

## **Geophysikalische Untersuchungen von Rohstoffen im Meer - Exploration und Nutzungsperspektiven**

### ***Submarine Resource Evaluation using Geophysics - Exploration and Future Usage***

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# Outline

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- Overview: Marine Geophysical Methods
- Germany needs Energy and Mineral Resources
- Marine Geophysical Exploration

Case Study 1: Submarine Gas Hydrates, Project SUGAR

Case Study 2: Seafloor Massive Sulfides, Project INDEX

- Summary

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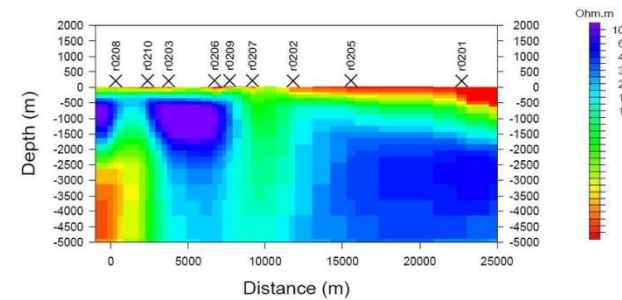
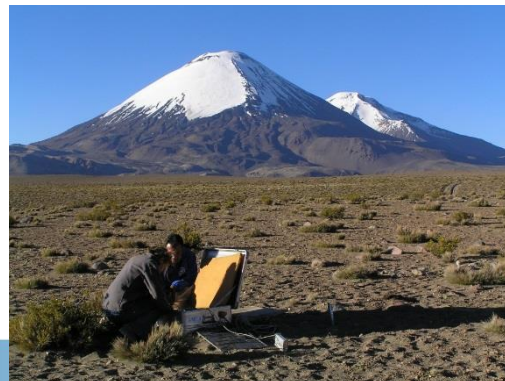
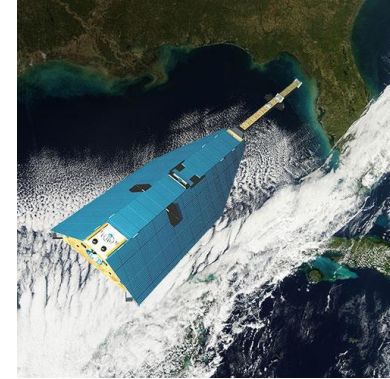
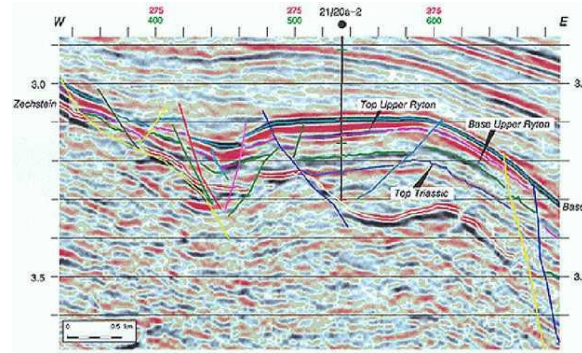
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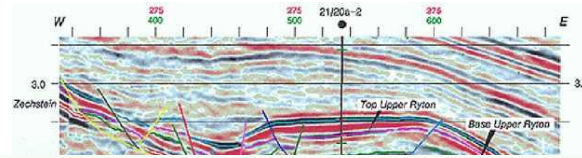
# What is Geophysics?



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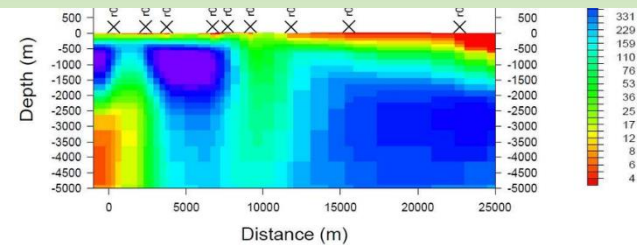
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# What is Geophysics?



## Understanding Earth systems using geophysical methods

- Plate tectonics
- Ground water systems
- Waste depositories
- Geo-engineering
- Energy Resources
  - Conventional (oil, gas, coal)
  - Unconventional (tight gas, oil sands, gas hydrates)
- Mineral Resources (ore deposits, Mn-nodules, massive sulfides)



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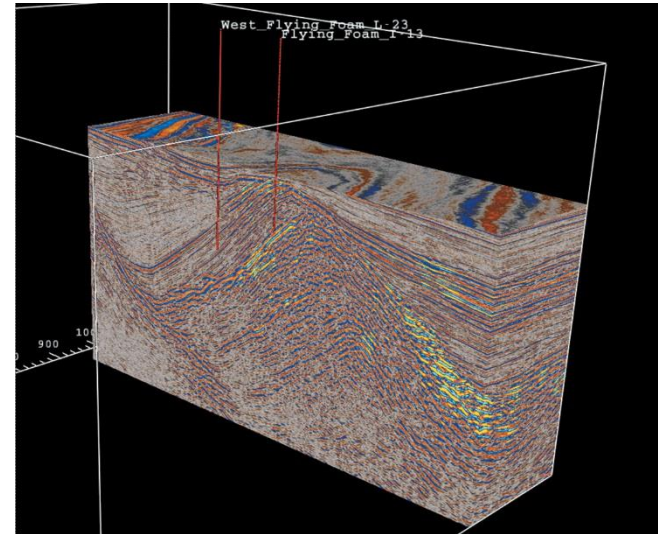
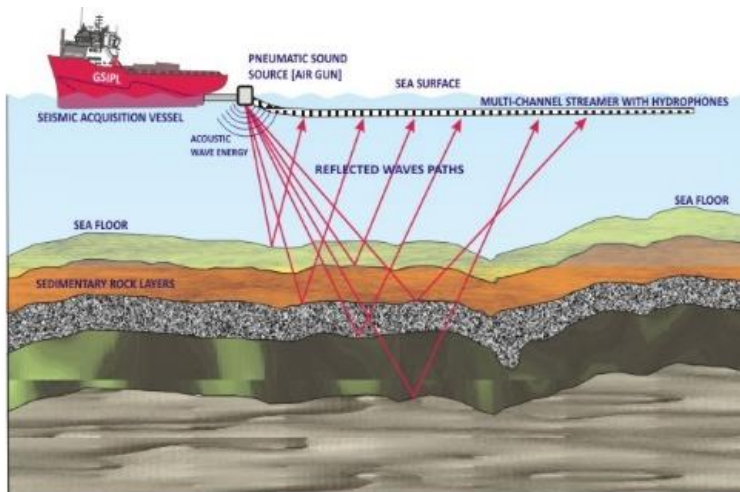
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# Marine geophysical resource exploration



## 2D / 3D Seismic

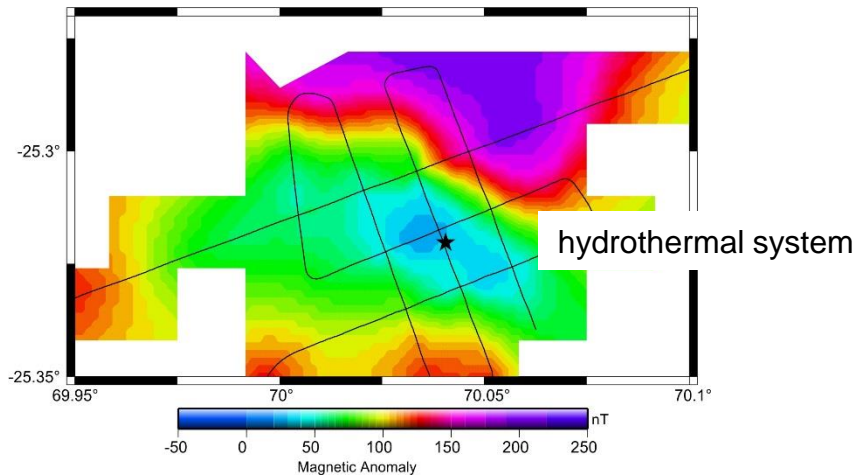
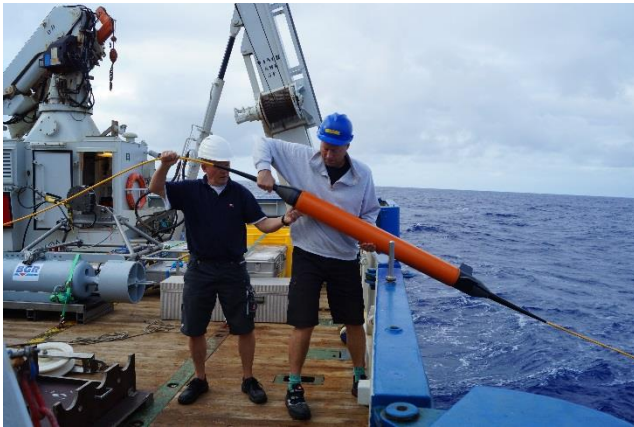
- Acceleration of ground / seafloor due to acoustic pressure waves
- High resolution structural images
- Seismic velocity information
- Density, porosity



# Marine geophysical resource exploration

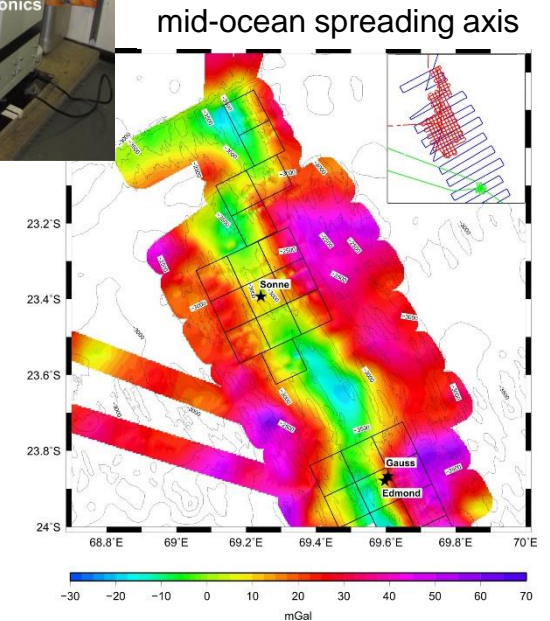
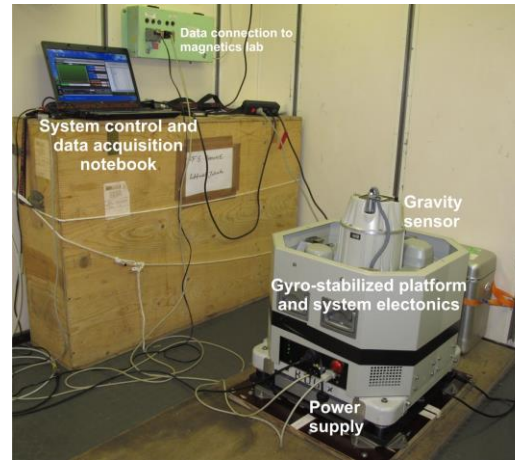
## Marine Magnetics

- Natural magnetization of rocks

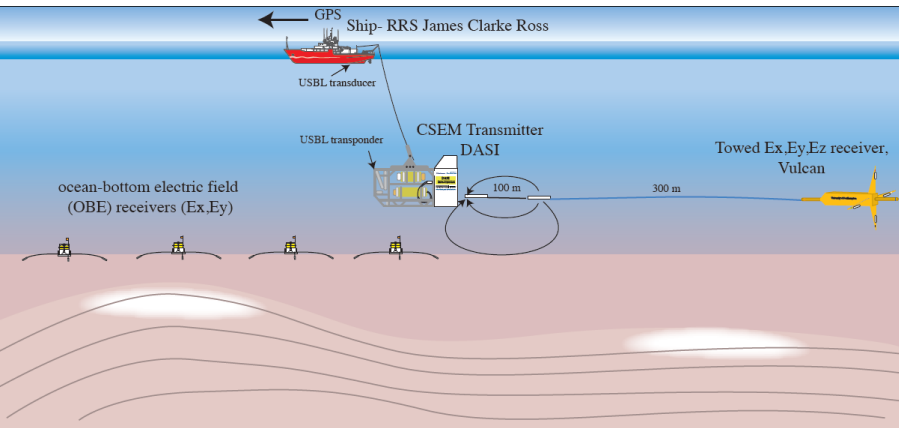


## Marine Gravity

- Natural density of rocks

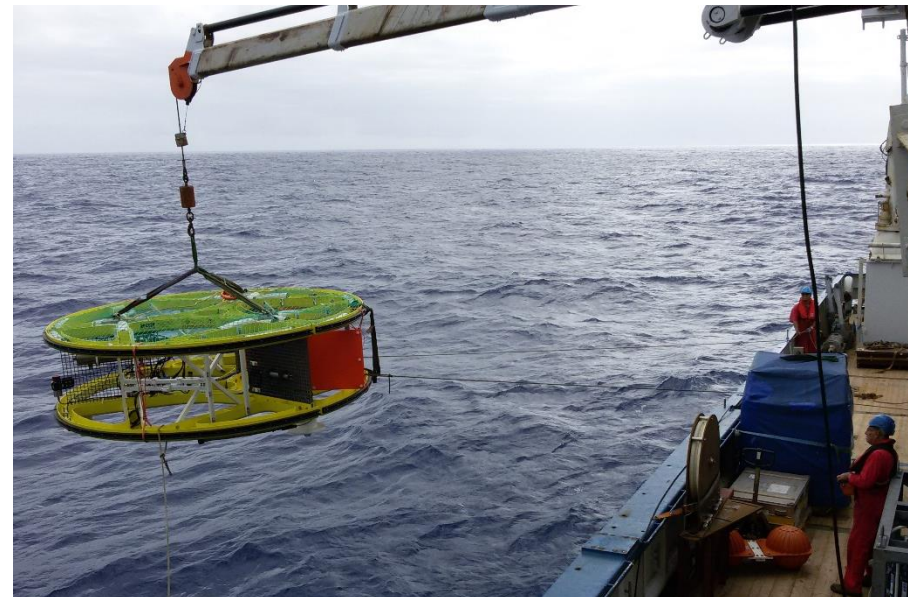
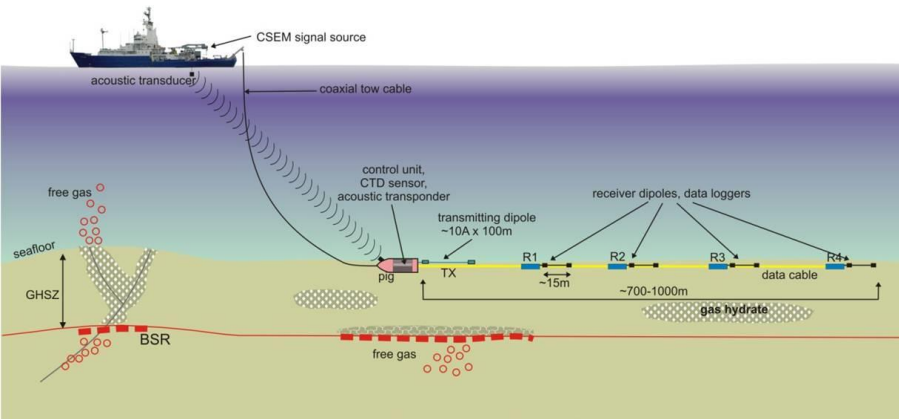


# Marine geophysical resource exploration



## Marine Electromagnetics (CSEM)

- Electrical properties of seafloor
- Porosity, nature of pore fluid





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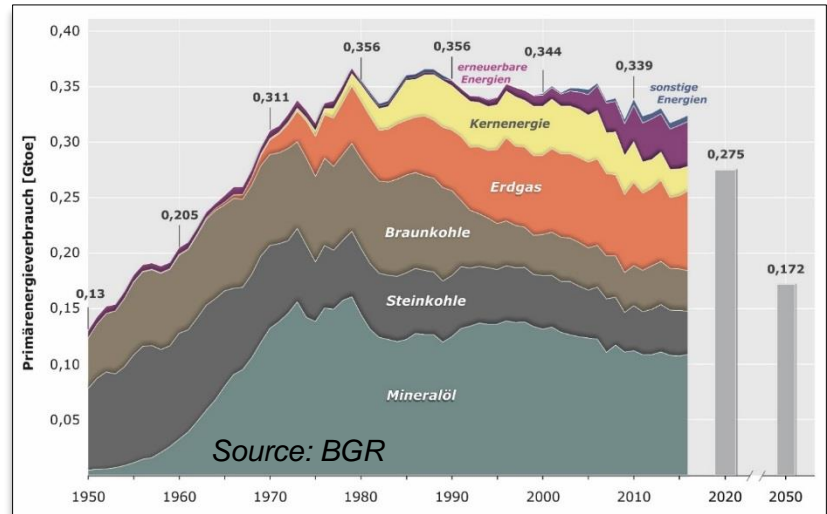
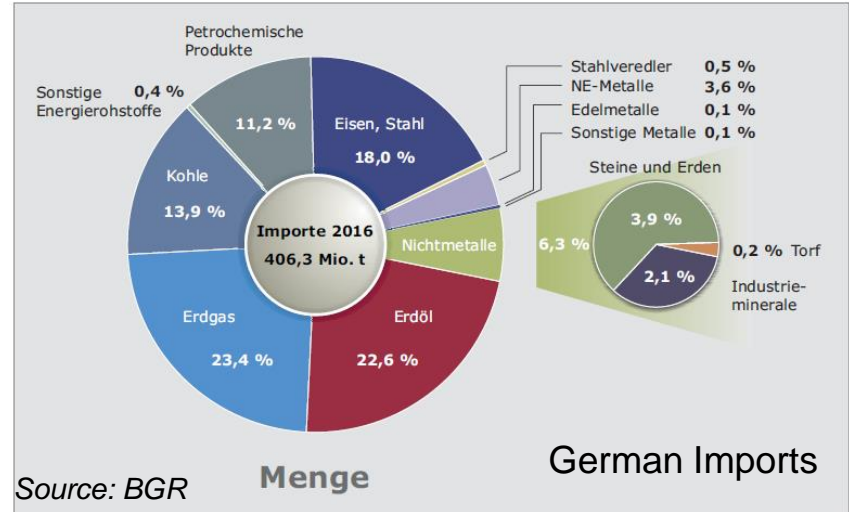
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- **Germany needs Energy and Mineral Resources**
- Marine Geophysical Exploration

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# Germany depends on Energy and Mineral Resources



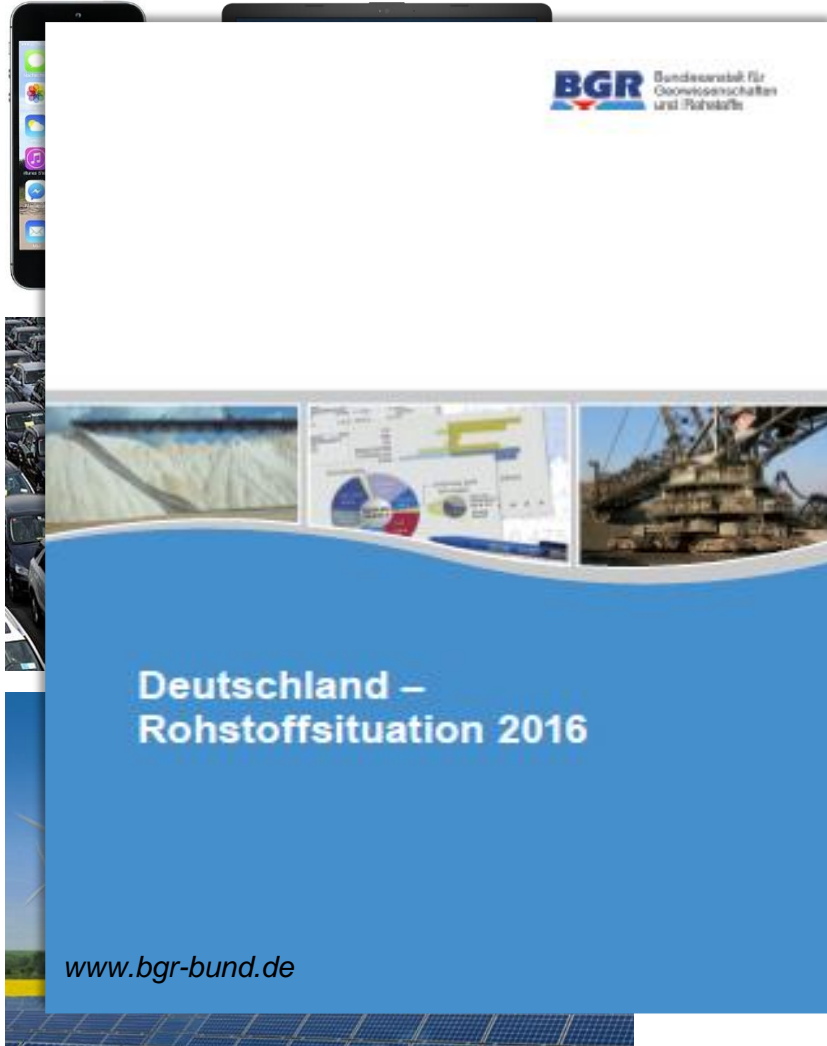
Oil, Gas, Coal, Cu, Sn, Pb, Ni, Te, Co, Au, Ag,...



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# Germany depends on Energy and Mineral Resources



Oil, Gas, Coal, Cu, Sn, Pb, Ni, Te, Co, Au, Ag,...

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- Germany needs Energy and Mineral Resources
- **Marine Geophysical Exploration**

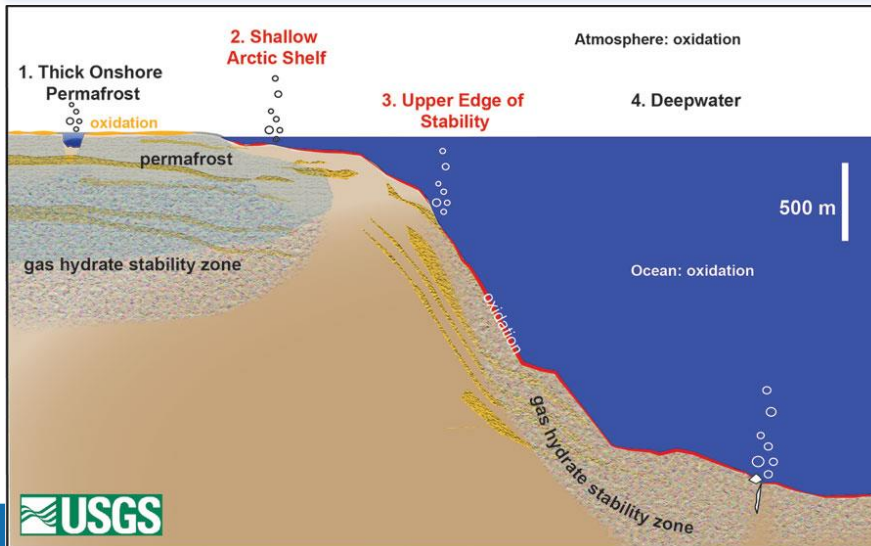
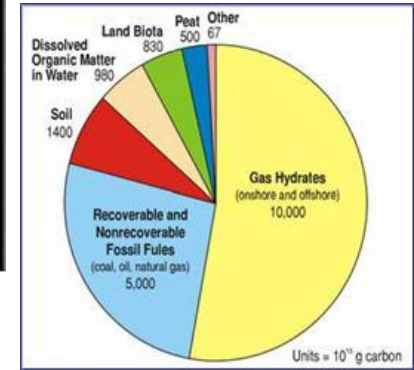
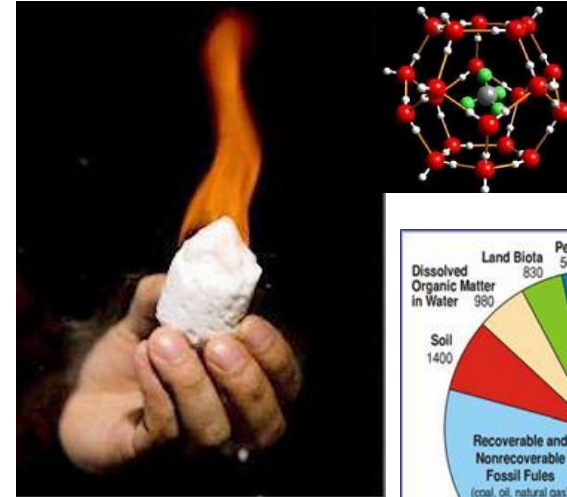
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# Submarine gas hydrate exploration

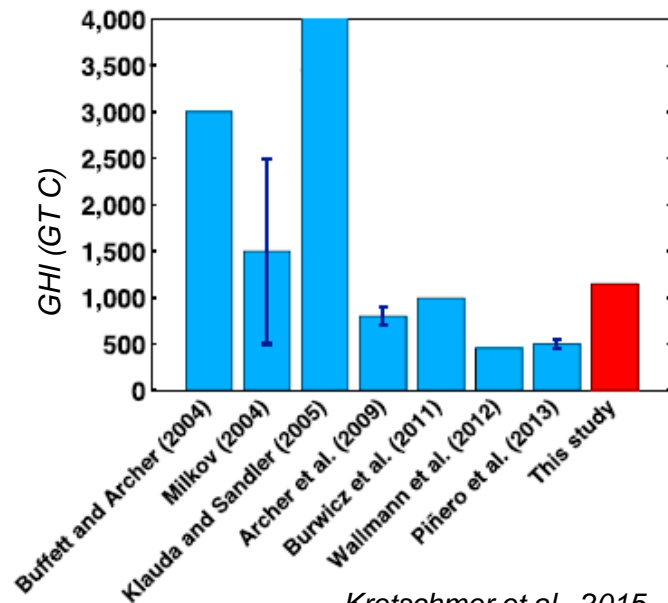
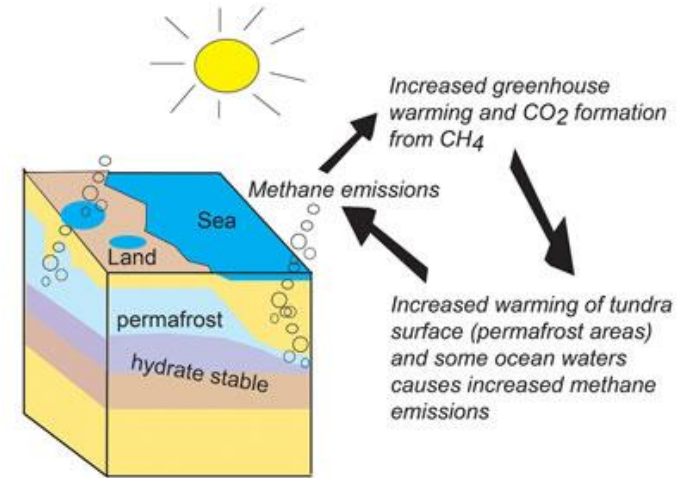
- Ice-like solids
- Cage-like molecule structure of water and gas (mainly methane)
- Stable at high pressure, low temperature
- Occurrence worldwide at continental margins, deep lakes, and permafrost
- Energy potential exceeds conventional resources (oil, gas, coal)



# Submarine gas hydrate exploration

## Problems and Challenges

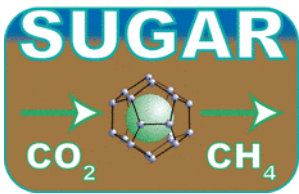
- Climate factor - CH<sub>4</sub> is potent greenhouse gas
- Accurate resource assessment
- Stability conditions require advanced methane production technologies (first production tests in permafrost, and offshore)



Kretschmer et al., 2015



JOGMEC, Japan, 2013, 2017



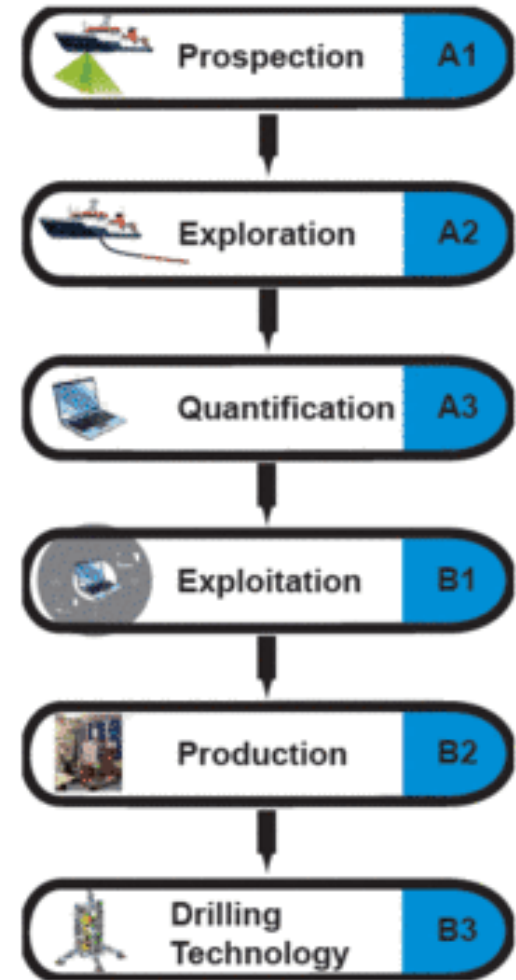
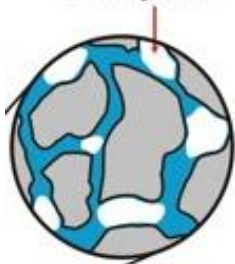
# Submarine gas hydrate exploration

- Joint Venture Project, 30 Partners from Academia and Industry
- Run time: 2008-2018 (3 phases)
- Funding: BMBF and BMWi

## Geophysics:

- Identification and quantification of gas hydrates
- **Seismic** → structural information, BSR, gas chimneys
- **Electromagnetic** → volume information, electrical properties (gas hydrate – resistive; pore fluid - conductive)

Gas Hydrate



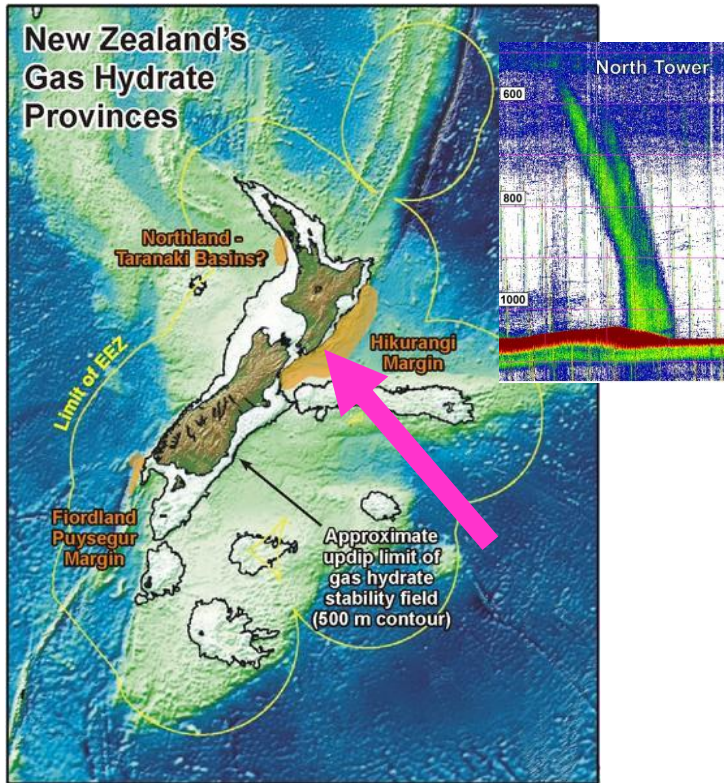
[www.sugar-projekt.de](http://www.sugar-projekt.de)



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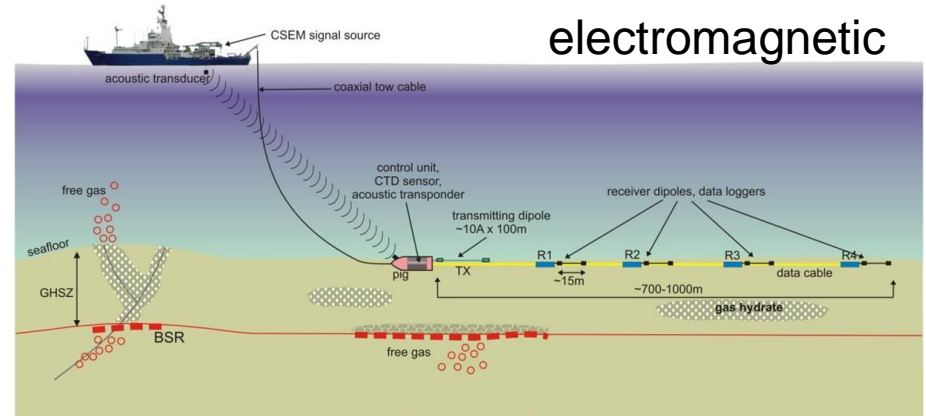
# Case Study: Gas Hydrate, New Zealand



seismic



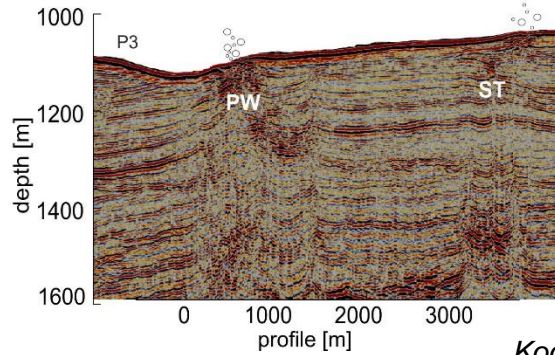
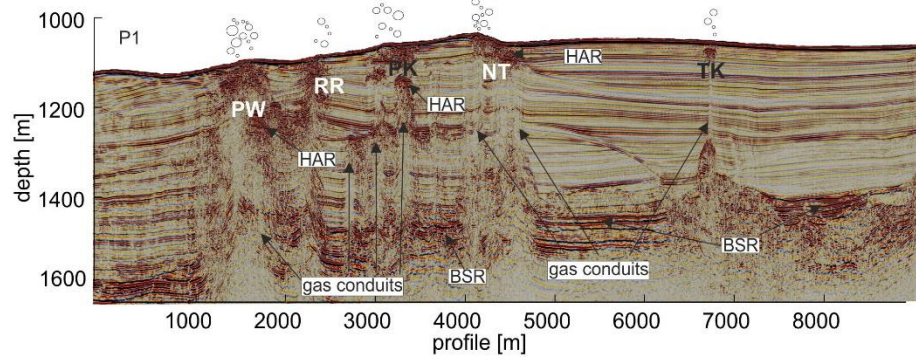
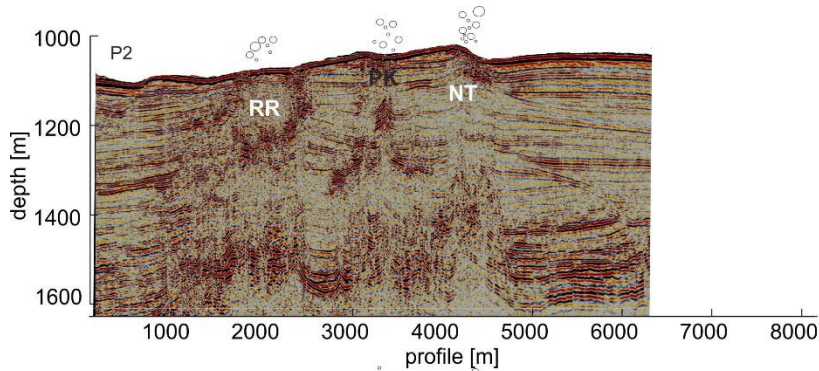
electromagnetic



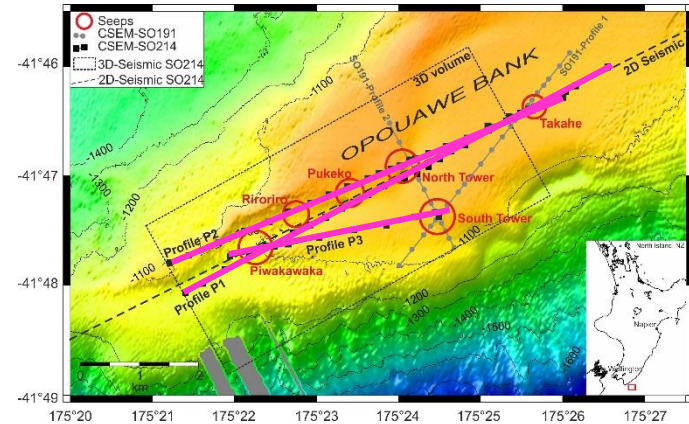
- 1100 m water depth (GH are stable)
- Methane seepage



# Case Study: Gas Hydrate, New Zealand



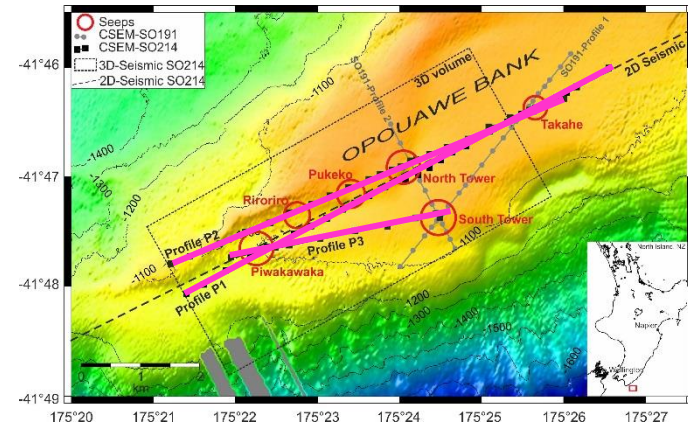
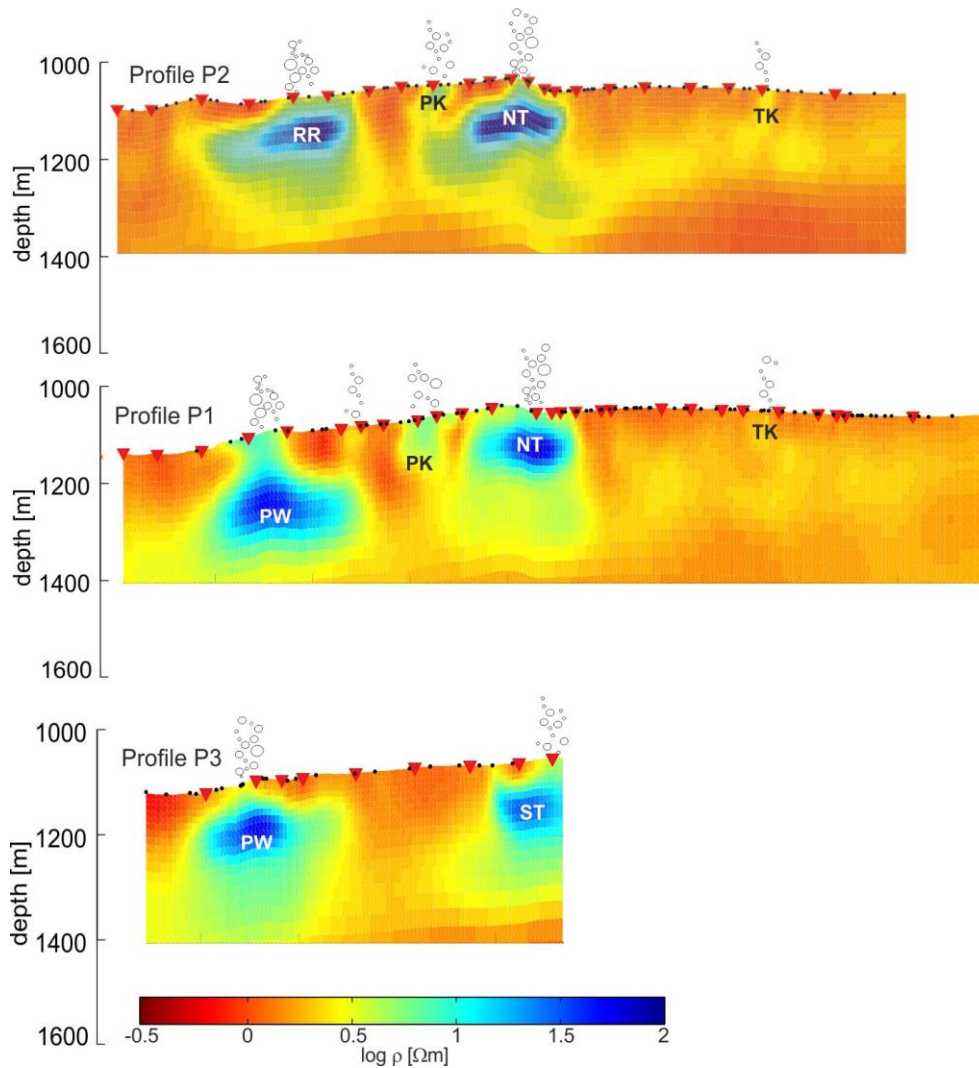
Koch et al., 2015



## 2D / 3D Seismic

- Bottom Simulating Reflector (BSR)
- Gas migration pathways
- Amplitude anomalies

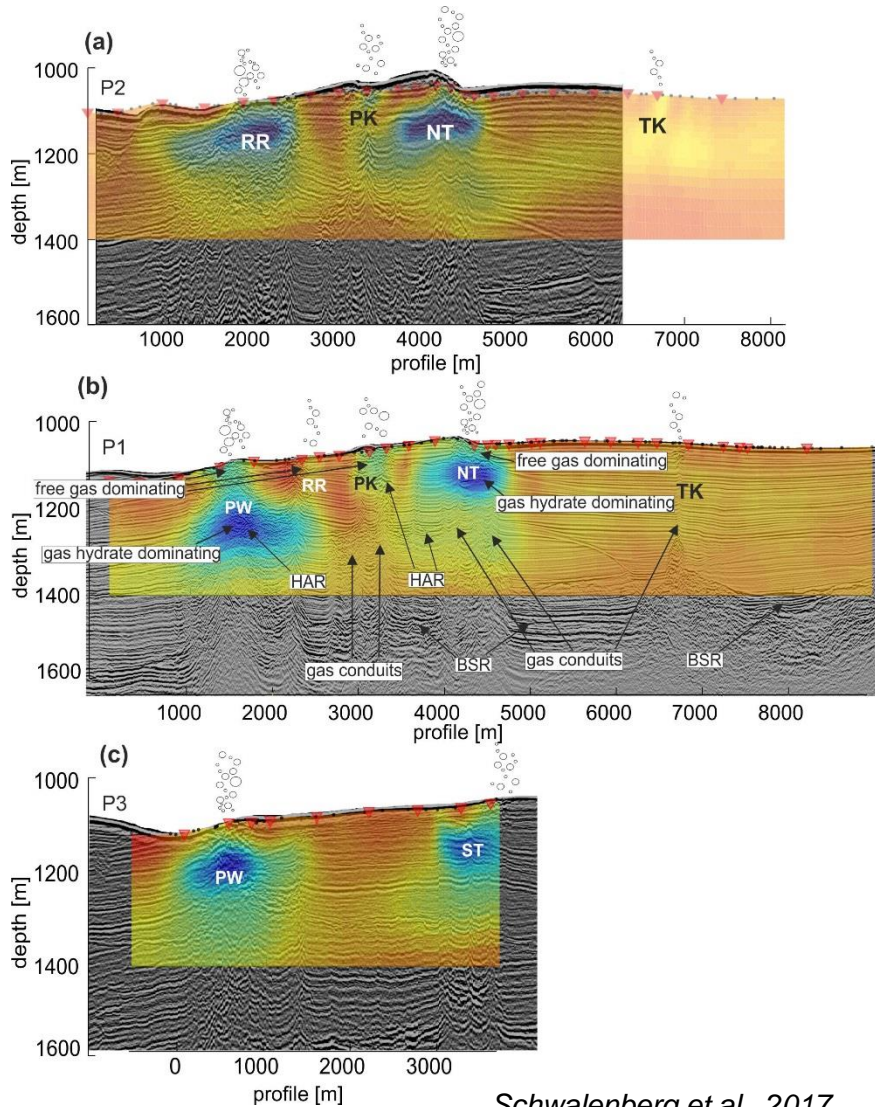
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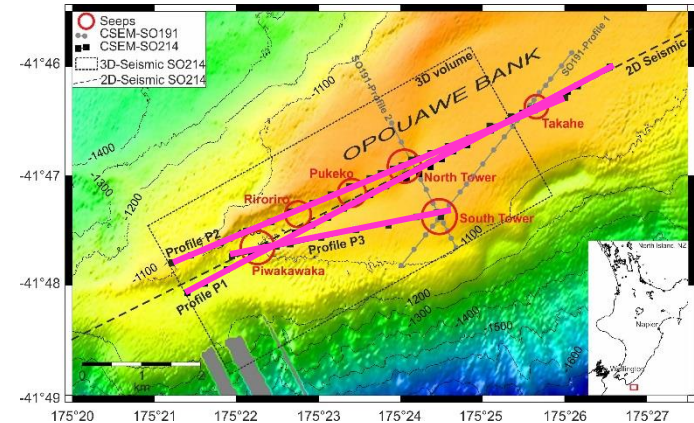
## 2D Electromagnetic

- High resistivity anomalies (free gas, gas hydrate)
- Volume information
- Spatial extent of anomalous zone
- Quantification

# Case Study: Gas Hydrate, New Zealand



Schwalenberg et al., 2017



## 2D Seismic + Electromagnetic

- Correlation of seafloor gas seeps, gas migration and high resistivity anomalies
- Gas hydrate at deeper parts
- Free gas / gas hydrate at shallow parts

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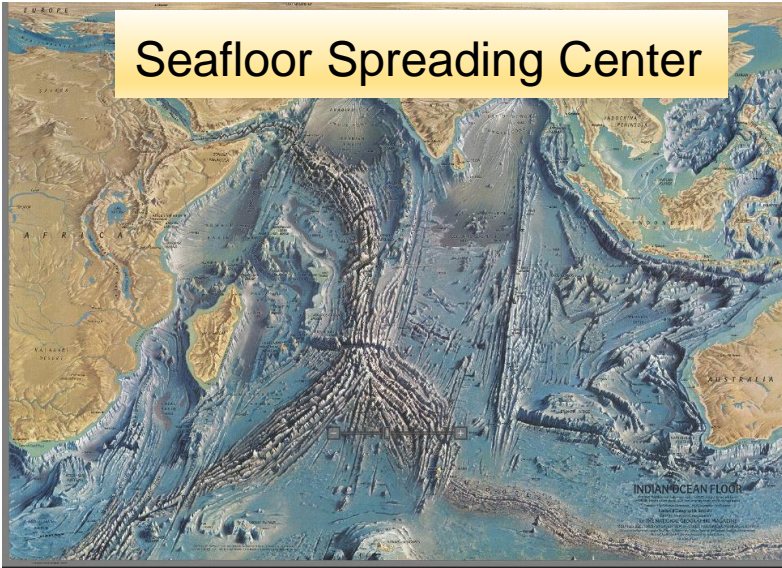
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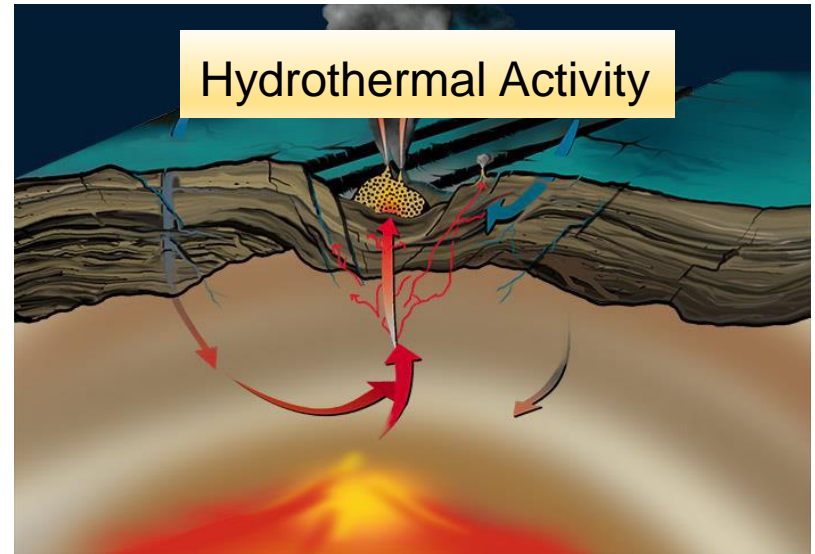
- Summary

# SMS – Seafloor Massive Sulfides

Seafloor Spreading Center



Hydrothermal Activity



Active Black Smoker



Source: BGR

Inactive Sulfide Chimney



Source: BGR

# SMS – Seafloor Massive Sulfides

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- Most sulfidic mineral deposits have formed in the ocean
- Contain high-grade minerals (CU, SN, CO, TE, AU, AG, rare earths, etc)
- Active system have sensitive biosphere
- Inactive system are of interest

## Challenges:

- Small-scale targets (soccer field) in deep waters (1500-4000m)
- Inactive fields have little to no surface expressions



# International Seabed Authority (ISA)

- Established 1994, Kingston, Jamaica, [www.isa.org](http://www.isa.org)
- Autonomous international organization under the 1982 UN Convention on the Law of the Sea (UNCLOS).
- 168 member states
- Regulates prospecting, exploration and exploitation of marine minerals in the international seabed area (belongs to all humankind)
- Licences for Mn-Nodules, Polymetallic Sulfides (SMS), Ferromanganese Crusts
- BGR has exploration licences for Mn-Nodules, and SMS



Source: BGR

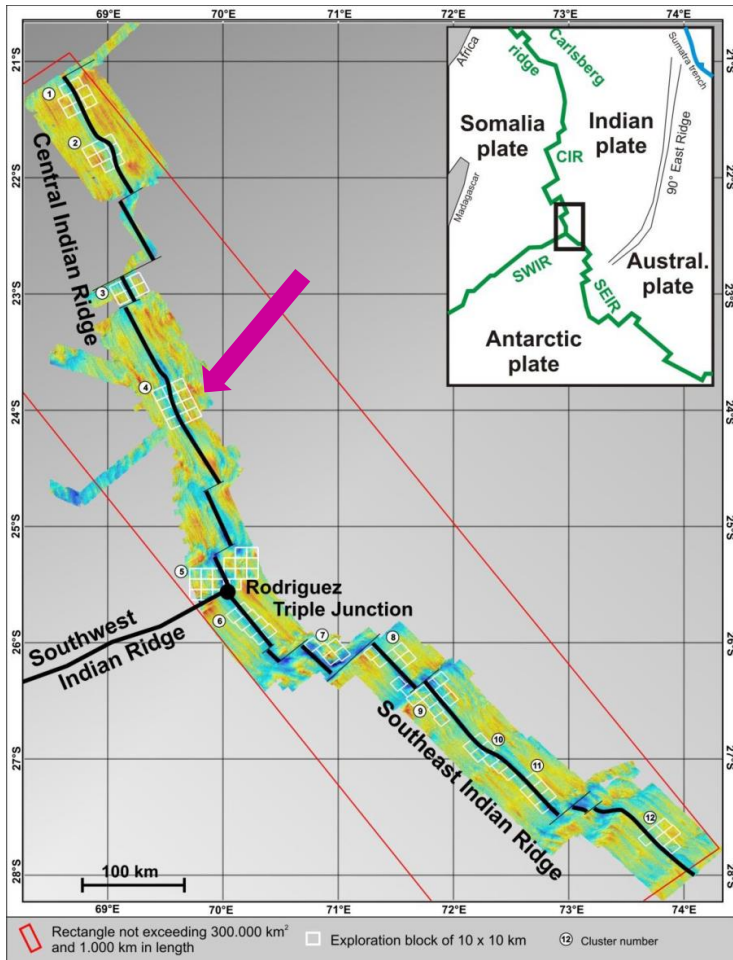


Source: BGR



Source: BGR

# Case Study: German SMS License Area, Indian Ocean

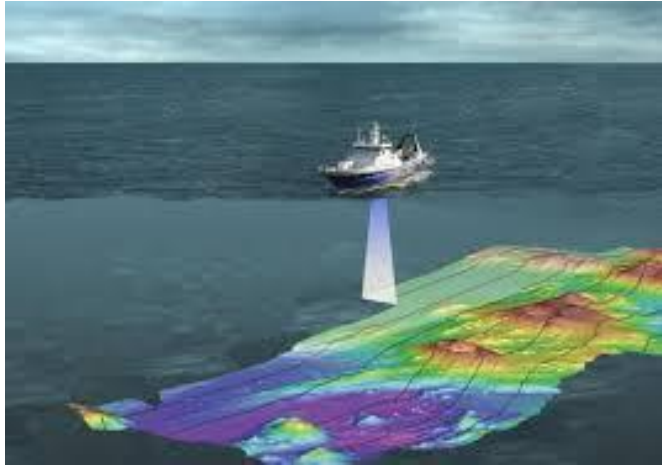


## Project INDEX

- BGR conducts annual cruises
- Identify inactive hydrothermal fields with SMS resource potential
- Multi-disciplinary approach: geology, geochemistry, geophysics, petrology, biology
- Environmental studies



# Case Study: German SMS License Area, Indian Ocean



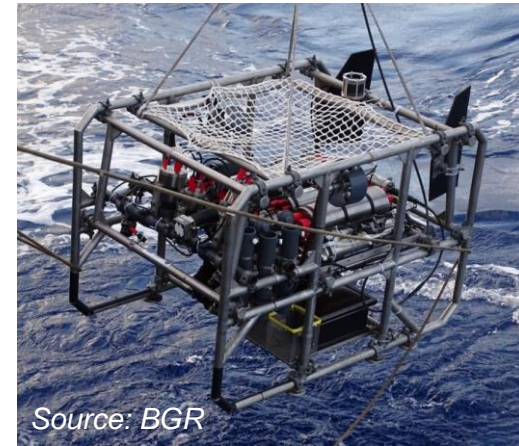
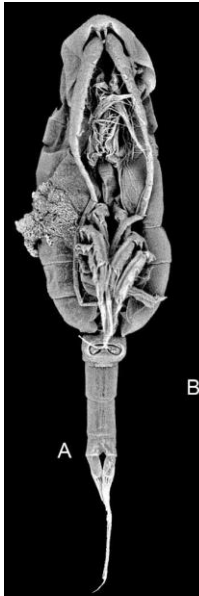
Seafloor Mapping

Water Column

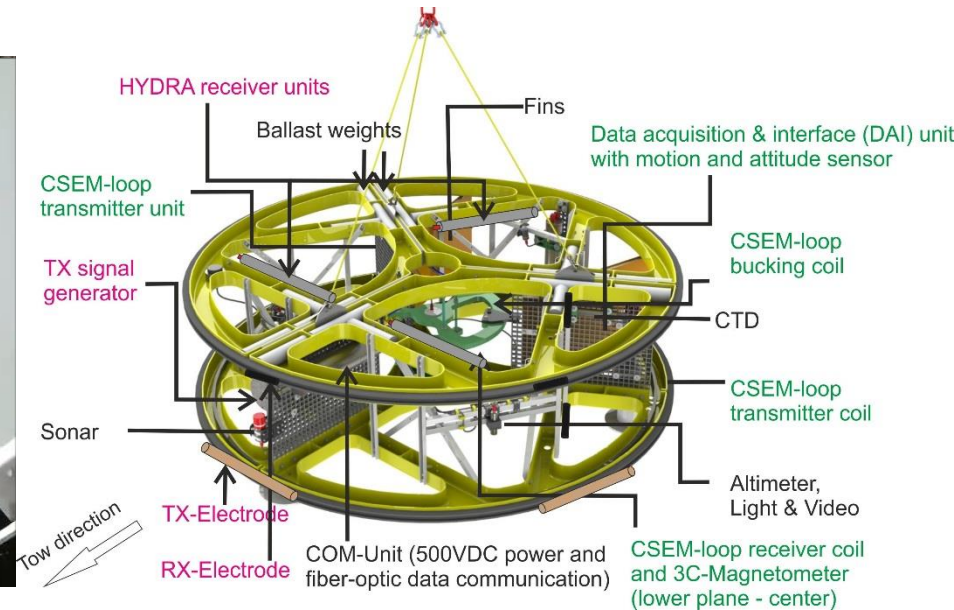
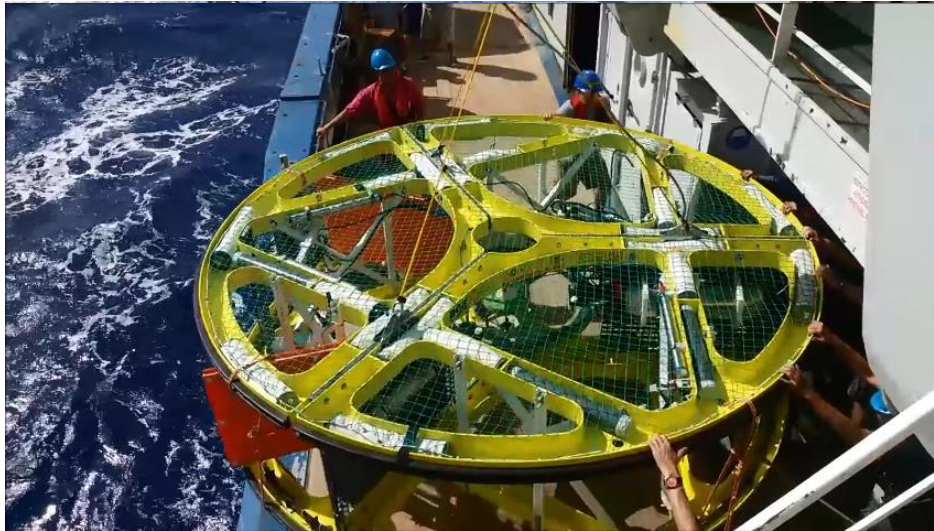
Video, Sampling

Biology

Geophysics



# GOLDEN EYE: Electromagnetic Deep Sea Profiler



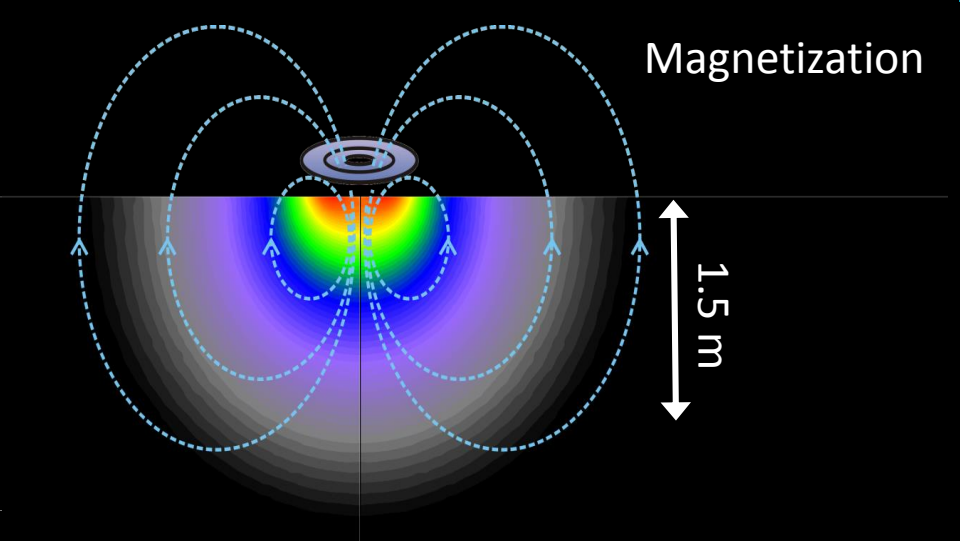
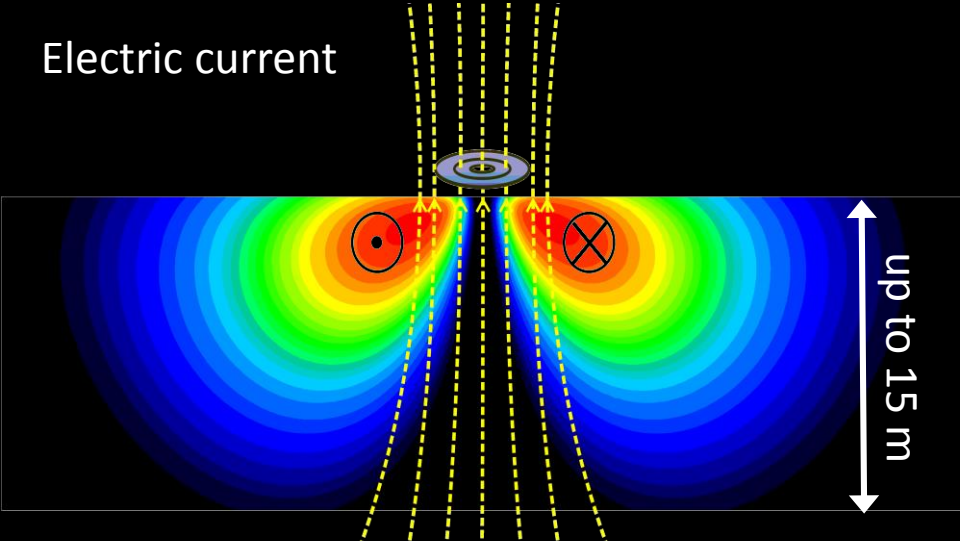
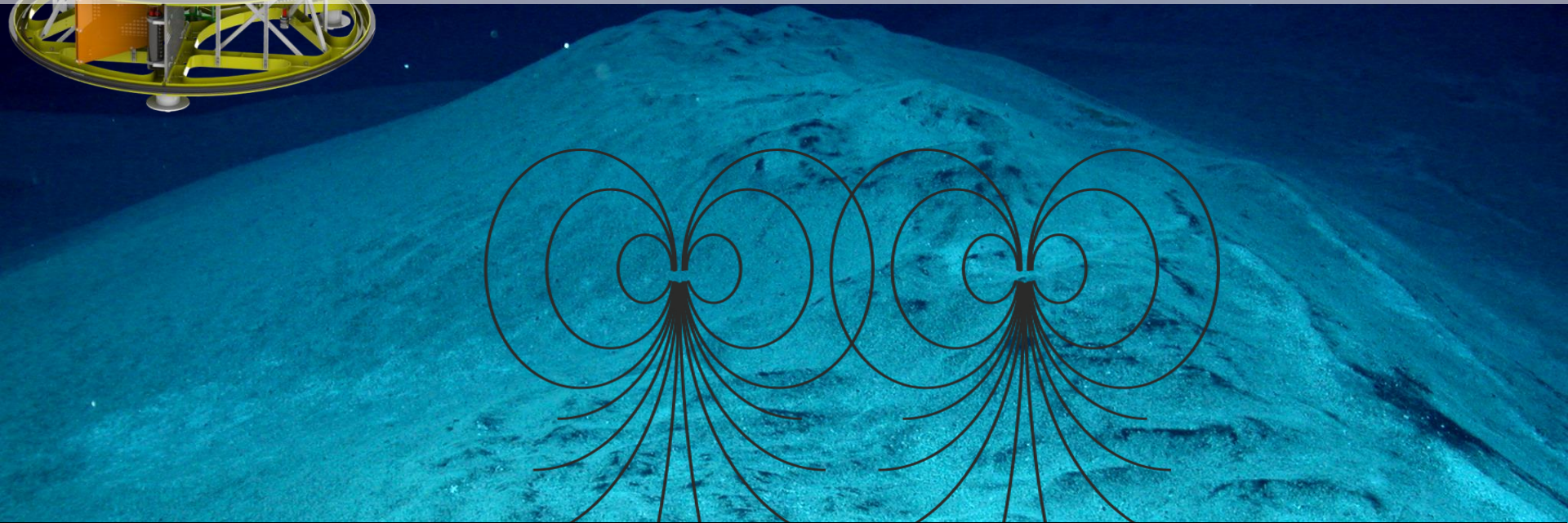
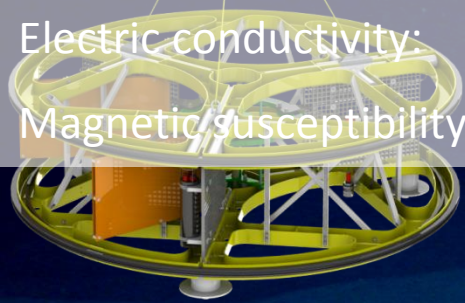
## General:

- Frame: modular, GFK, non-conductive, non-magnetic material
- Power, communication: CU + optical fiber
- Depth resolution: seafloor to ~20m below
- Depth rating: 4000 / 6000m water depth

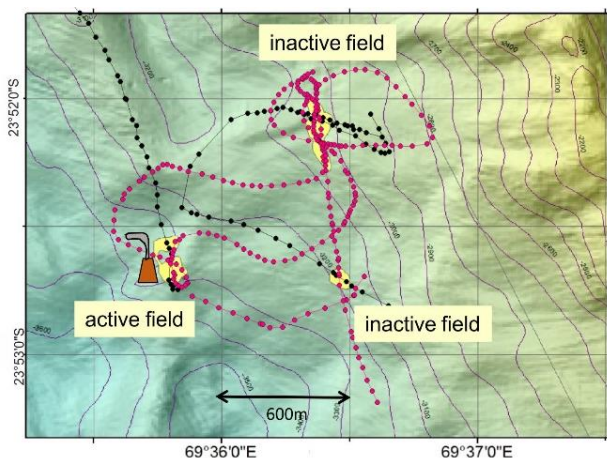
## Sensors:

- CSEM Loop System (conductivity, susceptibility)
- Electric Dipole-Dipole System (conductivity, chargeability)
- Video, Altimeter, Magnetometer, Sonar, CTD

Frequency range: 15 Hz – 20 000 Hz ; Transmitter:  $I = 30 \text{ A}$   
Electric conductivity: Inversion of amplitude and phase of 6-12 operation frequencies  
Magnetic susceptibility: Magnetic field of the subsurface, measured at low frequencies

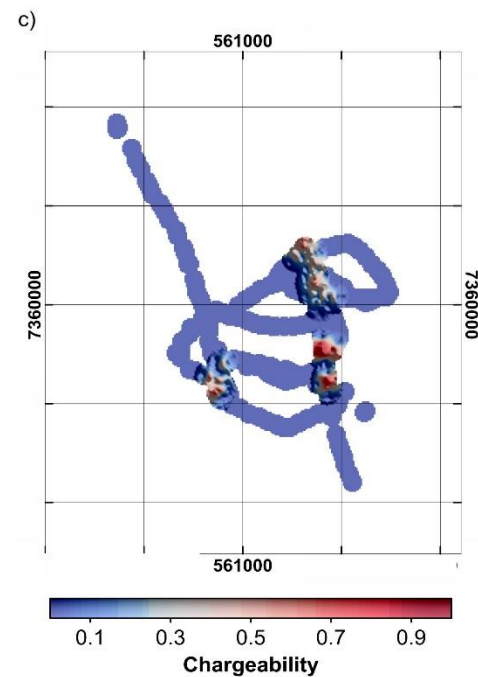
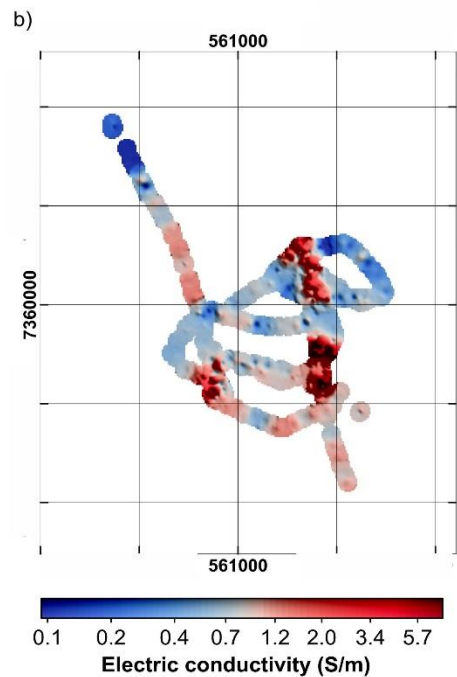
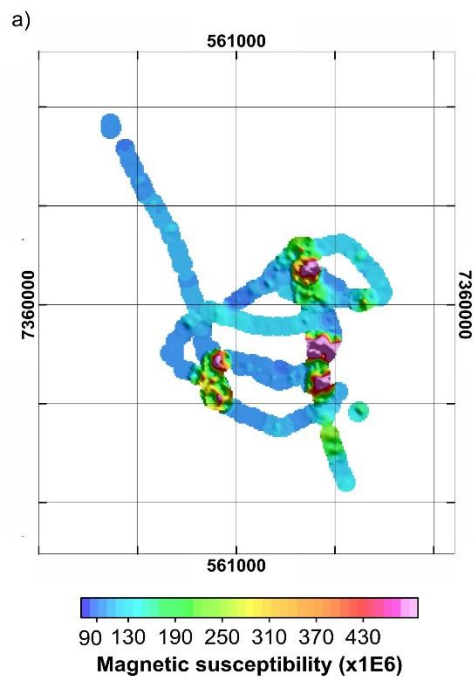


# GOLDEN EYE: Electromagnetic Deep Sea Profiler



## Results:

- High conductivity, susceptibility and chargeability correlate with active and inactive hydrothermal fields
- Anomalies extend beyond video observations
- First **Golden Eye** deep sea survey proves eligibility for SMS exploration



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- Geophysics offers a wide range of methods for submarine resource exploration
- Geophysics is a standard in offshore oil and gas exploration (identification, quantification, drill site pre-study)
- Project **SUGAR**: Submarine gas hydrates have potential as a possible future energy resource
- Project INDEX: New geophysical developments (e.g. GOLDEN EYE) aim at improved mineral resource potential evaluation

*SUGAR-Project was funded by BMBF and BMWi*

*INDEX cruises are conducted by the BGR in the CIR license area, supported by funds from BMWi*



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