

Hydrocarbon seeps, new mud volcanoes, and the search for a new young source rock in the westernmost Barents Sea

Rune Mattingsdal
Geologist

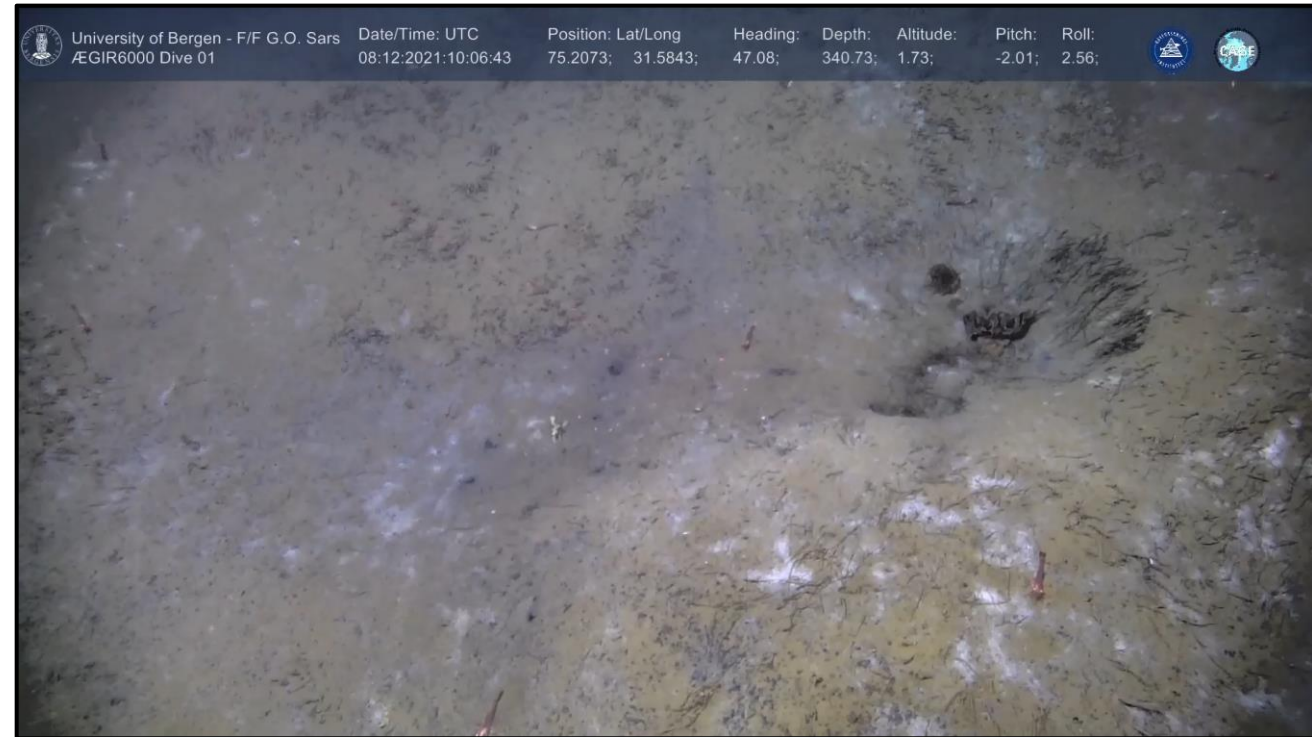
*Exploration Seminar, Barents Sea
Stavanger, 23-24 October 2024*



SOKKELDIREKTORATET

Outline

- Background
- A new young source rock
- Natural hydrocarbon seeps in the westernmost Barents Sea
- New mud volcanoes
- Seep geochemistry summarized
- Conclusions

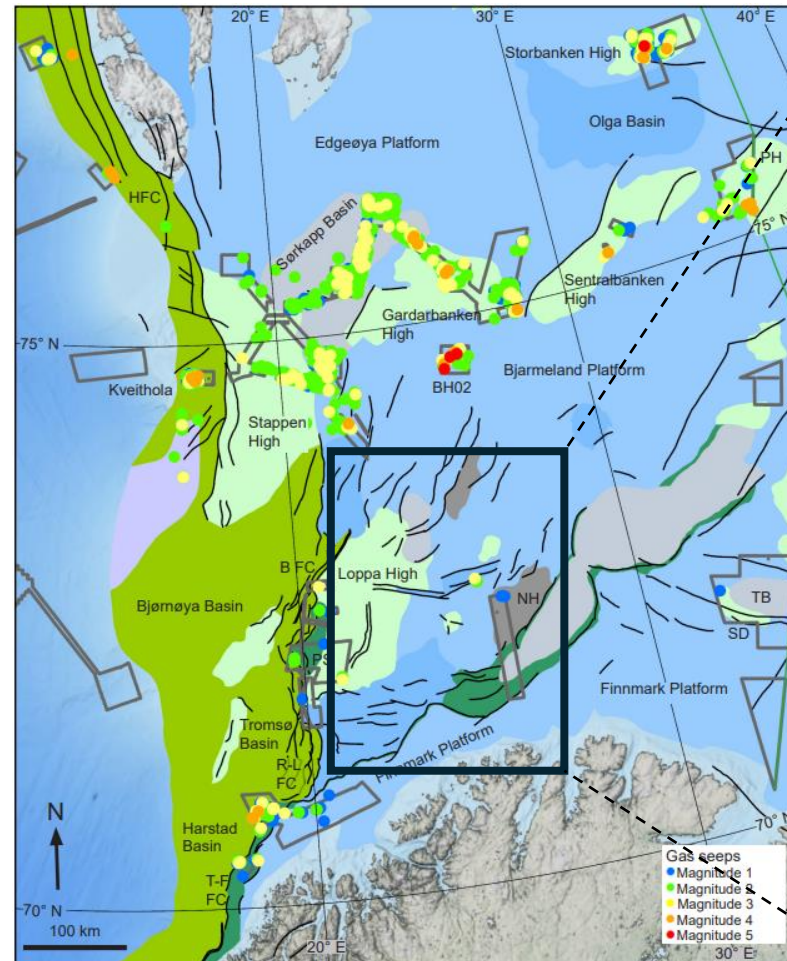


Example of natural oil and gas seepage on top of the Sentralbanken high, Northern Barents Sea.

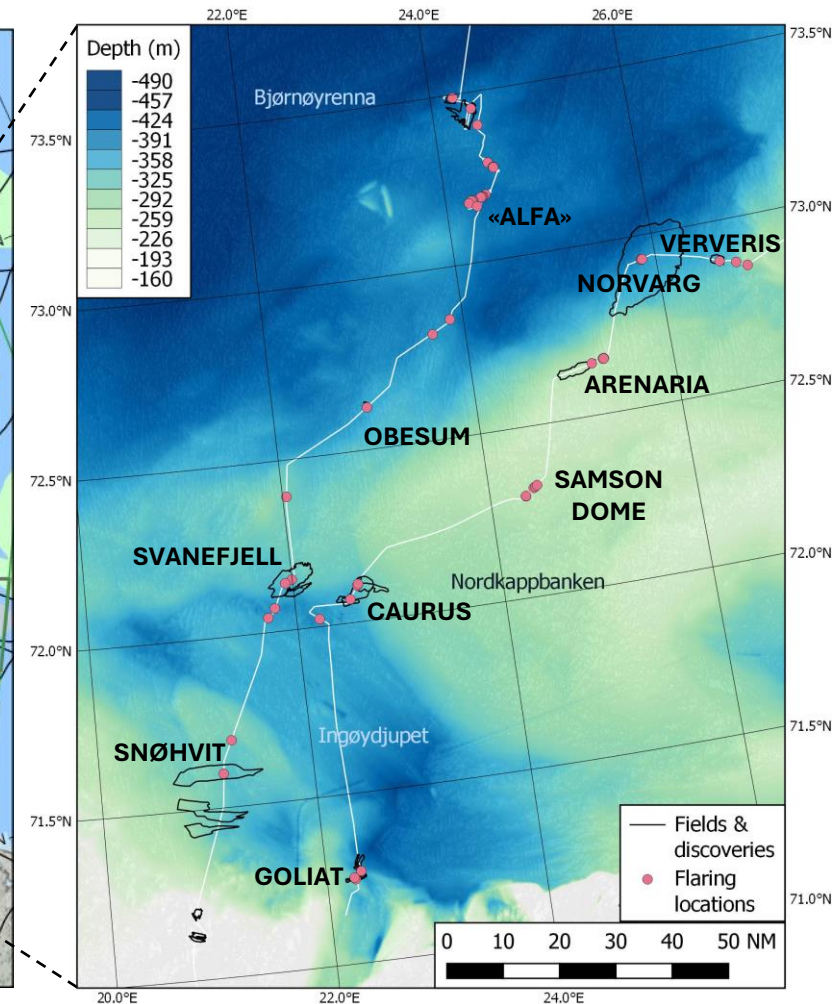
ROV video: CAGE/UiT

Background

- Thousands of natural gas seeps have the last years been confirmed in the Barents Sea.
- Very strong geological control of the seepage.
- Most seepage in the northern Barents Sea.
- In the southern Barents Sea, many gas discoveries have confirmed natural gas seepage.



Thorsnes et al. (2023)



From CAGE20-2 cruise report (2020)

Several new research papers on natural seepage in the Barents Sea

Science of the Total Environment 907 (2024) 167788

Contents lists available at ScienceDirect


Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

ELSEVIER

An Arctic natural oil seep investigated from space to the seafloor

Giuliana Panieri ^{a,f,*}, Claudio Argentino ^a, Sofia P. Ramalho ^b, Francesca Vulcano ^c, Alessandra Savini ^d, Luca Fallati ^d, Trond Brekke ^f, Giulia Galimberti ^d, Federica Riva ^d, João Balsa ^b, Mari H. Eilertsen ^{c,e}, Runar Stokke ^{c,e}, Ida H. Steen ^{c,e}, Diana Sahy ^g, Dimitri Kalenitchenko ^{a,h}, Stefan Büenz ^a, Rune Mattingdsdal ⁱ



Panieri et al. (2024):

- *Oil seep west of Svalbard with Tertiary or younger source rock.*
- *Discharge volume to the sea surface of 3.7 – 22.5 barrels of oil per day.*
- *Remarkably, the inhospitable oil-impregnated sediments were colonized by abundant infaunal organisms.*

nature communications

Article <https://doi.org/10.1038/s41467-023-37514-9>

Widespread natural methane and oil leakage from sub-marine Arctic reservoirs

Received: 3 January 2022

Accepted: 17 March 2023

Pavel Serov ¹✉, Rune Mattingdsdal², Monica Winsborrow¹, Henry Patton ¹ & Karin Andreassen¹

Serov et al. (2023):

- *The northern Norwegian Barents Sea is one of the most active submarine methane release hotspots globally.*

frontiers | Frontiers in Earth Science

TYPE Original Research
PUBLISHED 11 July 2024
DOI 10.3389/feart.2024.1404027

Check for updates

Geological and glaciological controls of 21,700 active methane seeps in the northern Norwegian Barents sea

Pavel Serov^{1,2*}, Karin Andreassen^{1,2}, Monica Winsborrow^{1,2}, Rune Mattingdsdal³ and Henry Patton^{1,2}

¹CAGE, Centre for Arctic Gas Hydrate, Environment and Climate, UiT–The Arctic University of Norway, Tromsø, Norway, ²Department of Geosciences, UiT–The Arctic University of Norway, Tromsø, Norway, ³Norwegian Offshore Directorate (NOD), Harstad, Norway

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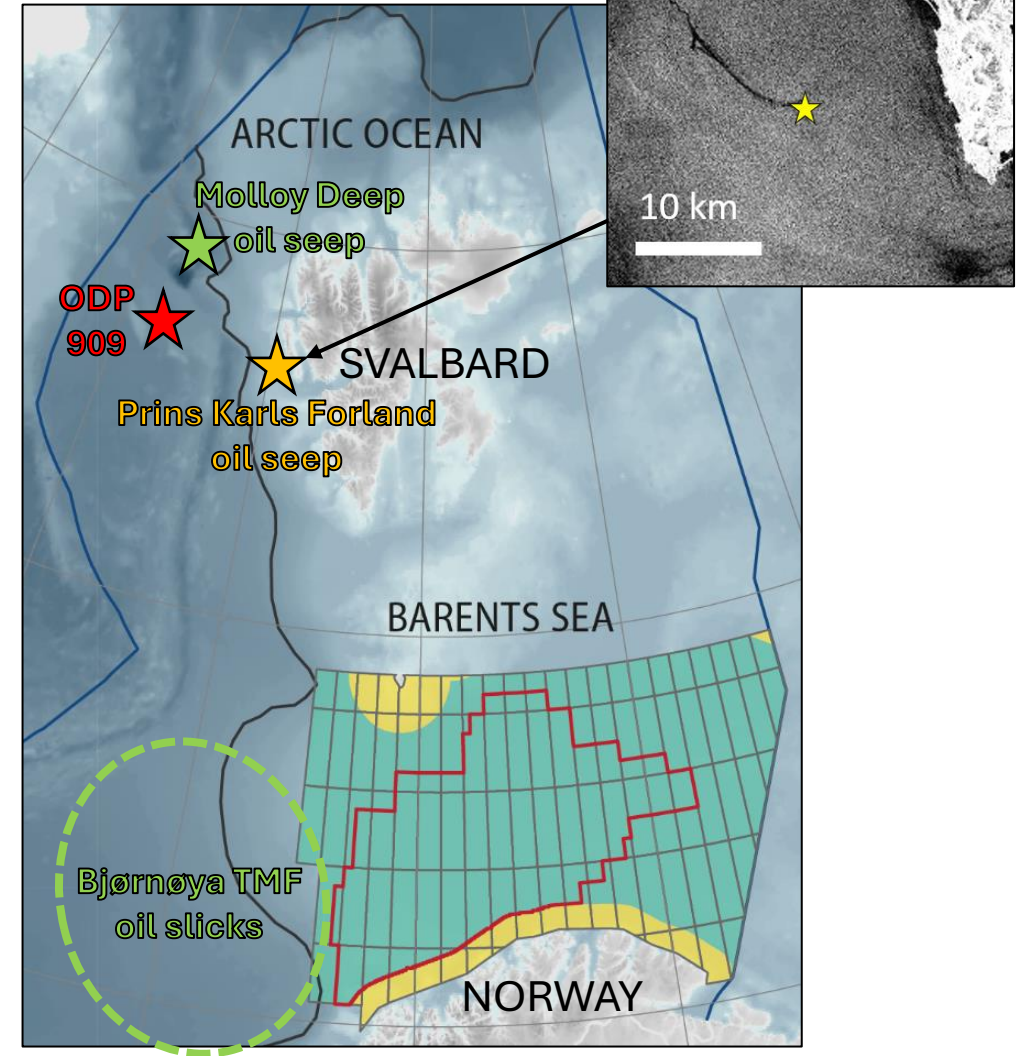
Serov et al. (2024):

- *Total seabed methane flux of ~10 000 ton/yr, one to two orders of magnitude higher than other globally known submarine methane seepage provinces.*

A new young source rock west of Svalbard

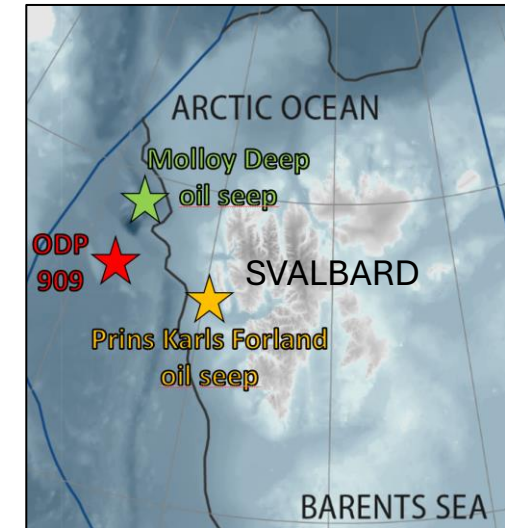
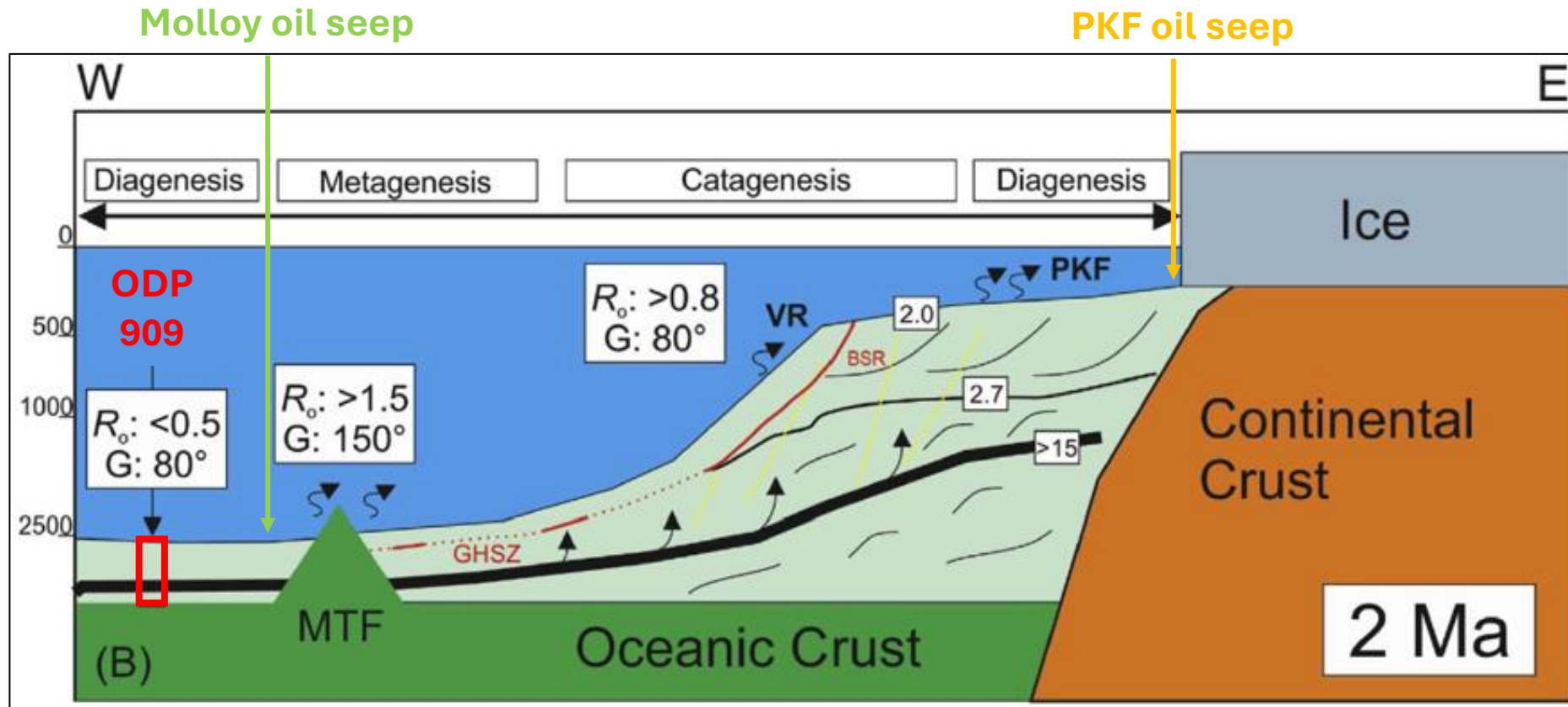
- **Prins Karls Forland (PKF) oil seep and slicks** (sampled by UiT in 2021)
 - Oil from new young source rock geochemically confirmed (Panieri et al., 2024)
- **ODP 909** (drilled in 1993)
 - Young Early-Middle Miocene deltaic derived source rock (Knies & Mann, 2002)
- **Molloy Deep oil seep** (sampled by UiB in 2022)
 - Oil from same young source rock as PKF
- **Bjørnøya Trough Mouth Fan oil slicks**
 - SAR-satellite observations of episodic clustered oil slicks

Satellite image: RADARSAT-2 Data and Products
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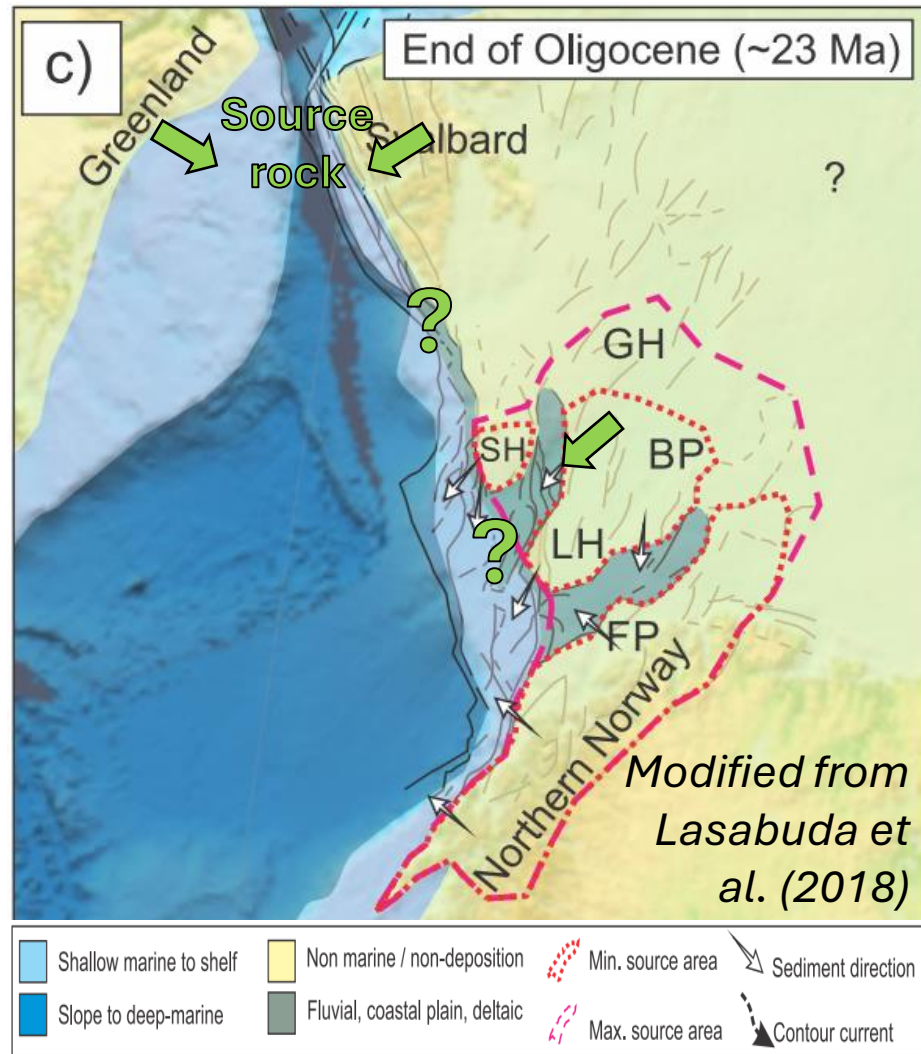
Petroleum System- Western Svalbard margin

- Early-Middle Miocen petroleum system active for the last ~6 million years (Knies et al., 2018).

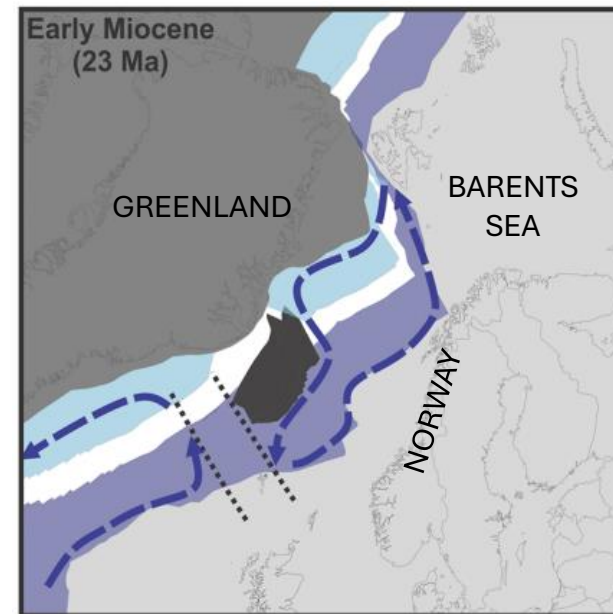


Knies et al. (2018)

Early-Middle Miocen Paleogeography and depositional environment

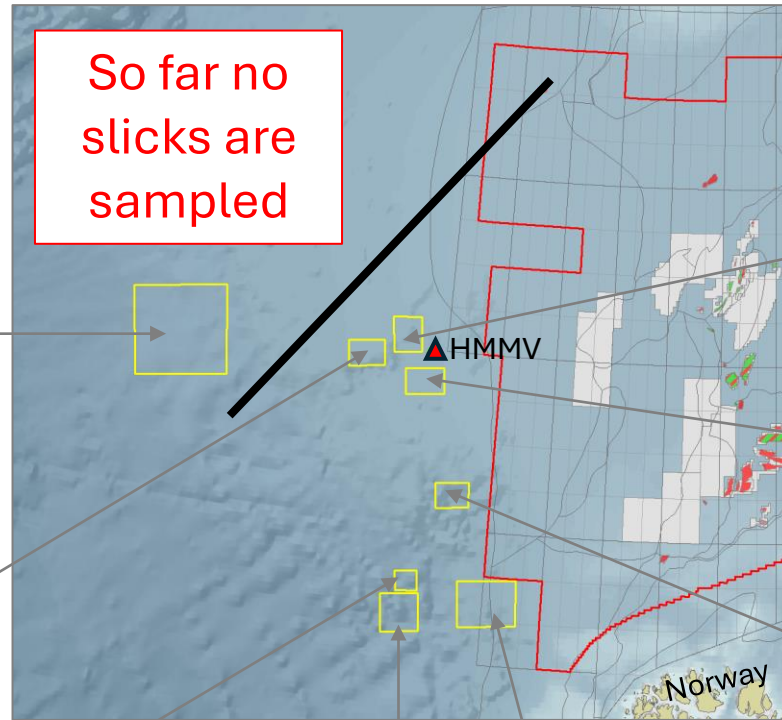
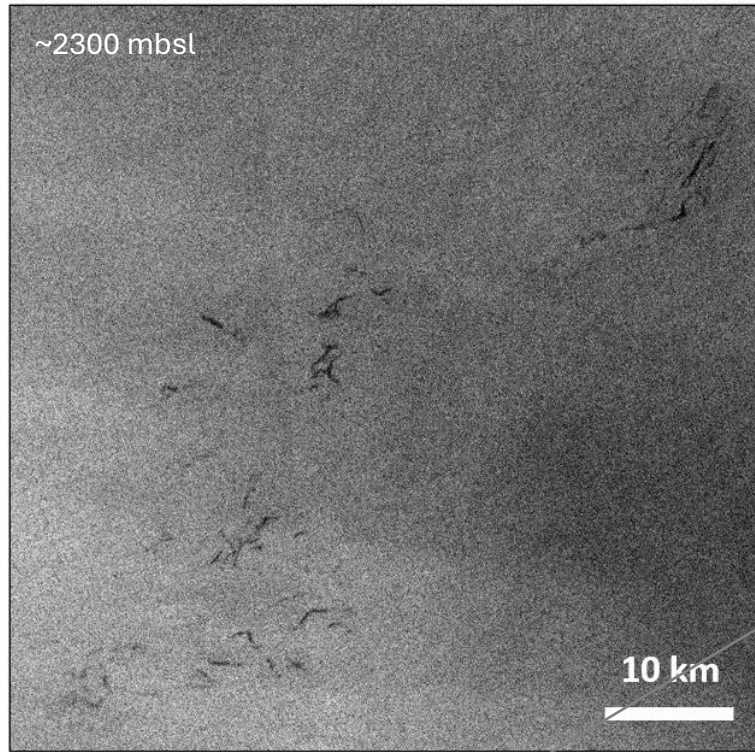


- Large parts of the Barents Sea shelf exposed.
- Possible large river deltas from Svalbard, NE Greenland and the SW Barents Sea
- Regionally confined circulation basin.

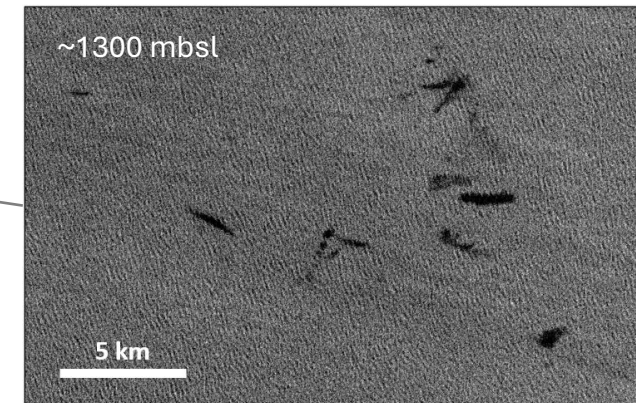
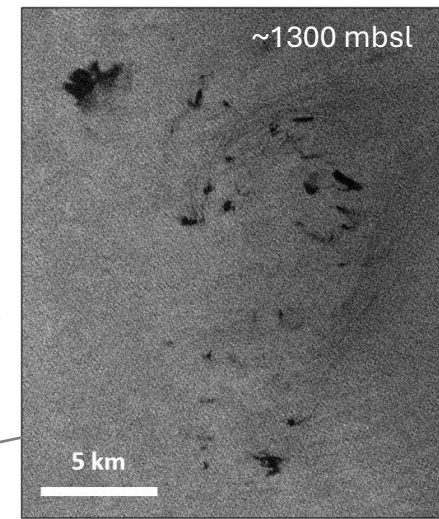


Rydningen et al. (2020)

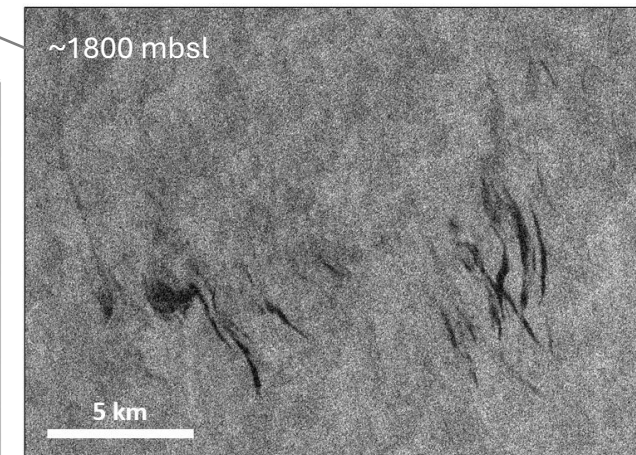
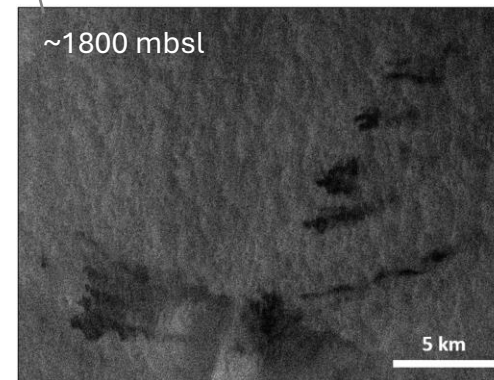
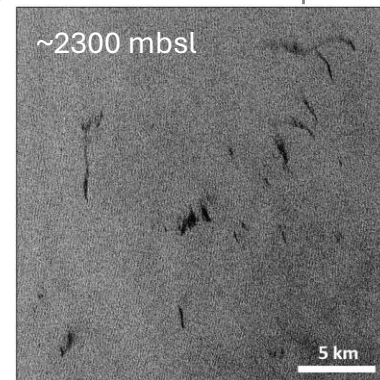
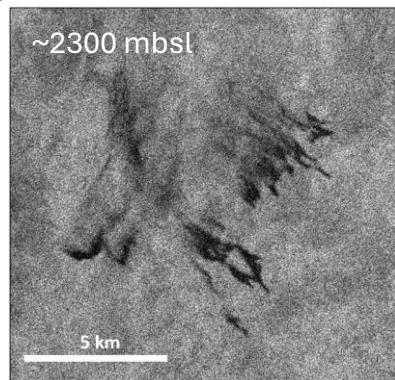
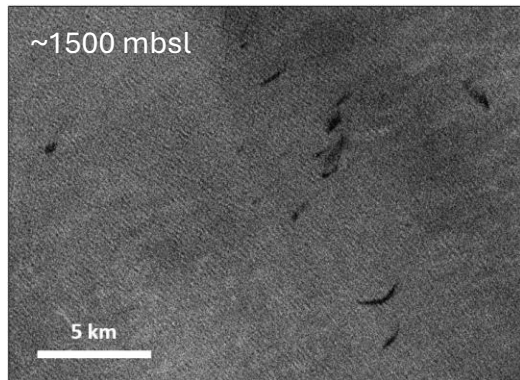
Oil slick observations on Bjørnøya fan



Satellite images:
Copernicus Sentinel-1
data 2018 and 2023,
processed by ESA.

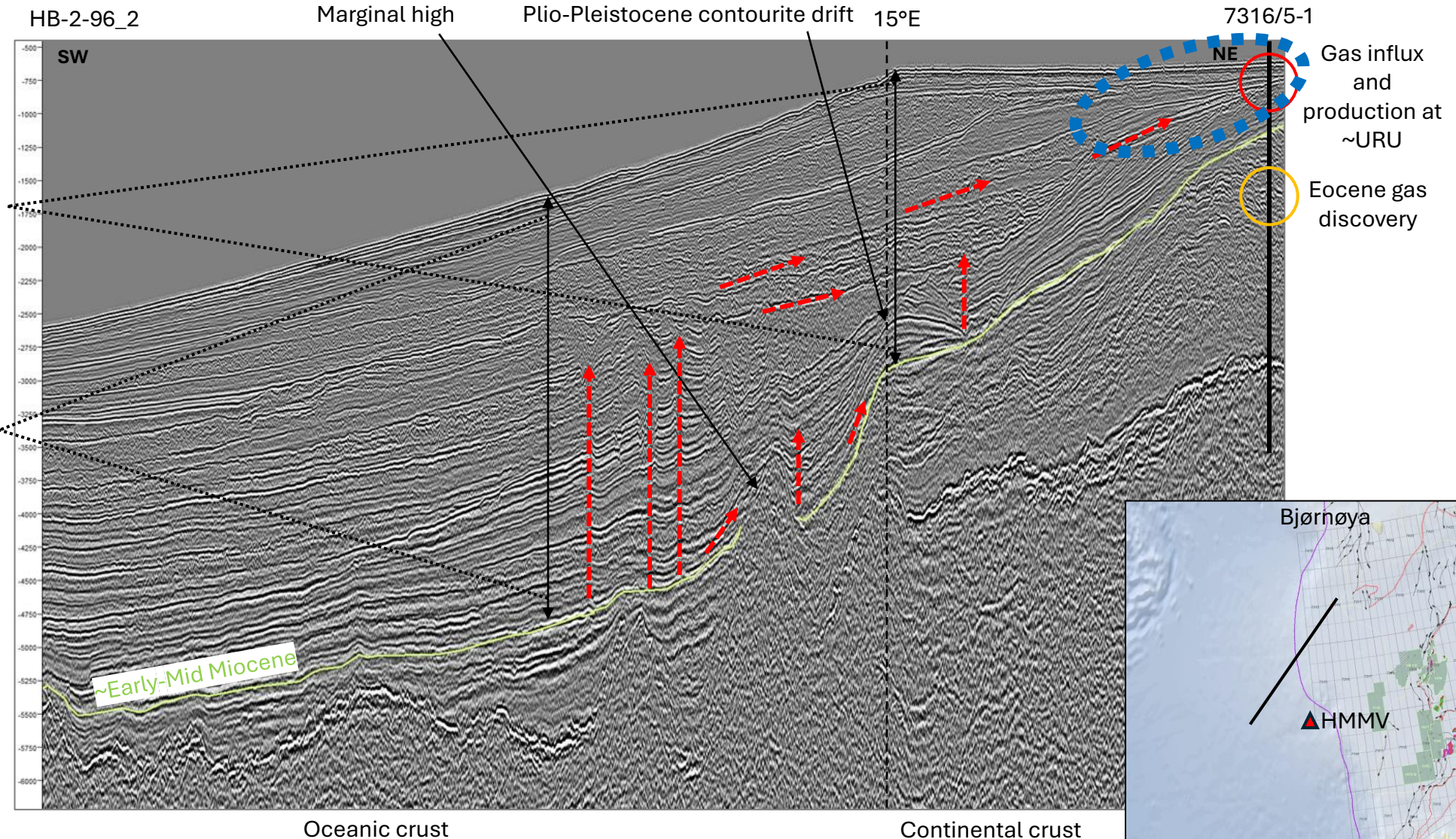


HMMV =
Håkon Mosby
Mud Volcano



Early-Middle Miocen source rock? burial on the Bear Island trough mouth fan

New Mud Volcanoes discovered in this setting further south

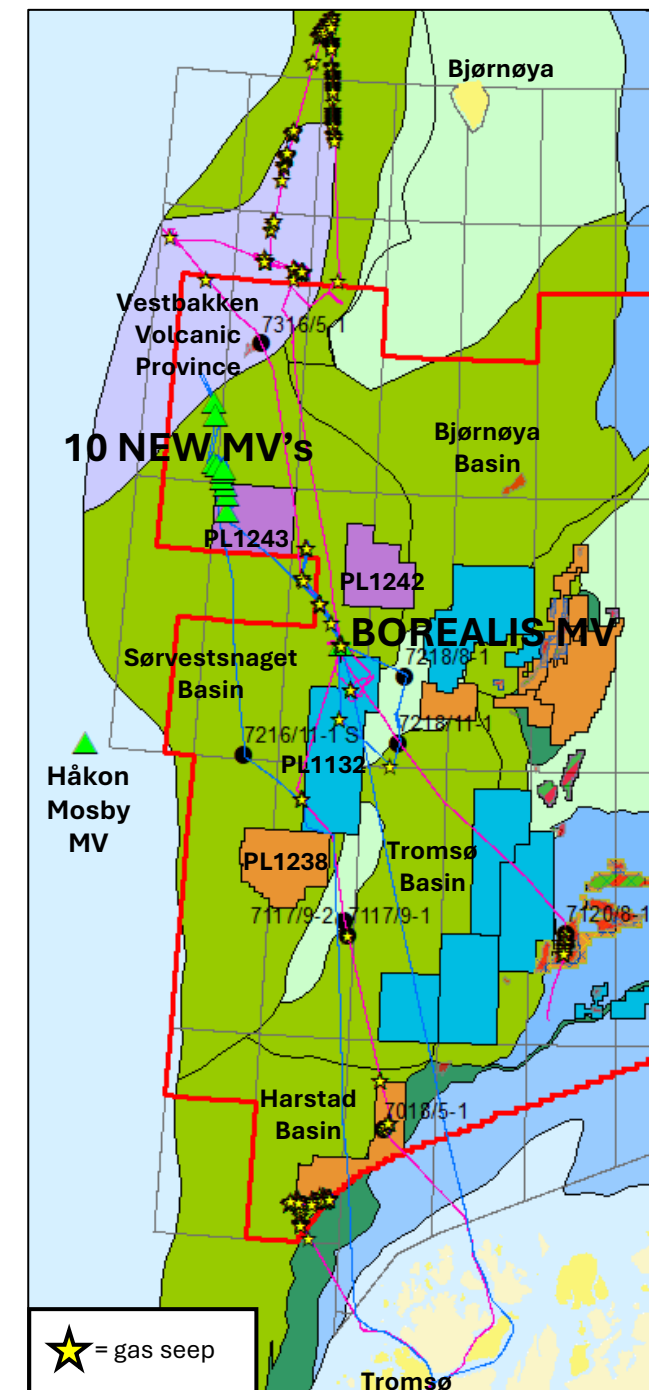


Different geothermal gradients over oceanic and continental crust.

- Vertical migration through faults ?
- Lateral migration up-dip along sandy Quaternary layers ?

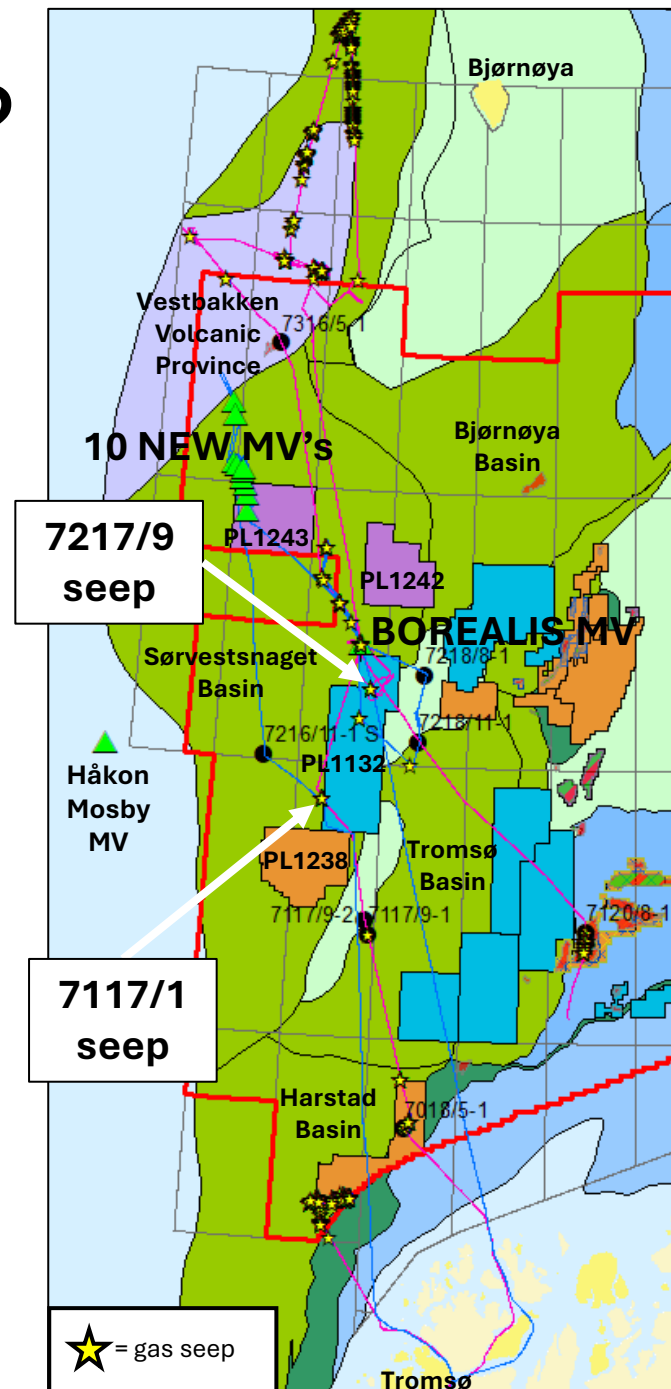
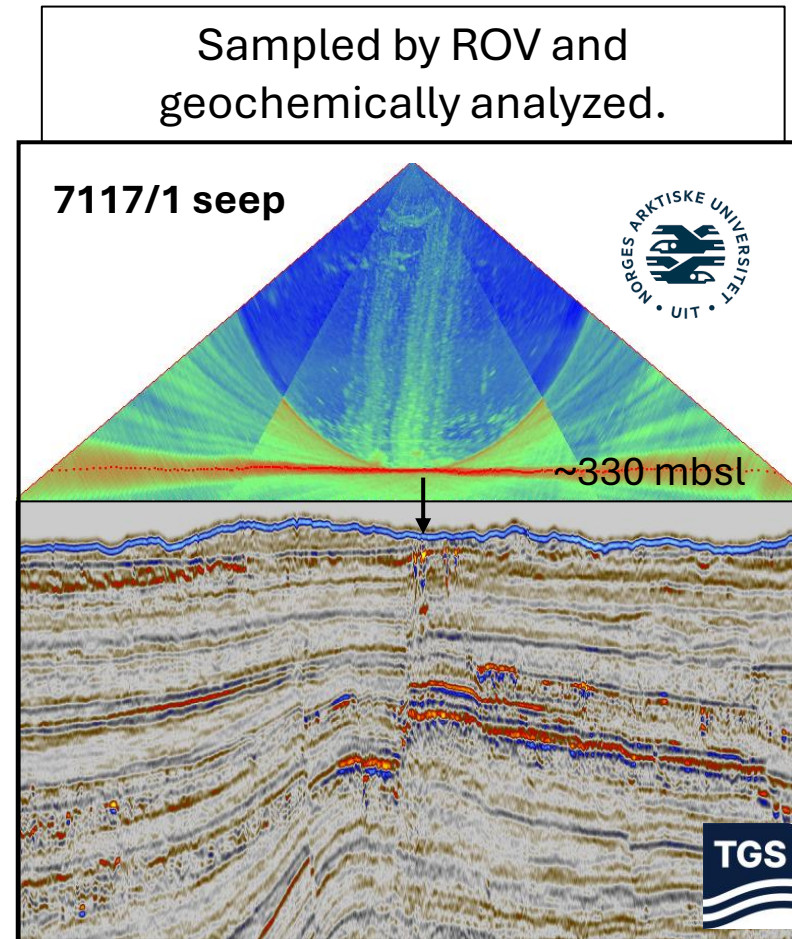
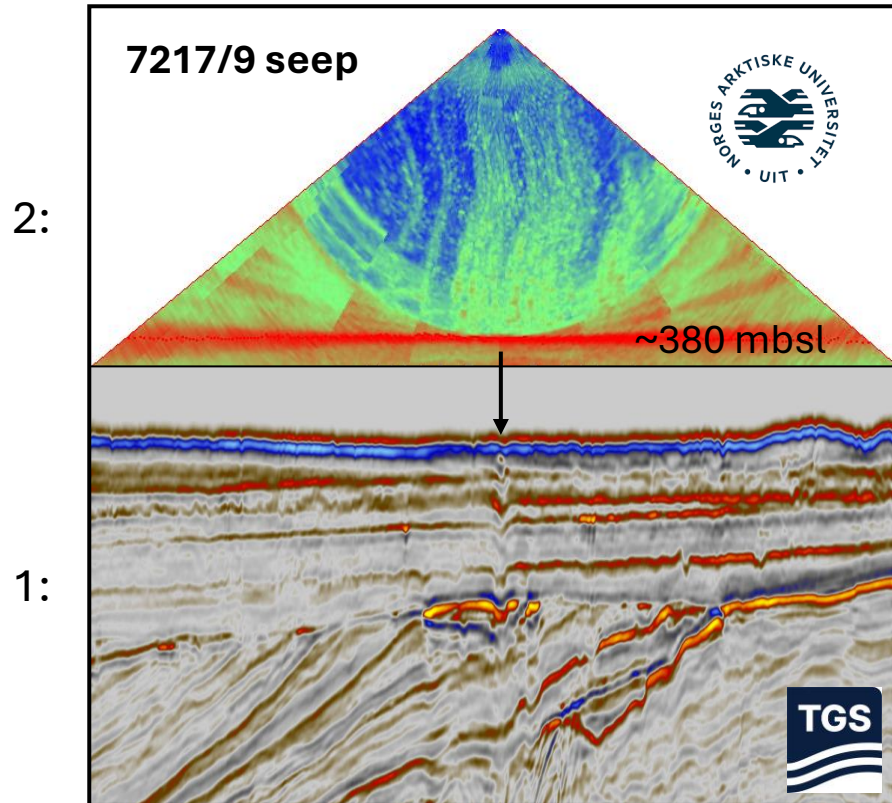
Several new research expeditions in the westernmost Barents Sea

- Many hundreds of natural gas seeps mapped, especially in the Vestbakken Volcanic Province and the Hornsund Fault Complex west and SW of Bjørnøya.
- Many of the gas seeps are also located in the Harstad- and Sørvestsnaget basins.
- Discovery of the Borealis mud volcano in the eastern Sørvestsnaget Basin in 2023.
- Discovery of 10 new mud volcanoes in the northern Sørvestsnaget Basin in 2024.
- ROV-sampling and geochemical analysis from both expeditions.



How are natural gas seeps located?

1. Seismic identification of bright spots / shallow gas.
2. Multibeam echosounder water column data.
3. ROV sampling.

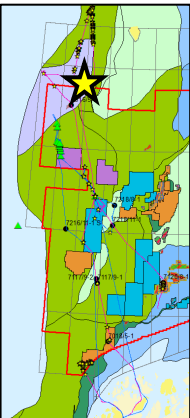


What can the seeps tell us?

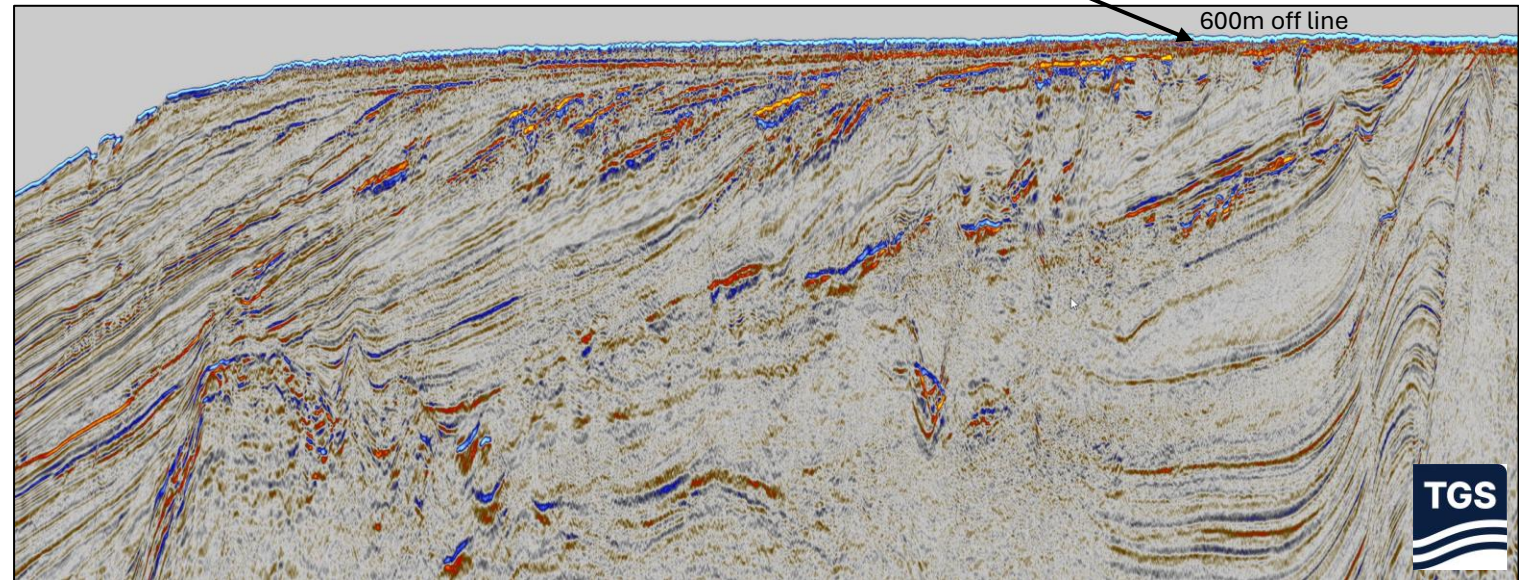
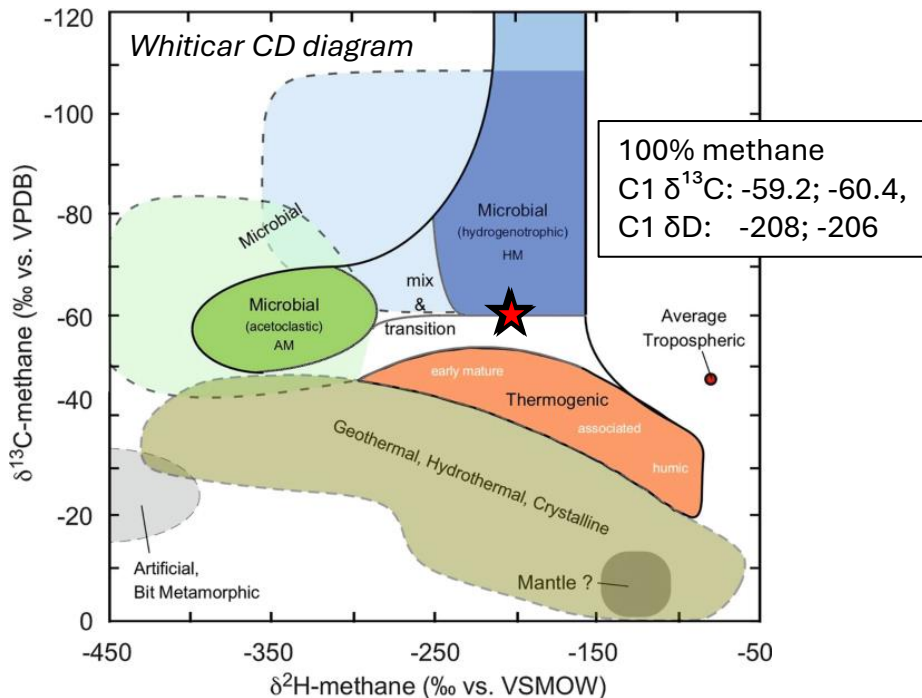
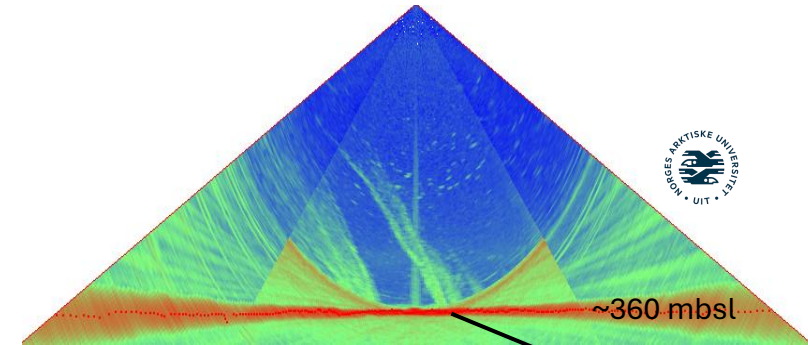
Vestbakken Volcanic Province, 7316/3 seep

2 gas samples:

- ~100% microbial/mixed methane gas.
- Tiny amounts of C2, C3 and C4 → Thermogenic input
 - Biodegraded gas → Unknown maturity



7316/3
seep

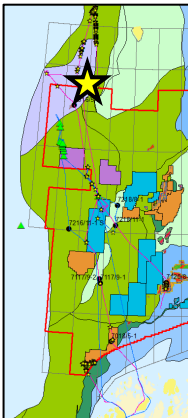
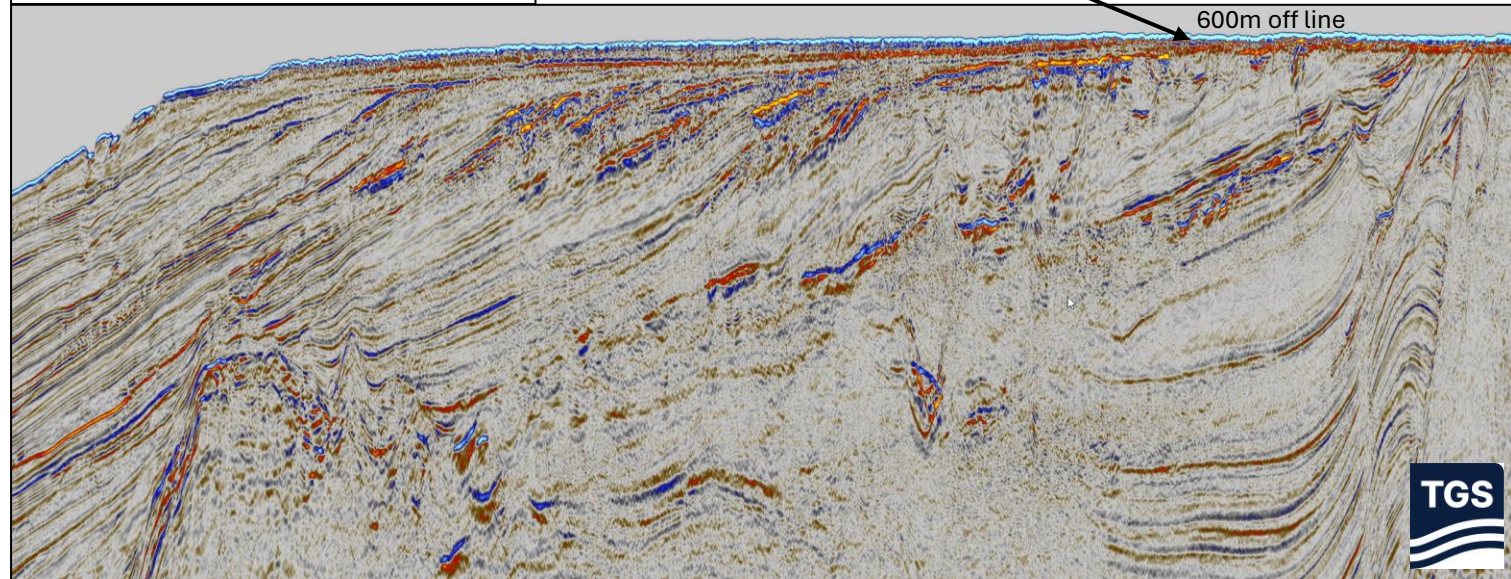
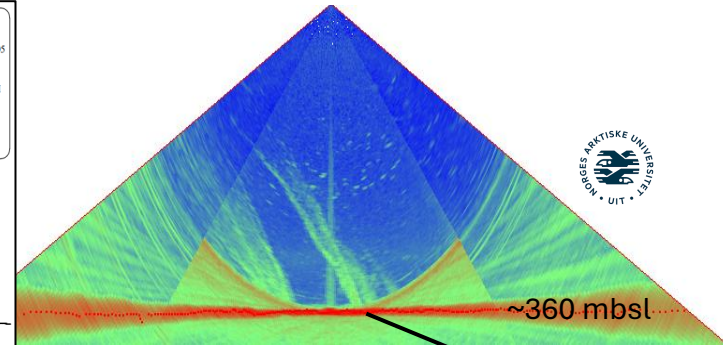
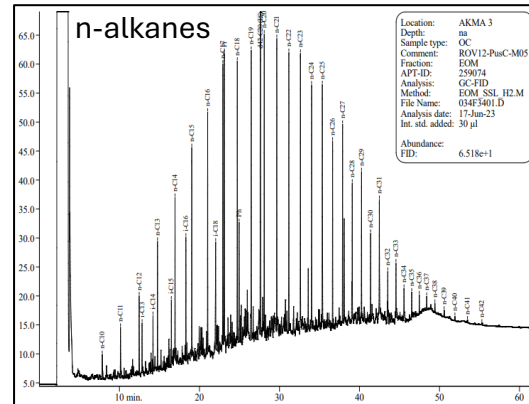


What can the seeps tell us?

Vestbakken Volcanic Province, 7316/3 seep

Sediment sample from gas seep analyzed for traces of oil:

- UCM hump → some biodegradation.
- N-alkanes ride on the back of the UCM → ongoing or late supply of oil.
- Sterane isomerization, and odd predominance of n-alkanes in the C23 – C35 range → Low maturity source rock.
- The aromatic steroids suggest the oil to be of mid oil maturity (heavy fraction).
- The light oil fraction based on naphthalenes and phenanthrenes, is of mid oil maturity.
- The $\alpha\beta$ sterane distribution (m/z 218) indicates deposition in an open to shallow marine/coastal environment.
- Oleanane absent → pre-Cretaceous source?

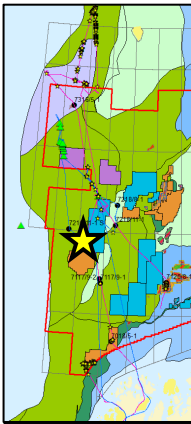


7316/3
seep



What can the seeps tell us?

Sørvestsnaget Basin, 7117/1 seep



**7117/1
seep**

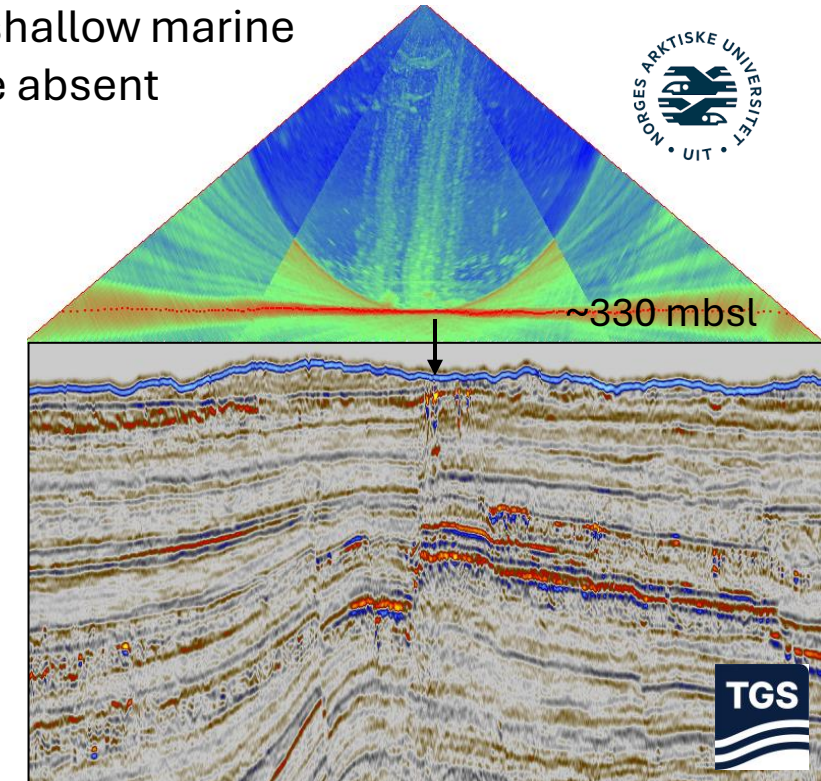
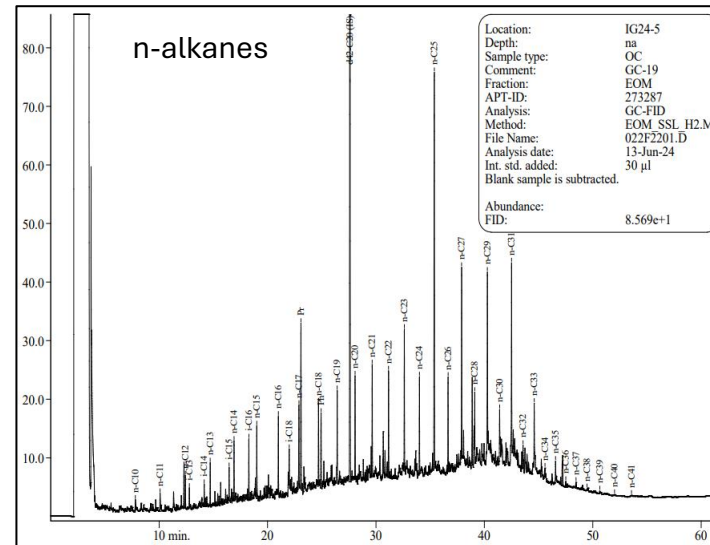
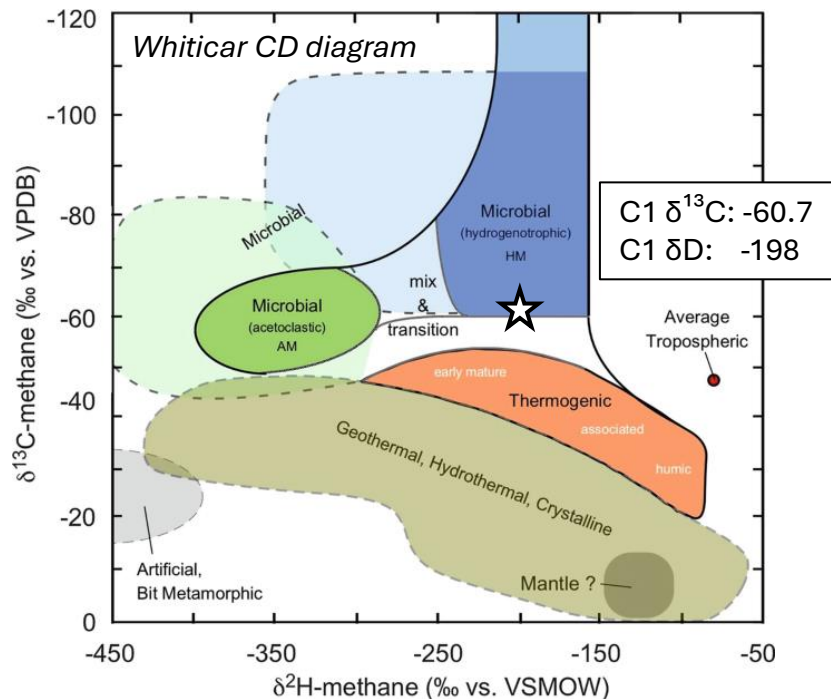


Gas sample:

- 99.9% microbial/mixed methane gas
- 0.1% ethane, propane and butane → Thermogenic input
 - Biodegraded → unknown maturity

Sediment sample from gas seep analyzed for traces of oil:

- Small, but ongoing/late supply of oil.
- Low maturity
- Open to shallow marine
- Oleanane absent



Mud Volcanoes

- An accumulation of clay or other fine-grained material that has flowed out together with gas, water and sometimes oil, either on the seabed or on land.
- Around the world MV's are often associated with hydrocarbon deposits, and may therefore be of interest in connection with exploration for oil and gas.



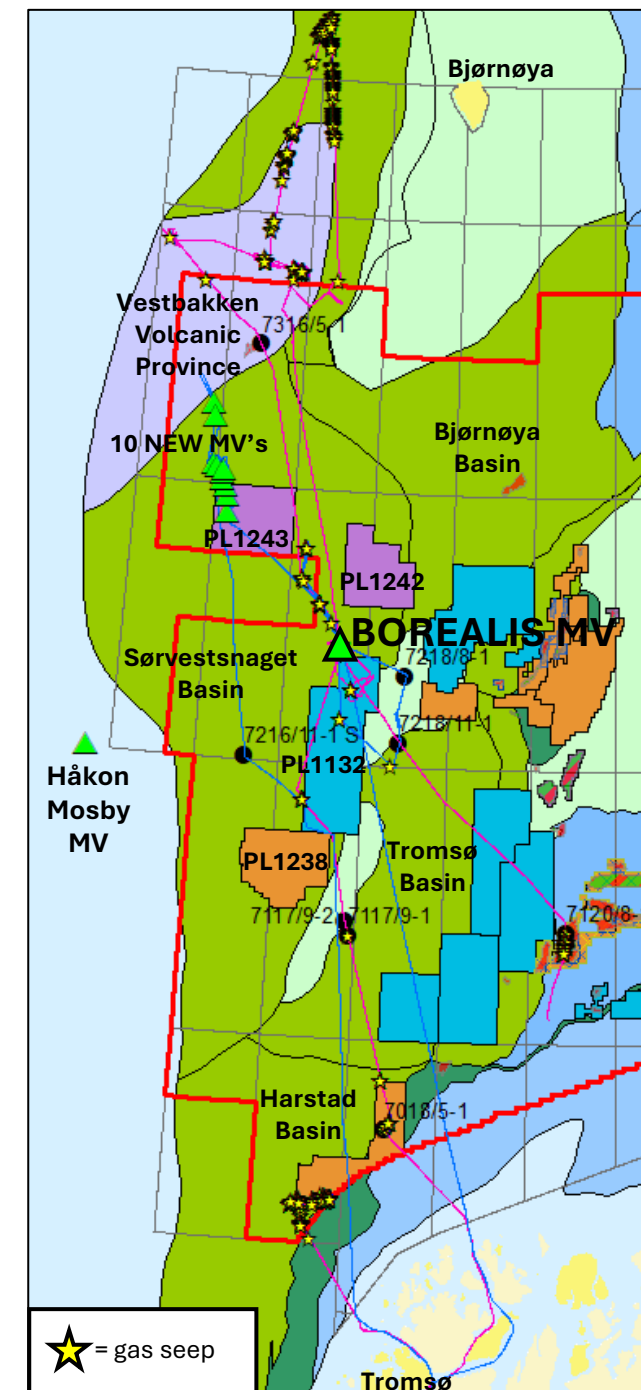
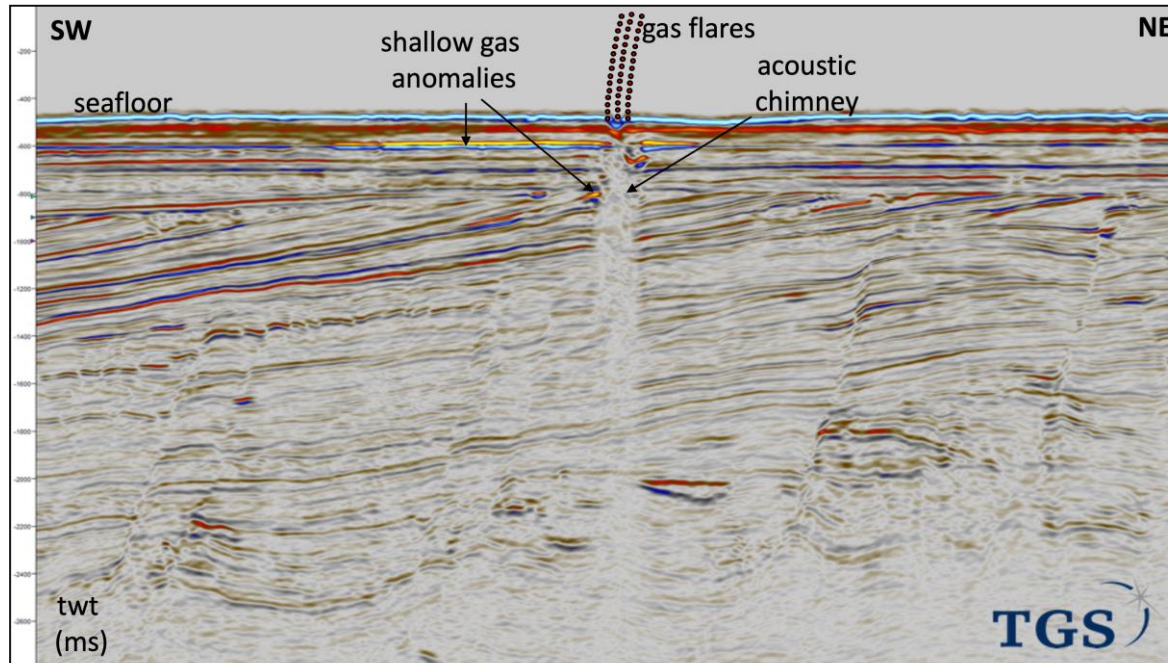
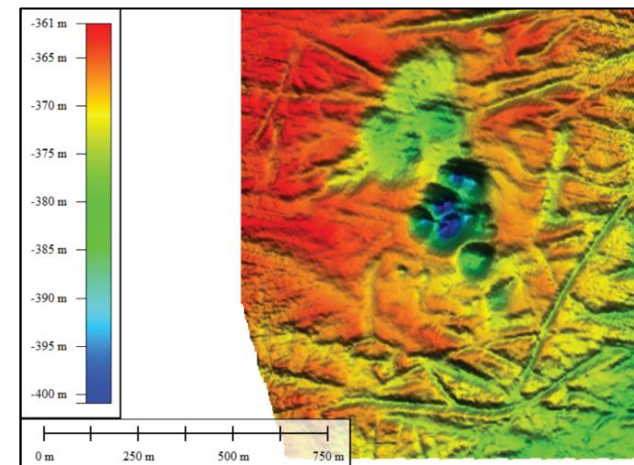
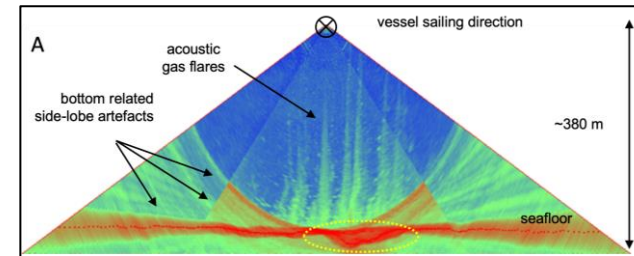
Mud pool (left) and mud flow (right) at Bakhar MV in Azerbaijan.



Crater-like morphology at Bakhar satellite MV in Azerbaijan with gryphons and pools in its central part.

Borealis Mud Volcano

- Expulsion of warm (11.5°C) Neogene sediments and the eruption of methane-dominated fluids from a localized site within a ~500 m diameter crater.
- Laterally extensive carbonate deposits on the seafloor around Borealis, suggesting long-lasting diffuse methane migration.

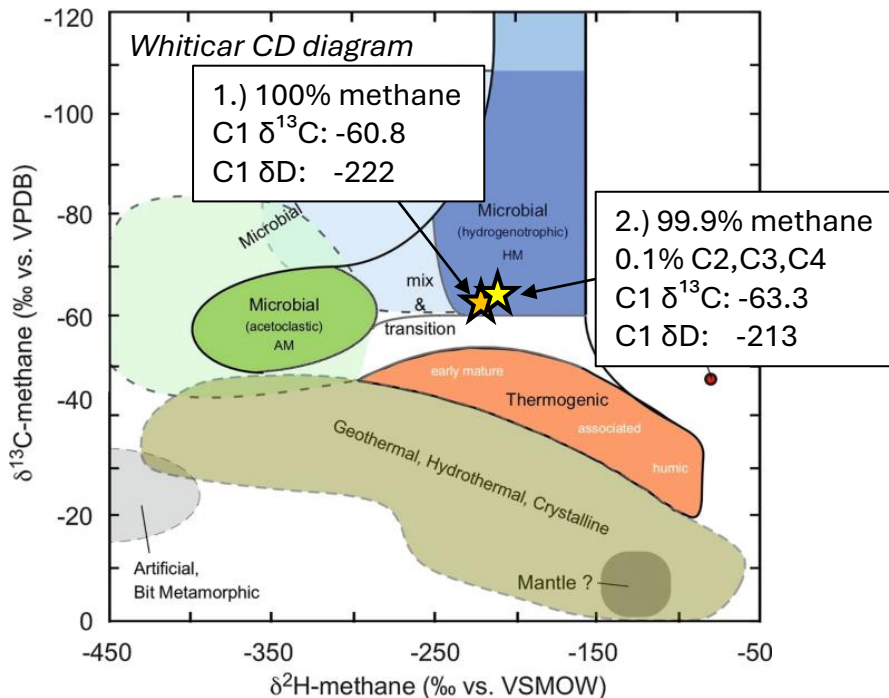
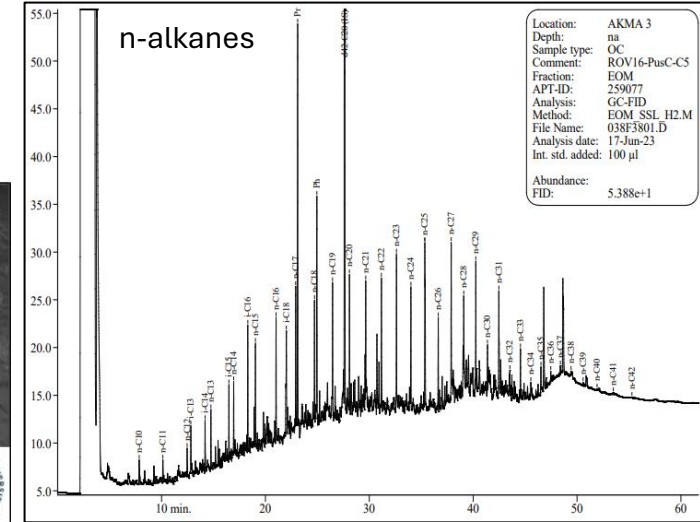
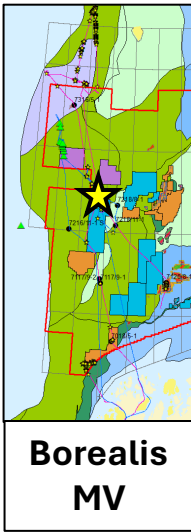


Panieri et al. (in review)

Borealis Mud Volcano geochemistry

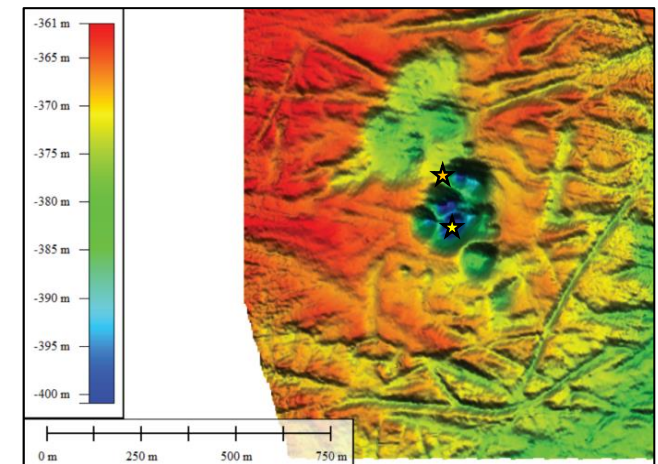
2 gas samples:

- 100% microbial methane gas.
- 99.9% microbial methane gas and 0.1% ethane, propane and butane.
 - Thermogenic input (biodegraded).



Sediment sample from gryphon (2.):

- Small, but ongoing/late supply of oil
- Low maturity
- Marine to shallow marine/coastal
- Oleanane absent

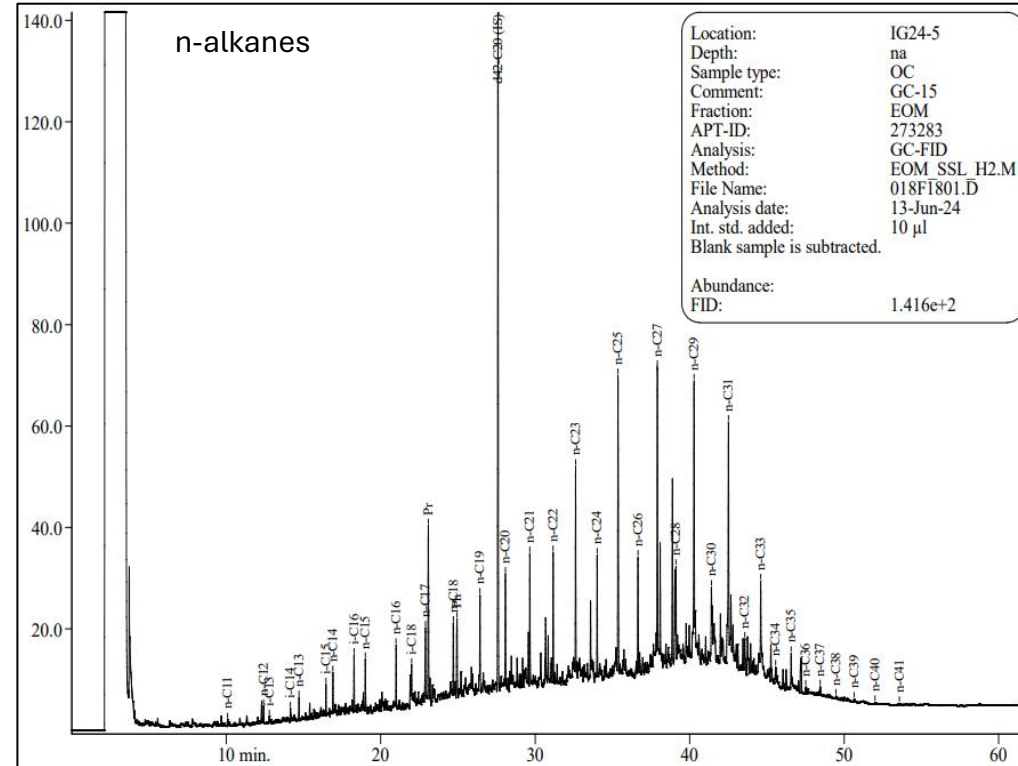
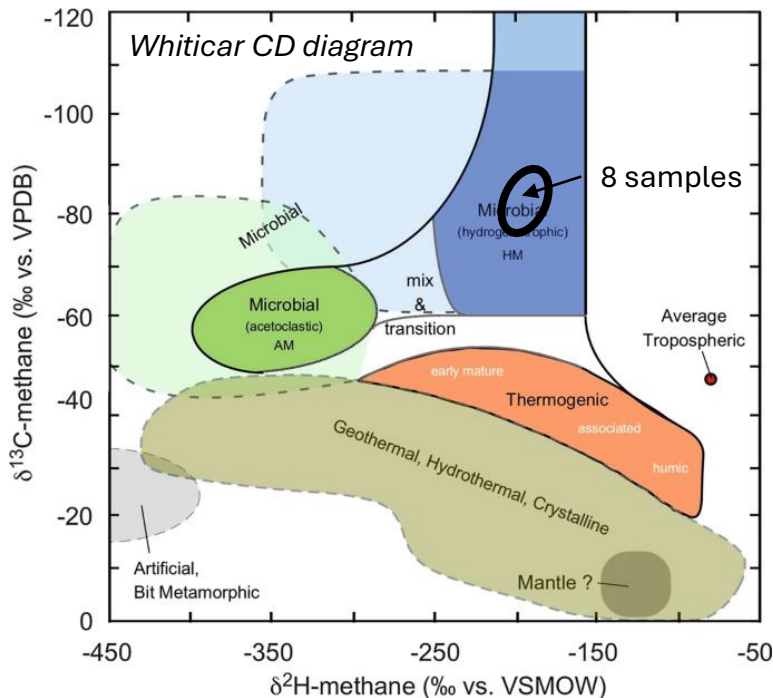


New Mud Volcanoes geochemistry

No gas bubbles.

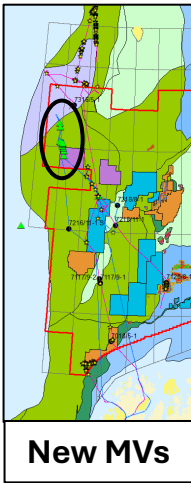
8 headspace gas samples (IsoJars):

- 99.4 – 99.9% microbial methane gas.
- Tiny amounts of C2 (0 – 0.08%).



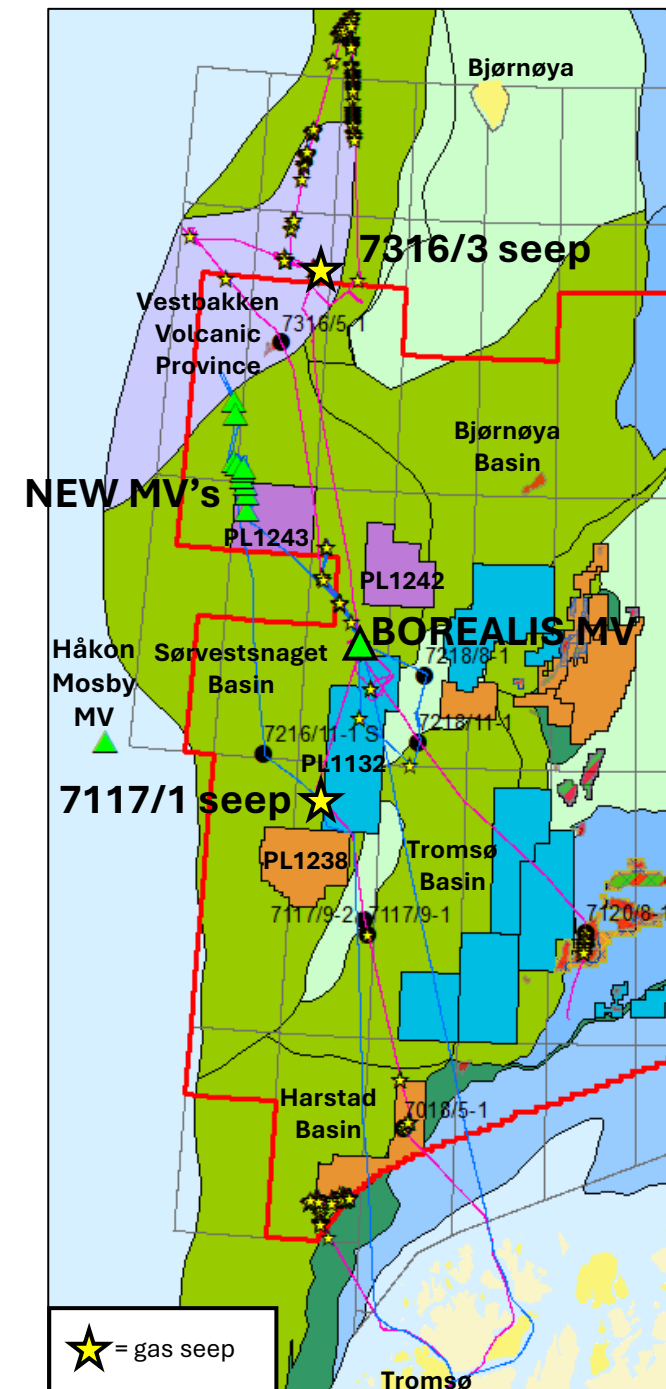
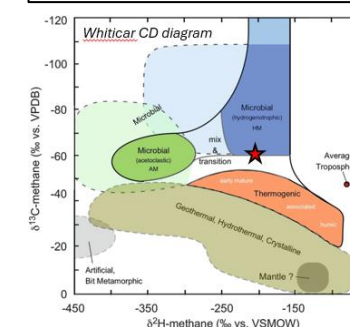
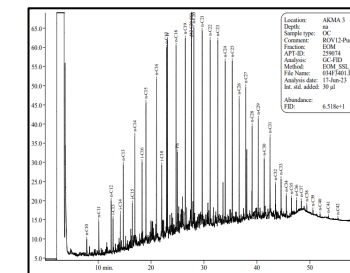
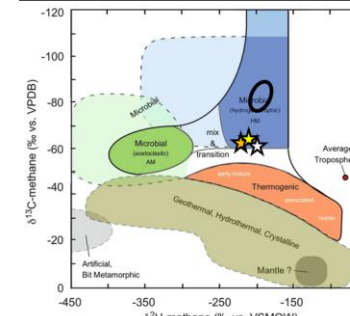
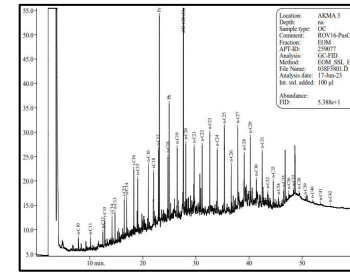
Traces of oil in sediment samples:

- Small, but ongoing/late supply of oil
- Low maturity
- Open to shallow marine/coastal
- Oleanane absent



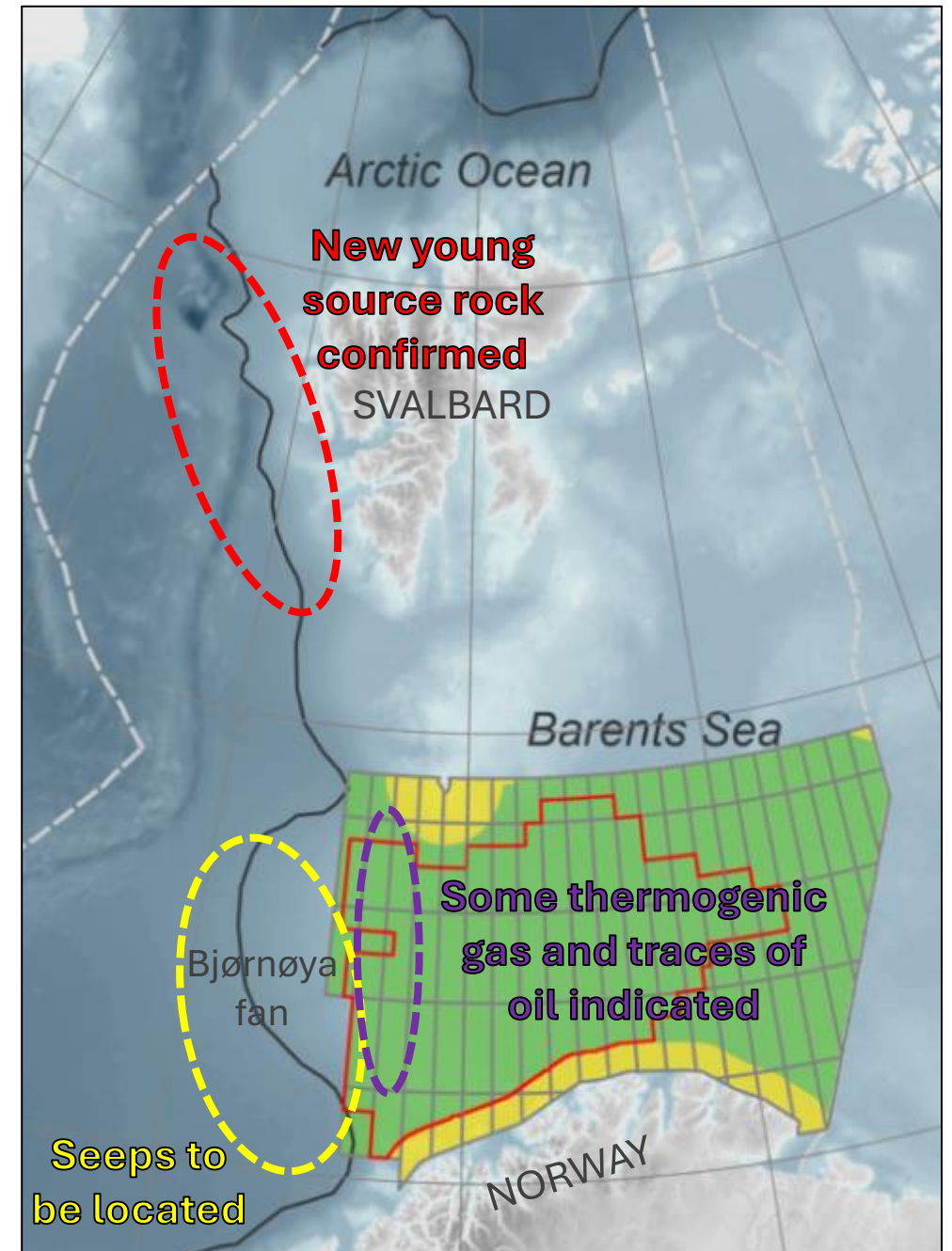
Seep geochemistry summarized

- Sørvestsnaget Basin seeps:
 - Small, but ongoing/late supply of low maturity oil.
 - Oil is from an open to shallow marine/coastal depositional environment.
 - Oleanane absent → Pre-Cretaceous oil?
 - 99.9% microbial/mixed methane gas, and 0.1% C2, C3 and C4 (thermogenic input, biodegraded); or 100% methane.
- Vestbakken Volcanic Province seep:
 - Ongoing/late supply of early- to mid mature oil (7316/3 seep).
 - Oil is from an open to shallow marine/coastal depositional environment.
 - Oleanane absent → Pre-Cretaceous oil?
 - ~100% microbial/mixed methane gas, with tiny amounts of C2, C3 and C4 (thermogenic input, biodegraded).



Conclusions

- A new young source rock is confirmed west of Svalbard.
 - Deltaic depositional environment.
 - Tertiary age, most likely from Early-Middle Miocene.
- If present below the Bjørnøya sedimentary fan west of the Barents Sea, the young source rock is most likely sufficiently buried for HC-generation.
 - Lack of samples (oil seep, slicks, borehole material) to test this hypothesis.
- Thermogene input (minor) indicated in some gas samples from the westernmost Barents Sea.
 - A thermogenic source rock must be present somewhere in the sub-surface.
 - Unknown maturity.
- Many sediment samples from gas seeps in the westernmost Barents Sea show traces of some oil.
 - Source rock of mostly low maturity, from an open to shallow marine environment, of mostly unknown age.
 - So far, no indications for the new young source rock.
 - Must locate and sample seeps further west.



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