P058 A SEA BED LOGGING (SBL) CALIBRATION SURVEY OVER THE ORMEN LANGE GAS FIELD

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Introduction

Remote resistivity sensing of buried resistive layers in conductive sediments, a concept called Sea Bed Logging (SBL), has been demonstrated both theoretically by Kong et al. (2002) and Eidesmo et al. (2002) and in practice by a survey over a known oil field offshore Angola in November 2000 (Ellingsrud et al. 2002). The Angola survey was run over an area which is ideal for the SBL technique mainly due to large water depth and shallow reservoir. In November 2002 ElectroMagnetic GeoServices (emgs) established by Statoil in February 2002, run another survey over the Ormen Lange gas field (operated by Norsk Hydro) offshore Norway. The survey was run in cooperation with InseisTerra and with Mulitwave Geophysical Company (MGC) as the operating company. The Ormen Lange field is the main hydrocarbon discovery in deep water areas offshore Norway (there is only one other discovery). The survey was run to calibrate the SBL technique, with focus on the improved source and receiver modules. Ormen Lange is a very challenging area for SBL, with rough seafloor topography, highly varying water depths, relatively large and varying distances from the sea floor down to the reservoir and varying low resistivities in the gas zone.

Method and equipment

The SBL technique is well described by Eidesmo et al. (2002) and Ellingsrud et al. (2002). Basically, a horizontal electrical dipole (HED) (Young and Cox, 1981 and Sinha et al., 1990) emits a low frequency electromagnetic (EM) signal into the underlying seabed and downwards into the underlying sediments. EM energy is rapidly attenuated in the conductive seafloor sediments because the pore space is normally water filled. In high resistive layers as e.g. hydrocarbon filled sandstones and at a critical angle of incidence the energy is guided along the layers and attenuated less (Kong et al. 2002). Energy is constantly refracted back to the seafloor and is detected by sea floor EM receivers. When the source-receiver distance (offset) is comparable to or greater than the depth of reservoir burial, the refracted energy from the resistive layer will dominate over directly transmitted energy. The detection of this guided and refracted energy is the basis of SBL (Ellingsrud et al. 2001).

Each EM receiver was dropped from the vessel and freely sinking to the seabed. Acoustic ultra short baseline (USBL) communication was used to establish exact receiver positions. At the seabed the receivers were held in position by concrete anchors. After the recording period an acoustic signal from the vessel triggered a release mechanism, causing the receivers to release from their anchors and floating back to the sea surface.

The HED antenna consists of two electrodes separated approximately 230m from each other with electrical contact to the seawater. The electrodes are positioned on a streamer section providing neutral buoyancy at depth. The streamer is towed behind an instrumented tow fish.

Each electrode is connected electrically to a signal source located on the tow fish. The output signal to the electrodes is monitored at the tail of the tow fish. The source transmits a continuous periodic signal with any curve shape and frequency ranging from 0.05 to 10Hz. The peak-to-peak current varies from zero to several hundreds Ampere.

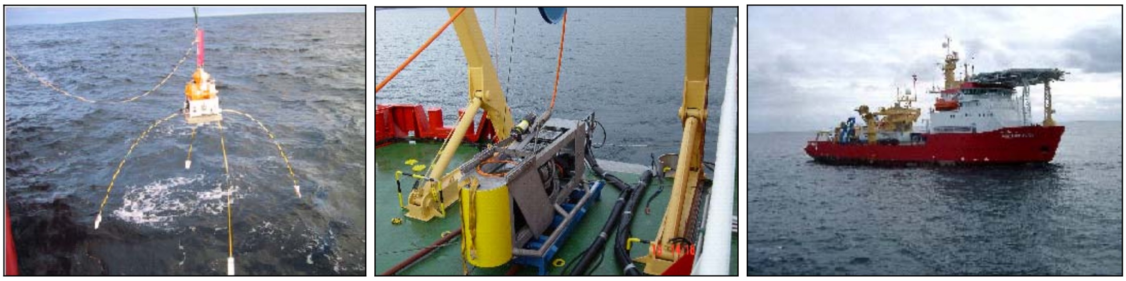

Figure 1: The left picture shows the first instrument dropped over Ormen Lange. All instruments have electrodes mounted at the end of each electrode arms, with lengths around 8m, giving two orthogonal electrical channels. The electric field measured at each channel is amplified and converted from analog to digital format before being recorded on an internal storage device. The EM source tow fish is displayed in the middle. The Polar Bjørn shown to the right was used as survey vessel.

The depth of the source above the seabed is continuously monitored by an echo sounder. Target altitude for the source is around 50-100m, but the very rugged seabed topography at Ormen Lange caused larger variations locally. The depth of the tow fish and the HED are controlled by the length of the umbilical running from the survey vessel. The umbilical cable also provides power and signal transmission between the vessel and the tow fish. The antenna position and its depth below the vessel are monitored by two acoustic USBL transponders, one at the tow fish and one located behind the tail electrode.

The Ormen Lange gas field

The Ormen Lange field (figure 2) is a large gas accumulation with an estimated GIIP of 570 x $10^9 Sm^3$ located 160km west of Kristiansund. The gas accumulation covers an area of approximately 350km2, and is mainly defined by seismic DHI observations. Water depths over the gas field range between 700 and 1100m, with highly variable seabed topography resulting from the Storegga submarine landslide. The Ormen Lange reservoir interval comprises the Jorsalfare and Egga Formations, and represents deep marine turbidite deposits of upper Cretaceous to Lower Tertiary age. Reservoir overburden in the SBL study area is around 1600m. Gas-filled reservoir intervals have resistivities around 30-50Ωm, while water-bearing sands and overburden generally show resistivities in the 0.5–2Ωm range.

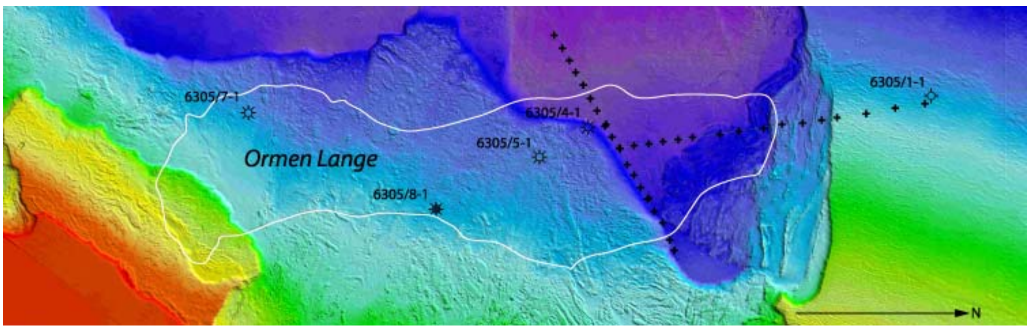

Figure 2: Bathymetry and wells in the Ormen Lange area. Crosses denote SBL receiver layout along N-S and SW-NE towlines. The OGC is outlined by the white curve.

Data acquisition and quality

The survey was designed with two 2D lines at the northern part of Ormen Lange (see figure 2). 34 EM instruments were dropped and 80km of source lines were towed with a sine wave signal of 0.25Hz. The SBL data were acquired as time series, and then processed by a windowed Fourier series analysis. The data quality was high with reliable information to an offset higher than 8km. This is both due to a high power source and high quality receivers. Data were processed and displayed as magnitude vs. offset (MVO) at the transmitted frequency.

Results

To identify possible MVO signatures related to Egga Gas we have here chosen to compare MVO data from the two receivers that are most likely to record Egga Water and Egga Gas scenarios. Receiver R19 located adjacent to the dry well 6305/1-1 (figure 4) is inferred to record an Egga Water or “dry well” scenario, while the southernmost receiver (R1) on the N-S towline (figure 4) should record an eventual additional return signal from Egga Gas. Comparison of MVO data from these two receivers (figure 3) shows systematically higher magnitudes at offsets higher than 2km for the receiver situated above Egga Gas. Receiver R1 shows a marked increase in magnitudes starting around 1.5km offset, with a maximum increase of ca. 40% relative to R19 at ca. 3-5km offset. A 40% increase in magnitude is in accordance with 1D modelling results for Egga Gas relative to Egga Water scenarios, although the modelling results predict maximum magnitudes should occur at larger offsets.

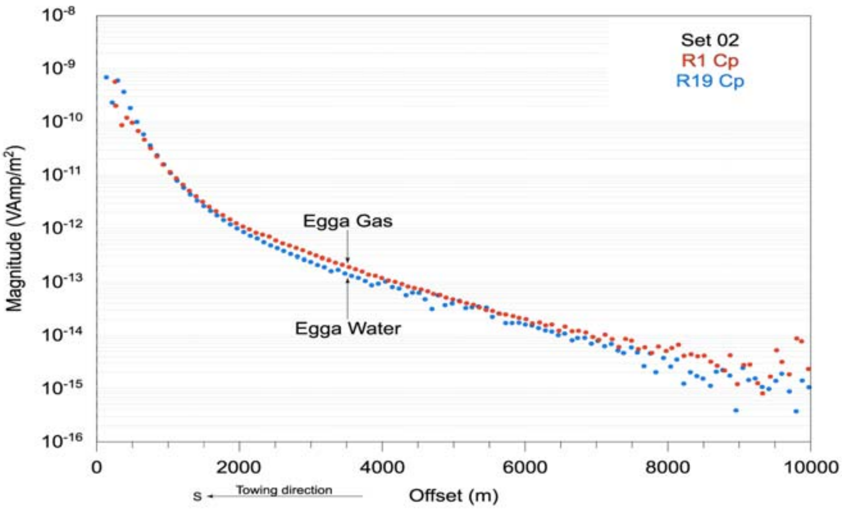

Figure 3: Comparison of MVO data for R1 and R19, located above Egga Gas and Egga Water, respectively. The electric fields are normalized by the source dipole moment, and the maximum polarization ellipse is calculated from the two orthogonal electrical channels.

To quantify differences in MVO signatures recorded along the two towlines we have normalised all MVO signatures by the MVO of the receiver situated above proven Egga Water (R19). Median filtered values of normalised magnitudes between 3.3 and 4.4km offset for the N-S towline are illustrated in figure 4, and display a step-wise variation in MVO signatures. Receivers located more than 4km south of well 6305/1-1 show systematically 20 to 40% higher magnitudes. Remark that this shift is opposite to potential contributions from water depth variations. Similar MVO responses are also evident along the NE-SW towline. We interpret the observed variation in EM response recorded along the two towlines to reflect changing underground resistivity parameters. The approximate location of the change in EM response is close to the estimated boundaries of the Ormen Lange field as defined by seismic amplitude anomalies.

Conclusions

SBL over the Ormen Lange gas field reveals higher MVO for EM receivers above Egga Gas compared to EM receivers above Egga Water. The observed EM anomaly partially correlates with inferred seismic boundaries for Ormen Lange, although a direct link between Egga Gas and the resistive layer responsible for the EM anomaly has not been established at present.

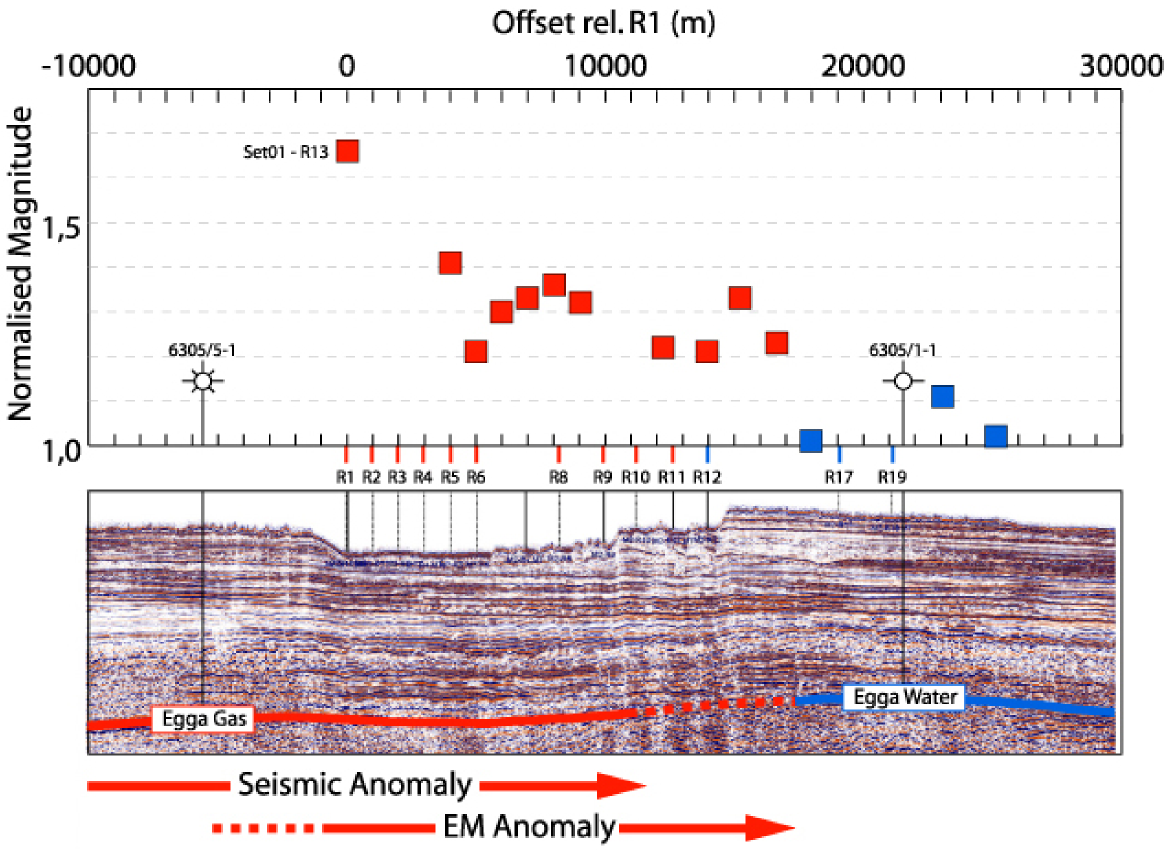

Figure 4: Normalized MVO responses at 3.3 to 4.4km after median filtering and seismic amplitude anomalies along the N-S towline (figure 2). The normalized MVO responses are located at positions approximately 4km from the receivers.

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