

## Marine CSEM Site Survey on Gas Hydrate Targets in the Danube Delta, western Black Sea

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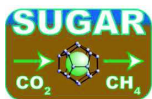
Burning Gas Hydrate



R/V Maria S. MERIAN in Varna, Bulgaria

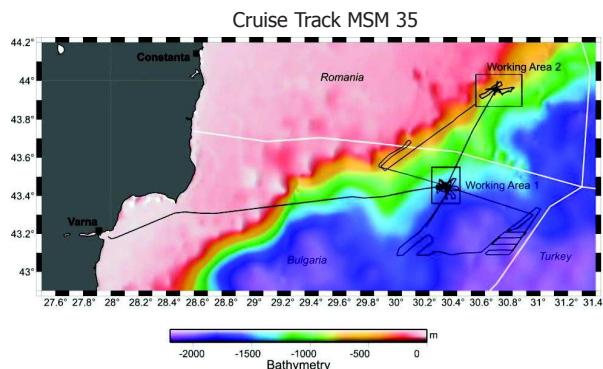
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## Project SUGAR-Site, RV MERIAN Cruise MSM35



### Submarine Gas Hydrate Reservoirs

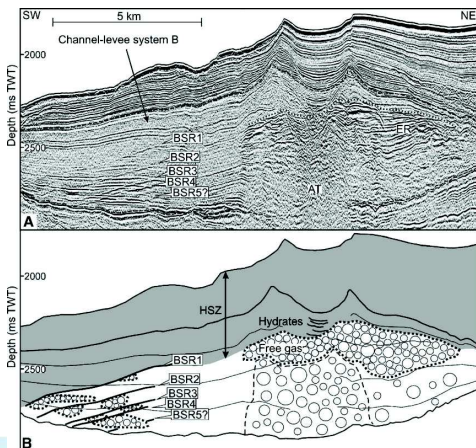
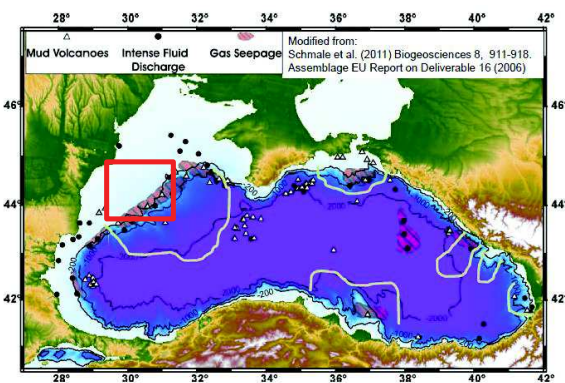
- German Joint Venture Project to investigate gas hydrates as a possible future energy resource and for CCS in hydrate form.
- 30 Partners, ~25 Mill. € in 6 years (2008-2014)
- MERIAN Cruise MSM 34: 06.12.2013 – 16.01.2014, Varna to Varna – Seismic, Geochemistry
- MERIAN Cruise **MSM 35**: 20.01. – 05.02.2014, Varna to Istanbul - **CSEM**
- **Objective:** geophysical **site survey** for a planned **test drill site** for methane production from gas hydrate



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## Gas Hydrates in the Western Black Sea

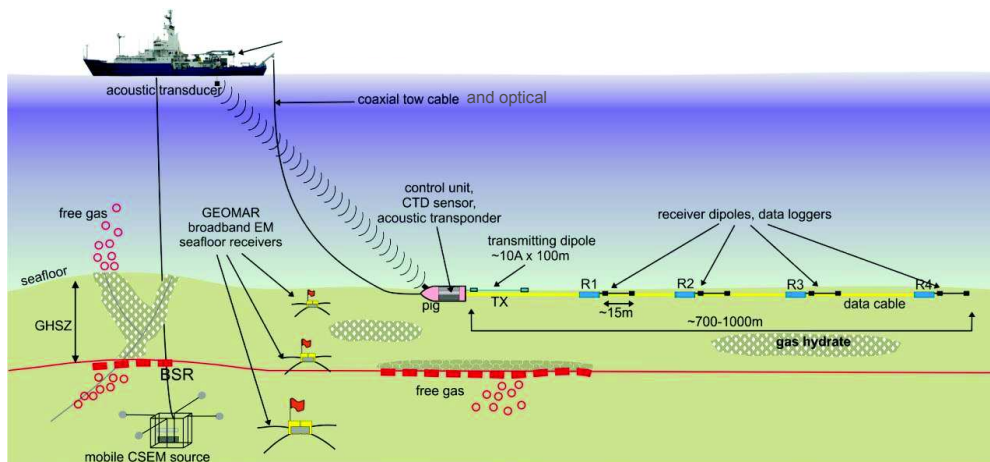
- Quasi-closed marginal sea, up to **19 km sediment layer** in the Western basin
- **Anoxic conditions** favour the formation of methane
- Widespread presence of oil and gas
- **Presence** of submarine **gas hydrates** inferred from seismic **bottom simulating reflectors (BSR)** marking the **base** of the **gas hydrate stability zone (GHSZ)**
- **Multiple BSR** due to climate-related sea level changes
- **Danube Delta** considered as a possible **test drill site** for **methane production** from gas hydrate



Popescu *et al.*, 2006

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## Two Marine CSEM Experiments




- HYDRA: seafloor towed electric dipole-dipole system → 2D profile data
- SPUTNIK: mobile CSEM Source & EM Receivers → 3D data set

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## HYDRA: seafloor-towed electrical dipole-dipole system




Tx Rx1 Rx2 Rx3 Rx4




**HYDRA**



**Pig**




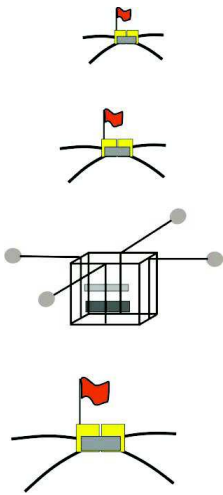
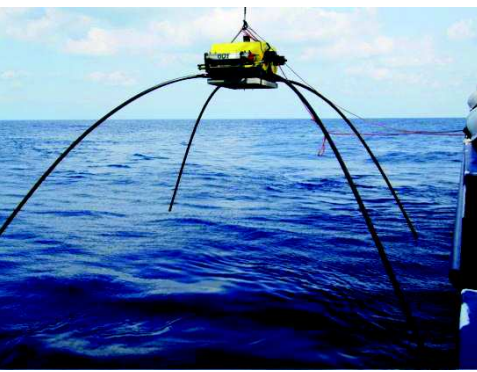
**Receiver Unit**



**New Seafloor Signal Generator**

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## SPUTNIK and Lobster EM Receiver

**GEOMAR**

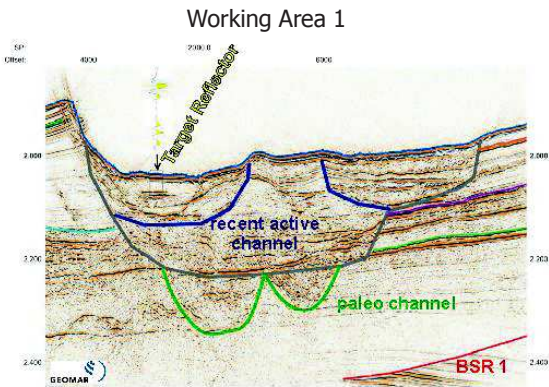
2 orthogonal 10 m long source dipoles

Seafloor EM receiver

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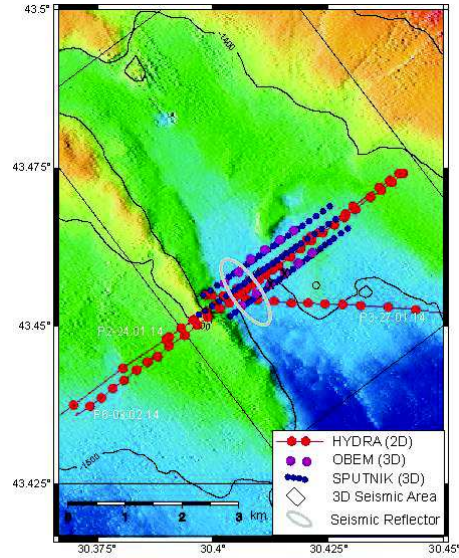
## Target Area: Danube Delta



Timo Zander, Geomar, 2014

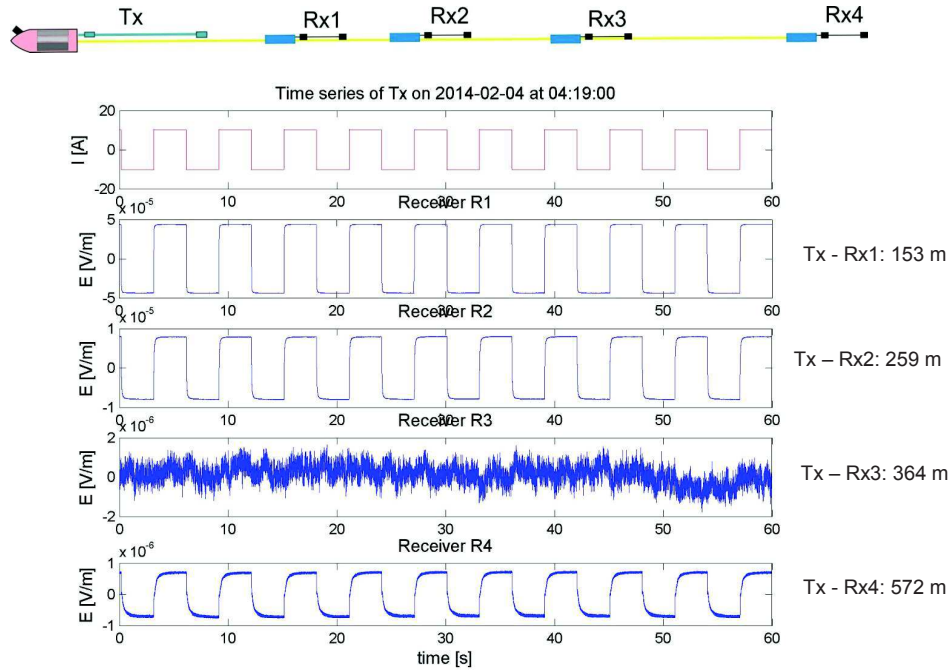
- Sediment filled Danube channel system
- High seismic amplitude reflections, partly inverted polarity
- Multiple BSR, BSR1 at ~330 mbsf
- High amplitude Target Reflector at about 100 mbsf

- 2D Survey with HYDRA, 3 profiles
- 3D Survey with SPUTNIK & LOBSTERS, 10 sites, 81 transmission points



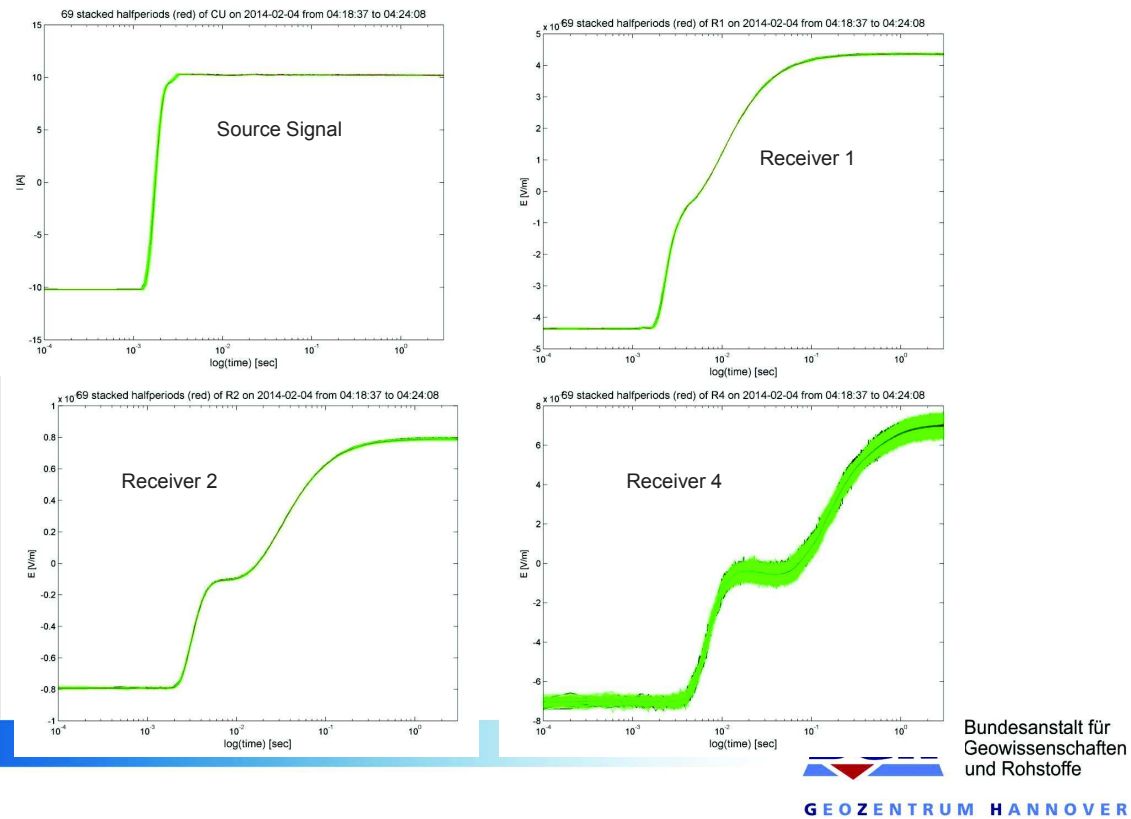
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## HYDRA Data Example



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## HYDRA Data Example

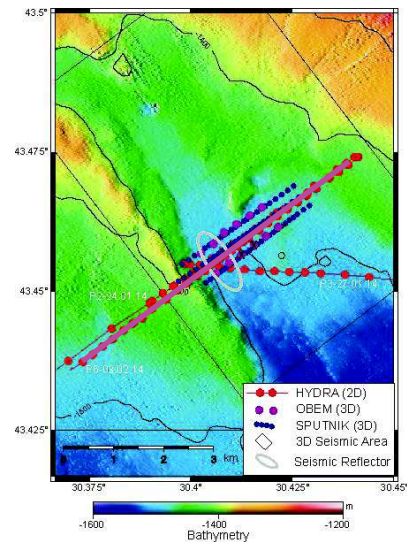


## Overview: HYDRA Data Inversion



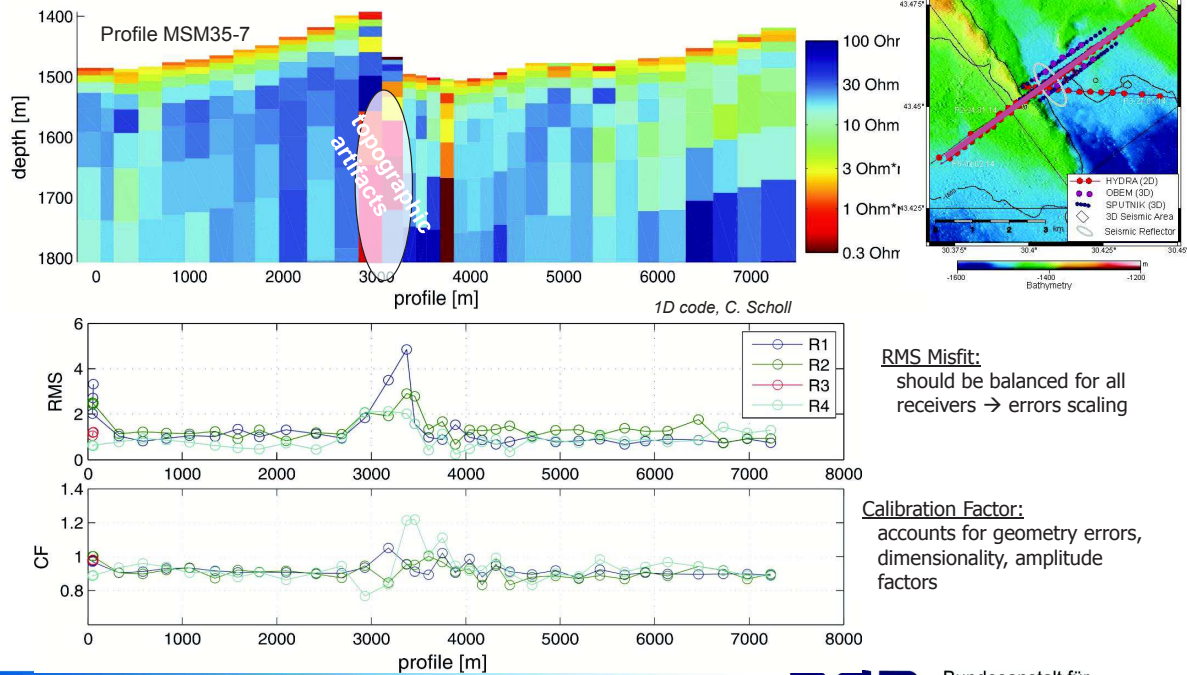
### Profile MSM 35-7:

- 1) 1D Occam Inversion (*code by Carsten Scholl, CGG-EM*)
- 2) 2D Occam Inversion (*code by Carsten Scholl, CGG-EM*)
- 3) 2D Occam Inversion MARE2DEM (*Kerry Key, Scripps*)
- 4) Comparison: Seismic  $\leftrightarrow$  CSEM
- 5) 1D Resolution Study, Marquardt Inversion with Random starting models (*C. Scholl*)
- 6) 1D Bayesian Inversion (*Romina Gehrman, UVIC / BGR*)



## Inversion 1

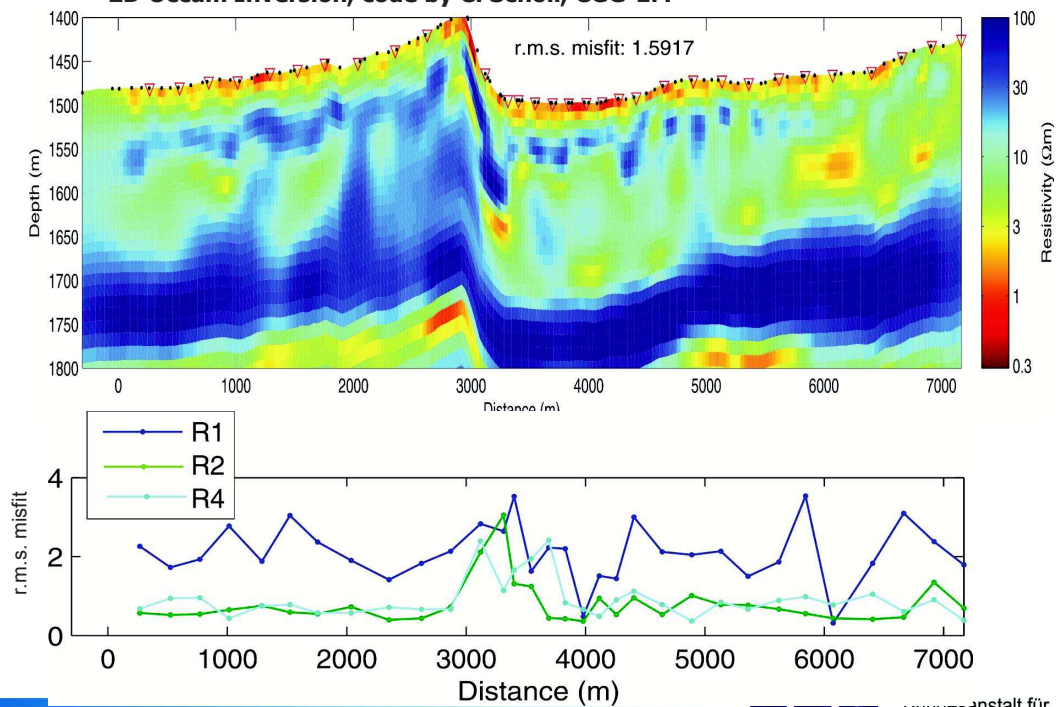
Stitched 1D Occam Inversion, code by C. Scholl, CGG-EM



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## Inversion 2

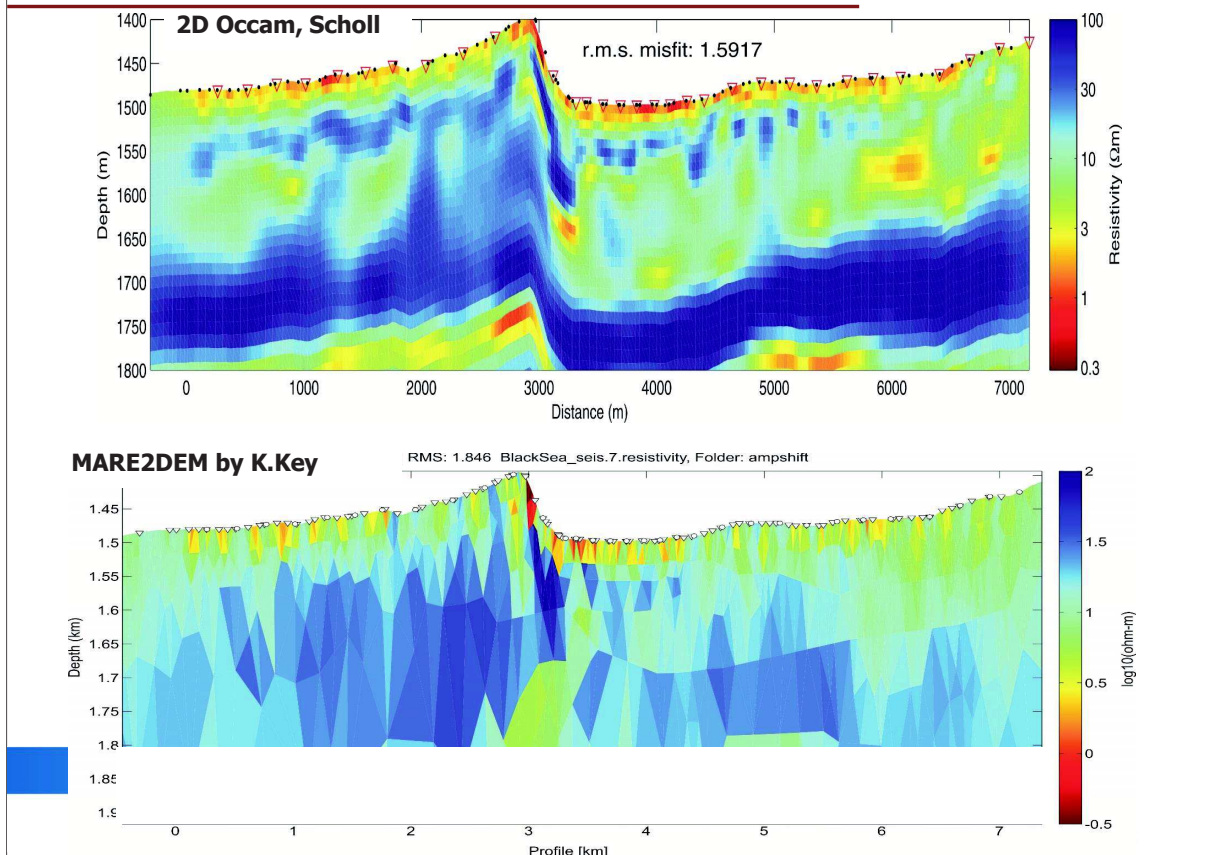
2D Occam Inversion, code by C. Scholl, CGG-EM



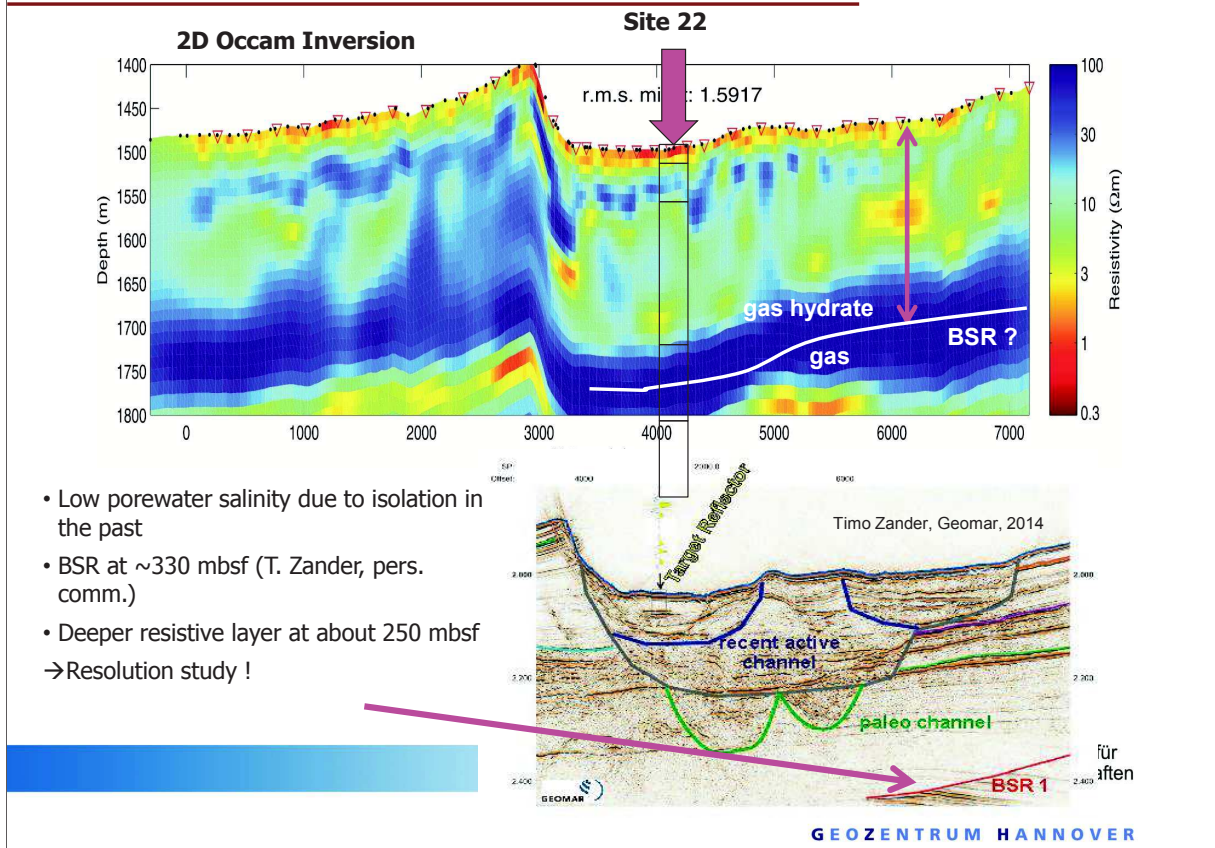
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### Inversion 3

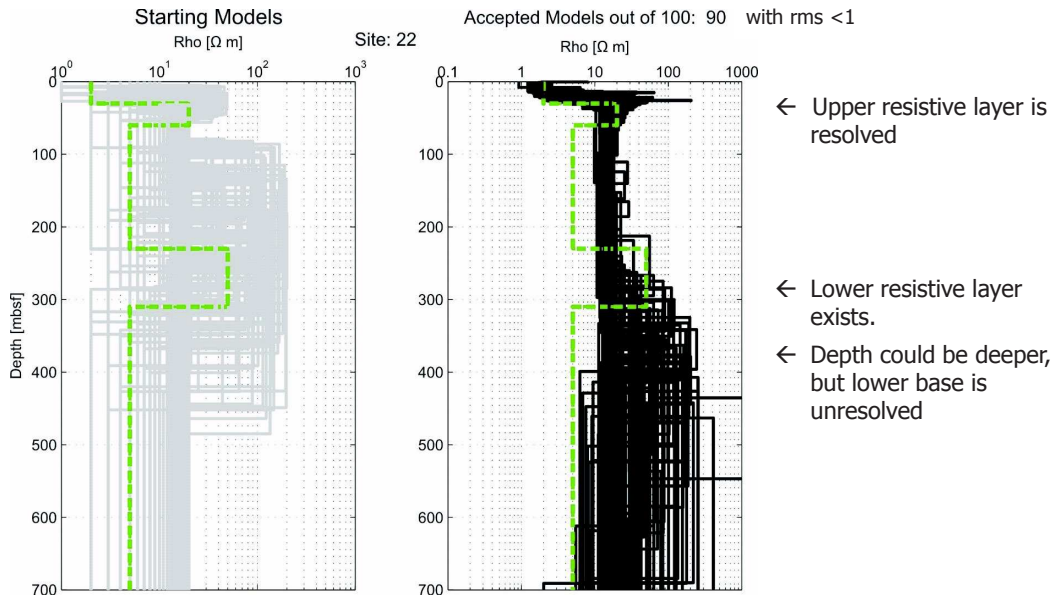


### Comparison: Seismic & CSEM

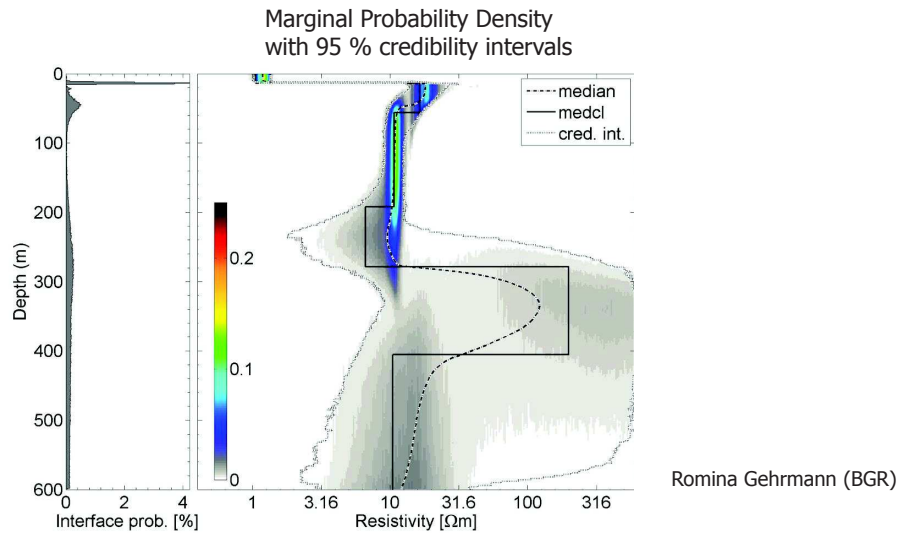


## 1D Resolution Study

### Random Starting Models for Marquardt Inversion



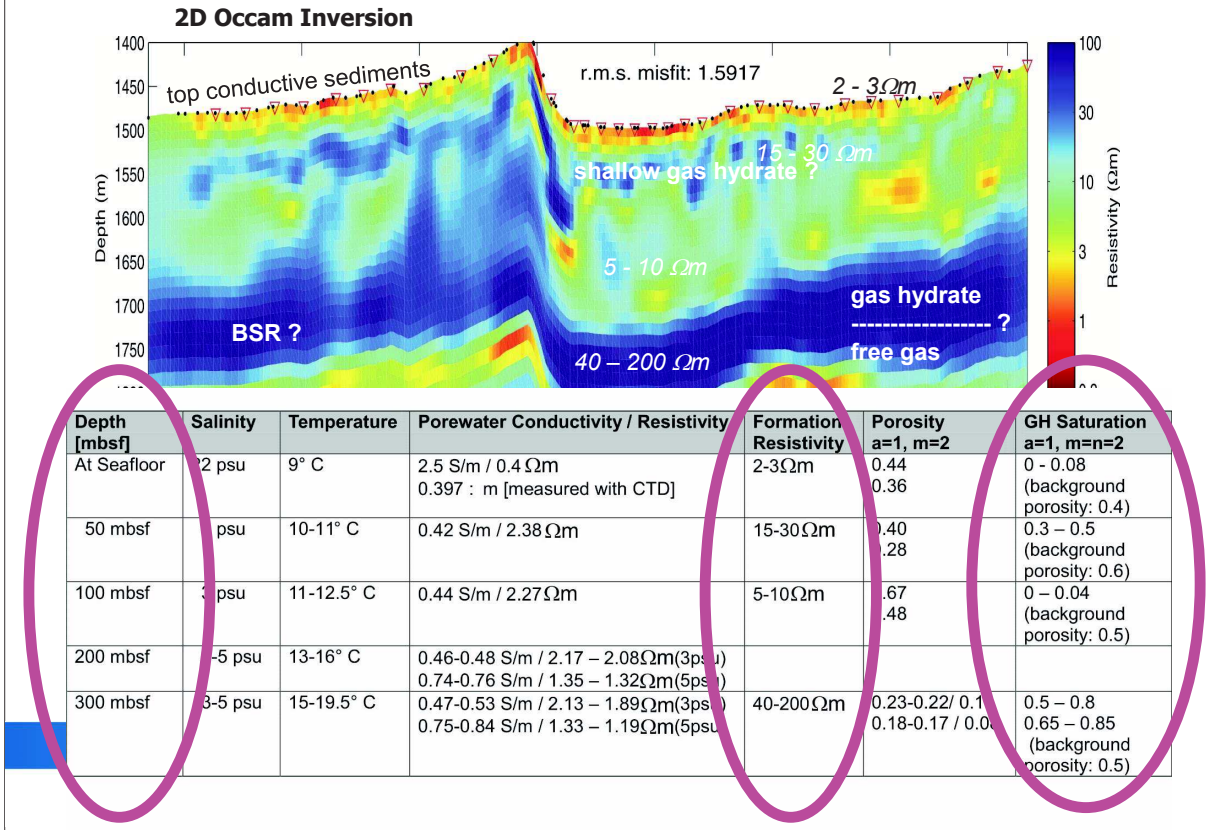
## 1D Bayesian Inversion, Site 22



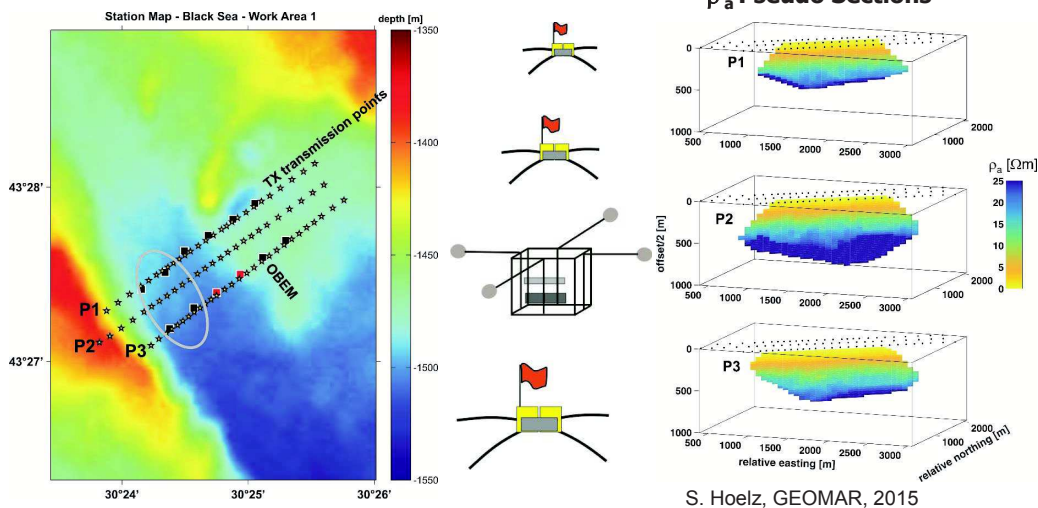
- Top layers: High interface probability and low uncertainties
- Bottom resistive layer: Existing, but low credibility and interface probability



## Interpretation

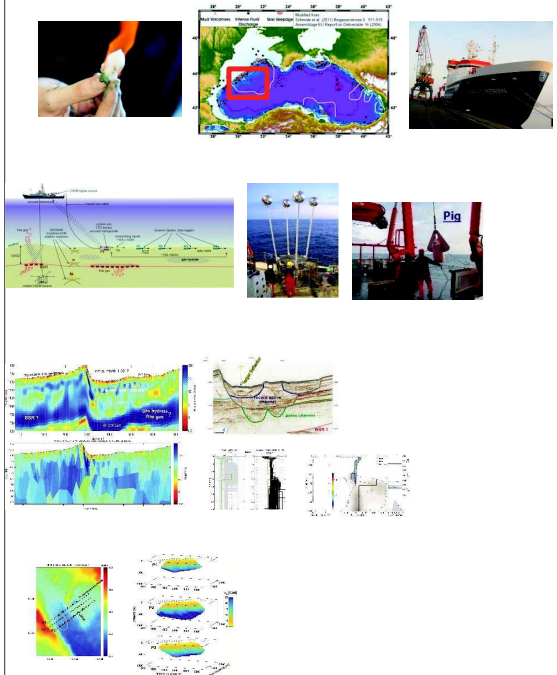


## Preliminary Results 3D Survey, Lobster & Sputnik



- General increase in resistivity with depth
- Higher penetration depth at profile P2
- Next step: 2D, 3D inversion

## Summary




- Objective: Evaluation of submarine gas hydrates in the Western Black Sea using CSEM
- MERIAN Cruise MSM35, January 2014
- Site Survey, Test drill site
- 2 CSEM Systems: HYDRA – 2D profiles, Sputnik, Lobster - 3D survey
- HYDRA: 1D/2D Inversion and Resolution Study.
- Comparison with seismic,
- High resistivity partly due to fresh porewater and high gas hydrate saturation
- 3D survey: Pseudo sections show increase in resistivity with depth

**Thanks for your attention!**



## Acknowledgements:

- We thank the Captain and Crew of M.S. MERIAN voyage MSM35
- Thanks to our technicians (Joachim Deppe, Boris Hahn, Martin Wollatz-Vogt, Patrick Schroeder)
- Carsten Scholl CGG-EM for 2-D Inversion of the data
- The  Project was/is supported by BMBF Grant 03G0688A, and BMWi Grant 03SX320Z
- Thanks to MAGSON GmbH, Berlin, for collaborations around electronic developments