SEAFLOOR CHARACTERIZATION BY ELECTROMAGNETIC BENTHIC PROFILING

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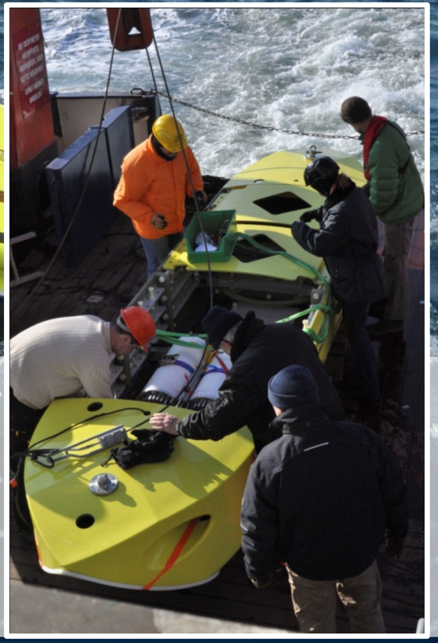
Benjamin Baasch   Thomas Frederichs



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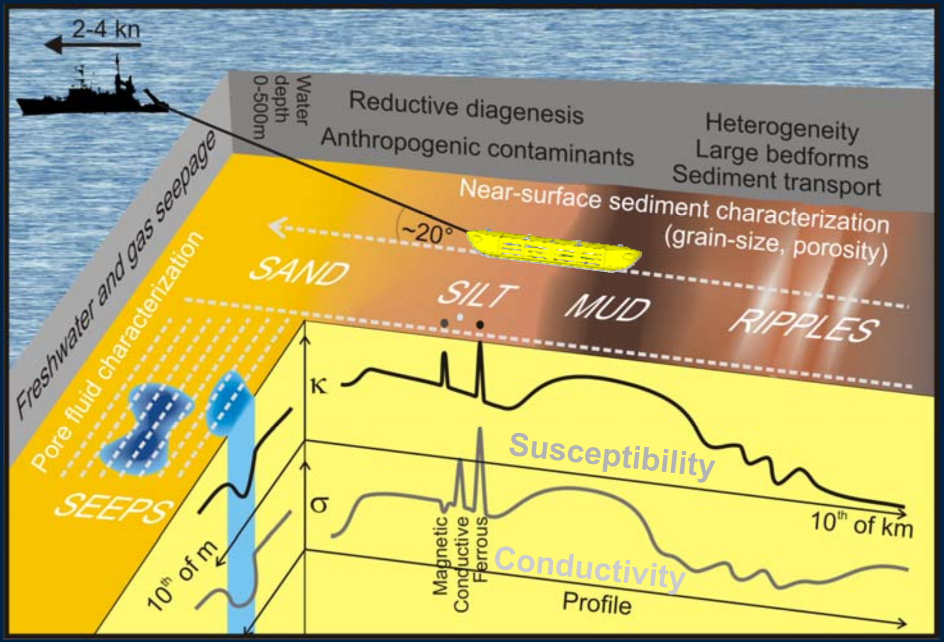
marum   Universität Bremen

Concept and outline



Electric Conductivity

- Relates to the porosity
- Discriminates sediment facies (by grain size and sorting → porosity)
- Detects freshwater or brine seepage
- Detects conductive (metal) objects

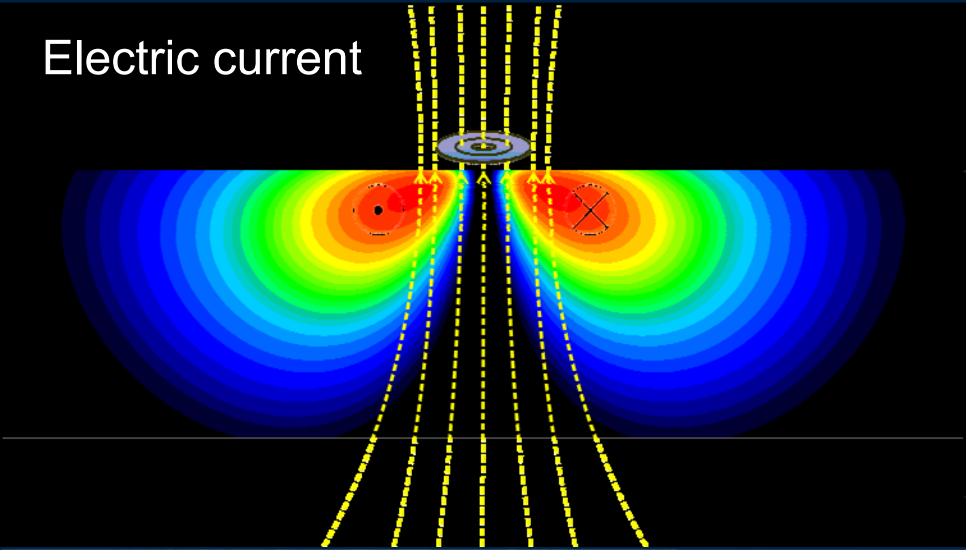
→ **Pore space and fluid**

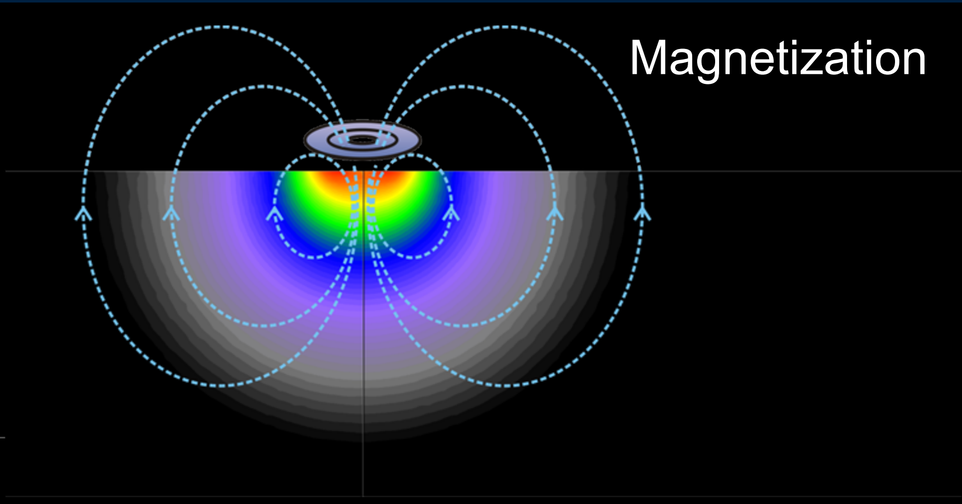
Magnetic Susceptibility → Solid phase / Mineralogy

- Discriminates sediment facies (by magnetite or clay content)
- Maps lateral facies boundaries (infills, sand bars, mud belts)
- Detects shallow reductive diagenesis (e.g. magnetite dissolution)
- Detects Fe metal objects (UXO/pollution by their ferromagnetic properties)

EM-Sensor specification

Sensor type:	GEM 3 - Frequency domain; concentric – coaxial coils
Manufacturer:	Aeroquest Sensortech (formerly Geophex)
Dimensions (diameter):	Transmitter: 0.96 m; Bucking: 0.64 m; Receiver: 0.40 m
Frequencies:	25 Hz – 40 000 Hz (25 Hz sampling rate)
	1-20 kHz → electric conductivity (quadrature)
	75 Hz → magnetic susceptibility (in-phase)
Resolution:	0.1% porosity (10^{-3} S/m), 1 ppm magnetite (10^{-6} SI)



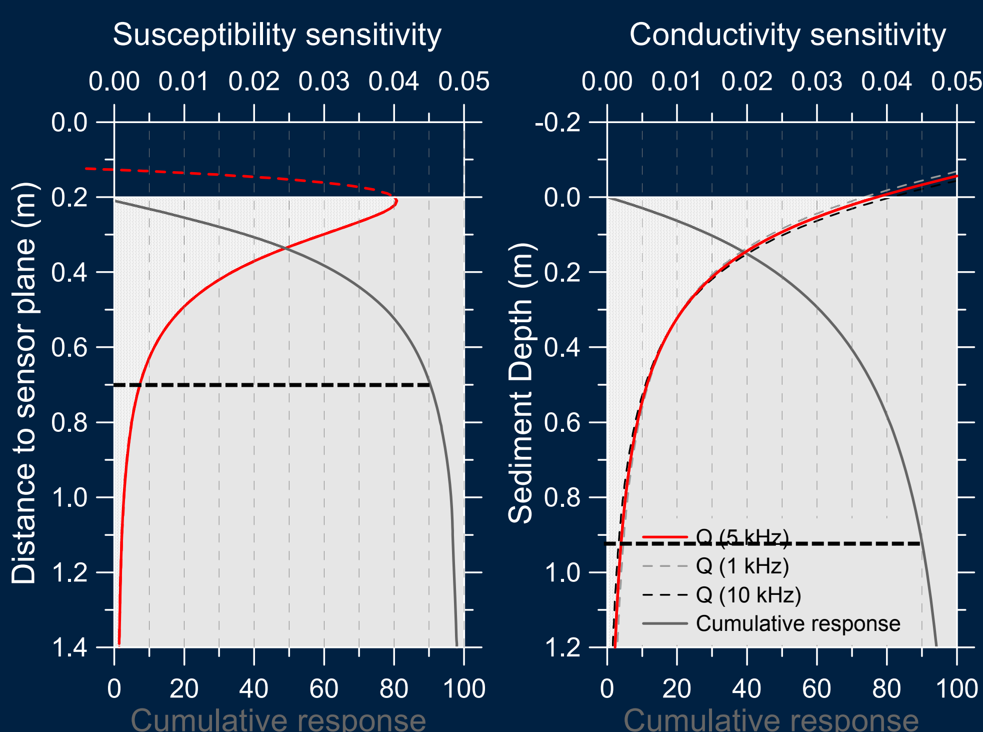


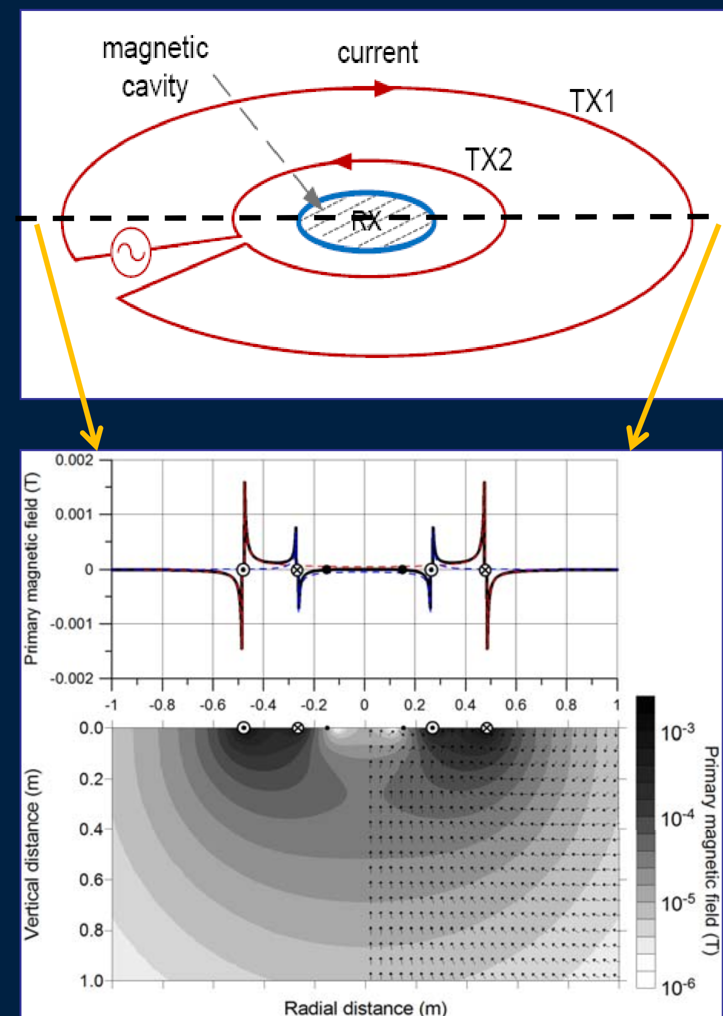
EM-Sensor specification

Elevation: 20 cm above seafloor

Sounding depth (90%): Susceptibility: 0-50 cm

Conductivity: 0-90 cm

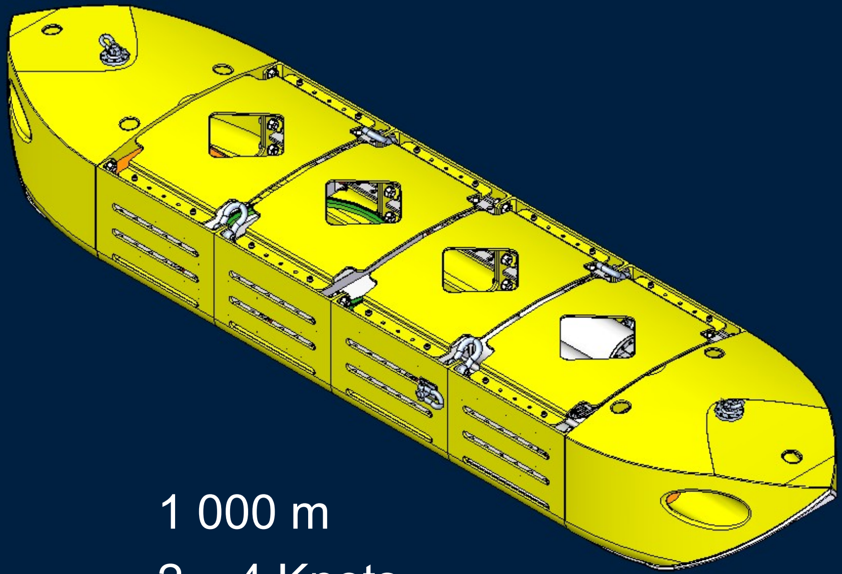




NERIDIS III setup

(Neritic Discoverer)

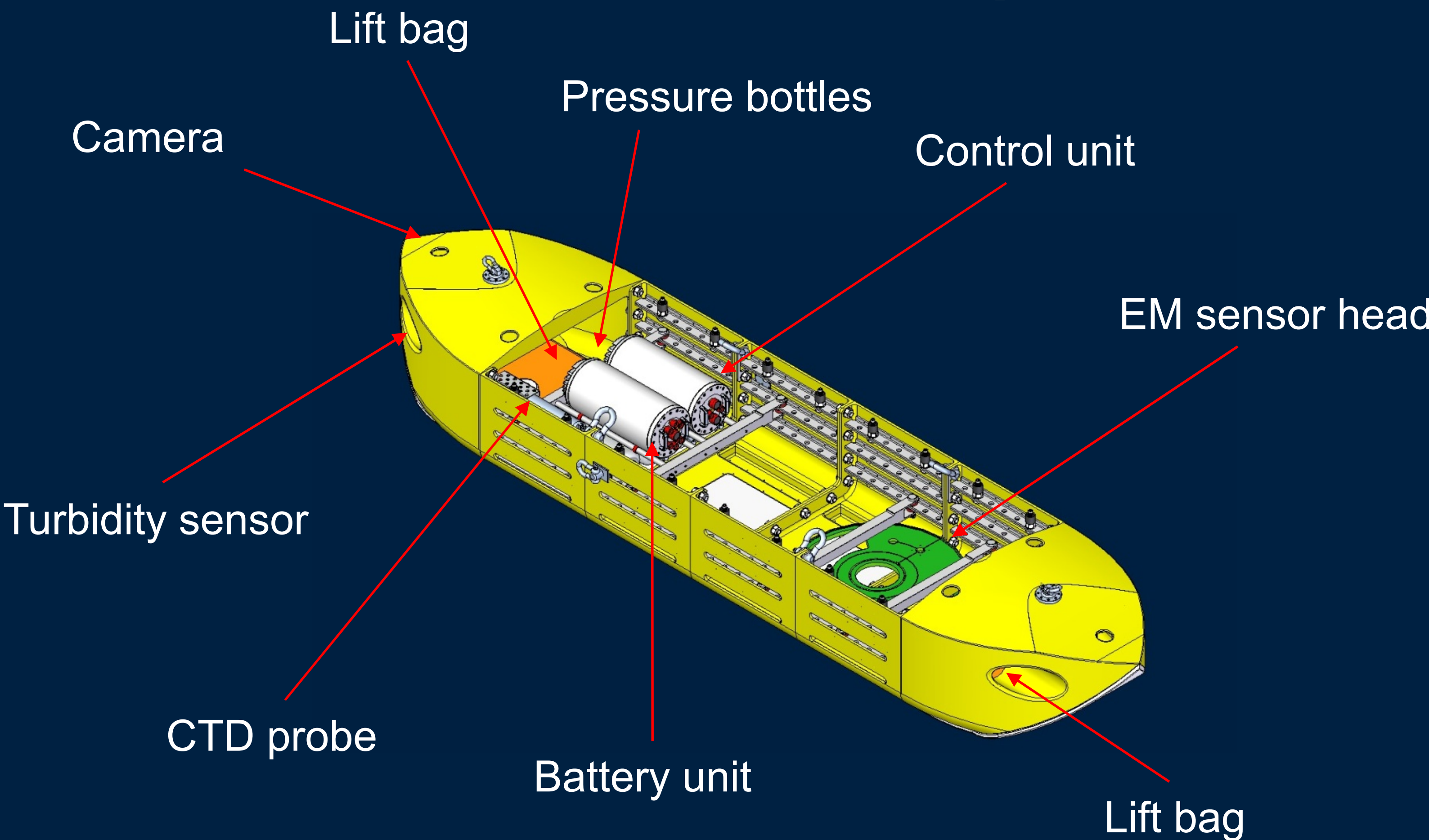
Dimensions (L x W x H): 5,2 m x 1,2 m x 0,8 m
Material: Fiberglass, POM
Weight: 930 Kg (in Air), ~ 400 Kg (in water)

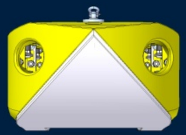


Operation depth: 1 000 m
Tow Speed: 2 – 4 Knots
Mission duration: 12 – 16 h
Electric power: 12V - 27Ah, 24V - 40Ah (Lithium Ion batteries)

NERIDIS III setup

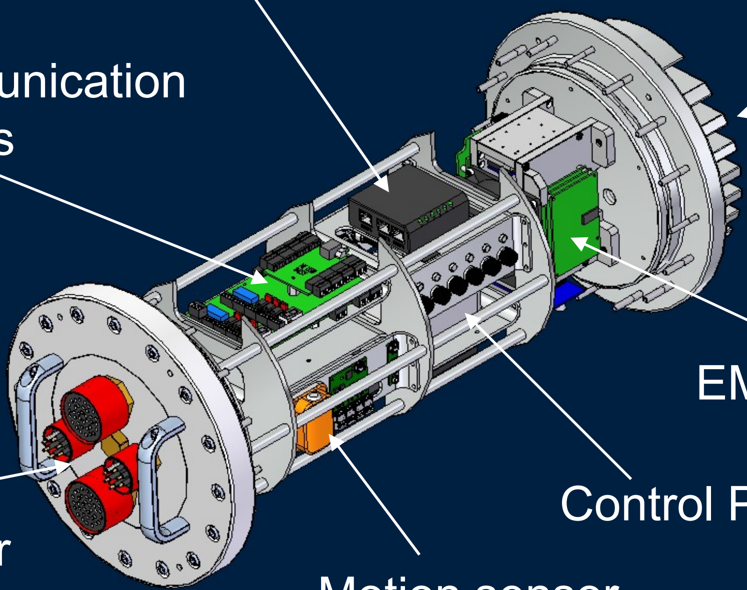
(Neritic Discoverer)

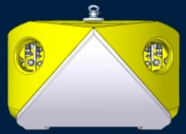




Control unit

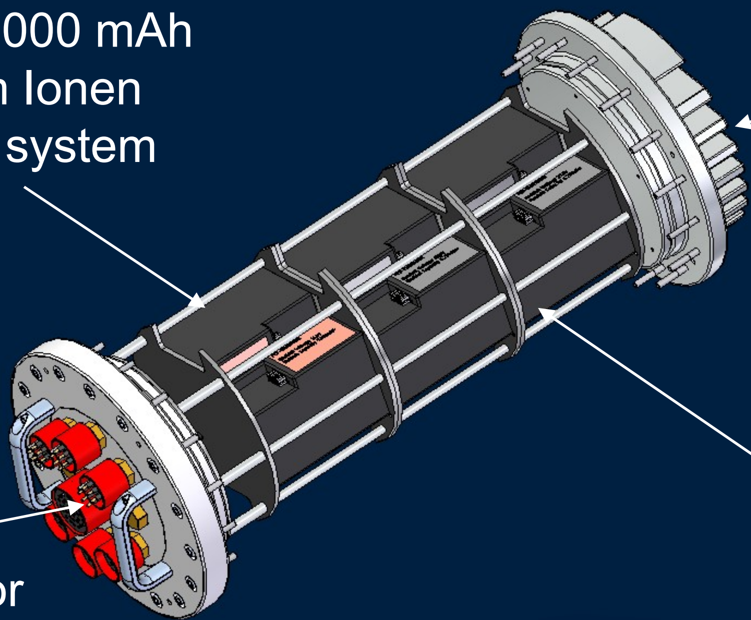
Dimensions (L x D):	0.7 m x 0.3 m
Material:	POM, aluminum
Weight:	48 Kg (in Air), ~ 3 Kg (in water)
Telemetry:	2 Mbit/s (via 10 km standard coaxial tow-cable)





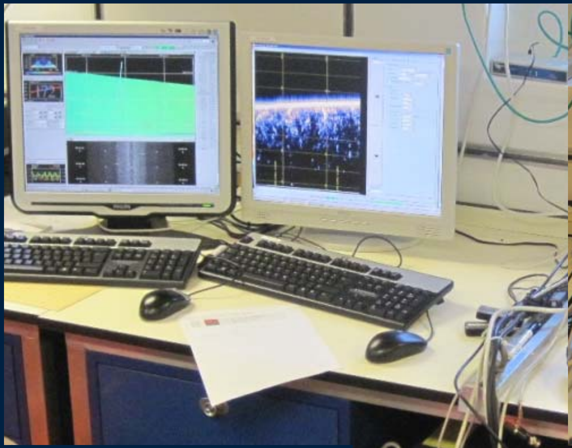
Battery unit

Dimensions (L x D): 0.7 m x 0.3 m
Material: POM, aluminum
Weight: 68 Kg (in Air), ~ 5 Kg (in water)

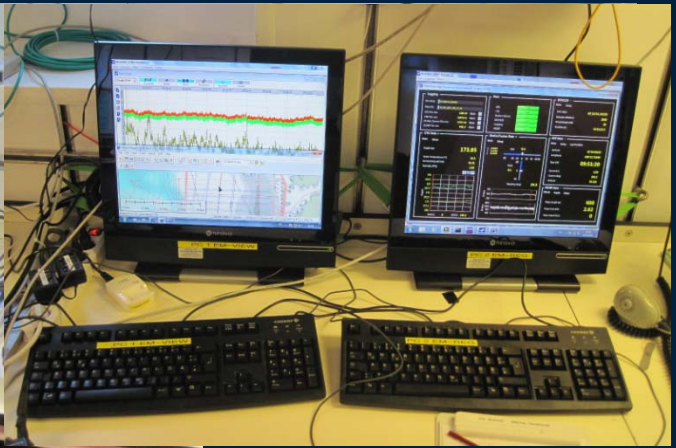


NERIDIS III operation

Multibeam Echosounder



EM data Sled control



Control rack

Deployment

Recovery

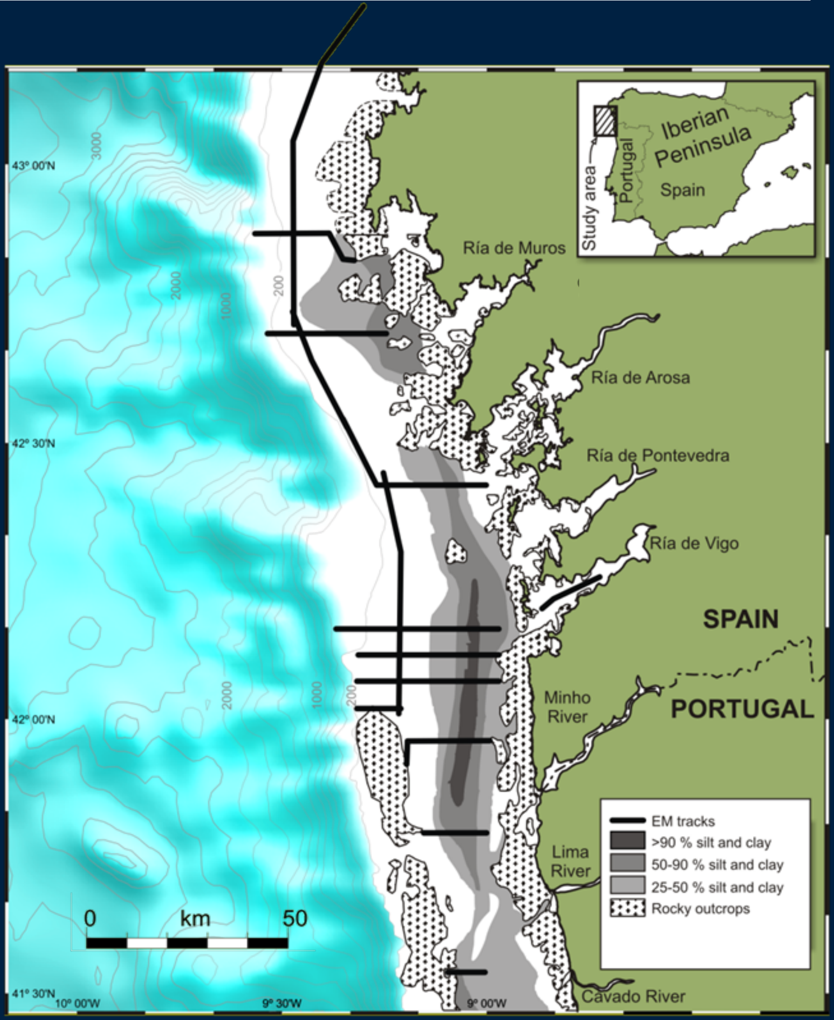
Case study: NW Iberian Shelf

Why study shelves

- Sedimentary pathway coast – deep sea
- Storage area for terrigenous material
- Ecological, economical importance

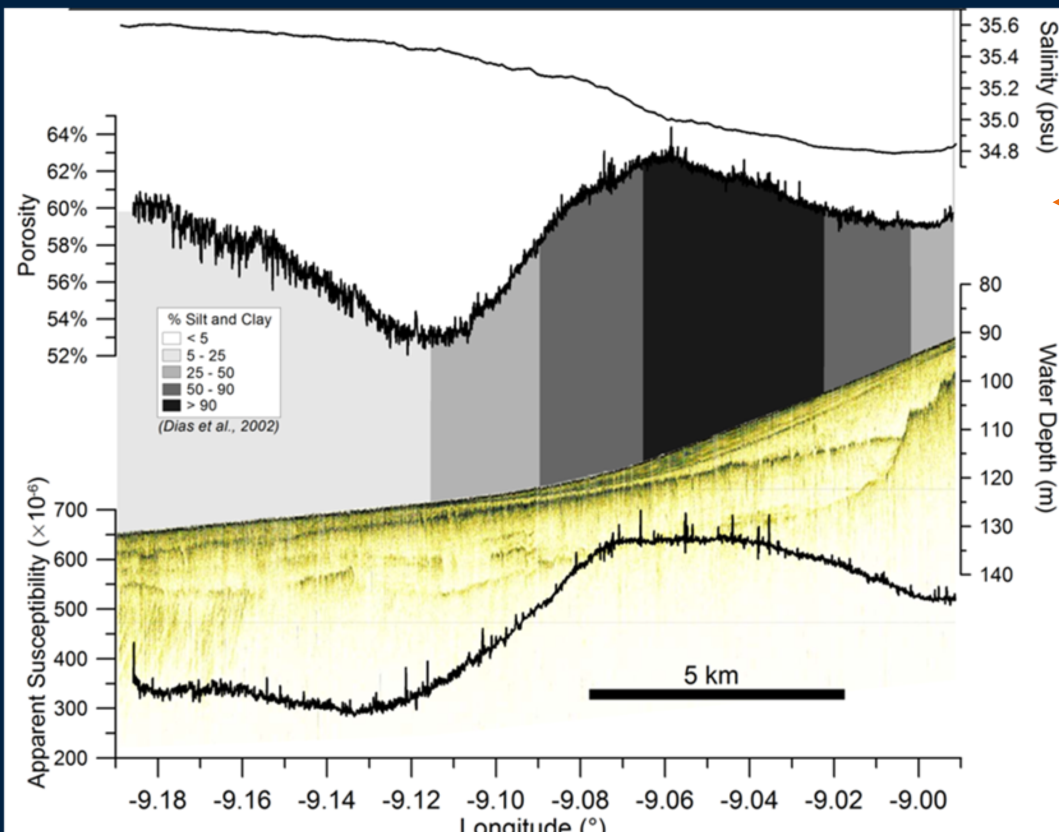
The NW Iberian continental shelf

- High energy, low accumulation regime
- Known mud belt structure (= modern sediment) but unknown sediment pathways to the deep sea
- Sedimentologically well characterized facies units



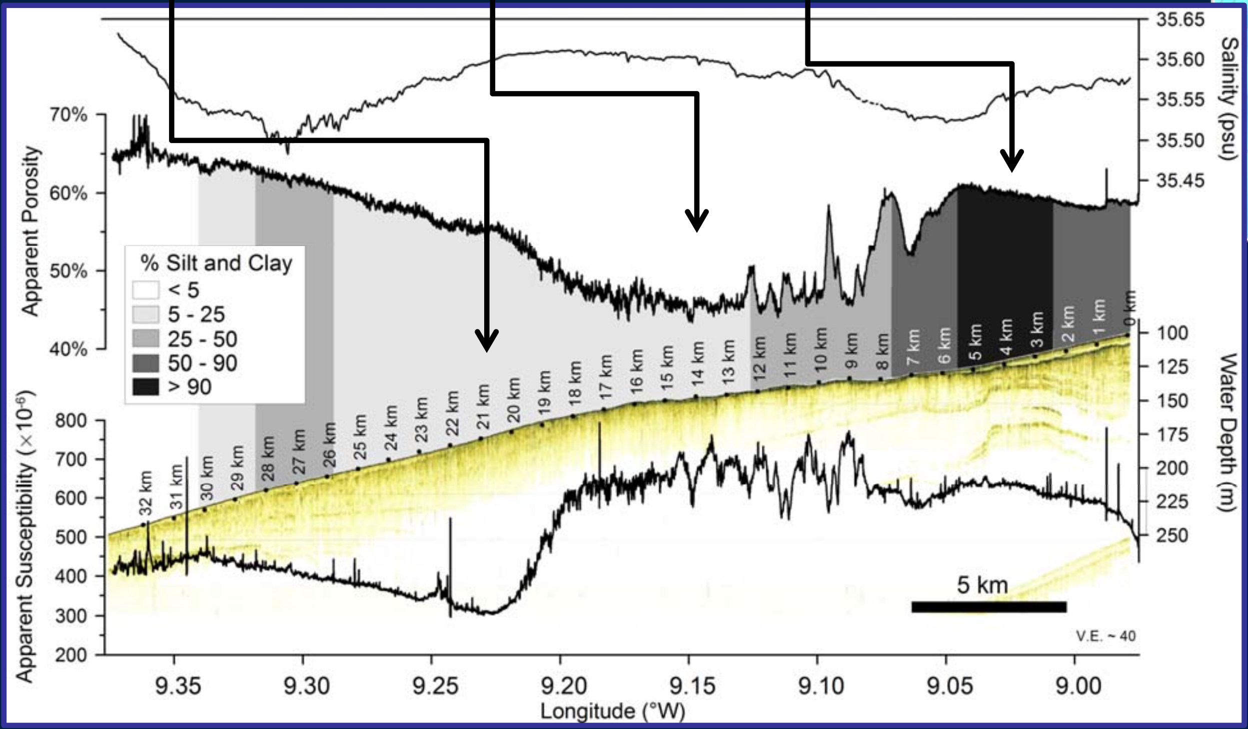
(Mud belt after Diaz et al. 2002)

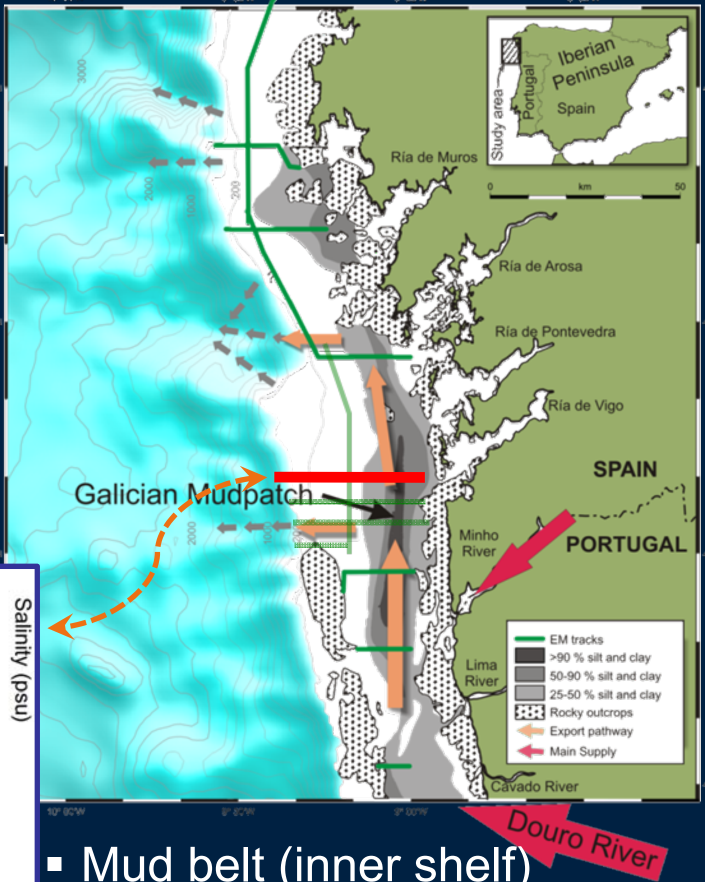
Shelf Profile I (42°02‘ N)



- Mud belt (mainly silt - fine sand)
  → **high** porosity and susceptibility
- Quartz sands on outer shelf
  → **low** porosity and susceptibility
- Asymmetric transition zones

Shelf Profile II (42°10‘ N)



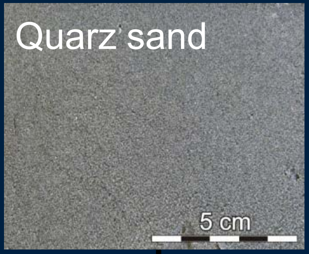


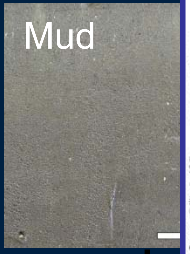
- Mud belt (inner shelf)
- Glauconite sand (mid shelf)
- Quarz sand (outer shelf)
- Mega ripples (undulations)
  Wavelength 0.6 - 1.5 km

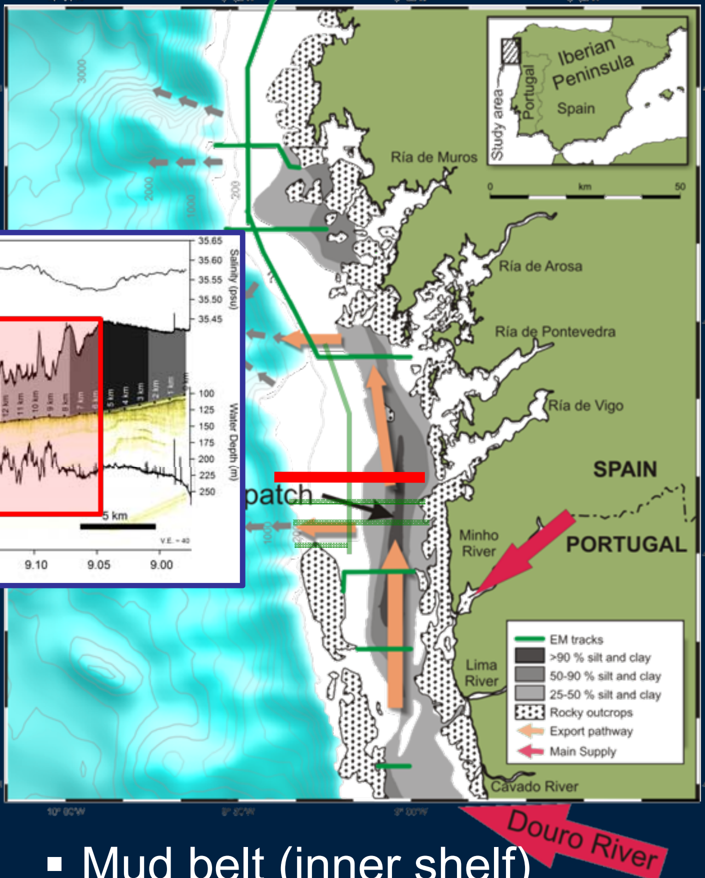
  Generally **lower porosity** and **higher susceptibility** on ridges

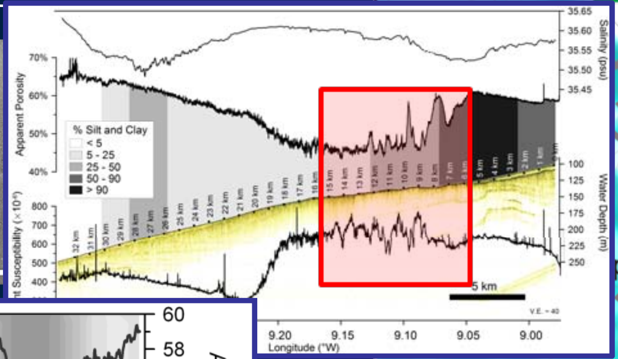
Müller et al. 2011 (in press)

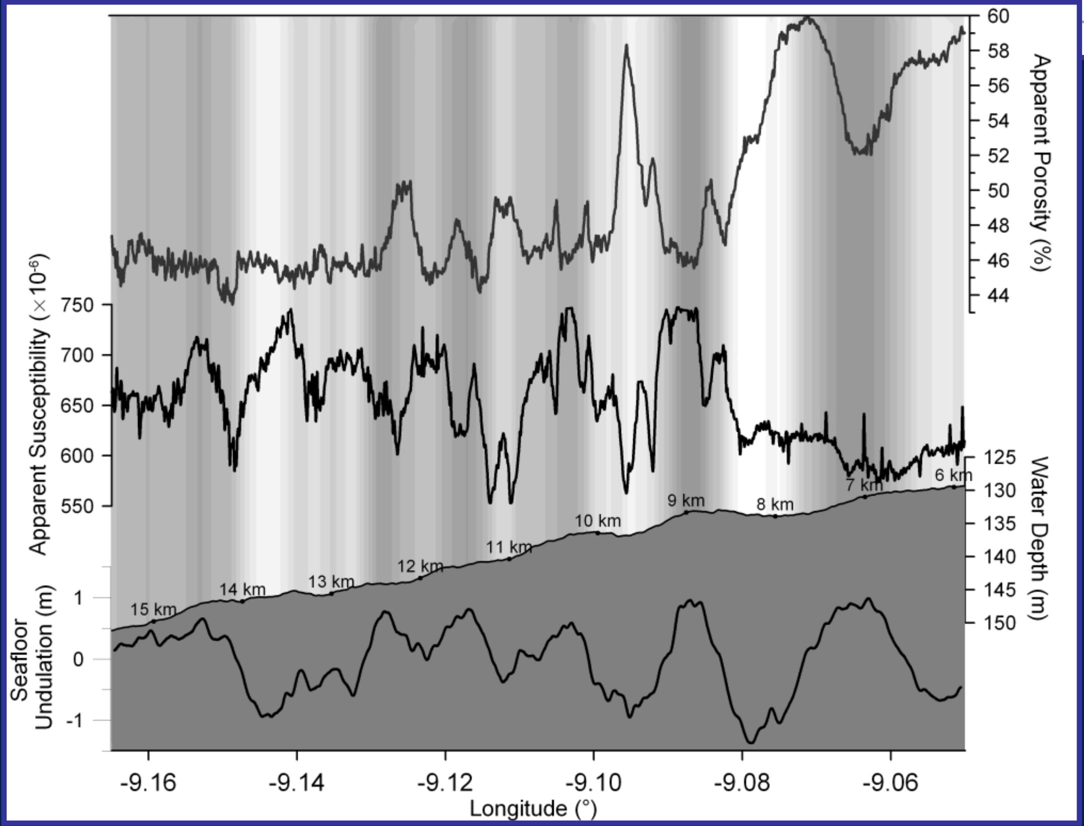
Shelf Profile II (42°10‘ N)











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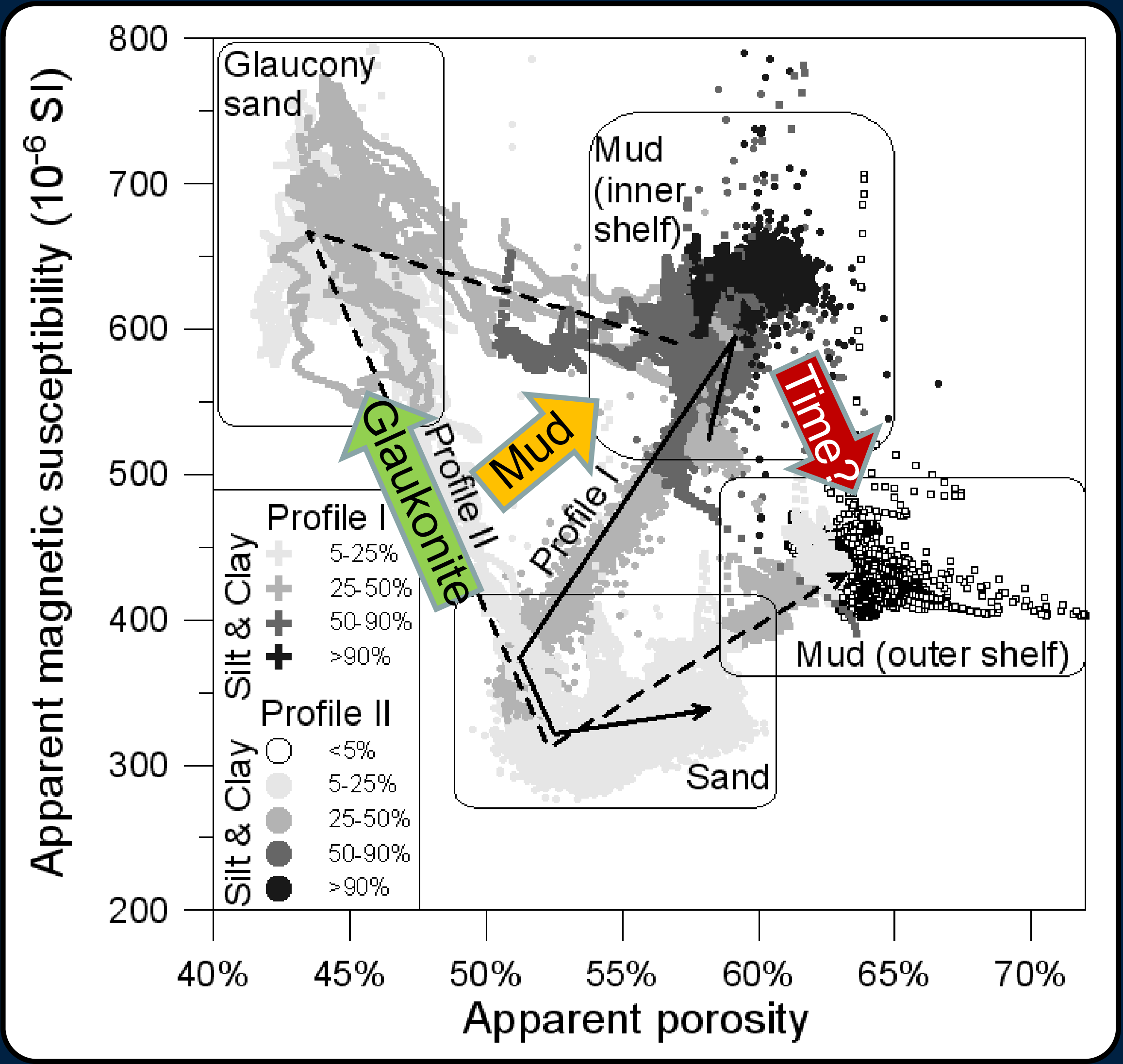
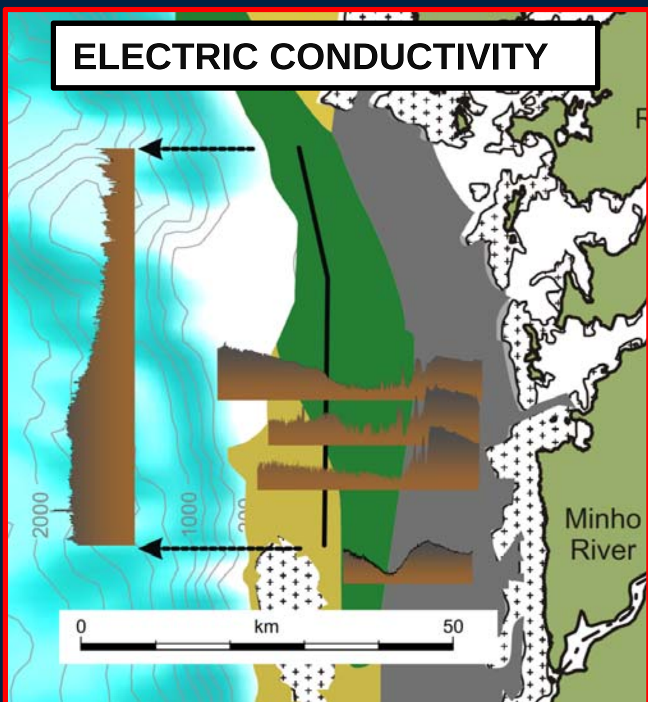
Sediment classification

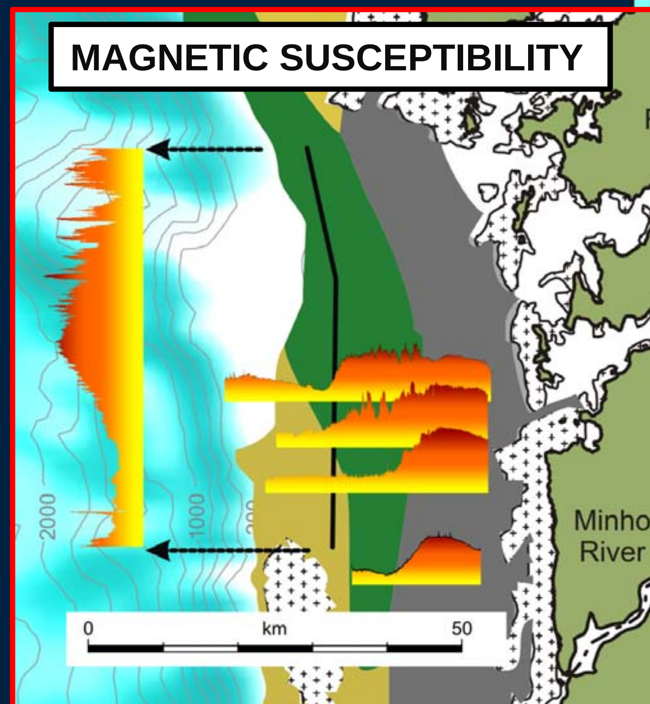


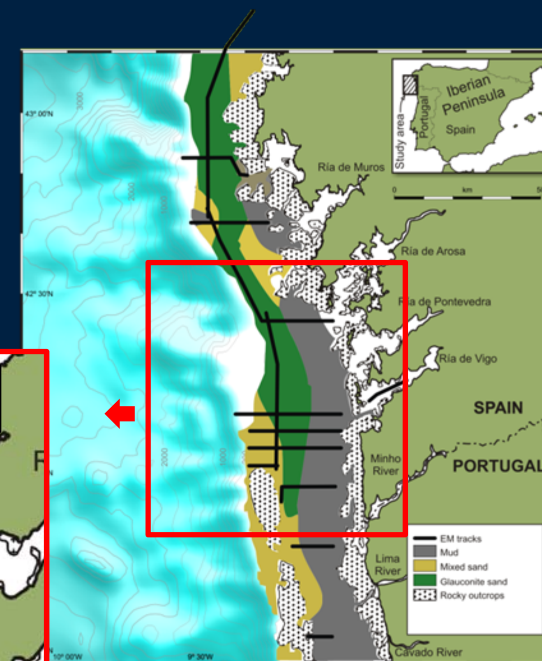
- Bivariate susceptibility vs. conductivity plots depict distributions and transitions of different shelf and slope facies
- After a sample-based laboratory calibration, transfer functions for other specific sediment properties of interest (mineralogy, stability) can be derived

Sediment distribution

- EM Profiles match well with mud distribution
- Identify sediment wave patterns
- Extend the knowledge and precisely map sediment distribution on the NW Iberian Shelf

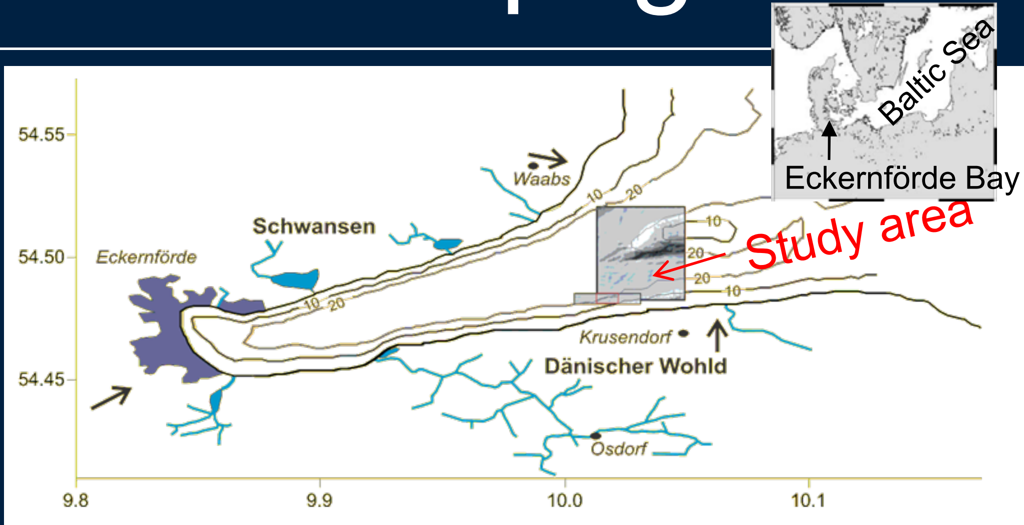


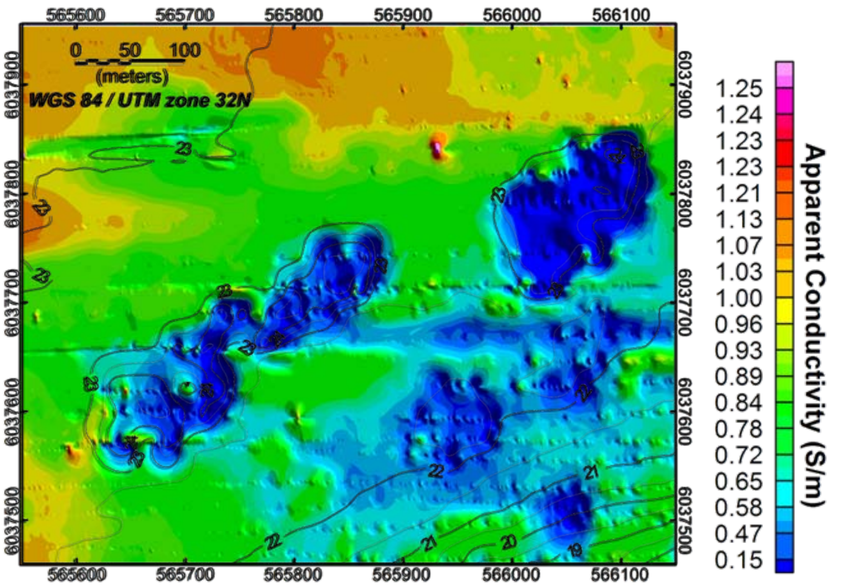


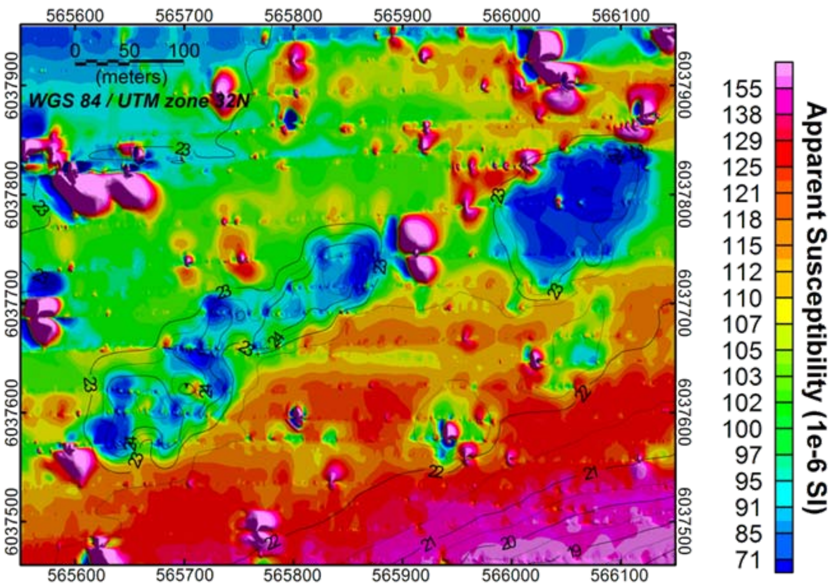


Case II: Freshwater seepage

- Pockmarks (morphological depressions) mark freshwater (or methane?) seeps
- Deep towed magnetometer maps the glacial substrata



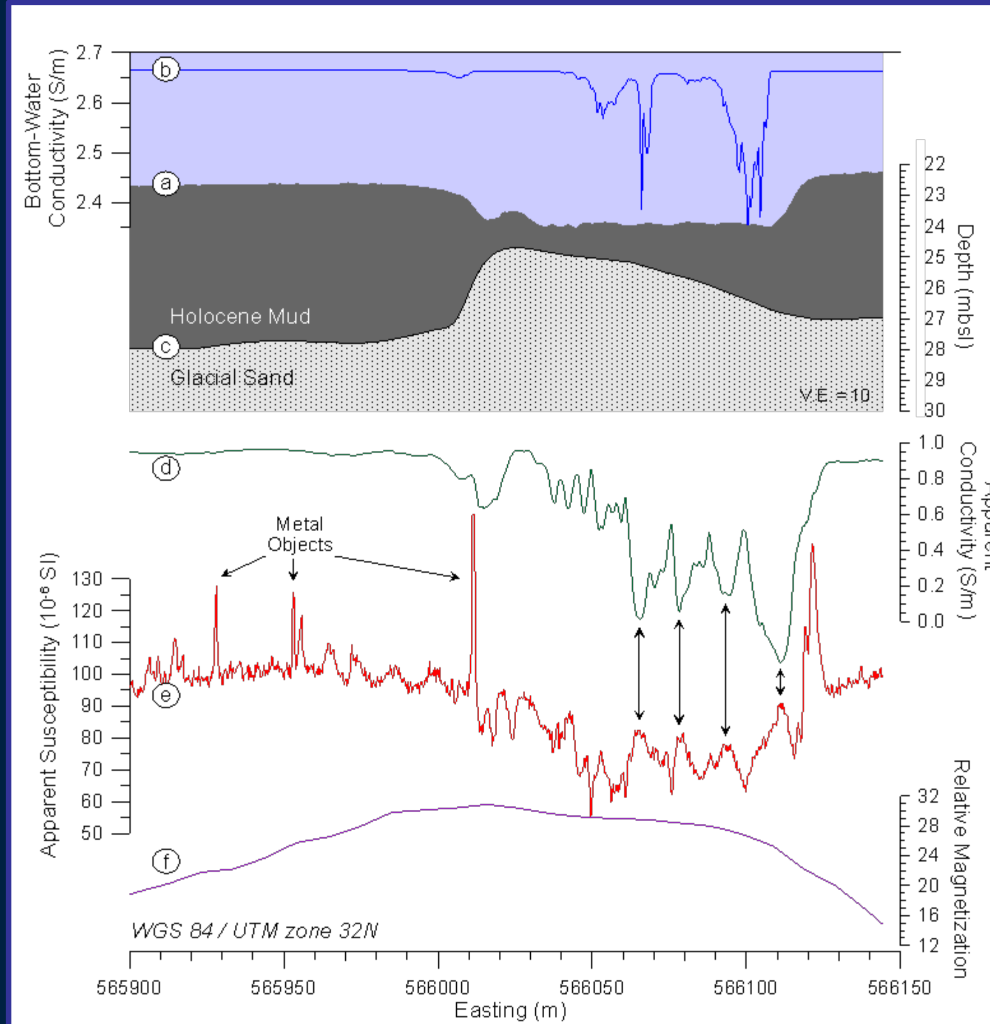




Müller et al. 2011 (Geo-Marine Letters)

Case II: Freshwater seepage

- CTD bottom water conductivity depicts recent freshwater seepage
- Pockmarks show up as 1-2 m deep morphologic depressions
- Holocene mud-cover is thinned in pockmarks
- Glacial sand-subsurface bulges below pockmarks
- Sediment conductivity and susceptibility are reduced within pockmarks
- Magnetometer images the glacial subsurface only



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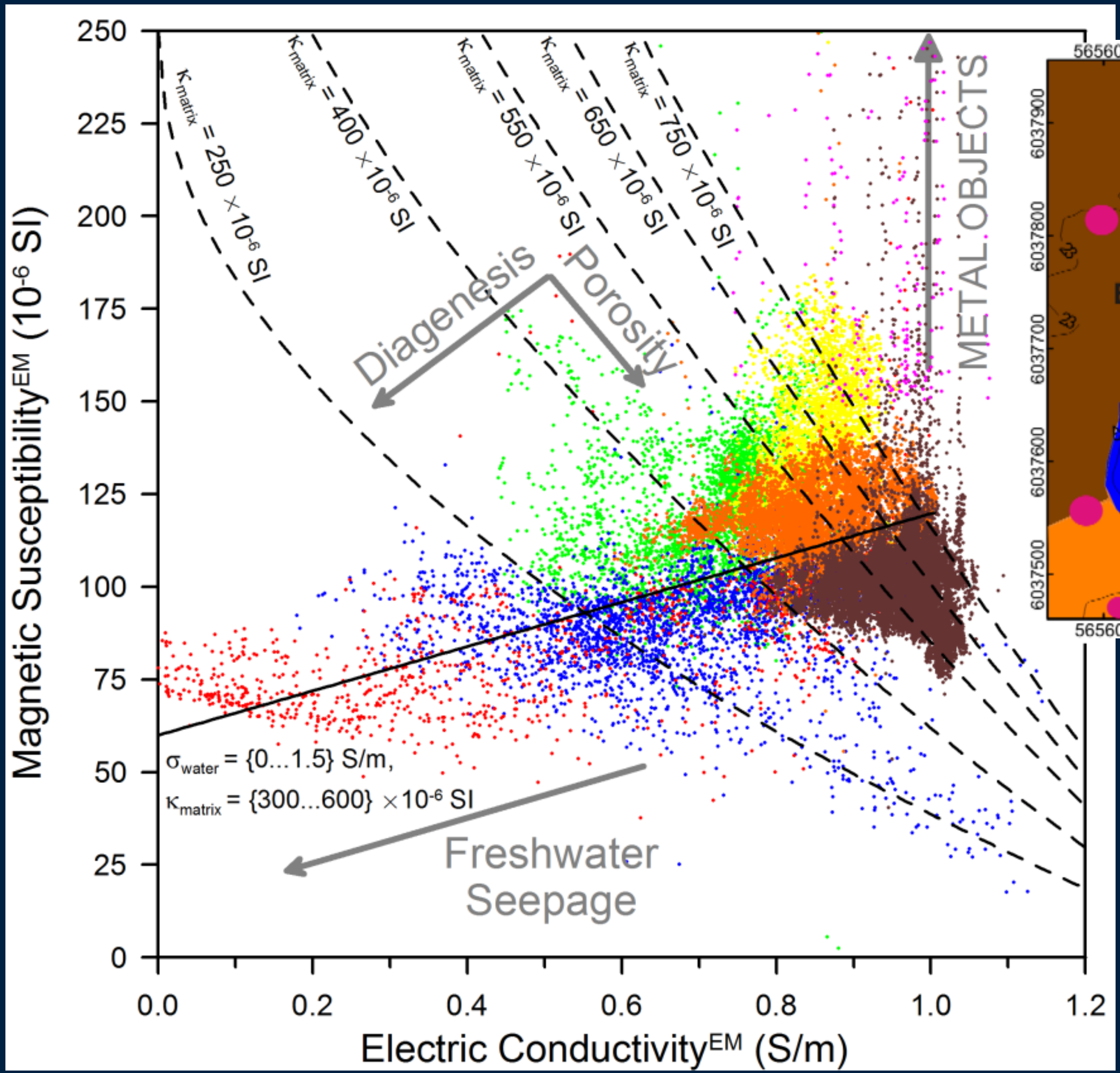

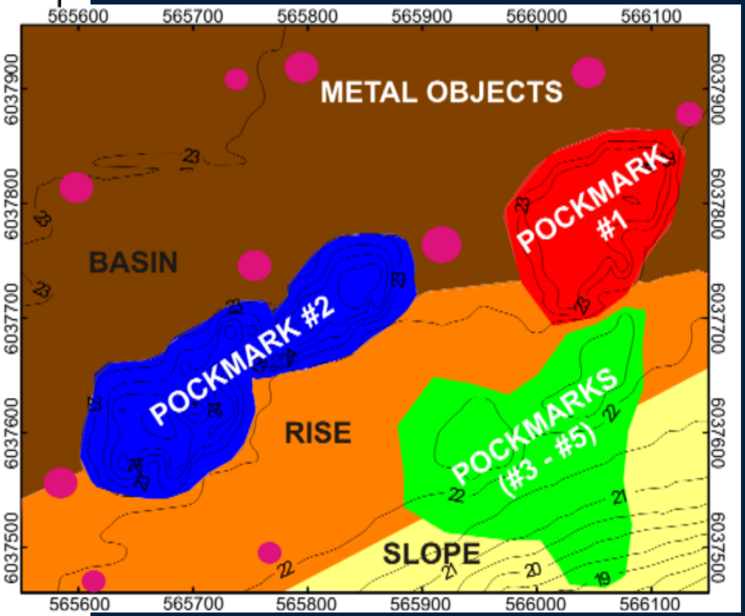

Bivariate κ vs. σ Plot

- Facies transitions from sand (slope) to silt (basin)
- Seeps vary in conductivity due to flow rates; susceptibility lowered by magnetite sulfidization

Conclusions

❶ We demonstrate the eminent potential of EM profiling for assessing the complex distribution of shallow marine surficial sediments

❷ Electric conductivity primarily relates to the fluid-filled pore space and detects salinity, porosity and grain-size variations

❸ Magnetic susceptibility mostly assesses solid particle characteristics such as terrigenous or iron mineral content, redox state and contamination level

❹ EM profiling reveals climatic, hydrodynamic, diagenetic and anthropogenic factors governing the sediments formation