Acoustic Seabed Classification in Martel Inlet, Antarctica Peninsula Using Multibeam Backscatter Data

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Abstract

The acoustic signal of a multibeam echo-sounder is mainly used to extract depth values from its travel time. However, the intensity of that signal with a proper processing can be analyzed as a bottom response, known as backscatter. This information has been used in inversion models to characterize seabed in terms of grain size and roughness. The model used in this paper is based on an angular analysis of the backscatter response, taking into account the sound-seabed relationship, which includes the transmitted and received sound level, acoustic beam patterns and acoustic attenuation in the water column. The aim of this analysis is to represent as accurately as possible the local glaciomarine environment dynamics of the Martel Inlet, Admiralty Bay, South Shetland Island, Antarctica. The multibeam bathymetry and backscatter data were processed and the acoustic classification model was generated in Geocoder 4.1. The generated grain size map was compared to a core sample in the area and to geological maps from previous work. As a result, the final model fit previous regional model, although it was not a good methodology for areas that contain coarse grains. This creates a discussion on the reliability of the method in a geological complex environment as a glaciomarine.

Introduction

The science of correlating acoustic properties to marine superficial sediments dates from early use of marine acoustics. This science of acoustic seabed classification has been driven by the development of commercial systems to classify seabed sediments for several applications like marine geology, submarine engineering and habitat mapping (Anderson *et al* ,2008).

Studies about the response of the Multibeam Echo Sounder (MBES), show that besides a satisfactory bathymetry, due to its 100 per cent ensonification of the seafloor, it is possible to analyze the intensity of the bottom response defined by the amplitude of the acoustic signal and correlate that information with bottom properties (Goff, 2000; Dartnell, 2004; Collier & Brown, 2005; Bartholomä, 2006; Lee *et al*, 2008). This response called backscatter carries important information about the seafloor morphology and its physical properties. According to Zietz and Elicker, 1995, it is possible to correct the intensity data for various influences like equipment characteristics, water column medium and acoustic losses. Thus, remaining variations in the data are due to the combination of acoustic information received from the bottom topography, bottom roughness, and other seabed properties such as sediment type and composition.

To achieve a reliable seafloor characterization, an accurate model should consider all these acoustic features, and relate them properly with prior geological information.

Local Geology

A geological background of the study area is important to validate the model. Martel inlet is part of the Admiralty bay in King George Island, Antarctic Peninsula (figure 1), and is surrounded by metavulcanic and metasedimentary rocks from Martel Inlet Group (Birkenmajer, 2003).

This area is an example of a glaciomarine environment, that include all areas in which glaciers reach the sea and influence sedimentation, ranging from fjords to those areas affected by iceberg drift and far distant from the source glaciers (Hambrey, 1994). As ice has a poor grain selection power, it is expected to observe areas with grain sizes varying from few a microns to several meters.

Acquisition

Multibeam data were collected by the navy's hydrographic center and granted for this research. Bathymetric and backscatter information were acquired and processed for the model characterization. A core sample was collected for granulometry and log analysis, and later comparison with the model parameters. The model was also compared to an existing grain size distribution map.

Data survey occurred between September and October of 2008. A Simrad EM3000 was installed on a pole portside of the vessel for multibeam data acquisition, together with a DGPS Nav2050 and the motion sensor unit MRU5. The attitude sensor was a gyro Seapath 20, and also, five sound velocity profiles (SVP) were deployed.

Bathymetric Processing

The bathymetric information data were processed using the softwares VBAProc and Workbench from the Starfix 9.1 Suite granted by Fugro Brasil. The VBA.proc was used to apply all the corrections and filters necessary to achieve an accurate result. The information from auxiliary equipments as the GPS, MRU, gyro and SVPs were processed separately and then merged with the MBES data to generate seabed topography information.

On the Workbench an additional filter to remove spikes was applied, as also some manually despiking. After that, a digital terrain model (DTM) was created using a 5 meters grid spacing.

Backscatter Processing

The software Geocoder 4.1 was used to process backscatter data. Processing workflow suggested on Conceição, 2009 was followed, so that all external influences can be considered.

To understand backscatter filters is important to consider the sonar equation[1], which represents the relationship between transmitted and received signal with all the meddium, bottom and equipment information.

$$EN = SL + DI - 2TL - NL + BS \quad (1)$$

Where En is the echo/noise ratio, SL is the source level, DI is the directivity index, TL is the transmission loss, NL is the noise level and BS is the backscatter.

During this processing the equipment model EM 3000 was considered to correct the transmitted/received power gain and beam pattern, and the medium properties were also considered to correct attenuation and spherical spreading losses.

An important positioning correction was applied with the slant range correction, which basically, using bathymetric information, convert the arrival angles of the seafloor echoes received by the sonar into true angles of incidence.

The AVG (Angle Varying Gain) correction, were applied to compensate the amplitude values reduced by the attenuation of the signal with the distance, analyzing the angular response.

To build a reliable backscatter mosaic other filters like anti-aliasing and speckle noise were applied.

Anti-aliasing removes signal components that have a higher frequency sampling at a lower resolution. That algorithm allows the assemblage of mosaics at any required resolution (Fonseca and Calder, 2005). Also the speckle noise filter removes the light or dark pixels created from out of phase wave interactions, preserving radiometric and edge information and spatial resolution (Mansourpour et al, 2006).

Acoustic Seabed Classification

Acoustic classification seabed models vary according to kind of analysis performed. The angular analysis was used in this paper. Although the spatial resolution is limited to the swath width (Fonseca and Calder, 2007), it gives a curve response for parameters like frequency, velocity, density, roughness, volume, grain size, tortuosity, porosity, permeability and loss and gamma factors. These features were analyzed into seafloor patches, which are defined as stack (average per angular bin) of 30 consecutive sonar pings, chosen to approximate the dimension of the swath width in the along-track direction.

A final model was created using all this parameters wired and compared with information acquired from core sample and logging.

Core sample and logging

In November 2009, a gravity core sample was collected near the Brazilian Antarctic station EACF (*Estação Antártica Comandante Ferraz*) at 62° 04.9843' S and 058° 22.6826' W, with 35.7 meters depth.

A gamma ray density log and magnetic susceptibility log (Figure 2) were performed at the multi sensor core logger (MSCL), and grain size analysis were also made at the Fluminense Federal University Sedimentology Laboratory to validate the acoustic classification model.

Results and Discussion

The grain size analysis in the two samples from the gravity core (table 1) showed a very irregular distribution, varying from gravel to mud, although a major fine sediments distribution can be observed.

The core logging showed interesting correlations. Gamma ray density values at the core surface had 0,01 kg/m³ difference from the value generated by the classification model for the patch located at the same area as the sample. Values of magnetic susceptibility revealed coherent with local geology expectation: terrigenous sediments with ferromagnetic mineral content. According to Potter, 2005, magnetic susceptibility can provide quantitative mineralogical information and ferromagnetic minerals like magnetite, have their cps values varying from 2^4 to 11^4 for example.

The final backscatter mosaic (figure 3) shows an area with different gains during acquisition, and as the area had a hydrographic survey as main purpose, power gain changes were not registered.

Gruber's grain size distribution map was generated from grab samples analysis and geological observation. The classes were defined, for example, as muddy gravel or gravely mud, which consider more than one phi value for a determinate class.

The acoustic classes generated in the model had individual phi values and is limited to -1 phi, which makes the analysis for coarse grain inconsistent.

Due to the glaciomarine environmental dynamics, the acoustic seabed classification model in Martel Inlet study area has revealed a very heterogeneous pattern of complex patchiness. This means that a grain size distribution model defined by acoustic classes derived from backscatter data and tied with grab samples may be more effective in geological complexes areas, than a grain size model generated directly from backscatter analysis.

Conclusions

Multibeam backscatter was processed and analyzed for grain size distribution purposes in Martel Inlet area. Core sample was also analyzed for granulometry and logging to validate the acoustic model. In the inversion model computed in Geocoder 4.1 a noticeable correlation with a previous grain size distribution map could be observed. However, the effectiveness of this classification method may be questioned for geological complex areas. Models with acoustic classes generated from MBES backscatter information should have a better response in this case.

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References

ANDERSON, J.T. *et al*. Acoustic seabed classification: current practice and future directions. *ICES Journal of Marine Science*, v. 65, p. 1004–1011, 2008.

BARTHOLOMÄ, A. Acoustic bottom detection and seabed classification in the German Bight, southern North Sea. *Geo–Marine Letters*. v. 26, p. 177–184. 2006.

BIRKENMAJER K. 2003 Admiralty Bay, King George Island (South Shetland Islands, West Antarctica): A geological monograph. ***Studia Geologica Polonica***. v. 120, p. 5–73.

COLLIER, J.S.; BROWN, C.J. Correlation of sidescan backscatter with grain size distribution of surficial seabed sediments. *Marine Geology*. v. 214, p. 431–449, 2005.

CONCEIÇÃO, F.V. Processing workflow of multibeam backscatter data from EM 3000 for sediment classification analysis. In : 11th International Congress of the Brazilian Geophysical Society, 2009, Salvador, Bahia, Brasil.

DARTNELL, P.; GARDNER, J.V. Predicting Seafloor Facies from Multibeam Bathymetry and Backscatter Data. *Photogrammetric Engineering & Remote Sensing*. v. 70, n. 9, p. 1081–1091, 2004.

FONSECA,L.; CALDER, B. Geocoder: an efficient backscatter map constructor. In: U.S. HYDROGRAPHIC CONFERENCE 2005, San Diego, CA, USA.

FONSECA, L.; CALDER,B. Clustering Acoustic Backscatter in the Angular Response Space. In: U.S. HYDROGRAPHIC CONFERENCE, 2007, Norfolk, USA.

GOFF, J.A.; OLSON, H.C.; DUNCAN, C.S. Correlation of side–scan backscatter intensity with grain size distribution of shelf sediments, New Jersey margin. *Geo–Marine Letters*. v. 20, p. 43–49, 2000.

GRUBER, N.L.S. *Contribuição ao estudo da sedimentação glaciomarinha da baía do Almirantado, Ilha Rei George, Antártica.* 1989. 174p. Dissertação (Mestrado) Curso de Pós-Graduação em Geociências, Universidade Federal do Rio Grande do Sul. Porto Alegre, RS.

HAMBREY, M.J. Glacial environments. UBC Press, Vancouver, Canada, 296 p. cap.7 Glaciomarine Processes and Sediments p.188 1994

LEE, G.H. *et al*. The acoustic diversity of the seabed based on the similarity index computed from Chirp seismic data. *ICES Journal of Marine Science*. v. 66, p. 227–236, 2008.

MANSOURPOUR, M. *et al* Effects and Performance of Speckle Noise Reduction Filters on Active Radar and SAR Images. Workshop on Topographic Mapping from Space, Ankara, Turkey. 2006

POTTER, D.K. Magnetic Susceptibility as a Rapid, Nondestructive Technique for Improved Rcal anda Scal Parameter Prediction. In : International Symposium of the Society of Core Analysts, 2005, Toronto, Canada.

ZIETZ, S.; ELICKER, C. Modeling and analysis of sonar backscatter intensity for ocean bottom classification, *Oceans '95*, Conference Proceedings, Vol.3, p. 1836-1839. 1995

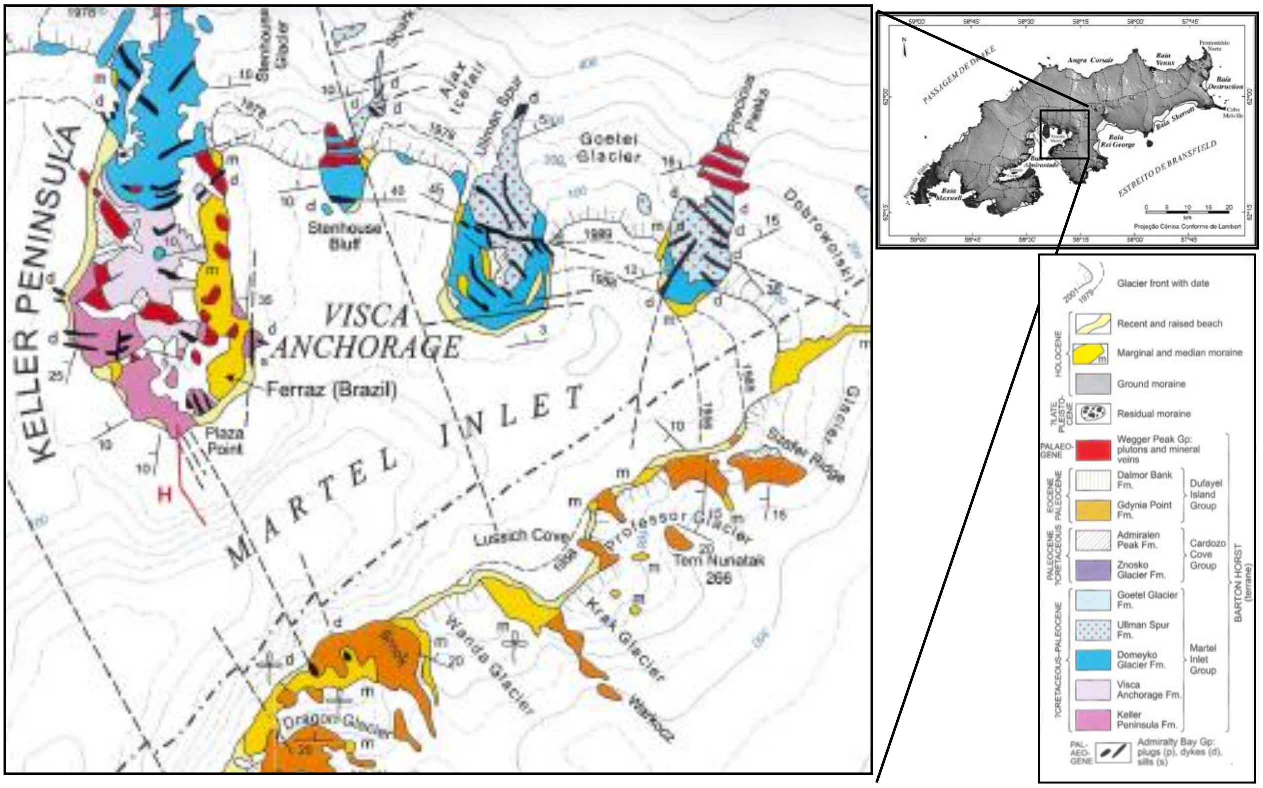

Figure 1 - Local geology of the study area, Martel Inlet. (Modified from Birkenmajer, 2003)

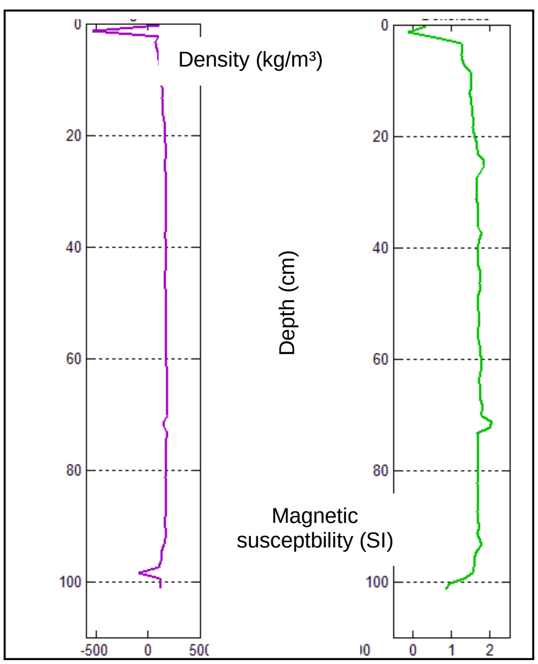

Figure 2 - Density from gamma ray (green) and magnetic susceptbility loggs (magenta).

Wentworth Grade	Phi scale Φ	Sample 1 (%): 0 to 0.1 m depth	Sample 2 (%): 0.7 to 0.8 m depth
Pebble	-2	31	-------
Granule	-1	6	9
Sand	0 to 3	14	16
Mud	3<	49	75

Table 1 - Granulometry of the gravity core sample.

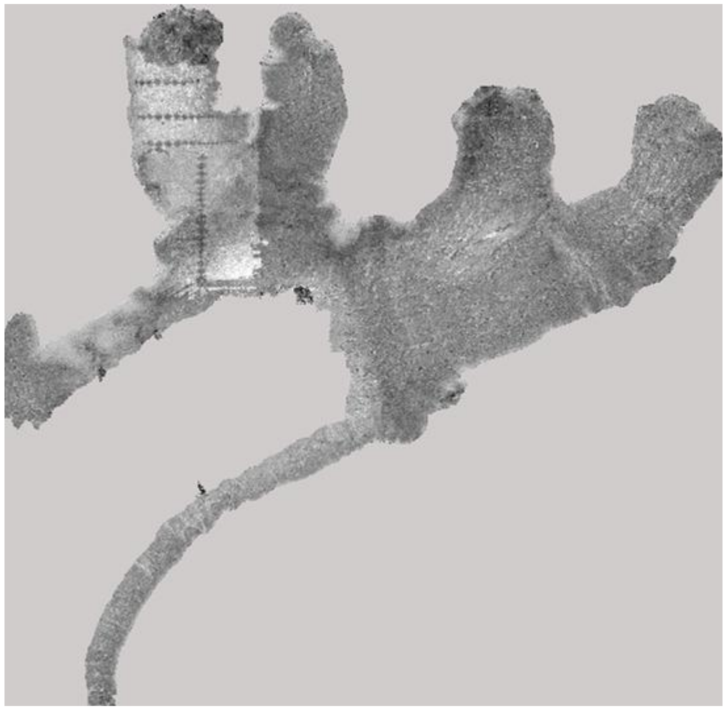

Figure 3 - Multibeam backscatter mosaic of Martel Inlet. The Northwest glacier entrance data shows the power difference gain.

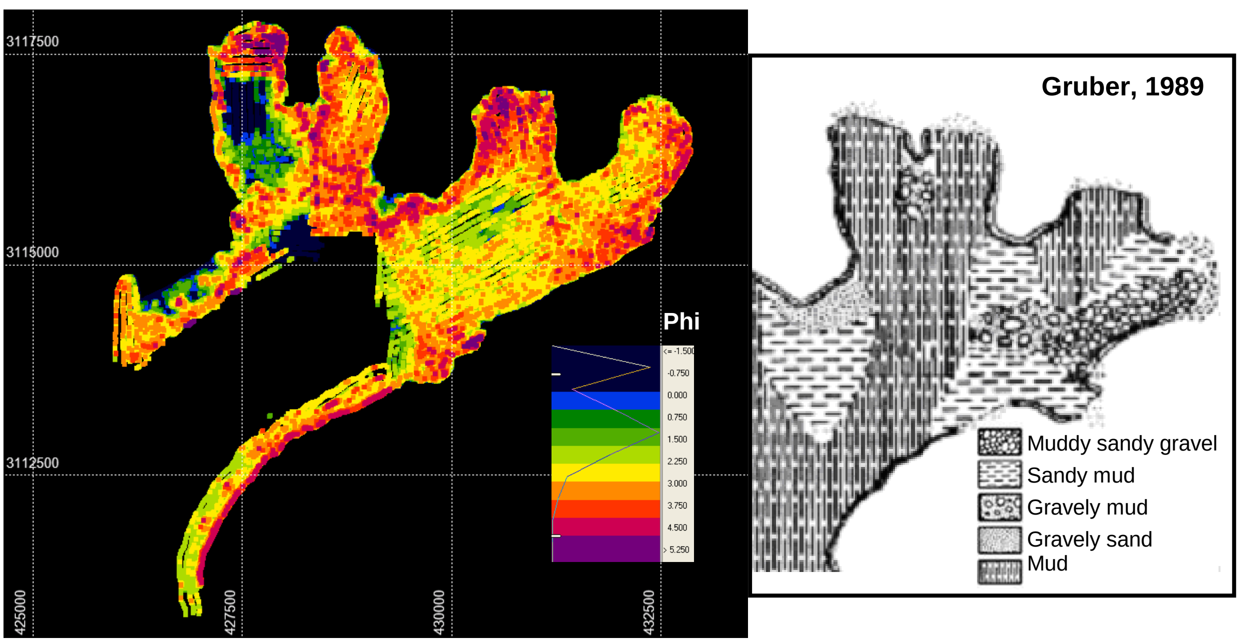

Figure 4 - Grain size distribution in Martel Inlet. (*Left*) Acoustic model from multibeam backscatter data. On the upper glacier entrance the “blue hole” is the effect of different power gain during survey. There is no multibeam data in the inner part of the map because of equipment’s depth limitation. (*Right*) Gruber’s grain size distribution (*modif.* Gruber, 1989).