GEOLOGICAL
SURVEY
OF
CANADA

DEPARTMENT OF ENERGY,
MINES AND RESOURCES

BULLETIN 242

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

J. A. Jeletzky

Ottawa
Canada
1976

Price, $7.00

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

1,500–1974–6455-6

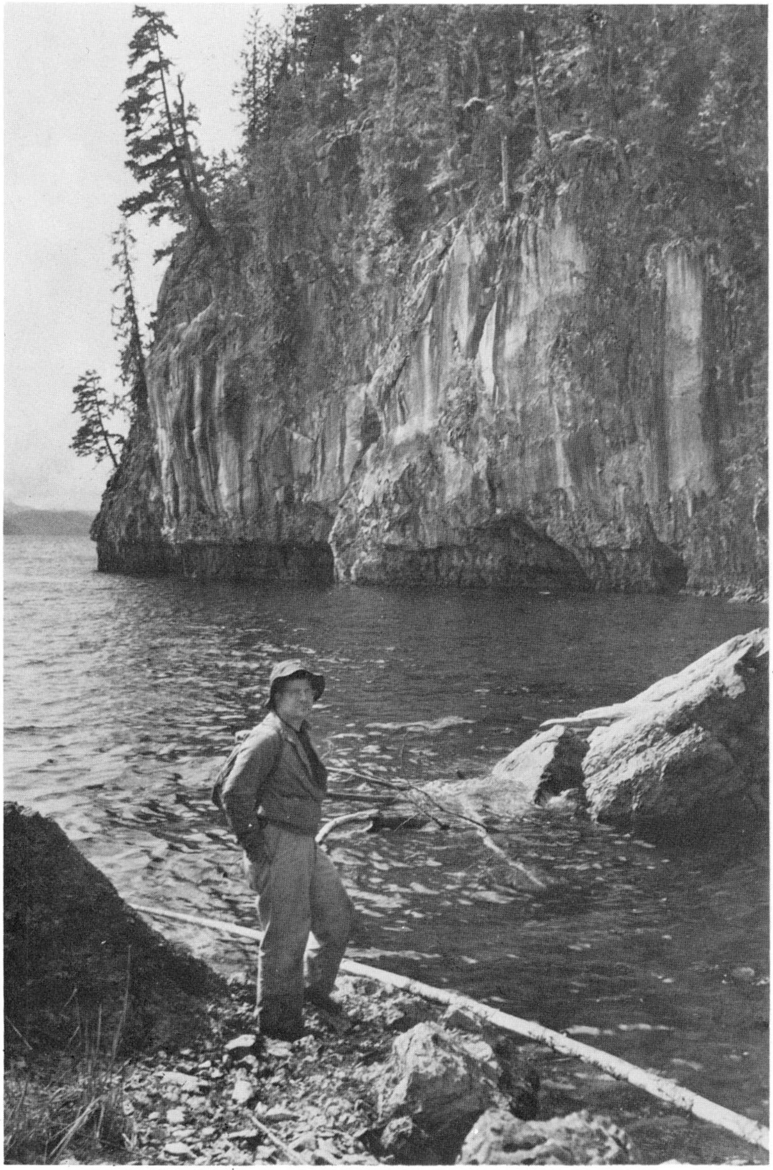
Technical Editor
E. J. W. IRISH

Critical Readers
H. GABRIELSE
B. S. NORFORD

Editor
DORCAS CUTHBERT

Text printed on Georgian offset smooth (brilliant white)
Set in Times Roman

Artwork by CARTOGRAPHIC UNIT, GSC



129212, 1–2–54

PLATE I. High bluffs of the Lower member of Quatsino Limestone in the southern side of a nameless rocky point about 2,000 feet southeast of Stewart Point, Holberg Inlet. View due northwest (toward Coal Harbour which is concealed behind the point) from the inner part of an embayment next southwest of the above-mentioned nameless point. Limestone strikes 340°–350° (obliquely to the right side of the photograph) and dips about vertical. The bedding shows well on the left side of the photograph near the tip of the point.

The Welleri Zone fossil locality GSC loc. 24335 is behind the Quatsino Limestone bluffs.

GEOLOGICAL SURVEY
OF CANADA

BULLETIN 242

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

By
J. A. Jeletzky

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
CANADA

Available by mail from Information Canada, Ottawa,
from Geological Survey of Canada, 601 Booth St., Ottawa,
and at the following Information Canada bookshops:

HALIFAX
1683 Barrington Street

MONTREAL
640 St. Catherine Street West

OTTAWA
171 Slater Street

TORONTO
221 Yonge Street

WINNIPEG
393 Portage Avenue

VANCOUVER
800 Granville Street

or through your bookseller

A deposit copy of this publication is also available for reference in
public libraries across Canada

Price: $7.00 Catalogue No. M42-242

Price subject to change without notice

Information Canada
Ottawa, 1976

PREFACE

A principal objective of the Geological Survey of Canada is the estimation of the potential abundance and probable distribution of mineral and fuel resources available to Canada. To make such estimates, a wide variety of data is needed, including information concerning the geological framework. In this report the age, structure, sequence, relationships, thickness, and origin of a thick succession of Triassic and Lower Jurassic volcanic and sedimentary rocks from northwestern Vancouver Island are described in great detail.

The detailed studies on which this report is based were done in 1953 and 1954, supplemented by some additional work in 1968 and 1969. Because luxuriant vegetation covers all lowland areas and most of the steeper slopes above high tide, the survey was confined to the well-exposed shoreline. Several interim reports have been published, but this report presents the first complete synthesis of the voluminous data collected by Dr. Jeletzky.

The report area is underlain mainly by the more than 25,000-foot-thick succession of volcanic and sedimentary rocks known as the Vancouver Group. It has long been recognized that an understanding of the sedimentary units of this group is essential if the geological history of this complex area is to be unravelled, and considerable attention is given to this. The nature and origin of the fault-block tectonic style that characterizes the relatively undeformed rocks of this geosynclinal region is discussed in detail.

This report, the result of many years of detailed field and laboratory studies by the author, is an important and significant contribution and will assist greatly those concerned with West Coast geology.

D. J. McLAREN,
Director, Geological Survey of Canada

OTTAWA, October 5, 1973

CONTENTS

PAGE

INTRODUCTION AND ACKNOWLEDGMENTS 1

STRATIGRAPHY 2

Table of formations 3

Vancouver Group 2

Karmutsen Subgroup 8

Amygdaloidal flows unit 8

Bonanza Subgroup 9

Sedimentary division 10

Quatsino Formation 10

Thinly bedded member 14

Arenaceous member 16

Sutton Formation (limestone) 19

Late Norian paleogeography 22

Volcanic division 26

Hecate Cove Formation 27

Latest Triassic (?Rhaetian) orogenic phase and the resulting facies and paleogeographic pattern 34

Tectonically and volcanically quiescent zone of the latest Triassic 38

Basal Jurassic volcanic unit 38

Cherty limestone unit 42

Grey volcanic unit 43

Matthews Island Formation 45

Uppermost Sinemurian volcanic unit 50

Uppermost Sinemurian argillite unit 53

?Dark grey volcanic unit 55

?Pliensbachian–?Toarcian greywacke unit 55

Lower Jurassic tectonic and depositional pattern of Insular Tectonic Belt 56

Depositional area of the Lower Jurassic part of Volcanic division 56

Sedimentary sequence of the Lower Jurassic tectonically and volcanically quiescent zone 57

Tuffaceous argillites of Buttle Lake area 57

Harbledown Formation of Queen Charlotte Strait 57

PAGE

STRATIGRAPHY (*conc.*)
Harbledown and Maude formations of Queen Charlotte Islands 58
Relationships of sedimentary Lower Jurassic sequences to the Volcanic division of Bonanza Subgroup 59
Scarcity of sediment in tectonically and volcanically quiescent zone 60
Volcanic cycles of the Volcanic division 60
Lower Jurassic depositional environments and tectonic movements of tectonically and volcanically active zone 61
Basal Jurassic environments 61
Sinemurian environments and tectonic movements 62
Pliensbachian–?Toarcian environments and early Pliensbachian uplift 63
Middle Jurassic Intrusions 63
Coast Intrusions 63
Results of Middle Jurassic orogeny 69
Late Jurassic and earliest Cretaceous time 70
Lower Cretaceous strata 71
Longarm Formation equivalents 72
Buchia crassicollis greywacke 72
Hauterivian siltstone unit 76
Upper Valanginian and ?Hauterivian greywacke–conglomerate unit 80
Inoceramus colonicus calcarenites 82
Barremian fine-grained greywacke unit 85
Barremian variegated clastic unit 89
Middle to late Barremian facies and paleogeography 92
Coal Harbour Group 95
Coarse arenite unit 96
Blumberg Formation 103
Upper Cretaceous strata 109
Upper shale unit 109
Nanaimo Group 114
Cedar district equivalents 114
?Early Tertiary Intrusions 117
?Sooke Intrusions 117
Oligocene and ?Miocene rocks 122
Carmanah Group 122
?Late Tertiary volcanic rocks 122

STRUCTURAL GEOLOGY 124
Previous investigations 124
Folds 125

PAGE

STRUCTURAL GEOLOGY (*conc.*)
Faults 127
Grant Bay fault 129
Browning Inlet fault 129
Galato Creek fault 130
Mahatta fault zone 132
Robson Cove fault 134
Shapland Cove fault 134
Ildstad fault zone 135
Aweisha Creek fault 135
Unnamed major faults between Neroutsos Inlet and the eastern shores of Holberg and Rupert inlets 135
Holberg fault 136
Rupert Inlet fault 138
Principal fault blocks 138
Forward Inlet fault block 139
Quatsino fault block 140
Coal Harbour fault block 141
Rupert Inlet fault block 142
Concluding remarks 142

REFERENCES 144

APPENDIX (39 measured sections) 161

INDEX 237

Illustrations

Plate I. Quatsino Limestone, Coal Harbour .... *Frontispiece*
IIA. Quatsino Limestone, Quatsino Narrows 149
IIB. Quatsino Limestone, Rupert Inlet 149
IIIA. Bonanza Subgroup, Sedimentary division, headwaters of Lippy Creek 150
IIIB. Close-up of the outcrop shown in Plate IIIA 150
IVA. Contact of Sutton Limestone and Hecate Cove Breccia, Banter Point 152
IVB. Bonanza Subgroup, Volcanic division, Mahatta Creek canyon 152
VA. Contact of *Inoceramus colonicus* calcarenites and Barremian fine-grained greywacke, Salmon Islands 153
VB. Over all view of lower part of section 29, headwaters of Lippy Creek 153

PAGE

Plate VIA. Close-up of bed 9, section 29, headwaters of Lippy Creek........... 154
VIB. Close-up of middle part of section 29, headwaters of Lippy Creek 154
VIIA. Basal beds of Coarse arenite unit, Winter Harbour........................ 155
VIIB. Units 33 to 38 of Coarse arenite unit, Winter Harbour................. 155
VIIIA. Coarse arenite unit, bed 11, section 32, Winter Harbour............... 156
VIIIB. Another view of section shown in Plate VIIIA................................ 156
IXA. Contact of Blumberg Conglomerate and Coarse arenite unit west of Lind Islet, Quatsino Sound.. 157
IXB. Uppermost beds of Coarse arenite unit, west of Lind Islet, Quatsino Sound... 157
XA. Greywacke member, Upper shale unit, Quatsino Sound, west of mouth of Bish Creek.. 158
XB. Blumberg Conglomerate, topmost bed of type section, Quatsino Sound... 158
XIA. Shale–siltstone member, Upper shale unit, Quatsino Sound, west of Ildstad Islets... 159
XIB. Close-up of the outcrop shown in Plate XIA................................. 159
XIIA. Dyke–like ?Sooke Intrusion, Quatsino Sound, west of Aweisha Creek.. 160
XIIB. Sill-like ?Sooke Intrusion cutting Nanaimo Group, headwaters of Lippy Creek.. 160

Figure 1. Sketch-map of Quatsino Limestone section at Kenny Point............. 12
2. Basal Norian (Kerri Zone) facies and paleogeography of the Quatsino Sound area... 15
3. Late upper Norian (upper Suessi time) facies and paleogeography of the Quatsino Sound area.. 23
4. Latest Triassic (?Rhaetian) facies and paleogeography of the Quatsino Sound area... 36
5. Composite diagrammatic reconstruction of Triassic and Lower Jurassic facies across northwestern part of Vancouver Island and Queen Charlotte Strait..*in pocket*
6. Upper Karnian to Toarcian (Quatsino to Maude formations inclusive) facies and tectonic zones of Insular Tectonic Belt.................*in pocket*
7. Upper Valanginian (*Buchia crassicollis* time) facies and paleogeography of the Quatsino Sound area.. 75
8. Hauterivian facies and paleogeography of the Quatsino Sound area.. 79
9. Lower Barremian ?and/or uppermost Hauterivian (time of the *Inoceramus colonicus* calcarenites) facies and paleogeography................. 86

PAGE

Figure 10. Upper Barremian (time of Barremian fine-grained greywacke unit) facies and paleogeography 94
11. Aptian (time of Coarse arenite unit) facies and paleogeography 102
12. Schematic block diagram illustrating paleogeographical–structural relationships of Coarse arenite unit and Blumberg Formation of Quatsino Sound 108
13. Albian (time of deposition of Blumberg conglomerates) facies and paleogeography 110
14. Facies and paleogeography of the late Nanaimo time (Cedar District or early late Campanian time) 116
15. Schematical structural map of Quatsino Sound area showing principal fault blocks, principal faults, and some of the major faults 127
16. Geological and structural sketch-map and profile of Stewart Point, Coal Harbour 137
17. Mesozoic and ?Tertiary rocks of Quatsino Sound, British Columbia .... *in pocket*
18. Mesozoic and ?Tertiary rocks of Quatsino Sound, British Columbia .... *in pocket*

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

Abstract

The report-area is underlain largely by a 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.

Only about 3,000 feet of the uppermost Karmutsen Subgroup is exposed within the area. These beds are overlain apparently conformably by 2,300 to 3,300 feet of variegated sediments of the Sedimentary division of the Bonanza Subgroup.

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., Coal Harbour–Alice Lake 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 Islands where 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 was 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) was 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, 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 stratigraphic–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 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- 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 occurs 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 and did not extend southward beyond the line defined by Suquash Creek, head of Neroutsos Inlet, and Kwakiutl Point. Its eastern limit was presumably situated somewhere beneath 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 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, as 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 fault-block 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.

Résumé

Le sous-sol de la région à l'étude se compose en majeure partie d'une succession de roches volcaniques et sédimentaires du Trias et du Jurassique inférieur appartenant au groupe de Vancouver dont l'épaisseur a plus de 25,000 pieds. La base du groupe n'affleure pas. Le groupe de Vancouver a été divisé en deux sous-groupes: celui de Karmutsen à sa partie inférieure et celui de Bonanza, comprenant le calcaire de Quatsino à sa partie supérieure.

Du sommet du sous-groupe de Karmutsen, environ 3,000 pieds seulement affleurent dans la région. Ces couches sont recouvertes, sans discordance apparente, par 2,300 à 3,300 pieds de sédiments bigarrés, de la division sédimentaire du sous-groupe de Bonanza.

Le vaste bassin marin karnien (c'est-à-dire au cours du Karmutsen et au début de Quatsino), qui s'étendait de beaucoup à l'est et à l'ouest de la région à l'étude, se transforma au début du Norien en une fosse sédimentaire relativement étroite, orientée vers le nord, puis fut par la suite fragmentée par des zones d'apport (des îles ?) vers la fin du Norien. Le faciès à structure complexe qui en résulta, formé de sédiments clastiques et calcaires (niveau à couches minces, niveau arénacé, calcaire de Sutton) fut interrompu par la dernière phase orogénique du Trias (début du Rhaetien ?) qui plissa les roches triassiques et y produisit des failles, si on en juge par le déchaînement coexistant du volcanisme. La crête d'au moins deux anticlinaux orientés vers le nord (les terrains tectoniques de Coal Harbour-Alice Lake) deviennent des zones d'apport déversant des matériaux pyroclastiques, des laves et des

matériaux clastiques volcaniques grossiers dans les fosses résiduelles marines de Neroutsos et de la côte Ouest.

La dernière phase orogénique du Trias et le volcanisme qui l'accompagna n'atteignirent pas la partie nord-est de l'île Vancouver, le détroit de la Reine-Charlotte ni les îles de la Reine-Charlotte, où la déposition d'argilites et de calcaires marins (couches supérieures des formations de Parson Bay et de Quatsino) se prolongea jusque dans la période jurassique. Ceci amena la division de la zone Insulaire tectonique en deux. La région située au sud-ouest, tectoniquement et volcaniquement active, comprenait toute la région à l'étude ainsi que les parties adjacentes au nord-ouest de l'île Vancouver. La région tectoniquement et volcaniquement calme comprenait les abords au sud-est, à l'est, au nord-est et au nord de la région à l'étude. Ce mode de déposition et de structuration se poursuivit jusqu'à la fin du Jurassique inférieur.

De 10,000 à 20,000 pieds de roches volcaniques en majeure partie andésitiques et de sédiments de la division volcanique du sous-groupe de Bonanza furent déposés au cours de la toute dernière fin du Trias et au début du Jurassique dans la région à l'étude et les régions adjacentes de la zone tectoniquement et volcaniquement active. On a subdivisé la division volcanique par ordre d'ancienneté comme suit: formation de Hecate Cove (nouvelle), unité volcanique de base du Jurassique, unité de calcaire à silex, unité volcanique grise, formation de Matthews Island (nouvelle), unité volcanique du plus récent Sinémurien, unité d'argilite du plus récent Sinémurien, unité volcanique gris foncé ?, et unité de grauwacke du Pliensbachien-Toarcien ? Il n'y eut que quelque 2,000 à 3,500 pieds d'argilites et de calcaires (formations de Harbledown et de Maude) qui furent déposés simultanément dans la zone calme, où il y avait évidemment pénurie de sédiments. On a interprété les sédiments interstratifiés de la division volcanique comme étant des apophyses des formations de Harbledown et de Maude de la zone calme.

L'orogenèse du Jurassique moyen et les intrusions batholiques de la côte qui l'accompagnèrent vinrent annihiler le mode de déposition et de structuration caractéristique du Jurassique inférieur. Dans la région à l'étude, le groupe Vancouver fut plissé pour former un homoclinal ouvert, orienté vers le nord et incliné vers l'ouest, comprenant apparemment le versant occidental de l'anticlinorium de l'île Vancouver. Ce comportement tectonique basiquement simple du Jurassique moyen se compliqua fortement par endroits sous l'influence d'intrusions côtières principalement syntectoniques. L'orogenèse du Jurassique moyen transforma toute la zone Insulaire tectonique en une région tectonique et provoqua la «migration» du volcanisme (volcaniques de Yakoun) de la zone active du Jurassique inférieur au sein de la zone calme de la même période.

Les intrusions côtières relevées dans la région à l'étude sont des filons, petits et grands, des pitons et, rarement, de petits stocks caractérisés par des textures porphyritiques allant du fin au grossier ou des textures amygdaloïdes, ou felsitiques. Ces plutons dioritiques à gabbroïques semblent être des apophyses et des coupoles de position très superficielle allant à hypabyssale, témoins de plus grosses masses intrusives hypocristallines encore enfouies en profondeur. On croit que ces intrusions cachées sont intimement reliées aux principaux massifs d'intrusions côtières de la chaîne Côtière, ou en représentent un prolongement direct.

Les données stratigraphiques et paléontologiques indiquent l'occurrence d'une seule époque majeure, géologiquement brève (bathonienne?), des intrusions côtières mésozoïques dans la région à l'étude et ailleurs dans l'île Vancouver. Ceci contredit l'hypothèse maintenant à la mode qui veut une activité ignée plus ou moins continue dans la Cordillère occidentale.

On n'a pas relevé dans la région de roches du Jurassique supérieur ou d'âge s'échelonnant du Herriasien ou Valanginien moyen. Apparemment, cette partie de l'île Vancouver demeura émergée et subissait l'érosion au cours de l'intervalle de temps qui suivit un soulèvement régional de la zone Insulaire tectonique à la suite de l'orogenèse du Jurassique moyen.

Le groupe de Vancouver et les intrusions côtières sont superposés en discordance par plus de 10,000 pieds de couches du Crétacé. Ces roches, exclusivement sédimentaires, d'origine partiellement marine, couvraient apparemment autrefois toute ou presque toute la région à l'étude mais disparurent au cours de l'érosion du post-Crétacé, à l'exception de quelques enclaves préservées au sein de grabens ou dans des structures synclinales.

Un groupe encore innommé, allant du Valanginien supérieur au Barrémien supérieur, équivalant à la formation de Longarm des îles de la Reine-Charlotte et à la partie crétacée du groupe de Relay Mountain de la fosse de Tyaughton, constitue la partie basale de la série crétacée. Ces roches, d'une épaisseur de 3,000 à 3,500 pieds, se subdivisent (par ordre ascendant) en: une grauwacke à *Buchia crassicollis*, une unité de siltstone du Hauterivien, une unité grauwacke-conglomérat allant du Valanginien supérieur au Hauterivien (?), les calcarénites à *Inoceramus colonicus*, une unité de grauwacke à grain fin du Barrémien et une unité clastique bigarée du Barrémien. Ces roches nécomiennes furent déposées dans une anse marine relativement peu profonde confinée entre la terre ferme de la péninsule de Brooks au sud-est et celle de la côte nord-est au nord-est. La transgression à pulsations qui dura du Valanginien supérieur au Barrémien supérieur s'avança graduellement vers l'est et le sud-est au-dessus de la région érodée du nord-ouest des terrains tectoniques du Jurassique moyen. Cette transgression atteignit son apogée pendant le Barrémien supérieur alors que toute la région à l'étude fut inondée et que les zones d'apport adjacentes furent pénéplanées essentiellement.

Les roches du Néocomien sont recouvertes, en concordance semble-t-il, par une série de roches clastiques à grain plutôt grossier et d'origine presqu'exclusivement non-marine; ce groupe, d'une puissance allant jusqu'à 8,000 pieds (?), a été nommé groupe de Coal Harbour (nouveau). Ces roches, datant de l'Aptien à l'Albien, se divisent en une arénite grossière à la base, d'une épaisseur de ?800 à ?5,390 pieds, et en la formation recouvrante de Blumberg (nouveau), d'une épaisseur d'au moins 3,000 pieds.

Le groupe non-marin de Coal Harbour est l'équivalant du groupe de Jackass Mountain de la fosse de Tyaughton. Il témoigne de la venue de l'orogenèse inter-régionale de l'Aptien (?Aptien supérieur) qui souleva fortement la région tectonique du Jurassique moyen qui était antérieurement pénéplanée et représente des dépôts de piedmont accumulés dans un bassin encaissé en voie d'effondrement de son côté nord-ouest. Le gros des matériaux clastiques grossiers provient apparemment des terrains fortement émergés de la péninsule de Brooks au sud-est de la région. Certains matériaux clastiques grossiers originèrent cependant de la région tectonique moins élevée couvrant la partie nord-est de l'île Vancouver. A l'encontre de la fosse de Tyaughton, la région à l'étude ne semble pas avoir été inondée par la mer albienne.

On trouve en certains endroits de la région au moins 680 pieds de schistes argileux marins du Cénomanien et du Turonien, ainsi que de petites quantités de sédiments clastiques grossiers. Cette unité plus récente de schistes argileux est le résidu d'érosion d'une invasion vers le sud-est de la phase finale de la mer de Haida des îles de la Reine-Charlotte sur la partie nord-ouest en effondrement de la région tectonique aptienne-albienne de l'île Vancouver. L'étendue de cette transgression du début du Crétacé supérieur demeure incertaine.

Le groupe de Nanaimo est représenté par une seule petite enclave qui est supportée en discordance (?) par les roches barrémiennes qui bordent le côté est de l'anse de Neroutsos. Ces grès à arkoses, de plus de 280 pieds d'épaisseur et faillés au sommet, équivalent seulement à la formation de Cedar District du Campanien supérieur de la région de Nanaimo-Comox. L'enclave de Neroutsos représente la partie centrale de l'anse nord de la fin de la mer de Nanaimo. Cette mer s'avança du nord-ouest ou de l'ouest (?), mais ne s'étendit pas au-delà d'une ligne définie par la rivière Suquash, le fond de l'anse de Neroutsos et la pointe de Kwakiutl. On croit que sa limite orientale se situait quelque part sous le détroit de la Reine-Charlotte.

Il existe quelques plutons, petits et moyens, à forme de filons et de pitons, qui envahirent les roches crétacées de la région. A cause de leur âge post-Nanaimo (c'est-à-dire post-Campanien) et de leur disposition suivant les plans de failles datant probablement du Tertiaire inférieur, on a établi pour le moment une correspondance entre ces plutons et les roches intrusives de Sooke du sud-est de l'île Vancouver et on les a assignés au début de l'Oligocène.

La composition minéralogique des roches intrusives de Sooke (?) va du granitique au gabbroïque. La taille restreinte de ces plutons, la prédominance des textures porphyritique, amygdaloïde et felsique allant du fin au grossier, ainsi que l'abondance dans leur périmètre de sédiments du Crétacé altérés métasomatiquement (halos thermiques) indiquent qu'ils constituent des apophyses et des coupoles, dont la position s'échelonne de très peu profonde à hypabyssale, témoins de plus gros plutons encore enfouis en profondeur.

On n'a pas relevé d'affleurements de roches sédimentaires du Tertiaire dans la région. Les roches volcaniques affleurant sur la rive nord de l'anse Holberg, et attribuées au Tertiaire supérieur (?) semblent être un faciès fortement induré et silicifié de la division volcanique du sous-groupe de Bonanza.

Plusieurs failles principales, d'allure nord-ouest ou ouest-nord-ouest et délinéant quatre ou cinq (?) blocs faillés de dimension grande à moyenne, en discordance structurale, dominent la structure actuelle de la région à l'étude. Une multitude de failles, majeures et mineures, étroitement espacées et orientées dans différentes directions, recoupent tous les principaux blocs faillés. Les failles normales et horizontales de décrochement prédominent, tandis que les failles de chevauchement à fort pendage sont rares. A une exception près, toutes les failles observées recoupent au hasard toutes les roches mésozoïques, y compris celles du groupe de Nanaimo. Il ne semble cependant pas qu'elles aient dérangé les roches intrusives de Sooke (?) datant probablement du début de l'Oligocène. Ces failles datent vraisemblablement du début du Tertiaire plutôt que de la fin du Crétacé. Elles pourraient cependant être plus récentes puisque l'on sait que toutes les failles majeures de la côte occidentale de l'île Vancouver recoupent les couches du Tertiaire (Oligocène et début du Miocène).

Le style tectonique des blocs faillés qui prédomine dans la région à l'étude et dans d'autres régions de la zone Insulaire tectonique fut causé par un contrôle quelque peu singulier de leurs assises. La présence partout d'un «bouclier» épais et rigide de roches volcaniques du Karmutsen dut empêcher l'élaboration de plissements serrés ou renversés au cours de la fin du Trias et du début du Jurassique. Avant la fin du Jurassique moyen, ces «assises volcaniques» furent renforcées davantage par l'invasion d'une multitude d'intrusions côtières, petites et grandes, et par l'induration ou le métamorphisme résultant des sédiments et des roches volcaniques du groupe de Vancouver. Les «assises magmatiques» qui en résultèrent déterminèrent le style tectonique ultérieur dans la région à l'étude et d'autres parties de la zone Insulaire tectonique en cédant aux tensions imposées par tous les mouvements tectoniques du Jurassique post-moyen par la seule production de failles, à grande et petite échelle. Les sédiments relativement minces du Jurassique post-moyen furent protégés en majeure partie contre les efforts de compression et ne purent subir de plissements, même modestes, excepté au voisinage de failles majeures ou principales. La prédominance de ce style tectonique de blocs faillés semble inaccoutumée dans une région par ailleurs typiquement géosynclinale (=orthogéosynclinale ou eugéosynclinale). On commence cependant à reconnaître, ailleurs dans la zone orogénique circumpacifique, d'autres exemples d'un tel comportement tectonique.

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 the 1953 and 1954 seasons, and also includes results obtained from work done during a supplementary survey 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 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 used 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, 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 ½ inch=1 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.

Original MS. submitted: July 1971.
Final version approved for publication: October 1973.

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).

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, p. 102A–104A; 1931, 1932, p. 23A–25A; 1933, p. 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 unpubl.) 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

Table of Formations

System and Series	Time-rock units: Stage	Time-rock units: Regional Zone	Group and Formation	Lithology and thickness (feet)
TERTIARY	Unknown and probably absent			
TERTIARY	Lower Oligocene? or younger?		?Sooke Intrusions	Granite porphyry, diorite porphyry, and gabbro; minor rhyolite, dacite, andesite, and diabase
TERTIARY	Intrusive contact with Cretaceous strata			
TERTIARY	Unknown and probably absent			
UPPER CRETACEOUS	Unknown and probably absent			
UPPER CRETACEOUS	Early upper Campanian	*Baculites* cf. *chicoensis* *Pterotrigonia evansana*	Nanaimo Group (Cedar District equivalent)	Arkoses and arkosic sandstones; 280+
UPPER CRETACEOUS	Unknown and probably absent by nondeposition (a major period of orogeny[1])			
UPPER CRETACEOUS	Cenomanian and ?younger		Upper shale unit (= Upper shale of Dawson, 1887)	Siltstone, shale, and some fine-grained greywacke; minor pebble-conglomerate and 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+
LOWER CRETACEOUS	Aptian		Coal Harbour Group (new): Coarse arenite unit	Coarse to medium-grained, commonly 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 folding of the rocks which occurs beneath the unconformity in addition to their uplift and erosion. Batholithic intrusions of granitic rocks may or may not accompany an "orogeny."

Table of Formations (cont.)

Time-rock units: System and Series	Time-rock units: Stage	Time-rock units: Regional Zone	Group and Formation			Lithology and thickness (feet)
				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. — — ? — — *Eulytoceras* aff. *phestum*	Longarm Formation equivalents (unnamed group)	Barremian fine-grained greywacke unit	Barremian variegated clastic unit 200± to 1,000±	*See* text for details of lithology and thickness of individual units
	Lower Barremian ?and/or latest Hauterivian	*Shasticrioceras* cf. *poniente*		*Inoceramus colonicus* calcarenites		*See* text for details of lithology and thickness of individual units
	Hauterivian	*Simbirskites (Simbirskites) broadi* — — — — ? — — — — *Homolsomites oregonensis* — — — — ?		*West*: Hauterivian siltstone unit *East*: Upper Valanginian and (?) Hauterivian greywacke–conglomerate unit	Unknown and apparently completely absent because of non-deposition	*See* text for details of lithology and thickness of individual units
	Upper Valanginian	*Buchia crassicollis* s. str.		*Buchia crassicollis* greywacke ? Hiatus		

Table of Formations (cont.)

<table>
<tr><th colspan="3">Time-rock units</th><th colspan="3" rowspan="2">Group and Formation</th><th rowspan="2">Lithology and thickness (feet)</th></tr>
<tr><th>System and Series</th><th>Stage</th><th>Regional Zone</th></tr>
<tr><td>UPPER JURASSIC AND BASAL CRETACEOUS</td><td colspan="6">Unknown and probably totally absent by nondeposition (a major interval of erosion)</td></tr>
<tr><td rowspan="2">MIDDLE JURASSIC</td><td>?Bathonian</td><td></td><td colspan="3">Coast Intrusions</td><td>Quartz diorite, diorite and gabbro; various dacitic to ?andesitic minor hypabyssal intrusions</td></tr>
<tr><td colspan="6">Intrusive contact with rocks of Vancouver Group</td></tr>
<tr><td rowspan="6">LOWER JURASSIC</td><td>?Toarcian</td><td>?Grammoceras sp.
—?— — — —?— —</td><td rowspan="6">Vancouver Group</td><td rowspan="6">Volcanic division of Bonanza Subgroup</td><td colspan="2" rowspan="2">?Pliensbachian–?Toarcian greywacke unit
1,000+ (both contacts covered)</td></tr>
<tr><td rowspan="2">Pliensbachian</td><td>Fanninoceras sp.
—?— — — —?— —</td></tr>
<tr><td>Acanthopleuroceras sutherlandbrowni
—?— — — —?— —</td><td colspan="2">?Dark grey volcanic unit
Thickness uncertain</td></tr>
<tr><td rowspan="3">Sinemurian</td><td rowspan="3">Echioceras (Melanhippites) harbledownensis
— — — — — — —
— — — — — — —
Asteroceras aff. obtusum
— — — — — — —
— — — — — — —
Arnioceras (Arniotites) kwakiutlanus</td><td>Uppermost Sinemurian argillite unit</td><td>Dark grey, tuffaceous argillites; some fine- to medium-grained greywacke and calcareous grit; minor impure limestone; 150+</td></tr>
<tr><td>Uppermost Sinemurian volcanic unit</td><td>Various waterlain pyroclastics and amygdaloidal to porphyritic lava flows; 300 to 600+</td></tr>
<tr><td>Matthews Island Formation (new)</td><td>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+</td></tr>
</table>

—?——?—

Table of Formations (cont.)

Time-rock units: System and Series	Time-rock units: Stage	Time-rock units: Regional Zone	Group and Formation			Lithology and thickness (feet)
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+
LOWER JURASSIC	?Middle Hettangian		Vancouver Group	Volcanic division of Bonanza Subgroup	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 JURASSIC	?Lower Hettangian		Vancouver Group	Volcanic division of Bonanza Subgroup	Basal Jurassic volcanic unit	Predominantly red to maroon intermediate to ?acidic, commonly porphyritic, unsorted and poorly to nonstratified volcanic breccia and tuff; considerable similarly coloured, amygdaloidal to porphyritic, acidic? to basic? lavas; 5,000 to ?7,000
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 to 2,500 ±
UPPER TRIASSIC	?Rhaetian	Mostly (except in residual ?Rhaetian depositional troughs; *see* Fig. 5, *in pocket*) an unconformity and hiatus of variable magnitude (early Rhaetian orogeny)				
UPPER TRIASSIC	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

Table of Formations (conc.)

Time-rock units: System and Series	Stage	Regional Zone	Group and Formation: Group	Subgroup	Formation	Lithology and thickness (feet)
UPPER TRIASSIC	Upper Norian	Lower subzone of Suessi Zone	Vancouver Group	Sedimentary division of Bonanza Subgroup	*West* *East*	Black, mostly more or less tuffaceous and/or arenaceous argillite; minor impure limestone; 300+ (or? more west of Neroutsos Inlet)
	Middle Norian	Columbianus Zone			Thinly bedded member	Massive to indistinctly bedded, cryptocrystalline, often cherty limestone (predominantly in the lower part of unit); thinly to medium bedded, often cherty limestone (predominantly in the upper part of unit); minor chert, pyroclastic and calcareous argillite interbeds; 600 to 2,500+
		?				
		Rutherfordi Zone				
		? ?				
		Magnus Zone				
		? ?				
	Lower Norian	Dawsoni Zone			Quatsino Formation	
		Kerri Zone				
UPPER TRIASSIC AND (?) OLDER	Upper Karnian and(?) older	Macrolobatus 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

intensely faulted and sheared, more or less altered or metamorphosed, pre-batholithic 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, p. 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), is 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 (?)lavas 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, unpubl.), 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 northwestern 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, p. 3–4; Jeletzky and Tipper, 1968, p. 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 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 Klootchlimmis 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, p. 7–12; 1954a, p. 1269; 1970b, p. 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 on the islands of Queen Charlotte Strait (Jeletzky, 1970b, p. 3–4, Figs. 1, 2) where a different formational nomenclature must be used for its equivalents (e.g., Parson Bay Formation; *see* Fig. 5, *in pocket*). 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, the 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, p. 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, at least in part.

Dolmage (1919, p. 32B), the author of the formational name Quatsino Limestone, defined 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 a type section, nor has this been done by any later worker to 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 one of them as the type section of the formation. All these sections are incomplete with neither the base nor the top of the formation exposed; each is 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. IIB), 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 *Projuvavites* 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 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 is 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. IIA), 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 of even a rough estimate of the thickness 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

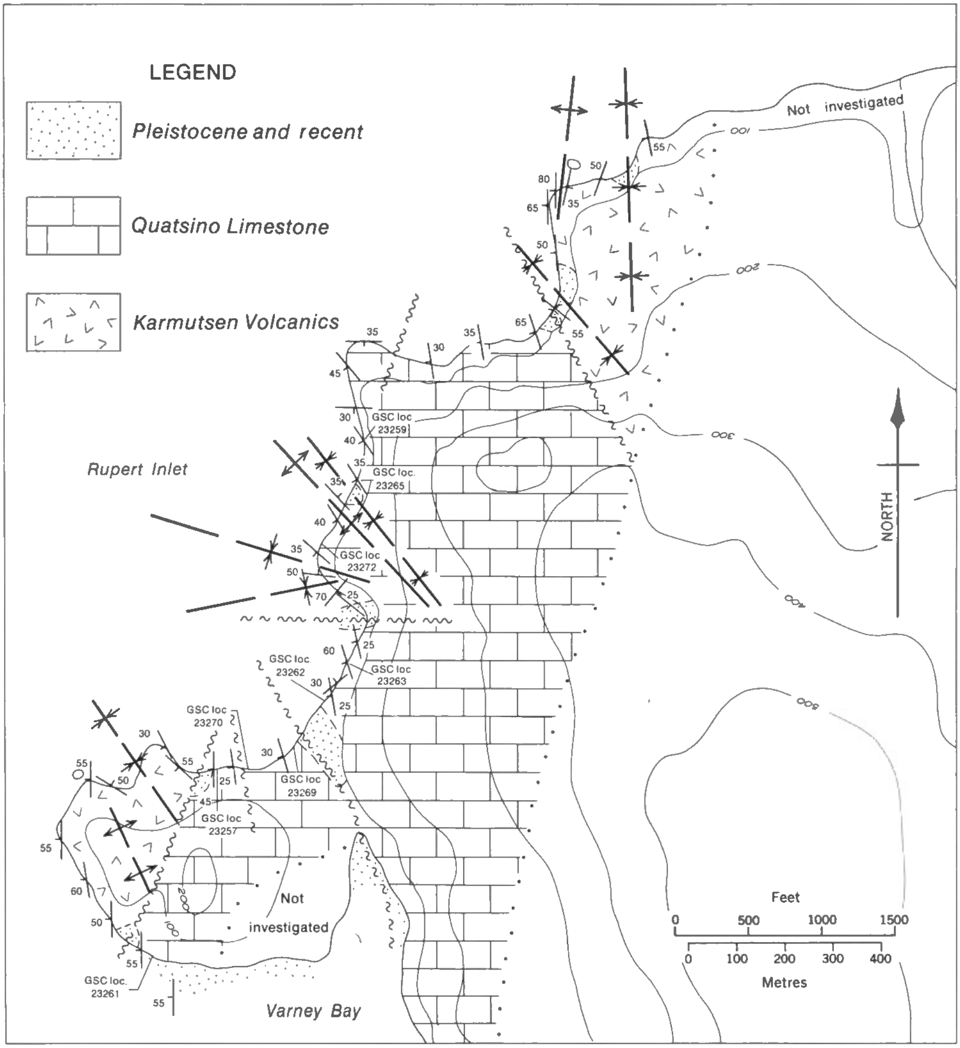


FIGURE 1. Sketch-map of Quatsino Limestone section at Kenny Point.

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, 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) the member 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 due to 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, despite 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, p. 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; cf. 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, p. 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, p. 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. Ammonites of the Dilleri Zone were discovered in the "Interlava Sediments" in the Campbell River area (Givens and Susuki, 1964; *see* Tozer, 1967, p. 82). This 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, calcareous argillites overlies 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, Appendix), a large number of such limestone beds persist to the very top of the

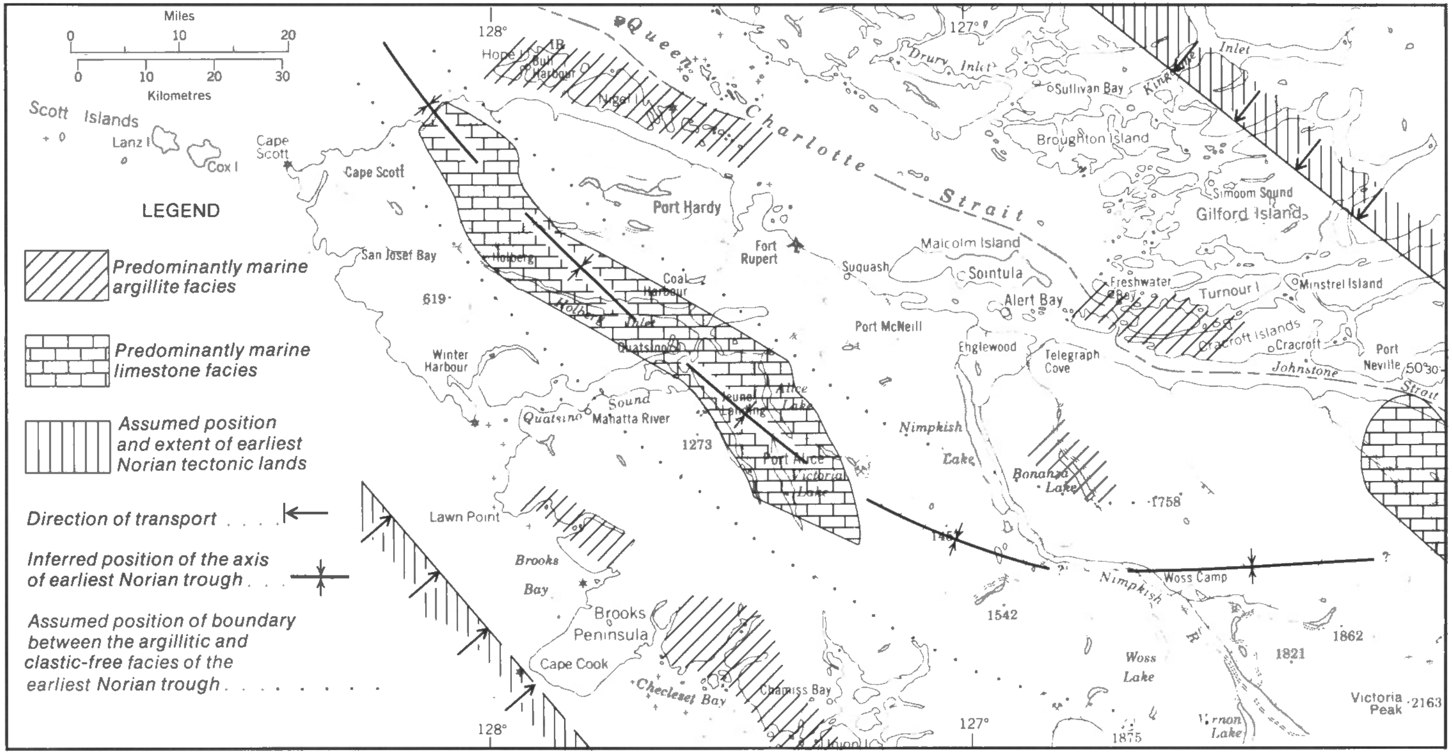


FIGURE 2. Basal Norian (Kerri Zone) facies and paleogeography of the Quatsino Sound area.

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 Atkins 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, Appendix).

No outcrops of the Thinly bedded member have been seen in the investigated parts of Rupert and Holberg inlets. The member either is missing due to faulting or does not outcrop 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 Atkins 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. 18 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, at least for this part of the unit. 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, p. 3–4, Fig. 1) in the Kyuquot–Esperanza area and elsewhere on the west coast of Vancouver Island (cf. p. 13–14, this report).

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, 1, 5, 6, and 7, are 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 8–15 of section 1. Only 127 feet of this unit is 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, 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* Fig. 17, *in pocket*). This unit did not yield any diagnostic fossils, and both 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* Units 4, 14, Sec. 1) of the Arenaceous and Argillite units of the Lippy Creek sections. Because of this and of the fact that it is 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 3–5 of section 1. Only 54 feet of this unit is actually exposed in this section. However, at least 80 feet of this unit is 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. Lithologically, this waterlain volcanic tuff is similar to the more fine grained facies of the overlying Hecate Cove Formation in Julian Cove (*see* p. 30) and on the west coast of Vancouver Island

(Jeletzky, 1950, p. 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 mylonitized, 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, 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, p. 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, p. 79–80), which appears to lack completely all 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, 1950, p. 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, 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 (pers. com., E. T. Tozer, April 10, 1970). The Arenaceous member is disconformably and apparently discordantly overlain by pyroclastic rocks of the Hecate Cove 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 the 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. Because of this and of the similar stratigraphic position of all units concerned, the Arenaceous member of eastern Quatsino Sound is considered 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, p. 9–11), and with the Lower limestone member of the Sutton Formation of the Buchholz Channel area. 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 applies to 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, or in any of the sections studied farther northeast at the headwaters of Lippy Creek. Its absence 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 nondeposition of the Upper limestone member there due to the effects of the early Rhaetian orogenic phase (*see* below).

The 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, 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* Fig. 17). All sections studied are intensely faulted, crumpled, commonly contorted, and invariably invaded 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. These intensely disturbed beds exhibit the following general sequence 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. It 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 nondiagnostic 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* Unit 6, Sec. 3).

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 of 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 the 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. In all sections studied, the base of the unit is covered or cut off by faults.

Age and correlation. Paracochloceras sp. indet. occurring in the Upper limestone member (GSC loc. 24333) indicates an Upper Suessi age (Tozer, 1967, p. 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 an apparently Late Triassic fauna (i.e., ?Rhaetian) in the topmost beds of the overlying Hecate Cove Formation (*see* p. 33–34) 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 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, p. 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, p. 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, p. 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, p. 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. 31), suggest the nondeposition (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 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 unit 3 of section 2. The eastern facies contains a much greater ratio of black, extremely calcareous argillites than does the Arenaceous member and many interbeds of various limestones which are absent in the latter unit. At the same time it is a more argillaceous and arenaceous unit than the equivalent unit 3 of the Banter Point section (*see* Sec. 2, 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 on 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 also occur 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* Unit 6, Sec. 3 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, 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.

Although it is 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 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. 24) 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 southeastward, at least to the eastern side of Alice Lake (Fig. 3). The apparent prevalence of dark grey, impure limestones of the 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

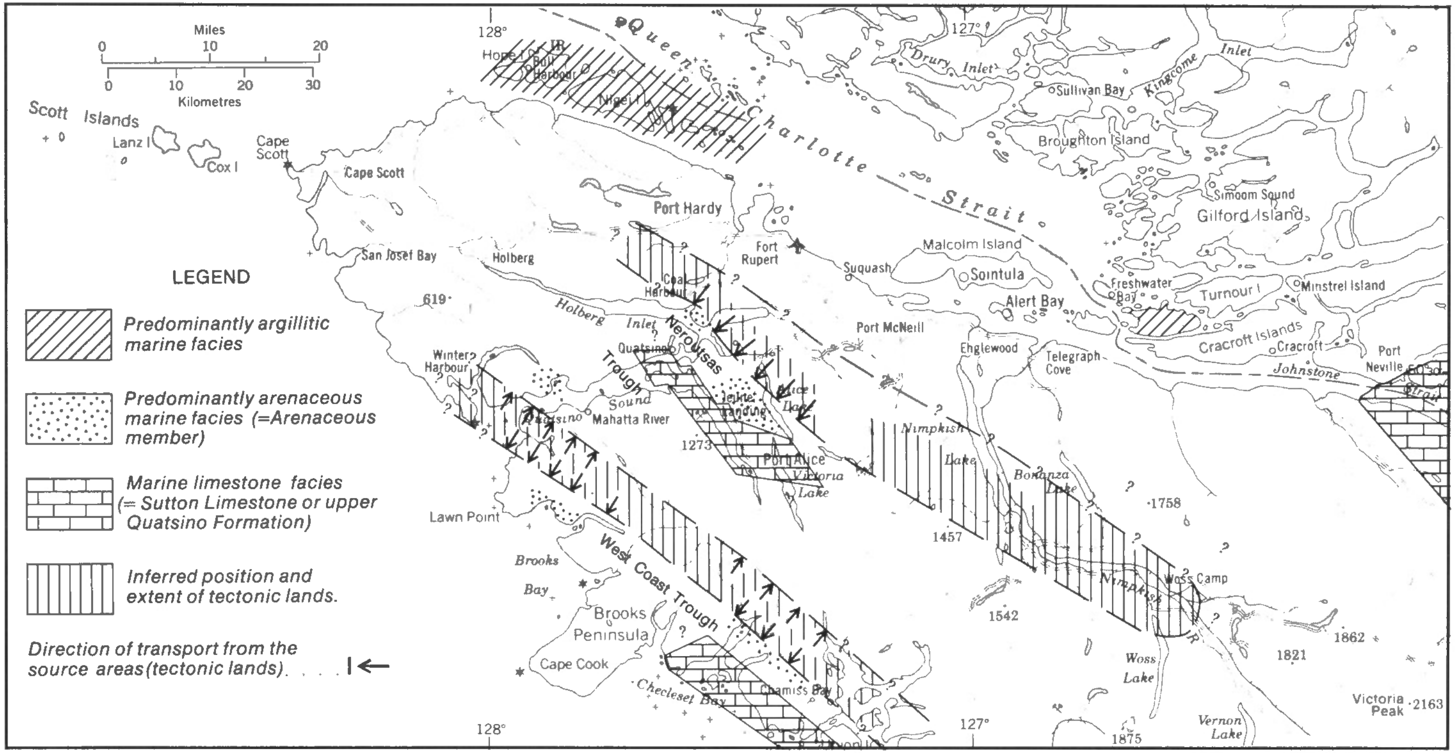


FIGURE 3. Late upper Norian (upper Suessi time) facies and paleogeography of the Quatsino Sound area.

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. 34) 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 northeastward 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 the Suessi Zone (*see* p. 22 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* Fig. 18, *in pocket*). Therefore, the eastern (or Smith Cove) and western (or Banter Point) facies of the 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, 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 the 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 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, p. 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, p. 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, and it was not 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–Mabbott Island–a point west of O'Connell Lake–headwaters of Klaskish River–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 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, p. 9–11; 1970b, p. 7–8; and unpubl.) 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 northeastward 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–Queen Cove in Esperanza Inlet.

Southeast of 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 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, porphyritic 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 Subgroup 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 the entrance to Quatsino Sound is almost certainly incomplete in the upper part, since it is overlapped unconformably by the Lower Cretaceous rocks (pers. com., J. E. Muller, 1969)[1].

---

[1] Since this was written Muller, Northcote, and Carlisle (GSC Paper 74-8, p. 22-23) have published a detailed description of this fossiliferous section. The description permits a confident correlation of individual units of the section with the following units of the Volcanic division of the report-area (descending order):

1. Units 12 and 11 correspond to the lower part of the Uppermost Sinemurian volcanic unit.
2. Unit 10 is a reduced, littoral to ?supratidal equivalent of the western facies of the Upper member of Matthews Island Formation. Lithologically it closely resembles some very coarse grained exposures of the member in Browning and Forward inlets.
3. Units 9–4 are an extremely strongly thickened, largely volcanic equivalent of the Intermediate waterlain tuff member of Matthews Island Formation.
4. Unit 3 is a shallow water (?upper littoral) equivalent of the Lower member of Matthews Island Formation.
5. Units 2 and 1 may possibly correspond to the upper part of the Grey volcanic unit. However, as already pointed out by Muller, Northcote, and Carlisle (ibid., p. 23), these units may be equivalents of units 12 and 11 of the section repeated by faulting.

The section does not include any equivalents of the Uppermost Sinemurian argillite unit, the Dark-grey volcanic unit, and the Pliensbachian–?Toarcian greywacke unit of other parts of northwestern Vancouver Island, nor does it include any equivalents of the Hecate Cove Formation and Basal Jurassic volcanic unit of the report-area. The first three units are presumably eroded away in the Cape Parkins area, while the last two units should be situated well beneath sea level in this structurally depressed area of northwestern Vancouver Island.

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 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 north-eastern corner of Rupert Inlet, and in the mouth of Waukwass Creek in its south-eastern corner.

In that part of the report-area west of Quatsino village, the predominantly andesitic to dacitic, grey, lavender, or maroon 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.

Despite 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, p. 17–19, Figs. 1, 2; this paper, Fig. 5), no sedimentary interbeds were observed in the division east of Quatsino 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* Figs. 17, 18). This task, however, was difficult because of the 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, p. 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, 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 psephitic), 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 characteristic 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 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 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 lithologically distinctive and stratigraphically valuable in other parts of the tectonically and volcanically active zone of the Insular Tectonic Belt (Jeletzky, 1970b, p. 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, p. 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, p. 3–5, Figs. 1, 2; and preceding pages of this report), and the writer sees no reason 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 volcanics 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 the report-area, the Hecate Cove Formation is widespread on the west coast of Vancouver Island, on Cowichan Lake (unpubl. pers. observations), and between Esperanza and Klaskino inlets (Jeletzky, 1950, p. 12–13; 1970b, p. 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, p. 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 rust- 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-sized 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 interbeds of dark green porphyritic lava with rust to pink phenocrysts of ?sodic plagioclase. The breccia fragments and pebbles are mainly 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, Sec. 4).

The adjacent, apparently continuous section 3 (*see* Appendix) represents a lithologically different facies of the lower part of the 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 a 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 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, p. 12–15; and unpubl.). The dips of foreset 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, 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. The rocks strike at 345 degrees and dip westward at 60 degrees 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 do 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 the 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, 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, despite the fact that its basal beds (corresponding to Units 1–3, 5 of Sec. 3, to Unit 1 of Sec. 2, and to Units 4–6 of Sec. 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 the order of 2,500 feet.

The only section (*see* Sec. 5, 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 suggest 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 Cove Formation. At the headwaters of Yogtook Creek, east of Victoria Lake, similar basic lavas have been seen at the base of the formation in the section of the third facies measured by J. E. Muller and visited by the writer in 1969. Such lavas are absent at the same level in section 7, in close proximity to sections 1 and 6.

What appears to be another outcrop-area of the third facies of Hecate Cove 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 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* Fig. 17).

Origin and environmental significance of some peculiar rock types. The Hecate Cove Formation includes a number of 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, p. 12–13). The volcanic breccia was subsequently renamed the "agglomeratic" 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., 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 were 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 (= "agglomeratic" 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 adjacent parts of the sea floor at that time. This explanation appears to be entirely satisfactory to the writer insofar as 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 the 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, were 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. In 1968, an abundant but indifferently preserved, probable Upper Triassic marine fauna was found 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 pectinids 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, p. 8–9; and earlier in this report), and the occurrence of the probable 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 the 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, p. 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, p. 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, p. 5–9, Figs. 1, 2).

Despite 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 characteristic of the partly flysch-like, preorogenic 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, p. 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 (cf. 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, p. 5–7, Figs. 1, 2).

The northwest-trending Neroutsos Trough continued to exist. Its eastern and western limits are believed to be roughly defined by 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) either is 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, 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 conglomerate and tuffaceous facies of the Arenaceous member. Equivalents of the Sutton Formation appear to be absent by nondeposition, 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, p. 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 by the northeastward facies changes of the Hecate Cove Formation in the Esperanza–Ououkinsh inlets segment of the west

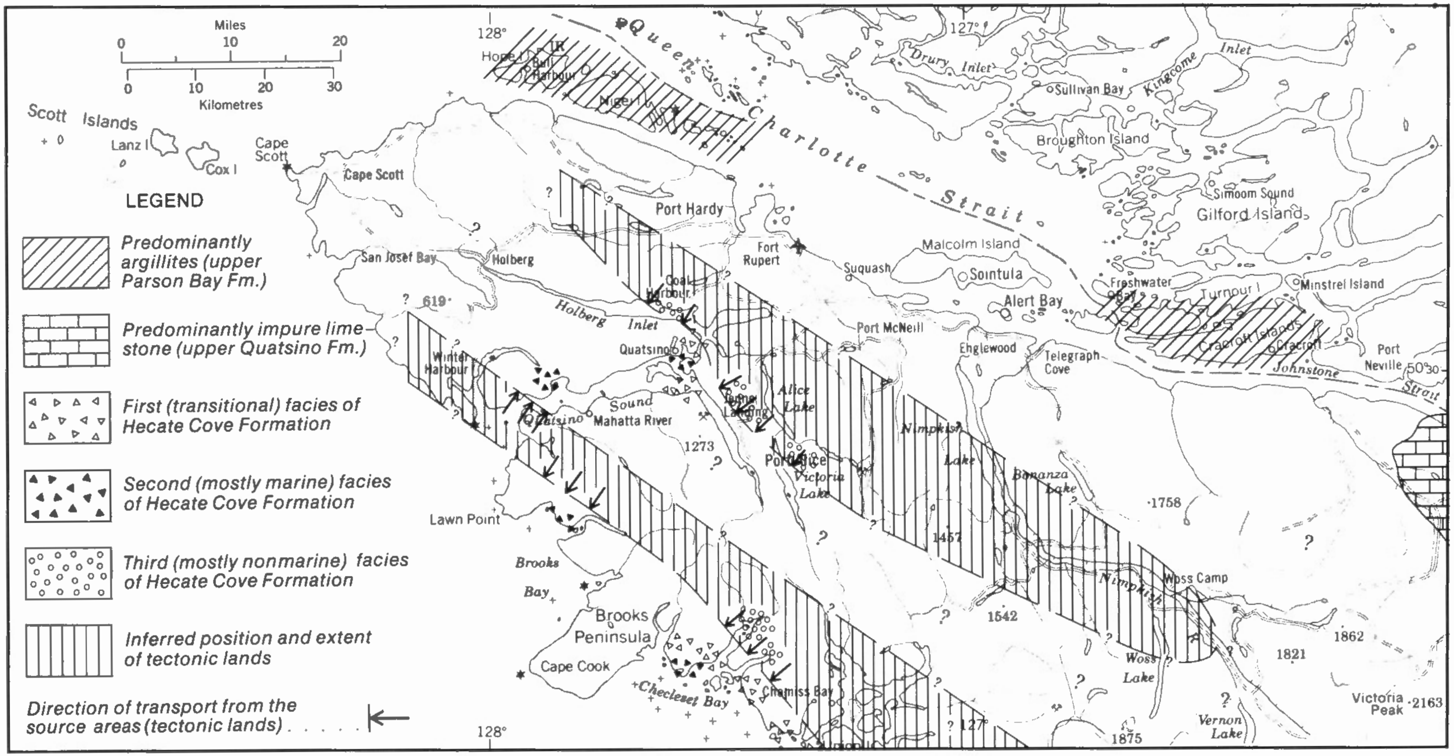


FIGURE 4. Latest Triassic (?Rhaetian) facies and paleogeography of the Quatsino Sound area.

coast described by Jeletzky (1970b, p. 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 believe 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 basinward 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* p. 29, 31), 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 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 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* p. 34–35).

The effects of the latest Triassic orogenic movements were felt strongly across the whole width of Neroutsos Trough. This is indicated by the ubiquitous, abrupt, or 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, *in pocket*). 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, p. 56, 59) or by black carbonaceous limestone of the upper Quatsino Formation with interbeds of tuffaceous argillite (Sutherland-Brown, 1966, p. 98, Fig. 6–11; 1968, p. 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, Fig. 6–11; Surdam, 1968, p. 20, Fig. 6).

Crickmay (1928, p. 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 areal extent 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. 39) pyroclastic rocks and lavas, which appears 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 the 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, 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, p. 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 Klootchlimmis and Kewquodie creeks on the southern shore of Quatsino Sound).

Pyroclastic rocks are characteristically unsorted to poorly sorted. Generally, 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 the Basal Jurassic volcanic unit seen by the writer.

About 600 feet of pyroclastic rocks and lavas, lithologically identical with those of section 8, outcrops 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, commonly more or less metamorphosed and strongly sheared, reappear 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 the southeastern corner of Rupert Inlet. The completely covered southern shore of the inlet is believed to be underlain by the Basal Jurassic volcanic unit for about 3 miles westward to the inferred position of the trace of Holberg fault (*see* Fig. 17). All these exposures are referred to the lower part of the Basal Jurassic volcanic unit.

A thin, 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, Sec. 29; Pl. VB) 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 Klootchlimmis 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, 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 Creek. 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. Because of this and 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.

Most of that part of the shoreline west of Brockton Island, about 1 mile long, was not traversed. 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 a 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, 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, Sec. 9) and on the easternmost tip of the latter (*see* Units 20, 21, 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, 3, Sec. 9 and Beds 17–19, 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, Sec. 9) and by the lithologically similar but thinner section exposed on the eastern tip of the largest Koskimo Islet (*see* Units 17–19, 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 units 4–6 of section 9, 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, 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 is 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 this section (*see* Secs. 9, 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 previously explained, 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, 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 the Grey volcanic unit. This sequence is believed to fill in 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 this 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 11–13 of the Koskimo Islets section 10. Neither the top nor the 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 lithologically similar 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 it 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. Despite 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 Creek (Pl. IVB), 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 westward toward 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* Fig. 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, 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, outcrops 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. IVB), are exposed in the banks of Mahatta Creek for some 500 yards upstream from its mouth (i.e., to the first waterfall). Neither the top nor the bottom of these rocks is exposed, but they seem to be referable to the lower part of the Grey volcanic unit.

The top of the above-mentioned rocks was not observed; however, because of the prevalent attitude and localization (*see* Figs. 17, 18), they are believed to grade upward 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. The latter rocks consist of as much as 1,000 feet of predominantly light grey to bluish grey, most 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, Appendix). However, in some other sections, such as that measured on the eastern side of Matthews Island (*see* Units 3, 4, 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 lithologically distinguishable from all other volcanic units of the Volcanic division described in this report due to the predominance of light grey to bluish grey, amygdaloidal, felsitic, 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 represents 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, much less 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. 48, Fig. 5), and overlies apparently conformably and gradationally (*see* Sec. 11) the probable Hettangian Cherty limestone unit. It could, therefore, be either of ?upper Hettangian or of basal Sinemurian (i.e., *Arietites bucklandi* zone; Frebold, 1951, p. 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 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 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 being 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-sized, northwest-trending, northwest-plunging folds (*see* Fig. 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 ½ mile east of an unnamed rocky point opposite the eastern end of Salmon Islands, and also in the bed of Monkey Creek between about ¾ and ⅞ mile above its mouth.

In 1968, an apparently isolated, intensely disturbed but generally anticlinally folded outcrop-area of the Matthews Island Formation was first discovered by J. E. Muller 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 Harbour. 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, 11, Sec. 16) suggests that the Intermediate waterlain tuff member of the more westerly sections (*see* Secs. 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 13–21) 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 three members, in ascending order:

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.

The lithology and thickness of these three members of the Matthews Island Formation change drastically eastward from the 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 thicken eastward (*see* below) and appear to lose all the conglomeratic and waterlain volcanic breccia interbeds and most of the waterlain volcanic tuff interbeds in this direction (*see* Unit 4, Sec. 15; Units 3–7, 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 $\frac{3}{4}$ 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 to 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 in 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 argillite 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 as compared with its typical development in the type section of the formation. Units 14–17 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 compared with 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, 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 13–21, 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.

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 suggest 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 so, 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. For a long time the formation was believed to be of Triassic 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, p. 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, p. 5–6). All the better preserved ammonites collected by the writer in the Lower argillite member of the formation have been determined recently by Dr. Hans Frebold (unpubl. intradepartmental fossil reports, 1968; pers. com., 1969) as *Arniotites kwakiutlanus* Crickmay, *Arniotites* sp. indet., *Arnioceras* sensu lato sp. indet., or *?Arnioceras* sp. indet. (*see* Bed 15, Sec. 14; Unit 11, Sec. 16; Unit 2, Sec. 17). The *Arniotites* (or *Arnioceras*) fauna is diagnostic of the late early Sinemurian *Arnioceras semicostatum* zone of International Standard (Frebold, 1951, p. 13–14; Arkell, 1956, p. 37). The basal Sinemurian *Arietites bucklandi* zone is not represented by fossils in the 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, Sec. 16).

All the better preserved 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, Sec. 16; Unit 4, Sec. 15; and GSC loc. 24303, ¾ mile up Monkey Creek). According to Frebold, the *Echioceras* (*Melanhippites*) *harbledownensis* fauna corresponds to the uppermost Sinemurian *Echioceras raricostatum* zone of International Standard (cf. Arkell, 1956, p. 37).

J. E. Muller's fossil collections from the outcrops of Matthews Island Formation outside of this report-area (GSC loc. 82892; identification by Dr. Hans Frebold in an unpubl. 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 *Crucilobiceras* spp. fauna in the overlying Uppermost Sinemurian argillite unit (*see* the following 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, 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, 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 almost 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, they permit the dating of waterlain pyroclastic rocks, sedimentary (especially limestone breccia) and mixed waterlain breccias of the Waterlain tuff and ?Basal variegated members which 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.,* 1964; Sutherland-Brown, 1966, p. 98, Fig. 6–11; 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 the Parson Bay area (Crickmay, 1928, p. 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, the Matthews Island Formation is correlative with the Sinemurian part of the Harbledown Formation (formerly upper member of Kunga Formation; *see* Jeletzky, 1970b, Footnote, p. 2) of Queen Charlotte Islands. The Harbledown Formation of Queen Charlotte Islands also has yielded *Arniotites* and *Echioceras* (*Melanhippites*) faunas (Sutherland-Brown, 1966, p. 84, 98, Fig. 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 identified latest Sinemurian ammonites in the early Pliensbachian argillite unit(*see* p. 54–55).

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, 14). It also outcrops on the western side of Nordstrom Cove (*see* Units 1, 2, Sec. 15), on the southern shore of Quatsino Sound east of Mahatta logging camp (*see* Units 1, 2, 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) close 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 mostly 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 coarse-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 Sinemurian volcanic unit (*see* Units 1, 2, 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 the 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 the exposed units differ from their equivalents farther east by being considerably thicker. The breccia fragments and psephitic clasts of the Lower waterlain pyroclastic unit of section 14 are, furthermore, invariably much coarser than are 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 Forward and Browning inlets.

The Upper waterlain pyroclastic unit 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 Matthews Island (*see* Units 1–7, Sec. 14), and only about 400 feet thick in sections 16 and 18 east of the Mahatta logging camp (*see* also Footnotes, p. 26 and 62), 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 the 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 suggest 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-southeast-trending welt situated immediately west of the area now occupied by 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 in the latest 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 the following 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 do 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 the 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 late Sinemurian or early Pliensbachian age. At that time the writer chose 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.

Distribution. The Uppermost Sinemurian argillite unit is exposed only in scattered, greatly disturbed, 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 $\frac{1}{3}$ mile east of Mahatta logging camp, and in the bed of Monkey Creek in the interval between $\frac{1}{2}$ and $\frac{3}{5}$ 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.

The basal 27 feet (and possibly as much as 42 feet) of the Uppermost Sinemurian argillite unit is 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.

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 degrees east (overturned?) are unconformably overlapped by the upper Valanginian *Buchia crassicollis* greywacke which conceals their stratigraphic base. The stratigraphic 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 1½ 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* Fig. 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 suggested 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, 24308) were found a few feet stratigraphically lower in the section. The discovery of these fossils prompted a tentative assignment, in a preliminary report (Jeletzky, 1970b, p. 13, Fig. 1), of the Uppermost Sinemurian argillite unit to the early Pliensbachian stage.

Subsequent collecting of 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 road-cut at old log-dump, Mahatta Creek. 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-

ing 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. 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 Kyuquot–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. 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, 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. These lavas appear to overlie outcrops of the ?Uppermost Sinemurian argillite unit on the northwestern side of the lagoon.

Age and correlation. In the Kyuquot–Esperanza 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 outcrops 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 to 200 feet of the unit is 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 (½- 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 lithologically similar 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, p. 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 suggest that they form part of the Volcanic division of the Bonanza Subgroup. The upper Valanginian *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, as 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°. 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, p. 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 it 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, p. 72B–74B; Surdam *et al.*, 1964, p. 226; Surdam, 1968, p. 20, Fig. 6; Sutherland-Brown, 1966, 1968; Jeletzky, 1970b, p. 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, Footnote 1, p. 2) and Maude formations 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 (unpubl. fossil reports; pers. com., 1968), the type Harbledown Formation contains the same Sinemurian ammonite faunas as does 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, p. 55, 56; Tozer, 1967, p. 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, p. 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. sutherland-browni* Frebold has been identified by Dr. Hans Frebold (unpubl. 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, Footnote 1, p. 2), 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 psephitic 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, p. 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 that they are 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 dust 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" despite 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.
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* 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, p. 11–16, Figs. 1, 2; and 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; cf. 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 one another 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.
4. Dark grey volcanic unit–Pliensbachian–?Toarcian greywacke unit.

Judging 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 the phase ended (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, p. 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 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, p. 8, 9; and previous sections of this report) must have been essentially bevelled before 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 (*see* previous sections of this report).

The predominantly fine grained, calcareous rocks of the ?Hettangian Cherty limestone unit in all its known sections suggest that the sea which 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, suggest 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 Matthews Island Formation 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 it was situated just off the west coast and extended at least from Cape Scott to Esperanza Inlet.[1]

The Sinemurian western source area apparently remained active in latest Sinemurian time, judging 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 Quatsino Sound area itself probably mostly remained 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.

---

[1] Since this was written this interpretation of facies and source area of the Sinemurian rocks was confirmed by the publication of a complete, well-exposed section of Matthews Island Formation measured by Muller (1970) at Cape Parkins, west coast of Vancouver Island (*see* Muller, Northcote, and Carlisle, GSC Paper 74-8, p. 22, 23). An exceptionally great thickness and a predominantly volcanic facies of the formation in this southwesternmost section is combined with largely coarse grained, shallow water to ?nonmarine facies of the sedimentary intercalations (*see* Muller, Northcote, and Carlisle, GSC Paper 74-8, p. 22, 23; this report, Footnote, p. 26). The section must have been situated immediately east of the Sinemurian western source area (a volcanically active cordillera-like welt or a volcanic archipelago) inferred by the writer.

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, at least in these parts of the zone. The coarse, nearshore 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 nonorogenic 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 as it obscures 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-sized 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). 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 (cf. Harper, 1967; Hutchinson, 1970).

This report is concerned primarily with the stratigraphic and structural relationships of the 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 the 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, at least within ancient orogenic belts.

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 macroscopic 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 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, p. 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 Creek and near the Yreka Copper mine, and a true diorite body at Old Sport mine. Gunning (1930, p. 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; unpubl.) and Zeballos–Nimpkish map-area (Hoadley, 1953). Most of the Quatsino Sound intrusives are, furthermore, sills, dykes, and irregularly shaped minor bodies, whose thickness fluctuates from a few inches to about 100 feet. It is, therefore, impossible either to show all these minor Coast Intrusions on the geological maps and profiles or to discuss all of them in the text. 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 1⅓ miles. In most cases, the maximum observed width of the larger Coast Intrusions of the report-area fluctuates between 100 feet and ½ 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, Sec. 21).

3. An intrusive body, about $\frac{3}{4}$ 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 porphyritic. 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. 73).

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 $\frac{2}{5}$ 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 ⅜ mile east of Salmon Islands (*see* Unit 12, Sec. 16).

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, 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 may be black, maroon, or rose-grey. Their textures vary 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 are usually restricted to its marginal parts and the porphyritic texture is 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 Intrusions of the western and northwestern parts of Quatsino Sound suggest that they are largely or even exclusively shallow-seated to hypabyssal apophyses and cupolas of the larger, possibly batholithic 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, 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 outline and lithology of this body shown in 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, p. 106A–107A) occurring east of Holberg Inlet, and inside Neroutsos Inlet. According to Gunning's (1930. p. 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, p. 99A, 106A; Bancroft, 1937, p. 4, 8); a Late Jurassic or Early Cretaceous age (Gunning, 1932, p. 23A); a Late Jurassic or Cretaceous age (Jeletzky, 1950, p. 36–38); a Late Jurassic and/or Early Cretaceous age (Hoadley, 1953, p. 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, p. 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 this report). However, the writer has found granitic, dioritic, and gabbroic pebbles of the Coast Intrusion 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, Sec. 21, Appendix) and one ?dacitic body at the head of Browning Inlet (*see* p. 73). 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. The Coast Intrusions are definitely post-Sinemurian, 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 Kyuquot–Esperanza area on the west coast of Vancouver Island, the writer (Jeletzky, unpubl.) 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 almost 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, p. 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 the conclusions of Beveridge and Folinsbee (1956, p. 20). 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 on the west coast of Vancouver Island in the proximity of Kennedy Lake (Sutherland-Brown, 1966, p. 85, 97, Fig. 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 before the end of deposition of the Vancouver Group. Also, there are no definite indications of the post-Middle Jurassic Mesozoic intrusions within the investigated part of Quatsino Sound, as 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, unpubl.), 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 pyroclastics and, to a lesser extent, by arenaceous to psephitic clastics of the Bajocian lower Yakoun Formation (Sutherland-Brown, 1968, p. 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 lithological 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* p. 57–58), 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 deposition 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, p. 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, p. 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 the 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, p. 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, p. 74–77, Fig. 7). These residual Late Jurassic marine troughs formed part of the late Mesozoic phase of the 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, p. 23–25; and Coast Intrusions, 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 Earliest 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 the 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 pene-contemporaneous invasion of the Coast Intrusions (Jeletzky, 1970b, p. 23–25; and 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 west and northwest of it (Jeletzky, 1965b, p. 72; 1970b, p. 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, p. 83B–99B) because of the reported occurrence of coal measures in some of their outliers. The results of this pioneer work were of great value to the writer because Dawson located all 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 stratigraphic 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 geol. map) appears to be improbable on structural grounds and, therefore, is not shown on the geological map.

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 inlet with the head of Spencer Cove, and the eastern shore of the cove. 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 Islands 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 a mile west of the mouth of Klootchlimmis Creek and that about ½ 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 2¼ 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 of this fault (Dawson, 1887, p. 91B, Fig. 2) or are limited by other major faults (e.g., 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, p. 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 a 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 the 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 Lake 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. 65).

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 corresponds 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 4–8 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 6–8 of the Forward Inlet section could, therefore, be concealed within this covered interval.

So far as is known, the *Buchia crassicollis* greywacke outcrops encountered in the bed of Kwatleo Creek represént the same basal part of the unit as do 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, 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, p. 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, p. 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, p. 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, p. 38–44, geol. map; 1965a, p. 64–65, Fig. 4), is probably due to their nondeposition 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 (unpubl. 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, p. 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 Islands (*see* below and Fig. 7). It is concluded, accordingly, that the late Valanginian transgression did not penetrate eastward beyond the line defined approximately by Fisherman Bay–headwaters of Macjack River–Ahwhichaolto Inlet–Salmon Islands.

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 Kyuquot–Esperanza area. This circumstance and the apparently complete absence of late Valanginian rocks in the Kyuquot–Esperanza area (Jeletzky, 1965a, p. 64–66, Fig. 4) suggest 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, p. 23–25) and was situated updip of its Callovian to mid-Valanginian deposition-area. The alternative hypothesis of a total subsequent (i.e., before 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

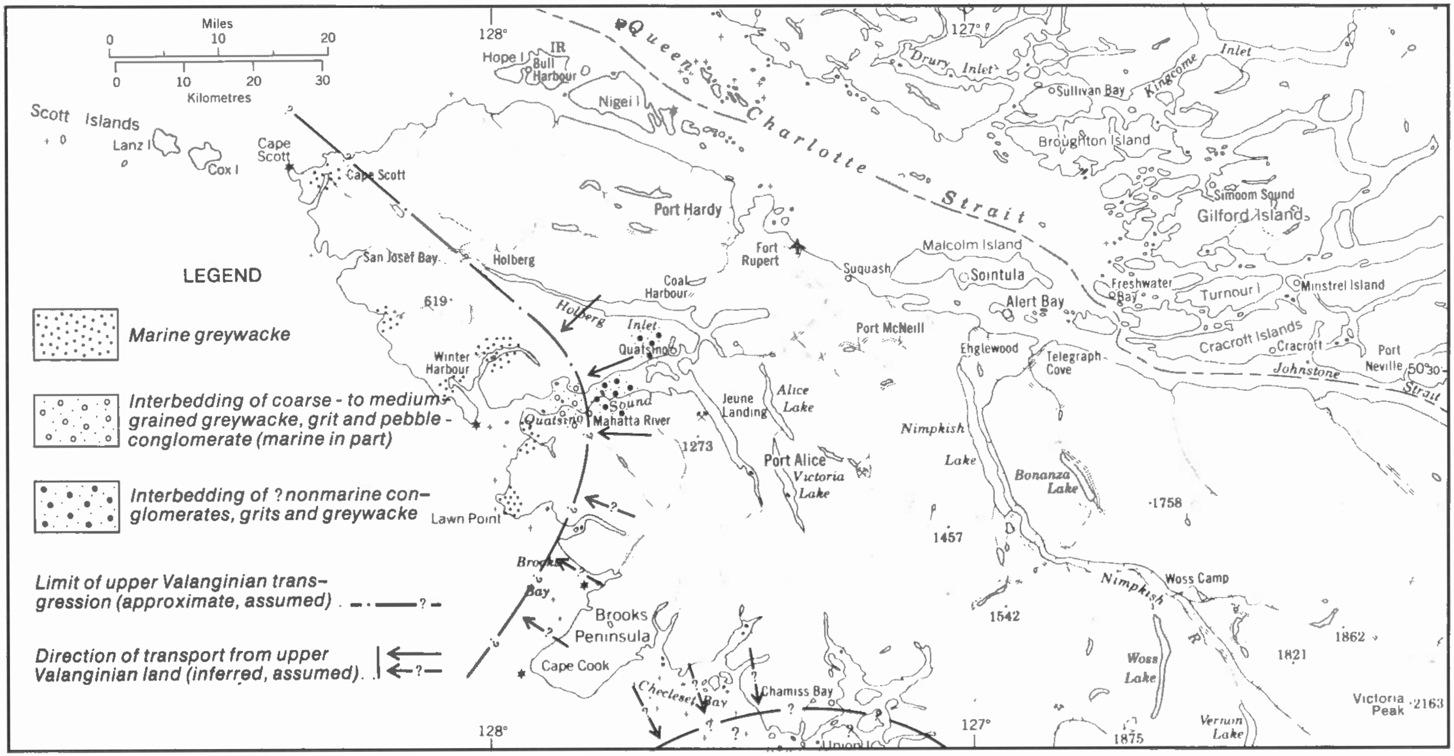


FIGURE 7. Upper Valanginian (*Buchia crassicollis* time) facies and paleogeography of the Quatsino Sound area.

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 Kyuquot–Esperanza embayment continued to exist in late Valanginian (i.e., *Buchia crassicollis*) time, it would have been separated from the contemporary Cape Scott–Quatsino Sound embayment by an extensive landmass centred in the positive fault block of Brooks Peninsula. The recent suggestion of a northeastern onlap of the early Cretaceous sea of Quatsino Sound (Muller, 1970, 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, 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 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, 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 the writer (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)[1] 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 (upper part only); 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; 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. The 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*

[1] Figured in Jeletzky, 1970d, Pl. XXIV, Fig. 6.

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, p. 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, p. 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 p. 84–85), 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 reflect 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 literally into the upper part of the largely nonmarine Upper Valanginian and ?Hauterivian greywacke–conglomerate unit somewhere between Forward Inlet and Salmon Islands. 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 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 Islands. Therefore, there is no reason to assume that the Cape Scott–Quatsino Sound embayment extended 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 Kyuquot–Esperanza low Lower Cretaceous outcrop-area (Jeletzky, 1950; 1954a; 1965a) reflects their nondeposition rather than subsequent erosion there.

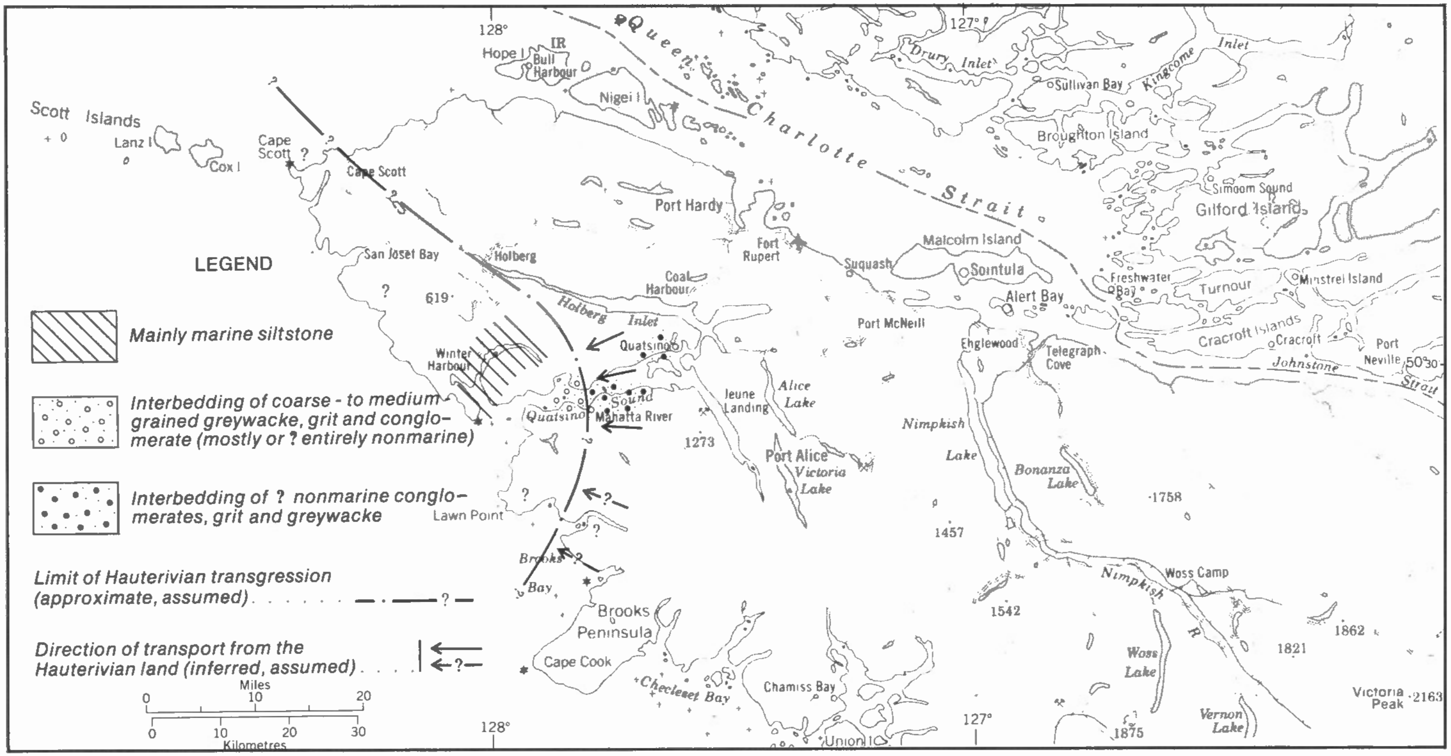


FIGURE 8. Hauterivian facies and paleogeography of the Quatsino Sound area.

Upper Valanginian 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 Islands; *see* Secs. 25, 26) sections. It is named accordingly the Upper Valanginian and ?Hauterivian greywacke–conglomerate unit.

Despite 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, Sec. 8), and on the southern shore of the sound, 1 mile west of the mouth of Klootchlimmis 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 Klootchlimmis 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, Appendix). Furthermore, numerous interbeds of the presumably marine black to grey siltstone and shale appear in the basal parts of these sections.

Although it is 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 eastern and? south-eastern source area. This westward change of facies of the unit is even better illustrated by other much more extensive sections (*see* Secs. 25, 26, Appendix) occurring about 3 miles farther west on Salmon Islands.

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 12–17, Sec. 26) was measured on the same island 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 Islands. 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 Islands 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, despite 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 Islands sections before the deposition of the *I. colonicus* calcarenites. The probable restriction of the upper Valanginian marine interbeds to the lower part of the Salmon Islands 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 Islands 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 the Salmon Islands 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 Islands 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, 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 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 Creek and Klootchlimmis Creek sections (*see* Secs. 8, 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, p. 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 Klootchlimmis Creek sections of this unit occur in any of the sections and borehole logs cited by

Dawson (1887, p. 90B–99B); (2) The presumably Barremian *Quoiecchia aliciae* fauna discussed later in this report occurs closely above the base of the Lower Cretaceous sequence in the Nuknimish Creek section (*see* below) and elsewhere in the vicinity of Apple Bay (Dawson, 1887, p. 94; J. E. Muller's unpubl. 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, Sec. 29); (5) The sections measured on the eastern side of Christensen Point Cretaceous outlier (Jeletzky, 1969, p. 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 Creek and Klootchlimmis Creek sections of the predominantly conglomerate 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 Islands, 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[1] which occurs throughout the thickness of the unit, commonly 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 Islands, 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,

[1] Figured by Jeletzky, 1970d, Pl. XXIV, Fig. 2.

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 Islands sections. None of these sections exposes the complete succession of the unit, but the combination of sections 26 and 27 (*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 units 6–11 of the latter section do not occur in section 27 and that the total thickness of *Inoceramus colonicus* calcarenites on Salmon Islands 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, Sec. 22) do not differ in their lithology from the Salmon Islands 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 the limestone member, which is underlain (seemingly conformably) by 2 to 3 feet of 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. *Inoceramus colonicus* calcarenites are mainly jointed and sheared and, locally, completely crushed and contorted. Their general strike varies from north 30 degrees west to north–south, and dips vary from more or less vertical to 25 degrees 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). Because of this and 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* (*Simbirskites*) cf. *broadi* zone of Taseko Lakes map-area (Jeletzky and Tipper, 1968) or the approximately contemporary *Hertleinites aguila* zone of northern California (Imlay, 1960, p. 180–181) as:

1. In Winter Harbour the *Inoceramus colonicus* calcarenites appear to overlie late Hauterivian siltstone containing *Simbirskites* (*Simbirskites*) *broadi* (*see* Units 1, 3, 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 Islands sections (*see* Unit 7, Sec. 27). The genus *Shasticrioceras* is not known to range below the uppermost Hauterivian *Hertleinites aguila* zone in California and Oregon (Imlay, 1960, p. 180–181) and the same appears to be true of the western Canadian Cordillera (Jeletzky, 1968, p. 103–104). The genus *Shasticrioceras* in general and its *S. poniente*-like forms in particular are, furthermore, rare to very rare in the uppermost Hauterivian beds and much more common in the succeeding, early to ?late Barremian *Shasticrioceras poniente* zone of California, Oregon, and western Canadian Cordillera (Imlay, 1960, p. 180, 198; Jeletzky, unpubl.). 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 being of 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 the following 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, 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 (cf. Figs. 7 and 8 with Fig. 9) along the northern coast of Vancouver Island, in Holberg and Rupert inlets, and east of Neroutsos Inlet.

The predominantly coarse clastic character 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 either the intervening part of the flanking landmass was relatively low or, 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 Islands 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 Islands and in Spencer Cove on the 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, 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. Wherever it was seen (e.g., Units 2, 3, Sec. 27), the contact with the underlying *Inoceramus colonicus* calcarenites is very abrupt and uneven. A bed of fine to medium pebble-conglomerate or coarse- to medium-grained, gritty and pebbly greywacke, ½ to 1½ feet

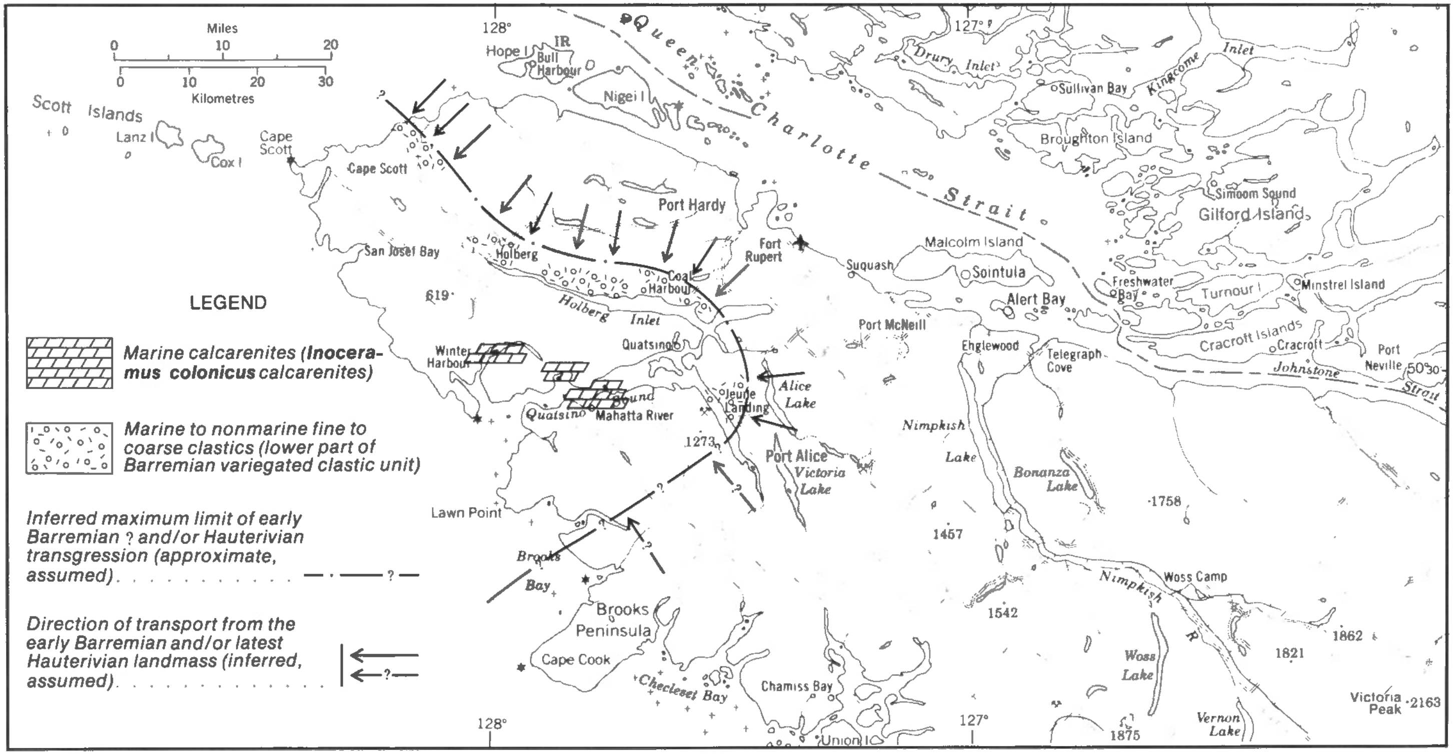


FIGURE 9. Lower Barremian ?and/or uppermost Hauterivian (time of the *Inoceramus colonicus* calcarenites) facies and paleogeography.

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 Islands sections (*see* Pl. VA). 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 Island, 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 Islands 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 a mile across its predominant strike of north 30 to 40 degrees west. The dips fluctuate between 5 and 25 degrees 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 Islands.

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) s. str., *Eulytoceras* aff. *phestum* (Matheron), ?*E.* n. sp. aff. *inequalicostatum* (d'Orbigny), ?*Argonauticeras* aff. *argonautarum* Anderson, and *Heteroceras* (*Heteroceras*) cf. *heliceroides* (Karsten) (figured by Jeletzky, 1970d, Pl. XXIV, Figs. 5, 7, 8, 10; Pl. XXV, Fig. 6) 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 time range of *Argonauticeras* is, however, but poorly known and its evidence is, therefore, discounted. Other taxa in the fauna include ?*Shasticrioceras* et gr. *poniente* Anderson, *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 centred 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, p. 216, 217, Fig. 1). The lower of these Manning Park area faunas contains *Eulytoceras* 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, p. 216, 217, Fig. 1).

On grounds stated by Jeletzky (1970c, p. 216), 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.

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 that it is 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 greywackes 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, p. 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, p. 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, p. 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. 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 in 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, p. 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, 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 borehole C drilled in the vicinity of Coal Harbour (Dawson, 1887, p. 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, p. 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, p. 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 ¾ 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, 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 unpubl.), has yielded *Inoceramus colonicus* Anderson which, at least in Quatsino Sound area, was found only in the lower Barremian ?and/or uppermost Hauterivian *Inoceramus colonicus* calcarenites (*see* p. 83–84). These biochronological data indicate an early Barremian ?and/or latest Hauterivian age for the lower beds 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 believe that the basal, so far unfossiliferous beds of the Basal coarse clastic member are older than the rest because these beds grade upward into the fossiliferous part of the member.

Quoiecchia aliciae Crickmay, ?*Aucellina* sp. indet., and other nondiagnostic 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 stratigraphic association of *Q. aliciae* with ?*Aucellina* sp. indet. in section 30 of the Siltstone-greywacke member is, therefore, a fair paleontological indication of mid- to late Barremian age (Jeletzky, 1958, p. 13–14; 1964, p. 64–68, Pls. XVIII, XX, XXII, corr. chart), as the genus *Aucellina* is not known to range down into the lower Barremian or Hauterivian. Moreover, 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) of 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, at least in part.

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, 82867, collected by J. E. Muller; unpubl. 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 reflect a considerable deepening (?outer neritic environment) of the central part of the Lower Cretaceous embayment of Quatsino Sound after the end of deposition of the *Inoceramus colonicus* calcarenites.

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, p. 127, 128, Units 5–7; Units 2–4, Sec. 29, this report), of that in the Christensen Point Cretaceous outlier on the northern shore of Vancouver Island (Jeletzky, 1969, p. 129, 130), and of those on the northern shore of Holberg Inlet (*see* Units 1–5, 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 Valanginian 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 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.

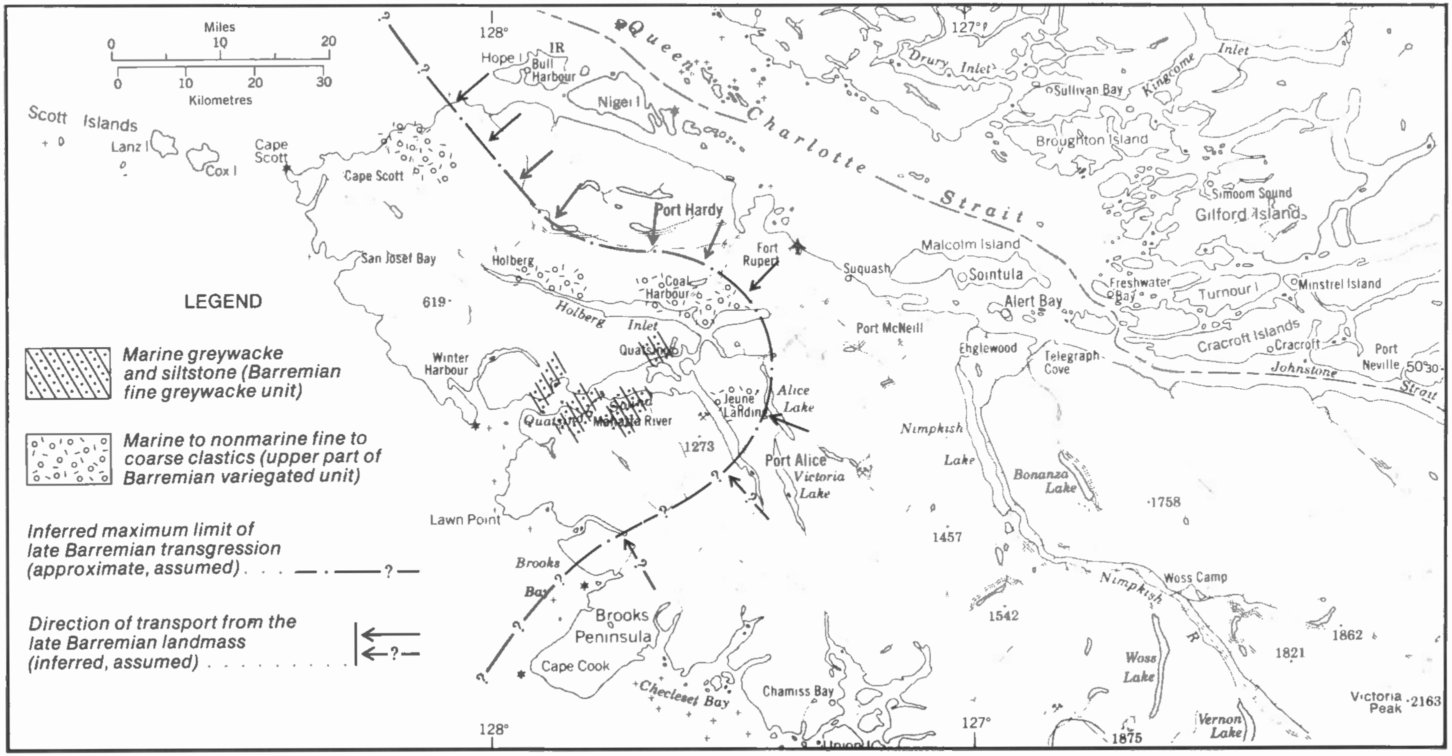


FIGURE 10. Upper Barremian (time of Barremian fine-grained greywacke unit) facies and paleogeography.

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. In the writer's opinion, the northeastern Barremian onlap of the sea proposed by Muller (1970, p. 47) is unfounded.

The apparently complete absence of cephalopods and the 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 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 suggests 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, p. 88, 89) recognized the general facies, stratigraphic, and structural equivalence of these rocks to those of the Jackass Mountain Group of the Tyaughton Trough. As interpreted by Jeletzky and Tipper (1968, p. 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, p. 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, p. 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 noncarbonaceous 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, 18; and 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 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. IXA). 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 unit. 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.

Despite 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 noncarbonaceous 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).

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 noncarbonaceous 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 noncarbonaceous 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 noncarbonaceous 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 noncarbonaceous facies. Judging by their different lithology, these two sections do not overlap.

The reference section of the noncarbonaceous 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 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 neither is 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, commonly gritty arenites of the Winter Harbour sections of the Coarse arenite unit are typical of its noncarbonaceous facies. They are mainly light grey, light green-grey, buff, or rust, 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 places, contain rows of concretions and lenses of impure limestone.

The finer grained arenites of the noncarbonaceous 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 noncarbonaceous facies of the Coarse arenite unit. Carbonaceous or coaly rocks and coal are characteristically absent, and even plant remains are rare in the noncarbonaceous 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 noncarbonaceous 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 noncommercial coal seams (Dawson, 1887, p. 92B–94B).

The most common rock type of the coal-bearing facies is dark grey to brown-grey, coarse- to medium-grained, often gritty, 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-gained, 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. 99), and the borehole logs described by Dawson (1887, p. 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, at present it does not seem advisable to map these poorly understood, coal-bearing clastic rocks separately and to name them formally. 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 noncarbonaceous 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, 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; Pl. IXA) 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. IXA). 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, thin (*see* Sec. 34) greywacke–siltstone section occupying the westernmost part of the above interval. This section is tentatively referred to the noncarbonaceous 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, 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, p. 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 nondiagnostic (Dawson, 1887, p. 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 noncarbonaceous 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, 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 stratigraphic and structural relationships observed in rocks of the coal-bearing facies of the unit in the eastern part of Quatsino Sound. It is, however, applicable to the noncarbonaceous 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 noncarbonaceous 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, p. 92B–94B, Fig. 2) represent the lower part of the Coarse arenite unit, which is either covered or faulted out in the noncarbonaceous facies of the Winter Harbour sections. According to Dawson (1887, p. 92B–93B), the highest coal-bearing zone of the formation occurring within the Coal Harbour outlier is 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 noncarbonaceous 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 noncarbonaceous 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 over all 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 the 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 at times the sea had apparently penetrated into the latter area.

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.

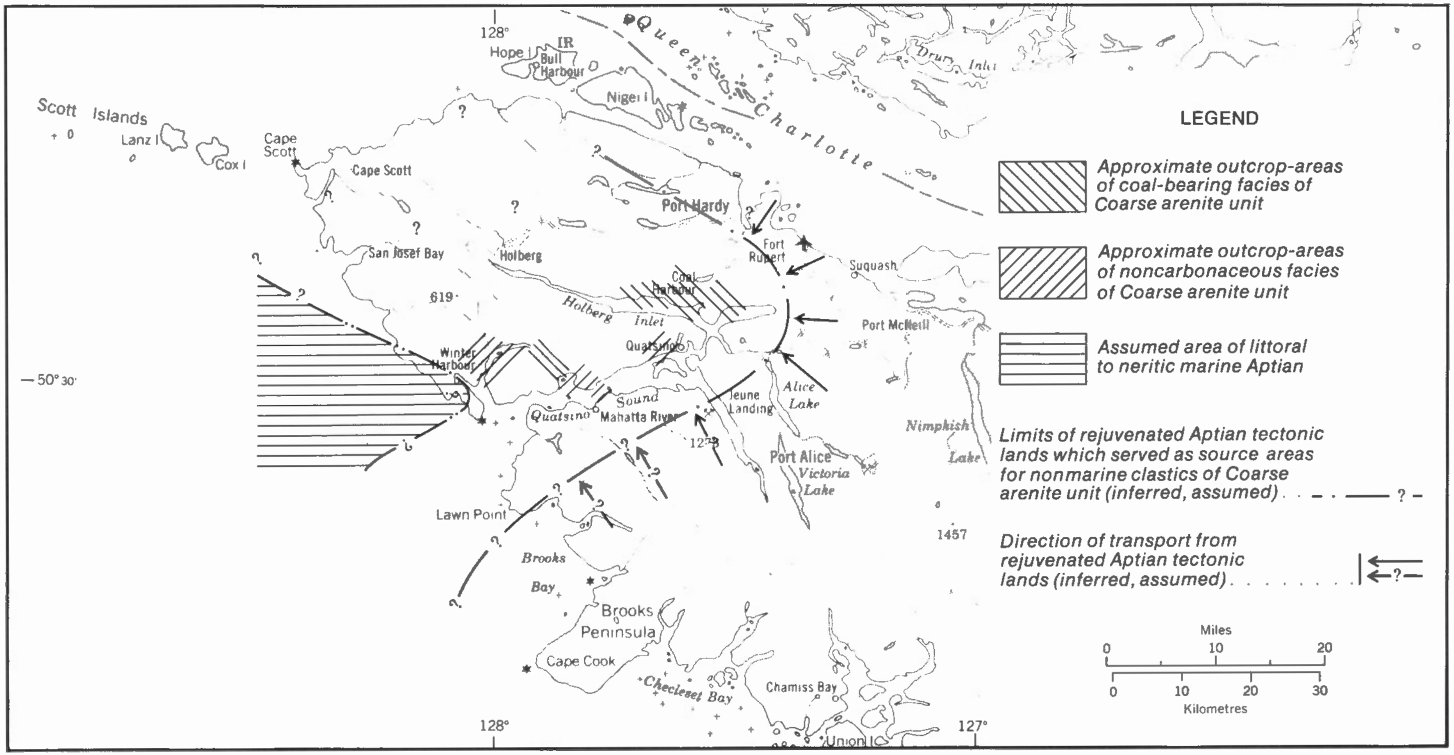


FIGURE 11. Aptian (time of Coarse arenite unit) facies and paleogeography.

The coarse- to medium-grained, often gritty subgreywackes and subquartzose to subfeldspathic sandstones predominant in the noncarbonaceous 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 noncarbonaceous 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 noncarbonaceous facies of the Coarse arenite unit makes it uncertain whether the deposition of the latter has been confined to the above-mentioned short periods 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 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 1½ miles east from its mouth offer the best known, essentially continuous section of the Blumberg Formation. This section (described as Sec. 36, 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 noncarbonaceous 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, p. 78B–81B) as occurring 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 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, p. 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 12–19 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. 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; Pl. IXA). It is estimated that only the basal 1,000 to 1,100 feet of the Blumberg Formation is 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, 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 mile or so, almost certainly harbours a major north- or northeast-trending fault.

The intensely faulted, sheared, 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 Ildstad Islets to the secondary point about ¾ 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, has 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, p. 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 Holberg fault (Dawson, 1887, p. 92B, 93B, Figs. 2, 17).

Age and correlation. As has been discussed in connection with the age of the Coarse arenite unit, all the Blumberg conglomerates appear to be of Albian 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, p. 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 Cretaceous outlier (Jeletzky, 1970a, p. 211). It is somewhat difficult to assume the wholesale destruction 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, p. 83–93, Fig. 6–12). 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 followed the occurrence of the principal tectonic phase of the interregional Aptian (apparently late Aptian) orogeny (Jeletzky and Tipper, 1968, p. 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 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, suggest 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

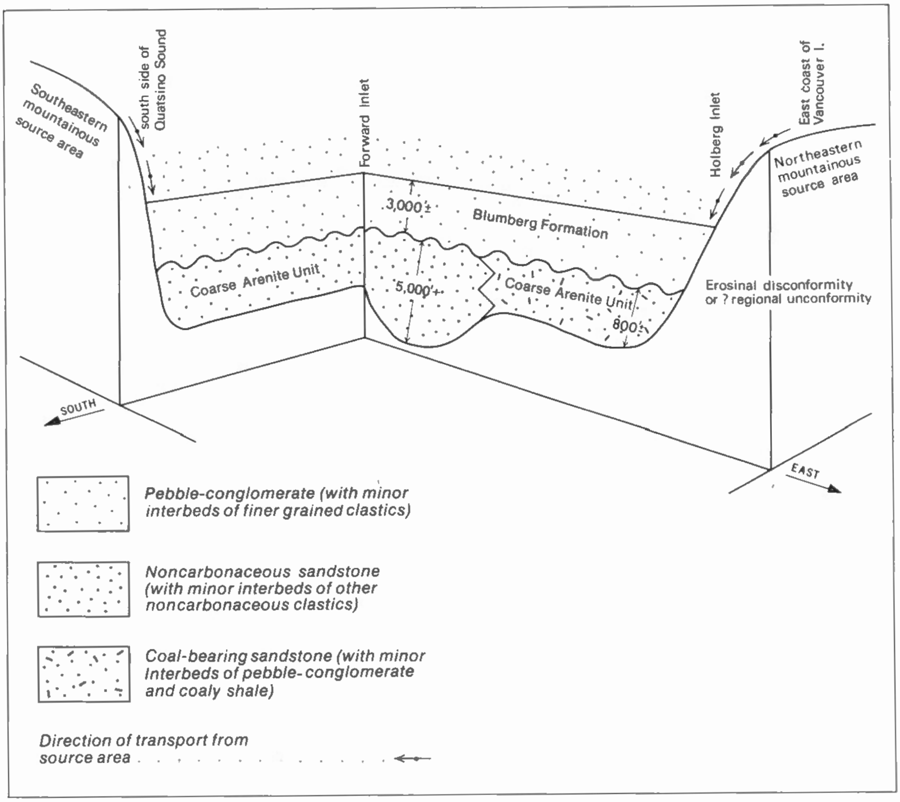


FIGURE 12. Schematic block diagram illustrating paleogeographical–structural relationships of Coarse arenite unit and Blumberg Formation of Quatsino Sound.

apparently complete absence of outcrops of the formation on the southern side of Quatsino Sound, a fact that is more reasonably ascribed to nondeposition 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 13 and the block diagram of Figure 12. 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 noncarbonaceous 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, pronouncedly northward-plunging syncline occupies the northern shore of Quatsino Sound between the point about 300 yards west of Ildstad 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, p. 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, Sec. 32, 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. 105).

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, p. 130, 131; 1970a, p. 211–212). There are reasons to believe that this outcrop-area of the Upper shale unit extends southeastward to the headwaters of Stranby 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.

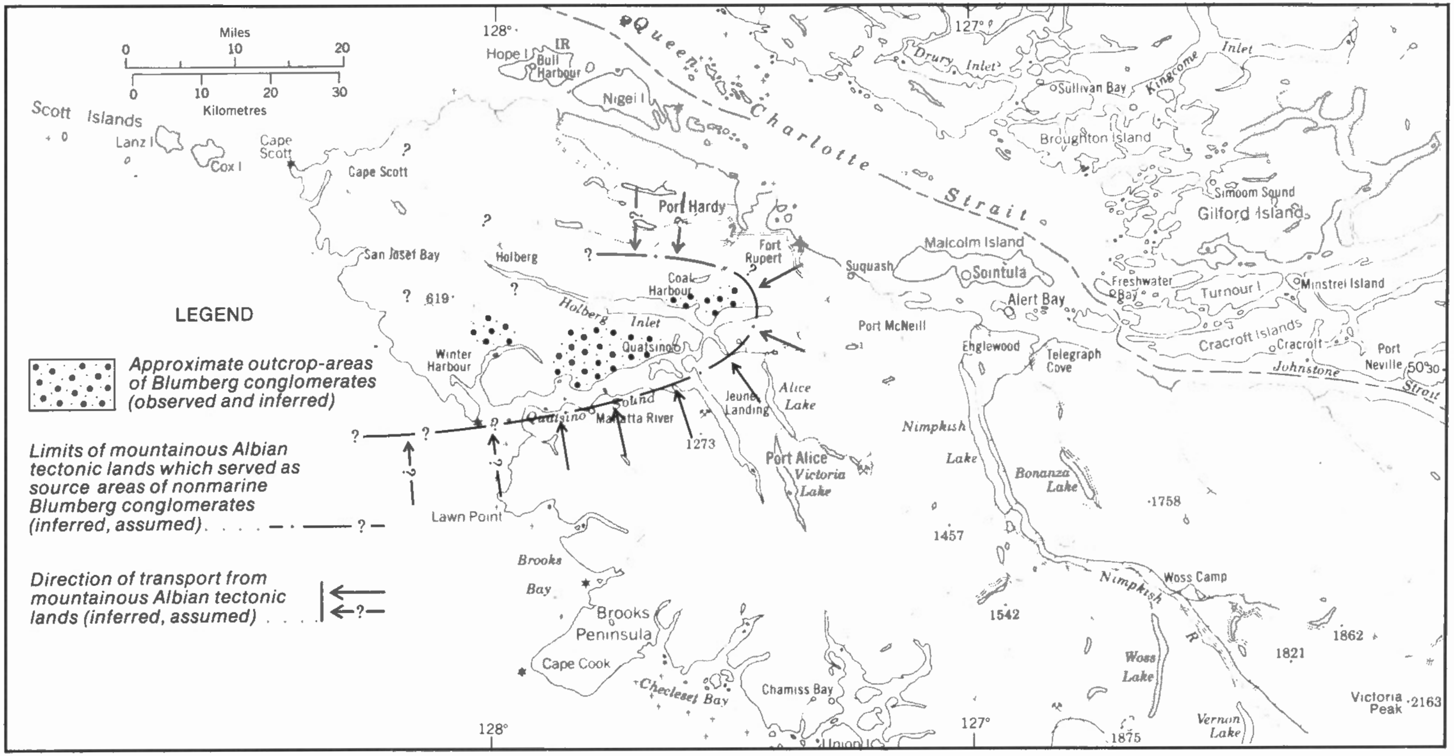


FIGURE 13. Albian (time of deposition of Blumberg conglomerates) facies and paleogeography.

The Greywacke member appears to be stratigraphically transitional between the uppermost exposed beds of the Blumberg Formation (*see* Unit 1, 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 ½ to 1½ 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 ¼- to 2-inch pebbles of grey shaly limestone and hard grey shale.

The thin but extremely important section 38 (*see* Pl. XA) 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 ½ mile along the shore before disappearing beneath beach deposits (*see* p. 105 and discussion of Unit 1, Sec. 36). Throughout this interval, the rocks 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 Ildstad 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 Ildstad 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 (Pl. XIB). Hard 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 commonly occur 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 1¾ 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 a 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 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 the west side 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, Sec. 32, Appendix). 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, 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, p. 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, p. 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 Ildstad Islets (Pl. XIA) 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 was seen only on the eastern limb of Christensen Point Cretaceous syncline where it contains 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, p. 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, p. 127–128; 1970a, p. 210), and the results obtained are presented below.

Location and stratigraphy. The half graben is about 2⅓ miles long, inclined to the southwest, and occurs high on the northeastern slope of a nameless 2,500-foot-high ridge 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, outcrops in the longest and best exposed section of the Nanaimo Group within the Neroutsos Inlet outlier (*see* Units 1, 2, 4–7, 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, 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 irregularly 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 sensu Usher 1952 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, p. 130, 132–133; 1970a, p. 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 last 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, p. 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 Creek 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 Creek 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 landmass in this direction, suggest that the late Nanaimo sea did not penetrate southward beyond the line defined by: Suquash mine–head of Neroutsos Inlet–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 support Sutherland-Brown's (1966, Fig. 6–7) idea about the continuous presence of a wide isthmus separating the Quatsino Sound–Suquash 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 (Jeletzky, 1971, p. 67–68, Figs. 18, 19; Fig. 14, this report) differs only from that proposed by Sutherland-Brown (1966, Fig. 6–7) in assuming its westward extension beyond the west coast of Vancouver Island.

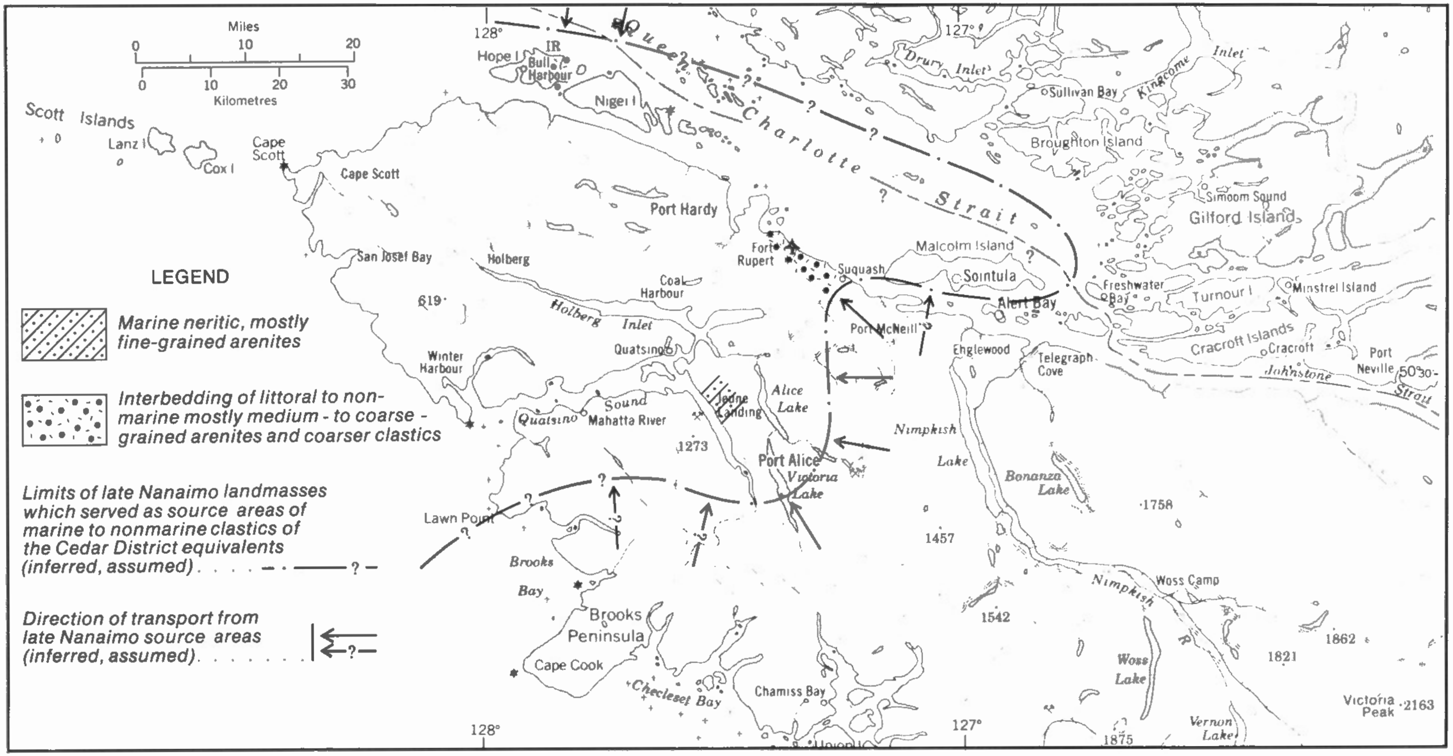


FIGURE 14. Facies and paleogeography of the late Nanaimo time (=Cedar District or early late Campanian time).

?Early Tertiary Intrusions

?Sooke Intrusions

A number of small- to medium-sized 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, stratigraphically, and structurally similar to the ?Lower Oligocene intrusions of the Sooke and Buttle Lake map-areas (cf. Gunning, 1931, p. 64A).

As with the Coast Intrusions, this report is concerned primarily with the stratigraphic 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, p. 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 rocks 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."

Geographical distribution and composition. Most of the observed ?Sooke Intrusions of Quatsino Sound are dykes and sills not exceeding 10 feet thick. 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.

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

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 of both a dark mineral and an 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* description of Units 7–10, 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. 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 one another 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 conglomerate.

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 vermilion-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 asl (*see* Unit 17a, 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 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 occurs in Linthlop 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 Linthlop 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 Linthlop 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; this 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, about 550 yards west of Linthlop 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 Linthlop 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) strata, 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, Sec. 39; Pl. XIIB). 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 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 Linthlop Islet) suggest 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. Coast Intrusions, p. 63, 66).

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 the lithological identity of the other altered sediments with those of thermal haloes surrounding the intrusions.

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, Sec. 39).

The post-Nanaimo intrusives of Buttle Lake map-area were originally dated by Clapp (1912, p. 106) as being of Eocene age. 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 the post-Cenomanian intrusions of Quatsino Sound are accordingly dated as being 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 recently mapped 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, 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 or 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 lithologically similar 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. 32) 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, p. 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, p. 104A) 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 as 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, p. 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, p. 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* p. 22–26, 34–38, 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 Figures 17 and 18. Despite 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 is 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, p. 104A–105A; p. 124, 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 despite 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, p. 18–23, Figs. 1, 2; and earlier sections of this report) suggests that the Early Jurassic faulting had preceded ?and/or accompanied the formation of this regional homocline.

The previously discussed (Jeletzky, 1970b, p. 21–23; and p. 56–63 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, p. 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-sized, 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. Most 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. 128) 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. 138) fault blocks are either strongly upthrown or strongly downthrown 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. Despite 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 Figures 17 and 18. These lesser faults split all principal fault blocks into innumerable 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.

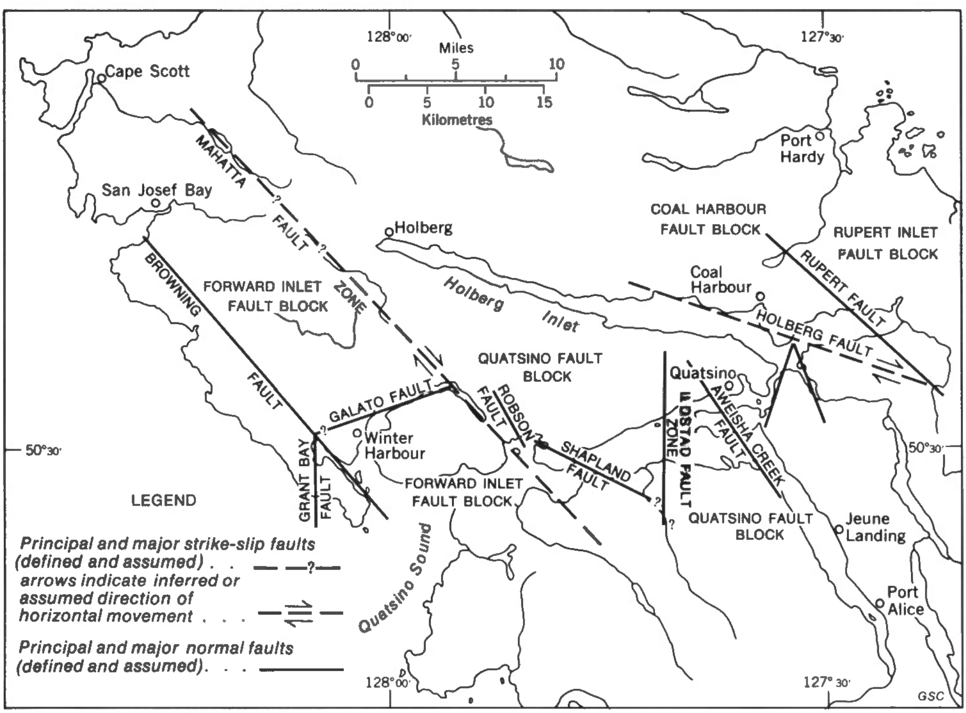


FIGURE 15. Schematical structural map of Quatsino Sound area showing principal fault blocks, principal faults, and some of the major faults.

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. Most 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, p. 5–9; and preceding sections of this report) the report-area must have been transected by a number of large faults before 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 evidence (*see* previous section, p. 126) for the occurrence of large-scale faulting during the tectonically and volcanically active early Jurassic time consists only of the obvious concentration of Coast Intrusions along the downthrown southwestern side of the Browning Inlet fault (*see* p. 130). 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 therefore 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 moulded 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, Fig. 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 last, 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 stratigraphic part of this report and/or shown on the 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 ?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 is 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 subsidiary 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 is faulted out along its surface. There is no way to determine the direction of dip and stratigraphic throw 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. However, this possibility should not be discounted as the sharp bend of Macjack River (*see* below) is suggestive of a recent left-lateral offset along the fault.

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 1½ miles above its mouth. This lineament extends farther northwest along the west coast of Vancouver Island and suggests the 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 of the invasion of several, apparently related, small- to medium-sized, 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 that it is an ancient pre-Coast Intrusion fracture. This pre-existing regional fracture could have facilitated the upward movement of the Coast Intrusions and explains 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 coalescence 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 ¼ 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 ¼ 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 is 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, gently to moderately north- to northeast-dipping rocks of the Coarse arenite unit (*see* description, 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, 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 its orientation, it is tempting to interpret the Galato Creek fault as a subsidiary 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 noncarbonaceous facies of the Coarse arenite unit are unknown. It seems safe to say, however, that more than 1,000 feet of rocks is 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 subsidiaries. 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 numerous major and minor, mostly northwest to north-northwest, and west-trending faults. These faults may be mere subsidiaries 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 Galato Creek fault.

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, p. 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 Koskimo and Salmon islands.

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 ⅓ 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, one of the faults 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 Figure 18. A considerable thickness of rocks of the Volcanic division may be faulted out along the trace of the Mahatta fault zone in this interval. Other splays appear to separate the disturbed rocks of the Grey volcanic unit from considerably older rocks of the lower part of the Basal Jurassic volcanic unit on the opposite side of the inlet. Therefore, it is impossible to estimate the thickness of strata missing. None of the faults of 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 $\frac{1}{8}$ to $\frac{1}{4}$ 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 mylonitized 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 of all the 5,000- 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 subsidiary 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 is 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 southwestward by the right-hand, strike-slip movements. Because of different possibilities in reconstructing the Forward Inlet and Koprino Harbour (including Salmon Islands) 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, 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 Cleagh 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 Ildstad fault zone to the southeast (Fig. 15).

Ildstad 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 ¼ mile wide, extends south into Ildstad Islets. The latter are underlain by more weathering-resistant (?indurated) parts of the individual tectonic slices of the fault zone.

Ildstad 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 Ildstad 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 Ildstad 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 Ildstad fault zone faults. However, there is every reason to believe 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 west-southwest side of Aweisha Creek fault is relatively downthrown 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 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 subsidiaries. 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, p. 90B–92B, Fig. 2, geol. maps) who described 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 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, p. 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* Figs. 15, 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, providing 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 from the approximately located trace of the Holberg fault.

The character and orientation of these drag-folds indicate that they are generated by strong right-lateral (dextral), strike-slip movements along the Holberg fault. Because of these folds, the remarkable straightness of the fault trace, and the complete dissimilarity of rock sequences occurring on either side, the writer interprets it as a

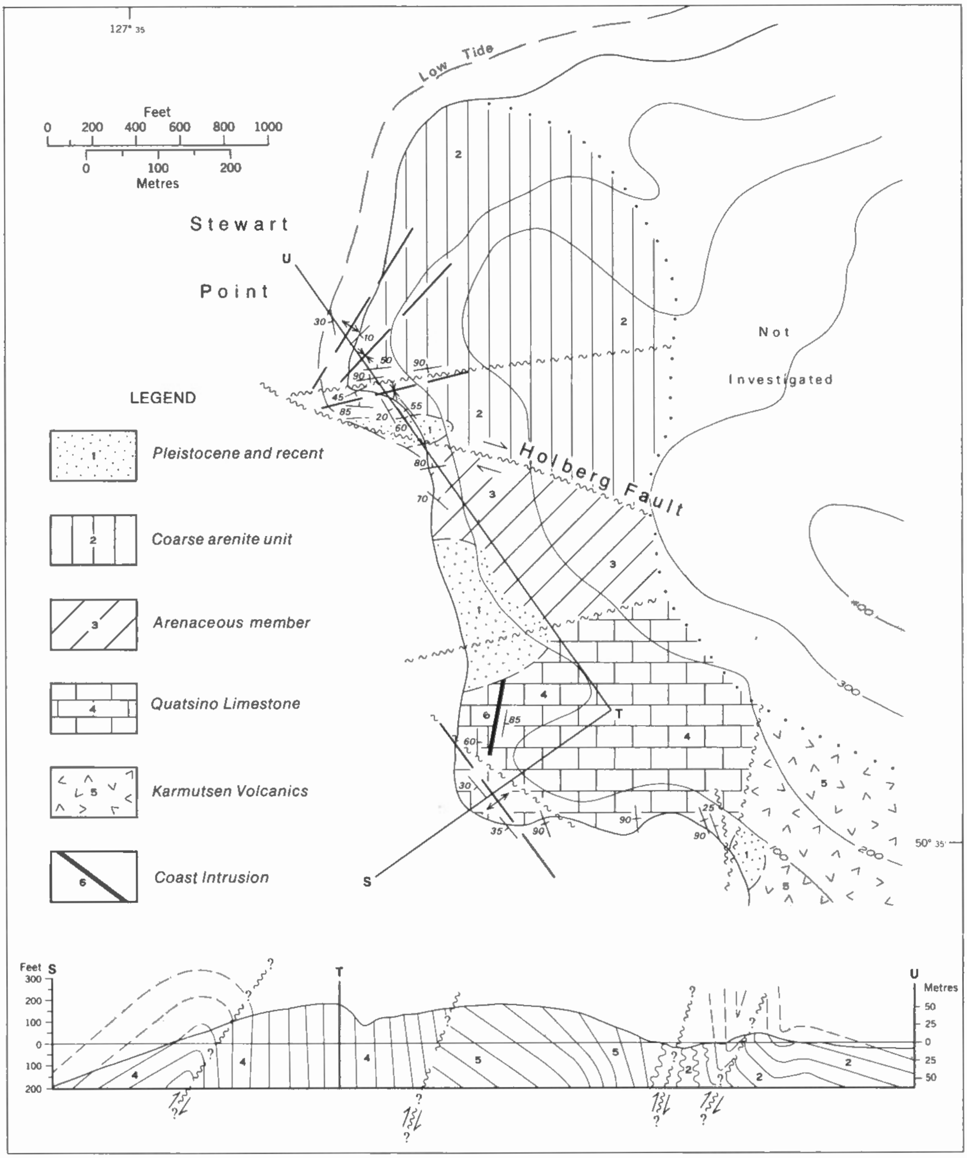


FIGURE 16. Geological and structural sketch-map and profile of Stewart Point, Coal Harbour.

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 that it is 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 1½ 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 the 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, p. 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, 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-sized) Coast Intrusions. These subordinate folds, which are restricted to the Forward Inlet fault block, appear to be superimposed on the previously mentioned, southwest-dipping, 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 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-sized 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. Cretaceous beds 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 the Browning Inlet 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. Despite 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, Ildstad Islets fault zone, and a number of unnamed major faults in the vicinity of Quatsino Narrows and Varney Bay (*see* Figs. 15, 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-sized, 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-sized) 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 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. XIA). 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. Despite 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-sized, 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 River 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-sized 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-sized, 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, p. 1–2; Muller, 1970, p. 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 paratectonics or Saxonian tectonics of nongeosynclinal 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, p. 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, p. 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. Amer., Spec. Paper 16, 339 p., 83 pls., 1 index map, 2 corr. tables, 3 figs.

Arkell, W. J.

1956: Jurassic geology of the world; Edinburgh and London, Oliver and Boyd, Ltd., 806 p., 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 p., 1 fig.

Beveridge, A. J. and Folinsbee, R. E.

1956: Dating Cordilleran orogenies; Trans. Roy. Soc. Can., ser. 3, sec. 4, v. 50, p. 19–43, 10 pls., 1 table, 4 figs.

Busnardo, R.

1965: Rapport sur l'Étage Barrémien; Mém. Bur. de Rech. Géol. et Minières, Colloq. sur le Crétacé inférieur, Lyons, 1963, p. 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 p., 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, p. 91–107, 1 table.

1917: Sooke and Duncan map-areas, Vancouver Island; Geol. Surv. Can., Mem. 96, 445 p., 12 pls., 6 maps, 2 figs.

Crickmay, C. H.

1928: The stratigraphy of Parsons Bay, British Columbia; Univ. Calif. Publ., Bull. Dept. Geol. Sci., v. 18(2), p. 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 p., 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, p. 30B–38B, 1 fig.

1921: West Coast of Vancouver Island between Barkley and Quatsino Sounds; Geol. Surv. Can., Sum. Rept. 1920, Pt. A, p. 12A–22A.

Eastwood, G. E. P.

1965: Replacement magnetite on Vancouver Island; Econ. Geol., v. 60, p. 124–148.

1968: Geology of the Kennedy Lake area, Vancouver Island, British Columbia; Brit. Columbia Dept. Mines, Bull. 55, 63 p., 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 p., 18 pls., 2 figs.

1959: Marine Jurassic rocks in Nelson and Salmo areas, southern British Columbia; Geol. Surv. Can., Bull. 49, 31 p., 5 pls., 1 table, 2 figs.

Frebold, H. (cont.)

1967: Position of the Lower Jurassic genus *Fanninoceras* McLearn and the age of the Maude Formation on Queen Charlotte Islands; Can. J. Earth Sci., v. 4, p. 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., v. 7(1), p. 1–21, 1 table, 9 figs.

Fyles, J. T.

1955: Geology of the Cowichan Lake area, Vancouver Island, British Columbia; Brit. Columbia Dept. Mines, Bull. 37, 72 p., 14 pls., 9 figs.

Givens, C. R. and Susuki, T.

1964: Late Triassic fauna from interlava sediments of east-central Vancouver Island (abstr.); Geol. Soc. Amer., Spec. Paper 76 (Abstr., 59th Ann. 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, p. 94A–143A, pls. 2–3, 1 map, figs. 4–8.

1931: Buttle Lake map-area, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1930, Pt. A, p. 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, p. 22–35, Fig. 3.

1933: Zeballos River area, Vancouver Island, British Columbia; Geol. Surv. Can., Sum. Rept. 1932, Pt. A II, p. 29–50, Fig. 4.

Harper, C. T.

1967: On the interpretation of potassium-argon ages from Pre-Cambrian shields and Phanerozoic orogens; Earth and Planetary Sciences Letters, p. 128–132.

Haycock, E.

1906: Geology of the west coast of Vancouver Island, British Columbia; Geol. Surv. Can., Ann. Rept., v. XV, Pt. A (1902–3), p. 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 p., 5 pls., 3 tables, 3 maps, 2 figs.

Hutchinson, W. W.

1970: Metamorphic framework and plutonic styles in the Prince Rupert region of the Central Coast Mountains, British Columbia; Can. J. Earth Sci., v. 7, No. 2, Pt. 1, p. 376–405, 14 figs., 4 tables.

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, p. 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 Dept. 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 p., 1 map, 1 fig.

1954a: Geological history of west coast of Vancouver Island and Quatsino Sound (abstr.); Bull. Geol. Soc. Amer., v. 65 (12/2), p. 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 p., 1 map.

Jeletzky, J. A. (cont.)
1958: Uppermost Jurassic and Cretaceous rocks of Aklavik Range, northeastern Richardson Mountains, Northwest Territories; Geol. Surv. Can., Paper 58-2, 84 p., 1 map, 1 corr. chart.
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 p., 2 figs.
1961b: Eastern slope, Richardson Mountains: Cretaceous and Tertiary structural history and regional significance; *in* Geology of the Arctic, v. 1, G. O. Raasch, ed., Univ. Toronto Press, p. 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., v. LVI (III), p. 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 p., 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 p., 22 pls., 4 text-figs.
1965b: Age and tectonic nature of the Strait of Georgia Seaway (abstr.); Geol. Surv. Can., Paper 65-2, p. 72.
1967: Stratigraphy and paleontology 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, p. 65–68.
1968: Stratigraphy and paleontology 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, p. 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, p. 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, p. 209–214.
1970b: Some salient features of early Mesozoic history of Insular Tectonic Belt, western British Columbia; Geol. Surv. Can., Paper 69-14, 26 p., 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, p. 214–223, 1 fig.
1970d: Cretaceous macrofaunas: *in* Geology and Economic Minerals of Canada; Geol. Surv. Can., Econ. Geol. Report 1, 5th edn., p. 649–662, pls. 23–28.
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, 92 p., 22 figs., 11 tables.

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 p., 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 p., 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, p. 293–336, pls. 13–22, geol. map.

Mackenzie, J. D.
1916: Geology of Graham Island, British Columbia; Geol. Surv. Can., Mem. 88, 221 p., 16 pls., 2 maps, 23 figs.

Matsumoto, T.
1959: Cretaceous ammonites from the upper Chitina Valley, Alaska; Kyushu Univ. Mem. Fac. Sci., ser. D, v. 8(3), p. 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 p., 3 figs.
1953: Correlation of the Triassic formations of Canada; Bull. Geol. Soc. Amer., v. 64, p. 1205–1228, 1 pl., 2 figs.

Mitchell, A. H. and Reading, H. G.
1969: Continental margins, geosynclines, and ocean floor spreading; J. Geol., v. 77(6), p. 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, p. 81–83, 1 geol. map.
1969: Northern Vancouver Island (92-E, K, L, 102-I); Geol. Surv. Can., Paper 69-1, Pt. A, p. 27–29.
1970: Northern Vancouver Island, British Columbia (92-E, K, L, 102-I); Geol. Surv. Can., Paper 70-1, Pt. A, p. 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 p., 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, p. 39–47, 2 tables, 2 figs.

Muller, J. E., Northcote, K. E., and Carlisle, D.
1974: Geology and mineral deposits of Alert-Cape Scott map-area, Vancouver Island, British Columbia; Geol. Surv. Can., Paper 74-8, 77 p., 11 tables, 2 maps, 15 figs.

Muller, J. E. and Rahmani, R. A.
1970: Upper Triassic sediments of northern Vancouver Island; Geol. Surv. Can., Paper 70-1, Pt. B, p. 11-18.

Northcote, K. E.
1969: Geology of the Port Hardy-Coal Harbour area; *in* Rept. Minister of Mines, 1968, Brit. Columbia Dept. Mines, p. 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. Amer., v. 71, p. 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, 276 p., 51 pls., 3 maps, 16 figs.

Silberling, N. J. and Tozer, E. T.
1968: Biostratigraphic classification of the marine Triassic in North America; Geol. Soc. Amer., Spec. Paper 110, 63 p., 1 pl., 1 fig.

Sitter, L. U., de
1956: Structural geology; 1st ed., New York, McGraw Hill Book Co., 552 p.

Stille, H.
1924: Grundfragen der vergleichenden Tektonik; Berlin, Gebr. Borntraeger Press, p. 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 p., illus.

Surdam, R. C.
1968: The stratigraphy and volcanic history of the Karmutsen Group, Vancouver Island, British Columbia; Contrib. Geol., Univ. Wyoming, v. 7, No. 1, p. 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 (abstr.); Geol. Soc. Amer., Spec. Paper 76, p. 226.

Sutherland-Brown, A.
1966: Tectonic history of the Insular Belt of British Columbia; Can. Inst. Mining Met., Spec. v. 8, p. 83–100, figs. 6–1 to 6–13.
1968: Geology of the Queen Charlotte Islands, British Columbia; Brit. Columbia Dept. Mines, Bull. 54, 226 p., 18 pls., 21 tables, 45 figs.

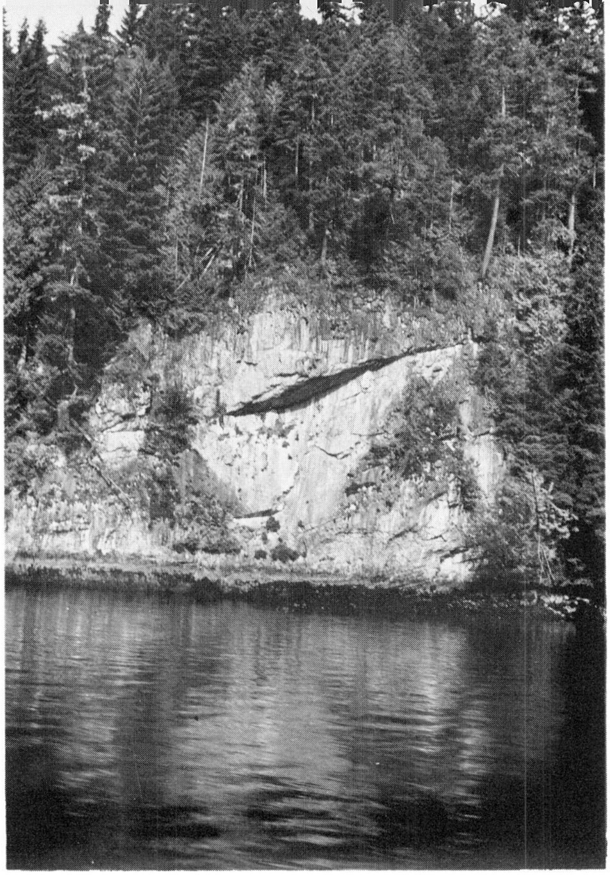
Terekhova, G. P.
1969: O nizhnei zone senomana v Anadyrsko-Koriakskoi oblasti [The lower zone of the Cenomanian stage in the Anadyr-Koriak province]; Sibirskoye Otdelenie Akad. Nauk SSSR, Tr. Sev.-Vost. Kompleks. Nauchno-Issledovatel'skogo Inst. No. 32, Magadan, p. 162–172, 5 pls. (in Russian).

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 p., 2 tables, 1 map, 8 figs.

Tozer, E. T.
1954: Late Norian (Triassic) fauna in southern Yukon and western British Columbia (abstr.); Bull. Geol. Soc. Amer., v. 65(12), p. 1315.
1967: A standard for Triassic time; Geol. Surv. Can., Bull. 156, 103 p., 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 p., 31 pls., 4 figs.

Whiteaves, J. F.
1889: On some fossils from the Triassic rocks of British Columbia; *in* Contributions to Canadian Palaeontology, v. I, Pt. 2; Geol. Surv. Can., p. 127–149, pls. 17–19.



A. A prominent (marked on marine chart 3617), sheer, 90-foot bluff of the Lower member of Quatsino Limestone in the western shore of Quatsino Narrows about 3 miles north of Ohlsen Point. View approximately due west from boat in mid-channel.

129145, 12–5–53

129214, 1–4–54

B. Exposures of exceedingly strongly sheared and jointed, partly contorted Lower member of Quatsino Limestone on the northern side of a nameless square-shaped cove of the northwestern shore of Rupert Inlet, about 1 mile northeast of the tip of Hankin Point. View toward north-northeast from the south side of the cove. Pronounced but widely spaced, deeply weathered joints dipping 30 to 40 degrees east (i.e., toward right side of the photograph) are not bedding. True bedding is represented by closely spaced joints striking 360°–010° and dipping 70 to 80 degrees west (i.e., toward the left side of the photograph).

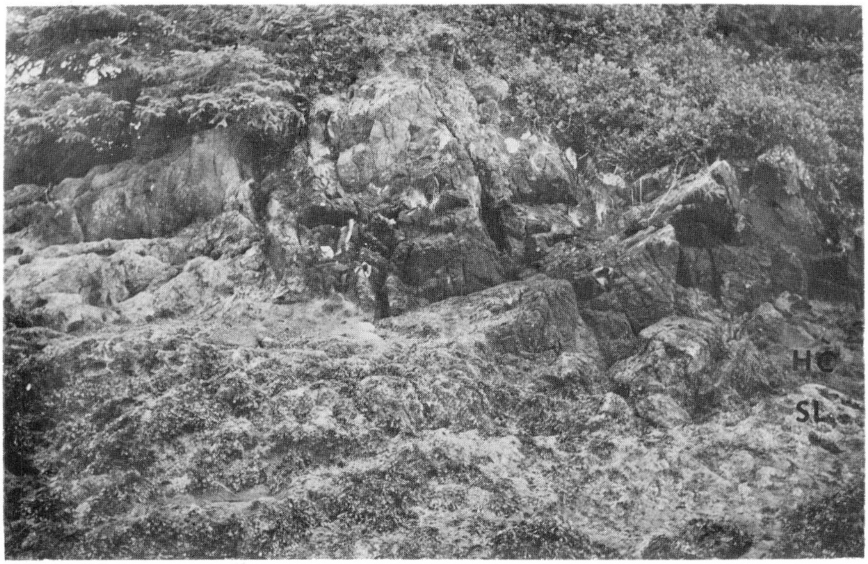
A. Exposures of the Arenaceous member of Sedimentary Division of Bonanza Subgroup in a small road fill quarry in the bed of a nameless left confluent of Lippy Creek where it crosses secondary logging road branching off the main Gibson Road at altitude $\pm$ 1,900 feet. The locality is situated about 3 miles northeast of Jeune Landing, northeast shore of Neuroutsos Inlet. View approximately due south-southeast (upstream). The man stands at the top of bed 8 of section 1 on the left side of the creek. The latter forms a small waterfall in the quarry wall mentioned in the description of bed 9. The upper 12 feet of bed 9 outcrops underneath bed 8 on the left side of the waterfall. The upthrown lower part of bed 9 occupies all of the quarry wall on the right side of the waterfall. The normal fault striking 215° and dipping 55°E cuts into the bed in the extreme right lower corner of the photograph. Beds 1, 3–5 of section 1 outcrop in the right slope of a gentle logged out hill in the middle part of the photograph in the barely visible bed of the left branch of the confluent. Section 6 was measured on the left side of the same hill in the bed of the right branch of the confluent. Both sections are almost completely hidden by vegetation. Bed 17 of section 1 outcrops on the left side of the bottom of the photograph (just left of the uprooted tree).

B. Southwestern corner of the quarry shown in Figure A. Both photographs are panoramic. The normal fault cutting through bed 9 of section 1 crosses obliquely the left side of the photograph upward from the 5-foot-long measuring stick. The second normal fault striking 315° and dipping 50–55° east is visible near the middle of the photograph. The base of bed 9 is exposed just above talus between these two faults. A third fault striking 245° and dipping 28° west cuts through the unit 9 near the right side of the photograph. Beds 10 and 11 are exposed underneath the base of bed 9 on the right (northwestern) side of the fault at the right edge of the photograph. View approximately due west from a pile of debris situated on northeastern side of the quarry near its entrance.

A. 153387, 3-7-69

B. 153387, 3-8-69

PLATE IV



153418, 7-8-69

A. The normal, ?paraconformable contact of Sutton Limestone (SL) and Hecate Cove breccia (HC) exposed at the tip of Banter Point southern shore of Quatsino Sound (see Units 1, 2, Sec. 2, p. 166). View due southeast from the boat stationed just offshore and obliquely across the strike of rocks which dip away from the camera and to the right.

129237, 4-3-54

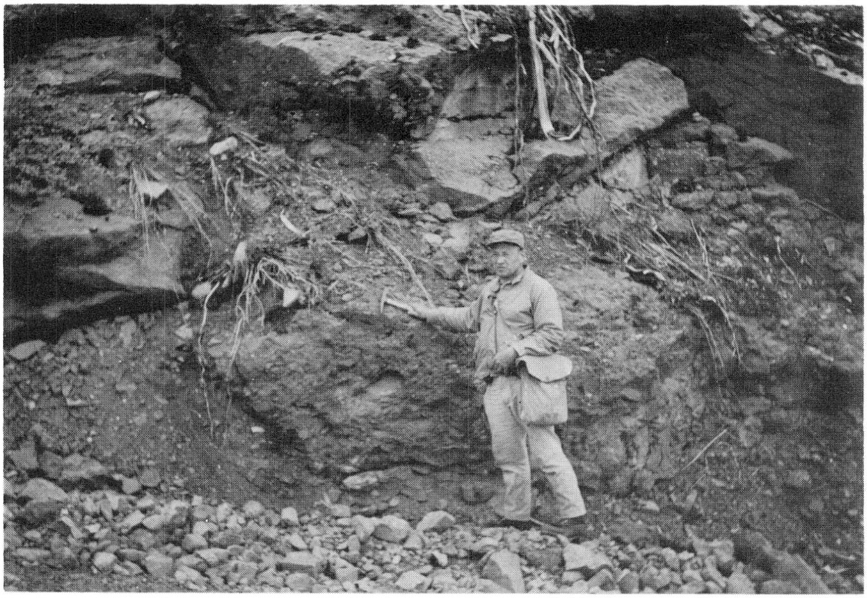
B. Lavas and pyroclastics of Grey volcanic unit exposed in the western wall of Mahatta Creek canyon approximately 500 yards above creek's mouth. View approximately due north (i.e., downstream). The upper part of the wall is built of dull green, finely to coarsely amygdaloidal lava (L). Four to five feet of green-blue to dull green, thinly bedded, waterlain volcanic tuff (T) outcrops beneath it to the water's edge. Rocks strike 230 to 240 degrees and dip 40 to 45 degrees west.

129232, 3-6-54

A. Erosionally disconformable and ?possibly regionally unconformable contact of *Inoceramus colonicus* calcarenites (C) with the overlying fine pebble-conglomerate of Barremian fine-grained greywacke (G) unit on northeastern side of the largest Salmon Island off the southern shore of Quatsino Sound (*see* Units 2, 3, Sec. 27 (p. 207)). View due west, more or less along the strike of beds.

153386, 3-6-69

B. Over all view of the lower part of section 29 (*see* p. 212) of the Barremian variegated clastic unit exposed in the northern side of main Gibson road on the left (northern) side of the right (southern) confluent of Lippy Creek at altitude ± 2,000 feet. Bed 8 of section 29 outcrops at the top left of the photograph (where the car is parked). The writer stands at the contact of beds 10 and 11 (i.e., at the base of Barremian sequence). All beds dip upslope away from the camera and strike, more or less, across the road. View due west (i.e., upsection).

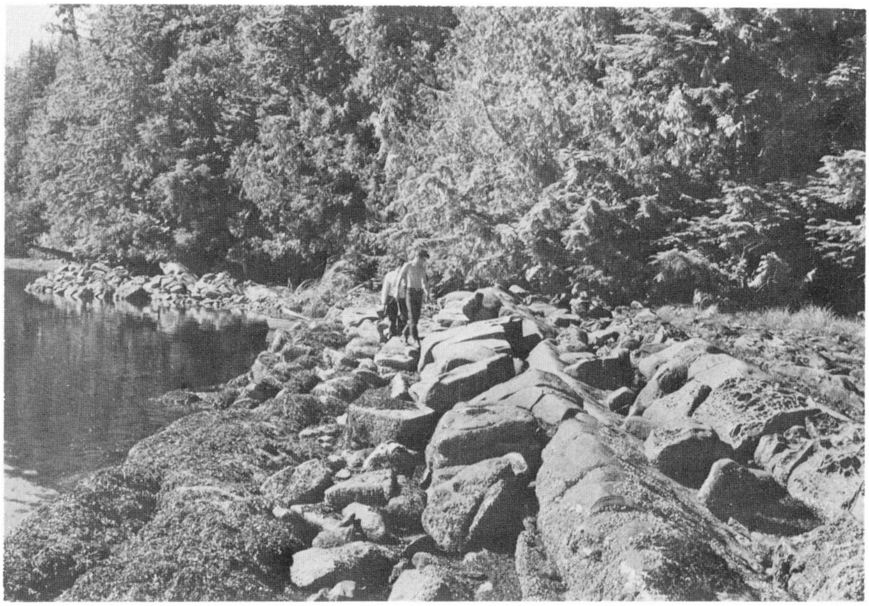


153383, 3-3-69

A. Close-up view of the pebble-conglomerate of bed 9, section 29. This bed is in the middle part of the section (i.e., halfway between the parked car and the writer) shown in Plate VB. View approximately due north (into the strike of rocks) from the opposite (southeastern) side of main Gibson Road. Beds dip to the left.

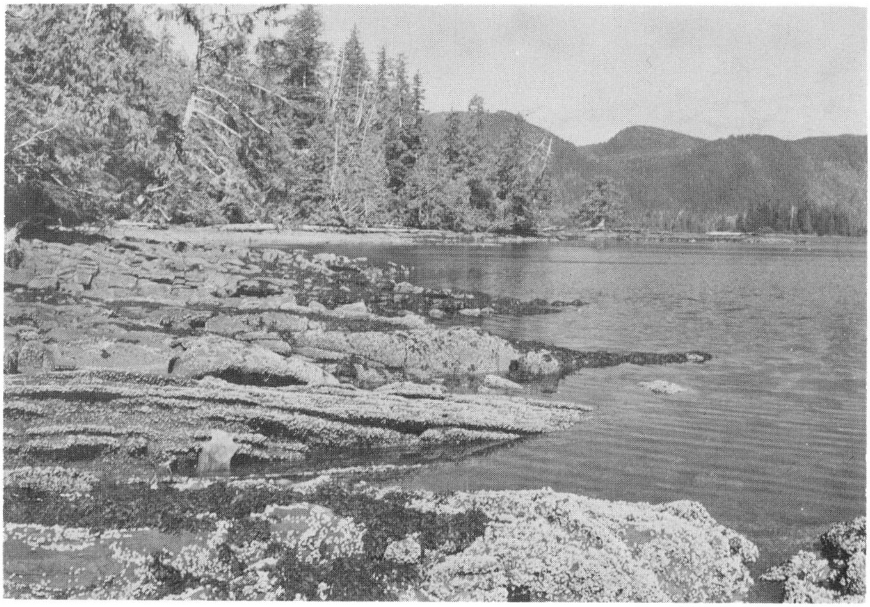
153382, 3-2-69

B. Close-up view of section 29. View of the middle part of the section shown in Plate VB just upsection from its part shown in Plate VIA. The photograph is a close-up of beds 8 and 9 (top part only is exposed near right rim of the photograph). The writer's hammer rests on one of the pebble-conglomerate interbeds in bed 8. View due northeast (obliquely downslope) from station on the road at the point about 60 feet from where the car is parked (Plate VB). Altitude of the rocks the same as in Plate VB, and they dip obliquely toward the camera.



129153, 13-5-53

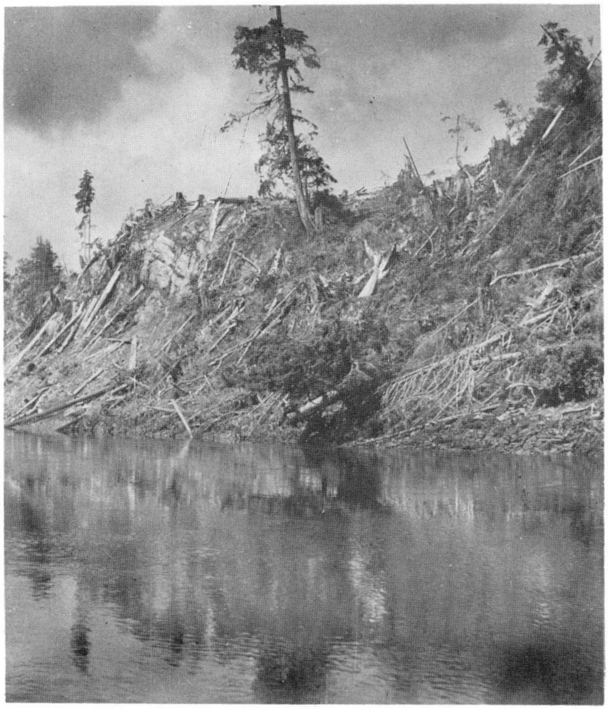
A. Basal exposed beds of noncarbonaceous facies of Coarse arenite unit in the northwest shore of Winter Harbour. View toward north-northwest (i.e., along the strike) of the upper part (within the upper 75 feet) of unit 39, section 33 (*see* p. 223) from the tip of the second point east of, and some 275 yards from the mouth of Galato Creek. Note the heavy bedding and locally honeycombed weathering habit characteristic of medium- to fine-grained greywacke of the unit.



129154, 13-6-53

B. Units 33 to 38 of the Coarse arenite unit in the northwest shore of Winter Harbour, section 33. View due northeast (i.e., upsection) from station at the tip of the second point east of, and some 275 yards from Galato Creek at the top of unit 39 of the section (*see* p. 222-223). The long, low rocky point with a single tree visible in the middle background is built of sandstones of unit 33. The logged out slope in the far background is on the northeast side of Ahwhichaolto Inlet.

A. Coal Harbour Group, Coarse arenite unit (Aptian). Bed 11 of section 32 which forms a 60- to 80-foot-high shelf in the northern shore of the narrow channel connecting Winter Harbour with Ahwhichaolto Inlet. The outcrop is at the western end of this channel. View toward northwest, that is, into the strike of the rocks which dip toward the right side of the photograph.



129230, 3-4-54

129231, 3-5-54

B. Another exposure of the characteristic intensively yellow- to rust-weathering sandstone of unit 11, section 32 of Coarse arenite unit. The bluff shown in the photograph is on the eastern side of a prominent rocky point situated next east of the mouth of Klayina Creek (the wooded valley of which is visible behind the bluff) at the head of Winter Harbour. The bluff shown in Figure A is on the western side of this point. View due north-northeast and more or less downdip.

129224, 2–6–54

A. Erosionally disconformable and possibly regionally unconformable contact between pebble-conglomerate of Blumberg Formation and underlying Coarse arenite unit in section 35 (see Units 1, 2, p. 225). The outcrop is on the northern shore of Quatsino Sound at the point about 100 yards west of Lind Islet. View due east (i.e., almost into the strike of the rocks). The head of the hammer is at the contact.

129226, 2–8–54

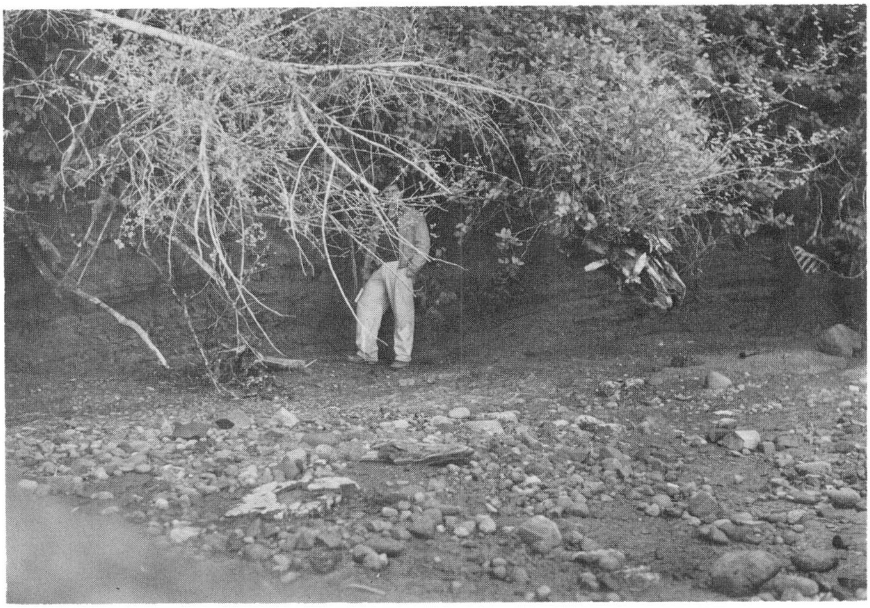
B. Uppermost beds of the coal-bearing facies of Coarse arenite unit in unit 2 of section 35 (see p. 226). The outcrop is on the northern shore of Quatsino Sound at the point ± 160 yards west of Lind Islet. View approximately northwest (i.e., obliquely downdip). The well-developed foreset beds of distinctly deltaic type dip approximately northeast.

153419, 8–1–69

A. Fossiliferous conglomerate (Cenomanian) of Greywacke member of Upper shale unit (see Unit 2, Sec. 38, p. 234) exposed on the northern shore of Quatsino Sound at the point about 600 feet west of the mouth of Bish Creek. The writer stands on beds of unit 2, section 38 which strike about 050 degrees and dip 19 degrees east (i.e., to the left) at that point. View due southwest (almost into the strike of rocks).

129222, 2–4–54

B. Close-up of isolated outcrop of dark grey pebble-conglomerate forming the visible top of Blumberg Formation (Albian) in its type section (see Unit 1, Sec. 36, p. 227). The hammer rests on a boulder of brownish green pebble-conglomerate lithologically identical with that occurring in the lower part of the formation. This suggests an intraformational period of erosion (see p. 227). Attitude of Blumberg Formation at this spot is unknown. View due north.



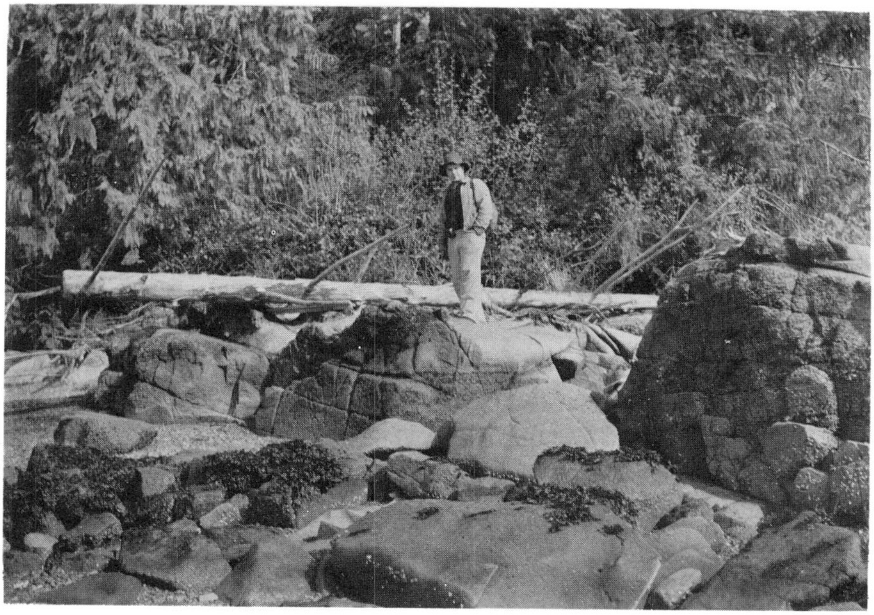
129217, 1–7–54

A. Outcrop of the Shale–siltstone member of the Upper shale unit (Cenomanian and ?later) on the tidal platform and in low, overgrown banks just above high tide limit on the northern shore of Quatsino Sound at the point about 300 yards west of Ildstad Islets (see p. 111). The shale strikes 340°–350° and dips 5 to 10 degrees west (i.e., to the left side of the photograph) in this easternmost outcrop of the unit. Note the undulating changes of dips probably attributable to the stress exerted by movements on adjacent Ildstad fault zone. View due north-northwest (i.e., into the strike).

129220, 2–2–54

B. Close-up of a small section of the outcrop (on tidal platform) shown in Plate XIA. Note the characteristic spheroidal weathering and conchoidal fracturing of the shale. View from above. Camera inclined downdip (i.e., toward the west).

PLATE XII



129216, 1–6–54

A. A dioritic? sill- or dyke-like body of ?Sooke Intrusions at least 100 feet wide, outcropping on the tidal platform of the northern shore of Quatsino Sound at the point about 1,000 yards west of the mouth of Aweisha Creek (*see* p.117–118).

153880, 2–8–69

B. A sill-like body of ?rhyolitic ?Sooke Intrusions (S) cutting late Upper Cretaceous arenites of Nanaimo Group (N) in section 39 (*see* Units 2, 3 this section) in headwaters of Lippy Creek, $2\frac{1}{3}$ miles northeast of Jeune Landing. The writer's hammer rests on the lower contact of the ?rhyolite with the Nanaimo arkoses (*see* p. 235). View approximately due northwest.

APPENDIX

Selected measured sections

(Units numbered from top to bottom of measured section)

Section 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. IIIA, 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) of unit	Thickness (feet) above base
	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, 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	
	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) 5½ to 6 feet below visible top of unit includes *Monotis* cf. *ochotica* var. *densistriata* (Teller); grades downward into unit 4; visible	30	196
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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 upper 4 to 4½ feet of the unit (GSC loc. 83911) include fragments of a probable 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 8½ to 9½ 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 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 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 2½ to 3½ 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 quarry (Pl. IIIA)		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 is exposed on the eastern side of the confluent's bed (i.e., of the waterfall; *see* Pl. IIIA) 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 contains several 6- to 18-inch interbeds of thinly bedded to laminated, dull grey argillite which locally are con-depositionally 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 of confluent's bed (Pl. IIIB), its northeastern 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 (¼ 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	4½	75
12	Interbedded dark grey to dark brown, soft shale and very fine grained, green-grey greywacke in ½- to 2-inch beds and lamellae; grades into underlying bed	3½	70½
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 9½ to 10½ 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 pele-		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	cypods; lithologically, the unit resembles 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
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	
	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) 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 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°37′36″W and the point about ½ mile farther southeast at latitude 50°29′26″N, longitude 127°36′53″W.

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 contains a fair number of limestone fragments in addition to prevalent volcanic fragments; the following 18 to 20 feet includes 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
	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. IVA) 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		

Unit	Description	Thickness (feet) of unit	above base
	an indeterminate pectinid 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 ½ mile southeast of its tip; strike is N5° 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.

RHAETIAN STAGE?

Volcanic Division

Hecate Cove Formation

Unit	Description	Thickness of unit	above base
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 includes 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, with abundant grey- to rust-coloured impure limestone matrix between clasts; occurs in 6-inch to 1½-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

MIDDLE JURASSIC

Coast Intrusions

Unit	Description	Thickness of unit	above base
4	?Diorite porphyry, dark grey, fine- to medium-grained and rich in medium-sized, calcitic amygdales; locally		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 latitude 50°32′26″N, longitude 127°36′00″W.

	HETTANGIAN STAGE?		
	Volcanic Division		
	Basal Jurassic volcanic unit		
1	Lava, predominantly maroon to brick-red, 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 Islet on which Quatsino Hotel and Post Office are situated; this is unit 9 of section 8 (*see* p. 176); visible	150 (est.)	2,154

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 of various volcanic rocks; a considerable percentage of clasts consists of bluish grey to dark grey, fine-grained to cryptocrystalline limestone, which includes 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 (honeycombed), 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 probable 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	
6	Limestone, dark grey, impure (mostly tuffaceous); contains abundant fragments and rounded (¼ inch to 3 inches) inclusions of lighter grey, softer limestone and 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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
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; contains 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 over all continuity of the sequence does		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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
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 ⅛ 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 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 a 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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?
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 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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-sized volcanic fragments embedded in abundant matrix of dull grey, whitish grey weathering limestone; lenses 3 to 5 feet thick and irregular 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
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 (pectinid?) 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 mylonitized 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) or 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. IIIA).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	RHAETIAN STAGE?		
	Volcanic Division		
	Hecate Cove Formation		
1	Basic lava, dark green to almost black, abundantly and coarsely porphyritic with many large, well-formed ?augite phenocrysts, groundmass felsitic to ?trachytic; 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, waterlain 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 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 unit 3 of section 1 (*see* p. 162); 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 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 feet. 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).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 noncalcareous; 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* p. 30–31); 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 6 and of beds 3 to 5 of section 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) of unit	Thickness (feet) above base
	LOWER CRETACEOUS		
	Upper Valanginian and ?Hauterivian greywacke–conglomerate unit		
1	Pebble-conglomerate, grey; fine to medium; 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.)	2,190
	?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) poorly exposed but probably conformable; cut by several dykes and irregular bodies of very porphyritic, medium- to coarse-grained ?dioritic intrusive rock	300 (est.)	2,155
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.)	1,855
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; the interval probably underlain by interbedding of these rocks throughout	700 (est.)	1,395
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.)	695

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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.)	535
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°W)..	60 (est.)	210
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 unit 1 of section 4 (*see* p. 168); 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
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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
4	Lava, light grey to bluish grey, speckled, fine amygdaloidal, massive; interbedded with some lavender to dark reddish grey 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 1½ 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).

?LATE HETTANGIAN STAGE (LOWER JURASSIC)

Volcanic Division

Grey volcanic unit

1	Volcanic tuff, dull rose to dull red, 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.)	779
2	Lava, grey, massive, aphanitic to fine-grained; considerably disturbed by faults and sheared; lower contact poorly exposed and may be faulted..	50 (est.)	699
3	Lava, purple-grey, banded, amygdaloidal; interbedded with 2- to 5-foot-thick bands of grey, massive, aphanitic to fine-grained (?trachytic) lava; lower contact appears to be conformable..	40 (est.)	649
4	Volcanic rock (?lava), dark grey, massive, aphanitic; base faulted; visible..	180 (est.)	609
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) of unit	Thickness (feet) above base
	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 (½ 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 (½- 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 2½-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. Twenty to forty feet below top, the cherty lamellae are largely replaced by 1- to 4-inch thick, irregularly limited, concretionary beds; 23 to 26 feet below top, rock is replete with 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 ½- 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 ½- to 1½-foot-thick beds; replete with laminae of black chert or very cherty limestone, ½ 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
14	Limestone, dark grey to black, thin-bedded to laminated (beds and layers, ½ 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
	?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 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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. 54) north of the mouth of Kwatleo Creek; strikes 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 ¼- to 1-inch thick interbeds of similarly coloured calcareous volcanic tuff; top covered, lower contact conformable; visible	25 (est.)	255
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 (¼ to ½ 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	

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	?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 (½- to 1-inch layers) or laminated; considerable number of similarly thick interbeds and laminae of black chert and siliceous shale; badly disturbed by faults or completely crushed; no estimate of thickness possible; exposures extend along the shore for about 400 feet and are in fault contact with 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 mile northeast of the mouth of Browning Inlet (latitude 50°29′40″N, longitude 128°02′40″W approximate).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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	1,144
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	1,124
	?UPPER HETTANGIAN		
	Volcanic Division		
	Grey volcanic unit		
3	Lava, grey, strongly amygdaloidal, commonly with pronounced pillow structures; medium to thinly banded; strongly sheared....................................	55	1,109

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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

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

Volcanic Division

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

Matthews Island Formation

Upper argillite member

2	Argillite, black to dark grey, locally arenaceous, thin 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 2½ miles southwestward of section 13 (latitude 50°29′06″N, longitude 128°02′30″W approximate).

SINEMURIAN (LOWER JURASSIC)

Volcanic Division

Uppermost Sinemurian volcanic unit

1	Lava, green-grey, bluish green, reddish to dull grey, purple and brick-red to maroon; these colours replace each other 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	
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 1½ 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
6	Volcanic breccia, reddish grey, medium (fragments from ⅛ 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
	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, ½ 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
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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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; contains 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 $1\frac{1}{2}$ feet thick; lamellae and layers (as much as 2 inches thick) of light grey, fine- to coarse-grained, partly tuffaceous, often calcareous greywacke, similarly coloured, impure limestone and interbeds 1 to 6 inches thick, or softer, fissile shale occur at regular intervals of from 1 to 5 feet thick; a $2\frac{1}{2}$-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. 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 (16); 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	?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) of unit	Thickness (feet) above base
	SINEMURIAN STAGE		
	Volcanic Division		
	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 3 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 arenaceous and/or tuffaceous; some thin layers and 1- to 2-foot-thick		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 ½ 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 Islands. 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 STAGE (LOWER JURASSIC)

Volcanic Division

Uppermost Sinemurian volcanic unit

1	Lava, light grey, abundantly and coarsely amygdaloidal; amygdules composed of grey 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 ½ 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 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 whole thickness 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 1½ feet; their numbers seem 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
	Waterlain tuff member equivalent (argillaceous facies)		
9	Argillite, black to brownish grey, partly tuffaceous or arenaceous; thinly bedded; some loaf-like concretions, 1–3		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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, 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 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* 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.)	

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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; 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 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
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	

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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, 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 covered interval 21 the rocks of unit 17 and units 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
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, 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, 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) of unit	Thickness (feet) above base
	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 3 is uneven 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 one another or even		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 Islands (latitude 50°27′36″N, longitude 127°47′06″W).

SINEMURIAN STAGE (LOWER JURASSIC)

Volcanic Division

Uppermost Sinemurian argillites

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N10–20°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 volcanic unit

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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
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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	matrix; minor interbeds of similarly coloured coarse-grained, tuffaceous, 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 Islands 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 stratigraphic top of the unit in proximity of ?dacitic intrusion occupying the southern side of the entrance to the lagoon; (*see* Coast Intrusions): strike N50–60°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
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 N60–70°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)	¾ 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).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	?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 N70°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
	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, 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 N80°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
7	Completely covered across general strike; probably underlain by the same greywacke as in units 6 and 8..............	110 (est.)	280

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N50°–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 is more calcareous and contains 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 locs. 23275, 23281); *Homolsomites quatsinoensis* (Whiteaves), *Acroteuthis* (*Acroteuthis*) 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

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) of unit	Thickness (feet) above base
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)

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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.)	274?

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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
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 greywacke, 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 N40–50°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 ½- 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 (⅛- to ½-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	3½	72
8	Irregular interbedding of pebble-conglomerate as in bed 7 with greywacke as in bed 6 and with fine- to coarse-grained, pebbly, bluish grey grit; the basal grit interbed overlaps erosionally disconformably and probably regionally unconformably the uneven surface of unit 9	3½	68½
	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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N70° 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) of unit	Thickness (feet) above base
	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 N30°–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,		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	slightly to moderately sandy, contains numerous, loaf-like to spheroidal concretions, 1–3 feet long and 6 inches to 1½ 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 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 8½ 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
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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N40–50°W to N30–40°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-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 N10°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 1½ 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 Klootchlimmis Creek (latitude 50°29′42″N, longitude 127°41′30″W).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N30°–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 N70–80°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 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 N10°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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N50°–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
	?HETTANGIAN STAGE		
	Volcanic Division		
	Basal Jurassic volcanic unit		
9	Volcanic breccia, green-grey for the most part but becomes tawny to reddish grey 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 Klootchlimmis 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 ½ 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 N50°E and dip 25° to 30° west; both contacts are covered; exposures poor and intermittent; visible........	25 (est.)	108
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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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-sized, better rounded pebbles or coarse grit; strikes N50°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 N20°–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 Island at the point about 600 feet east of the base of section 26 (latitude 50°27′48″N, longitude 127°48′14″W).

LOWER CRETACEOUS

Upper Valanginian and (?)Hauterivian greywacke–conglomerate unit

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
1	Greywacke, bluish grey, coarse-grained and gritty, massive-looking and concretionary weathering; numerous inclusions and interbeds of fine to coarse grit; corresponds to unit 15 of section 26 (*see* p. 206); 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 N60–70°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 1½ 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		

Unit	Description	Thickness (feet) of unit	above base
	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
5	Siltstone, blackish grey to almost black, strongly conchoidally weathering; slightly arenaceous, strike N40°–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 Island 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 island at latitude 50°27′ 48″N and longitude 127°48′22″W.

LOWER CRETACEOUS

Lower Barremian and/or ?Uppermost Hauterivian

Inoceramus colonicus calcarenites

Unit	Description	of unit	above base
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 N50–60°W, dip 50–55° east; top concealed beneath the sea on the northern side of the island; 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
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 consists 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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
7	Pebble-conglomerate, brownish grey; fine to coarse; pebbles are embedded 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 1½ 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 1½-foot-thick interbed of such coquina about 3 feet below the top; attitude as in		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	underlying beds; lower contact appears to be gradational	11	177
11	Pebble-conglomerate, medium to coarse, blackish to brownish grey, tightly packed; locally contains much calcareous, sandy matrix; 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- to 3-inch layer of very fine pebbles embedded in calcareous, sandy matrix	4	166

Upper Valanginian and (?)Hauterivian greywacke–conglomerate unit

?Hauterivian

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N50–60°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 N60–70°W, dip 40–45°E; base concealed beneath the sea on the southwestern end of the island; visible	55	150
14	Covered by sea water within a narrow channel separating the southwestern end of largest Salmon Island 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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N70°–80°W, dip 45°–50°E; top covered; visible	38 (est.)	60

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 Island (latitude 50°27′48″N, longitude 127°48′10″W).

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.)	192½
	Good exposures of unit 1 occur only about 240 feet east of the "neck" of the island on the western side of which section 26 was measured; however, the rocks of 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 island.		
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 and uneven and erosionally disconformable (Pl. VA) or regionally unconformable; thickness varies from ½ to 1½ feet within short distances.............	1½	157½

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N50°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. Limestone 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; 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 N40–50°E, dip 25°–30° west; base concealed beneath the sea near the southeastern tip of the island; 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 Island (latitude 50°28′00″N, longitude 127° 48′06″W).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 1½ feet thick, and inclusions of similarly coloured, brownish grey weathering, calcareous, locally fossiliferous greywacke; strike N40–50°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 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 2½ miles west of Alice Lake on the western side of a short, north-trending secondary logging road of the Rayoneer Co. Ltd., branching off Gibson Road 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 of about 20 yards 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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
	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 (½″–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 outcrops poorly and intermittently for 180 yards along the partly eroded roadbed and in overgrown road-cuts of secondary logging road; the lowermost visible 16 feet is 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 ⅛″ to ½″ predominate); mostly very poorly rounded and commonly grades into a mixed (sedimentary–volcanic) very fine breccia or coarse to very coarse, waterlain volcanic (crystal?) tuff; matrix appears to be tuffaceous to arenaceous; 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;		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 3½′ above base (GSC loc. 82955); top covered, visible	18	81
9	Pebble-conglomerate, coarse to fine, mottled greenish grey (*see* Pl. VIA, 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 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 (⅛″ to ½″) 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 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 Intrusions seen; upper contact gradational and rare scattered pebbles continue to occur in basal 6″–12″ of unit 8; attitude as in underlying 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	dark grey, sandy clay with scattered, ¼″ to ½″, 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-conglomerate; strike 335°, dip 18°W.................	13	37

LOWER JURASSIC

Volcanic division of Bonanza Subgroup (undivided)

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 2½ feet are bright orange, 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 of the unit; apparent strike in the topmost 6 feet is N15°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).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 has 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.)	
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) has yielded *Quoiecchia aliciae* Crickmay and other indeterminate pelecypods: the lowermost 3 to 4 feet exposed (GSC loc. 24292) has 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) of unit	Thickness (feet) above base
	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.)	4½
2	Oyster bank consisting of *Ostrea* (s. lato) sp. indet. (GSC loc. 82929) in greywacke matrix as in bed 1; lower contact gradational	½	3½
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, 1½ 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.

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 N30–40°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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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.)	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, multicoloured (with alternating grey, reddish, and tawny lamellae) sandy siltstone; strike N40°W, dip 40°E; both contacts gradational	200 (est.)	2,385
3	(?)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.)	2,185
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.)	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 N50–60°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
7	Completely covered for about 20 feet across general strike and thought to contain a major northwest-trending fault	20 (est.)	
	Blumberg Formation		
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 are intensely sheared and		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	jointed and shattered by countless, normally minor, strike and cross faults forming a great number of small to large fault blocks; general strike N30–40°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 again become 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 N40°–50°W and dip 75° to 80°E; the rocks are jointed, sheared, and cut by numerous minor strike faults; lower contact is abrupt and 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
	Coarse arenite unit		
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
11	Sandstone (subgreywacke?), light grey to brownish grey, intensively yellow to rusty weathering, mainly coarse and gritty (*see* Pl. VIIIA); 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 N70°W to N30°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 coloration 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.)	1,100

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N60°–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
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 Ahwhichaolto Inlet	120 (est.)	

UPPER CRETACEOUS

Cenomanian or ?Turonian stage

Upper shale unit

Shale–Siltstone Member

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 contains 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), aphanitic limestone; some ¼-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 N50°–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* unit 13); visible	250 (est.)	

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	This exposure of the Upper shale unit is evidently a part of a downdropped fault block of the Upper Cretaceous rocks unrelated to 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 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 (Pl. VIIIB).		
	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 from there, 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).

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 N50°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 N70°W, dips 25° to 30°E; lower contact poorly exposed but apparently conformable	90 (est.)	4,074

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
5	Greywacke (or subgreywacke?), grey, medium-grained, resistant and mostly massive looking; locally thinly bedded; strikes fluctuate from about east–west to N60°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 N60°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 N60–70°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 N60–70°W and dips 10° to 15°E; the dips decrease to 3–5°E near the top of the unit; rocks are strongly 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 N70°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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
13	Covered around the mouth of Denad Creek 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 honeycombed 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 N60°W, dip 35°E; both contacts conformable and gradational; the unit outcrops around a major wooded point covering the mouth of Denad Creek 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 N60°–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 (½ 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
19	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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N70°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 N80°W, dip 30°N; top covered; lower contact gradational.........................	42 (est.)	2,118
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 N70°W and dips vary from 30° to 40°W, strike near the top is N70°–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 is composed predominantly of dark grey, fine-grained, very argillaceous greywacke; strike N60°–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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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
29	Sandstone (subgreywacke?), grey-green, coarse-grained, gritty, resistant, heavily bedded; regularly tilted and not disturbed otherwise; strike N80°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 N50–60°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 and 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 fine-grained, friable greywacke and arenaceous shale as in unit 32 are rare or absent; strike N50°–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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N50°–60°W, dips 35° to 40°E, and the rocks are virtually undisturbed otherwise; both contacts conformable and gradational	255 (est.)	480
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 multicoloured lamellae), fine-grained, friable greywacke; no fossils of any kind; near the base the rocks strike N50°–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-quarters mile wide, between the mouth of Aweisha Creek and the extensive exposures of Blumberg Formation west from there (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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	coloured, soft and friable, fine-grained, partly laminated, clayey greywacke; strike N30°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 N20°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

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); numerous large pyrite crystals; this intrusive dyke strikes N50°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 N10°E, dips 40°W; both contacts cut off by intrusive rocks of dykes 7 and 9	45 (est.)	125

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 intrusive dyke strikes north–south and dips about 90°	2	
	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 N10°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 N30° 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 indistinguishable from those of the underlying beds; higher up these pebbles become rare; strike N70°E, dip 25° to 30°W; contact with bed 2 sharp, somewhat uneven and suggestive of an erosional disconformity (Pl. IXA); top not reached in the shore bluffs; visible up to	100 (est.)	280

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 conglomeratic and gritty interbeds until it is composed almost exclusively of fine-grained greywacke irregularly interbedded with an equal amount of dark grey to multicoloured (in thin layers or laminae), laminated, more or less arenaceous, locally somewhat carbonaceous siltstone (Pl. IXB); 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 N50°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
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 1½ 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 N70°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 N40°–50°W and dips from 3° to 10° west; top and base concealed, visible	15 (est.)	29

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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).

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 ½ 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 pebble-conglomerate probably derived from the underlying Lower Cretaceous rocks occur more rarely; the presence of boulders of conglomerate lithologically identical with that characterizing the lower part of the Blumberg Formation (*see* Pl. XB) 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* p. 105); 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.)	
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 N10°–20°W, dip 20° to 25°E; lower contact conformable and gradational	15 (est.)	2,880

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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 N20°W to N10°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 this interval; elsewhere it strikes north–south to N10°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 is 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

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 sulphide 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.)	

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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
	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 ½ 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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	greywacke and pebbly grit are rare; strikes range from N80°W to N40°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 throughout 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.)	
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 N40°–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		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 N20°E and dip 20°W; upper contact covered; lower contact appears to be conformable; visible..	60 (est.)	80
19	Pebble-conglomerate as in overlying beds; strike N10°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 vermilion-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.)	

Section 37. (*Field No. 251/2-6, 1954*). Measured on the northern shore of Rupert Inlet between the point 2¼ 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).

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 In-		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	trusions 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 ½ to 1½ 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.: *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.)	
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

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
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
	Coarse arenite unit		
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
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 ½- 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.

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	UPPER CRETACEOUS		
	Cenomanian Stage		
	Upper shale unit		
	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 N50°E and dips 19°E; top covered; lower contact gradational; visible	3	8½
2	Pebble-conglomerate, fine to medium (½- 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, ½-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	½	5½
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	
	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 altitude ± 2,100 and 2,500 (latitude 50°28′15″N, longitude 127°29′ 00″W).

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	UPPER CRETACEOUS		
	Nanaimo Group		
	Cedar District equivalents		
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.)	261.5
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 throughout; no attitude; base and top covered; assumed thickness..	70	111.5
	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 ¼″ 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 N10°E with dip 5°W; top concealed everywhere, visible up to..........	6	
	The above-described rhyolitic dyke outcrops throughout an interval, about 15 yards long, at the northern end of previously mentioned secondary logging road (*see* Pl. XIIB).		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	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 intensively crossbedded; some crossbeds are large (1–3 feet across), low, scalloped, and apparently deltaic to beach type; some interbeds of indistinctly bedded, massive-looking sandstone; persistent and reliable strike N40°E to N50°E with dips about 10°W; outcrops mostly poor and discontinuous	25	41½
5	Pebble-conglomerate, fine to very fine, pebbles from ⅛″ to ¼″ 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	4	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, sensu Usher, 1952, *Inoceramus chicoensis* Anderson, *Inoceramus* ex aff. *balticus* Böhm, and "*Rhynchonella*" *suciensis* Whiteaves; visible	4½	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 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

INDEX

PAGE

Acanthopleuroceras cf. *sutherlandbrowni*....58, 59
Acanthotriletes cf.... 232
Acanthotriletes varispinosus.... 232
Acroteuthis (*Acroteuthis*) sp. indet....74, 196
Acroteuthis (*Boreioteuthis*) aff. *impressa*.... 83, 88, 91, 92, 199, 209, 210
Acroteuthis (?*Boreioteuthis*) sp. indet.... 207
Acroteuthis cf. *pseudopanderi*....82, 91, 211
"agglomeratic" limestone....32, 33
Ahwhichaolto fault zone.... 99
Ahwhichaolto Inlet....39, 40, 42, 43, 44, 71, 73, 74, 76, 78, 97, 98, 100, 104, 112, 130, 131, 132, 133, 214, 215, 217
Alberni map-area.... 69
Alberta.... 107
Albian....67, 82, 95, 96, 100, 103, 106, 107, 108, 109, 111, 113, 134, 229, 231, 232
Alert Bay.... 138
Alice Lake....22, 24, 25, 114, 209
Amygdaloidal flows unit.... 8
Appendicisporites perplexus....107, 232
Appendix.... 161
Apple Bay....35, 72, 82, 90, 99, 122, 123, 214, 226
Aptian....82, 88, 93, 95, 96, 100, 101, 103, 107, 109, 113, 114
Aptian tectonic land.... 101
Arenaceous member....16, 17, 18, 19, 21, 24, 25, 34, 35, 49, 133, 141, 162, 172, 173, 174
Argillite unit....17, 18, 162, 172, 173, 174
?*Argonauticeras* aff. *argonautarum*....88, 209
Arietites bucklandi....44, 48
arietitid ammonites....48, 49, 185, 188
Arnioceras kwakiutlanus.... 44
Arnioceras semicostatum.... 48
Arnioceras sensu lato sp. indet....48, 189
?*Arnioceras* sp. indet....48, 185
Arniotites (genus)....48, 50, 58
Arniotites kwakiutlanus....48, 49
Arniotites vancouverensis.... 58
?*Astarte* sp. indet....113, 199, 209
Asteroceras aff. *A. obtusum*.... 49
Atkins Cove.... 16
Aucella piochii....73, 74
?*Aucellina* sp. indet....92, 209, 213

PAGE

Aweisha Creek....72, 80, 81, 82, 99, 106, 118, 135, 175, 223, 225
Aweisha Creek fault.... 135

Baculites cf. *chicoensis*.... 114, 236
Baculites (*Sciponoceras*) n. sp. ex aff. *kossmati*.... 234
Bajocian stage....67, 68, 69, 70
Balaklava Island....58, 59
Banter Point....21, 24, 29, 30, 166, 167, 174
Barkley Sound.... 63
Barremian fine-grained greywacke unit....85, 87, 88, 89, 93, 96, 100, 131, 207, 209
Barremian stage....40, 67, 72, 80, 81, 82, 83, 84, 85, 87, 88, 89, 90, 91, 92, 93, 95, 100, 207, 212, 214
Barremian variegated clastic unit....87, 89, 90, 91, 92, 93, 96, 99, 100, 107, 114, 209, 210, 213, 214, 236
Basal coarse clastic member....90, 92
Basal Jurassic volcanic unit....27, 30, 34, 41, 42, 53, 61, 122, 132, 133, 134, 138, 139, 140, 141, 168, 175, 176, 179, 191, 202, 203, 213
Basal Pliensbachian volcanic unit.... 50
Basal variegated member....46, 47, 48, 49, 190
Bathonian stage.... 70
Berriasian stage.... 67
Bish Creek....109, 111, 112, 118, 140, 227, 234
Black argillite member....57, 58
Black carbonaceous limestone member.... 58
Blumberg conglomerates....107, 109, 118, 119, 120
Blumberg Creek....103, 121
Blumberg Formation....95, 96, 97, 99, 100, 101, 103, 104, 105, 106, 107, 108, 109, 111, 112, 118, 119, 120, 121, 132, 133, 134, 135, 215, 223, 225, 227, 228, 229, 230, 231
Bonanza Group....1, 8, 26, 28
Bonanza Lake.... 24
Bonanza Subgroup....9, 13, 14, 16, 42, 49, 51, 54, 56, 58, 59, 60, 68, 77, 122, 123, 125, 126, 139, 140, 141, 142, 211, 236

Bonanza Volcanics....142, 236
Brockton Island.... 40
Brooks Bay.... 74
Brooks Peninsula....13, 25, 71, 74, 76, 78, 85, 103, 107, 115, 122, 133
Browning Inlet....45, 46, 47, 50, 51, 52, 53, 54, 55, 62, 65, 67, 72, 73, 78, 126, 128, 129, 130, 131, 181, 182, 194
Browning Inlet fault....128, 129, 130, 132
Browning Inlet lagoon.... 139
Buchholz Channel....19, 29, 31, 167
Buchia crassicollis....54, 56, 65, 67, 73, 74, 77, 80, 81, 129, 195, 196, 197, 200, 203, 206, 207
Buchia crassicollis greywacke unit....72, 73, 74, 76, 77, 81, 131, 132, 195, 196
Buchia n. sp. aff. *inflata*.... 203
Buttle Lake (map-area)....9, 22, 24, 49, 57, 59, 69, 117, 121

Callovian stage....67, 70, 74
Campanian stage....114, 128
Canadian Western Cordillera.... 143
Cape Parkins.... 25
Cape Scott....62, 63, 74, 76, 78, 104, 122, 138
Carmanah Group.... 122
Cascade Mountains.... 88
Catala Island.... 55
Cedar District equivalents....114, 235, 236
Cedar District Formation.... 115
Celtites (?) *vancouverensis*....48, 192
Cenomanian stage....95, 107, 109, 111, 112, 113, 121, 122, 128, 217, 234
Cherty limestone unit....34, 41, 42, 43, 44, 54, 60, 61, 62, 132, 133, 139, 176, 178, 180, 181
Christensen Point....74, 78, 82, 85, 89, 90, 92, 93, 107, 109, 112, 113
Christensen Point Cretaceous outlier.... 107
Cicatricosisporites australiensis.... 232
Cicatricosisporites pallidus.... 232
Cicatricosisporites perforatus....107, 232
Cicatricosisporites sp....106, 232
Cleagh Creek....41, 72, 81, 134, 202
Cliffe Point.... 45
Coal Harbour....22, 24, 25, 72, 81, 82, 89, 90, 91, 95, 98, 99, 100, 107, 136
Coal Harbour–Alice Lake tectonic land....24, 35, 37, 125
Coal Harbour Cretaceous outlier....91, 95, 96, 100, 101, 103, 106, 136
Coal Harbour fault block....138, 141
Coal Harbour Group....90, 95, 104, 141, 214, 218, 223, 224, 225, 226, 227, 229, 231
Coal Harbour village.... 91
Coarse arenite unit....17, 90, 91, 96, 97, 98, 99, 100, 101, 103, 104, 106, 107, 109, 118, 131, 132, 135, 138, 214, 216, 218, 223, 224, 225, 226, 233
Coast Intrusions....2, 19, 45, 47, 54, 58, 63, 64, 65, 66, 67, 68, 71, 72, 103, 104, 117, 121, 122, 123, 126, 128, 129, 130, 139, 140, 142, 143, 167, 178, 180, 185, 187, 189, 194, 197, 201, 205, 211, 227, 229, 231, 236
Coast Mountains....63, 64
Coast Range.... 14
Coetkwaus Creek....138, 141
Columbianus Zone.... 16
Comox basin.... 115
Cowichan Lake....21, 25, 29, 56
Craspedodiscus cf. *discofalcatus*....78, 83, 84
Craspedodiscus (= *Hertleinites*).... 78
Crucilobiceras crucilobatum.... 54
Crucilobiceras sp. indet.... 55
Crucilobiceras spp....49, 52, 54
Cyathidites cf.... 232
Cyathidites minor.... 232

Dactylioceras.... 59
?Dark grey volcanic unit....55, 61, 63, 194
Dawsoni Zone.... 13
Deltoidospora sp.... 232
Denad Creek....104, 219, 220
Dentalium (s. lato) sp. indet.... 199
Desmoceras (*Pseudouhligella*) ex aff. *ezoanum*.... 234
Desmoceras (*Pseudouhligella*) *japonicum*.... 112
Dicotyledons.... 107
Dictyoconites sp. indet.... 13
Diggs Islet.... 120
Dilleri Zone....9, 14
Discotropites.... 11
Dockyard Islet.... 120
Drake Island....10, 19

Early Tertiary Intrusions.... 117
East Cove....105, 119, 120
Echioceras (*Melanhippites*) *harbledownensis*.. 47, 49, 50, 52, 53, 54, 58, 188
Echioceras raricostatum.... 49
Echioceras sp. indet....49, 187
Eocene.... 121
Eoderoceratidae (family).... 54
Eogunnarites unicum.... 234
Eotetragonites ex gr. *wintunius*.... 88
Entolium balteanum....54, 55
Esperanza Inlet....25, 29, 62, 130
Esperanza Peninsula.... 13
Eucalycoceras ex aff. *shastense*.... 113
Eulytoceras aff. *phestum*....87, 88, 209
Eulytoceras ex gr. *subfimbriatum*.... 88
?*Eulytoceras* n. sp. aff. *inequalicostatum*....87, 88
Eulytoceras sp. indet.... 207

PAGE

Fisherman Bay....74, 132
Flat Top Mountain....65, 129
Forward Inlet....43, 44, 45, 46, 47, 50, 51, 52, 62, 64, 65, 71, 72, 74, 78, 101, 134, 181, 192
Forward Inlet fault block....130, 139, 140

Franklin Creek Volcanics.... 20

Galato Creek....25, 45, 67, 71, 76, 97, 130, 131, 195, 196, 198, 218, 223
Galato Creek fault....130, 131, 132
Georgia Strait.... 70
Gibson road....40, 163, 174, 209, 235
Gleicheniidites senonicus.... 232
Gooding Cove.... 25
Graham Island.... 67
Grant Bay fault....129, 130, 132, 139
Grassy Island.... 68
Greenwood Point....43, 45, 65
Grey volcanic unit....34, 42, 43, 44, 45, 46, 47, 53, 61, 132, 133, 139, 177, 179, 181, 186, 191, 192
Greywacke member....109, 111, 112, 113, 234
Greywacke unit....17, 163

Haida Formation....67, 107, 112, 113
Halobia.... 13
Halobia alaskana....12, 13, 14
Hamlin–Broad zone.... 78
Hankin Point....72, 106, 136, 231
Haploxylon-type.... 232
Harbledown Formation....27, 38, 49, 50, 55, 57, 58, 59, 60, 63, 68
Harpoceras (genus).... 59
Harrison Lake.... 70
Hauterivian..40, 73, 74, 77, 78, 80, 81, 82, 83, 84, 85, 91, 92, 93, 135, 195, 206
Hauterivian siltstone unit....76, 77, 87, 131, 195, 198
Hawisnakwi Creek....10, 112, 135, 140
Hazard Point.... 65
Hecate Cove....27, 28, 168
Hecate Cove Formation....16, 17, 18, 19, 20, 21, 24, 27, 28, 30, 31, 32, 33, 34, 35, 37, 41, 43, 49, 52, 53, 61, 66, 123, 128, 133, 162, 166, 167, 168, 169, 171, 173, 174, 175
Hemihoplites n. sp. aff.... 88
Hemihoplites soulieri.... 88
?*Hemihoplites* sp. indet....87, 88
Hertleinites aguila....78, 84
Heterastridium sp. indet....18, 163
Heteroceras (*Heteroceras*) cf. *heliceroides*.... 87, 88, 89
Heteromorphs.... 93
Hettangian stage....34, 38, 42, 43, 44, 57, 61, 168, 175, 176, 179, 181, 191, 202
Hisnit Islets.... 25

PAGE

Hohoae Point.... 25
Holberg fault.... 40, 72, 99, 124, 128, 135, 136, 138, 140, 141, 142
Holberg Inlet....8, 11, 15, 22, 27, 29, 32, 35, 67, 82, 84, 85, 89, 92, 95, 106, 107, 122, 123, 135, 136, 213
Holberg village.... 109
Homolsomites aff. *oregonensis*.... 77
Homolsomites oregonensis....77, 199, 200
Homolsomites packardi.... 77
Homolsomites quatsinoensis....74, 196, 200
Honshu Island arc.... 143
Hope–Galiano Island.... 58
Hope Island.... 115
Hope–Nigei Island.... 58
Hoplotropites....11, 13
Hypophylloceras cf. *onoense*.... 88

Ildstad Islets....106, 109, 111, 113, 135
Ildstad (Islets) fault zone....134, 135, 140
Ingersoll Creek.... 64
Inoceramus aff.... 113
Inoceramus aff. *quatsinoensis*....88, 209
Inoceramus chicoensis.... 236
Inoceramus colonicus....78, 80, 81, 83, 89, 91, 93, 204, 205, 208
Inoceramus colonicus calcarenites....82, 83, 84, 85, 87, 88, 89, 91, 93, 131, 198, 204, 208
Inoceramus crippsi.... 234
Inoceramus ex aff.... 234
Inoceramus ex aff. *balticus*.... 236
Inoceramus incelebratus.... 113
Inoceramus labiatus.... 113
Inoceramus pictus.... 234
Inoceramus sp. indet....74, 112, 113, 196, 200, 217
Insular Lower Cretaceous Trough.... 74
Insular Tectonic Belt..22, 24, 29, 34, 38, 55, 56, 58, 59, 60, 61, 62, 69, 70, 71, 124, 125, 126, 127, 143
Insular Trough.... 95
Intermediate amygdaloidal lava member.... 51
Intermediate waterlain tuff member....46, 47
Iron River.... 57
Island Arc.... 143
"Island Intrusions".... 63

Jackass Mountain Group....88, 95
Japanese Archipelago.... 143
Jesdal Islet....28, 168, 169, 175
Johnstone Strait.... 59
Julian Cove....17, 19, 20, 30, 66, 135, 167, 174
Jurassic Coast Intrusions.... 117

Kains Peninsula.... 43
Kakwina Cove.... 11

PAGE

Karmutsen lavas....13, 211
Karmutsen Subgroup....8, 9, 11, 26, 39, 140
Karmutsen Volcanics..2, 8, 20, 123, 138, 142
Karnian stage....9, 14, 28, 59
Kashutl Inlet.... 25
Keith River.... 74
Kennedy Lake....56, 68
Kenny Point....11, 12, 13
Keogh River....115, 142
Kerri Zone....13, 14
Kewquodie Creek....41, 82, 87, 88, 135, 141
Kitten Islet....27, 168
Klaskino Inlet....18, 19, 21, 25, 29, 35, 37, 132
Klaskino Sound....16, 25
Klaskish River.... 25
Klayina Creek.... 218
Klootchlimmis Creek....10, 40, 72, 80, 81, 82, 201, 202
Koprino Cretaceous outlier....134, 135, 140, 141
Koprino Harbour....10, 17, 18, 24, 25, 35, 37, 52, 53, 64, 71, 72, 82, 83, 87, 98, 99, 101, 104, 105, 106, 109, 118, 119, 120, 121, 134, 141, 171
Koprino River.... 120
Koskimo Harbour.... 45
Koskimo Islets....39, 41, 42, 43, 133, 134, 139, 176, 177, 179
Kultus Cove....29, 37
Kunga Formation....57, 58
Kwakiutl Point....74, 115
Kwatleo Creek....53, 54, 55, 65, 71, 73, 129, 139, 180
Kyuquot–Esperanza area....55, 56, 62, 63, 68, 69, 70, 74, 78

Lakken Point.... 11
Late Hettangian stage.... 177
Late late Norian stage....172, 173, 174
Late Norian stage....162, 168
Late Tertiary volcanic rocks.... 122
Latest Sinemurian argillite unit.... 52
Lawn Point.... 74
Leeson Creek.... 182
Leeson Lake.... 131
Lind Cove.... 101
Lind Islet....98, 103, 105, 118, 119, 225, 226, 227, 231
Linthlop Islets....105, 119, 120, 121
Lippy Creek....14, 16, 17, 18, 19, 21, 29, 40, 89, 91, 93, 95, 114, 162, 173, 209, 235
Lippy Point.... 25
Longarm Formation....72, 89, 95
Lower argillite member....46, 47, 48, 49, 62, 185, 189, 192

PAGE

Lower Barremian and/or (?)Upper Hauterivian.... 198
Lower Barremian and/or (?)Uppermost Hauterivian....204, 208
Lower Cretaceous conglomerates.... 67
Lower limestone member.... 19
Lower Pliensbachian.... 194
Lower Pliensbachian argillite unit....53, 56
Lower Sinemurian....181, 192
Lower waterlain pyroclastic unit....51, 52
Lycopod.... 106
Lycopodiumsporites austroclavatidites.... 232
Lycopodiumsporites sp.... 232
Lytoceratid ammonites....74, 93

Mabbott Island.... 25
Macjack River....74, 130
Maestrichtian stage....122, 128
Magnus Zone.... 13
Mahatta Creek....43, 44, 46, 54
Mahatta fault (zone)....43, 45, 71, 99, 105, 120, 124, 128, 132, 133, 134, 135, 139, 140, 141
Mahatta logging camp....45, 46, 48, 50, 52, 53, 54, 187, 193
Malksope Inlet.... 25
Manning Park.... 88
Marble River....8, 10, 13
Matthews Island....44, 45, 129, 183
Matthews Island Formation....34, 40, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 55, 57, 58, 60, 61, 62, 63, 65, 68, 129, 139, 141, 181, 182, 184, 186, 188, 189, 190, 192, 198
Maude Formation....55, 57, 58, 59, 60, 63, 69
Metaplacenticeras cf. *pacificum*.... 115
Microderoceras (genus).... 54
Miocene.... 122
Mojsisovicsites kerri.... 13
Monkey Creek....45, 47, 50, 51, 53, 54, 66, 72, 133, 134, 141
Monocolpate.... 232
Monotis....13, 162, 163, 164, 165, 173
Monotis cf. *ochotica* var. *densistriata*....18, 162, 174
Monotis cf. *salinaria*.... 18
Monotis salinaria....18, 163, 164, 165
Monotis subcircularis....18, 22, 165
Montgomery Point.... 45
Mount Brandes.... 132
Mount Waddington....77, 78
Mya sp. indet.... 213

Nanaimo basin.... 115
Nanaimo Group....114, 115, 117, 120, 121, 128, 140, 142, 210, 235, 236

Narrow Island....39, 72, 100, 106, 138, 231, 233
Neocomian.... 67
Neomegalodon sp.... 169
Neroutsos Inlet....10, 11, 16, 19, 67, 81, 82, 84, 85, 89, 93, 95, 114, 115, 120, 135, 209, 235
Neroutsos Trough....24, 25, 35, 37
Nigei Island.... 58
Nimpkish Lake....59, 117, 136
Nimpkish map-area....13, 59, 124
Nordstrom Cove....25, 45, 48, 50, 186, 187
Norian stage....14, 16, 28, 33, 34, 38, 57, 61, 162, 165, 166
North Harbour.... 65
Nuknimish Creek....27, 82, 91, 122, 136, 213, 214

O'Connell Lake.... 25
Ohlsen Point....16, 31
Old Sport mine.... 64
Oligocene....117, 122, 128
One Tree Formation.... 68
Orr Islet.... 32
Osmundacidites wellmanii.... 232
Ostrea (s. lato) sp. indet....92, 214
Ououkinsh Inlet....9, 14, 25
Oxfordian.... 95
Oyster River.... 115

Palaeocardita sp.... 169
Palynomorphs.... 106
Paracochloceras sp. indet.... 20
Parson Bay.... 49
Parson Bay Formation....14, 29, 38, 57, 59
Partschiceras infundibulum....88, 209
Pectenids (indet.)....88, 172
?*Pholadomya* sp. indet.... 213
Phylloceratids (indet.)....88, 93
Pinus sp.... 232
Planorbis.... 178
Pleuromya vancouverensis.... 88
Plicatula? sp.... 33
Pliensbachian argillite unit.... 50
Pliensbachian stage....53, 54, 55, 56, 57, 58, 59, 63, 126, 129
Pliensbachian–?Toarcian greywacke unit.... 55, 56, 60, 61, 63, 126, 139
Pliocene.... 128
Port Alexander.... 58
Port Hardy....115, 142
Port McNeill....115, 122, 136
Prideaux Point....71, 72, 103, 105, 119
Projuvavites.... 11
Protetragonites cf. *quadrisulcatus*.... 199
Protetragonites sp. indet.... 200
"*Pterocera*" sp. indet.... 88
Puzosia (*Puzosia*) aff. *dilleri*.... 113

Quatse Lake....24, 138
Quatsino fault block....139, 140, 141
Quatsino Formation....8, 10, 14, 16, 20, 22, 29, 38, 57, 136, 140, 143
Quatsino Limestone....2, 10, 11, 13, 49, 114
Quatsino Narrows....8, 11, 16, 140
Quatsino Sound....16, 21, 22, 28, 37, 39, 40, 43, 45, 48, 49, 50, 51, 52, 53, 54, 57, 62, 63, 66, 67, 68, 71, 72, 74, 76, 78, 80, 81, 82, 83, 84, 85, 87, 89, 91, 92, 93, 95, 97, 100, 101, 103, 104, 107, 108, 109, 112, 113, 114, 115, 117, 118
Quatsino village....39, 45, 72, 97, 135, 140, 168
Queen Charlotte Islands....22, 24, 50, 57, 58, 59, 67, 68, 70, 89, 107, 112
Queen Charlotte Strait..10, 57, 58, 59, 70, 115
Queen Cove.... 25
Quoiecchia aliciae....82, 91, 92, 95, 96, 99, 100, 213, 214

Raricostatum Zone....49, 52, 53, 54, 55
Rayoneer Co. Ltd.... 209
Red Island.... 39
Relay Mountain Group.... 72
Rhaetian stage....33, 34, 38, 57, 61, 125, 128, 162, 166, 167, 168, 169, 171, 173, 174
Rhynchonella suciensis.... 236
Robson Cove....71, 99, 105, 120, 133, 141, 171
Robson Cove fault....134, 140, 141
Robson Island....129, 183, 192
Rupert Arm.... 136
Rupert Inlet....8, 11, 16, 27, 39, 52, 64, 66, 72, 82, 84, 85, 93, 99, 101, 103, 106, 107, 126, 135, 136, 138, 141, 231
Rupert Inlet fault....135, 136, 138, 141, 142
Rupert Inlet fault block.... 142
Rutherfordi Zone.... 13

Sagenites sp.... 165
Salmon Island....45, 66, 72, 74, 78, 80, 81, 82, 83, 84, 85, 87, 132, 134, 187, 193, 194, 203, 204, 207, 209
San Josef Bay.... 130
Saxonian tectonics.... 143
Schloss Island....104, 120, 133
Section 1....162, 174
2.... 166
3.... 167
4.... 168
5.... 171
6....173, 174
7.... 174
8.... 175

PAGE

Section 9 ... 176, 181
10 ... 177, 179, 180
11 ... 179
12 ... 181
13 ... 182
14 ... 182, 183, 186
15 ... 186
16 ... 187, 194
17 ... 192
18 ... 193
19 ... 194
20 ... 195
21 ... 196, 200
22 ... 198
23 ... 201
24 ... 202
25 ... 203
26 ... 203, 204, 207
27 ... 207
28 ... 209
29 ... 209, 236
30 ... 213
31 ... 214
32 ... 214
33 ... 218
34 ... 223
35 ... 225
36 ... 227
37 ... 231
38 ... 234
39 ... 209, 235
Sedimentary division ... 74, 140, 162, 166, 168, 172, 173, 174, 211, 236
Selaginella sp. ... 232
Serpula-like worm tubes ... 210
Shale–siltstone member ... 111, 112, 113, 217
Shapland Cove ... 105, 134, 230
Shapland Cove fault ... 134, 135, 140, 230
Shasticrioceras ... 84
Shasticrioceras cf. *poniente* ... 84, 88, 208
Sherberg Islet ... 175
Siberia ... 107
Sieward Hill ... 25
Siltstone–greywacke member ... 90, 91, 92, 213, 214
Simbirskites (*Simbirskites*) *broadi* ... 77, 78, 83, 198, 199
Simbirskites (*Simbirskites*) *lecontei* ... 78, 199
Sinemurian stage ... 34, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 58, 59, 61, 62, 65, 66, 129, 182, 183, 184, 186, 187, 188, 190, 193
Smith Cove ... 19, 24, 29, 30, 66, 135, 167
Sooke (Intrusives) Intrusions ... 67, 68, 90, 107, 117, 118, 119, 120, 121, 122, 128, 224, 225, 228, 229, 235
Southwestern tectonic land ... 25
Speetoniceras-Simbirskites (*Hollisites*) ... 77
Spencer Cove ... 43, 44, 71, 82, 83, 87, 97, 99, 133, 141, 171

PAGE

Sproat Lake ... 56, 62, 69, 70
Stewart Point ... 11, 13, 17, 72, 98, 99, 106, 136
Straggling Islands ... 122
Stranby River ... 109
Suessi Zone ... 18, 19, 20, 21, 22, 24, 29, 34, 35, 57, 58
Suquash (area) basin ... 115
Suquash Creek ... 115
Suquash mine ... 115
Sutton Formation (or Limestone) ... 10, 18, 19, 20, 21, 24, 25, 27, 34, 35, 66, 166, 168

?*Tancredia* sp. indet ... 213
Taseko Lake map-area ... 72, 77, 78, 83
Tatchu Creek ... 55
Tatlayoko Lake ... 70
Ten-o-suh River ... 105
Tertiary ... 122, 126, 128, 130, 134, 140, 143, 228, 229, 235
Tertiary ?Sooke Intrusions ... 64
Tetragonites ex aff. *T. jacksonense* ... 113
Tetragonites sp. indet ... 113
Texada Island ... 115
Thinly bedded member ... 14, 18, 49, 74, 165
Toarcian stage ... 54, 56, 57, 58, 59, 63, 126, 129
Toxaster ... 113
?Tricolpate ... 232
Trigonia (*Pterotrigonia*?) cf. *kayana* ... 199
Triplanosporites sp. ... 232
Tropidoceras sp. ... 59
Tsugaepollenites cf.
Tsugaepollenites mesozoicus ... 232
Tuffaceous argillites ... 57
Turonian stage ... 107, 112, 113, 217
Twin Peaks ... 122
Tyaughton Trough ... 72, 95

Union Island ... 13, 14
Upper argillite member ... 46, 47, 48, 49, 51, 52, 62, 182, 184, 186
Upper Hettangian ... 181, 186, 192
Upper Shale unit ... 104, 105, 107, 109, 111, 112, 113, 217, 234
Upper Valanginian ... 195, 196, 206
Upper Valanginian and ?Hauterivian greywacke–conglomerate unit ... 80, 81, 82, 83, 91, 135, 175, 201, 202, 203, 206
Upper waterlain pyroclastic member ... 51, 52, 53
Upper Yakoun Formation ... 67
Uppermost Sinemurian argillite unit ... 49, 51, 52, 53, 54, 55, 60, 61, 63, 65, 68, 133, 139, 141, 180, 188, 193
Uppermost Sinemurian volcanic unit ... 50, 51, 52, 53, 61, 62, 65, 133, 139, 141, 182, 183, 186, 187, 193

PAGE

Valanginian..40, 54, 56, 65, 67, 68, 72, 74, 76, 77, 78, 80, 81, 82, 83, 85, 95, 135
Valanginites n. sp. ex aff. *V. nucleus*............. 77
Vancouver Group............2, 8, 32, 33, 65, 72, 90, 103, 104, 117, 124, 125, 126, 135, 136, 139, 140, 141, 142, 197, 201, 205, 227, 229, 231
Vancouver Island–Queen Charlotte Islands Trough... 95
"Vancouver series".. 124
Varney Bay................................10, 11, 14, 140
Verrucosisporites sp.. 232
Vitreisporites pallidus...................................... 232
Volcanic division................26, 27, 28, 39, 42, 44, 49, 54, 55, 56, 57, 58, 59, 60, 69, 77, 126, 129, 130, 132, 138, 139, 140, 141, 162, 166–168, 171–194, 198, 202, 203, 211, 212, 213

Waterlain breccia unit.................................... 27

PAGE

Waterlain tuff member......................49, 62, 182, 184, 187
Waterlain tuff member equivalent................ 188
Waukwass Creek..24, 27
Wedel Island....................................97, 131, 198
Welleri Zone..11, 13, 14
West Coast Trough.. 25
Weyla sp...48, 190
Winter Harbour..........45, 46, 47, 50, 65, 67, 71, 73, 76, 83, 84, 97, 98, 100, 101, 104, 109, 112, 130, 131, 132, 195, 196, 198, 214, 217, 218
Woss Lake.. 22

Yakoun Formation.............................59, 69, 70
Yogtook Creek...32, 35
Yreka Copper mine.. 64

Zeballos–Nimpkish map-area......................64, 65
Zenaad River... 104

BULLETINS

Geological Survey of Canada

Bulletins present the results of detailed scientific studies on geological or related subjects. Some recent titles are listed below (Information Canada No. in brackets):

215 Brachiopods of the Arisaig Group (Silurian-Lower Devonian) of Nova Scotia, *by* Charles W. Harper, Jr., $5.00 (M42-215)

216 Baffin Island sandurs: a study of Arctic fluvial processes, *by* M. Church, $6.00 (M42-216)

217 The geology and petrology of the alkaline carbonatite complex at Callander Bay, Ontario, *by* John Ferguson and K. L. Currie, $2.00 (M42-217)

218 Keweenawan volcanic rocks of Michipicoten Island, Lake Superior, Ontario (41N). An eruptive centre of Proterozoic age, *by* R. N. Annells, $5.00 (M42-218)

219 Lower Cretaceous Bullhead Group, between Bullmoose Mountain and Tetsa River, Rocky Mountain Foothills, northeastern British Columbia, *by* D. F. Stott, $6.00 (M42-219)

220 The stratigraphy and mineralogy of the Sokoman Formation in the Knob Lake area, Quebec and Newfoundland, *by* I. S. Zajac, $5.00 (M42-220)

221 Chitinozoa and Acritarcha of the Hamilton Formation (Middle Devonian), southwestern Ontario, *by* J. A. Legault, $4.00 (M42-221)

222 Contributions to Canadian Paleontology, *by* D. E. Jackson, *et al.*, $6.00 (M42-222)

223 Ordovician trilobites from the Keele Range, northwestern Yukon Territory, *by* W. T. Dean, $2.00 (M42-223)

224 Carboniferous and Permian stratigraphy of Axel Heiberg Island and western Ellesmere Island, Canadian Arctic Archipelago, *by* R. Thorsteinsson, $6.00 (M42-224)

225 Quaternary stratigraphy of the Moose River Basin, Ontario, *by* R. G. Skinner, $3.00 (M42-225)

226 Sedimentology of Pleistocene glacial varves in Ontario, Canada Part "A", and Nature of grain-size distribution, Part "B", *by* Indranil Banerjee, $4.00 (M42-226)

227 The Bennett Lake Cauldron Subsidence Complex, British Columbia and Yukon Territory, *by* M. B. Lambert, $6.00 (M42-227)

228 Quaternary geology and geomorphology of Assiniboine and Qu'Appelle valleys of Manitoba and Saskatchewan, *by* R. W. Klassen, $4.00 (M42-228)

229 Metamorphic and plutonic rocks of northernmost Ellesmere Island, Canadian Arctic Archipelago, *by* Thomas Frisch, $4.00 (M42-229)

230 Triassic rocks of the Southern Canadian Rocky Mountains, *by* D. W. Gibson, $4.00 (M42-230)

231 *Yohoia* Walcott and *Plenocaris* n. gen. arthropods from the Burgess Shale, Middle Cambrian, British Columbia, *by* H. B. Whittington, $3.00 (M42-231)

232 Conodonts of the Waterways Formation (Upper Devonian) of northeastern and central Alberta, *by* T. T. Uyeno, $4.00 (M42-232)

234 Evolution of a Middle and Upper Devonian sequence from a clastic coastal plain–deltaic complex into overlying carbonate reefs and banks, Sturgeon-Mitsue area, Alberta, *by* L. F. Jansa and N. R. Fischbuch, $5.00 (M42-234)

235 Contributions to Canadian Paleontology, *by* A. J. Boucot, *et al.*, $6.00 (M42-235)

236 Palynologic analyses of Upper Mesozoic and Cenozoic rocks of the Grand Banks, Atlantic Continental Margin, *by* G. L. Williams and W. W. Brideaux, $5.00 (M42-236)

237 Carboniferous ammonoids and stratigraphy in the Canadian Arctic Archipelago, *by* W. W. Nassichuk, $7.00 (M42-237)

241 Silurian Ostracoda from Anticosti Island, Quebec, *by* M. J. Copeland, $5.00 (M42-241)

242 Mesozoic and ?Tertiary rocks of Quatsino Sound, Vancouver Island, British Columbia, *by* J. A. Jeletzky, $7.00 (M42-242)

243 The Jurassic Faunas of the Canadian Arctic: Lower Jurassic ammonites, biostratigraphy and correlations, *by* Hans Frebold, $4.00 (M42-243)