WS9-A02

CSEM - Where Do We Stand and Where Can We Go?

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SUMMARY

CSEM was established as an industry 12 years ago by several service companies that offered 2D CSEM commercially. The presentation will focus on how CSEM has developed as a commercial tool since the first commercial introduction 12 years ago and look into the future.

The technology has gone through a significant development. The most important step was from 2D to 3D wide azimuth data enabled by improvements in equipment, operations, inversion and streamlined processing of large data volumes. Both horizontal and vertical resistivity cubes are now inverted, enabling mapping of anisotropy and CSEM is no longer limited to deep-water applications.

Wide-azimuth 3D surveys will most likely be the main way to acquire CSEM data also in the future. In future processing and inversion, magnetic field data will be used more to improve imaging, especially in shallow water. In general MT data will also be used more which implies stationary seafloor receivers with both electric and magnetic sensors (Ex, Ey, Hx and Hy).

CSEM will see deeper (stronger sources), get better resolution and improved data will be processed jointly with seismic, resulting in improved imaging. Moreover, the data will be used as an important part in the oil companies workflow.

Introduction

CSEM used for remote detection of hydrocarbons was introduced by Statoil offshore Angola November 2000 (*Ellingsrud et al. 2002, Constable 2010*). Less than two years later an industry was established by several service companies that offered 2D CSEM commercially. What has changed since the introduction 12 years ago and what can be predicted for the next decade to come?

Method – where does CSEM stand today?

The first commercial CSEM survey was conducted over the Ormen Lange field in The Norwegian Sea in 2002/2003. The results were of sufficient quality to be accepted by key players in the oil industry (*Røsten et al. 2003*), leading to the “real” test of CSEM as a commercial exploration tool with the well-known Troll West Gas Province survey of 2003 (*Johansen et al. 2005*).

Since the early days the technology has gone through a significant development. The most important step was from 2D to 3D wide azimuth data enabled by improvements in equipment, operations, inversion and streamlined processing of large data volumes. Both horizontal and vertical resistivity cubes are now inverted, enabling mapping of anisotropy and CSEM is no longer limited to deep-water applications (*Mittet 2008; and Mittet and Morten 2013*).

Today, CSEM is mainly acquired as large-scale 3D regional surveys seen in the Barents Sea, Brazil and Mexico. Data, previously used for drill-or-drop decisions is now viewed in a regional context and for reserve estimation and portfolio optimization. Interpretation of CSEM data is used as a strategic decision tool in licensing rounds, farm-in farm out, prospect ranking and evaluation of leads and prospects, change drilling locations and relinquish acreage. CSEM is sensitive to the resistivity-thickness product, and combined with area, CSEM can be used in volumetric estimates (*Gabrielsen et al. 2013*). This opens up for resource estimates, as a supplement to traditional seismic methods, and appraisal studies and 4D.

Figure 1 Volumetric estimates from the Polheim platform in the Barents Sea. The estimates are based on CSEM, geometry and Monte Carlo simulations. The estimates fit with Skrugard and Havis. A new lead has the same potential but presence of reservoir sand has to be justified.

Another application is the combination of CSEM and MT to map structures defined by salt and basalt. The idea was proposed more than a decade ago (*MacGregor and Sinha 2002*), but only recently have there been successful surveys. In the past 12 years data has been acquired in basins all around the world and the oil industry is gradually accepting CSEM. Many wells have been drilled, both before and after

CSEM surveys and the statistics show that the predicted results are valid (*Hesthammer et al. 2010; and Buland et al. 2011*).

The main question is: has CSEM been a success? From a technical perspective, absolutely but commercially, market acceptance is not yet complete.

The future – where does CSEM go the next decade?

Wide-azimuth 3D surveys will be the main way to acquire CSEM data also in the future. In future processing and inversion, magnetic field data will be used more to improve imaging, especially in shallow water. In general MT data will also be used more which implies stationary seafloor receivers with both electric and magnetic sensors (E_x , E_y , H_x and H_y).

Due to the inherent attenuation in a conductive earth, CSEM has limitations regarding resolution and depth of investigation. One obvious solution is to increase the S/N ratio. At present, a deep water dipole source transmits 1250 A and a shallow water source 7200 A. Source currents can be increased, but require stronger power generators, higher capacity umbilicals, larger electrodes, cables, winch and handling systems. Is 20.000 A or even 50.000 A attainable? Possibly, but the most realistic near future goal is 10.000 A, almost an order of magnitude stronger than the existing deep water source.

The receiver noise ratio can be reduced by larger magnetic coils, longer electric antenna arms, better amplifiers and new electrodes with a potential noise reduction of one order of magnitude. And good

data is imperative! In a long term perspective higher quality more data points in denser grids are important. From an operational point of view this calls for smaller receivers. A combination of excellent S/N ratio and smaller receivers means innovation of a new generation of smaller sensors. Future vessels will carry more receivers; deploy denser 3D grids resulting in improved imaging. Based on statistics, computers will be 50 – 60 times faster within 10 years. This opens up for efficient modeling, smaller grid cells and better 3D inversion far less dependent on starting models. Statistics for the models themselves will be better. Two very important steps in processing will be joint-and integrated 3D inversion of MT and CSEM and joint full-wave form inversion of CSEM and seismic data. The latter will potentially improve velocity and resistivity volumes describing the same geology.

Conclusion

What does this mean for oil companies? Future 3D CSEM operations will cover larger areas with larger and denser grids. CSEM will see deeper with better resolution and improved data will be processed jointly with seismic, resulting in improved imaging. Moreover, the data will be used as an important part in the workflow where different volumes will be interpreted jointly on a workstation. The G&G staff gains a better understanding of the subsurface, which again leads to improved well positioning and discoveries even in traps not so easily seen by seismic alone (e.g. stratigraphic traps).

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