H010 EM seabed logging on the Troll Field

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Abstract

A seabed logging R&D study was conducted on the Troll Field in December 2003 – January 2004. Different EM waveforms and frequencies were tested to optimize the hydrocarbon response from this shallow water gas and oil field. The survey consists of 41 receivers, deployed along a line crossing the Oil Province, the Western Gas Province and the Eastern Gas Province of the Troll Field. All receivers recorded two orthogonal components of the horizontal electric field, and 12 receivers measured in addition two orthogonal components of the horizontal magnetic field.

The R&D study was carried out as an attempt to qualify seabed logging for shallow waters (less than 500 m) and optimize acquisition parameters for such cases. Up until now the marine controlled source EM method has been qualified for use in deep waters (more than 1000 m water depth) mainly because of the disturbing influence from the air wave in shallower water areas. The Troll Field seabed logging data is of excellent quality and helps in solving problems related to shallow water applications of this method.

Introduction

SeaBed Logging (SBL) is a remote sensing technique, which gives information about subsurface resistivity variations by the use of electromagnetic energy. The method has been demonstrated both theoretically (Kong *et al.*, 2002) and in practice, by several calibration and commercial surveys (Ellingsrud *et al.*, 2002 and Røsten *et al.*, 2002). This abstract presents selected results from an experimental SBL survey across the Troll Field. The overall objective of the study was to obtain an improved understanding of the SBL measurements in shallow waters and thereby improve the interpretation methods.

The surveys are performed by towing an electromagnetic source above an array of receivers deployed on the seabed. The source is a horizontal electric dipole which emits a low frequency, continuous electromagnetic signal both into the seawater and downwards into the subsurface. The array of seabed receivers records the transmitted signals, which depend on the resistivity structure of the subsurface. A detailed description of the method is given in Eidesmo *et al.* (2002) and Farrelly *et al*. (2004).

Equipment and Survey Performance

The receivers are dropped from the survey vessel and sink freely down to the seabed. Acoustic ultra short baseline communication (USBL) is used to establish the exact receiver positions. The receivers are held in position at the seabed by a concrete anchor. After the recording period, an acoustic signal from the vessel triggers a release mechanism, causing the receivers to release their anchors and float back to the surface. Figure 1 shows photographs of a receiver when dropped from the survey vessel and the EM source at the surface. The receivers consist roughly of a buoyancy system (five yellow spheres at the top of the receiver), a data acquisition unit (white cubic box), an anchor (grey plate) and removable horizontal sensors. The system may include up to two pairs of orthogonal electric sensors (long yellow arms) and two magnetic sensors.

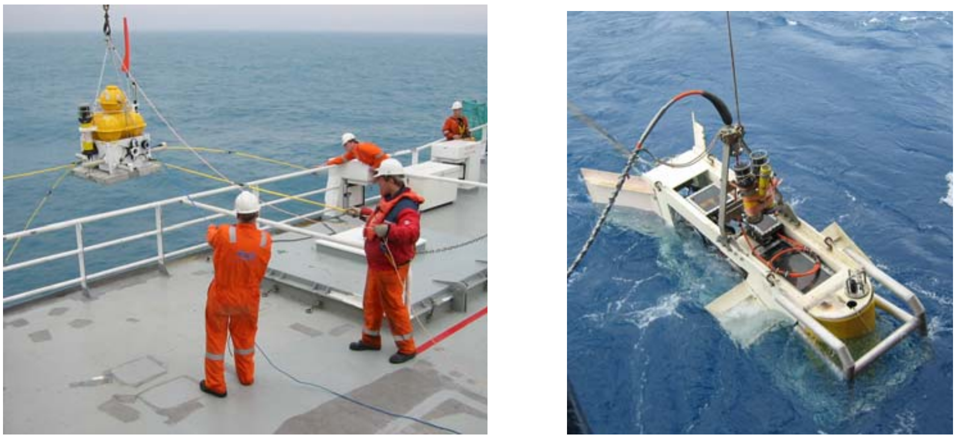

Figure 1: Deployment of receiver and tow fish.

The source is a horizontal electric dipole (HED), towed behind an instrumented tow fish on a neutrally buoyant streamer. A photograph of the tow fish is shown in Figure 1 (right). The HED consists of two electrodes which are separated by approximately 230 m. Each electrode is electrically connected to a signal generator, which transmits a continuously periodic signal with any curve shape and a frequency ranging from 0.05 to 10 Hz. The peak-to-peak current is kept constant during a survey and a maximum current of 1000 A may be applied. The distance from the source to the seabed is continuously monitored by an echo sounder on the tow fish and held between 25 and 35 metres. An umbilical connects the source with the survey vessel and the depth of the tow fish and HED are changed by varying the length of the umbilical. The umbilical cable also provides power and signal transmission between the vessel and the tow fish. The source position is monitored by two acoustic USBL transponders, one at the tow fish and one located behind the tail electrode.

Survey Layout over the Troll Field

The Troll field is the largest gas discovery on the Norwegian shelf and is located in the north-eastern part of the North Sea.The field may be roughly divided into three parts; the Oil Province, the Western Gas Province and the Eastern Gas Province. The reservoir interval consists of Jurassic (Sognefjord Fm.) sandstones, and is approximately 100 m thick and 1.6 km long along the SBL survey line for the Oil Province. The reservoir interval of the Western Gas Province has a triangular shape with a maximum thickness of about 300 m and is 8.4 km long along the SBL survey line. Hydrocarbon filled sands show very high average resistivities up to 250 Ωm and occur at a burial depth of 1000 m. Water bearing Sognefjord Fm sandstones and overburden sediments show resistivities in the 1 – 2.5 Ωm range.

The Troll R&D survey comprises one line, crossing the Oil Province, the Western Gas Province and the northern part of the Eastern Gas Province (Figure 2). The line was towed twice, in opposite directions. The first line was run with a standard 0.25 Hz square pulse from SW to NE (Line 01). The second is run from NE to SW with two different pulses. First, a combination of three sine pulses (0.12, 0.48 and 0.96 Hz, Line 02), and second, a 0.1 Hz spike pulse (Line 03).

The survey consists of 41 receivers. The total distance between the receivers is 21.6 km. The source was towed along the profile covering a length of 10 km outside the end receivers R01 and R41. The water depth gradually increases from 333 m in the SW to 350 m in the NE. All receivers measured two orthogonal components of the horizontal electric field. In addition two orthogonal components of the horizontal magnetic field were measured by 12 receivers.

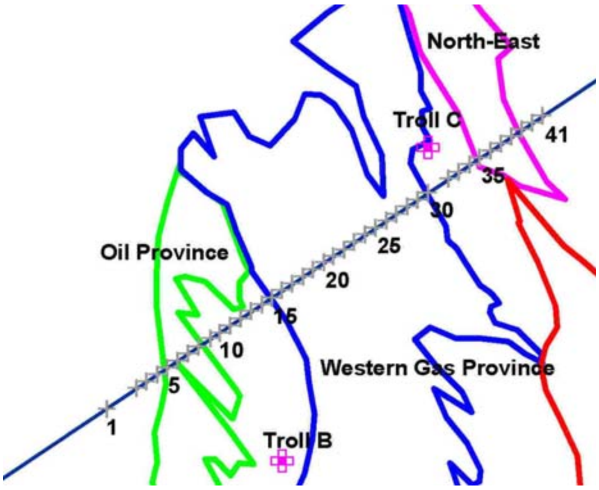

Figure 2: Troll SBL Survey Layout

Field Results

The receivers record the electric and magnetic fields as time series before they are processed into the frequency domain and combined with navigation data. The receiver registrations are then presented as Magnitude Versus Offset (source receiver distance) – also termed MVO plots and Phase Versus Offset – PVO plots.

The data quality of the Troll R&D survey is excellent with reliable information up to 10 km offset. This is illustrated in Figure 3 showing MVO results for receivers R16, R25 and R41.

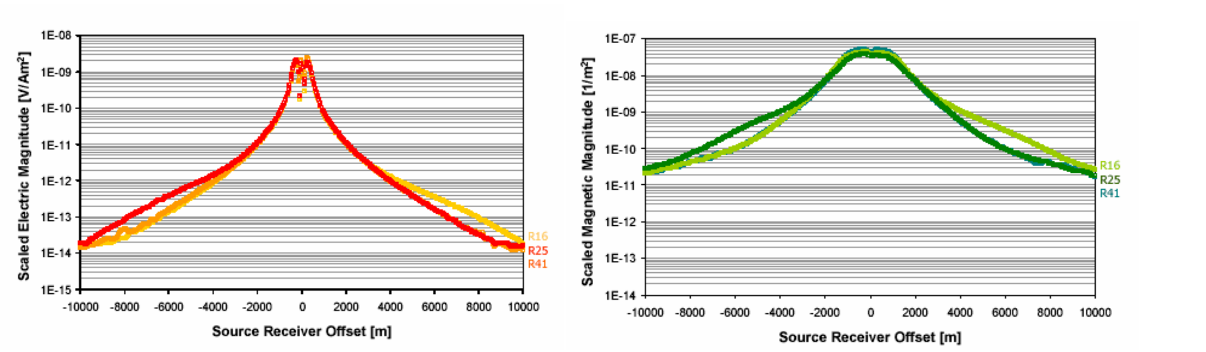

Figure 3: Electric magnitude (left) and magnetic (right) recorded during in- and out-towing for receivers R16, R25 and R41 (0.25 Hz square wave).

The receivers record comparable electric and magnetic magnitudes for offsets less than 2.5 km and offsets above 10 km.

In order to quantify the difference between recorded MVO signatures, normalised magnitudes relative to a reference receiver are presented. The reference receiver is chosen primarily on the basis of data quality and should, in addition, represent MVO data gathered in an area with no likely subsurface hydrocarbons. The normalised electric and magnetic magnitudes obtained for receivers R16 and R25 during in- and out-towing are shown in Figure 4. Receiver R41, out-towing is used as reference. The electric and magnetic responses are both very strong, but behave quite differently. The magnetic magnitude increases more rapidly than the electric magnitude and reaches a peak for offsets between 5 and 7 km. The electric magnitude has a peak between 7 and 9 km and the maximum value is somewhat smaller than the corresponding normalized magnetic magnitude.

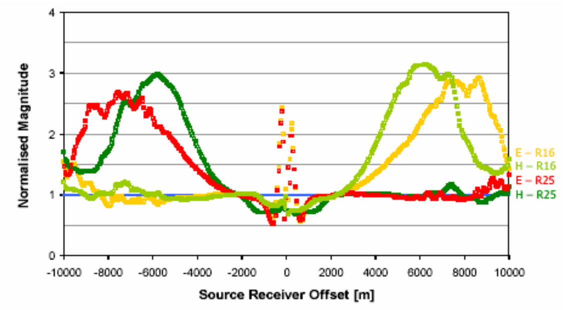

Figure 4: Normalized electric and magnetic magnitudes for receivers R16 and R25 for both in- and out-towing (0.25 Hz). Reference receiver is R41 out-towing.

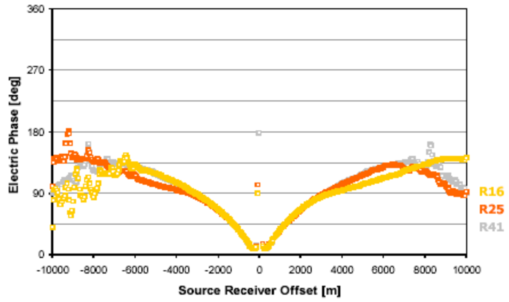

Figure 5: Electric phase versus source receiver offset for receivers R16, R25 and R41 for both in- and out-towing (0.25 Hz).

Reprocessed electric phase data of receivers R16, R25 and R41 are shown in Figure 5. The location of the receivers is shown in Figure 1. The PVO response is low for receiver R25, in-towing and receiver R16, out-towing as expected.

Conclusions

The EM seabed logging data across the Troll Field is of excellent quality. The seabed logging results show very strong anomalies in magnitude across the central part of the field. The electric and magnetic MVO responses are significantly different. This indicates a potential for extracting increased information about subsurface resistivity variations from combined measurements. Also the phase response is good and may be used for imaging methods.

Acknowledgements

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References

Ellingsrud, S., Sinha, M.C., Constable, S., MacGregor, L.M., Eidesmo, T. & Johansen, S., 2002: ”Remote sensing of hydrocarbon layers by Sea Bed Logging (SBL): results from a cruise offshore Angola”. *The Leading Edge*, **21**, 972 - 982

Kong, F.N., Westerdahl, H., Ellingsrud, S., Eidesmo, T. and Johansen S., 2002: “SeaBed Logging: A possible direct hydrocarbon indicator for deep sea prospects using EM energy”. *Oil & Gas Journal*, May 13.

Røsten, T., Johnstad, S.E., Ellingsrud S., Amundsen, H.E.F., Johansen S., and Brevik, I., 2003: “A SeaBed Logging (SBL) calibration survey over the Ormen Lange gas field”. *EAGE 65th Conference and Exhibition, Extended Abstracts.*

Farrelly, B., Ringstad, C., Johnstad, S.E. and Ellingsrud, S., 2004, ”Remote characterization of hydrocarbon filled reservoirs at the Troll Field by Sea Bed Logging”. *EAGE Fall Research Workshop on Advances in Seismic Acquisition Technology*, Greece, 19 –23 September.