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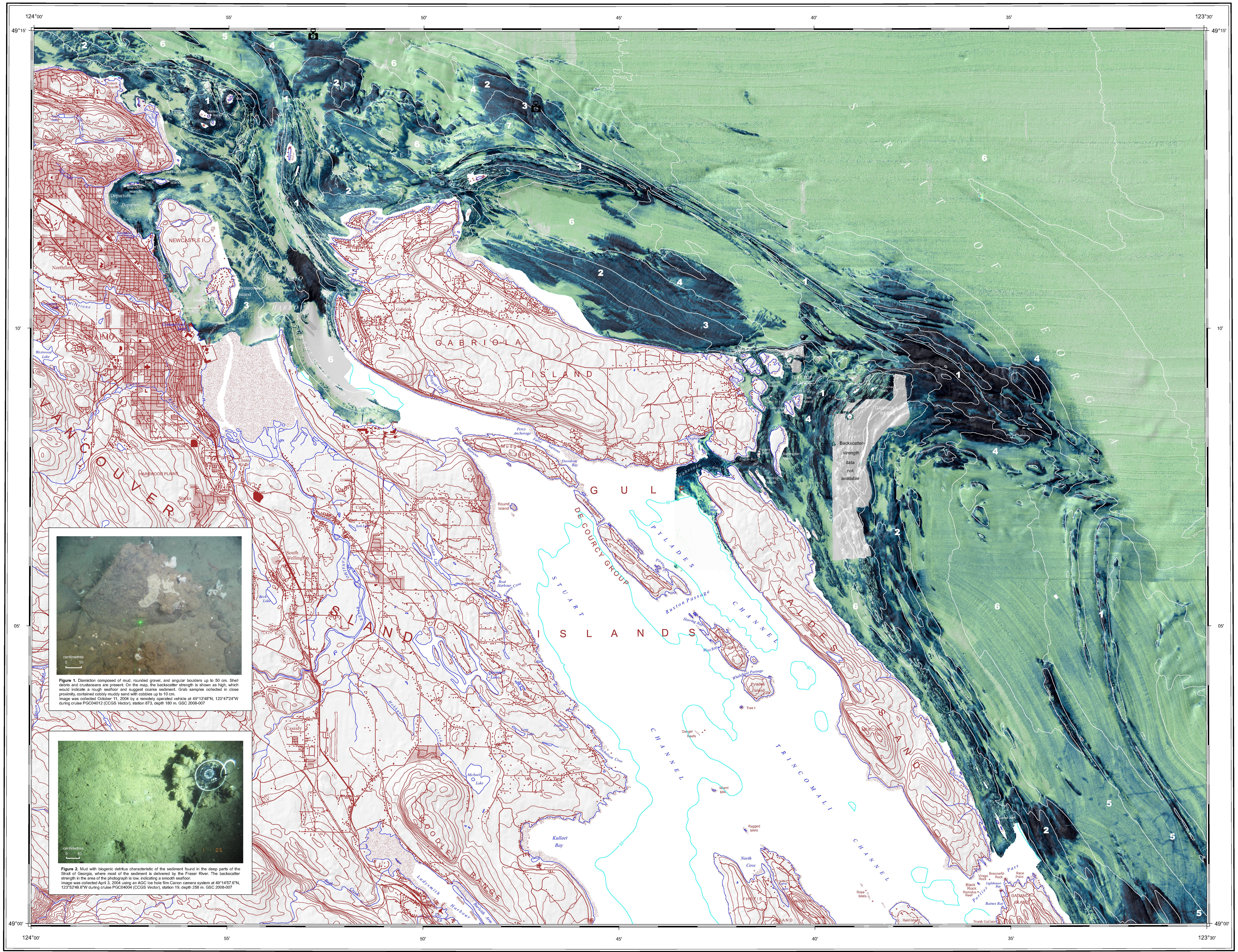

Figure 1. Diamicton composed of mud, rounded gravel, and angular boulders up to 50 cm. Shell debris and crustaceans are present. On the map, the backscatter strength is shown as high, which would indicate a rough seafloor and suggest coarse sediment. Grab samples collected in close proximity, contained cobbly muddy sand with cobbles up to 10 cm.
Image was collected October 11, 2004 by a remotely operated vehicle at 49°13'48"N, 123°47'24"W during cruise PGC04012 (CCGS *Vector*), station 873, depth 180 m. GSC 2008-007

Figure 2. Mud with biogenic detritus characteristic of the sediment found in the deep parts of the Strait of Georgia, where most of the sediment is delivered by the Fraser River. The backscatter strength in the area of the photograph is low, indicating a smooth seafloor.
Image was collected April 3, 2004 using an AGC Ice hole film Canon camera system at 49°14'57.6"N, 123°52'48.6"W during cruise PGC04004 (CCGS *Vector*), station 19, depth 258 m. GSC 2008-007

DESCRIPTIVE NOTES

INTRODUCTION

This backscatter strength map is the second map of a three-map series of the seafloor offshore Nanaimo, British Columbia. The map sheet covers the Strait of Georgia east of Nanaimo, including Gabriola Island and Valdez Island. The colours on the map depict backscatter strength draped over a digital elevation model of seafloor topography, artificially illuminated from the northwest. Bathymetric contours derived from multibeam sonar data are shown as white lines superimposed on the backscatter image and have a contour interval of 50 m. Outside the backscatter strength image, bathymetric contours are shown as blue lines with a contour interval of 50 m; these data were provided by the Canadian Hydrographic Service.

The first map in the three-map series displays sun-illuminated seafloor topography along with colour-coded bathymetry derived from multibeam sonar data (Picard and MacLeod, 2008). Interpretation of surficial geology and identification of key geological features are shown on the third map in the series (Picard, 2009).

BACKSCATTER STRENGTH

Multibeam bathymetric data were collected from 1997 to 2005 using Kongsberg-Simrad EM1002 and EM3000 multibeam echo sounders aboard the Canadian Coast Guard Ships (CCGS) *RB Young* and *Vector*, and the CCGS *Puffin*, *Revisor,* and *Otter Bay*, respectively. The EM1002 operates at a frequency of 95 kHz producing 111 beams and is generally used for water deeper than 50 m and up to a maximum of 1000 m. The EM3000 operates at a frequency of 300 kHz utilizing 127 beams and is used for shallow water, up to 100 m. Both systems cover an arc of 120°, and ensonify a narrow strip of seafloor along track. The EM1002 transducer was mounted on an electrically operated ram. On the CCGS *Puffin*, *Revisor*, and *Otter Bay,* the EM3000 was mounted in the keel. In order to meet International Hydrographic Organization standards for bathymetric data collection, the line spacing was such that a full overlap of the swath was collected. The Differential Global Positioning System was used for navigation, providing positional accuracy of ±5 m. The survey speed averaged 6 knots. The speed of sound in water was measured prior to and during the multibeam sonar data collection and was used to correct for the effect of sonar beam refraction. The data were adjusted for tidal variation using recorded observations or pseudotides calculated from tidal predictions and observations by the Canadian Hydrographic Service.

Multibeam systems simultaneously record high-resolution depth data and co-registered backscatter strength data. The backscatter strength can be represented in two ways: the amplitude, which is the average amplitude per beam and the sidescan, which represents a time-series of the returned amplitude along one beam. The EM1002 and EM3000 systems logged backscatter strengths ranging from 0 to -128 dB. To reduce the dynamic range of the recorded data, the systems applied a partial correction to the backscatter strength values for varying angles of incidence, using Lambert's law for angle variation assuming a flat seafloor (Dartnell and Gardner, 2004). Backscatter strength is calculated using calibration values for the electronics and transducers established at the time of instrument manufacture. Without further calibration during data collection, backscatter strength values may be inaccurate; however, the relative signal is still useful, and differences in the backscatter strength for different seafloor materials are discernable.

Some features in the backscatter strength data may be artifacts from data collection, environmental conditions during the survey, and data processing. A proprietary software was used to process the data, correcting for beam pattern artifacts, as well as the imbalance between port and starboard signal amplitude. After applying corrections, some artifacts are still visible. The orientation of the survey track lines can, in some instances, be identified by faint parallel stripes in the image (for example near 49°14'50"N, 123°49'00"W). Artifacts are also visible in areas where the multibeam systems automatically changed in pulse length because of changes in depth (for example near 49°12'00"N, 123°40'20"W).

Courtney and Shaw (2000) summarized the relationship of backscatter strength to seafloor sediment. Backscatter is often used as a proxy for surficial sediment type; however, there exists no direct relationship between backscatter amplitude and surficial sediment type. For an angle of incidence greater than about 20° (specular range), there is a correspondence between backscatter strength and surficial sediment roughness. This correlation can be used for cursory mapping and sediment identification. Coarse gravel and cobbles tend to be locally rough and return high amplitudes for wide-angle backscatter signals, whereas sand and fine-grained materials can be locally smooth with a much lower backscatter strength return. Because backscatter strength is a function of a suite of acoustical variables, it is prudent to interpret backscatter images in conjunction with other geophysical data (seismic-reflection profiles, sidescan-sonar sonograms), geological samples of seafloor materials, and seafloor photographs. Groundtruth surveying and accompanying interpretation is an essential component in the production of the surficial geology map.

BACKSCATTER DISTRIBUTION

Multiple seafloor surveys involving two multibeam systems mounted on four different vessels over a period of eight years contributed to this backscatter strength map. Modifications to the multibeam sonar systems between surveys, the use of different vessels, and the use of different systems were all factors that were considered during the data interpretation, since they likely affected the returned backscatter strength between data sets. Such variables are difficult to monitor and assess consistently. Consequently, to minimize these factors, the following method was applied: one backscatter data set was identified as the reference data set and was given the optimum colour ramp enhancing all sediment types. The colour ramps of the adjacent data sets were then adjusted to the reference data set. The overlapping areas of two adjacent data sets cover the same sediment type and therefore have the same backscatter-strength values. Using this method facilitated the interpretation of the backscatter-strength data and enhanced visual presentation.

Using information from geophysical surveys, sediment sampling surveys, unpublished remotely operated vehicle observations (L.K. Yamanaka, Department of Fisheries and Oceans, pers. comm. 2005), still camera pictures, as well as interpretation of the seafloor geomorphology, backscatter-strength data was correlated to different types of surficial material, and was used as a proxy for sediment type in areas where only backscatter-strength data is available.

In this study, the backscatter-strength values are grouped into three zones differentiated using distribution curves of the backscatter-strength frequencies within each data set. The three zones distinguish three environments. The first environment is represented by high backscatter strengths ranging between -20 dB and -40 dB, and includes areas of bedrock outcrop, mixtures of coarse sand and gravel, and diamicton. Figure 1 is a photograph representative of the higher range of the backscatter strength. In this case, roughness and seafloor composition are the two main factors influencing the backscatter strength. Bedrock environments (seabed texture 1) are discernable by strong and discontinuous acoustic backscatter strength when compared to adjacent lower strengths. The lower strengths represent the veneer originating from the eroded bedrock or the unconsolidated sediments covering the bedrock. In the sun-illuminated topographic map (Picard and MacLeod, 2008), bedrock has a distinctive ridge-like morphology. Other areas of relatively high and uniform backscatter strength include mixtures of coarse sand and gravel (seabed texture 2) and diamicton (seabed texture 3). Diamicton consists of sediments ranging from mud to boulders. In some of the areas where diamicton is identified, boulder fields are also present (*see* symbols on Map 2118A, (Picard, 2009)). These sediments were observed in grab samples, photographs, and on sidescan sonograms. They also appear as complex environments in the sun-illuminated relief images.

Intermediate backscatter strength areas include gravely sand (seabed texture 4), present in the transition zone between the bedrock unit and the mud basins, in areas within the differentially eroded bed planes of the bedrock outcrops where sediments accumulate, and in areas of reworked glaciogenic sediments (seabed texture 4) (*see* Fig. 5 on Map 2118A (Picard, 2009)). This second classification of backscatter strength also includes features such as dredge spoil sites (seabed texture 5), consisting mostly of gravel and sand strewn on sandy mud seafloor. The sites appear as circular to oval patches and streaks having high backscatter strength.

The third and most distinctive environment is characterized by low backscatter strengths, ranging from -45 dB to -60 dB. The seafloor photograph in Figure 2 shows the muddy sediments, typical of the lower range of backscatter strengths found in Strait of Georgia. Low backscatter strengths are usually associated with soft and well sorted sediments, typically sandy mud and mud (seabed texture 6) (Picard, 2009). These sediments are generally found in bathymetric lows such as basins and troughs (Picard, 2009). At a much larger scale, but nevertheless important, are small low backscatter areas distinctly enclosed within high backscatter strengths indicating the presence of sponge reefs (seabed texture 7). The adjacent high backscatter-strength areas are interpreted as the glacial material the sponges colonize (Conway et al., 2005).

ACKNOWLEDGMENTS

The master and the crew of the CCGS *R.B. Young*, *Revisor*, *Otter Bay*, *Puffin*, and *Vector* were instrumental in the multibeam sonar and groundtruthing surveys. The Canadian Hydrographic Service (CHS) collected and processed the multibeam sonar data. The authors thank R. Kung and K. Iwanowska for geographical information system and cartographic support. The map was reviewed by B.J. Todd and J.V. Barrie. This work was part of GSC Project X43 (K. Conway, leader) in the Geoscience for Ocean Management Program.

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Picard, K. and MacLeod, R.F.
2008: Sun-illuminated seafloor topography, Nanaimo, British Columbia, Geological Survey of Canada; Map 2117A, scale 1:50 000.

LEGEND

SEABED TEXTURE (INTERPRETED)

1 *Bedrock*

2 *Mixture of coarse sand and gravel*

3 *Bouldery mud and/or diamicton*

4 *Gravelly sand and muddy gravelly sand*

5 *Dredge spoils: gravel and sand over mud*

6 *Sandy mud or mud*

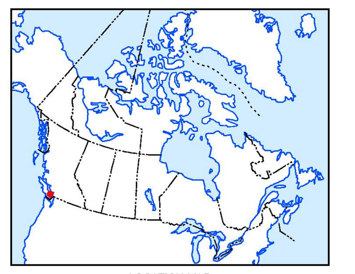
7 *Sponge reefs*

Seafloor photograph (see figures). . . . .

-108 | -45 | -30 | -25 | -3
Low — Approximate backscatter instensity (dB) — High

Published 2009

Copies of this map may be obtained
from the Geological Survey of Canada:
601 Booth Street, Ottawa, Ontario K1A 0E8
625 Robson Street, Vancouver, British Columbia V6B 5J3
490, rue de la Couronne, Québec, Quebec G1K 9A9
1 Challenger Drive, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2



LOCATION MAP

Author: K. Picard

Multibeam bathymetric data collected by Canadian Hydrographic Service, 1997, 1999–2002, 2005

Multibeam bathymetric data compiled the Geological Survey of Canada, 2007

Digital cartography by R.F. MacLeod, GSC (Pacific)

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

MAP 2119A

BACKSCATTER STRENGTH AND SHADED SEAFLOOR RELIEF

NANAIMO

BRITISH COLUMBIA

Scale 1:50 000/Échelle 1/50 000

kilometres 1 0 1 2 3 4 kilomètres

Universal Transverse Mercator Projection
North American Datum 1983

This map is not to be used for navigational purposes

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain 1983

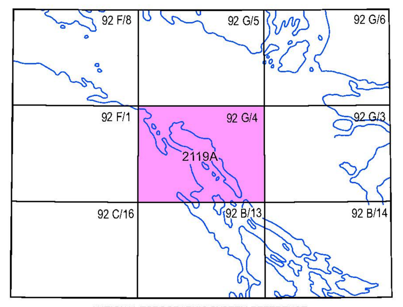
Cette carte ne doit pas être utilisée aux fins de navigation

Digital base map from data compiled by Geomatics Canada, modified by GSC (Pacific)

Digital bathymetric contours in metres supplied by the Canadian Hydrographic Service and GSC (Pacific)

Magnetic declination 2009, 17°52'E decreasing 12.0' annually

Depth in metres below mean sea level



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE

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2009: Backscatter strength and shaded seafloor relief, Nanaimo, British Columbia; Geological Survey of Canada, Map 2119A, scale 1:50 000.

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