37 (Field No. 251/2-6, 1954). Measured on the northern shore of Rupert Inlet between the point 2 1/4 miles north-northeast of the tip of Hankin Point (latitude 50°35'27"N, longitude 127°31'06"W) and the southwestern shore of a deep nameless cove behind Narrow Island (latitude 50°35'40"N, longitude 127°29'24"W).

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER CRETACEOUS (ALBIAN)		
	COAL HARBOUR GROUP		
	Blumberg Formation		
1	Pebble conglomerate, medium grey; medium to fine, clasts consist predominantly of various volcanic rocks of the Vancouver Group and acidic to gabbroic Coast Intrusions present in comparable ratios; few sedimentary clasts; top and base concealed; visible	20 (est.)	1,272
2	?Arkose, light grey, coarse to medium grained, medium hard; a 5- to 6-inch thick interbed of bluish grey, fine-grained greywacke forms the visible base; top and base covered; visible	10 (est.)	1,252
3	Mostly covered but includes some small and poor outcrops of fine pebble conglomerate and coarse, pebbly grit lithologically similar to that of unit 1; strike about east-west and dips 25° to 30° south; probably underlain by these rocks throughout; assumed thickness	300 (est.)	1,242
4	Almost completely covered; probably underlain by rocks as in unit 3	120 (est.)	942
5	Coal, black with brownish tinge, soft, bituminous, impure; some interbeds of black carbonaceous shale; the bed does not seem to be persistent along the strike as it splits into 3 or 4 seams each 1/2 to 1 1/2 feet thick which are separated by similarly thick interbeds of black, carbonaceous shale within 20 to 30 feet westward; the coal contains the following palynomorphs (GSC-C-4309) identified by William S. Hopkins Jr.:		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	Lycopodiumsporites austroclavatidites (Cookson) Pocock, Lycopodiumsporites sp., Gleicheniidites senonicus Ross, Deltoidospora sp., Cyathidites cf. C. minor Couper, Triplanosporites sp., Osmundacidites wellmanii Couper, Acanthotriletes cf. A. varispinosus Pocock, ?Selaginella sp., Verrucosisporites sp., Cicatricosisporites perforatus (Baranov, Nemkova, and Kondratiev) Singh, Cicatricosisporites australiensis (Cookson) Potonié, Cicatricosisporites sp., Appendicisporites perplexus Singh, Vitreisporites pallidus (Reissinger) Nilsson, Pinus sp. haploxylon-type, Cupressaceae (Juniperus?), Tsugaepollenites cf. T. mesozoicus Couper, Monocolpate, ?Tricolpate; age: probably Albian, top covered; visible	3 (approx.)	822
6	Pebble conglomerate, fine to medium; grey, lithologically similar to that of beds 1 and 3; occurs in beds and members from 2 to 40 feet thick alternating with similarly thick beds and members of coarse pebbly grit and coarse-grained, pebbly sandstone; strike approximately east-west, dips 25° to 30° south; outcrops are normally poor and both contacts covered	450 (est.)	819
7	Pebble conglomerate, medium to coarse, dark grey, hard and resistant, tightly packed; lithologically similar to that of units 1, 3 and 6; almost devoid of interbeds and pods of grit and sandstone; forms a sharp, dagger-like point of the shoreline	100 (est.)	369
8	Covered inside of a long indented cove and possibly underlain by a unit of softer rocks; across general strike	100 (est.)	

Unit	Description	Thickness (feet)	Height Above Base (feet)
9	Pebble conglomerate as in unit 7; strike about east-west, dip 30° south; forms another sharp, dagger-like point of the shoreline	150 (est.)	269
10	Greywacke, bluish grey to brownish grey, fine to coarse grained, gritty and pebbly locally but does not seem to include any interbeds or pods of grit or pebble conglomerate	36 (est.)	119
11	Pebble conglomerate, medium to coarse (3 to 6 inch pebbles predominate); grey; lithologically similar to that of beds 1, 3, 6, 7, 9; includes considerable pods, lenses, and interbeds of pebbly grit and coarse grained, commonly gritty sandstone (includes both arkose- and greywacke-like types); carbonized wood occurs in the lower part; strike north 70° to 80° west, dips 25° southwest	45 (est.)	83
12	Interbedding of coarse grit and fine pebble conglomerate as in overlying beds, bluish grey; scattered larger pebbles occur throughout the thickness; locally grades into coarse-grained gritty greywacke; pebbles and grit particles are commonly composed of carbonaceous shale and greywacke apparently derived from the underlying bed 13; lower contact uneven, sharp and obviously erosionally disconformable; upper contact gradational	1	38
	<u>Coarse arenite unit</u>		
13	Greywacke, dark grey, hard and resistant, fine grained, silty; grades laterally into similarly coloured, very arenaceous siltstone; small pods, lenses, and thin layers of coaly siltstone; and very low grade coal occur locally; bed contains numerous small, carbonized fragments of wood, bark, and leaves; complete leaves and fern fronds are exceedingly rare	1	37

Unit	Description	Thickness (feet)	Height Above Base (feet)
14	Shale, blackish grey to brownish grey, carbonaceous and sometimes coaly (especially in topmost 6-10 inches); some laminae, thin layers and interbeds of grey, fine- to medium-grained greywacke	4	36
15	Greywacke, light to medium grey, fine to medium grained, very silty, thinly bedded and weathers flaky; upper contact gradational.....	13	32
16	Covered and probably underlain by greywacke as in bed 15	3	19
17	Greywacke, light grey to bluish grey, brownish grey weathering, hard and massive-looking; fine to medium grained and commonly silty; coarse quartz grains and grit particles dispersed throughout the bed; strike north 60° west, dip 25° west	11	16
18	Siltstone, dark grey to brownish grey, arenaceous; commonly contains pods, lenses and 1/2- to 1-foot interbeds of black coaly siltstone and very low grade coal; upper contact uneven, sharp and obviously erosionally disconformable; base concealed beneath beach deposits inside a narrow lagoon situated behind Narrow Island; visible up to	5	5

Section 38 (Field No. JA-F69-14/1-3, 1969). Measured on the tidal shelf of the northern shore of Quatsino Sound some 600 feet west of the mouth of Bish Creek (on southeastern limb of small markedly southwest-plunging anticline). Latitude 50°30'43"N, longitude 127°44'12"W.

UPPER CRETACEOUS

CENOMANIAN STAGE

Upper shale unit

Unit	Description	Thickness (feet)	Height Above Base (feet)
	Greywacke member		
1	Greywacke, brownish grey when fresh, weathers dull brown, fine grained, hard and dense, massive-looking but actually thinly bedded, partly calcareous; only indeterminate shell fragments seen; strikes N 50°E and dips 19°E; top covered; lower contact gradational; visible	3	8 1/2
2	Pebble conglomerate, fine to medium (1/2- to 2-inch pebbles predominate), mottled dull brown, calcareous to very calcareous, hard and dense; elongated to angular limestone and shale pebbles predominate; some flattened clayballs were noted also; rich in matrix consisting of coarse- to fine-grained greywacke (gritty) or fine to coarse grit, also contains numerous laminae, 1/2-inch to 2-inch interbeds and pods of grit; fossils mainly occur at the gradational contact of beds (1) and (2); this Cenomanian fauna (GSC loc. 83932) includes: Desmoceras (Pseudouhligella) ex aff. ezoanum Matsumoto, Baculites (Sciponoceras) n. sp. ex aff. kossmati Nowak, Eogunnarites unicum (Yabe), Inoceramus ex aff. I. crippsi Mantell and several indeterminate pelecypods and gastropods	1/2	5 1/2
3	Greywacke, dull brown in fresh and weathered state, fine grained, thinly bedded to laminated; contains some worm burrows; mostly friable; interbedded with dull grey somewhat sandy, friable shale (outcrops poor); base concealed in the anticline's axis attitude as in bed 1; visible	5	5
4	Completely covered in the axis of the anticline (across the strike)	96	

Unit	Description	Thickness (feet)	Height Above Base (feet)
	On the western side of the covered interval, greywacke of bed 3 reappears with the attitude: strike 350°dip 42°W. Inoceramus ex aff. I. pictus Mantell (GSC loc. 83931) was found in bed 3 on the western limb of this anticline.		

Section 39 (Field No. JA-F68-13/8-9, 1968). Measured on the north side of Lippy Creek, 2 miles east of Neroutsos Inlet, on the northwestern side of short secondary logging road branching off the main Gibson Road at the altitude ±2,150 and on the eastern slopes above this road between the altitudes ± 2,100 and 2,500. Latitude 50°28'15"N, longitude 127°29'00"W.

UPPER CRETACEOUS

Nanaimo Group

Cedar District Equivalent

1	Arkose, dull brown with rust-coloured spots, fine grained, extremely uniform and indistinctly bedded, friable; strikes 355° and dips 20° west; no identifiable fossils seen; top and base covered; visible in the steep banks of a small left confluent of Lippy Creek (near its head at the altitude ±2,450 to 2,280 feet) crossing a 170-foot high, steep, logged out top part of the slope	150 (est.)	281½
2	Almost completely covered, logged out 100-foot high slope between the top of unit (3) and a terrace-like step forming the base of slope where unit 1 is exposed; scattered outcrops of arkose more or less as in unit (4) and probably underlain by this rock thoughout; no attitude; base and top covered; assumed thickness	70	131½

Unit	Description	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR (?) HIGHEST UPPER CRETACEOUS		
	?SOOKE INTRUSIONS		
3	Rhyolitic intrusive rock, light-blue, bluish white or cream white when fresh, weathers buff- maroon- or rust-coloured; completely unaltered and friable; very porphyritic and amygdaloidal; matrix between phenocrysts felsitic; medium- to large-grained phenocrysts consist predominantly of dirty white ?potash feldspar (75%) and quartz (more than 10%); many 1/4" to 1", irregularly rounded to vermiform amygdules are completely filled with quartz; numerous similarly shaped, completely to partly empty vesicles are commonly lined with a ?chalcedony crust; rock is massive; lower contact abrupt, apparently even but discordant (a dyke) since it cuts across several individual crossbeds of unit 2 within a couple of feet along strike and its attitude differs from that of underlying unit 4; strike of the contact is N 10° E with dip 5° W; top concealed everywhere, visible up to	6	
	The above described rhyolitic sill outcrops throughout an interval, about 15 yards long, at the northern end of previously mentioned secondary logging road (see Pl. XII, Fig. B).		
	UPPER CRETACEOUS		
	Nanaimo Group		
	Cedar District equivalents		
4	?Arkosic sandstone, whitish grey to buff and mottled when fresh, weathers bright to light orange; coarse grained, partly gritty; feebly to strongly ferruginous; friable; mostly well and thinly bedded or laminated and		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	intensively crossbedded; some of crossbeds are large (1-3 feet across), low, scalloped and apparently of deltaic to beach type; some interbeds of indistinctly bedded, massive-looking sandstone; persistent and reliable strike N 40°E to N 50°E with dips about 10°W; outcrops mostly poor and discontinuous	25	41½
5	Pebble conglomerate, fine to very fine, pebbles from 1/8" to 1/4" predominating; mottled brown-grey, friable, contains abundant gritty and coarse-grained greywacke matrix; pebbles almost exclusively composed of volcanic rocks (mostly of the Bonanza volcanic types) and of black argillite, greywacke, and limestone presumably derived from the Sedimentary division of the Bonanza Subgroup; very few (if any?) clearly recognizable granite Coast Intrusion pebbles seen; pebbles mostly poorly to moderately well rounded; grades upward into bed 4 through a 6- to 8-inch bed of pebbly, coarse grit	6	16½
6	Greywacke, bluish grey when fresh, weathers chocolate-brown and chunky, later spheroidally, ferruginous, medium hard, fine grained, indistinctly but thinly bedded; base concealed; contact with bed 5 abrupt but even and apparently conformable; fairly common fauna (GSC loc. 82958) found in the uppermost 1 foot of the bed includes Baculites cf. chicoensis Meek, Inoceramus chicoensis Anderson, Inoceramus ex aff. balticus Böhm and "Rhynchonella" suciensis Whiteaves; visible ..	4 1/2	12½
7	A completely covered interval about 20 yards long along the previously mentioned secondary logging road (i.e. direction about 350°). This interval is the same as unit 1 of section 29 and separates this section from the here described Nanaimo Group section. Barring		

Unit	Description	Thickness (feet)	Height Above Base (feet)
	the most unlikely occurrence of a fault (rocks on both sides are concordant, have very low dips, are neither sheared nor contorted and do not exhibit any calcitic veinlets or stringers), this covered interval conceals a disconformable (more likely unconformable) contact between the Nanaimo Group and the underlying Barremian variegated clastic unit.		
	Estimated thickness of covered rocks	8	8