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## Controlled Source Electromagnetic Imaging in Areas of Complex Geology

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### Abstract

The Controlled Source EM Imaging (CSEMI) method, in which a low frequency signal is transmitted from a source to an array of seafloor receivers, is rapidly gaining acceptance as an exploration tool. Early surveys demonstrated that in areas of relatively simple geological structure, positive results could be obtained from CSEMI surveys. However these settings represent only a small proportion of exploration targets. The presence of resistive structure in the background section (for example salt, tight carbonate or shallow gas and hydrates) increases the complexity of CSEMI surveys. Despite this, with careful survey design, data acquisition and data analysis positive results have been obtained.

### Introduction

The adoption of 3D seismic at the end of the last century dramatically improved drilling success. The annual spend by the hydrocarbon industry on seismic acquisition now exceeds \$5 billion, and the resulting data are an integral part of risk management and drilling strategies. However, despite this the majority of exploration wells drilled globally are commercially unsuccessful. To make a significant improvement in exploration performance more prospects must be tested to avoid relinquishing productive acreage, including those prospects considered high risk (for example stratigraphic plays, which often have little or no seismic expression).

There is therefore a pressing need for a non-invasive technology able to minimise the risk of drilling unsuccessful exploration wells by confirming (or otherwise) the presence of hydrocarbons prior to drilling. Controlled source electromagnetic imaging (CSEMI) can do just that. Whilst seismic data identify the geological structures that may contain hydrocarbons, under many circumstances they do not reveal the presence of hydrocarbons themselves.

The presence of hydrocarbons in a reservoir typically increases its electrical resistivity compared to the surrounding water saturated sediments by an order of magnitude or more. This property of hydrocarbon saturated reservoirs is commonly exploited well logging applications. However these methods require a borehole to be drilled. CSEMI provides a method of determining the resistivity within an identified prospect before drilling. CSEMI detects and delineates resistive sub-seafloor layers, which can be associated with hydrocarbons, and gives an indication of their spatial extent. If correctly applied, this means that the possibility of drilling dry exploration wells is significantly reduced, as is the need for extensive appraisal drilling.

### The CSEM method

The CSEM method has been in use for over 20 years in the academic sector, where it has been applied to the study of fluid properties in the earth (e.g. Evans et al., 1994, Constable et al., 1996, MacGregor et al, 1998,2001). CSEM surveys utilise a high powered horizontal electric dipole source towed at around 30m above the seafloor in up to 3km of water. This transmits a low frequency signal (typically in the range 0.01-10Hz) to an array of seafloor receivers, which detect and record the resulting electromagnetic fields. The variation in the amplitude and phase of this received signal as a function of source-receiver separation and geometry, and signal frequency, allows the resistivity of the underlying seafloor to be determined at scales of a few tens of metres to depths of several kilometres, through a combination modelling, geophysical inversion and imaging.

### Application

The CSEMI method has been applied in a variety of exploration settings including West Africa, SouthEast Asia and the North Atlantic. Early surveys concentrated on Tertiary reservoir systems in deepwater areas (for example Ellingsrud et al. 2002). These demonstrated that in areas of relatively simple geological structure, including deepwater turbidites and channel systems, positive results could be obtained from CSEMI surveys.

In many situations, however, the geology of the area to be surveyed is somewhat more complex. The presence of resistive structure in the background section can significantly