Methane Hydrates in CSEM Surveys – Analysis of a Recent Data Example

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Summary

Near-offsets data from a recently acquired deepwater Seabed Logging (SBL) survey are analyzed for shallow resistive structures. A model consistent with known methane hydrate properties is found to explain anomalies on a length scale of a few hundred meters observed in the data. For the survey at hand, the lateral near-seabed resolution of the present – day SBL technique was determined to ~100m for source frequencies of up to 10 Hz. The importance of accurate hydrate maps to improve data quality in SBL processing is illustrated by placing a synthetic reservoir below the hydrates found and observing its response. Beyond, the study demonstrates the usefulness of CSEM (controlled – source electromagnetic) techniques in general to map shallow resistive structures for drilling hazards and possible future exploration of methane hydrates as energy reservoirs.

Introduction

With increasing deep offshore hydrocarbon exploration, there has been considerable interest in the characterization of methane hydrates (McConnell et al., 2003) as a drilling hazard and also as a potential energy source (Matsuzawa et al., 2006). The enhanced resistivity of methane hydrates of ~3-20 Ωm compared to typical ocean bottom resistivities of ~0.5-2 Ωm, together with their shallow depths suggest CSEM – methods for characterization, whereas the first survey was reported by Scripps (Weitemeyer et al., 2006). Since the response of a shallow resistive target can be comparable to a deep hydrocarbon reservoir, hydrates have to be taken into account in the processing of SBL data. Particularly, a standard procedure is normalization of measured MVO (magnitude versus offset) and PVO (phase versus offset) longitudinal electrical (Ex) and lateral magnetic (Hy) data with real or synthetic reference data (Eidesmo et al., 2002). Figure 1 (Johansen et al., 2005) shows the normalized MVO/PVO response exhibiting a characteristic enhancement in normalized amplitude and depression in relative phase difference above a resistive body. The wrong conclusions can be drawn if, in a prospect with strong presence of hydrates (see Figure 2 for an illustration), a synthetic background model lacks hydrate structures or real background data with a different gas hydrate distribution are chosen.

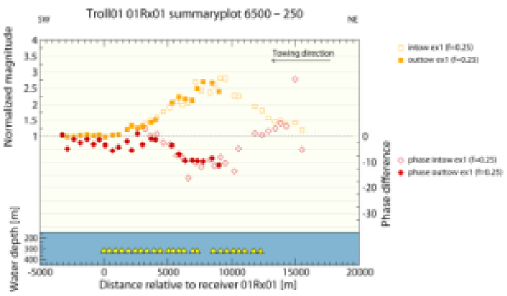

Figure 1. SBL standard processing example: magnitude and phase versus offset plots normalized to one receiver in a line. Plotting of data at midpoint between receiver and transmitter enables summary of one entire acquisition line in one plot. Only the offset range 6000m +/- 250m is plotted.

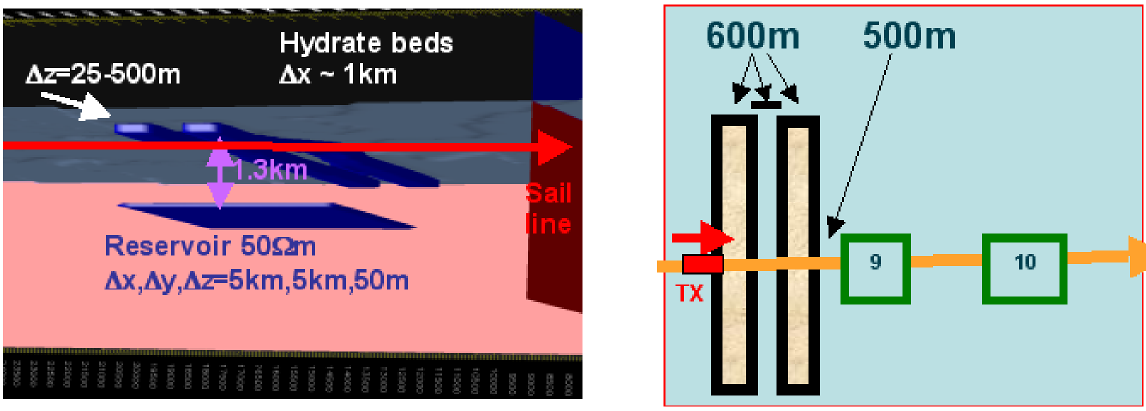

Figure 2. Left panel: illustration of hydrate patches with a characteristic length scale of ~1 km at a 1.7 km water depth above a synthetic target reservoir. Right panel: Top view of hydrate patches with the location of the receivers RX9 (“9”) and RX 10 (“10”) with 1.25km spacing.

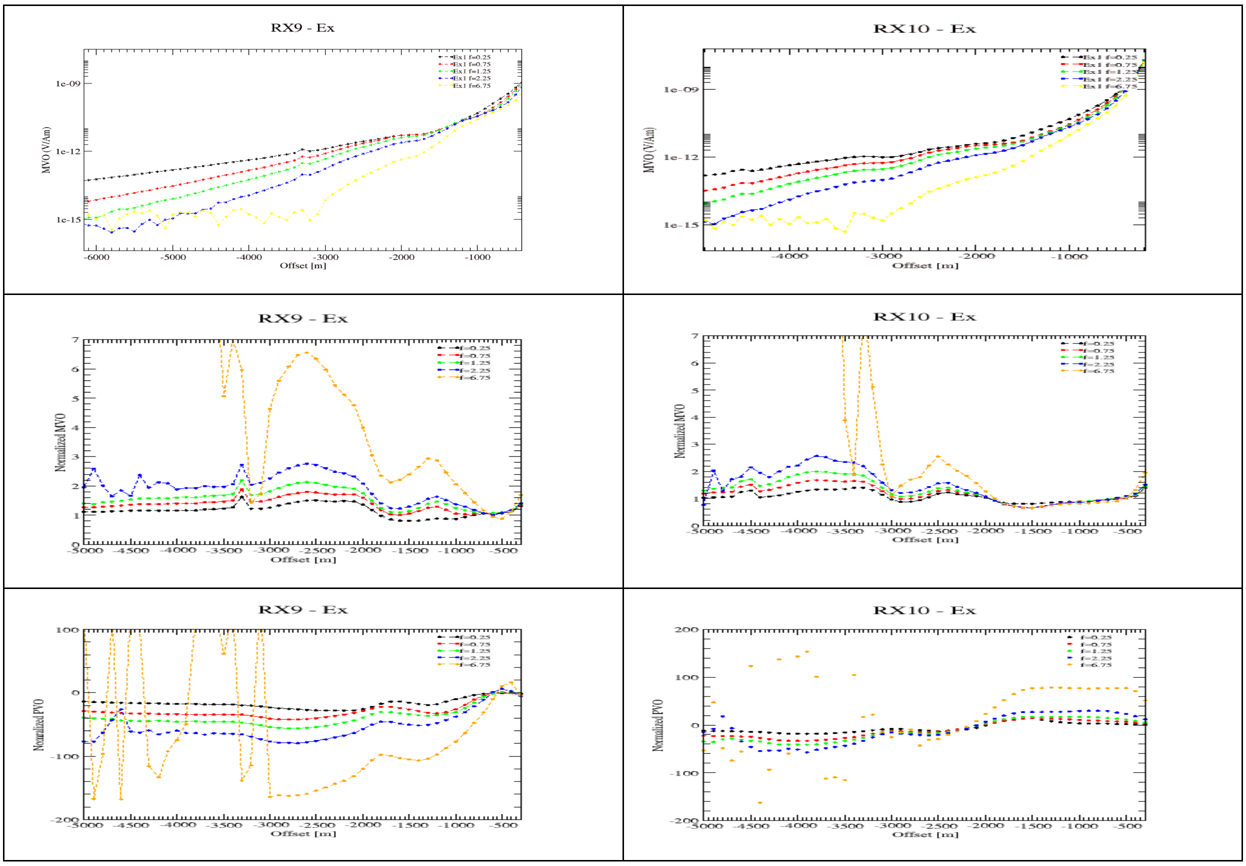

Figure 3. Ex - data from two receivers from a recent deep – water SBL survey: RX9 (LHS) and RX10 (RHS), respectively, see also RHS in Figure 2. Plots for different frequencies: 0.25Hz (black), 0.75Hz (red), 1.25Hz (green), 2.25Hz (blue), 6.75Hz (yellow). Upper panel: non – normalized MVO plots. Center panel: normalized MVO plots. Bottom panel: PVO – difference plots. The red boxes illustrating the locations of the methane hydrate patches are not exactly drawn to scale.

Methodology

We appreciate having been granted client permission to present short – offsets data from two receivers exhibiting a methane hydrate signature. The receiver spacing was 1.25 km, and the survey was conducted in 2006 in ocean depths of about 1.7 km. The data are presented in Figure 3. The inferred locations and extents of the hydrate beds are illustrated in the center and bottom panels by dashed red

boxes. The upper panels show the MVO plots, the center panels the normalized MVO plots to a 2 Ωm – halfspace response, and the lower panels the respective relative difference – PVO plots. Five frequencies between 0.25 Hz and 6.75 Hz are plotted. The content in the source signal is such that the highest frequency mode hits the noise floor at an offset of 3km, resulting in the loss of any interpretable signal at that offset. Consistent with the skin depth attenuation ~f –0.5, the 2.25 Hz – mode crosses the noise floor at an offset of about 5 km.
The data in Figure 3 were reproduced using a manual matching of the observed widths of the anomalies with hydrate beds of varying thicknesses of up to a few hundred meters, and an assumed resistivity of 7 Ωm. Synthetic data were produced using an EMGS – proprietary FDTD – code (Maaø, 2006). The best fit, see Figure 4 for the matching synthetic data, was obtained for two methane hydrate patches of each 600 m long, spaced 600 m apart, and each with a thickness of 250 m (right panel in Figure 2; the lateral width is commensurate with the symmetry of only data from one line released). The prospect contains substantial depth variations (~300 m variation over survey area). Hence, it was verified that the anomalies are not mainly caused by topography, which is shown in the top panels in Figure 4. It is obvious that the deviation caused by the topography is small compared to the observed anomalies. Exceptions are only short offsets, at which the FDTD code used was less accurate.

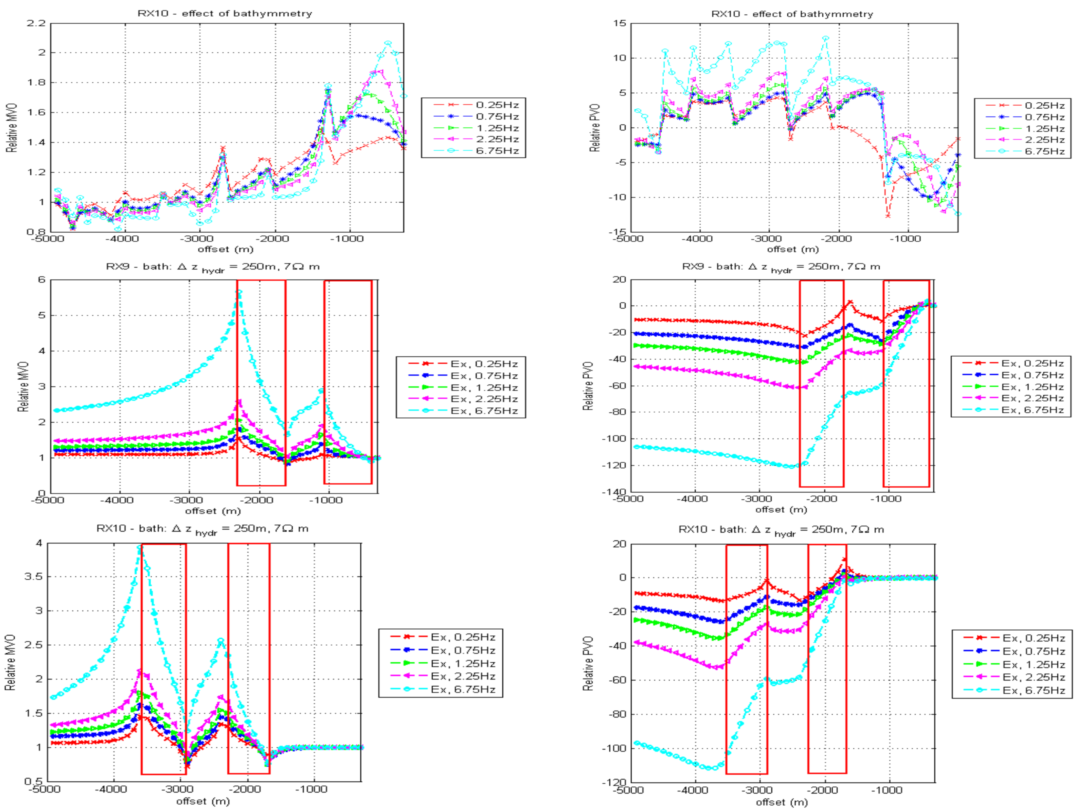

Figure 4. Synthetic Ex – data for RX9 and RX10, both MVO (LHS) and PVO (RHS) plots. Five different frequencies are shown: 0.25 Hz (red), 0.75Hz (blue), 1.25 Hz (green), 2.25 Hz (magenta), 6.75 Hz (cyan). Top panels: synthetic comparison – without hydrates – of real (from echo – sounding) vs. flat topography. Center and bottom panels: synthetic data for optimized hydrate model from RHS in Figure 2 matching measured RX 9 and RX 10 – data. The red boxes illustrating the location of the hydrate boxes are not exactly drawn to scale.

Conclusions

The work presented shows the potential to use CSEM techniques such as SBL to map shallow resistive structures with respect to drilling hazards and possibly non-conventional fossil fuels (gas hydrates) in the future. The appropriate analysis can be accomplished with the present-day technological setup of SBL, where for the analyzable frequency content of up to ~10Hz, a lateral resolution of ~100m was determined from the sensitivity of the response to varying widths of the hydrate patches. The dipole source length thereby used was 275 m, with a source altitude above seabed of 30 m. The benefits to standard SBL processing of being able to accurately map the shallow subsurface are demonstrated in Figure 5. Data for a synthetic reservoir at 1.3 km depth below seabed and hydrates are analyzed using both a background model with and without the hydrate model obtained. Whereas the quality of the normalized MVO data considerably improves with knowledge of the hydrate map, the phase data prove to be less sensitive to the shallow resistive structure, which has already been observed in previous surveys.

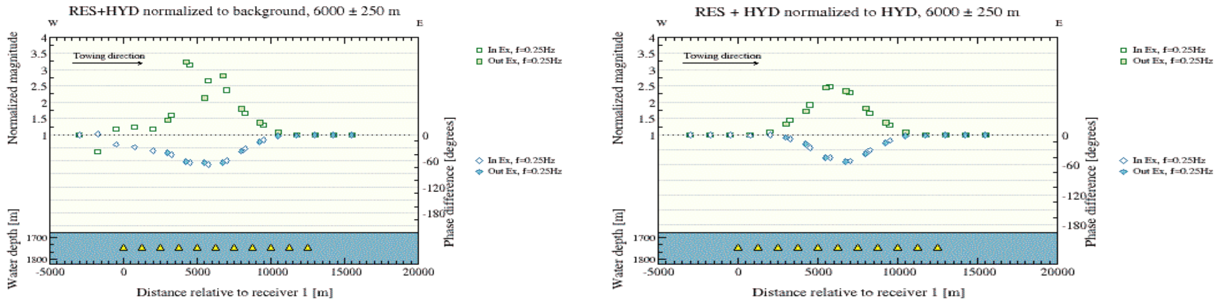

Figure 5. Normalized MVO/PVO difference – summary plots analogous to Figure 1. Data for the synthetic reservoir shown on the LHS of Figure 2 and the hydrate model resulting from the above analysis (RHS of Figure 2). Left panel: reference receiver without hydrates. Right panel: reference to synthetic data based on a geological model with the hydrate distribution.

References

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