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# Sub-basalt imaging using marine controlled source electromagnetic sounding

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## Introduction

The presence of high velocity layers, such as basalt, carbonate or salt, can make the detection and characterisation of sediments lying beneath using conventional seismic techniques a difficult task. In such situations complementary information derived from measurements of electrical resistivity can provide valuable additional constraints on the structure. The electrical resistivity of basalt, carbonate or salt is typically in the range 100-1000 m, whereas the resistivity of the surrounding sedimentary sequences is typically 1-10 m. This marked contrast in resistivity is an ideal target for electromagnetic prospecting techniques.

Electrical resistivity, like seismic velocity, can be measured using a controlled source and array of receivers in a survey whose geometry is under the direct control of the investigator. This has the advantage that the survey parameters can be tuned to the target of interest to optimise the sensitivity of the resulting data to the structure of interest.

Several marine electromagnetic techniques have been developed in recent years to address the problem of mapping offshore electrical resistivity structure. One such technique, marine controlled source electromagnetic (CSEM) sounding in the frequency domain, has been successfully applied to the study of oceanic lithosphere (e.g. Young & Cox, 1981; Constable & Cox, 1996) and several combined electromagnetic/seismic studies of active mid-ocean ridges have been performed (e.g. Evans et. al, 1994; MacGregor, Constable & Sinha, 1998; MacGregor, Constable & Sinha 2000). In this paper we concentrate on the application of CSEM sounding to the problem of detecting and quantifying sub-basalt sediments in offshore areas.

## Method

The CSEM method uses a horizontal electric dipole source to transmit a low frequency (typically a few tenths to a few tens of Hertz) electromagnetic signal to an array of seafloor receivers that measure two orthogonal components of the horizontal electric field. During a survey the source is towed around and through the array of receivers. By measuring the amplitude and phase of the signal detected by each receiver as a function of source-receiver geometry and separation, the resistivity structure of the underlying seafloor can be determined at scales of between several tens of metres and several kilometres.

## Modelling results

The resolution capabilities of marine CSEM sounding in the context of sub-basalt exploration have been investigated by a combination of iterative forward modelling and inversion of synthetic datasets in terms of 1- and 2-dimensional resistivity structures, in order to establish whether sub-basalt sediments can be detected and if so how well their depth of burial, thickness and properties can be determined.

The model studies suggest that the marine CSEM technique can indeed be used to detect sediments beneath 2-3 km of basalt, and can provide useful information on their extent and properties. The base basalt boundary can be located to within 10% of its depth in the examples shown and base basalt/sediment topography resolved. Finally it can be demonstrated than small scale heterogeneities in the basalt, which can cause significant scattering of seismic energy, have little or no effect on the CSEM data.

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## Conclusion

The CSEM method can be used to provide valuable information on the structure and properties of the sub-surface in technically demanding environments. The technique is particularly powerful if combined with the results of other geophysical surveys. For example inclusion of the upper-basalt boundary determined from seismic studies, can improve resolution of deeper structure by the CSEM data. Resistivity values from well-logs can also be used to constrain the CSEM interpretation and hence improve the resolution achieved. By combining several complementary prospecting techniques better constraints on the sub-surface structure can be achieved than from any single technique. In such multi-disciplinary experiments, we have shown that marine CSEM sounding can make a major contribution.

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