

## Synthesis of Offshore Robotics, Multiphysics & Digital Technologies for Deep-Sea Mineral Exploration

Anna Lim, Johan Mattsson, Thorbjørn Rekdal, Trond Crantz

# Disclaimer

---

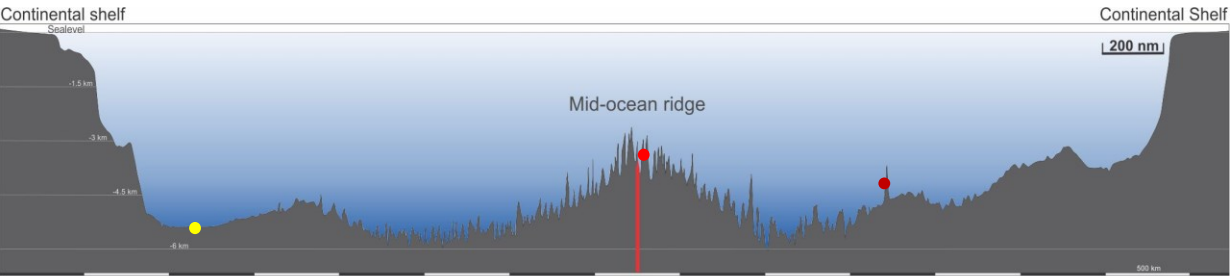
The slides in this presentation were used to accompany an oral talk given on October 21, 2021. The information in this slide deck is given in summary form and does not purport to be complete.



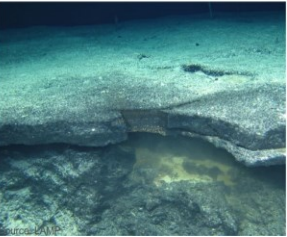
The content of this presentation cannot be published, copied, or distributed to any third party without the written consent of *Argeo*.

If you have questions regarding the content, please contact the author at [anna.lim@argeo.no](mailto:anna.lim@argeo.no)



# Deep-Sea Minerals – Understanding the challenges



	Seafloor Massive Sulfides (SMS) ●	Polymetallic Nodules (PMN) ●	Cobalt-rich Ferromanganese Crusts (CFC) ●
Geological setting	In hydrothermally active areas Mid-ocean ridges, back-arc basins	In soft seabed Abyssal plains, oceanic plateaus	On surface of bare rocks Seamount flanks & summits
Average water depth	500 – 5000 m	4000 – 6000 m	800 – 4000 m
Dimensions	~250 m x 250 m	~0.15 m x 0.1 m	~500 m x 0.25 m
Sites in Norway	15 sites (active & inactive)	No discoveries	10 sites
			

DEEP & REMOTE

Underwater  
Robotics

RELATIVELY SMALL

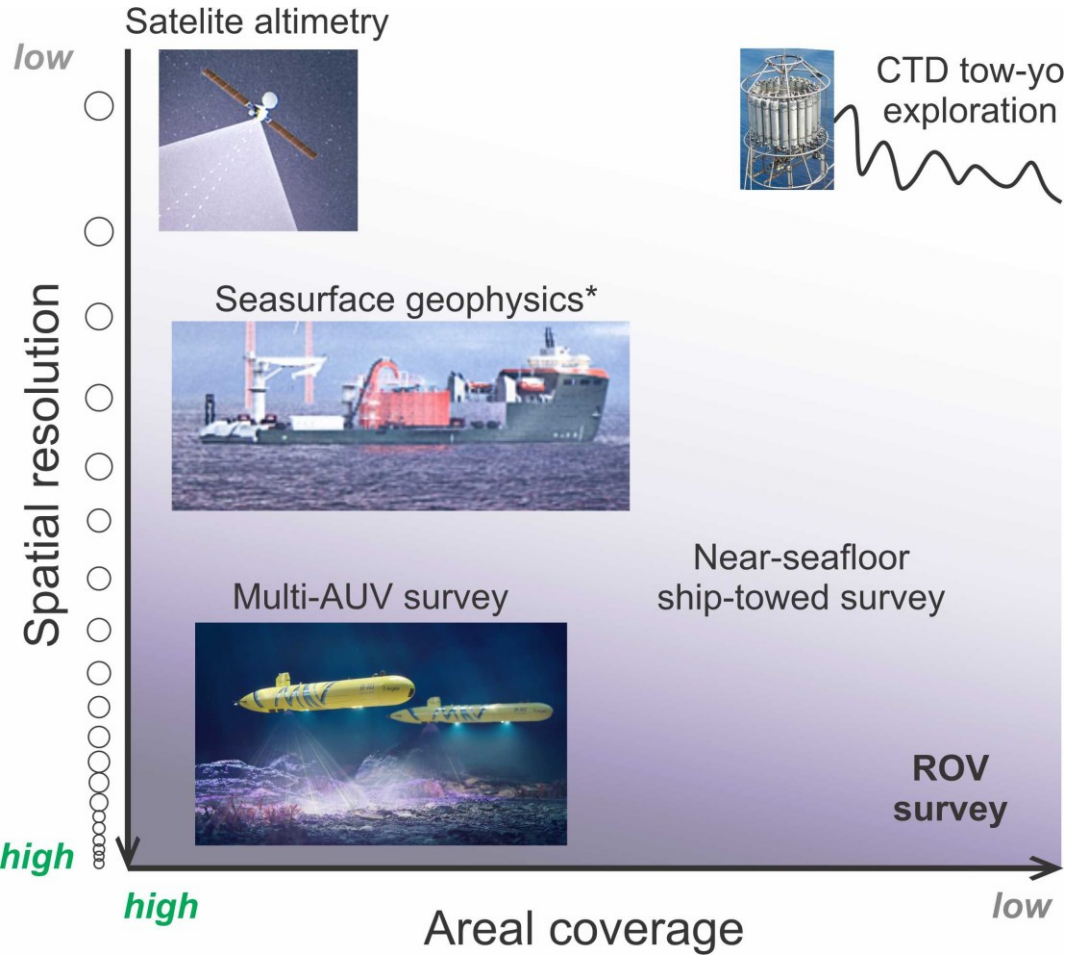
near-seafloor  
surveying

DIVERSE / COMPLEX

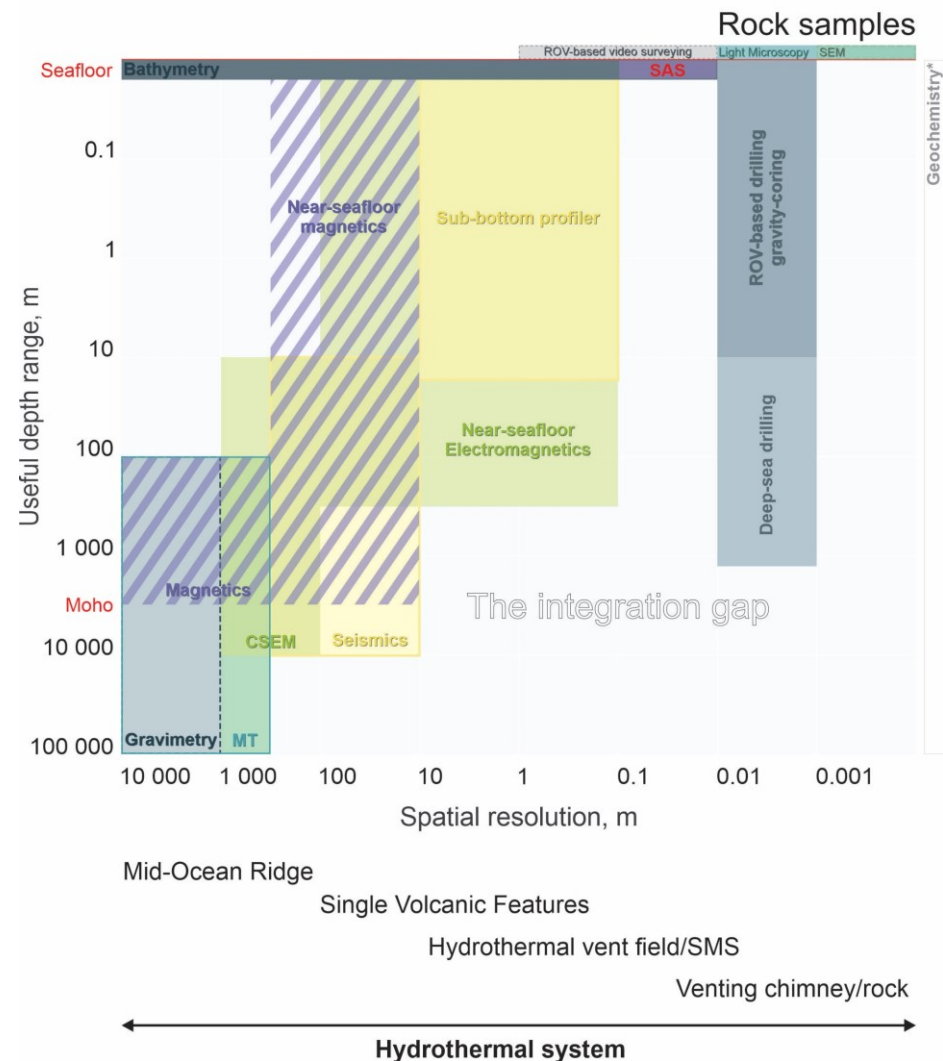
multiphysics  
sensors

UNDEREXPLORED

at ~ 3.5 ROV  
speed and high  
areal coverage  
rate



# Near-seafloor AUV surveys to resolve deposits and maximize exploration success



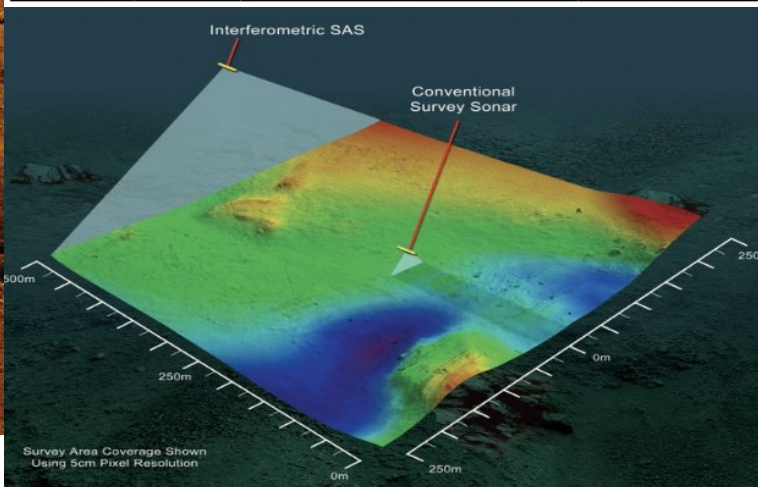
Sensor type	Application
Multibeam Sonar	Seafloor mapping / backscatter strength
Synthetic Aperture Sonar	Seafloor imaging / mapping
Camera and Laser	UHD seafloor imaging
Magnetometer	Subsurface characterization
Sub-Bottom Profiler	Subsurface structure
Active source EM system	Detection and delineation of conductive bodies in 3D
CTD, Oxygen, CH <sub>4</sub> , pH, Turbidity, Redox	Water column analysis / anomaly detection

**Simultaneous acquisition**  
High **data quality** at 3-3.5 kn  
Up to **~440 m footprint**



# SAS – bridging the gap. Seafloor mapping and exploration with highest ACR

Speed		MINSAS 120		
Knots	m/s	Range meters (per side)	ACR w/o Gap Filler km <sup>2</sup> /hr	ACR w/ Gap Filler km <sup>2</sup> /hr
3.00	1.54	220	1.71	2.44
3.50	1.80	208	1.88	2.69
4.00	2.06	181	1.88	2.68
4.50	2.32	160	1.87	2.66
5.00	2.57	143	1.86	2.65
8.00	4.12	87	1.80	2.57



- High-resolution seafloor imaging – up to 2x2 cm
- Simultaneous bathymetry – up to 6x6 cm
- Highest areal coverage rate (ACR)
- Seafloor mapping
- Geomorphological analysis
- Environmental mapping
- Exploration – at least 2 discoveries at AMOR (Denny et al., 2015)
- Groundtruthing

*\*Under-appreciated exploration tool*

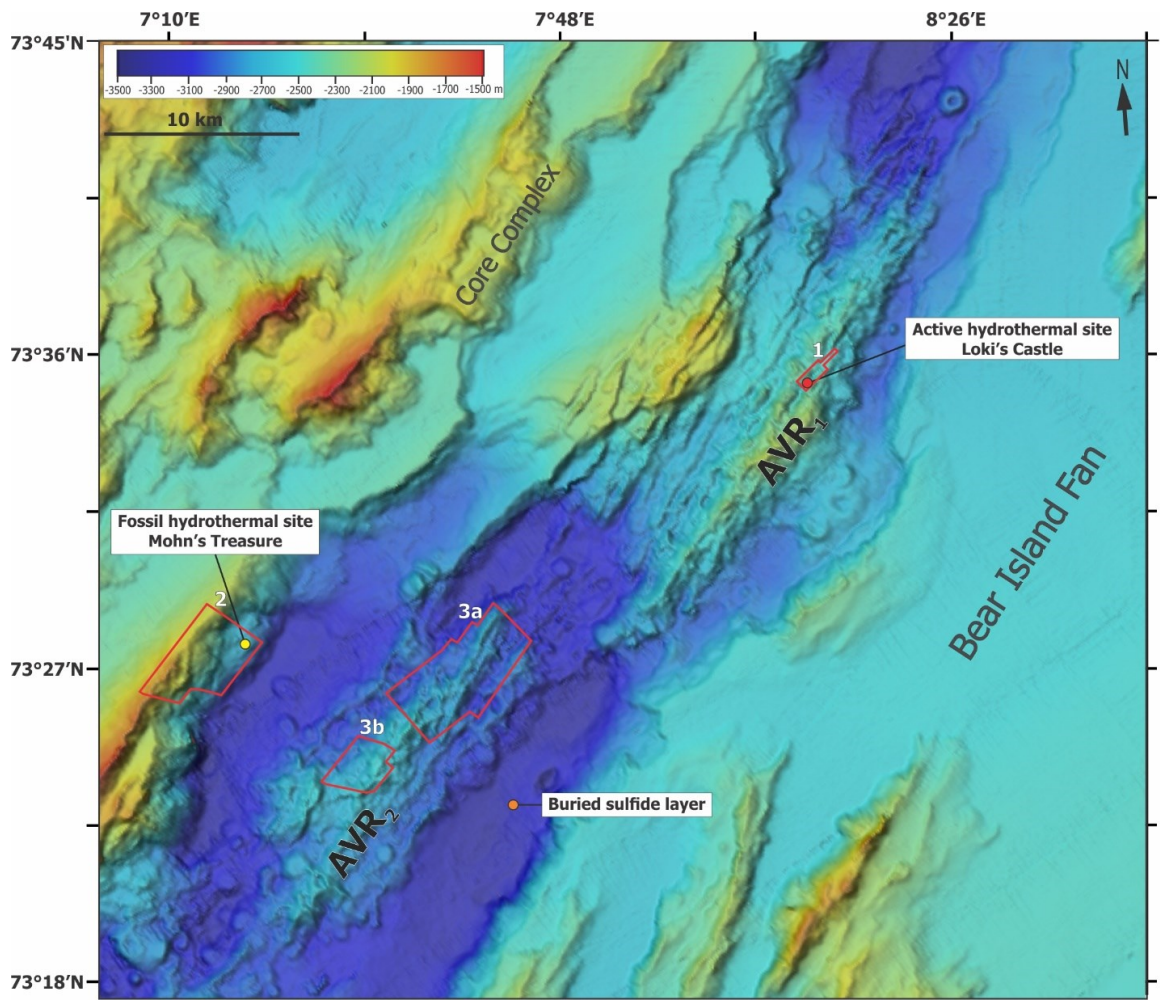


Argeo

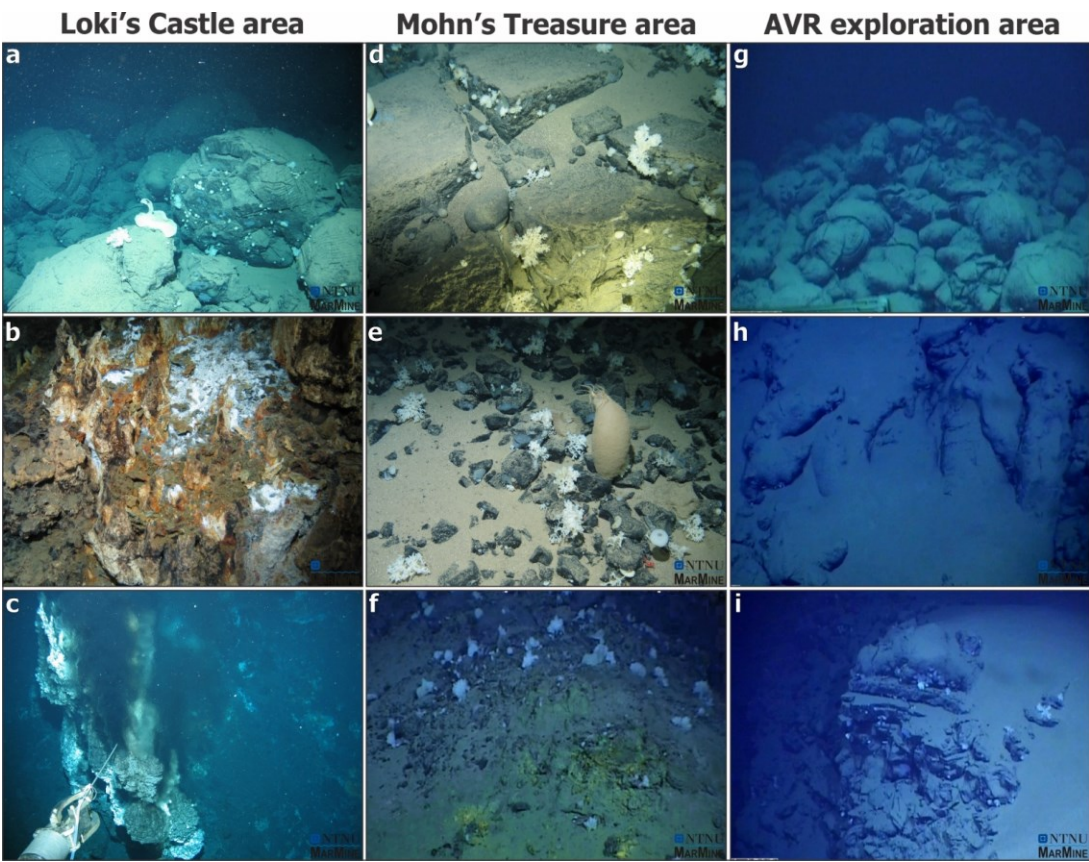
Source: Kraken robotics minSAS.



# Multiphysics – appreciating geological complexity

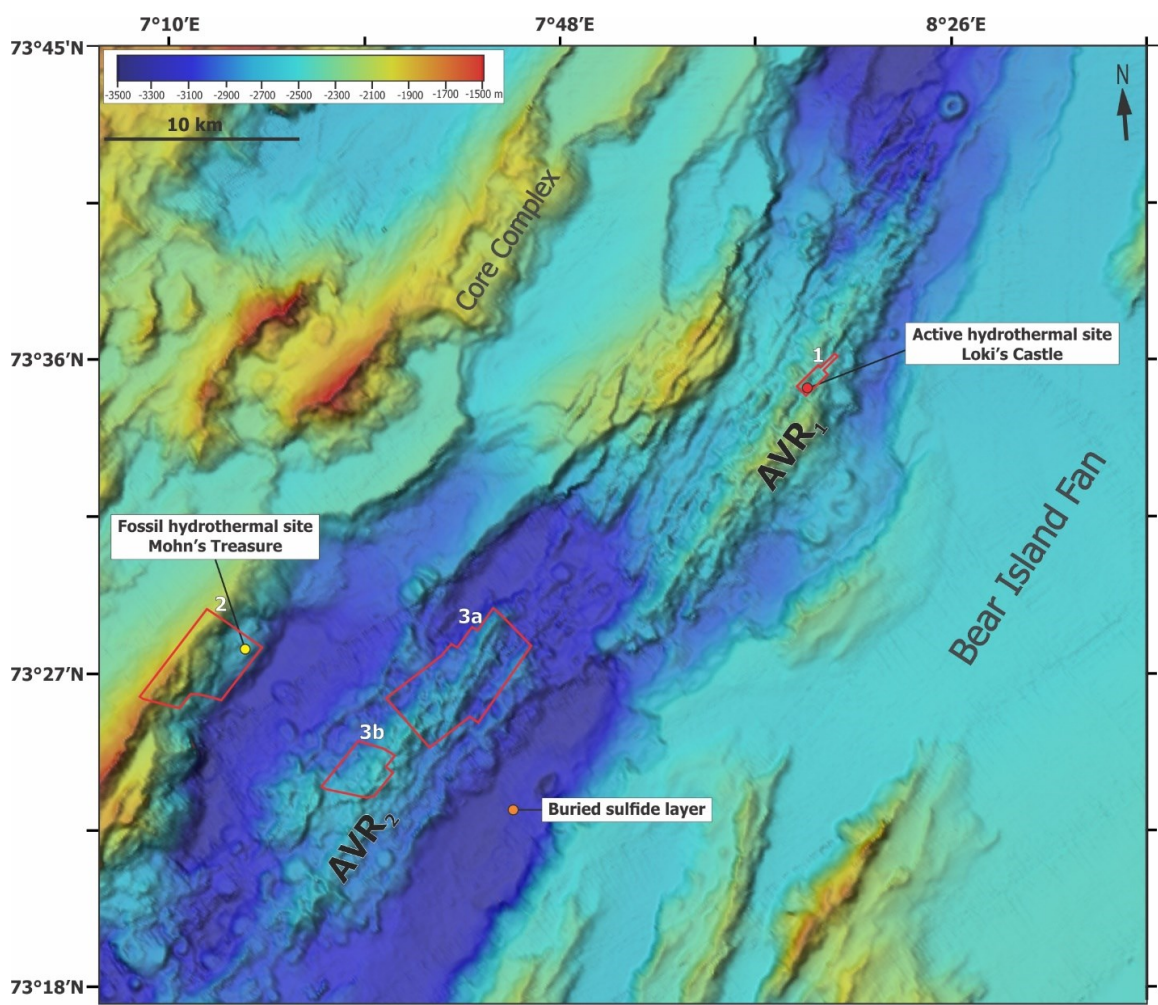


## Dataset: Imagery



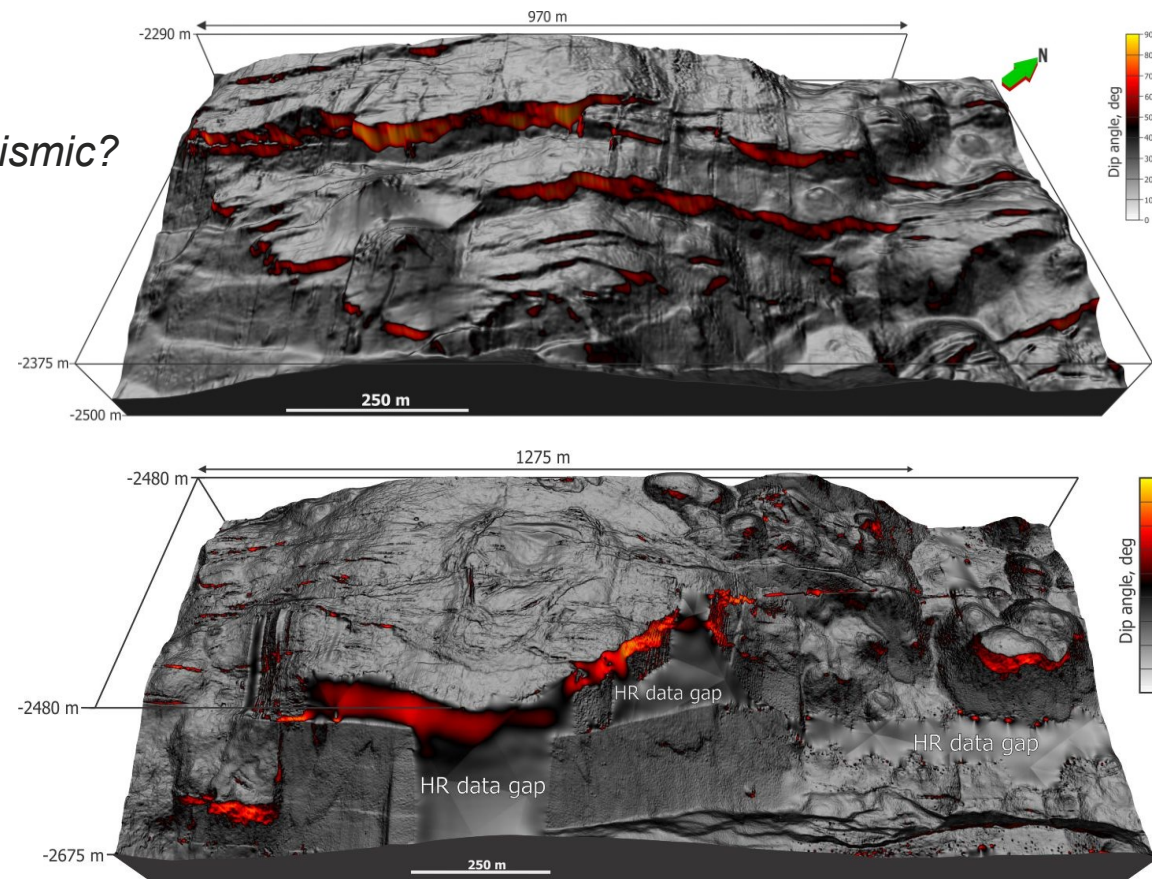


# Multiphysics – appreciating geological complexity



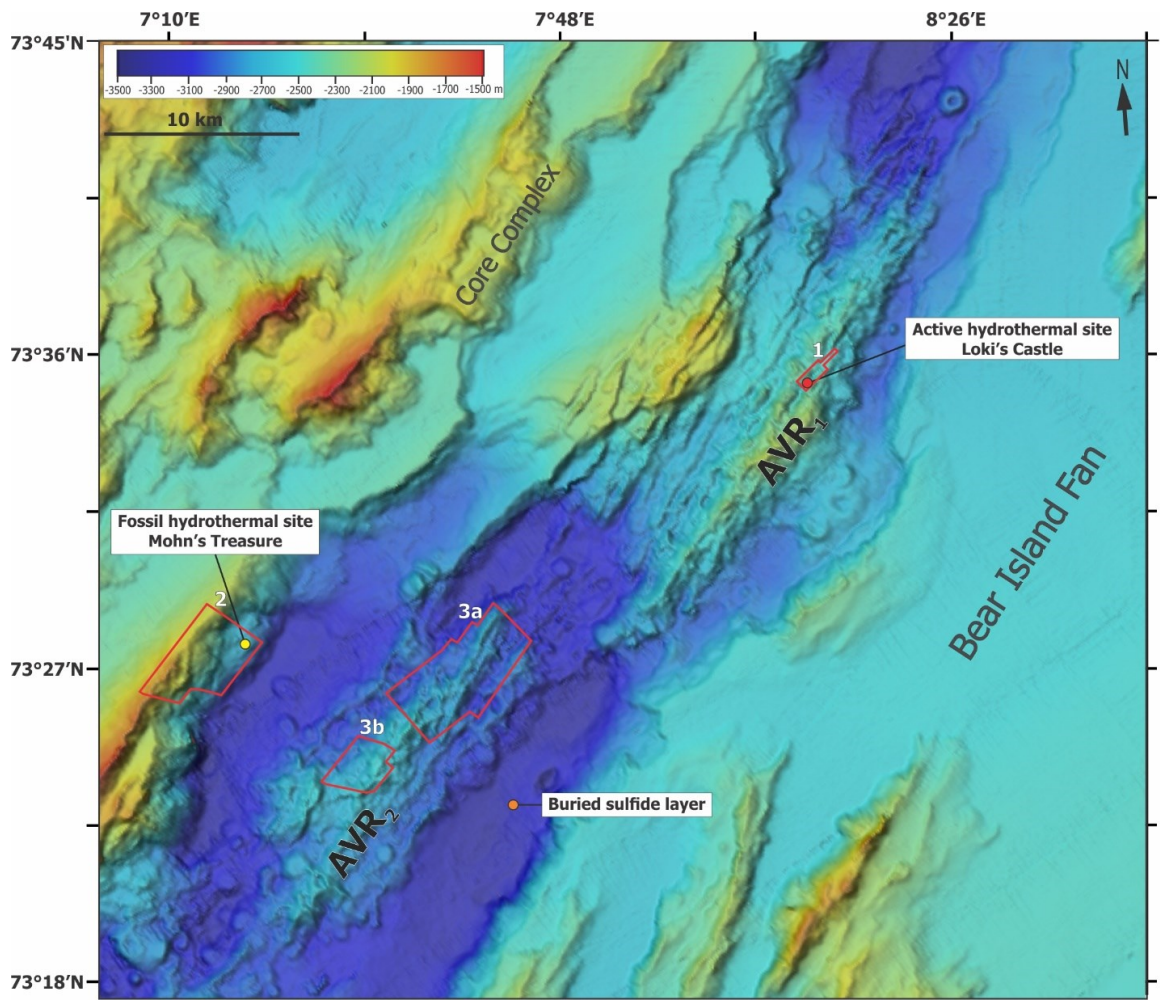
Dataset: Bathymetry – structural approach

\*Seismic?

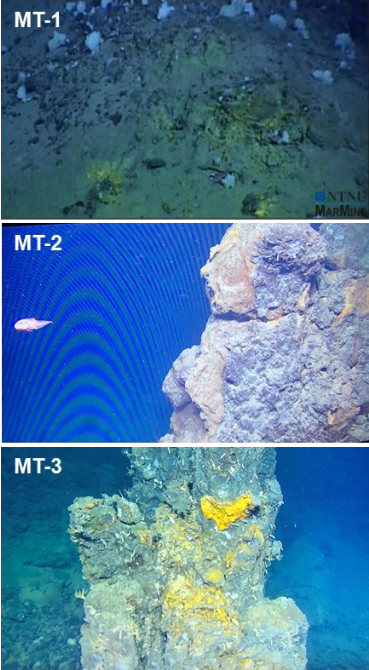
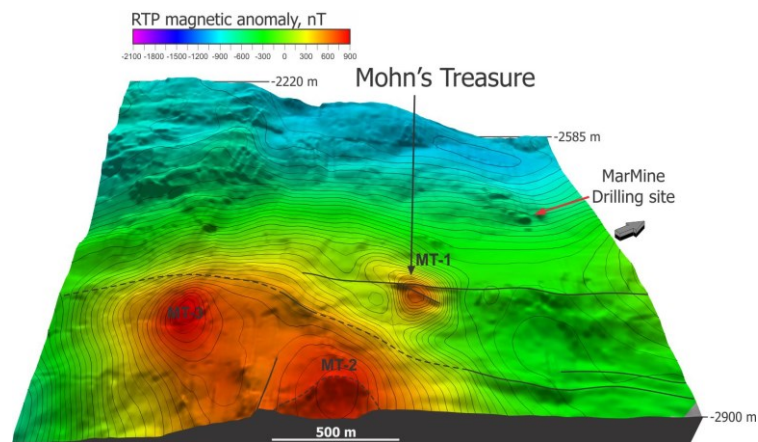




# Multiphysics – appreciating geological complexity



## Dataset: Bathymetry + Magnetics + Imagery + Samples

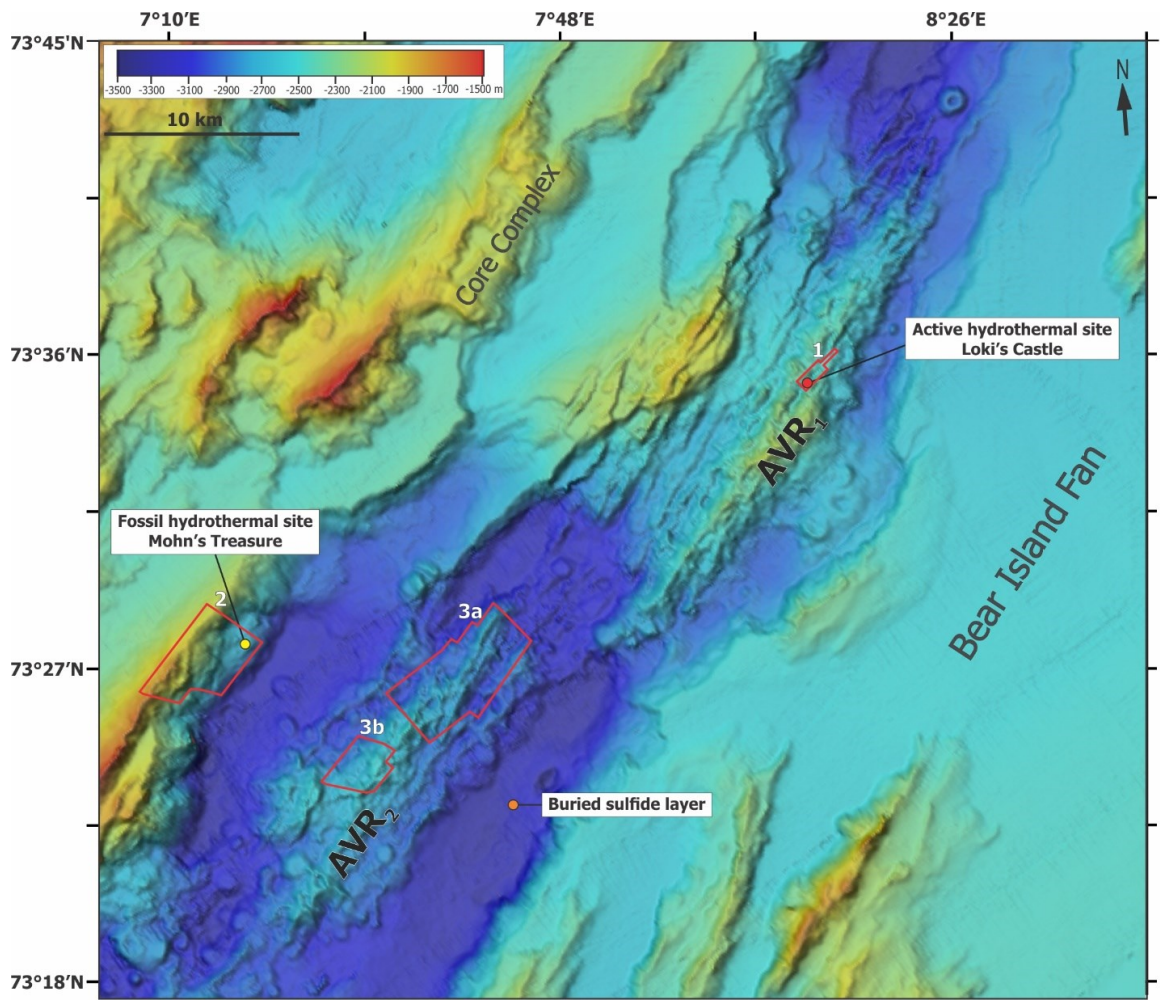


Geophysical data are key!

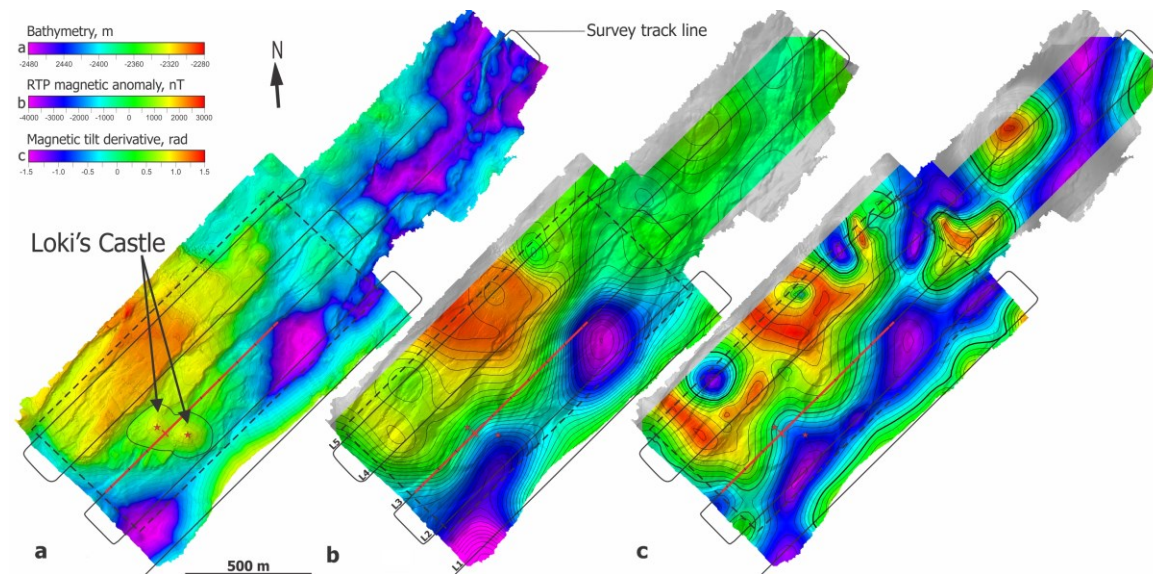
...and so is the context



# Multiphysics – appreciating geological complexity



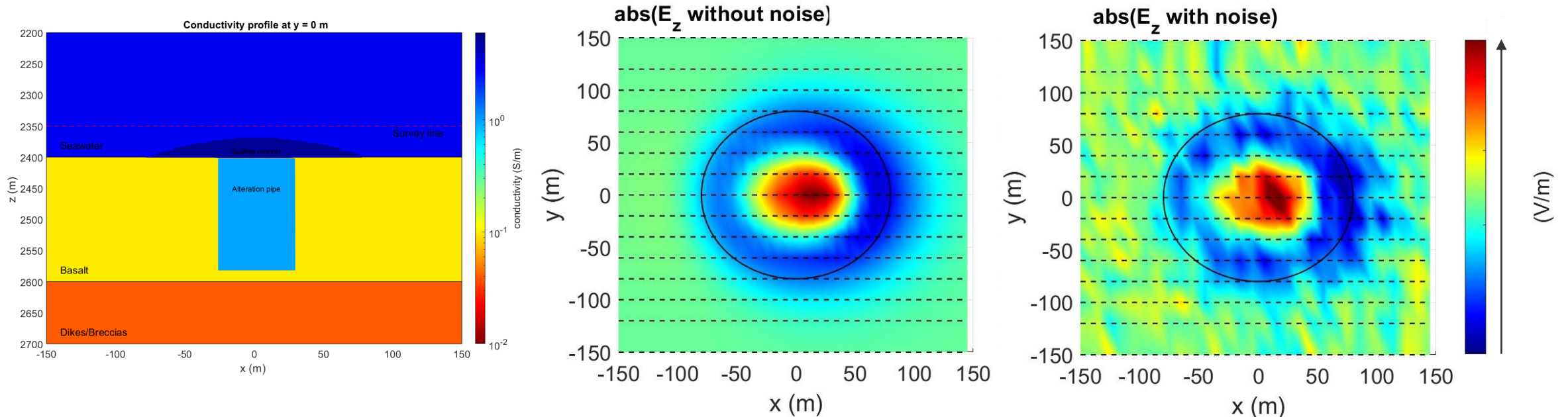
Dataset: Bathymetry + Magnetics + Imagery + Samples



...and so is the context



# CSEM with inline Source and Receiver AUVs – a 3D modeling example



- Both **electric and magnetic data** amplitude coincide with horizontal extent of the deposit
- Vertical thickness and conductivity structure can be determined from **3D inversion** of the EM data over all survey lines together
- Suitable for the **detection and delineation** of **both Seafloor Massive Sulfides (SMS) and polymetallic crusts (PMC)**
- Argeo AUV-CSEM acquisition system can also be used passively for **SP** and **magnetic** field measurements; and for **IP** surveying



# All-AUV CSEM – patent-pending solution for both SMS and Crusts

