Geophysical Exploration using Seabed Logging in an Area with Non-hydrocarbon Resistivity Anomalies

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Marine controlled source electromagnetic (MCSEM) survey termed as Seabed Logging (SBL) can be used for detection of deeply buried hydrocarbons. The method has been verified on known hydrocarbon fields offshore Angola and Norway. Here we present SBL data across an offshore arch in the Norwegian Sea. A horizontal electric dipole source induced increased SBL responses (up to 250% gain in MVO) measured at the south-western part of the study area compared to south-eastern part. This finding satisfies the existence of strong seismic reflectors representing sills with ~300 Ωm resistivity within the depth range between ~1100 and 2500 m below the seafloor.

Remote detection of high-resistivity strata shows fairly good agreement with forward 3D SBL modelling simulation results. A comparatively better match between modelled and measured data was achieved by introducing a moderately high resistive (10 m) layer correspond to moderately strong seismic reflector 1000 m below the seafloor at the central part of the structure. Likely candidates for this layer could either be a HC layer or a thin, highly fractured and discontinuous sill. However this resistivity for the sill layer (10 m) is probably unrealistically low. If the resistivity is kept at 300 µÙm, the sill must be very thin and possibly not visible on the seismic section. It therefore, suggests that the measured SBL response cannot be fully explained by the simplified geological model with sills alone.

1D Inversion and Analysis of Marine Controlled-Source EM Data

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Marine Controlled-source electromagnetic data are now routinely collected over promising oil and gas prospects identified by seismic investigations. They allow an identification of resistive layers at depth, thereby pointing to possible oil and gas bearing sediments, where conductive salt water has been displaced by resistive oil or gas.

We present results from an investigation of the applicability of one-dimensional inversion of the data. Data noise has not been measured by the contractor, so we have developed a noise model by inspection of the individual data sets to make it possible to perform a meaningful inversion and analysis. Inversion is carried out with multi-layer models and L1-optimization and with 4-layer models in the least-squares sense.

A general analysis of the resolution capabilities of the MCSEM method regarding buried resistive layers has been carried out within the framework of 1D inversion. The analysis addresses the importance of including prior information on water layer resistivity and thickness and the dependence on the frequencies used.

For the data set in question, the model sections display a resistive layer at a depth of ~800 m below the sea bottom. While the thickness and resistivity of the layer are not well determined, the product of the two, the resistance, is well resolved. This parameter is indicative of the total amount of possible hydrocarbons.

A Marine Controlled Source Electro-Magnetic Survey of the "XYZ" Discovery Offshore "ABC" in West Africa

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In early 2006 a Marine Controlled Source Electro-Magnetic Survey (CSEM) was carried out over the “XYZ” discovery offshore “ABC” in West Africa.

The target comprises a complex reservoir system within a much larger but simpler structure and one of the challenges of the survey was to see what level of reservoir detail could be seen by the CSEM data.

The target reservoirs are further complicated by overlying gas sands, varying water bottom and channelised shallow section all of which need to be taken into account in the survey design, acquisition, and subsequent data processing and interpretation.

This talk will discuss the survey, planning, modelling, acquisition and some of the results seen to date.

Controlled source electromagnetic imaging in complex environments

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CSEM surveys have been used successfully in a variety of settings including West Africa, Southeast Asia, The Gulf of Mexico and the North Atlantic. Early surveys concentrated on Tertiary reservoir systems in deepwater areas. These demonstrated that in areas of relatively simple geological structure, including deepwater turbidites and channel systems, positive results could be obtained from CSEM surveys. However these settings represent only a small proportion of potential exploration targets. In particular to date the method has been limited to relatively deep water (300m or more). This is because in shallow water, signals that have interacted with the (extremely resistive) air can have a severe impact on the recorded signals and can dominate the response. To test possible solutions to the airwave problem a survey was carried out in 115m of water in the North Sea, on a known gas reservoir lying at around 1600m below seafloor. Initial inversions of the result give an image of the subsurface which unambiguously resolves the presence of resistive structure associated with the gas reservoir. The image is improved by including structural information on the subsurface from seismic data, and adding additional information on the geo-electric background from CSEM receivers off-target. When this is done, resolution of both the lateral extent of the reservoir, and the resistivity within it improve dramatically.

Final results agree well with the resistivity of the gas reservoir measured in well-log data. By extending the operating envelope into shallow water the range of potential exploration and appraisal targets has been dramatically increased.

Land EM Techniques for Prospect Identification, Evaluation & De-Risking

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"Land Magneto-Tellurics (MT) have been used in onshore oil and gas exploration around the world for around 50 years, typically in areas where seismic is not working as well as we would like. Its use has become more prevalent recently as other Electro Magnetic exploration usage has been more in the public eye particularly with the advent of its marine cousin technologies Marine MT and Controlled Source EM.

Land MT is often used in areas where there are nasty rocks close or near to surface such as salt, volcanics, basalts, carbonates etc and hence, the method is used in sub salt, sub basalt, sub volcanic and sub carbonate region around the world.

The method is also very applicable in areas of complex structure such as overthrust zones where the seismic wavefront is often fully dispersed after passing through the first layer or two.

Areas of MT applications over the last 50 years include North and South America, Canada, Onshore Europe, Faroe Islands,the Middle east, Indian sub continent, Australia and the Far East and of course the FSU.

Questions that MT can answer include things like :

How thick are the nasty rocks, where are they very thick and thin ?

What is their structural shape ?,

How regionally and vertically extensive are they ?

What is under them...high resistivity other nasty rocks or nicer low resistivity prospective sedimentary section ?

What is the shape of the over-thrusts, what resistivity rocks are under them ?

Modern MT when combined with new well to well, crosshole and well to surface techniques offers hope and promise for improved resolution and more effective 3D solutions.

This presentation will outline the method, how it works, talk about practical applications of the technique and show some intersting case study examples