GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 83-21

LATE QUATERNARY MORPHOLOGIC DEVELOPMENT AND SEDIMENTATION, CENTRAL BRITISH COLUMBIA CONTINENTAL SHELF

J.L. LUTERNAUER
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Available in Canada through

authorized bookstore agents
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Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Ontario, Canada K1A 0S9

and from

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

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

Cat. No. M44-83/21E	Canada: $4.00
ISBN 0-660-11453-4	Other countries: $4.80

Price subject to change without notice

Critical readers

C.F.M. Lewis
G.J. Yorath

Original manuscript submitted: 1982-10-1
Approved for publication: 1983-04-15

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LATE QUATERNARY MORPHOLOGIC DEVELOPMENT AND SEDIMENTATION – CENTRAL BRITISH COLUMBIA CONTINENTAL SHELF

Abstract

The physiography of Queen Charlotte Sound is dominated by banks capped with sand and gravel and troughs floored with gravel, sand and mud. Grounded ice, probably including that of the Fraser Glaciation, sculpted most morphologic features and strongly influenced the present sediment distribution. The oceanographic regime which prevailed when sea level was lower contributed to the formation of valleys at bank margins and the concentration of heavy minerals on banks and probably determined the depth of the present shelf break.

Inlets on the southern mainland coast of the shelf are the principal sources of sediment presently supplied to the shelf. This material, composed of olive green organic- and smectite-rich muds, is accumulating on the shelf almost exclusively in a section of trough adjacent to the mouths of these inlets.

Probably the most mobile terrigenous sediment on banks, fine to very fine sand, is being reworked from glacigene deposits and swept onto bank margins. Although foraminifers and molluscan skeletal carbonate in places are dominant components of bank sediments, their concentration across the shelf is highly variable because of differences in wave and current climate, dilution by terrigenous detritus and, possibly, proximity to upwelling, nutrient-rich, slope waters.

The best sorted, nonencrusted finer gravels and clean sands best suited for construction materials are most concentrated on the eastern, shallower part of Goose Island Bank. The most extensive skeletal carbonate beds, a potential source of lime for use in the manufacture of cement, extend for several tens of kilometres in a 10-15 km wide band adjacent to northern Vancouver Island and the Scott Island chain. The highest concentration of heavy mineral rich "black sands" are found at or near the 100 m depth on northern Cook Bank.

Résumé

La physiographie du détroit de la Reine-Charlotte est dominée par des bancs couronnés de sable et de gravier et des creux tapissés de gravier, de sable et de boue. La glace échouée, y compris probablement celle de la glaciation de Fraser, a sculpté la plupart des éléments morphologiques et a fortement influencé la répartition actuelle des sédiments. Le régime océanographique qui dominait lorsque le niveau de la mer était plus bas a contribué à la formation de vallées aux marges des bancs et à la concentration de minéraux lourds sur les bancs; il aurait également déterminé la profondeur de l'accore actuel.

Les baies du littoral continental sud du plateau sont la source principale des sédiments qui s'accumulent présentement sur le plateau. Composé de boues vert-olive riches en matières organiques et en smectite, ce matériel s'accumule presque exclusivement dans une section de creux adjacente aux embouchures des baies.

Les sédiments terrigènes les plus mobiles des bancs, soit les sables fins à très fins, proviennent de dépôts glaciaires et sont transportés jusqu'aux marges des bancs. Par endroits, les carbonates formés de foraminifères et de squelettes de mollusques sont les éléments dominants des sédiments des bancs; toutefois, leur concentration varie beaucoup en travers du plateau en raison de la différence dans le régime des vagues et des courants, de la dilution par des matériaux détritiques terrigènes et peut-être de la proximité des eaux ascendantes du talus, riches en éléments nutritifs.

Les graviers et les sables propres non incrustés les mieux triés et les plus utiles pour la construction sont concentrés sur la partie est moins profonde du banc de l'île Goose. Les plus vastes couches de carbonate squelettique, source possible de chaux pour la fabrication du ciment, recouvrent plusieurs dizaines de kilomètres dans une bande de 10 à 15 km de large, adjacente à la partie nord de l'île Vancouver et de la chaîne des îles Scott. La plus forte concentration de "sables noirs" riches en minéraux lourds se trouve plus ou moins à 100 m de profondeur sur la partie nord du banc Cook.

INTRODUCTION

This report presents the results of the first detailed study of the morphology and sediments of a part of the British Columbia continental shelf adjacent to the strongly glaciated mainland coast (Holland, 1964). Earlier sedimentologic studies have been carried out in the area encompassed by Queen Charlotte Sound (Fig. 1), by the University of British Columbia Institute of Oceanography (1963), Murray and Mackintosh (1968), Wiese (1969), and Shell Canada Limited (in the course of exploratory surveys during the late 1960s).

This report, which includes some data presented in an earlier unpublished study (Luternauer, 1972), describes the following aspects of Queen Charlotte Sound sediments: grain size, clay mineralogy, colour and the total concentration of (a) heavy minerals, (b) skeletal carbonate, (c) noncarbonate organic carbon and (d) coarse (0.354 to 0.500 mm) "glauconite" pellets in the sand plus mud fraction. Subbottom character of the Sound is interpreted from short cores and continuous seismic profiles. Features on the seafloor are described from side-scan sonar records and underwater photographs.

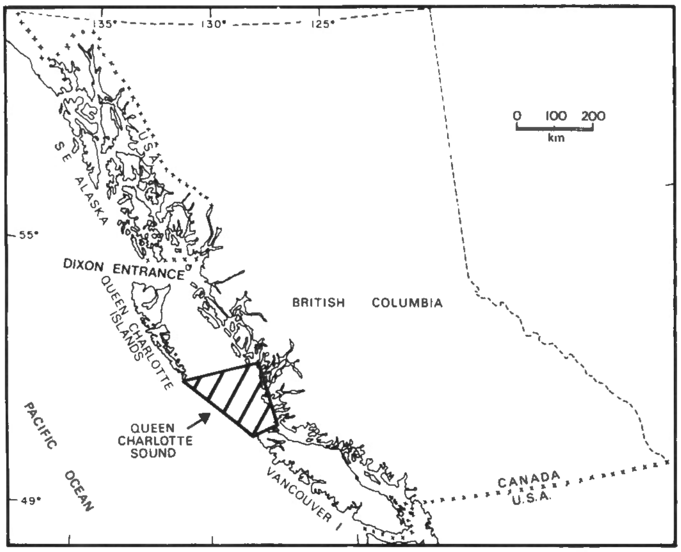

Figure 1. *Index map.*

The laboratory and field data and the available information on the morphology and regional setting of the shelf, form the basis for an evaluation of the influence of (a) late Pleistocene glaciation, (b) structural relationships and faulting, (c) sea level changes, (d) oceanographic climate, (e) present day river discharge and (f) organic productivity on the physiography and/or sediment distribution.

REGIONAL SETTING AND MORPHOLOGY OF QUEEN CHARLOTTE SOUND

Physiographic Setting and Morphologic Description of the Sound

According to Holland's (1964) classification of British Columbia physiography, Queen Charlotte Sound lies within the southern part of the Hecate Depression (Fig. 2) which extends from northern Vancouver Island to southeastern Alaska. This depression is bounded on the east by the Coast Mountains and on the west by the mountains of the Queen Charlotte Islands and the open Pacific Ocean. Major subdivisions adjacent to Queen Charlotte Sound are the Nahwitti Lowland of northern Vancouver Island and Hecate Lowland of the British Columbia mainland. These lowlands are generally below 610 m in elevation and are considered by Holland to be remnants of Tertiary erosion surfaces. Milbanke Strandflat, a rocky platform, largely below 33 m in elevation, lies along the western edge of Hecate Lowland. Culbert (1971) suggested that the strandflat is a "mature erosion surface modified by wave action." Back-cutting erosion by coastal piedmont glaciers, sea level fluctuations coupled with wave abrasion, and frost weathering have been considered instrumental in the formation of similar features in Norway (Holtedahl, 1960, 1970).

The bathymetry and physiographic subdivisions of Queen Charlotte Sound are shown on Figure 3. Geographic names are those used on Canadian Hydrographic Service charts; those enclosed by quotation marks are unofficial. The principal physiographic features in Queen Charlotte Sound are broad banks and troughs. Secondary features include valleys at bank margins and broad channels on bank tops, flats and ridges in troughs, terraces, and isolated depressions. Although some lineations in the Sound match those on the adjacent mainland, the physiography of the shelf and mainland is generally markedly dissimilar in that the floor of the Sound is not dissected by as dense a network of narrow depressions and has a considerably more subdued relief (Fig. 4).

Peacock (1935) considered that the great depth of fiords such as those on the mainland adjacent to the Sound resulted not only from glacial excavation and possible incomplete postglacial rebound but also deep fluvial erosion during a Tertiary uplift. Culbert (1971) claimed local relief on the mainland can more readily be attributed to "block subsidence of the fiord zone."

Geological and Geophysical Setting

Queen Charlotte Sound is adjacent to the modern triple junction of the North American, Pacific and Juan de Fuca plates at the base of the continental slope (Keen and Hyndman, 1979). Geophysical evidence suggests that oceanic crust is migrating to the northwest parallel to the base of the slope off the Queen Charlotte Islands and easterly to southeasterly towards and beneath Vancouver Island (Riddihough, 1977).

Although the Sound is adjacent to the most seismically active areas in Canada (Milne et al., 1978), during the period 1899-1977 no earthquakes of magnitude 5 or greater (Richter scale) have occurred within the Sound (Rogers, 1982).

Rocks on the mainland adjacent to the Sound are mainly Mesozoic and Tertiary plutons (Roddick et al., 1966; Baer, 1967). The dominant structural grain is northwesterly. Small shear zones, commonly parallel to this trend, are abundant, but faults with proven displacement are scarce (Roddick et al., 1966). A major, albeit inactive, dislocation zone apparently extends for approximately 300 km along the mainland coast northwest of Price Island (Fig. 3; Souther, 1966). The orientation of many of the fiords on the mainland coincides with a subordinate northeasterly to easterly grain which may have been established prior to the northwesterly structural grain (Roddick et al., 1966).

Within the Insular Belt (Muller, 1977), which comprises Vancouver Island and Queen Charlotte Islands, the dominant structural grain has been established by northwesterly trending dextral faults, associated folds, and zones of intermediate plutonic rocks which dislocate sedimentary and volcanic rock strata of late Paleozoic to Tertiary age (Sutherland Brown, 1966, 1968; Muller et al., 1974; Roddick et al., 1976).

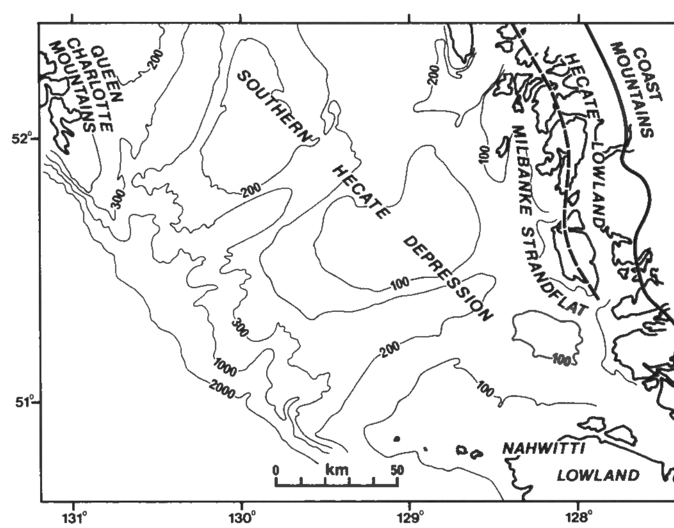

Figure 2. *Major physiographic units in the vicinity of Queen Charlotte Sound. (after Holland, 1964). Bathymetric contours in metres.*

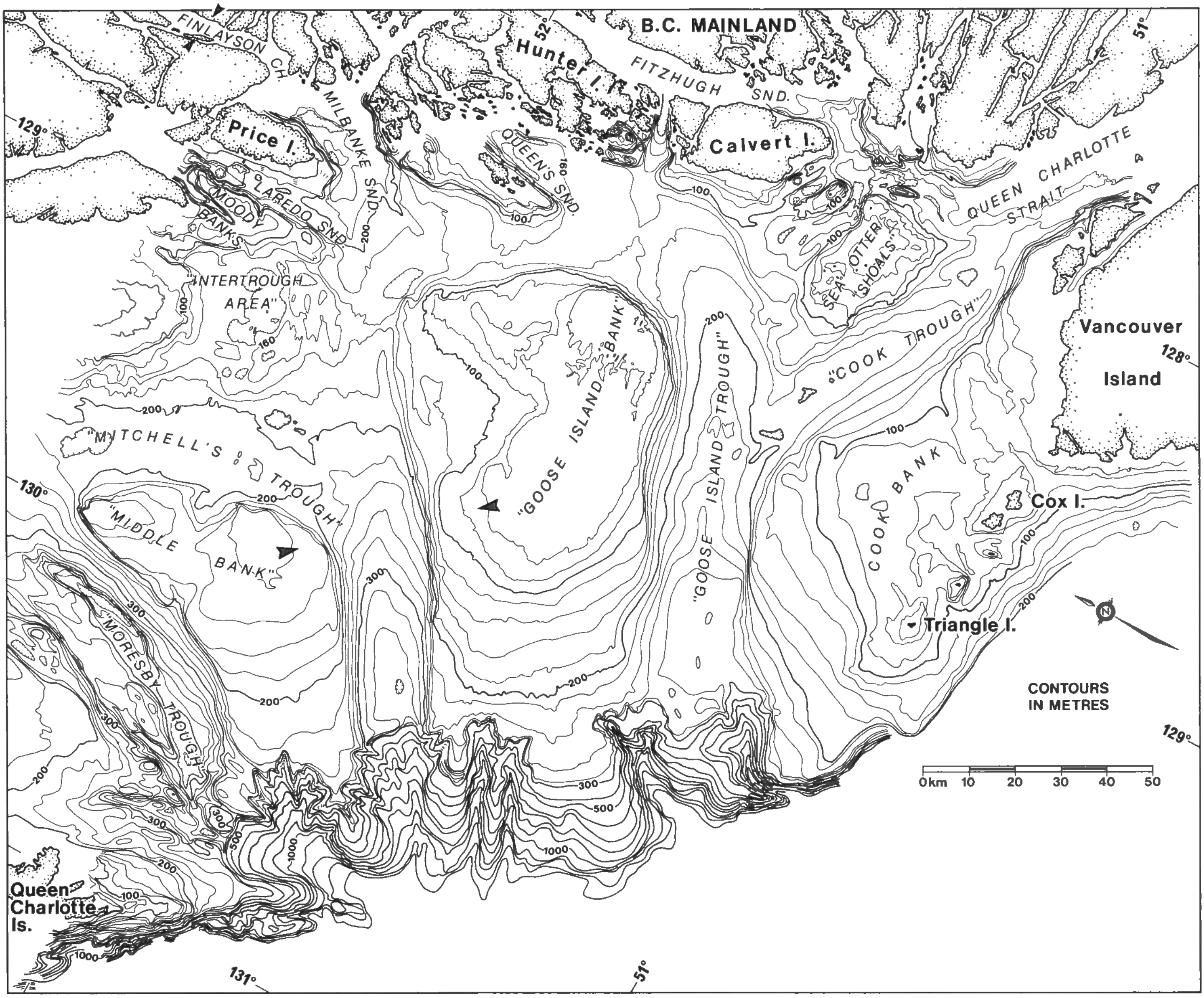

Figure 3. Bathymetry of Queen Charlotte Sound. Contoured principally from Canadian Hydrographic Service field sheets compiled during 1958-59 employing Decca-Hi Fix navigation system. Areas 20 km from the coast were compiled from Canadian Hydrographic Service charts and Shell Canada Ltd. bathymetric map for area. Arrow heads indicate locations of bathymetric profiles in Figure 4.

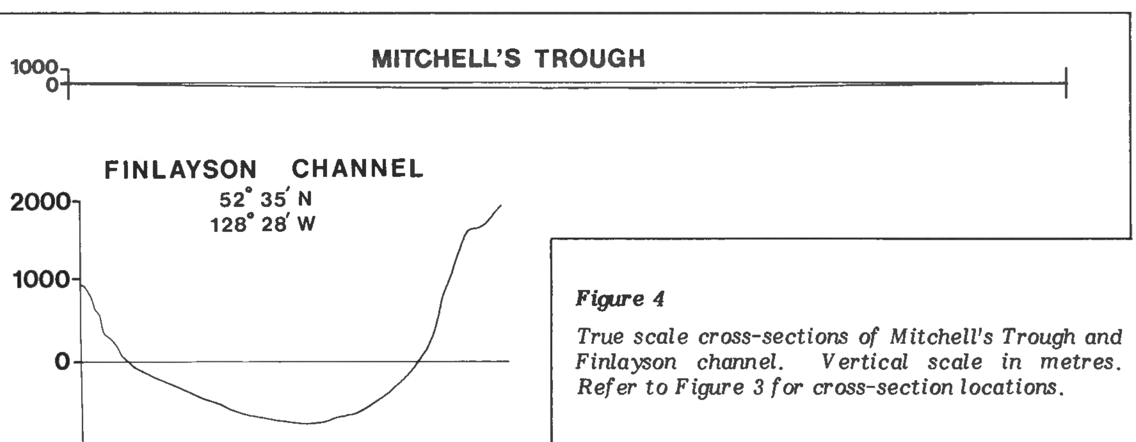

Figure 4

True scale cross-sections of Mitchell's Trough and Finlayson channel. Vertical scale in metres. Refer to Figure 3 for cross-section locations.

Interpretations of the origin of Queen Charlotte Sound have been presented by Chase et al. (1975), Stacey (1975) and Yorath and Chase (1981). The most recent of these suggests that as the area now occupied by the Sound drifted over the Anahim mantle plume (Bevier et al., 1979) during the Tertiary, what may have been a continuous landmass rifted apart to form a basin into which mid and late Tertiary marine clastics were deposited (Shouldice, 1971, 1973).

Glaciation

Baer (1967) estimated that Pleistocene glacier ice reached a height of at least 2300 m on the mainland adjacent to the Sound where some of the largest icefields in British Columbia are found. Substantial late Pleistocene ice thicknesses on the mainland are indicated by the local glacio-isostatic depression of the crust: (a) Armstrong (1966) determined that "land in Kitimat-Terrace valley [on the mainland approximately 200 km north of the Sound] was depressed at least 300 m below its present elevation..." and (b) Andrews and Retherford (1978) reported that the late Pleistocene marine limit along the mainland coast of the Sound is "at least 40 m on Calvert Island and most likely 120+ m."

Howes (1981) established that the maximum observed level of the marine limit achieved immediately following the retreat (12 000-13 000 years ago) of the Fraser Glaciation ranges from a possible 175 m along the northeast coast of Vancouver Island to approximately 20 m on the northwest coast. This relationship led him to suggest that ice "was thicker on the east coast versus the west coast...".

Sutherland Brown (1968) suggested that locally generated late Wisconsin glaciers covered Queen Charlotte Islands and coalesced with the Cordilleran ice sheet somewhere in the western Hecate Depression. He further suggested that ice (and any sediment it might have been carrying) from only the southernmost quarter of the Queen Charlotte Islands was directed into Queen Charlotte Sound by the part of the mainland ice sheet that flowed through the Sound (this contention is supported by Wiese's (1969) preliminary study of the heavy mineral distribution in the northern Sound).

Clague et al. (1982) established that the late Quaternary sea level history of mainland British Columbia and eastern Vancouver Island contrasts sharply with that of the Queen Charlotte Islands and western Vancouver Island. In the former areas relative sea level is known to have fallen from about 13 000 to about 6000-9000 years ago (when in some areas it was 12 m or more lower than at present). It then generally rose through late Holocene time. In contrast, relative sea level on the Queen Charlotte Islands was below the present level from sometime before 13 700 years ago until approximately 9500-10 000 years ago. At the close of the Pleistocene relative sea level then rose until about 7500-8500 years ago when it was generally about 15 m above present. The succeeding drop in sea level (evident also on the west coast of Vancouver Island) apparently occurred in the last 5000-6000 years. The divergence of sea level patterns has been attributed to the collapse of a subcrustal forebulge during ice retreat and tectonic uplift of the outer coast (Clague et al., 1982; Riddihough, 1982).

The following evidence points to a limited and (or) short-lived extension of late Wisconsin ice across the Queen Charlotte Sound shelf and suggests that the outer part of the shelf may have undergone only minor glacio-isostatic depression during the Fraser Glaciation: (a) northern and southern mainland late Wisconsin coastal glaciers achieved their maximum extension about 15 000 years B.P. but had retreated from the outermost mainland coast (but not necessarily the fiords) by about 12 000-13 000 years B.P. (Clague et al., 1980; Clague, personal communication, 1983);

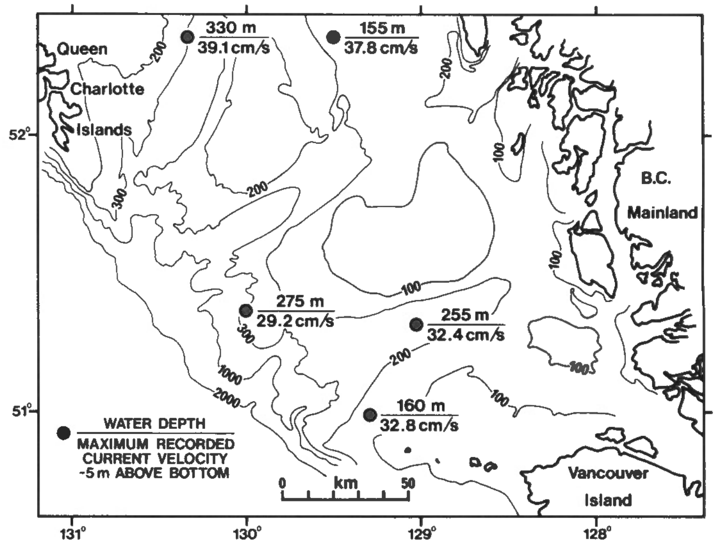

Figure 5. Maximum bottom current velocities recorded while spring tides were running in June-July, 1977. Extracted from data supplied by R.E. Thomson (Institute of Ocean Sciences, Sidney, B.C.).

(b) northeast Pacific near-surface ocean waters may have been as warm approximately 15 000 years B.P. as they now are (Moore, 1973); (c) sea level was rising during the Fraser Glaciation (Clague et al., 1982) and collapse of a marine ice sheet may be very rapid during a rise in sea level even in polar ocean water (Thomas and Bentley, 1978), and (d) late Wisconsin ice appears to have thinned abruptly from the mainland coast towards Queen Charlotte Islands and western Vancouver Island (Clague, 1975; Howes, 1981; and Clague et al., 1982).

After ice had retreated from the coast emergence was rapid and by 10 000 years B.P. sea levels in the Sound were close to those at present (Clague et al., 1982). Sea level continued to drop relative to land, albeit at a slower pace, but may have been up to several metres below present mean sea level during much of middle and late postglacial time (Fladmark, 1974; Andrews and Retherford, 1978; Clague et al., 1982).

Oceanography

Currents, water structure and tidal movements within the Sound have been studied principally by the Pacific Oceanographic Group (1955a,b), Barber (1957a,b, 1958), Canadian Hydrographic Service (1957), Bell (1963) and more recently by Dodimead (1980) and R. Herlinveaux, S. Huggett and R.E. Thomson (in preparation). These studies have (a) defined general tidal flow patterns in the Sound (Canadian Hydrographic Service, 1957), (b) suggested that basin geometry influences movement of local water masses (Bell, 1963; R.E. Thomas, personal communication); (c) indicated that surface water movement in the Sound can be influenced by daily and seasonal wind patterns and by northward coastal water residual flows (R. Herlinveaux, personal communication, 1982); (d) suggested that upwelling occurs in the vicinity of the Scott Islands chain (bounded by Triangle and Cox islands) (R. Herlinveaux, personal communication, 1982); (e) demonstrated that currents 5 m above the bottom can exceed 30 cm/s at depths as great as 325 m (Fig. 5) (R.E. Thomas, personal communication); and (f) detected the movement of deeper halocline water from the open sea into Queen Charlotte Sound. This water intrudes particularly deeply into the Sound (up to Queen Charlotte Strait) during the summer when land drainage is at its maximum and winds are mainly from the northwest, but there appears to be sufficient year round surface outflow to maintain deep water inflow during all seasons, at least over the deeper shelf areas (Barber, 1958).

Carter (1973) noted that "during the maximum annual storm [along the Canadian west coast] bottom surge velocities in water shallower than 150 m equal or exceed 30 cm/sec" and that this storm surge coupled with local tidal currents may be capable of generating net transport of at least fine sands on the southern Vancouver Island shelf. More recently, Yorath et al. (1979) have shown that storm surges are capable of transporting coarse sands and carbonate shell hash to depths of 105 m on the northwestern Vancouver Island shelf.

Sediment Sources

A review of earlier studies of the character of sedimentation off British Columbia leaves no doubt that glaciers contributed large amounts of sediments to the continental margin during the Pleistocene (Mathews, 1958; Nayudu and Enbysk, 1964; Carter, 1973). Supply of sediment to Queen Charlotte Sound during Holocene time has been sharply reduced because no rivers of consequence flow directly onto the shelf (Tully, 1952) and little sediment is introduced either through Queen Charlotte Strait (Cockbain, 1963) or from the north as the major rivers north of the Sound drain mainly across Dixon Entrance (Crean, 1967; Thomson, 1981). Many sediment-charged rivers on the mainland empty into deep fiords which act as settling basins for much of the land-derived detritus. As material in suspension during periods of highest discharge in typical British Columbia fiords is finer than 49 microns (Pickard and Giovando, 1960), silts are the coarsest sediment that presently can reach the shelf through the fiords. Silt and clay which does reach the shelf must be derived mainly from the large plume of less saline water discharged during the summer from the fiords in the vicinity of the Sea Otter Shoals (Dodimead, 1980).

FIELD AND LABORATORY PROCEDURES

Field

All grab sampling, coring and underwater photography was performed from the following Canadian Forces Auxiliary Vessels at the indicated times: "Laymore" (June 12-17, 1967), "Endeavour" (July 7-13, 1967; August 19-30, 1968 and June 16-21, 1969). Continuous seismic reflection profiles were obtained in 1973 with 16 cm^3 and 82 cm^3 air gun sources by D.L. Tiffin from the "Endeavour". High resolution profiling was performed during May 30th-June 10th, 1981 from the Canadian Survey Ship "Hudson" with a Huntec ('70) Ltd. Deep Tow System (50-500 joules boomer). Side viewing sonar records were acquired on the same cruise with a system developed by Jollymore (1974) and operated by A. Boyce of the Atlantic Geoscience Centre.

Navigation for the 1967-73 cruises was accomplished, depending on weather conditions and distance from shore, by employing various combinations of Decca radar, radio beacon, Loran-A, dead reckoning and detailed bathymetric maps (position accuracy: better than one half sampling interval distance). Navigation for the "Hudson" cruise was accomplished with the integrated BIONAV system employing mainly LORAN C and satellite position fixing (position accuracy: ± 200 m).

Grab samples were collected primarily with a Petersen device although, on occasion, a La Fond-Dietz clam snapper was used. If the sample was a mud, muddy sand or well sorted sand, no more than a litre was retained. Sufficient gravelly sediment was collected to fill at least a 4 litre container. If insufficient sample was obtained during an earlier cruise attempts were made during subsequent cruises to obtain larger samples. An attempt was made to extract live organisms, especially holothurians, from muddy sediments to prevent them from affecting organic carbon determinations. Two- or four-metre-long barrels having inner diameters of 7.5 cm were used for gravity coring. The floor of the Sound was photographed at eleven locations (of which nine are discussed in this report) with an Edgerton, Germeshausen and Grier camera and strobe unit.

The site at which samples and underwater photographs were obtained for this study are shown in Figure 6. Seismic profile and sonogram trackline locations are displayed in Figure 22.

Laboratory

After having been treated for the removal of organic matter (with H_2O_2) and salt, subsamples were analyzed for grain size (0.5 ϕ sieve interval for all but the mud fraction) according to conventional sieve and pipette techniques (Folk, 1965; Ingram, 1971; Galehouse, 1971). Mean size, standard deviation and skewness were calculated using a computer by the method of moments (McBride, 1971). The computer program defined mid-size-interval points from a linearly interpolated and extrapolated log-probability cumulative frequency curve.

Mineralogy of the <2 μm fraction of 38 surficial samples and several core subsamples was determined by standard X-ray diffraction techniques (Warshaw et al., 1960; Brindley, 1961a; Kodama and Oinuma, 1963 and Biscaye, 1964). Component clay and other minerals were identified from diagnostic diffraction peaks and responses to various chemical treatments (Weaver, 1958; Bradley and Grim, 1961; Brindley, 1961b; MacEwan, 1961; Walker, 1961; Kodama and Oinuma, 1963 and Biscaye, 1964).

The colour of moist sediments was estimated from the Geological Society of America Rock Colour Chart (1963).

A determination was made of the heavy mineral concentration (expressed as weight per cent) within the 0.177-0.063 mm fraction of best sorted samples with similar mean sizes (ranging from 0.125 to 0.250 mm) using standard bromoform methods (Folk, 1965). Total concentration in a sample was estimated by multiplying the proportion of heavy minerals in the examined size fraction by the proportion of the total sample represented by the analyzed size fraction.

The concentration of coarse, test-free glauconite pellets (the term glauconite is here used as it is defined by Burst (1958)) was determined by point counting a total of 300 grains in the 0.354-0.500 mm size fraction of all samples in which grains of this size were present. Rock fragments, mineral grains, shell material, faecal matter and glauconite pellets were identified. Glauconite pellets were distinguished from faecal pellets by their irregular shape and by their colour (the ovoid faecal pellets tend to be light olive grey (5y 5/2) – pale olive (10y 6/2) while the glauconite is moderate olive brown (5y 4/4)). The weight per cent proportion of 0.354-0.500 mm glauconite in a sample was approximated by multiplying the grain count percentage by the proportion of the entire sample represented by the size fraction analyzed.

The concentration of skeletal carbonate within the sand plus mud fraction of samples was determined with the Chittick Apparatus (Dreimanis, 1962) after being ground finer than 0.5 mm in a mortar and pestle. Noncarbonate organic carbon content concentration was calculated by first determining the total organic carbon content within the sand plus mud fraction of the sample using a Leco Carbon Analyzer and subtracting from this the calculated concentration of skeletal carbon in the sample.

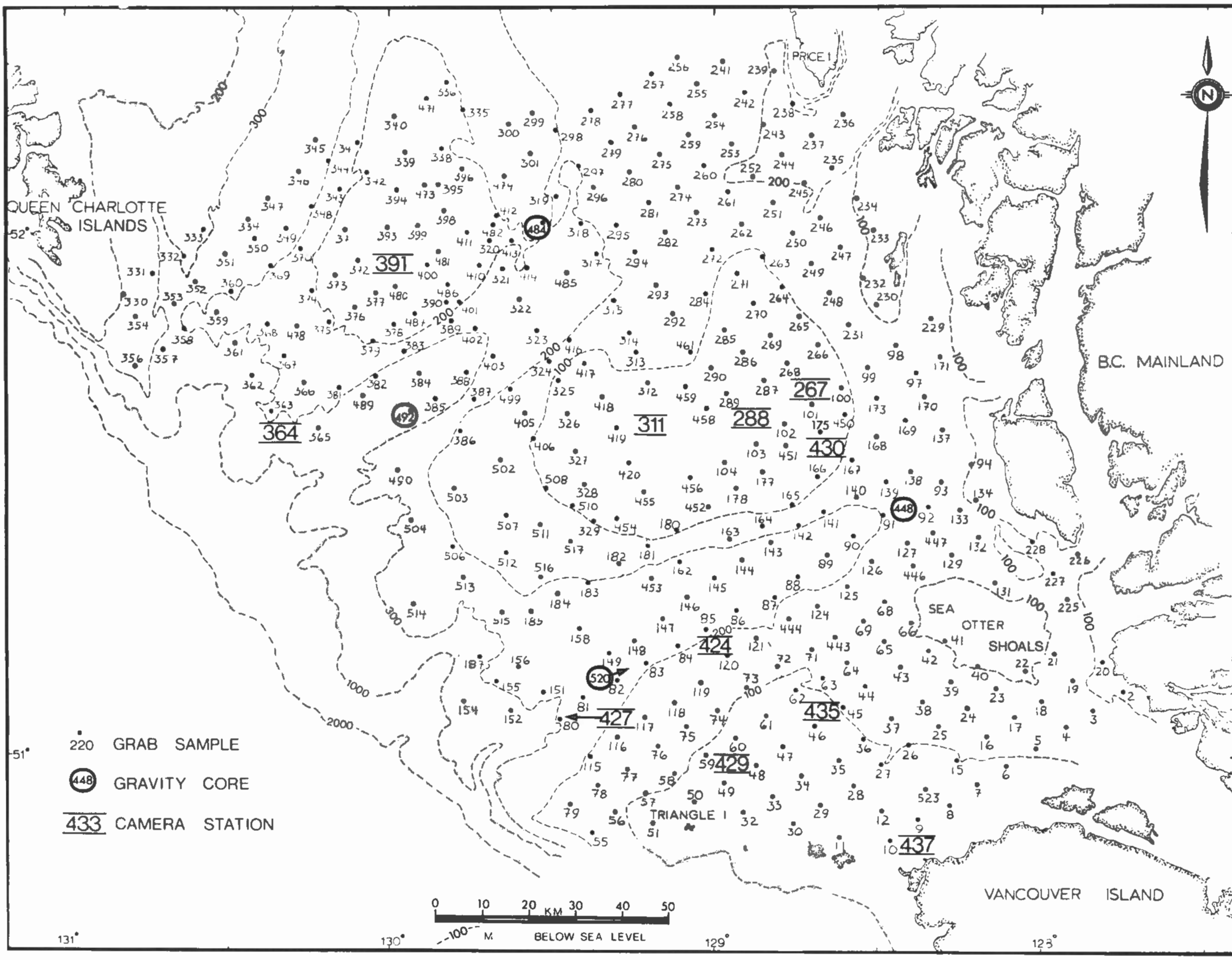

Figure 6. Location of grab and core samples and camera stations.

Foraminifera were extracted from one core and examined by B.E.B. Cameron and C. Rodrigues. The internal structure of cores was examined by means of industrial X-rays. (Film: Kodak type M film with Snofront Screen; Source Power: 4.5 mA and 80KV: Exposure time: two minutes).

RESULTS

Grain-Size Distribution

Sediments within Queen Charlotte Sound are classified into arbitrary mean size – standard deviation – skewness categories and mapped (Fig. 7,8). Figure 8 can be considered only a very generalized representation of the sediment distribution within the Sound, determined entirely from the character of the sediment samples acquired. Bottom photographs and sonograms, which are described in a following section, reveal that the various sediment populations are interrelated in a far more complex fashion.

Sediments from areas of the seafloor shallower than 100 m are virtually free of mud (Fig. 9). A gradual increase in mud content is apparent for most sediment lying between 100 and 140 m. Within this depth range only those samples recovered from the vicinity of the Sea Otter Shoals area, near the principal present-day source of sediments, have a substantial proportion of mud. Between 140-160 m (which includes the depth range of the inlet mouths) the mud-to-sand ratio increases sharply. Highest mud concentrations were found in sediments lying between 160-200 m, but in approximately three quarters of all samples recovered from depths greater than 160 m (which include those of the outer and northern shelf) mud constitutes less than one third of the sediment.

Bottom Photographs

Ripples evident in photographs taken of the seafloor in different areas of the Sound (Fig. 6) have been classified according to Harm's (1969) scheme. Compass vane and compass in photographs measure 25 cm and 8 cm, respectively.

Sediments at Station 437 (Fig. 10a,b) on Cook Bank near the coast of Vancouver Island are carbonate-rich sands and gravels (Fig. 10a). In Figure 10b both the compass vane and the kelp at the bottom left hand corner of the photo indicate that a current is flowing in a north-northeasterly direction. The particles suspended over the ribbon of kelp at the right of the photo as well as the high energy linguoid ripples suggest this current is capable of sweeping coarse sand and fine gravel size detritus across the seafloor.

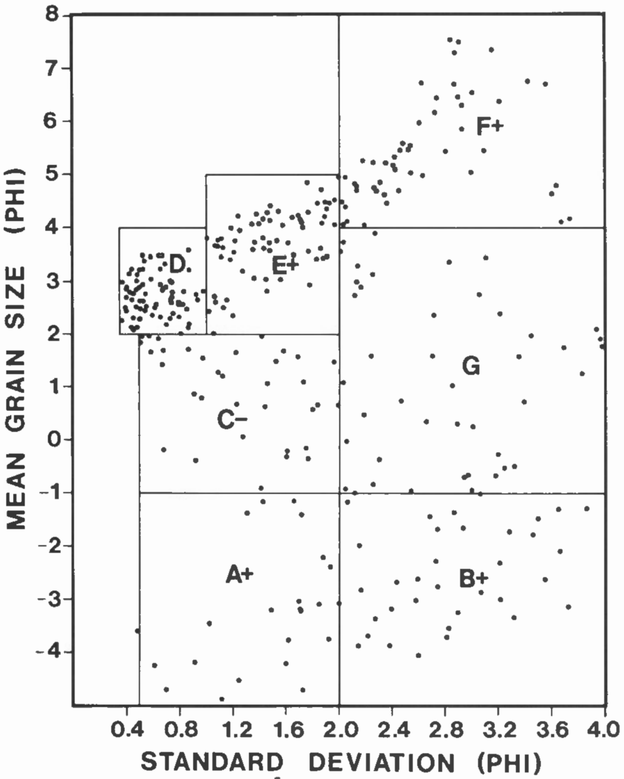

Figure 7. *Mean size – skewness – sorting categories used to map sediment distribution displayed in Figure 8. Dominant skewness sign displayed by samples in each category indicated by + or –. No sign is indicated in categories D and G where no strong tendency is displayed.*

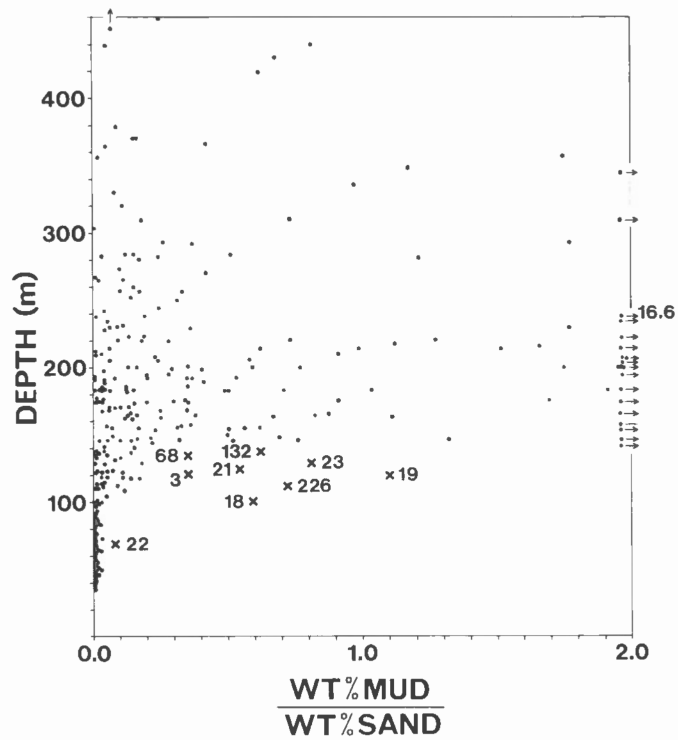

Figure 9. *Plot of the ratio of weight per cent mud to weight per cent sand vs sample depth. Numbered dots represent samples collected in the vicinity of the Sea Otter Shoals.*

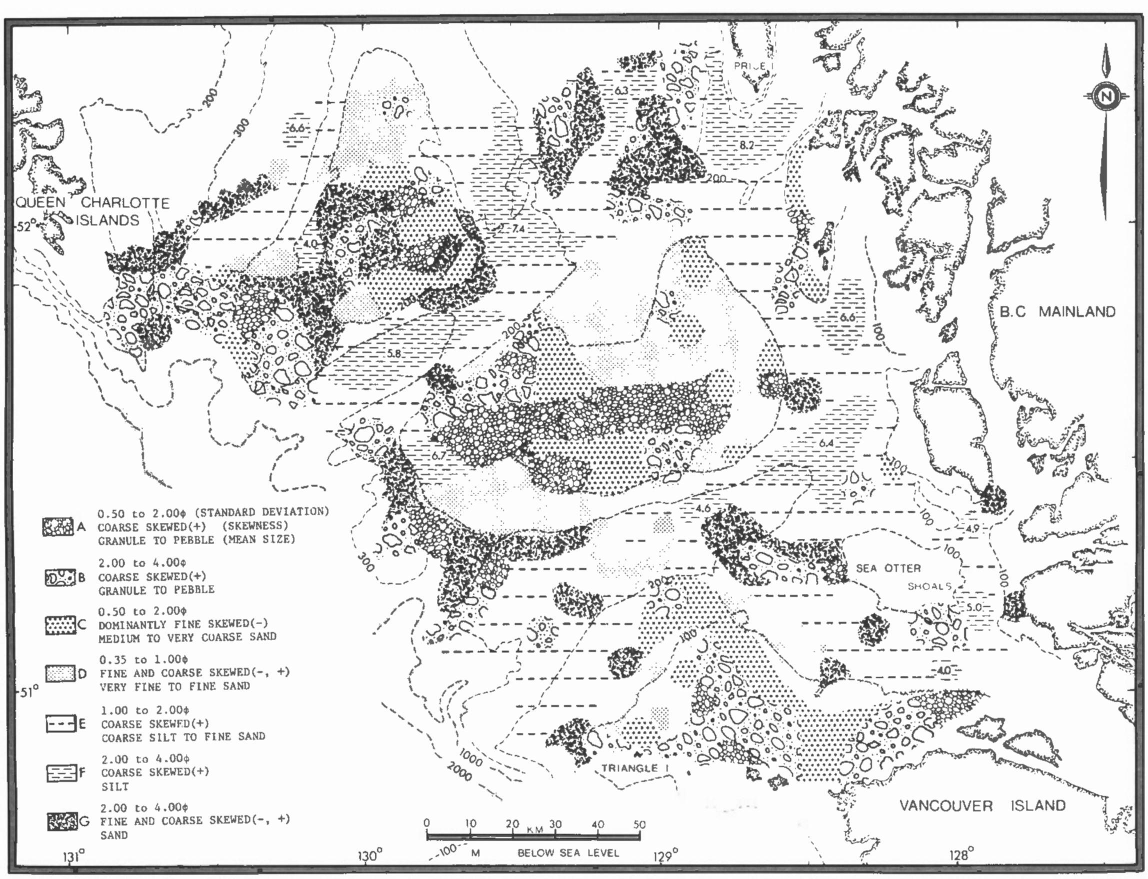

Figure 8. *Sediment distribution in Queen Charlotte Sound determined and extrapolated from the character of sediments collected at sites indicated in Figure 6. Local minimum mean grain size indicated in areas having type F sediments.*

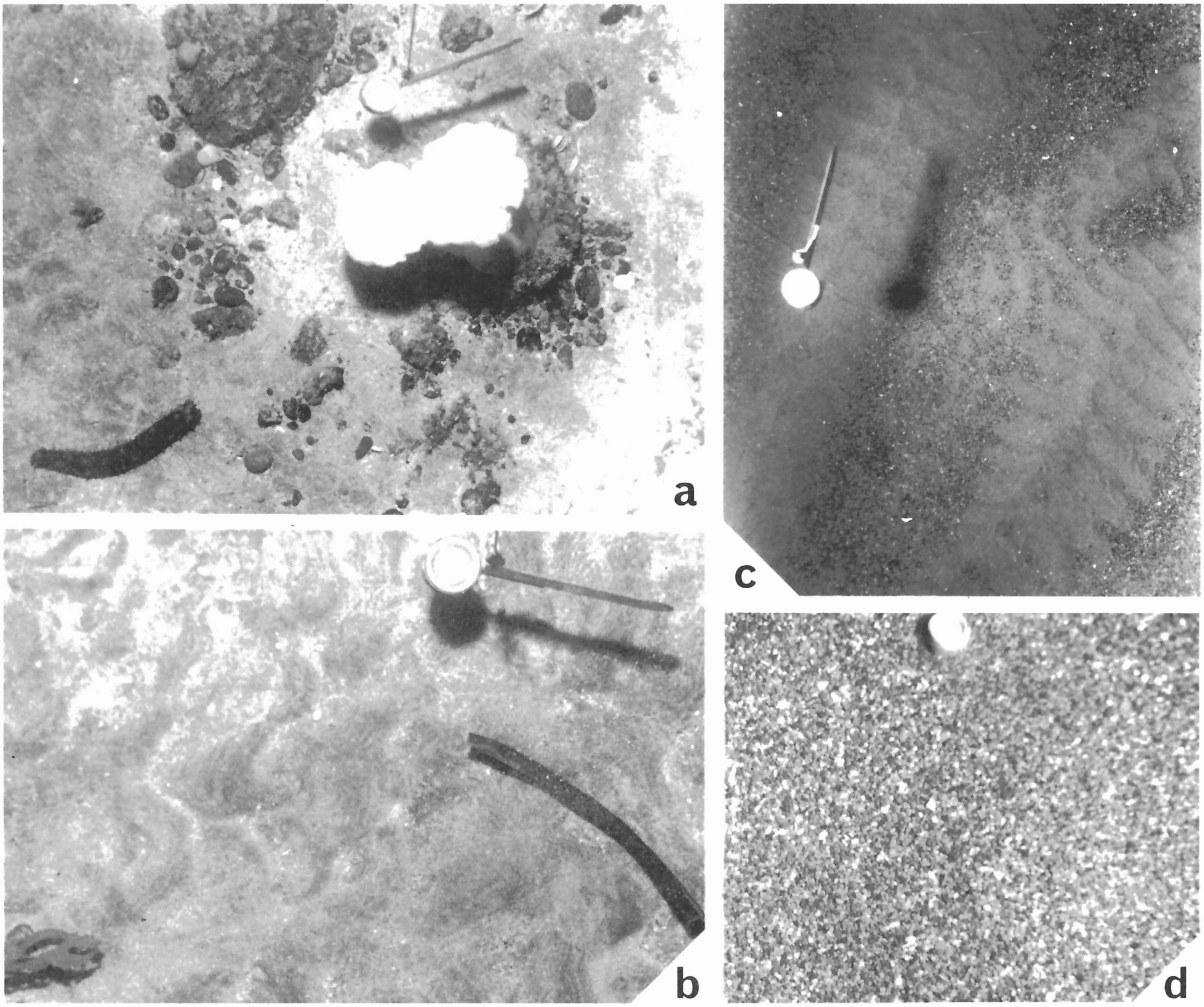

Figure 10

a.b. Camera station No. 437; Cook Bank (40 m).

a. *Holothurian, pelecypod, and white plumed anemone on poorly sorted shelly gravel surface. Carbonate productivity here is one of the highest off western Canada.*

b. *Linguoid current ripples have formed in response to high north-south flowing tidal currents.*

c. *Camera station No. 267; Goose Island Bank (37 m). Low energy current ripples (oriented east-west) are superimposed on wave generated symmetrical ripples (oriented north-south). Wave and current action is strong enough to sort both sand and gravel.*

d. *Camera station No. 311; Goose Island Bank (50 m). Blanket of very well sorted rounded pebbles.*

Canadian Hydrographic Service chart 3744 indicates that surface currents in this area can be as high as 150 cm/s. High energy linquoid current ripples also were present at a deeper site on the bank (Station 429) where the bottom is blanketed with very fine to fine (Group D) sands.

Although water depth at Station 435 (Fig. 11d) is similar to that at Station 429, sediments at the former site probably are coarser (Group C sands) as ripples are poorly defined and the dense network of snail trails suggest these sediments are not readily mobilized (Kulm et al., 1975).

The seafloor at Station 267 (Fig. 10c) near the shallowest part of Goose Island Bank, is blanketed with what appear to be two distinct sediment types: sands and a well sorted basal gravel (Fig. 10c). East-west striking, low energy current ripples are superimposed on larger north-south striking, wave generated, symmetrical ripples. Well sorted rounded pebbles (Fig. 10d) without associated sand were photographed at somewhat greater depth on the same bank at Station 311 (these sediments are very similar to those collected at Station 450) (Fig. 6,7,8).

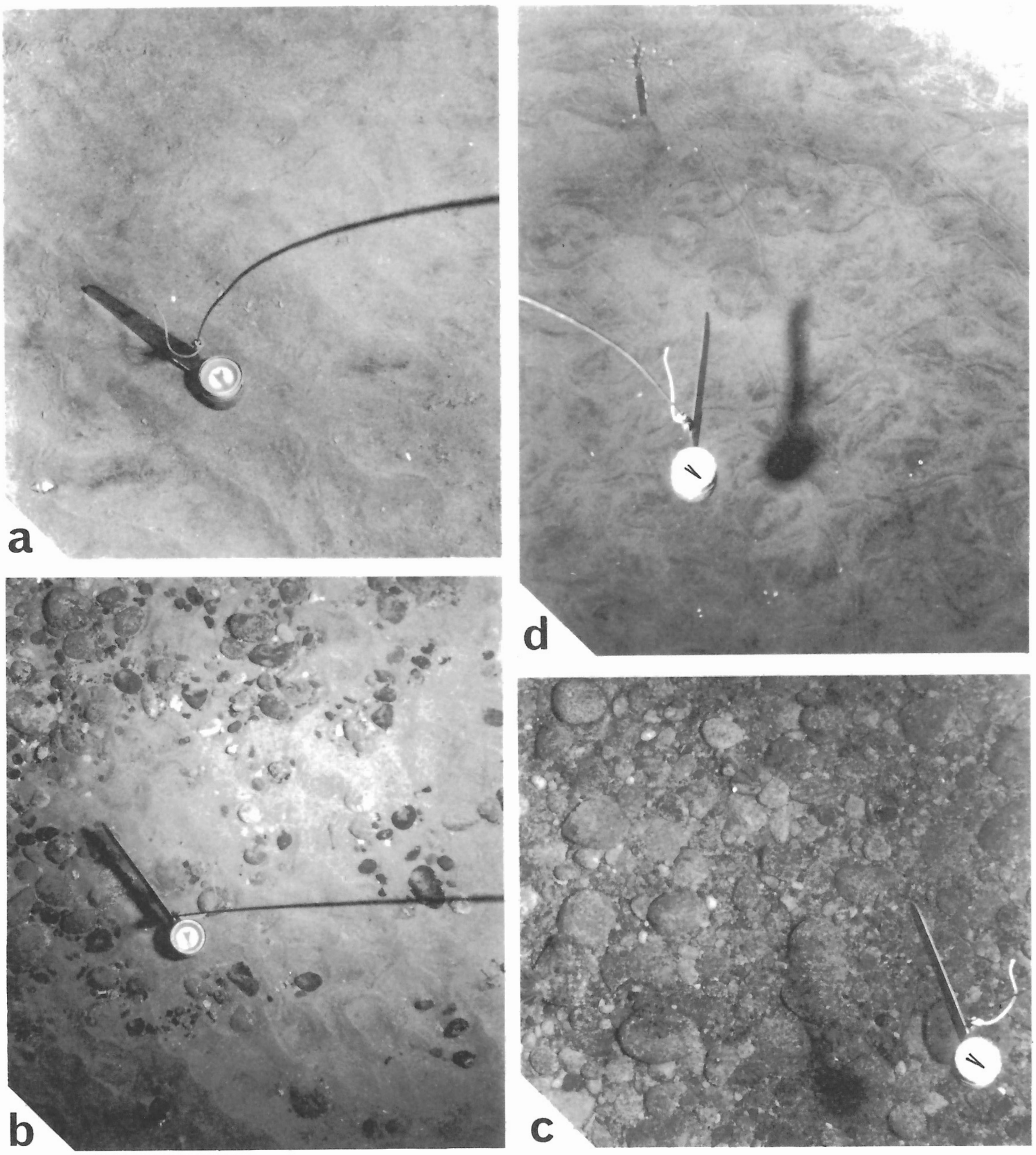

Figure 11

a, b, c. Camera station No. 430; Goose Island Bank (35-40 m).

a. Indistinct wave generated symmetrical ripples in sand.

b. Intermixed sand and gravel.

c. Dense pavement of immobile, heavily encrusted gravels.

d. Camera station No. 435; Cook Bank (73 m). Weak wave generated symmetrical ripples in what probably is medium to coarse sand. Note dense network of snail trails.

Figures 11a,b,c illustrate the extreme changes in sediment character evident over relatively short distances (approximately 3.5 km) at similar depths on Goose Island Bank. Figures 12a,b reveal that the seafloor at Station 391 on Middle Bank is blanketed with debris ranging from boulders to poorly sorted gravelly (Group G) sands. The sand size sediments there consist of a high proportion (up to 51 per cent by weight) of foraminifera and may thus be as mobile as terrigenous sands of the same mean size at shallower depths (Schafer and Prakash, 1968). The north-northeasterly flowing bottom current, which inclines the crinoid radii in Figure 12a, probably has contributed to the formation of the well defined, wave dominated combined flow ripples in Figure 12b. Photographs of the outer part of Goose Island Trough (Stations 424 and 427; Fig. 12c,d), in areas where the seabed is blanketed mainly with Group E silts and fine sands, display an abundant fauna and evidence of bioturbation, but no hydraulic bedforms.

Sonograms

The record representing a section of the shallowest part of Goose Island Bank (Fig. 2,3,13A-A') displays alternating bands of high (dark) and low (light) acoustic reflectivity. The bands mainly reflect differences in sediment character as relief is very muted (relief on these Deep-Tow records is an artifact of the system). As coarser sediments tend to reflect acoustic energy more strongly than do finer sediments (Swift

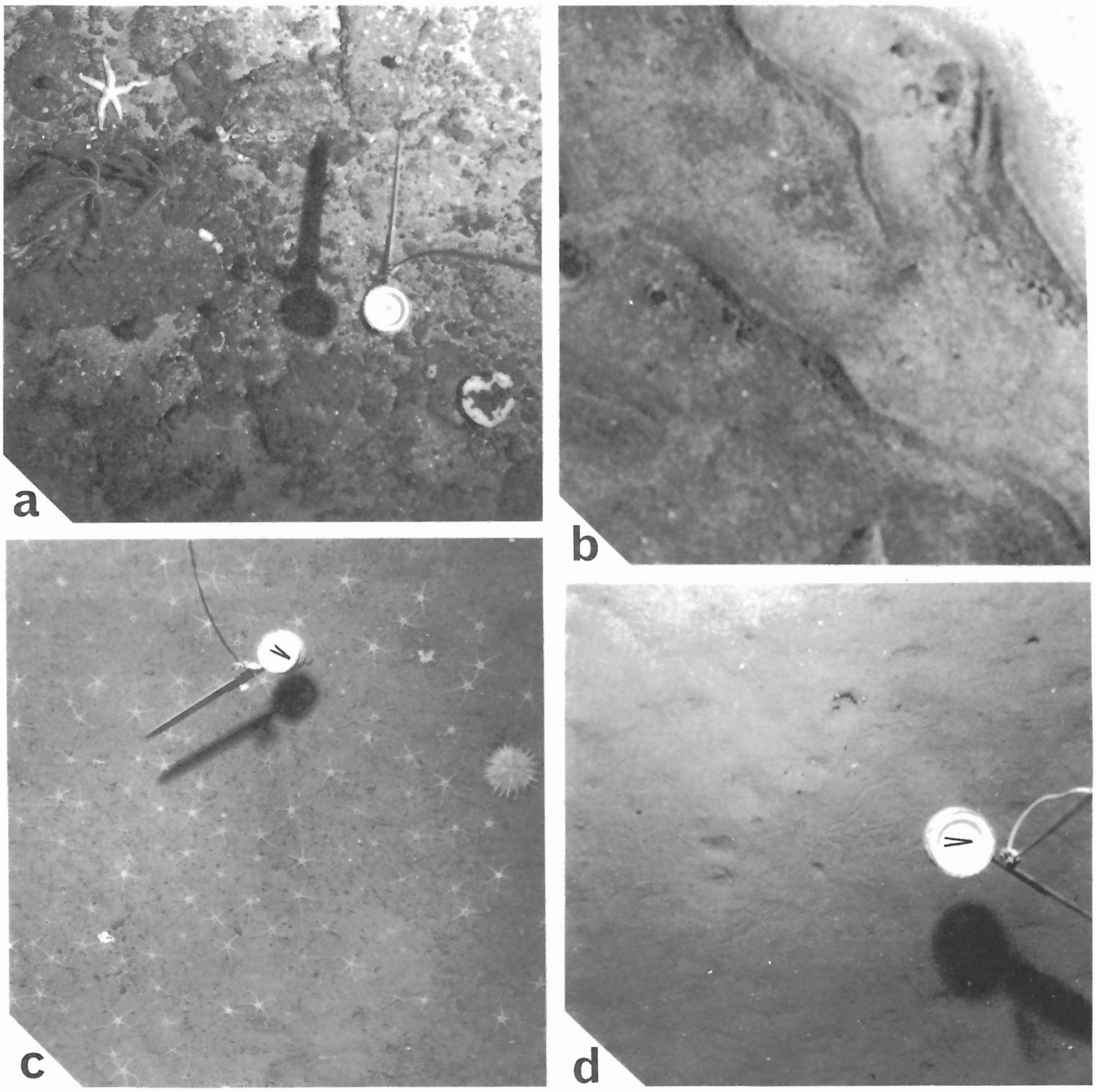

Figure 12

a, b. Camera station No. 391; Middle Bank (130 m).

a. Wave dominated combined flow ripples with lee slopes facing north in foraminifera-rich gravelly sands.

b. Variety of organisms (asteroid, crinoids, and sponges) inhabiting rock strewn bank surface.

c. Camera station No. 424; Goose Island Trough (183 m). Muddy seafloor inhabited by ophiuroids and echinoids.

d. Camera station No. 427; Goose Island Trough (250 m). Muddy seafloor on which are evident burrow holes and trails but no hydraulic bedforms.

and Freeland, 1978), the dark bands may define zones with higher concentrations of gravel (Groups A,B sediments) and lighter bands those areas blanketed mainly with well sorted fine (Group D) sands. Elongated sand patterns displayed in Figure 13A-A' may represent flow parallel "current lineations" (McKinney et al., 1974; Swift and Freeland, 1978) and (or) flow transverse sand patches (Belderson et al., 1972). The darker bands can be considered "deflation zones" (Swift et al., 1978) i.e. areas in which most sand has been swept clear of the basal gravel (Fig. 10c,10d,11c). When the distortion in scale parallel to with respect to that normal to the ship's track is compensated for, the average orientation of the lineations is about 20°T.

The record across outer Intertrough Area (Fig. 22,14) displays crisscrossing grooves varying in width and length and scattered closed depressions. The former probably are relict iceberg furrows (Belderson et al., 1972; King, 1976); the latter possibly are ice-scour craters (McLaren, 1982). The deepest occurrence of a furrow evident on records acquired across the length of Mitchell's Trough is at 200 m at the bend in the trough.

Clay-Size Sediment Mineralogy

Based on the height of the first order basal peaks in X-ray diffractograms (Fig. 15) it is concluded that chlorite and smectite are the dominant phyllosilicates in bottom sediments. Illite tends to be somewhat less abundant and only trace amounts of kaolinite and vermiculite (or mixed layer clays) are present. Small amounts of quartz, feldspar and amphiboles probably also are present.

Heavy Minerals

Extraction of heavy minerals from best sorted sands having similar mean size revealed that the six samples with the highest concentrations, numbers 27 (91 m), 63 (122 m), 74 (102 m), 180 (82 m), 510 (92 m) and 512 (174 m) (Fig. 16) have mean sizes ranging from 0.145 to 0.205 mm. All but the last of these samples fall within a 40 m depth range centred about 100 m. Three of the samples lie near well defined or muted canyons on the northern margin of Cook Bank. The other three lie along the southwestern margin and slope of Goose Island Bank. The weight per cent proportion of magnetite in the heavy mineral fraction of the above samples ranges from six and eight per cent (numbers 512, 74, 27) to 29 per cent (number 63).

Glauconite

Glauconite was found either enclosed in foraminiferal tests or in a free state (in the latter case it often retains the form of the host test) (Fig. 17). Although glauconite is present in most sediment groups on the shelf (Fig. 16), few if any of the sediments have large concentrations of the coarsest, test-free and, presumably, better developed glauconite. However, a high proportion of the shelf edge – upper slope sediments have a relatively high concentration of these glauconite pellets, an association suggested earlier by the work of Murray and MacKintosh (1968). The genesis of what appears to be similar test-associated glauconitic matter on the Norwegian shelf has been described by Bjerkli and Östmo-Saeter (1973).

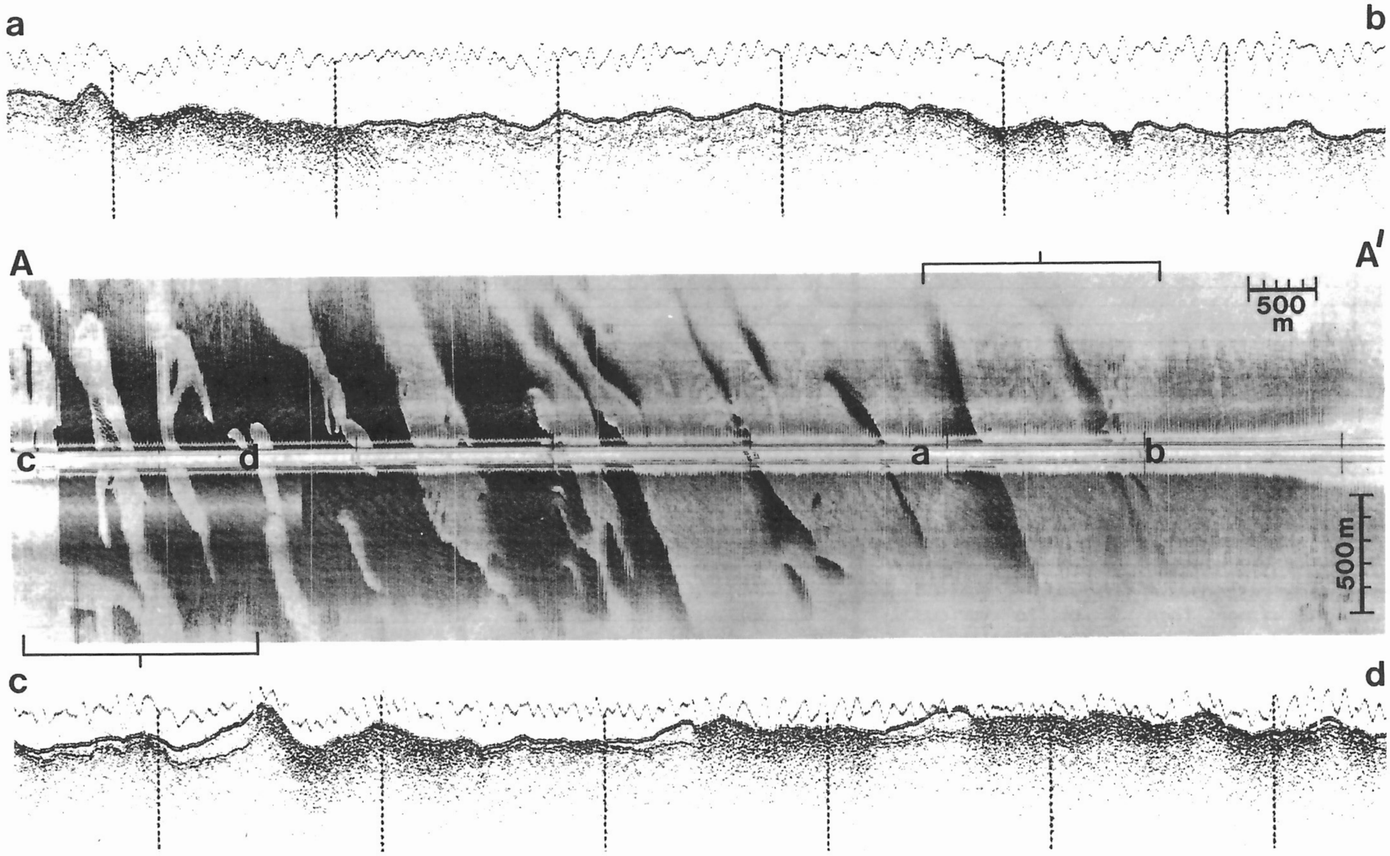

Figure 13. Sonogram and Deep-Tow seismic records of shallowest part of Goose Island Bank. Maximum thickness of sand lenses in Deep-Tow section cd: ~2 m. Refer to text for interpretation (GSC Line 81-1 to 2).

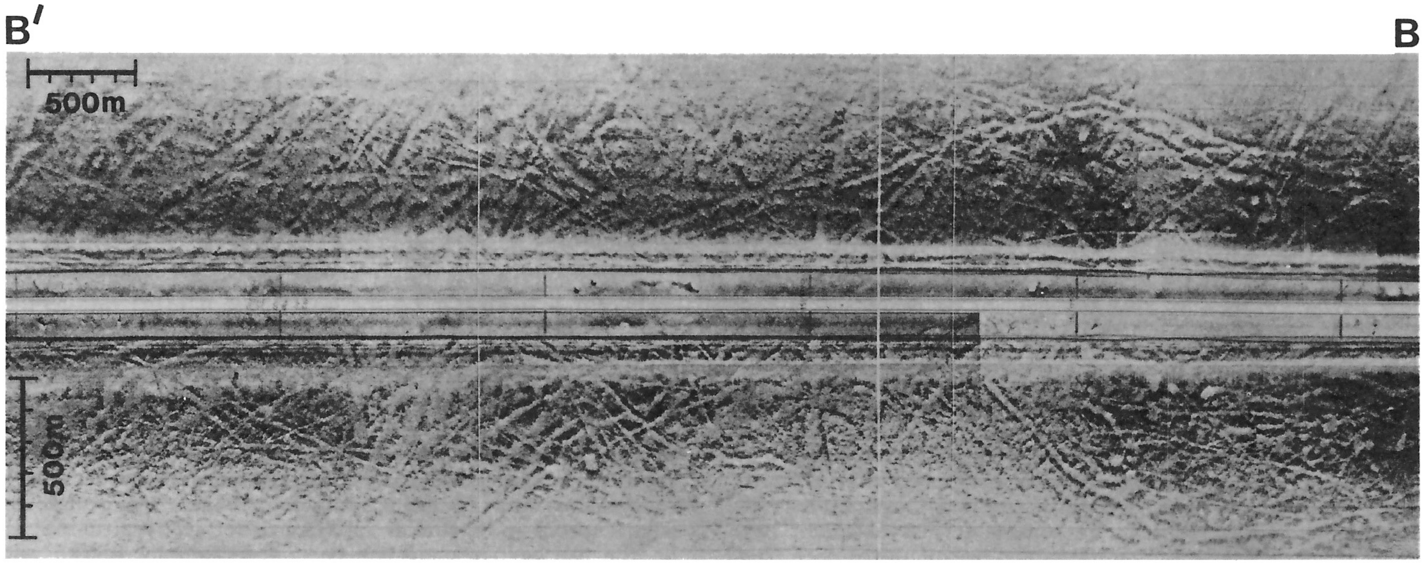

Figure 14. Sonogram of central Intertrough Area displaying relict ice furrows (GSC Line 81-2 to 3).

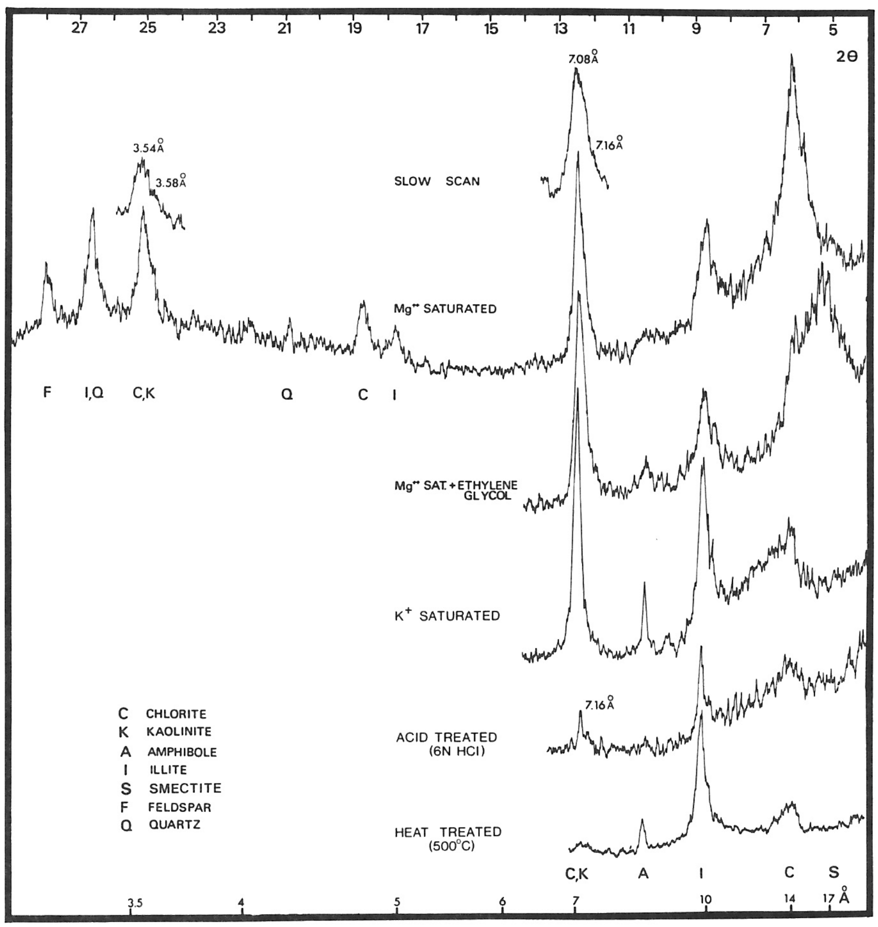

Figure 15

X-ray diffractograms illustrating representative responses of fractions of bottom samples finer than 2 μm to various analytical treatments (Cu Kα ratiation).

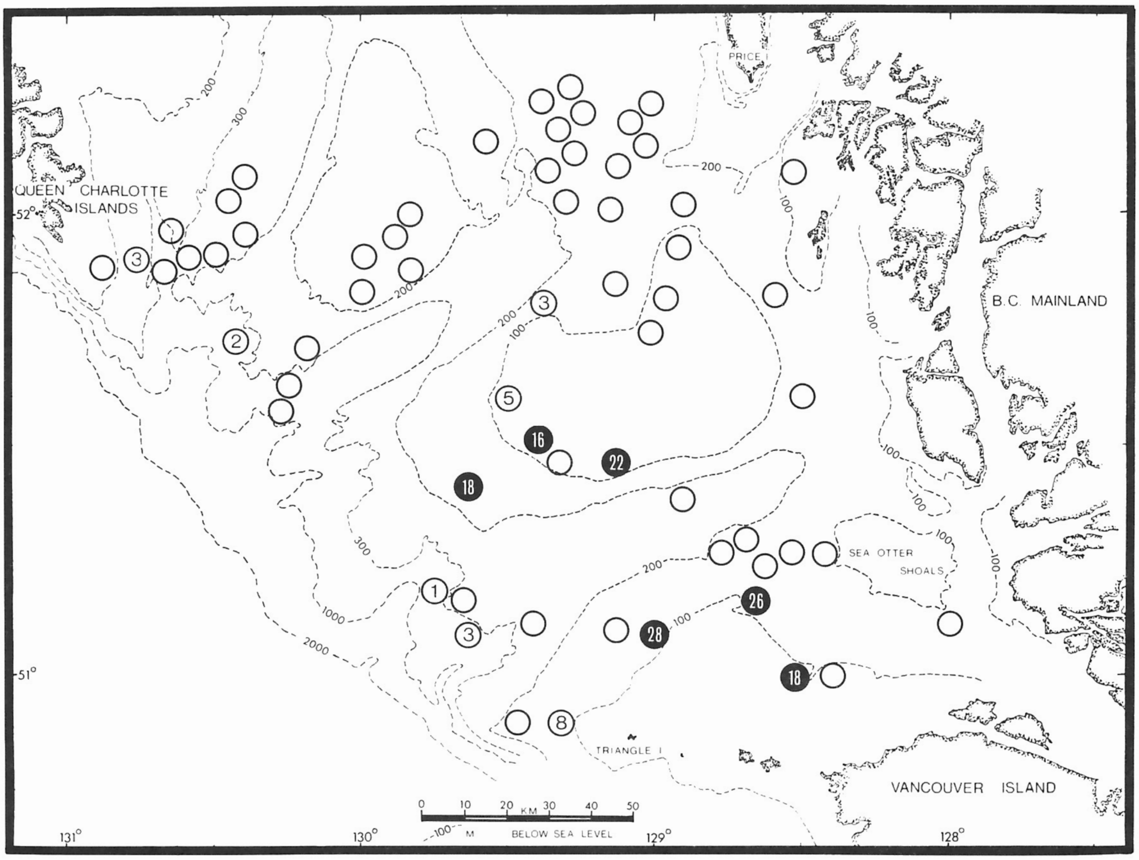

Figure 16. Glauconite pellet and heavy mineral distribution. Numbered black dots indicate total concentration (weight per cent) of 0.177-0.063 mm heavy minerals in best sorted sands with similar mean sizes (0.45-0.205 mm). Numbered open circles indicate total concentration (weight per cent) of coarse (0.345-0.250 mm) glauconite pellets in the mud plus sand fraction. Unnumbered open circles indicate sites where coarse glauconite was present but constituted <1% by weight of mud plus sand fraction.

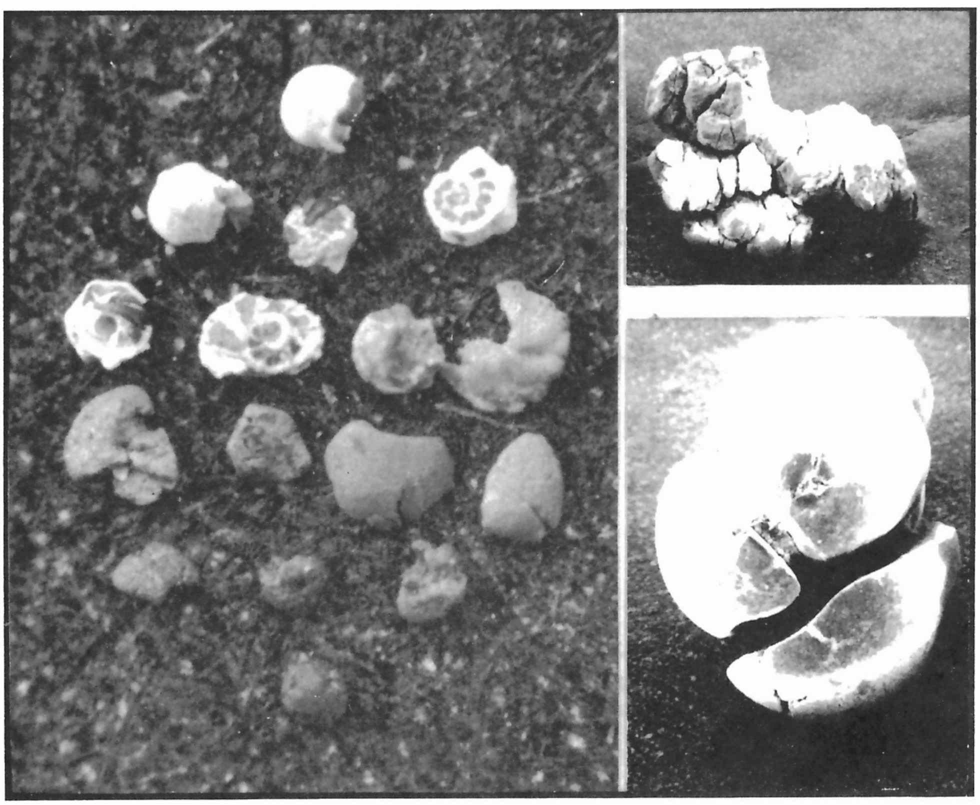

Figure 17

The photo at left displays a variety of semi-enclosed and test-free glauconite particles found in Queen Charlotte Sound sediments. The tests and pellets range in size from 0.354 to 1.00 mm. On the right are two samples of what are identified as test-free glauconite pellets ranging in size from 0.354 to 0.500 mm.

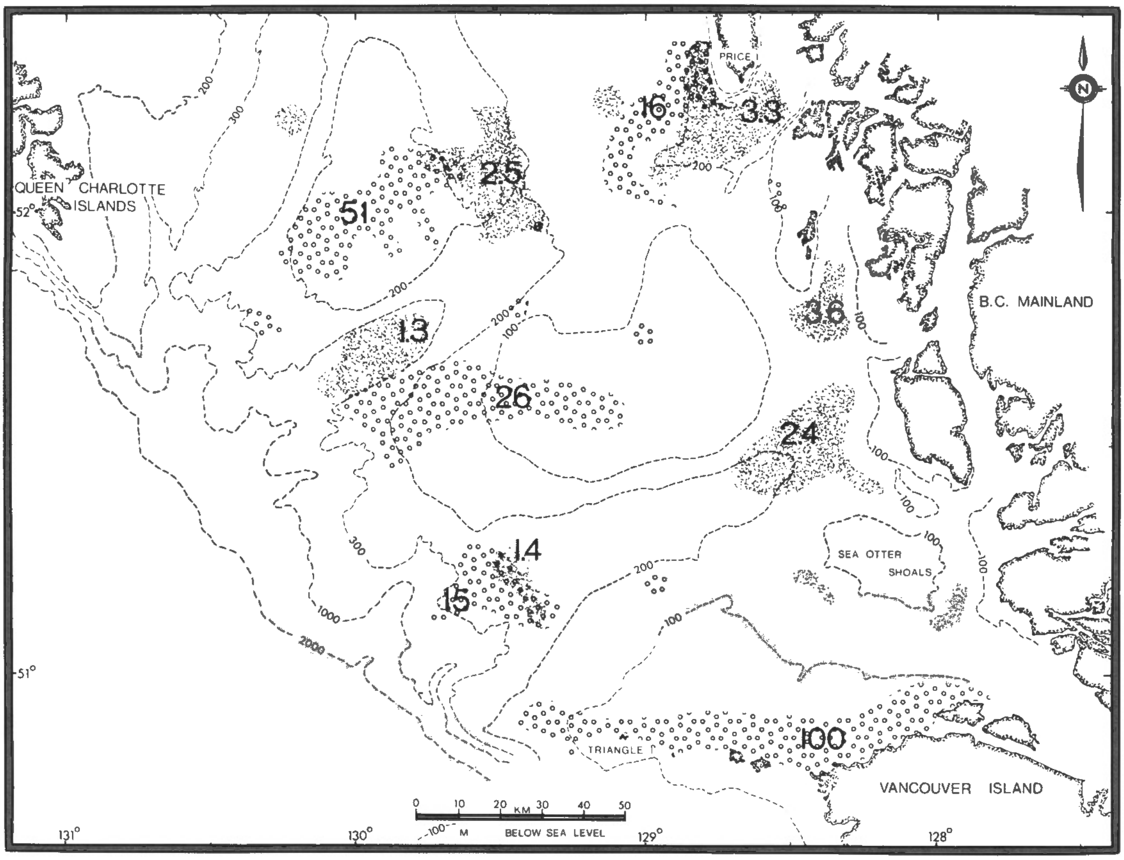

Figure 18. *Distribution of skeletal carbonate and noncarbonate organic carbon concentration as weight per cent of total mud plus sand fraction. Open circle areas: >10% skeletal carbonate; finely stippled areas: >1.0% non-skeletal organic carbon. Local maximum indicated.*

Skeletal Carbonate

Carbonate detritus is sparsely distributed (Fig. 18). Seventy-five per cent of the samples contain less than 4 per cent by weight carbonate matter within the sand plus mud fraction. Highest carbonate concentrations are found on banks in association with coarse, poorly sorted terrigenous sediments. Molluscan shell fragments are clearly the dominant carbonate component on the bank to depths of approximately 100 m. Within the Intertrough Area (160 m) the carbonate fraction consists of subequal parts of molluscan shell hash and foraminiferal tests. At similar or greater depths on the outer shelf foraminiferal tests dominate the carbonate fraction.

Noncarbonate Organic Carbon

Organic carbon content of the sand plus mud fraction of the sediments generally is very low (Fig. 19). Values are highest for the fine muds at the mouths of Queen and Milbanke sounds, moderate along Goose Island Trough northwest of the Sea Otter Shoals and in Mitchell's Trough flats, and low at the outer reaches of Mitchell's and Goose Island troughs. Noncarbonate organic carbon is virtually absent on the banks. Only a weak inverse relationship is displayed between organic carbon content and sediment mean grain size.

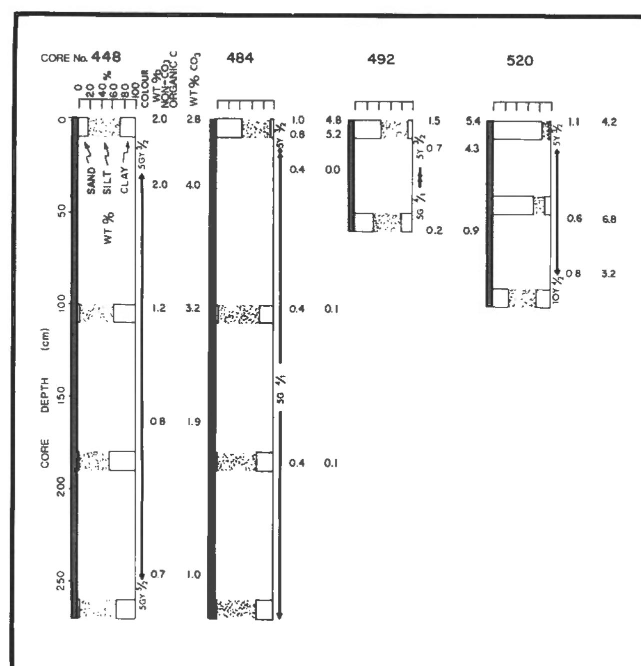

Figure 19. *Vertical distribution of grain size, colour and organic content in cores obtained in Queen Charlotte Sound.*

Gravity Cores

Core 448 obtained from that portion of Goose Island Trough northwest of the Sea Otter Shoals (Fig. 6) exhibits a general downward decrease in grain size (but is essentially a clayey silt throughout) and organic content (Fig. 19). Colour grades from greyish olive green (5 GY 3/2) at the top (Fig. 20A) to dusky yellow green (5 GY 5/2) at the bottom. X-ray photographs revealed distinct laminations only in the upper third of the 275 m long core (not illustrated). The bottom two thirds appears to be a massive deposit with a few small molluscan shells (Fig. 21).

Core 484 from Mitchell's Trough flats (Fig. 6) is capped with an olive grey (5Y 3/2) slightly clayey silt-sand with low to moderate amounts of organic matter, somewhat similar to that in core 448 (Fig. 19). These sediments overlie, at a sharp contact, 30 cm of intercalated dark greenish grey (5G 4/1) clayey silt and material similar to that at the top of the core (Fig. 20, core C_1). The remaining length of the core is entirely dark greenish grey clayey silt (Fig. 20, core C_2). Foraminiferal assemblages dominated by **Epistominella** sp. obtained from the lower sediments suggest they were deposited in a late Quaternary open shelf environment (B.E.B. Cameron, personal communication, 1974). The bottom three quarters of the core is more silty and has less organic matter than the sediments at equivalent depths in core 448 (Fig. 19).

The uppermost sediments in core 492 from the outer part of Michell's Trough (Fig. 6) are similar in grain size and colour to those at the top of core 484 (Fig. 19). These overlie at a sharp contact (Fig. 20, core B) dark greenish grey sandy clayey silt similar to, but somewhat coarser than, that in the lower unit of core 484. X-ray images (Fig. 21) indicate the greyish olive green sandy silt at the top of the core is laminated whereas the dark greenish grey finer sediment in the lower portion of the core may be massive.

Core 520 from the outer part of Goose Island Trough (Fig. 6) exhibits a downward increase in grain size from clayey silty sand to clayey sandy silt (Fig. 19). At equivalent depths noncarbonate organic carbon concentrations generally are higher than in cores 492 and 484, but less than in core 448. On average, carbonate concentration is higher in core 520 than in any other core. Colour grades from olive grey (5Y 3/2) to greyish olive (10Y 4/2). X-ray photographs (Fig. 21) reveal that coarse laminations and, possibly, cross-bedding are present to a depth of 60 cm in the core below which the sediments are very finely laminated or massive.

Proportions of chlorite and illite tend to increase slightly with depth at the expense of smectite in olive grey and greyish olive green sediments in cores 520 and 448, but are distinctly dominant in the dark greenish grey sediments below the unconformities in cores 484 and 492.

In summary, sediment structure, texture and composition changes gradually downward in Goose Island Trough cores whereas deeper deposits in Mitchell's Trough cores are separated from surface muds, accumulating under present conditions by a sharp, possibly erosional, unconformity and are distinguishable from them by all the following characteristics: greenish grey vs olive grey colour, finer grain size, lower organic but higher chlorite and illite contents and finer or less well-defined laminations.

Continuous Seismic Profiles

Line drawing interpretations of selected seismic records presented in this section delineate major reflectors, identify the uppermost laterally continuous angular unconformity (heavy line) and, in certain cases, parallel bedded or acoustically transparent sediments capping the stratigraphic section (stippled). Profile locations are displayed in Figure 22. Sediment thicknesses are calculated assuming a sound velocity of 1500 m/s.

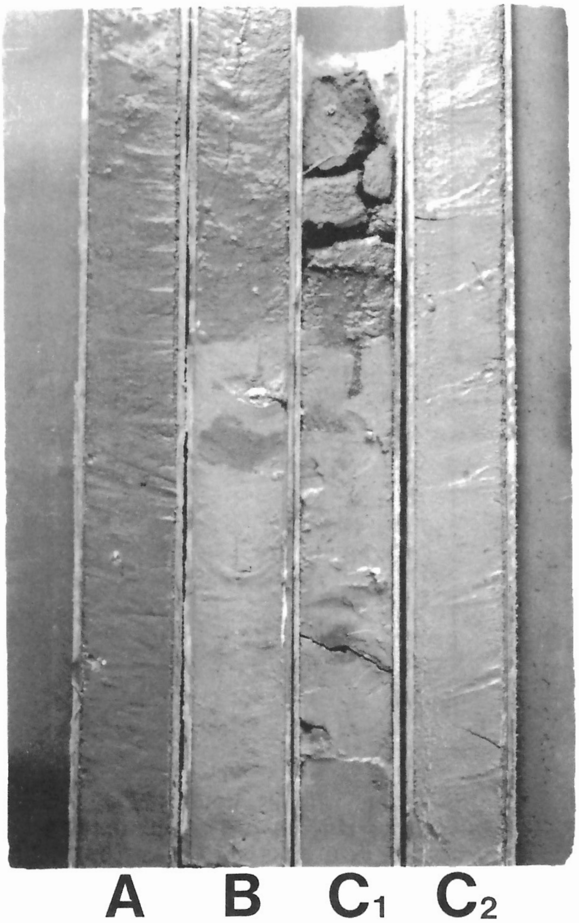

Figure 20. *Photographs of representative sections of cores obtained in Queen Charlotte Sound troughs.*

A. Core No. 448. Inner Goose Island Trough. Uppermost 50 cm of core. The entire core displays fairly uniform colour (greyish olive to dusky yellow green) characteristic of muds lying on present seafloor.
B. Core No. 492. Outer Mitchell's Trough. Section of core displays major unconformity (29-30 m from top) between upper olive grey sand-silt and lower, predominantly dark greenish grey, clayey sandy silt. Whitish patch near contact represents remains of a bivalve.
C_1 and C_2. Core No. 484. Central Mitchell's Trough. C_1 represents uppermost and C_2 lowermost section of 275 cm core. Note similarity between this core and core No. 492 at contact between darker, coarser, upper sediments and lighter, finer, lower sediments. In this core the unconformity lies 17 cm from top of core. The protrusion of darker sediment into underlying silts probably is an infilled burrow hole.

Profile A-A' (Fig. 23): Folded (?) units which lie adjacent to and, possibly, under Middle Bank are unconformably overlain by generally flat lying beds which, in turn, are unconformably overlain by laterally discontinuous sediments (~100 m thick) which appear to cap this section and extend from the trough onto adjacent banks. The upper unconformity delineates at least two distinct V-forms (scour and fill features?) about 30-40 m deep and 1-2 km wide. The Middle Bank wall of the trough appears primarily to reflect an erosional origin whereas the Goose Island Bank wall is more likely an accretionary feature. Another record (not illustrated), however, displays what appear to be truncated units on this wall approximately 15 km to the southwest of this site.

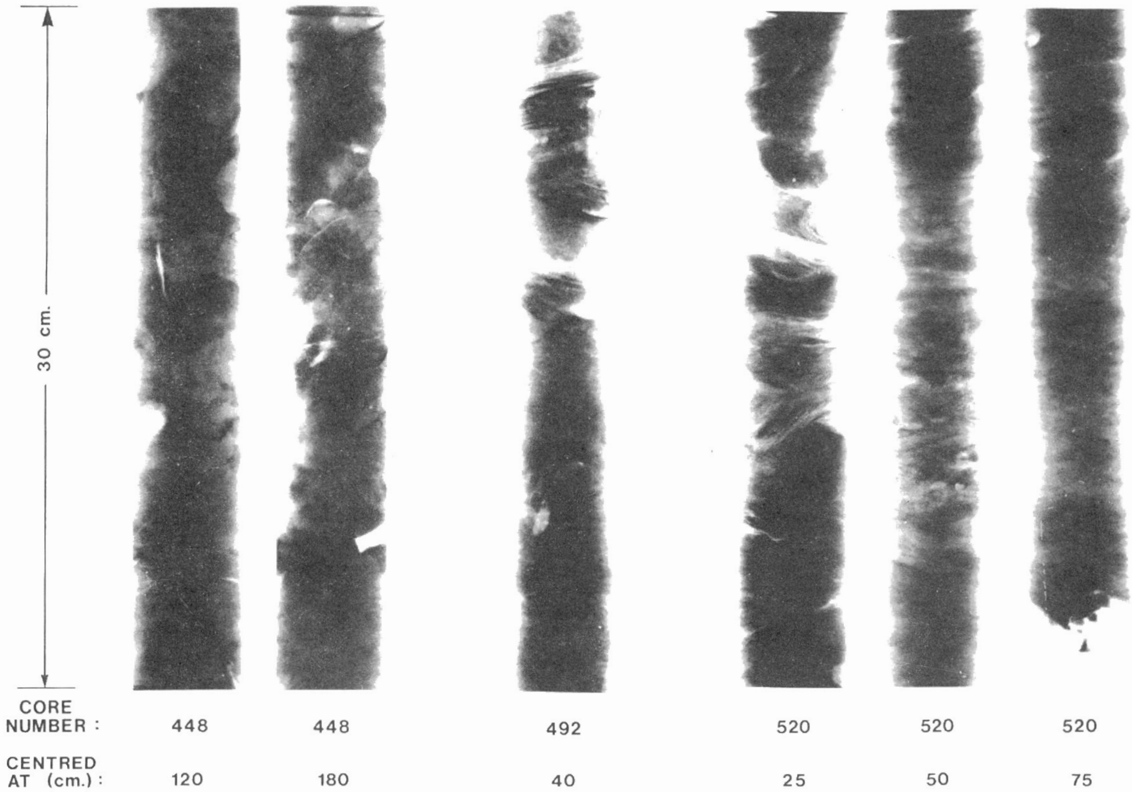

Figure 21. *Representative X-ray images of sections of cores obtained in Queen Charlotte Sound. Deeper parts of core 448 (inner Goose Island Trough) are massive. Core 492 (outer Mitchell's Trough) displays well developed coarse laminations and what appears to be crossbedding in the sandy sediments capping the core. Core 520 (outer Goose Island Trough) displays crossbedding at its top which grades into flat lying finer laminations which in turn grade into a very finely laminated or massive deposit at the bottom.*

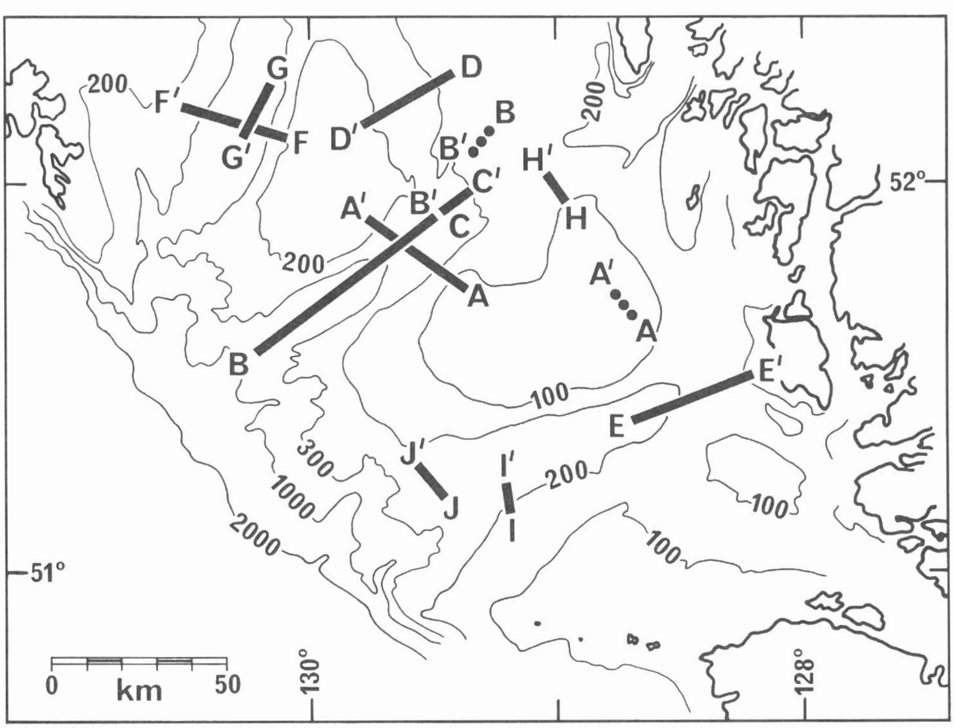

Figure 22. *Index map of locations of seismic profile tracklines (heavy lines) and side viewing sonar tracklines (dotted lines). Contours in metres.*

Profile B-B' (Fig. 24): The apparently folded "bedrock" core evident in the preceding profile is here draped by a thick succession of parallel beds which extends down Mitchell's Trough and under the slope. These beds are unconformably overlain by irregularly stratified sediments which are as much as 75 m thick (or ~100 m if a sound velocity of 2000 m/s. is assumed). Deep-tow seismic records indicate that horizontally bedded, transparent material capping the sequence in places along the outer trough is no more than about 5 m thick. The shelf edge sill appears to consist of a core of the deeper parallel bedded strata overlain with a thin veneer of what is probably poorly sorted detritus. Similar stratigraphic relationships are displayed in a seismic profile along the axis of Goose Island Trough (not illustrated).

Profile C-C' (Fig. 25): This profile is an extension of Profile B-B'. Deeper parallel bedded units are unconformably overlain by a sequence of laterally discontinuous layers which are capped by apparently flat lying, relatively thin bedded deposits having a maximum thickness of about 20 m.

Profile D-D' (Fig. 26): On the mainland (left) end of the profile what probably is crystalline bedrock outcrops on the seafloor and slopes below the surface of Mitchell's Trough flats. Approximately half way across the trough a wedge of gently sloping, parallel-bedded sediments abuts this surface and, in places, may outcrop on the trough floor. Above an erosional surface extending across both the crystalline and sedimentary sequences lie what appear to be mainly horizontally bedded sediments which now form the floor of the trough. On a profile extending from Goose Island to the mainland (not illustrated) the contact between crystalline and sedimentary rocks also underlies the trough floor.

Profile E-E' (Fig. 27): The domed feature at the base of this section probably is a subbottom extension of Sea Otter Shoals crystalline rocks. A thick succession of seaward dipping sediments over this bedrock core is in unconformable contact with overlying irregularly bedded sediments which form a continuous cover over this part of the shelf. At the centre of this section the sedimentary column is capped by parallel bedded sediments having a maximum thickness of about 35 m.

Profiles F-F' and G-G' (Fig. 28): The air-gun record (F-F') normal to the axis of Moresby Trough indicates that parallel bedded deposits are concentrated in the central depression which is bounded on the east by a relatively steep scarp of either erosive or tectonic origin. The deep-tow seismic record depicting the central area along a trackline (G-G') oriented obliquely to the thalweg of the trough reveals (a) what appear to be slump blocks at the base of the scarp, (b) truncated sediment layers at the floor of the deepest trench within the trough and (c) an upper sequence of sediments (maximum thickness ~30 m) to the west of the trench with bedding which is laterally continuous and uniformly thick over several kilometres. These sediments overlie, in places unconformably, a similar sequence of strata which may extend beneath the lower, essentially featureless, terrace on the northwestern flank of the trough. These laterally continuous deposits have been derived from the west-northwest and have ponded behind and overridden a now buried rise.

Profile H-H' (Fig. 29): This record suggests bank top sediments are prograding across the northernmost flank of Goose Island Bank to a depth of 170 m onto the irregularly bedded deposits which form the floor of the Intertrough Area. An acoustically discontinuous irregular surface underlies the disjunctly bedded sediments. Other records indicate a comparable wedge of sediments is also accumulating off the southeastern margin of the bank but extends only to 100 m depth.

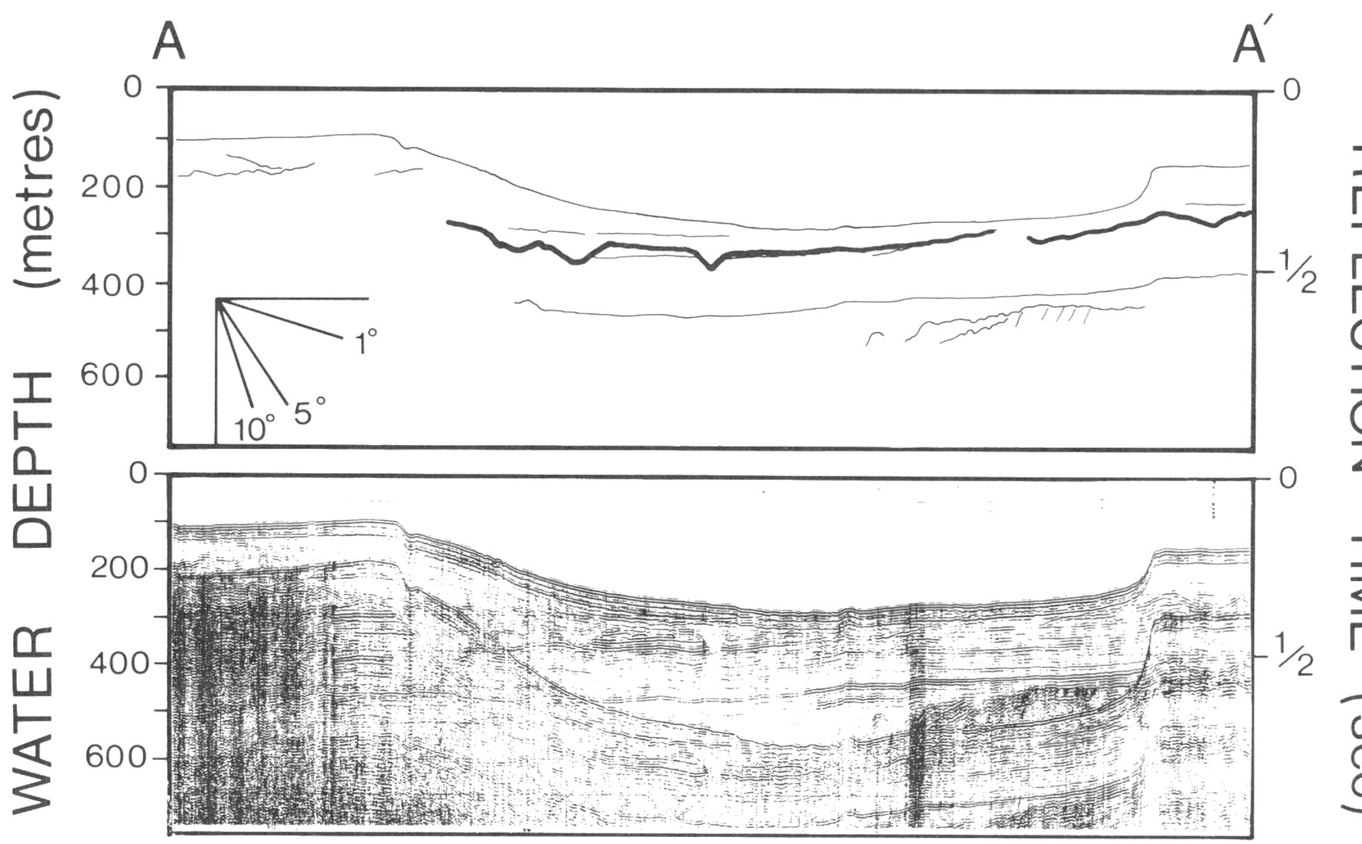

***Figure 23**. Air-gun seismic profile A-A' across central Mitchell's Trough. Refer to text for interpretation (GSC Line 73-13).*

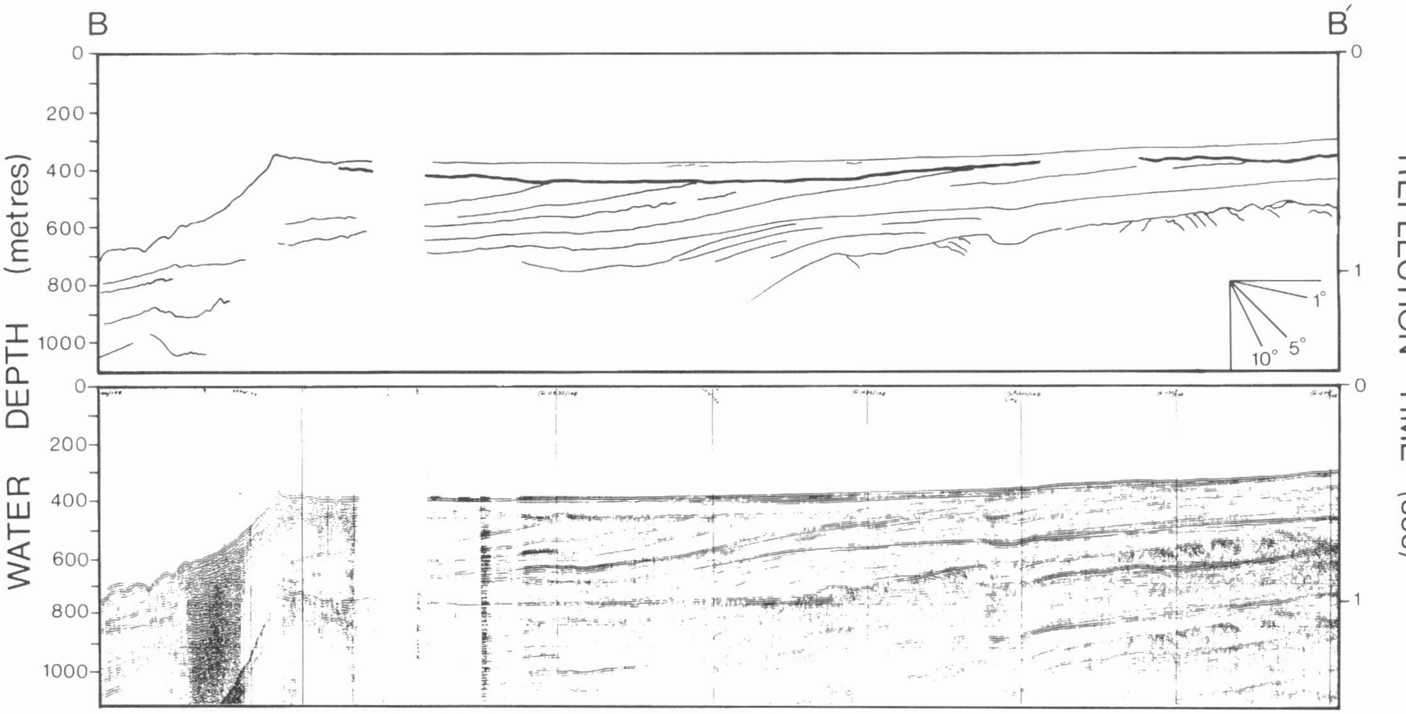

Figure 24. *Air-gun seismic profile B-B' along axis of outer Mitchell's Trough. Refer to text for interpretation (GSC Line 73-12).*

Profile I-I' (Fig. 30): Sediments probably derived from Cook Bank are shown here to have ponded behind and overridden a now buried rise or ridge. Much of the sequence of sediments may represent glacial outwash deposits. The relatively thin, chaotic bedding of some of the sediments on the flank of Cook Bank, however, suggests slope failure and concommitant turbidity flows also may have contributed to sediment deposition in Goose Island Trough.

Profile J-J' (Fig. 31): Irregularly bedded sediments having a maximum thickness of about 50 m unconformably overlie older deposits. The sediment column is capped by parallel bedded sediments which have accumulated asymmetrically across the trough floor suggesting they have been derived primarily from the north.

In summary, the seismic records appear to indicate that:

1. The present shelf and slope surface has developed on a sequence of sediments which prograded westward over what probably is crystalline bedrock on the inner shelf and sedimentary bedrock on the outer shelf (Fig. 24).
2. During a major glaciation the shelf was scoured across its entire width (Fig. 24) and to depths as great as 75-100 m below the present floor of the part of troughs at the centre of the shelf (Fig. 23).
3. Sills at the shelf edge are erosional remnants of possibly pre-Pleistocene or early Pleistocene deposits (Fig. 24). Mid-shelf ridges are, in places, continuous with irregularly bedded (drift?) deposits (Fig. 25) overlying parallel bedded sediments.
4. Sections of troughs parallel to the mainland coast lie along the contact between crystalline coastal rocks and thick sediments underlying the shelf (Fig. 26).

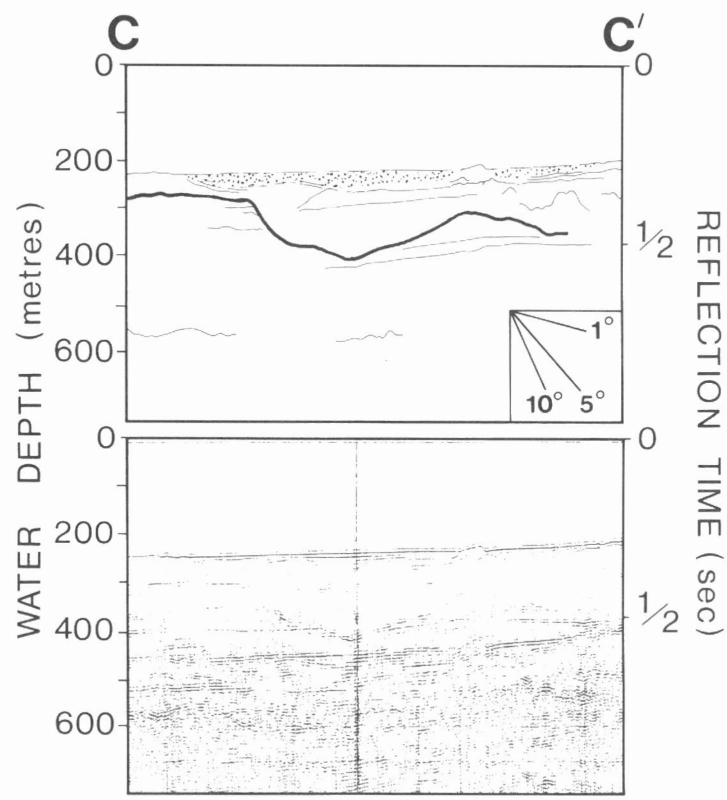

Figure 25. *Air-gun seismic profile C-C' at the bend in Mitchell's Trough. Refer to text for interpretation (GSC Line 73-12).*

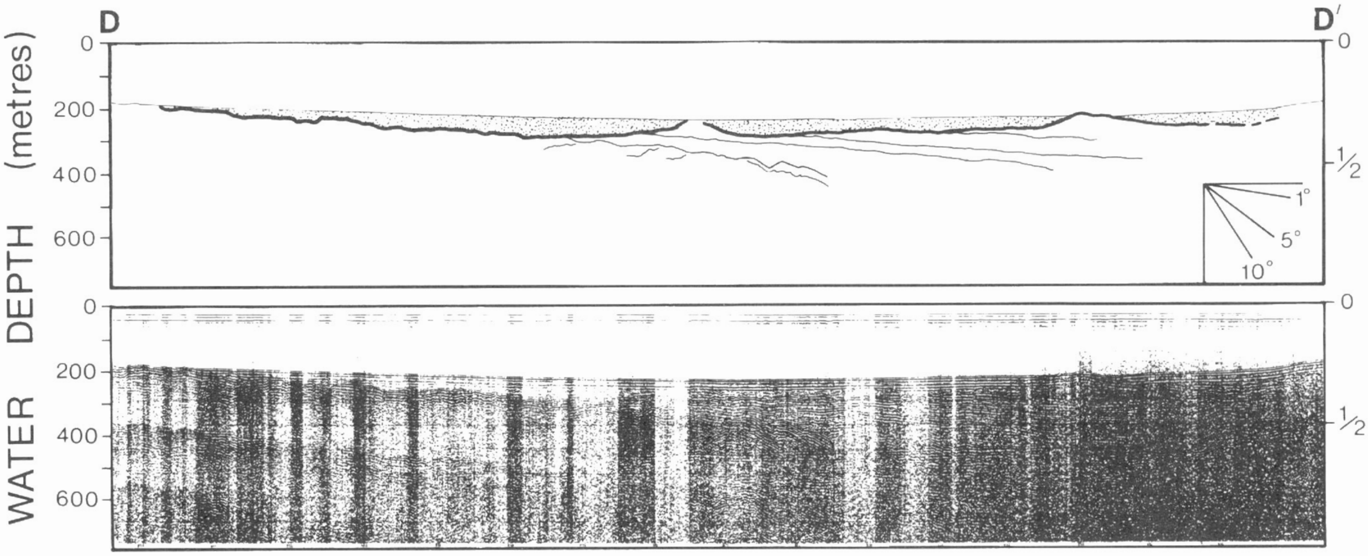

Figure 26. *Air-gun seismic profile D-D' across central Mitchell's Trough flats. Refer to text for interpretation (GSC Line 73-4).*

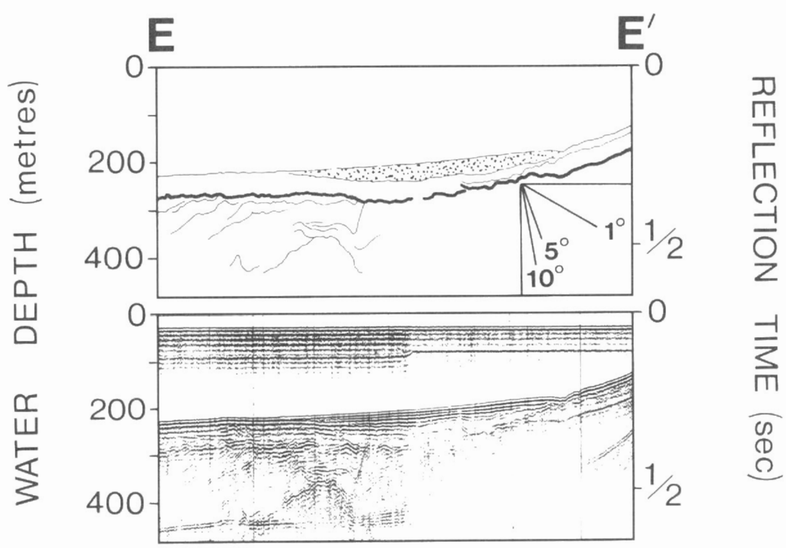

Figure 27

Air-gun seismic profile E-E' along axis of Goose Island Trough north of Sea Otter Shoals. Refer to text for interpretation (GSC Line 73-37).

5. The lower terrace on the northwest flank of Moresby Trough is underlain by a sequence of uniformly bedded outwash deposits (Fig. 28).
6. Eroded sedimentary strata lie at or near the sediment-water interface in the deepest basin within Moresby Trough (Fig. 28).
7. Troughs (with the possible exception of Moresby Trough) are not fault bounded nor do they lie along identifiable fault lineations (Fig. 23, 26, 29, 30, 31).
8. Now-infilled shallow troughs linked Milbanke Sound across the Intertrough Area to Mitchell's Trough (Fig. 29).
9. Outer trough walls of Goose Island Trough are more consistently accretionary in character than those of the more northerly troughs (Fig. 23, 28, 30).
10. Thickest accumulations of localized parallel bedded (mud?) deposits (~30 m thick) underlie the lower terrace on the northwestern flank of Moresby Trough and form the uppermost deposits at the bend in Mitchell's Trough and in Goose Island Trough north of the Sea Otter Shoals (Fig. 25, 27, 28). If it is assumed that these deposits have been accumulating from 13-15,000 years B.P. to the present, the average sedimentation rate at these isolated sites is 2-3 mm/a. (Even these few sites however, may not all be major present day sediment sinks.)
11. Currents are sweeping sediments to the north and south of the eastern side (Fig. 29) and, possibly, to the southwest of the western part of Goose Island Bank (Fig. 31).

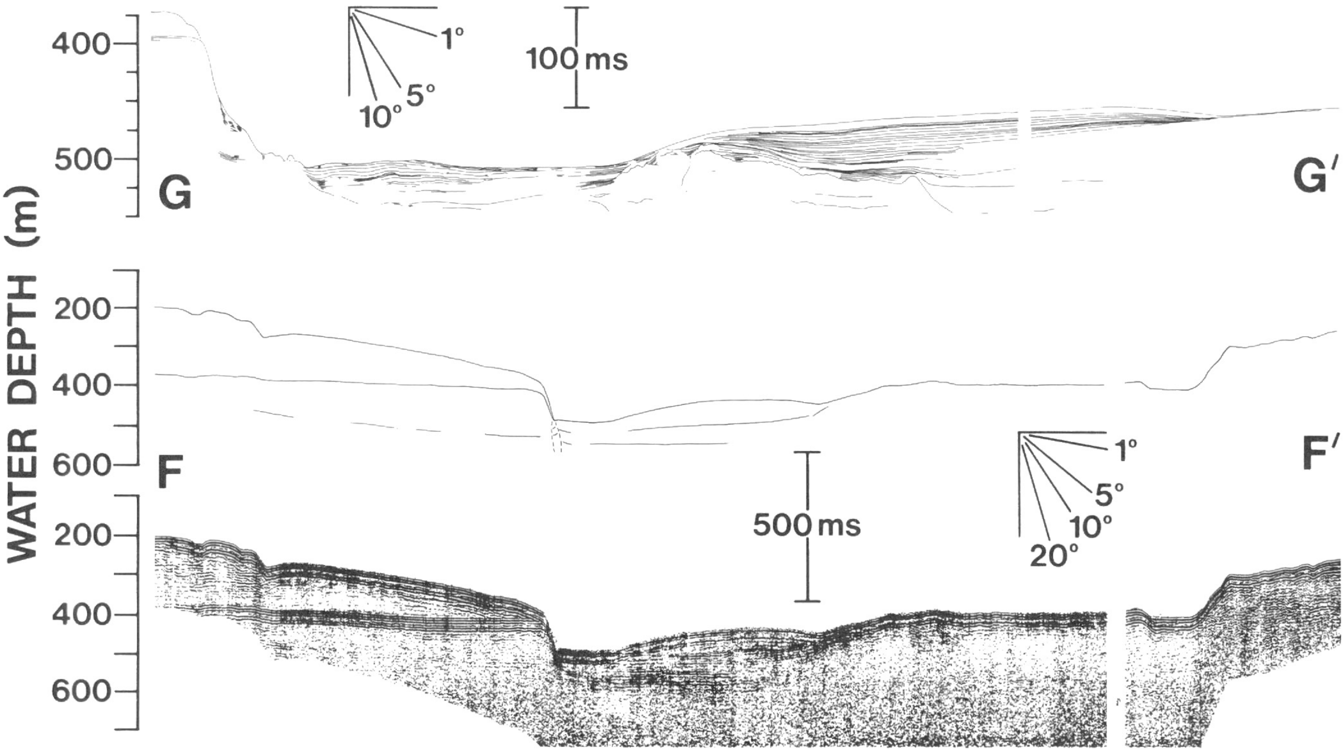

Figure 28. Air-gun seismic profile F-F' across outer Moresby Trough. Refer to text for interpretation (GSC Line 73-5). Deep-Tow high resolution seismic profile G-G' obliquely crosses axis of outer Moresby Trough. Refer to text for interpretation. (GSC Line 81-22 to 21).

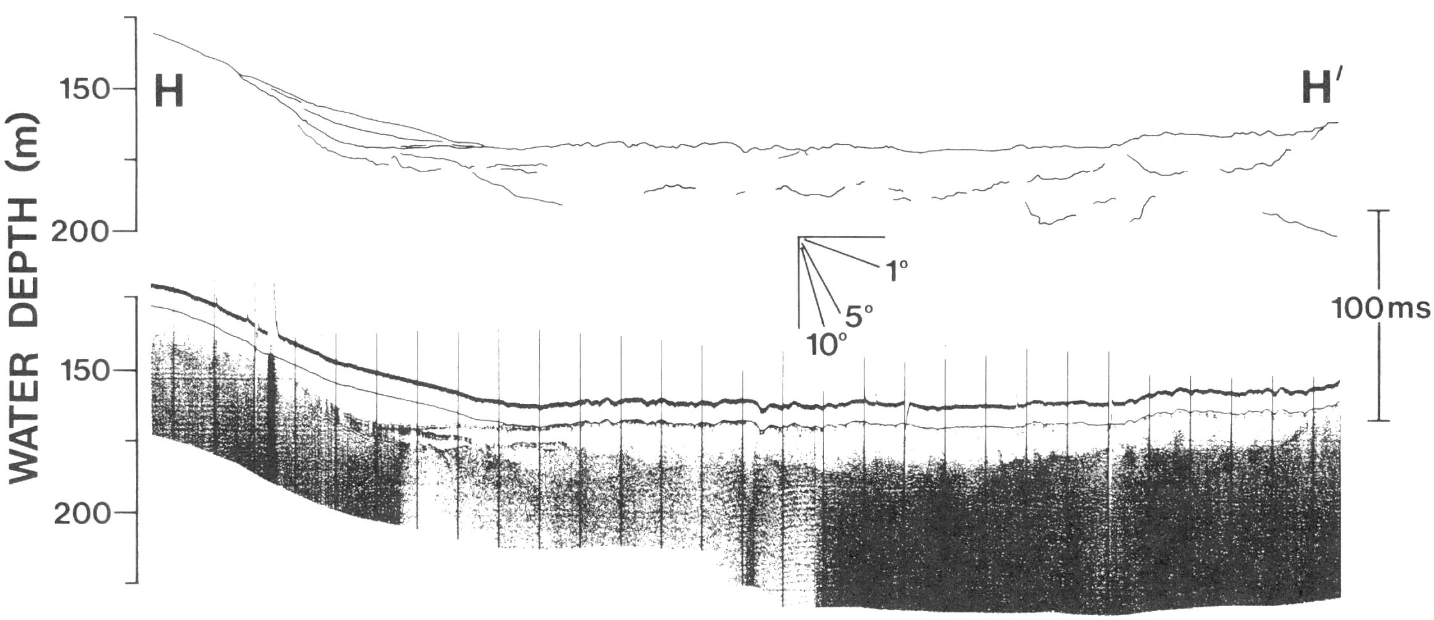

Figure 29. Deep-Tow high resolution seismic profile H-H' across the northeastern margin of Goose Island Bank. Refer to text for interpretation (GSC Line 81-1 to 2).

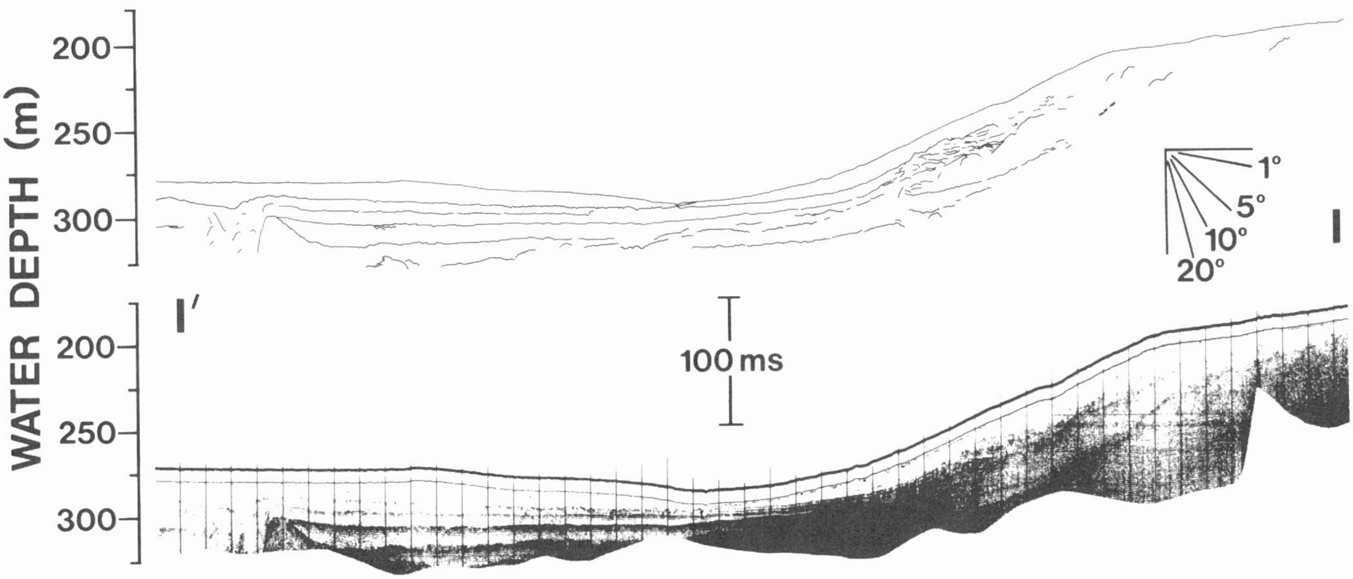

Figure 30. Deep-Tow high resolution seismic profile I-I' across the southern flank of outer Goose Island Trough. Refer to text for interpretation. (GSC Line 81-4 to 5).

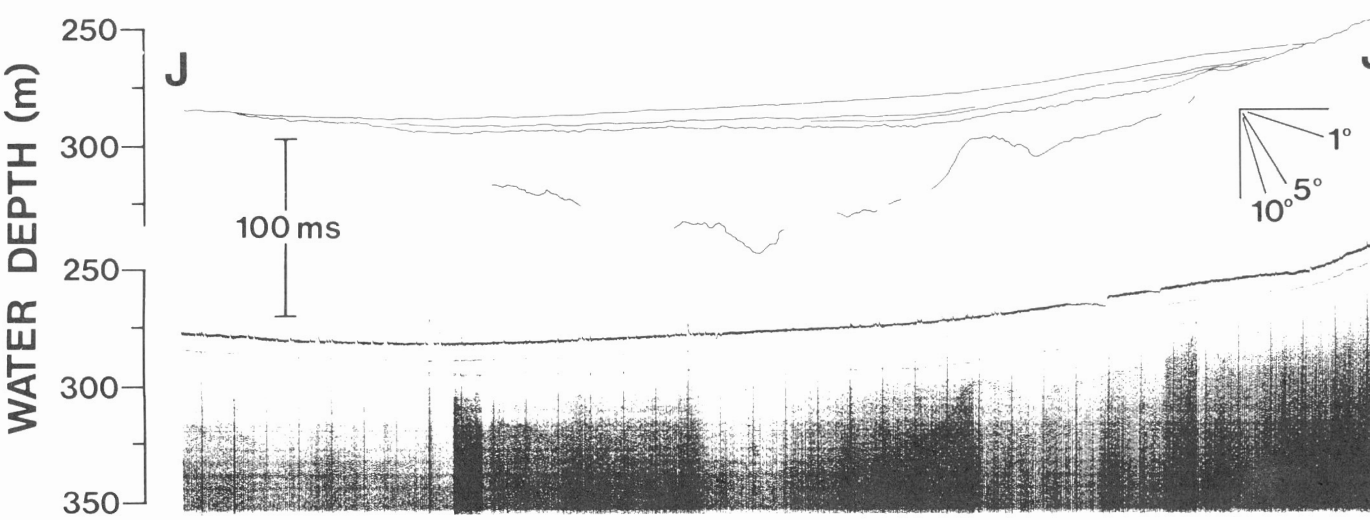

Figure 31. Deep-Tow seismic profile J-J' across the northern flank of outer Goose Island Trough. Refer to text for interpretation (GSC Line 81-5 to 6).

DISCUSSION

Structural/Stratigraphic Influence on Shelf Physiography

The gap between the Queen Charlotte Islands and Vancouver Island offered the only unobstructured passage for Pleistocene ice spilling off the central Coast Mountains. This breach in the Insular Belt must have determined to a large extent the general northeast-southwest trend of the troughs in Queen Charlotte Sound. The specific orientation and location of different segments of the troughs, however, probably were defined by local structural and stratigraphic lineations such as those, for example, that are considered to have influenced the orientation of "marginal channels" off glaciated coasts (Holtedahl, 1958, 1970; Grant, 1972).

These geomorphic features lie at high angles to the dominant direction of ice movement (in the Sound it is assumed to have been from the northeast to the southwest). Their orientation is considered to reflect selective glacial erosion of a fault zone and (or) the contact between crystalline coastal rocks and the thick sedimentary deposits on the shelf (Holtedahl, 1970; Grant, 1972). Examples in Queen Charlotte Sound are the section of Goose Island Trough between Goose Island Bank and the mainland and the flats portion of Mitchell's Trough which are oriented normal to the presumed principal directions of local ice flow and lie along stratigraphic contacts. There is no evidence to indicate that faulting has influenced the glacial excavation of these trough sections.

Factors which may have been instrumental in defining the specific location and orientation of the troughs which generally parallel the direction of ice flow are somewhat more obscure. Cook Trough parallels lineaments on both the adjacent mainland and northern Vancouver Island and may lie along a deep fault or stratigraphic contact. Outer Moresby Trough and outer Goose Island Trough may lie along the contact between more indurated Tertiary and less indurated younger deposits on the shelf. The low level of seismicity of the Queen Charlotte Sound area would suggest that even if future surveys confirm that Moresby Trough does lie along a fault it probably is not the locus of major present motion.

As crystalline rock probably underlies the Intertrough Area, it is possible that this broad area of low relief is a submerged and now buried extension of the Milbanke Strandflat. Submerged strandflats, in fact, have been recognized off other glaciated coasts (Holtedahl, 1958, 1970).

Ice Contact and Proglacial Features

The ridges crossing troughs are probably recessional or end moraines deposited at the terminus of a grounded ice lobe or below an ice shelf a relatively short distance beyond the grounding line (Barnett and Holdsworth, 1974; Fillon, 1975). King et al. (1972) suggested that sills lying along a shelf edge develop as a consequence of fracturing and calving of glaciers where water depth increases aburptly, presumably because of the diminished erosive capacity of ice and (or) by the release of enclosed detritus under these circumstances.

The complex of features at the intersection of Cook Trough and Goose Island Trough is similar to the morainal and ice contact landforms (kames, kettles, esker?) associated with stagnant or receding glaciers on land (Flint, 1957). Consequently, the anomalously deep, well sorted, fine sands in Goose Island Trough immediately to the west of this area possibly represent relict outwash fan deposits. As the ridges at the bend in Mitchell's Trough are the same depth as the features at the intersection of Cook and Goose Island troughs, they may represent contemporaneous stagnation sites of receding grounded glaciers.

The morphology and sediment character of the Intertrough Area, a part of the Sound which still displays evidence of intense scouring by icebergs, resembles that found on areas of low relief, both on land and in the sea, which have been glaciated relatively recently (Holmes, 1965: refer to Figures 500 and 504; Flint, 1957; Fillon, 1976; Van der Meer et al., 1976). Ice receding across the Intertrough Area flushed fine sediment into the adjacent trough to form Mitchell's Trough flats (the area less than 220 m deep). Middle Bank inhibited dispersal of this glacial outwash to Moresby Trough. What detritus did accumulate in this sediment-starved basin seems to have been derived primarily from ice which approached and retreated across western Hecate Strait. This ice probably stagnated on or over the shallower hummocky terrace on the northwestern flank of Moresby Trough and formed the featureless deeper terrace which is underlain by uniformly bedded outwash deposits.

Outwash from ice which had stagnated at the muted sill which extends between Goose Island Bank and the Intertrough Area may have buried a shallow trough which linked Milbanke Sound to Michell's Trough and led to the formation of (a) the low, long, spit-like ridge (at 120 m) extending across what may be a fault controlled embayment on the north side of Goose Island Bank, (b) the shallow elongate canyon just north of the ridge and (c) the parallel bedded deposits nestled in depressions in drift at the head of the transverse section of Mitchell's Trough.

Formation of Troughs and Banks

The formation of troughs on the West Antarctic shelf (e.g. Hughes, 1975; Thomas and Bentley, 1978) and Labrador shelf (Fillon, 1975) has been attributed at least in part to scouring by ice streams within submerged grounded ice sheets. The same mechanism can also explain the formation of troughs in Queen Charlotte Sound where the relief is, and probably was at the time of excavation, too muted to have contained isolated submerged valley glaciers which extended across the shelf. Formation of the troughs must postdate that of the aprons of sediment at the southwest of Goose Island and Middle Banks as troughs dissect the aprons. Consequently, the aprons may be outwash deposits laid down ahead of an advancing ice sheet and reworked by waves and currents.

When ice streams retreated along troughs they mantled the previously scoured surface with glacial debris including the identified ice contact and proglacial deposits. As ice sheets are expected to retreat more slowly on higher ground where they may remain grounded longer than in adjacent troughs (Thomas and Bentley, 1978) masses of ice may have been stranded on bank tops after trough ice had receded past the banks. Meltwater streams coursing through caverns at the base of this ice probably formed the channels on Cook and Goose Island banks.

Glacial sediments constituting the banks accumulated on bedrock platforms (eg. the northward extension of Nahwitti Lowland which probably underlies Cook Bank and at the top of the parallel bedded units which underlie Middle Bank). The height of such platforms and the volume of glacial debris deposited at any one site largely determined the highly discordant depths of the banks. The gentle seaward concavity of the terraced surface of Middle and Goose Island banks suggests it also reflects the effects of surf and (or) wave scour.

Extent of Ice Grounding During the Fraser Glaciation

Although no deposits on the shelf have been dated, certain lines of evidence suggest Fraser ice not only could have been grounded on the shelf but that grounding may have extended across the entire shelf:

1. If it is accepted that during the Fraser Glaciation (a) the outer shelf underwent little or no depression (and may as a result have been shallower or no deeper than the isostatically depressed inner shelf) and (b) sea level was lowered ~75-100 m, an ice thickness of probably no more than 300-400 m (1.1 times water depth) was required for an ice sheet to be grounded at the depth of the base of the drift deposits in Mitchell's Trough (75-100 m below the seafloor of the central shelf but less than that at the outer shelf). This ice thickness is less than half of the minimum probably required to induce the estimated 120+ m depression along the northwestern coast of Vancouver Island if the ratio of glacioisostatic depression to ice thickness of about 0.10 to 0.15 presumed to have prevailed on the mainland is applied to this area.
2. Icebergs from what is assumed to be the last major glacial event scoured the seafloor to depths at least as great as 200 m on the present inner half of the shelf.
3. Margins of the outer part of the troughs are still well defined, shelf edge sills are still apparent and Moresby Trough has a sharply irregular relief. If such features are pre-Fraser in age they would have had to survive blanketing by debris discharged during the retreat of a penultimate glaciation and during the full cycle of Fraser Glaciation. Furthermore these features were exposed to tidal current and wave erosion and sediment redistribution during successive regressions and transgressions of the sea that have occurred during the >67,000 years (Clague, personal communication, 1982) that elapsed since the penultimate glaciation.

An alternate possibility, that grounded ice of the Fraser Glaciation extended only part-way across the shelf within troughs, is supported by these considerations:

1. Sea level was rising during the last major glaciation and local water temperatures were nonpolar and may well have been similar to those at present.
2. Well-preserved deposits considered to have an ice front or ice contact origin (including outwash) are concentrated on the central and inner shelf.
3. Relief is more muted and depths generally are shallower toward the mainland and Vancouver Island coasts. This suggests that deposition from the last phase of glaciation was limited largely to that part of the shelf closest to major icefields.

A third possibility is that grounded ice reached the shelf edge but retreated rapidly to mid-shelf from whence it more gradually made its final withdrawal.

Apparently abrupt thinning of the ice front in the vicinity of Queen Charlotte Sound and the relatively short duration of the Fraser Glaciation favour the second alternative. Persistence of the glacigene physiographic features on the outer shelf if they were formed by pre-Fraser ice may have been promoted by gravel armouring of the seafloor and very limited sediment discharge by Fraser ice.

Impact of Lower Sea Levels

Intense tidal currents which swept over Cook Bank after ice had retreated or was no longer grounded but before the sea attained its present level, may have scoured the very gently inclined valleys at the margins of the bank. It is not readily apparent why these are not equally well developed valleys on the other banks, especially, the shallower Goose Island Bank. Cook Bank valleys may have been at least partly scoured in bedrock and, consequently, may be relatively stable features.

Turbulent tidal flows and wave action (Evans, 1939; Rao, 1957; Dubois, 1972; May, 1973) on Cook and Goose Island banks when sea level was lower initiated the sorting of sediments and contributed to the production of the deposits rich in heavy minerals now found at or near 100 m at the margins of these banks.

Curray (1969) suggested that the depth of the break in slope of continental shelves has been mainly controlled (barring post-Pleistocene isostatic movements) by shallow water processes active when sea level was 100-150 m lower because most shelf breaks lie within this depth range. As the constructional parts of the Queen Charlotte Sound shelf break lie at twice this depth and there is no reason to expect that the shelf edge has undergone depression since the Late Wisconsin, mechanisms other than shallow water oceanographic processes must have shaped its character. If we consider (a) that bottom photographs reveal vigorous sediment transport to depths of 130 m, (b) that mud is only a minor component of the majority of sediments on the outer shelf even at depths greater than 160 m, (c) that near bottom currents at 255 m can exceed 30 cm/s and (d) that cores obtained at or near 300 m near the shelf edge reveal what appear to be crossbedded, sandy, near-surface sediments, it is obvious that oceanographic processes are now, or were in a very recent past, capable of mobilizing at least fine sands on the seafloor over most of the outer shelf.

The evidence from this shelf coupled with what is known of shelf edge dynamics in other areas (Southard and Stanley, 1976) make it reasonable to propose, then, that when Late Wisconsin ice (which probably did not markedly depress the outer shelf) was flushing sediment across the Sound and sea level was as much as 100 m lower, bottom turbulence probably was high enough over the site of the present shelf edge to mobilize at least sands and muds and permit continuous accumulation of material mainly below that depth.

Present Sediment Dispersal and Deposition

The bulk of new terrigenous detritus supplied to Queen Charlotte Sound is transported during the summer in surface and near-surface waters from the mouths of fiords in the vicinity of Sea Otter Shoals. The Coriolis effect coupled with a northward coastal water residual flow tends to direct this silt-charged water to the right as it enters the Sound, whereas prevailing northwesterly winds move near-surface waters to the southwest. Examination of surficial sediment distribution, cores and seismic records suggests that the greatest lateral and vertical accumulation of muds having a character similar to that of muds on the present seabed lie in inner Goose Island Trough north of Sea Otter shoals and not in Cook Trough suggesting that the Coriolis effect and the coastal flow more strongly influence the dispersal direction of suspended sediment newly discharged into the Sound than do northwesterly winds. Some mud, which gradually settles through the water column as the meltwater plume crosses the shelf, is probably carried back to the inner shelf floor by advective transport (McCave, 1972) in the colder, more saline bottom waters which most deeply intrude the Sound during the summer.

The location of the major site of present sediment discharge into the Sound, water circulation patterns, and the intensity of wave and current activity on the shelf have insured that (a) mud is not accumulating at depths shallower than 140 m (except near the southeastern coast in the path of the plume of less saline water) and (b) for any given depth surficial sediments generally are finer on the more sheltered inner and southern parts of troughs and or inlet mouths. Although high sediment transport (Hein et al., 1974) may have helped maintain test-free glauconite at low concentrations on the shelf, that it is present at all probably is a reflection of the generally slow sedimentation rates (Degens, 1965). The somewhat higher concentrations found in muds on the slope indicate that even fine sediment there is being deposited very slowly (Degens, 1965; Hein et al., 1974).

Surficial muds in the Sound have a higher proportion of smectite than the subbottom greenish grey clay size sediments or the muds in the Taku Estuary (Kunze et al., 1968) and Glacier Bay (O'Brien and Burrell, 1970) in southeastern Alaska which are derived from present day glacial abrasion of rocks similar to those on the mainland adjacent to Queen Charlotte Sound. This suggests that the more temperate climate conditions which now prevail immediately south of Alaska encourage chemical "stripping" of chlorite, hornblende and mica, leading to the formation of smectite (Weaver, 1958; Keller, 1970).

The gross inverse relationship between noncarbonate organic carbon concentration and grain size of enclosing sediments could be governed by a number of conditions: (a) coarser sediments are more permeable and thus permit organic matter to be oxidized rapidly, (b) particulate organic matter tends to deposit together with fine grained clastic sediments and (c) clay size particles enriched in clay minerals have large capacitities to adsorb organic molecules (Bader, 1962; Thomas, 1969 and Naidu et al., 1975).

The tendency for noncarbonate organic carbon to decrease gradually with depth in a core may indicate a tendency for organic matter to oxidize after burial. The abrupt change in organic content at the sharp contact between the surface sediments and the dark greenish grey mud more likely reflects a fundamental change in the nature of the sediments and mode of sedimentation. The virtual lack of particulate organic matter in the underlying sediments may be due to the low clay mineral content of glacial flour or it may indicate that these muds were deposited too rapidly to allow enough time for substantial organic adsorption and development of a rich bottom fauna. It is possible these muds were deposited under ice but the absence of drop stones and presence of **Epistominella** would argue against this.

The highest concentration of well sorted sediments falls within the 2-3 ϕ size range. Inman (1963) has established that sands of this size have the lowest threshold friction velocities of any sediment. Hamilton et al. (1980) have proposed that "repeated selective entrainment by tidal currents in a virtually closed sediment system [as exists on Queen Charlotte Sound banks]..." lead to the formation of such well sorted mobile sands (it is possible, however, that considerable sorting may already have been achieved, if, as probably is the case, these sediments were deposited as outwash). The above authors have suggested that the fine sand population will gradually blanket the seafloor and inhibit mobilization of coarser grades which ambient currents would otherwise be capable of transporting. It can be expected, however, that fine sands will eventually be swept clear of the banks by tidal flows which are known to induce unidirectional sediment transport (Off, 1963; Houboult, 1968; Belderson and Kenyon, 1969; Kenyon and Stride, 1970; Ludwick, 1974; and Luternauer, 1976, 1978).

The distribution of best sorted fine to very fine sand and the nature and orientation of ripples suggest tidal currents are moving this sediment from Cook Bank onto its northern flank. Photographs of the sands on the eastern edge of this bank reveal a dense network of snail trails. These features probably are preserved because these sediments generally are coarser and are not likely to be as frequently mobilized as finer sands on which no evidence of trails is found. The less frequent or intense abrasion which these sediments probably undergo may also explain why quartz grains within these sands retain a yellow brown, presumably iron oxide, coating. The coating may have been acquired in a subaerial beach environment (Dolan, 1970) or in a river (Judd et al., 1970) or even in their present environment (Swift and Boehmer, 1972). Swift (1969) and Emery and Niino (1963) have stressed the importance of subaerial exposure in the formation of iron-stained shelf sands, but the critical factor governing the formation of such a stain is the availability of ample amounts of magnetite (which is abundant in these sands) and (or) ilmenite (Miller and Folk, 1955) which can alter readily to limonite under oxidizing conditions (Ollier, 1969).

The distribution of best sorted sands on Goose Island Bank, the character and orientation of bedforms evident in photographs, the orientation of what may be flow parallel "current lineations" and the cross sectional geometry of deposits at the margins of the bank revealed in seismic profiles, strongly indicate that fine sands are being washed by the combined action of waves and tidal currents from the sandy gravels and gravelly sands (Stanley, 1968) mainly towards the north and southwest. The morphologic character of Goose Island Bank is also compatile with such a dispersal pattern: slopes are very gentle to the north and southwest but relatively abrupt toward the south and southeast. Yellowed sands and snail tracks are also evident on this bank and probably occur where sediments are transported only under storm conditions or by spring tidal currents. The glauconite on the bank probably formed in foraminiferal tests which were subsequently split open and carried off in the fashion described by Keller and Richards (1967).

The area on Middle Bank covered by well sorted fine sand appears very small when compared to areas mantled by the same sediment type on Goose Island and Cook banks. This probably reflects the lower ambient wave energies on this, the deepest, bank. As is the case for the other banks, sands appear to be washed to the north and south.

The broadest terraces at the tops of banks all lie above 140 m. Goose Island Bank is the shallowest bank and probably is undergoing most active planation. Cook Bank probably is also being eroded, but to a lesser extent because it is somewhat sheltered from Pacific storm waves and swells by the Scott Islands. The presence of wave dominated combined flow ripples on Middle Bank suggest it is a zone of intermittent erosion occurring mainly during storms. On both Cook Bank and Goose Island Bank foraminiferal tests are very sparse. On much of Middle Bank tests are extremely abundant, although they tend to be concentrated in very poorly sorted sandy gravels. Schafer and Prakash (1968) have found that "the size of Foraminiferal tests and the possible entrapment of air or some other gas makes them most susceptible to erosion and transport by currents. This is especially true of abandoned foraminiferal tests which are no longer inhabited by the living animal." Currents are probably strong enough to sweep forams off Cook and Goose Island banks. On Middle Bank they may settle out when weather conditions are less severe. During a storm foraminiferal tests are washed from better sorted sands on Middle Bank but are not as readily dislodged from poorly sorted sediments trapped between the boulders on the bank surface.

The recorded concentrations of skeletal carbonate in Queen Charlotte Sound lend further support to earlier studies that indicate that abundant carbonate-rich sediments may develop at high latitudes where the supply of terrigenous detritus is low (Chave, 1967; Hoskin and Nelson, 1969; Milliman, 1971; Muller and Milliman, 1973). On Cook Bank upwelling of nutrient-rich slope waters probably has further contributed to the accumulation of coarse shell hash deposits.

Environmental and Economic Considerations

1. Information on the character of bottom materials presented in this report coupled with available data on the occurrence of specific ground fish (Westrheim, 1974) may identify possible substrate/fish associations which warrant further investigations. Examination of bottom photographs and sediment distribution can contribute to more precise mapping of ground which can be trawled without equipment damage and may help identify ways in which trawling equipment may be redesigned to render it more suitable for operation in local waters.

2. Information included herein about the nature of surficial sediments, the extent and water depth to which sediments are mobilized, and the location and size of possible faults in the Sound will have to be considered if and when drilling platforms are being designed for hydrocarbon exploration in the Sound.

3. Pollutants released in the course of hydocarbon exploration or exploitation which settle to the seafloor probably would collect in the inner parts of troughs and inlet mouths, be adsorbed in the smectite rich sediments and could, potentially, disrupt benthic deposit feeders (Hatcher and Segar, 1976; Hein et al., 1979). Drilling and production waste falling onto sand-pebbly bank surfaces probably would not seriously impair this habitat because of the mobility (Anderson et al., 1981) and abrasiveness of these materials. Hydrocarbons trapped within boulder beds, however, may persist substantially longer and affect sessile organisms and ground fish.

4. The best sorted, nonencrusted finer gravels and clean sands best suited for construction materials are most concentrated on the eastern, shallower part of Goose Island Bank. The most extensive skeletal carbonate beds, a potential source of lime for use in the manufacture of cement, extend for several tens of kilometres in a 10-15 km wide band adjacent to northern Vancouver Island and the Scott Island chain. The highest concentration of heavy mineral rich "black sands" are found at or near the 100 m depth on northern Cook Bank. What are probably equivalent deposits at the mouth of the Nahwitti River, which flows on to Cook Bank, have been described by the British Columbia Department of Mines and Petroleum Resources (Anonymous, 1980). It is noted that these deposits contain gold which, however (a) is very fine, (b) is only sufficiently concentrated to be worked after certain storms and (c) is associated with high concentrations of magnetite.

CONCLUSIONS

1. The continental shelf and slope surface of Queen Charlotte Sound has formed on sediments which prograde mainly from the mainland coast over bedrock cores.

2. Some inshore sections of troughs which can be considered "marginal channels" lie at or near the contact between crystalline coastal rocks and offshore sedimentary deposits.

3. Moresby, the deepest trough is the only feature which may lie along a fault active during the late Quaternary.

4. Partially submerged grounded ice sheets enclosing ice streams sculpted morphologic features on the shelf and strongly influenced the present sedimentary framework.

5. Partially submerged ice having a thickness of the same order of magnitude as that suspected to have blanketed the western part of northern Vancouver Island during the late Wisconsin Fraser Glaciation probably was capable of grounding on the outer shelf to the depth of the uppermost laterally continuous unconformity (which is 75-100 m below the trough floor of the centre of the shelf) if it is assumed the submerged shelf was not markedly depressed.

6. Much of the material constituting the slopes of Goose Island and Middle Bank between the bank tops and continenal slope probably was deposited ahead of the ice sheet which scoured the troughs. These sediments were subsequently reworked by late Pleistocene seas.

7. The following ice contact and proglacial features or deposits are present on the shelf: terminal and/or recessional moraines, kame and kettle topography, an esker, and outwash sands and muds.

8. The progressively greater depth and increased morphologic irregularity of the outer parts of more northerly troughs suggests that deposition by late Wisconsin ice was concentrated in the areas adjacent to the mainland and Vancouver Island coasts.

9. Abrupt seaward thinning of the relatively short-lived late Wisconsin ice front in the vicinity of Queen Charlotte Sound suggests ice grounding may have extended in troughs no further than the shallower ledge on the northwestern slope of Moresby Trough and the mid-shelf moraines and ice front deposits in Mitchell's and Goose Island troughs, all of which lie at or near 200 m depth.

10. The height of bedrock platforms and/or volume of glacial debris deposited at any one site is largely what governed the discordant depths of shelf banks and not surf-scouring during a sea level minimum.

11. Intense tidal currents sweeping over banks after ice had retreated or was no longer grounded, but at a time prior to the sea attaining its present level, scoured bedrock and formed the well defined but very gently inclined valleys at the margins of Cook Bank. They also contributed to the formation of the heavy mineral deposits now found mainly at or near 100 m at the margins of Goose Island and Cook Bank.

12. The depth of the constructional (progradational) break in slope at the shelf edge has been controlled by relatively deep water oceanographic processes. At the time of the late Wisconsin glacial maximum, when the bulk of sediment was being discharged across the shelf, turbulence was probably high enough over the site of the present shelf edge to maintain at least sand and mud in suspension and permit continuous accumulation of material mainly below that depth.

13. The Coriolis effect and northward coastal water residual flow are directing the bulk of new sediment discharged into the Sound from inlets on the southern mainland coast towards the part of Goose Island Trough north of Sea Otter Shoals. Fine, suspended sediment also may be carried into the inner sound from the outer shelf by advective transport. Olive grey-green mud appears not to be accumulating at depths shallower than 140 m (except near the southeastern coast in the path of the plume of less saline water) and forms only a thin veneer (~30 cm) in Mitchell's Trough. For any given depth muds generally are finer on the more sheltered inner shelf and inlet mouths than on the outer shlef.

14. Estimated highest average Holocene sedimentation rates on the shelf (~2-3 mm/a) are found at isolated sites of fine sediment accumulation in northwestern Moresby Trough, at the bend in Mitchell's Trough and in Goose Island Trough north of the Sea Otter Shoals. The latter site may be the only location where sediments still are accumulating.

15. Smectite in olive grey surficial muds may have been formed as a consequence of present-day chemical "stripping" of chlorite, hornblende and mica derived from mainland rocks.

16. Most noncarbonate organic carbon is accumulating in deeper, more sheltered inshore parts of troughs and inlet mouths floored by smectite rich muddy sediments.

17. The relatively low concentrations of organic matter in subbottom, chlorite and illite rich greenish grey muds unconformably underlying surficial muds may reflect the low clay mineral content of constituent "glacial flour" and/or very rapid deposition which did not allow time for organic adsorption or development of a rich bottom fauna.

18. The most mobile glaciogene sediments in the sound are well sorted 2-3 ϕ sands. This population is being selectively washed from poorly sorted glacial debris on banks and gradually blanketing vast areas of bank surfaces. It is possible, however, that parts of bank surfaces are covered with relict outwash sands which were fairly well sorted when deposited. Sands will eventually be swept clear of bank tops by the combined effects of intense wave turbulence and tidal current transport.

19. Well sorted 2-3 ϕ sands are being swept (a) onto the northern flanks of Cook Bank, (b) towards the north and southwest of Goose Island Bank and (c) probably, at a slower, rate to the north and south of the shallower parts of Middle Bank.

20. The highest concentration of foraminifers within the sand plus mud fraction was found on Middle Bank, the deepest bank, in poorly sorted sediments scattered among boulders which may shelter the deposits somewhat from all but more extreme storm surges and tidal currents.

21. The highest concentrations of skeletal carbonate are found in a 10-15 km wide band extending along northern Vancouver Island and Scott Island Chain. A combination of fast currents, minimal terrigenous input and nutrient-rich upwelling slope waters probably have contributed to the development of this deposit.

22. This study has generated information:

    1. of direct relevance to local studies of groundfish/substrate associations and commercial groundfishing hazards.
    2. which may help design platforms suitable for local drilling conditions and which will help predict the behaviour of pollutants released in the course of any future hydrocarbon explorations.
    3. will help determine the economic potential of local sand, gravel, carbonate and heavy mineral deposits.

ACKNOWLEDGMENTS

J. Clague and C. Yorath critically reviewed earlier drafts of this report. T. Forbes helped proofread the final draft.

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APPENDIX

Primary characteristics of samples

EXAMPLE:

QCS# 254 52°13' 129°0' 133
1.492 2.225 -0.488 12.360 79.570 8.070 0.5 16

WHICH REPRESENTS:

SAMPLE NO. / LOCATION / DEPTH IN METRES

MEAN PHI / STANDARD DEVIATION PHI / SKEWNESS PHI / WT% GRAVEL / WT% SAND / WT% MUD / WT% NON-CO_3 ORGANIC CARBON / WT% CO_3

Sample No.	Location (lat.)	Location (long.)	Depth (m)	Mean phi	Standard deviation phi	Skewness phi	Wt% gravel	Wt% sand	Wt% mud	Wt% non-CO_3 organic carbon	Wt% CO_3
QCS# 2	51°8'	127°45'	73	3.294	0.462	0.489	0.0	97.023	2.977	0.3	1
QCS# 3	51°5'	127°51'	120	3.484	1.994	0.525	1.773	72.859	25.367	0.8	2
QCS# 4	51°3'	127°55'	147	3.352	1.815	1.452	0.0	86.242	13.758	0.6	1
QCS# 5	51°1'	128°1'	146	2.922	0.715	0.454	0.0	94.880	5.120	0.4	2
QCS# 6	50°59'	128°6'	51	-3.160	1.980	0.914	88.428	11.335	0.238	0.0	0
QCS# 7	50°57'	128°11'	55	-6.048	0.594	0.112	100.00	0.0	0.0	0.0	0
QCS# 8	50°54'	128°17'	37	-5.416	0.455	0.453	100.000	0.0	0.0	0.0	0
QCS# 9	50°52'	128°22'	44	-0.028	1.260	-0.430	16.862	83.090	0.049	0.0	20
QCS# 11	50°51'	128°37'	49	-1.081	2.098	0.244	54.897	43.721	1.382	0.0	20
QCS# 10	50°50'	128°28'	53 (trace of gravel)								
QCS# 12	50°54'	128°29'	64	1.884	1.405	-1.084	6.029	93.810	0.161	0.1	16
QCS# 15	51°0'	128°15'	80	2.362	0.529	-0.087	0.0	99.919	0.081	0.0	1
QCS# 16	51°2'	128°10'	163	3.407	1.641	1.329	0.0	80.231	19.770	0.7	3
QCS# 17	51°4'	128°5'	153	4.046	2.049	1.175	0.0	81.132	18.868	0.7	2
QCS# 18	51°6'	128°0'	100	-1.049	4.492	0.503	60.132	25.060	14.808	1.0	8
QCS# 19	51°9'	127°54'	119	5.028	2.410	0.932	0.0	47.740	52.260	0.9	2
QCS# 20	51°11'	127°49'	49	-0.588	3.299	0.008	49.458	49.273	1.269	0.0	0
QCS# 21	51°12'	127°57'	123	4.304	2.037	1.175	0.0	64.798	35.202	0.7	2
QCS# 22	51°10'	128°3'	68	-2.952	3.043	0.581	74.920	23.188	1.892	0.0	0
QCS# 23	51°8'	128°8'	128	-1.795	4.539	0.736	72.040	15.413	12.547	0.0	0
QCS# 24	51°6'	128°13'	166	2.961	1.435	1.613	0.0	88.060	11.941	0.5	1
QCS# 25	51°4'	128°19'	164	4.119	1.630	1.625	0.0	72.318	27.682	0.7	2
QCS# 26	51°2'	128°24'	99	0.165	2.988	-0.381	30.914	68.378	0.708	0.0	1
QCS# 27	50°59'	128°29'	91	2.674	0.530	-0.202	0.0	99.462	0.538	0.1	1
QCS# 28	50°56'	128°34'	55	-5.166	1.050	1.908	98.777	1.202	0.021	0.0	0
QCS# 29	50°54'	128°40'	88	-3.941	2.121	0.925	89.100	10.809	0.090	0.0	0
QCS# 30	50°52'	128°45'	55	-4.784	1.707	1.331	93.423	6.560	0.017	0.0	0
QCS# 32	50°53'	128°54'	60 (trace of gravel)								
QCS# 33	50°55'	128°9'	64	-2.762	2.409	0.611	79.933	19.675	0.392	0.2	21
QCS# 34	50°57'	128°44'	82	2.200	0.484	-0.493	0.0	99.937	0.063	0.0	2
QCS# 35	51°0'	128°37'	66	0.603	1.208	-0.879	6.404	93.585	0.011	0.1	0
QCS# 36	51°2'	128°32'	95	2.776	0.384	0.201	0.0	99.791	0.209	0.1	1
QCS# 37	51°4'	128°27'	122	2.800	0.678	0.067	0.0	97.426	2.574	0.1	1
QCS# 38	51°6'	128°21'	175	3.636	1.461	1.365	0.0	74.398	25.602	0.6	1
QCS# 39	51°9'	128°16'	165	3.035	2.232	1.076	1.116	85.236	13.648	0.5	1
QCS# 40	51°10'	128°12'	99	2.107	0.851	0.537	0.0	96.691	3.309	0.0	0
QCS# 41	51°13'	128°17'	95	2.257	0.636	-0.599	0.390	98.776	0.835	0.0	0
QCS# 42	51°12'	128°21'	146	3.235	0.674	0.621	0.0	91.194	8.806	0.5	2
QCS# 43	51°10'	128°25'	192	3.907	1.176	2.195	0.0	73.849	26.151	0.7	1
QCS# 44	51°8'	128°32'	161	3.489	0.853	2.962	0.0	89.570	10.430	0.4	0
QCS# 45	51°6'	128°36'	119	3.129	0.484	0.702	0.0	97.206	2.794	0.2	1
QCS# 46	51°4'	128°41'	64	1.347	0.652	0.135	0.0	99.983	0.017	0.0	0
QCS# 47	51°1'	128°47'	55 (trace of gravel)								
QCS# 48	50°59'	128°52'	68	-3.272	1.684	0.840	92.204	7.762	0.034	0.0	0
QCS# 49	50°57'	128°58'	68	2.222	0.431	-0.007	0.0	99.939	0.061	0.1	0
QCS# 50	50°55'	129°4'	68	-0.238	1.726	-0.276	31.425	68.550	0.024	0.0	0
QCS# 51	50°52'	129°11'	62	-6.297	0.630	0.712	100.000	0.0	0.0	0.0	0
QCS# 55	50°51'	129°22'	168	2.855	0.640	1.004	0.0	94.354	5.646	0.5	1
QCS# 56	50°53'	129°18'	123	0.392	2.173	-0.157	26.401	70.336	3.263	0.7	26
QCS# 57	50°55'	129°12'	88 (trace of gravel)								

QCS# 58	50°58'	129°7'	100				
2.578	0.428	0.707	0.0	99.213	0.787	0.2	2
QCS# 59	51°0o'	129°1'	86				
2.428	0.460	-0.196	0.0	99.849	0.151	0.1	1
QCS# 60	51°2'	128°56'	84				
1.892	0.548	0.272	0.0	99.779	0.221	0.0	0
QCS# 61	51°5'	128°50'	80				
-1.036	2.521	-0.131	47.803	52.017	0.180	0.1	6
QCS# 62	51°8'	128°45'	73				
0.792	0.897	-0.124	2.319	97.669	0.012	0.0	0
QCS# 63	51°9'	128°40'	122				
2.547	0.509	0.160	0.0	99.713	0.287	0.0	0
QCS# 64	51°11'	128°35'	170				
3.373	1.091	2.641	0.0	92.674	7.326	0.4	1
QCS# 65	51°14'	128°29'	192				
3.871	1.236	1.993	0.0	74.336	25.663	1.0	2
QCS# 66	51°16'	128°24'	111				
-4.963	1.095	2.030	98.510	1.440	0.050	0.0	0
QCS# 68	51°18'	128°29'	133				
0.644	3.375	0.649	40.910	43.839	15.251	0.7	9
QCS# 69	51°16'	128°32'	183				
-1.024	2.979	-0.031	42.588	54.022	3.390	0.3	14
QCS# 71	51°12'	128°42'	174				
2.927	0.459	0.676	0.0	98.516	1.484	0.3	0
QCS# 72	51°10'	128°48'	110				
1.193	1.071	-0.229	2.981	96.958	0.062	0.0	0
QCS# 73	51°8'	128°53'	100				
2.306	0.735	-0.550	0.0	99.780	0.220	0.1	0
QCS# 74	51°5'	128°59'	102				
2.801	0.391	0.119	0.0	99.852	0.148	0.1	1
QCS# 75	51°3'	129°5'	124				
1.498	2.696	-0.560	19.531	75.088	5.381	0.4	3
QCS# 76	51°1'	129°10'	145				
3.586	1.053	2.154	0.0	88.092	11.908	0.7	4
QCS# 77	50°58'	129°16'	157				
3.107	1.258	2.488	0.0	95.069	4.931	0.7	3
QCS# 78	50°56'	129°21'	173				
3.477	1.759	1.553	0.0	86.973	13.027	0.6	9
QCS# 79	50°54'	129°28'	192				
3.686	1.515	1.624	0.0	81.852	18.149	0.6	9
QCS# 80	51°4'	129°29'	280				
3.529	1.417	1.674	0.359	85.326	14.315	0.6	4
QCS# 81	51°7'	129°24'	265				
-1.400	3.630	0.280	60.994	35.120	3.885	1.0	9
QCS# 82	51°9'	129°18'	238				
3.389	1.892	1.180	0.0	84.033	15.967	0.8	9
QCS# 83	51°11'	129°12'	223				
1.8883	3.432	-0.061	19.975	67.289	12.736	0.6	3
QCS# 84	51°13'	129°7'	230				
2.714	0.964	0.266	0.0	91.942	8.058	0.5	1
QCS# 85	51°14'	129°1'	205				
2.479	0.786	0.872	0.0	94.658	5.342	0.3	1
QCS# 86	51°17'	128°56'	223				
3.491	1.461	2.033	0.0	88.445	11.555	0.4	1
QCS# 87	51°19'	128°49'	208				
3.956	2.178	1.084	0.907	80.068	19.024	0.6	2
QCS# 88	51°21'	128°45'	220				
2.276	2.696	0.086	12.640	74.256	13.104	05.	1
QCS# 89	51°23'	128°39'	214				
4.407	1.884	1.345	0.0	61.598	38.402	0.8	1

QCS# 90	51°26'	128°34'	207				
4.760	1.745	1.163	0.0	33.661	66.339	0.3	2
QCS# 91	51°28'	128°29'	194				
6.372	2.886	0.404	0.0	15.305	84.695	0.9	3
QCS# 92	51°29'	128°21'	157				
6.224	2.912	0.404	0.0	16.429	83.571	0.3	3
QCS# 93	51°32'	128°18'	154				
4.128	1.878	1.392	0.0	68.909	31.090	0.8	8
QCS# 94	51°34'	128°13'	100				
2.889	0.351	0.604	0.0	99.509	0.491	0.0	1
QCS# 97	51°44'	128°23'	141				
5.487	2.469	0.756	0.0	26.502	73.499	1.3	3
QCS# 98	51°47'	128°26'	155				
4.548	2.332	0.917	0.0	63.961	36.039	1.7	3
QCS#99	51°46'	128°32'	146				
3.702	1.095	2.196	0.0	82.910	17.090	0.5	1
QCS# 100	51°42'	128°37'	92				
1.881	0.495	-0.034	0.0	99.982	0.018	0.0	1
QCS# 101	51°41'	128°42'	37				
2.003	0.431	-0.325	0.0	99.985	0.015	0.0	1
QCS# 102	51°38'	128°47'	40				
1.611	0.660	-1.110	1.598	98.396	0.006	0.0	3
QCS# 103	51°36'	128°52'	46				
-1.495	1.696	0.356	68.033	31.937	0.031	0.0	4
QCS# 104	51°34'	128°58'	46				
-2.298	1.860	0.552	76.606	23.394	0.0	0.0	0
QCS# 115	51°0'	129°23'	183				
3.638	1.350	2.043	0.0	89.250	10.750	0.4	3
QCS# 116	51°2'	129°18'	174				
3.723	1.407	1.967	0.0	83.527	16.473	0.6	4
QCS# 117	51°4'	129°13'	155				
4.054	1.695	1.744	0.0	76.276	23.724	0.7	4
QCS# 118	51°6'	129°8'	137				
2.539	1.053	0.098	0.0	96.104	3.896	0.5	5
QCS# 119	51°9'	129°2'	137				
1.573	1.209	-0.175	3.348	95.294	1.359	0.0	1
QCS# 120	51°12'	128°58'	137				
-3.453	2.250	0.941	85.639	14.064	0.297	0.2	28
QCS# 121	51°14'	128°52'	146				
0.578	1.978	-0.259	32.261	67.716	0.023	0.0	0
QCS# 124	51°18'	128°41'	183				
-3.411	3.298	0.407	72.190	26.817	0.993	0.3	2
QCS# 125	51°20'	128°35'	183				
2.352	1.010	-0.172	0.0	95.102	4.898	0.2	1
QCS# 126	51°23'	128°31'	174				
4.025	1.702	1.589	0.0	73.927	26.073	0.6	1
QCS# 127	51°25'	128°25'	164				
4.777	2.291	1.019	0.0	53.465	46.535	1.2	3
QCS# 129	51°24'	128°16'	128				
3.458	1.193	1.944	0.0	84.722	15.278	0.4	3
QCS# 131	51°20'	128°8'	137				
2.716	0.410	0.475	0.0	99.280	0.720	0.8	5
QCS# 132	51°26'	128°12'	137				
4.067	1.461	1.505	0.0	61.556	38.445	1.4	3
QCS# 133	51°29'	128°15'	100				
1.936	1.042	0.149	0.0	97.485	2.515	0.2	3
QCS# 134	51°30	128°12'	91				
2.279	0.588	-0.596	0.967	97.941	1.092	0.1	0
QCS# 137	51°38'	128°18'	146				
5.375	2.448	0.793	0.0	30.722	69.278	1.3	2

QCS# 138	51°33'	128°24'	174	6.074	2.708	0.528	0.0	15.752	84.248	2.3	3
QCS# 139	51°32'	128°28'	183	5.891	2.590	0.583	0.0	22.172	77.828	2.4	3
QCS# 140	51°30'	128°34'	183	5.439	2.522	0.723	0.0	34.377	65.623	1.4	2
QCS# 141	51°28'	128°40	183	4.320	2.032	1.240	0.0	67.058	32.942	1.1	2
QCS# 142	51°27'	128°44'	183	4.083	1.412	1.720	0.0	66.739	33.261	0.8	2
QCS# 143	51°25'	128°49'	200	4.626	2.123	1.169	0.0	56.467	43.533	0.9	2
QCS# 144	51°23'	128°55'	220	4.612	2.26	1.012	0.0	57.695	42.305	0.8	1
QCS# 145	51°21'	129°00'	230	2.484	0.804	0.648	0.0	94.605	5.395	0.2	1
QCS# 146	51°19'	129°05'	256	3.641	1.597	1.778	0.0	85.531	14.469	0.5	1
QCS# 147	51°16'	129°09'	256	2.675	0.900	0.649	0.0	91.236	8.764	0.3	1
QCS# 148	51°14'	129°15'	284	3.989	1.330	1.711	0.0	66.305	33.695	0.7	3
QCS# 149	51°12'	129°19'	293	0.300	4.169	-0.143	37.723	49.586	12.691	0.6	5
QCS# 151	51°8'	129°31'	284	3.674	1.198	2.108	0.0	86.616	13.384	0.5	4
QCS# 152	51°5'	129°37'	450	3.978	1.563	1.1593	0.0	79.981	20.019	0.5	3
QCS# 154	51°6'	129°46'	420 (trace of gravel)								
QCS# 155	51°9'	129°40'	274	-3.273	2.376	0.843	84.611	13.990	1.398	0.0	14
QCS# 156	51°10'	129°36'	274 (trace of gravel)								
QCS# 158	51°15'	129°25'	293	4.875	1.983	1.135	0.0	36.057	63.944	1.4	4.
QCS# 162	51°23'	129°3'	200	4.373	1.825	1.431	0.0	63.008	36.992	0.8	2
QCS# 163	51°25'	128°53'	170	2.980	1.344	1.818	0.0	90.617	9.383	0.3	1
QCS# 164	51°27'	128°52'	155	3.148	0.501	0.846	0.0	96.280	3.720	0.0	0
QCS# 165	51°29'	128°46'	73	1.888	0.554	0.047	0.0	99.961	0.039	0.0	0
QCS# 166	51°32'	128°41'	40	2.045	0.415	-0.257	0.0	99.972	0.028	0.0	4
QCS#167	51°34'	128°35'	146	3.678	1.074	2.137	0.0	82.910	17.090	0.1	2
QCS# 168	51°37'	128°30'	150	1.821	3.944	-0.064	24.015	50.553	25.431	0.8	2
QCS# 169	51°39'	128°25'	146	4.177	1.363	1.699	0.0	56.655	43.345	0.7	1
QCS# 170	51°42'	128°21'	137	3.331	1.168	1.947	0.0	87.576	12.424	0.5	1
QCS# 171	51°45'	128°18'	146	4.726	2.116	0.919	0.0	43.126	56.875	1.5	3
QCS# 173	51°41'	128°30'	146	4.232	1.533	1.713	0.0	65.689	34.310	0.6	2
QCS# 175	51°38'	128°40'	36	2.178	0.345	0.254	0.0	99.845	0.155	0.0	2
QCS# 177	51°33'	128°50'	46	-3.294	1.689	0.892	91.630	8.352	0.018	0.0	0
QCS# 178	51°31'	128°56'	46	-3.617	2.803	0.394	73.041	26.943	0.016	0.1	1
QCS# 180	51°25'	129°7'	82	2.438	0.544	-0.040	0.0	99.890	0.110	0.0	0
QCS# 181	51°25'	129°12'	110	2.242	0.641	0.073	0.0	99.753	0.247	0.1	0
QCS# 182	51°23'	129°18'	146	2.422	0.374	0.047	0.0	99.961	0.039	0.1	0
QCS# 183	51°20'	129°23'	192	3.369	0.565	0.751	0.0	92.653	7.347	0.4	1
QCS# 184	51°19'	129°29'	220	2.012	3.919	-0.131	20.020	62.674	17.306	0.8	5
QCS# 185	51°17'	129°34'	238	-3.824	1.900	1.113	90.393	9.531	0.076	0.0	0
QCS# 187	51°12'	129°43'	457	3.648	2.023	1.180	0.0	81.260	18.740	0.2	3
QCS# 225	51°18'	127°55'	119	2.417	1.113	0.347	0.0	90.366	9.634	0.5	3
QCS# 226	51°24'	127°53'	111	-0.354	3.181	-0.080	42.475	53.676	3.849	0.3	1
QCS# 227	51°22'	127°58'	440	4.909	2.612	0.820	0.0	54.910	44.560	1.3	4
QCS# 228	51°25	128°2'	110	2.631	1.043	0.299	0.0	90.044	9.956	0.5	1
QCS# 229	51°50'	128°20	154	6.644	2.608	0.381	0.0	9.322	90.677	3.6	5
QCS# 230	51°52'	128°30'	71	-0.269	0.660	0.114	9.123	90.860	0.017	0.0	0
QCS# 231	51°50'	128°35'	137	-3.218	3.707	0.636	75.536	20.417	4.048	0.6	4
QCS# 232	51°55'	128°33'	88	-1.794	3.270	0.108	59.213	40.500	0.287	0.2	7
QCS# 233	52°0'	128°31'	64	-1.449	1.293	0.680	72.514	27.151	0.334	0.0	0
QCS# 234	52°4'	128°34'	71	0.974	1.443	-1.153	8.710	90.957	0.333	0.5	30
QCS# 235	52°7'	128°38'	214	4.866	2.031	1.012	0.0	39.631	60.369	0.9	4
QCS# 236	52°13'	128°36'	238	8.164	2.710	-0.087	0.0	5.673	94.327	3.3	7
QCS# 237	52°11'	128°42'	238	7.449	2.821	0.088	0.0	10.973	89.026	3.2	6
QCS# 238	52°15'	128°46'	192	4.398	2.009	1.289	0.0	65.202	34.797	1.6	8
QCS# 239	52°18'	128°49'	205	4.617	2.440	0.810	0.0	63.176	36.824	1.6	10
QCS# 241	52°19'	128°58'	55	-5.675	1.046	0.186	100.000	0.0	0.0	0.0	0
QCS# 242	52°16'	128°54'	92	-5.595	0.583	1.887	100.000	0.0	0.0	0.0	0
QCS# 243	52°12'	128°51'	210	4.546	3.587	0.119	6.594	48.930	44.476	1.3	5
QCS# 244	52°9'	128°48'	214	6.372	2.722	0.386	0.0	17.799	82.202	2.7	5
QCS# 245	52°5'	128°43'	183	4.627	1.856	1.275	0.0	49.067	50.933	1.0	3
QCS# 246	52°2'	128°41'	164	4.139	1.226	1.783	0.0	59.913	40.087	0.6	3

OCS# 247	51°58'	128°27'	155	4.449	1.987	1.114	0.0	61.939	38.061	0.6	2
QCS# 248	51°53'	128°42	139	3.538	1.112	2.284	0.0	87.188	12.812	0.3	2
QCS# 249	51°57'	128°42'	148	4.207	1.444	1.741	0.0	58.967	41.033	0.4	4
QCS# 250	52°0'	128°46'	164	4.328	1.466	1.601	0.0	54.884	45.116	0.3	4
QCS# 251	52°4'	128°49'	168	4.289	1.891	1.883	0.0	74.103	25.897	0.4	1
QCS# 252	52°6'	128°53'	189	3.355	3..086	0.332	8.959	64.603	26.438	1.3	3
QCS# 253	52°10'	128°57'	170	-0.602	3.227	0.022	46.839	46.843	6.318	0.4	10
QCS# 254	52°13'	129°0'	133	1.492	2.225	-0.488	12.360	79.570	8.070	0.5	16
QCS# 255	52°17'	129°3'	155	4.074	3.717	0.383	5.036	62.995	31.969	0.7	7
QCS# 256	52°20	129°7'	141	1.666	3.673	0.039	24.314	61.949	13.736	0.6	6
QCS# 257	52°20'	129°11'	157	3.978	1.955	1.151	0.0	73.770	26.229	0.7	8
QCS# 258	52°15'	129°8'	166	6.297	3.195	0.332	0.0	32.655	67.345	1.3	6
QCS# 259	52°11'	129°4'	113	-1.459	2.849	0.110	56.128	42.670	1.201	0.1	13
QCS# 260	52°13'	129°2'	128	-0.755	2.948	-0.103	43.927	54.018	2.055	0.2	9
QCS# 261	52°5'	128°57'	157	4.001	1.381	1.971	0.0	75.322	24.678	1.3	2
QCS# 262	52°1'	128°55'	183	-1.524	2.666	0.242	63.191	35.615	1.194	0.5	10
QCS# 263	51°56'	128°51'	73	0.489	1.787	-0.430	23.763	76.137	0.100	0.0	1
QCS# 264	51°54'	128°48'	95	3.074	0.406	0.551	0.0	98.885	1.115	0.1	1
QCS# 265	51°51'	128°44'	75	3.128	0.424	0.415	0.0	98.585	1.415	0.0	2
QCS# 266	51°47'	128°40'	77	2.852	0.509	0.367	0.0	98.673	1.327	0.0	3
QCS# 267	51°43'	128°43'	37 (camera station)								
QCS# 268	51°45'	128°47'	55	2.525	0.723	-1.089	0.820	98.792	0.388	0.0	3
QCS# 269	51°48'	128°49'	64	2.492	0.607	-0.480	0.0	99.751	0.249	0.0	1
QCS# 270	51°52'	128°53'	62	1.391	1.948	-0.654	13.980	83.716	2.304	0.0	0
QCS# 271	51°55'	128°56'	80	2.406	0.488	-0.236	0.0	99.646	0.354	0.1	1
QCS# 272	51°58'	129°0'	120	3.405	0.645	0.521	0.0	90.435	9.565	0.1	1
QCS# 273	52°2'	129°3'	155	-2.400	3.188	0.420	69.393	26.164	4.443	0.4	8
QCS# 274	52°5'	129°7'	135	-0.794	2.929	-0.042	44.193	53.323	2.484	0.2	14
QCS# 275	52°9	129°10'	165	4.929	2.520	0.851	0.0	53.396	46.603	0.7	6
QCS# 276	52°12'	129°14'	162	2.308	3.197	0.256	17.565	59.660	22.775	0.8	8
QCS# 277	52°16'	129°17'	146	-3.098	3.196	0.995	81.695	13.914	4.391	0.0	0
QCS# 278	52°14'	129°22'	155	-3.941	2.361	0.957	90.851	7.576	1.573	0.0	0
QCS# 279	52°10'	129°19'	159	-1.758	2.722	0.356	65.297	32.084	2.619	0.7	9
QCS# 280	52°7'	129°15'	155	2.268	1.184	0.281	0.0	91.219	8.781	0.4	4
QCS# 281	52°3'	129°12'	168	3.517	1.336	1.766	0.0	79.806	20.194	0.6	4
QCS# 282	52°0'	129°9'	164	-2.704	3.529	0.401	68.607	27.816	3.577	0.2	4
QCS# 284	51°53'	129°1'	111	3.381	0.630	0.470	0.0	91.492	8.508	0.0	1
QCS# 285	51°49'	129°58'	84	-1.563	3.477	0.154	57.409	41.643	0.947	0.1	2
QCS# 286	51°46'	128°55'	49	1.630	0.848	-0.664	1.465	98.535	0.0	0.0	2
QCS# 287	51°43'	128°51'	71	2.756	0.464	-0.361	0.0	99.622	0.378	0.1	4
QCS# 288	51°38'	128°52'	38 (camera station)								
QCS# 289	51°42'	128°57'	62	2.531	0.710	-1.494	1.218	98.547	0.234	0.0	4
QCS# 290	51°45'	129°1'	81	2.564	0.722	-0.241	0.0	99.066	0.934	0.1	10
QCS# 292	51°51'	129°7'	117	3.726	0.992	2.717	0.0	85.655	14.345	0.2	
QCH# 293	51°54'	129°11'	137	2.373	0.383	0.732	0.0	99.621	0.379	0.0	0
QCS# 294	51°58'	129°14'	175	5.077	2.399	0.963	0.0	37.108	62.892	0.8	0
QCS# 295	52°1'	129°18'	186	2.565	1.143	0.928	0.0	89.038	10.962	0.1	3
QCS# 296	52°5'	129°22'	186	0.387	4.348	0.309	42.968	42.157	14.875	0.5	6
QCC# 297	52°8'	129°24'	200	5.138	2.335	0.909	0.0	36.286	63.714	1.0	5
QCS# 298	52°11'	129°30'	204	6.453	2.983	0.266	0.0	20.943	79.056	1.2	6
QCS# 299	52°14'	129°33'	214	5.143	2.244	0.830	0.0	50.270	49.730	1.2	4
QCS# 300	52°12'	129°38'	218	4.613	1.853	1.346	0.0	47.129	52.871	0.6	4
QCS# 301	52°9'	129°34'	216	4.957	2.974	0.320	2.498	36.639	60.863	0.9	6
QCS# 311	51°33'	129°4'	50 (camera station)								
QCS# 312	51°43'	129°12'	92	3.060	0.465	0.549	0.0	98.233	1.767	0.1	2
QCS# 313	51°47'	129°14'	110	2.740	0.813	-0.173	0.0	97.600	2.400	0.1	1
QCS# 314	51°49'	129°15'	122	3.397	0.499	0.639	0.0	94.622	5.378	0.2	1
QCS# 315	51°52'	129°18'	177	2.547	0.483	0.119	0.0	99.032	0.968	0.1	0
QCS# 317	51°58'	129°21'	200	6.610	2.851	0.305	0.0	13.956	86.044	2.4	5
QCS# 318	52°1'	129°24'	200	7.267	3.134	0.125	0.0	9.625	90.375	2.4	6

QCS# 319	52°4'	129°29'	196				
7.210	2.857	0.132	0.0	7.732	92.268	2.5	7
QCS# 320	51°59'	129°41'	183				
1.755	0.492	0.112	0.0	99.853	0.147	0.0	2
QCS# 321	51°56'	129°39'	210				
1.933	0.788	0.874	0.0	97.110	2.890	0.2	1
QCS# 322	51°52'	129°36'	250				
2.666	3.034	0.425	11.138	67.897	20.965	0.8	4
QCS# 323	51°49'	129°33'	260				
5.354	3.075	0.543	0.0	55.562	44.438	0.6	3
QCS# 324	51°45'	129°30'	137				
2.109	0.681	-0.424	0.0	99.754	0.246	0.0	2
QCS# 325	51°43'	129°29'	92				
-2.460	1.915	0.398	79.835	20.104	0.061	0.0	4
QCS# 326	51°40'	129°27'	73				
-1.010	2.024	0.016	51.470	48.455	0.076	0.0	5
QCS# 327	51°35'	129°25'					
-1.238	1.645	0.101	57.806	42.101	0.093	0.0	26
QCS# 328	51°32'	129°23'	70				
-0.481	0.899	0.718	27.674	72.326	0.0	0.0	3
QCS# 329	51°27'	129°22'	91				
-3.120	1.677	0.882	91.031	8.793	0.177	0.0	0
QCS# 330	51°53'	130°49'	212				
-2.702	2.569	0.652	80.146	19.609	0.245	0.0	0
QCS# 331	51°56'	130°43'	265				
0.207	2.874	-0.306	31.322	67.125	1.552	0.1	3
QCS# 332	51°57'	130°38'	283				
0.249	2.641	-0.223	35.864	62.127	2.009	0.2	2
QCS# 333	52°0'	130°34'	228				
-1.256	2.046	0.314	58.343	39.977	1.679	0.0	0
QCS# 334	52°2'	130°26'	366				
-0.199	4.287	0.238	46.705	37.556	15.739	0.8	3
QCS# 335	52°14'	129°46'	197				
2.950	0.563	0.829	0.0	96.200	3.800	0.2	1
QCS# 336	52°17'	129°49'	192				
2.036	0.845	-0.129	0.0	99.604	0.396	0.0	1
QCS# 338	52°10'	129°50'	183				
3.380	1.870	1.623	0.0	89.137	10.863	0.3	2
QCS# 339	52°9'	129°57'	148				
3.153	0.847	-0.382	0.0	92.949	7.051	0.3	7
QCS# 340	52°13'	129°59'	141				
2.908	0.728	-0.043	0.0	96.044	3.956	0.2	4
QCS# 341	52°10'	130°6'	206				
3.937	1.705	1.598	0.0	79.609	20.392	0.5	5
QCS# 342	52°7'	130°4'	168				
2.407	0.832	0.365	0.0	96.707	3.293	0.1	2
QCS# 343	52°5'	130°9'	234				
2.522	0.773	0.655	0.0	95.104	4.896	0.3	2
QCS# 344	52°8'	130°11'	292				
4.143	1.682	1.600	0.0	73.223	26.777	0.4	3
QCS# 345	52°11'	130°13'	480				
6.619	3.540	0.096	0.0	35.034	64.966	1.6	4
QCS# 346	52°7'	130°16'	440				
2.244	0.781	0.985	0.0	94.988	5.012	0.1	1
QCS# 347	52°4'	130°22'	370				
2.796	2.150	1.279	0.0	85.987	14.013	0.3	1
QCS# 348	52°3'	130°14'	310				
2.965	1.545	1.304	0.0	84.354	15.646	0.3	3
QCS# 349	52°1'	130°19'	370				
2.734	1.440	1.397	0.0	86.610	13.390	0.2	1
QCS# 350	51°59'	130°25'	430				
4.395	1.885	1.372	0.0	59.420	40.580	0.6	4
QCS# 351	51°58'	130°32'	420				
4.389	1.909	1.336	0.0	61.721	38.279	0.1	6
QCS# 352	51°54'	130°35'	365				
-1.870	3.439	0.273	57.379	40.476	2.145	0.2	3
QCS# 353	51°52'	130°39'	320				
-3.335	2.874	0.917	80.225	17.822	1.953	0.3	4
QCS# 354	51°51'	130°47'	230				
-5.141	0.718	1.913	99.588	0.412	0.0	0.0	0
QCS# 356	51°45'	130°47'	244 (trace of gravel)				
QCS# 357	51°47'	130°42'	585				
-0.113	2.041	-0.123	38.669	61.110	0.221	0.0	0
QCS# 358	51°49'	130°38'	304				
-3.757	2.197	0.772	86.334	13.608	0.058	0.0	1
QCS# 359	51°51'	130°36'	276 (trace of gravel)				
QCS# 360	51°53'	130°29'	356				
1.395	1.517	-0.227	5.218	92.576	2.205	0.1	3
QCS# 361	51°48'	130°28'	356				
-6.346	0.361	0.159	100.00	0.0	0.0	0.0	0
QCS# 362	51°44'	130°25'	530				
1.595	1.568	0.151	0.0	93.820	6.180	0.2	3
QCS# 363	51°40'	130°22'	254 (trace of gravel)				
QCS# 364	51°37'	130°18'	494 (trace of gravel)				
QCS# 365	51°39'	130°12'	375				
-4.147	2.575	1.184	86.797	12.089	1.114	0.4	4
QCS# 366	51°43'	130°16'	238 (trace of gravel)				
QCS# 367	51°46'	130°19'	242				
-1.084	3.505	-0.074	43.492	54.425	2.083	0.0	12
QCS# 368	51°50'	130°22'	230				
-4.786	0.676	0.207	99.963	0.037	0.0	0.0	0
QCS# 369	51°56'	130°22'	330				
3.145	0.540	0.849	0.0	92.157	7.843	0.3	4
QCS# 370	51°58'	130°16'	284				
3.573	1.072	2.634	0.0	89.211	10.789	0.4	4
QCS# 371	52°0'	130°8'	155				
-0.757	3.156	0.034	49.567	47.001	3.432	0.0	48
QCS# 372	51°57'	130°6'	146				
-2.192	3.641	0.347	65.530	29.877	4.593	0.0	0
QCS# 373	51°55'	130°10'	175				
4.010	3.650	0.190	11.661	46.246	42.093	0.1	22
QCS# 374	51°54'	130°14'	200				
-0.901	4.151	0.243	52.137	41.312	6.550	0.3	16
QCS# 375	51°50'	130°11'	197				
1.168	3.808	0.375	30.010	54.228	15.761	0.0	0
QCS# 376	51°52'	130°6'	175				
0.230	4.397	0.184	41.245	45.245	13.410	0.0	34
QCS# 377	51°53'	130°2'	159				
-1.744	2.910	0.368	66.911	31.738	1.351	0.1	21
QCS# 378	51°50'	129°59'	174				
2.194	0.710	-0.086	0.0	99.402	0.598	0.1	1
QCS# 379	51°48'	130°3'	190				
2.754	0.657	0.770	0.0	95.914	4.086	0.2	2
QCS# 381	51°43'	130°9'	267				
1.491	3.333	-0.454	17.838	74.779	7.383	0.3	3
QCS# 382	51°44'	130°2'	310				
4.648	2.258	1.036	0.0	57.941	42.059	1.1	4

QCS# 383	51°47'	129°57'	270				
4.381	2.345	1.168	0.0	70.409	29.591	0.5	2
QCS# 384	51°44'	129°54'	344				
5.177	2.167	0.971	0.0	27.486	72.515	1.2	5
QCS# 385	51°41'	129°51'	336				
4.443	1.960	1.203	0.0	50.749	49.251	1.0	4
QCS# 386	51°38'	129°46'	192				
-1.369	3.848	0.423	60.697	32.654	6.649	0.5	16
QCS# 387	51°41'	129°44'	256				
3.813	2.255	1.137	0.0	75.346	24.654	0.6	5
QCS# 388	51°44'	129°45'	310				
5.396	2.512	0.752	0.0	29.722	70.279	1.3	5
QCS# 389	51°50'	129°48'	252				
3.534	1.846	1.651	0.0	87.763	12.237	0.5	3
QCS# 390	51°51'	129°49'	150				
1.497	1.671	-0.602	7.475	89.690	2.835	0.0	4
QCS# 391	51°55'	129°55'	130 (camera station)				
QCS# 393	52°1'	130°0'	131				
-2.363	2.711	0.552	74.828	23.418	1.754	0.0	51
QCS#394	52°5'	129°58'	147				
1.125	1.108	-0.224	5.531	93.915	0.553	0.2	4
QCS# 395	52°6'	129°51'	119				
-0.447	2.283	0.169	46.915	50.624	2.461	0.1	26
QCS# 396	52°7'	129°46'	183				
4.212	1.755	1.378	0.0	58.579	41.422	0.9	16
QCS# 398	52°3'	129°49'	115				
-4.608	1.221	2.014	97.544	2.352	0.105	0.0	0
QCS# 399	52°1'	129°54'	122				
-3.786	2.792	0.780	83.604	15.712	0.685	0.4	43
QCS# 400	51°56'	129°53'	132				
0.654	2.447	-0.548	20.914	78.023	1.063	0.1	12
QCS# 401	51°52'	129°47'	192				
1.585	0.563	0.140	0.0	99.699	0.301	0.1	1
QCS# 402	51°49'	129°44'	282				
3.190	2.125	1.190	0.0	80.732	19.267	0.4	2
QCS# 403	51°46'	129°40'	282				
5.353	2.792	0.580	0.0	45.282	54.718	0.7	3
QCS# 405	51°40'	129°35'	117				
-1.091	3.039	0.336	64.003	31.615	4.381	0.7	23
QCS# 406	51°37'	129°33'	100				
-4.287	1.579	1.466	95.319	4.481	0.200	0.0	0
QCS# 410	51°56'	129°43'	146				
-0.922	2.238	0.131	54.471	44.573	0.956	0.2	12
QCS# 411	52°0'	129°45'	113				
-0.392	1.584	0.060	39.083	60.379	0.538	0.1	5
QCS# 412	52°2'	129°40'	200				
4.014	1.858	1.480	0.0	73.930	26.070	0.4	6
QCS# 413	51°59'	129°45'	198				
3.995	2.027	1.184	0.0	71.355	28.645	0.4	4
QCS# 414	51°56'	129°35'	208				
7.413	2.883	0.119	0.0	6.577	93.423	2.1	6
QCS# 416	51°48;	129°26'	183				
-2.077	2.136	0.453	74.467	24.973	0.560	0.2	11
QCS# 417	51°45'	129°24'	84				
0.577	1.820	-0.450	23.614	76.319	0.067	0.0	0
QCS# 418	51°42'	129°20'	59				
0.538	1.423	-0.371	19.356	80.556	0.088	0.0	3
QCS# 419	51°38'	129°18'	51				
-0.294	1.589	-0.041	39.529	60.386	0.085	0.9	8

QCS# 420	51°33'	129°16'	47				
-3.535	1.005	1.092	97.573	2.395	0.031	0.0	0
QCS# 424	51°13'	129°4'	183 (camera station)				
QCS# 427	51°5'	129°28'	250 (camera station)				
QCS# 429	50°58'	128°58'	77 (camera station)				
QCS# 430	51°34'	128°38'	38 (camera station)				
QCS# 435	51°2'	128°37'	73 (camera station)				
QCS# 437	50°51'	128°22'	40 (camera station)				
QCS# 443	51°14'	128°38'	200				
2.898	2.117	1.345	0.0	88.487	11.513	0.6	3
QCS# 444	51°16'	128°46'	195				
3.268	2.812	0.793	0.0	78.402	21.598	0.6	8
QCS# 446	51°22'	128°23'	135				
2.848	1.764	1.420	0.0	91.121	8.878	0.3	8
QCS# 447	51°26'	128°20'	115 (trace of gravel)				
QCS# 448	51°30'	128°23'	187 (gravity core only)				
QCS# 450	51°40'	128°36'	40				
-3.695	0.457	0.046	100.000	0.0	0.0	0.0	0
QCS# 451	51°36'	128°47'	40				
-3.281	1.465	0.346	93.945	6.055	0.0	0.0	0
QCS# 452	51°29'	129°1'	51				
-2.901	2.142	0.626	83.039	16.950	0.011	0.0	0
QCS# 453	51°21'	129°11'	220				
2.573	0.920	0.649	0.0	92.040	7.960	0.2	1
QCS# 454	51°28'	129°18'	59				
-3.171	1.830	0.905	89.650	10.326	0.025	0.0	0
QCS# 455	51°31'	129°13'	49				
-0.988	1.394	0.176	54.923	44.986	0.091	0.0	0
QCS# 456	51°32'	129°4'	48				
-0.436	1.747	-0.097	40.489	59.388	0.123	0.0	9
QCS# 458	51°40'	129°1'	66				
2.036	0.466	0.372	0.0	99.746	0.254	0.0	0
QCS# 459	51°43'	129°5'	84				
2.684	0.439	0.327	0.0	99.568	0.432	0.1	2
QCS# 461	51°46'	129°4'	102				
3.308	0.516	0.674	0.0	95.189	4.811	0.1	1
QCS# 471	52°15'	129°53'	126 (trace of gravel)				
QCS# 473	52°6'	129°53'	128				
0.713	0.951	-0.212	6.572	92.976	0.452	0.0	0
QCS# 474	52°6'	129°38'	222				
5.238	2.403	0.844	0.0	26.125	73.874	1.0	9
QCS# 480	51°54'	129°58'	148				
1.002	2.009	-0.549	20.156	79.266	0.578	0.0	1
QCS# 481	51°58'	129°51'	135				
1.465	0.956	-0.241	0.0	99.522	0.478	0.0	3
QCS# 482	52°1'	129°40'	183				
2.645	2.104	1.160	1.070	84.803	14.127	0.4	6
QCS# 484	52°1'	129°31'	220				
4.751	2.108	1.076	0.0	44.031	55.969	1.0	5
QCS# 485	51°56'	129°27'	210				
2.443	0.535	0.461	0.0	98.952	1.048	0.1	1
QCS# 486	51°54'	129°49'	139				
-4.325	0.588	0.816	100.000	0.0	0.0	0.0	0
QCS# 487	51°51'	129°55'	150				
1.012	1.710	-0.623	13.073	85.258	1.670	0.0	0
QCS# 489	51°42'	130°5'	357				
5.774	2.913	0.459	0.0	36.436	63.564	0.6	3

QCS# 490	51°33'	129°58'	232				
-2.837	2.721	0.704	79.315	18.646	2.039	0.9	21
QCS# 492	51°40'	129°56'	348				
4.746	2.109	1.125	0.0	46.139	53.861	1.5	5
QCS# 499	51°42'	129°37'	183				
2.708	0.730	0.342	0.0	96.248	3.752	0.2	2
QCS# 502	51°34'	129°39'	137				
-4.276	0.890	2.524	97.794	2.168	0.038	0.0	0
QCS# 503	51°31'	129°48'	164				
4.704	3.622	0.204	5.280	44.720	50.000	1.0	17
QCS# 504	51°28'	12956'	244				
0.952	2.836	-0.134	31.282	55.228	13.491	0.0	0
QCS# 506	51°24'	129°48'	214				
2.613	0.723	1.036	0.0	93.965	6.035	0.2	1
QCS# 507	51°28'	129°38'	152				
6.664	3.406	0.062	0.0	25.637	74.363	0.0	0
QCS# 508	51°31'	129°31'	92				
-1.250	1.403	0.331	66.518	33.482	0.0	0.0	0
QCS# 510	51°29'	129°26'	92				
2.297	0.574	0.148	0.0	99.604	0.396	0.0	1
QCS# 511	51°27'	129°32'	137				
2.415	0.591	0.256	0.0	99.018	0.982	0.0	1
QCS# 512	51°24'	129°38'	174				
2.846	0.501	1.086	0.0	97.159	2.841	0.1	0
QCS# 513	51°21'	129°46'	229				
-3.857	1.600	3.228	97.791	0.793	1.416	0.0	0
QCS# 514	51°18'	129°55'	260				
-3.091	2.556	0.852	82.162	15.525	2.313	0.0	0
QCS# 515	51°17'	129°39'	229				
1.707	3.971	0.112	25.508	54.508	19.675	0.6	8
QCS# 516	51°21'	129°32'	183				
2.805	0.480	1.233	0.0	97.353	2.647	0.4	0
QCS# 517	51°25'	129°26'	137				
2.611	0.384	0.319	0.0	99.726	0.274	0.0	0
QCS# 520	51°11'	129°14'	292 (gravity core only)				
QCS# 523	50°56'	128°21'	55				
1.842	0.626	0.296	0.0	99.717	0.283	0.0	0