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HESQUIAT FORMATION (NEW): A NERITIC CHANNEL AND INTERCHANNEL DEPOSIT OF OLIGOCENE AGE, WESTERN VANCOUVER ISLAND, BRITISH COLUMBIA

J. A. JELETZKY

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ABSTRACT

The name Hesquiat Formation is proposed for a mappable, Oligocene (Lincoln to lower Blakeley molluscan stages), clastic unit, at least 2135 m (7000 ft.) thick, that outcrops on the west coast of Vancouver Island between Bajo and Rafael points. The succession was mapped and described previously by Jeletzky as division C of the local Tertiary sequence.

The Hesquiat Formation is distinguished by an extreme lithological diversity, little rounding and sorting of arenaceous and rudaceous clasts, and the common occurrence of plastic mass flow phenomena. It features a lateral and vertical alternation of two principal rock types which comprise units between 15 and 183 m (50-600 ft.) together with interbedded thinner beds and lenses. The two principal rock types are: (a) a recessive shale-clayey sandstone lithofacies consisting predominantly of a thin- to thick-bedded, cyclical (flyschoid) alternation of various argillaceous rocks with coarser grained rocks composed mainly of fine- to very fine grained clayey sandstone and pebbly mudstone; and (b) a resistant sandstone-conglomerate lithofacies consisting predominantly of an irregular interfingering of medium- to coarse-grained, gritty and pebbly greywacke and tightly packed, hard, pebble to boulder conglomerate and pebbly mudstone. The thicker units of each lithofacies usually include minor interbeds and pods of the other rock type.

The shale-clayey sandstone lithofacies appears to lack any signs of turbiditic redeposition and, in spite of a partly flyschoid appearance, is considered to be almost entirely a suspension-settled deposit.

The sandstone-conglomerate lithofacies contains no features suggestive of littoral or inner neritic traction current deposition. All observed features suggest deposition as a result of plastic mass flow. However, this deposit differs from deposits of typical deep-water plastic mass flow in its irregular alternation of rock types, poor sorting and rounding of clasts, apparent absence of delicate dish-like structures and sole markings, common presence of pebbly mudstones, and erosional or erosionally discordant contacts with the underlying shale-clayey sandstone facies. The lithofacies is considered to be a proximal plastic flow deposit which was trapped within the neritic zone close to the source area.

Outcrop-areas dominated by a cyclical alternation of the two lithofacies are localized within the known outliers of the formation, are distinctly channel-like or shoestring-like in shape, and appear either to be flanked or surrounded by larger outcrop-areas of the contemporary shale-clayey sandstone lithofacies. This distribution, together with the contained sedimentary features, suggest that these outcrop-areas are fossilized channel-fill deposits. The intervening outcrop-areas dominated by the contemporary shale-clayey sandstone lithofacies are interpreted to be the fossilized interchannel deposits.

The erosional channels of Hesquiat Formation are concentrated on Hesquiat Peninsula, oriented north-south, and appear to become thinner and to disappear southward. The principal outcrop-area of the channel-fill facies is situated on the western side of Hesquiat Peninsula between Escalante Point and the southern side of Homeis Cove. It includes the type section of the formation and consists of at least seven stratigraphically superimposed alternations of the two main lithofacies.

The contained foraminifers were interpreted as suggestive of a bathyal depositional environment, by micropaleontologists. However, the common presence within the formation of indigenous, outer neritic macrofossils, such as molluscs and crabs, and the characteristic lithology dominated by proximal plastic mass flow deposits and lacking proximal and distal turbidites, indicate that most or all of the Hesquiat Formation was deposited in the outer to outermost neritic zone of the eastern shelf of Tofino Basin.

The shallow-water depositional environment of the Hesquiat Formation suggests its origin as a shallow-water submarine fan restricted to the shelf zone of the ancient ocean with sediments derived directly from coarse-textured, depositionally unstable delta(s)

The alternating sequences in the channel-fill deposits reflect pulsating uplifts of the adjacent tectonic land of Vancouver Island coupled with sufficient subsidence of Tofino Basin to trap the sediments.

RÉSUMÉ

L'auteur propose de nommer "Formation d'Hesquiat" une série clastique de l'Oligocène (des étages coquilliers Lincoln à Blakeley inférieur) suffisamment importante pour être portée sur la carte; cette formation, d'une épaisseur d'au moins 2 135 m (7 000 pieds), affleure sur la côte ouest de l'île Vancouver entre les pointes Bajo et Raphaël. L'auteur a déjà porté cet ensemble sur la carte et l'a décrit comme étant la division C de la série tertiaire de cette région.

La formation d'Hesquiat, se distingue par: sa lithologie extrêmement diversifiée, ses roches clastiques allant des sables aux rudites aux grains peu arrondis et mal classés et de nombreuses manifestations du phénomène de glissement en masse plastique (écoulement). Elle met en évidence l'alternance, latérale et verticale, de deux types principaux de roches qui constituent des unités allant de 15 à 183 m (50 à 600 pieds) d'épaisseur, dans lesquelles sont intercalées des lentilles et des couches moins épaisses. Ces deux types principaux de roches sont: (a) un faciès de régression, grès schisteux et argileux où prédomine l'alternance, par cycles (genre flysch), de couches plus ou moins épaisses de diverses roches argileuses comprenant surtout des grès argileux à grains fins ou très fins et des pelites graveleuses; et (b), un faciès de grès-conglomérat très résistant où prédomine un ensemble irrégulièrement interstratifié de grauwacke à grains moyens et grossiers, gréseuse et graveleuse, de conglomérat dur et compact, constitué de cailloux et de blocs, et de pélite graveleuse. Les couches les plus épaisses de chacun de ces faciès comportent en général des intercalations ou des lentilles peu importantes constituées de roches de l'autre faciès.

Apparemment, le faciès de grès schisteux et argileux ne montre aucun signe de remaniement par turbidité et, bien qu'il présente des caractères de flysch, on considère qu'il s'agit d'un dépôt formé presqu'entièrement par décantation.

Le faciès de grès-conglomérat ne comporte aucune particularité qui permette de penser que les sédiments aient été déposés par des courants de traction, en bordure ou à proximité du littoral. L'observation de tous les traits de ce faciès suggère que le dépôt résulte d'un glissement en masse, par écoulement plastique. Cependant, ce dépôt se distingue des autres dépôts typiques de l'écoulement plastique en eau profonde par plusieurs points: il y a alternance irrégulière de différents types de roches; les fragments sont mal classés et peu arrondis; on y note l'absence apparente de structures délicates en forme de plats (dish structures) et de marques de moulages; on y trouve fréquemment des pélites graveleuses; et enfin, il y a des contacts d'érosion, discordants ou non, avec le faciès de grès schisteux et argileux sous-jacent. L'auteur pense que ce faciès est celui d'un dépôt d'écoulement plastique sur faible distance qui a été arrêté dans la zone néritique près de la région d'origine des matériaux clastiques.

Les zones d'affleurements où prédomine l'alternance cyclique des deux faciès lithologiques se trouvent à l'intérieur des klippes reconnues comme étant constituées par cette formation; on reconnaît distinctement, dans l'ensemble de ces affleurements une configuration en canaux ou en lacets et il apparaît que ces derniers sont bordés ou entourés par des zones d'affleurements plus étendues où les roches ont le même âge, mais avec le faciès de grès schisteux et argileux. Cette répartition, ainsi que les particularités sédimentaires de la Formation laissent supposer que ces zones d'affleurements sont des remplissages de chenaux fossilisés. On peut interpréter les zones d'affleurements où domine le faciès de grès schisteux et argileux, comme des sédiments déposés entre les chenaux fossilisés.

Les chenaux d'érosion de la formation d'Hesquiat se trouvent pour la plupart dans la péninsule Hesquiat; ils sont parallèles à une direction nord-sud et semblent s'amincir puis disparaître vers le sud. La principale zone d'affleurements du faciès de remplissage de chenaux se situe dans la partie ouest de la péninsule Hesquiat, entre la pointe Escalante et le côté sud de Homeis Cove. C'est là qu'a été prise la série type de la Formation, qui comporte au moins sept alternances stratigraphiquement superposées des deux principaux faciès lithologiques.

Selon les micropaléontologues, les foraminifères présents indiquent un dépôt en milieu bathyal. Cependant, la présence simultanée dans la Formation de macrofossiles néritiques autochtones ou allogènes (mollusques et crabes), et les caractères lithologiques caractéristiques, (prédominence des dépôts par écoulement plastique sur de faibles distances et absence de turbidites, d'origine proche ou lointaine), indiquent que la formation d'Hesquiat, (en majeure partie ou en totalité) s'est déposée au delà du plateau continental de l'est du bassin Tofino, ou à l'extrême limite de sa zone néritique.

Etant donné que la formation d'Hesquiat s'est sédimentée dans des eaux peu profondes, on peut penser qu'elle était à l'origine un cône d'alluvion sous-marin peu profond qui ne s'étendait pas au delà du plateau continental de l'ancien océan, et que ses sédiments provenaient directement d'un ou de plusieurs deltas instables (dont les conditions de sédimentation étaient instables et la texture des matériaux grossière).

L'alternance des séries du faciès correspondant à un remplissage de chenaux reflète les soulèvements intermittents du massif tectonique adjacent de l'Île Vancouver, alors que la subsidence du bassin Tofino était suffisante pour que les sédiments y fussent pris au piège.

HESQUIAT FORMATION (NEW): A NERITIC CHANNEL AND INTERCHANNEL DEPOSIT OF OLIGOCENE AGE, WESTERN VANCOUVER ISLAND, BRITISH COLUMBIA (92E)

INTRODUCTION AND ACKNOWLEDGMENTS

The writer deliberately excluded the discussion of specific depositional environments of the predominantly marine rocks of the Oligocene Division C outcropping on the west coast of Vancouver Island in the Hesquiat-Nootka map-areas (92E) from his preliminary report (Jeletzky, 1954, p. 8, 9, legends of geol. maps 1, 2). Such discussion, with his conclusions on the subject, were intended for the final report on the Tertiary and Mesozoic rocks of the Hesquiat-Nootka area (Jeletzky, in prep.) which was far advanced already in 1958 but had to be set aside because of preoccupation with other departmental projects.

Recently, however, other workers (Cameron, 1971, 1972, 1973, 1975; Tiffin *et al.*, 1972) have published opinions regarding the age and depositional environment of these Tertiary rocks, based mainly on the contained microfossils; opinions that are opposed to those held by the writer which are based on a study of both the stratigraphy and macrofossil content of the succession. The present paper, therefore, is written in order to present the long-assembled but so far only briefly mentioned (Jeletzky, 1973, p. 352-354) stratigraphic and paleontologic data and information on which the writer bases his own ideas and conclusions regarding the age and depositional environment of the Division C without waiting for the completion of the above mentioned final report. It was decided, also, to name this important unit formally at this time.

This paper is largely limited to the discussion of sedimentological and environmental interpretation of the previously described and mapped outcrop-areas and sections of the Hesquiat Formation. The writer has tried not to repeat the already published information, but to provide the most exact references to the sections and other related data throughout the text and the explanations of illustrations of this paper. The paper must be used, therefore, in conjunction with the previously published papers of the writer (e.g. Jeletzky, 1954, 1973).

All macroinvertebrate fossils listed in this paper have been identified and dated by the writer, who has also taken all photographs of outcrops and sedimentary structures published therein. Miss Jeanne White photographed the fossils illustrating the paper. Tertiary macroplants listed in the report were identified by Dr. Wayne Fry, Paleontology Department, University

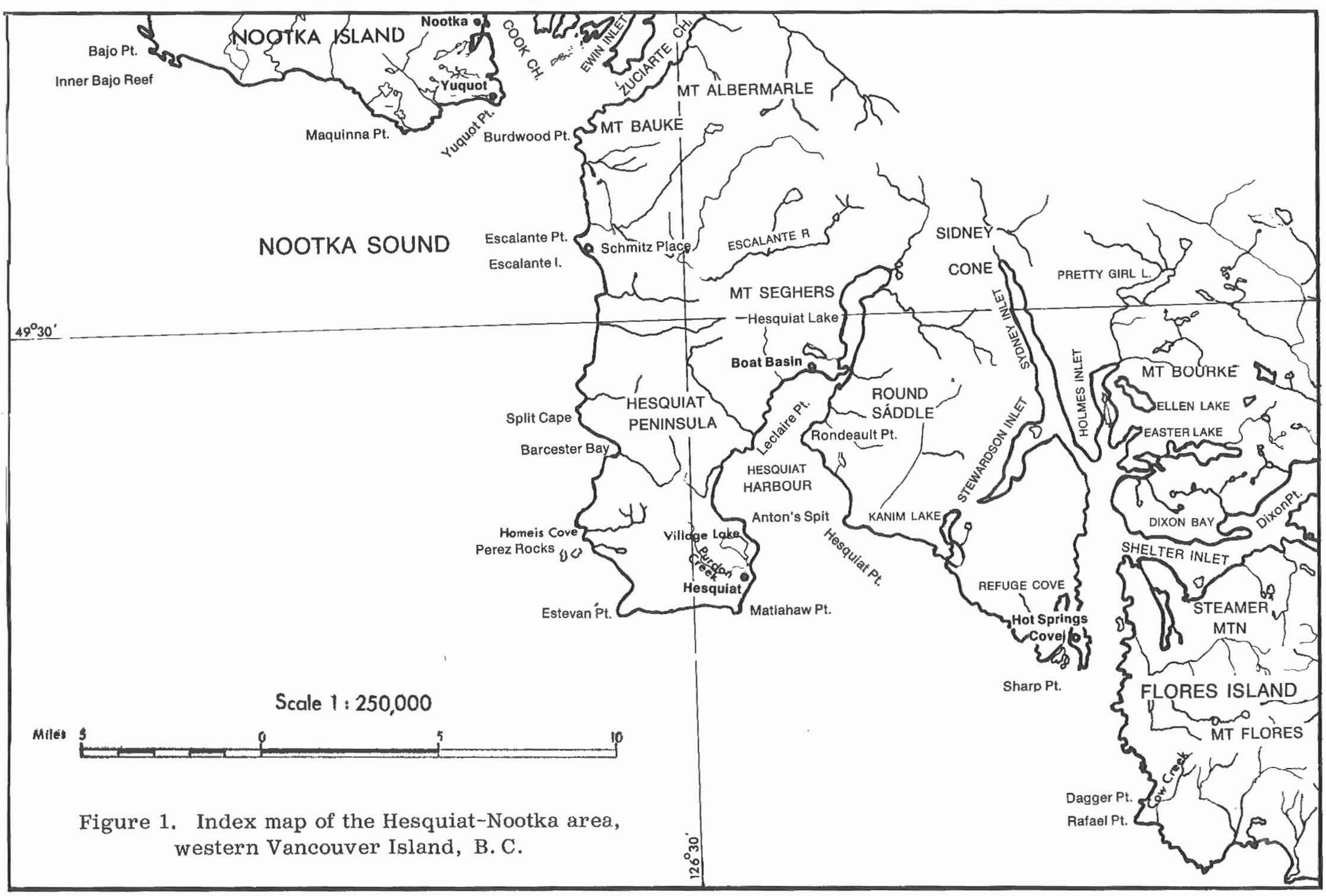

Figure 1. Index map of the Hesquiat-Nootka area, western Vancouver Island, B.C.

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of California, Berkeley, U. S. A. Dr. Fry has contributed, futhermore, a note evaluating the climatological environment of the macroflora of the Hesquiat Formation. Dr. D. L. Jones, U. S. G. S., Menlo Park, California, U. S. A., provided important information about the redeposited nature of all macrofossils found in the Pigeon Point Formation.

HISTORICAL REMARKS

Following the fairly recent, general recognition of turbidites as a widespread major class of marine sediments, Shouldice (1971), Cameron (1971, 1972, 1973, 1975), and Tiffin *et al.* (1972) attempted to classify the rocks of Division C, originally mapped and comprehensively described by Jeletzky (1954), as deep-water (i. e. bathyal) turbidites. This conclusion failed to take into account the common presence of undoubtedly indigenous (i. e. not redeposited) shelf-type macroinvertebrates and plants in Division C, as recorded by Jeletzky (1954). Cameron (ibid.) relied explicitly and exclusively on the evidence of foraminifers; evidence that is considered to be unreliable by the writer (Jeletzky, 1973). When commenting briefly on these ideas of Cameron (ibid.), Jeletzky (1973, p. 353, 362) stressed that the indistinct and irregular, mostly lenticular bedding of the coarse clastics of Division C of Nootka Island and equivalent upper beds of the division on Hesquiat Peninsula, coupled with an apparent absence of graded bedding, is not consistent with a turbiditic, deep-water origin for these rocks and their formation as part of deep-sea fans deposited on the basal part of a steep continental slope or on the continental rise. Jeletzky (loc. cit.) favoured, instead a hypothesis involving the deposition of these rocks as slump deposits and fluxoturbidites which were formed within scour channels on the upper part of a relatively steep submarine slope (this somewhat ambiguous statement did not necessarily mean the continental slope).

Other lithological types of Division C on Nootka Island and Hesquiat Peninsula have been interpreted tentatively as outer neritic deposits. However, Jeletzky (1973, p. 359, 360) admitted the possible presence of some deeper water, flysch-like sediments in the lower part of Division C in the Bajo Point area on Nootka Island and the possibility of deposition of: "... argillaceous to arenaceous ?proximal turbidites of Division C ..." "in a more rapidly subsiding ?uppermost bathyal 'furrow' adjacent to the strongly elevated southeastern shoreline of the embayment".

HESQUIAT FORMATION (NEW)

The formal name Hesquiat Formation is proposed here for the sequence of rocks previously described informally by Jeletzky (1954, p. 19-21, 25-27) as Division C. The name is derived from the Hesquiat Peninsula where the typical facies of the formation is best exposed and reaches the maximum thickness. The known geographical extent of Hesquiat Formation (i. e. of Division C) on the west coast of Vancouver Island has been discussed previously by Jeletzky (1954) and represented graphically on two geological maps.

TYPE SECTION

The longest known exposure of Hesquiat Formation, described and mapped by Jeletzky (1954, p. 28-42, geol. map 1; this paper, Appendix, Fig. 2), and occurring on the northwestern side of Hesquiat Peninsula between the southeastern base of Escalante Point and the axial part of Hesquiat Syncline at the point about 2. 8 km (1. 75 miles) south of the head of Barcester Bay, is selected herewith as the type section of the formation. So defined, the type section of the formation includes units 1 to 63 inclusive of the original description, and an uncertain but considerable (at least several hundred feet) thickness of lithologically similar, strongly disturbed strata situated between the top of bed 63 and the axis of Hesquiat Syncline (*see* Pl. 6, fig. 2). The contact with the underlying Escalante Formation is not exposed at the type section and the top of the unit is not reached in the axis of Hesquiat Syncline. However imperfect, this type section is far superior to all other known sections of the formation and, because of the limited, previously fully surveyed (Jeletzky, 1954, geol. maps 1, 2) extent of its exposures, it is not likely that a better type section will be found anywhere on Hesquiat Peninsula, or for that matter anywhere else in the area.

THICKNESS AND CONTACTS

The approximately measured and estimated thickness of the exposed part of Hesquiat Formation in the type section is more than 2135 m (7000 ft.) according to Jeletzky (1954, p. 25). In contrast to the conclusions of Cameron (1972, p. 201; 1973, p. 19), the writer believes that this section does not include any significant repetitions of beds, since all individual units are lithologically distinctive and there appears to be a definite , biochronologically significant upward change of the macroinvertebrate content (*see* below) within the formation. Moreover, the thickness actually measured by Jeletzky (1954, p. 25) appears to be a minimum as most of the faults transecting the section appear to be either normal faults or normal faults with a considerable strike-slip component. Such faults trend to cause disappearance of parts of the faulted sequence from the measured profile and thus reduce the overall thickness of the section concerned instead of increasing it. The writer did not see much evidence of major thrust faulting (which would cause a repetition of beds and units) on the northeastern limb of Hesquiat Syncline, even though thrusting is pronounced in its axial part and on the southwestern flank (Jeletzky, 1954, p. 42, 49) Consequently, the reduced estimates of the thickness of Hesquiat Formation proposed by Cameron (1972, p. 201; 1973, p. 19) are thought to be considerably underestimated. Based on the reasons given, the writer (Jeletzky, 1954, p. 25) suggested that the true thickness of the type section of the Hesquiat Formation may be in the order of 3050 m (10 000 ft.). This suggestion is supported by the consideration that the greywackes exposed on Escalante Island and Escalante Rocks (several hundred feet thick) are considered more likely to be an additional thick member of the type Hesquiat Formation faulted out on the mainland rather than a laterally displaced fault block of the Escalante Formation (see Jeletzky, 1954, geol. map 2).

The lower contact of Hesquiat Formation is covered in its type section. However, this contact is gradational in other sections of the formation on the east side of Hesquiat Peninsula (Jeletzky, 1954, p. 24) and at Bajo Point, Nootka Island (Jeletzky, 1954, p. 18).

Within the type-area of the Hesquiat Formation, its basal beds, comprising the First shale-clayey sandstone of Jeletzky (1954, p. 28, 44), rest apparently conformably on the neritic to lower littoral, mostly fine-grained, concretionary sandstones of the Escalante Formation (= Division A of Jeletzky, 1954, p. 22-25). The onset of deposition of the argillaceous rocks of Hesquiat Formation reflects the same marked deepening and ?northward and eastward spread of the Tertiary basin of western Vancouver Island as that reflected by the onset of deposition of Division B (Jeletzky, 1954, p. 25; 1973, p. 359, Fig. 2).

The upper contact of Hesquiat Formation - a pronounced erosional disconformity with Division D (Pl. 3, fig. 2) - was observed only in one section on the tidal flat off Bajo Point (Jeletzky, 1954, p. 21). This erosional boundary does not seem to represent any biochronologically measurable hiatus and appears to be a local, possibly submarine feature only (Jeletzky, 1973, p. 359).

AGE AND CORRELATION

The general age and correlation of the Hesquiat Formation (formerly Division C) have been discussed by Jeletzky (1954, p. 8, 9, 56-62; 1973, p. 352-354, Fig. 1). The writer's original recognition of an Oligocene age for the formation is confirmed by additional evidence (Jeletzky, 1975a) indicating a Lincoln (= upper Refugian) age for the underlying Escalante Formation (formerly Division A). The discovery of diagnostic Lincoln gastropods and a diagnostic Lincoln pectinid in the lower part of the Escalante Formation on Hesquiat Peninsula and Nootka Island, respectively (Jeletzky, loc. cit.) indicates a complete absence of lower Refugian or upper Narisian (i.e. Keasey or upper Eocene) rocks in the Tertiary sequence of the Hesquiat-Nootka and Esperanza-Kyuquot areas.

In spite of this evidence, Cameron (1971; 1972; 1975, p. 18) disagrees with the writer's conclusions and favours a late Eocene age for the lower parts of Divisions B and C based on their microfaunal content.

At least three different macroinvertebrate faunas occur in the exposed sequence of the Hesquiat Formation on Hesquiat Peninsula. The oldest fauna is restricted to units 1 to 20 of the type section (*see* Appendix) and to units 1 to 6 of the Leclaire Point section (*see* Jeletzky, 1954, p. 44), and is the same as that of the lower part of Division B on Nootka Island (Jeletzky, 1973, p. 339). On Hesquiat Peninsula, this fauna was not found above the 366 m (1200 ft.) level (approx.) in the type section of the Hesquiat Formation and above the 231.5 m (700 ft.) level in the Leclaire Point section. The fauna includes the following forms on Hesquiat Peninsula:

Propeamussium cf. *P. waylandi* Arnold

Nuculana chehalisensis Weaver

Yoldia n. sp. aff. *Y. chehalisensis* Weaver

Teredo sp. indet.

?*Tellina* sp. indet

Crassatelites sp. indet.

?*Pachydesma gastonensis* (Clark)

Acila (sensu lato) sp. indet.

Molopophorus cf. *M. stephensoni* Dickerson

Miopleiona sp. indet.

Viviparus sp. indet.

Dentalium cf. *D. porterensis* Weaver

Dentalium sp. indet.

Portunites alaskensis Rathbun

Eumorphocorystes naselensis Rathbun

Ranina cf. *R. americana* Withers.

The following plants are associated with marine macroinvertebrates in the Leclaire Point section (*see* Jeletzky, 1954, p. 44, unit 6; identifications by Dr. Wayne Fry, University of California, Berkeley):

cf. *Pisonia* sp. indet.

Cinnamomum sp. indet.

Glyptostrobus sp. indet.

?*Juglans* sp. indet.

Because of the presence of *Molopophorus* cf. *M. stephensoni* Dickerson, the apparent absence of all the above-mentioned crab species in overlying beds, and the absence of *Turritella porterensis* Weaver, the fauna listed is assigned the same earliest Lincoln (i.e. earliest Refugian or early Oligocene) age as the Escalante Formation fauna listed and partly figured by Jeletzky (1973, 1975a). Both faunas are placed in the *Molopophorus stephensoni* Zone of Durham (1944; *see* Jeletzky, 1975a for further details).

The Fourth shale-clayey sandstone member of the type section of Hesquiat Formation (*see* Appendix, unit 47) contains an abundant macroinvertebrate fauna (GSC locs. 20262, 91279, 91280 and 91281). The following forms have been identified to date:

Acila shumardi (Dall)

Thyasira cf. *T. disjuncta* (Gabb)

?*Nemocardium lincolnensis* Weaver

?*Ervillia oregonensis* Dall

?*Corbicula* sp. indet.

Turritella porterensis Weaver

Goniobasis ex aff. *G. coombsi* Weaver

?*Viviparus* sp. indet.

Molopophorus sp. indet.

Galeoidea sp. indet.

Dentalium (sensu lato) sp. indet.

?*Rhynchonella* (sensu lato) sp. indet.

indeterminate crab (claw fragment)

Because of the presence of *Turritella porterensis* and the apparent absence of all diagnostic crabs of the preceding fauna, and of *Molopophorus stephensoni* (cf. Jeletzky, 1975a), this fauna is assigned a middle Lincoln age and placed into the *Turritella porterensis* Zone of Durham (1944).

The presence of this middle Lincoln fauna about 579 m (1900 ft.) stratigraphically above the highest known occurrence of the early Lincoln fauna on the Hesquiat Peninsula (*see* Appendix, unit 20) is important in suggesting the absence of any major repetition of beds in this interval of the type section of the Hesquiat Formation.

The younger beds of the type section did not yield any diagnostic fossils. They are, however, placed mainly into the lower Blakeley Stage of molluscan standard (= late Oligocene) because of the occurrence of diagnostic faunas of that type (i.e. of *Echinophoria rex* Zone) at intervals through most of the succession, which is 610 to 752 m (2000-2500 ft.) thick, and consists of almost exclusively argillaceous rocks, outcropping on the west side of Hesquiat Peninsula between the southern side of Homeis Cove and the southern fringe of the tidal flat of Estevan Point. The highest occurrence of this fauna is in shaly beds situated 362 to 396 m (1200-1300 ft.) stratigraphically below the recognizable equivalent of the Sixth resistant sandstone-conglomerate member of the type section which outcrops on the southern side of Homeis Cove (Jeletzky, 1954, p. 42, 43, geol. map 1). This fauna, not previously recorded (GSC locs. 21737 and 23938), includes:

Acila (Truncacila) pudgetensis (Clark)

Nucula hannibali Clark

Yoldia blackleyensis Durham

Propeamussium cf. *P. waylandi* Arnold

Turcicula cf. *T. santacruzana* Arnold

Fusinus (Priscofusus) sp. indet.

Marginella cf. *M. shepardae* Tegland

?*Cylichnina* sp. indet.

Polinices (sensu lato) sp. indet.

Dentalium cf. *D. porterensis* Weaver

Rhynchonella cf. *R. washingtonensis* Weaver

The lowest occurrence of this fauna is 30.5 to 36 m (100-150 ft.) stratigraphically above the visible base of the unit on the tidal flat off Estevan Point. These beds have yielded the following macroinvertebrates not listed previously (GSC loc. 21731):

Acila packardi Clark

Propeamussium cf. *P. waylandi* Arnold

Yoldia sp. indet.

pelecypods, gen. et sp. indet.

Marginella shepardae Tegland

Cylichnina sp. indet.

Terebratalia n. sp. ex aff. *T. transversa* Sowerby

Rhynchonella (sensu lato) sp. indet.

Carpinus grandis Unger (a dicotiledonous plant

carbonized fossil wood

small fragments of coal.

This lower Blakeley fauna is the same as the lower Blakeley fauna collected on the eastern side of Hesquiat Peninsula (Jeletzky, 1954, p. 48, 59) in rocks which cannot be related lithostratigraphically to the succession of the type section of Hesquiat Formation.

The presence of this lower Blakeley molluscan fauna in beds corresponding to the interval of the type section of the Hesquiat Formation between the Fourth shale-clayey sandstone and Sixth resistant sandstone-conglomerate members is indicative of the absence of any major repetition of beds within that part of the type section.

The younger, apparently unfossiliferous, beds of the type section of Hesquiat Formation are placed tentatively into the lower Blakeley Stage (i.e. *Echinophoria rex* Zone; *see* Durham, 1944; Jeletzky, 1973, p. 348, 353-354, Fig. 1) because of the presence of the lower Blakeley fauna in the apparently correlative topmost exposed beds of the Hesquiat village section of Hesquiat Formation (*see* Jeletzky, 1954, p. 48).

Only the early Lincoln fauna occurs in the rocks of Hesquiat Formation (formerly Division C) outcropping on Hesquiat Point (Jeletzky, 1954, p. 50), within the Kanim Lake outlier (Jeletzky, 1954, p. 51, geol. map 1) and in the middle fault block of Tertiary rocks outcropping on Flores Island (Jeletzky, 1954, p. 53, 54, geol. map 1). The rocks outcropping in these outliers of the Hesquiat Formation are correlative, therefore, with the basal 366 m (1200 ft.) of the type section.

The rocks outcropping within the northern fault block of the Hesquiat Formation, situated north of Dagger Point on Flores Island, did not yield any diagnostic macroinvertebrates and, therefore, cannot be dated more precisely.

The rocks of the Hesquiat Formation (i.e. Division C of Jeletzky, 1954, p. 18, 20; 1973, p. 352-354) outcropping on Inner Bajo Reef, Nootka Island cannot be dated directly because of the absence of diagnostic macroinvertebrates. However, they undoubtedly represent either the lower part of the *Echinophoria apta* Zone or the upper part of the *Echinophoria rex* Zone of the Blakeley Stage because of their stratigraphic position between definitely dated successions of rocks (*see* Jeletzky, 1973, p. 353). This section of the Hesquiat Formation is correlated, therefore, tentatively with the upper part of the Hesquiat Peninsula succession which contains the lower Blakeley (i.e. *Echinophoria rex*) fauna.

PALEOENVIRONMENTAL INTERPRETATION OF MACROINVERTEBRATE FAUNAS

Cameron (1973, p. 20; 1975, p. 18) discounts the paleoenvironmental evidence of macroinvertebrate faunas contained in the Hesquiat Formation and other Tertiary units of western Vancouver Island because of their allegedly reworked character. In this connection, Cameron (1975, p. 18) pointed out the presence of reworked molluscan faunas in many of the massive conglomerates apparently forming part of the Hesquiat Formation of this report.

The writer was fully aware (e.g. Jeletzky, 1954, p. 20; 1973, p. 353) of the fact that many of the unfossiliferous and fossiliferous concretions, which commonly occur in the resistant sandstone-conglomerate members of the formation, were reworked from the underlying shale-clayey sandstone members during the intraformational episodes of submarine erosion (i.e. channelling; discussed later in this report). However, some of the calcareous sandstone or shale concretions occurring in the resistant sandstone-conglomerate members of Hesquiat Formation differ from the numerous, obviously rolled concretions in their irregularly rounded shape and rough surface (e.g. unit 19 of the type section; *see* Appendix). In itself, this feature is not conclusive as such concretions could have been ripped up from the underlying shale-clayey sandstone member without being transported far enough to be appreciably rolled. However, it contradicts Cameron's (1973, p. 20; 1975, p. 18) idea of turbiditic redeposition of such shallow-water fossiliferous concretions into a bathyal environment. Regardless of their possible local rip-up and short distance transportation, the macroinvertebrate content of the irregularly rounded concretions indicates a shelf environment for the shale-clayey sandstone members immediately underlying the coarse-grained sandstone or pebble-conglomerate units and, consequently, the deposition of the latter in a shelf environment. Even more convincing evidence of a shallow-water origin for some resistant sandstone-conglomerate members in the lower part of Hesquiat Formation is provided by the common presence of thick-shelled, deeply burrowing pelecypods preserved in life-like position with valves either closed or partly open (Pl. 2, fig. 6). The presence of these pelecypods provides excellent evidence that the enclosing sandstones and conglomerates were deposited in a lower littoral or inner neritic environment.

Cameron (1975, p. 18) did not mention and, apparently, did not consider the environmental implications of the known presence (Jeletzky, 1954, p. 28-31, 44; 1973, p. 347, 348) of excellently preserved, obviously indigenous molluscs, crabs, and leaves in most of the shale-clayey sandstone members of the lower part of the Hesquiat Formation. The lower Lincoln fauna, that occurs also in the lower part of Division B on Nootka Island (Jeletzky, 1973, p. 347, 348) characterizes the basal 366 m (1200 ft.) of the type section of the Hesquiat Formation. It is present, also, in the Leclaire Point, Hesquiat Point, and Flores Island sections. This fauna could not have been redeposited into the bathyal environment by turbidity currents for the same reasons as those which apply to the equivalent Nootka Island fauna (*see* Jeletzky, 1973, p. 347, 348). Additional evidence against the redeposition of these two faunas is supplied by an invariably rough-surfaced and irregularly rounded appearance of concretions containing their fossils. Furthermore, concretions of this type have been produced recently experimentally within the span of a few days (Zangrel, 1971, p. 1217, Fig. 8) indicating a very early diagenetic origin for the concretions in the Hesquiat Formation. To document the excellent preservation of diagnostic Lincoln fossils of the lower part of the Hesquiat Formation, which matches exactly that of the fossils of the equivalent Nootka Island fauna, some of the best-preserved crab specimens found are illustrated in Plate 2, figures 3, 5. The characteristic rough-surfaced and irregularly rounded appearance of fossiliferous concretions containing this fauna is well displayed in Plate 2, figure 4.

The shallow-water macroinvertebrate fauna of the lower part of the Hesquiat Formation is not confined to the concretions. At several places, it was found in moderately indurated argillaceous or shale-like, fine arenaceous rock devoid of concretions (*see* Jeletzky, 1954, p. 44; units 6 and 10 of Appendix). The excellent preservation of mostly flattened pelecypods represented by single but complete and unabraded valves oriented along the bedding planes, a similar preservation of gastropods and scaphopods, and the presence of complete to almost complete dicotiledonous leaves, leaves no doubt of the indigenous nature of this neritic fauna. The presence of poorly rounded to angular fragments of coal, abundance of fragments of *Teredo*-bored wood, bark, and leaves, and the presence of brackish to nonmarine gastropods (*Viviparus* sp. indet., ?*Corbicula* sp. indet.) suggest a proximity of these fossil localities either to a delta front or to a river estuary.

The paleoecological data presented appear to be ample on which to base the conclusion that the shale-clayey sandstone members of the basal 366 m (1200 ft.) of the type section of Hesquiat Formation and the equivalent beds of the formation outcropping elsewhere in the area have been deposited in the same quiet, possibly stagnant outer to ?inner neritic environment as have the lithologically similar rocks of the lower part of Division B on Nootka Island (*see* Jeletzky, 1973, p. 347). For these reasons, the writer cannot agree with Cameron's (1971, p. 92; 1975, p. 18) unsupported claim of the bathyal depth of deposition and a proximal turbiditic origin for the argillaceous rocks of this part of Hesquiat Formation.

The macroinvertebrate faunas found in the middle and upper parts of the Hesquiat Formation are, in the writer's opinion, all indigenous, outer to outermost neritic faunas. Some of these faunas, however, exhibit depositional or post-depositional phenomena which, conceivably, could lead to their misinterpretation as redeposited faunas if they were not studied in considerable detail. These particular faunas will be discussed below:

1. The macroinvertebrate fauna occurring in interbedded shale and sandstone beds of the Fourth shale-clayey sandstone member of the type section of Hesquiat Formation (i. e. *Turritella porterensis* fauna of the preceding section; *see* also unit 47 of the Appendix) occurs in beds extremely churned up by slumping and/or plastic mud flow. Numerous rounded to angular fragments, up to 15 cm (6 in.) across, of light grey, fossiliferous, argillaceous rock derived from surrounding beds are engulfed in each of the three beds of fossiliferous, medium- to coarse-grained, gritty sandstone occurring within the fossiliferous succession (i. e. GSC locs. 20262, 91279, 91280, and 91281). The sandstones themselves are considerably disturbed and commonly broken into irregularly shaped, rounded to angular fragments up to 0. 3 m (1 ft.) long and 7. 6 cm (3 in.) thick. Locally, the two rock types form a thoroughly mixed "porridge-like" mass. In spite of this, most of the outer neritic fossils (*see* preceding section for the list) are complete, excellently preserved shells (in the case of the pelecypods, the single valves are mostly concave upward), lack any signs of abrasion and are oriented along bedding planes (*see* Pl. 2, fig. 7). The gastropods commonly are preserved with their fragile initial whorls intact and *Dentalium* shells are almost invariably complete and oriented along bedding planes. Furthermore, the fossils are not sorted according to their size and shape and the rarely occurring fragments of shells are invariably angular and unabraded. Finally, the same fossils occur both in the sandstone beds and in the surrounding argillaceous rocks as noted in the description of unit 47 (*see* Appendix). The shape of the rock fragments indicates that the sediments were soft during transportation and the state of preservation of the fossils indicates that the scale of lateral movement was small. Generally, this largely plastic deformation was in the form of a widespread injection of unconsolidated to semi-consolidated, argillaceous sediment of the member into the relatively thin, intercalated (also unconsolidated to semi-consolidated) sand beds. An example of apparently similar injection was figured by Cameron (1973, p. 20, fig. 2).

The arenaceous grains and larger clasts of the sandstone beds probably were redeposited by plastic mass flow (or grain flow; *see* Stauffer, 1967, p. 491) into their present-day, outer neritic environment (as determined by the indigenous molluscan fauna of the surrounding predominantly argillaceous beds; *see* above and in the preceding section). This is indicated by the apparently complete absence of shallow-water traction current structures, the extremely poor rounding of grains (subangular grains are prevalent) and their very poor sorting by size, the presence of abundant grains and fragments of coal, pieces of *Teredo*-bored wood and poorly preserved plant and bark fragments. These features of the sandstones suggest, furthermore, their direct derivation (i. e. bypassing the beach or littoral environment) from rapidly rising, mountainous tectonic land situated closely to the north of the present-day outcrops of the Fourth shale-clayey sandstone member. Some poorly preserved, fragmented marine shells occurring in these sandstones probably are redeposited also. However, the sandstones probably were inhabited by neritic molluscs after their redeposition, judging by the excellent preservation of most of the shells contained in their arenaceous matrix and their specific identity with molluscan shells occurring in the argillaceous matrix.

2. The abundant lower Blakeley molluscan fauna occurring at several levels in units 2 and 3 of the Hesquiat village section (*see* Jeletzky, 1954, p. 47, 48) commonly exhibits disorderly lens- or pod-like accumulations of fossils and irregularly rounded, rough-surfaced, calcareous, concretion-like masses in coarser grained interbeds within the almost exclusively argillaceous sequence (Pl. 3, fig. 1). Some fossils occur as completely unabraded, sharp-edged fragments of varying size and shape. However, most of the fossils are complete, more or less deformed to flattened but excellently preserved shells, which do not exhibit any signs of abrasion (Pl. 2, fig. 8). Furthermore, a considerable number of deformed to completely flattened, commonly severely cracked pelecypods occur with valves still closed (Pl. 2, figs. 1, 2). Nor is there any sign of sorting of these extremely diversified fossils according to size or shape; all fossils, from the largest pelecypods and gastropods present to large foraminifera visible with the naked eye, occur together forming disorderly accumulations often situated either underneath or next to isolated or locally concentrated concretions. Finally, the same fossils occur either irregularly concentrated or scattered in shale or siltstone which is interbedded with the coarser grained interbeds, lenses, and pods. The conclusion is inescapable that the accumulations of typical outer neritic macroinvertebrates of the Hesquiat village section (Jeletzky, 1954, p. 47, 48) were transported only a very short distance from their original habitat in argillaceous sediments of units 2 and 3. The severely deformed or flattened but closed pelecypod shells could not have survived any prolonged transportation without falling into fragments. The same is true of the severely deformed to flattened and severely cracked but still complete and excellently preserved single-valved pelecypods, gastropods, and scaphopods comprising the bulk of the fauna. Finally, the unsorted, unabraded invariably angular fragments of shells could not have survived any prolonged transport.

The accumulations of macroinvertebrates evidently were formed as a result of an extensive post-depositional but pre-lithification flowage of still plastic, argillaceous sediments and their forcible injection into the still plastic coarser grained (mostly sandy siltstone or fine-grained, clayey sandstone) sediment which contains the bulk of the fossils. Coarser sediment grains and fossils with their unworn, angular fragments accumulated around displaced or indigenous concretions or other larger bodies (i. e. pieces of fossil wood, exceptionally large shells) whenever they began to impede the flow of plastic mud.

Therefore, according to the writer's interpretation of the data, it is improbable that the lower Blakeley macroinvertebrate fauna was redeposited by turbidity currents from an even moderately distant outer neritic habitat into the bathyal environment. There is, on the contrary, a good reason to think that the allegedly bathyal fauna of foraminifers associated with these macroinvertebrates is, in fact, a misinterpreted outer neritic microfauna, as this was already suggested by some micropaleontologists (e. g. Miss Ann Tipton and Dr. Gordon Hornaday; *see* Jeletzky, 1973, p. 346).

All other occurrences of apparently reworked macroinvertebrate fauna in the predominantly argillaceous rocks of the Hesquiat Formation (e. g. in the breccia-like rock on Flores Island; *see* Jeletzky, 1954, p. 53) appear to be attributable to plastic flowage, over a short distance, of unconsolidated to semiconsolidated argillaceous sediments and their injection into still plastic coarser grained sediments. None of these macroinvertebrate faunas are considered by the writer to have been redeposited in the sense of its transportation from a shallow-water into a bathyal environment.

A number of other occurrences of outer neritic macroinvertebrate fauna in the upper and ?middle parts of Hesquiat Formation do not exhibit any signs of redeposition and are considered to be indigenous. This is particularly true of several macroinvertebrate faunas (e. g. GSC locs. 23938, 21740, 21737, 21731, 21726, 21724, 21732 and 21728) found in the predominantly argillaceous facies outcropping on the southern shore of Hesquiat Peninsula between Matlahaw and Estevan points (*see* Jeletzky, 1954, p. 43). The same applies to macroinvertebrates found in the much more arenaceous, inner neritic to littoral facies outcropping on the west coast of Flores Island (*see* Jeletzky, 1954, p. 54, 55; and this paper, p. 23-26).

The environmental interpretation, presented in this paper, of the macroinvertebrate faunas discovered to date in the Hesquiat Formation, indicates the outer shelf origin of all beds and units containing these faunas and, hence, the outer shelf environment of deposition of most or all of the formation.

PRINCIPAL LITHOLOGICAL TYPES AND THEIR ENVIRONMENTAL SIGNIFICANCE

This section summarizes the writer's published (Jeletzky, 1954, 1973) and unpublished observations of the macroscopic lithological features and sedimentological structures of the principal rock types of the Hesquiat Formation and his attempts to interpret the depositional significance of these features and structures by analyzing them in conjunction with the more reliable (than the microfossils) evidence of the associated macroinvertebrate faunas. No petrographic investigation of the rocks of Hesquiat Formation was made.

The individual rock types are discussed under the headings of the two principal facies of the Hesquiat Formation - the shale-clayey sandstone and resistant sandstone-conglomerate facies - previously recognized and mapped by the writer (Jeletzky, 1954, p. 26, 27, geol. maps 1, 2).

Ratios of principal lithological types

The ratios of the principal lithological types discussed in this paper vary greatly from one section to another. In the type section of Hesquiat Formation, which contains the maximum amounts of all coarse-grained clastic types (*see* Appendix), the ratios are:

1. Shale, siltstone, and clayey fine-grained to very fine grained sandstone .... 45% (approx.)
2. Sandstone, resistant, coarse- to medium-grained .... 32% (approx.)
3. Conglomerate, pebble to boulder, hard, clast-supported (i. e. tightly packed) .... 17% (approx.)
4. Pebbly mudstone .... 6% (approx.)

In contrast to these ratios, the predominantly argillaceous sections measured on the southwestern limb of Hesquiat Syncline between Homeis Cove and Estevan Point and between Matlahaw Point and Estevan Point (both unpublished) contain less then 10 per cent of conglomerate and coarse- to medium-grained, resistant sandstone combined. The ratio of pebbly mudstone increases, however, to between 7 and 12 per cent. The remainder of their thicknesses consists of various argillaceous rocks grouped under the shale-clayey sandstone facies, which may or may not contain a few thin interbeds, lenses, and pods of coarser grained clastics.

Because of extreme lithological variability and numerous lateral changes of its principal lithological types within short distances, both across and along the strike, the Hesquiat Formation cannot be distinguished because of the prevalance of any one lithologically distinctive type of rock. Instead, it is characterized by extreme lithological diversity, poor sorting and rounding of clasts (psammitic and psephitic), and the common occurrence of plastic mass flow phenomena.

Shale-clayey sandstone facies

Two macroscopically distinctive principal types can be distinguished among the rocks comprising the shale-clayey sandstone facies of Hesquiat Formation (Jeletzky, 1954, p. 26). The first type comprises grey to dark grey, massive to fissile, argillaceous rocks tentatively referred to as shale and siltstone by Jeletzky (ibid.).

These rocks contain abundant hard, calcareous sandy to silty concretions. Units 1 and 2 of the type section of the Hesquiat Formation typify this "shale" (*see* Appendix). The composition of the "shale" appears to vary from a true shale, consisting predominantly of clay-size particles, to a mudstone-like rock consisting largely of silt-size particles with a greater or smaller admixture of clay and very fine to fine arenaceous particles. This mudstone commonly grades into very silty, fine- to very fine grained greywacke-type sandstone.

The commonly fossiliferous concretions of massive to fissile "shale" are irregularly rounded, rough-surfaced, and lack any signs of redeposition (Pl. 2, fig. 4). As already noted by Jeletzky (1973, p. 347), when discussing similar "shales" of Nootka Island, the appearance of the concretions combined with a complete absence of grading and sole markings, and with an excellent preservation of the indigenous macroinvertebrates militates against an assumption of redeposition of this shale by turbidity currents.

Penecontemporaneous slump structures, or those preceding the lithification of sediments, commonly are present. They include various types of convolution structures (Pl. 4, fig. 1), flame structures (Pl. 4, fig. 2), injection structures (Cameron, 1973, p. 20, Fig. 2; and this report in the section on environment evaluation of fossils), and a complex slumping or plastic sediment flow causing either a thorough churning up of argillaceous and fine arenaceous sediments or a breccia-like intermixing of shale with overlying or interbedded coarser grained clastics (e.g. unit 47 of the type section; *see* Appendix). The common occurrence of these textures attests to the instability of depositional environment of the "shale". The amount of lateral displacement involved in the slumping and plastic flowage of the "shale", however, appears to be small for the already presented reasons.

Contacts with the underlying coarser grained rocks characteristically are conformable and gradational (Jeletzky, 1954, p. 26). Those with the overlying coarse grained rocks are always erosionally disconformable and marked by deep and wide erosional channels cut into the underlying "shale" units (Pl. 1; Pl. 5, fig. 2; Pl. 6, figs. 2, 3).

The presence of locally numerous, neritic, indigenous macrofossils indicates that this type of "shale" was deposited in the same outer neritic environment as the lower part of Division B on Nootka Island (*see* Jeletzky, 1973, p. 347). However, unlike Nootka Island, the periods of depositional calm on Hesquiat Peninsula characterized by "shale" deposition alternated with those of depositonal unrest when the "shale" was first eroded and channelled by the slumping or flowing of sediment masses and subsequently overlain disconformably by allochthonous coarser grained sediments of the resistant sandstone conglomerate members (*see* below).

In the mixed, fine to coarse clastic channel-fill facies (*see* p. 18-23 and Fig. 2) of Hesquiat Formation, the massive to fissile, concretionary "shale" is prevalent in the lower part of the Hesquiat Formation on both sides of Hesquiat Peninsula (*see* Jeletzky, 1954, p. 44-47 and Appendix). These beds comprise a shallower water facies of the formation deposited in closer proximity to the shoreline than were the younger beds. This "shale", however, is by no means absent in the "channel-fill facies" of the middle to upper parts of the Hesquiat Formation exposed immediately to the north of the axis of the Hesquiat Syncline, on its southwestern flank, and on the Inner Bajo Reef, Nootka Island (*see* p. 22-23 and Fig. 2).

The "shale" is equally common in the several sections throughout the exposed thickness of the predominantly argillaceous "interchannel facies" of the formation as illustrated by the section situated between Leclaire Point and Anton's Spit, that measured on Hesquiat Point, and that measured between Hesquiat village and Matlahaw Point (Jeletzky, 1954, p. 47-49).

The second principal type of shale-clayey sandstone facies is a thinly bedded [1.3-20.3 cm ($\frac{1}{2}$-8 in.)] to laminated, multicoloured (mainly alternating brown, light grey, dark grey, and tawny beds and/or laminae), predominantly argillaceous rock with or without small to medium-sized [7.6-15.2 cm (3-6-in.) long and 1.3-10.2 cm ($\frac{1}{2}$-4 in.) thick] tawny to rusty-weathering, ferruginous pancake- to discus-like concretions of calcareous to non-calcareous shale or siltstone. This type may or may not include (Pl. 3, fig. 3; Pl. 4, fig. 3) variable ratios of layers and/or thin to medium beds of resistant fine- to coarse-grained sandstone. This rock type is exemplified by units 52 to 56 of the type section (*see* Appendix) and by unit 2 of the Hesquiat village section (*see* Jeletzky, 1954, p. 47; this paper, Pl. 3, fig. 1). However, it is represented better in a measured, but so far unpublished, section on the tidal shelf off Estevan Point (Pl. 4, fig. 3). The lithological composition of this thinly bedded to laminated "shale" varies from true shale dominated by clay-size particles to a shale- or siltstone-like, silty, very fine grained sandstone. The intermediate rock varieties referred to as siltstone by Jeletzky (1954), consist mostly of silt-size particles with a greater or lesser admixture of clay and very fine arenaceous particles. Thin beds and laminae of shale, siltstone, and shale-like sandstone alternate rhythmically, producing a regularly banded flysch-like succession (Pl. 3, fig. 3; Pl. 4, fig. 3). The silty and sandy, generally harder and more resistant beds and laminae overlie the shaly beds and laminae with an abrupt but generally even contact. No distinctly erosional contacts were observed by the writer. No true grading of particles and no clearly recognizable Bouma (1962) sequences were observed above the abrupt contacts. When any depositional textures are present, they consist of small-scale (a few mm to 6 cm across), low-angle current crossbedding overlain either by an interval of very fine parallel laminations, and/or by that of a massive shale. These structures can be compared only to units CD or CDE of the Bouma (1962) sequence. No sole markings of any kind were observed.

The banded type of shale-clayey sandstone facies is characterized by a rapid lateral variation of thickness and lithological composition of its individual beds and layers. These lateral changes are related, obviously, to the distribution of the channel and interchannel facies of Hesquiat Formation discussed below (*see* p. 18-23, Fig. 2). For example, recurring interbeds of medium- to coarse-grained, resistant sandstones tend to become more numerous and to thicken laterally in the direction of recognized outcrop-areas of the channel facies. Conversely, the recurring interbeds of fine-grained, clayey sandstone and various argillaceous rocks tend to become less numerous and either to thin or to wedge out in this direction. An excellent example of such facies changes was observed on the northern side of Barcester Bay (*see* p. 20 and Pl. 3, fig. 3). Furthermore, the cyclical deposition of the argillaceous to finely arenaceous rocks (mostly in the proximity of known outcrop-areas of channel facies; *see* p. 22-23) is interrupted locally by deposition of minor and major pods, lenses, and lenticular interbeds of medium- to coarse-grained, gritty and pebbly sandstones, pebbly mudstones, and tightly packed conglomerates erosionally disconformable with underlying rocks.

The absence of grading, erosional contacts and sole markings is not in accord with the turbiditic mode of deposition of the superficially flysch-like, banded type of the shale-clayey sandstone facies. The same applies to the characteristically present, rapid lateral and vertical facies changes which sharply distinguish the banded rocks of Hesquiat Formation from true flysch (i. e. deep-water turbidites). The latter is characterized by the absence of a "rapid variation (lateral and vertical) in the composition of the sediments, other than the alternation of sandstones and shales" (Dżułyński and Walton, 1965, p. 3).

Like other shallow-water, flysch-like (e. g. Hubert, 1972, p. 109; Kingma, 1958) sediments, the banded type of shale-clayey sandstone facies apparently was deposited by bottom currents. In our particular instance such currents must have been generated by frequent but localized episodes of slumping and/or plastic mass flowage of sediments which recurred throughout the time of deposition of Hesquiat Formation and are comprehensively described below (e. g. p. 26-27). The temporary bottom currents resulting from this slumping must have been too short-lived and too localized (as evidenced by the above-discussed sedimentological characters of banded rocks) to either significantly erode the previously formed argillaceous sediments or to raise turbulent sediment clouds able to deposit graded turbidites. These bottom currents must have been sufficiently strong initially to temporarily arrest the grain-by-grain deposition of argillaceous (or even argillaceous and silty) sedimentation. As their power gradually decreased, however, after the conclusion of every individual episode of slumping and/or plastic mass flowage, the deposition by settling from suspension of fine- to very fine sandy or silty sediment was followed by that of more and more argillaceous varieties either exhibiting a parallel lamination or devoid of any textures (i. e. massive-looking).

The minor to major inclusions of rudites and coarse-grained arenites occurring locally in the banded type of shale-clayey sandstone facies are believed to have resulted not from bottom current action but from episodic spillover of the channellized mass flows into adjacent parts of interchannel areas (*see* description of units 47 and 52 to 56 in Appendix and description of interchannel facies).

The thin bedded to laminated type of predominantly argillaceous sediments appear to be relatively less common in the channel and interchannel facies (*see* p. 18, 23, Fig. 2) of the lower part of Hesquiat Formation. Outcrops of this lower part are restricted to the northern part of the peninsula and, therefore, were situated in closer proximity to the shoreline than was the rest of the formation. In contrast, these sediments are much more common in the channel facies of the middle and upper parts of the formation outcropping farther to the south (i. e. farther offshore). These sediments finally become widespread to prevalent in the southernmost known exposures of the interchannel facies of the formation (i. e. on the southern shore of Hesquiat Peninsula between Matlahaw and Estevan points). These spatial relationships suggest a generally deeper water environment of deposition for the bedded to laminated type of predominantly argillaceous sediment compared with the massive or fissile type of "shale". However, the presence of rare to numerous, indigenous outer to outermost neritic macroinvertebrates in several units of this shale (*see* section on environmental evaluation of macroinvertebrates), the apparent absence of any diagnostic evidence of turbiditic redeposition, and the relative rarity of slumping and plastic mass flow phenomena strongly suggest that most of the units of the thinly bedded to laminated, predominantly argillaceous sediments were deposited in the outer to outermost part of the shelf rather than on the upper part of the continental slope proper. It is possible, however, that some of the units of these sediments either entirely devoid of macroinvertebrates or containing only rare representatives of depth-tolerant pelecypods (e. g. *Acila, Yoldia, Thyasira*) and brachiopods (e. g. *Rhynchonella* sensu lato) have been deposited in the bathyal depth (i. e. on the continental slope proper).

The upper, exclusively argillaceous part of the reduced (*see* Jeletzky, 1954, p. 18-20; 1973, p. 352-354) Hesquiat Formation on Inner Bajo Reef, Nootka Island provides an illuminating example of the post-sedimentary destruction of bedding in the massive "shale". The shale of this unit was found to be massive and fissile throughout and to lack any macroscropically obvious bedding and lamination. However, some concretionary masses, 6 m (20 ft.) long and 1. 2 m (4 ft.) thick, of very hard, mainly calcareous shale tend to be noticeably bedded to laminated (Pl. 4, fig. 2). In some of these masses, thin beds [1. 2-5. 1 cm (0. 5-2-in.)] and laminae exhibit well-developed penecontemporaneous convolutions, some of which have the shape of typical flame structures (Pl. 4, fig. 2). The convolutions are invariably overturned southwestward indicating the corresponding direction of paleoslope. The complete absence of bedding in the "shale" proper and its strong development in the presumably very early diagenetic concretionary masses suggest a post-depositional destruction of the originally present bedding and lamination in the former by the activity of mud-eating organisms and their preservation in the latter because of very early lithification of the concretionary masses (cf. Zangrel, 1971, p. 1217, Fig. 8).

Resistant sandstone-conglomerate facies

Jeletzky (1954, p. 26) pointed out that the resistant sandstone-conglomerate members of the Hesquiat Formation consist principally of an irregular interbedding of sandstone, conglomerate, and pebbly mudstone.

Sandstone

This sandstone, which is the predominant lithological type in the resistant sandstone-conglomerate facies, is hard, calcareous to noncalcareous, weathers to buff, rust and grey-yellow colours, and develops a honeycombed surface in calcareous variants (Pl. 3, fig. 2). It comprises 50 to 55 per cent of the estimated thickness of this facies in the type section and forms about 40 per cent of its thickness (est.) in the Leclaire Point section. The sandstone is mainly coarse grained (less commonly medium grained), commonly gritty and pebbly, and firmly indurated but not silicified (not quartzite-like). Most of the sandstone units are compositionally and texturally immature (greywacke-like), characterized by subrounded to subangular grains, poorly sorted as to grain size, and are macroscopically free of carbonaceous grains and particles. However, locally there are minor pods and interbeds of carbonaceous to coaly sandstone, intercalated beds and pods of sandstone containing scattered grains, pebbles and/or lamellae of shiny coal, and those containing abundant fragments of plants and wood (Jeletzky, 1954, p. 53; unit 47 of Appendix). Irregularly rounded, rough surfaced concretions of hard, calcareous sandstone as much as 25.0 cm (10 in.) in diameter and variously shaped, lenticular masses up to 4.5 m (15 ft.) long and about the same in height, of similar sandstone are common in most units. Presumably these masses have been ripped up from the underlying rocks (*see* Pl. 1; Pl. 5, fig. 2).

The soles of sandstone beds and members locally carry large loadcast structures, some of which resemble the step-like loadcast structures of Stauffer (1967, Figs. 10a, b). Other structures, observed locally, include the injection structures described previously, penecontemporaneous slump structures, and general postsedimentary but pre-lithification brecciation of the rock (*see* preceding sections). Dish structures of Stauffer (1967, p. 493, Fig. 9) have not been observed.

The sandstone characteristically comprises units of between 6 and 30.5 m (20-100 ft.) or beds between 0.15 and 4.5 m (6 in.-15 ft.). These units and beds are normally massive to indistinctly bedded. Thin bedding or lamination is present in places but uncommon. Such bedding and/or lamination in the medium to very thick units is usually subparallel and indistinct. Cross-bedding and ripple-marks have not been observed.

Similar types of sandstone occur also as irregularly shaped pods and lenses up to 15 m (50 ft.) long and 4.5 m (15 ft.) thick within the thick units of other rock types (Pl. 5, fig. 2), including the argillaceous rocks of the shale-clayey sandstone facies (*see* Jeletzky, 1954, p. 30, beds 14-19 inclusive).

The contacts of sandstone units with other lithological types occurring within the individual resistant sandstone-conglomerate members are extremely variable. They may be gradational (*see* Jeletzky, 1954, p. 26, 34, bed 45 of type section), sharp but even, or sharp, uneven and markedly erosional. The presence of scattered or congregated outsize clasts, sometimes reaching giant proportions (*see* Jeletzky, 1954, p. 30, unit 19; p. 34, unit 43; p. 46, unit 16) is a characteristic feature of these sandstones. Beds 48, 51 and 57C of the type section of Hesquiat Formation (*see* Appendix) and bed 13 of the Leclaire Point section (Jeletzky, 1954, p. 46) are typical of this rock type.

Conglomerate

The term conglomerate is restricted here to those types of cemented rudites in which the clasts are tightly packed and which, consequently, are clast-supported. Another distinctive feature of the conglomerate is the predominantly gritty to arenaceous matrix. The intention of this definition is to exclude the pebbly mudstone type of rocks which are described subsequently. However, the two types commonly are gradational laterally and vertically (e.g. units 44 and 57 of the type section; *see* Appendix). There are also numerous transitions through pebbly sandstone to the typical resistant coarse grained sandstone.

The conglomerates of Hesquiat Formation consist of a heterogeneous mixture of volcanic, plutonic, metamorphic and sedimentary clasts ranging from very fine pebbles (or grit) to 3 by 3 by 15.5 m (10 by 10 by 50 ft.) square blocks. Metamorphic volcanic and pyroclastic clasts include most of the rock types occurring in the Vancouver Group and presumably are derived from it. Plutonic clasts are almost exclusively granitoid types probably derived from the Middle Jurassic Coast Intrusions rather than from the ?Eocene Sooke Intrusions. Sedimentary pebbles are mostly rolled argillaceous and arenaceous, sometimes fossiliferous concretions. They are derived from the underlying shale-clayey sandstone members of the Hesquiat Formation as indicated by a distinctive lithology and sometimes fossil content (i.e. Lincoln crabs). Sandstone pebbles, presumably derived from the underlying resistant sandstone-conglomerate members, as well as from the now destroyed Jurassic and Lower Cretaceous sedimentary sequences (*see* Cameron, 1975, p. 18, Fig. 2) are generally rare. However, they may be common locally in basal parts of some conglomerate units (e.g. Jeletzky 1954, p. 38, unit 57). Counting of clasts to determine their ratios in conglomerate units was not attempted. According to rough estimates, however, the volcanic, metamorphic, and pyroclastic clasts derived from the Vancouver Group appear to be less common, than the plutonic pebbles. Sedimentary pebbles appear to be less common, generally, than either of the preceding two groups. However, particular instances have been noted where they are the prevalent type among the clasts (*see* Cameron, 1975, p. 18, Fig. 2; Jeletzky, 1954, p. 20, 29, unit 5). Rounded or angular, evidently locally ripped-up fragments or blocks of sandstone, shale, or siltstone are mostly restricted to the basal parts of conglomerate beds and members (Pl. 5, fig. 2).

Conglomerates of the Hesquiat Formation are characterized by extremely poor sorting of clasts according to size. Most beds and lenses consist of a disorderly accumulation of clasts ranging from fine, which measure from 0.6 to 1.3 cm (¼-½-in.), to coarse, which measure from 15.2 to 22.9 cm (6-9-in.), commonly with the addition of boulders and blocks (Jeletzky, 1954, p. 45, unit 7; units 34, 44 and 50 of Appendix of this report). Boulders and blocks, locally, are a prominent component of virtually unsorted, massive, conglomerate beds containing abundant clasts of various rock types ranging in size from grit to blocks roughly 3 by 3 by 15.5 m (10 by 10 by 50 ft.). A good example of such a conglomerate was illustrated by Cameron (1975, p. 18, Fig. 2). Bedding within individual, very thick units of the conglomerate is, with few exceptions (e.g. unit 5 of type section; *see* Appendix), poorly developed and lenticular or absent (Pl. 6, fig. 3; Cameron, 1973, p. 19, Fig. 1; 1975, p. 18, Fig. 2).

The conglomerate occurs mainly either interfingered with or as lenticular, thin to thick beds, lenses, pods and stringers (including isolated rows of pebbles) within thick beds or members of other rock types of resistant sandstone-conglomerate members and, sometimes, within argillaceous rocks or clayey sandstones (e.g. units 32, 44, 48, 57 and 63 of the type section; *see* Appendix and also Pl. 1; Pl. 5, fig. 2; Pl. 6, fig. 3).

As noted by Jeletzky (1954, p. 26 and elsewhere in the description of individual sections), the basal conglomerate units of all resistant sandstone-conglomerate members overlie disconformably, and sometimes (Cameron, 1973, p. 91, Fig. 1; 1975, p. 18, Fig. 2; this paper, Pl. 1; Pl. 5, fig. 2; Pl. 6, fig. 3) discordantly, the deeply eroded surfaces of underlying shale-clayey sandstone members. Most of the lenticular beds, lenses, variously shaped pods and stringers of conglomerate interfingering with other rock types within the resistant sandstone-conglomerate members also have erosionally disconformable lower contacts (as for example within unit 63; *see* Pl. 1; Pl. 5, fig. 2) evidently representating local cut-and-fill structures between 2 and 46 m (6.6-150 ft.) long and up to about 2 m (6.6 ft.) deep. The upper contacts of the thick conglomerate beds and members are mainly gradational (e.g. units 45, 46, 50, 51, 57 and 58 of the type section *see* Appendix). The same is true of the upper contacts of the irregular lenses and pods of conglomerate interfingering with other rock types within the individual resistant sandstone-conglomerate members (e.g. units 31, 32, 44, 45 of the type section; *see* Appendix and Pl. 5, fig. 2). The exceptions appear to be due to a series of cut-and-fill episodes occurring at about the same place and following each other at short intervals (e.g. Pl. 1).

Pebbles and grit particles of conglomerates are mostly poorly rounded with subrounded to subangular clasts prevalent. Boulders are always poorly rounded to angular and blocks are nearly always angular (Pl. 6, fig. 3; Cameron, 1975, p. 18, Fig. 2). No distinct graded bedding was observed in most conglomerate units, but there is a tendency for outsize clasts (e.g. boulders and blocks) to be concentrated in the lower parts of some thick beds and members. There is also a tendency for an upward fining of pebbles in some beds culminating in the upward intergradation of conglomerates first into pebbly shale, or pebble sandstone and then into resistant coarse-grained sandstone. In the writer's opinion, such upward fining sequences reflect either a gradual settling down of larger and consequently heavier clasts within the mass flows or a gradual waning of plastic mass flow in the channels and have nothing to do with true turbidity currents (i.e. formation of turbulent sediment clouds and subsequent redeposition from them). Neither imbrication nor cross-stratification was observed in the conglomerates and the orientation of pebbles seems to be random in all the more closely studied units. Except for redeposited fossiliferous concretions and rare fragments of lithified wood, no fossils have been seen.

Pebbly mudstone

The third important lithological component of the resistant sandstone-conglomerate facies is a "dumped" conglomeratic-argillaceous rock type grouped with the conglomerate in the definition of the facies (Jeletzky, 1954, p. 28) but informally referred to as "pebbly shale" (i.e. unit 4 of the type section; *see* Appendix) or as "shale (or siltstone) with dispersed small and large pebbles" (i.e. unit 20 of the type section; *see* Appendix) in the description of measured sections of the Hesquiat Formation. Following the usage of Crowell (1957), this rock type will be called henceforth pebbly mudstone. This term is used herewith for a more or less homogeneous (i.e. devoid of bedding), matrix-supported mixture of pebbles, cobbles, grit and arenaceous particles but with predominant silt to clay particles. The ratios of arenaceous, silt, and clay particles vary widely (*see* Pl. 6, fig. 3) so that some pebbly mudstone (e.g. unit 4 of the type section; *see* Appendix) approach true "pebbly shale" while others (e.g. unit 31 of the type section; *see* Appendix) approach and merge imperceptibly into fine- to very fine grained, clayey or silty sandstone Yet another closely related rock type is pebbly, fine- to coarse-grained sandstone (e.g. unit 19 of the type section; *see* Appendix).

The currently widely used term "pebbly mudstone" is appropriate for this rock type in that it reflects at once the highly variable composition and the invariable presence of large amounts of clay, silt and sand particles in it.

Pebbly mudstone forms a significant but always minor component of most of the studied sections of the Hesquiat Formation. In the type section, it comprises only about 6 per cent of the total estimated thickness and about 13 per cent of the estimated thickness of all resistant sandstone-conglomerate members. Furthermore, the pebbly mudstone is almost restricted to the middle and upper parts of the type section overlying the basal 366 m (1200 ft.) that contains the neritic early Lincoln fauna. This phenomenon is matched by the apparently complete absence of pebbly mudstone in the equivalent lower Lincoln beds of the Leclaire Point section on the eastern shore of Hesquiat Peninsula (*see* Jeletzky, 1954, p. 44-46) and in the inner neritic to littoral early Lincoln facies of the Hesquiat Formation on Flores Island (Jeletzky, 1954, p. 53-55; and this paper, p. 23-26).

In the middle and upper parts of Hesquiat Formation the ratio of pebbly mudstone increases distinctly southward (i.e. offshore) on the western and the eastern side of Hesquiat Peninsula. Instead of about 6 per cent of pebbly mudstone present in the beds of the type section overlying the Fourth shale-clayey sandstone member on the northeastern limb of Hesquiat Syncline, some 12 per cent of pebbly mudstone has been estimated in the approximately equivalent, predominantly argillaceous section exposed on the southwestern limb of the same syncline between Homeis Cove and Estevan Point. The southward (i.e. offshore) increase of the ratio of pebbly mudstone is even more pronounced on the eastern side of the peninsula where it increases from apparently nothing in the Anton's Spit-Matlahaw Point argillaceous section (Jeletzky, 1954, p. 47-49) exposed on the northeastern limb of Hesquiat Syncline to some 7 to 8 per cent in the equivalent, predominantly argillaceous section outcropping on the southwestern limb of the same syncline between Matlahaw and Estevan points (Fig. 1). Even though the outcrops are either poor or absent within the greater part of the eastern side of Hesquiat Peninsula, the southward increase of the ratio of pebbly mudstone does not seem to be in doubt.

The pebbly mudstones include the same types of volcanic, igneous and sedimentary clasts as the associated pebble conglomerates of Hesquiat Formation. The roughly estimated ratios of clast types appear to be the same in the two rock types concerned. The rounded or angular, locally complexly twisted or rolled, evidently locally ripped-up fragments or blocks of sandstone, shale or siltstone appear to be more common in pebbly mudstones than they are in the associated conglomerates.

All larger clasts are poorly to very poorly rounded, with subangular to subrounded sand grains and subangular to subrounded rudaceous clasts (*see* Pl. 6, figs. 2, 3) prevalent. The largest cobble- to boulder-size clasts, which are less common in pebbly mudstones than they are in associated conglomerates, are mostly subangular and the rare block-size clasts are always subangular to angular. As a rule, no sorting of clasts according to the size or distinct vertical grading within individual beds or members was observed in most of the units studied. However, some beds exhibit the same tendency for an upward fining of clasts as do the conglomerates.

All pebbly mudstone beds or units are notably lenticular and are replaced laterally either by typical packed conglomerate with arenaceous matrix or by various other clastic rocks within very short [2-30 m (6.6-100 ft.)] distances (e.g. units 52-56, 57 of the type section; *see* Appendix). Pebbly mudstone, like the conglomerate and sandstone, also occurs as lenses, pods and thin beds within thick units of other rock types of both facies (*see* Jeletzky, 1954, p. 49; units 33 and 57 of the type section; *see* Appendix).

The pebbly mudstones (or paraconglomerates) apparently were deposited from mud-charged slurries which flowed down the submarine channels of the southward inclined shelf slope of the Hesquiat sea as plastic mass (debris) flows of one kind or another. The absence of bedding, the presence of characteristically complex interfingering with other rock types, and the absence of well-defined and laterally persistent vertical grading indicates that no redeposition by turbidity currents was involved. The locally present, laterally impersistent upward fining apparently reflects the same gradual settling of larger and consequently heavier clasts within the mass flows or a gradual waning of the flowage in the channels as similar fining in conglomerates. The downslope movement of the slurries of pebbly mud apparently caused considerable erosion of the previously deposited argillaceous sediments forming the slopes and bottom of the submarine channels.

Sedimentological interpretation of resistant sandstones and conglomerates

The resistant sandstones and conglomerates of the resistant sandstone-conglomerate facies are characterize by an absence of sedimentological features indicative of the action of either traction currents or suspension-settled (or grain-by-grain) deposition. Except for the inner neritic to littoral facies of Hesquiat Formation (*see* below), such structures as large-scale cross-bedding, wave or current ripple-marks, or current scours were not observed either on the bedding planes or on the upper surfaces of the resistant sandstone beds This fact combined with the apparently complete absence of indigenous upper littoral macroinvertebrate fossils (the rarely occurring macroinvertebrates are exclusivel lowermost littoral or neritic types; *see* section on environmental interpretation of macroinvertebrates) and the rarity or absence of indigenous fossils in genera indicate deposition of the resistant sandstones and conglomerates of this facies below the wave base level.

The extremely characteristic lenticular alternation of the resistant sandstones and conglomerates with one another and with other rock types (*see* Jeletzky, 1954, p. 26, 27 and in preceding sections of this paper), their occurrence as lenses, pods and stringers in thick units of the other rock types, the commonly strongly churned-up appearance of the rocks in general, and the complete absence of clearly defined, laterally persistent grading precludes their interpretation as proximal turbidites. The writer does not agree that the presence of loadcast structures on the sole surfaces of resistant sandstone and conglomerate units is diagnostic of turbiditic origin as claimed by Cameron (1975, p. 18). As noted by Dżułyński *et al.* (1959), Stauffer (1967, p. 502) and other workers, loadcast structures occur in a number of other depositional environments, including that of plastic mass flow (= grain flow = fluxoturbidites). Moreover, Cameron's (ibid.) claim of the presence of loadcasts in the resistant sandstone-conglomerate facies is based, in part at least, on what the writer considers as a misidentification of submarine erosional channels which were depicted as "megaloadcasts" (*see* Cameron, 1973, p. 19, Fig. 1). The presence of the penecontemporaneous slumping phenomena in the resistant sandstone-conglomerate facies likewise is not diagnostic of its turbiditic redeposition, contrary to the opinion of Cameron (1973, p. 20, Fig. 2; 1975, p. 18). Finally, the same is true of the previously discussed penecontemporaneous soft-sediment injection structures (*see* Cameron, 1973, p. 20, Fig. 2) which are not indicative of either the deep-water environment or the turbiditic redeposition of sediments. Thus, in combination with the common presence of indigenous neritic (mostly outer neritic) macroinvertebrates in the adjacent shale-clayey sandstone members and, rarely, in the interbeds of resistant sandstone in the latter, the absence of diagnostic sedimentological indications of turbiditic redeposition in the rocks of the resistant sandstone-conglomerate facies contradicts its proposed (Cameron, 1975, p. 18) interpretation as either proximal or distal turbidites.

The apparently complete absence of sedimentological features indicative of either shallow-water or deep-water turbiditic deposition, and its generally massive to indistinctly bedded appearance, allies the resistant sandstone-conglomerate facies of Hesquiat Formation with the peculiar class of largely arenaceous sediments described as fluxoturbidites by Kuenen (1958) and Dżułyński *et al.* (1959, p. 1114), as plastic mass flow deposits by Dott (1963, p. 30, 31, Fig. 7C), and as grain flow deposits by Stauffer (1967, p. 497, 499). The term "plastic mass flow deposits" will be used in this paper in preference to two other synonyms because of its conceptual applicability to all mass flow deposits regardless of their grain or clast size. Stauffer's (ibid.) term "grain flow deposits" does not seem to be easily applicable either to mud flowage or to that containing rudaceous size clasts. The term "fluxoturbidites" of Kuenen (1958) and Dżułyński *et al.* (1959) is most unfortunate in implying a close genetic relationship to turbidites which does not appear to exist. The writer follows Dott (1963) and Stanley and Unrug (1972) in denying the validity of the commonly expressed idea (e. g. Sanders, 1965; Stauffer, 1967, p. 503; Lowe, 1972, p. 79) that the process of plastic mass flow may be either derived from turbidity currents or assisted by the latter. Only a reverse connection appears to be mechanically feasible.

An even more important depositional feature shared by the resistant sandstone-conglomerate facies (including the pebbly mudstones and pebbly sandstones representing its extreme lithological types) with plastic mass flow deposits is the characteristic presence of outsize clasts. This feature, also, supports the idea of deposition of this facies of Hesquiat Formation by the process of plastic mass flowage (*see* Stauffer, 1967, p. 491, 492).

In spite of the important depositional features it shares with the typical plastic mass flow deposits (= fluxoturbidites = grain flow deposits), the resistant sandstone-conglomerate facies differs considerably from these extremely homogeneous, commonly almost structureless deposits. The typical plastic mass flow deposits lack the invariably poor to very poor sorting and rounding of grains and clasts of this facies of the Hesquiat Formation. The characteristic, irregular alternation of lenticular beds, lenses, pods, and stringers of resistant sandstone and pebble conglomerate with one another and other rock types, including pebbly mudstones and those of the shale-clayey sandstone facies, so characteristic of the resistant sandstone-conglomerate facies, is decidedly uncommon, although present, in the plastic mass flow deposits studied by Stauffer (1967, p. 492, 493, Figs. 7b, 8c, 11a). Another even more important distinction is the apparently complete absence of delicate internal and sole markings common in the Californian grain flow deposits described by Stauffer (1967, p. 500). Neither "dish structures" nor "delicate sole markings" have been observed in the resistant sandstone-conglomerate facies of the Hesquiat Formation. One more distinction consists in the characteristic presence of erosionally disconformable to erosionally discordant lower contacts and the widespread occurrence of slide and slump phenomena in the resistant sandstone-conglomerate facies of the Hesquiat Formation. This erosional behaviour of the coarse clastics of the formation appears to be responsible, in part at least, for the poor sorting and rounding of its grains and clasts and for the commonly churned appearance of the rocks. Yet another distinction consists in the previously discussed widespread occurrence of penecontemporaneous to preconsolidation injection of surrounding argillaceous rocks into the resistant sandstone-conglomerate facies. This phenomenon of a forcible squeezing of soft mud into coarse grained sediments can be explained only by pressure generated by slumping and resulting plastic mass flow of the sediments of the Hesquiat Formation.

All these sedimentological features contrast with the Californian and other previously mentioned plastic mass flow deposits while being suggestive of an influence of submarine slides and slumps.

This distinction is important since Stauffer (1967, p. 500) expressly denies the involvement of sliding and slumping in the deposition of typical plastic mass flow deposits studied by himself; he states: "most of the beds involved cannot be the results of clastic submarine slides. Such slides would not produce the observed faint but delicate internal structures. And the sudden impact of a moving slide on a mud bottom would be expected to mark and indent that bottom, producing soles unlike the observed ones, which where they are marked at all, bear peculiar and often intricate markings".

In the writer's opinion, the morphological distinctions of the resistant sandstone-conglomerate facies from those of the typical plastic mass flow deposits is the result of their different depositional environment. Unlike the typical plastic mass flow, deep-water (continental slope) deposited sandstones described by Dżułyński *et al.* (1959), Stauffer (1967, p. 499, 500) and other workers, the resistant sandstone-conglomerate facies of the Hesquiat Formation is thought to have been deposited largely or entirely in an outer neritic environment. This is supported by the paleoecological analysis of the macroinvertebrate content of the interbedded shale-clayey sandstone members carried out in the previous sections of this paper and, less directly, by the churned appearance, highly irregular bedding, and disorderly alternation of the individual rock types.

The characteristic (Jeletzky, 1954, p. 26, 27 and earlier in this paper) irregular alternation of resistant sandstones and typical conglomerate units with small and large [from a few mm to about 6 m (¼ in.-20 ft.) thick] lenticular beds, lenses, pods, and stringers of pebbly mudstone, pebbly sandstone, fine grained clayey sandstone and various argillaceous rocks indicates an incomplete mixing of these various, originally separate sediment types which were incorporated into the debris flow in the course of its downward movement. This feature, which is much less common, but by no means absent, in the plastic mass flow deposits studied by Stauffer (1967, p. 492, 493, Figs. 7a, 8a, 11a) reflects the extremely localized and episodic nature of the slumping and flowage of sediments in the erosional channel(s) of the Hesquiat Formation. It suggests, moreover, their proximity to the inferred northern source area and agrees, in turn, with their macrofaunally demonstrated shelf environment of deposition. The process probably was complicated further by downslumping of the channel's slopes resulting in the addition of yet more different rock types to the flowing mass of debris (as in glaciers). The characteristic heterogeneity of the coarse clastics of the Hesquiat Formation is thus yet another indication of the relatively short distances [probably between 3.2 and 24 km (2-15 mi)] they have travelled as plastic mass flow deposits

Because of the above considerations, the resistant sandstone-conglomerate facies of the Hesquiat Formation appears to be a "proximal" plastic mass flow deposit -- deposited rather more closely to its shoreline source area, than the typical plastic mass flow deposits. Such "proximal" mass flow deposits apparently did not travel nearly as far away from the sites of submarine slumps and slides which gave birth to them as did the Californian and other previously mentioned typical or "distal" mass flow deposits. The latter were shown to be deep-water deposits accumulating either on the continental slope or on the continental rise (*see* Stauffer, 1967, p. 499, 500, 507, Fig. 16). Hence they travelled a much longer distance from the source area. Consequently, they have lost the typical churned-up appearance characteristic of the resistant sandstone-conglomerate facies, have become much better sorted, and acquired all other characteristic sedimentological features of "distal" mass flow deposits.

Origin and environmental implications of pebbly mudstones

The derivation of rudaceous clasts in the pebbly mudstones have been recognized as a difficult sedimentological problem since the publication of Crowell (1957). Crowell (ibid., p. 1003-1005) ascribed the transportation of these pebbles into a muddy environment on the continental slope to the triggering action of earthquakes resulting in the development of turbidity currents. This explanation was disputed by Dott (1963, p. 126) who rightly concluded (according to this writer) that pebbly mudstones are a gravity-triggered slope deposit representing "arrested flows which just surpassed their liquid limits, but regained cohesion thixotropically before a true turbidity current could form". However, Dott (loc. cit.) failed to indicate a likely depositional environment in which such arrested flows of pebbles could form. The answer to the riddle was provided by recent research of Stanley and Unrug (1972, p. 305, 306) in the Mediterranean Sea off the Provençal coast of France. They discovered that it is neither the triggering action of earthquakes nor that of turbidity currents but the seasonal input from fluvial sources that is responsible for transportation of gravels to a site where mud is normally deposited. Stanley and Unrug (1972, p. 305, 306) state:

> "The presence of fluvial source inputs along land-enclosed, mobile basins such as this (i.e. Provençal basins; writer's remark) provide a key to the problem. Dives (D.J.S.) made in 1967 and 1968 off the Var and Paillon Rivers at Nice revealed large (10 to 50 cm diameter) subangular to rounded carbonate cobbles and boulders on a sloping mud bottom (fig. 16). The initial conditions for pebbly mudstone formation are thus met. Mud is derived from the normal suspended load discharged by rivers at the coast during most of the year. Extensive plumes of suspended matter at the delta mouth are recognized from the air (fig. 17); large volumes of sediment in the water column seriously reduce visibility under water and hamper the diver's observation of the bottom in this area. Gravels, the bed-load of rivers and torrents draining the adjacent Maritime Alps, are transported to the coast where they form small, coarse-textured deltas such as the one at the mouth of the Var (fig. 17A). Abrasion during lateral near-shore transport of pebbles and cobbles along the coast (the coarse-textured strandlines belt or "cordon littoral") accentuates their rounding.
>
> "The extremely narrow coastal platform onto which the gravels are transported is bounded by 3° to 6° slopes. The lateral transport of gravels directly onto the slope is a seasonal event, i.e., occurring during flood stages and during periods of strong near-shore current (storm-wave) activity. Once transported beyond the river mouth and onto the mud-covered slope, gravels apparently begin a journey which extends to the basin plain at depths exceeding 2400 m (Bourcart, 1964).

"A most interesting observation was made during a dive to about 25 m at the mouth of the Paillon River at the Baie des Anges (fig. 16B). Large cobbles and some boulders (fig. 16C, D) rest on steep (5° to 10°) slopes near the head of the Paillon Canyon (fig. 16A). When touched lightly, rounded blocks were made to slide on the slick mud surface for distances of 10 to 30 cm. It is quite probable that the sudden introduction of additional coarse sediments onto this already unstable mud-gravel surface during flood stages would result in oversteepening, almost immediate failure, and a mass transfer of the unstable deposits downslope. Cores collected off the Provençal coast frequently penetrate mixture of mud and gravels (fig. 18). Evidence that pebbles move rapidly downslope to the basin apron and plain is provided by oil- and tar-coated pebbles in dredge hauls (tar accumulates on pebbles at the strand line) and by direct visual observation of the bottom (Gennesseaux, 1962a, 1962b, 1966)".

Stanley and Unrug's (loc. cit.) research disproved Crowell's (1957) suggestion of a turbidity origin for pebbly mudstones, while confirming the gravity-triggered plastic mass flow origin suggested by Dott (1963, p. 126). According to Stanley and Unrug (1972, p. 303, 305):

"There appears to be a gradation between viscous fluid flow, represented by turbidity current suspension, and plastic mass flow. However, a pebbly mudstone origin would preclude considerable lateral movement as a turbulent suspension generally associated with turbidity current flows. Unrug (1959), Dott (1963) and others infer that in many cases turbidity currents have resulted from mass flows. The fact that in most sections pebbly mudstones are less common than turbidites could be used as supporting evidence. Triggering of mass movements leading to pebbly mudstone formation includes earthquakes, overloading due to extemely rapid sediment buildup (such as off deltas) and oversteepening and undercutting of slopes".

Because of an intimate connection existing between pebbly mudstones in the recent basins and the hydrography and hypsography of adjacent landmasses, pebbly mudstones are extremely valuable paleogeographical indices. As pointed out by Stanley and Unrug (1972, p. 307, 308):

"Mapping the pebbly mudstone distribution in a paleobasin serves to draw inferences on: (a) the position of source input along the basin margin (including river mouths and small deltas); (b) the mineralogy and morphology of the source terrain being drained by the fluvial network that carries terrigenous sediments to the basin; (c) the nature of the platform and relation of the slope to the coastline; and (d) the breaks in slope (i.e. within the slope-apron-basin plain complex). In all cases known to the authors, pebbly mudstone deposits serve as indicators of lateral introduction and transport of sediment into a basin. This facies, unlike some slumps that are initiated within the basin trough in the manner suggested by Kuenen (1967), is a most valuable criterion for distinguishing transverse basin slope sedimentation."

The mode of origin of pebbly mudstones proposed by Dott (1963) and its further developments by Stanley and Unrug (1972) appear to be valid in principle. However, for reasons presented earlier in this paper, the writer cannot agree with the conclusion of Stanley and Unrug (1972, p. 291, Fig. 2) that pebbly mudstones are sediments confined to the continental slope and continental rise and do not occur either on the shelf or on the shelf break. This conclusion is theoretically unsound in so far as the above workers themselves have demonstrated conclusively that, unlike true turbidites, pebbly mudstones (and by implication pebbly sandstones) are forming under conditions which do not necessitate much lateral movement of the sediment. Moreover, the excess of lateral movement is apt to destroy a pebbly mudstone in that it would tend to produce too much momentum in the plastic mass flow concerned for that flow to be "arrested" and "to regain its cohesion thixitropically" before its transformation into a turbidity flow. Therefore, on theoretical grounds, pebbly mudstones and turbidites forming part of the same episode of sedimentation cannot be expected to be deposited in the same deep-sea depositonal environments. Contrary to Stanley and Unrug's (1972, p. 291, Fig. 2) conclusions, one must expect pebbly mudstones to be largely confined to more proximal depositional environments than the turbidites. This theoretical prediction is in the best agreement with the previously discussed, macropaleontologically documented conclusion that most or possibly all of the pebbly mudstones of the Hesquiat Formation have been deposited on the outer part of the continental shelf above the shelf break.

The outer shelf depositional environment of pebbly mudstones of the Hesquiat Formation seemed to be most exceptional at first, since the writer was unable to find any direct reference to the presence of pebbly mudstones in the shelf areas of recent seas. Only the cited description of the diving expedition of D. F. Stanley (*see* Stanley and Unrug, 1972, p. 305) in the shallow waters off Provençal coast and the presence of pebbly mudstone-like interbeds in the shallow-water cores collected in this area (Stanley and Unrug, 1972, p. 305, Fig. 18) provide an indication that pebbly mudstones are being deposited now in such an environment. The inference of a steady downslope removal of most pebbles observed in this muddly shelf environment made by Stanley and Unrug (loc. cit.) may be valid in this particular instance because of the extremely narrow character of the Provençal shelf. However, as it will be shown, the same reasoning does not apply to some other accumulations of pebbles in muddy neritic environments.

A study of geological literature revealed a few well-documented examples of the occurrence of pebbly mudstones in shallow-water (outer shelf) paleoenvironment. Some of these instances are familiar to stratigraphers and paleontologists. However, their existence and implications apparently escaped the attention of those marine geologists, oceanographers, and sedimentologists responsible for the most recent attempts at the reappraisal of the continental margin sedimentation. The best known example is that of pebbly mudstones (and regular conglomerates) lithologically identical to those of the Hesquiat Formation occurring in a thick, mainly argillaceous upper Tithonian to Valanginian unit (i. e. so-called Knoxville and Paskenta groups of Anderson, 1938, 1945) of the Great Valley sequence of California. The pods, lenses, and thick lenticular beds of these pebbly mudstones and conglomerates are interbedded with abundantly fossiliferous rocks of undoubted neritic origin (e. g. Crowell, 1957, p. 995-998, Fig. 5, Pl. 1, figs. 1, 2, Pl. 2, figs. 1, 2; Bailey *et al.*, 1964, p. 124, Table 18; Ojakangas, 1968, p. 1001; and personal observations in 1966). Because of their localized lenticular nature, erosional contacts with, and a deep channelling into the underlying argillaceous rocks, the above-mentioned pebbly mudstones and conglomerates evidently are upper Tithonian to Valanginian channel fill deposits. However, the indigenous (e. g. not redeposited) character of macroinvertebrate fauna occurring in the underlying and overlying predominantly argillaceous rocks leaves no doubt that the submarine channels concerned were crossing not a continental slope but a mud-covered, more or less markedly inclined, eastern shelf zone of the Late Jurassic to early Early Cretaceous Great Valley miogeosyncline of California.

Another good example is the fossiliferous, outer neritic, pebbly mudstone (referred to as conglomeratic argillite by the authors concerned) recently reported from the eugeosynclinal Orca Group in Prince William Sound, southeastern Alaska (Plafker and MacNeil, 1966 p. B64-B66, Figs. 3, 4). This mid- to late Eocene pebbly mudstone contains concretions of calcareous argillite frequently containing excellently preserved, outer neritic (muddy bottom facies) crab and molluscan fossils. These concretions are accepted as probably "reliable indicators of the age of the conglomeratic argillite bed" by Plafker and MacNeil (1966, p. B65) and so evidently are considered to be indigenous early diagenetic structures. The writer has no doubts about the indigenous character of these Orca Group macroinvertebrates for reasons presented previously in the section devoted to the environmental evaluation of the paleoecologically similar early Lincoln fauna of the Hesquiat Formation.

Yet other neritic pebbly mudstones have been observed by Mertie (1933, p. 127, 128) in the Yakataga Formation (Miocene) of Lituya Bay, southeastern Alaska. There an abundant fauna of neritic molluscs occurs in "shales" containing scattered, poorly rounded clasts unsorted as to size. The direct association of these molluscs with pebble- to boulder-size clasts leaves no doubt about the neritic origin of the rock concerned and Mertie (1933, p. 128) emphatically points out that the clasts do not represent glacial debris.

The allegedly glacial conglomerates of the Oligocene Poul Creek and Miocene Yakataga formations described by Taliaferro (1932, p. 755, 759, 762, 772) from several districts of southeastern Alaska also appear to be neritic pebbly mudstones rather than marine glacial deposits.

This is suggested by their lithological similarity with pebbly mudstones of the Hesquiat Formation, presence of neritic crabs and molluscs "in shales and sandstones interbedded with shale-matrix conglomerates" (Taliaferro, 1932, p. 758), and the improbability of truly glacial conditions in pre-Pleistocene time. However, more work is needed to rule out the marine glacial origin of clasts contained in these formations.

The depositional environment of the pebbly mudstones of the Upper Cretaceous Pigeon Point Formation in California is now in dispute. Lowe (1972) interprets the Pigeon Point Formation as a deep-sea canyon and slope channel deposit while Tyler (1972) argues for its shoreline and lagoonal origin. However, the writer was informed by Dr. D. L. Jones, U. S. G. S., Menlo Park, U. S. A. (written comm., March 13, 1975) that all shallow-water macrofossils found in the formation are "redeposited" and that the depositional environment of the fossiliferous Member D of the formation may even be deeper than was suggested by Lowe (1972). The Pigeon Point Formation must, therefore, be excluded from a consideration as a possible shallow-water channel deposit.

The above examples are deemed to be sufficient to refute the presently prevalent idea that pebbly mudstones are characteristic deep-water sediments diagnostic of the continental slope and continental rise environments. As in so many other cases, lithology alone proves to be an unreliable criterion. It is the fossils, and particularly the paleoenvironmentally more reliable macroinvertebrates (*see* Jeletzky, 1973), that permit definitive conclusions about the depositional environment of any particular examples of pebbly mudstones.

The prevalent opinion regarding the exclusively deep-water origin or marine pebbly mudstones appears to be an outgrowth of the current preoccupation of sedimentologists, marine geologists, and oceanographers with the deep-water sediments of recent oceans and their alleged fossil equivalents. The study of recent and fossil shallow-water sediments is, unfortunately but perhaps understandably, neglected by these workers. The pendulum of research interests had, so to say, swung too far in the direction of the study of deep-water sediments. This swing appears to be a reaction to the perhaps equally strong former preoccupation of geoscientists with the shallow-water sediments and rocks. Because of the above tendency, it seems likely that yet other examples of neritic pebbly mudstones are lingering in the guise of deep-water deposits. It is to be hoped that the discussion given here will cause the workers concerned to reappraise their reliance on the currently used lithological and micropaleontological criteria of depositional environments and to turn to the more reliable evidence of macroinvertebrate fossils.

Differentiation of pebbly mudstones from glacio-marine pebbly deposits

The difficulties involved in the differentiation of true (i. e. deposited by a submarine plastic mass flow) pebbly mudstones from lithologically similar tillites were discussed by Crowell (1957, p. 1005, 1006). As mentioned in the preceding section, this problem is particularly acute in the case of glacio-marine pebbly deposits that have been reported from the Tertiary Poul Creek and Yakataga formations of southeastern Alaska (e. g. Taliaferro, 1932; Miller, 1951, 1953, 1961) and the Tertiary rocks of Sakhalin (e. g. Alekseichik, 1952, p. 471-472). The latitudinal proximity of these alleged Tertiary glacio-marine deposits to the roughly contemporary Tertiary deposits of Vancouver Island and the definitely cold-water character of macroinvertebrate faunas of the latter (*see* Jeletzky, 1973, p. 336-338, 346) might suggest a glacio-marine origin for pebbly mudstones of the Hesquiat Formation. However, this is unlikely for the following reasons:

1. The pebbly mudstones of Hesquiat Formation appear to lack completely the glacially striated cobbles and boulders which characteristically occur in the undeniable glacio-marine Pleistocene pebbly deposits of Middleton Island, southeastern Alaska (*see* Miller, 1953);

2. The macroflora occurring in a number of argillaceous units of the Hesquiat Formation (*see* section on age and correlation for details) in association with the Oligocene (Lincoln to lower Blkeley) cold-water marine invertebrates "appears to have been a warm temperate one and may have had an intermingling of temperate and tropical forms" according to Dr. Wayne Fry, University of California, Berkeley (unpubl. intradepartmental fossil report of Dec. 16, 1955); and

3. The characteristic presence of rip-up fragments of underlying rocks in, and of erosionally disconformable to erosionally discordant contacts at the base of each pebbly mudstone unit of Hesquiat Formation. As noted by Stanley and Unrug (1972, p. 306):

> "The pebbly mudstone units frequently contain angular fragments of siltstone rip-up clasts; the lower surfaces of these lenses display irregular erosional scour-like surfaces (fig. 19). Inspection of these deposits indicates that, in some cases, pebbly mudstone lenses are composite in origin; interbedded sandstone layers have been partially eroded by successive mass-gravity flows transporting a mixture of mud, sand, and gravel along the bottom. Erosional features preserved at the base of surfaces serve to distinguish mass-gravity transported tilloids from poorly sorted (mud to boulder), ice-rafted, glacio-marine slope deposits of the type found on slopes in higher latitudes (Brundage *et al.*, 1967; Stanley and Cok, 1968)."

The validity of the last mentioned distinction appears to be doubtful to the writer. Scour channels filled with more or less distinctly sorted and stratified sandstone and conglomerate have indeed been recorded in the true glacio-marine pebbly deposits of Middleton Island (Miller, 1953, p. 33, 34) which appear to be shallow-water deposits because of the character of their macroinvertebrate fauna. However, the sum of the diagnostic features presented here appears to be ample to rule out a glacio-marine origin for the pebbly mudstones of Hesquiat Formation.

Channel-fill and interchannel deposits

As previously reported by Jeletzky (1954, p. 26, 27; and in the preceding sections), the clastic rocks of the Hesquiat Formation exhibit important lateral changes of facies consisting of a partial to complete pinching out of coarse arenaceous and rudaceous clastics of the resistant sandstone-conglomerate members and their replacement by argillaceous to fine grained arenaceous rocks lithologically similar to those of the intervening shale-clayey sandstone members. The outcrop-areas characterized by a cyclical alternation of resistant sandstone-conglomerate and shale-clayey sandstone facies are strongly localized within the known outliers of the Hesquiat Formation. Their most extensive exposures have a distinctly channel-like or a shoe-string-shaped outline and are flanked (and apparently surrounded on three sides) by much more extensive areas of predominantly to exclusively argillaceous contemporary rocks. Therefore, and because of other characteristic lithological and sedimentological features of the coarse grained rocks which were discussed in the preceding sections, these outcrop-areas, characterized by a cyclical alternation of resistant sandstone-conglomerate and shale-clayey sandstone facies of Hesquiat Formation, are interpreted as fossil channel-fill deposits in the now generally accepted sense of Stanley (*in* Stanley *et al.*, 1969), Stanley and Unrug (1972), Lowe (1972), Nelson and Nilsen (1974) and other workers. The intervening predominantly to exclusively argillaceous rocks of the Hesquiat Formation are interpreted as interchannel deposits. Though lithologically and sedimentologically identical with certain modern channel-fill and interchannel deposits of the continental slope and continental rise, described above, the corresponding facies of the Hesquiat Formation differ radically in their depositional environment. As discussed in the preceding sections of this report, they are thought to have been deposited largely or possibly entirely on the outer part of the continental shelf. One has to conclude, accordingly, that at least the fossil channel-fill and interchannel deposits are not restricted to the bathyal and abyssal environments, contrary to the now prevalent opinion of sedimentologists, marine geologists, and oceanographers.

Channel-fill facies

Within the Tertiary outlier of Hesquiat Peninsula there are three outcrop-areas dominated by the above-defined, channel-fill deposits (*see* Fig. 2):

1. The ribbon-like strip of the western shore extending from Escalante Point to the southern side of Homeis Cove (*see* Jeletzky, 1954, p. 28-42, geol. maps 1, 2 and in Appendix for further details);

2. The linguliform strip of the eastern shore confined between the nameless point situated about 2.4 km (1.5 m.) north of Leclaire Point and the southern base of Leclaire Point (*see* Jeletzky, 1954, p. 47-49, geol. map 1 for further details); and

3. A small area at the tip of Matlahaw Point (*see* Jeletzky, 1954, p. 49, geol. map 1 for further details).

Elsewhere in the report-area, the only other small outcrop-area of the channel facies that is known, is on the Inner Bajo Reef off the tip of Bajo Point, Nootka Island (*see* Jeletzky, 1954, p. 19-21, geol. map 2; 1973, p. 352-354).

Barcester Bay (or principal) channel

This outcrop-area of the channel-fill facies is named herein the Barcester Bay (or principal) channel because of the excellent outcrops on the tidal flats of Barcester Bay on the western side of Hesquiat Peninsula. It consists of seven, stratigraphically superimposed, major resistant sandstone-conglomerate members interbedded with seven major shale-clayey sandstone members. The whole sequence of these fourteen units, representing Lincoln and lower Blakeley generations of this submarine channel, is exposed only on the northeastern limb of Hesquiat Syncline where it comprises the type section of Hesquiat Formation (*see* Jeletzky, 1954, p. 28-42, geol. map 1; this paper, Fig. 2). Only the uppermost two resistant sandstone-conglomerate members (i.e. the sixth and seventh) and the intervening shale-clayey sandstone member (together representing the lower Blakeley generation of this channel) reappear on the southwestern limb of the syncline. There, they outcrop as far as the southern side of Homeis Cove before being cut out by erosion (Jeletzky, 1954, p. 43). The underlying 610 to 762 m (2000-2500 ft.)-thick sequence of almost exclusively argillaceous rocks outcropping farther south between Homeis Cove and Estevan Point (*see* Jeletzky, 1954, p. 43, 44, geol. map 1; this paper, Fig. 2) is still of early Blakeley age in its entirety according to the macroinvertebrate fauna. The early Blakeley age of this argillaceous sequence indicates its correspondence to most of that part of the type section of Hesquiat Formation which is confined between the Fourth Shale-clayey sandstone member and the Sixth resistant sandstone-conglomerate member (*see* section on age and correlation for further details). This indicates the southward pinching out of at least the Fifth resistant sandstone-conglomerate member somewhere in the interval between Barcester Bay and Estevan Point. Therefore, and because of the apparent absence of the resistant sandstone-conglomerate facies of the Hesquiat Formation in the only well drilled by Shell Canada Ltd. off Nootka Sound and Hesquiat Peninsula (Shouldice, 1971, p. 417, 418, Figs. 16, 17), it is inferred that all of the resistant sandstone-conglomerate members of the Barcester Bay (or principal) channel become laterally replaced by the predominantly to exclusively argillaceous interchannel facies somewhere in the interval between Homeis Cove and Estevan Point. In other words, this active Oligocene underwater channel apparently petered out somewhere within this interval throughout its existence, as shown in Figure 2.

The channel to interchannel facies changes are not directly observable anywhere within the outcrop belt of the Barcester Bay (or principal) channel of the Hesquiat Formation, since all seven thick resistant sandstone-conglomerate members appear to persist laterally between the low tide mark and the forest fringe. However, there are strong indications of the lateral westward and eastward petering out of these members throughout this outcrop belt.

The northeast-southwest traverse of the northern half of the interior of Hesquiat Peninsula from the northern margin of the Tertiary outcrops to the northeastern corner of Barcester Bay (*see* Jeletzky, 1954, geol. map 1; this paper, Fig. 2) indicates the absence of most of the major resistant sandstone-conglomerate members (i.e. first to fourth inclusive) which are exposed on the western and eastern coasts of the peninsula and project into the line of the traverse. The Fifth resistant sandstone-conglomerate member is present still in the northeastern corner of Barcester Bay (*see* Jeletzky, 1954, geol. map 1). However, its complete disappearance farther east in the central part of the peninsula is suggested by its lateral facies changes described below, by the generally flat, almost featureless relief of the corresponding area, and by the complete absence of the resistant sandstone-conglomerate facies within the corresponding part of the eastern coast between Leclaire Point and Hesquiat village (*see* Jeletzky, 1954, geol. map 1). A number of shorter traverses inland along small creeks crossing the southern part of Hesquiat Peninsula, and a survey of the shores of Village Lake failed to reveal the presence of any sizable outcrop-areas of the resistant sandstone-conglomerate facies of Hesquiat Formation. In combination with the generally flat, almost featureless, relief and mainly swampy character of the interior of the southern part of Hesquiat Peninsula clearly visible from the air and on aerial photographs, these data indicate a complete eastward disappearance of all resistant sandstone-conglomerate members outcropping in the corresponding interval of the west coast. All these members apparently become replaced laterally, within a few hundred metres of the west coast of Hesquiat Peninsula, by predominantly argillaceous rocks representing a direct westward continuation of the interchannel facies occupying the east coast between Leclaire and Matlahaw points (*see* Fig. 2).

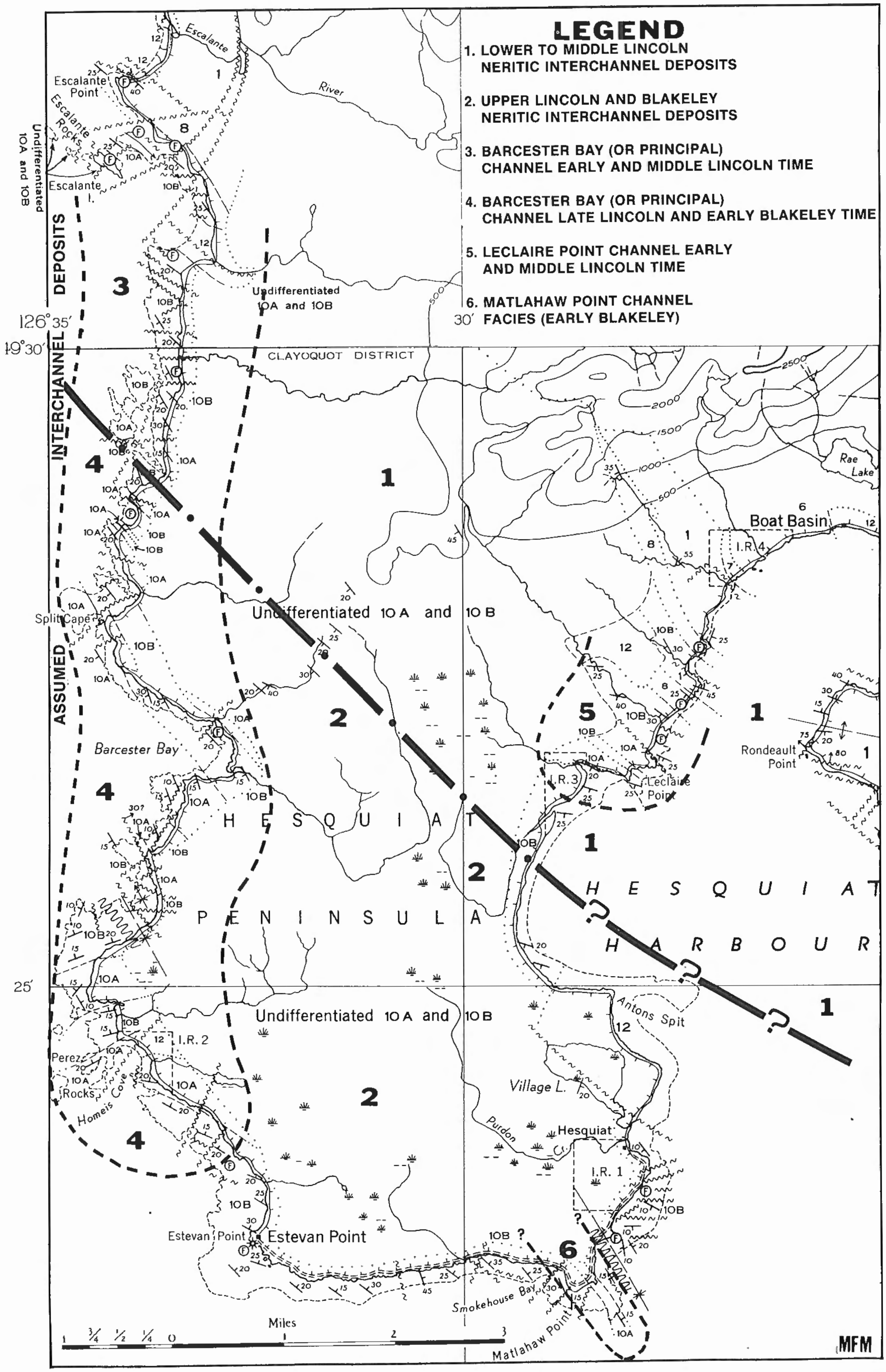

Figure 2. Interpretation of depositional environments of principal lithological types of Hesquiat Formation on Hesquiat Peninsula. Geological data from Jeletzky (1954, geol. maps 1, 2). See there for explanation of all symbols.

Additional evidence of an eastward thinning to zero of the resistant sandstone-conglomerate members of the Barcester Bay (or principal) submarine channel is provided by the following lateral facies changes and contact relationships observed within the outcrop belt on the west coast of Hesquiat Peninsula.

The Fifth resistant sandstone-conglomerate member is almost exclusively conglomeratic and includes a large proportion of boulder- to block-size clasts in its westernmost available outcrops on the coast north of Split Cape (*see* Appendix, units 50, 51 of the type section). Moreover, it cuts into the underlying argillaceous rocks of the Fifth shale-clayey sandstone member for at least 15 m (50 ft.). This deeply eroded contact is accompanied by an angular discordance of 5 to 10 degrees. The easternmost outcrops of this member studied in the northeastern corner of Barcester Bay and along the lower course of a nameless small creek emptying into the sea at that point (*see* Appendix, unit 51 of the type section) consist, in contrast, almost exclusively of coarse-grained, partly gritty, resistant sandstone which is no more than 46 m (150 ft.) thick. The outcrops north of Split Cape are interpreted herein as the mid-channel facies whereas those of the north-eastern corner of Barcester Bay appear to be a marginal facies of the same channel.

The Sixth resistant sandstone-conglomerate member exhibits similar but even more pronounced lateral facies changes. On the northwestern side of Split Cape (*see* Appendix, unit 57 of the type section; Cameron, 1973 p. 19, Fig. 1), this member is represented by the same extremely coarse textured, presumably mid-channel facies as the underlying Fifth resistant sand-stone-conglomerate member. The contact with the underlying Sixth shale-clayey sandstone member is erosionally disconformable and possibly is an angular unconformity. The section exposed on the south-eastern side of Barcester Bay contains much less con-glomeratic rock than that at Split Cape and the average size of conglomeratic pebbles is much smaller (*see* Appendix, units 57a-57h of the type section). Further-more, there is a definite tendency for conglomerate interbeds to attenuate eastward and, in places, to become replaced laterally by coarse grained, gritty and pebbly sandstone and/or pebbly mudstone within this eastern outcrop-area (a tidal shelf). There is every reason to conclude that the eastern outcrop-area discussed previously of the Sixth resistant sandstone-conglomerate member represents the eastern marginal facies of the Barcester Bay (or principal) submarine channel of Hesquiat Formation which becomes replaced laterally by the predominantly argillaceous interchannel facies a short distance farther eastward (i.e. within the forested upper shore).

A gradual eastward lateral replacement of the basal 91.5 m (300 ft.) of the conglomeratic mid-channel facies of the Sixth resistant sandstone-conglomerate member (i.e. of unit 57 of the type section; *see* Appendix) by the regularly banded, flysch-like shale-clayey sand-stone rocks is extremely well displayed on the wide tidal shelf in the middle part of the northern side of Barcester Bay (*see* Jeletzky, 1954, geol. map 1, aerial photograph A5901-68; this paper, Pl. 3, fig. 3).

The outcrop-area of the Sixth resistant sandstone-conglomerate member on the southern side of Homeis Cove exhibits southeastward lateral changes similar to its lateral changes on the southeastern side of Barcester Bay (Jeletzky, unpubl. final report). Namely, all conglomerate interbeds either become thinner south-eastward across the tidal shelf or become gradually replaced in this direction by pebbly mudstone, or by coarse grained, gritty and pebbly sandstone. A more detailed analysis and placement of the eastern boundary of the channel-fill facies is precluded by the scarcity or absence of outcrops in the interior of Hesquiat Peninsula and a complete absence of boreholes there.

The western margin of the Barcester Bay (or principal) submarine channel of the Hesquiat Formation is everywhere concealed beneath the sea off the western coast of Hesquiat Peninsula. There are clear indications, however, that the channel did not extend far off this coast. Firstly, the average pebble size within unit 5 of the type section of Hesquiat Formation (*see* Appendix) appears to decrease northwestward between Schmitz Place and Escalante Point (*see* Fig. 1). Secondly, it is unlikely that the wide and deep channel of Nootka Sound could have been excavated in the resistant rocks of the channel-fill facies of Hesquiat Formation. It is much more likely that the powerful marine erosion which destroyed most of the onshore outcrops of the Tertiary rocks within the Hesquiat-Nootka map-area, was reduced in effectiveness when it reached the channel-fill facies on the western side of Hesquiat Peninsula (and elsewhere in the area). It is this slowing down of marine erosion that appears to be responsible for the survival of Hesquiat Peninsula till the present, and its forming an exceptionally large outlier of Tertiary rocks protruding for some 19.2 km (12 m.) westward into the Pacific Ocean. Because of the above considerations, the western margin of the Barcester Bay (or principal) submarine channel of Hesquiat Formation appears to be concealed beneath the waters of Nootka Sound only a few hundred metres off the western coast of the peninsula (more precisely just off the westernmost reefs fringing this coast) as shown in Figure 2.

According to the writer, the channel-fill facies of the Barcester Bay (or principal) submarine channel of Hesquiat Peninsula represents seven successive periods of deposition of coarse arenaceous to rudaceous mass flow deposits, each of which appears to correspond roughly, lithologically and genetically but not environ-mentally, to members A and B of the Pigeon Point Formation (*see* Lowe, 1972, p. 75-81). Each one of these periods of mass flow deposition must have been preceded by a shorter or longer period of non-deposition and erosion of submarine channels in accordance with the conceptual scheme of deposition of submarine channel-fill deposits (e.g. Stanley *in* Stanley *et al.*, 1969; Stanley and Unrug, 1972; Lowe, 1972, p. 79, 80; and in preceding sections of this paper). The actual existence of these erosional and non-depositional phases within the channel-fill facies is confirmed by the erosion of the surfaces of each of the underlying shale-clayey sandstone members and the erosionally disconformable to erosionally discordant character of the lower contacts of all studied principal resistant sandstone-conglomerate members. The gradual waning and then almost complete cessation of plastic mass flow processes is recorded in the locally observable upward fining of sediments within all of the resistant sandstone-conglomerate members. Furthermore this waning and/or almost complete cessation is indicated by the deposition of predominantly suspension (or grain-by-grain) settled shale-clayey sandstone members on top of each resistant sandstone-conglomerate member. Some slumping and plastic mass flowage obviously took place throughout the duration of every one of these quiescent episodes as denoted by the presence of minor lenticular beds, lenses, and pods of resistant sandstone, conglomerate, and pebbly mudstone in argillaceous sediments of all shale-clayey sandstone members and other phenomena described in the preceding sections.

Neither the total depth of the Barcester Bay (or principal) submarine channel of the Hesquiat Peninsula nor the shape of its cross-section can be estimated. It is possible, however, to estimate the minimum amount of erosion of the underlying rocks for some of the individual resistant sandstone-conglomerate members. The greatest amount of such erosion is involved in the "angular disconformities" observed in the type section of the Hesquiat Formation (e. g. units 50, 63; *see* Appendix) at the base of the Fifth resistant sandstone-conglomerate member and, within the succession, of the Seventh resistant sandstone-conglomerate member. Like other erosional disconformities within the channel-fill facies, these "angular disconformities" are attributable not to the tectonic folding and truncation of the underlying rocks but to their angular truncation by the erosional activity of the clay and sand slurry which flowed down the Barcester Bay (or principal) submarine channel of the Hesquiat Peninsula. Similar erosional truncations of underlying rocks within an individual formation have been described by Tyler (1972, p. 550, Fig. 21) from the Pigeon Point Formation in California. However, the scale of the erosional truncations in the channel facies of Hesquiat Formation is considerably larger than that of the published Pigeon Point examples. The largest erosional discordance seen by the writer (Pl. 1) truncates at least 61 m (200 ft.) of the variegated rocks of the Seventh resistant sandstone-conglomerate member and overlies them with an angular discordance of from 15 to 30 degrees.

Leclaire Point channel

This small and short (i. e. in the direction parallel to the coast line) area of the channel-fill facies occurring on the eastern side of Hesquiat Peninsula (*see* Fig. 2), consists of only two resistant sandstone-conglomerate members and two shale-clayey sandstone members. All members are of early Lincoln age (i. e. *Molopophorus stephensoni* time) and so are contemporary with only the basal part of the Barcester Bay (or principal) submarine channel of the peninsula which contains the same macroinvertebrate fauna [i. e. approximately with its basal 366 m (1200 ft.) interval from the base of the formation to the top of the Second shale-clayey sandstone member]. The Second resistant sandstone-conglomerate member of the Leclaire Point submarine channel is overlain conformably and apparently gradationally by a thick succession of almost exclusively argillaceous rocks estimated to be at least 1525 m (5000 ft.) thick. This sequence of interchannel facies of Hesquiat Formation occupies all of the eastern coast of the peninsula between the southern base of Leclaire Point and the axis of Hesquiat Syncline just north of Matlahaw Point. It includes the argillaceous equivalents of the succession between and including the Third resistant sandstone-conglomerate member and the Seventh resistant sandstone-conglomerate member of the Barcester Bay (or principal) submarine channel. This correlation is based on the presence of the lower Blakeley macroinvertebrate fauna in the uppermost units exposed (*see* section on age and correlation for further details).

The channel-fill facies of the Leclaire Point submarine channel is lithologically, sedimentologically and environmentally identical to that of the already discussed Barcester Bay (or principal) submarine channel. Therefore, and as the section concerned was described by Jeletzky (1954, p. 44-46) in considerable detail, these questions will not be discussed in this paper.

The absence, on the eastern side of Hesquiat Peninsula, of any coarse-textured units corresponding to the majority of the resistant sandstone-conglomerate members of the Barcester Bay (or principal) submarine channel, is attributable to the Leclaire Point channel becoming inactive either within or immediately after the end of early Lincoln time. Subsequently, it was soon filled with the predominantly or entirely argillaceous sediments of the interchannel facies. The Barcester Bay submarine channel, in contrast, remained intermittently active throughout the recorded duration of the Hesquiat Formation (*see* Pl. 6, fig. 2).

Like the Barcester Bay (or principal) submarine channel, the lateral channel to interchannel facies changes cannot be seen within the outcrop belt of the Leclaire Channel of the Hesquiat Formation since both of its thick resistant sandstone-conglomerate members persist laterally between the low-tide mark and the forest fringe. However, there are indications of a rapid lateral westward and eastward petering out of these two members.

The westward thinning and final disappearance of the resistant sandstone-conglomerate members of the Leclaire Point submarine channel is suggested by the results of the northeast-southwest traverse of the northern half of the interior of Hesquiat Peninsula. If they were present, these members should project across and occur on this line of traverse. However, this is not the case as mentioned in the preceeding section. Also the previously mentioned, generally flat and almost featureless relief of the corresponding area of the interior of the peninsula supports this conclusion. Shorter traverses in the forested areas adjacent to the east coast of the peninsula (*see* Jeletzky, 1954, geol. map 1) also suggest westward thinning of these two resistant sandstone-conglomerate members within about 1. 6 km (1 mi) from the coast, as indicated in Figure 2.

The evidence concerning the separation of the Barcester Bay and Leclaire Point submarine channels from each other by an intervening zone, several kilometres wide, of interchannel facies, as well as the paleontological dating of these two channel-fill facies, indicates that the northeastern shelf of the Oligocene sea of Tofino Basin was transected by at least two major active submarine channels during the early (i. e. early Lincoln) stages of the Oligocene transgression. The reasons for the early abandonment of the Leclaire Point channel and the persistence of the Barcester Bay (or principal) channel are obscure.

The reasons for the writer's belief that the eastern margin of the Leclaire Point channel was situated just off the east coast of the Hesquiat Peninsula (*see* Fig. 2) are exactly the same as those given in the case of the western margin of the Barcester Bay (or principal) channel. First, the deep and wide Hesquiat Harbour is unlikely to have been excavated in the rocks of the resistant channel-fill facies and, second, the outcrops of the Hesquiat Formation occupying Hesquiat Point belong exclusively to the mostly argillaceous interchannel facies. Furthermore, the seaward-protruding, bold outline of the segment of the coast occupied by the channel-fill facies of the Leclaire Point channel contrasts strongly with the landward-concave, receding outline of the adjacent segment of the shoreline (i. e. between Leclaire Point and Anton's Spit) occupied by the predominantly argillaceous rocks of the interchannel facies (*see* Jeletzky, 1954, geol. map 1; this paper, Fig. 2). Finally, there are some suggestive lateral changes in the lithology of the channel-fill facies of Leclaire Point channel and the equally suggestive directions of soft sediment deformations (*see* Pl. 4, fig. 1).

A commonly occurring alternation of pebble conglomerate and resistant sandstone in the Second resistant sandstone-conglomerate member of Hesquiat Formation in the Leclaire Point section (*see* Jeletzky, 1954, p. 46, units 12, 13) can be interpreted as indicating the position of this section at the eastern margin of the Leclaire Point channel, where the channel may have been characterized by frequently recurring overflows of its presumably leveed rim. These overflows apparently began abruptly and resulted in deposition of conglomeratic interbeds overlying the sandstone and mudstone beds with sharp, frequently uneven, obviously erosional contacts. The abrupt and uneven upper contacts of these conglomeratic interbeds suggest an equally abrupt termination of the overflows. This sequence is believed to represent, therefore, an alternation of frequent but short, abruptly beginning and ending, periods of deposition of argillaceous, arenaceous and rudaceous sediments on top of the eastern levee of the Leclaire Point submarine channel. The southeastern to eastern direction of slumping of soft sediment folds observed in unit 5 of the section (*see* Jeletzky, 1954, p. 44; this paper, Pl. 4, fig. 1) suggests an eastern direction of paleoslope and is believed to correspond to the same eastern levee of the Leclaire Point channel.

The downslope (i. e. southward) extension of the Leclaire Point channel is unknown because the rocks of the Second resistant sandstone-conglomerate member plunge beneath the younger rocks of the interchannel facies at the southern flank of Leclaire Point and do not reappear on the southwestern limb of the Hesquiat Syncline. The small area of the channel-fill facies outcropping at the tip of Matlahaw Point (also see below) consists of lower Blakeley rocks. Therefore, it is much younger than any part of the Leclaire Point channel-fill facies and cannot represent its southern extension. No attempt was made to indicate the subsurface extent of the Leclaire Point channel-fill facies in Figure 2. However, it is unlikely to extend southward beyond the southern part of Hesquiat Peninsula for the same reasons as those given for the Barcester Bay (or principal) channel.

Matlahaw Point outcrop-area

An apparently isolated, small, outcrop-area of channel-fill facies occupies the tip of Matlahaw Point between the low-tide mark and the forest fringe (*see* Jeletzky, 1954, p. 49, units 6, 7). The only unit of the channel-fill facies at this location is 36. 5 to 38 m (120-125 ft.) thick and overlies disconformably a thick, predominantly argillaceous sequence of interchannel facies rocks containing lower Blakeley macroinvertebrates. Therefore, and because of its occurrence on the lower plate of a major, northeastward dipping thrust (*see* Jeletzky, 1954, p. 49, geol. map 1), the Matlahaw Point channel-fill unit is either correlative with, or somewhat younger than, the Homeis Cove exposures of the Sixth resistant sandstone-conglomerate member of the Barcester Bay channel.

A definitive evaluation of the Matlahaw Point outcrop-area of the channel-fill facies is not yet possible. However, the conglomeratic unit 7 (Jeletzky, 1954, p. 49) was observed to pinch out on the tidal shelf approximately 45 m (150 ft.) southeast of the tip of Matlahaw Point (Jeletzky, unpubl. final report) and to become replaced laterally by an irregular interbedding of resistant coarse grained, pebbly sandstone and pebbly siltstone. It is assumed, accordingly, that the Matlahaw Point unit of the channel-fill facies peters out completely within a few hundred yards southeast of its exposure-area. Although it was not possible to trace the Matlahaw Point unit into the Homeis Cove outcrop-area of the Sixth resistant sandstone-conglomerate member of the Barcester Bay (or principal) channel across the swampy and almost featureless interior of Hesquiat Peninsula, the two units definitely project into each other (*see* Fig. 2). Therefore, it seems possible that the Matlahaw Point outcrop-area is a short-lived offshoot of the Barcester Bay (or principal) submarine channel which formed during either the last or the second to last (more likely) major episode of plastic mass flowage down this channel (a temporary overflow accompanied by erosion). More work is needed either to confirm or to reject this suggestion, which was accordingly not indicated in Figure 2.

Inner Bajo Reef outcrop-area

The small outcrop-area of the channel-fill facies of the Hesquiat Formation occupying most of the Inner Bajo Reef and the tip of Bajo Point, Nootka Island was studied in some detail (Jeletzky, 1954, p. 19-21, geol. map 2; 1973, p. 352-354). Like the Matlahaw Point outcrop-area, it cannot be evaluated definitively at present. However, the writer doubts the feasibility of a previously made suggestion (Jeletzky, 1954, p. 25) that this outcrop-area is a lateral, northwestern extension of the channel-fill facies outcropping on Hesquiat Peninsula (i. e. a short-lived offshoot of either the last or the second to last major episode of mass flowage down the Barcester Bay channel). Although not impossible, this idea appears to be difficult to reconcile with the inferred (*see* earlier in this section) presence of a wide zone of interchannel facies of Hesquiat Formation beneath Nootka Sound. It seems more likely that the Inner Bajo Reef outcrop-area of the channel facies is an erosional remnant of an independent, southwest-trending, early Blakeley submarine channel which funnelled plastic mass flowage of sediments from a delta composed of coarse textured sediments that arose in late Oligocene (i. e. early Blakeley) time somewhere in the interior of the present Nootka Island. A southwestern rather than southern direction of the suggested Bajo Point submarine channel is indicated by the southwestward overturning of penecontemporaneous slump folds in the uppermost shale-clayey sandstone member of this section (Pl. 4, fig. 2).

Interchannel facies

The areal distribution and the lithology of the interchannel facies of Hesquiat Formation were described in the preceding sections in connection with the discussion of adjacent outcrop-areas of the channel facies. However, it is necessary to point out that the lithology of the interchannel facies is rather variable from one section to another and from one outcrop-area to another The briefly described (Jeletzky, 1954, p. 43, geol. map 1) Matlahaw Point-Smokehouse Bay area is, for example, characterized by an abundance of small inclusions, pods, lenses and lenticular beds of coarse- to medium-grained resistant sandstone, pebble conglomerate, and pebbly shale within the predominantly shale-clayey sandstone facies. So far as it is possible to judge, these coarser grained inclusions are extremely irregularly shaped, discontinuous, and small to medium in size. Lenses and lenticular beds more than 6 m (20 ft.) thick and 61 m (200 ft.) long are the exception and most are considerably smaller. These arenaceous to rudaceous rocks interfinger irregularly with the commonly distinctly and thinly bedded to laminated, flysch-like arenaceous and argillaceous rocks. This Matlahaw Point-Smokehouse Bay variant of the interchannel facies is flanked on the northeast by the previously described slightly younger Matlahaw Point outcrop-area of the channel facies. Toward the southwest, it appears to grade laterally into a large Smokehouse Bay-Estevan Point-Homeis Cove outcrop-area of a typical interchannel facies consisting almost exclusively of argillaceous and fine- to very fine grained arenaceous rocks, which were described in the section on the shale-clayey sandstone facies. The Matlahaw Point-Smokehouse Bay outcrops of the interchannel facies are interpreted accordingly as an area of frequent and minor to extensive spillover of the channel-fill sediments carried either by the unexposed older phase of the Matlahaw Point submarine channel or by another adjacent channel concealed either by the sea or by the forest. No similar lithologically variegated "spillover" areas have been observed either within or at the exposed margins of the other large area of interchannel deposits outcropping between the southern side of Leclaire Point and the axis of Hesquiat Syncline north of Matlahaw Point (*see* Jeletzky, 1954, p. 46-49, geol. map 1). However, as mentioned previously in the section on the shale-clayey sandstone facies, coarser grained inclusions, pods and even larger lenses and interbeds [up to 0. 61 m (2 ft.) thick and some 30. 5 m (100 ft.) long] may occur locally in this outcrop-area of the interchannel facies. The previously discussed mud to fine sand flowage and the injection of these argillaceous to fine arenaceous sediments into the pods, lenses and interbeds of coarser grained sediments are widespread in all known exposure-areas of the interchannel facies.

Inner neritic to littoral facies and the position of southeastern shoreline

Jeletzky (1954, p. 53) earlier noted the abundantly macrofossiliferous nature of the predominantly arenaceous rocks of the Hesquiat Formation (formerly Division C) outcropping within the middle Tertiary fault block on Flores Island. It was noted also (Jeletzky, 1954, p. 63, 64) that on Flores Island: "the shoreline of the Oligocene sea was situated to the southeast and east of the coastal plain now occupied by the Tertiary marine sediments". However, no explicit paleoecological analysis of these rocks was attempted in the preliminary report.

The lower or Sandstone-shale member outcropping closer to the eastern base of Rafael Point than the Resistant sandstone-conglomerate member (Jeletzky, 1954, p. 53, geol. map 1) appears to be an exclusively inner neritic to littoral deposit because it contains an abundant and variegated, indigenous fauna of pelecypods, gastropods, echinoids and crabs at many levels. The argillaceous interbeds of the Sandstone-shale member are considered to be largely or entirely inner neritic (or upper sublittoral) deposits since the macroinvertebrate fauna found therein is more variegated than the outer neritic fauna of the lower Lincoln shale-clayey sandstone members of the formation on Hesquiat Peninsula and, also, because it includes a much larger ratio of ornate gastropods and thick shelled, deeply burrowing pelecypods. These macroinvertebrates, occurring for the most part in concretions, are almost exclusively complete, excellently preserved specimens lacking any signs of fragmentation or abrasion by wave action. As mentioned in the section on the environmental interpretation of macroinvertebrate faunas, the local presence of brecciated or convoluted fossiliferous rocks (e. g. Jeletzky, 1954, p. 53) merely attests to the depositional instability of the shelf slope but does not indicate any redeposition into the bathyal zone of the rocks and fossils concerned.

The arenaceous and rudaceous interbeds of the local Sandstone-shale member appear to be mainly or exclusively littoral deposits. The thin to medium and fairly regularly bedded sandstones are often coquina-like. They are composed, commonly, of small fragments of molluscan shells and contain many larger fragments and complete to nearly complete shells of these fossils. This fauna also includes a considerable ratio of echinoid (cidaroid) spines and their fragments. The matrix of the conglomeratic interbeds has commonly the same coquinoid composition as the above-described sandstone interbeds and frequently contains large fragments and complete shells of the same macroinvertebrates. The above data, and the apparent absence of complete pelecypod shells with valves tightly closed or only slightly gaping, suggests a high-energy (i. e. open beach), upper rather than lower littoral environment.

The thick, Resistant sandstone-conglomerate member [91. 5-106. 5 m (300-350 ft.) thick] outcropping on the southern side of Rafael Point closer to its tip (Jeletzky, 1954, p. 53, 54, geol. map 1) is only superficially similar to the mass flow deposited, resistant sandstone-conglomerate members of Hesquiat Peninsula. This predominantly regularly bedded and mainly medium- to thick-bedded unit (Pl. 5, figs. 1, 3) includes many extremely calcareous sandstone beds rich in fragments and complete shells of ornate shallow-water gastropods including *Epitonium condoni* Dall, *Priscofusus* sp., and others, large, thick-shelled pelecypods including common *Ostrea* (sensu lato) *lincolnensis* Weaver, scaphopods, and numerous spines of cidaroid echinoids. Some of these shelly sandstones grade locally into coquinoid impure limestones. The matrix of gritty and conglomeratic interbeds is almost invariably calcareous, and commonly rich in fragments and complete shells of the same shallow-water macroinvertebrates as those occurring in the sandstone. It may grade locally into coquinoid impure limestone. Upper surfaces of sandstone beds are covered locally by large, low-crested, symmetrical ripple-marks (up to several metres across) (*see* Pl. 5, fig. 3) and interference ripple-marks. The sum total of the above data clearly indicates that the Resistant sandstone-conglomerate member concerned is a littoral, and almost certainly upper littoral, deposit formed by traction currents and waves in a highly active (open beach) marine environment.

The common presence of *Ostrea* (sensu lato) *lincolnensis* Weaver suggests a somewhat lowered salinity of the depositional environment of this Resistant sandstone-conglomerate member, closely resembling that of the Tatchu Point outlier of the Escalante Formation (*see* Jeletzky, 1975a). This member presumably was deposited on coarse sandy to pebbly beaches in close proximity to the delta of a river draining the youthful, early Oligocene tectonic land of central Vancouver Island (*see* Fig. 3).

The above environmental interpretation suggests that the sometimes huge, oversize clasts (*see* Pl. 5, fig. 3) of the Vancouver Group volcanics commonly occurring in the Resistant sandstone-conglomerate member have a different origin than the oversized clasts occurring in the channel-fill facies of Hesquiat Formation on Hesquiat Peninsula. These blocks, which are up to 6 m (20 ft.) long and 1. 8 m (6 ft.) thick, and which are angular to poorly rounded, probably either fell from the cliffs or rolled down the steep slopes fringing the open sea beaches of the early Lincoln sea on Flores Island. Their imperfect rounding apparently was achieved subsequently by abrasion by waves and sand grains in the intertidal zone where they found their final resting place. There is, thus, no evidence that the coarse textured delta inferred to exist immediately inland from the present site of Rafael and Dagger points (*see* Fig. 3) was depositionally unstable like its Hesquiat Peninsula counterpart.

The inferred deposition of this Resistant sandstone-conglomerate member, within a few hundred metres in front of the southeastern shoreline of the early Lincoln sea, finds further support in the presence of strong lateral facies changes of the Hesquiat Formation within the middle fault block of the Tertiary rocks. As already mentioned by Jeletzky (1954, p. 55, geol. map 1), the local Sandstone-shale member of the Hesquiat Formation does not reappear on the northwestern side of Rafael Point, where the rocks of the local Resistant sandstone-conglomerate member outcrop continuously to the southwestern base of Dagger Point and grade downward into the conglomeratic rocks of the Escalante Formation (i. e. Division A of Jeletzky, 1954, p. 54, geol. map 1). These facies relationships indicate a rapid northwestward pinching out of all argillaceous interbeds of the Sandstone-shale member within the intervening interior part of Rafael Point. The writer explains these relationships by the rapid convergence of the littoral exposures of the Hesquiat Formation with the northwest-southeast-trending shoreline of the early Lincoln sea. In the writer's opinion, this Lincoln sea shoreline almost coincides with the present-day shoreline of the Pacific Ocean at the southern base of Dagger Point. At the northern base of this point, however, the shoreline apparently is shifted right laterally inland for an indetermined distance along a major southeast-trending fault (*see* Jeletzky, 1954, geol. map 1). The reported presence of layers of carbonaceous shale in the bed of Cow Creek (Brewer, 1921; Jeletzky, 1954, p. 63, 64) possibly may help to evaluate the horizontal displacement involved if and when it is confirmed by future work.

As far as it is known at this time, the middle fault block of the Tertiary rocks on Flores Island comprises the only known outcrops of the littoral facies of Hesquiat Formation, such as must have fringed the whole extent of the eastern margin of the Hesquiat-Nootka embayment of the Tofino Basin.

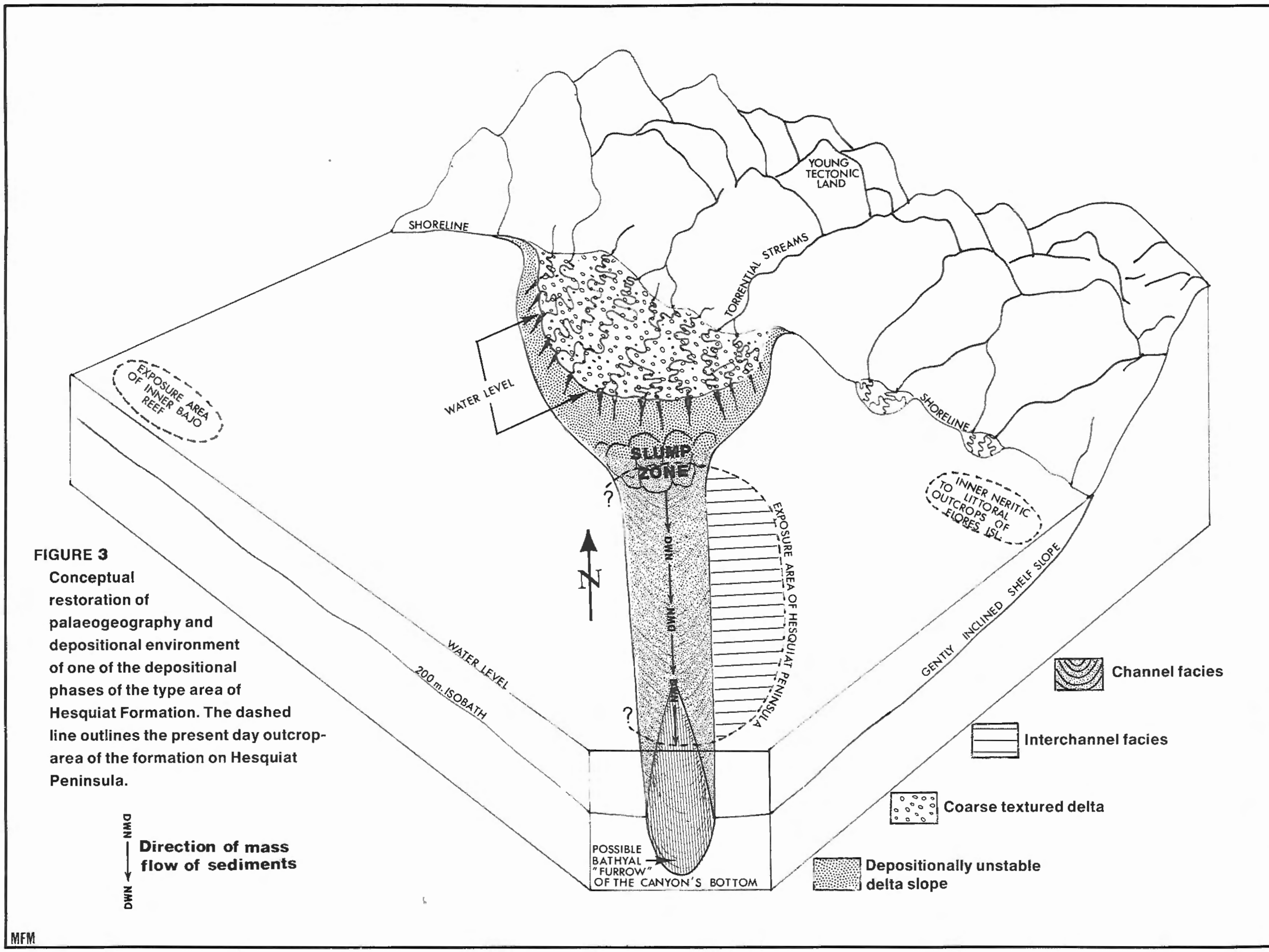

FIGURE 3
Conceptual restoration of palaeogeography and depositional environment of one of the depositional phases of the type area of Hesquiat Formation. The dashed line outlines the present day outcrop-area of the formation on Hesquiat Peninsula.

The lithology, sedimentology and depositional environment of the lower Lincoln beds of Flores Island assigned to the inner neritic to littoral facies of Hesquiat Formation in this paper differ very strongly from the previously discussed equivalent beds of the formation, including its type section. They would have been assigned to a formational unit of their own, except for the small size of the only known outcrop-area.

GENERAL CONCLUSIONS

Probable reasons of cyclical alternation of mass flow deposited and suspension settled sediments

As discussed previously in this report, the depositional regime of some of the active submarine channels of the Hesquiat Formation is characterized by a cyclical alternation of several (up to seven in the Barcester Bay channel) major periods of plastic mass flowage and deposition with equally prominent periods of deposition of predominantly or entirely suspension settled sediments. The preservation of the record of such a depositional regime, representing anywhere from two to seven successive generations of fossil submarine channels, appears to be a most exceptional event since the writer was unable to find a comparable example in the literature accessible to him on fossil submarine valleys and canyons. All fossil submarine channels (all deep-sea features) known to him, such as Dohem Channel (Normark and Piper, 1969), Pigeon Point Canyon (Lowe, 1972), Butano Canyon (Nilsen and Simoni, Jr., 1973; Nelson and Nilsen, 1974), Megano Channel (Dickas and Payne, 1967), Annot Channel (Stanley and Unrug, 1972), etc., appear to record but a single channel generation (i. e. a single major cut-and-fill episode) corresponding to one shale-clayey sandstone and one resistant sandstone-conglomerate member of the channel-fill facies of the Hesquiat Formation.

The regularly cyclical pattern of plastic mass flowage and deposition appears to differ drastically from the other pattern of plastic mass flow and deposition which is common to the channel and interchannel facies of the Hesquiat Formation. The latter pattern is characterized by a highly irregular, rare to common occurrence of small- to medium-size pods, lenses and lenticular beds of the resistant sandstone-conglomerate facies within thick beds and members of the shale-clayey sandstone facies. The lower contacts of these coarse grained interbeds are erosional. This irregular depositional pattern may be explained (following Stanley and Unrug, 1972, p. 305, 306; *see* also previous sections of this paper) by a seasonal introduction of coarse sand and gravel from coarse-textured delta(s) into the mud-covered environment of the outer shelf. It also may represent minor, localized cut-and-fill episodes caused by occasional overflowing of major channels by coarse grained sediments and their resulting spillover into the adjacent parts of interchannel areas. However, neither of these two explanations (which are by no means mutually exclusive) appears to be adequate to explain the pattern involving repeated plastic mass flow deposition of continuous bodies, up to 200 m (675 ft.) thick and commonly more than 1.6 km (1 mi.) in length, of the resistant sandstone-conglomerate facies (i. e. First to Seventh resistant sandstone-conglomerate members in the Barcester Bay channel; *see* Appendix and Fig. 2). The deposition time of such bodies must have been measured not in years but in millenia. Nor does it seem possible to explain these major, presumably rather prolonged, episodes of mass flowage and deposition of coarse grained clastics by their having been triggered by earthquakes. The sediment bodies involved seem to be too large and at the same time too localized for such an origin. Such a hypothesis appears to be applicable only to the previously mentioned, small- to medium-size, individualized episodes of deposition of the resistant sandstone-conglomerate facies.

However attractive it may seem, it does not appear possible to explain the above-mentioned cyclical depositional pattern by invoking a series of transgression-regression episodes involving the whole land and sea area of the Oligocene Hesquiat-Nootka embayment of Tofino Basin. The vertical succession of marine facies observed in Division B on Nootka Island (Jeletzky, 1973, p. 359, Fig. 2) suggests instead a gradual deepening and widening of the Oligocene basin, at least during early and middle Lincoln time, corresponding to the time of deposition of the greater part of the Hesquiat Formation on Hesquiat Peninsula (except for the uppermost beds containing the lower Blakeley macroinvertebrate fauna). The inferred regression during late Lincoln and earliest Blakeley time on Nootka Island (Jeletzky, 1973, p. 359, Fig. 2) apparently was an isolated, minor event which replaced an upper bathyal regime by an only slightly more shallow outermost neritic regime.

The depositional regime of Hesquiat Formation on Hesquiat Peninsula also is characterized by an apparently complete absence of an alternating transgression-regression pattern. As mentioned previously, all evidence available would oppose an assumption that the depth of active submarine channels decreased markedly (i. e. from outer neritic to inner neritic or littoral) during the major episodes of plastic mass flowage and deposition. These data are consistent with the continuity of the largely or ?entirely outer neritic depositional regime within the areas of interchannel facies of Hesquiat Formation indicated by the persistence of argillaceous facies and outer to outermost neritic macroinvertebrate faunas there. Moreover, the evidence available is at least somewhat suggestive of a weak (i. e. within the outer neritic zone) but continuous deepening of the Oligocene sea on Hesquiat Peninsula during the time of deposition of the Hesquiat Formation. This pattern of events, corresponding in part to that of Division B on Nootka Island, is suggested in particular by the gradual replacement of the massive concretionary "shales" prevalent in the lowermost part of the Hesquiat Formation by the somewhat deeper but still outer neritic thinly bedded to laminated, regularly banded, argillaceous to very finely arenaceous rocks which are more common or prevalent in the middle and upper part of the formation. The previously mentioned increase of the ratio of pebbly mudstones in the upward succession of Hesquiat Formation on Hesquiat Peninsula also may be interpreted as suggesting a gradual deepening of the Oligocene sea at that time.

The nearshore facies of the Hesquiat Formation outcropping on Flores Island (*see* above) does not exhibit any features suggestive of a pulsating transgressional-regressional regime any more than does its outer neritic facies. Finally, there is no evidence available within the preserved outcrop-areas of the Hesquiat Formation that would indicate, or even suggest, a southward progradation of the coarse textured Oligocene delta which is inferred to have existed immediately to the north or northeast of the type-area of the formation on Hesquiat Peninsula.

These data, which indicate the existence of either a stationary outer neritic regime or a nearly continuous northward-directed transgression of the Oligocene sea across the Nootka-Hesquiat embayment of Tofino Basin, suggest that the cyclical alternation of major episodes of mass flowage and deposition with those of deposition from suspension was caused by tectonic events confined to the adjacent, youthful Oligocene tectonic land of Vancouver Island. These tectonic events apparently consisted of recurrent uplifts of the mountainous landmass, causing the rejuvenated rivers and torrents to dump masses of poorly sorted, coarse, arenaceous to rudaceous sediments at the shoreline, sharply increasing the sediment supply of restricted coarse-textured delta(s) of the type described by Stanley and Unrug (1972, p. 305, 306). These deltas will be discussed in the following sections of this paper. The depositional instability of the fronts of these deltas, discussed below must have been greatly increased by the increased supply of coarse grained sediments. This must have resulted, in turn, in a strong increase of slumping sliding, and mass flowage of the sediments at the delta front and on the adjacent parts of the gently sloping shelf. The latter continued to subside steadily to counteract the upbuilding by the deposited sediments. In the writer's opinion, only the occurrence of such relatively long-lasting periods of tectonic uplift and a rapid wasting of the rejuvenated tectonic land can account for the repeated occurrence of major episodes of plastic mass flowage and deposition within active submarine channels of the report-area. The cyclical alternation of these episodes with the major episodes of largely to entirely suspension settled deposition of fine grained clastics within the same submarine channels indicates an alternation of the phases of uplift with somewhat prolonged periods of tectonic quiescence within the tectonic land concerned. The intervening, larger areas of the interchannel facies of the Hesquiat Formation (Fig. 2) were either unaffected or relatively little affected (e. g. the apparent spillover area of Matlahaw Point-Smokehouse Bay) by the episodes of plastic mass flowage and deposition. This was apparently due, generally, to effective canalization of the bulk of coarse grained sediments.

The apparently opposed sense of tectonic movements consisting of an almost (or at least largely) steady subsidence and infilling of the northeastern shelf area of Tofino Basin and pulsating tectonic uplifts within the adjacent tectonic land, can be explained either by fault block movements or by hinge movements of these parts of the report-area. The fault block movement hypothesis involves the postulated presence of an intermittently active, major northwest-trending fault (or faults) along the northeastern shoreline of the Oligocene Hesquiat-Nootka embayment of Tofino Basin.

The assumption of a hinge-like style of tectonic movements would involve a series of rotary movements of the northeastern flank of Tofino Basin around a northwest-trending axis situated at or near its northeastern shoreline. Such an asymmetrical type of hinge movement was invoked recently by Jeletzky (1975b, p. 50, Fig. 22) to explain the paleogeography and facies pattern of Early Albian time in northern Yukon.

The evidence now available does not permit a choice between the two alternative hypotheses. However, the writer is inclined to favour the fault block movement hypothesis, considering the well-established presence of suitably situated, major, northwest-trending Tertiary faults within the report-area.

The nature of the principal source of coarse clastics

The Hesquiat Formation reaches its maximum known thickness on Hesquiat Peninsula. The coarse textured channel-fill facies of the formation is largely restricted to the northern part of this peninsula and passes laterally into finer grained clastics toward the south (*see* Fig. 2). Northwestward, on Nootka Island, the formation is replaced laterally by the largely contemporary suspension-settled argillaceous rocks of Division B (*see* Jeletzky, 1954, p. 25, geol. maps 1, 2; 1973, p. 353, Fig. 1). Eastward of Hesquiat Peninsula on Flores Island, the channel-fill and interchannel facies of the formation are replaced laterally by a largely arenaceous, more shallow water (inner neritic to littoral) either suspension-settled or traction current transported facies (*see* Jeletzky, 1954, p. 53-55; this paper, p. 23-26). These facies relationships clearly indicate that the principal source of the coarse textured, outer neritic, plastic mass flow sediments of the Hesquiat Formation was situated nearby to the north or possibly to the northeast of its present outcrop-area on Hesquiat Peninsula where the Tertiary rocks apparently were completely destroyed by subsequent erosion.

The deposition of the outer neritic channel and interchannel deposits of Hesquiat Formation, as they are actually developed on Hesquiat Peninsula and elsewhere, depended on the presence of some kind of a depositionally unstable, steep, slide- and slump-prone submarine slope farther inshore. Only such a nearshore slope could effectively substitute the continental slope which facilitated the deposition of the recent and fossil, deep-water equivalents (i. e. plastic mass flow deposits) of the Hesquiat Formation. Within the shelf zone such a slope is more likely to occur at the forefront of a constructive (i.e. sediment-rich) delta of the type described by Shepard (1955; 1967; 1973, p. 337, 338). As mentioned previously, Stanley and Unrug (1972) explicitly derive pebbly mudstones of the Provençal coast from such coarse textured deltas. Stauffer (1967, p. 507, Fig. 1) favours, in contrast, the deposition of his Californian examples of plastic mass flow deposits seaward of a shoreline either lacking or almost lacking a shelf and devoid of deltaic sediment influxes. However, Stauffer (1967, p. 501, 502) aptly noted that the theoretical prerequisites of a plastic mass flow are just as well fulfilled by the presence of a steep but relatively short, depositionally unstable slope; he states: "The initial dispersion of a granular mass could be accomplished by its beginning to slide on a steep slope. The flow, once dispersed, could then be selfsustaining on lesser slopes."

Another possible alternative is the presence of a steep scarp of a major fault closely paralleling the open Oligocene shoreline of the report-area shoreward of a broad, gently inclined shelf zone. The presence of such fault(s) within the report-area is probable because of considerations presented in connection with the discussion of reasons for the pronounced cyclicity of the depositional regime of the channel-fill facies on Hesquiat Peninsula. The writer considers the existence of such fault(s) as the more likely of the two alternative tectonic patterns capable of explaining some of the observed features of the depositional and structural regime of the area. The second alternative is the possibility of rotational movement along an axis trending along the shoreline and situated in its proximity. However, unlike the structural and depositional influence of such a fault, its purely sedimentological influence was apparently minor. The prevalent sedimentological influence of the coarse textured delta inferred to exist immediately to the north of the present day outcrop-area of the Tertiary rocks on Hesquiat Peninsula manifests itself in the following lithological properties of the sediments of the Hesquiat Formation:

1. The poor to imperfect rounding of rudaceous clasts in all conglomerate and pebbly mudstone beds of the Hesquiat Formation. This poor to imperfect rounding indicates that the clasts have been derived directly from a coarse-textured delta bypassing the pebbly beach environment. Any clasts that had experienced a lateral, nearshore transport along the coast and/or passed through a pebbly beach environment prior to their incorporation into the plastic mass flow deposit would be much better rounded than the clasts of Hesquiat Formation.

2. The grains of coarse- to medium-grained sandstones of all resistant sandstone-conglomerate members are just as poorly rounded as their rudaceous clasts. This suggests the same depositional history for the arenaceous particles as for the rudaceous clasts.

3. The local abundance of well-preserved to fragmentary plants; grains, pebbles, fragments, and lamellae of shiny coal; and pieces of *Teredo*-bored wood in rocks of the formation.

4. The presence of freshwater macroinvertebrates (e.g. *Viviparus* sp. indet., ?*Corbicula* sp. indet.) in some marine faunas of the type section of the formation.

The coarse to very coarse texture of the resistant sandstone-conglomerate members of the Hesquiat Formation is indicative also of the highly elevated, rugged, rapidly wasting nature of the Oligocene land of Vancouver Island flanking the Hesquiat-Nootka embayment of Tofino Basin on the northeast. As pointed out by Stanley (*in* Stanley *et al.*, 1969, p. DJS-9-11) such textures

> "suggest a high-standing land area and a high rate of sedimentation on the relatively narrow shelf platform producing oversteepening and periodic failure of the rapidly accumulating sediments. This high rate of sedimentation seems to be localized, i.e. most probably seaward of deltas built by mountain rivers carrying coarse sediments along their steep gradients to the coast. This interpretation is suggested by the typical association of coarse-grained sediment shoe-string bodies and abundant plant detritus (Fig. DJS-46) as noted in the Maritime Alps and Carpathian examples."

This interpretation is illustrated in the schematical block diagram of Figure 3. It explains satisfactorily the above-mentioned lithological contrast between the largely contemporary Hesquiat Formation and Division B. The principal outcrop-area of the former pinpoints the position of a coarse textured, rapidly growing Oligocene (Lincoln and early Blakeley) delta. This delta was formed by rapid mountain rivers and seasonal torrents which drained the rugged and high Oligocene tectonic landmass of Vancouver Island. This rugged mountainous coastline must have been similar orographically to that of the Maritime Alps of southern France (*see* Stanley and Unrug, 1972, p. 305-306) or to that of many areas of the present-day west coast of North America with the sea lapping against the coast mountains.

Probable reasons for shelf entrapment and preservation of channel deposits

The largely or perhaps entirely outer neritic character of the channel and interchannel deposits of the Hesquiat Formation indicates the existence of a fairly broad, gently outwardly inclined shelf in front of the predominantly rudaceous to coarse arenaceous delta discussed in the preceding section. This shelf was at least 24 km (15 mi.) wide (probably considerably wider) judging by the present day width of outcrops of the Hesquiat Formation on Hesquiat Peninsula and the postulated width of the original, more shallow water zone north therefrom. The effectiveness of this shelf as a sediment trap is suggested by the circumstance that, so far as known, the only deep well of Shell Canada Ltd. drilled in front of Nootka Sound and Hesquiat Peninsula did not encounter any rocks similar to the channel-fill facies of Hesquiat Formation (*see* Shouldice, 1971, p. 417, 418, Figs. 16, 17). The inferred deposition of the bulk of the coarser textured sediments of that facies of Hesquiat Formation resulting from plastic mass flow within the presently exposed northeastern shelf of the Tofino Basin must be due to a special set of conditions. As noted recently by a number of sedimentologists (e.g. Stanley *in* Stanley *et al.*, 1969; Morris, 1971; Stanley and Unrug, 1972; Lowe, 1972, p. 79), active submarine canyons and valleys are primarily linear zones of sediment movements rather than sites of sediment deposition. As pointed out by Lowe (1972, p. 79): "Only the least mobile sediment transport systems are likely to deposit a substantial amount of sediment within active canyons or channels. These deposits, moreover, will survive erosion by latter currents only if the overall activity of the channel is decreasing".

The apparently exceptional accumulation and preservation of the outer neritic channel-fill facies of Hesquiat Formation was caused by the combination of a continuing, rapid subsidence of this zone with an equally rapid infilling by an accumulation of predominantly argillaceous clastics. Another important factor appears to be the opposition of tectonic movements occurring within this basin to those occurring within the adjacent youthful tectonic land of the Oligocene Vancouver Island.

The hypothesis of an opposed sense of tectonic movement helps to explain the preservation of the channel-fill facies of the Hesquiat Formation once it was deposited within the shelf zone. However, it does not clarify the reasons for the entrapment of this facies within the shelf zone. The entrapment of sediment was most likely caused by the shortness of the depositionally unstable delta front (*see* preceding section). Because of this inferred shortness, the initial impetus provided by the slumping and sliding of the delta front was likely insufficient to produce plastic mass flows capable of crossing the shelf and spilling over the shelf break farther offshore.

Another possible explanation is a small extent (?off Nootka Island only; *see* Jeletzky, 1973) or even an almost complete absence of a deep-water zone within Tofino Basin. The still poorly known Oligocene sediments of the offshore wells (Shouldice, 1971, p. 417, Figs. 16, 17) seem to be so similar lithologically to those of Division B and to the interchannel facies of Hesquiat Formation that they may have been deposited in the same outer to outermost neritic environment. No flyschoid-type sediments are mentioned by Shouldice (1971) and the micropaleontological evidence of a deep-water depositional environment of the sediments encountered in these deep wells appears to be inconclusive to the writer (*see* Jeletzky, 1973). Moreover, the presence of an outer neritic facies among these sediments was indicated by Shouldice (1971, p. 417). Because of the above considerations and the absence of the Oligocene rocks in two of the southern Shell Canada wells (Shouldice, 1971; Tiffin *et al.*, 1972, p. 290), it seems possible to the writer that the Oligocene generation of Tofino Basin, of which the Nootka-Hesquiat embayment formed a part, was not a major oceanic basin wide open to the west. It could have been, instead, a minor, relatively shallow, partly or even entirely land-encircled, residual trough (a successor basin in the sense of Eisbacher, 1974, p. 274), largely devoid of bathyal depths even in the middle part. If so, there may have been no shelf break and no continental slope off the Hesquiat Peninsula-Flores Island segment of the basin. Either one of the combinations of submarine topographical features postulated herein could have been responsible for the arrest of the downward movement of most or all of the slumps, slides and plastic mass flows within a short distance of the depositionally unstable delta front. The erosional phases of each plastic flow episode presumably were short and restricted to its initial stage only. They were followed presumably by much longer periods of accumulation of the channel-fill deposits within the excavated, blindly ending submarine channels. These deposits apparently were filling each generation of channels to, or almost to, the rim.

The above discussed depositonal set up of the Hesquiat Formation appears to be unlike any set up recorded within the shelf zones of contemporary seas. Nor does it conform closely to any of the hypothetical types of pre-Quaternary continental shelves constructed by Curray (1967; *in* Stanley, *et al.*, 1969; p. JC-VI-1-18, Fig. JC-VI-7), even though the shelf itself approaches one of the types postulated by Curray (*in* Stanley *et al.*, 1969, p. JC-VI-14, Fig. JC-VI-7e).

Possible presence of deep-water (bathyal) deposits

The somewhat ambiguous suggestion made previously (Jeletzky, 1973, p. 359, 362) regarding the deposition of "argillaceous to arenaceous ?proximal turbidites of Divison C (i.e. those deposited on the western side of Hesquiat Peninsula; the writer's remark) "......" in a more rapidly subsiding ?uppermost bathyal 'furrow' adjacent to the strongly elevated southeastern shoreline of the embayment" needs a clarification and an adjustment. This suggestion was based originally on the apparently complete absence of macroinvertebrate fossils in the late Lincoln and early Blakeley beds of the type section [i.e. from the Fourth resistant sandstone-conglomerate member of the type section (*see* Appendix) to the equivalent of the Sixth resistant sandstone-conglomerate member on the southern side of Homeis Cove (*see* Jeletzky, 1954, p. 42, geol. map 1; this paper, Fig. 2)]. This situation appeared to contrast strongly with the abundantly to sparsely macrofossiliferous character of the roughly equivalent (mainly or ?entirely lower Blakeley) rocks in the Hesquiat village-Matlahaw Point section (*see* Jeletzky, 1954, p. 48) and on the southern shore of Hesquiat Peninsula between Matlahaw and Estevan points (these faunas have always been considered to be indigenous by the writer). The few macroinvertebrates studied prior to the completion of the 1973 paper (i. e. Jeletzky, 1973) from the fossil localities situated between Homeis Cove and the tidal flats south of Estevan Point were not considered relevant as they were suspected to be redeposited. This opinion was later changed. These two areas of apparently contrasting paleoenvironment coincide respectively with the distribution of the late Lincoln to early Blakeley channel-fill facies and that of the roughly contemporary (mainly or ?entirely early Blakeley) interchannel facies (*see* Fig. 2). It is these contrasting macrofaunal relationships that suggested to Jeletzky (1973, p. 359, 363) the possibility of a considerably greater, possibly bathyal, depth of water within the late Lincoln to early Blakeley generation of the principal (or western) erosional channel of the Hesquiat Peninsula compared with that of the outer neritic depths within the adjacent contemporary interchannel area. An assumption of such a major difference in the depth of water between adjacent channel and interchannel areas appeared to be compatible with some published examples (e. g. Shepard and Dill, 1966; Shepard, 1973, p. 325-327, Figs. 11-16) of similar relationships in contemporary oceans. It also seemed to offer a possible solution to some (though by no means all) of the previously discussed contradictory micro- and macrofaunal data. To elucidate further the meaning of the "?uppermost bathyal furrow" of Jeletzky (1973, p. 359, 362), this hypothetical feature is indicated in Figure 3. It must be stressed emphatically, however, that the writer, more recently, has come to doubt the feasibility of this idea. First, the thinly bedded to laminated, regularly banded, predominantly argillaceous type of the shale-clayey sandstone facies outcropping between Homeis Cove and Estevan Point (*see* earlier in this paper and Pl. 4, fig. 3) is no longer thought to be of proximal turbiditic origin. Second, it does not appear feasible any longer to question the indigenous nature of any of the lower Blakeley macroinvertebrate faunas found in the interval between Homeis Cove and Estevan Point and on tidal flats south of Estevan Point (*see* section on environmental interpretation of macroinvertebrate faunas for further details). These data make it difficult to interpret the predominantly argillaceous lower Blakeley rocks concerned as deep-water (i. e. bathyal) deposits. Because of the outer neritic character of this adjacent interchannel facies, it seems much more likely that the late Lincoln to early Blakeley generation of the channel was not a deep canyon-like feature representing the head part of a deep-sea canyon crossing the continental slope, but a broad and relatively shallow submarine valley which ended blindly within the wide, gently inclined shelf area surrounding the postulated Oligocene delta shown in Figure 3. As mentioned elsewhere in this paper (*see* p. 29), the coarse textured mass flow deposits filling this generation of the channel apparently were unable to cross the northeastern shelf of the Hesquiat-Nootka embayment of the Oligocene sea because of the insufficient initial impetus provided by slumping and sliding off the steep delta front (*see* section on the nature of the principal lateral source of Hesquiat Formation for further details). Because of the above considerations, the late Lincoln to early Blakeley generation of the Barcester Bay (or principal) channel of the Hesquiat Peninsula is shown in Figure 2 as ending blindly within the outer neritic interchannel facies just south of Homeis Cove.

The lateral extent of the early to mid-Lincoln generation of the principal channel is unknown as the older rocks concerned disappear beneath the cover of upper Lincoln to lower Blakeley rocks north of Barcester Bay and do not reappear within the exposed part of the southwestern limb of Hesquiat Syncline anywhere between Homeis Cove and the tidal flats south of Estevan Point. However, there are no reasons to assume that any part of the bottom of the early to mid-Lincoln generation of the channel was overdeepened in comparison with the late Lincoln to early Blakeley generation. This is suggested by the previously discussed presence of excellently preserved, undoubtedly indigenous, outer neritic molluscs and crabs of an early and middle Lincoln age within the confines of the channel. The probability of a continuing northward-directed transgression of the sea throughout Lincoln time is also contrary to the assumption of an overdeepening of the bottom of the early to mid-Lincoln generation of the principal Hesquiat Peninsula channel as compared with its late Lincoln to early Blakeley generation.

Is the Hesquiat Formation a submarine fan?

The Tertiary unit designated as the Hesquiat Formation in this paper recently was classified as a deep-sea fan deposit (Cameron, 1975, p. 18). However, the preceding sedimentological and environmental analysis of the formation raises grave doubts in the writer's mind regarding the validity of this assignment. Although it is largely a product of submarine channel and interchannel deposition forming a distinctly thickened sedimentary lens (a depocentre), the Hesquiat Formation is considered here to be either predominantly or completely a shelf deposit. It includes several mostly or entirely disconnected ribbon- to tongue-shaped areas of largely or entirely outer neritic channel-fill deposits. These deposits were derived immediately from the adjacent, slumping and sliding delta front(s) by means of a short distance mass flowage. These areas of channel-fill facies are separated from each other by larger areas of largely or possibly entirely outer neritic interchannel deposits which were derived mostly by suspension settling from the same delta front(s). The whole, apparently fan-shaped and possibly formerly upward bulging sediment body of Hesquiat Formation is flanked by lithologically and environmentally distinctive, and considerably thinner, mostly suspension settled units. These are Division B on Nootka Island and Tatchu Point and the inner neritic to littoral strata of Hesquiat Formation on Flores Island. The nature of the seaward front of the Hesquiat Formation is somewhat uncertain but its channel facies probably peters out within the shelf zone of Tofino Basin.

Though geometrically and depositionally similar to a deep-sea fan, the Hesquiat Formation is environmentally and genetically unlike it. The term deep-sea fan is applied, by general agreement (e. g. Stanley and

Unrug, 1972; Mutti, 1974; Normark, 1970, 1974; Shepard, 1973; Whitaker, 1974), to fan-like clastic bodies occurring on the basal part of the continental slope, continental rise and adjacent parts of abyssal plain. The sediments of these fans consist predominantly of shelf deposits funnelled down deep-sea canyons and valleys dissecting the continental slope.

Because of these genetic and environmental distinctions the Hesquiat Formation cannot be classified as a deep-sea fan. It appears to represent, instead, the apparently first known example of an ancient shelf or shallow water marine fan. The writer knows of only one somewhat similar sedimentary body described in the literature - the so-called Reserve Fan in Lake Superior (Normark, 1974, p. 61, Fig. 4). However, this shallow-water fan is an entirely man-made sedimentary body. The geometrical and sedimentological analysis of the Reserve Fan carried out by Normark (ibid.) demonstrated that at least the man-made fans, possessing diagnostic features of deep-sea fans, can form at present in relatively shallow, essentially shelf depths. The preceding analysis of the Hesquiat Formation indicates that genetically and environmentally similar shelf fans also were forming naturally in the pre-Quaternary shallow seas in areas adjacent to the river deltas.

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APPENDIX

Description of the type section of Hesquiat Formation

The following section is reproduced here essentially as originally published by Jeletzky (1954, p. 28-41). The original arrangement of beds and members from the base to the top, instead of the customary arrangement from the top to the bottom, was retained to permit the use in this paper of the bed and member numbers used by Jeletzky (1954, p. 28-41). The original thicknesses measured in feet have been supplemented by approximate metric equivalents. Furthermore, graphs have been added providing cumulative upward footages and equivalent metric thicknesses from the base of the section. Most of the beds have been measured by pacing across their prevalent strikes and by computing approximate true thicknesses in the office, using their average true dips. The citation of minimum and maximum values usually reflects either marked variations of dip within individual beds or members or the uncertainty resulting from their faulting and/or contortion. In some instances minimum and maximum values have been cited in order to reflect pronounced changes of thicknesses within a short distance along the strike.

The section was measured on the tidal shelf of the western side of Hesquiat Peninsula on the northeastern limb of Hesquiat Syncline between the southern base of Escalante Point and the axis of Hesquiat Syncline at the point about 1.8 km (1.12 mi) south of the northwest corner of Barcester Bay (*see* Jeletzky, 1954, geol. maps 1, 2; this paper, Figs. 1, 2).

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
	First shale-clayey sandstone member		
	(Bed No. 1 represents the base of Division C)		
1	Shale, ash-grey to dark grey, fissile to massive, with rows of septaria-like, limy concretions up to 3-4.5 m (10-15 ft) in diameter, and of small, variously shaped, sandy, shaly, and limy concretions; in the lowermost 4.5 to 7.5 m (15-25 ft), the latter carry well-preserved index species of crabs: *Portunites alaskensis* Rathbun and *Eumorphocorystes naselensis* Rathbun, together with some molluscs and plant remains; base not exposed	±53(±175)	±53(±175)
2	Shale, ash-grey, sandy, grading into sandy siltstone, fissile to massive; rich in variously shaped, small, calcareous, sandy concretions, which carry well-preserved crab remains of *Portunites alaskensis* Rathbun and *Eumorphocorystes naselensis* Rathbun	9-12(30-40)	62-65(205-215)
3	Sandstone, fine- to medium-grained, clayey, shale-like; mostly thinly bedded to laminated and multicoloured, with light yellow, light green, and tawny laminae and layers alternating throughout most of the succession	76-91(250-300)	138-156(455-515)
	First resistant sandstone-conglomerate member		
4	Pebbly shale, dark grey, fissile, grading into pebbly siltstone, rich in small to large pebbles and rounded to irregularly shaped sandstone and shale concretions; overlies zone 3 with an uneven and sharp contact indicating an erosional disconformity; upward becomes more and more sandy and grades imperceptibly into zone 5	9-11(30-35)	147-167(485-550)

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
5	Pebble-conglomerate, relatively well-bedded; in addition to pebbles derived from rocks of the Vancouver Group and the Coast Intrusions, contains numerous pebbles of sandstone, rolled shaly concretions, and angular pieces of these rocks, which apparently were derived from the underlying Tertiary rocks; pebbles vary widely in size and are embedded in sandy or gritty matrix, their size decreasing markedly upward and, apparently, to the southwest; top concealed beneath the ocean	9-11(30-35) (visible)	156-178(515-585)
6	Interval covered by beach deposits or by the water of the bay; believed to be the site of a major northwesterly trending fault zone; width across strike	457-876(1500-2550)	- -
	Second shale-clayey sandstone member		
7	Shale, dark grey, very sandy; occurs in isolated patches within a strip of beach deposits; very badly contorted and crushed	±15(±50)	171-193(565-635)
8	Shale, dark grey, sandy; interbedded with similar sandstone; includes at least one bed of pebble-conglomerate similar to bed 5; badly contorted and crushed. The following fossils were collected from concretions in a shale bed: *Portunites alaskensis* Rathbun, fossil leaves, twigs and needles of *Sequoia* (in a broad sense) sp. indet., top not exposed	±15(±50) (visible)	186-208(615-685)
9	Interval covered by beach deposits (?a fault)	±15(±50)	201-223(665-735)
10	Shale, dark grey, sandy, fissile, interbedded with beds and layers of the laminated, shale-like sandstone and siltstone; fossil leaves, small pieces of coal, *Dentalium* sp. indet., and pelecypods (genus and species indet.) were collected from midway of this zone; top not exposed	±23(±75) (visible)	224-246(740-810)
11	Covered by beach deposits (?a fault with northwesterly trend)	±9(±30)	233-255(770-840)
12	Rocks entirely similar to those of zone 10	±6(±20)	239-261(790-860)
13	Sandstone, buff-coloured, coarse grained, resistant	2-2.5(6-8)	241-263(796-868)
14	Sandstone, fine- to medium-grained, shale-like, clayey, thinly bedded to laminated; includes some beds and layers of similarly looking, laminated, sandy to pure shale and siltstone up to 1.5-3.0 m (5-10 ft.) thick	91-107(300-350)	332-370(1096-1218)
15	Sandstone, similar to that of bed 13, but with a honeycombed surface and thinly bedded	6-8(20-25)	338-378(1116-1243)
16	Sandstone, similar to that of zone 14	30.5(±100)	368-409(1216-1343)
17	Sandstone, similar to that of beds 13 and 15	±3(9-10)	371-412(1225-1353)
18	Sandstone, similar to that of beds 14 and 16	30.5-46(100-150)	401-458(1325-1503)

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
19	Sandstone, brownish grey, coarse grained, calcareous, with dispersed pebbles and gritty particles; in the lower part contains concretions of shale with rough surfaces, which are apparently in place; these concretions carry crab remains of *Portunites alaskensis* Rathbun [(Bed 19 and all the rocks in its vicinity are very irregularly and strongly contorted, heavily faulted, and apparently thrust upon the underlying rocks in the northerly direction. The estimated displacement of the overthrust rocks amounts to 4. 5-6. 0 m (15-20 ft.) or more)]	3-4. 5 (10-15)	404-462 (1335-1518)
20	Shale, grey, sandy, fissile, with numerous concretions of calcareous shale; pods and lenses of grit, and dispersed small and large pebbles occur commonly in this zone. Index crab species *Portunites alaskensis* Rathbun and *Eumorphocorystes naselensis* Rathbun were collected in the calcareous concretions; this is the highest recorded occurrence of these fossils in Division C on Hesquiat Peninsula	±4 (12-14)	408-466 (1347-1532)
21	Pebble-conglomerate, coarse, lithologically similar to that of bed 5; forms a lenticular bed	0-1 (0-3) Fluctuates from almost nil to some 1 metre within short distances	408-467 (1347-1535)
22	Sandstone, brownish grey, coarse grained, thickly bedded, resistant	4. 5-6 (15-20)	412-473 (1362-1555)
23	Shale, dark grey, fissile; at certain levels carries large, calcareous, septaria-like concretions and small, rounded, calcareous, grey concretions; overlies bed 2 conformably	±46 (±150)	458-519 (1512-1705)
24	Shale, multicoloured, laminated; with large, calcareous, septaria-like concretions and small, rounded, calcareous, grey concretions, covered with a red or tawny crust; overlies zone 23 conformably	76-91 (250-300)	534-610 (1762-2005)
25	Sandy shale and siltstone interbedded with shaly, fine grained, clayey sandstone; conformably overlies zone 24; top cut off by a major fault zone of westerly to northwesterly trend	11-12 (35-40) (visible)	545-622 (1797-2045)
26	Shale, dark grey, brownish weathered, partly laminated and sandy; interbedded with beds 0. 3 to 1. 5 m (1-5 ft.) thick of resistant, coarse grained, brownish weathered, grey sandstone and grit, which occur at intervals of from 0. 9 to 6 m (3-20 ft.); bottom and top cut off by major faults of westerly to northwesterly trend	30. 5-36 (100-120) (visible)	575-658 (1897-2165)

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
27	Sandstone, dull green to light grey, coarse grained, gritty, resistant, occurs in beds from 0. 3 to 1. 5 m (1-5 ft.) thick; bottom of this zone is cut off by a major fault of westerly to northwesterly trend	9-11(30-35) (visible)	584-669(1927-2200)
28	Shale, grey, laminated; interbedded with superficially similar, fine grained, shale-like, clayey sandstone; rocks are badly faulted and sheared; top of the zone cut off by a major fault of northwesterly trend	9-11(30-35) (visible)	593-680(1957-2235)
	Second resistant sandstone-conglomerate member		
29	Sandstone, bluish grey, coarse grained, resistant; bottom concealed under the topsoil at the fringe of the forest	±6(±20) (visible)	599-686(1977-2255)
30	Sandstone, fine- to coarse-grained, laminated, impure	4. 5-6(15-20)	603-692(1992-2275)
31	Shale, grey, thinly bedded to laminated, sandy; interbedded with superficially similar, fine grained sandstone; both are rich in dispersed pebbles in the upper 2. 4 or 3 m (8 or 10 ft.); poorly exposed in part; contact with bed 32 is poorly exposed but seems to be disconformable	±12(±40)	615-704(2032-2315)
32	Pebble-conglomerate, coarse to medium, similar to bed 5; forms lenticular beds from 0. 9 to 2. 1 m (3-7 ft.) thick; interfingered with the similarly thick lenticular beds, lenses, and pods of coarse grained, resistant sandstone, grit, and, in one or two places, of light grey, partly sandy, fissile shale; grades into bed 33 imperceptibly; shattered into fault blocks from several square yards to several scores of square yards by a dense net of minor faults	27-30. 5(90-100)	642-734(2122-2415)
33	Shale, light grey to ash-grey, sandy; locally containing numerous dispersed pebbles and pods of grit; lower beds contain lenses and layers of pebble-conglomerate	11-12(35-40)	653-746(2157-2455)
34	Sandstone, grey, mostly thinly bedded, partly shale-like, fine- to coarse-grained; interbedded with layers and pods of coarse grit and fine pebble-conglomerate	15-18(50-60)	668-764(2207-2515)
35	Pebble-conglomerate, coarse to fine; interbedded with beds and lenses of brownish grey grit and coarse grained resistant sandstone	8-9(25-30)	676-773(2232-2545)
36	Sandstone, greenish grey to greenish yellow, resistant, coarse grained, gritty; top not exposed	4. 5-6(15-20) (visible)	680-779(2247-2565)
37	Covered interval occupied by beach deposits; assumed to represent the site of a major fault or of a fault zone	±15(±50)	695-794(2297-2615)

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
	Third shale-clayey sandstone member		
38	Sandstone, brownish grey, resistant, slabby, coarse grained, in beds from 9. 15 to 30. 5 cm (0. 3-1. 0 ft.); interbedded with beds 0. 6 to 0. 9 m (2-3 ft.) thick of finely grained, laminated sandstone; base not exposed	9-11(30-35) (visible)	704-805(2327-2650)
39	Shale and siltstone, dark grey, superficially similar lithologically to the overlying shale-clayey sandstone members	82-91(270-300)	786-896(2597-2950)
40	Sandstone, dark grey, shale-like, laminated to thinly bedded, fine grained; interbedded with considerable thin beds and layers of resistant, coarse grained, brownish grey sandstone	61-64(200-210)	847-960(2797-3160)
41	Shale, brownish grey to tawny, laminated	18-20(60-65)	865-980(2857-3225)
42	Pebble-conglomerate, tightly packed, hard; the lowermost pebbles embedded in the underlying shale	0. 15-0. 30(0. 5-1)	- -
43	Sandstone, buff coloured, coarse grained, poorly sorted; carries numerous, small to large pebbles up to 10. 2 to 15. 2 cm (4-6 in.) in diameter, irregularly dispersed in sandy matrix	3-3. 5(10-12)	868-983(2867-3237)
	Third resistant sandstone-conglomerate member		
44	Pebble- to boulder-conglomerate, in beds from 1. 5 to 3. 6 m (5-12 ft.) thick, which form from 70 to 80 per cent of the total thickness of the zone; large boulders and blocks up to several feet in diameter occur in beds of fine to coarse pebble-conglomerate; interfingered with conglomerate beds are several lenticular beds of coarse grained, resistant, brownish grey sandstone and grit, rich in dispersed, small and large pebbles, and from 1. 5 to 2. 4 m (5-8 ft.) thick; beds of sandy, grey shale rich in dispersed pebbles also occur in this conglomerate zone; in some conglomerate beds abundant rounded fragments of light grey shale were observed; the conglomerate zone rests on an uneven and apparently eroded surface of bed 43 with a sharp, erosional contact	30. 5-46(100-150)	898-1029(2967-3387)
45	Sandstone, yellowish grey, coarse grained, gritty; grades downward into conglomerate of zone 44	1-2(4-6)	899-1031(2971-3393)
	Fourth shale-clayey sandstone member		
46	Sandstone, grey, fine- to coarse-grained, weak to resistant; interfingered with minor beds and layers of sandy shale, and with a few thin beds and layers of coarse grit and fine pebble-conglomerate; minor fine grained, shale-like, clayey sandstone and sandy shale, some locally rich in dispersed pebbles and nests of grit; grades downward into zone 45	9-11(30-35)	908-1042(3001-3428)

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
47	Shale, dark grey to tawny, laminated; interbedded with similarly coloured, fine grained, shale-like, clayey sandstone; beds of coarse grained, partly gritty, resistant, dark to light grey sandstone from 0.15 to 0.6 m (0.5-2 ft.) thick occur in this zone at intervals ranging from 0.3 to 3 m (1-10 ft.); small (mostly only up to a few cm in diameter), rounded or irregularly shaped, marcasitic, shaly, and limy concretions, with a red to tawny crust (? limonitic crust) occur commonly both in shale and in clayey sandstone beds; a few, grey, light yellowish weathering, septaria-like concretions were observed in shale beds. Beds of coarse grained sandstone are commonly rich in small lenses, pods, and pieces of coal, in pieces of fossil wood, and in poorly preserved fragments of plants and bark. Determinable fossils were found only in one zone of laminated, grey shale some 4.5 to 6 m (15-20 ft.) thick and including five to six beds of coarse grained, resistant sandstone, which occurs some 36 m (120 ft.) above the base of the zone; here the rocks commonly contain abundant fragments and small pods of coal, disintegrated plant remains, and marine shells, which include among others *Dentalium* sp. indet., *Acila* sp. indet. (?cf. *shumardi* Dall), and *Nucula* sp. indet.; fossils occur both in shale and in sandstone; in the former, however, they mostly do not occur in the same layers with plant remains and coal	116-122 (380-400)	1024-1164 (3381-382
	<u>Fourth resistant sandstone-conglomerate member</u>		
48	Sandstone, greenish to yellowish grey, light coloured, coarse grained, partly gritty, resistant, interfingered throughout with a considerable, but locally variable, amount of lenses and lenticular beds of grit and pebble-conglomerate; at the base, a bed of coarse pebble-conglomerate 4.5 to 6 m (15-20 ft.) thick persists across the outcrop of this member; overlies the uneven, apparently eroded surface of the Fourth shale-clayey sandstone member (i.e., zone 47) with a sharp, erosional contact; strongly faulted	21-46 (70-150) Varies locally from 21 to 46 metres possibly owing to faulting	1045-1210 (3451-397
	<u>Fifth shale-clayey sandstone member</u>		
49	Shale, dark grey, fissile, laminated, with small marcasitic and limy shale concretions, which are covered with a red to tawny (? limonitic) crust; thin beds of resistant, coarse grained sandstone occur at more or less regular intervals (as in overlying and underlying shaly zones and members); the upper 13.5 m (45 ft.) are built almost exclusively of pure shale, whereas the lower 16.5 m (55 ft.) consist of sandy shale, interbedded with considerable thinly bedded to laminated, shale-like, clayey sandstone and coarse grained, resistant sandstone	30.5 (100)	1075-1240 (3551-404

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
	Fifth resistant sandstone-conglomerate member		
50	Boulder- to cobble-conglomerate; most beds carry blocks up to 3 by 15 m (10 by 50 ft.) square, or more, of slates and volcanic and pyroclastic rocks of the Vancouver Group, granitic rocks of the Coast Intrusions, and greenish sandstones, apparently derived from the older Tertiary members; cobbles and boulders are of the same composition as the blocks; only a few minor lenticular beds and lenses of fine pebble-conglomerate, grit, and coarse grained, gritty sandstone were observed in the upper part of this conglomerate zone; the lowermost conglomerate bed rests with a very sharp contact on the deeply eroded, uneven surface of the Fifth shale-clayey sandstone member; an angular unconformity of 5 to 10 degrees at the contact	91-107(300-350)	1166-1347(3851-4428)
51	Sandstone, light yellow to greenish grey, coarse grained, heavily bedded, resistant; interfingered with numerous beds, lenses, and pods of grit, and pebble-conglomerate; relative amount of sandstone and conglomerate beds varies widely along strike, and conglomerate may predominate locally; grades downward into conglomerates of bed 50; top concealed beneath the sea	8-11(25-35) (visible)	1174-1358(3876-4463)
52	Covered by the waters of a deep, narrow bay; at the head of the bay, and in the mouth of a small creek, are poor outcrops of sandstones and sandy shales	61-76(200-250)	1235-1434(4076-4713)
	Sixth shale-clayey sandstone member		
53	Sandstone, grey, thinly bedded, fine- to coarse-grained, partly shale-like, interbedded with minor layers and beds of dark grey shale; base concealed beneath the sea	71-91(250-300) (visible)	1306-1525(4326-5013)
54	Shale, dark grey, thinly interbedded with fine- to medium-grained, dark grey to brownish grey sandstone	14-15(45-50)	1320-1540(4371-5063)
55	Shale, dark grey, laminated, mostly pure; interbedded with thin layers and beds of fine- to coarse-grained, partly resistant sandstone; shale rich in irregularly shaped, shaly and marcasitic concretions from 1.25 cm to 10 cm (½ in.-4 in.) in diameter, covered with a brick-red to tawny crust; grades upward into bed 56	106.5-122(350-400)	1426-1662(4721-5463)
56	Sandy shale, dark grey, laminated, rich in dispersed small pebbles and in grit particles; small pods of grit	3.5-4.5(10-15)	1429-1666(4731-5478)
	Sixth resistant sandstone-conglomerate member		
57	Pebble-conglomerate, coarse to fine, interfingered with highly variable amounts of beds, lenses, and pods of coarse, resistant sandstone, grit, and pebbly to gritty shale and siltstone; conglomerate beds predominate		

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
	in this zone on both sides of Split Cape and thin gradually toward the southeast to be replaced by gritty sandstones, pebbly shales, and other rocks; within Barcester Bay this resistant sandstone-conglomerate member disappears beneath the sea to reappear on the south-eastern side of the bay in its full thickness.		
	On the northwestern side of Split Cape, at least 90 to 105 m (300-350 ft.) of this resistant sandstone-conglomerate member is exposed above the top of the Sixth shale-clayey sandstone member, but its top is concealed beneath the sea. The basal beds of the member at Split Cape carry abundant sandstone pebbles, which are apparently locally derived; contact with the underlying Sixth shale-clayey sandstone member is very sharp and uneven, and evidently represents an erosional disconformity.		
	The inner northeastern shore of Barcester Bay again exposes the rocks that underlie the Sixth resistant sandstone-conglomerate member; the upward succession there is as follows:		
	<u>Fifth resistant sandstone-conglomerate member</u>		
51	Sandstone, light yellow to yellowish green, massive to heavily bedded, coarse grained, partly gritty; some plant remains occur in the lower beds; base not exposed	6-8(20-25)	1435-1674(4751-55
	<u>Sixth shale-clayey sandstone member</u>		
52 to 56	Regular interbedding of clayey, partly shale-like sandstones and sandy, laminated, partly multicoloured shales, interrupted at irregular intervals by several zones of coarse grained, resistant sandstones, with lenticular beds, layers, and pods of pebble-conglomerate some 1.5 to 4.5 m (5-15 ft.) thick. This succession is stratigraphically equivalent to beds 52 to 56 of the section north of Split Cape, but it is not possible to compare them bed by bed	213.5-228.5(700-750) (? or more)	1648-1902 (5451-6253)
	Beyond a covered interval of several hundred feet across the predominant strike of the rocks, the following, upper part of the Sixth shale-clayey sandstone member reappears on the southeast side of Barcester Bay		
56	Sandstone, brownish grey, medium grained, resistant; with interbeds of softer, grey, clayey sandstones and sandy siltstones; base not exposed	46-61(150-200)	1694-1963(5601-64
	<u>Sixth resistant sandstone-conglomerate member</u>		
	The following succession of this resistant sandstone-conglomerate member is exposed on the southeastern shore of Barcester Bay and farther southwest along the shore:		

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
57a	Pebble conglomerate, coarse to fine, hard; with interbeds, lenses and pods of various sandstones; overlies bed 56 with a sharp contact suggestive of an erosional disconformity	±15 (±50)	- -
57b	Sandstone, soft, friable, clayey, grading into siltstone	±15 (±50)	- -
57c	Sandstone, yellowish grey to rust coloured, partly honey-combed, resistant, coarse grained; with minor beds, lenses, and pods of soft or hard pebble-conglomerate	23-26 (75-85)	- -
57d	Sandstone, soft, fine- to medium-grained; with numerous pebbles; interbedded with sandy shale containing abundant pebbles or with hard pebble-conglomerate	21. 5-24. 5 (70-80)	- -
57e	Pebble-conglomerate, coarse; interbedded with minor lenticular beds and lenses of softer pebble-conglomerate, with an abundant sandy matrix, and with minor beds or lenses of coarse grained, gritty or pebbly sandstone	55-61 (180-200)	- -
57f	Sandstone, light grey, coarse grained, resistant to soft; interbedded with similar looking, pebbly sandstone and shale, minor beds of soft or hard pebble-conglomerate, and some fine grained, clayey sandstone	55-61 (180-200)	- -
57h	Shale, dark grey, sandy; abundant pebbles; overlies zone 57f with a sharp, uneven contact suggestive of an erosional disconformity	±30. 5 (±100)	- -
	Seventh shale-clayey sandstone member		
58	Shale, multicoloured, laminated; with variously shaped limy concretions; grades downward into zone 75h	152. 5-167. 5 (500-550)	1846-2130 (6101-7003)
	Seventh resistant sandstone-conglomerate member		
59	Pebble-conglomerate, coarse to medium; with lenses of coarse grained, partly honeycombed, brownish weathered sandstone; contact with zone 58 is poorly exposed, but appears to be conformable although sharp	±5 (16-17)	1851-2134 (6117-7020)
60	Shale, grey; with abundant pebbles and sandy grains; contains irregular pods and lenses of solidly packed, hard conglomerate; contact with bed 59 is indistinct, but it appears to be gradual	±23 (±75)	1874-2158 (6192-7095)
61	Sandstone, grey, rusty to buff weathered, coarse grained, heavily bedded; contains loaf-like, rusty weathered sandstone "concretions" (actually ripped up masses of only partly consolidated sediment) up to 3. 6 m (12 ft.) in maximum diameter and 1. 2 or 1. 5 m (4 or 5 ft.) thick	±3 (±10)	1877-2161 (6202-7105)

Unit	Lithology	Thickness metres (feet)	Height Above Base metres (feet)
62	Sandstone, grey, thinly bedded to laminated, fine- to coarse-grained, soft and friable	±7 (±20)	1884-2168 (6222-7125)
63	Pebble-conglomerate, coarse to fine; with pods and lenses of grit and sandstone resembling those of bed 61; contains high, rounded to angular sandstone "concretions" (i. e. ripped-up masses) similar to those of bed 61 in their dimensions; pods and lenses of light grey to whitish-grey, calcareous sandstone also occur in this bed; the relative amount of sandstone and conglomerate beds and lenses varies greatly within short distances along the strike, so that one or other rock type may predominate locally; bed 63 overlaps unconformably beds 58 to 62 inclusive, its base truncating their tops within some 150 yards along strike; an angular unconformity of some 15 to 30 degrees was measured at the contact of bed 63 with the underlying beds	7-15 (20-50)	1891-2183 (6242-7175)

PLATE 1

128976, 11-8-1952

Strong erosional discordance within the Seventh resistant sandstone-conglomerate member of the channel facies (Barcester Bay channel) of Hesquiat Formation exposed on the west side of Hesquiat Peninsula at the point approximately 1. 8 km (1. 2 mi) north of Homeis Cove. The flat tidal shelf on the right half of the photograph exposes from right to left beds 58 to 60 inclusive of the type section (*see* Appendix and Fig. 2) which are numbered accordingly. The precipitous hogsback on the left is built of bed 63 of the same section which forms an erosional discordance of 15 to 30 degrees with the above-mentioned older beds. All beds dip at low angles toward the left. View north 15° to 20° west into the outer part of Barcester Bay. Split Cape is in the extreme right middle background. Southeastern part of Nootka Island, with Nootka Cone almost behind Split Cape, is in the far backgroung on the right.

PLATE 2

Figure 1. *Acila (Acila) gettisburgensis* Reagan, 1909. Hypotype. GSC loc. 21733. GSC 43083. Lower Blakeley molluscan stage (upper Oligocene). Hesquiat Formation, Vancouver Island, west coast, east side of Hesquiat Peninsula, unit 2 of the Hesquiat village section, on tidal shelf near high-water mark at point about 274 m (900 ft.) southeast of shore bluffs flanking the southern part of Hesquiat village (*see* Jeletzky, 1954, p. 47, 48, geol. map 1 for further details). A complete shell which was extremely deformed and cracked during the early diagenesis of the sediment (soft-sediment deformation). 1a, left lateral view; 1b, right lateral view; 1c anterior view. All photographs are natural size.

Figure 2. *Acila (Acila) gettisburgensis* Reagan, 1909, Hypotype. GSC loc. 21733, GSC 43212. Same age, locality, and preservation as for the specimen reproduced in figure 1. 2a, left lateral view; 2b, right lateral view; 2c, anterior view. All photographs are natural size.

Figure 3. *Portunites alaskensis* Rathbun, 1926. GSC loc. 20261. GSC 43213. Lower Lincoln molluscan stage (lower Oligocene), *Molopophorus stephensoni* zone. Vancouver Island, west coast, northwestern side of Hesquiat Peninsula, small rocky shelf halfway between the southern base of Escalante Point and eastern end of Escalante Island. Collected in place in the lowermost 4.5 to 7.5 m (15-25 ft.) of the exposed thickness of unit 1 of the First shale-clayey sandstone member (*see* Appendix and Fig. 2). Ventral view of an almost perfectly preserved, quite undeformed, adult female still buried in part in a very early diagenetic concretion; collected in place in the shale. Introduced to demonstrate the indigenous character of the early Lincoln macroinvertebrate fauna occurring in the type section of Hesquiat Formation. x1.

Figure 4. Outside view of the concretion containing the *Portunites alaskensis* specimen reproduced in figure 3. Introduced to illustrate the irregularly rounded shape and the rough-surfaced appearance of this obviously indigenous concretion. x1.

Figure 5. *Eumorphocorystes naselensis* Rathbun, 1926. GSC loc. 20529. GSC 43214. The same age and general locality as for the specimen of *Portunites alaskensis* reproduced in figure 3. However, it was collected farther south in place from unit 20 of the Second shale-clayey sandstone member of the Hesquiat Formation (*see* Appendix and Fig. 2). The fossil locality is situated below high-tide mark about 2.4 km (1.5 mi.) south of the nameless rocky point closing from southwest the nameless broad bay next southeast to Escalante Point. This almost complete (posterior appendages are partly dismembered by scavengers), feebly diagenetically deformed and cracked specimen is introduced to demonstrate the indigenous character of the early Lincoln macroinvertebrate fauna occurring in the type section of the Hesquiat Formation. 5a, view from above; 5b, lateral view. Both photographs are natural size.

Figure 6. *Crassatelites* sp. indet. GSC loc. 21744. GSC 43215. Lower Lincoln molluscan stage (lower Oligocene), *Molopophorus stephensoni* zone. Vancouver Island, west coast, Escalante Island off the tip of Escalante Point on the west side of Hesquiat Peninsula. Collected from the 61 m (200 ft.)-thick sandstone member presumably either faulted out on the mainland or concealed within covered interval 6 of the type section of the Hesquiat Formation (*see* Appendix). A complete, bivalve specimen damaged during extraction from hard sandstone. Introduced to illustrate the typical mode of preservation, with valves gaping or closed, of deeply burrowing, lower littoral to innermost neritic pelecypod fauna of this sandstone member attesting to its indigenous character. x1.

Figure 7. A fossiliferous slab of shale affected by post-sedimentary mud flowage. GSC loc. 91280. GSC 43216. Middle Lincoln molluscan stage (middle or ?lower Oligocene), *Turritella porterensis* zone. Vancouver Island, west coast, west side of Hesquiat Peninsula, collected on the tidal shelf at the point about 7.2 km (4.5 mi.) south of Escalante Point from shale lump squeezed into the middle of three fossiliferous sandstone interbeds occurring about 36.5 to 42.5 m (120-140 ft.) stratigraphically above the base of unit 47 of the type section of Hesquiat Formation (*see* Appendix and Fig. 2). Introduced to illustrate the perfect perservation of pelecypods of the fauna, the unabraded appearance of mostly deformed and cracked pelecypod shells and their angular fragments (marked 1), and a complete lack of sorting of fossils according to size and shape (note the large foraminifer shell lodged next to the left valve of *?Ervillia oregonensis* Dall, marked 2). A perfectly preserved left valve of *Thyasira* cf. *T. disjuncta* (Gabb) is marked 3. x3 (approx.).

Figure 8. A richly fossiliferous slab of massive, argillaceous rock (?mudstone) affected by mud flowage. GSC loc. 91282. GSC 43217. The same age and general locality as for specimens illustrated in figures 1 and 2 but collected about 182.8 m (600 ft.) east (i.e. seaward) of the high-tide mark on the tidal flat from the extremely churned up, argillaceous rock surrounding sandstone inclusions reproduced in Plate 3, figure 1. Introduced for the same reason as the fossiliferous slab reproduced in figure 7. Two perfectly preserved single valves of *Yoldia* cf. *Y. blakeleyensis* Durham are marked 1. A deformed and cracked but nearly complete shell of *Dentalium* cf. *D. porterensis* Weaver is marked 2. A perfectly preserved, incomplete shark tooth is marked 3. Note the presence of numerous disorderly scattered large foraminifer shells and those of various small gastropods and pelecypods. x1.

Plate 2

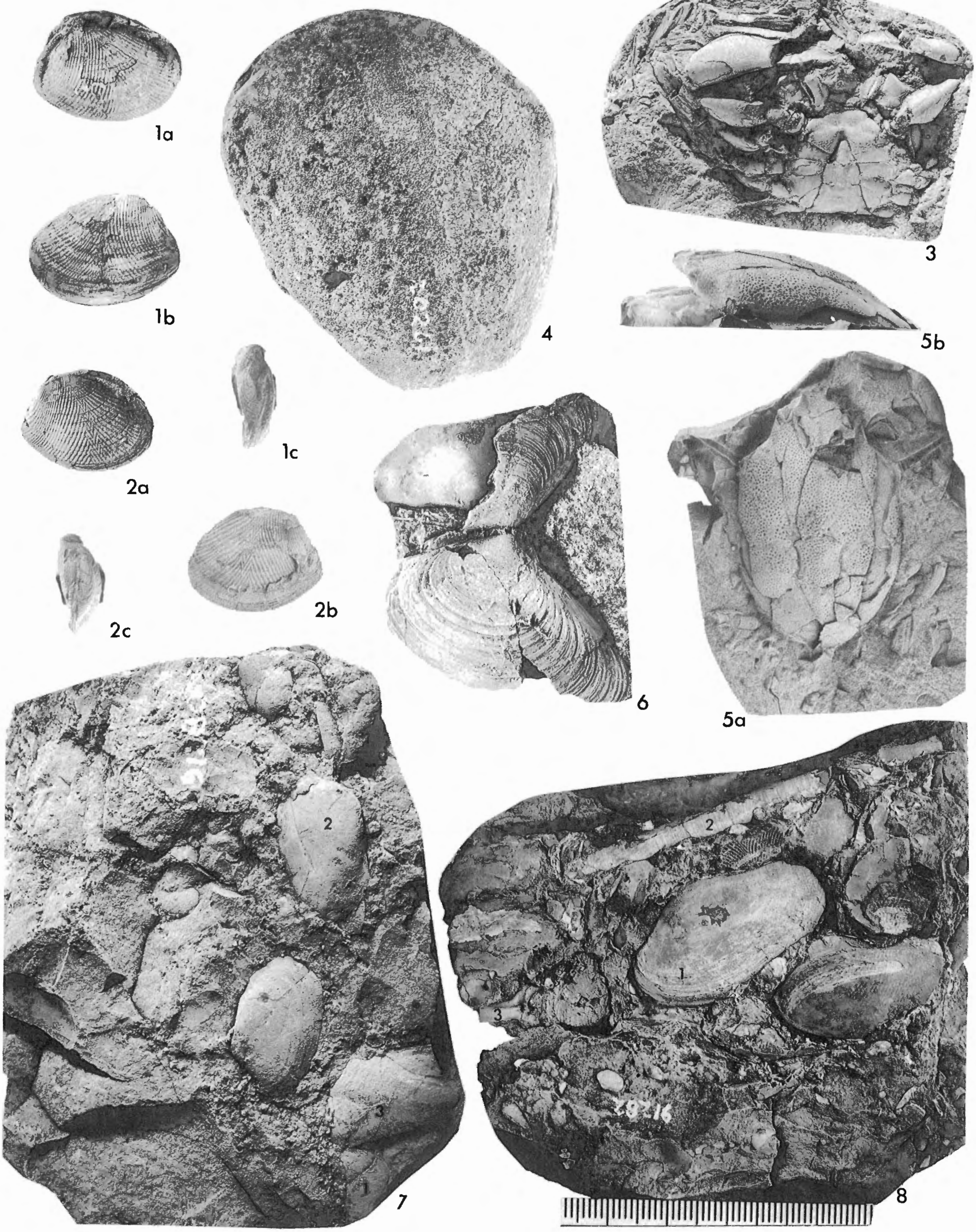

PLATE 3

202819

Figure 1. Soft-sediment flowage (mostly mud flowage) and injection in the predominantly argillaceous unit 2 of the abundantly fossiliferous section of Hesquiat Formation exposed on the east side of Hesquiat Peninsula in front of Hesquiat village (*see* Jeletzky, 1954, p. 47, 48, geol. map 1 for further details). View northwest (obliquely updip) across the shelf and roughly toward Hesquiat village. The photographed rocks are roughly in the position of fossil locality marked F on geological map 1. The whitish grey, concretionary lenses of fine- to coarse-grained, locally gritty sandstone have been strongly deformed and displaced by mud flowage. Judging by adjacent, less disturbed parts of the outcrop (*see* Pl. 6, fig. 1), they originally formed one or more rows of concretion-like lenses within the thick argillaceous unit 2. The uniformly grey, massive-looking argillaceous rock surrounding the arenaceous lenses is strongly churned up or porridge-like as a result of mud flowage. Both rock types are commonly richly fossiliferous (*see* Pl. 2, figs. 1, 2, 8).

202819-A

Figure 2. Contact of dark grey, concretionary, sandy siltstone of Hesquiat Formation (marked H) with coarse-grained, gritty and pebbly, calcareous sandstone of the basal part of Divison D (marked D) on Inner Bajo Reef, Nootka Island (*see* Jeletzky, 1954, p. 21, geol. map 2). View northwest (i.e. approximately downdip). The upper surface of the Hesquiat shale is truncated erosionally (?a submarine erosion) by the basal bed of Division D, as indicated by wedging out of the row of white calcareous concretions toward the right side of the photograph.

128862, 11-8-51

Figure 3. Thinly bedded to laminated, flyschoid phase of the shale-clayey sandstone facies of Hesquait Formation exposed on the tidal flat in the middle part of the northern side of Barcester Bay, Hesquiat Peninsula. The rocks in the foreground form part of beds 52 to 56 of the Sixth shale-clayey sandstone member of the type section (*see* Appendix and Fig. 2). View due north-west, approximately along the strike, which undulates considerably within the outcrop due to tear faulting. Light coloured, protruding beds are built of fine- to coarse-grained, partly hard and resistant sandstone. The intervening wider, recessive, darker coloured intervals are underlain by mostly thinly bedded argillaceous rocks, interbedded with clayey, fine- to very fine grained, multicoloured sandstone. The coarse-grained sandstone-conglomerate beds of the Sixth resistant sandstone-conglomerate member outcrop on the tidal flat in the extreme left background. These rocks replace the finer grained rocks of the Sixth shale-clayey sandstone member (foreground) laterally (*see* Jeletzky, 1954, geol. map 1). The regularly banded flyschoid phase of the shale-clayey sandstone facies outcropping in the foreground differs from that outcropping at Estevan Point (*see* Pl. 4, fig. 3) in the presence of numerous interbeds of fine- to coarse-grained, resistant sandstone.

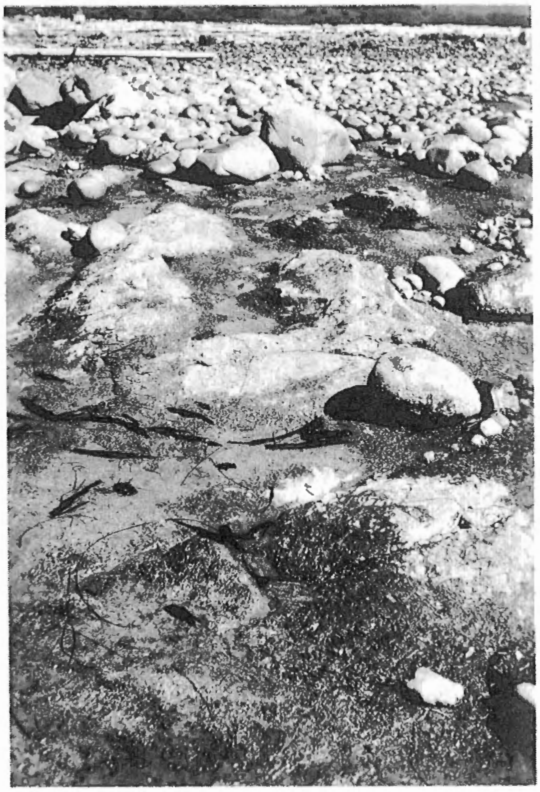

FIG. 1

FIG. 2

FIG. 3

PLATE 4

202819-C

Figure 1. Soft-sediment convolutions and flowage phenomena in argillaceous rocks of unit 5 of Leclaire Point section of Hesquiat Formation. East side of Hesquiat Peninsula, tidal shelf at the point about 0. 6 km (0. 4 mi.) north of the tip of Leclaire Point. The photographed beds are in the lower third of unit 5 of the section (*see* Jeletzky, 1954, p. 44, geol. map 1 for further details). View northeast (obliquely updip) along the tidal flat. The light-coloured bed of sandy siltstone with the hammer on it was convoluted when still soft and pliable in direction roughly perpendicular (i. e. toward east-southeast) to the strike of the beds. Convolutions are open folds with southeastern (i. e. left-sided to the observer) limbs characteristically steeper than the northwestern limbs. This indicates a southeastern to eastern direction of slumping (possible result of a current caused by a spillover from Leclaire Point channel) and hence a similar direction of local paleoslope (possibly eastern levee of Leclaire Point channel) indicated by an arrow. The overlying dark grey shale bed (closer to the camera) is completely churned up by mud flowage. The underlying, thinly bedded to laminated, grey argillaceous beds in the background are essentially undisturbed.

202819-B

Figure 2. Soft-sediment slumping in argillaceous rocks of the uppermost shale-clayey sandstone member of Hesquiat Formation. Middle part of Inner Bajo Reef, Nootka Island, at the point about 91. 5 m (300 ft.) southeast (i. e. across the strike) of the contact of Hesquiat Formation and Division D reproduced in Plate 3, figure 2 (*see* Jeletzky, 1954, p. 20, 21, geol. map 2 for further details). View approximately northwest (i. e. downdip). The contact of the light-coloured, thinly bedded to laminated, partly slumped, sandy siltstone with the underlying dark grey, massive-looking shale is very sharp and somewhat uneven (?erosional). However, no graded bedding but only small-scale current crossbedding was observed above this contact. Most convolutions in the middle part of sandy siltstone are either asymmetrical with steeper southwestern (i. e. left-sided to the observer) flank or overturned toward southwest (i. e. leftward). This, and the similar orientation of the flame-like structures, indicate the local southwestern direction of traction currents and the same direction of local paleoslope (*see* p. 9 for further details).

202894, 2-3-72

Figure 3. Thinly bedded to laminated, flyschoid phase of the shale-clayey sandstone facies of Hesquiat Formation outcropping on the tidal flat immediately south of Estevan Point lighthouse, Hesquiat Peninsula. View approximately north (i. e. downdip; *see* p. 8 for further details).

FIG. 1

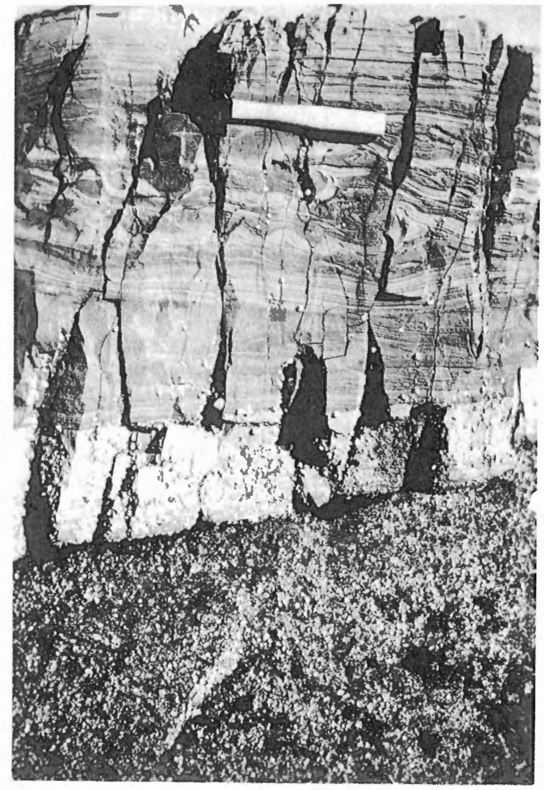

FIG. 2

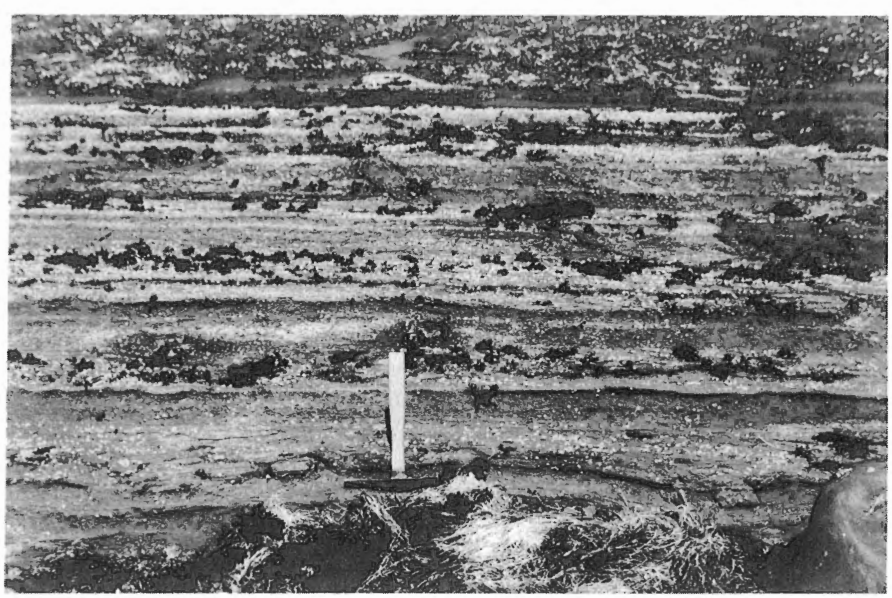

FIG. 3

PLATE 5

202893, 14-7-51

Figure 1. A typical outcrop of the littoral facies of Hesquiat Formation (i. e. "Resistant sandstone-conglomerate member" of Jeletzky, 1954, p. 54; *see* also this paper, p. 23-26) forming a northwest-trending rocky ridge just off the wooded tip of Rafael Point, Flores Island. View northwest, approximately into the strike of the unit. Protruding, resistant beds are coarse- to medium-grained, gritty and pebbly sandstone. Thin, recessive beds are mostly fine-grained, richly fossiliferous sandstones. Rocks dip to the left (i. e. toward southwest) at 25 degrees.

128975, 11-7-52

Figure 2. Close-up of extreme left part of Plate 1 reproducing the strong erosional discordance within the Seventh resistant sandstone-conglomerate member of the channel facies of Hesquiat Formation (*see* Pl. 1). The close-up shows textural detail of beds 63 (above the discordance), and 60 (below the discordance which are numbered accordingly in the photograph. The whitish grey, rounded sandstone masses within grey, coarse-grained sandstone of bed 63 (left foreground) appear to be oversized clasts of soft sediment locally ripped up from the channel walls or bottom. Note the extremely irregularly lenticular alternation of pebble conglomerate and sandstone in bed 63. View due approximately southwest (obliquely downdip).

128872, 14-8-51

Figure 3. Outcrop of simple and interference ripple-marked (*see* left foreground), coarse grained, gritty and pebbly sandstone of the littoral facies (i. e. "Resistant sandstone-conglomerate member" of Jeletzky, 1954, p. 54; *see* also this paper, p. 23-26) of the Hesquiat Formation on the northeast side of Rafael Point, Flores Island, at point about 137 m (150 yds) northeast of the point's tip. Note the very large blocks of presumably locally derived volcanic rocks of Vancouver Group described in the text (*see* p. 24). View approximately east-southeast (i. e. obliquely updip) toward the western base of the point. The rocks strike southeast and dip southwest at 25 degrees.

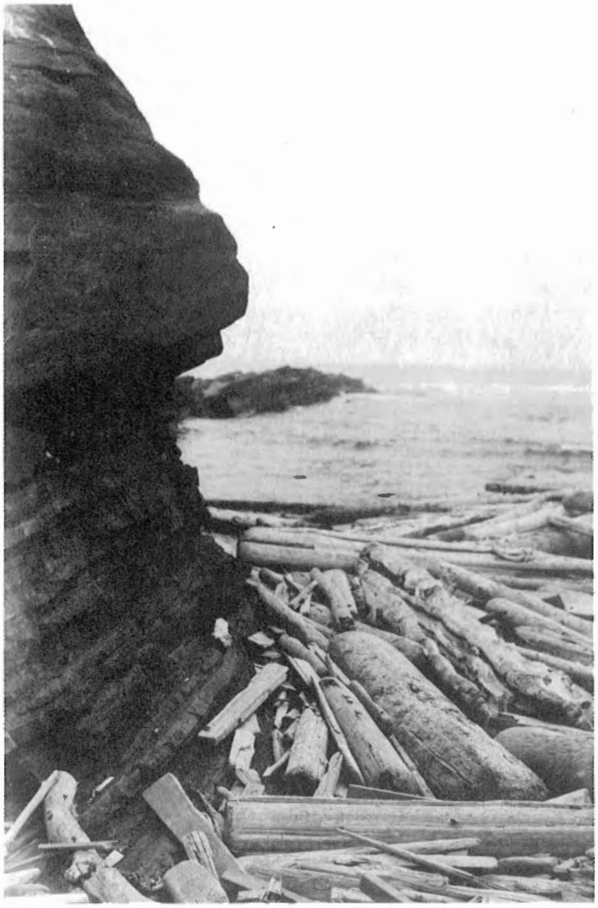

FIG. 1

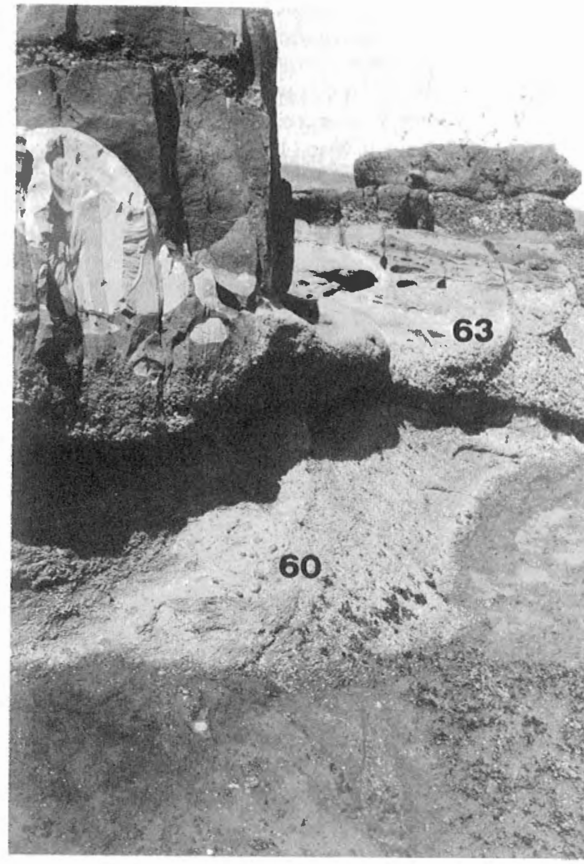

FIG. 2

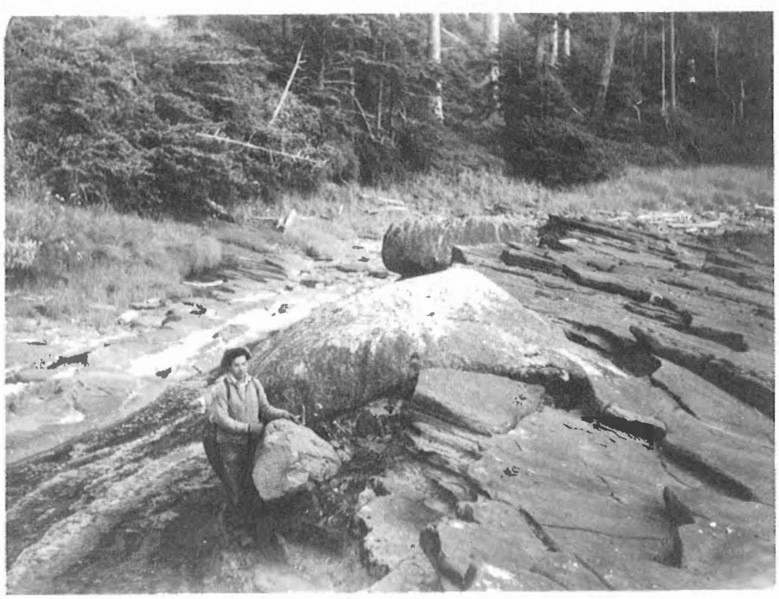

FIG. 3

PLATE 6

128936, 6-7-52

Figure 1. Medium to thick [15. 2-61 cm; (6 in. -2ft.)] interbedding of prevalent argillaceous (darker coloured) with subordinate coarse to fine arenaceous (lighter coloured), resistant rocks of the interchannel facies of Hesquiat Formation. Vancouver Island, east coast of Hesquiat Peninsula at the point about 0. 8 km (0. 5 mi.) southeast of the mouth of Purdon Creek and approximately at the southern end of Hesquiat village (*see* Jeletzky, 1954, geol. map 1; this paper, Fig. 1). The photographed bluff overlooking the high-tide mark is about 5. 5 m (18 ft.) high. It consists of rocks which are only gently tilted and undisturbed otherwise (no soft-sediment deformation or mud flowage observed). The rocks form part of the abundantly fossiliferous unit 2 exposed on the tidal shelf nearby (*see* Jeletzky, 1954 p. 47, 48). The contrast between the post-sedimentary behaviour of the beds reproduced in this photograph and their equivalents shown in Plate 3, figure 1 illustrates the local nature and the minor scale of mud flowage so commonly affecting the shale-clayey sandstone facies of the Hesquiat Formation.

128982, 12-6-52

Figure 2. Erosionally discordant overlap of shale-clayey sandstone facies of the Hesquiat Formation by pebbly mudstone of an unnamed resistant sandstone-conglomerate unit in the axial part of Hesquiat Syncline. The photographed exposure is situated on the western side of Hesquiat Peninsula shown in geological map 1 of Jeletzky (1954). It is about 4 km (2. 5 mi.) south of Split Cape. These badly disturbed beds are believed to be somewhat younger (*see* Jeletzky, 1954, p. 42, geol. map 1) than the Seventh resistant sandstone-conglomerate member of the type section of Hesquiat Formation. View approximately east from tidal shelf's edge. Introduced to demonstrate the continuation of active channel regime in the Barcester Bay (or principal) channel until the end of the recorded time of deposition of the Hesquiat Formation.

202895, 2-6-72

Figure 3. Erosionally disconformable and possibly erosionally discordant contact of the First resistant sandstone-conglomerate member of the type section of the Hesquiat Formation with the underlying First shale-clayey sandstone member (*see* Appendix and Fig. 2). Vancouver Island, west coast, western side of Hesquiat Peninsula at the point about 0. 8 km (0. 5 mi.) south-southeast of the tip of Escalante Point. View approximately due south (i. e. obliquely downdip) from station at the northern base of a nameless rocky point situated immediately northeast of Escalante Island. Unit 3 of the type section occupies the lowermost foreground and is marked "ss". Lower part of unit 4 marked "pm" underlies all of the rounded rocky knoll on which the hammer rests. Unit 5, marked "pc" is in the extreme background beyond the sandy and grassy zone concealing the upper part of unit 4. Arrow indicates the contact between units 3 and 4. Note strong and disorderly lateral and vertical variation in the lithology of unit 4 within shortest distance. It ranges from an almost regular, partly clast-supported conglomerate to slightly pebbly mudstone or sandstone.

FIG. 1

FIG. 2

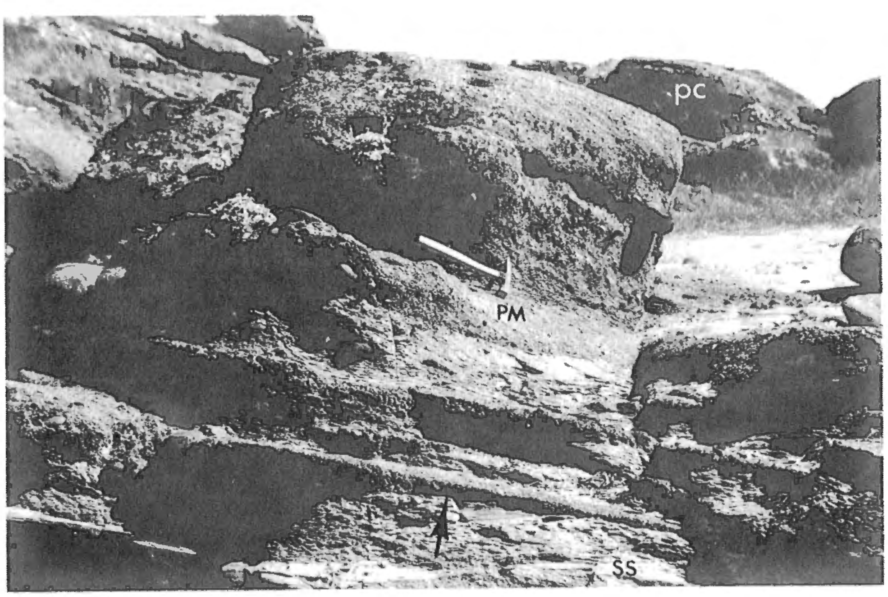

FIG.3