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Study on Gas Hydrate Targets in the Danube Delta with the Sputnik Controlled-Source Electromagnetic System

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1. Motivation

- Methane hydrates are a potential energy resource and of high societal relevance. However, quantifying them may be difficult with conventional seismics.
- Electrical resistivities of sediments vary strongly with changing hydrate concentrations. They provide additional, independent information for better hydrate concentration estimates.
- In 2014, we conducted marine controlled-source electromagnetic (CSEM) and seismic experiments in the Black Sea (Fig.1&2) where multiple bottom simulating reflectors (BSR), which may map base of hydrate layers, were observed.
- The experiments were carried out to guide a drilling campaign on RV Meteor (M142) in November/December of this year.

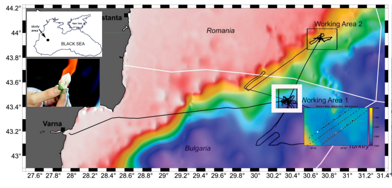

Fig. 1: Map of the Danube delta region in the Black Sea and location of workareas.

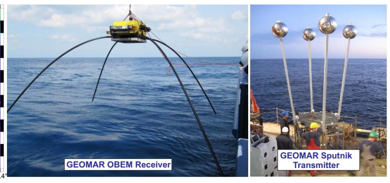

Fig. 2: GEOMAR CSEM system. (left) ocean bottom electromagnetic (OBEM) receivers; (right) SPUTNIK transmitter system , which allows for measurements with two orthogonal transmitter polarizations at each transmitter location.

2. CSEM Data and Resistivity Models

For a preliminary resistivity model, we construct a grid of common midpoints (CMP) and invert the data of all TX-RX combinations, whose midpoints fall into the respective grid cell, in terms of a 1-D layered model (Fig. 3 & 4, respectively).

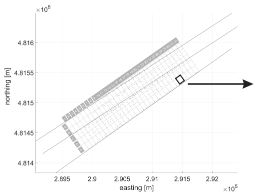

Fig. 3: CMP inversion grid (grey lines) with five profiles (A to E) and seismic profiles (black lines).

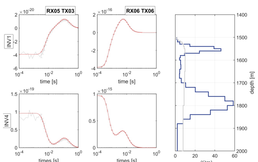

Fig. 4: Inversion result for CMP grid (E,27):(left) data fit of the CMP inversion; (right) start and final models (grey and blue lines, respectively).

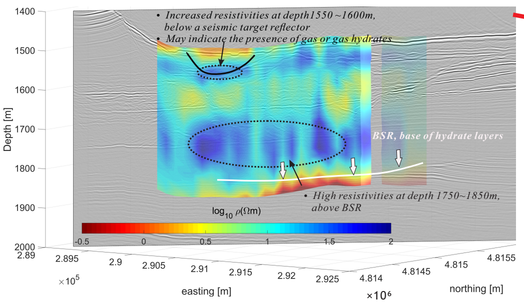

Fig. 5: Stiched section of 1D CMP inversion model (profile C) co-rendered with seismic P-cable reflection data. High resistivities (blue) are indicative of either low porosity or pore space filled with resistive material such as gas hydrate or fresh water. Low resistivities (red) indicate higher porosities, possibly in combinations with conductive pore fluid of higher salinity.

3. Estimation of Gas-Hydrate Saturation

The gas-hydrate saturation S_h may be derived by using Archie's Law *(Archie, 1942)*:

$$S_h=1-(\sigma_{sf}/\phi^m\sigma_f)^{1/n}$$

where:

- σ_{sf} : bulk conductivity of the seafloor.
- ϕ : porosity measured on drill cores (workarea 2) and derived from seismic velocities *(Dannowski et al., 2016; Fig. 6)* using the Hamilton equation *(Hamilton et al.,1978)*.
- σ_f : conductivity of the pore fluid derived from salinity measurements (workarea 2, Fig. 7).
- m,n: material constants from lab measurements at GFZ.

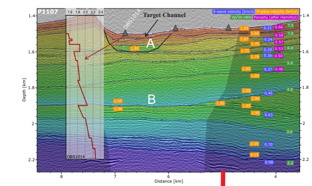

Fig. 6: Velocity model derived from OBS data. Insert shows Vp profile underneath OBS1014.

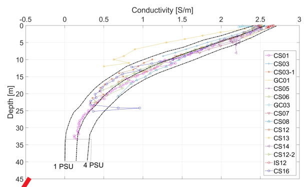

Fig. 7: Pore fluid conductivity drived from salinities measured on drill cores from workarea 2.

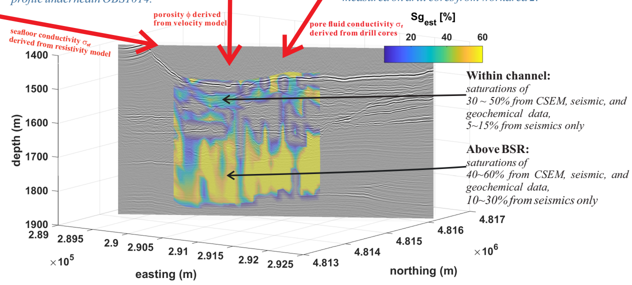

Fig. 8: Estimation of gas or gas-hydrate saturations.

Differences between methods could be explained either by underestimation of saturations by seismics (lack of velocity anomaly in homogeneously saturated layer or presence of small gas fractions in gas-hydrate stability field) or by incorrect assumptions made for the estimations from CSEM data (e.g. decreased pore fluid salinity at greater depths).

4. Summary of Results

- Models indicate presence of highly resistive regions that may be associated with gas-hydrate (or gas) occurrences.
- Improved hydrate saturation model through combination of seismic and CSEM data shows:
  a) Shallow zone of high saturations of 30~50% within drill target region (seismically inferred values are only 5~15%).
  b) Deeper zone of high saturations of 40~60% above BSR (seismically inferred values are 10~30%).

5. Acknowledgement

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6. References

Archie G E. The electrical resistivity log as an aid in determining some reservoir characteristics[J]. Transactions of the AIME, 1942, 146(01): 54-62.
Dannowski, A., Bialas, J., Zander, T. and Klaeschen, D. (2016). Shear wave modelling of high resolution OBS data in a gas hydrate environment of the Danube deep-sea fan, Black Sea. AGU Fall Meeting 2016, 12.-16.12.2016, San Francisco, USA.
Hamilton E.L., (1978). Sound velocity-density relations in sea floor sediments and rocks, J. Acoust. Soc. Am., 63, 366.
Zander, T., Haeckel, M., Berndt, C., Chi, W. C., Klaucke, I., Bialas, J., Klaeschen, D., Koch, S. and Atgin, O. (2017). On the origin of multiple BSRs in the Danube deep-sea fan, Black Sea. Earth and Planetary Science Letters, 462. pp. 15-25. 2016.

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