THE FEASIBILITY STUDY OF CSEM METHOD FOR PROSPCET HYDROCARBONS IN THE BALTIC SEA AREA

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Introduction

The feasibility study of CSEM method was planned after seismic survey in order to confirm distribution of hydrocarbon prospect in the Baltic Sea. The feasibility study consisted of reservoir resistivity analysis and CSEM sensitivity. In addition the study involved CSEM inversion and design of 2D and 3D surveys in the Baltic Sea. In the following, the term "sensitivity" is used to describe the difference in the EM response from a hydrocarbon filled reservoir (target model) and a brine filled reservoir (background model) that can be measured with either the marine controlled source electromagnetic (CSEM) method. To evaluate the "sensitivity" it was compute the electromagnetic response for both, the hydrocarbon filled reservoir and the water filled reservoir and evaluate the difference between the target and the background response with respect to the measurement uncertainty for the CSEM. The measured CSEM response is sensitive to the transverse resistance (TR) of a thin resistor in the subsurface. The transverse resistance is the integral of resistivity over depth:

$$TR = \int \rho \, dz, \qquad \text{in discrete terms:} \qquad TR = \rho \cdot \Delta Z$$

Two resistivity anomalies with the same transverse resistance will give the same CSEM response. The anomalous transverse resistance (ATR) transverse resistance is the integral over the resistivity contrast above a background value:

$$ATR = \int \Delta\rho \, dz = \int \rho_{Target} - \rho_{Background} \, dz, \qquad \text{in discrete terms:} \qquad ATR = \Delta\rho \cdot \Delta Z$$

were ρ_{Target} is the vertical resistivity of the resistivity anomaly (i.e. a HC reservoir), ΔZ is the thickness of the resistivity anomaly and $\rho_{Background}$ is the resistivity of the background. The ATR is a key sensitivity parameter for CSEM sensitivity, two resistivity anomalies with the same ATR will have the same CSEM sensitivity. In this study, 30 target scenarios where investigated. The CSEM response was computed for all target-models and the background models for a range of frequencies and receiver-source offsets.

Results

The reservoir resistivity analysis was used to establish pay resistivity ranges for vertical resistivity (Rv) and horizontal resistivity (Rh) as input to sensitivity modeling. The models of background resistivity were constructed based on the well data from Baltic Sea area. The rock physics models were constructed to predict the reservoir resistivity of each of the target scenarios (it was five different models to reflect all scenarios). The results of the predicted reservoir resistivity is calculate ATR (anomalous transverse resistance). The ATR range based on the modelling results and NetPay of each target scenario. The ATR was calculated for P10, P50 and P90 option.

The CSEM sensitivity scans were run with background resistivities based on well log observations and targets. The resulting sensitivity scans are compared to area and ATR range (P10, P50, P90 – it is variant of probability). The sensitivity sampling takes acquisition and target geometry into account. The sensitivity sampling was performed for ATR's representing P10, P50, P90 resistivity. The sensitivity is calculated for the electric field and the up-down separated field.

2D and 3D acquisition geometries were tested for towlines both along and across the prospect. It was decided to focus on acquisition geometries along the prospect as this is where the highest sensitivity is observed. The P10 case (the biggest object) shows high sensitivity for towing along the prospect. The P50 case shows–moderate sensitivity. The P10 case shows low sensitivity. 2.5D and 3D inversion tests were carried out to assess if and how the P10, P50 and P90 scenarios will be reconstructed (imaged) by inversion. The same 2D and 3D survey geometry were used in the CSEM inversion study. Input to the inversion is a start model and data of specific frequencies and offsets. The input data are based on 3D modelling of the synthetic model.

Conclusions

The CSEM sensitivity evaluation has high sensitivity to the P10 target, moderate sensitive to the P50 target and very low sensitive to the P90 target. In 2D, a receiver spacing not larger of 2 km was needed to image the P10 target and not larger than 1 km receiver spacing to image the P50 target. In 3D, a receiver grid spacing of 1x1, 2x2 and 3x3 km imaged the target as a resistivity elevation above the basement. The 3D P50 case did also show an elevated resistivity above the basement, however, this was much less pronounced than for the P10 case.

Sensitivity modelling and inversion tests suggests that P10 cases is well within the imaging threshold for CSEM. However, for smaller accumulations as P90-P50 it will be more challenging to make robust decisions. Close integration between CSEM and seismic is vital to evaluate the nature of observed resistors.

A 3D acquisition with a minimum of 2 km receiver spacing is recommended to do a robust imaging of possible hydrocarbon accumulations. With a larger receiver spacing a target might not be imaged sufficiently.

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