Dynamic models as marine mineral prospecting tools

Underwater Mineral Conference, St. Petersburg, USA

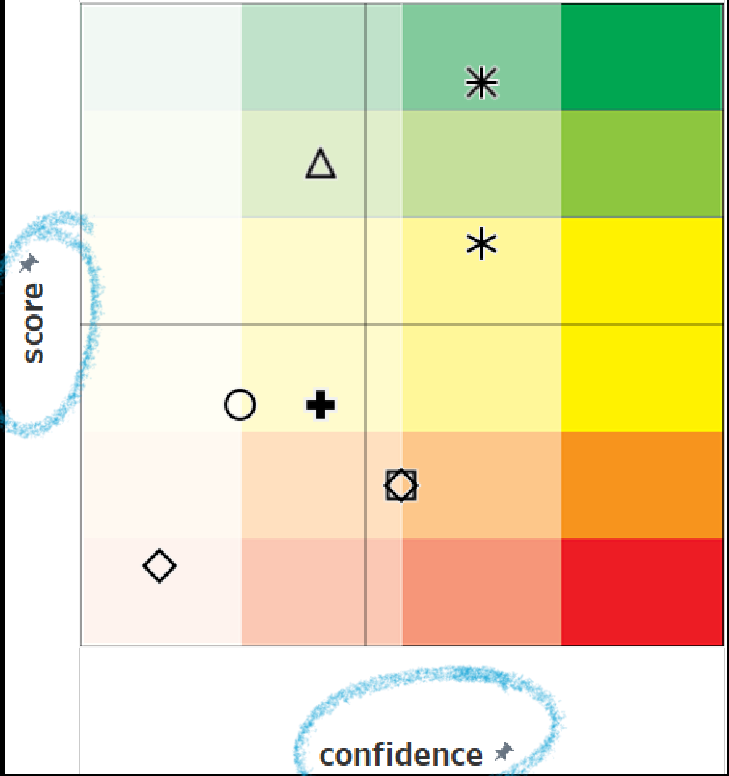
OCTOBER 4th 2022

Ebbe H. Hartz, *AkerBP, Oslo, Norway*
Dani W. Schmid, *Bergverk, Sandefjord, Norway*
Alban Souche, *Bergverk, Sandefjord, Norway*
Karthik Iyer, *Geomodelling Solution, Zurich, Switzerland*
Tobias Baumann, *SmartTectonics, Mainz, Germany*
Geir Jansson, *AkerBP, Oslo, Norway*

(What) Can oil industry contribute to deep sea mining?

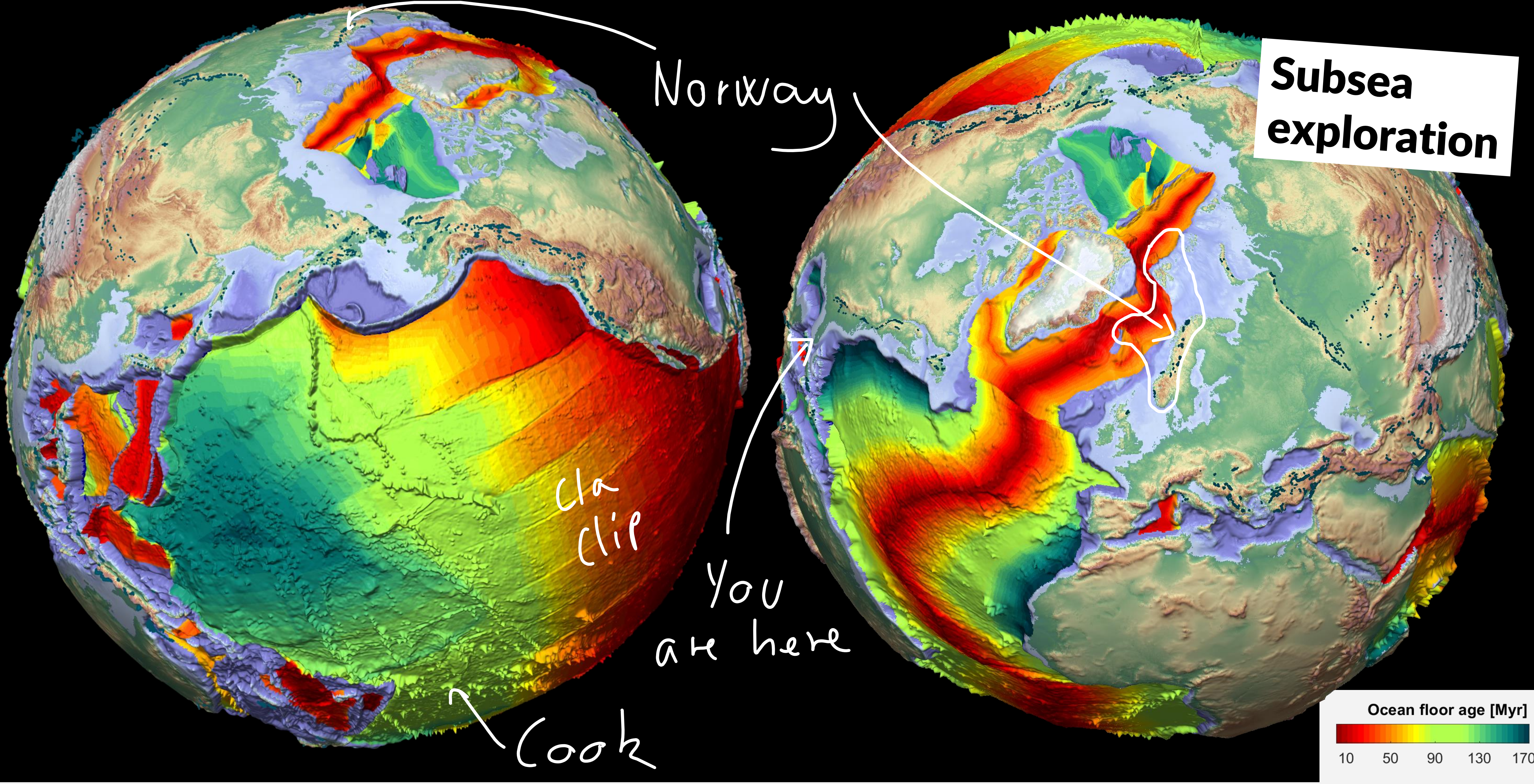
Operation incl. floating production

Approach



Subsea exploration

Subsea exploration

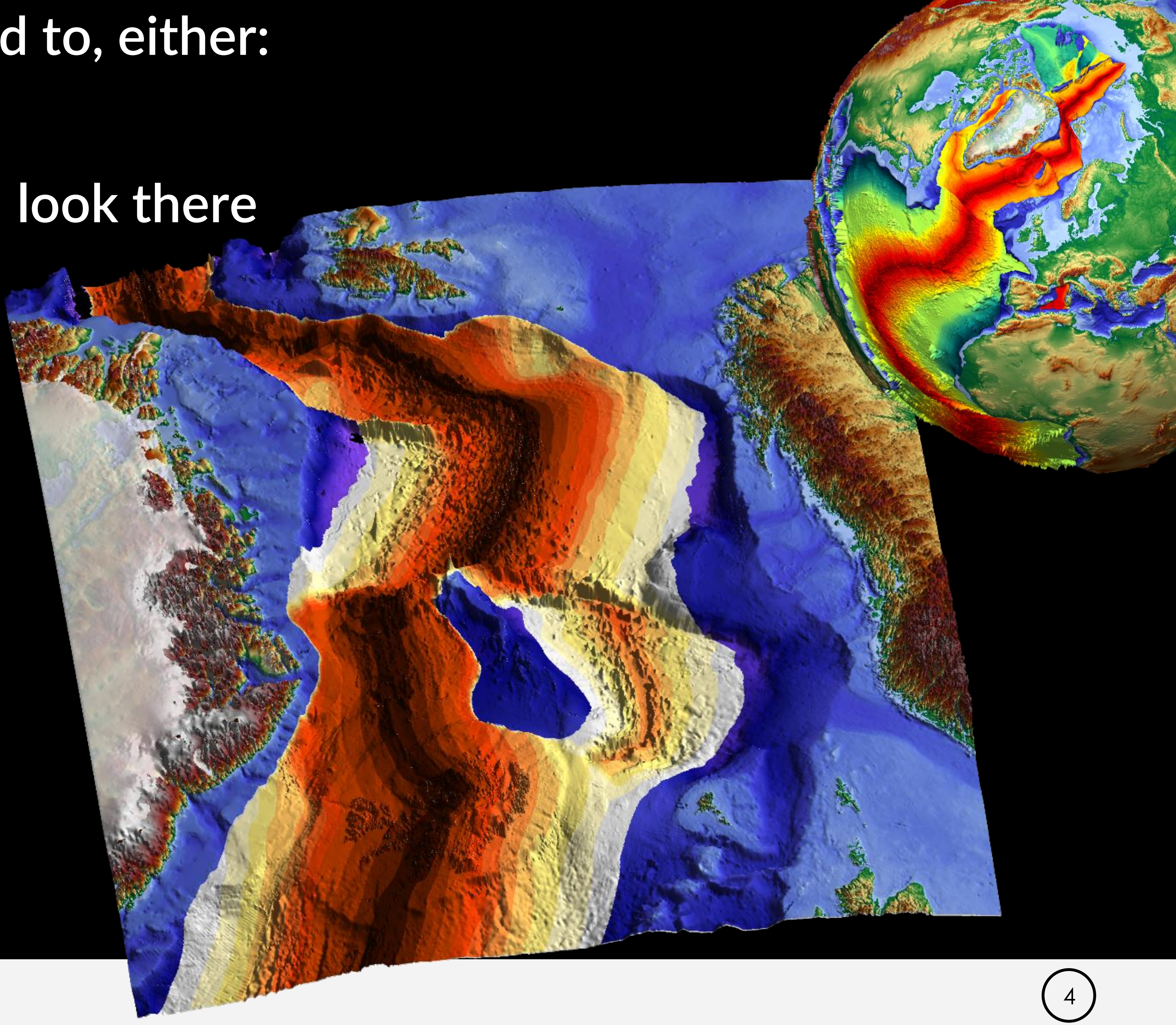


To find something we need to, either:

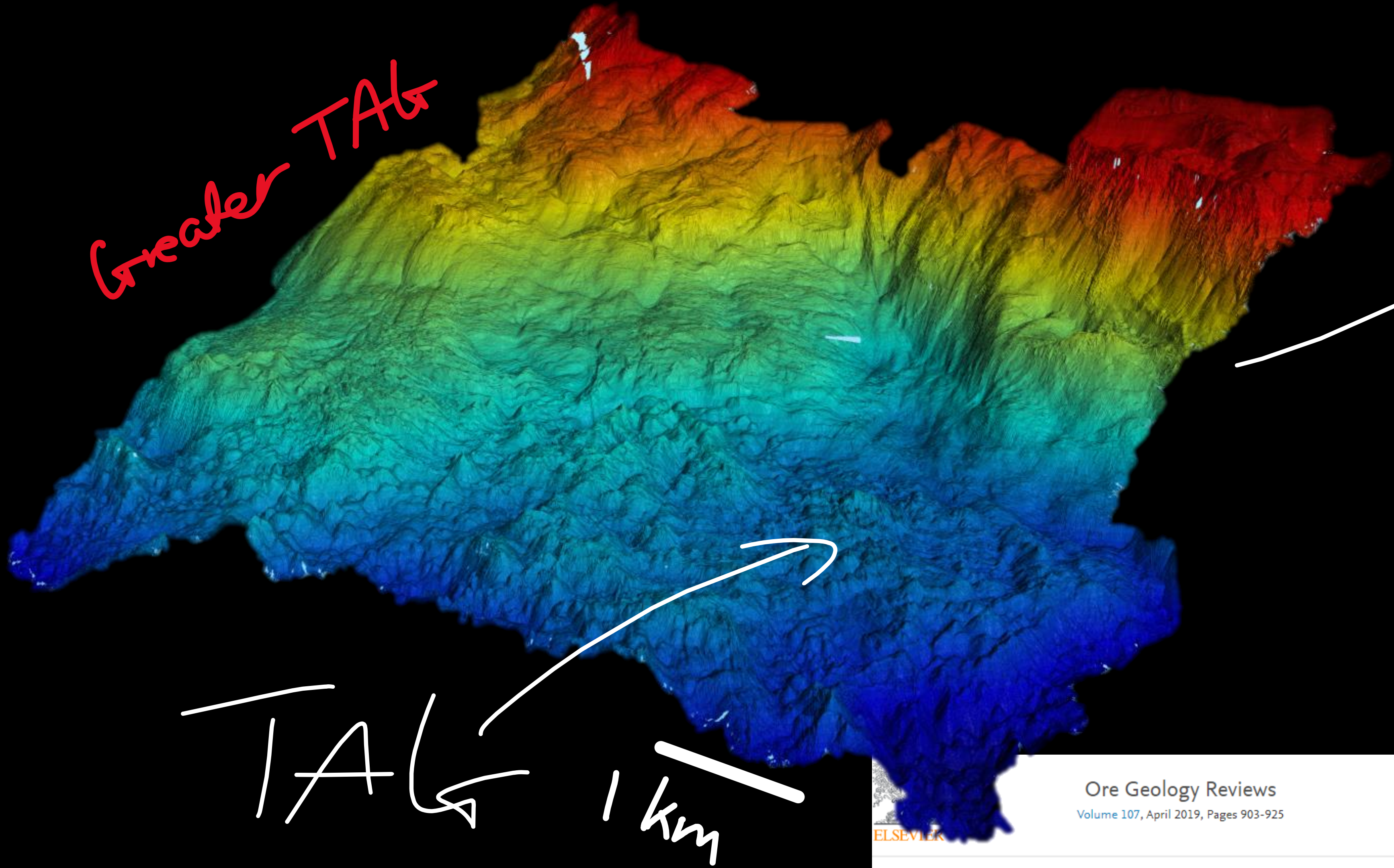
1) Look for it, randomly
2) Predict where it is, and look there
3) Predict where it is not,
   and look elsewhere

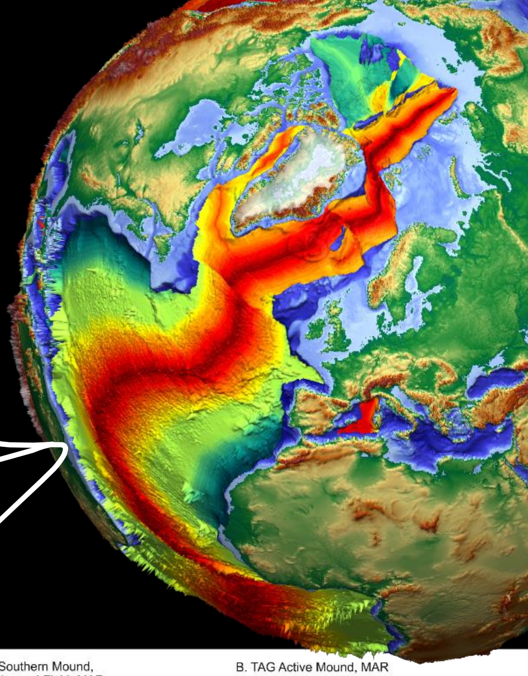
Difficult/Low cost/

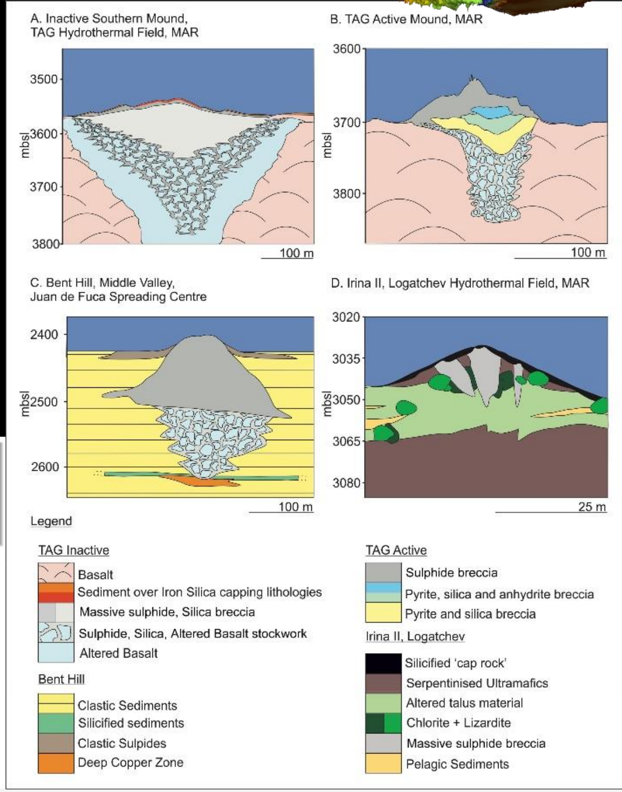
No harm



Can algorithms find resources if we have the right data?







ELSEVIER

Ore Geology Reviews
Volume 107, April 2019, Pages 903-925

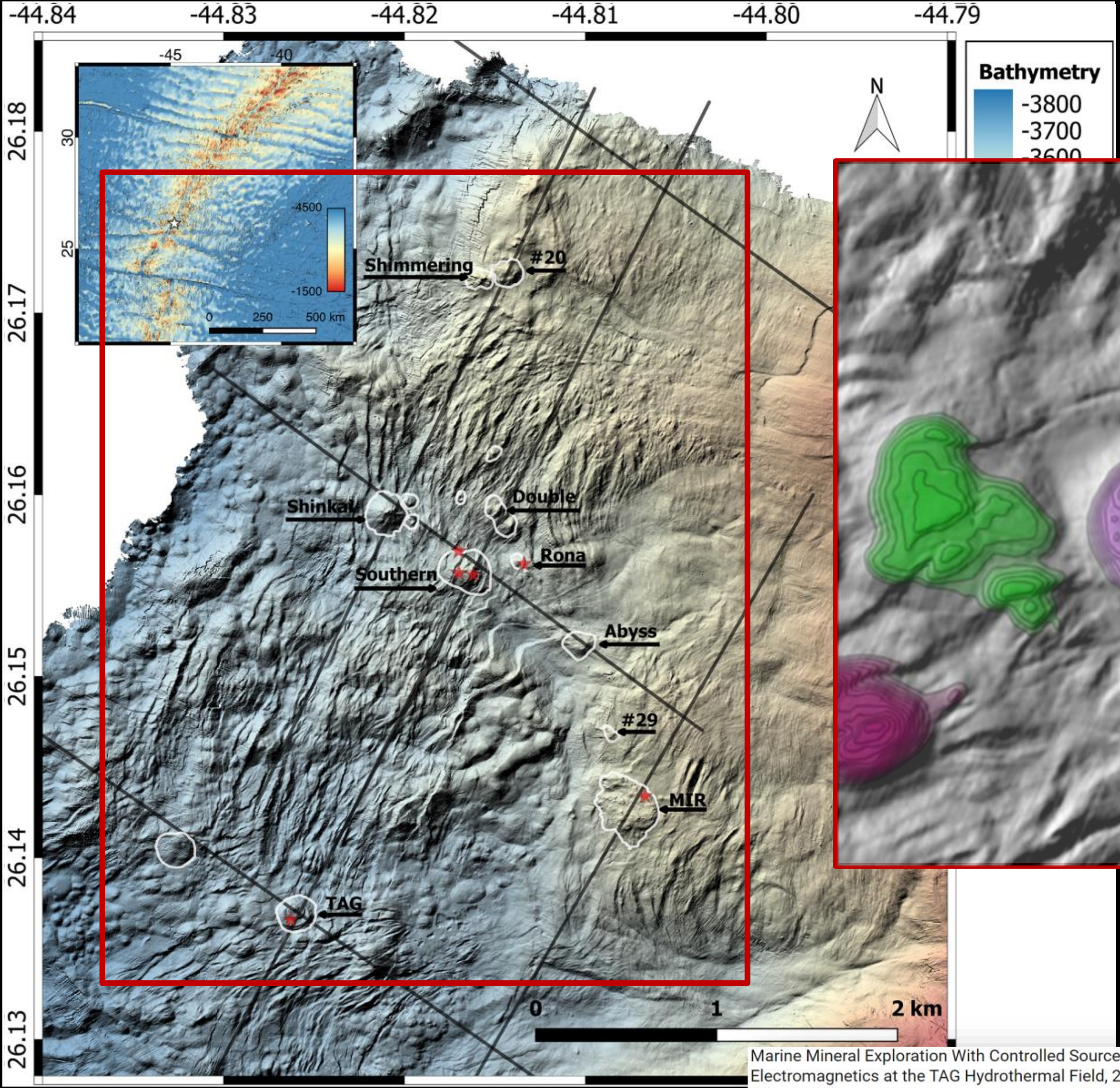
Invited Review Article

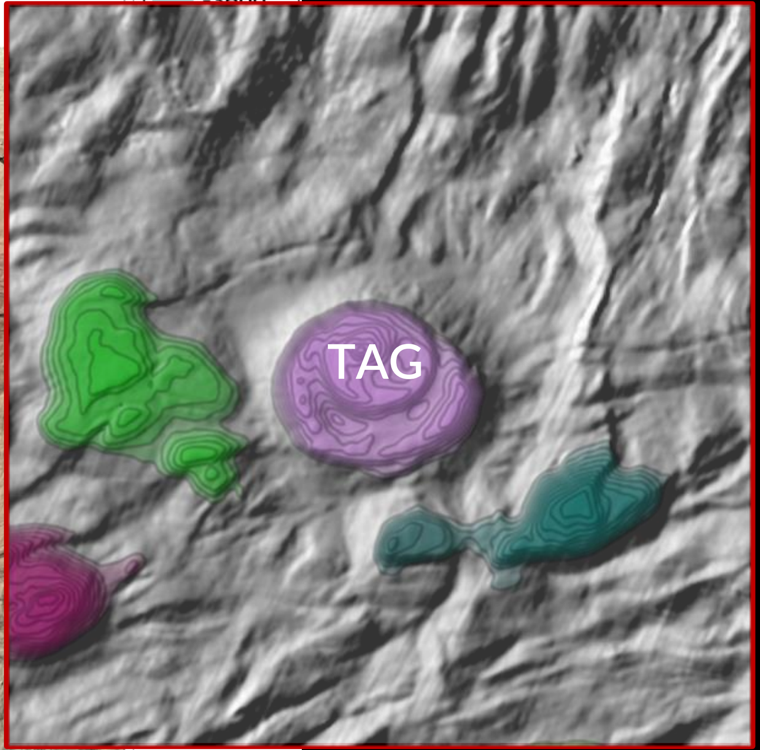
Geological fate of seafloor massive sulphides at the TAG hydrothermal field (Mid-Atlantic Ridge)

Bramley J. Murton [a], Berit Lehrmann [a], Adeline M. Dutrieux [b], Sofia Martins [c, d], Alba Gil de la Iglesia [a, f], Iain J. Stobbs [b], Fernando J.A.S. Barriga [c], Jörg Bialas [d], Anke Dannowski [d], Mark E. Vardy [a, g], Laurence J. North [a], Isobel A.L.M. Yeo [a], Paul A.J. Lusty [e], Sven Petersen [d]

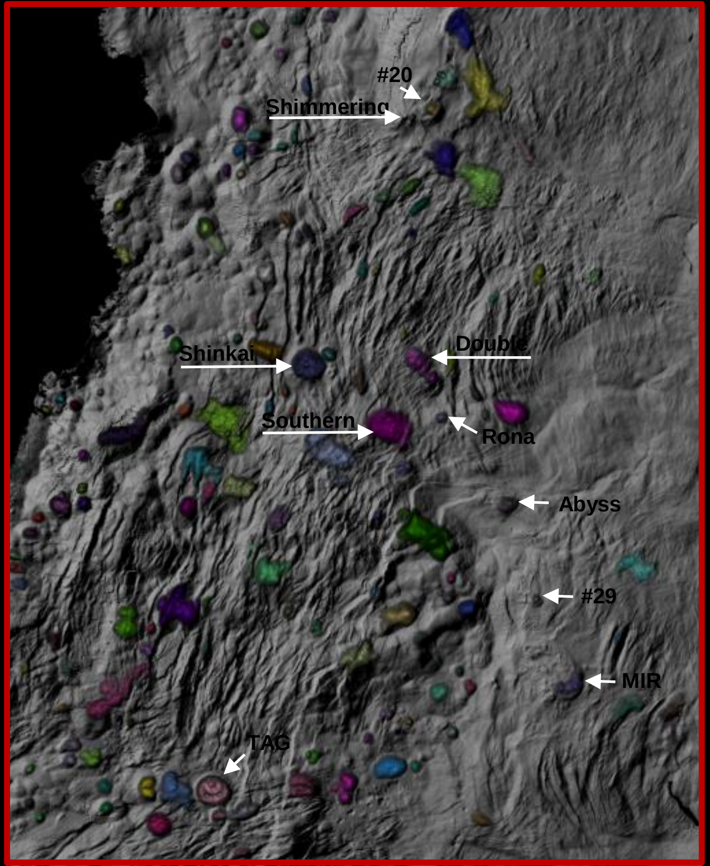
AkerBP

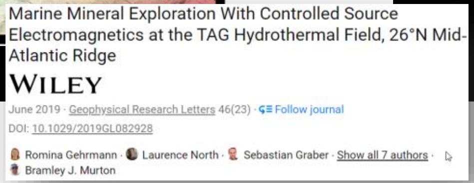
Can algorithms find resources if we have the right data? Yes!





Our algorithm find all known discoveries




Marine Mineral Exploration With Controlled Source Electromagnetics at the TAG Hydrothermal Field, 26°N Mid-Atlantic Ridge

WILEY

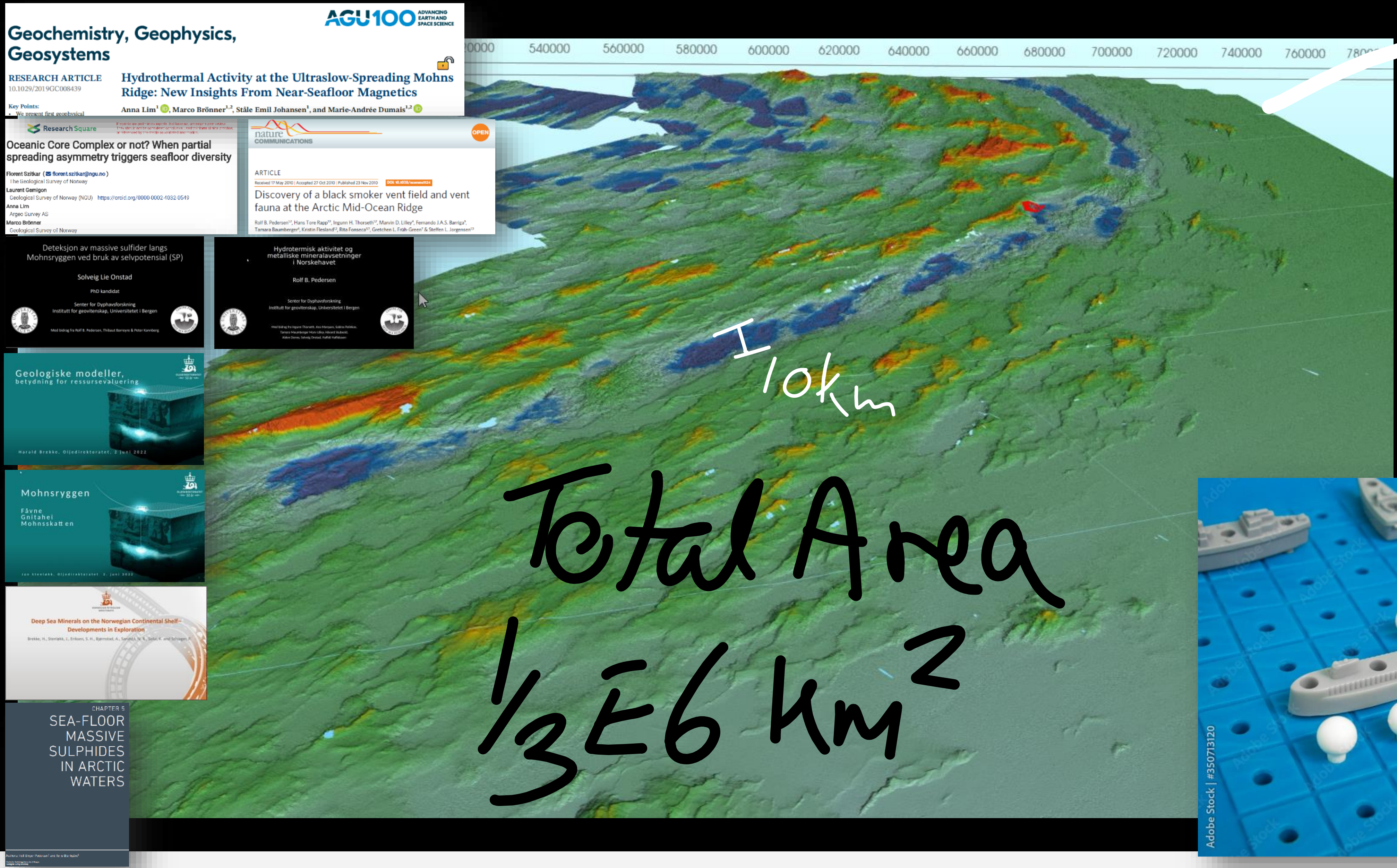
June 2019 · Geophysical Research Letters 46(23) · Follow journal

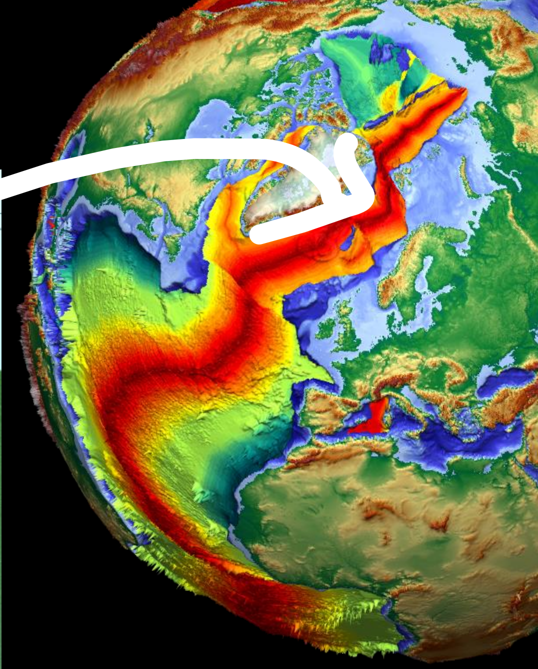
DOI: 10.1029/2019GL082928

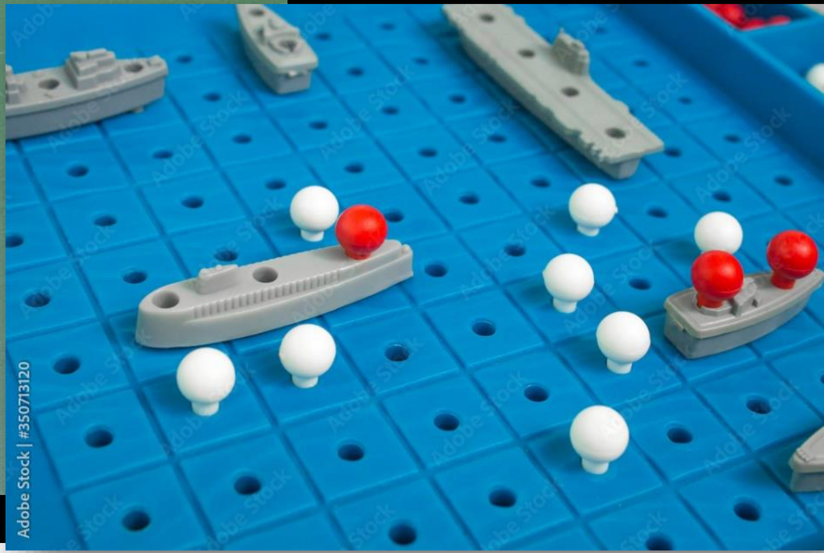
Romina Gehrmann · Laurence North · Sebastian Graber · Show all 7 authors · Bramley J. Murton

but also many apparent 'false positives'
(greatly reduced area of detailed sampling)

The key challenge is where to look in the Norwegian EEZ!

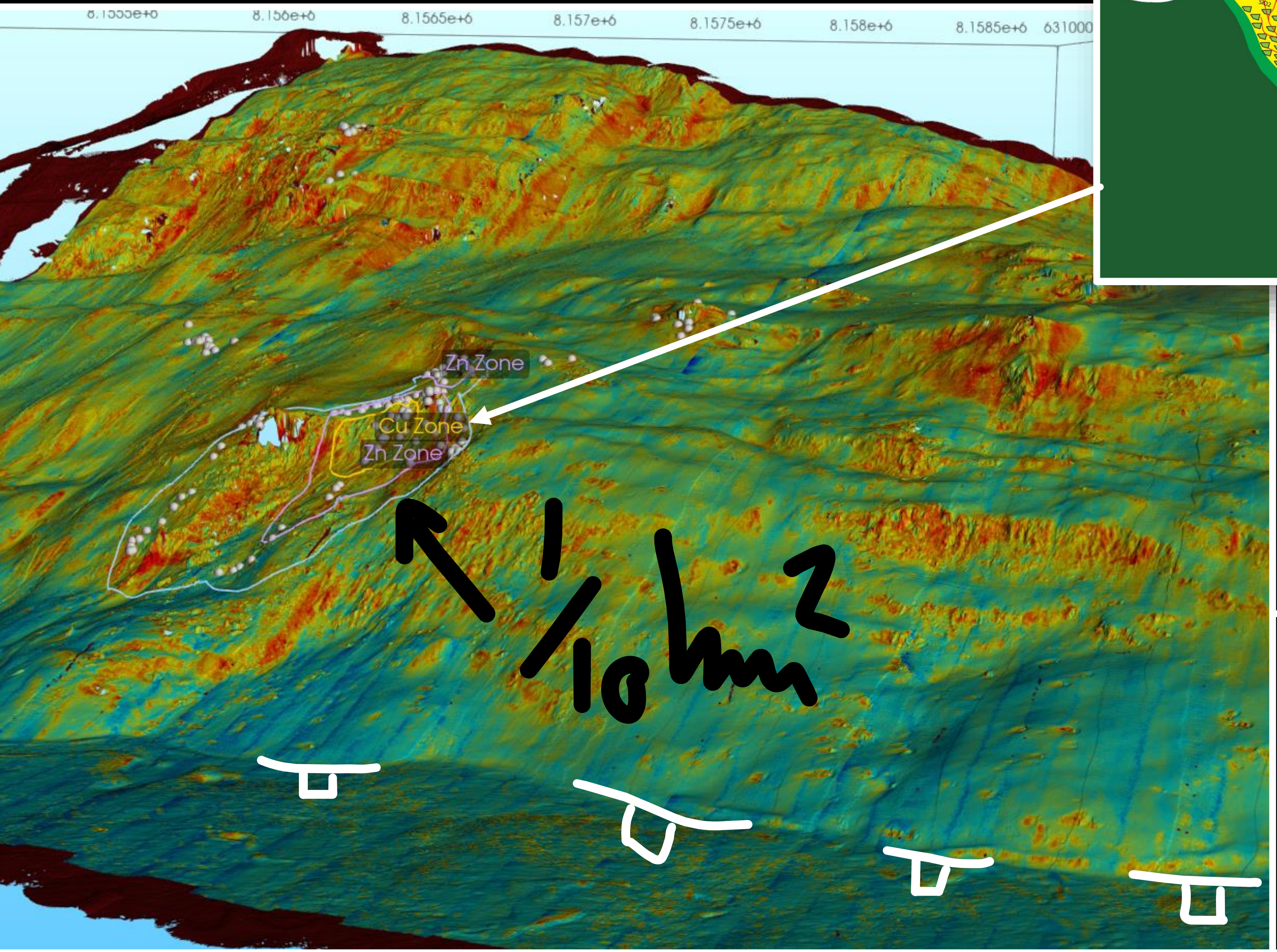


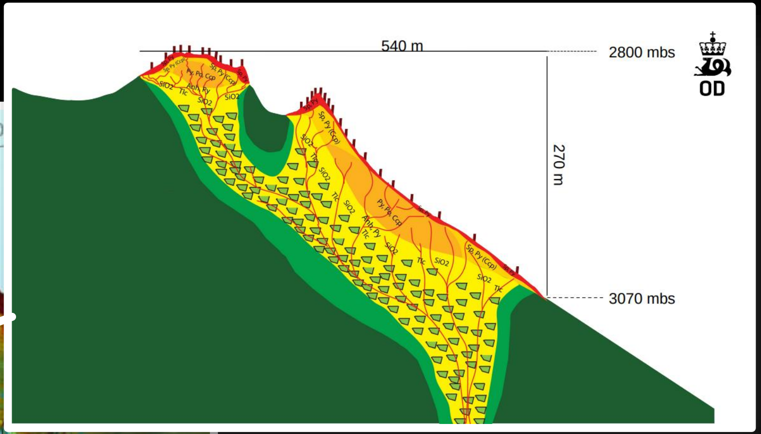


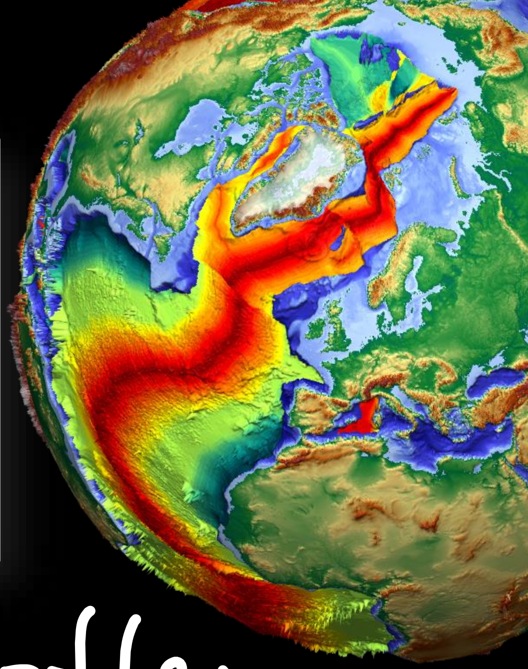


What we are looking for: Mohn's Treasure

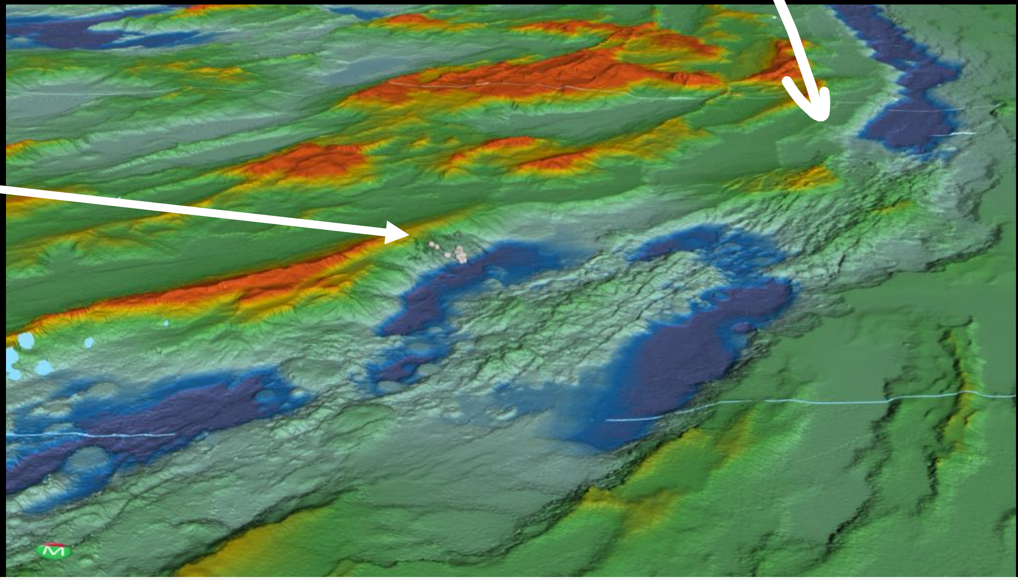
Promising discoveries already made and published



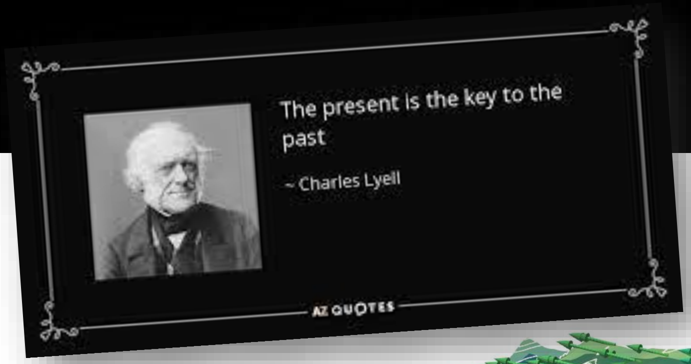


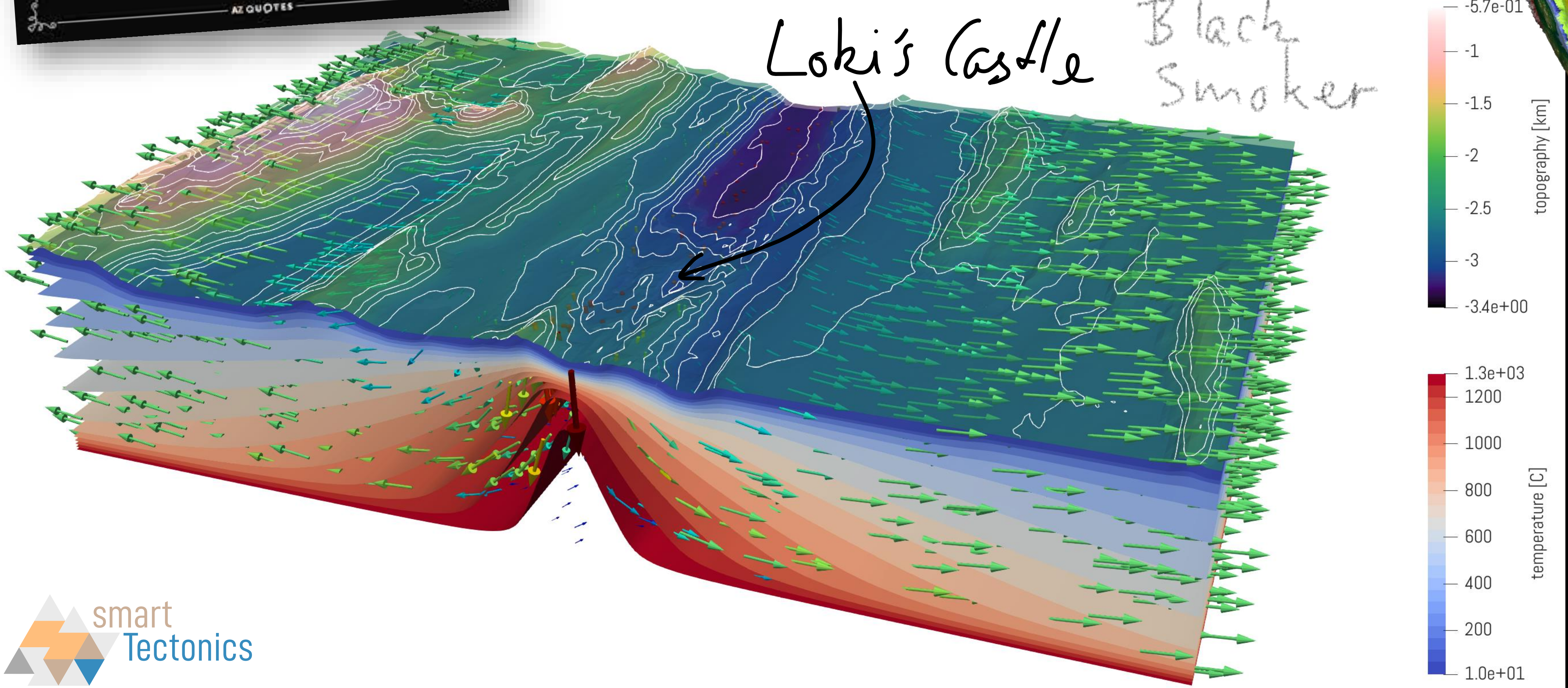


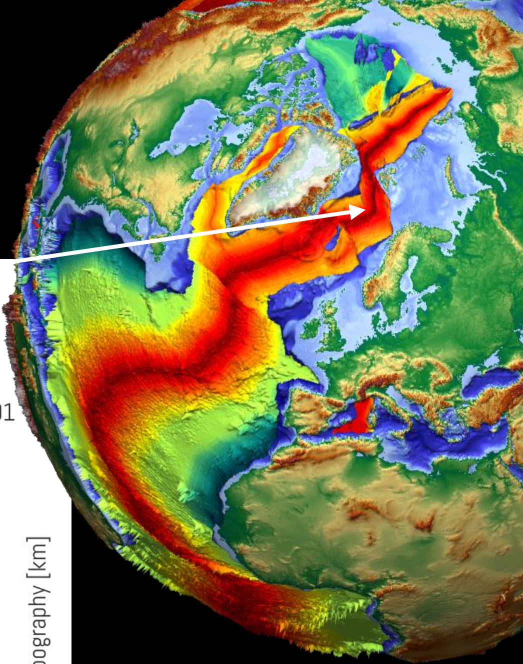
Loki's Castle



Geodynamic models of Loki's Castle (active black smoker)

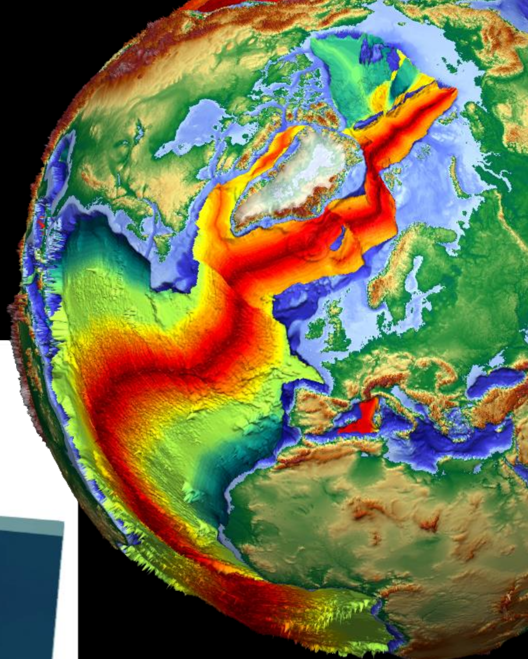


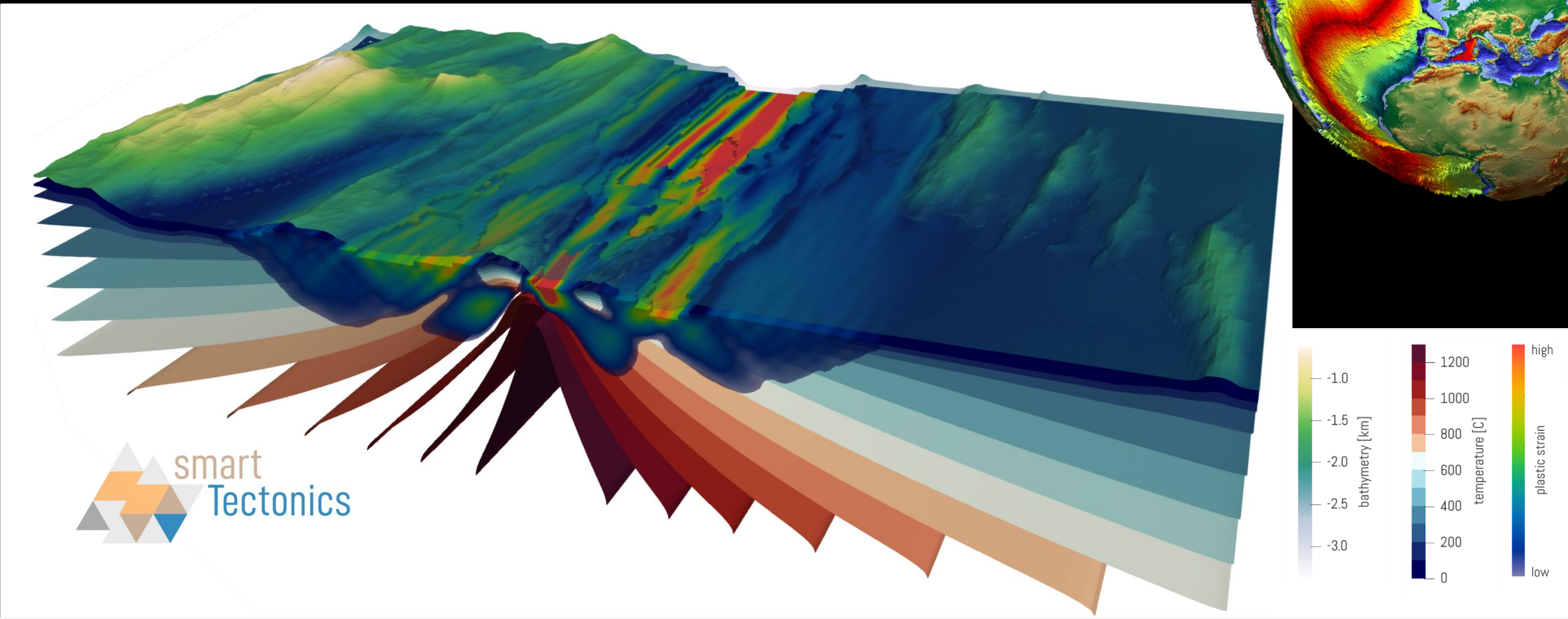




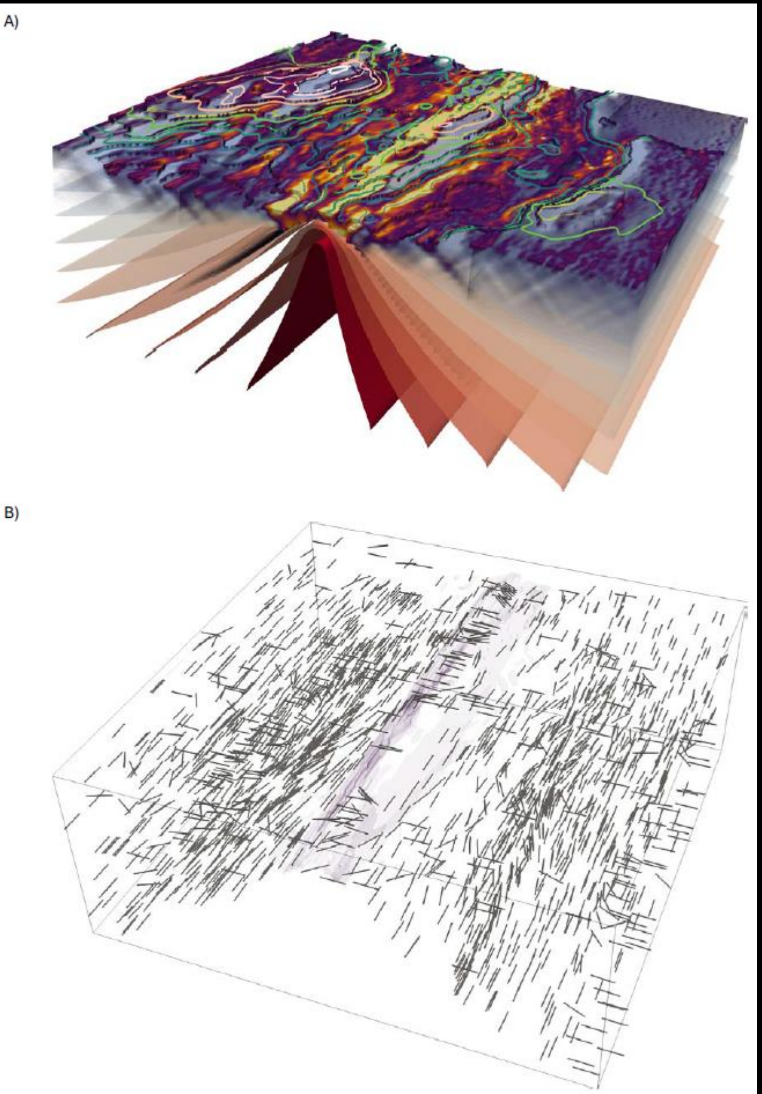
smart Tectonics

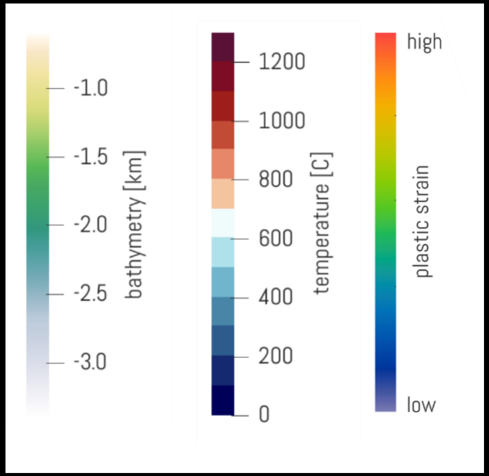
Geodynamic models of Loki’s Castle (active black smoker)

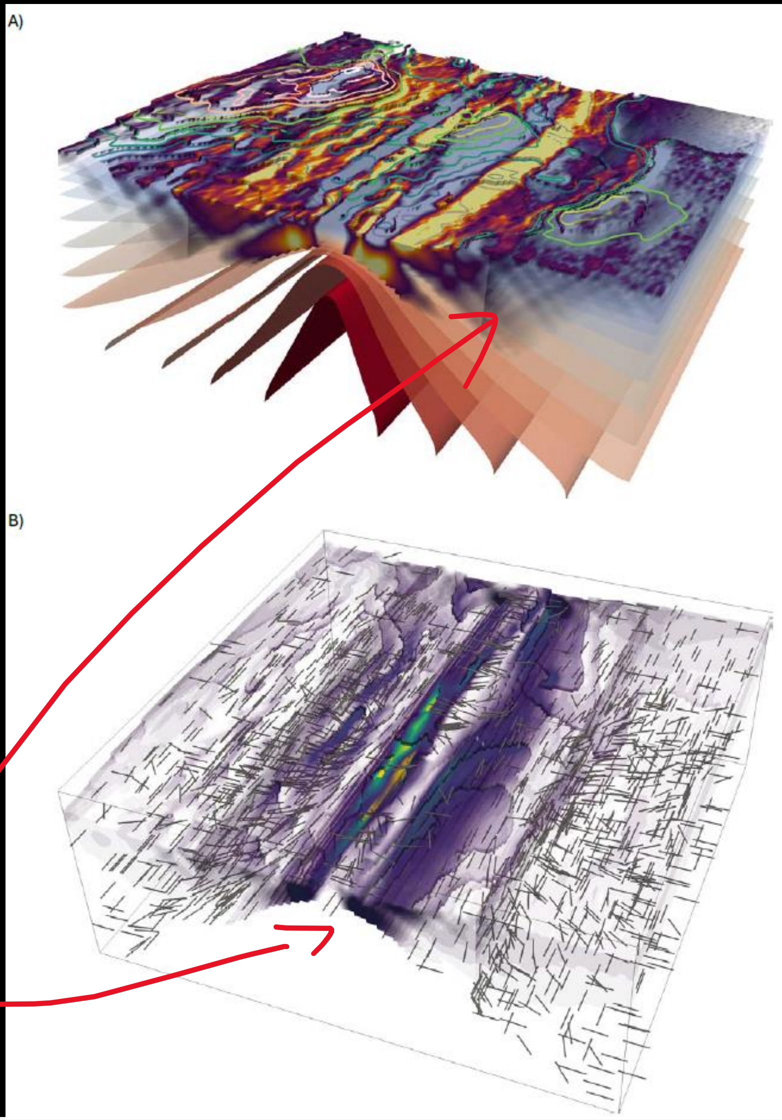




Geodynamic models of Loki’s Castle (active black smoker)







1000 yrs

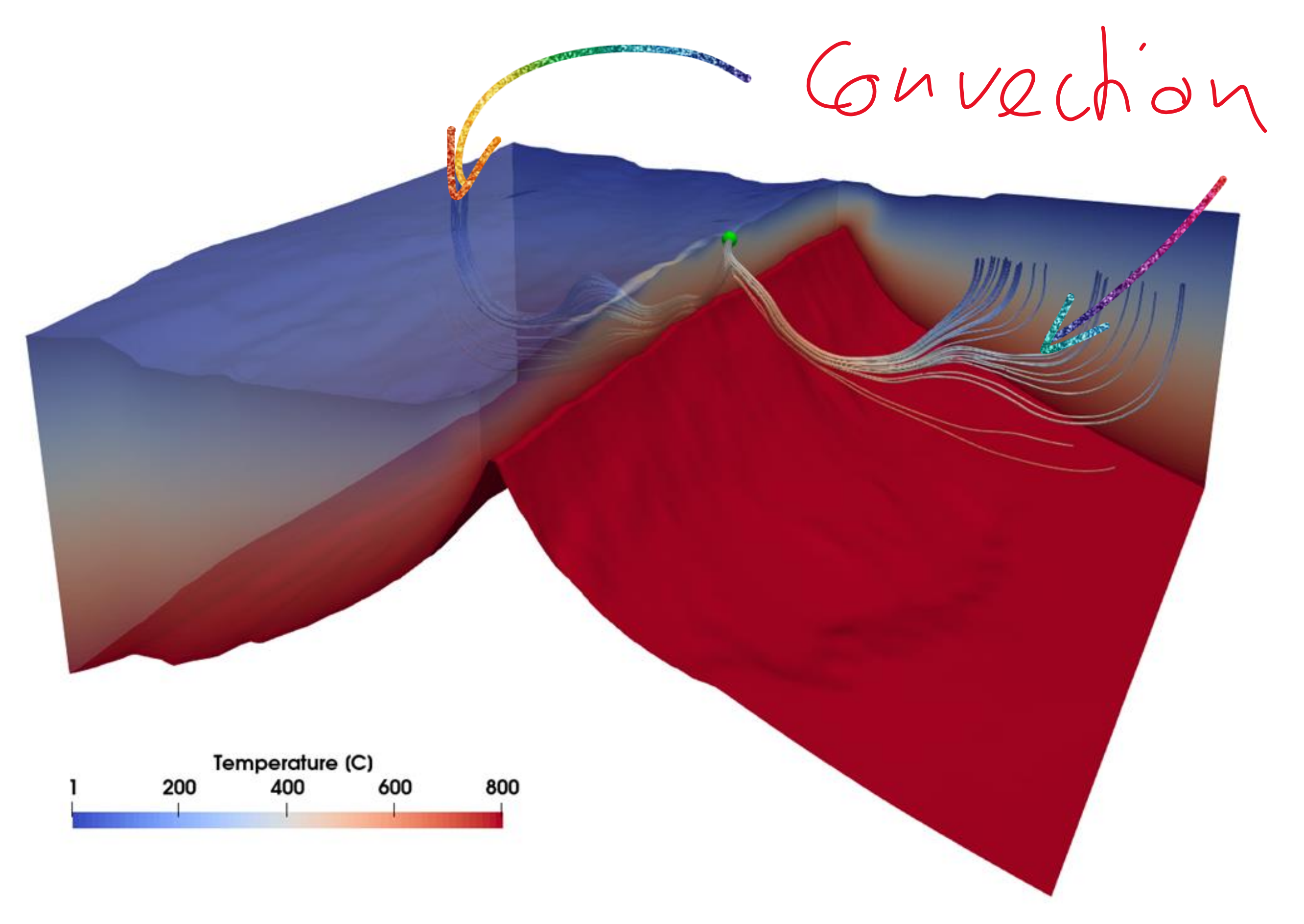
7800 yrs

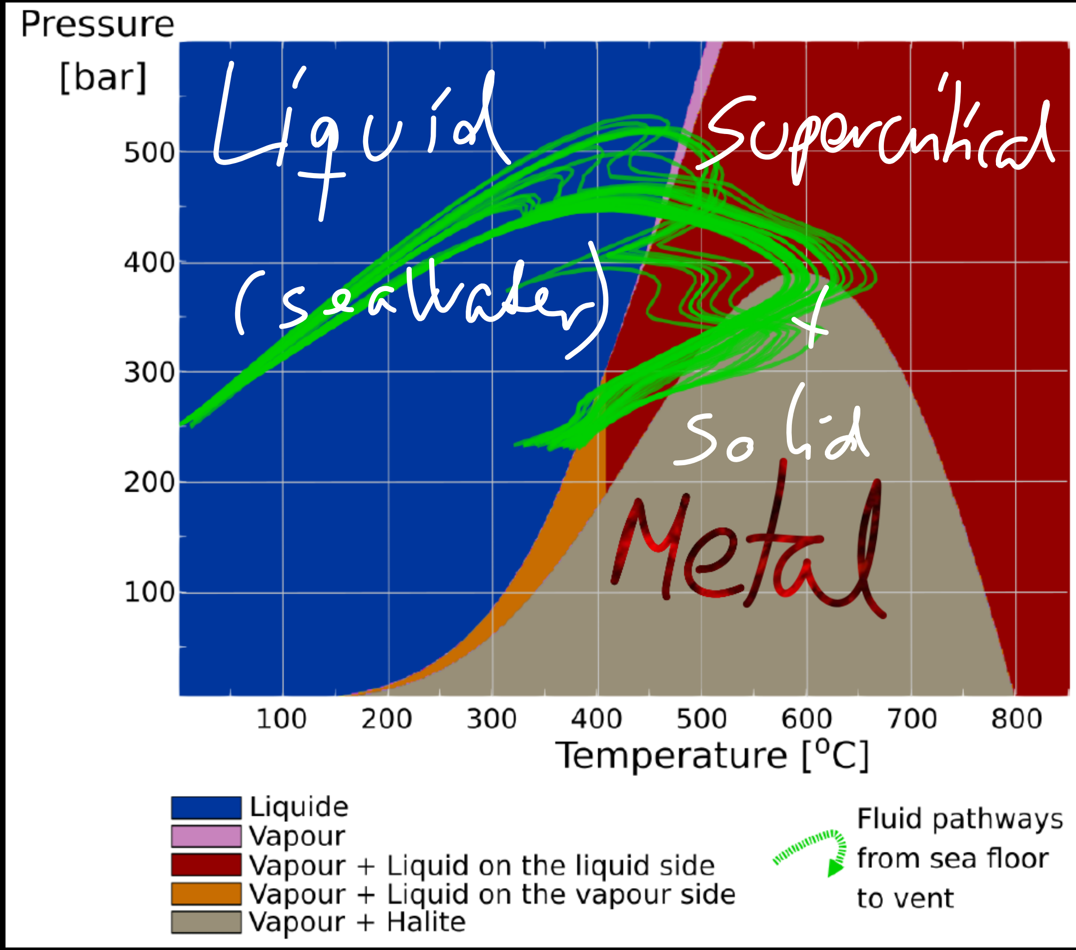
Faults conduits hydrothermal

Hydrothermal model of Loki's Castle (active black smoker)

(Petroleum and) Mineral System Modeling involve dynamic models tracing **solids**, **liquids** and **vapours** through space (permeability), stress, **pressure, temperature and time**

+ pH
Eh

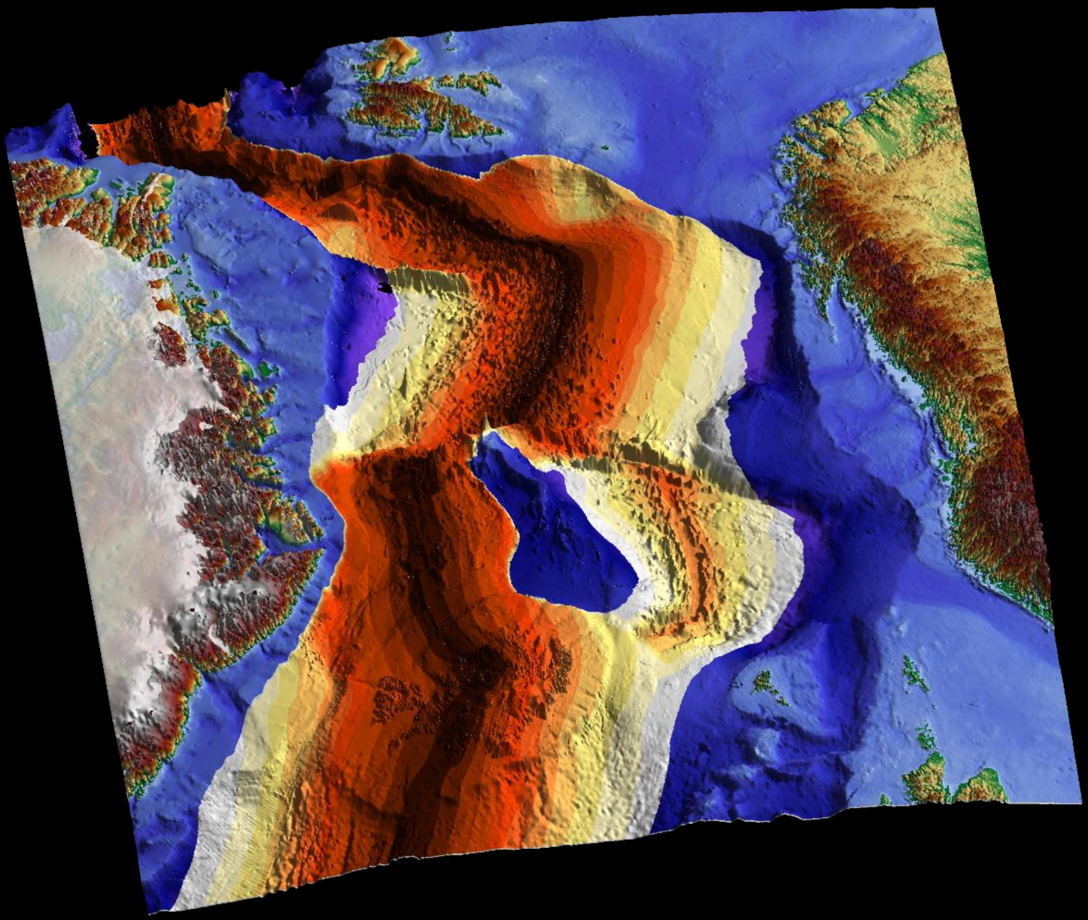


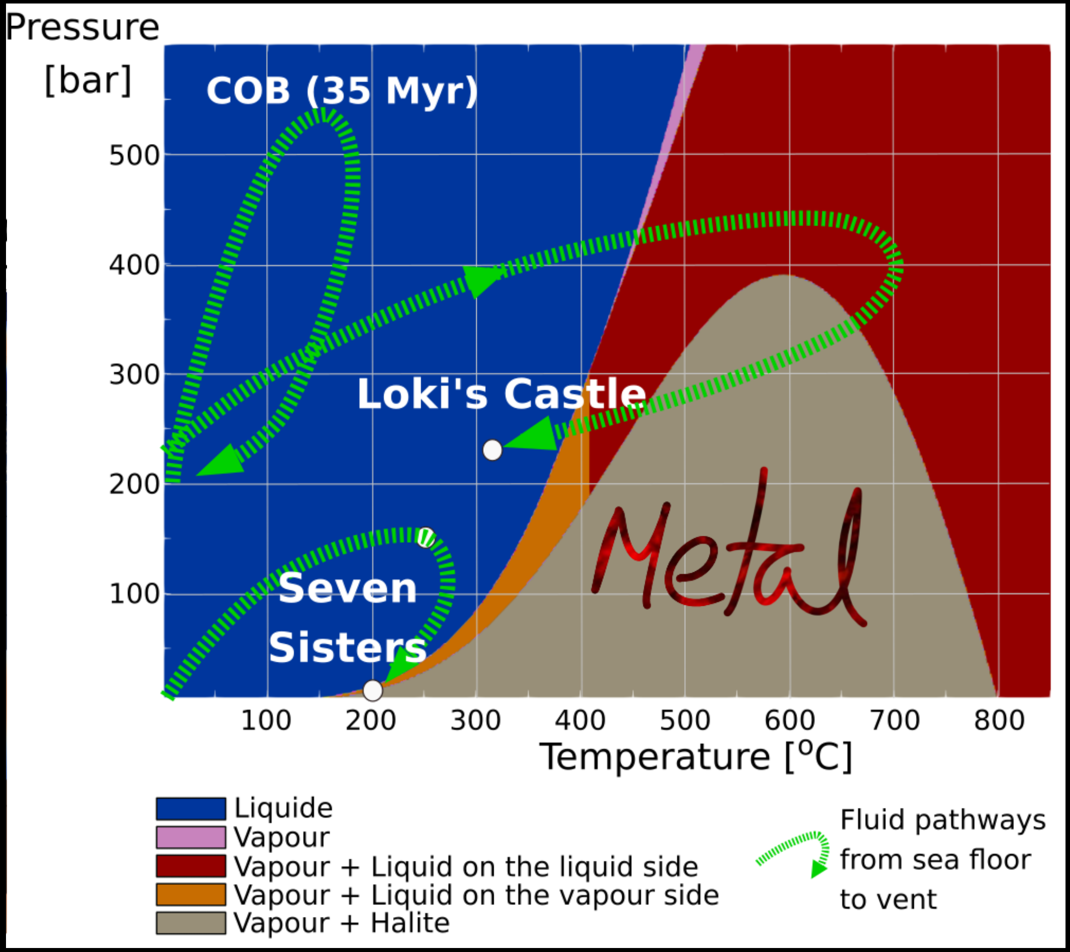


Hydrothermal models of North Atlantic sites

(active black and white smokers)

Suggest where we should not explore





Status Norwegian eSMS

Promising discoveries already made and published

Small areas with high value concentration of ‘easy refinement common’ metals

Is there enough total volumes to start an industry?

consequence

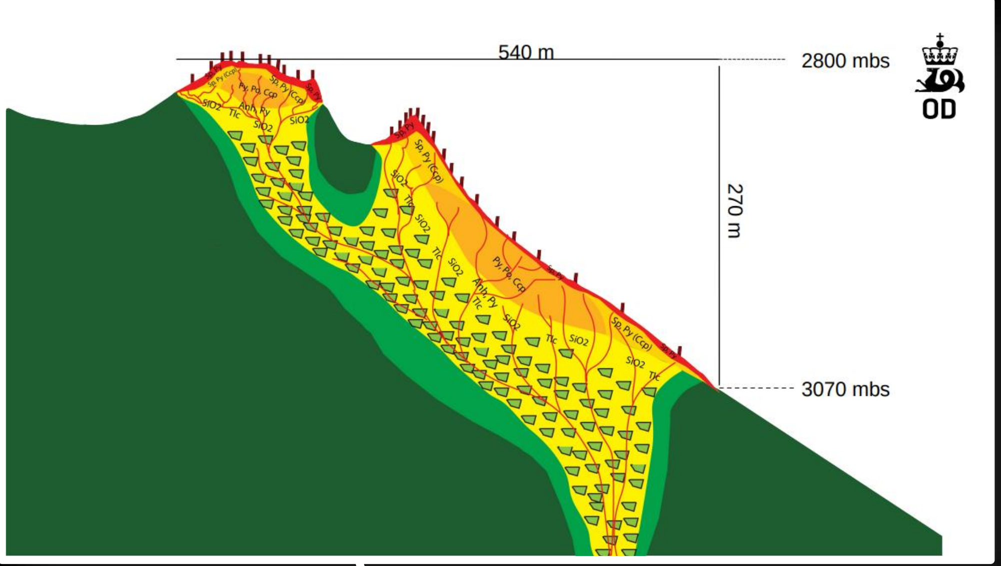
1 kg Cu

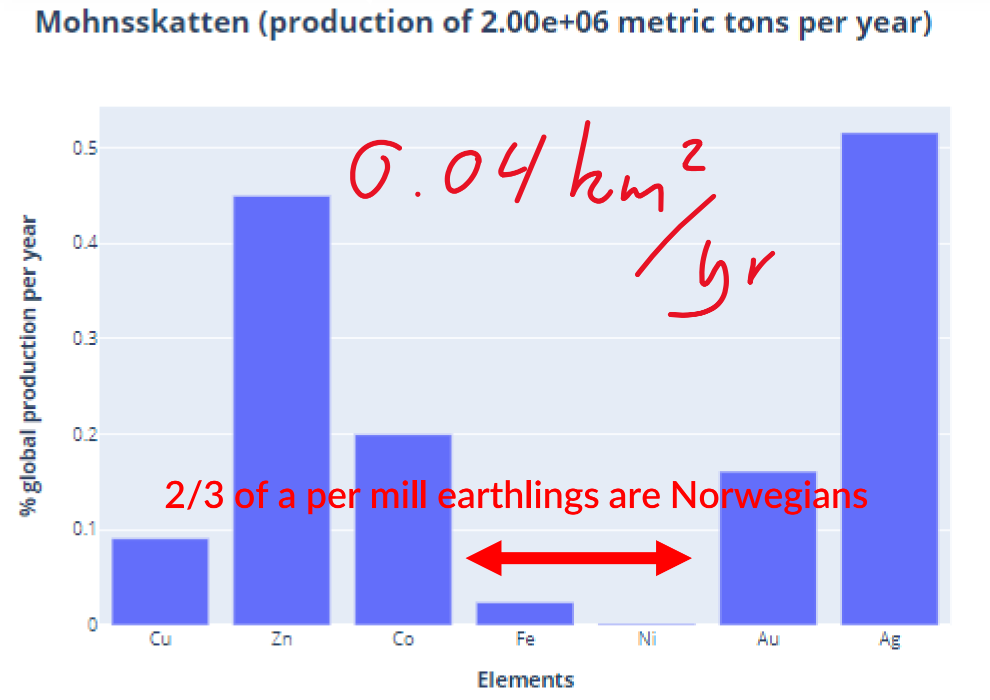
(Cu, Zn, Co, Au, Ag)

IF you know where to look, eSMS are probably easy to find.

Where to look?

Can probably be mined with deep sea-modified tools @ fair cost



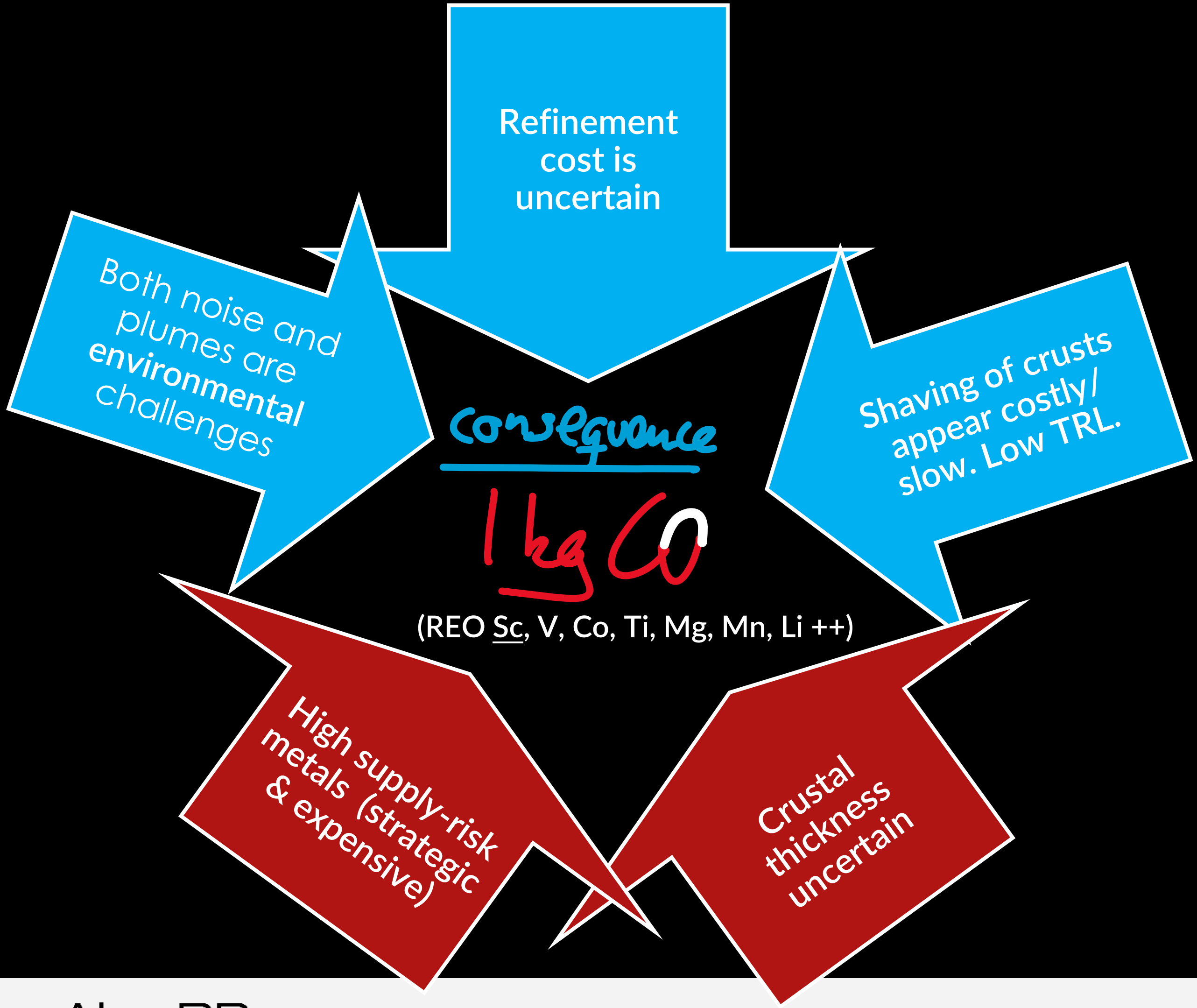


Refs: Stenløk (2022), Brekke (2022) i.e. NPD data release 2022 @ www.NPD.no

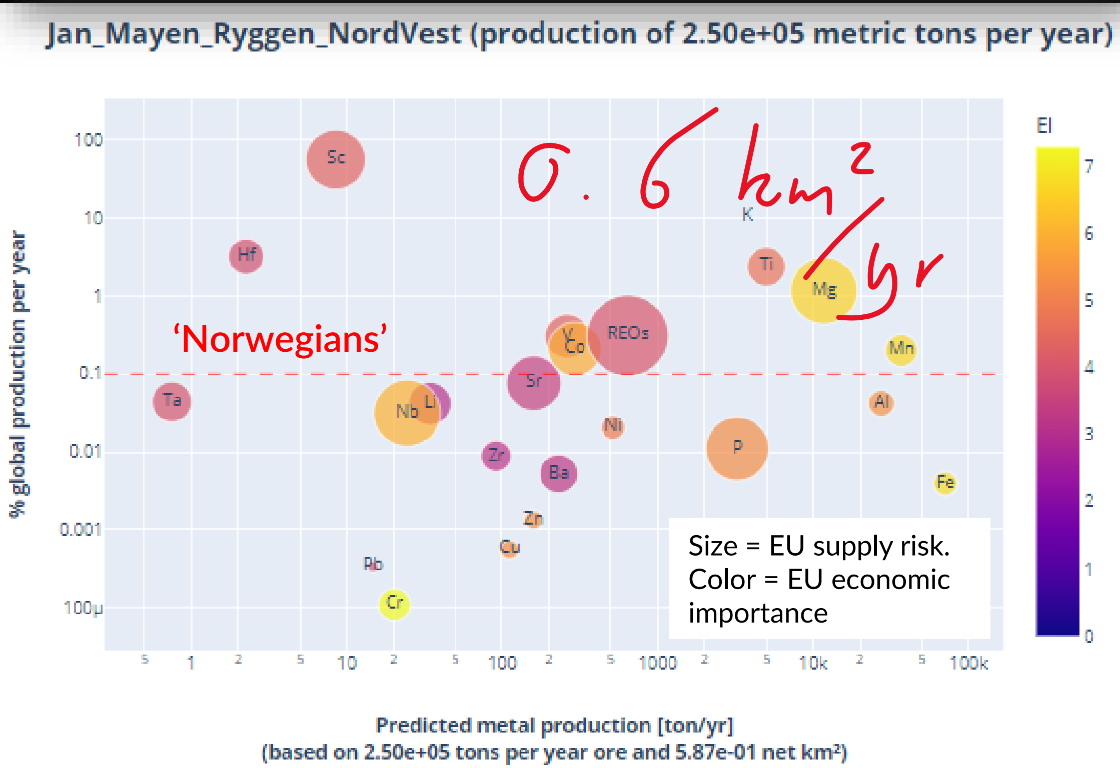
Status Norwegian FM crusts

Appear abundant, and locally thick.

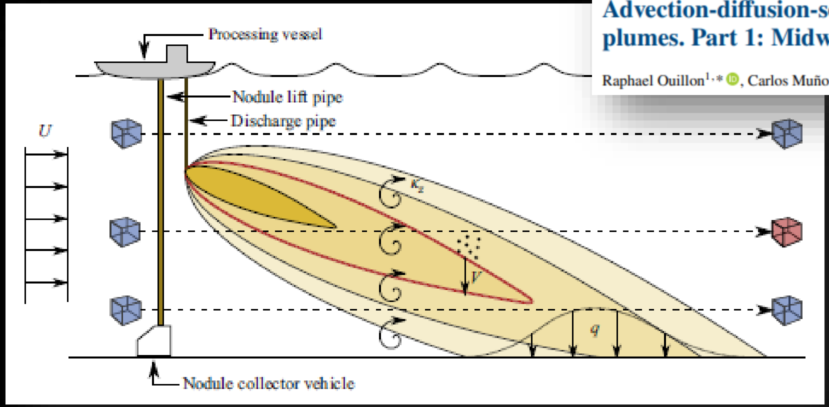
Production and environmental cost needs further work



Crust surface habitat



Plume models for FM *Nodules*

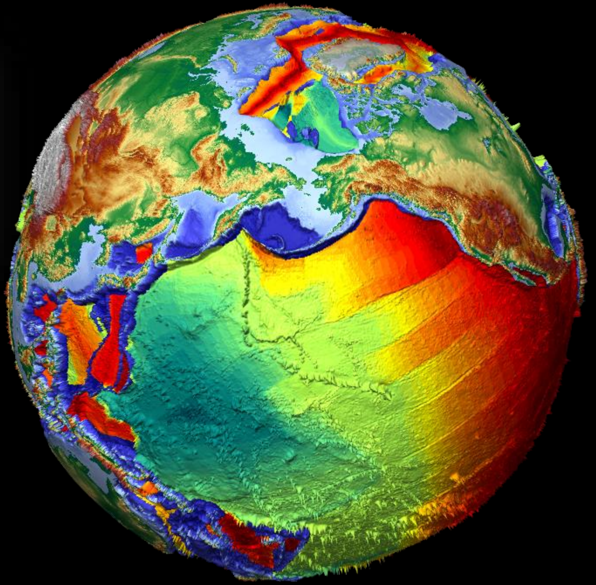


Flow (2022), **2** E22
doi:10.1017/flo.2022.20
FLOW CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Advection-diffusion-settling of deep-sea mining sediment plumes. Part 1: Midwater plumes

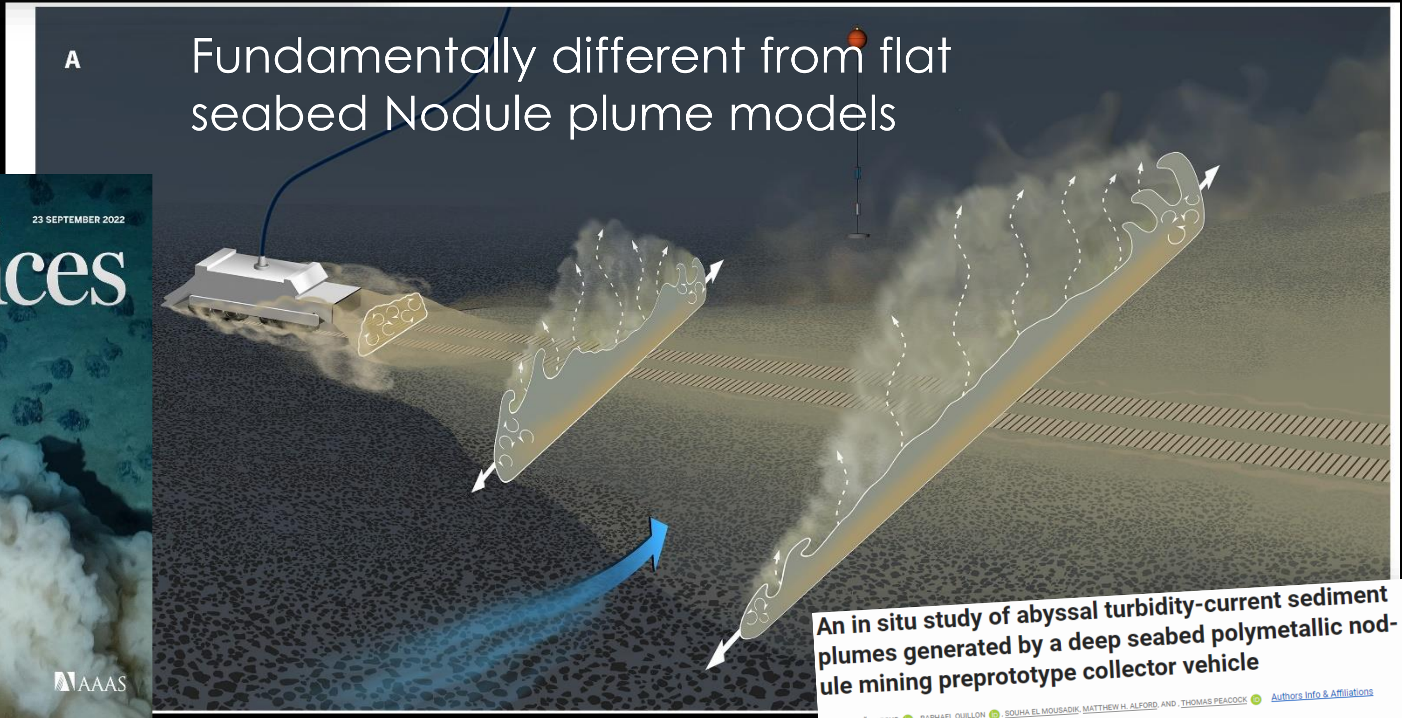
Raphael Ouillon[1,*], Carlos Muñoz-Royo[1], Matthew H. Alford[2] and Thomas Peacock[1]



Both noise and plumes are environmental challenges

consequence

1kg CO



Fundamentally different from flat seabed Nodule plume models

An in situ study of abyssal turbidity-current sediment plumes generated by a deep seabed polymetallic nodule mining preprototype collector vehicle

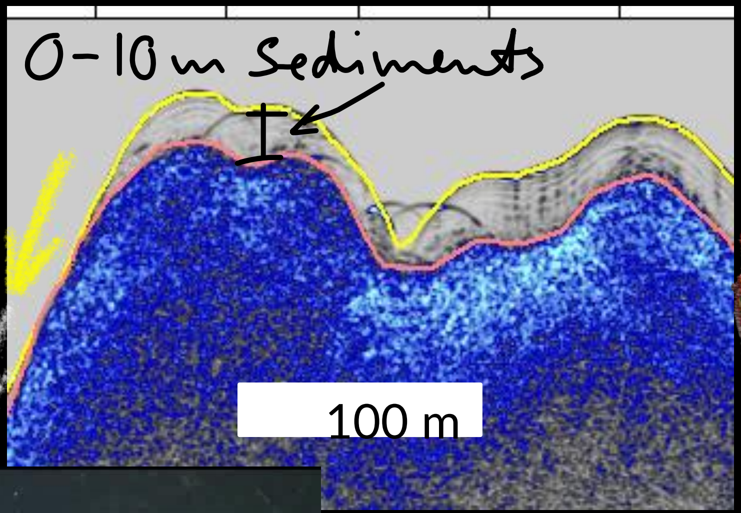
CARLOS MUÑOZ-ROYO, RAPHAEL OUILLON, SOUHA EL MOUSADIK, MATTHEW H. ALFORD, AND THOMAS PEACOCK Authors Info & Affiliations

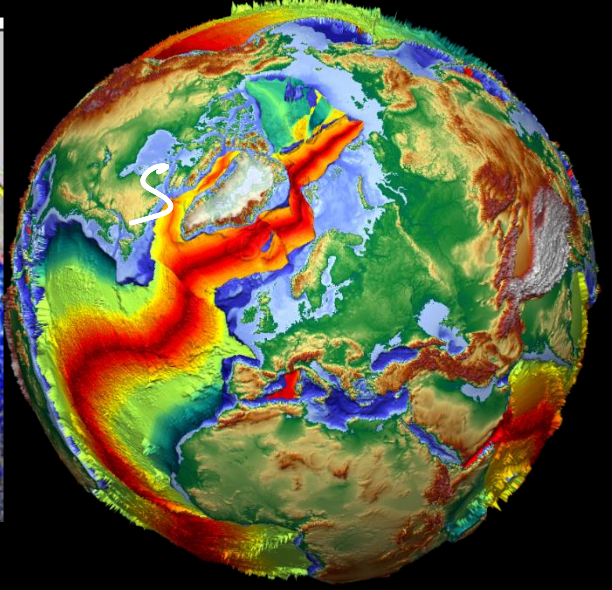
SCIENCE ADVANCES • 21 Sep 2022 • Vol 8, Issue 38 • DOI: 10.1126/sciadv.abn1219

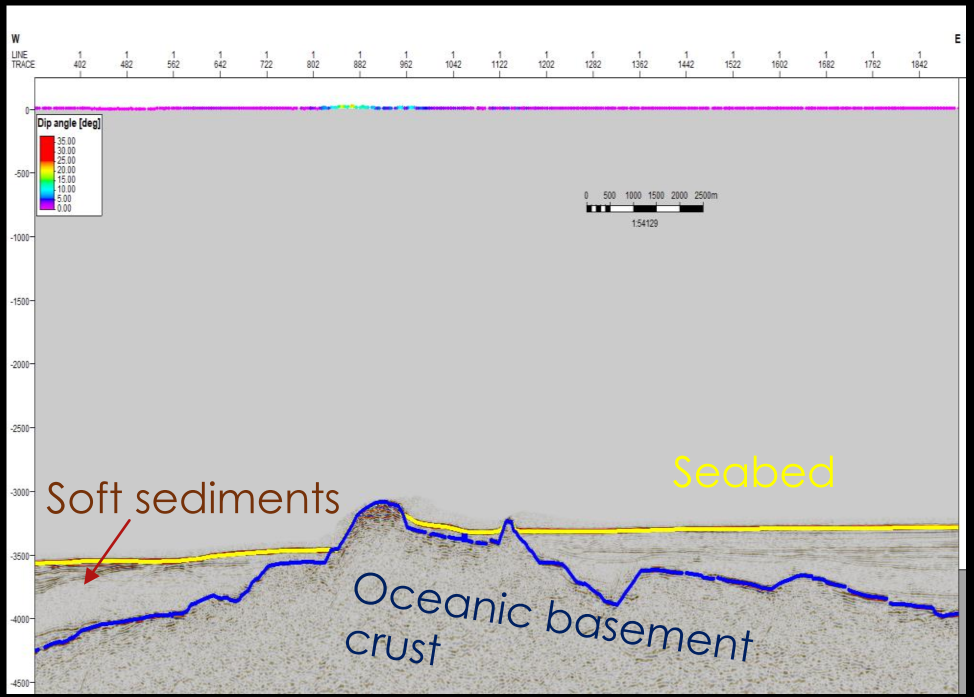
Movie on the next slide

Plume models for FM **Crusts**

Machine learning algorithms recognize and quantify ‘life’



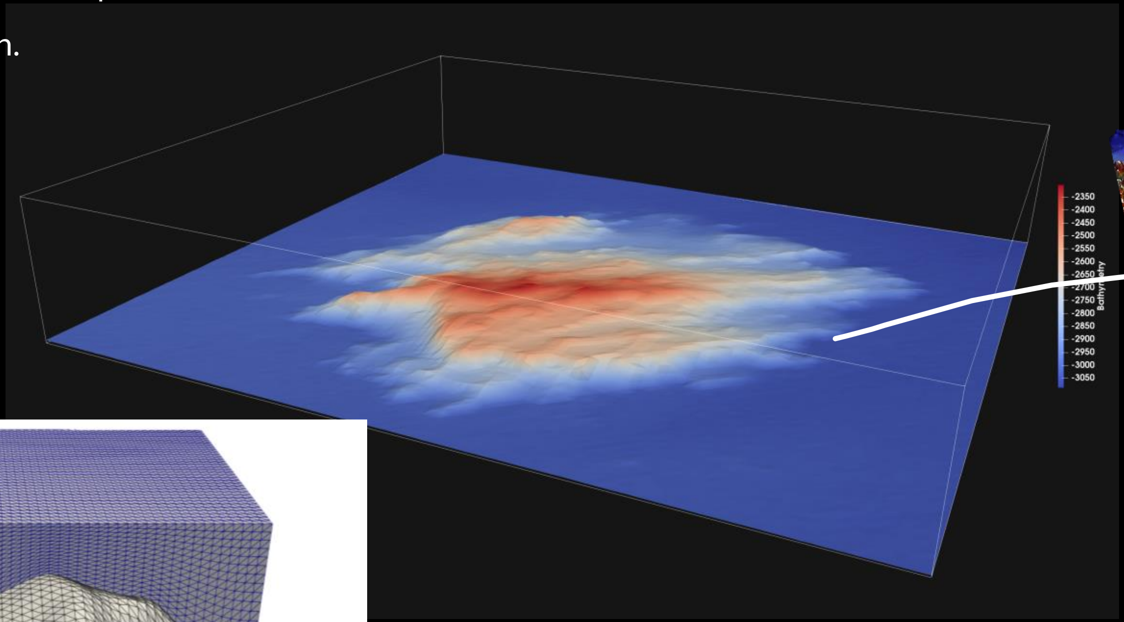


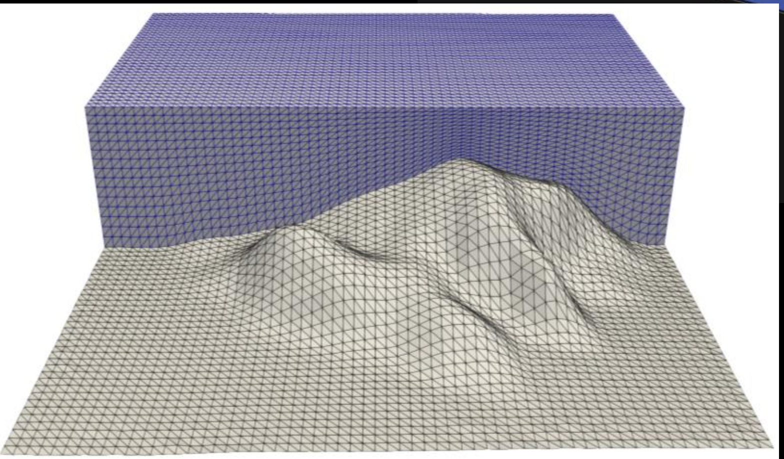


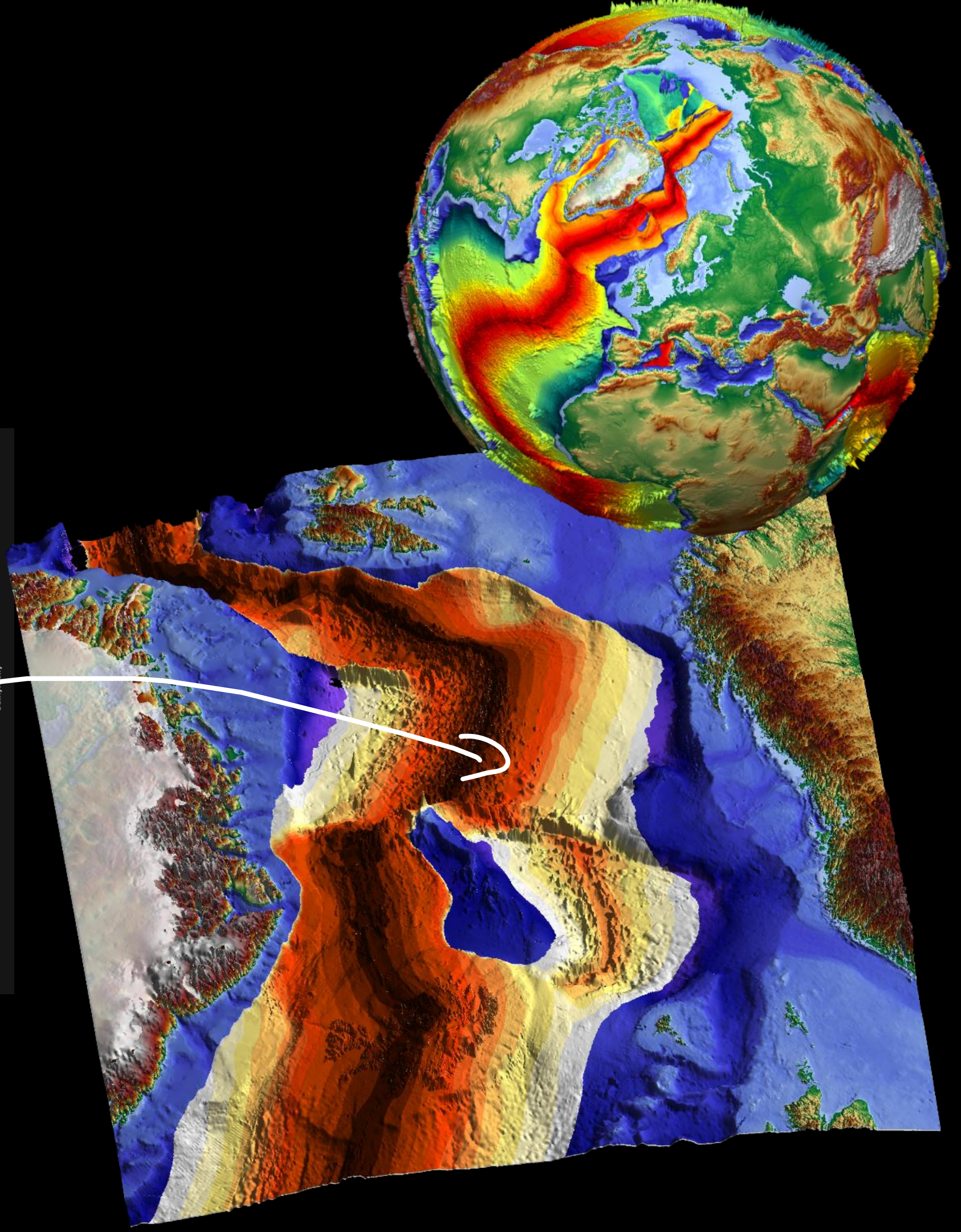
Video reference (Youtube): NPD and University of Bergen (in house analysis: of sponges)
Subbottom profile data: NPD data release 2022 @ www.NPD.no

Plume models for FM Crusts

- Study potential impact of seabed mining on the biosphere.
- What happens to reinjected debris.
- Quantify the amount of area affected and the locations.
- Test case: Norwegian sea mount, height=800m, extent=15km*15km.
- Flow resolved with 10m vertical resolution up to the surface and 5s time step. LES turbulent model based on open-source OASIS Navier-Stokes solver.
- High quality custom mesh.



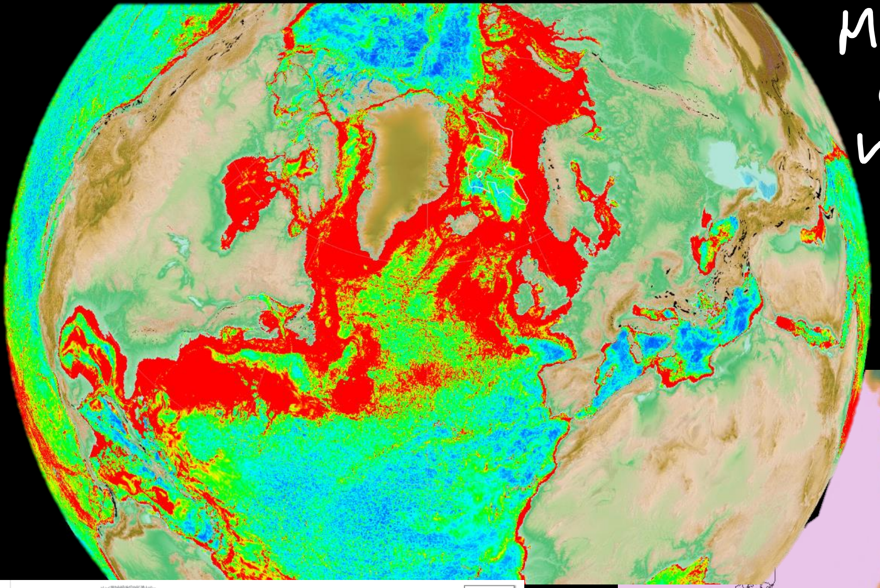




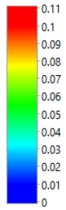
AkerBP

Movie on the next 3 slides

Plume models for FM Crusts



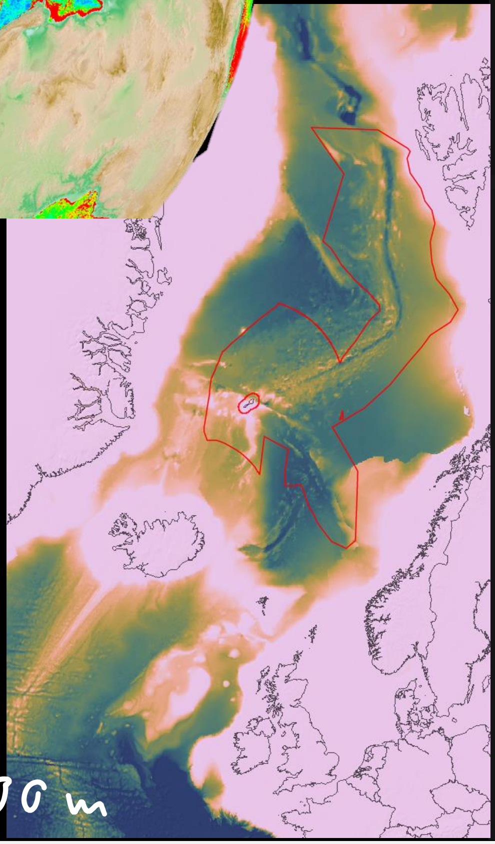
Max current m/s



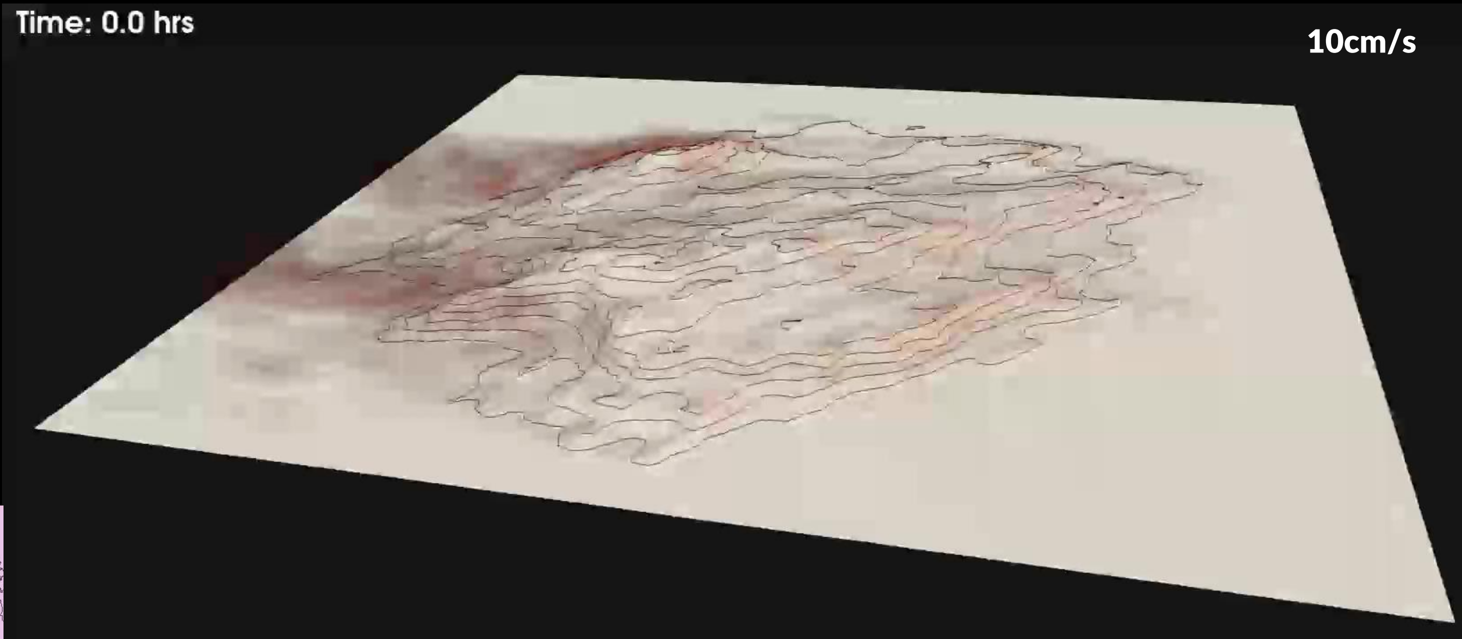
ELSEVIER
Earth and Planetary Science Letters
Volume 489, 1 May 2018, Pages 228-240

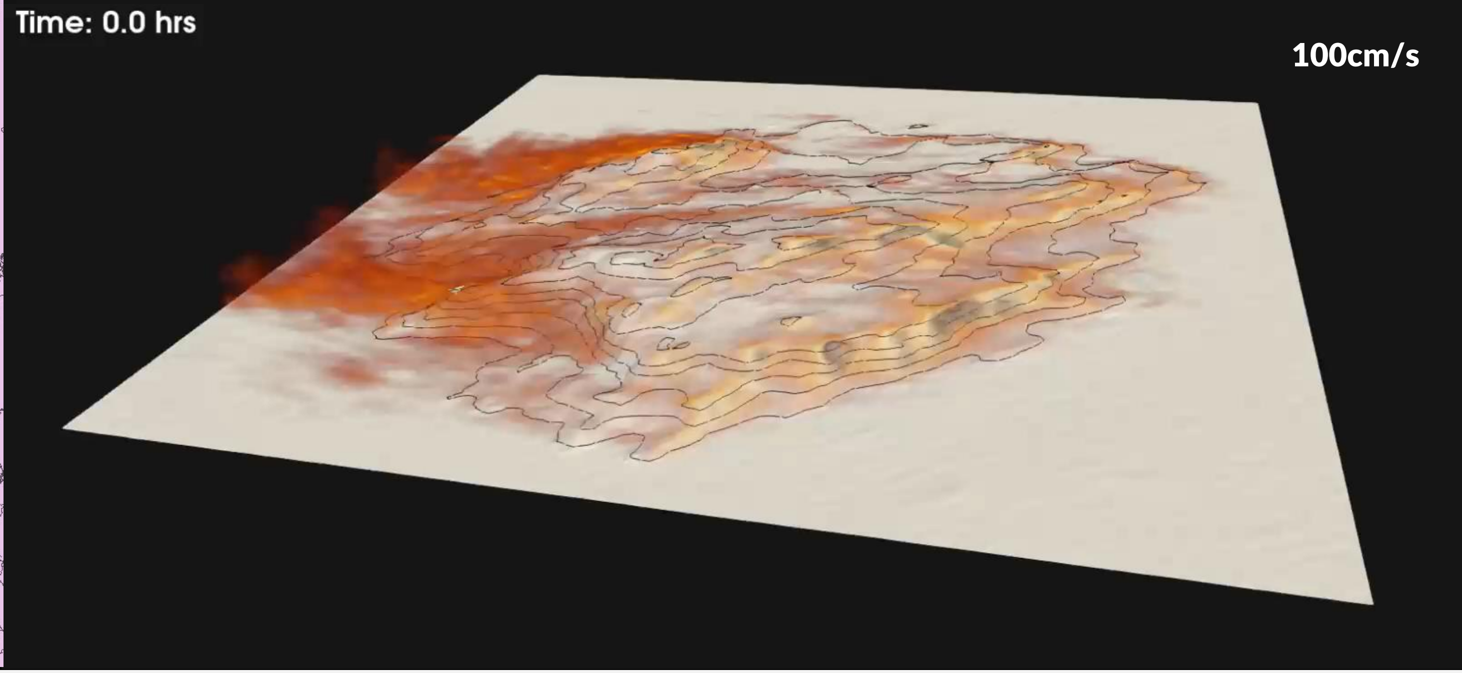
Controls on the global distribution of contourite drifts: Insights from an eddy-resolving ocean model

Amanda C. Thran [a], Adriana Dutkiewicz [a], Paul Spence [b, c], R. Dietmar Müller [a, d]



Colorscale −500 to −4000 m

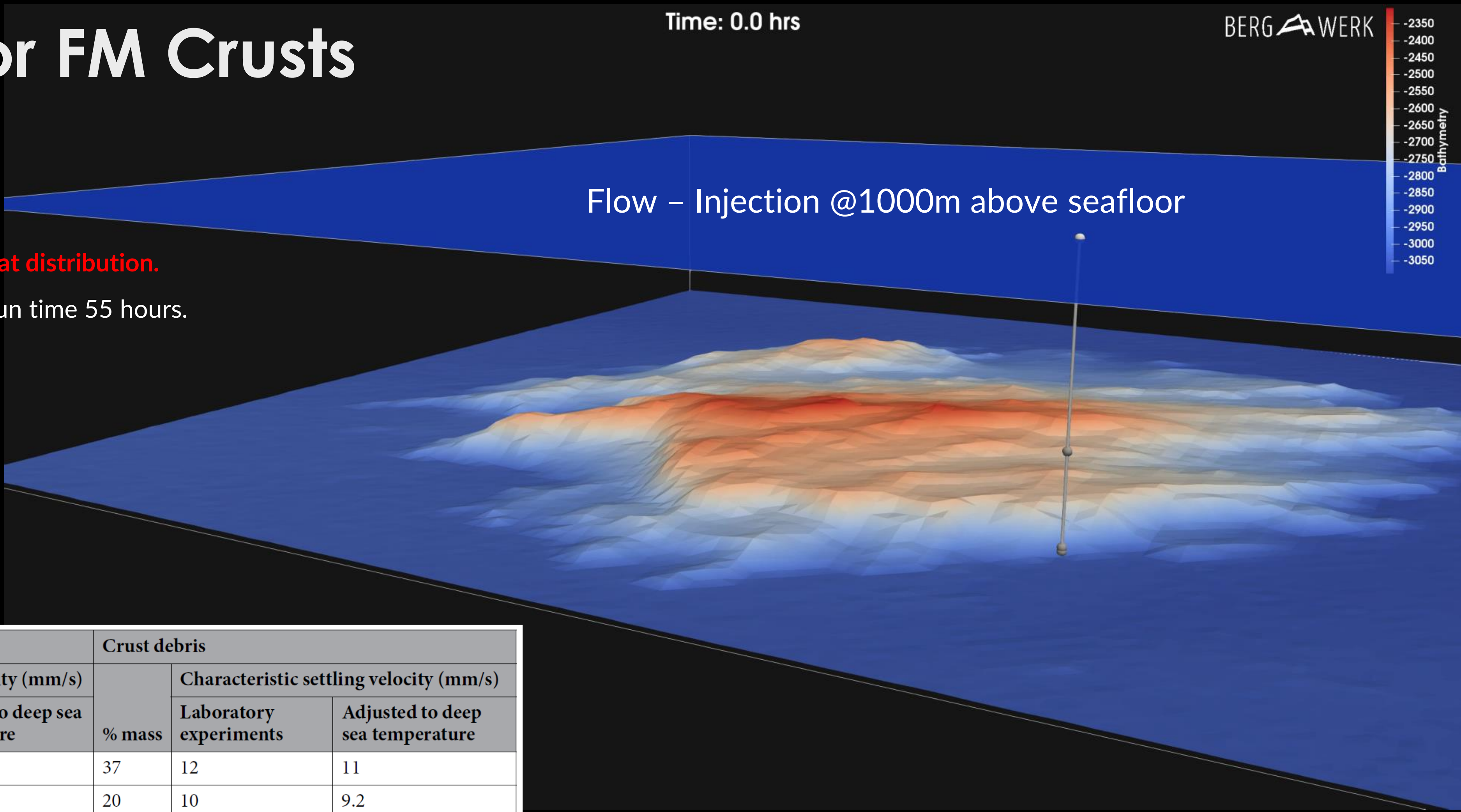




Plume models for FM Crusts

STATUS ANALYSIS

- Background velocity: 10cm/s
- Settling velocity f(particle size, density)
- Injected particle sizes from 2mm to, 30µm flat distribution.
- Inject at different depth for 10 hours, total run time 55 hours.
- Explicit particle tracking.



Particle size (µm)	Sediment			Crust debris		
		Characteristic settling velocity (mm/s)			Characteristic settling velocity (mm/s)	
	% mass	Laboratory experiments	Adjusted to deep sea temperature	% mass	Laboratory experiments	Adjusted to deep sea temperature
>160	54.25	13 or more	12 or more	37	12	11
120–160	23.25	7	6.5	20	10	9.2
40–120	10.5	2.6	2.4	20.5	3	2.7
<40	3.75	0.2	0.18	19	0.5	0.46
	0.0	0.025	0.023	1	0.025	0.023
	8.75	0.004	0.0036	2.5	0.004	0.0036

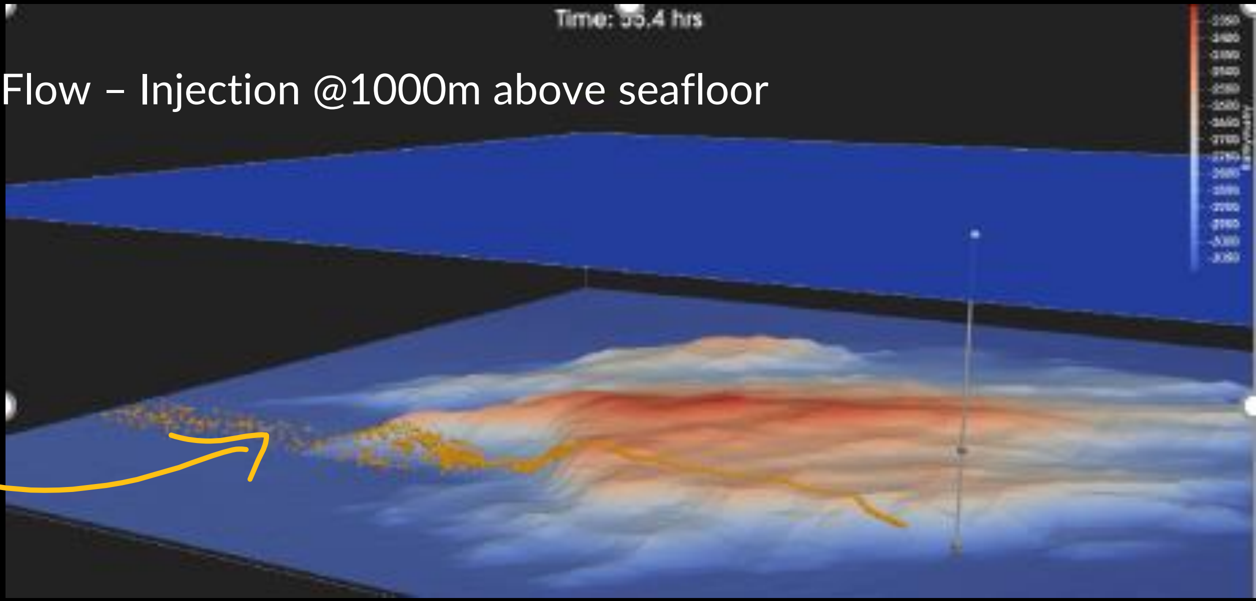
Table 4. Characteristic distribution of floc sizes and settling velocities.

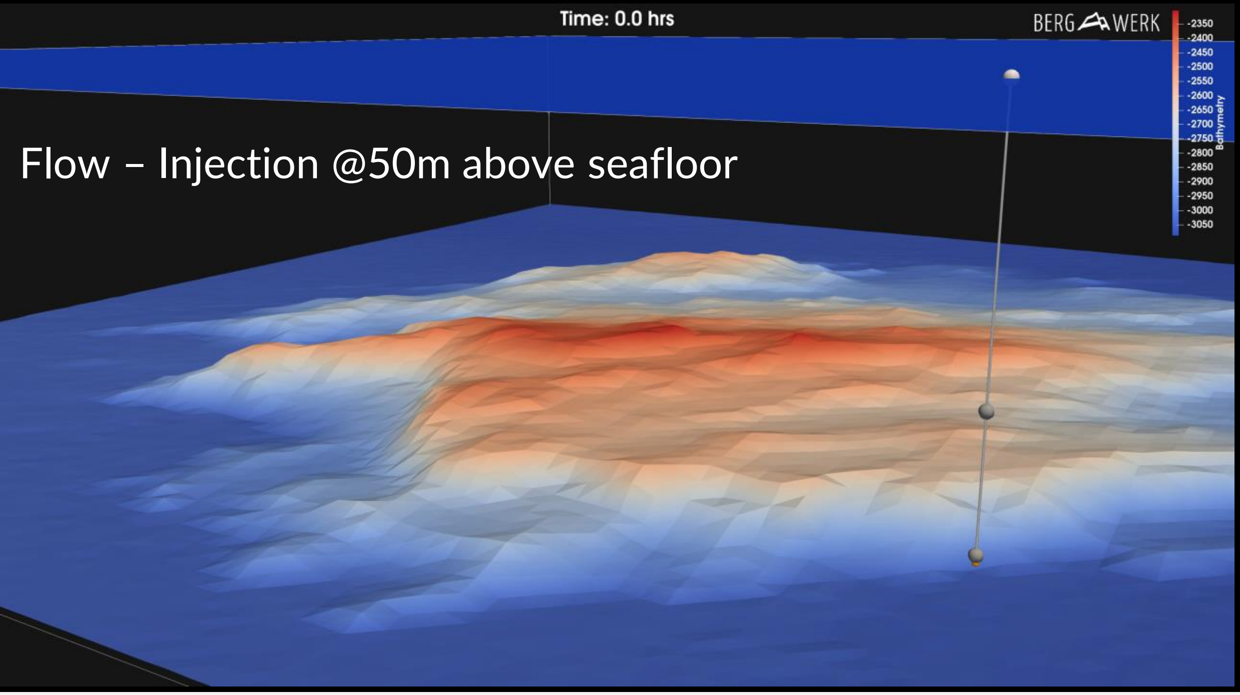
Source: Spearman et al. 2020, Nature Scientific Reports

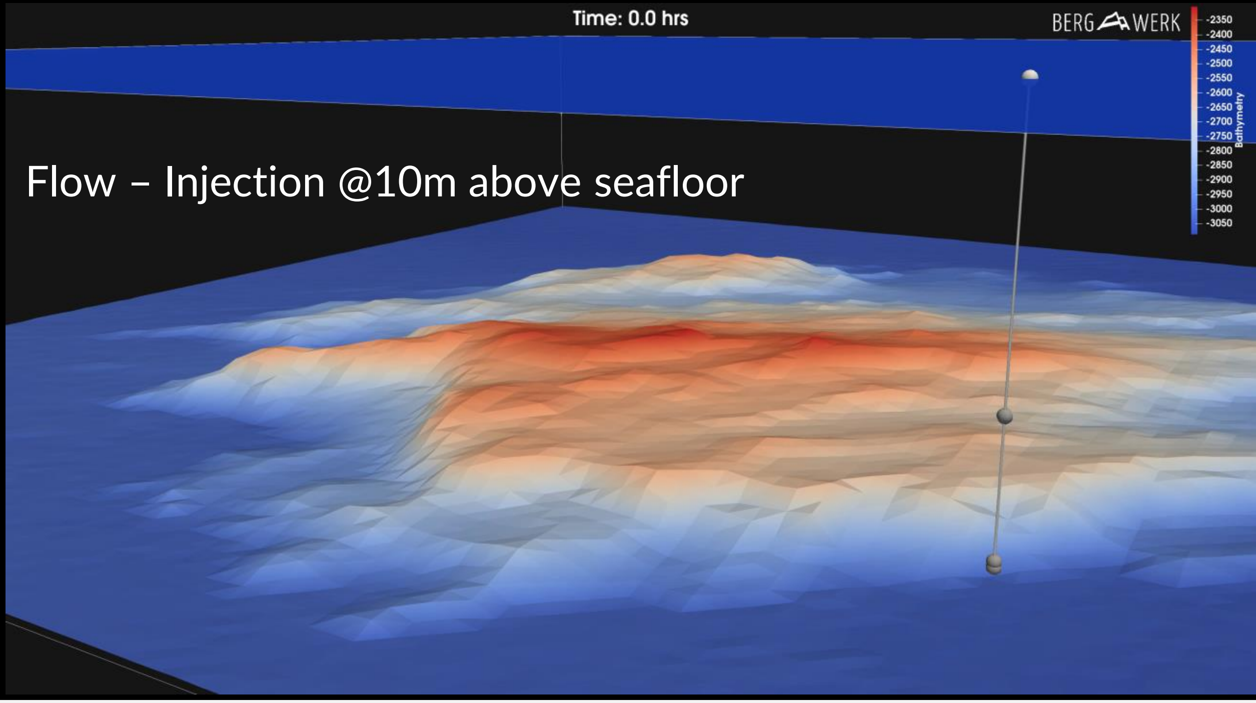
Plume models for FM Crusts

ONGOING ANALYSIS

- Study potential impact of seabed mining on the biosphere.
- Analyze thickness of particle graveyards.
- **Small 10cm/s velocities can move a lot of sediments over time.**
  Natural or man-made!
- Need good control over injection depth and **particle size and density.**
- Pre and post mining monitoring/ sediment samples.
- Need to know flow currents (magnitude, direction, type).

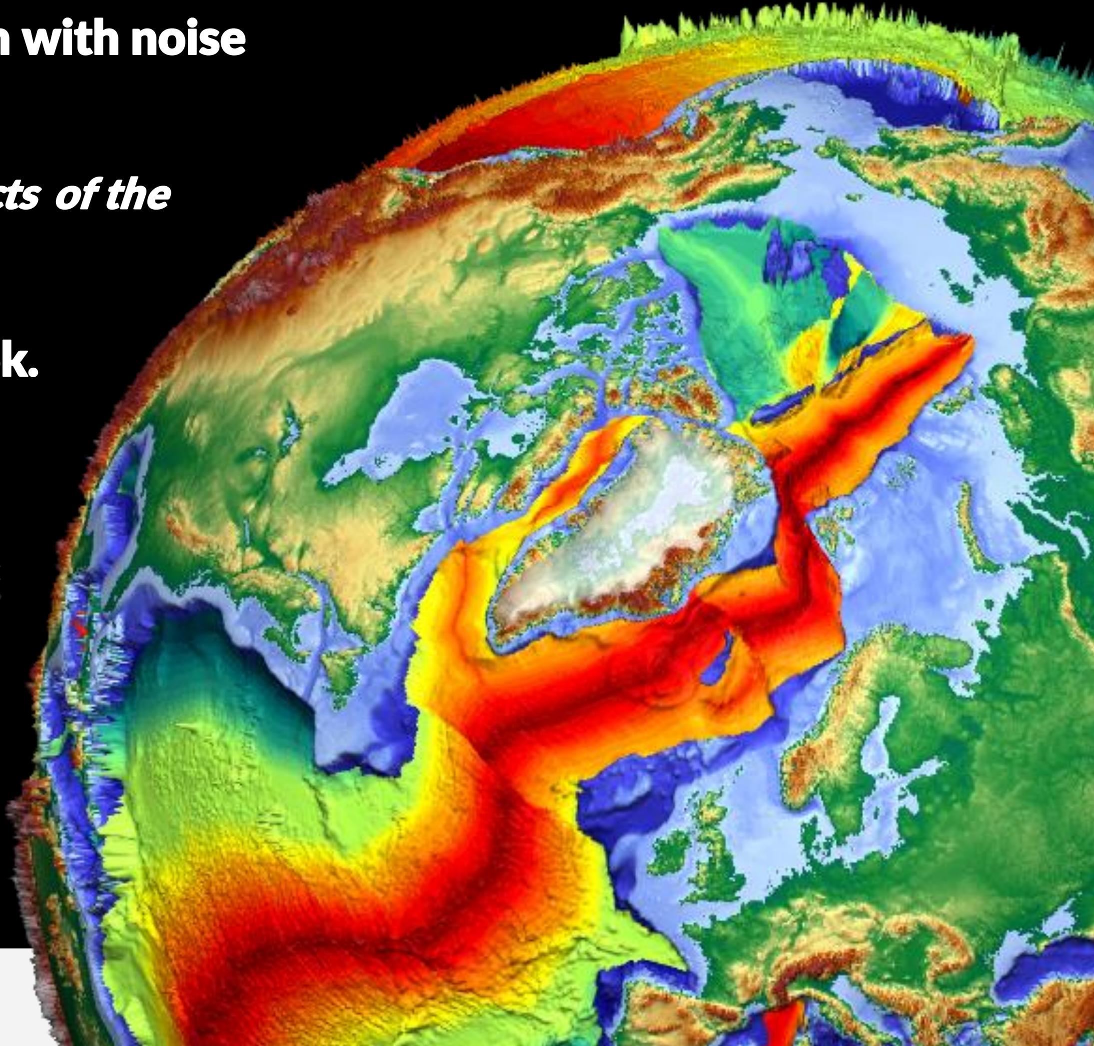






Notes

- **Deep sea minerals deposits (both eSMS and FM crusts) in Norwegian waters have high resource densities**
    - ***Very small areas (<< 1 km^2) needs to be mined to equal per capita use.***
    - ***Norway has an advanced offshore industry, and a good working relationship between authorities and industry.***
- **Mine-sites are small, but it is prudent not to harm the wider ocean with noise or plumes.**
    - ***We are working on engineering, ocean modeling and data-aspects of the environmental challenges.***
- **Algorithms can (assist) finding resources, if we know where to look.**
    - ***The area is huge!***
    - ***Marine mineral system modelling is still in its infancy.***



Questions?

in the coffee break

AkerBP

www.akerbp.com