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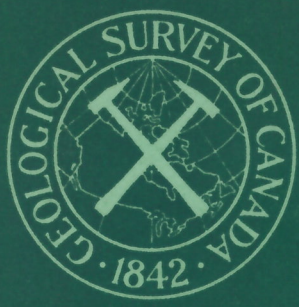

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 52

PALAEOECOLOGY OF THE MARINE PLEISTOCENE FAUNAS OF SOUTHWESTERN BRITISH COLUMBIA

Frances J. E. Wagner

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By
Frances J. E. Wagner

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PREFACE

Study of the surficial deposits on the southern coast of British Columbia indicates several advances and retreats of glaciers. As the deposits formed by them are the material on and in which construction now proceeds, a clear understanding of the nature and sequence of deposition is desirable for intelligent planning.

Much may be learned of the environment in which the deposits were formed by a study of the marine shells they contain and this report is based on such a study.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, November 26, 1958

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PALAEOECOLOGY OF THE MARINE PLEISTOCENE FAUNAS OF SOUTHWESTERN BRITISH COLUMBIA

Abstract

This report is based on studies in the lower Fraser Valley region and in the Qualicum-Alberni area of Vancouver Island. In it are listed all marine species from Pleistocene and Recent deposits identified by the writer together with those listed in earlier publications. All lived within a period dating back to about 25,000 years before the present.

It is concluded that the water temperature for the oldest Pleistocene faunas was comparable to the present temperature of Bering Sea, and for the younger Pleistocene faunas to that of northern Gulf of Alaska. Early Recent faunas indicate a somewhat warmer temperature. Warming of the sea apparently lagged slightly behind that of the land.

All forms lived in shallow water, 20 fathoms or less, in bays or estuaries.

Résumé

Le présent rapport se fonde sur des études effectuées dans la vallée inférieure du Fraser ainsi que dans la région de Qualicum-Alberni (île Vancouver). Il contient la liste de toutes les espèces marines des formations pléistocènes et récentes qui ont été identifiées par l'auteur, en plus de la liste des espèces dont il est fait mention dans des publications antérieures au présent rapport. Les plus anciennes parmi ces espèces remontent à environ 25,000 ans.

On en conclut que la température de l'eau à l'époque où vivaient les animaux les plus anciens du pléistocène se compare à la température actuelle de la mer de Béring. Pour ce qui est des animaux marins pléistocènes plus récents, la température de l'eau dans laquelle ils vivaient était à peu près égale à celle de la partie septentrionale du golfe d'Alaska. Quant aux faunes du début de l'époque récente, la température de leur habitat aurait été légèrement plus élevée. La mer paraît s'être réchauffée un peu moins rapidement que le continent.

Tous ces animaux vivaient en eau peu profonde, par 20 brasses au plus, dans des baies ou dans des estuaires.

Chapter I

INTRODUCTION

The purpose of this study, begun during the 1951 field season, is to enumerate the marine Pleistocene species found in the area, and to attempt to interpret on the basis of the fossil record the ecological conditions of the non-glacial intervals of the past 25,000 or more years.

The faunas come primarily from the lower Fraser Valley area of the British Columbia mainland, and from the Qualicum district of Vancouver Island. Material from other collections of the Geological Survey of Canada is also considered, as well as faunal lists by various authors from localities both within the particular areas examined by the writer and from adjacent areas. All collections are from sediments of Pleistocene age or younger. Except for plants found in several of the formations, all species collected are marine.

Acknowledgments

This report is based on a thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy at Stanford University, California. The problem was suggested by W. A. Bell, formerly Director of the Geological Survey of Canada, and facilities for field work were provided by the Geological Survey. Study of the faunas was carried out under the direction of Dr. Myra Keen of Stanford University, whose advice and criticism throughout the course of the work have been invaluable. S. W. Muller of Stanford University also offered valued criticism and advice. During the 1951 field season the writer was attached to a field party in the Vancouver area under J. E. Armstrong. Some time was also spent in the Qualicum district of Vancouver Island with a field party under J. G. Fyles. Assistance in the field was rendered by members of the field parties of the aforementioned officers. W. M. Draycot of Lynn Creek guided the writer to many localities in the area north of Burrard Inlet. The writer wishes to acknowledge her indebtedness to all of these persons.

General Character of the Area

The mainland part of the area under consideration extends from the International Boundary north about 25 miles to North Vancouver, and east a maximum distance of 30 miles from the Strait of Georgia (*see* Figure 1 in pocket).

The upland areas of the region, which rise to an elevation of from 200 to 400 feet above sea-level, are composed of sediments that, for the most part, are of Pleistocene age. Glacial, fluvioglacial, fluvial, and marine deposits are present.

Seven upland areas are distinguishable. The southernmost of these, Sunnyside Upland, extends north from Semiamu-Campbell River valley to Nicomekl-Serpentine valley. Parallel to this, but isolated from it by Boundary Bay, is Point Roberts Upland which is joined to the mainland by the delta of Fraser River. Between Nicomekl-Serpentine valley on the south and east, Fraser River on the north, and Fraser River delta on the west is Newton Upland. Burrard Peninsula, on which the cities of Vancouver and New Westminster are situated, lies to the northwest of this between Fraser River and Burrard Inlet. East of Newton Upland is Clayton Upland which is bordered on the northwest by Serpentine River, on the north by the lowlands along Fraser River, and on the southeast and south by Nicomekl River. To the south of this, partly in Surrey municipality and partly in Langley municipality, is Campbell Upland. Another larger and less abruptly rising upland area lies to the east of Campbell Upland.

The surface of the uplands is fairly irregular. The bordering slopes are generally abrupt and exhibit wave-cut terraces in many places. Sections 100 to 200 feet high are exposed in sea-cliffs on the western sides of Sunnyside and Point Roberts Uplands, and on the northwestern end of Burrard Peninsula. Mesozoic and Tertiary rocks are prominent north of Burrard Inlet, and outcrops of Tertiary rocks are known in the northern part of Burrard Peninsula.

The valley of the Serpentine and Nicomekl Rivers is broad and flat, and at its seaward end has an average elevation of 8 feet above sea-level. To the northwest, the valley joins the delta of Fraser River. Marine sands and clays and flood-plain material form these lowland areas. In the Fraser River delta, adjacent to Newton Upland, is a large peat bog. Smaller peat bogs occur elsewhere in the lowlands.

North of Burrard Inlet, Pleistocene deposits occur along the flanks of the Coast Mountains. Fossiliferous beds of Pleistocene age are reported from a maximum elevation of about 500 feet, and glacial till is known from as high as 2,000 feet.

The major part of the upland area originally had a cover of mixed deciduous-coniferous forest, but much of this has been removed. Burrard Peninsula and the region between Burrard Inlet and the Coast Mountains to the north are built up, being now the sites of the cities of Vancouver, New Westminster, North Vancouver and West Vancouver. The southern uplands have many small farms. Numerous roads give easy access to the whole area.

On Vancouver Island, the writer visited the area around Qualicum, east of Beaufort Range, and crossed the mountains to examine sections in the vicinity of Alberni. The coastal area east of Beaufort Range slopes from sea-level up to an elevation of about 500 feet along the flanks of the mountains. Rivers flowing across it into the Strait of Georgia have cut deep valleys. For the most part, the area is heavily wooded, and best exposures are in sea-cliffs and along rivers. West of the mountains the Pleistocene sediments are found at low elevations around the head of Alberni Inlet.

Previous Study

Earlier studies were confined mainly to the Recent faunas of the west coast and to Mesozoic and Tertiary rocks and their faunas; those of Pleistocene age have been largely neglected. Recent faunas of the northwestern United States, British Columbia, and Alaska were described by numerous writers beginning about 1845 with Gould. From then until the beginning of the twentieth century, prominent workers in this field were Baird, Bartsch, Carpenter, Dall, Dawson, Lord, Newcombe, E. A. Smith, Stearns, Taylor, and Whiteaves. Since the turn of the century, contributions to the knowledge of these faunas have been by Bartsch, Dall, Oldroyd and Willett.

Burwash (1918, p. 87)[1] mentioned fossil shells from Central Park, Vancouver. Papers by Berry and Johnston (1922, p. 136) and Johnston (1923, p. 44) are concerned mainly with fossil plants, but Johnston (1923, p. 44) also lists shells from several localities south of Fraser River. Crickmay (1925, p. 140, and 1929, p. 205) lists shells from two localities in the Vancouver area. The most recent list is by Draycot (1951, p. 21). Fossil shells are reported from the Pleistocene deposits of southeastern Vancouver Island by Clapp (1912 and 1914), Hannibal (unpublished MS.), Newcombe (1893a), and Richardson (1872).

Pleistocene geology and palæontology of nearby areas are discussed by Arnold, Bartsch, Dall, Dawson, Hannibal, Palliser and Willis.

[1] Names and dates in parentheses are those of references cited in Bibliography at the end of this report.

Chapter II

STRATIGRAPHY AND FAUNAL DISTRIBUTION

With the exception of members of the Coast Intrusions and a few outcrops of Tertiary sedimentary and igneous rocks in the northern part of Burrard Peninsula, the area between North Vancouver and the International Boundary consists of unconsolidated Pleistocene deposits. On Vancouver Island, the Mesozoic sedimentary and volcanic rocks of Beaufort Range are flanked on both east and west by unconsolidated Pleistocene sediments. The stratigraphic sequences for the lower Fraser Valley area and the Qualicum districts are outlined in Tables I and II, respectively.

Fossils have been found in nine of the formations on the mainland, and in three on Vancouver Island. The organic remains are primarily of marine invertebrates, although both leaves and wood have been found, in some cases directly associated with the invertebrates. Except for a single small shark tooth

Table III

Stratigraphic Distribution and Relative Abundance of Species of the Various Taxonomic Groups

Taxonomic Group	Number of Species in Units											
	Lower Fraser Valley Area									Vancouver Island		
	Nicomekl	Newton	Cloverdale	Sunnyside	Bose	Capilano	Whatcom	Abbotsford	Richmond Delta	Unit C	Unit J	Unit K
Foraminifera	3	1	1	2	0	0	2	0	0	0	0	0
Brachiopoda	0	1	0	1	0	0	0	0	0	0	0	0
Pelecypoda	27	25	12	25	12	14	20	2	6	12	24	19
Gastropoda	18	16	2	14	0	2	9	0	2	5	16	4
Scaphopoda	0	0	0	0	0	1	0	0	0	0	1	1
Annelida	1	1	2	1	1	1	2	0	0	1	1	1
Ostracoda	0	0	0	1	0	0	0	0	0	0	0	0
Cirripedia	1	1	0	1	1	1	1	0	1	2	1	0
Decapoda	0	1	1	0	0	0	0	0	0	0	0	0
Echinoidea	1	1	0	1	0	1	1	0	0	0	2	0
Totals	51	47	18	46	14	20	35	2	9	20	45	25

from the Sunnyside formation, no vertebrate remains have been reported. Molluscs are the dominant group, forming roughly 90 per cent of the total number of invertebrates. Table III shows the abundance of species of the various groups according to their stratigraphic position.

Because of their relative abundance, molluscs form the basis for an analysis of the palæoecology of the area. All the species found in the Pleistocene sediments, with the probable exception of *Yoldia* (*Yoldiella*) *keenae* n. sp., are still living in the waters along the west coast. Sufficient data are available regarding the ecological requirements of most of the species to enable conclusions to be drawn concerning conditions during Pleistocene time.

Table IV is a check list of all species of invertebrates collected during the present study. Geographic positions of the fossil localities are indicated by number on Figure 1. The following faunal lists and descriptions are arranged in stratigraphic order.

Table IV

Stratigraphically Arranged Check List of Invertebrate Species from the Pleistocene and Recent Deposits of Southwestern British Columbia

Species	Formations											
	Lower Fraser Valley									Vancouver Island		
	Nicomekl	Newton	Cloverdale	Sunnyside	Bose	Capilano	Whatcom	Abbotsford	Richmond Delta	Unit C	Unit J	Unit K
Thais lamellosa (Gmelin)									x			
Mya arenaria Linné	x	x		x					x			x
Littorina scutulata Gould	x	x		x					x			x
Schizothaerus capax Gould		x		x		x	x		x			x
Macoma inconspicua (Broderip and Sowerby)	x	x				x		x	x			x
Saxidomus giganteus (Deshayes)	x	x		x		x			x		x	x
Protothaca staminea (Conrad)	x	x		x	x	x			x		x	x
Balanus crenatus Bruguière	x	x		x	?	x	x		x	x	x	
Clinocardium nuttallii (Conrad)	x	x	x	x	x	x	x	x	x		x	x
Clinocardium ciliatum (Fabricius)	x	x	x	x	x	x	x			x	x	x
Macoma calcarea (Gmelin)	x	x	x	x	x	x	x			x	x	x
Mya truncata Linné	x	x	x	x	x	x	x			x	x	x
Nuculana minuta (Fabricius)	x	x	x	x	x	x	x			x	x	x
Serpula vermicularis Linné	x	x	x	x	x	x	x			x	x	x
Serripes groenlandicus (Bruguière)	x	x	x	x	x	x	x			x	x	x
Hiatella arctica (Linné)	x	x		x	x	x	x			x	x	x
Mytilus edulis Linné	x	x		x	?	x	x			x	x	x
Strongylocentrotus dröbachiensis Müller	x	x		x		x	x				x	

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Table IV—*Cont.*

Species	Formations											
	Lower Fraser Valley Area									Vancouver Island		
	Nicomekl	Newton	Cloverdale	Sunnyside	Bose	Capilano	Whatcom	Abbotsford	Richmond Delta	Unit C	Unit J	Unit K
Macoma incongrua (Martens)	x	x	x	x	x	x	x			x	x	x
Nucula tenuis (Montagu)	x	x	x			x	x			x	x	
Margarites pupillus (Gould)	x	x		x		x					x	x
Chlamys hindsii (Carpenter)	x	x	x	x	x		x				x	
Nuculana fossa (Baird)	x	x	x	x	x		x			x	x	x
Elphidium sp.	x	x	x	x			x					
Trichotropis cancellata Hinds	x	x	x	x			x				x	
Chlamys hericius (Gould)	x	x		x			x				x	
Natica aleutica Dall	x	x		x			x				x	
"*Lora*" sp.	x	x					x					
Propeamusium alaskense Dall	x	x					x				x	
Propebela quadra (Dall)	x	x					x				x	
Natica clausa (Broderip and Sowerby)		x					x			x	x	x
Pandora grandis Dall		x					x				x	
Spirorbis sp.			x				x					
Axinopsida serricata (Carpenter)	x						x				x	
Buccinum plectrum Stimpson	?	x	x			?					?	
Lepeta concentrica (Middendorff)		x		x								
Hemithyris psittacea (Gmelin)		x		x								
Clinocardium blandum (Gould)	x	x	x	x			x			x		x
Clinocardium fucanum (Dall)	x	x		x							x	
Neptunea lyrata (Gmelin)	x	x		x			?			x	?	
Spisula voyi (Gabb)	x			x			?					
Turbonilla sp.	x	x		x			x					
Modiolus modiolus (Linné)	x	x		x								
Acteocina culcitella (Gould)	x			x							x	
Axinopsida viridis (Dall)	x			x							x	
Lacuna cf. *L. solidula* Lovén	x			x						?	?	
Macoma irus (Hanley)	x			x							x	x
Odostomia ("*Evalea*") *barkleyensis* Bartsch	x			x								
Odostomia ("*Amaura*") *sillana* Dall and Bartsch	x			x								
decapod		x	x									
Acmaea digitalis Eschscholtz	x	x		x							x	x
Littorina sitkana Philippi	x	x										
Neptunea pribiloffensis Dall							x					
Oenopota pribilova (Dall)							x					
Dentalium cf. *D. rectius* Carpenter						?					x	x
Alvania compacta Carpenter				x								
Astarte alaskensis Dall				?						x		
? *Cerithiopsis* sp.				x								
Leptonidae, near *Pseudopythina*				x								

Table IV—*Conc.*

Species	Formations											
	Lower Fraser Valley									Vancouver Island		
	Nicomekl	Newton	Cloverdale	Sunnyside	Bose	Capilano	Whatcom	Abbotsford	Richmond Delta	Unit C	Unit J	Unit K
ostracod				x								
Yoldia (*Yoldiella*) *keenae* n. sp.				x								
Chlamys beringianus (Middendorff)			x									
Acmaea pelta Eschscholtz		x										
Chlamys jordani (Arnold)		x										
Colus jordani (Dall)		x									x	
Polinices pallidus (Broderip and Sowerby)		x									x	
Psephidia sp.		x										
Acteocina eximia Baird	x										x	
Chlamys cf. *C. kincaidi* Oldroyd	x											
Odostomia (*Evalea*) *columbiana* Dall and Bartsch	x										x	
Oenopota alaskensis Dall	x						?			x	x	
Transennella tantilla (Gould)	x										x	x
unidentified foraminifer	x											
Chlamys islandica (Müller) ?												x
? *Brisaster* sp.											x	
Pandora filosa Carpenter											x	
Puncturella galeata (Gould)											x	
Yoldia (*Megayoldia*) *thraciaeformis* Storer											x	
Balanus evermanni Pilsbry										x		
Odostomia ("*Amaura*") *martensi* Dall and Bartsch										x		

Lower Fraser Valley Area

Nicomekl Formation

This formation is the oldest from which fossil invertebrates have been obtained in the mainland part of the area (*see* Table II). Lithologically it consists of sand and silt, with minor amounts of gravel. The sediments are predominantly of freshwater origin, but deltas along the western margin of the land area were formed in marine waters. The fossils are from these deltaic parts of the formation. Only casts and moulds of the shells are found in the upper beds of the formation, with actual shells preserved in the lower beds below the zone of leaching. Where the actual shells are present, many pelecypods are found in living position or

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show only minor disturbance by wave action. Only casts are reported from locality 5. Distribution of species throughout the areal extent of the formation is extremely variable, ranging from three species at locality 3 to forty-six species at locality 7 (Table V).

Table V

Faunal List, Nicomekl Formation

Species	Localities						
	1	2	3	4	5	6	7
Foraminifera							
Elphidium spp. (2)						x	
unidentified foraminifer						x	
Pelecypoda							
Nucula tenuis (Montagu)							x
Nuculana fossa (Baird)	x	x					x
Nuculana minuta (Fabricius)	x						x
Chlamys hericius (Gould)	x						
Chlamys hindsii (Carpenter)		x	x	x			x
Chlamys cf. *C. kincaidi* Oldroyd							x
Chlamys sp.	x						x
Propeamusium alaskense Dall							x
Mytilus edulis Linné		x			x	x	x
Modiolus modiolus (Linné)						x	x
Axinopsida serricata (Carpenter)							x
Axinopsida viridis (Dall)							x
Clinocardium blandum (Gould)							x
Clinocardium ciliatum (Fabricius)		x		x			x
Clinocardium fucanum (Dall)							x
Clinocardium nuttallii (Conrad)		x		x	x		x
Clinocardium sp.					x	x	x
Serripes groenlandicus (Bruguière)		x				x	x
Transennella tantilla (Gould)							x
Saxidomus giganteus (Deshayes)		x		x	x	x	x
Protothaca staminea (Conrad)				x			x
Macoma calcarea (Gmelin)						x	x
Macoma incongrua (Martens)		x	x				x
Macoma inconspicua (Broderip and Sowerby)							x
Macoma irus (Hanley)							x
Macoma sp.	x				x	x	x
Spisula voyi (Gabb)						x	x
Mya arenaria Linné							x
Mya truncata Linné							x
Mya sp.						x	
Hiatella arctica (Linné)							x

Table V—*Conc.*

Species	Localities						
	1	2	3	4	5	6	7
Gastropoda							
Acmaea digitalis Eschscholtz			x				
Margarites pupillus (Gould)							x
Odostomia (*Evalea*) *columbiana* Dall and Bartsch							x
Odostomia (*Evalea*) *barkleyensis* Bartsch							x
Odostomia ("*Amaura*") *sillana* Dall and Bartsch							x
Odostomia sp.						x	x
Turbonilla sp.							x
Littorina scutulata Gould							x
Littorina cf. *L. sitkana* Philippi							x
Lacuna cf. *L. solidula* Lovén							x
Trichotropis cancellata Hinds				x			x
Natica aleutica Dall							x
Natica sp. or *Polinices* sp.						x	x
? *Buccinum* sp.							x
Neptunea lyrata (Gmelin)							x
"*Lora*" sp.							x
Oenopota alaskensis Dall							x
Propebela quadra (Dall)							x
Acteocina culcitella (Gould)							x
Acteocina eximia Baird							x
Annelida							
Serpula vermicularis Linné	x	x			x	x	x
Cirripedia							
Balanus crenatus Bruguière							x
Balanus sp.		x		x			
Echinoidea							
Strongylocentrotus dröbachiensis Müller						x	x

Fossil Localities

1. Highlands sand and gravel pit, Keith Road, North Vancouver. Elevation 50′. GSC loc. 17257. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
2. Burquitlam golf course, between Port Moody and New Westminster. Elevation about 300′. GSC loc. 21439. Coll. J. E. Armstrong, 1952.
3. Hume Park, New Westminster. Elevation about 100′. GSC loc. 21437. Coll. J. E. Armstrong, 1952.

4. Greater Vancouver gravel pit, North Road, Sapperton. Elevation about 100′. GSC loc. 21444. Coll. J. E. Armstrong, 1952.
5. Sand pit south of King George VI highway, lot 9, block 5 north, range 2 west, Surrey municipality. Elevation about 115′. GSC loc. 21581. Coll. F. J. E. Wagner, 1951.
6. Ditch along Clover Valley Road ¼ mile south of Tynehead station. NE¼, sec. 6, twp. 9, Surrey municipality. Elevation 75′. GSC loc. 17244 and 17627. Coll. W. L. Brown, 1949 and W. M. Draycot, 1950.
7. Excavation southeast of intersection of Elgin and McLellan roads. NW¼, sec. 3, twp. 2, Surrey municipality. Elevation 130′. GSC loc. 17611 and 21621. Coll. W. M. Draycot, 1950 and F. J. E. Wagner, 1951.

Odostomia (*Evalea*) *columbiana* Dall and Bartsch, *Oenopota alaskensis* Dall, and *Transennella tantilla* (Gould) have not been found in any other of the mainland formations, but they have been found on Vancouver Island, mainly in younger formations. *Chlamys* cf. *C. kincaidi* Oldroyd and *Acteocina eximia* Baird, although not found by the writer in other than the Nicomekl formation, have been recorded from the Newton and Cloverdale, respectively, by Crickmay (1925, p. 140; 1929, p. 206). The apparent restriction of the unidentified foraminifer to this formation is not significant as no organized study was made of the microfossils.

Newton Formation

The Newton formation, which is widely distributed over much of the upland areas, is composed of poorly sorted till-like mixtures, stony clayey silt, and minor clay, silt, sand, and gravel. It was deposited in the period during and immediately following the wasting and retreat of the Vashon continental ice-sheet. Previously this formation was mapped as normal till, although Johnston (1923, p. 50) suggested that it might have been deposited by floating ice or shelf ice. Fossils are common, and occur much as in the Nicomekl formation, i.e., casts above and actual shells below, although many localities have only casts.

Thirty-two localities were examined, from which forty-seven species have been identified. The most species occurring at any one locality was twenty-seven, and the fewest was two. Most of the species live today in less than 20 fathoms of water. Some are free-swimming, but most are burrowing or attached forms. Three species are apparently confined to the formation. They are *Acmaea pelta* Eschscholtz, *Chlamys jordani* (Arnold), and *Psephidia* sp. Two others, *Colus jordani* (Dall) and *Polinices pallidus* (Broderip and Sowerby) are known from younger deposits on Vancouver Island, but have not been found in other than the Newton formation on the mainland. The three confined species were found at only one locality each, and may therefore be considered valueless as index fossils for the formation. The same may be said for *Colus jordani* and *Polinices pallidus,* which were each found at only two localities.

Distribution of the forty-seven species at the thirty-two localities studied is shown in Table VI.

Table VI

Faunal List, Newton Formation

Species	Localities																															
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Foraminifera																																
Elphidium sp.												x																				
Brachiopoda																																
Hemithyris psittacea (Gmelin)		x																														
Pelecypoda																																
Nucula tenuis (Montagu)												x											x								x	x
Nucula sp.											x		x										x	x								x
Nuculana fossa (Baird)	x		x	x				x	x		x	x	x	x	x	x	x	x	x				x		x			x		x	x	x
Nuculana minuta (Fabricius)			x			x		x			x	x			x			x	x			x	x	x				x		x	x	x
Nuculana sp.		x			x													x		x									x			
Chlamys hericius (Gould)			x			x									x	x	x	x					x									
Chlamys hindsii (Carpenter)	x	x	x	x			x	x	x	x		x		x	x	x	x	x	x		x	x	x								x	x
Chlamys cf. *C. jordani* (Arnold)																		x														
Chlamys sp.			x												x			x			x											x
Propeamusium alaskense Dall												x				x		x														
Mytilus edulis Linné				x	x					x				x				x	x	x				x	x		x	x		x	x	x
Mytilus sp.														x															x			
Modiolus modiolus (Linné)				x																												
Pandora grandis Dall														x				x														
Clinocardium blandum (Gould)							x	x	x	x					x	x	x				x		x									x
Clinocardium ciliatum (Fabricius)			x	x							x	x		x	x	x	x	x					x							x		x
Clinocardium fucanum (Dall)			x														x	x														x
Clinocardium nuttallii (Conrad)	x		x	x	x							x		x																		
Clinocardium sp.	x	x	x	x	x				x		x		x	x	x	x	x		x	x	x	x	x	x	x			x	x	x	x	x
Serripes groenlandicus (Bruguière)	x			x							x	x		x		x	x		x		x		x	x	x	x	x	x			x	x
Psephidia sp.																																x
Saxidomus giganteus (Deshayes)				x			x							x																x		x
Protothaca staminea (Conrad)														x																		
Macoma calcarea (Gmelin)			x	x			x	x	x		x		x	x		x	x	x	x			x	x	x	x		x	x			x	x
Macoma incongrua (Martens)	x		x	x						x	x	x		x										x						x		x
Macoma inconspicua (Broderip and Sowerby)			x																											x		
Macoma sp.				x		x					x			x															x	x	x	x
Schizothaerus capax Gould														x																		

Table VI—*Conc.*

Species	Localities																															
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Pelecypoda—*Conc.*																																
Mya arenaria Linné					?																											
Mya truncata Linné	x			x							x	x		x		x			x	x			x	x			x	x		x	x	x
Hiatella arctica (Linné)			x							x	x	x			x	x	x		x				x	x			x	x		x	x	x
Gastropoda																																
Acmaea digitalis Eschscholtz																												x				
Acmaea pelta Eschscholtz									x																							
Lepeta concentrica (Middendorff)												x																				
Margarites pupillus (Gould)									x																							
Turbonilla sp.	x																															
Littorina scutulata Gould											x																					
Littorina sitkana Philippi											x																					
Trichotropis cancellata Hinds	x		x	x											x								x									x
Natica aleutica Dall																x																x
Natica clausa (Broderip and Sowerby)			x	x		x										x				x				x								
Polinices pallidus (Broderip and Sowerby)																			x													x
Polinices sp.																															x	x
Buccinum plectrum Stimpson																															x	x
Colus jordani (Dall)																										x		x				
Neptunea lyrata (Gmelin)																																x
Propebela quadra (Dall)											x					x																
"*Lora*" sp.																			x			x	x									
Annelida																																
Serpula vermicularis Linné	x		x	x						x	x	x		x	x	x		x			x		x						x	x	x	x
Cirripedia																																
Balanus crenatus Bruguière															x																	
Balanus sp.			x	x										x					x				x	x	x			x	x		x	x
Decapoda ?																																
unidentifiable specimen				x																												
Echinoidea																																
Strongylocentrotus dröbachiensis Müller	x			x							x	x		x	x					x		x										

Fossil Localities

8. Southwest corner of Bowen Island. Elevation about 25′. Coll. F. J. E. Wagner, 1951.
9. Horseshoe Bay. Elevation 30′. GSC loc. 17255. Coll. W. L. Brown, 1949.
10. Rattenbury Road, West Vancouver. Elevation about 200′. GSC loc. 17248. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
11. North of Patterson Cove, West Vancouver. Elevation 290′. GSC loc. 17246. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
12. Road below Southborough, west of Wescot Road, British Properties, West Vancouver. Elevation 300′. GSC loc. 17254. Coll. W. L. Brown, 1949.
13. Dollarton Road, North Vancouver. Elevation about 25′. GSC loc. 16405. Coll. J. E. Armstrong, 1948.
14. Small ravine west of GSC loc. 21432, Spanish Banks cliff, Vancouver. Elevation about 80′. GSC loc. 21433. Coll. J. E. Armstrong, 1952.
15. Spanish Banks cliff, Vancouver. Elevation about 80′. GSC loc. 21432. Coll. J. E. Armstrong, 1952.
16. Marine Drive near Spanish Banks, Vancouver. Elevation about 50′. GSC loc. 21434. Coll. J. E. Armstrong, 1952.
17. Southwest Marine Drive, just west of Musqueam Reserve, Vancouver. Elevation about 175′. GSC loc. 21440. Coll. J. E. Armstrong, 1952.
18. 53rd Avenue, between Inverness and Sherbrooke Streets, Vancouver. Elevation about 200′. GSC loc. 21601. Coll. J. E. Armstrong, 1951.
19. Trans-Mountain Pipeline tank farm, south face of Burnaby Mountain. Elevation 375′. GSC loc. 24000. Coll. J. E. Armstrong, 1953.
20. Austin and Gutenberg Roads, Burquitlam. Elevation 425′. GSC loc. 24001. Coll. J. E. Armstrong, 1953.
21. Burnaby municipal garbage dump. Elevation 425′. GSC loc. 17245. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
22. Head of road to Tsawwassen Beach. Lot 24, NW.¼, sec. 3, twp. 5, Delta municipality. Elevation 175′. GSC loc. 21607. Coll. F. J. E. Wagner, 1951.
23. Boundary Bay gravel pit, west side. Lot 1, SE.¼, sec. 3, twp. 5, Delta municipality. Elevation about 150′. GSC loc. 17241. Coll. W. L. Brown, 1949.
24. Boundary Bay gravel pit; southeast corner. Lot 1, SE.¼, sec. 3, twp. 5, Delta municipality. Elevation about 150′. GSC loc. 17243. Coll. W. L. Brown, 1949.
25. Boundary Bay gravel pit, south side. Lot 1, SE.¼, sec. 3, twp. 5, Delta municipality. Elevation about 150′. GSC loc. 21586. Coll. F. J. E. Wagner, 1951.
26. Ocean Park sea-cliffs. Elevation 100 to 150′. GSC loc. 17612. Coll. W. M. Draycot, 1950.
27. Ocean Park sea-cliffs; 100 yards south of GSC loc. 17612. Elevation 100′. GSC loc. 17613. Coll. W. M. Draycot, 1950.
28. Ocean Park sea-cliffs; 1,000 yards south of GSC loc. 17612. Elevation 175′. GSC loc. 17614. Coll. W. M. Draycot, 1950.
29. Ocean Park sea-cliffs; in amphitheatre 100 yards wide, south of Ocean Park station. Elevation 35′ and higher. GSC loc. 17615. Coll. W. M. Draycot, 1950.
30. Ocean Park sea-cliffs; at Culvert 68.08 on Great Northern Railway, 2,010′ south of Ocean Park station. Elevation 100 to 150′. GSC loc. 17616. Coll. W. M. Draycot, 1950.
31. Ocean Park sea-cliffs, northwest of White Rock. Elevation 65′. GSC loc. 17617. Coll. W. L. Brown, 1950.
32. Ocean Park sea-cliffs, below south end of United Church camp property. NE.¼, sec. 7, twp. 1, Surrey municipality. Elevation about 125′. GSC loc. 21582. Coll. F. J. E. Wagner, 1951.
33. Ocean Park sea-cliffs; 80′ north of GSC loc. 21582. Elevation 100 to 150′. GSC loc. 21584. Coll. F. J. E. Wagner, 1951.
34. Ocean Park sea-cliffs; about 125′ south of GSC loc. 21582. Elevation 100 to 150′. GSC loc. 21585. Coll. F. J. E. Wagner, 1951.
35. Ocean Park sea-cliffs; about 25′ west of GSC loc. 21585. Elevation 100 to 150′. Coll. F. J. E. Wagner, 1951.
36. Ditch along Stokes Road. NE.¼, sec. 20, twp. 1, Surrey municipality. Elevation 215′. GSC loc. 17629. Coll. W. M. Draycot, 1950.
37. Well, 300 yards west of intersection of Stokes and Nichol Roads. SE.¼, sec. 17, twp. 1, Surrey municipality. Elevation 305′. GSC loc. 17618. Coll. O. L. Hughes, 1950.

38. Bank of brook 600′ east of, and parallel to, King George VI highway. NW.¼, sec 12, twp. 1, Surrey municipality. Elevation 130′. GSC loc. 17626. Coll. W. M. Draycot, 1950.
39. Ditch, east of King George VI highway. NE.¼, sec. 12, twp. 1, Surrey municipality. Elevation 125′. GSC loc. 17625 and 21622. Coll. W. M. Draycot, 1950 and F. J. E. Wagner, 1951.

Cloverdale Formation

Sediments of the Cloverdale formation are silt, silty clay, and clay with minor sand, gravel, and poorly sorted till-like mixture. Fossils come from the silty and gritty phases. This formation is present in the lowland areas, at elevations generally below 100 feet. Therefore locality 40 is only questionably referred to it. The shells there are reported to be from a blue silt, which lithologically could well be from the Cloverdale formation, but they are at 440 feet above sea-level.

A total of eighteen species, counting those from locality 40, has been found. Ten of these are from the three localities that are definitely Cloverdale. Occurrences of these species are shown in Table VII. Except for *Chlamys beringianus* (Middendorff) from locality 40, all of the species are known from, and most are common in, at least some of the other formations. Actual shells were present at all localities, and some of the pelecypods had the valves intact.

Table VII

Faunal List, Cloverdale Formation

Species	Localities			
	40	41	42	43
Foraminifera				
Elphidium sp.				x
Pelecypoda				
Nucula tenuis (Montagu)				x
Nuculana fossa (Baird)		x		
Nuculana minuta (Fabricius)		x		x
Nuculana sp.			x	
Chlamys beringianus (Middendorff)	x			
Chlamys hindsii (Carpenter)	x		x	
Clinocardium blandum (Gould)	x			
Clinocardium ciliatum (Fabricius)	x			
Clinocardium nuttallii (Conrad)	x			
Clinocardium sp.		x		
Serripes groenlandicus (Bruguière)	x			
Macoma calcarea (Gmelin)	x			x
Macoma incongrua (Martens)	x			
Macoma sp.			x	
Mya truncata Linné	x			
Gastropoda				
Trichotropis cancellata Hinds	x			
Buccinum plectrum Stimpson	x			
Annelida				
Serpula vermicularis Linné	x	x	x	
Spirorbis sp.	x			
Decapoda				
unidentified specimen	x			

Fossil Localities

40. Shelburn refinery excavation, Burnaby Mountain. Elevation 440′. GSC loc. 28804. Coll. A. Ross, 1956.
41. Clay pit northeast of intersection of Rankin and Bose roads. SE.¼, sec. 15, twp. 2, Surrey municipality. Elevation 35′. GSC loc. 21583. Coll. F. J. E. Wagner, 1951.
42. Ditch on east side of Pacific highway, ½ mile north of Bose Road. Line between NW. and SW. quarters, sec. 17, twp. 8, Surrey municipality. Elevation about 35′. GSC loc. 21605. Coll. F. J. E. Wagner, 1951.
43. Kanaka Creek, N.½, sec. 10, twp. 12, Maple Ridge municipality. Elevation about 90′. GSC loc. 21436. Coll. J. E. Armstrong, 1952.

Sunnyside Formation

The Sunnyside is a littoral sand with some silt and silty clay found mainly in the upland areas. Fossils are generally well preserved, with many burrowing pelecypods still in living position. A layer of worn shells, indicative of deposition in an area affected by wave action, occurs directly above the shells that are in place. The shells are in a sandy silt that grades downward through silt to silty clay.

This formation has yielded an abundant fauna. Only three localities have been discovered, but from these forty-six invertebrate and one vertebrate species have been recognized (Table VIII). Six species have not been recorded from other formations, either in the lower Fraser Valley area or on Vancouver Island. They are:

Yoldia (*Yoldiella*) *keenae* n. sp.
Astarte sp.
Leptonidae, genus indet.
but near *Pseudopythina*
Alvania compacta Carpenter
? *Cerithiopsis* sp.
Ostracod

The *Astarte,* however, may not be confined to the formation. *A. alaskensis* Dall has been reported from the Cloverdale ? formation by Crickmay (1929, p. 206), and has been found by the writer on Vancouver Island in sediments of the Quadra group.

Table VIII
Faunal List, Sunnyside Formation

Species	Localities		
	44	45	46
Foraminifera			
Elphidium spp. (2)		x	
Brachiopoda			
Hemithyris psittacea (Gmelin)			x
Pelecypoda			
Nuculana fossa (Baird)		x	
Nuculana minuta (Fabricius)		x	x
Yoldia (*Yoldiella*) *keenae* n. sp.	x		x
Chlamys hericius (Gould)		x	
Chlamys hindsii (Carpenter)	x	x	x
Chlamys sp.		x	

Table VIII—*Conc.*

Species	Localities		
	44	45	46
Pelecypoda—*Conc.*			
Mytilus edulis Linné	x	x	x
Modiolus modiolus (Linné)	x		
Astarte sp.	x		
Axinopsida viridis (Dall)			x
Leptonidae, close to *Pseudopythina*	x		
Clinocardium blandum (Gould)		x	x
Clinocardium ciliatum (Fabricius)		x	
Clinocardium fucanum (Dall)		x	
Clinocardium nuttallii (Conrad)		x	x
Clinocardium sp.	x		x
Serripes groenlandicus (Bruguière)	x	x	x
Saxidomus giganteus (Deshayes)	x	x	x
Protothaca staminea (Conrad)		x	x
Macoma calcarea (Gmelin)		x	x
Macoma incongrua (Martens)	x	x	x
Macoma irus (Hanley)	x		x
Macoma sp.	x	x	
Spisula voyi (Gabb)	x		
Schizothaerus capax Gould		x	
Mya arenaria Linné			x
Mya truncata Linné		x	x
Hiatella arctica (Linné)	x	x	x
Gastropoda			
Acmaea digitalis Eschscholtz			x
Lepeta concentrica (Middendorff)		x	
Margarites pupillus (Gould)	x		x
Odostomia (*Evalea*) *barkleyensis* Bartsch	x		
Odostomia ("*Amaura*") *sillana* Dall and Bartsch			x
Odostomia sp.	x		
Turbonilla (*Pyrgolampros*) sp.	x		
Littorina cf. *L. scutulata* Gould	x		x
Lacuna cf. *L. solidula* Lovén	x		
Alvania compacta Carpenter	x		
? *Cerithiopsis* sp.	x		
Trichotropis cancellata Hinds	x		x
Natica aleutica Dall	x		
Natica sp. or *Polinices* sp.			x
Neptunea lyrata (Gmelin)			x
Acteocina culcitella (Gould)			x
Annelida			
Serpula vermicularis Linné	x	x	x
Ostracoda			
unidentified specimen		x	
Cirripedia			
Balanus crenatus Bruguière	x		x
Echinoidea			
Strongylocentrotus dröbachiensis Müller	x	x	x
Vertebrata			
shark tooth	x		

Fossil Localities

44. Ditch on west side of Clover Valley Road, $\frac{3}{10}$ mile south of Hjorth Road, NE.$\frac{1}{4}$, sec. 6, twp. 9, Surrey municipality. Elevation 115′. GSC loc. 21578. Coll. F. J. E. Wagner, 1951.
45. Ditch, Tsawwassen Indian Reserve. Lot 26, sec. 3, twp. 5, Delta municipality. Elevation about 185′. GSC loc. 17634 and 21576. Coll. J. E. Armstrong, 1950 and F. J. E. Wagner, 1951.
46. Ditch on west side of Point Roberts Road, $\frac{2}{5}$ mile south of Raith Road, NE.$\frac{1}{4}$, sec. 10, twp. 5, Delta municipality. Elevation about 40′. GSC loc. 21577. Coll. F. J. E. Wagner, 1951.

Bose Formation

The Bose formation comprises an unsorted and unstratified mixture of gravel and sand, with the gravel predominating. These sediments form spits, bars, and beaches, and lag-gravel veneers on the upland areas. Fossils are in the form of casts and moulds. Only fourteen species have been recognized, of which twelve are pelecypods (Table IX). No species is restricted to the formation.

Table IX

Faunal List, Bose Formation

	Localities					
	47	48	49	50	51	52
Pelecypoda						
Nuculana fossa (Baird)				x		
Nuculana minuta (Fabricius)				x		
Chlamys hindsii (Carpenter)				x	x	x
Chlamys sp.					x	
Mytilus sp.	x					
Clinocardium ciliatum (Fabricius)				x		
Clinocardium nuttallii (Conrad)		x				
Clinocardium sp.	x	x	x	x	x	x
Serripes groenlandicus (Bruguière)				x		
Protothaca staminea (Conrad)	x					
Macoma calcarea (Gmelin)				x		
Macoma incongrua (Martens)				x	x	
Macoma sp.	x	x				
Mya truncata Linné				x		x
Hiatella arctica (Linné)	x			x	x	x
Annelida						
Serpula vermicularis Linné				x	x	x
Cirripedia						
Balanus sp.	x					

Fossil Localities

47. Cut at corner of Joly Street and Lorne Avenue, Copper Cove. Elevation 150′. GSC loc. 16406. Coll. J. E. Armstrong, 1948 and F. J. E. Wagner, 1951.
48. Gravel pit near St. Mary school, North Vancouver. Elevation 480′. GSC loc. 17250. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.

49. Sand pit south of King George VI highway, near Patullo Bridge. Lot 9, block 5 north, range 2 west, Surrey municipality. Elevation about 150′. GSC loc. 21581. Coll. F. J. E. Wagner, 1951.
50. Boundary Bay gravel pit; northeast corner. Lot 1, SE.¼, sec. 3, twp. 5, Delta municipality. Elevation 150′. GSC loc. 17242. Coll. W. L. Brown, 1949.
51. Boundary Bay gravel pit, middle of north side. Lot 1, SE.¼, sec. 3, twp. 5, Delta municipality. Elevation about 150′. GSC loc. 17251. Coll. W. L. Brown, 1949.
52. Boundary Bay gravel pit; north end of west side. Lot 1, SE.¼, sec. 3, twp. 5, Delta municipality. Elevation about 150′. Coll. F. J. E. Wagner, 1951.

Capilano Formation

Except in the eastern part of the area, the sands and gravels of the Capilano formation are found only north of Fraser River, and in the westernmost regions they do not extend south of Burrard Inlet. The sediments were deposited as channel fillings and deltas. Fossils occur as casts in the deltaic parts of the formation. Fine-grained sand forms the fossiliferous beds at some localities and silty clay interbedded with the sand and gravel at others.

Eight fossil localities were discovered from which twenty species were identified (Table X). The most species from a single locality was fourteen and the fewest three. There are no index fossils for the formation, all species being present in some or all of the other formations.

Table X

Faunal List, Capilano Formation

Species	Localities							
	53	54	55	56	57	58	59	60
Pelecypoda								
Nucula tenuis (Montagu)						x		
Nuculana minuta (Fabricius)			x					
Mytilus edulis Linné	x				x	x	x	
Clinocardium ciliatum (Fabricius)						x		
Clinocardium nuttallii (Conrad)				x	x			x
Clinocardium sp.	x	x	x	x	x	x	x	
Serripes groenlandicus (Bruguière)			x		x			
Saxidomus giganteus (Deshayes)		x				x		x
Protothaca staminea (Conrad)		x				x		x
Macoma calcarea (Gmelin)		x				x		
Macoma incongrua (Martens)		x				x		
Macoma inconspicua (Broderip and Sowerby)						x		
Macoma sp.	x	x	x	x	x	x	x	
Schizothaerus capax Gould				x				
Mya truncata Linné		x			x	x	x	x
Hiatella arctica (Linné)			x		x		x	
Gastropoda								
Margarites pupillus (Gould)			x					
Buccinum sp.			x					

Table X—*Conc.*

Species	Localities							
	53	54	55	56	57	58	59	60
Scaphopoda								
unidentifiable specimen						x		
Annelida								
Serpula vermicularis Linné						x		
Cirripedia								
Balanus crenatus Bruguière			x					
Echinoidea								
Strongylocentrotus dröbachiensis Müller						x		

Fossil Localities

53. Gravel pit at end of Rabbit Lane, British Properties, West Vancouver. Elevation about 495′. GSC loc. 17249. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
54. Corner of Leovista and Glenview, Capilano Highlands. Elevation 375′. GSC loc. 17253. Coll. W. L. Brown, 1949.
55. Mountain Park highway, ½ mile north of Keith Road, North Vancouver. Elevation about 200′. GSC loc. 17247. Coll. W. L. Brown, 1949.
56. North Vancouver garbage dump, Lynn River west of Lillooet Road and north of Keith Road. Elevation 190′. GSC loc. 17256. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
57. West side of Lillooet Road, just south of Lynn Valley cemetery and ¾ mile north of Keith Road. Elevation 215′. GSC loc. 17258. Coll. J. E. Armstrong, 1948, W. L. Brown, 1949 and F. J. E. Wagner, 1951.
58. "Windy Trench", Lillooet Road. Elevation 400′. GSC loc. 17259. Coll. W. L. Brown, 1949 and F. J. E. Wagner, 1951.
59. 8,000′ north of Deeks gravel pit, Coquitlam. Elevation 500′. GSC loc. 23999. Coll. J. E. Armstrong, 1953.
60. Haney municipal gravel pit. NE.¼, sec. 21, twp. 12, Maple Ridge municipality. Elevation about 125′. GSC loc. 21438. Coll. J. E. Armstrong, 1952.

Whatcom Formation

The Whatcom formation is related to valley glaciers of post-Vashon time. It is of glacio-marine origin, and is lithologically similar to the Newton formation, i.e., stony clayey silt, stony silty clay, clay, silt, and minor sand and gravel. North of Fraser River, the formation is found east of Pitt River, and south of the Fraser it is east of a line from Fort Langley through Langley Valley.

Fossils are found both as casts and actual shells. Of the thirty-five species recognized (Table XI) only two have yet to be recorded from any of the other formations, on either the mainland or Vancouver Island. These are *Neptunea pribiloffensis* Dall and *Oenopota pribilova* (Dall). Neither is of sufficiently widespread distribution to be considered as an index species for the formation.

Table XI

Faunal List, Whatcom Formation

Species	Localities																		
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
Foraminifera																			
Elphidium spp. (2)													x		x				
Pelecypoda																			
Nucula tenuis (Montagu)					x							x	x			x			
Nuculana fossa (Baird)					x							x		x	x	x			
Nuculana minuta (Fabricius)			x		x	x	x		x		x	x	x			x	x		
Nuculana sp.				x				x											
Chlamys hericius (Gould)									x		x			x					
Chlamys hindsii (Carpenter)					x			x		x						x			
Propeamusium alaskense Dall					x							x				x			
Mytilus edulis Linné		x					x		x			x	x	x	x				
Modiolus modiolus (Linné)												x							
Pandora grandis Dall								x											
Axinopsida serricata (Carpenter)					x											x			
Clinocardium blandum (Gould)												x							
Clinocardium ciliatum (Fabricius)													x	x					
Clinocardium nuttallii (Conrad)												x							
Clinocardium sp.			x		x	x	x		x		x	x	x			x	x		x
Serripes groenlandicus (Bruguière)					x						x	x		x		x	x		
Macoma calcarea (Gmelin)		x		x					x			x	x						
Macoma incongrua (Martens)									x	x		x	x	x	x				
Macoma sp.			x			x	x		x		x	x							
Spisula voyi (Gabb)									x										
Schizothaerus capax Gould									x										
Mya truncata Linné				x					x		x	x	x	x	x	x			
Mya sp.					x														
Hiatella arctica (Linné)					x		x		x		x	x	x	x	x	x			
unidentifiable shell fragments																		x	
Gastropoda																			
Trichotropis cancellata Hinds					x								x	x		x			
Natica aleutica Dall						x						x							
Natica clausa (Broderip and Sowerby)					x									x		x			

Neptunea pribiloffensis Dall	x																			
? *Neptunea* sp	x																			
Oenopota pribilova (Dall)					x												x			
Oenopota sp							x													
Propebela quadra (Dall)					x												x			
"*Lora*" sp					x								x							
unidentifiable specimen														x						
Annelida																				
Serpula vermicularis Linné					x	x		x		x	x	x					x			
Spirorbis sp					x															
Cirripedia																				
Balanus crenatus Bruguière															x	x	x			
Balanus sp				x	x								x	x						
Echinoidea																				
Strongylocentrotus dröbachiensis Müller					x										x		x			

Fossil Localities

61. Haney brickyard, Coquitlam map-area. Elevation about 75′. GSC loc. 27014. Coll. J. E. Armstrong, 1954.

62. Dewdney Trunk Road, near Stave Falls. Elevation about 400′. GSC loc. 27017. Coll. J. E. Armstrong, 1954.

63. Gravel pit on north fork of Hairsine Creek. Elevation about 400′. GSC loc. 27018. Coll. J. E. Armstrong, 1954.

64. Silverdale Creek, back of Mission City. Elevation about 125′. GSC loc. 27015. Coll. J. E. Armstrong, 1954.

65. Well, corner of Bell and Berry Roads. NW.¼, sec. 25, twp. 7, Langley municipality. Elevation 175′. GSC loc. 17628. Coll. W. M. Draycot, 1950.

66. Right bank of tributary of Nicomekl River, south of Murrayville cemetery. NE.¼, sec. 36, twp. 7, Langley municipality. Elevation 125′. GSC loc. 17630. Coll. W. M. Draycot, 1950.

67. Well, east end of Bradshaw Road. NE.¼, sec. 36, twp. 7, Langley municipality. Elevation (fossil horizon) 130′. GSC loc. 17619. Coll. J. G. Fyles, 1950.

68. Left bank of south branch of Nicomekl River, ¼ mile northwest of Johnson Town, Line Road. NE.¼, sec. 25, twp. 7, Langley municipality. Elevation 95′. GSC loc. 21602. Coll. F. J. E. Wagner, 1951.

69. Well, SE.¼, sec. 15, twp. 7, Langley municipality. Elevation 135′. GSC loc. 17621. Coll. O. L. Hughes, 1950.

70. Well, North Bluff Road ¼ mile west of Carvoth Road. NE.¼, sec. 10, twp. 7, Langley municipality. Elevation (fossil horizon) 195′. GSC loc. 17623. Coll. O. L. Hughes, 1950.

71. SE.¼, sec. 10, twp. 7, Langley municipality. Elevation 270′. GSC loc. 17624. Coll. W. M. Draycot, 1950.

72. Ditch along north side of Campbell Creek Road. SE.¼, sec. 10, twp. 7, Langley municipality. Elevation 240 to 250′. GSC loc. 17252, 17622 and 21580. Coll. W. L. Brown, 1949, W. M. Draycot, 1950 and F. J. E. Wagner, 1951.

73. Road-cut on Trans-Canada Highway, just east of Otter Road. NW.¼, sec. 26, twp. 10, Langley municipality. Elevation 325′. GSC loc. 21442 and 21579. Coll. F. J. E. Wagner, 1951 and J. E. Armstrong, 1952.

74. Otter Road, NW.¼, sec. 14, twp. 10, Langley municipality. Elevation about 325′. GSC loc. 21443. Coll. J. E. Armstrong, 1952.

75. Bank of brook crossing Otter Road near the International Boundary. SW.¼, sec. 2, twp. 10, Langley municipality. Elevation about 200′. GSC loc. 21441. Coll. J. E. Armstrong, 1952.

76. Well, SW.¼, sec. 25, twp. 10, Langley municipality. Elevation about 375′. GSC loc. 17628. Coll. W. M. Draycot, 1950.

77. Pipeline cut across Nathan Creek near Jackman Road. Elevation 90′. GSC loc. 24004. Coll. J. E. Armstrong, 1953.

78. Mount Lehman Road, 2½ miles north of Trans-Canada Highway. Elevation 260′. GSC loc. 24003. Coll. J. E. Armstrong, 1953.

79. Fishtrap Creek Road. Elevation 375′. GSC loc. 24005. Coll. J. E. Armstrong, 1953.

Abbotsford Formation

The Abbotsford formation, which is also related to post-Vashon valley glaciation, has the same general areal distribution as the Whatcom formation. It comprises recessional outwash sand and gravel, with some ice-contact gravel, sand, and lenses of till and glacio-marine sediments. The single fossil locality known, number 80 on the map, is a gravel pit in Lot 280 G1 of twp. 9, Pitt Meadows municipality. (This is GSC loc. 21435, collected by J. E. Armstrong, 1952.) The fossils are from about 50 feet above sea-level. Only two species, *Clinocardium nuttallii* (Conrad) and *Macoma inconspicua* (Broderip and Sowerby) were found. Both of these are shallow-water species, and probably lived in a deltaic zone where the outwash sands and gravels were being deposited in the marine waters then flooding the Fraser Valley.

Richmond Delta Deposits

The Richmond Delta sand, silt, clayey silt, silty clay, and clay were deposited by Fraser River in the coastal areas. Nine species, all of them now living off parts of the southern British Columbia coast, have been identified from a single locality. The shells were collected from an excavation and come from a position estimated to be about 8 feet below present sea-level. This locality, No. 81 (GSC loc. 21606, Coll. F. J. E. Wagner, 1951), is on the south side of Raith Road, 0.3 mile west of Boundary Bay, NW.¼, sec. 10, twp. 5, Delta municipality. The species are:

Pelecypoda

Clinocardium nuttallii (Conrad)
Saxidomus giganteus (Deshayes)
Protothaca staminea (Conrad)
Macoma inconspicua (Broderip and Sowerby)
Schizothaerus capax Gould
Mya arenaria Linné

Gastropoda

Littorina scutulata Gould
Thais lamellosa (Gmelin)

Cirripedia

Balanus crenatus Bruguière

One species common along the coast today, *Thais lamellosa,* has been found in no older formation. All these species are recorded from Indian shell heaps of the coastal areas of British Columbia and the State of Washington. A list of species from several middens along the southern coast of British Columbia is included for comparison (Table XII).

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Table XII

Faunal List, Indian Middens

Species	Localities		
	82	83	84
Pelecypoda			
Chlamys hindsii (Carpenter)			x
Mytilus edulis Linné			x
Clinocardium nuttallii (Conrad)	x	x	x
Saxidomus giganteus (Deshayes)	x	x	x
Protothaca staminea (Conrad)	x	x	x
Macoma sp.			x
Schizothaerus capax Gould	x	x	x
Mya sp.			x
Gastropoda			
Acmaea pelta Eschscholtz			x
Thais lamellosa (Gmelin)	x	x	x
Cirripedia			
Balanus sp.			x
Echinoidea			
Strongylocentrotus dröbachiensis Müller			x

Localities

82. Midden behind Boundary Bay school. NE.¼, sec. 10, twp. 5, Delta municipality. Coll. J. E. Armstrong, 1951.
83. North of Raith Road and east of Point Roberts Road. Lot 8, SW.¼, sec. 14, twp. 5, Delta municipality. Coll. F. J. E. Wagner, 1951.
84. Road just east of Crescent Beach station. SE.¼, sec. 18, twp. 1, Surrey municipality. GSC loc. 17620. Coll. W. M. Draycot, 1950 and F. J. E. Wagner, 1951.

Qualicum District, Vancouver Island

The stratigraphic column for the Qualicum district of Vancouver Island is similar to, but less complicated than, the column for the lower Fraser Valley (*see* Table II). Fyles (1956) has not named units below the rank of group and the writer proposes to designate the units of formational rank by letter for easy reference.

Unit C

Unit C is most closely equivalent to the Nicomekl formation with regard to age and mode of origin. Lithologically it consists of silt, stony clay, and till-like materials, with basal laminated silt and clay. Exposures are in the coastal area along Strait of Georgia. Fossils are generally well preserved, but have been moved by wave action to some extent because, although many of the pelecypods have their valves intact, the shells show no preferred orientation. Of the twenty

species identified, only two are apparently confined to the unit. These are *Balanus evermanni* Pilsbry and *Odostomia* (*"Amaura"*) *martensi* Dall and Bartsch. *B. evermanni* has not previously been reported as a fossil.[1] Type locality of *B. evermanni* is the junction of Clarence Strait and Behm Canal, Alaska.

Locality 87 is of particular interest. There silts containing marine shells can be traced laterally into silt and fine sand with interbedded peat and driftwood. The plant species recognized are spruce, pine, hemlock, cedar and fir.[2] The spruce and pine are abundant, the hemlock is common, and the cedar and fir are rare. The peat and wood have been dated by the radiocarbon method at about 25,000 years before the present (Olson and Broecker, 1957).

Table XIII

Faunal List, Unit C (Quadra)

Species	Localities							
	85	86	87	88	89	90	91	92
Pelecypoda								
Nucula tenuis (Montagu)				x		x	x	
Nucula sp.	x	x		x			x	
Nuculana fossa (Baird)		x	x	x		x	x	
Nuculana minuta (Fabricius)	x	x		x		x		
Nuculana sp.		x	x		x		x	x
Mytilus edulis Linné		x		x	x			
Astarte alaskensis Dall		x						
Clinocardium blandum (Gould)						x	x	x
Clinocardium ciliatum (Fabricius)		x		x	x		x	
Clinocardium sp.	x	x			x		x	x
Serripes groenlandicus (Bruguière)		x	x	x	x	x	x	x
Macoma calcarea (Gmelin)	x	x	x	x			x	x
Macoma incongrua (Martens)			x					
Macoma sp.					x			
Mya truncata Linné	x		x	x			x	
Mya sp.	x							
Hiatella arctica (Linné)	x		x	x	x	x	x	x
Gastropoda								
Odostomia (*"Amaura"*) *martensi* Dall and Bartsch						x		
Lacuna sp.								x
Natica clausa (Broderip and Sowerby)		x						
Neptunea lyrata (Gmelin)							x	
Oenopota alaskensis Dall							x	
Annelida								
Serpula vermicularis Linné	x							
Cirripedia								
Balanus crenatus Bruguière								x
Balanus evermanni Pilsbry		x			x		x	
Balanus sp.		x						

[1] Bousefield, E. L., National Museum of Canada, personal communication.
[2] Fyles, J. G., Geological Survey of Canada, personal communication.

Fossil Localities

85. Exposure east of highway, 2¼ miles north-northeast of Cumberland. Elevation 305′. GSC loc. 21609. Coll. J. G. Fyles, 1951.

86. Sea-cliffs on east side of Denman Island, just north of Komas Bluff. Elevation less than 25′. GSC loc. 17640 and 21599. Coll. J. E. Armstrong, 1950 and F. J. E. Wagner, 1951.

87. Road-cut on Island highway, about ⅕ mile east of Chef Creek. Elevation about 80′. GSC loc. 21600. Coll. F. J. E. Wagner, 1951.

88. West bank of creek northwest of Bowser flowing into Strait of Georgia about opposite the southern end of Denman Island. Elevation 100′. GSC loc. 21612. Coll. F. J. E. Wagner, 1951.

89. Sea-cliffs northwest of Bowser, about 200 yards southeast of GSC loc. 21612. Elevation 80′. Coll. F. J. E. Wagner, 1951.

90. Dashwood sea-cliffs, directly north of the first railway crossing on Island highway east of Dunsmuir. Elevation ? 50′. GSC loc. 21619. Coll. J. G. Fyles, 1951.

91. Dashwood sea-cliffs. Elevation about 110′. GSC loc. 21597. Coll. F. J. E. Wagner, 1951.

92. Dashwood sea-cliffs, about 800 yards east of GSC loc. 21597. Elevation approximately 70′. GSC loc. 21598. Coll. F. J. E. Wagner, 1951.

Unit J

This unit is composed of clay, silt, sand, and some poorly sorted till-like material of marine, and possibly glacio-marine, origin. It is the correlative of the Cloverdale formation of the mainland. It has, however, many more species than the Cloverdale formation. Forty-five different species have been recognized (Table XIV), as compared with eighteen for the Cloverdale formation, and all but five of those found in the Cloverdale formation are found also in Unit J. Four species have yet to be found in other than Unit J. They are *Yoldia* (*Megayoldia*) *thraciaeformis* Storer, *Pandora filosa* Carpenter, *Puncturella galeata* (Gould), and an echinoid doubtfully referred to the genus *Brisaster*. Sixteen other species have not yet been discovered in other formations on Vancouver Island, but are known from one or more formations in the lower Fraser Valley area.

West of Beaufort Range, in the district around Alberni, only casts of the shells were found. Associated with these were casts of leaves and pine needles. The consensus of opinion of several botanists consulted was that specific determinations were not possible for the leaf imprints.[1] However, they believed that, besides the pine, the collection probably includes *Dryas,* alder, and blueberry. At locality 109, on Englishman River east of Beaufort Range, wood and leaves were found with the shells. Identification of *Dryas* leaves shows them to be of an Arctic, rather than a mountain species.[1] This corroborates the evidence of the molluscan species that the climate was still considerably colder than at present.

[1] Fyles, J. G., Geological Survey of Canada, personal communication.

Table XIV

Faunal List, Unit J (Capilano)

Species	Localities																
	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
Pelecypoda																	
Nucula tenuis (Montagu)				x	x												x
Nucula sp.							x						x	x			x
Nuculana fossa (Baird)	x	x	x	x	x	x	x		x	x					x	x	x
Nuculana minuta (Fabricius)	x	x	x	x	x		x		x	x						x	
Nuculana sp.			x					x			x		x				
Yoldia (*Megayoldia*) *thraciaeformis* Storer				x													x
Yoldia sp.														x			
Chlamys hericius (Gould)		x															
Chlamys hindsii (Carpenter)	x	x		x		x	x	x	x							x	
Chlamys sp.	x	x						x			x						
Propeamusium alaskense Dall			x														
Mytilus edulis Linné	x		x	x		x		x		x							
Pandora filosa Carpenter									x								
Pandora grandis Dall				x					x								
Axinopsida serricata (Carpenter)															x		
Axinopsida viridis (Dall)																	x
Clinocardium blandum (Gould)		x													x		
Clinocardium ciliatum (Fabricius)				x					x						x		
Clinocardium nuttallii (Conrad)	x						x								x		
Clinocardium sp.	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x
Serripes groenlandicus (Bruguière)			x	x							x			x	x	x	
Transennella tantilla (Gould)				x													
Saxidomus giganteus (Deshayes)	x			x													
Protothaca staminea (Conrad)	x		x														
Macoma calcarea (Gmelin)		x	x	x						x	x	x		x	x	x	x
Macoma incongrua (Martens)	x	x	x	x						x						x	x
Macoma irus (Hanley)	x															x	
Macoma sp.				x			x	x					x				x
Mya truncata Linné	x		x	x							x				x		x
Mya sp.					x					x							
Hiatella arctica (Linné)	x	x	x	x			x	x		x			x	x	x	x	x
Gastropoda																	
Acmaea digitalis Eschscholtz	x																
Acmaea sp.	x																
Puncturella galeata (Gould)		x															
Margarites pupillus (Gould)	x																
Odostomia (*Evalea*) *columbiana* Dall and Bartsch		x															
Odostomia sp.	x	x															
Lacuna sp.	x																
Trichotropis cancellata Hinds		x	x	x			x									x	
Natica aleutica Dall		x															
Natica clausa (Broderip and Sowerby)	x	x														x	
Natica sp.	x	x		x													x
Polinices pallidus (Broderip and Sowerby)				x													
Buccinum sp.		x														x	
Neptunea sp.																	x
Colus jordani (Dall)			x														
Oenopota alaskensis Dall				x			x										
Propebela quadra (Dall)		x	x	x													
Oenopota sp. or *Propebela* sp.				x													
Acteocina culcitella (Gould)				x													
Acteocina eximia Baird				x													
Scaphopoda																	
Dentalium cf. *D. rectius* Carpenter																	x

Table XIV—*Conc.*

Species	Localities																
	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
Annelida																	
Serpula vermicularis Linné	x	x	x	x						x						x	
Cirripedia																	
Balanus crenatus Bruguière		x								x							
Echinoidea																	
? *Brisaster* sp.							x										
Strongylocentrotus dröbachiensis Müller																	x

Fossil Localities

93. Southern end of Hornby Island. Elevation 250′. GSC loc. 21608. Coll. J. G. Fyles, 1951.
94. Cut along the railway about 500 yards due east of Deep Bay. Elevation 110′. GSC loc. 21617. Coll. J. G. Fyles, 1951.
95. Road-cut on Island highway about ¾ mile east of Chef Creek. Elevation 105′. GSC loc. 21588. Coll. F. J. E. Wagner, 1951.
96. Road-cut on Island highway about $\frac{9}{10}$ mile east of Chef Creek. Elevation 100′. GSC loc. 21596. Coll. F. J. E. Wagner, 1951.
97. Gravel pit west of Somass River, near Alberni. Elevation about 100′. GSC loc. 21593. Coll. F. J. E. Wagner, 1951.
98. Dolan's gravel pit, northwest of Alberni. Elevation about 100′. GSC loc. 21594. Coll. F. J. E. Wagner, 1951.
99. Gravel pit about 2½ miles northwest of Alberni. Elevation 100′. GSC loc. 21591. Coll. F. J. E. Wagner, 1951.
100. Cut on south side of B., S. and W. Co. logging road, 200 yards northwest in GSC loc. 21611. Coll. F. J. E. Wagner, 1951.
101. Cut on south side of B., S. and W. Co. logging road, 100′ southwest of Great Central highway and 900′ west of Somass River bridge, west of Alberni. Elevation 75′. GSC loc. 21611. Coll. F. J. E. Wagner, 1951.
102. Ditch on south side of Canadian highway in Alberni, 100′ east of Esquimalt and Nanaimo Railway. Elevation 100′. GSC loc. 21610. Coll. F. J. E. Wagner, 1951.
103. Cliff on south side of Little Qualicum River about ¼ mile upstream from the junction with Whiskey Creek. Elevation 180′. Coll. F. J. E. Wagner, 1951.
104. South side of Little Qualicum River, about 100′ east of locality 103. Elevation 180′. Coll. F. J. E. Wagner, 1951.
105. Cut on west bank of Whiskey Creek, about ¾ mile due north of GSC loc. 21613. Elevation 225′. GSC loc. 21614. Coll. F. J. E. Wagner, 1951.
106. Cut below old railway grade on east bank of Whiskey Creek, ⅜ mile southeast of junction with Little Qualicum River. Elevation 250′. GSC loc. 21613. Coll. F. J. E. Wagner, 1951.
107. Ditch across pasture at Arrowsmith No. 1 farm, west of Qualicum. Elevation 275′. GSC loc. 21590. Coll. F. J. E. Wagner, 1951.
108. Well, just west of French Creek and south of the Esquimalt and Nanaimo Railway, near Parksville. Elevation 125′. GSC loc. 21616. Coll. J. G. Fyles, 1951.
109. Cliff on east bank of Englishman River, about ½ mile southwest of Island highway and 2¾ miles due southeast of Parksville. Elevation about 175′. GSC loc. 21589. Coll. F. J. E. Wagner, 1951.

Unit K

Unit K comprises gravel, sand, silt, clay, and till-like materials, partly in the form of wave-washed lag veneer. It correlates with the Sunnyside and Bose formations of the mainland. Twenty-five species have been identified from two fossil localities (Table XV). Only one species is apparently restricted to the formation. This has been tentatively referred to *Chlamys islandica* (Müller).

At locality 111 casts of shells occur in the upper part of the fossilliferous zone, with actual shells below. Casts of fragments of leaves are associated with the shell casts. The leaf fragments were unidentifiable.

Table XV

Faunal List, Unit K (Capilano)

Species	Localities	
	110	111
Pelecypoda		
Nuculana fossa (Baird)	x	
Nuculana minuta (Fabricius)	x	x
Chlamys islandica (Müller) ?	x	
Chlamys sp.	x	
Mytilus edulis Linné	x	x
Clinocardium blandum (Gould)	x	
Clinocardium ciliatum (Fabricius)	x	x
Clinocardium nuttallii (Conrad)	x	x
Clinocardium sp.	x	x
Serripes groenlandicus (Bruguière)	x	x
Transennella tantilla (Gould)	x	
Saxidomus giganteus (Deshayes)	x	
Protothaca staminea (Conrad)	x	
Macoma calcarea (Gmelin)	x	x
Macoma incongrua (Martens)	x	x
Macoma inconspicua (Broderip and Sowerby)	x	
Macoma irus (Hanley)	x	
Schizothaerus capax (Gould)	x	
Mya arenaria Linné	x	
Mya truncata Linné		x
Hiatella arctica (Linné)	x	x
Gastropoda		
Acmaea digitalis Eschscholtz	x	
Margarites pupillus (Gould)	x	
Littorina scutulata Gould	x	
Natica clausa (Broderip and Sowerby)	x	
Scaphopoda		
Dentalium cf. *D. rectius* Carpenter		x
Annelida		
Serpula vermicularis Linné	x	

Fossil Localities

110. East side of Denman Island, just south of GSC loc. 21599. Elevation about 115′. GSC loc. 21615. Coll. J. G. Fyles, 1951.

111. Cliff on south side of Kinkade Creek, about $\frac{1}{10}$ mile upstream from the junction with Little Qualicum River. Elevation 200′. GSC loc. 21595. Coll. F. J. E. Wagner, 1951.

Additional Faunal Records

Few studies have been made of the Pleistocene faunas of either the lower Fraser Valley area or Vancouver Island. Prior to 1948, when the stratigraphic study of the Vancouver district was initiated by Armstrong, fossil marine invertebrates were recorded from the area only by Johnston (1923, pp. 49, 50) and Crickmay (1925, p. 140 and 1929, p. 206). Since then, one further list has been given by Draycot (1951, p. 21). On Vancouver Island, fossil assemblages have been reported from around Victoria by Clapp (1912, p. 120), Hannibal (unpublished MS.), Newcombe (1914, pp. 107-109), and Richardson (1872, p. 94). Fossils from Comox have been recorded by Hannibal (unpublished MS.), and from the Nanaimo district by Clapp (1914, p. 92). Several collections by Armstrong from outside the Qualicum area have been identified by the writer and are listed on page 39 of this report. Pleistocene faunas have been recorded also from the Puget Sound region of Washington by Arnold and Hannibal (1913, p. 598), Bretz (1913), Frizzell (1930, pp. 120-121), Hannibal (unpublished MS.), and Henderson (1927, pp. 1-3).

Johnston (1923, pp. 49, 50) listed shells from two localities south of Fraser River. From the coast west of White Rock he recorded the following species:

Pelecypoda

Cardium cf. *corbis* Martyn
Pecten (*Chlamys*) *islandicus* Möller
Leda pernula Möller
Macoma calcarea Gmelin
Mya truncata Linné
Mytilus edulis Linné

Gastropoda

Buccinum sp.

Crustacea

Balanus rostratus dalli Pilsbry

Johnston's second locality is the same as that described by Crickmay (1925, p. 140), and it is of interest to compare the two faunal lists. The locality is a road-cut on the Pacific highway about 2,100 yards south of the Fraser River bridge opposite New Westminster. The elevation is approximately 70 feet above mean sea-level. Species found by Johnston are:

Pelecypoda

Pecten hindsii Carpenter
Pecten hindsii var. *navarchus* Dall
Pecten (*Chlamys*) *islandicus* Möller
Leda pernula Möller
Cardium (*Protocardia*) *centifilosum* Carpenter
Macoma inquinata Deshayes
Saxidomus giganteus Deshayes
Spisula catilliformis Conrad
Mya truncata Linné
Saxicava arctica Linné
Astarte alaskensis Dall

Gastropoda

Puncturella noachina var. *galeata* Gould
Polinices (*Euspira*) *draconis* Dall
Acteocina cerealis Gould

Crickmay recorded the following from this same locality:

Strongylocentrotus cf. *dröbachiensis* Müller
Terebratalia transversa var. *caurina* Gould
Leda fossa var. *vaginata* Dall
Leda fossa var. *sculpta* Dall
Pecten (*Chlamys*) *hindsii* Carpenter
P. (*C.*) *hindsii* var. *jordani* Arnold
P. (*C.*) *hindsii* var. *kincaidi* Oldroyd
P. (*C.*) *hindsii* var. *navarchus* Dall
Pododesmus (*Monia*) *macrochisma* Deshayes
Astarte alaskensis Dall
Cardium ciliatum Fabricius
Cardium corbis Martyn
Serripes groenlandicus Gmelin
Saxidomus giganteus Deshayes
Paphia (*Protothaca*) *staminea* var. *ruderata* Deshayes
Macoma incongrua Martens
Macoma brota Dall
Macoma calcarea Gmelin
Macoma inquinata Deshayes
Spisula (*Hemimactra*) *voyi* Gabb
Schizothaerus capax Gould
Mya truncata Linné
Panomya ampla Dall
Lora cf. *fidicula* Gould
Admete couthouyi Jay
Chrysodomus liratus Martyn
Trichotropis cancellata var. *quadricarinata* A. Adams
Lacuna cf. *porrecta* Carpenter

Lacuna cf. *unifasciata* Carpenter
Natica (*Cryptonatica*) *clausa* Broderip and Sowerby
Puncturella galeata Gould
Serpula sp.
Balanus rostratus var. *apertus* Pilsbry

These two lists are not in complete agreement. Crickmay's has more than twice the number of species that Johnston's has, and not all of Johnston's species are to be found in Crickmay's list. *Leda pernula, Cardium centifilosum, Spisula catilliformis, Polinices draconis,* and *Acteocina cerealis* appear only in Johnston's record. Crickmay (1925, p. 140) thought that some of the discrepancies might be due to differences of opinion regarding the identity of the species. However, he stated that not having seen Johnston's specimens, he was unable to explain this lack of agreement. He questioned Johnston's identification of *Pecten* (*Chlamys*) *islandicus,* and thought that it was probably *P.* (*C.*) *kincaidi.*

According to the lithological description of the localities, the fossils are from the Newton formation. Comparison of these lists with the writer's faunal list for the Newton formation (Table VI) shows a considerable lack of agreement. A few of the discrepancies are more apparent than real. Nomenclatural revision has taken place over the years, with consequent changes in name for some species. Therefore, in several instances, the same species appears on both lists but under different names.

The name "*Cardium corbis* Martyn" has been incorrectly applied by numerous authors to *Cardium nuttallii* Conrad. Keen (1926, p. 120) gives two reasons for the unavailability of Martyn's name: Martyn's *Universal Conchologist* has been rejected by many authors as not consistently binomial, and Conrad in 1869 recognized that the West American species is not the same as the one figured by Martyn. Thus, the first available name for this species is *C. nuttallii* Conrad, 1837. This species comes now under the genus *Clinocardium. Chrysodomus liratus* Martyn is also affected by the rejection of Martyn's work; the species is now properly referred to *Neptunea lyrata* (Gmelin).

Macoma inquinata Deshayes is a synonym of *M. irus* (Hanley), and juveniles of *Acteocina culcitella* (Gould) were formerly identified as a separate species (Dall, 1922, p. 96) under the name of *A. cerealis* Gould. At the generic level three changes may be noted. *Leda* becomes *Nuculana,* all of the species of *Cardium* in these lists now come under the genus *Clinocardium,* and *Saxicava* yields to the prior *Hiatella.*

Twenty-five of the forty-seven species in Table VI of this bulletin do not appear in Johnston's and Crickmay's lists, and twenty-two of the forty-three species in their lists are not found in Table VI. Some of the discrepancies here are possibly due to differences of opinion concerning identification of the species.

Two other collections were recorded by Crickmay (1929, p. 206). He made one collection from a sewer excavation on the south side of Marine Drive, 150 yards west of Angus Street, near the south end of Granville Street, Vancouver.

The shells came from a 7-foot bed of fine blue silt underlain by till and overlain by a considerable thickness of crossbedded sand. The formation is presumably Cloverdale. The species obtained were:

Vermes
- *Serpula* sp.
- *Spirorbis* sp.

Echinodermata
- *Strongylocentrotus dröbachiensis* Müller

Brachiopoda
- *Hemithyris psittacea* Gmelin
- *Laqueus californicus* var. *vancouverensis* Davidson
- *Terebratalia transversa* var. *caurina* Gould

Pelecypoda
- *Leda fossa* var. *sculpta* Dall
- *Leda fossa* var. *vaginata* Dall
- *Chlamys hindsii* Carpenter
- *Chlamys hindsii* var. *kincaidi* Oldroyd
- *Chlamys hindsii* var. *navarchus* Dall
- *Pododesmus macrochisma* Deshayes
- *Mytilus edulis* Linné
- *Astarte alaskensis* Dall
- *Thyasira gouldii* Philippi
- *Axinopsis sericatus* Carpenter
- *Cardium corbis* Martyn
- *Cardium fucanum* Dall
- *Cardium ciliatum* Fabricius
- *Serripes groenlandicus* Gmelin
- *Saxidomus giganteus* Deshayes
- *Paphia staminea* var. *ruderata* Deshayes
- *Macoma incongrua* Martens
- *Macoma brota* Dall
- *Macoma calcarea* Gmelin
- *Macoma inquinata* Deshayes
- *Macoma nasuta* Conrad
- *Spisula voyi* Gabb
- *Schizothaerus capax* Gould
- *Mya intermedia* Dall
- *Panomya ampla* Dall
- *Cryptomya californica* Conrad
- *Saxicava arctica* Linné
- *Saxicava pholadis* Linné

Gastropoda
- *Acteocina eximia* Baird
- *Lora* cf. *fidicula* Gould
- *Admete couthouyi* Jay

Beringius cf. *marshalli* Dall
Chrysodomus liratus Martyn
Trichotropis cancellata var. *quadricarinata* Adams
Natica janthostoma Deshayes
Lepeta concentrica Middendorff
Margarites pupillus Gould

Crustacea
Balanus crenatus Bruguière

The second collection was made by Johnston from the Port Haney brickyard. The locality was mentioned (1923, p. 50), but the species were never listed. Species found were:

Pelecypoda
Leda fossa var. *sculpta* Dall
Chlamys hindsii Carpenter
Cardium ciliatum Fabricius
Macoma calcarea Gmelin

Gastropoda
Chrysodomus liratus Martyn
Natica clausa Broderip and Sowerby

The shells were found in the stony lower part of the stratified clay exposed in excavations at the brickyard. They are possibly of the Whatcom formation.

A composite list for the lower Fraser River area by Draycot (1951, p. 21) has the following species:

Pelecypoda
Axinopsis viridis Dall
Clinocardium blandum Gould
Clinocardium ciliatum Fabricius
Clinocardium comoxense Dall
Clinocardium nuttallii Conrad
Macoma incongrua von Martens
Macoma calcarea Gmelin
Macoma irus Hanley
Macoma secta Conrad
Mya truncata Linné
Mya var. *arenaria* Linné
Sphenia ovoidea Carpenter
Mytilus edulis Linné
Nucula belloti A. Adams
Nucula tenuis Montagu
Nuculana minuta Fabricius
Pandora (*Kennerlia*) *grandis* Dall
Pecten (*Propeamusium*) *alaskense* Dall
Delectopecten alaskense Dall, 1898

Pecten (*Chlamys*) *hericius* Gould
Pecten (*Chlamys*) *hindsii* Carpenter
Pecten (*Chlamys*) *jordani* Arnold
Protothaca tenerrima Carpenter
Protothaca staminea Conrad
Saxicava arctica Linné
Serripes groenlandicus Bruguière
Saxidomus giganteus Deshayes
Spisula voyi Gabb
Thyasira barbarensis Dall
Transennella tantilla Gould

Gastropoda
Acmaea sp., probably *A. persona* Eschscholtz
Acteocina culcitella Gould
Colus jordani Dall
Lacuna porrecta Carpenter
Lepeta concentrica Middendorff
Littorina sitkana Philippi
Margarites pupillus Gould
Neptunea sp.
Chrysodomus liratus "Martyn"
Natica clausa Broderip and Sowerby
Odostomia (*Evalea*) *vancouverensis* Dall and Bartsch
Puncturella galeata Gould
Polinices sp.
Trichotropis cancellata Hinds
Turrid not yet determined
Lora viridula Fabricius

Crustacea
Balanus
Hyperia galba Montagu
crab's claw

Annelida
Serpula
Spirorbis

Sarcodina
Order Foraminifera. A few of the genus *Elphidium*

Comparison of these lists with the writer's shows a number of differences. As before, a few of these may be due to differences of opinion, and some are differences of name only, with two different names for the same species reflecting nomenclatural changes in the time interval between the lists. *Axinopsis viridis* and *Axinopsida viridis* are synonymous, as are *Paphia staminea* and *Protothaca*

staminea. Other changes were noted following the Newton formation lists of Johnston and Crickmay. *Delectopecten alaskense* Dall in Draycot's list may possibly be an error for *D. vancouverensis* (Whiteaves). However, as stated previously, no attempt can be made to account for these discrepancies without seeing the collections in question. These last three lists contain sixteen species new to all the lists.

Several collections were made by Armstrong, Draycot, and the writer between 1950 and 1953 in the northern part of the State of Washington. They are recorded in Table XVI. Three formations are represented.

Table XVI

Faunal List, Washington State Collections

Species	Localities					
	17635	21587	17632	17631	21587(a)	24002
Pelecypoda						
Nucula tenuis (Montagu)				x		?
Nucula sp.			x			
Nuculana fossa (Baird)		x	x	x	x	x
Nuculana minuta (Fabricius)		x	x	x		
Chlamys hindsii (Carpenter)	x	x	x	x		
Chlamys sp.		x	x			
Propeamusium alaskense Dall			x			
Mytilus edulis Linné		x				
Clinocardium blandum (Gould)			x	x		
Clinocardium ciliatum (Fabricius)			x	x		
Clinocardium fucanum (Dall)			x	x		
Clinocardium sp.		x	x	x		x
Serripes groenlandicus (Bruguière)		x	x	x		
Saxidomus giganteus (Deshayes)		x	x			
Protothaca staminea (Conrad)	x	x				
Protothaca staminea var. *ruderata* (Deshayes)		x				
Protothaca sp.			x			
Macoma calcarea (Gmelin)			x	x	x	x
Macoma incongrua (Martens)	x	x	x	x		x
Macoma irus (Hanley)	x	x				
Mya truncata Linné				x		?
Hiatella arctica (Linné)		x	x		x	
Gastropoda						
Trichotropis cancellata Hinds	x	x				
Natica clausa (Broderip and Sowerby)		x				
Natica sp.		?	x			
Annelida						
Serpula vermicularis Linné	x	x	x	x		
Cirripedia						
Balanus sp.		x	x			

Fossil Localities

17635. Sea-cliffs at Marietta, Washington. Coll. J. E. Armstrong, 1950. Nicomekl formation.
21587. Sea-cliffs at Marietta, Washington. Elevation 10 to 30′. Coll. F. J. E. Wagner, 1951. Nicomekl formation.
17632. Semiahmoo Road, $\frac{3}{10}$ mile southeast of fork, one road leading to Birch Point and the other to Alaska Packers Assn. cannery. NW.$\frac{1}{4}$, sec. 11, T. 40 N, R.1 W, Whatcom county, Washington. Coll. W. M. Draycot, 1950 and F. J. E. Wagner, 1951. Newton formation.
17631. Drayton Harbor, Washington. Coll. W. M. Draycot, 1950. Newton formation.
21587 (a). Sea-cliffs at Marietta, Washington. Coll. F. J. E. Wagner, 1951. Newton formation.
24002. Bank of Bertrand Creek about $\frac{1}{2}$ mile south of International Boundary and a mile west of Aldergrove Customs. Elevation 125′. Coll. J. E. Armstrong, 1953. Whatcom formation.

From Vancouver Island, Clapp (1914, p. 92) listed *Saxicava rugosa, Mya truncata* and *Leda fossa* from the interglacial deposits of the Nanaimo map-area, and *Cardium islandicum, Leda fossa, Saxicava rugosa, Natica clausa* (?) and *Balanus crenatus* (?) from the vicinity of Victoria (1912, p. 120). He cited no exact localities. Richardson (1872, p. 94) referred to a locality east of Saanich road, 5 miles from Victoria at an elevation of 300 feet above sea-level, and said that "some of the shells appear to me to be the same as the recent species". No determinations of the species were given.

Newcombe (1914, pp. 107-109) described several localities near Victoria, and cited fossils as follows:

> The earliest notice I can find of these interior beaches is a note by Mr. James Richardson in the Report of the Geological Survey for 1871-72, p. 94, where he reports a shell-bed to the east of the Saanich road, at a height of about three hundred feet above the sea.
>
> The first beach of the kind examined by the writer was one to which attention was called by Mr. F. Pemberton, of Victoria, in 1889. He told me that during the removal of black soil ... near Ross Bay Cemetery ... a large quantity of shells were being exposed under the peat. I found that under a foot or two of decayed vegetable matter containing freshwater shells were the following marine species: *Cardium corbis* Mart., *Macoma calcarea* Gmel., *Mya truncata* L., *Mytilus edulis* L., *Saxicava arctica* L., and *Saxidomus giganteus* Desh.
>
> Three years later, ... I collected at Mount Tolmie all of these species and an additional *Cardium* now no longer living in these waters, *Cardium decoratum*. (My diagnosis was confirmed by Dr. Dall of Washington.)

He said of a locality at Lost Lake, near the foot of the prominent monadnock called Cedar Hill or Mount Douglas:

> On the side of a shallow cut here I noticed *Macoma nasuta* and *inquinata,* in addition to the species already noted. It was in this region, though not clearly identified, that Mr. Richardson collected his specimens referred to.

His last-mentioned locality was in a hollow between Spring Ridge and the Protestant orphanage.

> Again after digging through an extensive peat bed, containing freshwater shells in perfect condition, at about four feet from the surface vast quantities of marine shells were exposed, together with two species of barnacle and a few fragments of elk-horn, apparently cut by a blunt instrument.
>
> Here I added to my list the following gastropods: *Natica clausa* B. & S. (of immense size), *Natica pallida* B. & S., *Margarita pupilla* Gld., and *Acmaea alveus* Conr., a species which lives on eel grass growing in shallow, quiet waters. To the bivalves were added a *Macoma* like *balthica* L., *Paphia staminea* Conr., *Schizothaerus nutallii* Conr., and *Zirphaea crispata* L.

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All of the above fossil occurrences are in the Saanich formation. Hannibal (unpublished MS.) listed fossils from the Saanich formation at Victoria, and from the Maywood formation at Victoria, Comox, and Denman Island. The Saanich formation is of Capilano age and the Maywood is Quadra. Hannibal's species from the Saanich formation are:

	Locality
Pelecypoda	
Cerastoderma corbis Mart.	1, 3
Cerastoderma decoratum Grwk.	3
Macoma inquinata Desh.	1, 2, 3
Macoma nasuta Conr.	1
Mya truncata L.	1, 2, 3
Mytilus edulis L.	1, 3
Protothaca staminea petiti Desh.	1
Saxicava arctica L.	1, 2, 3
Saxidomus giganteus Desh.	1, 3
Schizothaerus nuttalli Conr.	1
Serripes grönlandicus Gmel.	3
Zirphaea crispata L.	1
Gastropoda	
Acmaea pelta Esch.	1
Cryptonatica clausa B. & S.	1
Euspira pallida B. & S.	1
Pupillaria pupilla Gld.	1

Locality 1: Bay Street and Cedar Hill Road, Victoria.
Locality 2: Valley south of Mount Douglas (Cedar Hill), Saanich Peninsula, Victoria.
Locality 3: Valley between Ross Bay and Beacon Hill Park, Victoria.

From the Maywood clays he records the following species:

	Locality
Brachiopoda	
Laqueus jeffreysi Dall	5
Pelecypoda	
Astarte alaskensis Dall	4
Cerastoderma comoxense Dall	5
Cerastoderma decoratum Grwk.	4, 5, 6
Chlamys jordani Arn.	5
Kennerlia grandis Midd.	6
Leda fossa Bd.	6
Leda	5, 6
Leda	6
Macoma calcarea Gmel.	6
Macoma inquinata Desh.	6
Macoma krausei Dall	6

Mya truncata L.	4, 5, 6
Mytilus edulis L.	5
Nucula polita Hanc.	5
Nucula	6
Propeamusium alaskense Dall	5
Saxicava arctica L.	4, 5, 6
Serripes grönlandicus Gmel.	5, 6
Thyasira gouldii Phil.	6
Gastropoda	
Bela harpa Dall	5
Buccinum strigillatum Dall	6
Cryptobranchia concentrica Midd.	5
Cryptobranchia clausa B. & S.	4, 5, 6
Euspira pallida B. & S.	6
Puncturella cooperi Cpr.	5

Locality 4: East side of Denman Island, near sea-level.

Locality 5: Point Holmes, Comox, Vancouver Island.

Locality 6: Dallas Road, Victoria.

Three recent collections from Vancouver Island from outside the Qualicum district are recorded below.

	GSC Loc. No.
Pelecypoda	
Nuculana fossa (Baird)	17638
Chlamys hindsii (Carpenter)	21620
Modiolus modiolus (Linné)	21620
Clinocardium sp.	17638, 17639, 21620
Serripes groenlandicus (Bruguière)	17638
Macoma inconspicua (Broderip and Sowerby) ?	17639
Macoma sp.	17638
Mya arenaria Linné	17638
Mya truncata Linné	17638, 21620
Hiatella arctica (Linné)	17639
Odostomia sp.	17638
Balanus sp.	17638
Strongylocentrotus sp.	17638

17638. Cowichan Head, Saanich Peninsula. Coll. J. E. Armstrong, 1950.

17639. Quinsam River, near Campbell River. Coll. J. E. Armstrong and W. L. Brown, 1950.

21620. Duncan Bay Pulp Mill, on shore 3 miles north of mouth of Campbell River. Coll. J. G. Fyles, 1951.

All but twelve of these species appear also in the writer's Vancouver Island records. Nomenclatural changes account for the other differences between the lists. Those species not found by the writer include *Nucula polita, Thyasira*

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gouldii, Cardium decoratum, Protothaca staminea petiti, Macoma krausei (= *M. moesta* Deshayes), *Macoma nasuta, Schizothaerus nuttalli, Zirphaea crispata, Acmaea alveus, Puncturella cooperi, Buccinum strigillatum,* and *Bela harpa.* Of these, *Zirphaea crispata* and *Acmaea adveus* are eastern species, and *Nucula polita* is apparently not North American. Hannibal's *Zirphaea crispata* is probably *Zirfaea gabbi* Tryon. *Clinocardium ciliatum* would undoubtedly be the species here listed as *Cardium islandicum. Cryptobranchia clausa* B. & S. in Hannibal's list is clearly intended to be *Cryptonatica clausa.*

Plate I illustrates some of the species previously unrecorded from the lower Fraser Valley area and from Vancouver Island.

Chapter III

PALÆOECOLOGY

The fossil assemblages form a valuable basis from which to determine the climatic conditions for the period in which they lived. They are recent enough that direct comparison with Recent faunas may be made, and methods applicable to the Recent west coast faunas for determination of geographic position may also be applied to the fossil faunas. The latitudes determined for the fossil assemblages give an indication of water temperatures at the time of deposition. From the data available, general conclusions regarding the depths of water in which the fossiliferous deposits were formed may also be drawn.

Latitude and Hydroclimate

In order to determine the corresponding present-day latitude, and hence the hydroclimate at the time of formation of each of the fossil assemblages, the median-of-midpoints method has been used. This method, devised by Schenck and Keen (1937), elaborated on by them subsequently (1940), and further revised by Schenck (1945) is an objective means of locating and showing the geographic trend of a molluscan assemblage. A northward-ranging assemblage will have its median to the north of the latitude at which the specimens were collected, and vice versa. North of the vicinity of Coos Bay, Oregon, all of the Recent assemblages show a majority of southward-ranging species.

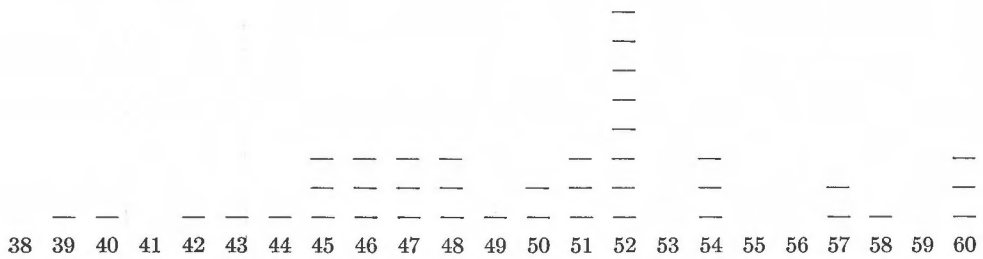
The procedure for determining the median of midpoints has been described by Schenck and Keen (1937; 1940) and Schenck (1945). Keen (1937) has tabulated the ranges of the west coast pelecypod, gastropod, and scaphopod species. In illustration of this method, the median of midpoints is herewith computed for the molluscan species from locality 7. The species, with their geographic ranges and midpoint of range, are listed below.

Species	Range (degrees N. lat.)	Midpoint
Nucula tenuis (Montagu)	32–73	52
Nuculana fossa (Baird)	48–66	57
Nuculana minuta (Fabricius)	33–72	52
Chlamys hindsii (Carpenter)	34–55	44
Chlamys cf. *C. kincaidi* Oldroyd	48	48
Propeamusium alaskense Dall	34–56	45
Mytiluss edulis Linné	28–74	51
Modiolus modiolus (Linné)	27–72	49
Axinopsida serricata (Carpenter)	34–56	45
Axinopsida viridis (Dall)	32–72	52
Clinocardium blandum (Gould)	48–54	51

Species	Range (degrees N. lat.)	Midpoint
Clinocardium ciliatum (Fabricius)	48–72	60
Clinocardium fucanum (Dall)	37–57	47
Clinocardium nuttallii (Conrad)	33–60	46
Serripes groenlandicus (Bruguière)	48–72	60
Transennella tantilla (Gould)	27–57	42
Saxidomus giganteus (Deshayes)	37–56	46
Protothaca staminea (Conrad)	23–73	48
Macoma calcarea (Gmelin)	37–72	54
Macoma incongrua (Martens)	33–72	52
Macoma inconspicua (Broderip and Sowerby)	33–72	52
Macoma irus (Hanley)	37–64	50
Spisula voyi (Gabb)	?48–69	58?
Mya arenaria Linné	37–49	43
Mya truncata Linné	48–72	60
Hiatella arctica (Linné)	8–72	40
Margarites pupillus (Gould)	34–60	46
Odostomia (*Evalea*) *columbiana* Dall and Bartsch	48–55	51
Odostomia (*Evalea*) *barkleyensis* Bartsch	48	48
Odostomia ("*Amaura*") *sillana* Dall and Bartsch	54	54
Littorina scutulata Gould	19–60	39
Littorina cf. *L. sitkana* Philippi	48–56	52
Lacuna cf. *L. solidula* Lovén	33–61	47
Trichotropis cancellata Hinds	44–56	50
Natica aleutica Dall	33–71	52
Neptunea lyrata (Gmelin)	37–71	54
Oenopota alaskensis Dall	48–66	57
Propebela quadra (Dall)	48–56	52
Acteocina culcitella (Gould)	33–58	45
Acteocina eximia Baird	37–58	47

The range and midpoint are in terms of the range of the Recent faunas as given by Keen (1937).

The next step is to tally each midpoint figure over its latitude along a horizontal scale, thus:



As the median is the latitude at which the middle species falls, divide the number of species in the list by two. In this instance N/2 = 20.

Determine the interval of latitude containing the middle species by counting up from the lower or left end of the distribution. In this distribution the interval of latitude is 50 degrees. To find the precise latitude of the median, interpolate as follows:

(a) Count the number of tallies below, i.e., to the left of this interval; in the above distribution, eighteen species fall below 50 degrees.

(b) Subtract this result from N/2 (20 — 18 = 2).

(c) Divide the result of step (b) by the number of tallies in the median interval and multiply by the width of the interval. In this example the width of the interval is 1 degree of latitude.

$$\frac{2 \times 1^\circ}{2} = 1.0^\circ$$

(d) Add this quantity to the lower limit of the median interval, thus obtaining the required median of midpoints.

$$50.0^\circ + 1.0^\circ = 51.0^\circ$$

Using Recent assemblages as a standard of comparison the method may be applied to an analysis of relative temperature conditions for Pleistocene faunules. For example, if the median of a fossil faunule collected at 49° N lat. is 60 degrees, it may be inferred that the organism lived in an environment colder than the present by at least several degrees. It has been noted that Recent assemblages collected between N lat. 48° and 50° have southward-pointing medians, but medians of Pleistocene assemblages from this area are northward-pointing. A considerable shift in isotherms is indicated.

With fossil assemblages, the depth of water in which the species lived must also be considered. Deep water, and therefore cold water, assemblages would give a higher latitude determination than those collected near shore where water temperatures, except in extreme northern regions, would be appreciably warmer. As a result, a fossil faunule having a median farther north than the actual latitude of collection might be from deep water or it might indicate that hydroclimatic conditions were colder at that place in the past. The Pleistocene faunules of the lower Fraser Valley area and of Vancouver Island indicate relatively shallow waters, 20 fathoms or less (*see* list, p. 50). Medians for Recent assemblages have been found to be consistent for shore collections and dredgings to a depth of 150 fathoms, and it may be assumed that medians for fossil collections from similar environments would be equally consistent (Schenck, 1945, p. 512). Therefore, any latitude higher than that of the collecting locality would indicate a colder hydroclimate at the time of deposition. Recent temperature conditions thus are used as the standard of comparison for interpreting the hydroclimate shifts of the past.

Schenck and Keen suggest that a minimum of twenty species is necessary for reliable results. With fewer species, certain factors, such as sampling errors, misidentifications, and inclusion of reworked or adventitiously introduced species, may alter the result by as much as 2 degrees of latitude. Therefore, many of the medians here listed are open to question because few of the localities have

yielded the recommended number of species. However, despite the paucity of species in many cases, the pattern of results appears to be sufficiently consistent to be of use in interpreting conditions of the past hydroclimate.

Table XVII gives the median of midpoints and corresponding present-day latitude for each fossil assemblage from the lower Fraser Valley area, and Table XVIII gives the same information for the Vancouver Island assemblages. Figure 2 shows the relationship between the latitude of the median of midpoints and the actual latitude of Recent collections. The corresponding present-day latitude of each fossil assemblage is considered to be the same as the latitude of collection would be if it were a Recent assemblage.

Table XVII

Medians of Midpoints and Corresponding Present-Day Latitudes of the Lower Fraser Valley Assemblages

Formation	Locality Number	Number of Species	Median of Midpoints	Corres-ponding Present-Day Latitude
Nicomekl	1	3	52.5	61.4
	2	8	52.0	61.25
	3	3	44.5	46.25
	4	6	47.0	55.25
	5	3	47.75	55.75
	6	7	54.5	62.1
	7	40	51.0	60.9
Newton	8	7	52.5	61.4
	9	1	44.0	45.75
	10	13	52.2	61.3
	11	13	52.5	61.4
	12	3	46.5	55.0
	13	3	52.5	61.4
	14	4	47.0	55.25
	15	5	52.5	61.4
	16	6	47.0	55.25
	17	5	51.5	61.1
	18	11	53.0	61.6
	19	12	52.6	61.5
	20	2	54.0	61.9
	21	13	51.75	61.2
	22	8	51.0	60.9
	23	13	52.75	61.5
	24	9	51.5	61.1
	25	11	51.25	61.0
	26	9	54.25	62.0
	27	3	60.5	66.7
	28	3	51.5	61.1
	29	3	54.5	62.1
	30	12	52.5	61.4
	31	8	53.0	61.6
	32	4	55.0	62.25
	33	2	49.0	60.25
	34	5	54.5	62.1
	35	9	52.5	61.4

Table XVII—*Conc.*

Formation	Locality Number	Number of Species	Median of Midpoints	Corresponding Present-Day Latitude
Newton—*Conc.*	36	—	—	—
	37	9	52.5	61.4
	38	10	53.5	61.75
	39	19	52.6	61.5
Cloverdale	40	11	54.5	62.1
	41	2	53.0	61.6
	42	—	—	—
	43	3	52.75	61.5
Sunnyside	44	16	49.0	60.25
	45	18	51.5	61.1
	46	22	50.5	60.7
Bose	47	—	—	—
	48	1	46.0	54.0
	49	—	—	—
	50	9	54.5	62.1
	51	3	44.5	46.25
	52	3	44.5	46.25
Capilano	53	1	51.0	60.9
	54	5	52.5	61.4
	55	4	47.0	55.25
	56	2	47.0	55.25
	57	5	51.5	61.1
	58	9	52.5	61.4
	59	3	51.5	61.1
	60	4	47.0	55.25
Whatcom	61	1	55.0	62.25
	62	2	52.0	61.25
	63	1	52.0	61.25
	64	2	55.0	62.25
	65	12	52.3	61.4
	66	2	52.0	61.25
	67	3	51.5	61.1
	68	2	45.0	53.2
	69	9	52.25	61.3
	70	2	51.0	60.9
	71	5	52.5	61.4
	72	16	52.0	61.25
	73	8	52.3	61.4
	74	10	52.5	61.4
	75	5	52.5	61.4
	76	13	52.5	61.4
	77	2	53.0	61.6
	78	—	—	—
	79	—	—	—
Abbotsford	80	2	47.0	55.25
Richmond Delta	81	88	47.0	55.25

Table XVIII

Medians of Midpoints and Corresponding Present-Day Latitudes of the Vancouver Island Assemblages

Formation	Locality Number	Number of Species	Median of Midpoints	Corresponding Present-Day Latitude
Unit C	85	4	53.0	61.6
	86	8	58.0	63.25
	87	6	55.0	62.25
	88	9	54.5	62.1
	89	4	52.0	61.25
	90	7	52.75	61.5
	91	11	54.75	62.2
	92	4	52.0	61.25
Unit J	93	14	49.0	60.25
	94	14	52.0	61.25
	95	21	52.3	61.4
	96	13	52.2	61.3
	97	3	52.75	61.5
	98	3	51.5	61.1
	99	7	50.5	60.7
	100	3	44.5	46.25
	101	6	52.0	61.25
	102	6	52.5	61.4
	103	3	60.5	66.7
	104	1	54.0	61.9
	105	—	—	—
	106	3	54.5	62.1
	107	9	54.5	62.1
	108	10	52.5	61.4
	109	9	52.8	61.5
Unit K	110	21	50.5	60.7
	111	10	52.5	61.4

In order to determine a latitude or range in latitude of each formation as a whole, either one of two methods might be used. Both give comparable results. One is to determine the median of midpoints and hence the corresponding present-day latitude using the total list of species found in the formation. The other is to derive a latitude range from the latitudes of the larger assemblages in each formation. In this case, assemblages with fewer than ten species would be disregarded unless the formation had no larger assemblages. Results for the lower Fraser Valley area formations are presented in Table XIX, and for Vancouver Island formations in Table XX.

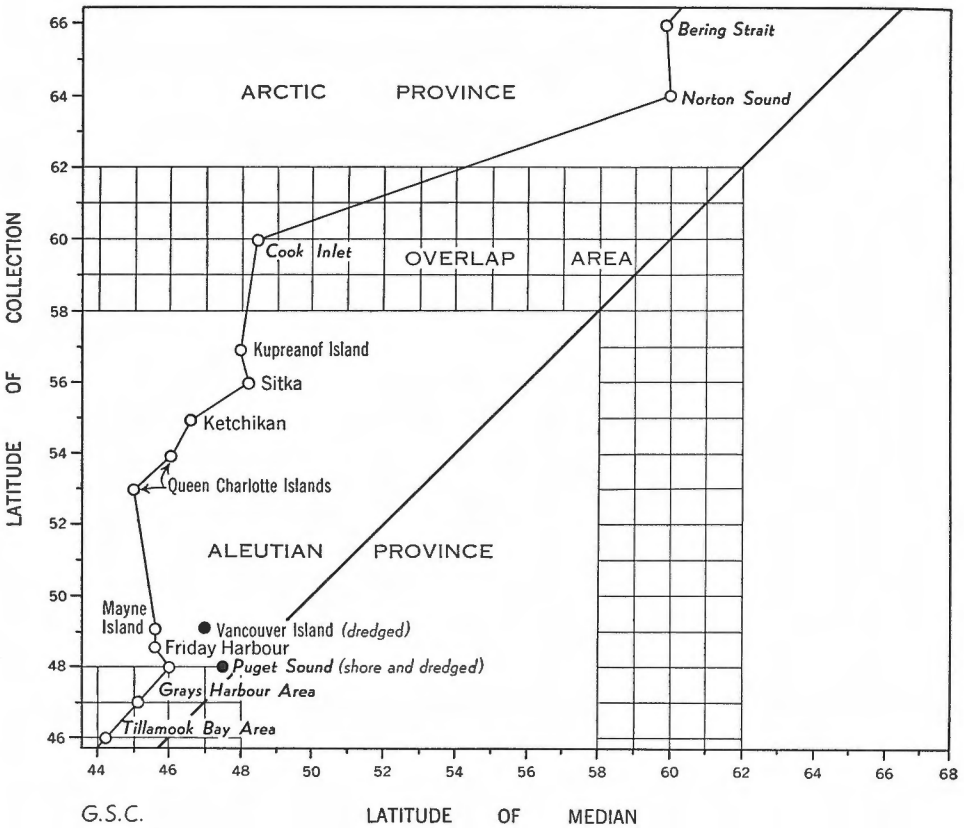


Figure 2. *Curve of medians of midpoints for sample West American Recent molluscan collections. Medians for shore collections are connected by unbroken line to show deviation from the norm, which is the heavy diagonal line. Provincial boundaries are superimposed for reference. (After Schenck, 1945.)*

Table XIX

Tabulation of Corresponding Present-Day Latitudes for the Lower Fraser Valley Formations

Formation	Number of Species	Latitude Range Based on Latitudes of Larger Assemblages	Latitude Based on Total Number of Species
Nicomekl	42	60.9–61.25	60.75
Newton	39	61.0–61.5	61.0
Cloverdale	14	62.1	61.6
Sunnyside	34	60.25–61.1	60.6
Bose	11	62.1	61.5
Capilano	15	61.1–61.4	61.25
Whatcom	21	61.4	61.5
Abbotsford	2	55.25	55.25
Richmond Delta	8	55.25	55.25

Table XX

Tabulation of Corresponding Present-Day Latitudes for the Vancouver Island Formations

Formation	Number of Species	Latitude Range Based on Latitudes of Larger Assemblages	Latitude Based on Total Number of Species
Unit C	16	62.1 –62.2	62.25
Unit J	38	60.25–61.4	60.9
Unit K	23	60.7 –61.4	60.7

Examination of Tables XIX and XX shows that water temperatures were similar during the deposition of the Nicomekl, Newton, Cloverdale, Sunnyside, Bose, Capilano, and Whatcom formations and Units J and K. Comparable conditions of temperature would be found today off the coast of Alaska, along the northern reaches of Cook Inlet and Prince William Sound. The latitude range for Unit C, which is believed to be slightly older than the Nicomekl formation, indicates somewhat colder conditions, such as prevail at present in the region around Cape Romanzof on the Alaskan coast north of the Aleutian Islands. Further support for more northern affinities of the Unit C faunas is found in the fact that, of all the species from the formation, more than twice as many appear on faunal lists for the area around Norton Sound than on lists for the Cook Inlet-Prince William Sound area. Furthermore, *Balanus evermanni,* although found also along the inside passages of southern Alaska, is probably to be regarded as a member of the Bering Sea fauna (Pilsbry, 1916, p. 213).

Results for the Abbotsford formation are based on only two species, and are therefore not reliable. The sediments were associated with the Sumas Valley ice, and accordingly would have been deposited under colder conditions than the species would indicate. Temperatures there were also probably comparable to those of Cook Inlet and Prince William Sound. By the time the Richmond Delta deposits were laid down, temperatures had ameliorated to the point where they were similar to those of the Ketchikan area at present. The Indian midden assemblages suggest the same temperatures as the Richmond Delta faunule, but undoubtedly the temperatures were warmer than indicated. The middens offer a very selective list of species, and are not representative of the indigenous fauna.

Bathymetric Range and Salinity Tolerance

Much of the literature on the Recent west coast faunas consists only of lists of species from different localities. Information regarding the depth requirements of the various species is most inadequate and is generally confined to a statement as to whether the shells were picked up on or near the shore, or were dredged from a specific depth. The total bathymetric range, and the optimum zone within the range, are noted for only a very few species. A number of species have no bathymetric niche recorded. Depth range data and information regarding preferred bottom conditions and living habits of the species are to be found in the references marked with an asterisk (*see* Bibliography).

Most of the species found fossil in the area are known to be truly marine. Exceptions are the mussels which are able to make physiological adjustment for dilutions of normal salinity of up to 50 per cent, and *Mya arenaria* which prefers brackish conditions. Barnacles and limpets, which are capable of closing out the fresh water, and some clams, which can withdraw to safe depths, may not be killed by temporary influxes of fresh water (MacGinitie, 1935, p. 669; MacGinitie and MacGinitie, 1949, p. 342).

A slight digression with reference to *Mya arenaria* is in order here. Representatives of this species along the west coast today are regarded by many to be descendants of individuals accidentally introduced into San Francisco Bay from the east coast in 1874. However, it is reported by Oldroyd (1927, p. 198) from Indian middens on the coast of Washington, and it is also referred to by W. Newcomb (1875, p. 415), C. F. Newcombe (1893a), and Swan (1952, p. 365) as being native on the west coast prior to Recent time. The presence of *M. arenaria* in the Nicomekl, Newton, Sunnyside, and Richmond Delta formations, and in Unit K, suggests proximity of at least some of the localities to sources of fresh water.

Lack of the most important data, the modal point of the depth range of each species, prevents the application of statistical methods in determining the depth for each assemblage. The median-of-midpoints method is not suitable because, in the few instances where the optimum depth of a species is known, the midpoint of depth is found to differ greatly from the optimum. This is

probably true for most, if not all, of the other species from the area, with the exception of species having a very limited range. However, estimates of the water depth in which each fossiliferous formation was laid down are possible from the data at hand.

Probably none of the formations was formed in more than 20 fathoms of water. Generally, the depth seems to have been considerably less. Results are summarized as follows:

Formation	Estimated Depth
Nicomekl	5–15 fathoms
Newton	0–15 fathoms
Cloverdale	10–15 fathoms
Sunnyside	low tide zone
Bose	low tide zone
Capilano	0–15 fathoms
Whatcom	10–20 fathoms
Abbotsford	tidal zone
Richmond Delta	tidal zone
Unit C	5–20 fathoms
Unit J	0–15 fathoms
Unit K	0–15 fathoms

Calculations based on Hannibal's lists for Vancouver Island give an estimated depth of from 10 to 20 fathoms for the Maywood formation, and suggest deposition in the low-tide zone for the Saanich formation. The Maywood formation is possibly equivalent to Unit C, and the Saanich formation to Unit K.

All of the assemblages suggest a bay or estuarine habitat. Two species, *Acmaea pelta* and *Volsella modiolus* are known to prefer open-coast conditions, and *Acmaea digitalis* prefers a protected outer coast (Ricketts and Calvin, 1952). The few representatives of these species found in the area are possibly hardy individuals that spread into, for them, less favourable habitats.

Bottom conditions are, in general, those indicated by the material in which the fossils are found. Species living on rocks in the low-tide zone, such as limpets, mussels, and the annelid *Serpula vermicularis* have most likely been washed into deeper waters after death.

Fossil Plants and Age Determinations

Evidence of land plants has been found in at least eight of the formations in the form of peat, driftwood, leaves, and leaf impressions. Sometimes, plant and marine molluscan remains were found in close association.

Plant materials have been obtained from most ages of Pleistocene sediments recognized in the lower Fraser Valley-Vancouver Island area. Berry and Johnston (1922, p. 136) list *Salix barkleyi* Anders, *Salix myrtilloides* Linné, *Chamaedaphne*

calyculata (Linné) Moench, *Kalmia glauca* Ait., and *Vaccinium ovalifolium* J. E. Smith. Also in their collection were fruits of a *Populus,* leaves of *Arctostaphylos,* fragments of the leaves of grasses or sedges, and lignified branches. To quote from Berry and Johnston (1922, p. 137):

> The fossil plants are clearly indicative of a bog, moor or heath environment, but that the region was in general forested and trees were near at hand is shown by the lignified branches and Populus fruits already mentioned, and by *Vaccinium ovalifolium* which is a shady forest shrub rather than a bog plant. Although it is impossible to arrive at perfectly conclusive results in dealing with so small an assemblage, there is nothing in the plants described that in my judgment warrants considering that the climate was especially different from what it is at the present time in this part of British Columbia.

Wood from the Quadra intertill sediments of the mainland has been dated by the radiocarbon method as older than 30,000 years (Armstrong, 1957, p. 5), and wood and peat from Unit D on Vancouver Island as about 25,000 years old (Olson and Broecker, 1957, p. 105). The material from Unit D included *Picea* sp. (possibly *P. sitchensis*), *Pinus contorta* Douglas, *Tsuga* sp., *Thuja* sp. (probably *T. plicata* Donn), and *Abies* sp. (Fyles, 1956). On the mainland, wood has also been found in the Whatcom formation, and at the base of till of Sumas age. The radiocarbon dates for these samples were 11,350±150 years (average for three localities), and 11,250±1,000 years (average of two localities) respectively (Armstrong, 157, p. 5). A date of 11,800 years for the Newton formation was based on marine shells (loc. cit.). Impressions of pine needles and leaves were found with impressions of marine shells in the clays of Unit J around Alberni on Vancouver Island. The leaves were of a *Dryas,* an alder, and a representative of the family Ericaceae. The *Dryas* was an Arctic rather than a mountain type. This same type of *Dryas* was found with shells at a section along Englishman River, in foreset beds of a delta the topset beds of which are at an elevation of 175 feet. Rare leaves and driftwood were obtained also from Units K and L. Climatic conditions as suggested by the small plant assemblages in general agree well with those indicated by the marine faunules. The one exception is the climatic interpretation of the Point Grey flora by Berry and Johnston (1922).

Summary

At least three major glaciations, namely Seymour, Semiamu, and Vashon, affected southwestern British Columbia, and a fourth glaciation, the Sumas, of more limited extent and duration, was operative along the Fraser River valley to within 25 miles of Vancouver. The ice of the Seymour and Vashon glaciers probably reached a thickness of more than 7,500 feet over the valleys and depressed the land relative to the sea a possible 1,000 feet or more (Armstrong, 1956, pp. 4-5). With the melting of the ice, the depressed land surface was subjected to marine invasion. The fossiliferous glacio-marine stony clays were deposited as the ice was melting back, the pebbles and cobbles in these clays probably being dropped from floating ice. The Olympic Peninsula of Washington was probably the first area to be freed of ice, followed by Vancouver Island,

the Strait of Georgia region, and finally the mainland area, as the ice moved back to the north and east into the mountains. Ice undoubtedly remained in the mountainous areas for a considerable time after it had disappeared from the coastal regions.

The Seymour ice-sheet must still have been in the Strait of Georgia region when Unit C was deposited. Land temperatures, however, had ameliorated sufficiently for forests to have become established. The plant assemblage from Unit D shows affinities with that of present-day coastal forests around Gulf of Alaska, but the marine invertebrates of the laterally equivalent Unit C suggest somewhat colder conditions. Generally, water temperatures respond less quickly than land temperatures to climatic changes, and it is probably this lag that is recorded here. Faunas living later in the Quadra interglacial period (i.e., in the Nicomekl formation) indicate a slight rise in water temperature, but it is not in proportion to the rise in land temperature suggested by the Point Grey formation floras according to the interpretation of Berry and Johnston (1922).

Little is known of the Semiamu glaciation which followed the Quadra interglacial. The tills and associated outwash were largely removed by later erosion, and the deposits that remain are poorly exposed.

With the spread of the Vashon glaciers to their fullest extent, the lower Fraser Valley area and Vancouver Island were again covered by ice and the land surface again depressed 1,000 feet or more relative to sea-level. And again marine invasion coincided with the withdrawal of the ice-sheet. As with the fauna of Unit C, the marine organisms found in the Newton formation did not wait for the complete disappearance of the ice from the area, but established themselves in close proximity to the waning glacier. Numerous shells in both formations mentioned in the foregoing were found in living position. Similar situations are known today. Tarr (1897, p. 227) cited an example of marine organisms living beneath the front of a glacier along the coast of Upper Nugsuak Peninsula, Greenland. Calving of the glacier causes considerable local disturbance of the population, but the organisms eventually re-establish themselves. Water temperatures are shown by the molluscs to have been similar to present temperatures of Cook Inlet and Prince William Sound, Alaska.

Most of the remaining fossiliferous formations represent the period of transition from Pleistocene to Recent time. Distinction between transition and strictly Recent deposits is here based upon whether or not the deposit may be observed in the process of forming. Thus, near-shore marine deposits, and the various types of non-marine deposits that may be seen forming today are classed as Recent; the marine off-shore and shore, estuarine, and deltaic deposits now raised above sea-level are referred to the transition period. Sediments attributable to the Sumas valley glaciers are also referred to this transition period. Deposits laid down prior to, or during, the retreat of the Vashon ice-sheet are regarded as Pleistocene. The Cloverdale, Sunnyside, Bose, Capilano, Whatcom, and Abbotsford formations, and Units J and K belong to the transition time between

Pleistocene and Recent. Invertebrate assemblages in all of these formations point to water temperatures similar to those of the Cook Inlet-Prince William Sound area today. The plant assemblages of Unit J concur with this conclusion.

Post-Vashon deposits still being formed are mainly non-marine. They include estuarine, deltaic, channel and flood plain, swamp, and slope gravels, sands, silts, clays, and peat. Marine sediments noted are in the littoral zone and in the seaward parts of the estuarine and deltaic depositional areas. The one fossil locality so far discovered is in the Richmond Delta deposits of the Fraser River delta. An apparent slight sinking of the delta area in Recent time is shown by the position of these low-tide zone shells 8 feet below present sea-level. Water temperatures had risen, but had not yet attained the present high. Comparable conditions today might be expected in the vicinity of Ketchikan, Alaska.

With the emergence of the unconsolidated deposits above sea-level, erosion again became operative. Most of the material removed has been from along the rivers and streams, and in the Fraser River delta area much of this material has probably gone into the formation of the delta itself. The sea-cliffs are, for the most part, protected from direct attack by the sea by wide tidal flats, and vegetation has held erosion of the upland areas to a minimum. Dissection of the upland areas, both in the lower Fraser River valley and on Vancouver Island, shows the erosion cycle to be in the youthful stage.

Depths of water in which the fossiliferous sediments were deposited were apparently not greater than 20 fathoms. Much of the deposition was in the littoral zone, especially in the lower Fraser River valley area. Around Vancouver Island, the waters tended to be somewhat deeper.

On the mainland, in the area north of Burrard Inlet, marine terraces have been recognized as high as 1,000 feet above the present sea-level. East of Beaufort Range on Vancouver Island, the observed maximum for marine deposits is on the order of 500 feet, and west of the mountains it is between 250 and 300 feet. These differences suggest that uplift of the land following release of the ice load has been of a differential nature. Where ice load was heaviest, and consequently depression of the land greatest, the highest expression of the subsequent marine invasion is to be found.

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Chapter IV

SYSTEMATIC PALÆONTOLOGY

One species, belonging to the subgenus *Yoldiella* of the genus *Yoldia* is believed to be new, and is herewith described. A second pelecypod, of the family Leptonidae, may be a new species, or even a new subgenus or genus, but it must remain undescribed until supplementary material is available. The single specimen, obviously a juvenile, is not suitable for description.

A name that occurs frequently in faunal lists from the Pleistocene deposits of the west coast is *Cardium comoxense* Dall [=*Clinocardium comoxense*]. However, specimens thus labelled that the writer has examined appear not to differ from *Clinocardium ciliatum* (Fabricius), a common species in the west coast deposits. Illustrations of the holotype, figured for the first time by Keen (1954, pl. 1, figs. 5, 7, 8), show a form apparently identical with *C. ciliatum.*

Dall (1900c, p. 1093) considered *C. comoxense* to be a variety of the species *C. californiense* (Deshayes), differing from it only by having the ribs much depressed and flattened, with the inter-spaces reduced to narrow, shallow grooves. *C. californiense* has 40 to 50 ribs; *C. ciliatum* has 30 to 38, and these have a V-shaped cross-section as compared to the flattened profile of those of *C. californiense.* The two species differ also in outline.

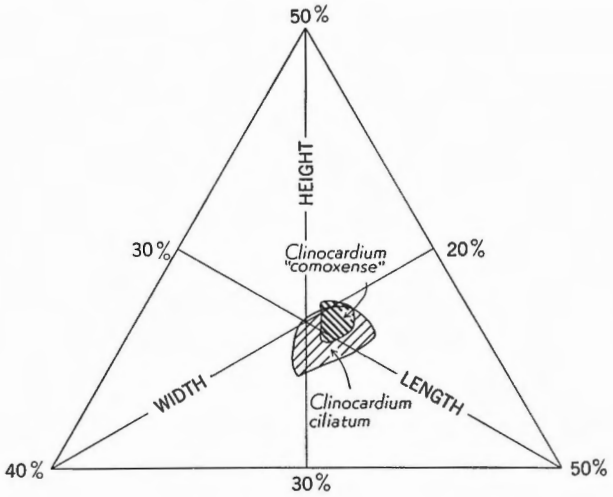
Rib counts of specimens of *C. ciliatum* in the collections of the Geological Survey show the number of ribs to vary between 30 and 35. Counts made on specimens labelled *C. comoxense* are within this range. Furthermore, graphic presentation of the height, length, and width relationships points to the sameness of the two forms (*see* Figure 3). Whether measurements of a greater number of specimens would radically alter the picture is a question that cannot be answered at the moment. At present, only a limited number of specimens is available for study. However, the writer believes that *C. comoxense* does not differ from *C. ciliatum.*

Description of New Species

Order PRIONODESMACEA
Suborder TAXODONTA
Family NUCULANIDAE
Genus *Yoldia* Möller, 1842
Subgenus *Yoldiella* Verrill and Bush, 1897

Type species of subgenus (by original designation): *Yoldiella lucida* (Lovén) =*Yoldia lucida* Lovén.

This group includes a large number of small, mostly deep-sea species with glossy, iridescent, ovate and usually wedge-shaped shells, nearly always having a slight postero-ventral sinuosity, which feebly defines an obscure, blunt, rostral region, without any definite carination. The shells do not gape, but close tightly, except



Clinocardium ciliatum						*Clinocardium "comoxense"*					
Height		Length		Width		Height		Length		Width	
mm.	%	mm.	%	mm.	%	mm.	%	mm.	%	mm.	%
12.0	35.8	13.3	39.7	8.2	24.4	15.5	36.6	15.8	37.3	11.0	26.0
18.0	36.2	18.7	37.6	13.0	28.1	18.2	36.5	19.2	38.5	12.4	24.8
19.1	35.3	21.2	39.1	13.8	25.5	22.1	35.5	23.7	38.2	16.4	26.3
20.1	34.7	21.1	36.5	15.6	26.9	23.9	36.7	24.8	38.0	16.4	25.1
25.8	35.9	28.6	39.8	17.4	24.2	26.4	35.9	28.1	38.2	19.0	25.8
30.5	35.7	33.3	38.9	21.6	25.2	28.3	36.7	29.5	38.3	19.2	24.9
32.7	35.3	36.6	39.5	23.2	25.0	31.0	37.0	32.0	38.2	20.6	24.6
35.6	36.9	35.9	37.2	24.6	25.5	36.1	37.2	36.2	37.2	24.8	25.5
38.8	36.7	39.1	37.0	27.6	26.1						
45.4	36.4	48.9	39.2	30.2	24.2						
46.4	37.1	47.9	38.3	30.6	24.4						

G.S.C.

Figure 3. ***Graphic presentation of the height, length, and width relationships of* Clinocardium ciliatum *(Fabricius) and* Clinocardium "comoxense" *(Dall).***

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that at the rostral angle of some species there may be a slight divergence. The internal cartilage, which is often relatively large, occupies a simple notch, which interrupts the hinge margin more or less completely and generally shows externally in a dorsal view; the notch usually terminates within on the inner or inferior surface of the hinge plate and is often bounded within by a slight ridge. A weak external ligament is present on the postero-dorsal margin. A relatively small, pallial sinus has been observed in a few of the species, but is usually indistinct. The siphon tubes, as observed in a few of the species, are slender and united for more than half of their length. (Verrill and Bush, 1897.)

Yoldia (*Yoldiella*) *keenae* n. sp.

Plate I, figures 16a, b, 18a, b

Description. Shell small, subovate, anterior end the longer and broader, smoothly rounded; posterior end slightly narrower, less broadly rounded than the anterior. Umbos small, not prominent, scarcely projecting above the dorsal margin of the shell, curved inward and backward. Surface of the shell marked with fine but distinct concentric lines of growth; periostracum yellowish brown, glossy. Antero-dorsal margin evenly curved and sloping gradually to the obtusely rounded anterior end; ventral margin broadly rounded, ascending more rapidly to the posterior end; postero-dorsal margin straight for a short distance next to the beak, then slightly convex with a gentle slope. Hinge margin thin and delicate, with the posterior part straight and the longer anterior part slightly curved. The two series of teeth, which are interrupted by the resilifer, spread out from beneath the beaks at a very obtuse angle. Teeth acute, erect and V-shaped; 18 anterior and 16 posterior in the holotype, 12 anterior and 10 posterior in the paratype, the 4 anterior and 3 posterior nearest the beaks minute in each case. Resilium occupying a broad notch; resilifer wide, slightly concave, extending back into the shell beneath the umbo. Broad, shallow pallial sinus, not clearly discernible.

Dimensions. Length, 3.5 to 7 mm; height, 5 to 10.5 mm; thickness not known.

Holotype. GSC No. 13983 in the collection of the Geological Survey of Canada. Collector, F. J. E. Wagner.

Paratype. GSC No. 11605.

Type locality. GSC locality No. 21577, NE.¼, sec. 10, twp. 5, Delta municipality, British Columbia. The paratype is from GSC locality No. 21578, NE.¼, sec. 6, twp. 9, Surrey municipality. These are localities 46 and 44 respectively on the map accompanying this report. Both specimens are from the Sunnyside formation, which is a fine sand. Both are left valves, and both are slightly damaged. The ventral margin of the holotype is chipped, and the paratype was broken and has been repaired. The periostracum is present on the paratype.

The associated faunas have thirteen species in common. In each, *Saxidomus giganteus* (Deshayes) is most abundant and occurs in living position. The fauna associated with the holotype comprises the following species:

Nuculana minuta (Fabricius)
Chlamys hindsii (Carpenter)
Mytilus edulis Linné
Axinopsida viridis (Dall)
Clinocardium blandum (Gould)
Clinocardium nuttallii (Conrad)
Clinocardium sp.
Serripes groenlandicus (Bruguière)
Saxidomus giganteus (Deshayes)
Protothaea staminea (Conrad)
Macoma calcarea (Gmelin)
Macoma incongrua (Martens)
Macoma irus (Hanley)
Mya arenaria Linné
Mya truncata Linné
Hiatella arctica (Linné)
Acmaea digitalis Eschscholtz
Margarites pupillus (Gould)
Odostomia (*"Amaura"*) *sillana* Dall and Bartsch
Littorina cf. *L. scutulata* Gould
Trichotropis cancellata Hinds
Natica sp. or *Polinices* sp.
Neptunea lyrata (Gmelin)
Acteocina culcitella (Gould)
Serpula vermicularis Linné
Balanus crenatus Bruguière
Strongylocentrotus dröbachiensis Müller

Species associated with the paratype are:

Chlamys hindsii (Carpenter)
Mytilus edulis Linné
Modiolus modiolus (Linné)
Astarte sp.
Leptonidae, genus indet. but near *Pseudopythina*
Clinocardium sp.
Serripes groenlandicus (Bruguière)
Saxidomus giganteus (Deshayes)
Macoma incongrua (Martens)
Macoma irus (Hanley)
Macoma sp.
Spisula voyi (Gabb)
Hiatella arctica (Linné)

Margarites pupillus (Gould)
Odostomia (*Evalea*) *barkleyensis* Bartsch
Odostomia sp.
Turbonilla sp.
Littorina cf. *L. scutulata* Gould
Lacuna cf. *L. solidula* Lovén
Alvania compacta Carpenter
? *Cerithiopsis* sp.
Trichotropis cancellata Hinds
Natica aleutica Dall
Serpula vermicularis Linné
Balanus crenatus Bruguière
Strongylocentrotus dröbachiensis Müller
shark tooth

Geological age. Late Pleistocene (Wisconsinan) or early Recent.

Discussion. Seven species of *Yoldiella* are listed from the west coast of North America, namely, *Y. siliqua* Reeve, *Y. intermedia* Sars, *Y. orcia* Dall, *Y. sanesia* Dall, *Y. oleacina* Dall, *Y. capax* Dall, and *Y. cecinella* Dall. *Yoldiella keenae* seems to be closest to *Y. oleacina.* The pattern of tooth distribution is the same in both, but in *Y. oleacina* the teeth are fewer with relation to the size of the shell. *Y. keenae* is wider in relation to length than *Y. oleacina,* but is proportionately narrower than *Y. orcia,* the only other of the west coast species having this tooth distribution. The other west coast species have either the same number of teeth in each series, or more in the posterior series than in the anterior.

Remarks. Only the two specimens of this species have as yet been found. The species is named for Dr. Myra Keen of Stanford University, California.

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PLATE I

Plate I

(Except where otherwise stated, all figures are natural size.)

Figure 1. *Propebela quadra* (Dall). Hypotype, GSC No. 12545; locality 21601; coll. F. J. E. Wagner, 1951. x 3.

Figure 2. *Oenopota alaskensis* Dall. Hypotype, GSC No. 12546; locality 21621; coll. F. J. E. Wagner, 1951. x 3.

Figure 3. *Alvania compacta* Carpenter. Hypotype, GSC No. 12547; locality 21578; coll. F. J. E. Wagner, 1951. x 5.

Figure 4. *Acmaea digitalis* Eschscholtz. Hypotype, GSC No. 12548; locality 21577; coll. F. J. E. Wagner, 1951. Fig. 4a, apical view; fig. 4b, side view.

Figure 5. *Hemithyris psittacea* (Gmelin). Hypotype, GSC No. 12549; locality 21577; coll. F. J. E. Wagner, 1951. Fig. 5a, exterior of pedicle valve; fig. 5b, exterior of brachial valve; fig. 5c, side view.

Figure 6. *Odostomia* (*Evalea*) *barkleyensis* Bartsch. Hypotype, GSC No. 12550; locality 21578; coll. F. J. E. Wagner, 1951. x 5.

Figure 7. *Odostomia* ("*Amaura*") *sillana* Dall and Bartsch. Hypotype, GSC No. 12551; locality 21621; coll. F. J. E. Wagner, 1951. x 3. *Amaura* Möeller 1842 (Mollusca) is a homonym of *Amaura* Geyer 1837 (Lepidoptera).

Figure 8. *Lacuna* cf. *L. solidula* Lovén. Hypotype, GSC No. 12552; locality 21578; coll. F. J. E. Wagner, 1951. x 5.

Figure 9. *Littorina scutulata* Gould. Hypotype, GSC No. 12553; locality 21601; coll. J. E. Armstrong, 1951. x 2.

Figure 10. *Natica aleutica* Dall. Hypotype, GSC No. 12554; locality 21578; coll. F. J. E. Wagner, 1951.

Figure 11. *Clinocardium ciliatum* (Fabricius). Hypotype, GSC No. 12555; locality 17631; coll. J. E. Armstrong, 150. Fig. 11a, exterior of right value; fig. 11b, interior of right valve. This specimen was previously labelled *C. comoxense* (Dall).

Figure 12. *Odostomia* (*Evalea*) *columbiana* Dall and Bartsch. Hypotype, GSC No. 12556; locality 21617; coll. J. G. Fyles, 1951.

Figure 13. *Odostomia* ("*Amaura*") cf. *O.* ("*A.*") *martensi* Dall and Bartsch. Hypotype, GSC No. 12557; locality 21619; coll. J. G. Fyles, 1951. x 3.

Figure 14. *Axinopsida serricata* (Carpenter). Hypotype, GSC No. 12558; locality 17611; coll. J. E. Armstrong, 1950. x 3. Fig. 14a, interior of left valve; fig. 14b, exterior of left valve.

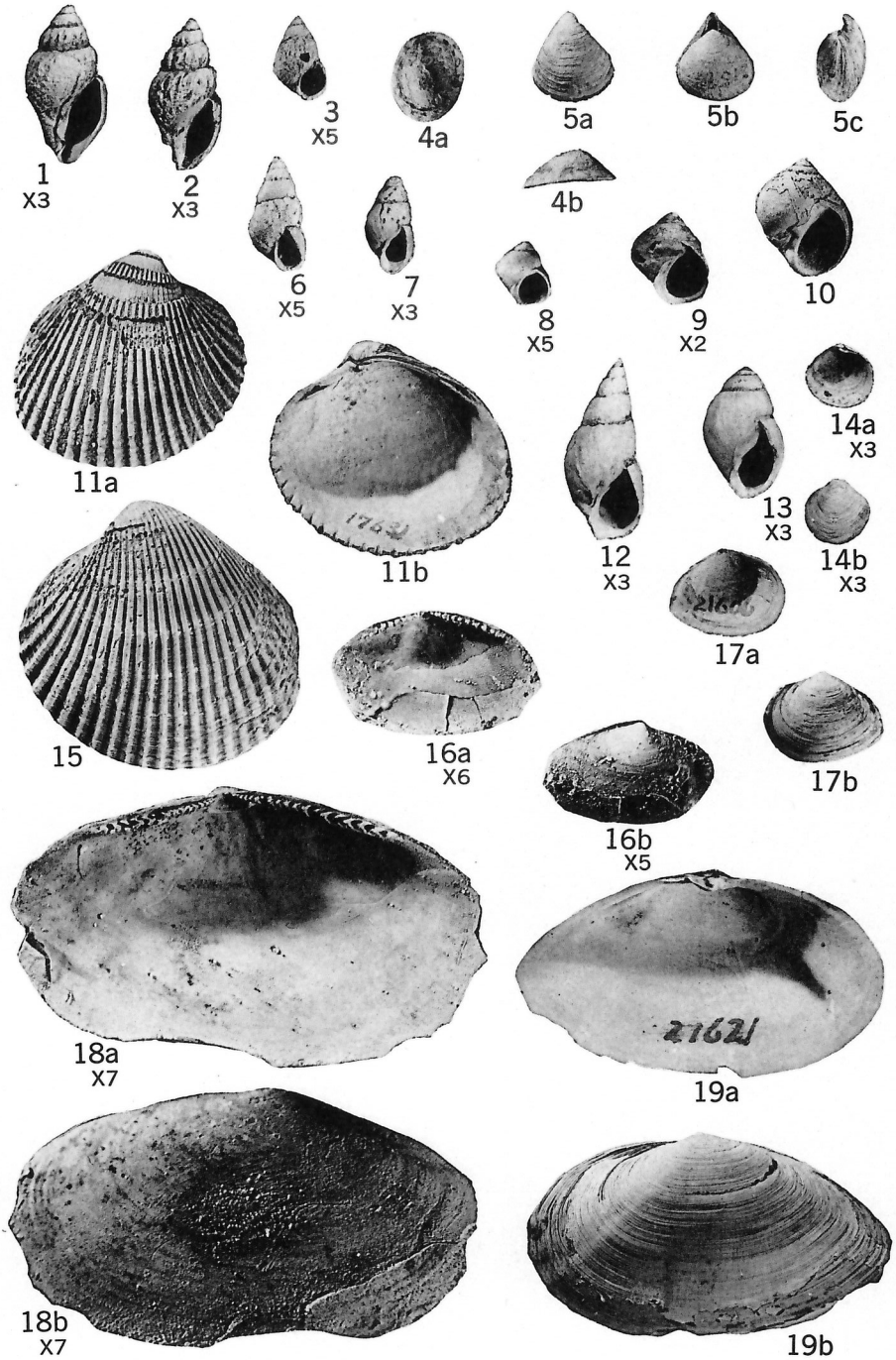
Figure 15. *Clinocardium ciliatum* (Fabricius). Hypotype, GSC No. 12559; locality 17632; coll. J. E. Armstrong, 1950. Exterior of left valve.

Figure 16. *Yoldia* (*Yoldiella*) *keenae* n.sp. Paratype, GSC No. 11605; locality 21578; coll. F. J. E. Wagner, 1951. Fig. 16a, interior of left valve, x 6; fig. 16b, exterior of left valve, x 5.

Figure 17. *Macoma inconspicua* (Broderip and Sowerby). Hypotype, GSC No. 12560; locality 21606; coll. F. J. E. Wagner, 1951. Fig. 17a, interior of left valve; fig. 17b, exterior of left valve. This species has been confused with *Macoma balthica* (Linné).

Figure 18. *Yoldia* (*Yoldiella*) *keenae* n.sp. Holotype, GSC No. 13983, locality 21577; coll. F. J. E. Wagner, 1951. x 7. Fig. 18a, interior of left valve; fig. 18b, exterior of left valve.

Figure 19. *Mya arenaria* Linné. Hypotype, GSC No. 12561; locality 21621; coll. F. J. E. Wagner, 1951. Fig. 19a, interior of left valve; fig. 19b, exterior of left valve.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