Descriptive Notes

STUDY AREA

Douglas Channel (Fig. 1) is part of the Kitimat fiord system that dissects the Coast Range of northern British Columbia, Canada (Macdonald et al., 1983). This map encompasses not only the fiord system but also parts of the adjacent continental shelf (Hecate Strait).

RECENT GEOLOGICAL HISTORY

About 15,000 to 14,000 years ago the region was covered by glacial ice that flowed to the southwest in Hecate Strait and thence into Moresby Trough (Barrie and Conway, 1999; Clague and James, 2002). Streamlined landforms developed under the grounded ice on the continental shelf, just outside the fiords. As deglaciation progressed, meltwater plumes deposited a blanket of glaciomarine silt outside the fiords. Icebergs impacted this unit, creating furrows and pits.

As the ice retreated inland, thick deposits of glaciomarine mud formed in fiord basins. Transverse moraines formed during halts in glacier retreat. Following further retreat, glaciomarine silt on top of these moraines failed in several places, notably at the south end of Squally Channel and at Kitkiata.

MODERN PROCESSES

The Kitimat fiord system is subject to high precipitation and high rates of snowpack melt. The region is seismically active, although less so than farther offshore, near the transform Queen Charlotte Fault (Rohr and Tryon, 2010). Several recent publications describe the extent to which mass transport processes have conditioned the seafloor (e.g. Conway et al., 2012, 2013). The preliminary evaluation of the evidence suggests that mass transport has occurred throughout the postglacial period, and continued to the modern day, as evidenced by the 1970s slope failures at Kitimat (Prior et al., 1983).

Strong bottom currents impact the fiord floors in some areas, creating alternating areas of scour and high sedimentation rate (Bornhold, 1983). Large deltas are found at the head of the fiord system, at Kitimat and Kitkiata, while numerous smaller, fan deltas (Prior and Bornhold, 1989, 1990) are found through the area, preferentially located in the upper fiord system.

The recent surveys have located reefs composed of glass sponges (Hexactinellida) within the fiord system. They have developed on 'hard' glacial substrates, as elsewhere in the fiords of the Pacific Northwest (see Stone et al., 2014).

MAPPING APPROACH

The area was mapped by the Canadian Hydrographic Service using Kongsberg Maritime multibeam sonar systems that provide high-resolution bathymetry of the sea floor as well as "backscatter strength", a derived attribute that correlates with sediment type at the seafloor. Figure 2 shows the distribution of backscatter strength in the fiord system. Other information used for mapping was derived from sub-bottom profiles, grab samples, photographs, cores, and bottom photographs.

The approach is similar to that of "seascape mapping" (e.g. Shaw et al., 2012) in which it assumed that the seafloor can be mapped in terms of units, each unit having a distinct combination of morphology, texture, and biota. However, it was felt that there were insufficient bottom photographs to adopt the exact same approach in the Douglas Channel region, so the seascape map units described here are essentially geomorphology and texture.

SEASCAPES OUTSIDE THE FIORDS

The seascapes are divided into two classes: those on the inner continental shelf outside the fiords, and those within the fiords. Outside the fiords bedrock is commonly exposed. Streamlined landforms were formed parallel to ice-flow direction. Moraines record temporary halts in the incremental retreat of grounded ice, and were formed normal to ice flow direction. Glaciomarine sediments were deposited by fallout from meltwater plumes, and were subsequently turbated by icebergs. Deposits of postglacial mud/sandy mud are found in areas of low current activity, while areas of winnowed/scoured seafloor, probably undertain by glaciomarine sediment, occur where currents are relatively strong.

FIORD SEASCAPES

Thirteen seascape classes are designated for the fiords. Fiord sidewalls consist of either bedrock or unconsolidated sediment, the latter consisting of a blanket of glaciomarine mud, with or without a cover of postglacial mud. Fiord floors are divided into either banks of postglacial mud up to 90 m thick, gas-charged in places, or areas of scour and winnowing, where underlying glaciomarine sediments are exposed at the sea floor under surface gravel lags. Figure 3 shows the differing acoustic character of these two seascapes at the south end of Douglas Channel. Moraines are located transverse to fiord axes, and consist of thick deposits of glacial diamict capped by glaciomarine mud. Deltas are grouped into two types: 1) large deltas at Kitimat and Kildala; and 2) the numerous fan deltas that form cone-shaped deposits banked against fiord sidewalls. Mass transport deposits are grouped as: 1) large, complex failures of probable Late Glacial age on the rear slopes of moraines; 2) debris flows and translational slides; 3) bedrock slump/rockavalanche; and 4) bedrock creep (i.e. sackung, Ambrosi and Crosta, 2006). One area of bioherms was mapped, and an area of anthropogenic disturbance was identified. The map also shows the distribution of pockmarks and gas masking. Figure 4 is a coloured, shaded relief image of an area at the south end of Devastation Channel (location on main map) showing several of the seascape types within the fiords. Figure 5 shows backscatter strength for the same area.

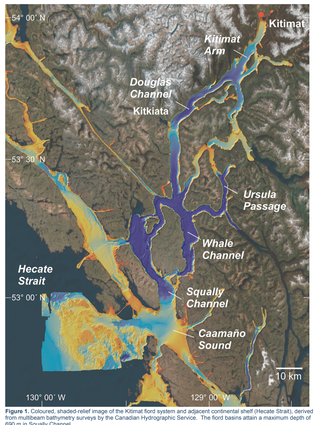

Figure 1. Coloured, shaded-relief image of the Kitimat fiord system and adjacent continental shelf (Hecate Strait), derived from multibeam bathymetry surveys by the Canadian Hydrographic Service. The fiord basins attain a maximum depth of 690 m in Squally Channel.

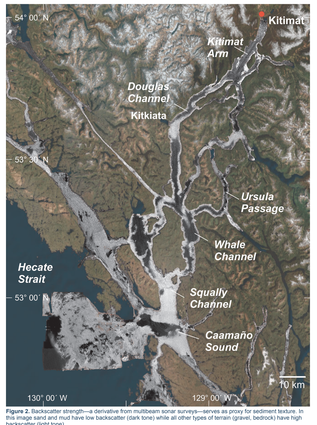

Figure 2. Backscatter strength—a derivative from multibeam sonar surveys—serves as proxy for sediment texture. In this image sand and mud have low backscatter (dark tone) while all other types of terrain (gravel, bedrock) have high backscatter (light tone).

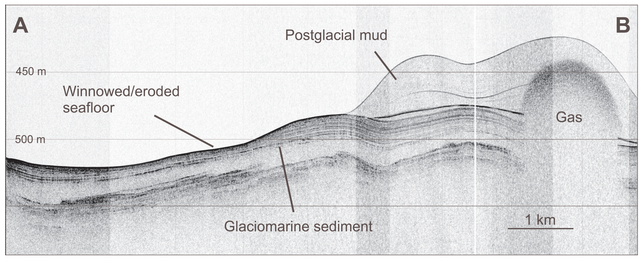

Figure 3. 3.5 kHz seismic reflection profile showing acoustically transparent postglacial mud adjacent to an area of seafloor winnowing and erosion in which acoustically stratified glaciomarine sediments are exposed at the sea floor. Location indicated on the principal map.

Abstract

This map depicts the geomorphology of the Kitimat fiord system, British Columbia, and is based on bathymetry and backscatter data from multibeam sonar surveys, complemented by 3.5 kHz sub-bottom profiler data, grab samples, cores, and bottom photographs. The coverage extends from the head of Kitimat Arm to Hecate Strait, and includes Douglas Channel. The seafloor is divided into classes based on morphology and texture. The classes include glacial landforms that record the advance and retreat of grounded ice, and a wide range of submarine slope failures. The map also shows that postglacial sediment distribution on the fiord floors is highly variable: large areas are current-scoured, so that underlying glaciomarine sediments are exposed. More than a hundred submarine fans deltas are present within the fiords.

Résumé

Cette carte illustre la géomorphologie du système de fjords de Kitimat, en Colombie-Britannique, et elle est fondée sur des données bathymétriques et des données de rétrodiffusion acquises lors de levés au sonar multifaisceaux, auxquelles s'ajoutent des données recueillies à l'aide d'un sondeur de sédiments à fréquence d'émission de 3,5 kHz, des échantillons prélevés par benne, des carottes et des photographies du fond marin. La zone couverte s'étend du fond du bras Kitimat au détroit d'Hécate et comprend le chenal Douglas. Le fond marin est divisé en classes selon la morphologie et la texture. Les classes englobent des reliefs glaciaires qui témoignent de l'avancée et du recul de la glace ancrée, ainsi qu'une vaste gamme de ruptures sous-marines de versant. La carte illustre également que la répartition des dépôts de sédiments postglaciaires sur le fond des fjords de vastes zones ont été érodées par les courants, ce qui a permis d'exposer les sédiments glaciomarins sous jacents. Plus d'une centaine d'éventails deltaïques sous-marins sont présents dans les fjords.

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2nd EDITION

CANADIAN GEOSCIENCE MAP 275

MARINE GEOLOGY

GEOMORPHOLOGY OF THE KITIMAT FIORD SYSTEM

British Columbia

Parts of NTS 103-A, NTS 103-H, and NTS 103-I

1:200 000

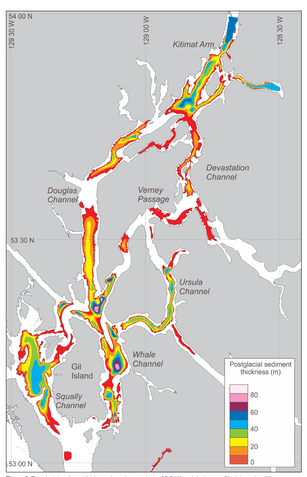

Figure 6. Postglacial sediment thickness based on analysis of 3.5 kHz sub-bottom profile data and multibeam bathymetry. The maximum thickness is slightly over 90 m at the south end of Whale Channel.

Acknowledgments

This work was part of a project managed by Dr. Gwyn Lintern under the aegis of Natural Resources Canada's Public Safety Geoscience Program. Robert Kung created and managed the ArcGIS project that contained multibeam bathymetry, backscatter strength, and other data sets. Scott Hayward processed GIS data in Dartmouth. Brian J. Todd reviewed the map and provided valuable advice.

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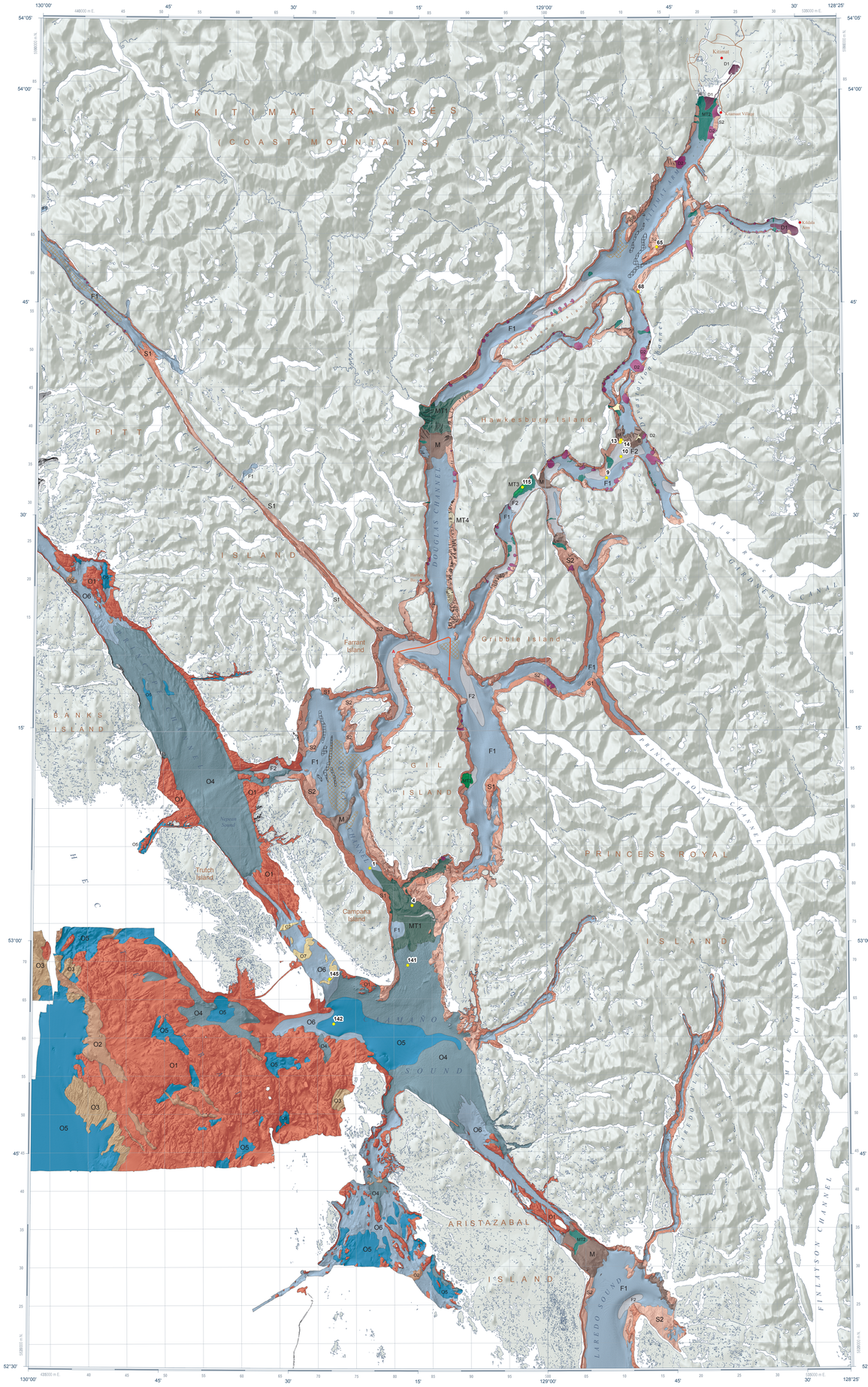


FIORD SEASCAPES

F1 Fiord sidewall – bedrock

Steeply sloping (> 40°) with bedrock outcrops separated by depressions containing gravelly sandy mud; attached fauna on exposed rock and infauna in depressions; high backscatter.

S2 Fiord sidewall – unconsolidated

Slopes > 10°, smooth surfaces or incised by gullies up to 10 m deep; consists of glaciomarine sediment with surface lag or a veneer of postglacial mud; generally gravelly sandy mud at the seabed (high backscatter) but also sandy mud (low backscatter).

F1 Fiord floor – postglacial mud

Gentle relief (slopes <10°) deposits of postglacial mud and sandy mud; commonly located in banks to either side of channel thalwegs; acoustically transparent or with moderate internal reflections; low backscatter; formed primarily by deposition of fluvial sediments, but also by reworking of glacigenic sediments.

F2 Fiord floor – winnowed/scoured

Low-relief (<2°) areas of non-deposition or erosion with glaciomarine mud exposed at the seafloor; some areas have a scalloped appearance with relief 0.5 to 2.0 m; surficial lag of muddy sandy gravel overlies acoustically stratified glaciomarine sediments; high backscatter; formed where bottom currents are relatively strong.

M Moraine

High-relief (>100 m) transverse ridges; gullied in places; acoustically incoherent glacial diamict draped by acoustically stratified glaciomarine mud; surface veneer of muddy gravel; high backscatter; formed at former ice margins during the retreat of grounded ice.

D1 Delta

Located where major rivers enter the fiords; stepped, concave profiles; slopes up to 15°; steeply-dipping internal reflections on acoustic records; chutes up to 15 m deep; generally gravel to sand at the seafloor; high backscatter; formed by deposition of delta foresets and bottomsets.

Fan delta

Fan-shaped deposits extending from sea level to depths of 300 m; slopes of 10° to 30°; chutes up to 1 m deep with transverse steps; generally coarse sediments (bouldery gravel to sand); high backscatter; small fan deltas may be separated from the coast by an area of bedrock (sediment bypassing); created by fluvial deposition where small to medium rivers enter the fiords.

Mt1 Mass transport complex

Large areas of seabed failure, with failure volume >1 km³ in Squally Channel; irregular relief including escarpments, gullies, depositional zones, and residual 'mesas' composed of acoustically stratified glaciomarine sediments; surficial sediment is muddy sandy gravel; high backscatter but low backscatter for small areas of post-failure sedimentation; created by failure of glaciomarine sediments draped over moraines, in the Late Glacial period. The area at Kitkiata may include failures but was more likely conditioned by an outburst flood.

Mt2 Debris flows / translational slide

Submarine slide deposits of differing ages, including fine-grained material and ranging up to boulders tens of metres in size; high backscatter except low backscatter where slides are buried by postglacial mud; the Kitimat slide (ca. 1970s) has complex morphology including remoulded debris, pressure ridges, depositional lobes, longitudinal shears, outrunner blocks; sand and muddy sand with some gravel; high backscatter; formed by failure of sediment on fiord sidewalls or delta fronts.

Mt3 Bedrock slump / rock avalanche

Slump is a convex mass extending ~ 1 km away from foot of bedrock slope; irregular surface with relief ~ 10 m; total volume 0.3 km³; veneered by Quaternary sediments with high backscatter (muddy sandy gravel); rock avalanche includes irregular bedrock blocks mantled by sand.

Mt4 Bedrock creep

Blocks up to 5 km long, detached from fiord sidewalls; rate of movement uncertain; may be equivalent to sackung (sagging bedrock on land); veneered by Quaternary sediments with gullies in places; high backscatter; formed by bedrock creep.

B Bioherm

Ridges located on top of glacial deposits with relief commonly 5–10 m; acoustically transparent with low backscatter; composed on glass sponges (Hexactinellida); also includes death assemblage of the giant acorn barnacle (*Balanus nubilus*) in Devastation Channel; classified as bioherms (reefs of fossilized biological remains with some sediment).

A Dredged area

Area of the Kitimat delta impacted by harbour activities; rectilinear dredge pits up to 6 m deep; anchor drag marks.

CONTINENTAL SHELF SEASCAPES

O1 Bedrock

Bedrock ridges and knoll with relief up to 30 m, separated by depressions containing glacial and postglacial sediments; high backscatter on outcrops, low backscatter in depressions.

O2 Moraine

Lobate ridges 100 m wide and 5–10 m high; linear ridges 7 km long and 30 m high; composed of acoustically incoherent glacial diamict; bouldery gravel at the seafloor; high backscatter; formed at the margins of grounded glacial ice.

O3 Streamlined ridge

Ridges up to 10 m high and 3 km long, tapering to the southwest; composed of acoustically incoherent glacial diamict; bouldery gravel at the seabed; high backscatter; formed parallel to the flow of grounded glacial ice.

O4 Glaciomarine sediment

Areas of low relief imprinted by iceberg furrows and pits; surface lag of sandy muddy gravel overlies draped, acoustically stratified, gravelly sandy mud; high backscatter; formed by deposition from glacial meltwater plumes.

O5 Postglacial mud / sandy mud

Low-relief banks with weak acoustic stratification in a semi-ponded style; mud and sandy mud; low backscatter; formed by deposition of reworked glacial sediments and fluvial sediments.

O6 Winnowed / scoured seafloor

Low relief, smooth seafloor; gravel lags; high backscatter; found where deposition of postglacial sediment is inhibited by currents.

O7 Bioherm

Narrow ridges with relief of up to 5 m, with low backscatter strength, located on top of glacial deposits, are tentatively identified as glass sponge (Hexactinellida) reefs.

Station photographs

Gully

Pockmarks

Gas masking

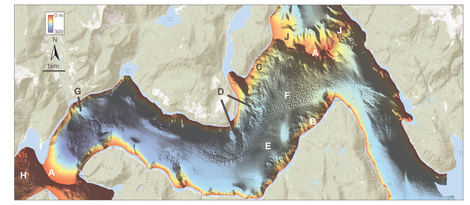


Figure 4. Coloured shaded relief image of an area at the south end of Devastation Channel showing elements found throughout much of the map area. These are moraines (A), bedrock fiord sidewall (B), unconsolidated sidewall (C), debris flows (D), bank of postglacial mud (E), winnowed/scoured seafloor (F), fan delta (G), rockfall (H), and bioherms (J).

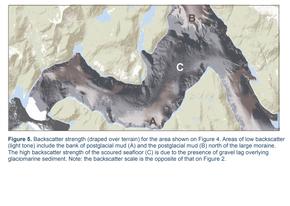
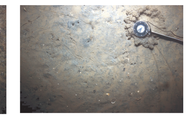


Figure 5. Backscatter strength (draped over terrain) for the area shown on Figure 4. Areas of low backscatter (light tone) include the bank of postglacial mud (A) and the postglacial mud (B) north of the large moraine. The high backscatter strength of the scoured seafloor (C) is due to the presence of gravel lag overlying glaciomarine sediment. Note: the backscatter scale is the opposite of that on Figure 2.

Station 01, Photo 106: **fiord- postglacial mud / sandy mud.** Depth of 673 m near the margin of an area of low backscatter. The seafloor is fine-grained, with scattered shell fragments, and a mottled appearance, with areas of dark blue and light brown. The associated grab sample consisted of dark olive-gray sandy mud.

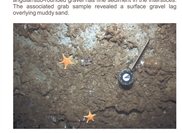
Station 04, Photo 03: **fiord-mass transport complex.** Depth 350 m in Squally Channel on a residual plateau of glaciomarine sediment with high backscatter strength. The pavement of sub-angular/sub-rounded gravel has fine sediment in the interstices. The associated grab sample revealed a surface gravel lag overlying muddy sand.



Station 09, Photo 21: **fiord-postglacial mud / sandy mud.** Depth 175 m at the south end of Devastation Channel on a bank of sediment with low backscatter strength. The seafloor has micro-roughness, and a mottled (dark blue/light brown) appearance, with animal burrows and tracks, and bivalve remains. The associated grab sample contained sandy mud.

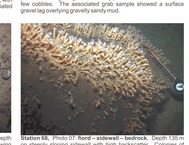
Station 10, Photo 13: **fiord: fiord floor-winnowed / scoured.** Depth 160 m at the south end of Devastation Channel in an area of 'scalloped' seafloor with high backscatter strength. The tightly packed sub-angular gravel is mostly pebble-sized, but includes a few cobbles. The associated grab sample showed a surface gravel lag overlying gravelly sandy mud.

Station 13, Photo 08: **fiord- bioherm.** Depth 125 m on the slope of a submarine moraine in Devastation Channel. The seafloor is covered by disarticulated tests of the giant acorn barnacle *Balanus nubilus*, with a profusion of other biota including sponges, anemones, brachiopods, urchins. The associated grab sample was comprised of barnacle plates.



Station 14, Photo 07: **fiord-bioherm.** Depth 85 m on top of a sponge reef — a ridge of acoustically transparent sediment with low backscatter on the crest of the submarine moraine in Devastation Channel. The seafloor is covered by glass sponges, mostly dead, with several sea stars visible. The grab sample consisted of sponge material in a matrix of mud.

Station 65, Photo 08: **fiord – sidewall – unconsolidated**. Depth 58 m on a section of fiord sidewall with high backscatter, showing sub-angular/sub-rounded pebbles strewn on a fine-grained seafloor. The associated grab sample showed gravel over coarse sand grading to clayey mud with depth.



Station 68, Photo 07: **fiord – sidewall – bedrock**. Depth 130 m on steeply sloping sidewall with high backscatter. Colonies of zoanthid anemones are present on the bedrock surface. Other photographs show glass sponges and sea stars. In the background the seafloor is fine-grained sediment. Other photographs show pebbles and cobbles with attached anemones and sponges.

Station 115, Photo 13: **fiord – bedrock slump / rock avalanche.** Depth 66 m in Fishtrap Bay, in an area with strong bottom currents and high backscatter. Bedrock outcrops are separated by depressions containing gravelly sandy seafloor littered with shell fragments, scattered anemones and sponges, and, in this instance, a sea pen. The associated grab sample consisted of gravelly sand with shell fragments.

Station 141, Photo 13: **Shelf – glaciomarine sediment.** Depth 252 m in an area of high backscatter with iceberg furrows and pits. Closely-packed sub-rounded pebbles, cobbles, and boulders have encrusting fauna. A sea star and fish are also visible. The grab sampler failed to penetrate but collected a single cobble, encrusted on top and clean below, suggesting the presence of an immobile, surficial lag.

Station 142, Photo 11: **Shelf – postglacial mud / sandy mud.** Depth 259 m in Caamaño Sound in an area of smooth seafloor with low backscatter, underlain by acoustically transparent sediment. The relatively smooth seafloor is marked by large burrows. Other photographs show numerous animal tracks. The associated grab sample consisted of dark olive sandy mud.

Station 145, Photo 11: **Shelf – winnowed / scoured seafloor.** Depth 53 m in an area of high backscatter, close to submarine moraines with sponge reefs on top. Sub-angular pebbles form a pavement, with sandy interstices. In this image a large anemone is present. Other photographs at this site show sponges, sea stars, and a bed of scallops. The associated grab sample showed gravelly sand overlying sandy mud.

Figure 7. Representative seafloor images from survey 2015002PGC, each covering an area approximately 1.25 x 0.85 m.

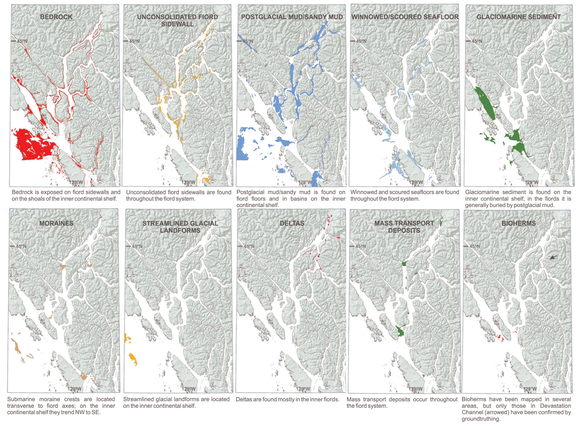


Figure 8. Distribution of seascape units. For this figure, distributions of bedrock inside and outside the fiord have been amalgamated, as have the distributions of postglacial mud.

Recommended citation

Shaw, J. and Lintern, G., 2016. Marine geology. Geomorphology of the Kitimat fiord system, British Columbia. Parts of NTS 103-A, NTS 103-H, and NTS 103-I; Geological Survey of Canada, Canadian Geoscience Map 275 (2nd edition, preliminary), scale 1:200 000. doi:10.4095/299793

Preliminary Preliminary Preliminary

Geological Survey of Canada
Canadian Geoscience Maps

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Canada

Authors: J. Shaw and D.G. Lintern

Geological compilation by J. Shaw

Cartography by S. Hayward and E. Everett

Map projection Universal Transverse Mercator, zone 9. North American Datum 1983

Preliminary Preliminary

Base map at the scale of 1:250 000 from Natural Resources Canada, with modifications.

Shaded relief image derived from the Canadian Digital Elevation Data (CDED) digital elevation model supplied by Canada Centre for Mapping and Earth Observation
Illumination: azimuth 345°, altitude 45°, vertical factor 10x

CANADIAN GEOSCIENCE MAP 275

MARINE GEOLOGY

GEOMORPHOLOGY OF THE KITIMAT FIORD SYSTEM

British Columbia

Parts of NTS 103-A, NTS 103-H, and NTS 103-I

1:200 000

5 0 5 10 15 20km

Preliminary Preliminary

Mean magnetic declination 2016, 18°22'E, decreasing 12.8' annually. Readings vary from 18°37'E in the NW corner to 18°08'E in the SE corner of the map.

This map is not to be used for navigational purposes.

Title photograph: Snow covered hills near Douglas Channel, British Columbia. Photograph by J. Shaw. 2016-001

Preliminary Preliminary

The Geological Survey of Canada welcomes corrections or additional information from users.

Data may include additional observations not portrayed on this map. See documentation accompanying the data.

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Preliminary

Preliminary publications in this series have not been scientifically edited.

Preliminary

2nd EDITION

CANADIAN GEOSCIENCE MAP 275

MARINE GEOLOGY

GEOMORPHOLOGY OF THE KITIMAT FIORD SYSTEM

British Columbia

Parts of NTS 103-A, NTS 103-H, and NTS 103-I