A05 REMOTE CHARACTERIZATION OF HYDROCARBON FILLED RESERVOIRS AT THE TROLL FIELD BY SEA BED LOGGING

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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, Røsten *et al.*, 2002, Amundsen *et al.*, 2004, and Wicklund and Fanavoll, 2004). This abstract presents preliminary results from a scientific SBL survey across the Troll Field. The overall objective of the study is to obtain an improved understanding of the SBL measurements 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 Ellingsrud *et al.* (2002).

Equipment and Survey Performance

The receivers are dropped from the survey vessel and sinks 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 realise mechanism, causing the receivers to release from their anchors and float back to the surface. Figure 1a shows a photograph of a receiver when dropped from the survey vessel. 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 to a maximum include two pairs of orthogonal electric sensors (long yellow arms) and two magnetic sensors (short grey cylinders).

The source is a horizontal electric dipole (HED), towed behind an instrumented tow fish on a neutral buoyant streamer. A photograph of the tow fish is shown in Figure 1b. 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 meter. 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 provides also 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.

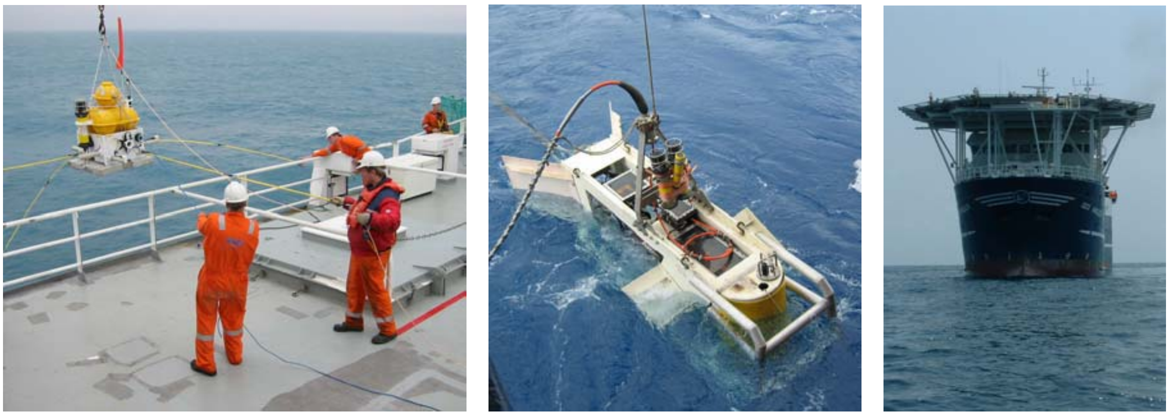

Figure 1: (a) Receiver deployment (b) Deployment of tow fish (c) Geo Angler. Vessel currently used by emgs to perform SBL surveys.

SBL Survey 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 roughly be separated in 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.

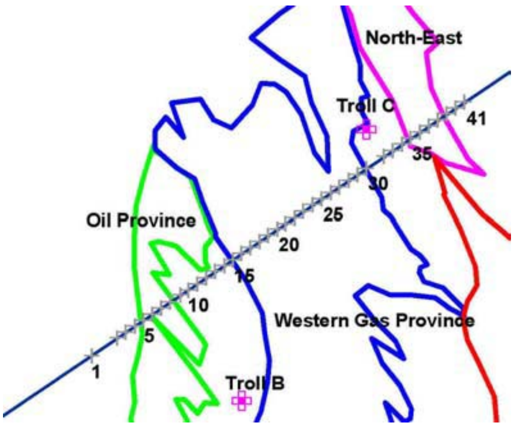

Figure 2: Layout of the Troll SBL survey

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 (Figure 2). The source was towed from SW to NE with a square pulse of 0.25 Hz, covering a length of 10 km outside the end receivers R01 and R41. The total distance between the receivers is 21.6 km. The water depth is gradually increasing from 333 m in the SW to 350 m in the NE. All receivers measured two orthogonal components of the horizontal electric field. Two orthogonal components of the horizontal magnetic field were, in addition, measured by 12 receivers.

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.

The data quality of the Troll survey is excellent, with reliable information up to 10 km in the best cases. This is illustrated in Figure 3, where the MVO results obtained for receivers R15 and R41 during out-towing are shown. Receiver R41 is located in an area with no likely subsurface hydrocarbons, while receiver R15 is located at the west border of the Western Gas Province.

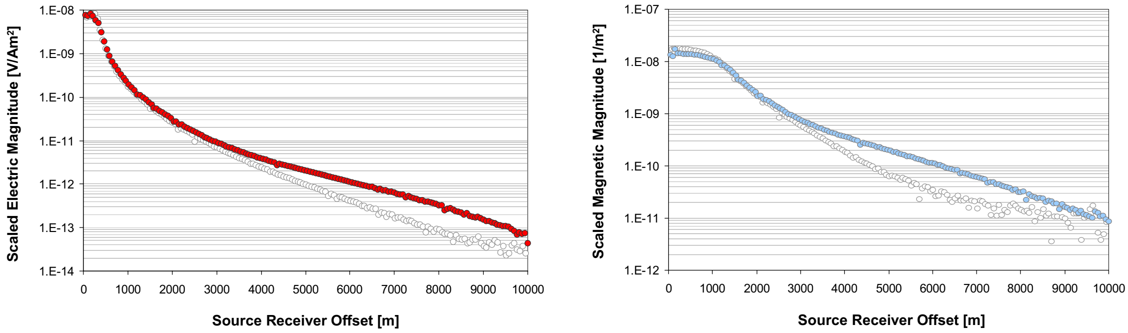

Figure 3: (a) Electric MVO data recorded during out-towing for receivers R41 (white) and R15 (red); (b) Magnetic MVO data recorded during out-towing for receivers R41 (white) and R15 (light blue).

Both receivers record comparable electric and magnetic magnitudes for offsets less than 2.5 km. A gradually increasing difference between the two receivers is observed until an offset of approximately 5 km for the magnetic magnitude and 8 km for the electric magnitude is reached. The difference in magnitudes start then to decrease and comparable magnitudes are obtained around an offset of 10 km.

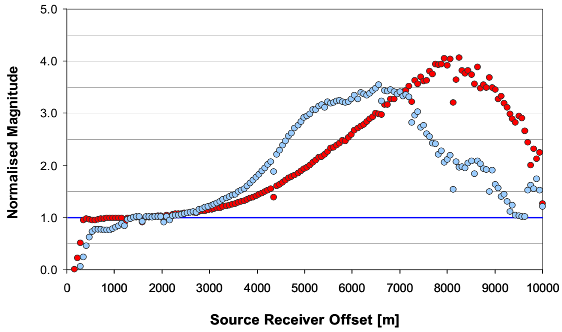

Figure 4: Normalized electric (red) and magnetic (light blue) MVO data obtained for receiver R15 during out-towing. Receiver R41, out-towing is used as reference.

In order to quantify the difference between recorded MVO signatures, normalised magnitudes relative to a reference receiver are presented. The reference receiver is mainly chosen 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 receiver R15 during 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 relatively flat peak for offsets between 5 and 7 km. The electric magnitude has, on the other hand, a sharp peak, which is observed around 8 km.

The normalised magnitudes obtained for each receiver at an offset interval of –5 ± 0.25 km (in-towing) and 5 ± 0.25 km (out-towing) are summarised in Figure 5(a). The data are shifted ±2.5 km relative to the receiver position (out- and in-towing, respectively), representing the midpoint between the source and the receiver. Figure 5(a) shows an initial weak decrease with a local minimum 1 km NE of receiver R01, a weak increase reaching a local maximum 4 km NE of receiver R01 and a second weak decrease reaching again a local minimum 7 km NE of receiver R01. The normalised magnitudes are then increasing substantially to a global maximum 11 km NE of receiver R01. A third local minimum is observed 13 km NE of receiver R01, then a weak increase before a constant value close to 1 is obtained 21 km NE of receiver R01. Notice that the electric and magnetic responses along the survey line are comparable, even though a different normalised MVO behaviour is recorded by the receivers.

Figure 5(b) shows an arbitrary 3D seismic section along the recorded SBL line. Superimposed SBL results indicate that the weak anomaly in SE (with a local maximum 4 km NE of receiver R01) corresponds to the Oil Province and that the strong anomaly (with a global maximum 11 km NE of receiver R01) corresponds to the Western Gas Province of the Troll Field.

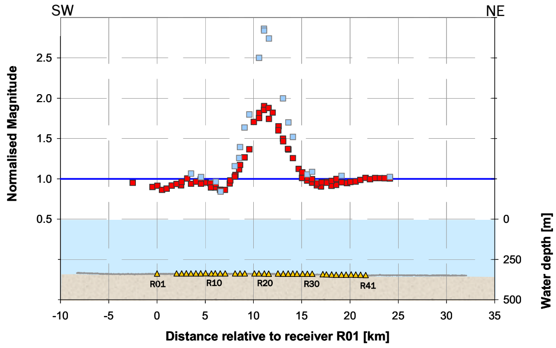

Figure 5(a): Line summary showing the average normalized magnitudes at an offset of 5km ± 0.25km. The red squares represent electric measurements and the light blue squares magnetic measurements. The yellow triangles show the receiver positions.

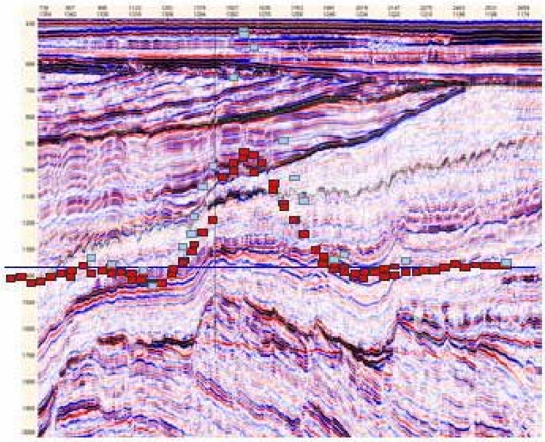

Figure 5(b): Line summary superimposed to an arbitrary 3D seismic section along the SBL line.

Conclusions

The SBL study recorded across the Troll Field shows a very strong anomaly across the large Western Gas Province. In addition, a weak anomaly is observed across the much smaller Oil Province. The electric and magnetic MVO responses are significantly different. This indicates a potential of extracting increased information about subsurface resistivity variations from combined measurements.

Acknowledgements

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