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Marine CSEM for Gas Hydrate Exploration Using a Seafloor-towed Multi-receiver System

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SUMMARY

In the past years BGR – the German Federal Institute for Geosciences and Natural Resources has been developing unique marine CSEM systems to explore the electrical attributes of the shallow seafloor. CSEM data are sensitive to the presence of resistive gas and gas hydrate in the sediment, and provide complementary volume information which, if used in connection with seismic and other exploration methods, e.g. drilling, allow for a better evaluation of the gas or gas hydrate resource potential. The gas hydrate setting differs from the exploration of conventional offshore oil and gas reservoirs as typical gas hydrate deposits are smaller in scale und at shallower depths below the seafloor. Therefore instrumentation and survey configurations need to be adapted. HYDRA, the seafloor-towed, multi-receiver system has been recently refined with a new signal generator and receiver units which both allow for online communication and data transfer. 1D and 2D inversions of CSEM data collected offshore New Zealand result in highly anomalous resistivities over several methane seep sites within the gas hydrate stability field which are believed to be caused by concentrated gas hydrates below the seeps.

Introduction

In the past years BGR – the German Federal Institute for Geosciences and Natural Resources, has been developing unique marine CSEM systems to explore the electrical attributes of the shallow seafloor. The applications have been exploration and quantification of submarine gas hydrates, shallow gas in shallow waters, and seafloor massive sulphide deposits. CSEM data are sensitive to the presence of resistive gas and gas hydrate in the sediment, and provide complementary volume information which, if used in connection with seismic and other exploration methods, e.g. drilling, allow for a better evaluation of the gas or gas hydrate resource potential. The gas hydrate setting differs from the exploration of conventional offshore oil and gas reservoirs as typical gas hydrate deposits are smaller in scale und at shallower depths below the seafloor. Therefore instrumentation and survey configurations need to be adapted. In this paper we focus on two aspects related to the exploration of gas hydrates using marine CSEM: Improvement of instrumentation and data interpretation.

Instrumentation

HYDRA is a seafloor-towed, electrical, multi-receiver system developed at BGR with the financial support of the German SUGAR-Project (www.sugar-projekt.de). The modular system consists of a 100m long transmitting dipole followed by a sequence of up to five 15m long receiving dipoles connected inline at offsets from150m to 850m (Figure 1). The 'pig', a pointy weight and instrument platform, is connected to the front end of the array, and hosts an acoustic transponder for positioning, a conductivity, temperature, density (CTD) sensor, the control unit, and recently a newly developed signal generator and communication unit for online communication and data transfer. The complete system is deployed astern of the vessel using the A-frame and the deep-tow coaxial and optical fibre cable provided by the vessel. Once it is aligned on the seafloor it is towed at low speeds around 1knot with the aim to derive the 2D resistivity distribution along selected profiles.
The typical source signal has a square waveform with a period of 4-6 sec and amplitudes from 12A to 20A peak to peak. The transient signal propagates by induction away from the source dipole through the ambient seawater and seafloor. Delay times and signal form recorded at the receivers can be interpreted in terms of the seafloor resistivity structure.

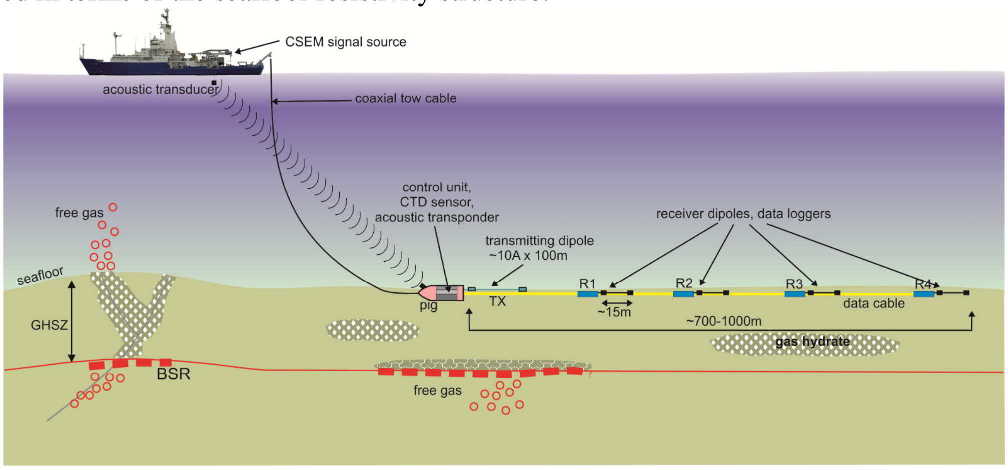

Figure 1 *Set-up of HYDRA, the seafloor-towed electrical dipole-dipole system.*

Since its first use in 2010 HYDRA underwent several improvements which have been successfully tested at sea including:

- Improvement of the analogue electronics, fast sampling, high signal resolution: 22bit @ 10kHz. This enables resolution of signals < 10nV
- Exact time base between recording units using high precision atomic clocks (drift ≤ 0.01msec/day).
- Development of a seafloor signal generator (current output up to 40A peak to peak).
- Online communication and data transfer via optical fibre of the deep-tow cable

- Online data transfer from receiver units
- Suppression of inductive noise from the transient source signal parallel to the seafloor data cable

These improvements led to high quality data, quality control during deployments, and reduced risk of data loss. However, there are several advantages, but also some limitations to the system:

- The offset between transmitting and receiving dipoles can be accurately measured, which is particularly relevant at short offsets. No expensive positioning and receiver assignment is required.
- Towing directly on the seafloor prevents loss of signal strength through the conductive seawater. With a source dipole moment more than one magnitude below typical commercial systems the same signal strength can be reached at the receiving dipoles.
- The array can be kept stationary over targets of interest to enhance stacking depth and signal quality.
- Only one component of the electric field, namely the inline component, is measured. However, the inline component has the greatest response to changes in seafloor resistivity.
- To avoid damage or even loss of the equipment, the system should be only deployed over soft sediments

Interpretation

The CSEM data we collected with HYDRA have been analyzed and interpreted using different strategies. We will show a data set collected over gas hydrate related methane seep sites offshore New Zealand. Initially, the apparent resistivity along profile is calculated for each transmitter-receiver offset separately applying 1D Marquardt inversion. This gives the average seafloor resistivity between the respective transmitting and receiving dipole. The next step is 1D Occam inversion of all available data jointly to a layered model with the goal to derive the vertical resistivity structure along profile. This results in smooth model structures, but may cause false results where 3D effects or lack of data coverage are present. 2D Occam inversion of all receiver data and including topography basically reflect the resistivity structure already found by 1D Occam inversion, but allow to better constrain the vertical and lateral extent of the anomalies. Finally, 3D forward modelling using COMSOL is applied to systematically study the extension from 2D to 3D.

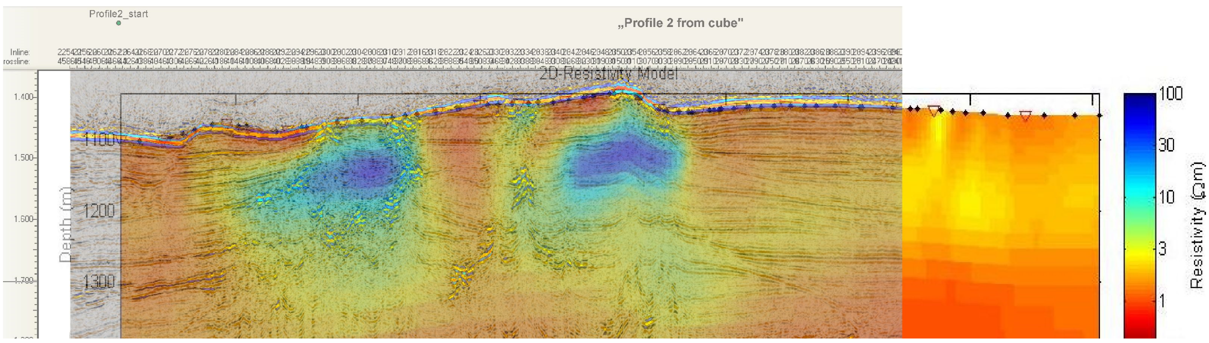

***Figure 2** CSEM and coincident seismic profile offshore New Zealand show highly anomalous resistivities (blue) and strong amplitude anomalies below seafloor seep sites. The high resistivities are believed to be caused by concentrated gas hydrates in the sediments. (Seismic section by courtesy of S. Koch, GEOMAR; 2D CSEM inversion code by C. Scholl, CGG Electro Magnetics)*

Conclusion

Refining marine CSEM instrumentation and inversion tools have been useful to collect high quality data and increase credibility of the model results. Seismic and CSEM anomalies over gas hydrate sites offshore New Zealand show a very good agreement (Figure 2). Archie's Law is used to derive an estimate of the gas hydrate concentration. However, accurate evaluation of the resource potential requires a better and thorough understanding of the gas hydrate system.