SOKKELDIREKTORATET

Hydrocarbon seeps and a new young source rock

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NPF Exploration Revived, Stavanger, 10-12 mars 2025

Satellite data: Copernicus Sentinel-1 data 2024, processed by ESA

Outline

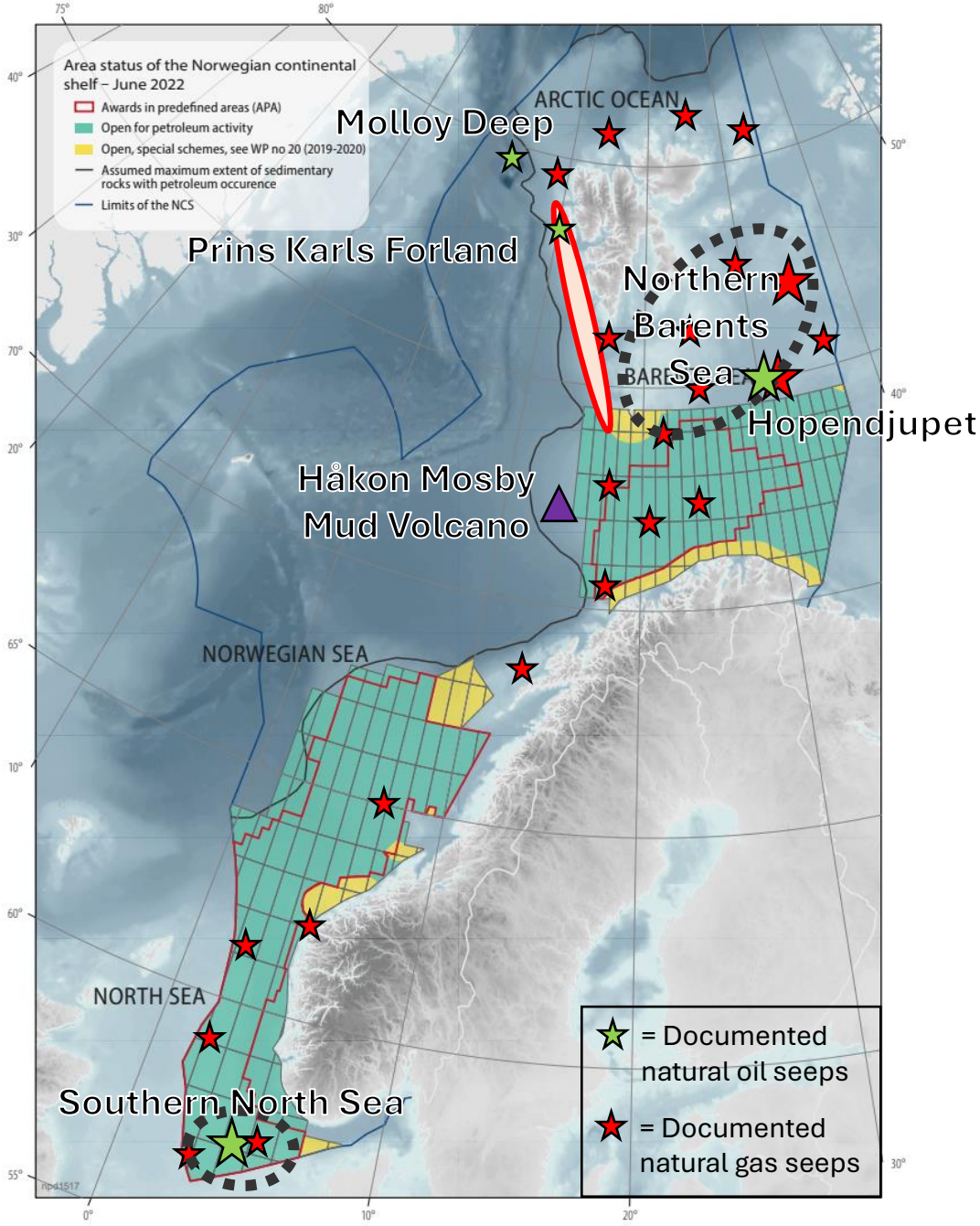
Hydrocarbon seeps and a new young source rock

- Summary from Exploration Revived 2023-talk: *«Oil seeps on the NCS»*
- Oil seeps, Miocene source rock and the petroleum system west of Svalbard
- Bjørnøya Fan - oil slicks and basin modelling
- Seeps and mud volcanos in the westernmost Barents Sea
- Geochemistry of oils and the Miocene source rock
- Wider regional presence of lower-middle Miocene source rock on the NCS
- Summary

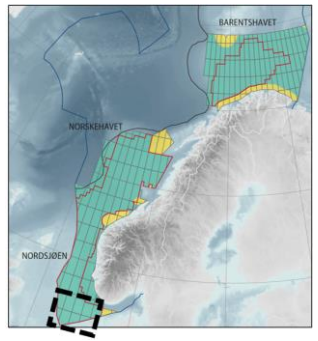
Photo: UiT/CAGE21-1

Summary from Exploration Revived 2023-talk, *«Oil seeps on the NCS»*

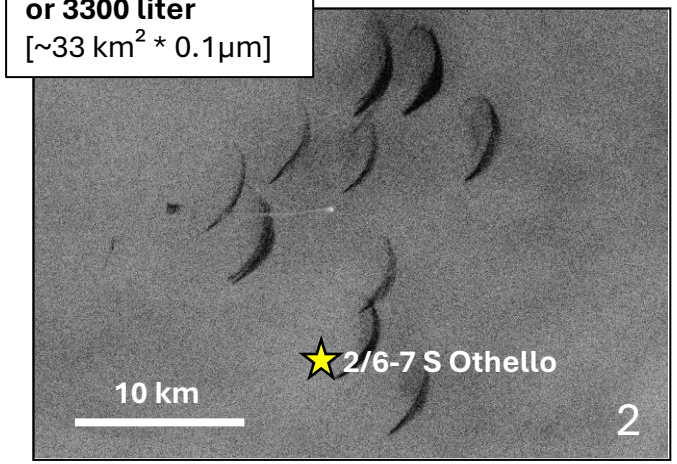
- Many thousands of gas seeps mapped in the Barents Sea, Norwegian Sea and the North Sea.
- SAR-satellite data indicates widespread oil seepage in the northern Barents Sea.
- SAR-satellite data from the southern North Sea indicates widespread episodic oil seeps.
- Several confirmed oil seeps in the Barents Sea and offshore Svalbard.
- Oil seeps outside Svalbard has confirmed a new young source rock.

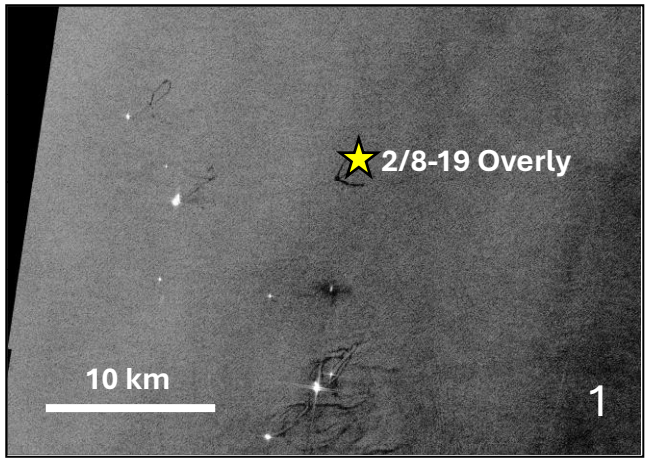


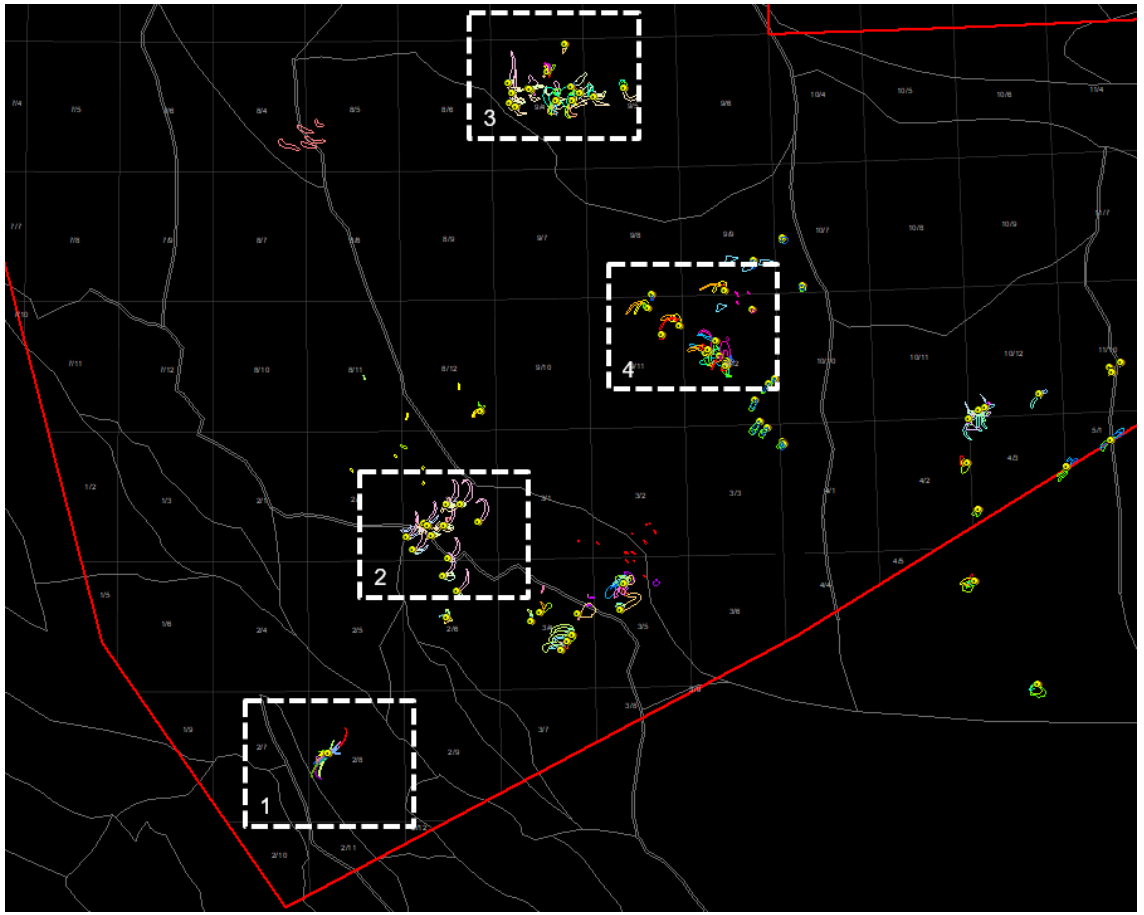
Episodic natural oil slicks in the southern North Sea



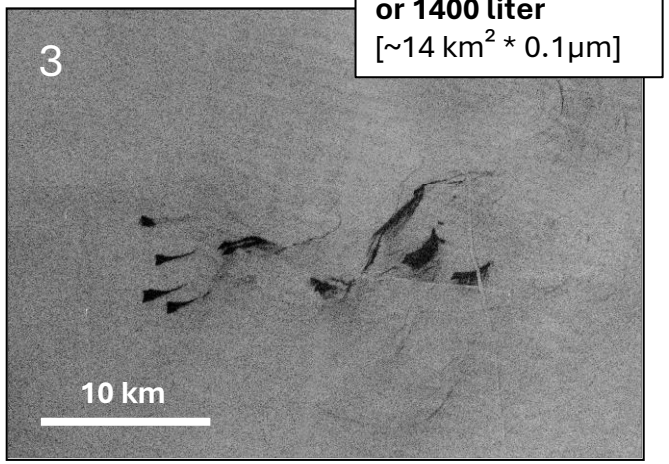
= 21 barrels of oil or 3300 liter
[~33 km^2 * 0.1µm]

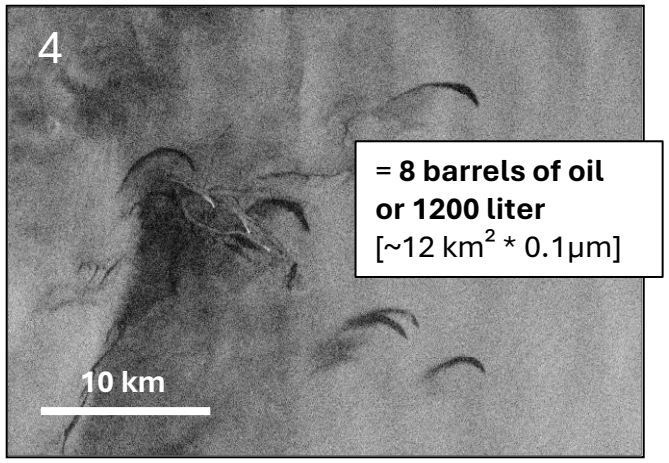






= 9 barrels of oil or 1400 liter
[~14 km^2 * 0.1µm]

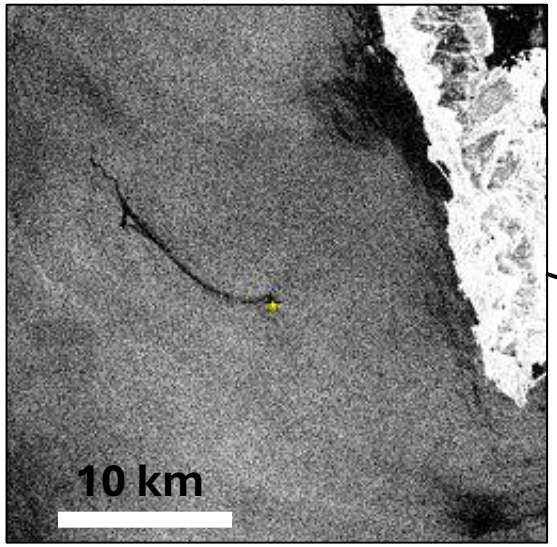


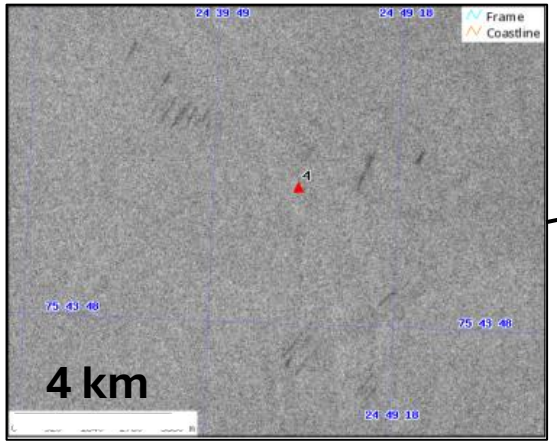


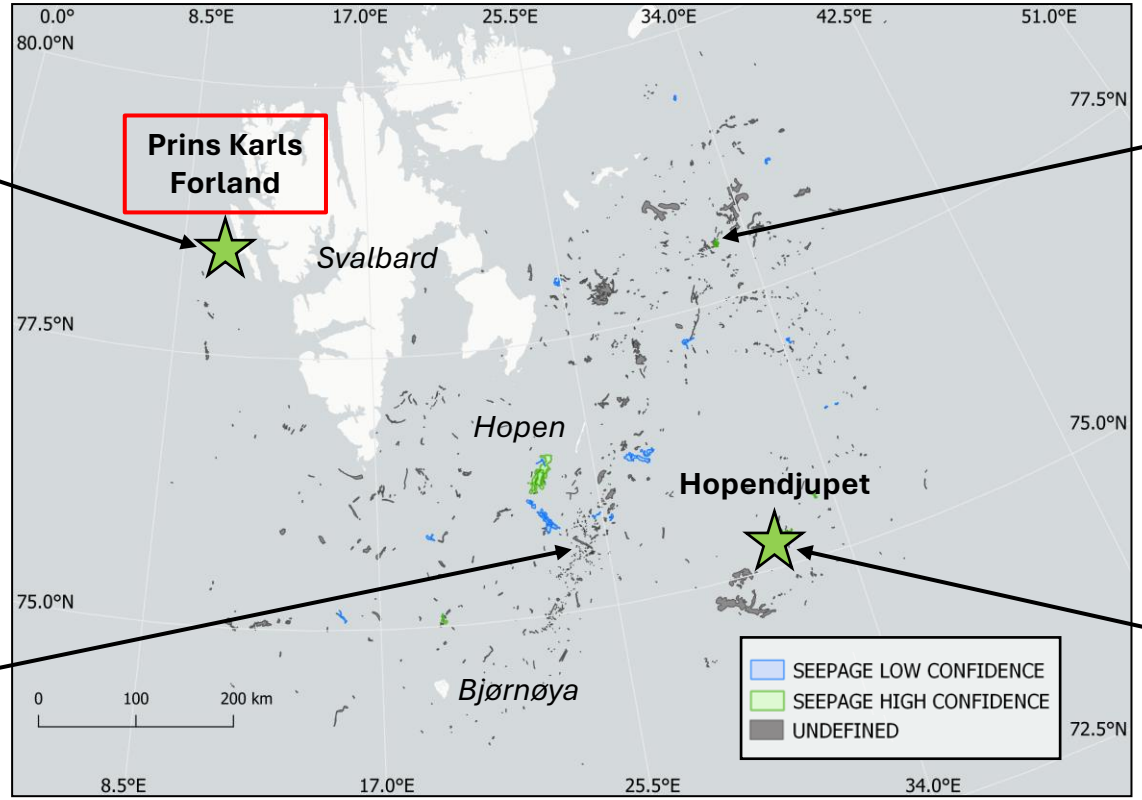
= 8 barrels of oil or 1200 liter
[~12 km^2 * 0.1µm]

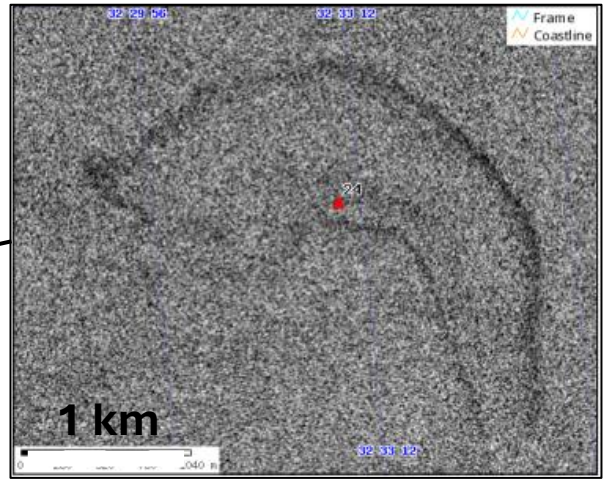
Satellite data: Copernicus Sentinel-1 data 2017-2021, processed by ESA.

Many potential natural oil slicks observed on SAR-satellite images in the northern Barents Sea









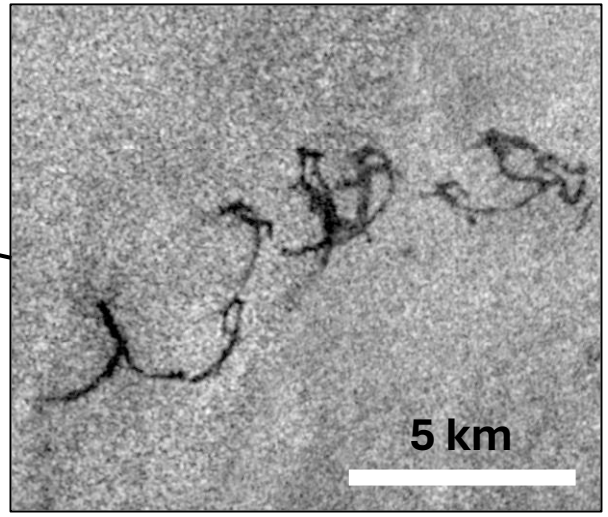


Figure compiled by Martine Espeseth (KSAT) for Sodir

Prins Karls Forland oil seep and slicks

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

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 Mattingsdal [i]

- *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.*

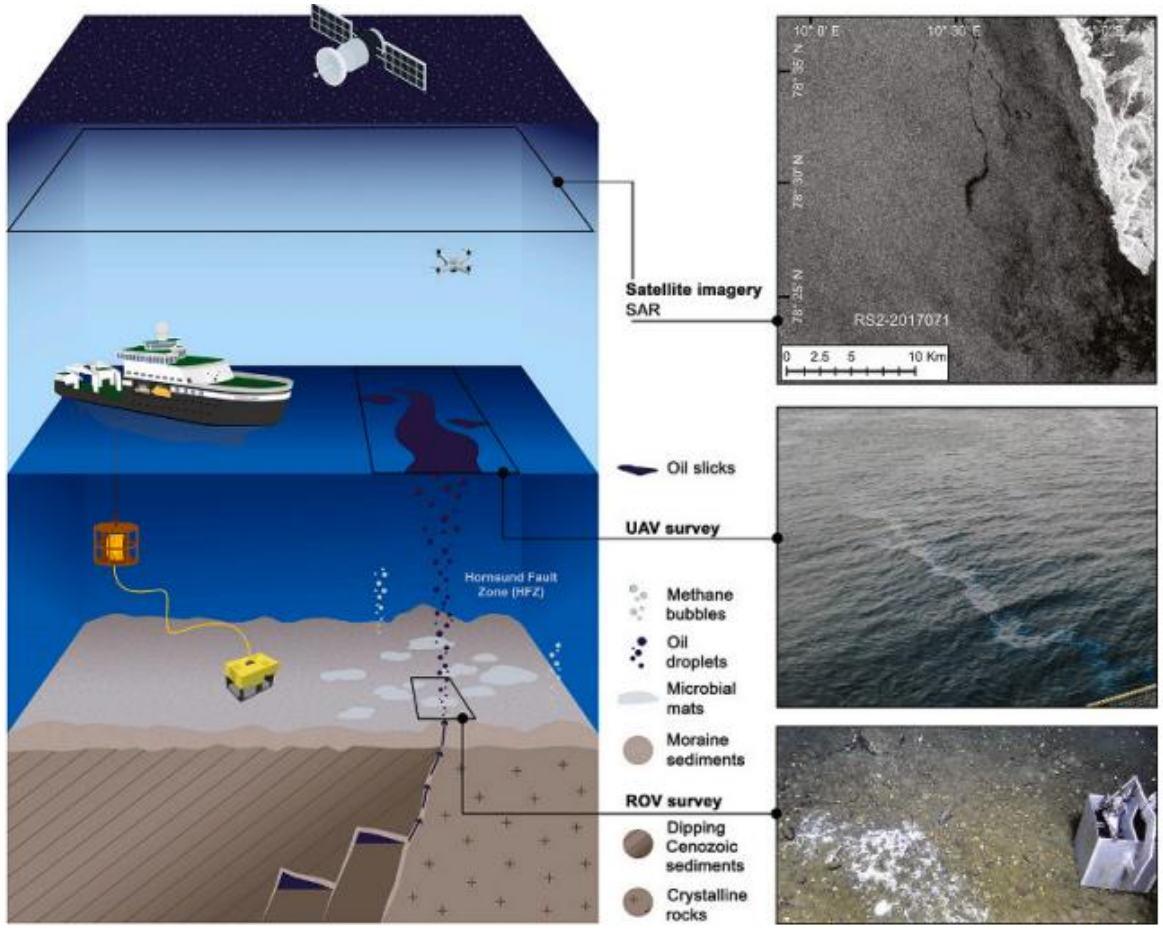
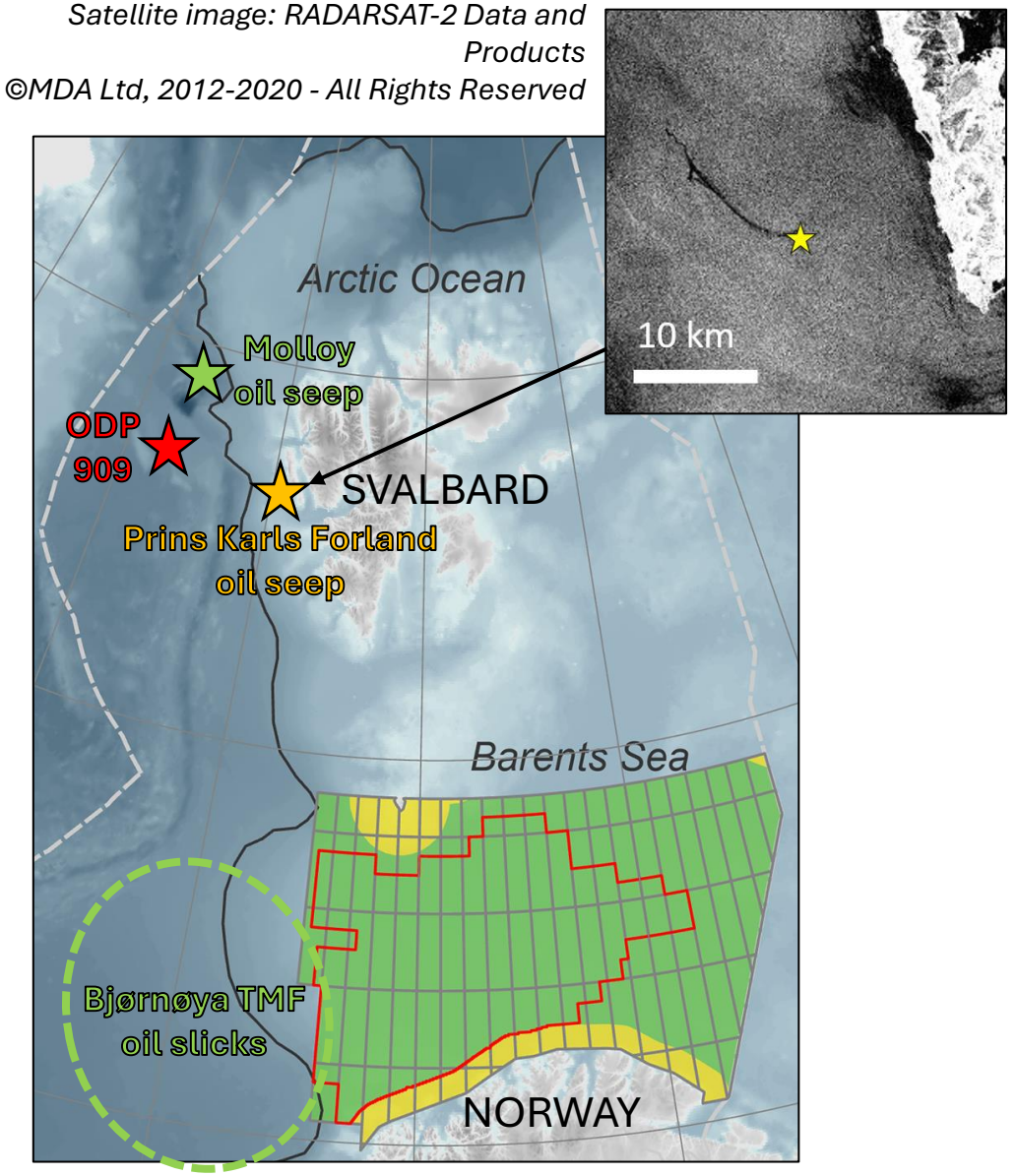


Figure: Panieri et al. (2024)

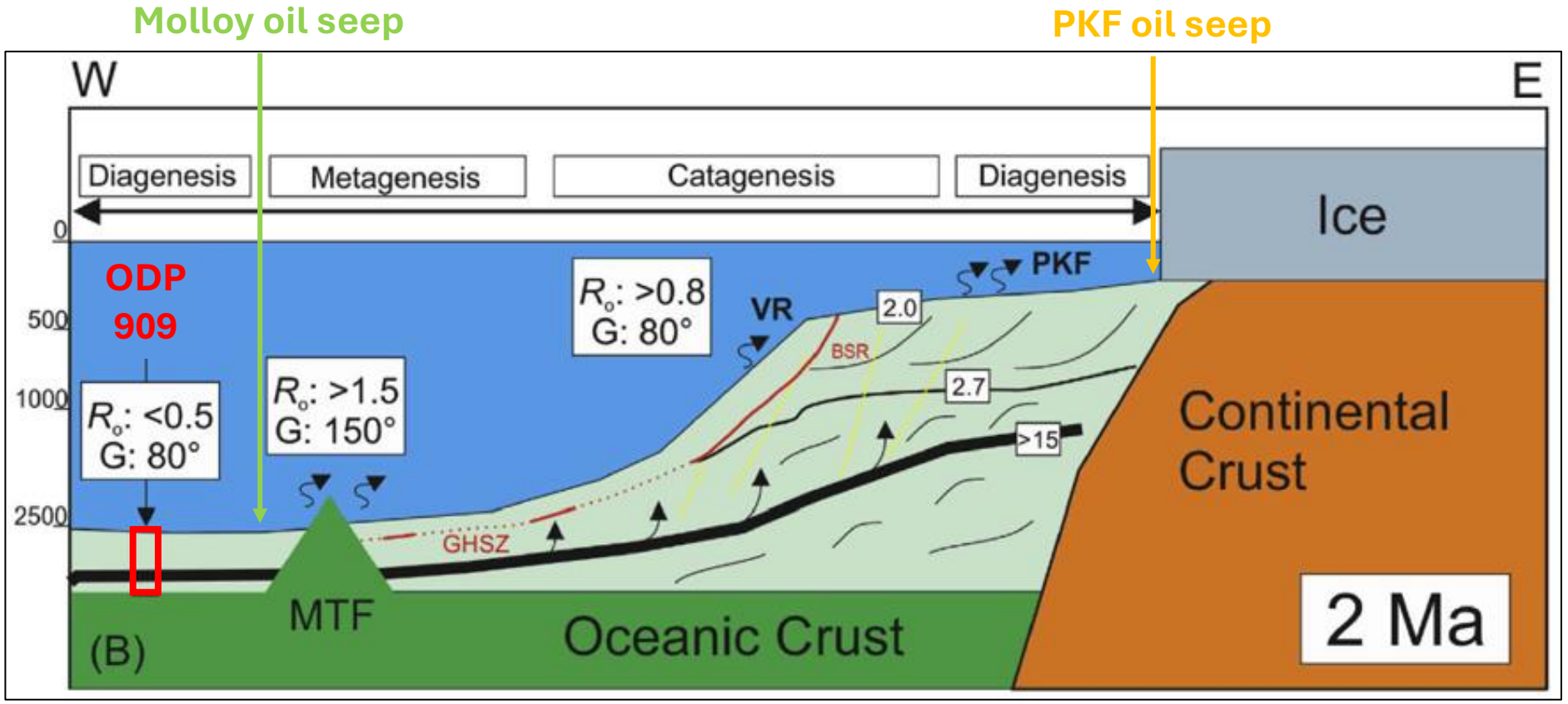
A new young source rock west of Svalbard

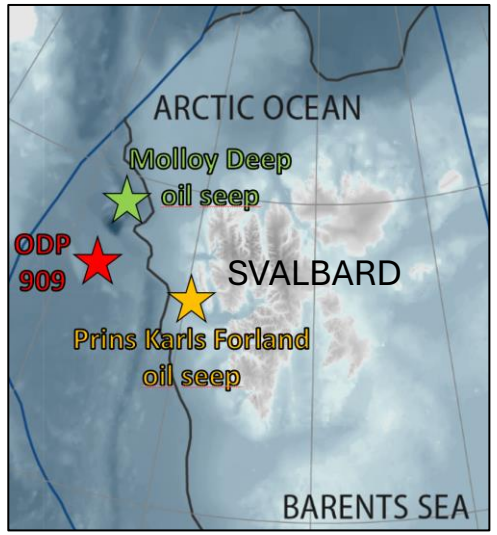
- **Prins Karls Forland (PKF) oil seep and slicks** (sampled by UiT in 2021)
  - Oil from new young source rock geochemically confirmed (Panieri et al., 2024)
- **ODP 909** (drilled in 1993)
  - Young Early-Middle Miocene deltaic derived source rock (Knies & Mann, 2002)
- **Molloy oil seep** (sampled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



Petroleum System- Western Svalbard margin

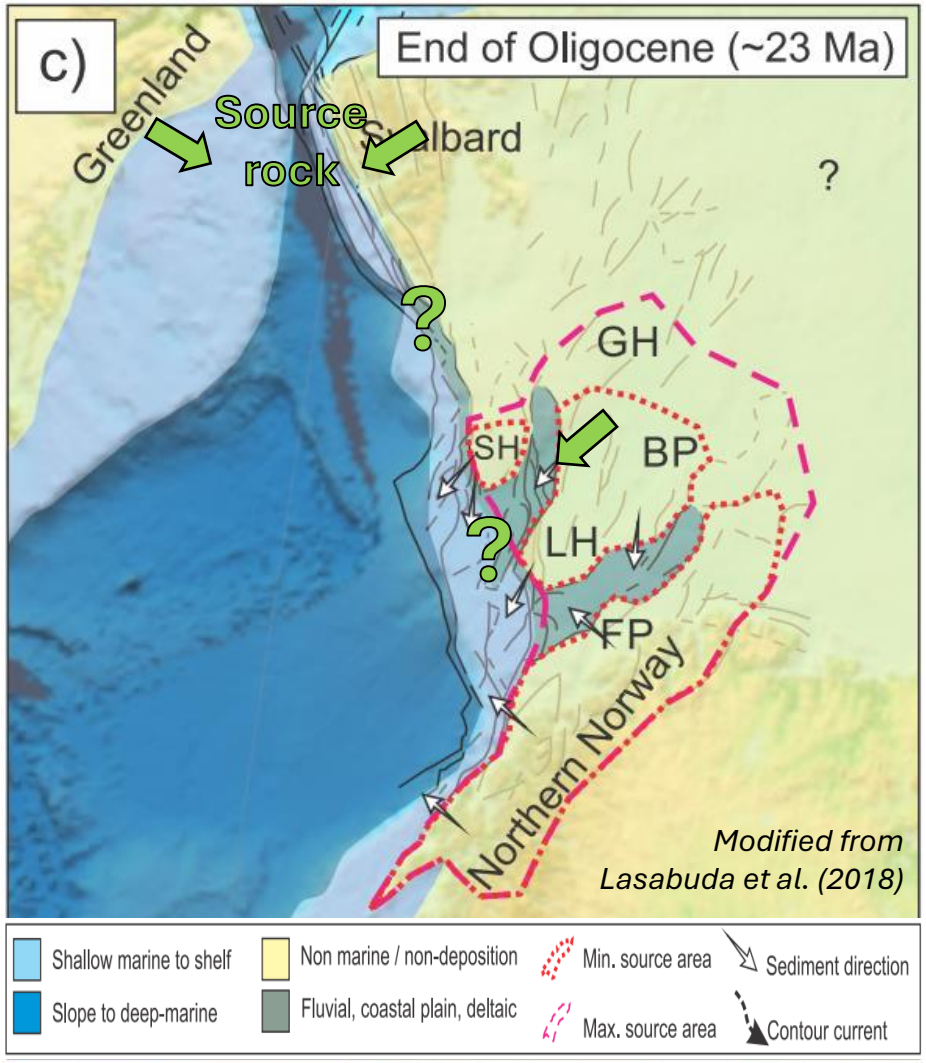
- Early-Middle Miocene petroleum system active for the last ~6 million years (Knies et al., 2018).



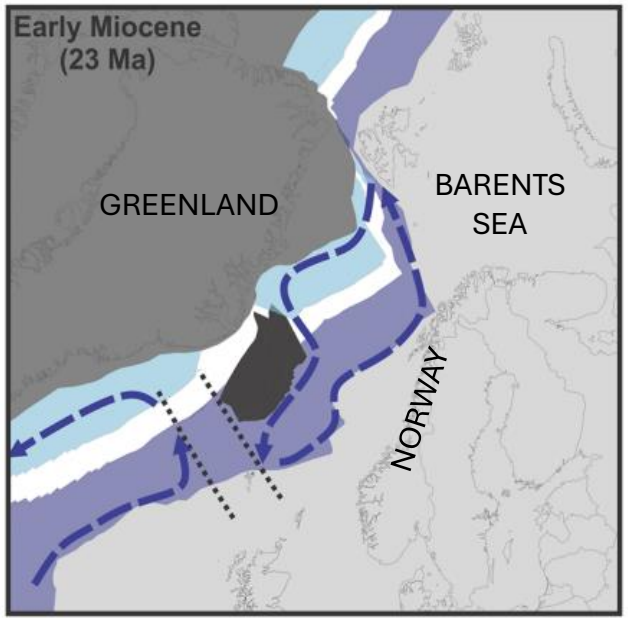


Knies et al. (2018)

Early-Middle Miocene 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.

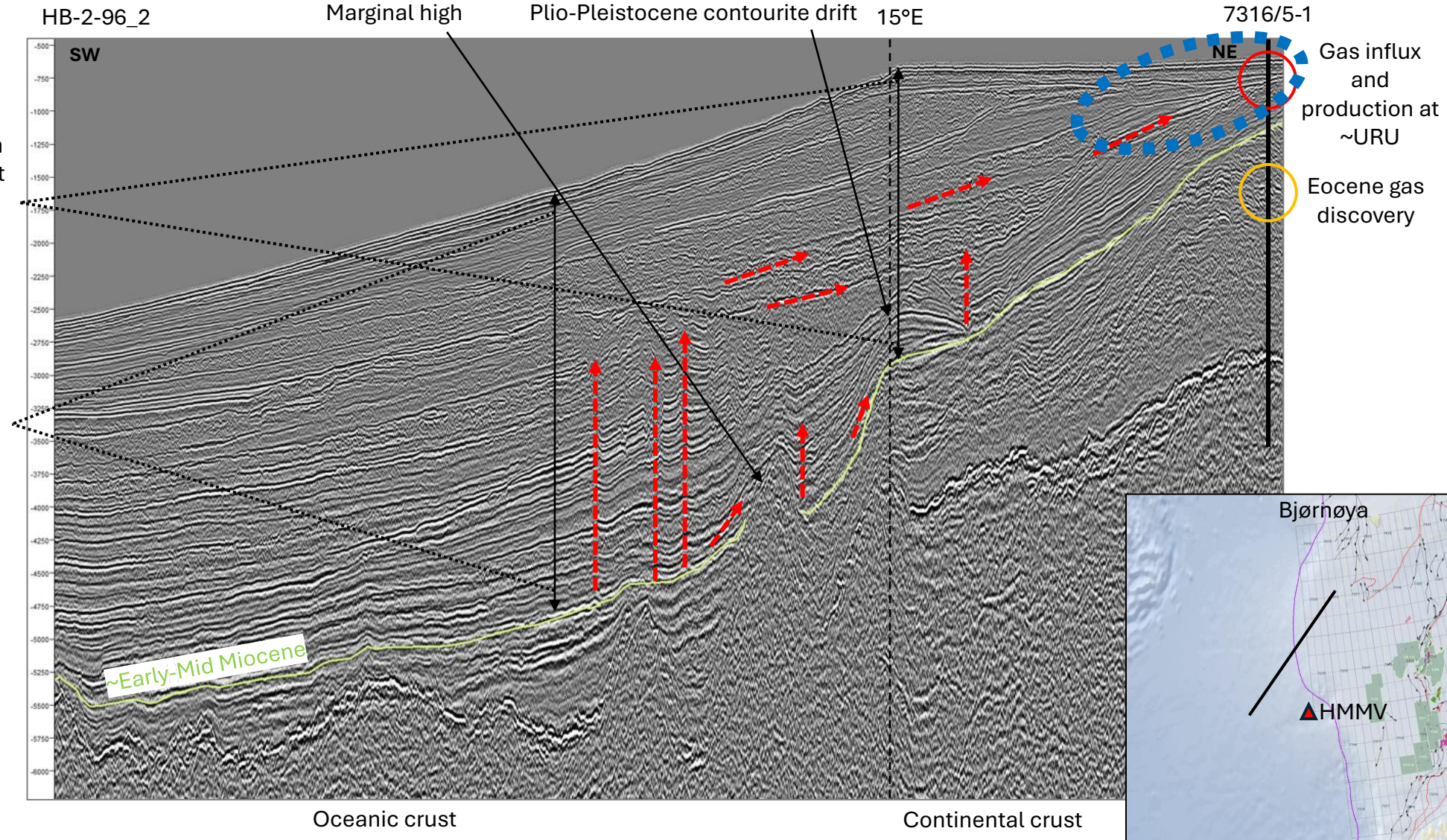


Rydningen et al. (2020)

Early-Middle Miocene source rock buried under the Bjørnøya trough mouth fan ?

New Mud Volcanoes discovered in this setting further south

Different geothermal gradients over oceanic and continental crust.

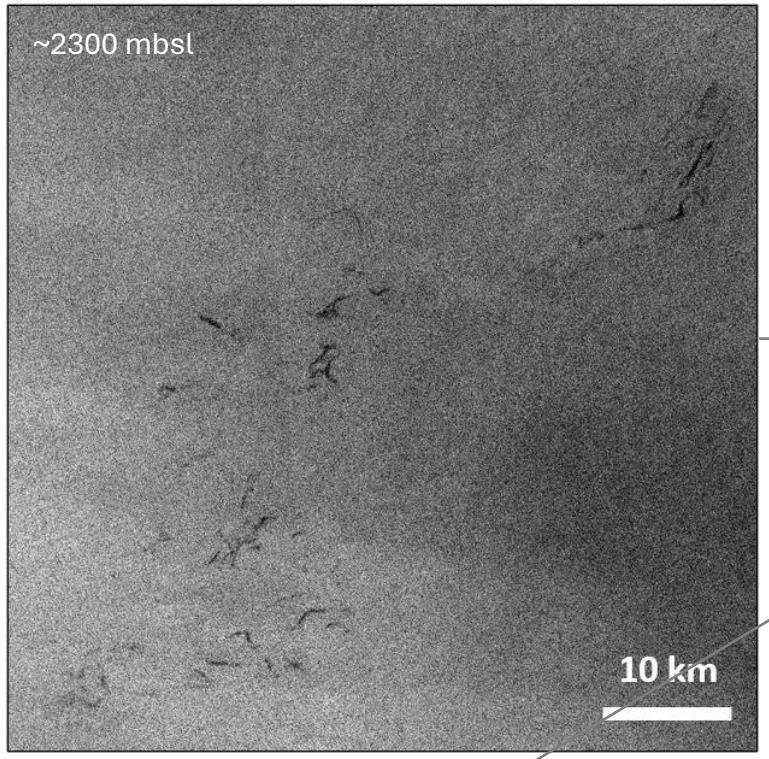


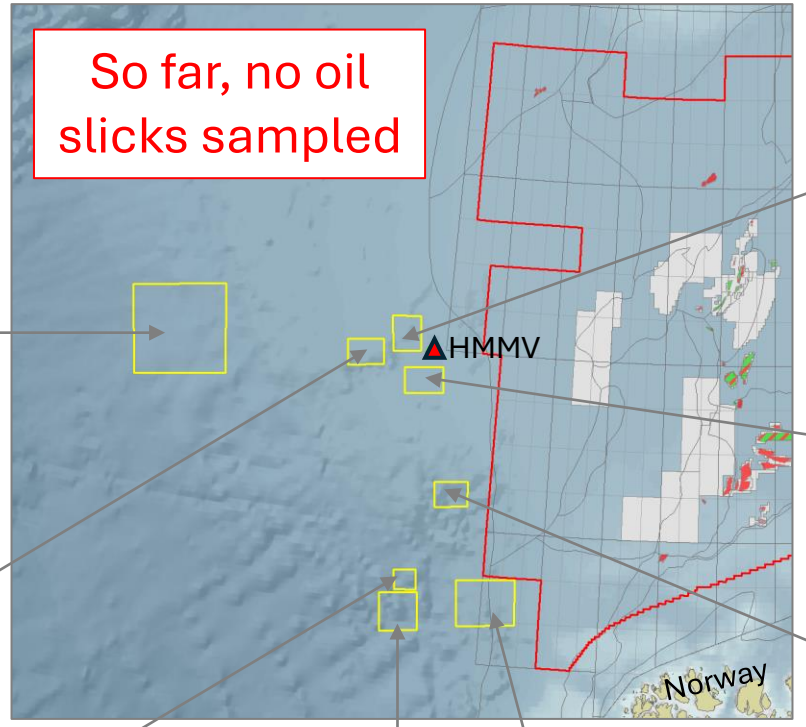
- Vertical migration through faults ?
- Lateral migration up-dip along sandy Quaternary layers ?

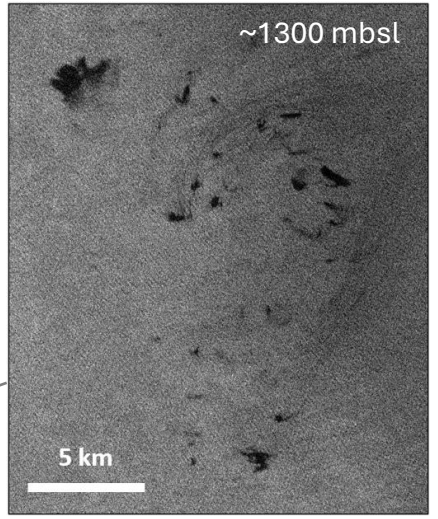
Satellite images: Copernicus Sentinel-1 data 2018 and 2023, processed by ESA.

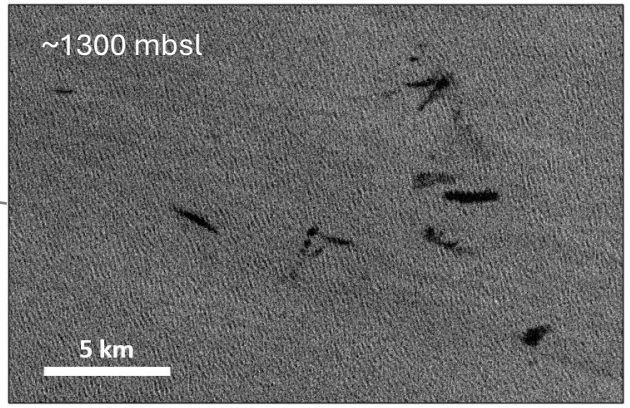
Oil slicks observed on Bjørnøya Fan

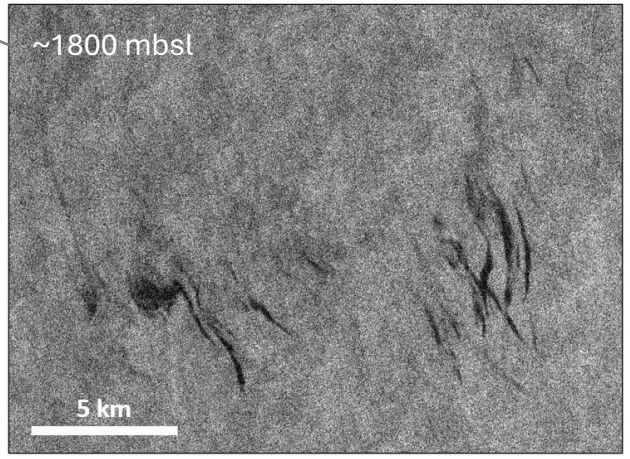
From Mattingsdal et al. (2024), EAGE 2024 Extended abstract

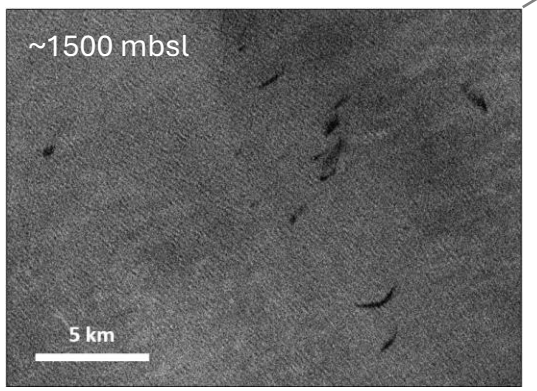


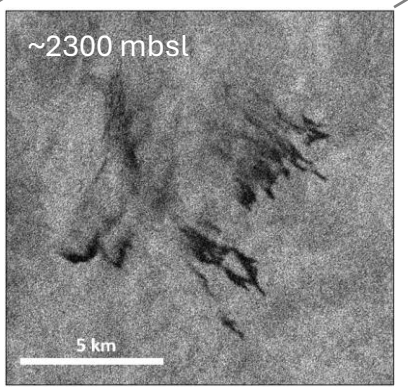


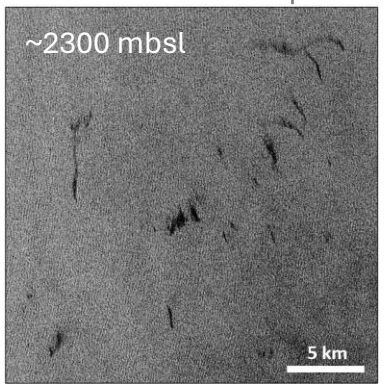


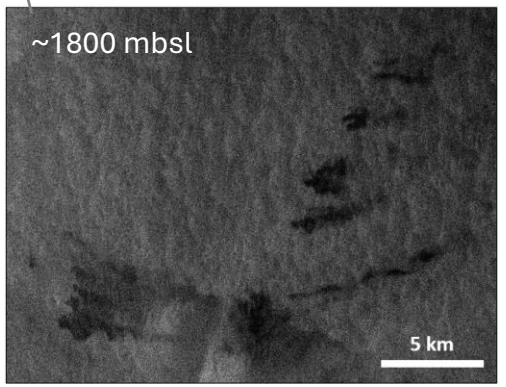












2D Basin modelling on the Bjørnøya fan

- The heat flow, thermal maturity and generation history for an early Miocene source rock was modelled to present day.

➢ The modelled vitrinite reflectance demonstrates that the Lower Miocene source rock is within the Main – Late Oil window for both modelled scenarios with varying stretching factors (Beta = 4 and 8).

- In both scenarios, maturation of the source rock initiated between 1,4-0,5 Ma as a result of burial depth.

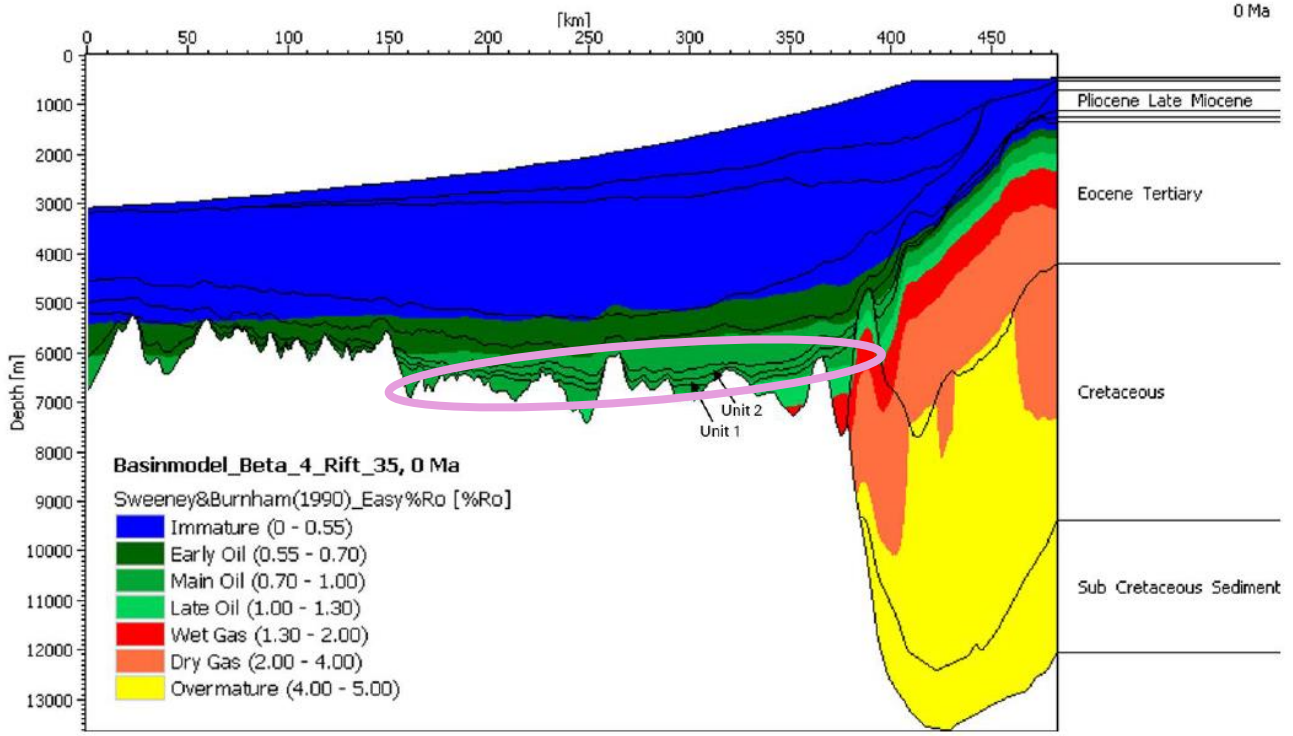
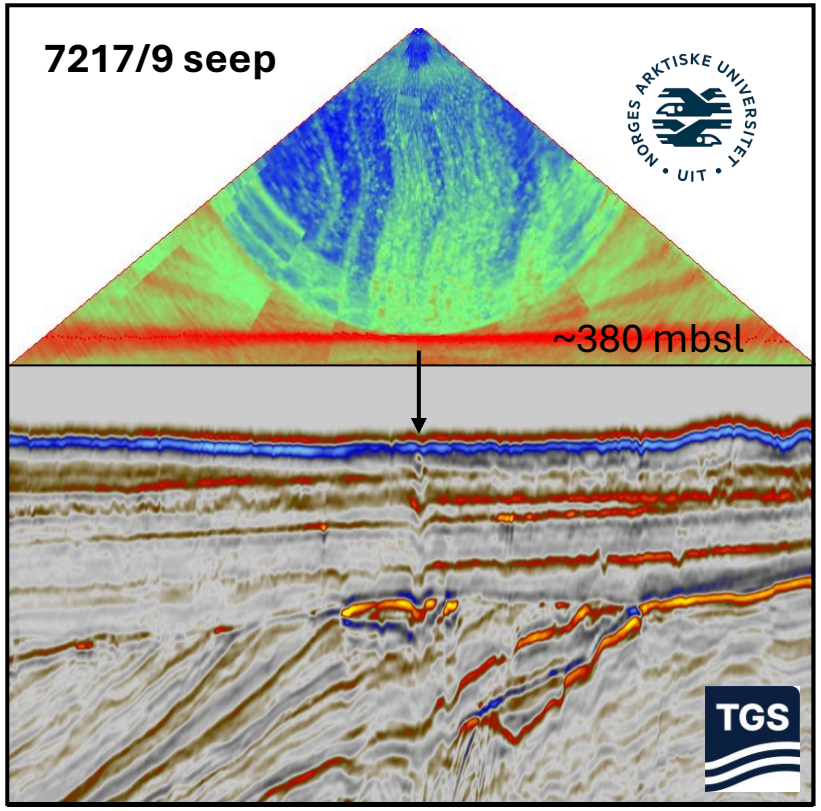
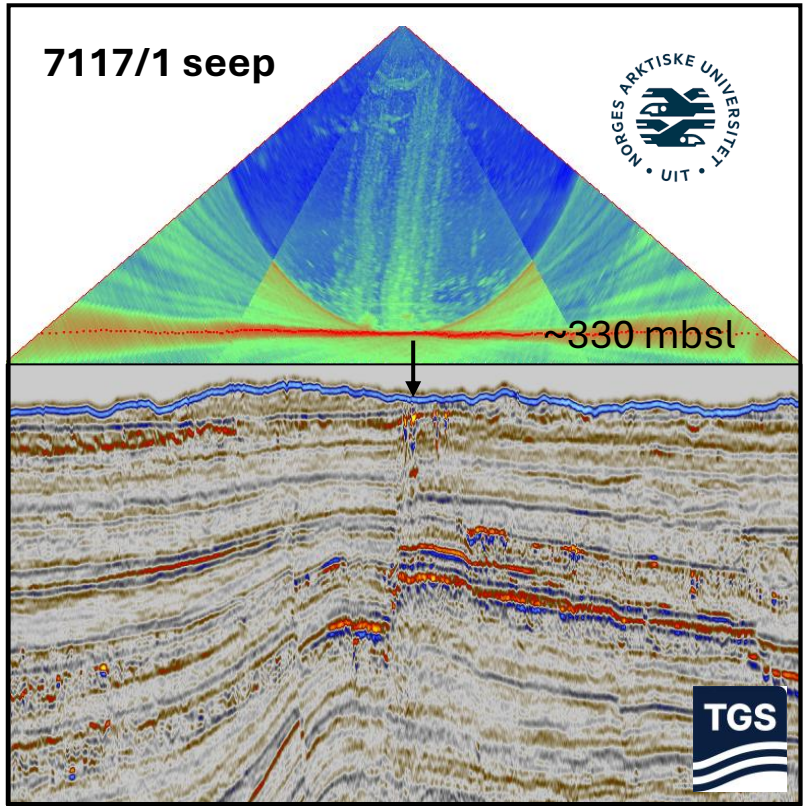


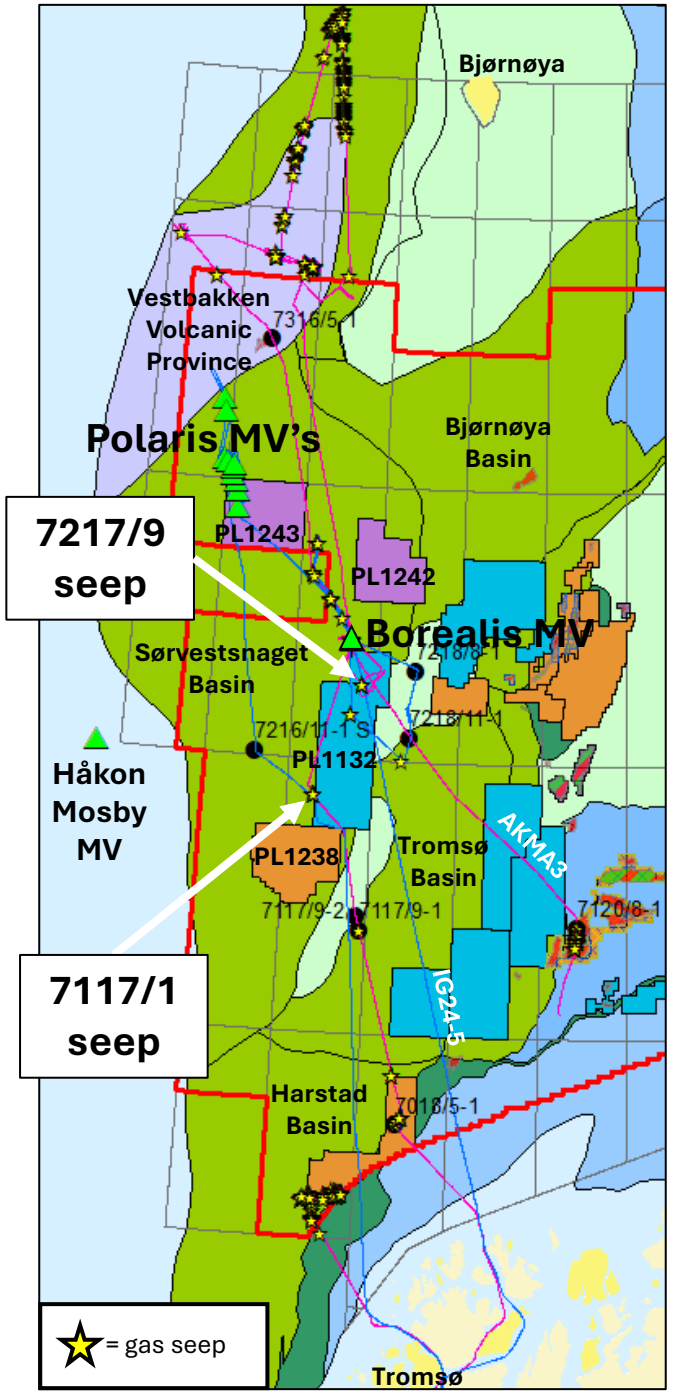
Figure from Exploro report for Sodir

Seep-studies in the westernmost Barents Sea

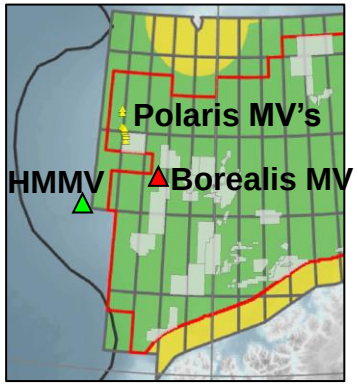
- Many sediment samples from gas seeps in the westernmost Barents Sea show traces of some oil.
- Geochemistry indicates source rock of mostly low maturity, from an open to shallow marine environment, of mostly unknown age.







Mud Volcanos in the Barents Sea



Håkon Mosby Mud Volcano

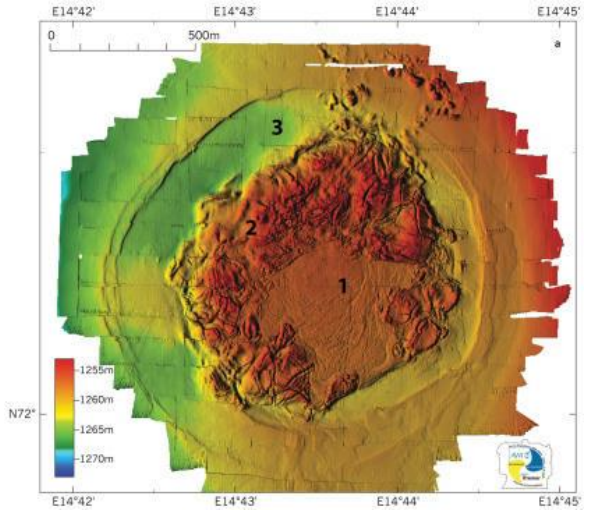
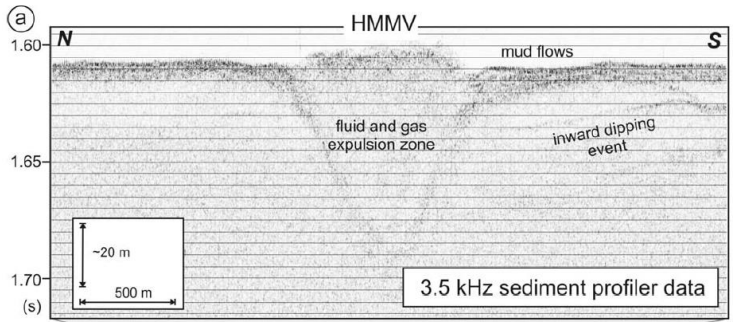
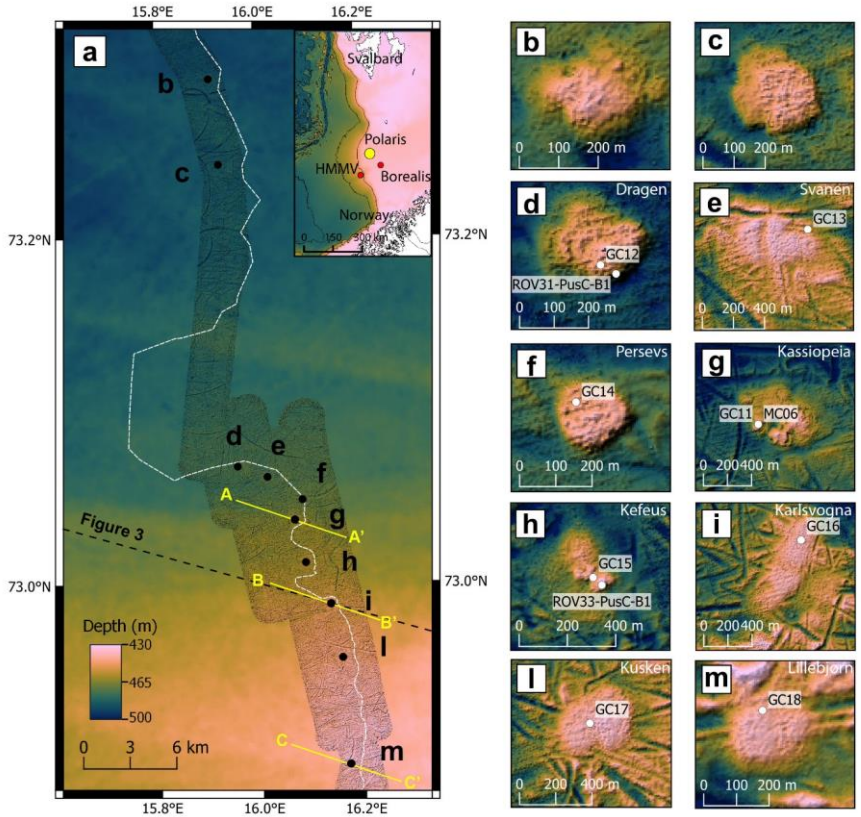


Figure: IFREMER



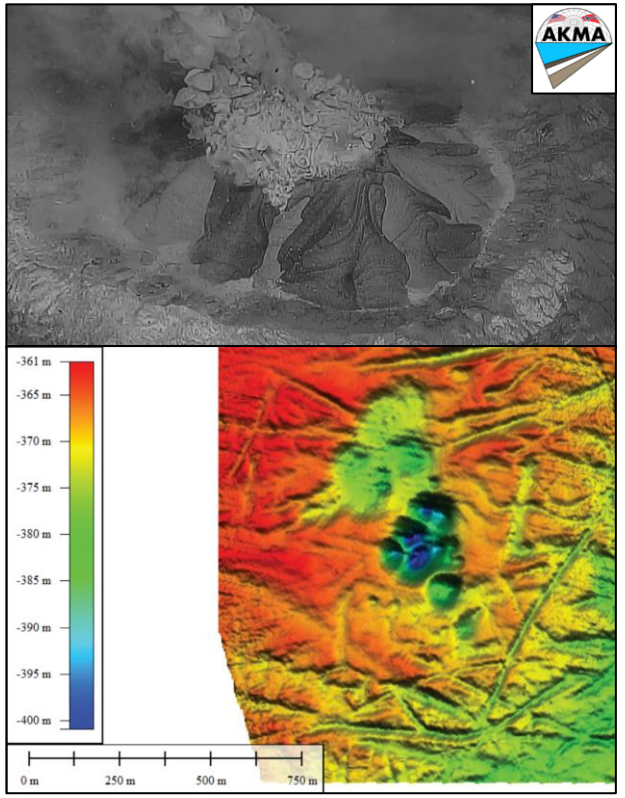
Berndt et al. (2006)

Polaris Mud Volcano Complex



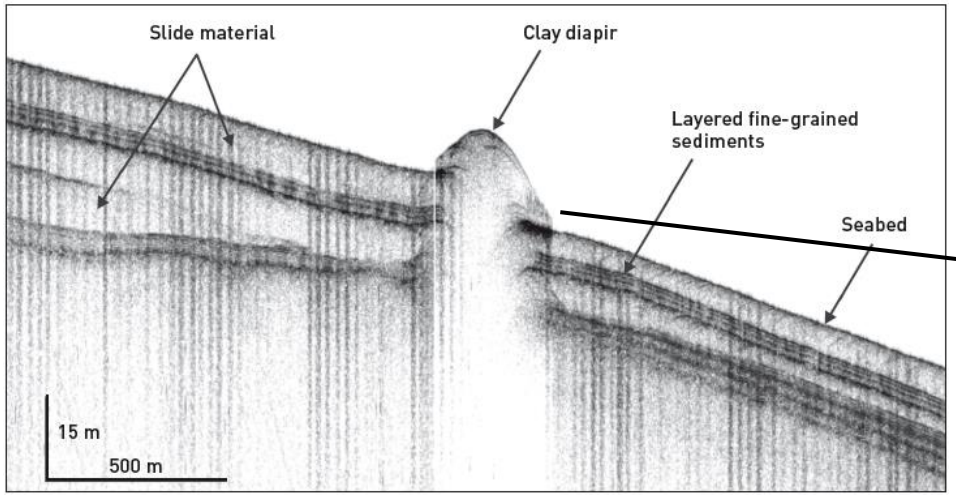
Argentino et al. (In review)

Borealis Mud Volcano

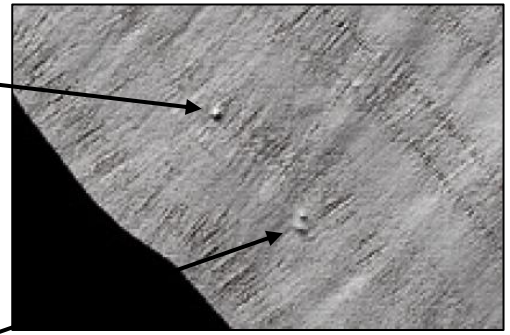


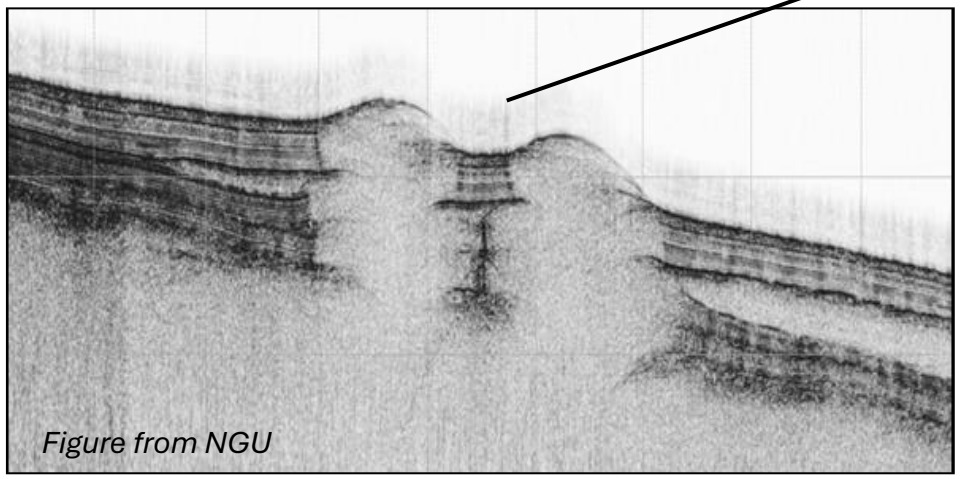
Panieri et al. (2025)

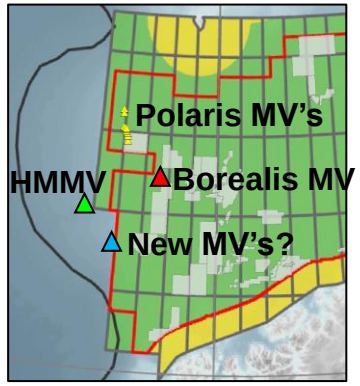
More Mud Volcanos ?



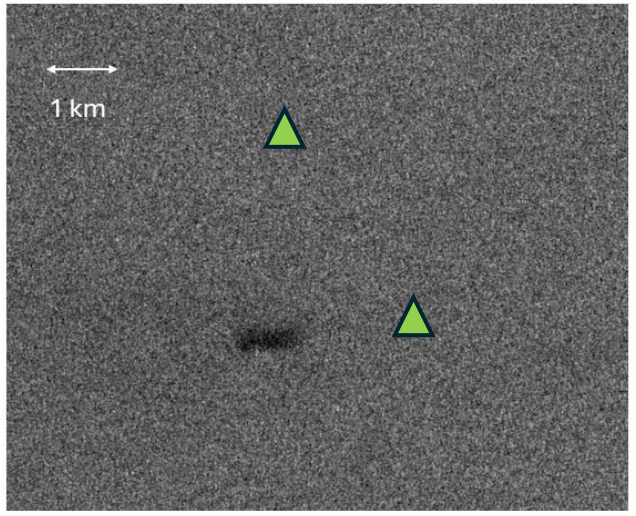
From Bøe et al. (2010)

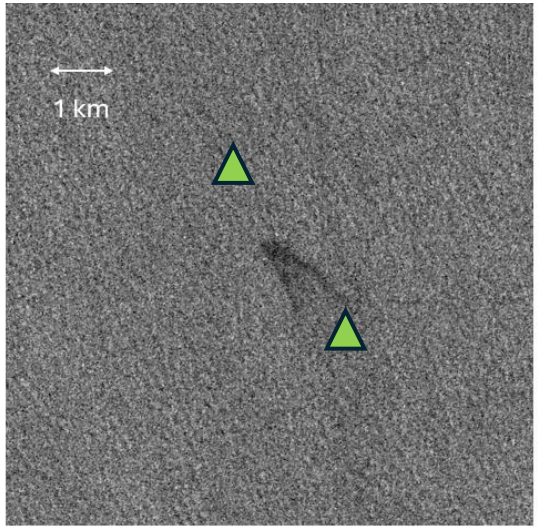






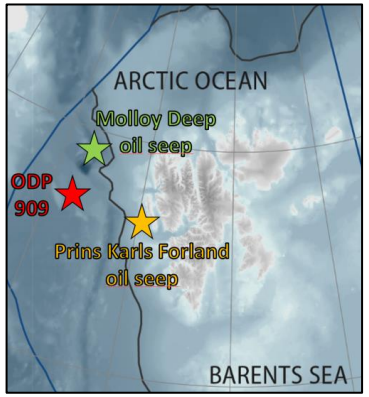
- Mounds on the slope on Bjørnøyvifta, SE of HMMV.
  - 5-10 m high
  - 200-400 m wide
  - Oil slicks?



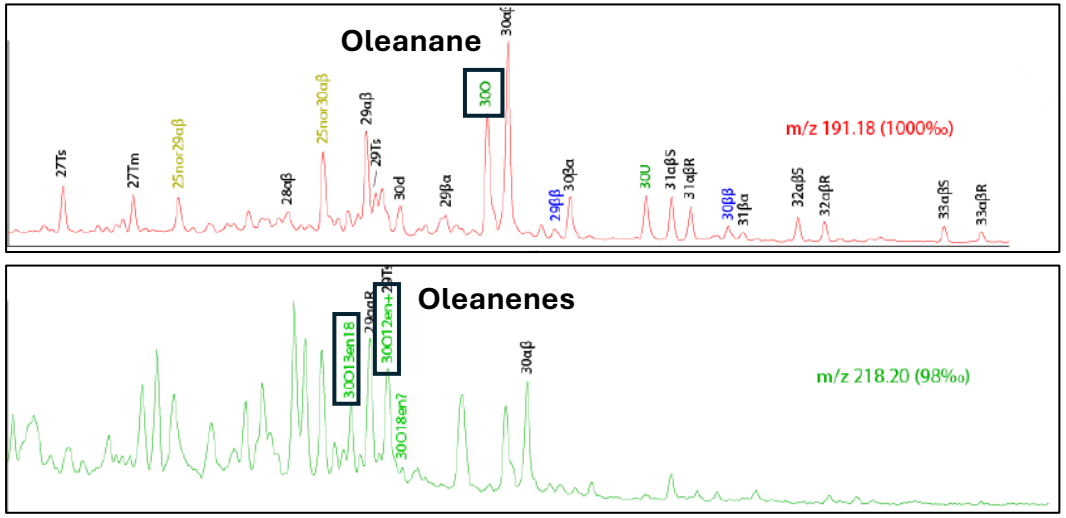


Satellite images: Copernicus Sentinel-1 data 2018 and 2020, processed by ESA.

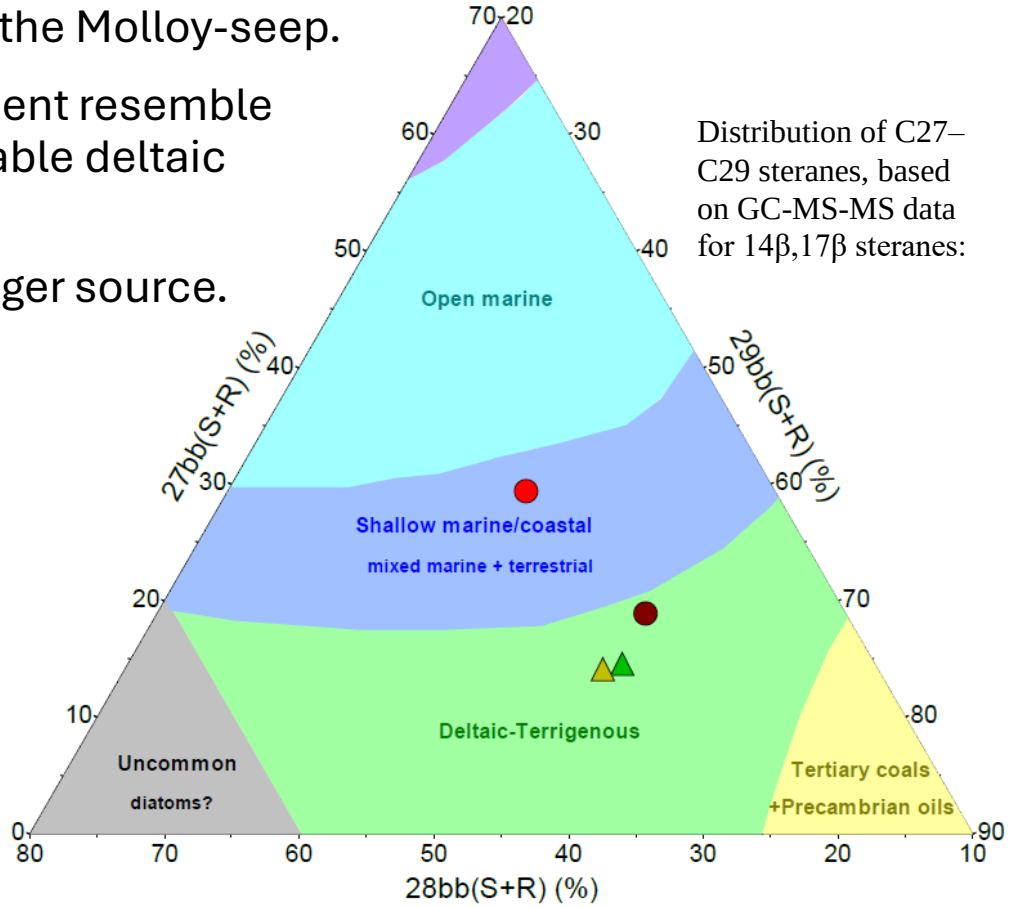
Geochemical signature of oils from the new young source rock



- The biomarkers from the PKF-seep appear almost identical to the Molloy-seep.
- Overall, the biomarker characteristics of source and environment resemble those of crude oils from the Niger Delta, suggesting a comparable deltaic depositional system → Mixed marine/deltaic source.
- Biomarkers suggest a Cretaceous, most likely Tertiary, or younger source.
  - Oleanane (from flowering land plants) present.



Distribution of C27–C29 steranes, based on GC-MS-MS data for 14β,17β steranes:

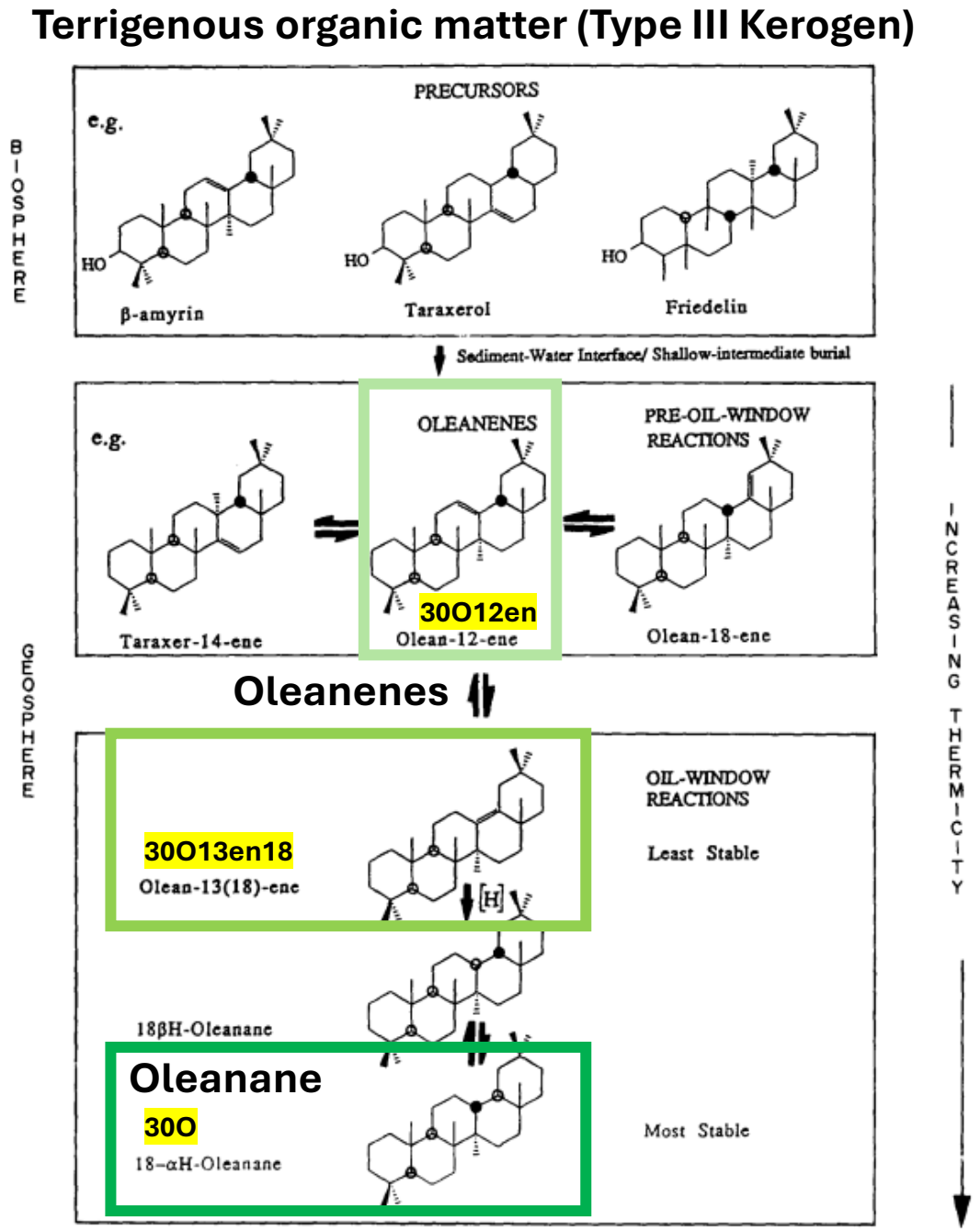


From APT geochemical interpretation report for NOD

Geochemical signature: Oleanane and oleanenes

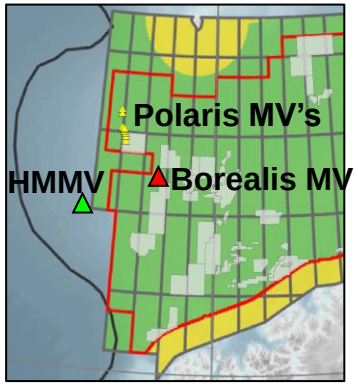
Eneogwe et al. (2002) – Source-derived oleanenes identified in Niger Delta oils:

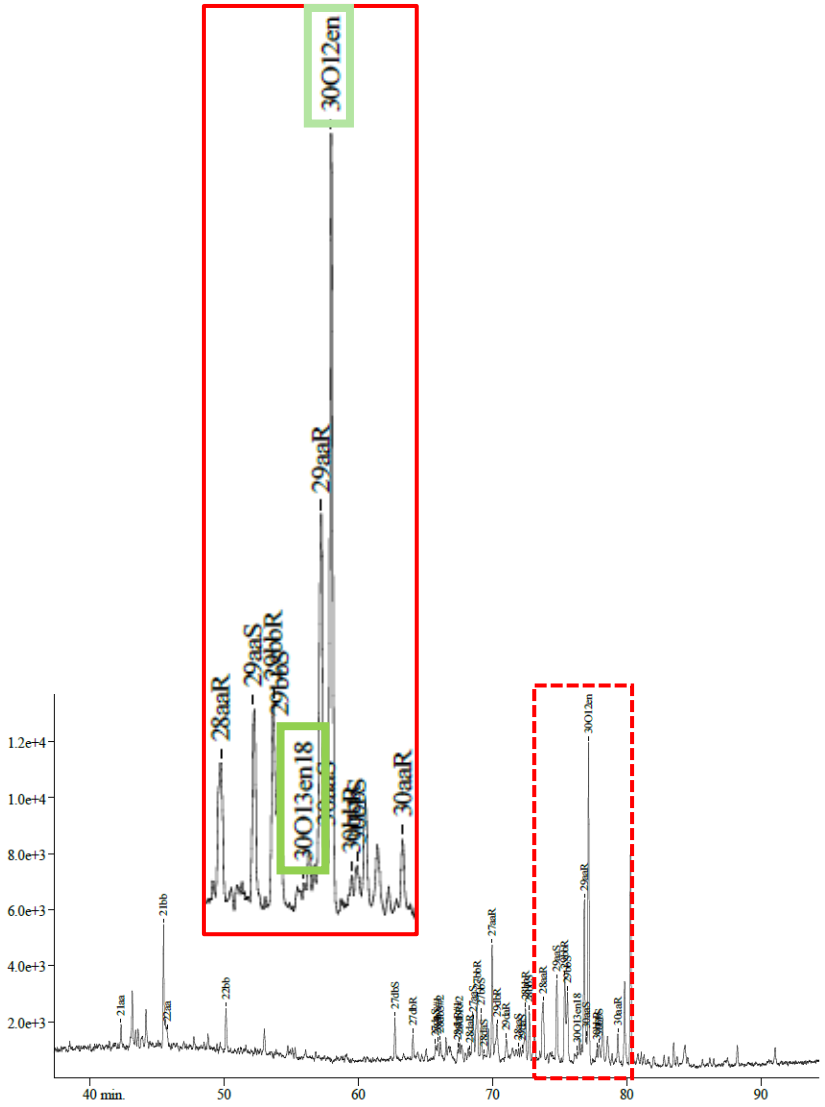
- Oleanenes are inherited directly from the source rock.
- Oleanenes can migrate with the rest of the oil.
- A good correlation exists between the abundance of oleanenes and the maturity status of the oils:
  - ➢ Oils generated at an early stage of hydrocarbon generation contain oleanenes, while those generated at peak of hydrocarbon generation do not contain oleanenes in identifiable quantities.



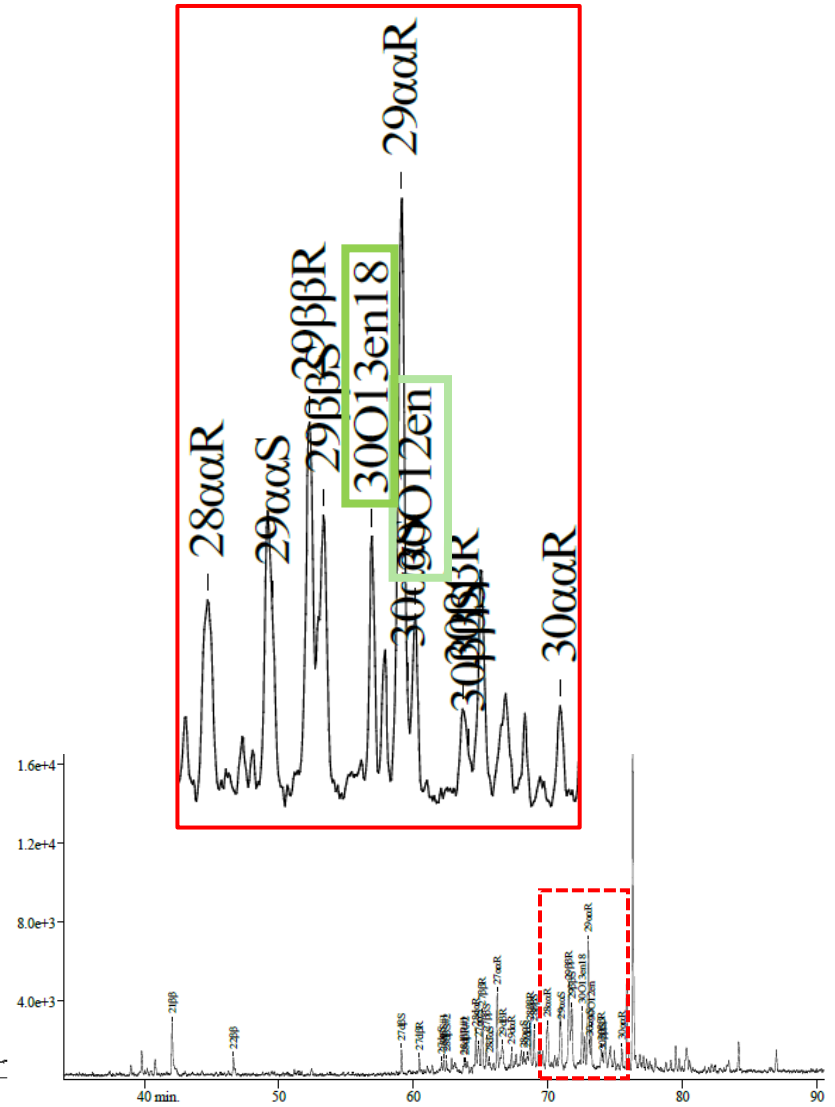
Oleanene – oleanane interconversions in the geosphere (Ekweozor & Telnaes 1990)

Oleanene in Western Barents Sea Mud Volcanos

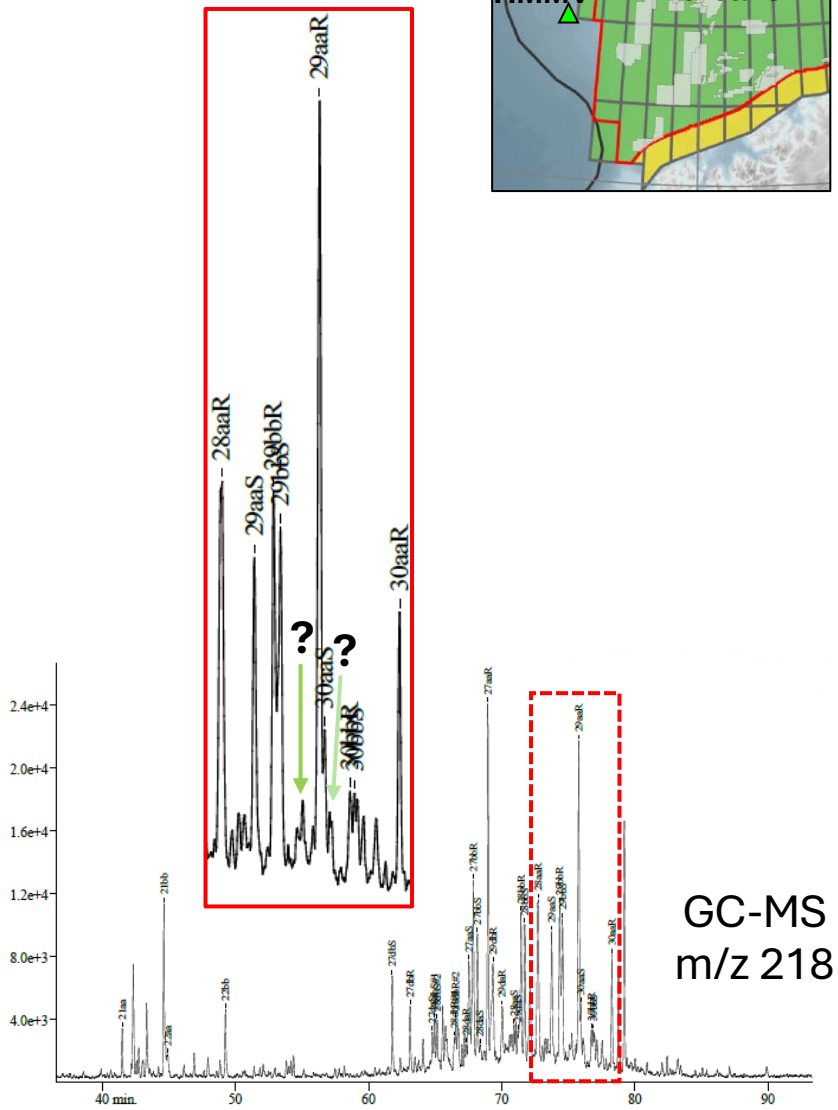




Håkon Mosby Mud Volcano



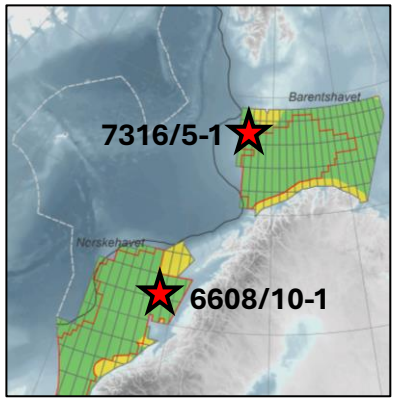
Polaris Mud Volcanos

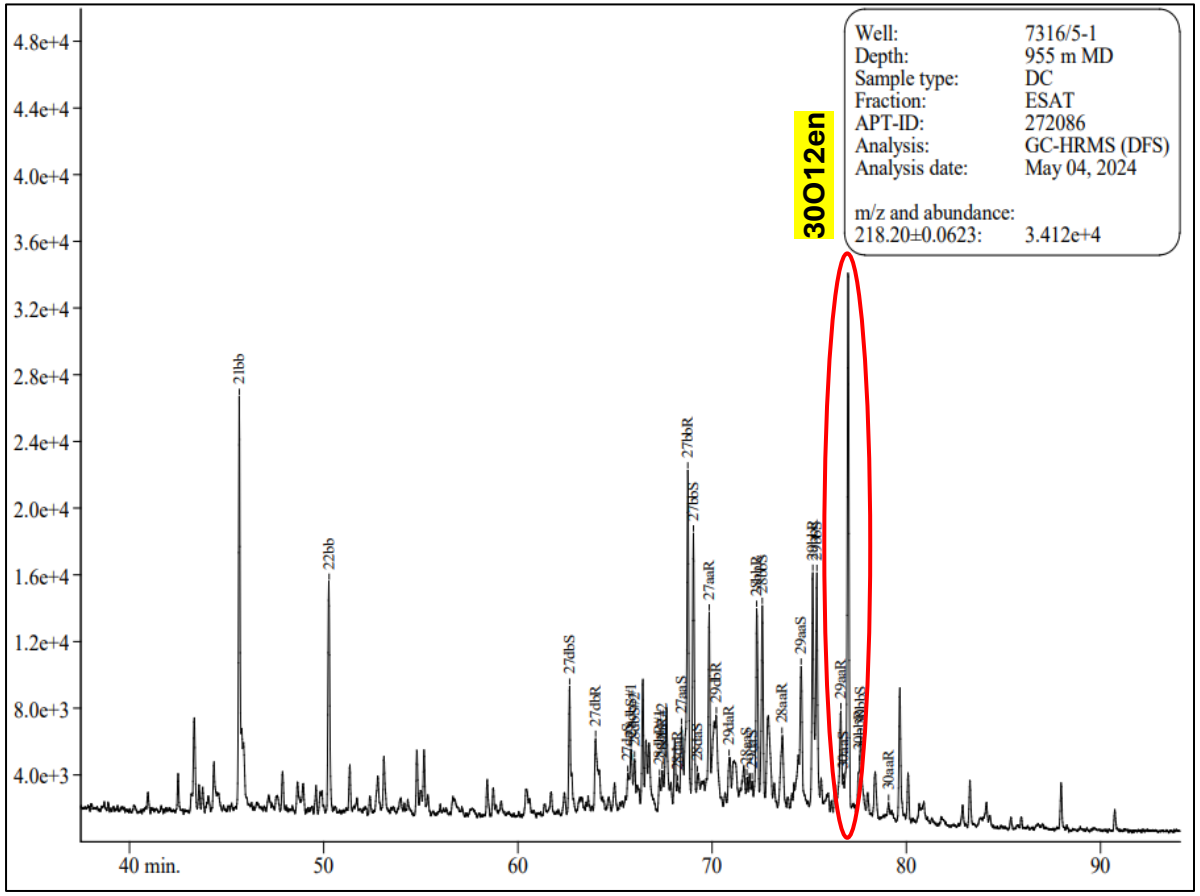


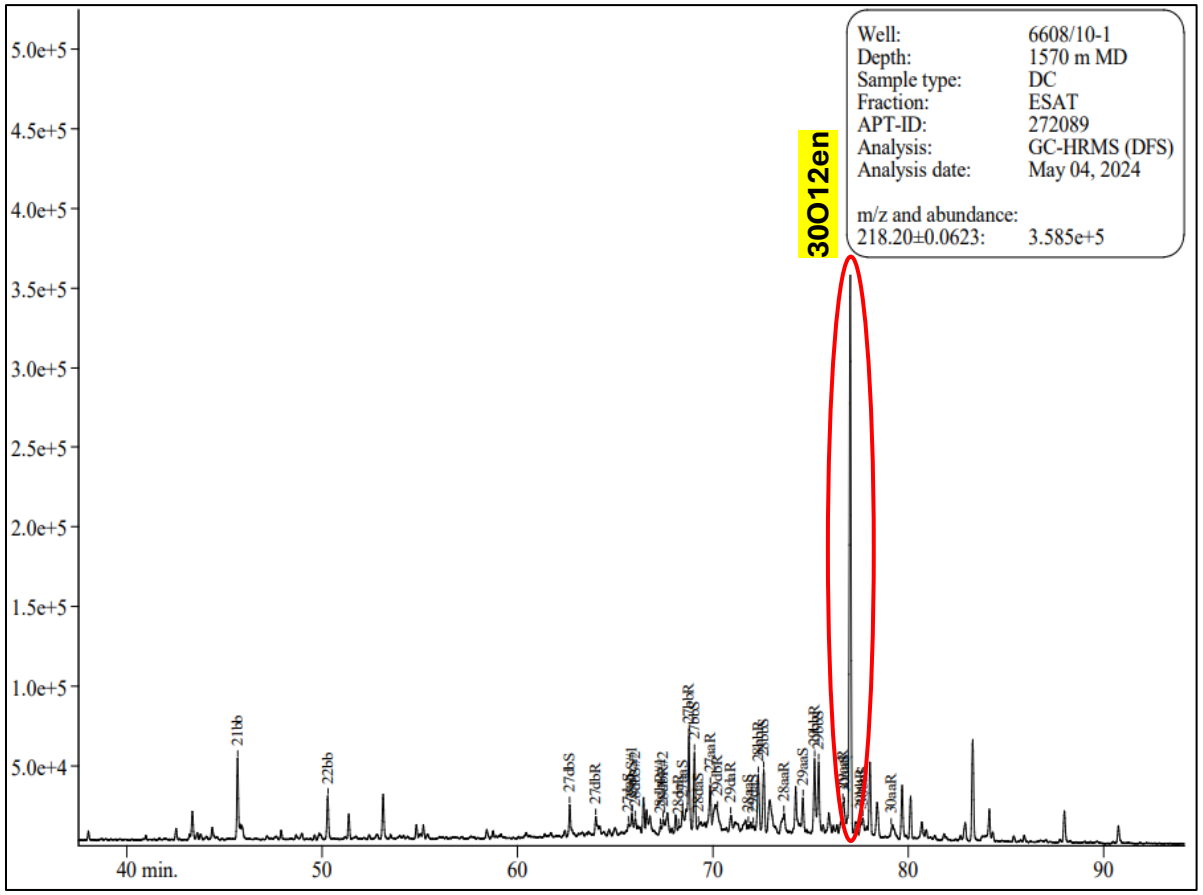
Borealis Mud Volcano

GC-MS
m/z 218

Oleanene in Lower Miocene source rock intervals

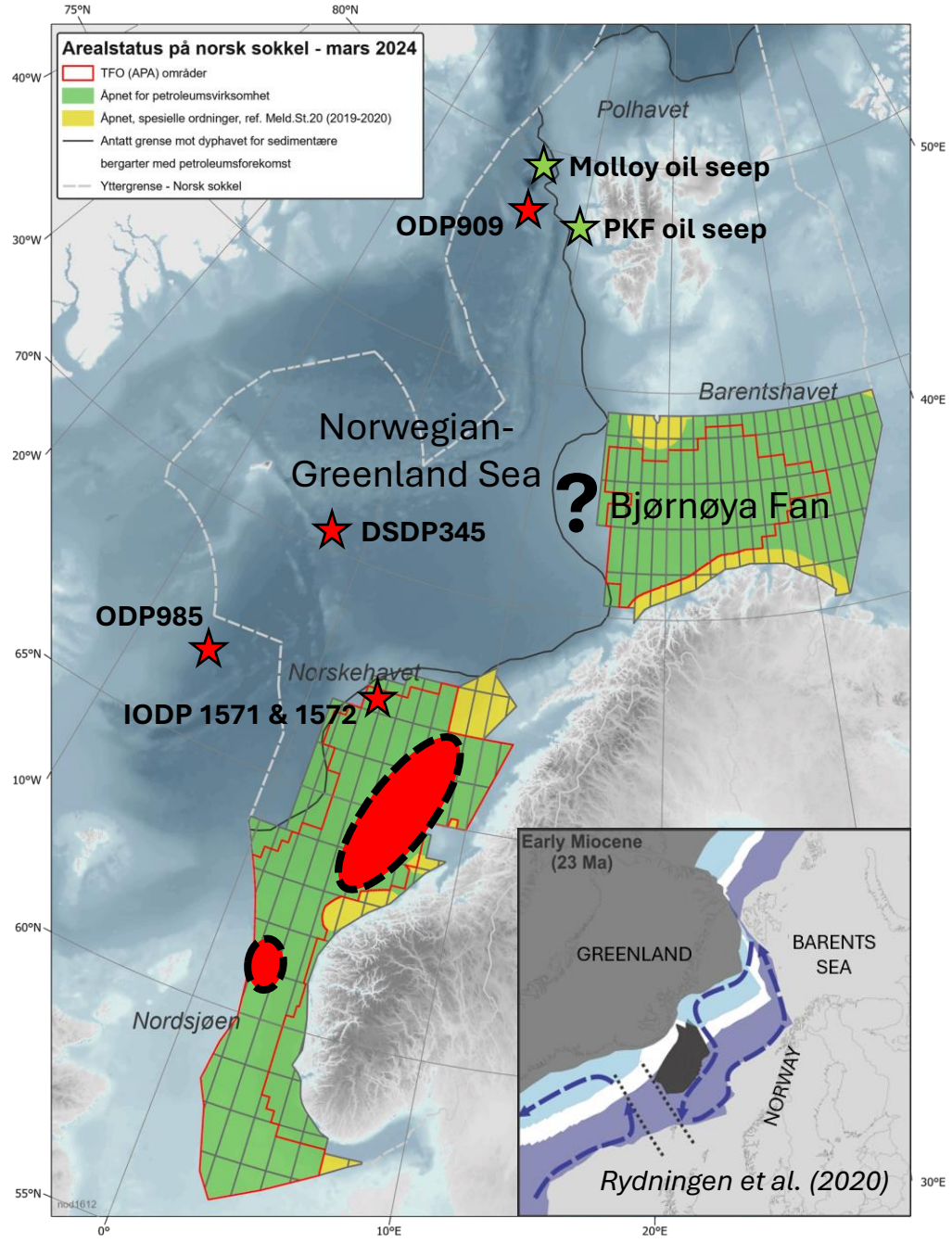






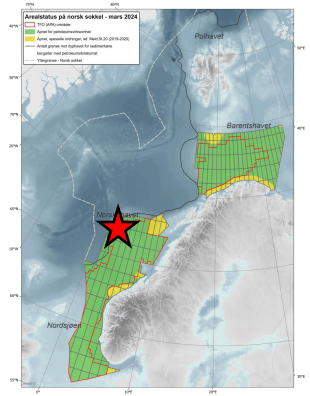
Indications for regional presence of a lower-middle Miocene source rock in the Norwegian-Greenland Sea

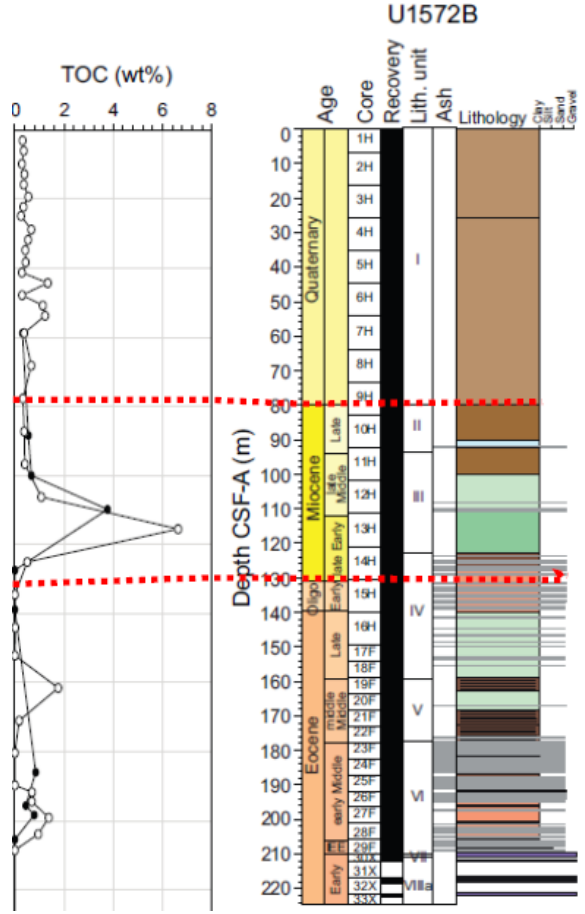
- **ODP909**: Early-Middle Miocene deltaic derived source rock (Knies & Mann, 2002). Presence of liquid hydrocarbons. (Stein et al., 1995)
- **DSDP345**: Oil migrated into unconsolidated Plio-Pleistocene sediments (Simoneit, 1976).
- **ODP985**: Dark, organic-rich terrigenous sediments from Lower Miocene, formed under anoxic conditions (Ikehara et al., 1999).
- **IODP1571&1572**: High TOC in 10-20 m thick immature Lower/Middle Miocene dark shales (PALMAR/Sverre Planke).
- **APA-area, Norwegian Sea**: Increased TOC and HI values in the upper Brygge Fm (Lower Miocene) in many wells. TOC in the range 1 to 6 %wt, and HI in the range 100 to 300 mg/g TOC. Given sufficient burial it is likely that this section will constitute an effective source rock (Screening performed for Sodir by Trond Brekke).
- **Tampen, Northern North Sea**: Screening of old wells show increased TOC values in the upper Hordaland Gp (~Lower Miocene). Land plant or mixed derived organic matter, immature, but with potential for oil and gas generation.



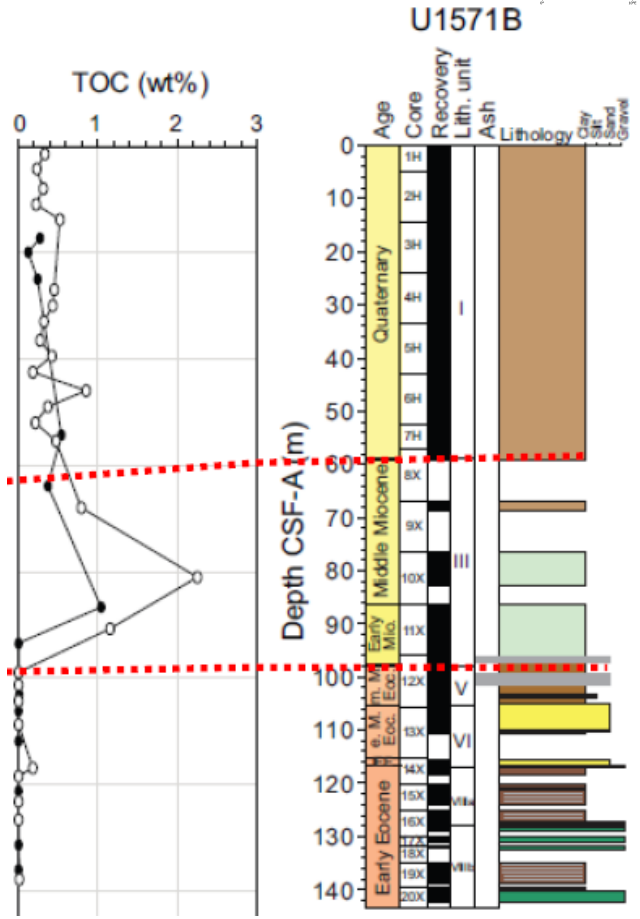
Skoll High (Vøring) IODP 1571 & 1572

- 40-50 m thick Miocene sequence based on ship-board analyses (2021).
- High TOC in Lower/Middle Miocene (10-20 m) (Upper Brygge Fm).



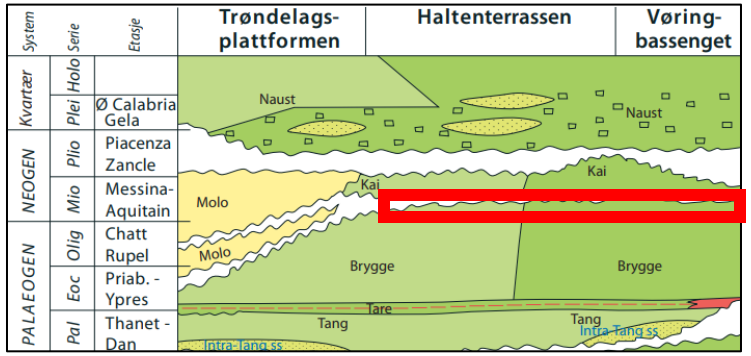


Picture: IODP 1572B

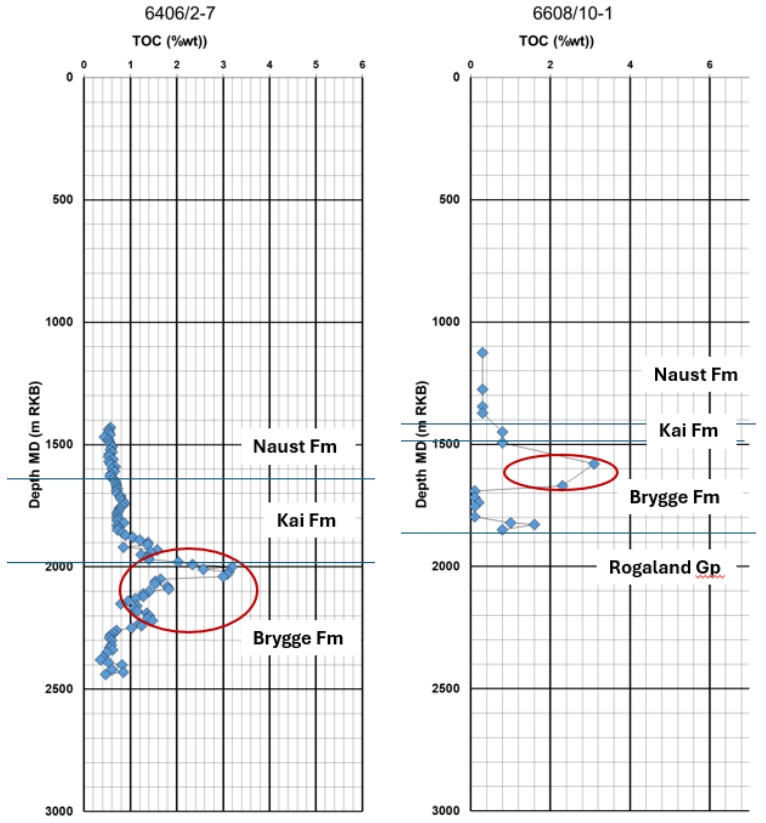


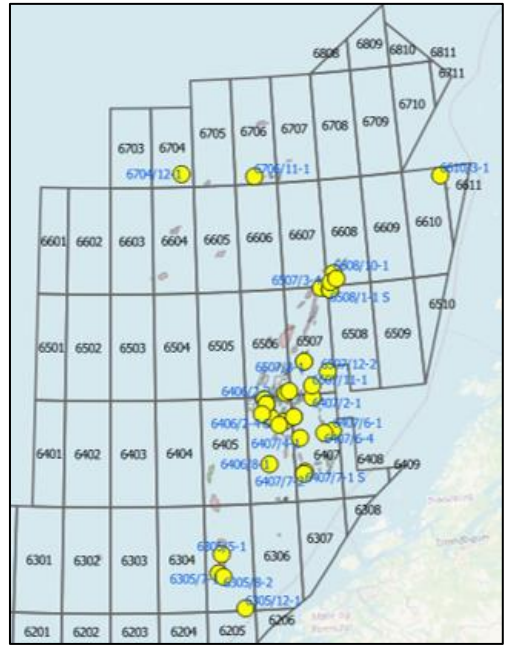
Credit: PALMAR / Sverre Planke

Regional Lower Miocene source rock in the Norwegian Sea ?



- Geochemical screening for Tertiary source rocks has identified potential source rock sequences that given sufficient burial depth likely will generate and migrate petroleum.
- The TOC and Rock-Eval data suggest that the best source is situated at top Brygge Fm level (Lower Miocene).

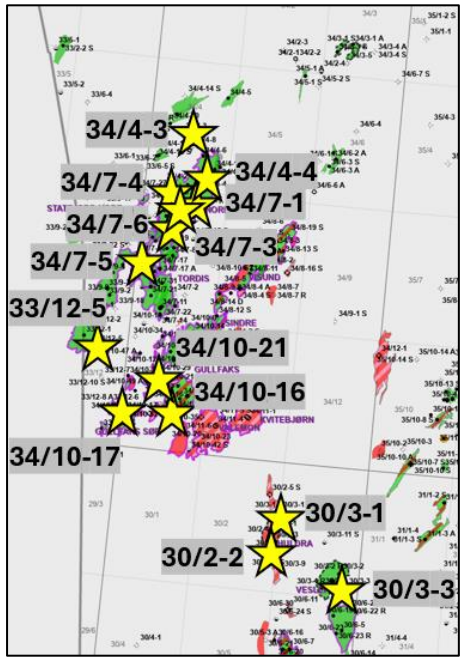


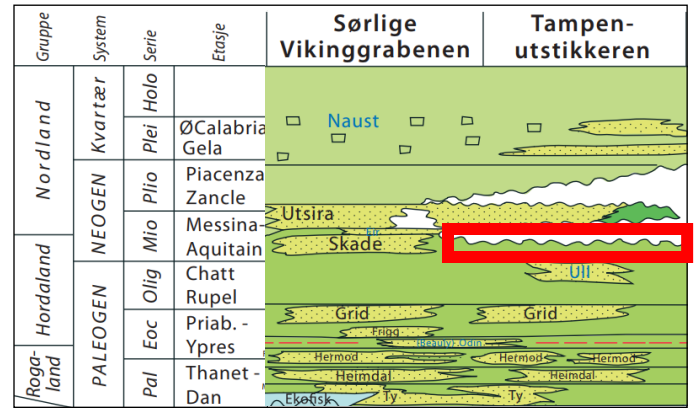


Screening of Miocene source rock for Sodir by Trond Brekke

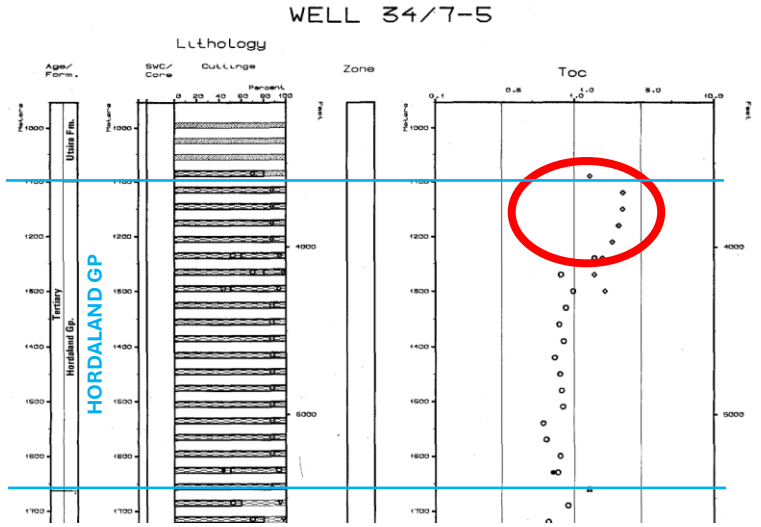
Regional Lower Miocene source rock in the North Sea (Tampen)?

- Screening of geochemical reports from old wells show increased TOC values in the upper Hordaland Gp (Lower-Miocene).
- Land plant or mixed derived organic matter, immature, but with potential for oil and gas generation.





34/7-5 (Statfjord Øst), 1985:
«(…) a light olive grey claystone of good to very good organic richness (…).»

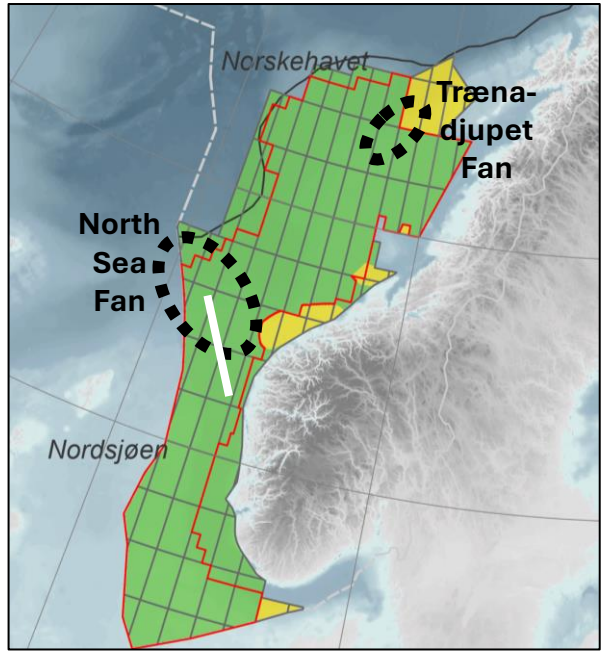


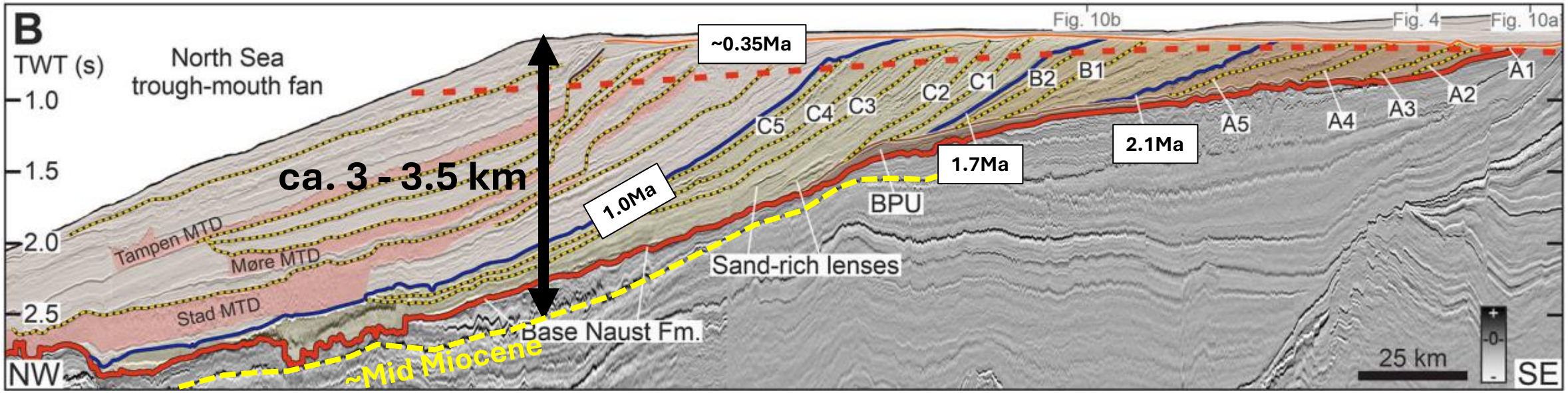
30/3-1 (Huldra), 1979:
«(…) mudstones generally good with values of 0.67-2.41% (TOC).»
«(…) contain land plant derived dominantly herbaceous and woody, with significant algal, organic matter.»
«The mudstones are a good but immature source for oil and gas.»

34/4-4 (Snorre), 1983:
«(…) potential source richness (…) rated as (…) good.»
«The mudstones (…) at 1.31-2.19% organic carbon.»
«They are however immature and no hydrocarbon generation has occured.»

Where else can the Lower-Middle Miocene source rock be mature ?

- The North Sea Fan
- The Trænadjupet Fan





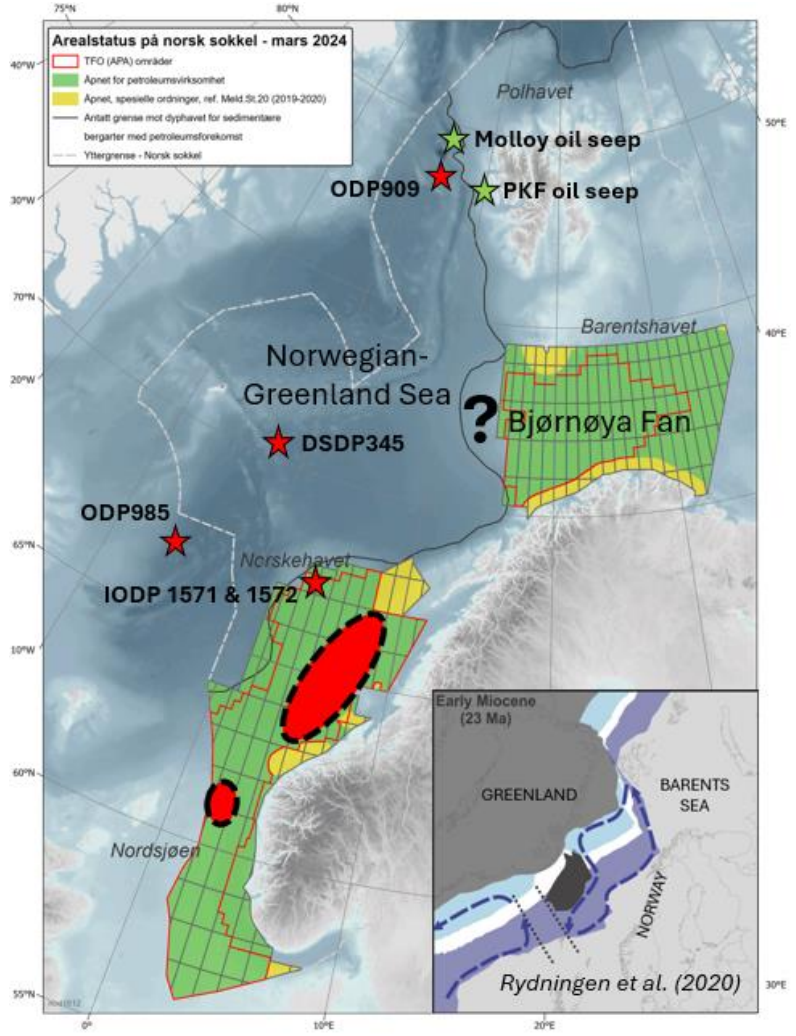
Løseth et al. (2022)

Summary

Hydrocarbon seeps and a new young source rock

- A working petroleum system with Lower-Middle Miocene source rock west of Svalbard proven.
- Anoxic conditions, deltaic derived source rock - Niger Delta analog oil.
- The source rock can be regionally present in the whole Norwegian-Greenland Sea area.
- Can be mature under thick Quaternary fans.

- Suggestion: Joint Industry Project via FORCE to look more into this?



SOKKELDIREKTORATET

Thank you for the attention

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