GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 78-9

BIOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE ESCALANTE AND HESQUIAT FORMATIONS (EARLY TERTIARY) OF THE NOOTKA SOUND AREA, VANCOUVER ISLAND, BRITISH COLUMBIA

B.E.B. CAMERON

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

1980

GEOLOGICAL SURVEY
PAPER 78-9

BIOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE ESCALANTE AND HESQUIAT FORMATIONS (EARLY TERTIARY) OF THE NOOTKA SOUND AREA, VANCOUVER ISLAND, BRITISH COLUMBIA

B.E.B. CAMERON

1980

Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

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

Cat. No.	M44-78/9E	Canada:	$3.50
ISBN –	0-660-10526-8	Other countries:	$4.20

Price subject to change without notice

Critical reader

C.J. Yorath

Author's Address

Pacific Geoscience Centre
Patricia Bay Institute of Ocean Sciences
9860 West Saanich Road
Sidney, British Columbia
V8L 3S2

Original manuscript submitted: 1977 - 12 - 2
Approved for publication: 1978 - 8 - 29

CONTENTS

Tables

Figures

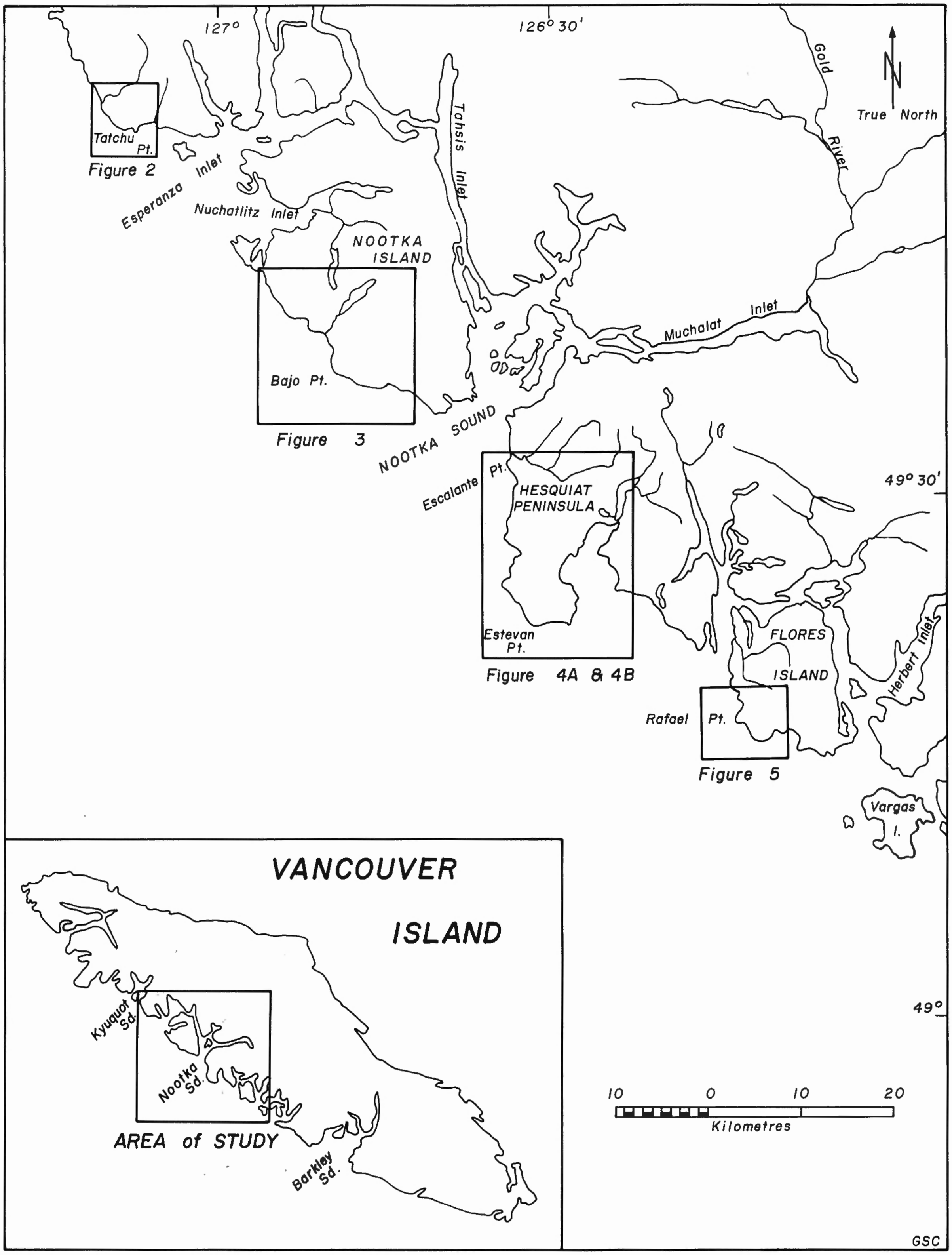


Figure 1. Index map of Nootka Sound area, Vancouver Island, British Columbia.

BIOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE ESCALANTE AND HESQUIAT FORMATIONS (EARLY TERTIARY) OF THE NOOTKA SOUND AREA, VANCOUVER ISLAND, BRITISH COLUMBIA

Abstract

The best exposures of early Tertiary rocks on the west coast of Canada occur in the Nootka Sound area of Vancouver Island. A detailed study of these rocks was undertaken to understand the depositional and tectonic framework of readily accessible parts of the Tofino Basin.

An exhaustive study of the microfaunas of the Escalante and Hesquiat formations of the Nootka Sound area led to the recognition of five foraminiferal assemblage zones within the succession. On the basis of the foraminifers, molluscs, and crustaceans, the ages assigned to the rocks range from Late Eocene to Early or Middle Oligocene. Local correlation with other west coast exposures are with rocks assigned to the Lincoln and Blakeley molluscan "stages" (Galvinian, Matlockian) and the Refugian and Zemorrian foraminiferal stages.

The Escalante Formation is a diachronous basal sandstone unit of Late Eocene age whose depositional environment is interpreted to vary from lower neritic to upper bathyal water depths in the type area to exclusively bathyal water depths elsewhere. The Hesquiat Formation of Late Eocene to Early or Middle Oligocene age is represented by proximal turbidites, including partly fluxoturbidites, in the type area and distal facies elsewhere. Sediments, sedimentary structures, and fossil collections indicate deposition of the Hesquiat Formation occurred in bathyal water depths as a submarine fan complex. Previous estimates of the total thickness of the Hesquiat Formation in the Nootka Sound area are found to be far in excess of their true stratigraphic thickness. This is explained by a highly complex network of faults and the concomitant difficulty in recognizing lithologic equivalents due to rapid facies changes.

Résumé

Les meilleurs affleurements de roches datant due début du Tertiaire que l'on ait rencontrés sur la côte ouest du Canada se trouvent dans la région de la baie Nootka, sur l'île de Vancouver. On a entrepris une étude détaillée de ces roches, afin de comprendre le cadre tectonique et les conditions de sédimentation qui ont caractérisé les parties facilement accessibles du bassin de Tofino.

Après un examen approfondi des microfaunes que contiennent les formations de Escalante et Hesquiat, dans la région de la baie Nootka, on a défini cinq zones à l'intérieur de la succession, en fonction des assemblages de foraminifères. L'étude des foraminifères, mollusques et crustacés nous a permis d'attribuer aux roches de cette succession un âge compris entre l'Eocène supérieur et l'Oligocène moyen ou inférieur. A l'échelle locale, on a pu établir des corrélations avec d'autres affleurements de la côte ouest, à savoir les "étages" à mollusques de Lincoln et Blakeley (Galvinien et Matlockien) et les "étages" à foraminifères du Réfugien et Zémorrien.

La formation d'Escalante est constituée par une unité diachrone, d'âge Eocène supérieur, composée de grès basal, dans laquelle le milieu de sédimentation est sans doute passé de néritique profond et bathyal supérieur dans la localité-type, à exclusivement bathyal dans les autres secteurs. La formation d'Hesquiat, dont l'âge se situe de l'Eocène supérieur à l'Oligocène moyen ou inférieur est représentée dans la localité-type par un faciès proximal à turbidites et parfois à fluxoturbidites, et un faciès distal ailleurs. Les sédiments, les structures sédimentaires et les groupes de fossiles indiquent que la sédimentation qui a créé la formation d'Hesquiat s'est produite dans des zones bathyales, sous forme de cônes d'alluvions sous-marins. On a constaté que les estimations que l'on avait faites de l'épaisseur totale de la formation d'Hesquiat, dans la région de la baie Nootka, dépassaient de beaucoup la puissance réelle de cette formation. Ceci s'explique par l'existence d'un réseau de failles très complexe, et donc par la difficulté à reconnaître les formations lithologiquement équivalentes, en raison des variations rapides de faciès.

INTRODUCTION

During the field seasons of 1969, 1971, 1972, and 1974, Tertiary rocks of the Nootka Sound map area (92 E) were examined and extensively sampled (Fig. 1). About 1030 samples were disintegrated and their contained microfossils extracted. Approximately 250 taxa, principally foraminifers, were isolated and will contribute to future detailed descriptions of these exposures and related offshore strata. For purposes of this report 71 of the recognized foraminifers which have biostratigraphic and/or palaeoenvironmental significance are discussed.

Tertiary rocks of the west coast are well exposed only on the modern tidal flats and are best examined during low tide. Most sections were measured with a tape and Brunton compass. Stratigraphic thicknesses were calculated for each measured interval using the average dip within that interval. Early in the study, the importance of fault repetition of portions of the sequence became evident. At major structural breaks and where covered intervals were encountered, the particular section was discontinued (see Figs. 4A and 4B). In this way, equivalent strata could be recognized on the basis of microfaunal succession despite the abrupt lithologic changes which are characteristic of the area.

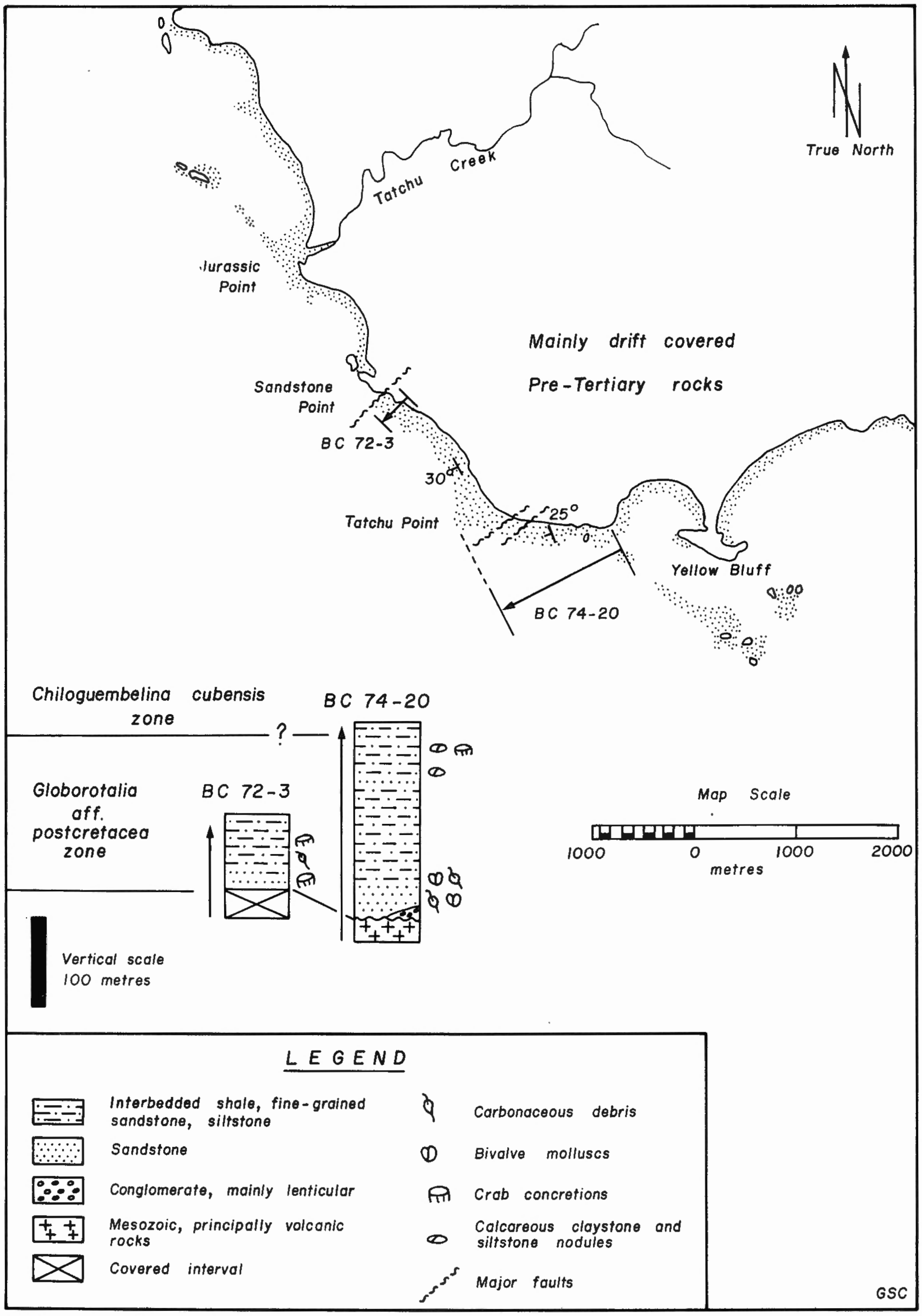


Figure 2. Preliminary biostratigraphy and generalized Tertiary succession at Tatchu Point.

Acknowledgments

Assistance in the field and laboratory was provided by S.E. Banninger, C.R. Rodriquez, S. Tolvanen, B. Griffin, and the late M. Atchison. The figures were drafted by S.E. Banninger. Grateful acknowledgment is extended to C.J. Yorath, J.E. Muller, and H. Gabrielse, Geological Survey of Canada, for their constructive criticisms of the text.

STRATIGRAPHY

The thickest and best exposed sequences of early Tertiary sedimentary rocks on Vancouver Island occur in the Nootka Sound area where two main highly contrasting clastic regimes are in evidence. The distal facies of the Hesquiat Formation consisting of a monotonous sequence of cyclic fine siltstone and shale is well exposed on the tidal flats of Nootka Island (Fig. 3). The proximal facies, the type area of the Hesquiat Formation, is exposed on the tidal flats on the western edge of Hesquiat Peninsula (Fig. 4A, B). There the rocks consist of a highly fractured succession of interbedded shale, siltstone, and sandstone whose sedimentary sequences are frequently interrupted by coarse lenticular conglomerate and sandstone.

Correlation between these contrasting facies has been difficult and often controversial (Cameron, 1971; Jeletzky, 1973, 1975) due to several factors, including interpretation of fossil collections for age determination (Table 2) and environmental significance, effects of faulting, and diachroneity of stratigraphic units (Table 1). Consequently, very heavy reliance on fossils (and in this report, especially Foraminifera) was necessary to resolve these problems. It was further necessary to pay strict attention to the mode of occurrence of the fossils especially in the proximal facies since stratigraphic reworking of molluscs, crustaceans, and foraminifers was very pronounced in some areas (for example, Fig. 4B, distribution of crab concretions).

Escalante Formation (Bancroft, 1937)

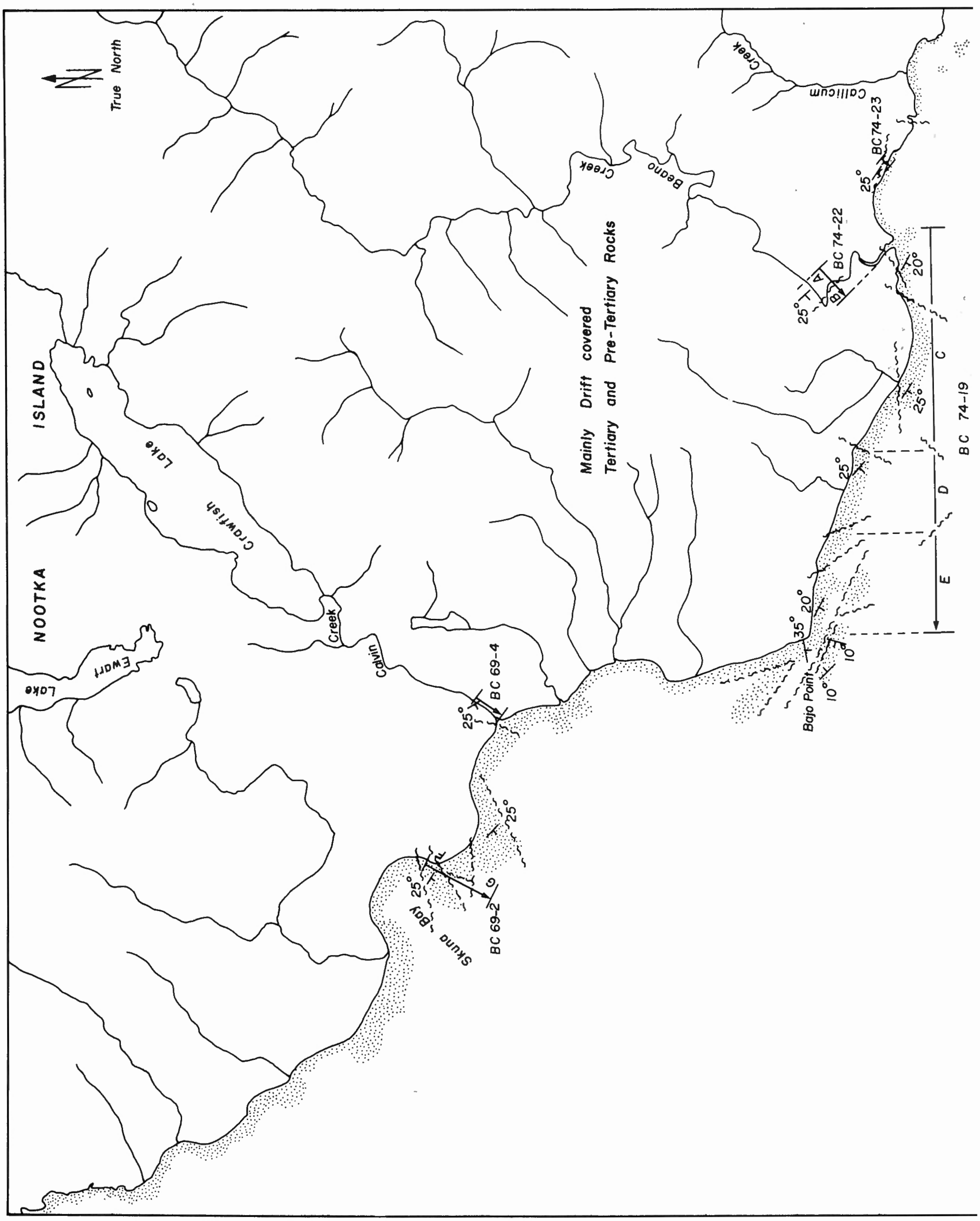
Type Section

The type section of the Escalante Formation is located on Escalante Point on the northwestern side of Hesquiat Peninsula (Fig. 4B, Section BC-71-1). There the formation is approximately 140 m thick and consists predominantly of highly fractured calcareous sandstone (Fig. 6, 7) with minor lenticular, shelly conglomerate and argillaceous sandstone.

Table 1

Foraminiferal Biostratigraphy and Stratigraphy, Nootka Sound Area

		Foraminiferal Zones	Stratigraphy Nootka Sound Area			
			Tatchu Point	Nootka Island	Hesquiat Peninsula	Flores Island
Oligocene	Zemorrian	undefined	not exposed	? Sooke Formation ? Hesquiat Formation? ?	West East not exposed ?	not exposed
		? **Bulimina** cf. **alsatica**		Hesquiat Formation	Hesquiat Formation	
		Turrilina alsatica				
Eocene	Refugian	**Chiloguembelina cubensis**				Hesquiat Formation
		Globorotalia aff. **postcretacea**	Hesquiat Formation / Escalante Formation	Escalante Formation	? Escalante Formation	? Escalante Formation
	Narizian	**Cibicides haydoni** ?	unknown	unknown	? unknown	? unknown


True North
NOOTKA ISLAND
Lake Ewart
Crawfish Lake
Calvin Creek
BC 69-4
Mainly Drift covered
Tertiary and Pre-Tertiary Rocks
Beano Creek
Callicum Creek
BC74-23
BC 74-22
BC 74-19
Bajo Point
Skuna Bay
BC 69-2

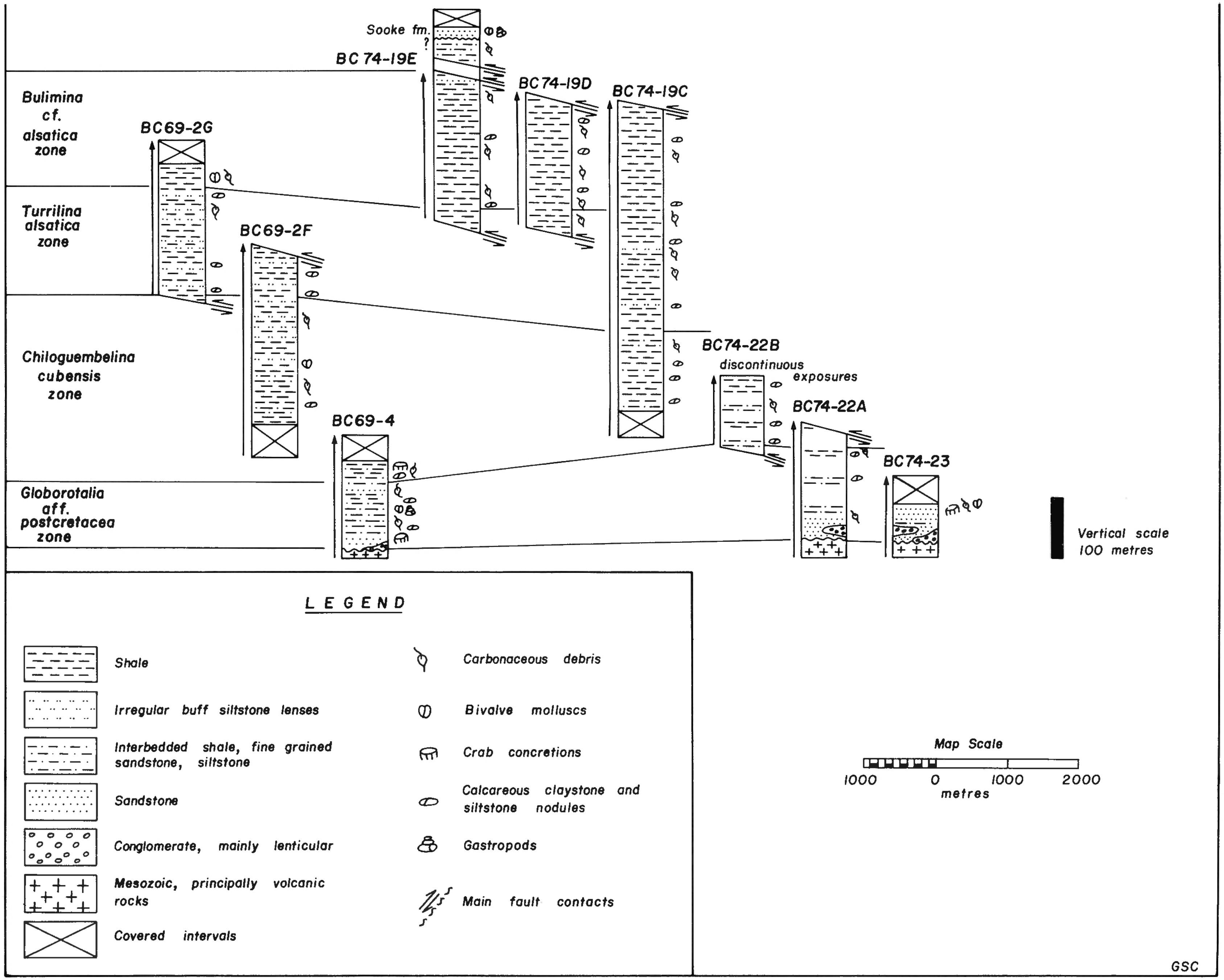


Figure 3. Preliminary biostratigraphy and generalized Tertiary succession, Nootka Island.

Table 2

Summary of West Coast Molluscan and Foraminiferal Stage and Zone Nomenclature

Epoch	Molluscan Armentrout, 1975, 1977 Stage	Molluscan Armentrout, 1975, 1977 Zone	California Foraminiferal Stages	Rau 1966	Weaver et al. 1944	Durham 1944	Jeletzky 1975a,b Nootka Sound	This Report Rock Units	This Report Foraminferal Zones
Oligocene	Juanian	**Echinophoria apta**	Zemorrian	"Upper"	Vaqueros	**Echinophoria apta**	?	?	?
	Matlockian	**Echinophoria rex**		"Lower"	"Blakeley"	**Echinophoria rex**	Oligocene: Hesquiat Formation	Hesquiat Formation	**Bulimina cf. alsatica**
									Turrilina alsatica
Eocene	Galvinian	**Echinophoria fax**	Refugian	**Cassidulina galvinensis**	"Lincoln"	**Turritella porterensis**			**Chiloguembelina cubensis**
						Turritella olympicensis			
		Echinophoria dalli		**Sigmomorphina schencki**		**Molopophorus gabbi**	Escalante Formation	Escalante Formation	**Globorotalia aff. postcretacea**
						Molopophorus stephensoni			
		Bathybembix columbiana			Keasey	**Turcicula columbiana**		?	**Cibicides haydoni** ?
		Unnamed late Eocene	Narizian	**Bulimina schencki** **Plecto-frondicularia** cf. p. **jenkisi**	"Tejon"	"Eocene"			

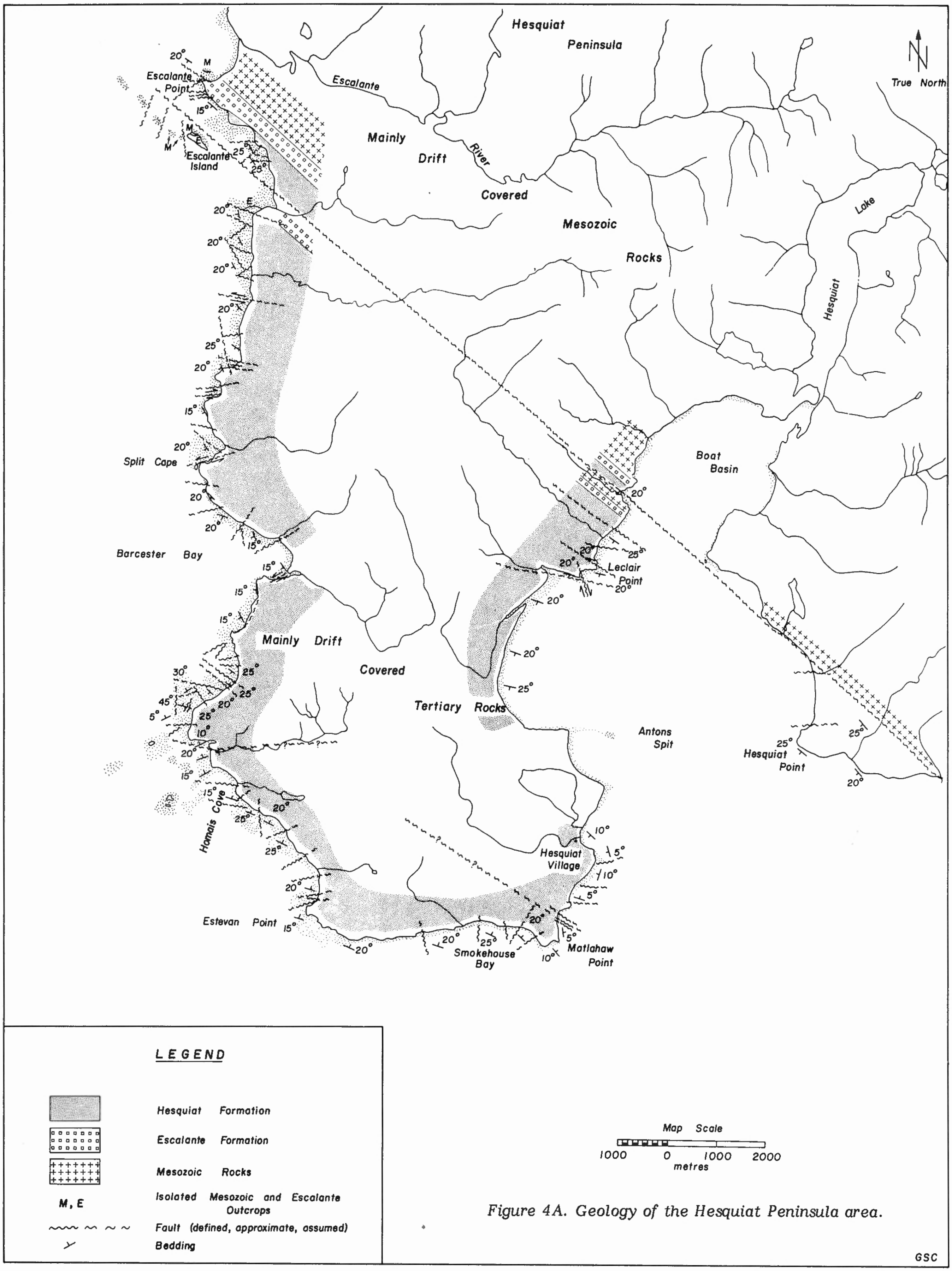
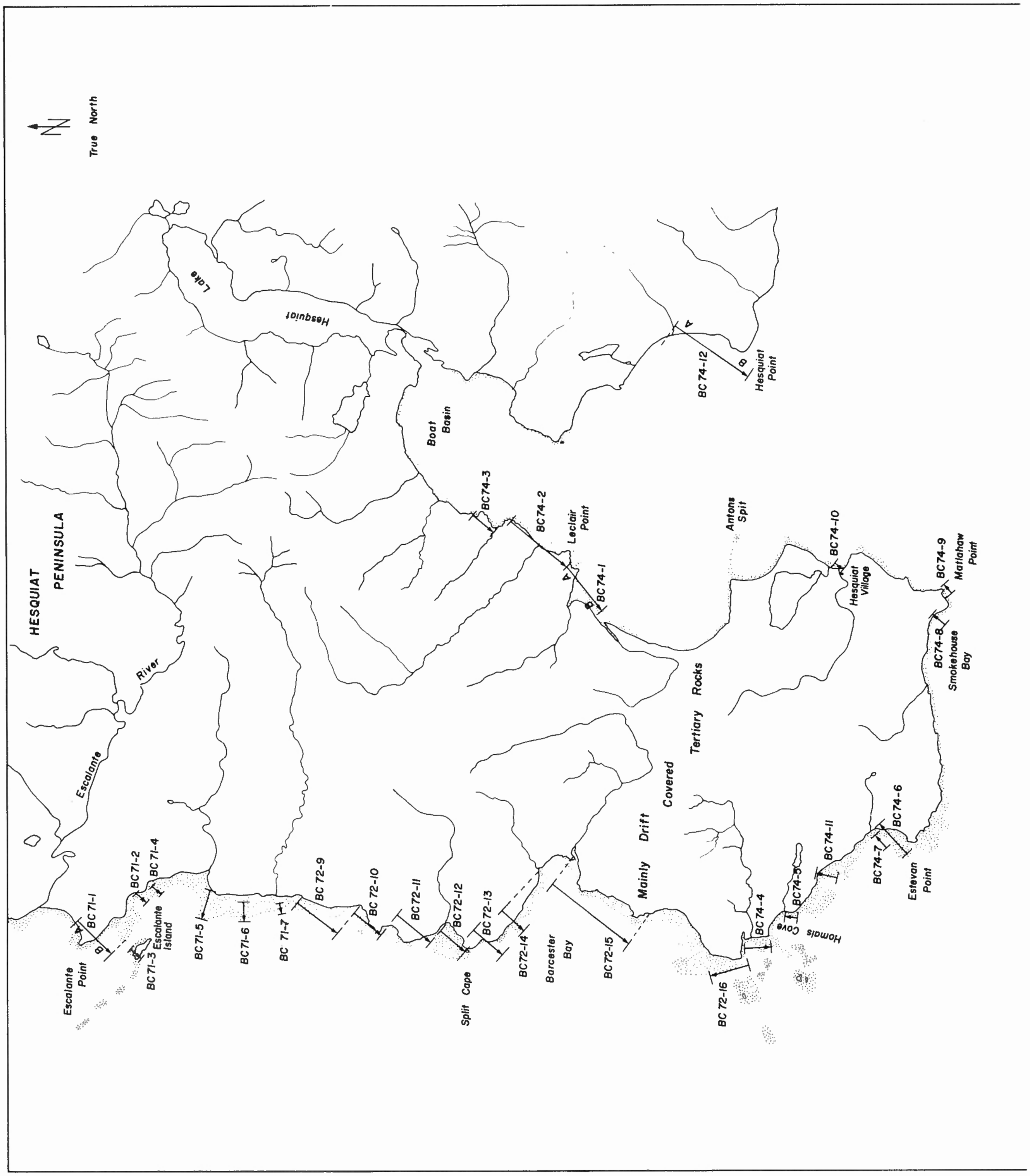


Figure 4A. Geology of the Hesquiat Peninsula area.


True North
HESQUIAT PENINSULA
Hesquiat Lake
Escalante River
Boat Basin
BC74-3
BC74-2
Leclair Point
BC74-1
Antons Spit
BC74-10
Hesquiat Village
BC74-9
Matlahaw Point
BC74-8
Smokehouse Bay
BC 74-12
Hesquiat Point
Mainly Drift Covered Tertiary Rocks
BC74-6
BC74-7
Estevan Point
BC74-11
BC74-5
Homais Cove
BC74-4
BC 72-16
BC72-15
Barcester Bay
BC72-14
BC 72-13
BC72-12
Split Cape
BC72-11
BC 72-10
BC 72-9
BC 71-7
BC71-6
BC71-5
BC71-4
BC71-2
BC71-1
BC71-3
Escalante Island
Escalante Point

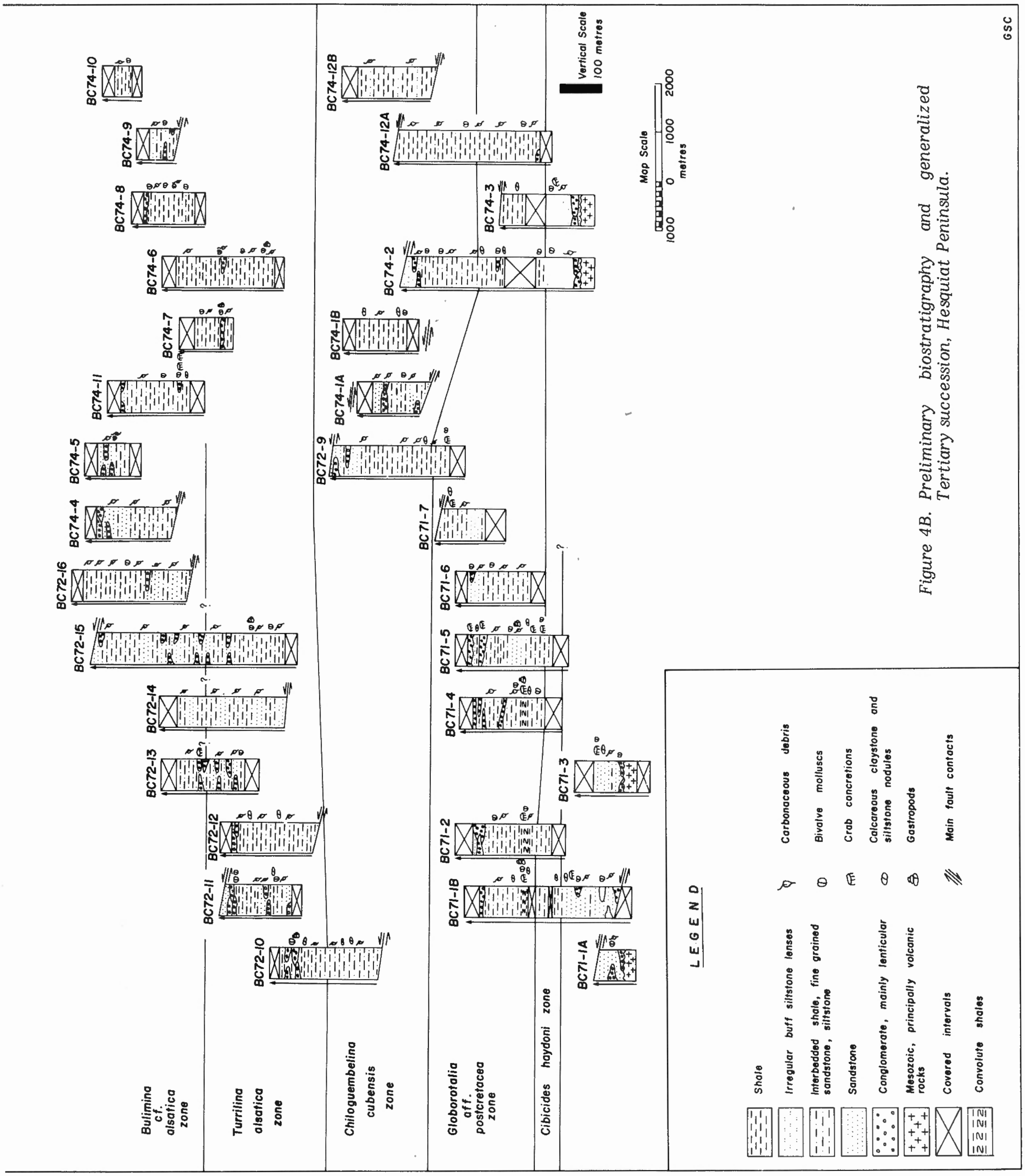


Figure 4B. Preliminary biostratigraphy and generalized Tertiary succession, Hesquiat Peninsula.

Disseminated carbonaceous material and rare fossil leaves occur throughout the succession. The upper part of the formation has many calcareous siltstone and fine grained sandstone nodules and concretions.

Contacts

A pronounced erosional unconformity separates the Escalante Formation from the underlying West Coast Crystalline Complex and Bonanza volcanics (Fig. 8). In the type area of the Escalante Formation, this contact is well exposed during low tides. The pre-Tertiary rocks show no indication of weathering at the contact and the overlying Tertiary conglomerate contains no rock types assignable to the West Coast Crystalline Complex or Bonanza volcanics. In several areas the Escalante Formation includes a variety of reworked molluscs, foraminifers, and large sandstone clasts of probable Jurassic age (Fig. 9). Jurassic sedimentary rocks have not been observed beneath the Tertiary in the study area but could be represented in the subsurface offshore.

The same basal contact relations are exposed at Tatchu Point, east side of Hesquiat Peninsula, Nootka Island, and Flores Island (Fig. 2, 3, 4, 5). Of particular significance is the contact exposed at low tide on Escalante Island (Fig. 4) and adjacent reefs. A critical examination of the rocks above the contact indicates they are part of the Escalante Formation and not part of the Hesquiat Formation as mapped by Jeletzky (1975b, p. 5). His conclusions with respect to the palaeoenvironment of the lower Hesquiat Formation based on the Escalante Island exposures are herein revised. The occurrence of the Escalante Formation on Escalante Island further provides physical evidence of fault repetition of the Tertiary. This fault alone reduces Jeletzky's estimates of the thickness of the Hesquiat Formation by at least several hundred metres (see Jeletzky, 1975b, p. 3).

The upper beds of the type Escalante Formation grade conformably into the overlying Hesquiat Formation through calcareous sandstone to finer grained, more argillaceous sandstone, siltstone, and shale interbeds. The contact is exposed in a broad bay approximately 1500 m southeast of Escalante Point (Fig. 4B, Section BC-71-1B). The same gradational contact was observed throughout the study area.

Age and Local Correlation

The lower part of the type section yielded no microfossils but on the basis of stratigraphic continuity with the upper part is assumed to be of late Eocene age (earliest Refugian or Narizian). The upper part of the sequence (transitional with the Hesquiat Formation) contains the oldest microfauna of the study area, the **Cibicides haydoni** zone. This assemblage is assigned a late Eocene (late Narizian to early Refugian) age. The diachronous nature of the Escalante Formation as suggested by Cameron (1973, p. 19) is supported by the occurrence of the younger **Globorotalia** aff. **postcretacea** assemblage in the lower beds of the Escalante Formation on Nootka Island (Fig. 3, Section BC-69-4), Flores Island (Fig. 5, Sections BC-74-17, BC-74-13), and elsewhere.

Hesquiat Formation (Jeletzky, 1975b)

Type Section

The type section of the Hesquiat Formation is located on the western side of Hesquiat Peninsula (Fig. 4B). The base of the formation is south of Escalante Point (top part, Section BC-71-1), while the apparent top occurs in a highly faulted area south of Barcester Bay (top of Section BC-72-16, Fig. 4B). The rocks of the Hesquiat Formation in its type area consist of a complex of interbedded sandy shale, partly graded cyclic sandstone-silty shale-shale interbeds and pebbly mudstone. Deposition of these sediments was frequently interrupted by lenticular boulder and pebble conglomerate units which are characterized by poor grading, poor development of sole marks, low clay content, abundant rip-up shale, and sandstone clasts and commonly contain reworked fossils. These attributes are sufficient to classify the conglomerate as fluxoturbidites (Dzulynski et al., 1959). The conglomerate becomes thinner and more widely dispersed laterally towards the top of the section, suggesting a distributory dissemination of the coarse clastics as opposed to the more channelized and thicker beds at the base.

Proximal turbidite facies are best represented in the type Hesquiat Formation and to a lesser extent on Flores Island (Fig. 5). The distal facies of the Hesquiat Formation is represented on Nootka Island, Tatchu Point, eastern Hesquiat Peninsula (part) and Hesquiat Point (see Fig. 2, 3, 4B) by a predominance of fissile to blocky silty shale and mudstone, interbedded with highly variable amounts of argillaceous siltstone and fine grained sandstone (Fig. 10-13). Calcareous concretions and nodules, buff weathering siltstone, and recessive weathering grey ash layers are present in most sections. These rocks characteristically have few megafossils but are extremely rich in foraminifers (benthic and planktonic). The latter indicate exclusively bathyal water deposition. Carbonaceous debris is common throughout. The restored thickest distal facies is on Nootka Island where approximately 820 m of section were measured (Fig. 3).

Estimates of the thickness of the Hesquiat Formation type section are difficult due to the high degree of faulting near the top of the section and fault repetition within the formation (Fig. 4B). The present study, however, suggests a thickness of approximately 1100 m (Fig. 4B), a figure considerably less than the 2135 m or possible 3050 m estimates of Jeletzky (1975b, p. 2-3). The more conservative thickness suggested herein appears to be due to repetition by faulting throughout most of the section (see discussion of Escalante Formation on Escalante Island).

Contacts

The Hesquiat Formation conformably overlies the Escalante Formation throughout the study area. The base of the formation is marked by a change from resistant sandstone of the Escalante Formation to softer more argillaceous sandstone, silty shale or interbedded shale, and sandstone. The top of the formation is not exposed on Tatchu Point, Flores Island, or Nootka Island. In the type area the top of the Hesquiat Formation is faulted. A reef off Nootka Island (Bajo Point) however exposes the Sooke Formation overlying a sequence of interbedded sandy shale and sandstone which may represent the upper part of the Hesquiat Formation (Fig. 3). The age of the rocks beneath the Sooke Formation at Bajo Point is uncertain because diagnostic megafossils and microfossils are absent or poorly represented.

Age and Correlation

The ages assigned to the Hesquiat Formation of the Nootka Sound area by various authors have been largely confused by the application of west coast "stage" terminology. This fact is largely attributable to the introduction of supposedly distinctive west coast "stage" nomenclature, including "Lincoln", "Blakeley", "Zemorrian", "Refugian" etc. by various authors (Table 2). The perpetration of this nomenclature along the west coast has lead to confusion with respect to international standards. A good example, is a comparison of the works of Jeletzky (1954, 1973, 1975a, b) and Cameron (1971, 1972, 1973, 1975, this paper).

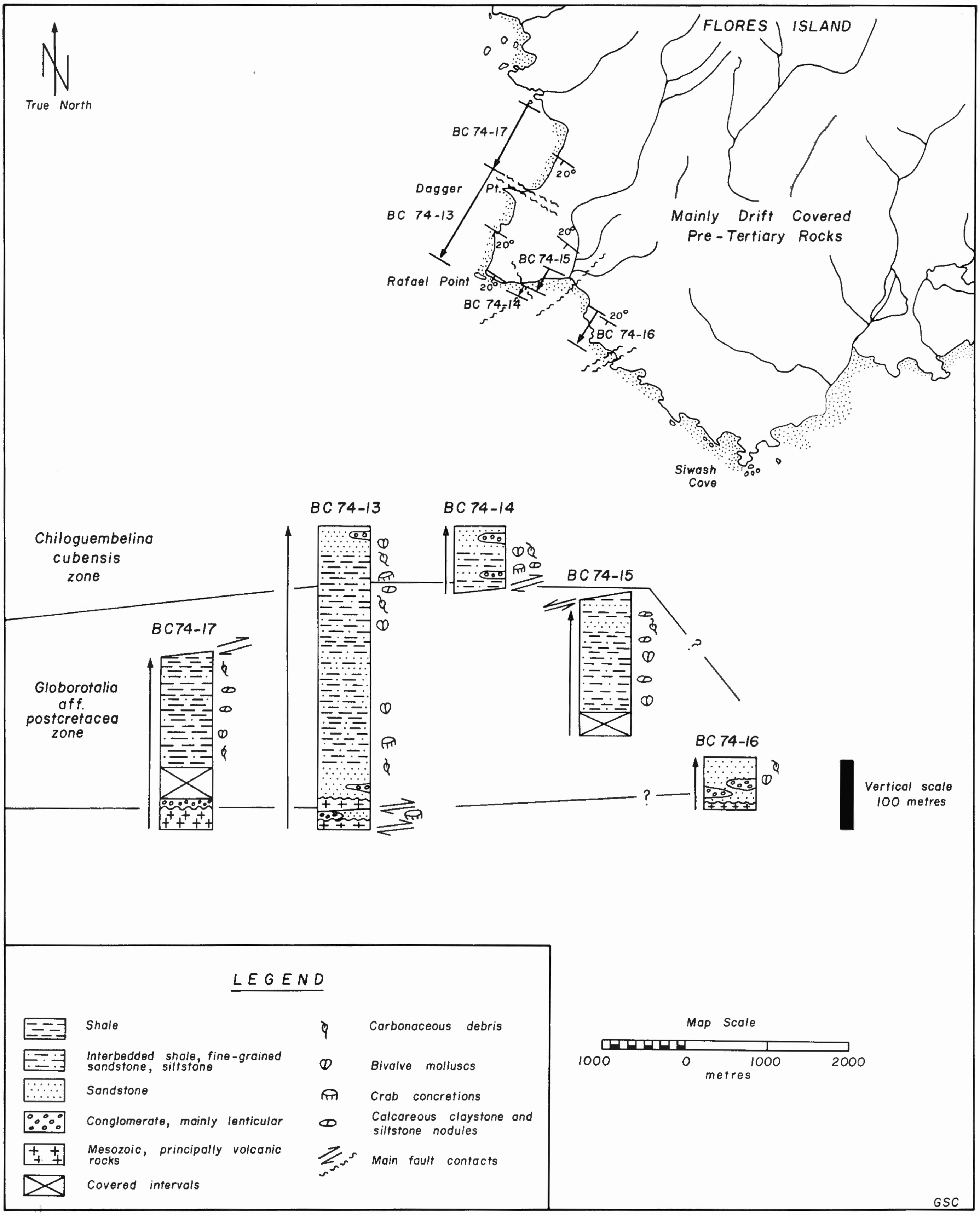


Figure 5. Preliminary biostratigraphy and generalized Tertiary succession, Flores Island.

Figure 6

Beds of the upper part of type Escalante Formation, western Hesquiat Peninsula, consist of slightly argillaceous sandstone with minor conglomerate pockets and lenses. The sequence is highly fractured but shows little lateral displacement along individual fractures. (Fig. 4B, Section BC-71-1). (GSC 203497)

The writer is in general agreement with Jeletzky's (1975a, b) "Lincoln" and "Lower Blakeley" age assignments for the Escalante and Hesquiat formations of the Nootka Sound area (Table 2). The correlation of these west coast molluscan "stages" with international stages, however, has been a subject of controversy for many years. Thus the "Lincoln Stage" of Jeletzky which is manifest in the molluscan faunas of the Escalante and lower Hesquiat formations is assigned an early Oligocene (Middle or upper Refugian) age (Jeletzky 1973, 1975b), whereas his overlying lower "Blakeley Stage" is assigned a late Oligocene (lower Zemorrian) age. Cameron (1971, 1972, 1973, 1975) assigned the rocks to the late Eocene (Narizian?, lower to upper Refugian) to early and middle Oligocene (lower to middle Zemorrian).

Recent biostratigraphic studies on the west coast of North America, especially with planktonic foraminifers and nannofossils (Lipps, 1967; Brabb et al., 1971; Berggren, 1971; Poore and Brabb, 1977) and molluscan faunas (Armentrout, 1975, 1977) favour the placement of the Eocene-Oligocene boundary at the top of the Refugian (foraminiferal stage) or Galvinian (west coast molluscan stage). Following this designation, the Eocene-Oligocene boundary in the Nootka Sound area is placed within the Hesquiat Formation at the top of the **Chiloguembelina cubensis** zone (="Lincoln" – lower "Blakeley" transition of Jeletzky, 1954, 1975b).

Abundant planktonic foraminifera from the Hesquiat Formation of the Nootka Sound area are presently under study and should provide an additional basis for biostratigraphic correlation of west coast rocks.

STRUCTURAL GEOLOGY

The study of the stratigraphy and facies equivalents of the Escalante and Hesquiat formations has been greatly complicated by faults, reworking of fossil assemblages, and rapid facies changes. Detailed stratigraphy and repetition of microfossil zones has provided evidence of two types of faults in the study area (Fig. 4A). A major northwest-trending fault between Escalante Point and Escalante Island is interpreted as a steep west-dipping reverse fault. This fault has been recognized on both the west and east sides of Hesquiat Peninsula and on Flores Island (Fig. 5, Dagger Point) but has not been observed in the Tertiary rocks of Nootka Island. Parts of the pre-Tertiary rocks, the Escalante and Hesquiat formations are repeated across the fault (see discussion of Escalante Formation). Similar faults may have affected younger parts of the Hesquiat Formation but their recognition is much less obvious.

A second fault system affecting the Escalante and Hesquiat formations throughout the study area consists of a complex of transcurrent predominantly left lateral faults (Fig. 4A). The main trends are west and southwest. The relative displacement across these faults varies from almost nil to several hundred metres (Fig. 6, 10). Evidence for relative movements across the faults was gained by describing continuous sections and recording the succession of biostratigraphic zones only within individual fault blocks (Fig. 4B). A comparison of adjacent faulted segments was then made throughout the study area which resulted in the recognition of the highly repeated nature of the Hesquiat Formation across these transcurrent faults.

DEPOSITIONAL ENVIRONMENT

Interpretation of the depositional environment of the Escalante and Hesquiat formations is complicated by rapid facies changes within sequences and the effects of reworking of megainvertebrate and microinvertebrate fossils. In addition it is important to consider sedimentalogical factors which provide evidence towards understanding the environment of deposition.

Foraminifera

The assessment of various species of foraminifers as environmental indicators can be done in two ways: specific identity with well documented occurrences in other Eocene and Oligocene rocks of the west coast (Bandy and Kolpack, 1963; Rau, 1964; Bandy and Arnal, 1969; Armentrout and Berta, 1977), or assuming that earlier Tertiary species probably reflect similar environmental conditions as do their modern phenotypes (Bandy, 1953, 1960, 1964; Uchio, 1960; Murray, 1973).

The following benthonic species occurring throughout the geographic extent of the Hesquiat Formation and parts of the Escalante Formation have been reported from the Eocene Cozy Dell Shale and Coldwater Sandstone of California (Bandy and Kolpack, 1963): **Bulimina sculptilis, Cassidulina**

globosa, Chilostomella sp. (czizeki and **ovoidea** types), **Cyclammina pacifica, Globobulimina** sp. (**pyrula** type), **Gyroidina condoni, Gyroidina girardana planata, Plectofrondicularia packardi multilineata, Plectofrondicularia packardi packardi, Uvigerina churchi,** and **Uvigerina garzaensis.** These and other forms closely similar to Nootka Sound species are interpreted by Bandy and Kolpack (1963) as reflecting water depths of approximately 1000 m. Comparisons with other published sources (Rau, 1964; Bandy and Arnal, 1969; Armentrout and Berta, 1977) further support this interpretation.

If phenotypic comparison of these Eocene and Oligocene species can be confidently made with modern forms, bathyal water depths are again indicated (Bandy, 1953, 1960; Uchio, 1960). Rare occurrences of known shelf foraminifers such as species of **Buccella, Buliminella, Elphidium, Epistominella, Florilus, Quinqueloculina** throughout most of the sequence lend further support to a bathyal water depth assignment for these beds. The suggestion by Jeletzky (1973, p. 346) that upwelling currents along the coast provided a cooler shelf environment for otherwise bathyal water foraminifers is considered to be improbable, as in this case, one might expect a mixing of deeper water and shelf forms. Obvious shallow neritic species occur infrequently on Flores Island and Hesquiat Peninsula (Table 3). These forms, **Elphidium** sp. aff. **E. californicum, Glabratella** sp., **Protelphidium** sp. and **Quinqueloculina** spp. are found in association with abraded oyster and echinoid debris and are only encountered in sandstone or gritty sandstone lenses. They are interpreted as having been transported into deeper water.

Distribution

Most of the bathyal water foraminifers listed previously occur in the Hesquiat Formation. They are most common in the shale facies at Tatchu Point, Nootka Island, east side of Hesquiat Peninsula, Hesquiat Point, and Flores Island. They are present in the pebbly mudstone and sandy shale both above and below conglomerate and sandstone lenses but occur less frequently in association with the conglomeratic facies. The paucity of calcareous foraminifers in and amongst these coarser clastics may be attributable to a winnowing effect during sedimentation, or, the tests may have been destroyed during deposition of coarse clastics in turbid conditions. These coarse clastic facies contain abundant agglutinating species, the same as those which are distributed in moderate numbers throughout the measured sections (Table 3).

The environmental interpretation of the type Escalante Formation is difficult due to the paucity of foraminifers within the sandstone and conglomerate. The lowest occurrence of in situ foraminifers recorded to date is approximately 70 m above the base of the type Escalante Formation. A meagre assemblage of agglutinating foraminifers has been recovered, including **Cyclammina pacifica, Haplophragmoides** sp., and **Cribrostomoides** sp. On the basis of these occurrences an estimate of lower neritic to upper bathyal water depths is tentatively assigned to this part of the formation. If this interpretation is valid, water depths must have increased rapidly during deposition in order to accommodate the rich bathyal **Cibicides haydoni** assemblage which makes its first occurrence approximately 140 m above the base.

The Escalante Formation on the east side of Hesquiat Peninsula (Fig. 4B, Sections BC-74-2, BC-74-3), on Escalante Island (Fig. 4B, Section BC-71-3), and the southern end of Flores Island (Fig. 5, Section BC-74-16) have yielded no in situ foraminifers. These sections are lithologically similar to the type Escalante Formation, although possibly not precisely the same age, and on the basis of described molluscs (Jeletzky, 1954, 1975a, b) a general lower neritic to upper bathyal water environment is assumed.

The Escalante Formation on Nootka Island and Tatchu Point has yielded good to excellent foraminiferal assemblages. On Tatchu Point, a good assemblage of foraminifers was collected within 2 m of the disconformable base of the Escalante Formation (Fig. 2, Section BC-74-20). The assemblage includes **Cyclammina pacifica, Uvigerina** cf. **atwilli, Haplophragmoides** spp., **Cribrostomoides** sp., **Pseudonodosaria** sp. and abundant, well preserved Jurassic (?) foraminifers, and is assigned to the **Globorotalia** aff. **postcretacea** zone. A bathyal water environment of deposition is suggested. It is of interest to note that this assemblage occurs stratigraphically below the abraded oyster-bearing sandstone described by Jeletzky (197a, p. 14) as evidence for intertidal deposition. The Escalante Formation on Nootka Island in two measured sections (Fig. 3, Sections BC-69-4 and BC-74-23) contains rich bathyal water foraminiferal assemblages assignables to the **Globorotalia** aff. **postcretacea** zone. Abundant and specifically diverse foraminifers have been recovered from within 5 m of the disconformable base of Section BC-69-4. Similarly diverse assemblages occur approximately 30 m above the base of Section BC-74-23.

Figure 7. Small conglomerate pocket of Escalante Formation on Flores Island associated with thick shelled disarticulated bivalve molluscs. Association identical to type Escalante Formation, west side of Hesquiat Peninsula (refer to Fig. 5, Section BC-74-16). (GSC 203497-A)

Table 3

Foraminifera from the Hesquiat Formation, Nootka Sound Area

	Cibicides haydoni zone	**Globorotalia** aff. **postcretacea** zone	**Chiloguembelina cubensis** zone	**Turrilina alsatica** zone	**Bulimina** cf. **alsatica** zone
Alabamina sp.					X
Anomalina sp. cf. **A. californiensis** Cushman & Hobson		/	/	X	X
Bolivina sp. cf. **B. marginata** Cushman		/	X	X	/
Bulimina sp. cf. **B. alsatica** Cushman & Parker					X
Bulimina schencki Beck		O			
Bulimina sculptilis laciniata Cushman & Parker		X	/		
Cancris joaquinensis Smith		O	/		X(= R^S)
Cassidulina crassipunctata Cushman & Hobson					X
Cassidulina galvinensis Cushman & Frizzell			/		X(= R^S)
Cassidulina globosa Hantken		X	O	X	R^S ?
Cassidulina kernensis Smith					X or R^S
Cassidulina sp.		O			/(= R^S)
Cassidulinoides sp.				/	X
Caucasina schwageri (Yokoyama)		O	X		
Caucasina sp.			/		
Ceratobulimina washburnei Cushman & Schenck			/		/(= R^S)
Chiloguembelina cubensis (Palmer)		X	O	/	
Chiloguembelina sp.		X	X	/	
Chilostomella sp.		X	/	/	X
Cibicides elmaensis Rau	X	O	X	X	O
Cibicides haydoni (Cushman & Schenck)	O			R^S	/(= R^S)
Cibicides hodgei Cushman & Schenck	X				/(= R^S)
Cibicides pseudoungerianus (Cushman) var.			/		
Cibicides spp.		X	X	/	O
Cyclammina pacifica Beck	O	O	X	X	X or R^S
Dentalina dusenburyi Beck			X		/(= R^S)
Elphidium sp. aff. **E. californicum** Cook (Mallory)			/(R^b)		/(= R^S & R^b)
Eponides sp. aff. **E. kleinpelli** Cushman & Frizzell		O	R^S ?		/(= R^S)
Gavelinella ? **willapaensis** (Rau)	/	X			X(= R^S)
Glabratella sp.			/(R^b)		/(= R^S & R^b)
Globigerina spp.		X	X	O	X
Globobulimina spp.	X	X	X	X	X
Globorotalia gemma Jenkins				X	
Globorotalia sp. aff. **G. postcretacea** (Myatliuk)		O			
Globorotalia spp.			X	/	
Gyroidina condoni (Cushman & Schenck)		X	/		
Gyroidina keenani (Cushman & Kleinpell)			X	X	
Gyroidina orbicularis planata Cushman			X	/	X
Gyroidina soldanii d'Orbigny		O	X		X(= R^S)
Hoeglundina eocenica (Cushman & Hanna)			/		X(= R^S)
Lenticulina spp.	/	X	X	/	/
Martinottiella sp. cf. **M. alabamensis** (Cushman)					X

	Cibicides haydoni zone	*Globorotalia* aff. *postcretacea* zone	*Chiloguembelina cubensis* zone	*Turrilina alsatica* zone	*Bulimina* cf. *alsatica* zone
Martinottiella eocenica Cushman & Bermudez		O	X	/ or R^s	/(=R^s)
Melonis sp. aff. **M. garzaensis** (Cushman & Siegfus)	X				O(=R^s)
Melonis planatus (Cushman & Thomas)		/	X	/	
Melonis pompilioides (Fichtel and Moll)	/	X	/	/	/ or R^s
Oridorsalis umbonatus (Reuss)		/	O		
Plectofrondicularia sp. cf. **P. gracilis** Smith				/	X
Plectofrondicularia packardi multilineata Cushman & Simonson		O	O	X	X
Plectofrondicularia packardi packardi Cushman & Schenck		O	/		O(=R^s)
Plectofrondicularia vaughani Cushman		/	/		/(=R^s)
Protelphidium sp.					/ or R^b
Pseudonodosaria sp. cf. **P. inflata** (Bornemann)			/	/	X
Pseudoparella sp.				/	X
Pullenia sp. cf. **P. bulloides** d'Orbigny		/			
Pyrgo spp.		/	/	/	/
Quinqueloculina spp.	/	/	/	/	O(=R^b) & R^s ?
Sigmomorphina pseudoschencki Rau					/(=R^s?)
Siphonodosaria spp.			/	X	O
Stilostomella spp.		X	X	X	O
Trifarina hannai (Beck)		/			
Trifarina sp.					O
Turrilina alsatica Andreae			/	O	/
Turrilina sp.					/
Uvigerina atwilli Cushman & Simonson	X	X	/		/(=R^s)
Uvigerina sp. aff. **U. churchi** Cushman & Siegfus	/				
"**Uvigerina cocoaensis** Cushman"	/	/	/		/(=R^s)
Uvigerina garzaensis Cushman & Siegfus		X	X		/(=R^s)
Uvigerina glabrans Cushman			/		
Uvigerina tumeyensis Lamb		X	/		
Vulvulina sp.		/			
miscellaneous agglutinating foraminifers	X	X	/	/	X
miscellaneous nodosarid foraminifers	/	X	/	X	X
miscellaneous polymorphinid foraminifers	/	/	/	/	X(=R^s ?)
ostracodes		/	/	/	X(=R^s & R^b)
megaspores	/	/	X	/	/
diatoms			X		/
radiolaria	/(=R^s)				
Jurassic or Lower Cretaceous foraminifers	/(=R^s)	/(=R^s)			

O = abundant, X = common, / = rare

R^s, R^b = reworked, either stratigraphically or bathymetrically (from equivalent strata into deeper water)

Note: Relative abundance decreases markedly in coarse clastic facies (especially west side of Hesquiat Peninsula).

Megainvertebrates

Following the publication of a brief report (Cameron, 1971), it was suggested by Jeletzky (1973) that the value of Tertiary molluscan faunas for biostratigraphic and environmental purposes was ignored or underestimated. Such was not the case. The environmental aspects of the megainvertebrates are of extreme interest and provide useful information.

Arthropods

Fossil crabs identified as **Portunites alaskensis** Rathbun, **Eumorphocorystes naselensis** Rathbun, and **Zanthopsis vulgaris** Rathbun by Jeletzky (1973) are characteristic components of the Escalante Formation. At least some of these forms have been recorded from the overlying Hesquiat Formation. During the course of field studies, the writer interpreted this crab assemblage to be in its original fossil environment in only four localities of the upper Escalante Formation: Sections BC-71-1, BC-74-3 and BC-71-3 (Fig. 4B) and Section BC-74-23 (Fig. 3, 14). At these four localities, the crab carapaces within the concretions are preferentially oriented parallel with the bedding. The many other localities from which fossil crabs have been collected (see Figs. 2, 3, 4 and 5) contain concretions in which the contained crabs show completely random orientation with respect to the bedding. The excellent state of preservation of the crabs has been presumed to indicate that they are preserved at their original death site (Jeletzky, 1975b). Admittedly, the crabs are well preserved but it is the concretions enclosing the crabs that are reworked and not the crabs themselves. The concretions however show little evidence of transport in the form of abrasion. A further indication of the reworked nature of the concretions is provided by their occurrences throughout the Hesquiat Formation on Hesquiat Peninsula. These crab-bearing concretions have been collected in abundance from grit lenses within strata mapped as "Blakeley" by Jeletzky (1954, 1975b) from the vicinity of Estevan Point (Fig. 4B, Section BC-74-11) and from Smokehouse Bay (Fig. 4B, lateral equivalent of Section BC-74-8). The presence of "diagnostic Lincoln crabs" (Jeletzky, 1973, p. 339) within his "Blakeley" strata is best explained by reworking. Although the fossil crabs have limited application towards environmental interpretation (Jeletzky, 1973, p. 347), the above discussion illustrates the problems of reworking in the sequence.

Molluscs

The relationships of the molluscs (especially the bivalves) to their enclosing sediment type is of utmost importance in palaeoenvironmental interpretation. The oysters described by Jeletzky (1975a, p. 14) from the Escalante Formation of Tatchu Point are "more or less worn, single, commonly fragmentary valves". Others are much better preserved. It is reasonable to assume therefore that some degree of transport is indicated. Broken, disarticulated, and worn oyster shells also are present in conglomerate and grit lenses on Flores Island (Fig. 5, Section BC-74-13) where they occur throughout the section. Well worn oyster fragments also have been recovered from gritty shale on the east side of Hesquiat Peninsula, on the tidal flats near Hesquiat Village (with **Acila gettisburgensis** Reagan of Jeletzky 1975, . . . "a fauna of deeper and quieter waters (facies of clayey sandstone and shale)." Jeletzky, 1954, p. 60)). Downslope reworking of oyster shells is obvious.

Although a detailed discussion of the environmental implications of all recorded molluscs from the Hesquiat Formation is beyond the scope of this paper, a few observations may be appropriate. Species of **Acila** (sensu Jeletzky, 1954, 1973, 1975b) occur throughout the Hesquiat Formation and according to Natland (1957, p. 544), this genus and others are "able to live in bathyal and abyssal parts of the sea". In addition to **Acila shumardi**, the mollusc **Thysira** cf. **T. disjuncta** has been recorded (Jeletzky, 1975b, p. 3) from Unit 47 of the type section of Hesquiat Formation. **Thysira** aff. **T. disjuncta** is one of an assemblage of deep water pelecypods recorded from the Wagonwheel Formation of California (Addicott, 1973, p. 10). The molluscs **Echinophoria** and **Bathybembix** have been identified from the "upper part of Division B" (=Hesquiat Formation, Nootka Island) (Jeletzky, 1973, p. 348). **Liracassis** (=**Echinophoria** of Jeletzky, 1973) and **Bathybembix** are listed by Addicott (1976, p. 441-442) as ranging in depth from outer sublittoral to bathyal. Many of the other molluscan species listed from the Hesquiat Formation are not used in support of Jeletzky's (1975b) environmental interpretation. The above discussion, however, may be sufficient to indicate that the supposed incompatibilities between foraminifers and molluscs for environmental interpretation are more imagined than real. Molluscan workers currently studying west coast depositional depths of Tertiary rocks are interpreting their assemblages as indicating much greater water depths than previously thought (Armentrout, pers. comm., 1978).

The molluscs of the lower part of the type Escalante Formation on Hesquiat Peninsula are shallow water forms. It is significant, however, that the thick shelled poorly preserved, bivalves are concentrated in conglomerate lenses and pockets suggesting some degree of transport. This association has been observed on Flores Island (Fig. 5, Section BC-74-16), on the east side of Hesquiat Peninsula (Fig. 4B, Section BC-74-3), on Escalante Island (Fig. 4B, Section BC-71-3), and on Nootka Island (Fig. 3, Section BC-74-23). A similar association also was recorded by Jeletzky (1975a, p. 11) in describing the occurrence of **Chlamis (Vertipecten) porterensis** on Nootka Island. Molluscs identified by Jeletzky (1975a) from these areas, appear to be compatible with the well developed bathyal water foraminiferal assemblages herein described.

Sedimentology and Sedimentary Structures

The complex lithological associations of the type Hesquiat Formation have been described in detail by Jeletzky (1975b). Detailed analyses of sediments, sequences, sedimentary structures, and related fossils are in preparation by the writer. A few preliminary remarks, however, are appropriate at this time.

Graded beds are variously developed in the Hesquiat Formation of the Hesquiat Peninsula area (Fig. 15) and range in development from poor to excellent. The thick conglomerate and sandstone in the proximal facies of western Hesquiat Peninsula (Fig. 4B) are characteristically heterogenous with poorly developed or no grading. Grading is evident however in the thinner sandstone units (Fig. 4B, Sections BC-72-13, BC-72-15). Well rounded reworked pre-Tertiary igneous and volcanic rocks comprise the bulk of the conglomerate facies. Sedimentary species are concentrated at the bases of the conglomerate lenses (Fig. 9) where their clast sizes are usually larger and more angular than those of plutonic and volcanic origin. No imbrication of clasts is apparent in these conglomerate units consequently no current vector is suggested. The sediments of the thick lenticular conglomerate are assumed to have been deposited by a mass-flow process (Normack and Piper, 1969). Well developed but thin graded units are found immediately adjacent to the major proximal facies throughout the Hesquiat Formation on western Hesquiat Peninsula. The lateral facies equivalents of these beds (Fig. 12) in predominantly shale and interbedded shale-siltstone-sandstone facies also show grading, but on a much finer scale (Nootka Island, Hesquiat Point, etc.).

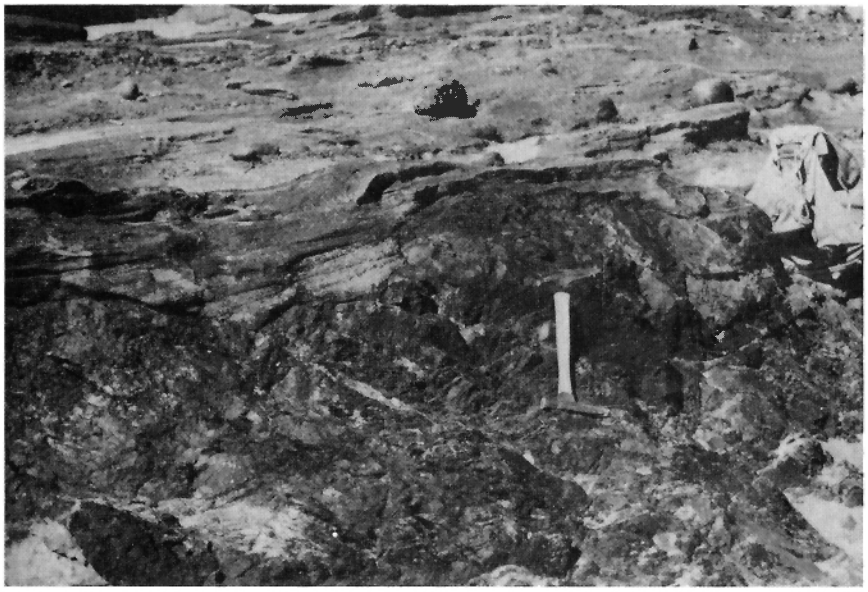


Figure 8

Erosional contact of Escalante Formation on exhumed surface of Bonanza volcanics, Flores Island (refer to Fig. 5, Section BC-74-16). (GSC 203497-B)

Figure 9

Chaotic fluxoturbidite facies with angular blocks of Jurassic (?) sandstone are incorporated in pebbly sandstone matrix of Hesquiat Formation, eastern Hesquiat Peninsula. The beds are finer grained towards the top. The top of a previous clastic influx is exposed at the lower right of the photograph (refer to Fig. 4B, Section BC-74-2). (GSC 203497-C).

Figure 10

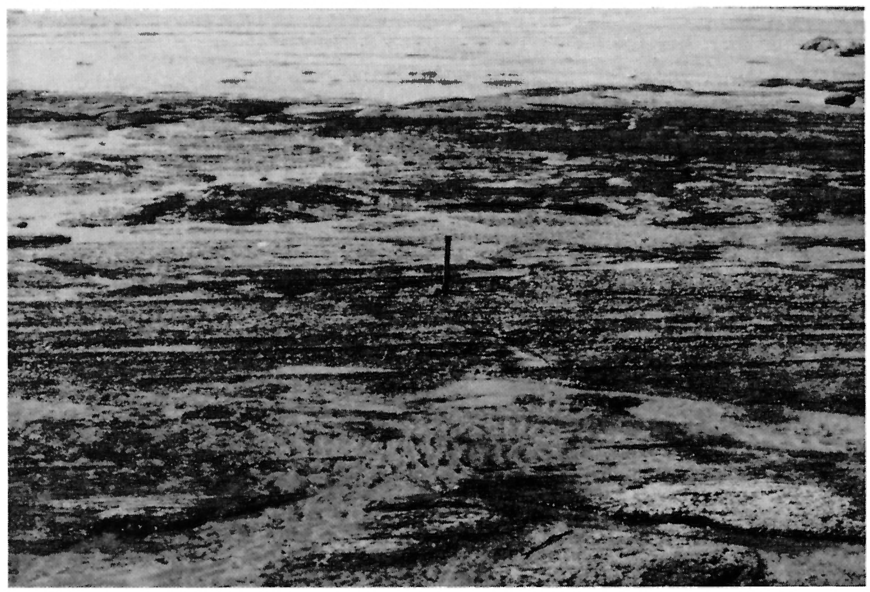
Hesquiat Formation on Flores Island shows typical development of distal sandstone-silty shale and shale interbeds (Fig. 5, Section BC-74-13). Fault in centre of photograph is left lateral with minor horizontal displacement. (GSC 203497-D)

Figure 11

Soles of sandstone beds (inverted) from the Hesquiat Formation with load casts and grooves occur at LeClair Point on east side of Hesquiat Peninsula. Laminated sandstone bed in lower right hand side contains abundant carbonaceous debris (Fig. 4B, Section BC-74-1). (GSC 203497-E)

Figure 12

Distal facies of Hesquiat Formation, east side of Hesquiat Peninsula, comprises soft shale and interbedded silty shale (refer to Fig. 4B, Section BC-74-1). (GSC 203497-F)



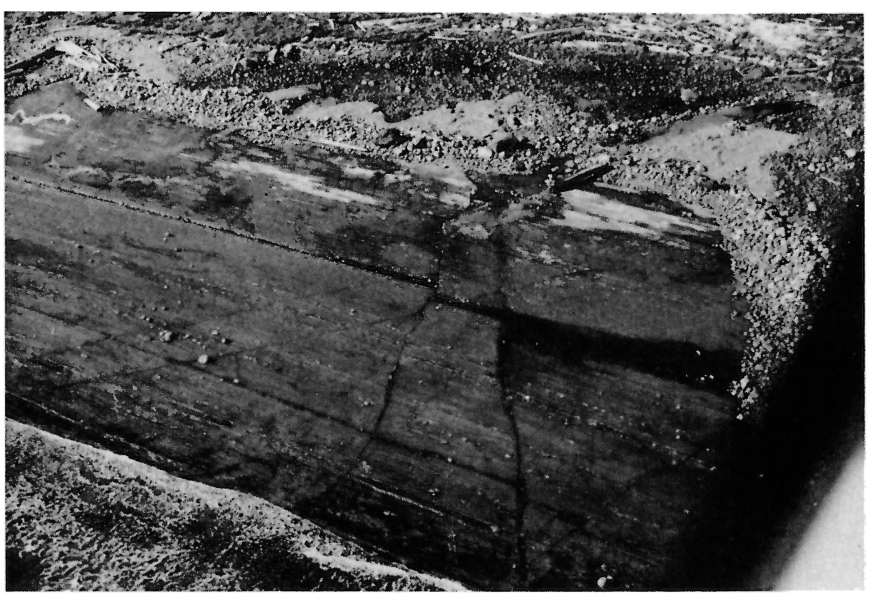


Figure 13

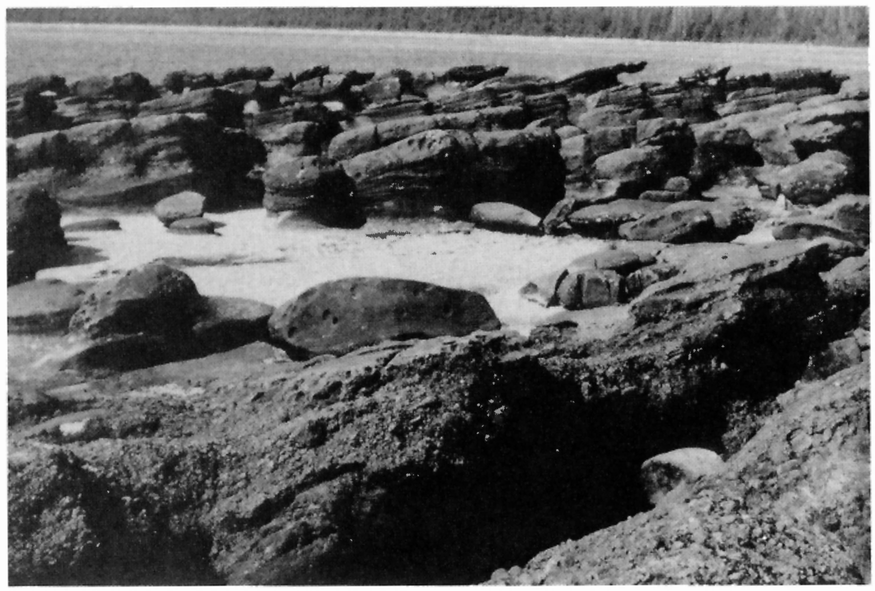
Distal facies of Hesquiat Formation, Estevan Point, south side of Hesquiat Peninsula (refer to Fig. 4B, Section BC-74-6). (GSC 203497-G)

Figure 14

Upper sandstone beds of the Escalante Formation exposed on Nootka Island (Fig. 3, Section BC-74-23). Abundant crab-bearing concretions occur at this locality with rich bathyal foraminifers 10-15 m stratigraphically below. Hesquiat Peninsula is visible in background. (GSC 203497-H).

Figure 15

Graded conglomerate, sandstone and argillaceous sandstone of the Hesquiat Formation; eastern Hesquiat Peninsula. Note lenticular nature of conglomerate beds. The bay in background in an area of distal shale and siltstone exposure (refer to Fig. 4B, Section BC-74-1). (GSC 203497-I)



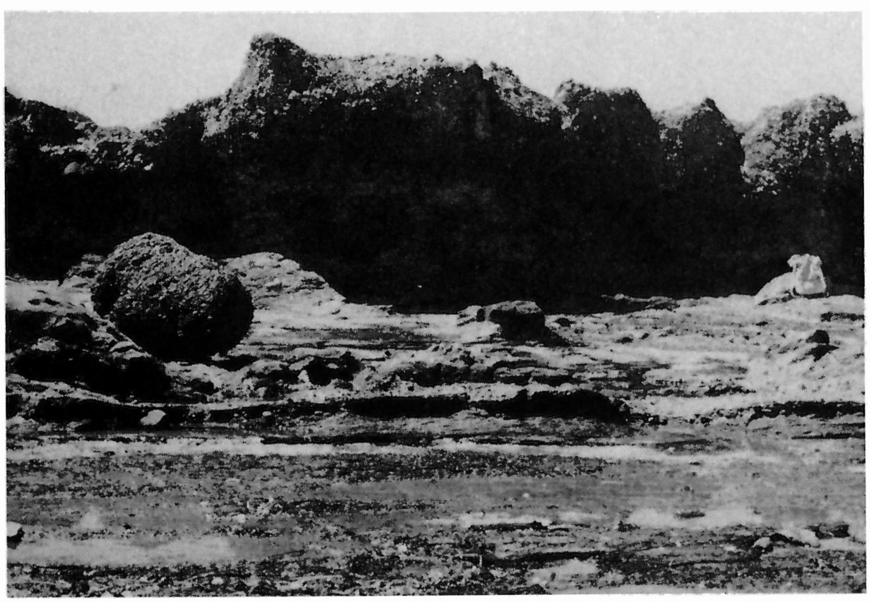


Figure 16

Sand-silty shale-shale sequence of the Hesquiat Formation, western Hesquiat Peninsula (foreground), succeeded by pebbly mudstone, is followed by a zone of pebbly sandstone with abundant rip-up clasts and finally massive fluxoturbidite (Fig. 4B, Section BC-72-10). This is representative of a typical proximal turbidite sequence on the west side of Hesquiat Peninsula. (GSC 203497-J)

Figure 17

Same locality as Figure 16, showing details of pebble mudstone zone with well developed rip-up clasts and disrupted sandstone beds. Shadow on right hand side is created by the massive fluxoturbidite cliff. (GSC 203497-K)

Figure 18

Hesquiat Formation, west side of Hesquiat Peninsula. Pebbly mudstone enclosed by shale-silty shale-sandstone. Erosional contacts of this type are present throughout the formation on western Hesquiat Peninsula (refer to Fig. 4B, Section BC-72-15). (GSC 203497-L)

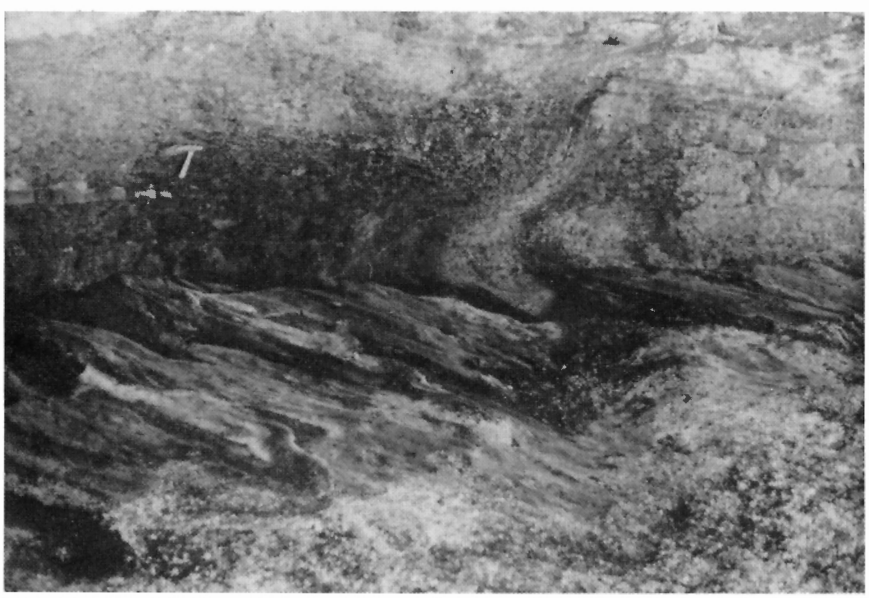


Figure 19

Hesquiat Formation, west side of Hesquiat Peninsula. Abrupt and erosional contact of pebbly mudstone and overlying fluxoturbidite creating a local angular discordance, a reflection of penecontemporaneous deformation of the softer sediments below. Note load cast development (refer to Fig. 4B, Section BC-72-11). (GSC 203497-M)

Pebbly mudstone (Crowell, 1957) is well developed in association with the main proximal facies throughout the Hesquiat Formation. They are invariably present beneath conglomerate lenses in all areas of outcrop on western Hesquiat Peninsula (Fig. 16, 17) and to a lesser degree at LeClair Point and Flores Island. The pebbly mudstone is believed to represent resedimented material from higher on the slope which was sufficiently viscous during its transport to rip-up considerable amounts of the underlying soft shale and sandstone (Fig. 17). The resulting churned mass scoured the underlying strata to a considerable degree (Fig. 18) and commonly created local angular discordances with the overlying coarse clastic units (Fig. 19). The distribution of pebbly mudstone throughout the proximal facies of the Hesquiat Formation is herein considered to be evidence for slope deposition throughout the formation.

Summary – Depositional Environment

Escalante Formation

The few foraminifers recovered from the upper part of the type Escalante Formation and its equivalent on the east side of Hesquiat Peninsula are indicative of a neritic to upper bathyal depositional environment. Rapid deepening ,however was necessary in view of the rich bathyal water assemblages recovered from the transitional beds to the overlying Hesquiat Formation. The Escalante Formation on Tatchu Point (Fig. 2), Nootka Island (Fig. 3), and Flores Island (Fig. 5) are interpreted to be deeper water resedimented equivalents of the type section on the basis of their abundant bathyal water foraminifers, slope type sedimentary structures, and abundance of transported shallower water fossils.

Hesquiat Formation

On the basis of contained microfauna and megafauna, and taking into account the sediments and sedimentary structures, the type Hesquiat Formation is interpreted to be an exclusively slope (bathyal water) deposit. Proximal facies are best represented in the type area where fluxoturbidites, graded turbidite units, and distal facies are juxtaposed by a high degree of faulting. Distal facies consisting of interbedded shale and siltstone are best represented on Nootka Island. The contrasting lithofacies in the study area are interpreted as representing deposition in various environmental equivalents within a bathyal water fan complex.

FORAMINIFERAL BIOSTRATIGRAPHY

The determination of the foraminiferal succession of the Nootka Sound Tertiary sequence is complicated by structural repetition of the rocks, rapid and abrupt facies changes and reworking, both stratigraphically and bathymetrically, of foraminifers, molluscs, and crustaceans. Detailed study of the fossils, taking into consideration the possible sources of interpretational error, has led to the recognition of five foraminiferal assemblage zones. The zones are named on the basis of a conspicuous element of the assemblage although this element need not necessarily be restricted to this zone nor always represented within the zone. Lists of microfossils occurring within each zone are not complete but include those species which appear to be most diagnostic for biostratigraphic and environmental interpretation. The zones will be described in ascending stratigraphic order.

Cibicides haydoni zone

Foraminifera of the **Cibicides haydoni** zone are the oldest known in the area. Except for fault repetition, they are known from only one locality, in the transitional beds between the type Escalante Formation and the overlying Hesquiat Formation of Escalante Point, on the west side of Hesquiat Peninsula. Foraminifera restricted to this zone include:

Cibicides haydoni (Cushman & Schenck)

Cibicides hodgei Cushman & Schenck

Melonis sp. aff. **M. garzaensis** (Cushman & Siegfus)

Uvigerina sp. aff. **U. churchi** Cushman & Siegfus

Other longer ranging species present include:

Cibicides elmaensis Rau

Cyclammina pacifica Beck

Gavelinella? **willapaensis** (Rau)

Globobulimina sp.

Lenticulina spp.

Melonis pompilioides (Fichtel & Moll)

Uvigerina atwilli Cushman and Simonson

Uvigerina cocoaensis Cushman

Uvigerina tumeyensis Lamb

Age

A late Eocene (late Narizian (of Mallory, 1959) to early Refugian (of Schenck and Kleinpell, 1936) age is assigned to beds containing this assemblage. The age of several species as interpreted by other west coast workers is summarized in the following table.

	Armentrout and Berta 1977	Cushman and Simonson 1944	Kleinpell and Weaver 1963	Mallory 1959	Rau 1964	Rau 1966	Rau 1967	Smith 1956	Sullivan 1962	Wilson 1954
Cibicides elmaensis	R				NR		R			
Cibicides haydoni		R	R		NR		N	R	R	R
Cibicides hodgei		R	NR	NR	NR	N	NR	R	NR	R
Gavelinella? willapaensis	R				N? R	N				
Uvigerina atwilli		R	R	R?			R	R	R	R
Uvigerina cocoaensis		R	R	R	R		R	R		R

N = Narizian, R = Refugian, NR = Narizian and Refugian

Globorotalia sp. aff. G. postcretacea zone

This assemblage is much more widely distributed than the **Cibicides haydoni** zone. It occurs in the basal beds of the Hesquiat Formation of Hesquiat Peninsula, and in the lithostratigraphic equivalents of the Escalante Formation at Tatchu Point, Nootka Island, and Flores Island. Foraminifera restricted to this zone include:

Globorotalia sp. aff. **G. postcretacea** (Myatliuk)

Bulimina schencki Beck

Cassidulina sp.

Caucasina schwageri (Yokoyama)

Eponides sp. aff. **E. kleinpelli** Cushman & Frizzell

Gyroidina condoni (Cushman & Schenck)

Pullenia sp. cf. **P. bulloides** d'Orbigny

Trifarina hannai (Beck)

Vulvulina sp.

Other longer ranging species include:

Anomalina sp. cf. **A. californiensis** Cushman & Hobson

Bulimina sculptilis laciniata Cushman & Parker

Cancris joaquinensis Smith

Cassidulina globosa Hantken

Chiloguembelina cubensis (Palmer)

Chiloguembelina sp.

Chilostomella sp.

Cibicides elmaensis Rau

Cyclammina pacifica Beck

Gavelinella? **willapaensis** (Rau)

Globigerina spp.

Globobulimina sp.

Gyroidina soldanii d'Orbigny

Lenticulina spp.

Martinottiella eocenica Cushman & Bermudez

Melonis planatus (Cushman & Thomas)

Melonis pompilioides (Fichtel & Moll)

Plectofrondicularia packardi multilineata Cushman & Simonson

Plectofrondicularia packardi packardi Cushman & Schenck

Plectofrondicularia vaughani Cushman

Uvigerina atwilli Cushman & Simonson

Uvigerina cocoaensis Cushman

Uvigerina garzaensis Cushman & Siegfus

Uvigerina tumeyensis Lamb

Age

A late Eocene (early Refugian (of Schenck and Kleinpell, 1936)) age is assigned to strata containing this assemblage. Many of these forms are well known along the west coast of North America and most are recorded from Refugian rocks or older. A close correlation with the **Sigmomorphina schencki** zone (Rau, 1958, 1966; Beikman et al., 1967) of Washington State is apparent.

Chiloguembelina cubensis zone

Strata containing foraminifera assigned to this zone are distributed throughout the map area and are present in the youngest exposures of the Hesquiat Formation on Tatchu Point and Flores Island. They occur in the middle part of the Hesquiat Formation on Hesquiat Peninsula and Nootka Island.

Foraminifera of the **Chiloguembelina cubensis** zone include many of the species from the older **Globorotalia** aff. **postcretacea** zone (see Table 3) as well as the first occurrences of:

Chiloguembelina cubensis (Palmer) – abundant

Bolivina sp. cf. **B. marginata** Cushman

Cassidulina galvinensis Cushman & Frizzell

Caucasina sp.

Ceratobulimina washburnei Cushman & Schenck

Cibicides pseudoungerianus (Cushman) var.

Dentalina dusenburyi Beck

Elphidium sp. aff. **E. californicum** Cook (Mallory)

Glabratella sp.

Globorotalia spp.

Gyroidina keenani (Cushman & Kleinpell)

Gyroidina orbicularis planata Cushman

Hoeglundina eocenica (Cushman & Hanna)

Ordidorsalis umbonatus (Reuss)

Pseudonodosaria sp. cf. **P. inflata** (Bornemann)

Siphonodosaria sp.

Stilostomella spp.

Uvigerina glabrans Cushman

Age

A late Eocene (late Refugian (of Schenck and Kleinpell, 1936)) age is assigned to these beds. Many of these forms are well known in Refugian rocks of the west coast. The assemblage is best compared with the **Cassidulina galvinensis** zone (Rau, 1966, 1967; Beikman et al., 1967) of the Lincoln Creek Formation.

Turrilina alsatica zone and Bulimina cf. alsatica zone

These two zones have much in common and eventually may be reduced to subzonal status. They are clearly younger than the **Chiloguembelina cubensis** zone but zonal indices are commonly masked by a large number of reworked older species (see Table 3).

Turrilina alsatica zone

Rocks enclosing foraminifers assigned to this zone are well represented on Nootka Island and Hesquiat Peninsula in the upper parts of the Hesquiat Formation. The most significant characteristic of the zone is an abundance of **Turrilina alsatica** Andreae as well as the first occurrences of:

Cassidulinoides sp. (of Rau, 1964)

Globigerina sp.

Globorotalia gemma Jenkins

Pseudoparella sp.

Siphonodosaria spp.

Stilostomella spp.

Other recorded species include:

- **Anomalina** sp. cf. **A. californiensis** Cushman & Hobson
- **Bolivina** sp. cf. **B. marginata** Cushman
- **Cassidulina globosa** Hantken (possibly reworked)
- **Chiloguembelina** sp.
- **Chilostomella** sp.
- **Cibicides elmaensis** Rau
- **Cibicides haydoni** (Cushman & Schenck) (reworked)
- **Cibicides** sp.
- **Cyclammina pacifica** Beck
- **Globobulimina** sp.
- **Gyroidina keenani** (Cushman & Kleinpell)
- **Lenticulina** sp.
- **Martinottiella eocenica** Cushman & Bermudez (possibly reworked)
- **Melonis pompilioides** (Fichtel and Moll)
- **Plectofrondicularia packardi multilineata** Cushman & Simonson
- **Pseudonodosaria** sp. cf. **P. inflata** (Bornemann)

Age

An early Oligocene (early Zemorrian (of Kleinpell, 1938)) age is assigned to these beds. Species restricted to the **Turrilina alsatica** zone are rare. Among the characteristic forms however, **Cassidulinoides** sp. (of Rau, 1964) appears to be characteristic of rocks assignable to the Zemorrian stage. Rau (1964) records this species from the upper Twin River Foramtion of the northern Olympic Peninsula, Washington State. The planktonic foraminifer **Globorotalia gemma** Jenkins (Jenkins, 1966) is known from the late Eocene to early Oligocene of New Zealand and recently has been recorded from the lower Rices Mudstone Member of the San Lorenzo Formation, California (Poore and Brabb, 1977). These authors suggest an early Oligocene, early Zemorrian age for those beds.

Bulimina cf. alsatica zone

The youngest part of the Hesquiat Formation in the Nootka Sound area contains a distinctive assemblage of foraminifers referred to as the **Bulimina** cf. **alsatica** zone. Reworking of older foraminiferal species into these beds is commonly extreme (see Table 3), and in some cases the recovered assemblage may consist of approximately 90 per cent of reworked forms. Critical evaluation of the collections, however, reveal some distinctive elements. The following make their first stratigraphic occurrence in the underlying **Turrilina alsatica** zone and also are well represented in the **Bulimina** cf. **alsatica** zone:

- **Cassidulinoides** sp. (of Rau, 1964)
- **Globigerina** sp.
- **Pseudoparella** sp.
- **Siphonodosaria** spp.
- **Stilostomella** spp.

In addition, the following species make their earliest stratigraphic occurrence:

- **Alabamina** sp.
- **Bulimina** sp. cf. **B. alsatica** Cushman & Parker (sensu Rau, 1964)
- **Cassidulina crassipunctata** Cushman & Hobson
- **Cassidulina kernensis** Smith (possibly reworked)
- **Martinottiella** sp. cf. M. **alabamensis** (Cushman)
- **Plectofrondicularia** sp. cf. **P. gracilis** Smith
- **Protelphidium** sp.
- **Sigmomorphina pseudoschencki** Rau (possibly reworked)
- **Trifarina** sp.
- **Turrilina** sp.

Other longer ranging and reworked species are listed in Table 3.

Age

Rocks containing foraminifers assignable to the **Bulimina** cf. **alsatica** zone are assigned an Oligocene, Zemorrian age. An early Zemorrian, early or middle Oligocene age is preferred, however, as the assemblage does not differ greatly from the preceding **Turrilina alsatica** zone. Foraminifers of the **Bulimina** cf. **alsatica** zone are similar to those reported by Rau (1964) from the early Zemorrian part of the Twin River Formation of the northern Olympic Peninsula.

SELECTED BIBLIOGRAPHY

Addicott, W.O.

1973: Oligocene molluscan biostratigraphy and paleontology of the lower part of the type Temblor Formation, California; U.S. Geological Survey, Professional Paper 791, 48 p.

1976: New molluscan assemblages from the Upper Member of the Twin River Formation, Western Washington: Significance in Neogene chronostratigraphy; Journal of Research of the U.S. Geological Survey, v 4, no. 4, July August, p. 437447.

Armentrout, J.M.

1975: Molluscan biostratigraphy of the Lincoln Creek Formation, Southwest Washington; Future energy horizons of the Pacific Coast; Paleogene Symposium and Selected Technical Papers: Annual Meeting of the Pacific Sections AAPG, SEPM, SEG, Long Beach, California, April 1975, p. 14-48.

1977: Cenozoic Molluscan Stages of Oregon and Washington. Pacific Northwest Cenozoic Biostratigraphy Symposium (abstract); Geological Society of America Annual Meeting, Seattle 1977.

Armentrout, J.M. and Berta, A.

1977: Eocene-Oligocene foraminiferal sequence from the northeast Olympic Peninsula, Washington; Journal of Foraminiferal Research, v. 7, no. 3, July, p. 216-233.

Bancroft, M.F.

1937: Gold-bearing deposits on the west coast of Vancouver Island between Esperanza Inlet and Alberni Canal; Geological Survey of Canada Memoir 204, 34 p.

Bandy, O.L.

1953: Ecology and paleoecology of some California Foraminifera: Part 1. The frequency distribution of Recent Foraminifera off California; Journal of Paleontology, v. 27, no. 2, p. 161-182.

1960: General correlation of foraminiferal structure with environment; International Geological Congress, XXI Session, Copenhagen, Report Part 22, p. 7-19.

Bandy, O.L. (cont'd)
1964: Foraminiferal trends associated with deep-water sands, San Pedro and Santa Monica basins, California; Journal of Paleontology, v. 38, no. 1, p. 138-148.

Bandy, O.L. and Arnal, R.E.
1969: Middle Tertiary Basin Development, San Joaquin Valley, California; Geological Society of America Bulletin, v. 80, no. 5, p. 783-819.

Bandy, O.L. and Kolpack, R.L.
1963: Foraminiferal and sedimentological trends in the Tertiary section of Tecolote Tunnel, California; Micropaleontology, v. 9, no. 2, p. 117-170.

Beck, R.S.
1943: Eocene Foraminifera from Cowlitz River, Lewis County, Washington; Journal of Paleontology, v. 17, no. 6, p. 584-614.

Beikman, H.M., Rau, W.W., and Wagner, H.C.
1967: The Lincoln Creek Foramtion, Grays Harbor basin southwestern Washington; U.S. Geological Survey Bulletin, 1244-1, p. 11-114.

Berggren, W.A.
1971: Tertiary boundaries and correlations; The Micropalaeontology of Oceans (ed., B.M. Funnell and W.R. Riedel), Cambridge University Press, p. 693-809.

Brabb, E.E. et al.
1971: Eocene (Refugian) nannoplankton in the Church Creek Formation near Monterey, Central California; U.S. Geological Survey Professional Paper 750-C, p. C44-C47.

Cameron, B.E.B.
1971: Tertiary stratigraphy and microfaunas from the Hesquiat-Nootka area, west coast, Vancouver Island (92 E); Report of Activities, Geological Survey of Canada, Paper 71-1, pt. B, p. 91-94.

1972: Tertiary foraminiferal succession of the western Cordillera and Pacific Margin; in Report of Activities, Geological Survey of Canada, Paper 72-1, pt. A, p. 198-201.

1973: Tertiary stratigraphy and microfaunas from the Pacific Margin, west coast, Vancouver Island; Report of Activities, Geological Survey of Canada, Paper 73-1, pt. A, p. 19-20.

1975: Geology of the Tertiary rocks north of Latitude 49°, west coast of Vancouver Island; Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 17-19.

Crowell, J.C.
1957: Origin of pebbly mudstones; Geological Society of America Bulletin, v. 68, no. 8, p. 993-1009.

Cushman, J.A. and Frizzell, D.L.
1940: Two new species of Foraminifera from the Oligocene, Lincoln Formation of Washington; Contributions from the Cushman Foundation for Foraminiferal Research, v. 16, no. 2, p. 42-43.

Cushman, J.A. and Hobson, H.D.
1935: A foraminiferal faunule from the type San Lorenzo Formation, Santa Cruz County, California; Contributions from the Cushman Foundation for Foraminiferal Research, v. 11, pt. 3 no. 158, p. 53-64.

Cushman, J.A. and Kleinpell, R.M.
1934: New and unrecorded Foraminifera from the California Miocene; Contributions from the Cushman Foundation for Foraminferal Research, v. 10, pt. 1, no. 140, p. 1-23.

Cushman, J.A. and Parker, F.L.
1947: Bulimina and related foraminiferal genera; U.S. Geological Survey Professional Paper 210 D, p. ii, 55-176.

Cushman, J.A. and Schenck, H.G.
1928: Two foraminiferal fanules from the Oregon Tertiary; University of California, Department of Geological Sciences, Bull., v. 17, no. 9, p. 305-324.

Cushman, J.A. and Siegfus, S.S.
1939: Some new and interesting Foraminifera from the Kreyenhagen shale of California; Contributions from the Cushman Foundation for Foraminiferal Research, v. 15, pt. 2, no. 206, p. 23-33.

Cushman, J.A. and Simonson, R.R.
1944: Foraminifera from the Tumey formation, Fresno County, California; Journal of Paleontology, v. 18, no. 2, p. 186-203.

Dott, R.H., Jr.
1963: Dynamics of subaqueous gravity depositional processes; American Association of Petroleum Geologists Bulletin, v. 47, no. 1, p. 104-128.

Durham, J.W.
1944: Megafaunal zones of the Oligocene of northwestern Washington; University of California Publications in Geological Sciences Bulletin, v. 27, no. 5, p. 84-104.

Dzulynski, S., Ksiazkiewicz, M., and Kuenen, Ph.H.
1959: Turbidites in flysch of the Polish Carpathian Mountains; Geological Society of America Bulletin, v. 70, no. 8, p. 1089-1118.

Fuechtbauer, H. and Mueller, G.
1974: Part II Sediments and Sedimentary Rocks 1; in Sedimentary Petrology by W.V. Engelhardt, H. Fuechtbauer, G. Mueller, E. Schweizerbart'sche Verlagsbuchhandlung, (Naegele u. Obermiller) Stuttgart, Halsted Press Division, John Wiley & Sons, inc.

Jeletzky, J.A.
1950: Stratigraphy of the west coast of Vancouver Island between Kyuquot Sound and Esperanza Inlet, British Columbia; Geological Survey of Canada, Paper 50-37, 52 p.

1954: Tertiary rocks of the Hesquiat-Nootka area, west coast of Vancouver Island, British Columbia; Geological Survey of Canada, Paper 53-17, 65 p.

1973: Age and Depositional Environments of Tertiary Rocks of Nootka Island, British Columbia (92 E): Mollusks Versus Foraminifers; Canadian Journal Earth Sciences, v. 10, no. 3, p. 331-364.

1975a: Age and depositional environment of the lower part of Escalante Formation, western Vancouver Island, British Columbia (92 E); in Report of Activities, Part C, Geological Survey of Canada, Paper 75-1C, p. 9-16.

1975b: Hesquiat Formation (New): A Neritic Channel and Interchannel Deposit of Oligocene Age, Western Vancouver Island, British Columbia; Geological Survey of Canada, Paper 75-32, 55 p.

Jenkins, D.G.
1966: Planktonic foraminiferal zones and new taxa from the Danian to Lower Miocene of New Zealand; New Zealand Journal Geology and Geophysics, v. 8, no. 6, p. 1088-1126.

Kleinpell, R.M.
1938: Miocene stratigraphy of California; America Association of Petroleum Geologists, Tulsa, Oklahoma, ix, 450 p.

Kleinpell, R.M. and Weaver, D.W.
1963: Oligocene biostratigraphy of the Santa Barbara embayment – Pt. 1 Foraminiferal faunas from Gaviota and Algeria formations; California University, Publications in Geological Sciences, v. 43, p. 1-77.

Kuenen, Ph.H.
1964: Deep-sea sands and ancient turbidites; in Developments in Sedimentology-Volume 3, Turbidities, Amsterdam, Elsevier Publishing Co., p. 3-33.

Lamb, J.L.
1964: The stratigraphic occurrences and relationships of some mid-Tertiary **Uvigerinas** and **Siphogenerinas**; Micropaleontology, v. 10, no. 4, p. 457-476.

Lipps, J.H.
1967: Planktonic Foraminifera, intercontinental correlation and age of California mid-Cenozoic microfaunal stages; Journal of Paleontology, v. 41, no. 4, p. 994-999.

Loeblich, A.R., Jr. and Tappan, H.
1964: Treatise on invertebrate paleontology, Part C, Protista 2; Geological Society of America, 2 v., 900 p.

Mallory, V.S.
1959: Lower Tertiary biostratigraphy of the California Coast Ranges; American Association of Petroleum Geologists, Tulsa, Oklahoma, viii, 416 p.

Murray, J.V.
1973: Distribution and Ecology of Living Benthic Foraminiferids; Crane, Russak & Co., New York, 274 p.

Myatliuk, E.V.
1950: Stratigraphy of flysch deposits from the northern Carpathians on the basis of the foraminiferal faunas; Mikrofauna SSSR, sbornib IV, Moscow (In Russian), p. 225-287.

Natland, M.L.
1957: Paleoecology of West Coast Tertiary sediments; in Treatise on Marine Ecology and Paleoecology, Geological Society of America, Memoir 67, no. 1, p. 543-572.

Nelson, H.C. and Nilsen, T.H.
1974: Depositional trends of modern and ancient deep sea fans; in Modern and Ancient Geosynclinal Sedimentation, Society of Economic Paleontologists and Mineralogists, Special Publication 19, p. 69-91.

Normark, W.R.
1974: Submarine Canyons and Fan Valleys: Factors Affecting Growth Patterns of Deep-Sea Fans; in Modern and Ancient Geosynclinal Sedimentation, Society of Economic Paleontologists and Mineralogists, Special Publication 19, p. 56-68.

Normark, W.R. and Piper, D.J.W.
1969: Deep-sea fan valleys, past and present; Geological Society of America Bulletin, v. 80, p. 1859-1866.

Poore, R.Z. and Brabb, E.E.
1977: Eocene and Oligocene planktonic foraminifera from the upper Butano sandstone and type San-Lorenzo Formation, Santa-Cruz Mountains, California; Journal of Foraminiferal Research, v. 7, no. 4, p. 249-272.

Rau, W.W.
1948: Foraminifera from the Porter Shale (Lincoln Formation), Grays Harbor County, Washington; Journal of Paleontology, v. 22, no. 2, p. 152-174.

1951: Tertiary Foraminifera from the Willapa River Valley of southwest Washington; Journal of Paleontology, v. 25, no. 4, p. 417-453.

1958: Stratigraphy and foraminiferal zonation in some of the Tertiary rocks of southwestern Washington; U.S. Geological Survey, Oil and Gas Investigations Chart OC-57, 2 sheets.

1964: Foraminifera from the northern Olympic Peninsula, Washington; U.S. Geol. Surv.. Professional Paper 374-G, p. G1-G33.

1966: Stratigraphy and Foraminifera of the Satsop River area, southern Olympic Peninsula, Washington; Washington Division of Mines and Geology, Bulletin 53, 66 p.

1967: Geology of the Wynoochee Valley quadrangle, Grays Harbor County, Washington; Washington Division of Mines and Geology Bulletin 56, 51 p.

Rau, W.W., Plafker, G., and Winkler, G.R.
1977: Preliminary foraminiferal biostratigraphy and correlation of selected stratigraphic sections and wells in the Gulf of Alaska Tertiary Province; U.S. Geological Survey, Open-File Report 77-747, 54 p.

Schenck, H.G. and Kleinpell, R.M.
1936: Refugian stage of the Pacific coast Tertiary; American Association of Petroelum Geologists Bulletin, v. 20, no. 2, p. 215-225.

Smith, H.P.
1956: Foraminifera from the Wagonwheel Formation, Devils Den District, California; California University, Publications in Geological Sciences, v. 32, no. 2, p. 65-126.

Snavely, P.D., Jr., Brown, R.D., Jr., and Roberts, A.E.
1958: Geology and coal resources of the Centralia-Chehalis district, Washington; U.S. Geological Survey Bulletin 1053, vi, 159 p.

Stanley, D.J. and Unrug, R.
1972: Submarine channel deposits, fluxoturbidites and other indicators of slope and base-of-slope environments in modern and ancient marine basins; in Recognition of Ancient Sedimentary Environments, Society of Economics Paleontologists and Mineralogists Special Publication 16, p. 287-340.

Sullivan, F.R.
1962: Foraminifera from the type section of the San Lorenzo Formation, Santa Cruz County, California; California University, Publications in Geological Sciences, v. 37, no. 4, p. 233-352.

Weaver, C.E. (chairman) et al.
1944: Correlation of the marine Cenozoic Formations of western North America; Geological Society of America Bulletin, v. 55, no. 5, p. 569-598.

Wilson, E.J.
1954: Foraminifera from the Gaviota Formation east of Gaviota Creek, California; California University, Publication in Geological Sciences, v. 30, no. 2, p. 103-170.

Uchio, T.
1960: Ecology of living benthonic Foraminifera from the San Diego area; Cushman Foundation for Foraminiferal Research, Special Paper 5, 72 p.

APPENDIX

References for identified species cited in this report.

References are made to those publications which include a description and illustration of each taxa. The originally assigned generic name is used in cases where these names have subsequently changed. Species cited in the text which are compared with (cf.) or show affinity with (aff.) known forms are included here but are only intended to indicate similarity.

Anomalina sp. cf. **A. californiensis** Cushman & Hobson	Cushman & Hobson, 1935, p. 64, plate 9, fig. 8.
Bolivina sp. cf. **B. marginata** Cushman	Cushman, 1925, p. 30, plate 5, fig. 5.
Bulimina sp. cf. **B. alsatica** Cushman & Parker	**B.** cf. **alsatica** Cushman & Parker; Rau, 1964, p. 618, plate 5, fig. 14.
Bulimina schencki Beck	Beck, 1943, p. 605, plate 107, figs. 28, 33.
Bulimina sculptilis laciniata Cushman & Parker	Cushman & Parker, 1937, p. 38, plate 4, fig. 4.
Cancris joaquinensis Smith	Smith, 1956, p. 98-99, plate 15, figs. 5, 6.
Cassidulina crassipunctata Cushman & Hobson	Cushman & Hobson, 1935, p. 63, plate 9, fig. 10.
Cassidulina galvinensis Cushman & Frizzell	Cushman & Frizzell, 1940, p. 43, plate 8, fig. 10.
Cassidulina globosa Hantken	Beck, 1943, p. 609, plate 108, figs. 7, 13, 14.
Cassidulina kernensis Smith	Smith, 1956, p. 100, plate 14, figs. 1, 3.
Cassidulinoides sp.	Rau, 1964, p. 623, plate 7, fig. 2.
Caucasina schwageri (Yokoyama)	**Bulimina** cf. **B. schwageri** (Yokoyama); Cushman & Simonson, 1944, p. 198, plate 32, figs. 11, 12.
Ceratobulimina washburnei Cushman & Schenck	Cushman & Schenck, 1928, p. 314, plate 45, fig. 1.
Chiloguembelina cubensis (Palmer)	**Gumbelina cubensis** Palmer, 1934, p. 74, figs. 1-6.
Cibicides elmaensis Rau	Rau, 1948, p. 173-174, plate 31, figs. 18-26.
Cibicides haydoni (Cushman & Schenck)	**Planulina haydoni** Cushman & Schenck, 1928, p. 316, plate 45, fig. 7.
Cibicides hodgei Cushman & Schenck	Cushman & Schenck, 1928, p. 315, plate 45, figs. 3-5.
Cyclammina pacifica Beck	Beck, 1943, p. 591-592, plate 98, figs. 2, 3.
Dentalina dusenburyi Beck	Beck, 1943, p. 599, plate 105, figs. 20, 23.
Elphidium sp. aff. **E. californicum** Cook (of Mallory)	Mallory, 1959, p. 184, plate 15, fig. 10
Eponides sp. aff. **E. kleinpelli** Cushman & Frizzell	Cushman & Frizzell, 1940, p. 42, plate 8, fig. 11.
Gavelinella? **willapaensis** (Rau)	**Valvulineria willapaensis** Rau, 1951, p. 447, plate 66, figs. 23-25.
Globorotalia gemma Jenkins	Jenkins, 1966, p. 1115-1118, fig. 11, nos. 97-103.
Globorotalia sp. aff. **G. postcretacea** (Myatluik)	**Globigerina postcretacea** Myatluik, 1950, p. 280-281, plate IV, fig. 3.
Gyroidina condoni (Cushman & Schenck)	**Eponides condoni** Cushman & Schenck, 1928, p. 313, plate 44, figs. 6, 7.

Gyroidina keenani (Cushman & Kleinpell)	Cushman & Kleinpell, 1934, p. 14, plate 3, figs. 10, 11.
Gyroidina orbicularis planata Cushman	Rau, 1948, p. 171-172, plate 31, figs. 12-14.
Gyroidina soldanii d'Orbigny	d'Orbigny, 1846, p. 155-156, plate VIII, figs. 10-12.
Hoeglundina eocenica (Cushman & Hanna)	**Epistomina eocenica** Cushman & M.A. Hanna, 1927, p. 53-54, plate 5, figs. 4, 5.
Martinottiella sp. cf. **M. alabamensis** (Cushman)	**Listerella laevis** Cushman, 1940, p. 54, plate 9, fig. 8.
Martinottiella eocenica Cushman & Bermudez	**Listerella gracillima** Cushman & Bermudez, 1937, p. 6, plate 1, figs. 27-28.
Melonis sp. aff. **M. garzaensis** (Cushman & Siegfus)	**Anomalina garzaensis** Cushman & Siefgus, 1939, p. 32, plate 7, fig. 3.
Melonis planatus (Cushman & Thomas)	**Nonion planatum** Cushman & Thomas, 1930, p. 37, plate 3, fig. 5.
Melonis pompilioides (Fichtel & Moll)	Loeblich & Tappan, 1964, p. 761-763, fig. 627, la, b.
Oridorsalis umbonatus (Reuss)	**Eponides umbonatus** (Reuss), Kleinpell, 1938, p. 322, plate VI, figs.9, 12.
Plectofrondicularia sp. cf. **P. gracilis** Smith	Smith, 1956, p. 93-94, plate 12, figs. 2-5.
Plectofrondicularia packardi multilineata Cushman & Simonson	Cushman & Simonson, 1944, p. 197, plate 32, figs. 2-4.
Plectofrondicularia packardi packardi Cushman & Schenck	Cushman & Schenck, 1928, p. 311, plate 43, figs. 14, 15.
Plectofrondicularia vaughani Cushman	Cushman, 1927, p. 112, plate 23, fig. 3.
Pseudonodosaria sp. cf. **P. inflata** (Bornemann)	**Pseudoglandulina inflata** (Bornemann); Rau, 1948, p. 168, plate 30, fig. 3.
Pullenia sp. cf. **P. bulloides** d'Orbigny	Kleinpell, 1938, p. 338, plate V, figs. 10, 13.
Sigmomorphina pseudoschencki Rau	Rau, 1951, p. 436, plate 64, fig. 11.
Trifarina hannai (Beck)	**Angulogerina hannai** Beck, 1943, p. 607-608, plate 108, figs. 26, 28.
Turrilina alsatica Andreae	Andreae, 1884, p. 120, plate 8, fig. 18.
Uvigerina atwilli Cushman & Simonson	Cushman & Simonson, 1944, p. 200, plate 33, figs. 2-4.
Uvigerina sp. aff. **U. churchi** Cushman & Siegfus	Cushman & Siegfus, 1939, p. 29, plate 6, fig. 16.
Uvigerina cocoaensis Cushman	Rau, 1951, p. 444, plate 65, fig. 28.
Uvigerina garzaensis Cushman & Siegfus	Cushman & Siegfus, 1939, p. 28-29, plate 6, fig. 15.
Uvigerina glabrans Cushman	Cushman, 1933, p. 13, plate 1, fig. 28.
Uvigerina tumeyensis Lamb	Lamb, 1964, p. 463-464, plate 1, fig. 10, plate 2, figs. 1-8, plate 3, figs. 1-2.