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# CSEM: a fast growing technology

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SEG Las Vegas 2008 Annual Meeting
“Recent Advances and the Road Ahead”

# CSEM: a fast growing technology

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**Introduction**

The past 10 years have seen the birth of a new exploration method: Sea Bed Logging, a special application of marine Controlled Source Electro Magnetic sounding (CSEM) used for direct hydrocarbon identification. The initial commercial version of SBL was introduced by the Norwegian oil company, Statoil, and was later span off to support the exploration market. For simplicity we use the phrase CSEM throughout the rest of this abstract instead of SBL. Presently the market is $200 Million USD. More than 400 surveys have been run in water depths ranging from 48 to 3392 meter and several discoveries have been reported (Smit,et al., 2006, Mittet et al., 2008). There is a total of 5 – 6 vessels operating around the globe today. New vessels also focusing on appraisal applications are planned.

**Methodology**

The method is based on hydrocarbons being more resistive compared to the conductive surrounding sediments, normally consisting of brine saturated rocks such as shale. A powerful electric dipole source is towed close to the sea floor and the transmitted energy propagates down through the subsurface. When the energy enters a hydrocarbon saturated reservoir the energy flows along the reservoir (can be described as a guided wave (Eidesmo et al. 2002) described by the Poyting vector (Weidelt, 2007)) due to the resistivity contrast between the reservoir and the conductive surroundings. Energy propagates back to the seafloor and signals are recorded by seafloor receivers. The recorded data contains information that can be used to distinguish between hydrocarbon and brine saturated formations and therefore increase the success rate when exploring for hydrocarbons. CSEM is therefore established as an important exploration tool (Ellingsrud et al., 2002, Srnka et al., 2006).

**Technology status and critical success factors**

CSEM has gone through substantial growth during the last couple of years, and a natural question to ask is; *can the market grow further?* From a technical view point it could, if critical criteria are fulfilled. Sensor and source technology has to be stable and reliable to produce high quality data. The technology has to be moved from single 2D lines to grids and 3D surveys, and the data must be processed and interpreted by tools as 3D inversion and imaging. Operations must be run in all water depths and data must be integrated with other geophysical methods. From a business view point the growth is dependent on one major factor, the industry has to fully accept CSEM and the value the data creates for the end users.

Today, CSEM data is generally of very high quality and acquired with stable and powerful sources that can transmit currents at 1250 A. Receivers have high sensitivity, and due to a new feature, automatic gain, the acquired data can cover a dynamic range of more than 180 dB with useful information. Figure 1 shows data acquired in very deep water where the airwave has very little effect. The black and green data represents the electric field out to an offset of approximately 13 km at a frequency of 0.4545 Hz. The magnetic data in purple has usable data out to 11 km. For both the electric and magnetic fields, the data does not go into saturation at short offsets. This additional near offset data expands the interpretational value of the data.

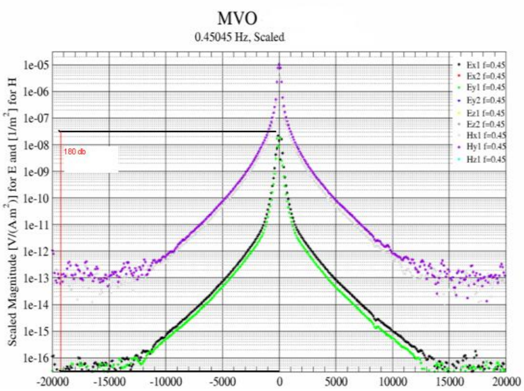


Figure 1: Magnitudes as a function of offset, acquired at a frequency of 0.4545 Hz. The green and black graphs represent the electric fields and the purple the magnetic fields. The data were acquired in deep water.

Positioning, orientation and timing are critical parameters for accurate 3D acquisition. Stable receiver clocks are required to avoid the introduction of phase errors. Recent advances in clock design have now reduced the timing error to less than 1 ms/day. The source is continuously synchronized with GPS and this results in a total source timing error of approximately 1 ms throughout a survey. Additionally, high power electronics also have to be stable to avoid drift. The typical total time drift seen during 2 weeks survey operations is 15 ms. This generates a phase drift of 1.3 degrees at 1 Hz. This is acceptable timing for 3D surveys where phase information is critical as errors in phase can cause pitfalls in the interpretation. 3D inversion also exists and the ability to acquire and process 3D data with full inversion is the most significant step towards a bigger market acceptance.

Previously, CSEM was considered a deepwater technique due to the air wave effects. However, CSEM is moved into shallow water by transient methods (tCSEM™) (Strack et al., 2008), Up/Down separation (Amundsen et al., 2006) and other modeling based techniques (Mittet et al., 2004, MacGregor et al. 2006). A recent publication also shows that the phase information can be used in normalizing data to give a better sensitivity to subsurface responses (Mittet, 2008). The practical water depth is therefore now given only by operational limitations.

CSEM data is well suited for integration with seismic data and can significantly enhance the value of 3D seismic cubes. 3D CSEM inversion results and 3D models can be delivered in SEGY format and compared directly with seismic data on a workstation.

From a technical point of view there is nothing that should stop the market from growing. The remaining issue then is how to grow the industry's acceptance of CSEM and use it on a routine basis? The growth rate will be dependent on the level of acceptance.

**What happens the next 5 years?**

Important improvements in the next 5 years can be focused on several issues. Depth of penetration is one; governed by frequency dependent attenuation, source power and receiver sensitivity. Stacking will help, but may reduce operational efficiency. Stronger sources will be developed within 5 years, but there exists physical limitations on how much power that practically can be injected from a vessel into the sea water. Stronger sources, however, will penetrate deeper, increase resolution, provide higher frequency content at shallow investigation depths, and in general, provide more frequencies for improved inversion results. Sensor technology will also be enhanced and a qualified guess is that the total dynamic range could be increased by 20 dB within 5 years.

Another important issue is operational efficiency. What will a 3D survey look like in 5 years time? Will the world be offered towed streamers and a source on the same vessel? It will be cost effective but technically challenging. As shown by the seafloor receiver data in figure 1, long offsets between source and receivers are required to get good depth information, at least 10 km. The inherently large wavelength of the CSEM signal opens up for larger receiver separation than in seismic but also larger streamer separation. A practical solution may require a streamer separation in the order of 500 m. A hypothetical future 16 streamer 3D vessel with 10 km long streamers will therefore totally cover an area of 75 $km^2$. To reduce attenuation the array has to be towed as close to the seafloor as possible, a potentially difficult task in deep water.

Operationally it will be more practical to tow the streamers just below the sea surface but then signal attenuation in deep water and the presence of airwaves becomes a challenge. Additionally, as the sensors would be towed in a conductive medium and the Earth's magnetic field, motion noise will be introduced on both electric and magnetic sensors. It is natural then to question if this is even possible or not. But the industry has taken on challenges before.

In the near future, large scale operations will likely be surveys conducted by dedicated vessels with large storage capacity for seafloor receivers, as shown in the picture in figure 2. As a consequence, increasing the number of receivers will generate increased the efficiencies. Large areas can be covered by coarse grids with a typical receiver spacing of 3 km, and give a relatively quick image of the resistivity distribution in the subsurface (figure 2). Dense 3D grids can be acquired for more detailed imaging of specific areas.

Seafloor cables will be another future acquisition method, and have been tested by others. Cables might be most efficient for appraisal purposes in shallow waters, as deeper waters may introduce operational challenges. The cables will be stationary on the seafloor while the source is towed. Upon completion of the necessary source tow, the cables are picked up and moved into next position. The operations will be similar to current-day seismic OBC surveys. Cable systems may also be practical for monitoring purposes.

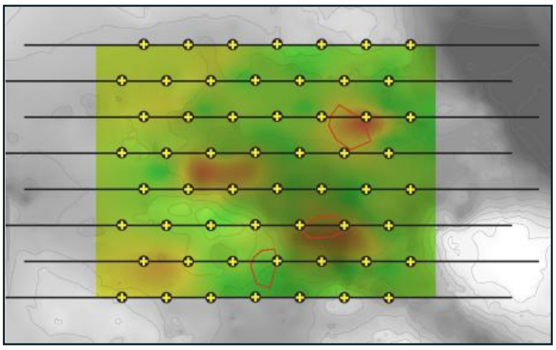

Figure 2: a) A new dedicated vessel with large receiver storage capacity. b) A typical course grid mapped responses. Denser 3D grids can be run over dedicated areas.

Within 5 years we also will see integrated geophysical hardware solutions. The most obvious advancement is the simultaneous acquisition of seismic and CSEM. Combined cable based systems are under development. To fully utilize the benefits of combined systems, integrated processing and interpretation routines are recommended. Commercial inversion software that combines low frequency CSEM data and very low frequency seismic data is appearing already.

Not so obvious is the need for multi-component measurements. These, however, will allow for better sub-salt and sub-basalt imaging and for full consideration of the anisotropy tensor.

**Conclusions**

Today CSEM is an established and important exploration tool. The data quality is high and the phase information reliable for 3D data acquisition. CSEM operations can be performed in shallow water and are generally only limited by operational issues. Data also can be integrated with seismic.

Soon we will also see large scale operations that can cover sizable areas in a more efficient way. The near future will bring cable solutions, integrated with seismic for appraisal purposes, and maybe a bit longer into the future, we may see towed streamers.

The technology is therefore well developed for market growth. The question that remains though is how quickly the industry can adopt the technology.

**Acknowledgements**

The authors want to thank Rune Mittet, chief scientist in emgs, for useful discussions and contributions, and Hans Roger Jensen, Hardware Manager emgs for receiver data .

**References**

Amundsen, L., Løseth, L., Mittet, R., Ellingsrud, S. and Ursin, B. [2006] Decomposition of electromagnetic fields into upgoing and downgoing components. *Geophysics*, Vol. **71**. No. 5 September – October, G211 – G223.

Eidesmo, T., Ellingsrud, S., MacGregor, L.M., Constable, S., Sinha, M.C., Johansen, S., Kong, F.N. And Westerdahl H. [2002] Sea Bed Logging (SBL), a new method for remote and direct identification of hydrocarbon filled layers in deepwater areas. *First Break*, **20**, 144-152.

Ellingsrud, S., Eidesmo, T., Sinha, M.C., MacGregor, L.M. and Constable, S. [2002] Remote sensing of hydrocarbon layers by SeaBed Logging (SBL): results from a cruise offshore Angola. *The Leading Edge*, **21**, 972–982.

MacGregor, L.M., Andréis, D., Tomlinson, J. and Barker, N. [2006] Controlled-source electromagnetic imaging on the Nuggets-1 reservoir. *The Leading Edge*, **25**, 984–992.

Mittet, R., Løseth, L. and Ellingsrud, S. [2004] Inversion of SBL data acquired in shallow water. *66th EAGE Conference and Exhibition*, Extended abstracts, E020.

Mittet, R., Brauti, K., Malana, H. And Wicklund, T.A. [2008] CMP inversion and post-inversion modelling for marine CSEM data, *First Break* Vol. **26**, August.

Mittet, R. [2008] Normalized amplitude ratios for frequency domain CSEM in very shallow water. *First Break*, Vol. **26**, November.

Smit, D., Saleh, S., Voon, J., Costello. M. and Moser, J. [2006] Recent Controlled Source EM results show positive impact on exploration at Shell. *SEG Expanded Abstract* , Vol **25**, 2536-3541.

Srnka, L.J., Carazzone, J.J., Ephron, M.S. and Eriksen, E.A. [2006] Remote reservoir resistivity mapping. The Leading Edge, **25**, 972–975.

Strack, K.M., Allegar, A., and Wilkinson, M. [2008] Marine time domain CSEM: an emerging technology, Presented at the *Non-Seismic workshop, Bahrain*.

Weidelt, P. [2007] Guided waves in marine CSEM. Geophysical Journal International, Vol **171**, 153-176.

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