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Geohazard identification and early reconnaissance for hydrocarbon potential using marine electromagnetic and high frequency acoustic methods

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Introduction

EM data and core samples collected in the Malin shelf (Ireland) area have been integrated with existing acoustic data from the Irish National Seabed Survey. The objective of this project is to use a combined acoustic and electromagnetic geophysical approach to study the near-seabed composition in a recently discovered shallow gas bearing area, involving core sample analysis, multibeam and single-beam backscatter classification, and a marine controlled-source electromagnetic method. This combined method enables us to map in an unprecedented way the upper 20m of the seabed and correlate the main geophysical parameters with the geological properties of the seabed, thus providing a unique tool for geohazard identification, seabed classification, fluid flow migration paths and sediment porosity.

Study area

The study area, approximately 750 km2, extends from the 7? 30'W to 8? 30'W, and from 55? 30' N to 56? 10'N (Fig. 1). This area, mapped in 2003 as part of the INSS program, is characterized by a newly discovered pockmark field, indicative of gas seepage. The pockmarks are distributed in clusters around the main structural lineaments, and can be found in excess of 220.

Seismic and acoustic data

The Geological Survey of Ireland has been producing acoustic seabed classification maps to different chart scales for water depths 50 to 200m since 2004. As a result of this pioneering ongoing research, it has become clear that multibeam and single beam backscatter data can be used combined to discriminate between different sediment types, although not without some margin of error. Backscatter amplitude values vary not only with the type of seabed but also with the range travelled and the angle of incidence of the beam at the seabed. The GSI has develop techniques to extract from the backscatter strength compensated values; tonal and textural vector features for a given patch of this image that lead to meaningful segmentation into classes. Multivariate analysis of backscatter data has been widely used to separate the data into different categories. Principal component analysis (PCA) together with K-means partitioning normally has been the chosen method because it optimizes the ability of a small number of the components to accurately represent the feature vectors. Backscatter data generally follow multimodal distributions that represent the complexity of the different seabed types and their different contributions. In order to capture most of the backscatter variability and correlate the results with the geotechnical properties of the sediment, a modified multivariate analysis design will be used to improve the results. Single beam classification will involve a similar methodology to the image analysis, but instead, use the digital echoshapes of the first echo at three different frequencies. Echoshape analysis will involve obtaining spectral, wavelet and shape vector features, extracting the three primary components and then clustering these records.

EM data

The towed EM system consists of a transmitter and three receivers. The transmitter generates an EM signal at 7 frequencies, and each receiver is tuned to measure three of these frequencies. The towed EM instrument measures the secondary magnetic field that has been induced in the ground by the transmitted (primary) signal. The data is inverted assuming a one-dimensional1 earth and a set of resistivities are obtained. These resistivities are then converted to apparent porosities using a simplified Archie’s law:

$$f=a^{(-1/m)}$$

where f is the porosity, a is the conductivity contrast and m is the "cementation" factor, with a value from 1.5 to 2.1. To do this last step we need to make some assumptions on the cementation parameter in the equation. The existence of groundtruthing data has provided us with proper values for the equation.

The instrument contains three receivers at 4m, 13m and 40m. Roughly, it can be stated that the first receiver measures the response of the upper 2m, the second up to 6.5m and the third, up to 20m. Thus, the upper 20m of the seafloor are well-characterized in terms of resistivies/porosities.

Discussion

From the analysis of these datasets we have produced comprehensive seabed surface sediment map for the region. In addition, acoustical catalogues containing geoacoustical classes have been created both for the swath bathymetry backscatter and single beam echo data. The latter is of particular significance as the catalogues can be used to extrapolate the results to other regions with similar seabed types.

There is a good correlation between pockmarks and low porosities. There seems to be an increase of the porosity on the edge of the pockmark and a drop below regional levels within. The resistivity of sediments depend of several factors: presence of fresh water, composition, gas, fluids like Cl, etc. The most likely interpretation of the decrease of porosities is that is caused by the presence of gas or by sediments being more compacted. Considering that pockmarks are generated by gas escaping from sediments, then it can be argued that the release of gas caused a re-sedimentation of sediments, making them more compact.