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USING CONTROLLED SOURCE EM METHODS TO CONSTRAIN PHYSICAL PROPERTIES OF THE UPPERMOST SEAFLOOR: AN EXAMPLE OF INSTRUMENTATION AND A CASE STUDY FROM A GAS POCK-MARK OFFSHORE IRELAND

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1. Introduction

The shallow section of continental shelf is a key interface between Earth and the ocean. This part of the seafloor provides a record of sedimentary history through the Holocene that can be interpreted in terms of changes in sediment supply and re-working. Important chemical fluxes pass through shallow sediments and into the ocean, including groundwater in coastal settings and fluxes of methane in deeper water.

In this paper, we outline how measurements of electrical resistivity are able to contribute to an understanding of the shallow seafloor. Resistivity provides a first order measure of seafloor porosity in sedimentary settings, allowing facies maps to be constructed, or changes in lithology to be identified. In unconsolidated sediments porosity is a key parameter to understanding fluid transport. Resistivity is sensitive to the salinity of pore-fluid, allowing identification of fresh groundwater. And finally, in areas of active gas seepage, there are often changes in pore-fluid salinity and temperature that resistivity measurements can identify, while accumulations of massive gas hydrate are thought to cause an increase in seafloor resistivity [1].

3. The towed EM system

The towed-electromagnetic (EM) system discussed in this paper consists of three main components, the deck electronics, a transmitter, and the receiver string. The seafloor components of the system (transmitter and receivers) form a 40 m-long array which is towed in contact with the seafloor at speeds of 1-2 knots.

The EM transmitter, a horizontal magnetic dipole, generates harmonic magnetic fields over a range of frequencies (~200 Hz – 200 kHz), and the three receivers, tuned to measure these magnetic fields, are towed at fixed distances behind (4m, 12.6m and 40m). At a given frequency the strength of magnetic fields decays away from the transmitter as a function of the conductivity of the seafloor (i.e., according to the skin depth), decaying more rapidly in more conductive media. The sensitivity of the magnetic dipole-dipole system, along with the physics of the propagation of the fields through the seafloor was presented in [2]. Further details of the system are given in [3].

Because the system maintains a fixed distance between source and receiver, it can be regarded as a mapping tool. In order to build up a map of sub-seafloor structure only relatively sparse coverage is

needed [4]. The resulting maps provide superior spatial coverage than conventional coring techniques and can measure porosities in regions where coring techniques fail to recover samples, but more importantly provides a means of interpolating between discrete core locations. Finally, the method provides estimates of physical properties where seismic reflection profiles are contaminated by strong bottom multiples or the presence of biogenic gas [5]. The system is, however, perfectly complementary to seismic methods and is best used in concert with high resolution seismic reflection techniques which define the stratal geometry while the EM data define the physical properties [7].

3. The Malin sea experiment

In 2006, we ran the system across an area of gas seepage in the Malin shelf area, offshore Ireland. Within the survey area, which generally has very flat bathymetry, more than 220 pockmarks, related to gas transport through the seafloor, are distributed in clusters around the main structural lineaments. Seismic data show disturbances in the sediments beneath pockmarks to depths of about 80m. The objective of the project is to use a combined acoustic and electromagnetic geophysical approach to study the near-seabed composition in a known shallow gas bearing area. The combination of these various methods should enable us correlate the main geophysical signatures and the geological properties of the seabed, providing a unique tool for geohazard identification, seabed classification, fluid flow migration paths and sediment porosity.

As an example of the type of data collected, we show EM coverage across a major depression and pock mark field in Figure 1. The data are presented as apparent porosities using Archie's law to convert half-space inversions of the raw data on each receiver – this is how data appear in real-time on board the ship. Porosities across the region are remarkably consistent, with very little variation. However, there are subtle changes observable as the system enters a pockmark. The transition into the basin is marked by an increase in porosity, most likely representing looser unconsolidated pelagic sediments. More detailed examination of the porosity profile shows a complex structure as the system enters a small pockmark. The 40m and 13m receivers show opposite behaviours, with data on the 40m receiver dropping slightly in value while the 13m receiver records slightly higher values.
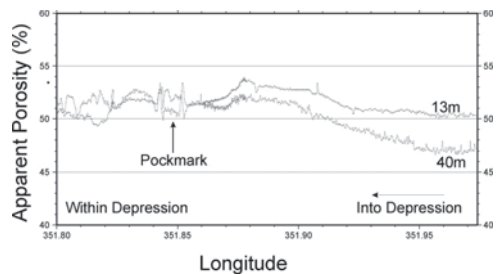
Figure 1. A profile entering the basin depression and crossing a small pock mark. Data are shown as apparent resistivities for the 13m and 40m receivers. The pockmark has complex structure, with a drop in porosity on the 40m receiver and an increase on the 13m receiver. Interpretation of this signal will depend on results from coring

3. Conclusions

Electrical resistivity measurement has proven to be a useful complement to other geophysical and sampling techniques. In some cases the EM system provides data where seismic surveys suffer from wipeout. The density of data provided in a typical survey is substantially greater than can be provided by coring and allows tighter estimates of sediment variability.

The use of EM methods in the Malin sea has increased our knowledge of the sediment layer in this area. From EM data we have extracted a regional map of porosities, showing higher porosities in deep of the basin, probably due to more unconsolidated sediments. The anomalies observed when crossing pockmarks can be used with acoustic data and ground-truthing to trace the path of gas seepage and map gas accumulations.

The use of controlled source EM techniques for deeper-probing industrial applications has not yet translated into interest in shallow studies, but the applications discussed in the example in this paper and the references therein, may stimulate such interest.

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IDENTIFICATION OF GEOMETRICALLY CONSISTENT INTEREST POINTS FOR 3D SCENE RECONSTRUCTION

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1. Introduction

Many applications in mobile and underwater robotics employ 3D vision techniques for navigation and mapping. These techniques usually involve the extraction and 3D reconstruction of scene interest points. Nevertheless, in large environments the huge volume of acquired information could pose serious problems to real-time data processing. Moreover, in order to minimize the drift, these techniques use data association to close trajectory loops, decreasing the uncertainties in estimating the position of the robot and increasing the precision of the resulting 3D models. When faced to large amounts of features the efficiency of data association decreases drastically, affecting the global performance.

We propose an algorithm that extracts image features that are consistent with the 3D structure of the scene. The features can be robustly tracked over multiple views and serve as vertices of planar patches that suitably represent scene surfaces, while reducing the redundancy in the description of 3D shapes. In other words, the extracted features will offer good tracking properties while providing the basis for 3D reconstruction with minimum model complexity.

In order to better understand the concept, consider the simple example in Fig. 1a, which illustrates a 2-D profile as the cross section of a 3-D relief. By extracting features around the edges of the slopes (marked in dark grey) and applying linear interpolation (dotted lines), a good initial approximation of the shape is obtained.

The algorithm consists in 2 parallel pipelines (see Fig. 2): photometric features extraction & tracking [1] [2] and geometric features extraction. In order to extract the geometric features, the algorithm computes an approximation of the scene shape (depth map) [4] by analyzing the pixel disparities between frames (optical flow) [3] (see Fig. 3a).
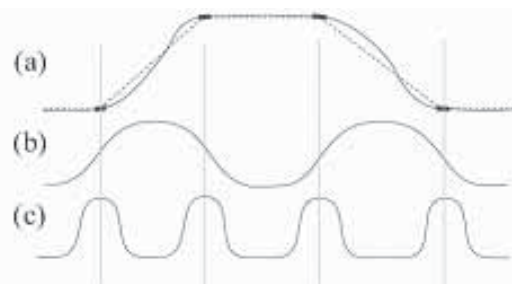

Figure 1. Simple 2D example of ideal features geometric extraction: (a) 4 feature points provide a good initial approx of the shape; (b) first derivative; (c) the 4 features correspond to the maxima of the second derivative.

By segmenting out high responses on the absolute value of the second derivative of the depth map (see Fig. 1c), we can extract the regions of interest corresponding to the edges of the objects present in the scene. On these regions we define 3 types of geometric features (Fig. 3b): line ends, line junctions and high curvature points.