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Marine time domain CSEM: an emerging technology

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Summary

Recent advances in electronics now enable time-domain, or transient CSEM data, to be reliably acquired in an offshore environment and make the leap from its dominant position in land EM to the marine world. Multiple surveys using autonomous receiver nodes have successfully acquired marine time domain CSEM data. The approach has shown particular benefit in shallow water since the method records only the secondary fields and the signal is not dominated by the primary field.

Introduction

For the past 40 years, the seismic method has been the geophysical workhorse of the oil industry. While it offers the best description of the reservoir shape and stratigraphy, it falls short on describing the fluid properties of the pore space as elastic waves predominantly travel through the rock matrix. In particular, many of the changes that take place during the production life of a reservoir do not exhibit a detectable acoustic property change. Recently, marine controlled-source electromagnetic (CSEM) methods have found hydrocarbons after their response to thin resistors was understood (Eidesmo et al. 2002). The use of marine CSEM has gained momentum, and has become one of the most significant technology developments in oil exploration since the advent of 3D seismic.

Among the CSEM methods, we use a time domain (tCSEM™) version which employs time variant magnetic fields of either natural or artificial origin that cause eddy currents within the conductive sediment layers (Strack 1992, 1999). These eddy currents are time variant as well and they cause a secondary EM-field that can be sensed with magnetic or electric sensors placed on the sea floor or in the wellbore. High resistivity lithologies and pore fluids are the resistors that alter this artificial electric field. Today, most service providers of CSEM technology transmit a frequency-targeted source into the Earth, often this is referred to as frequency domain CSEM or fCSEM. This source is almost always a continuous square-wave and both the active source and the subsurface response are recorded at nodes distributed along the seafloor. As a consequence, the much larger primary field often swamps the weaker Earth response (secondary field), particularly at short source receiver offsets and in water depths of less than 200 m. This shallow water affect is commonly called the airwave phenomena.

Methodology

With recent advances in electronics, time-domain, or transient CSEM data can now be reliably acquired in an offshore environment and make the leap from its dominant position in land EM to the marine world. With time-domain CSEM one transmits a current into the Earth and charges the subsurface. The current is then switched off and the charge drains from the Earth. Transient responses to this artificial electric field are then measured by sensors that record both the electric and magnetic components. Because the time domain method is only measuring the secondary field it offers a solution to the shallow water limitations that confront frequency-targeted techniques (Weiss 2007, Avdeeva et. al. 2007). The duration of these "on" and "off" times of the source are optimized to each particular problem. Additionally, every current switch represents the initiation time, or time zero, for a given transient. Figure 1 shows a typical time domain source waveform and the resulting electric and magnetic fields.

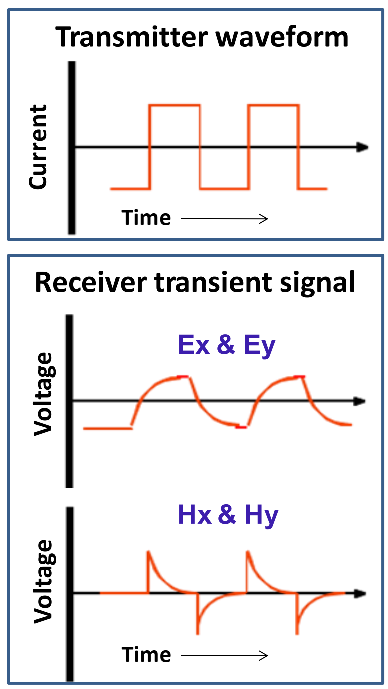

Figure 1: Time domain source waveform and its resulting electric and magnetic fields.

Marine time domain CSEM

Like seismic, which synchronizes the recorded response with its impulsive source, transients have a start and finish that correlate to current changes in the source. For each source receiver offset, we obtain a unique transient and can leverage this time-offset relationship in our processing and interpretation of the data. As time-domain CSEM is collected in a style similar to seismic it can be robustly integrated with seismic data and utilize the processing strengths of seismic where one can apply noise suppression, signal enhancement (stacking and filtering) and imaging algorithms. The integration with seismic is particularly important, as the EM method is based on the physics of diffusion and is of much lower natural resolution than that of seismic which is based on acoustic/elastic wave propagation.

Since the time domain method records only the Earth's response and is broadband, it has the potential to detect weak reservoir responses due to low resistivity contrast or complex shape. The recorded transient is a combination of the airwave, the ocean wave, and the subsurface or sediment wave. Water depth, sediment resistivity and target resistivity determine the timing of these diffusion phenomena. As mentioned earlier, by recording in the absence of the active source, the airwave phenomena can also be potentially isolated from the subsurface and ocean wave response in shallow water. In figure 2 the airwave is shown to separate as a function of time and offset.

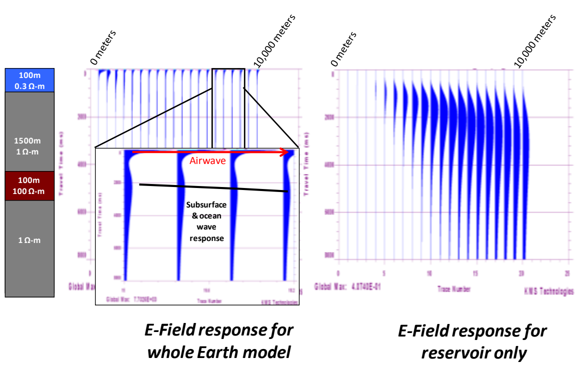

Figure 2: Time domain 1D forward model for a typical reservoir in shallow water. Transients are treated like seismic traces and create a common receiver gather.

In fact, a similar reservoir produces a larger time domain response in shallow water than it does in deep, as shown in figure 3.

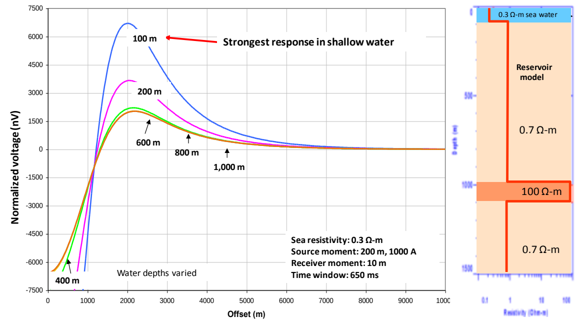

Figure 3: Time domain electric field response for the same resistor placed in various water depths. The same reservoir produces a larger response in shallow water than it does in deep

Nodal acquisition

Multiple time domain CSEM surveys have been collected by industry and it will likely have the same range of applications as conventional frequency domain CSEM, from reconnaissance to prospect specific. BP collected the first successful commercial time domain CSEM survey in the shallow (70 m to 1110 m) waters of the Mediterranean Sea off the coast of Egypt (Thomsen et.al. 2007). The survey for BP was carried out by Electromagnetic Geoservices (EMGS) under the scientific advice of KMS Technologies. Through careful system response evaluation and cross calibration of the hardware we were able to use the latest generation of commercial hardware to generate quality time domain CSEM data with the same operational efficiency and overhead as that of a fCSEM survey.

More recently, additional time domain CSEM surveys have been conducted by EMGS in the Gulf of Mexico and in the North Sea. Data quality from these surveys was excellent and matched the anticipated response. Figure 4 shows an example of the recorded electric and magnetic fields. Analysis of a long offset electric field transient shows very low system noise (see figure 5).

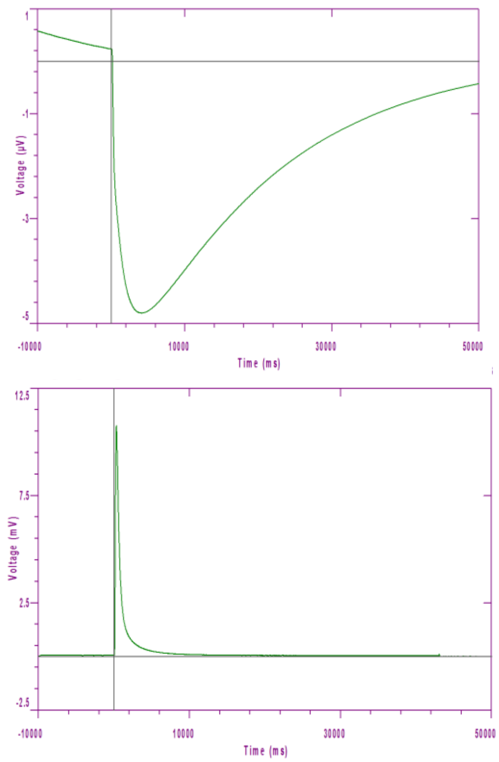

Figure 4: Acquired time domain data; electric field transient (top) and the corresponding magnetic transient (bottom).

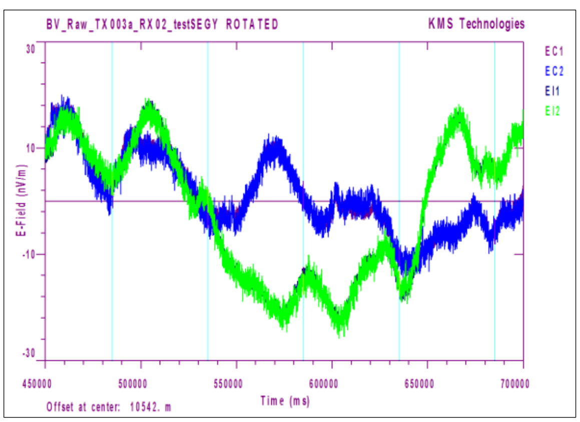

Figure 5: Electric field transient at an offset distance of 10,542 meters where S/N approaches 1.

Cable based acquisition

For tighter acquisition and appraisal and production applications the nodal system is augmented by a cabled system, presently under development. The tCSEM™ ocean bottom cable system will record both electric and magnetic field measurements and will provide denser sensor spacing than is typically afforded by nodal systems alone. Figure 6 portrays one scenario for an integrated node and cable based acquisition system. Dense sensor spacing is particularly important since lateral resolution of the method is scalable to it. In other words, the denser the receiver spacing, the better your lateral resolution and the integration with single well and borehole-to-surface measurements. As the cable system has a very high degree of precision for positioning repeated deployments and will advance the use of EM technology for reservoir monitoring through the acquisition of time lapse surveys. Additionally, the system will feature buoy based recording and real time quality control of data, and is deployable with VSO seismic cable system to provide a direct integration with the seismic method.

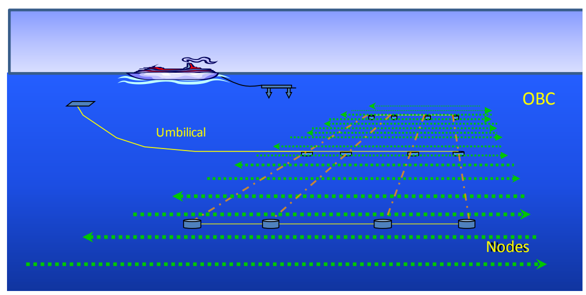

Figure 6: Integrated node and cable acquisition for EM reservoir illumination.

Conclusions

It has been shown that time domain CSEM can be reliably acquired in a marine environment. Node based surveys have acquired multiple datasets in a variety of basins where the recorded transient responses match those of pre-survey models. The method has shown particular promise in shallow waters where the primary field dominates the recorded signal. Developments are underway to augment the nodes with a cabled system.

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EDITED REFERENCES

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REFERENCES

Avdeeva, A. D., M. Commer, and G. A. Newman, 2007, Hydrocarbon reservoir detectability study for marine CSEM methods: Time-domain versus frequency-domain: Presented at the 77th Annual International Meeting, SEG.

Eidesmo, T., S. Ellingsrud, L. M. MacGregor, S. Constable, M. C. Sinha, S. Johansen, F. N. Kong, and H. Westerdahl, 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.

Strack, K. M., 1992, Exploration with deep transient electromagnetics—Introduction and indexes: Elsevier.

———1999] Advances in electrical logging tools for reservoir characterization: Advances in exploration geoelectromagnetism: Presented at the 61st Annual International Conference and Exhibition, EAGE.

Thomsen, L., D. Meaux, S. Li, C. Wesiss, A. Sharma, N. Allegar, and K. Strack, 2007, Novel marine electomagnetics: From deep into shallow water: Recent advances and road ahead: Presented at the 77th Annual International Meeting, SEG.

Weiss, C., 2007, The fallacy of the shallow-water problem in marine CSEM exploration: Geophysics, **72**, A93–A97.

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