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THE ARCTIC UNIVERSITY OF NORWAY

Interaction of submarine tailings with natural sediments in Ranfjorden and Bøkfjorden.

Sedimentary processes, geochemistry and dispersion patterns.

Content

- The project
- Study areas
- Materials & methods
- Results
- Conclusion

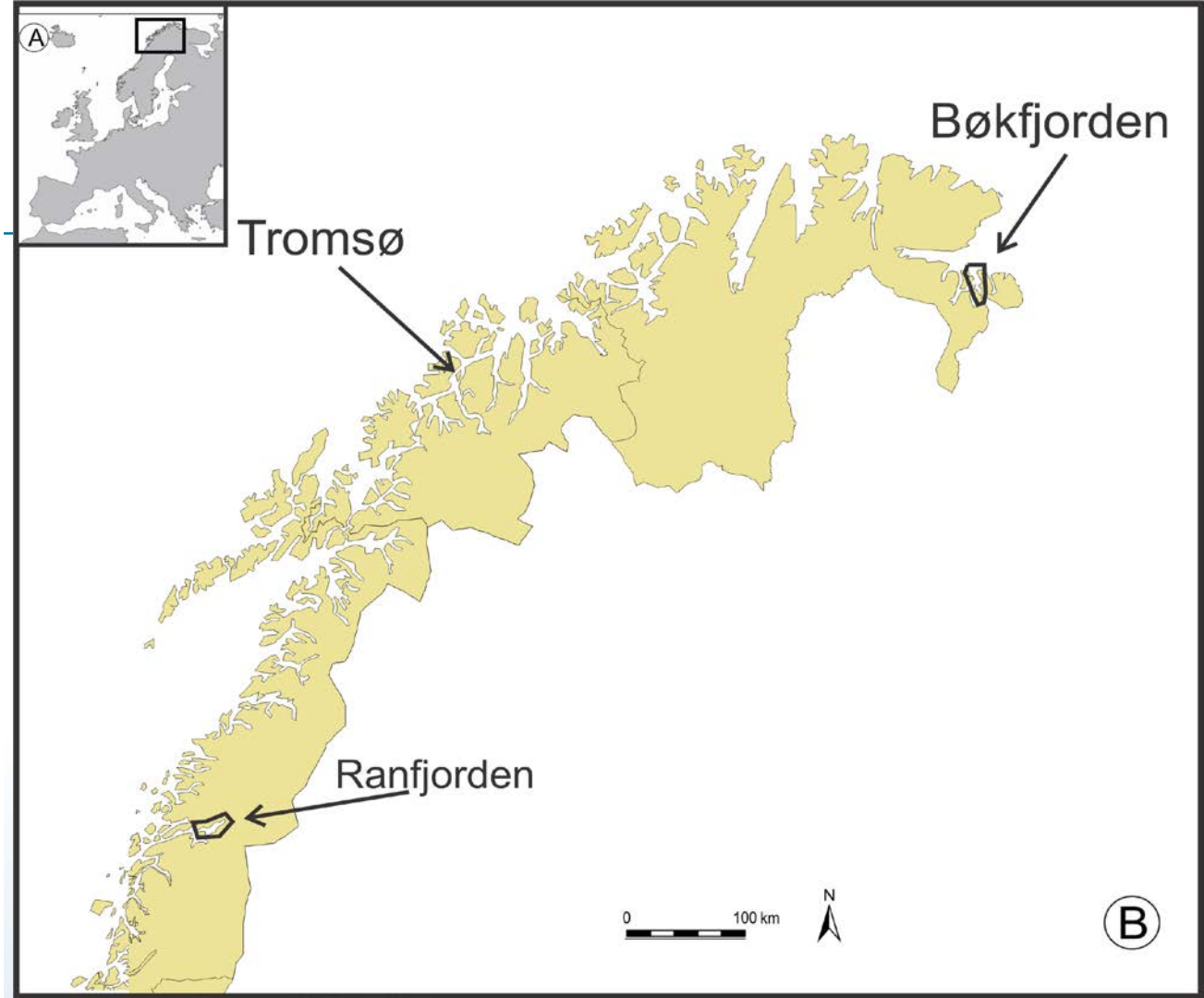
The project

- Part of NYKOS WP3
  - study of three comparable fjords
- Three theses:
  - Nikolai Figenschau (me)
    - Bøkfjorden, Stjernsundet & Ranfjorden
  - Anders Haugen
    - Randfjorden
  - Anette Klev
    - Bøkfjorden
- Main supervisor
  - Matthias Forwick (UiT)
- Co-supervisors:
  - Juho Junttila (UiT)
  - Aivo Lepland (NGU)
  - Nicole Baeten (NGU)

- Objective:
  - Study the impact of Submarine Tailings Placement (STP)
    - Interaction of tailings and natural sediments
    - Sedimentary processes
    - Dispersion patterns

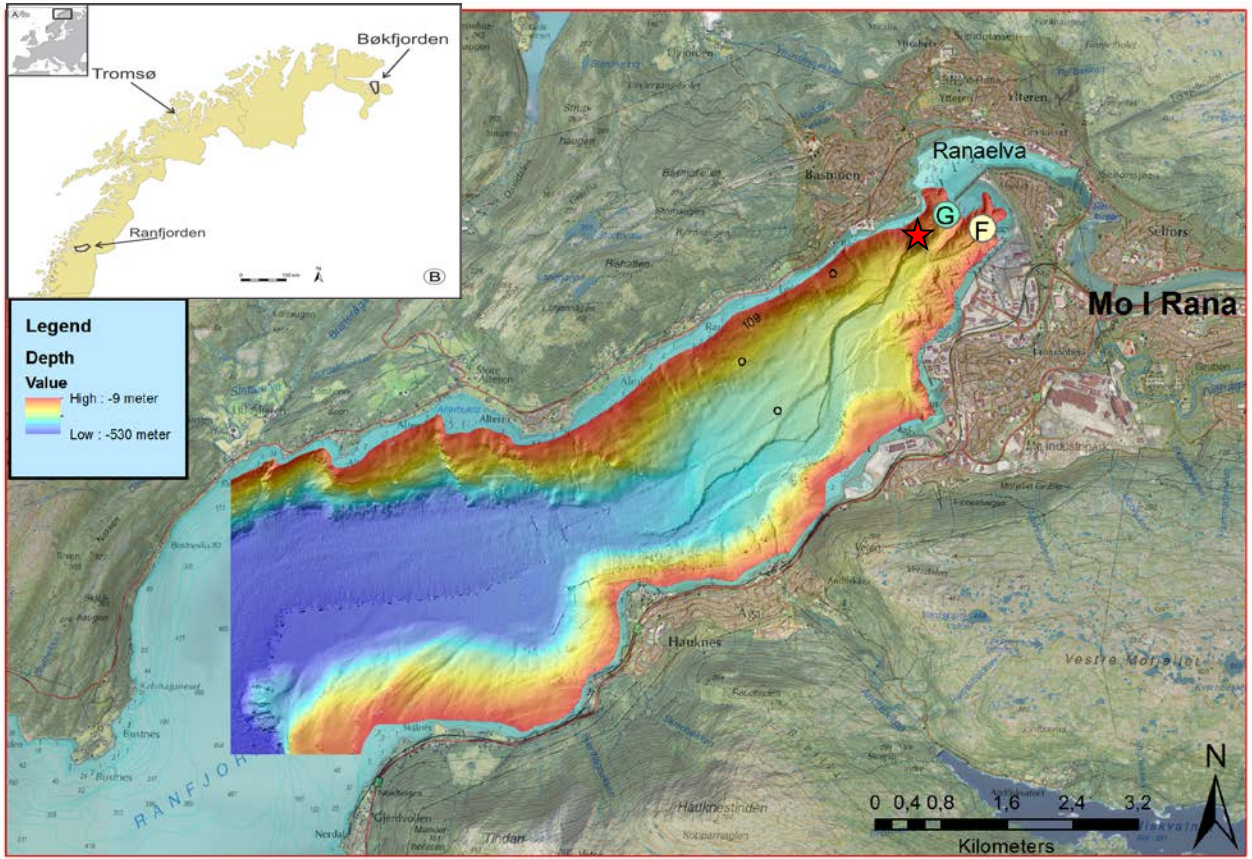
Study areas

- Two fjords – Bøkfjorden and Ranfjorden
- All associated with STP from local mining activity
  - Sydvaranger Gruve (iron) in Bøkfjorden
    - Bonded iron formation (BIF)
    - Magnetite
  - Rana Gruber (iron) in Ranfjorden
    - High Fe-grade metamorphosed sedimentary rocks
    - Hematite
    - Magnetite

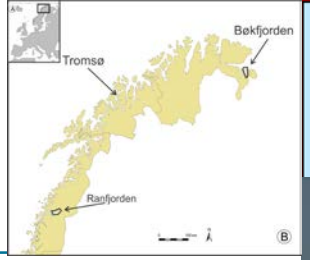


Ranfjorden

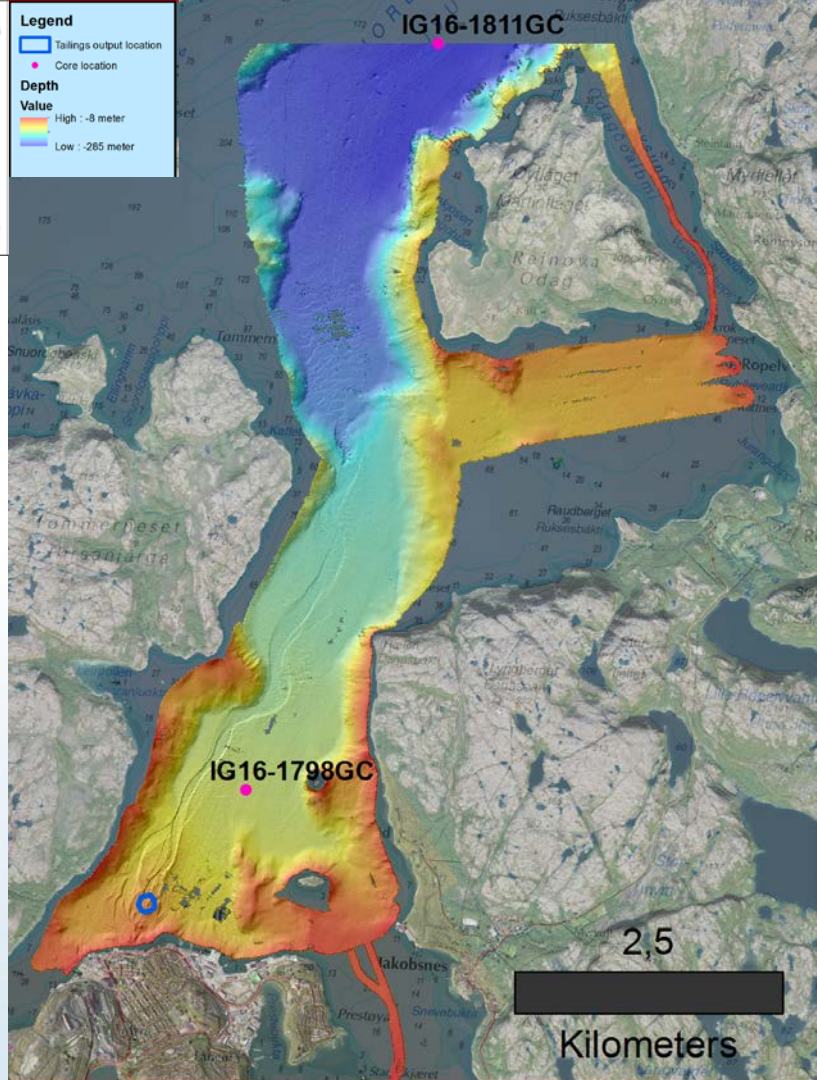
- 26 km long, 530 m deep
- Recipient of tailings since since late 1800
  - Fe, Cu, Pb and Zn
  - Coking plant and iron works
  - Still active (Fe)
- 1965 - 2014
  - Two discharge sites
    - Coarse-grained = G
    - Fine-grained = F
- 2014 – present
  - One discharge site (star)
    - Combined particles
- Ranelva plays a key factor
  - High input of freshwater
  - High input of sediments
- Relatively steep slopes
  - 6° inclination
- Flat, deep basin



Bøkfjorden

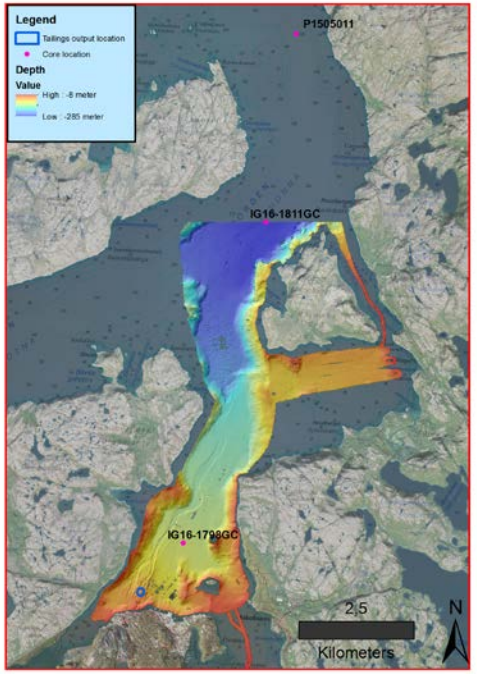


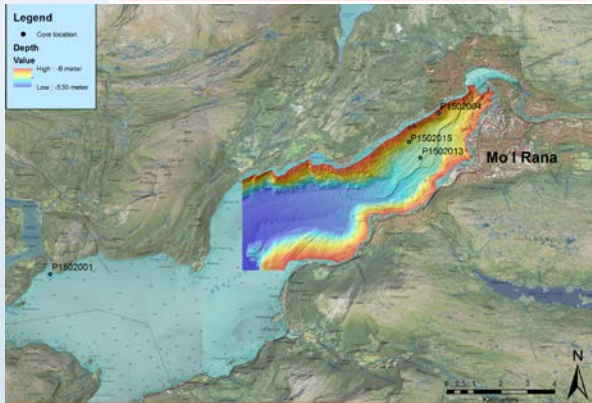
- 17 km long, 285 m deep
- Mining activity since 1906
  - Recipient of tailings since 1971
    - Halt in production since 1997 – 2009
    - Mine closure in 2015
    - Inactive since
- One discharge site (blue dot)
- Pasvik elva important for water circulation
- Flat, shallow inner basin
- Flat, deep outer basin

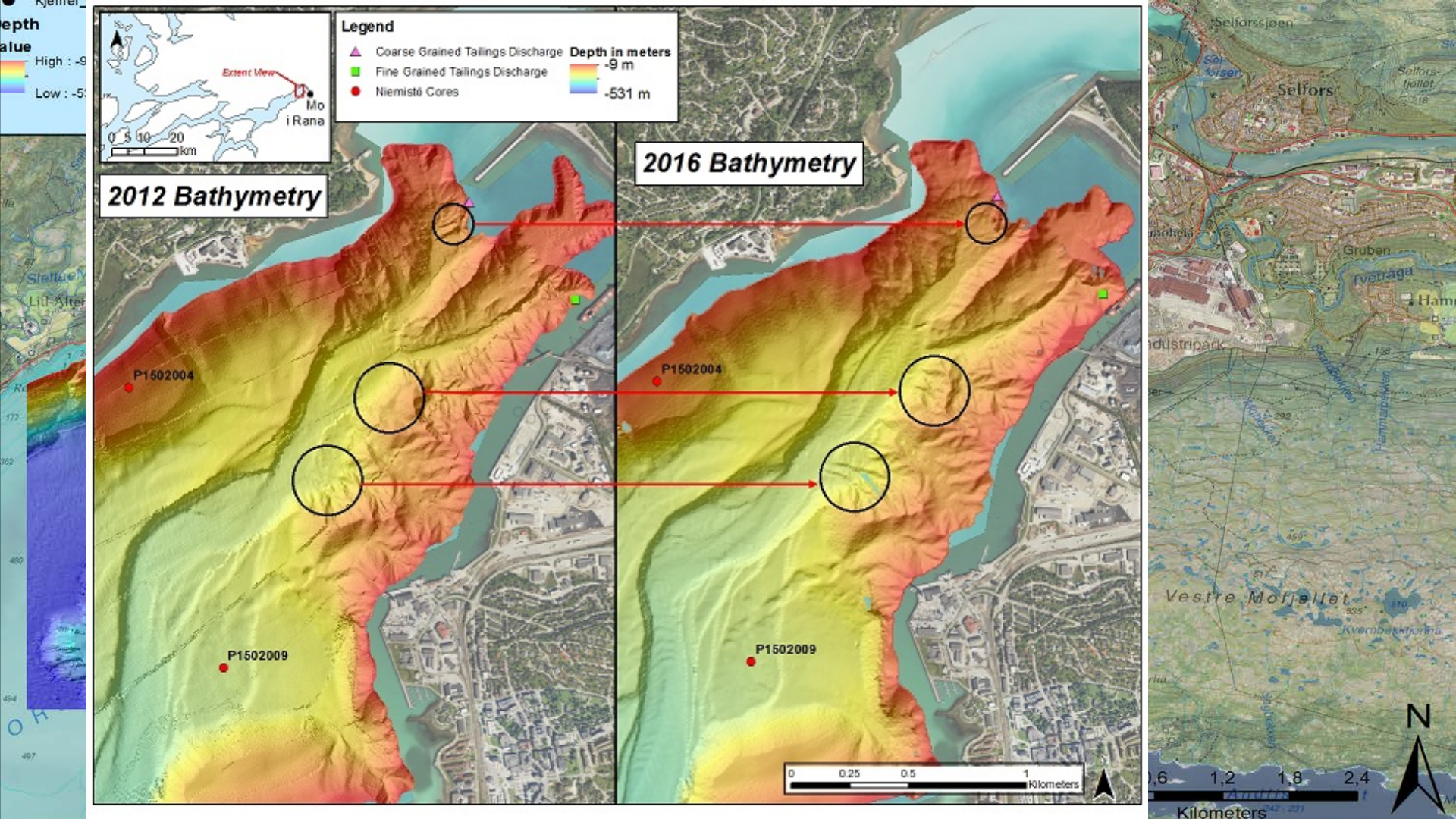


Material and methods

- Data base:
  - 61 sediment cores
  - SWATH Bathymetry & TOPAS Seismic
- Multi-proxy analyses of 10 cores
  - Physical analysis
    - Grainsize distribution analysis
    - Magnetic susceptibility analysis
    - X-radiography
  - Geochemical analysis
    - Qualitative & quantitative X-ray fluorescence analysis
      - XRF core scanner and XRF spectrometry
  - Bulk mineral assemblage (NGU)

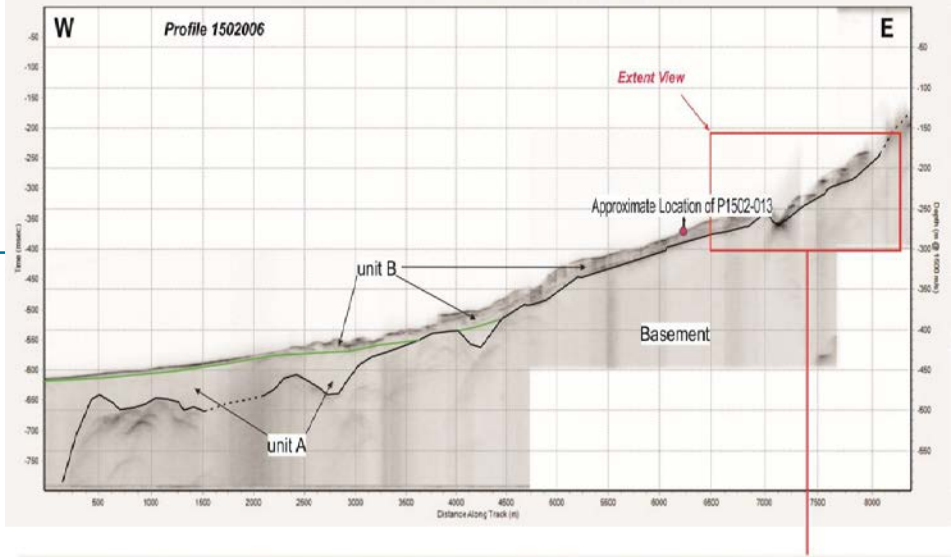


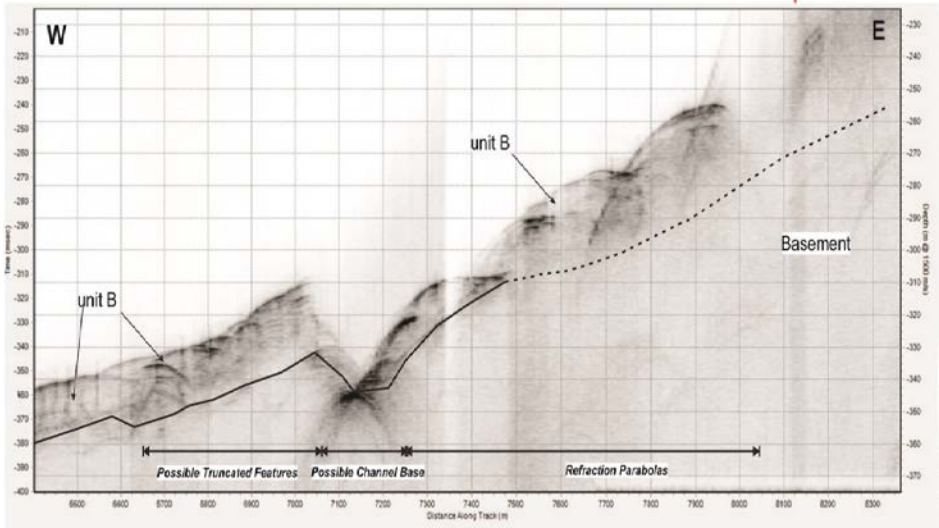



Legend
Coarse Grained Tailings Discharge
Fine Grained Tailings Discharge
Niemistö Cores
Depth in meters
-9 m
-531 m
Extent View
Mo i Rana
0 5 10 20 km
2012 Bathymetry
2016 Bathymetry
P1502004
P1502009
P1502004
P1502009
0 0.25 0.5 1 Kilometers
N
Selfors
Gruben
Vestre Moffjellet
0,6 1,2 1,8 2,4
Kilometers

TOPAS Seismic

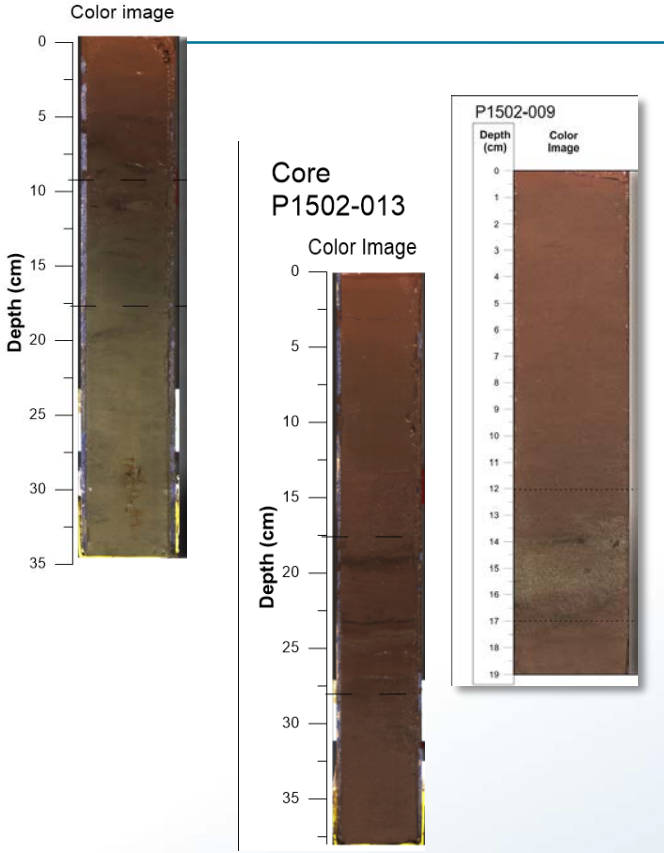
- Two distinct units
  - We focus on Unit B
    - – Acoustic laminated
    - Truncated
      - Out-fjord movement
      - Hemipelagic sedimentation and turbidity currents
    - Chaotic and blocky features in the east
      - Mass movements
        - » Debris flow lobes
    - Submarine channel bed
      - Erosive
      - Accumulation

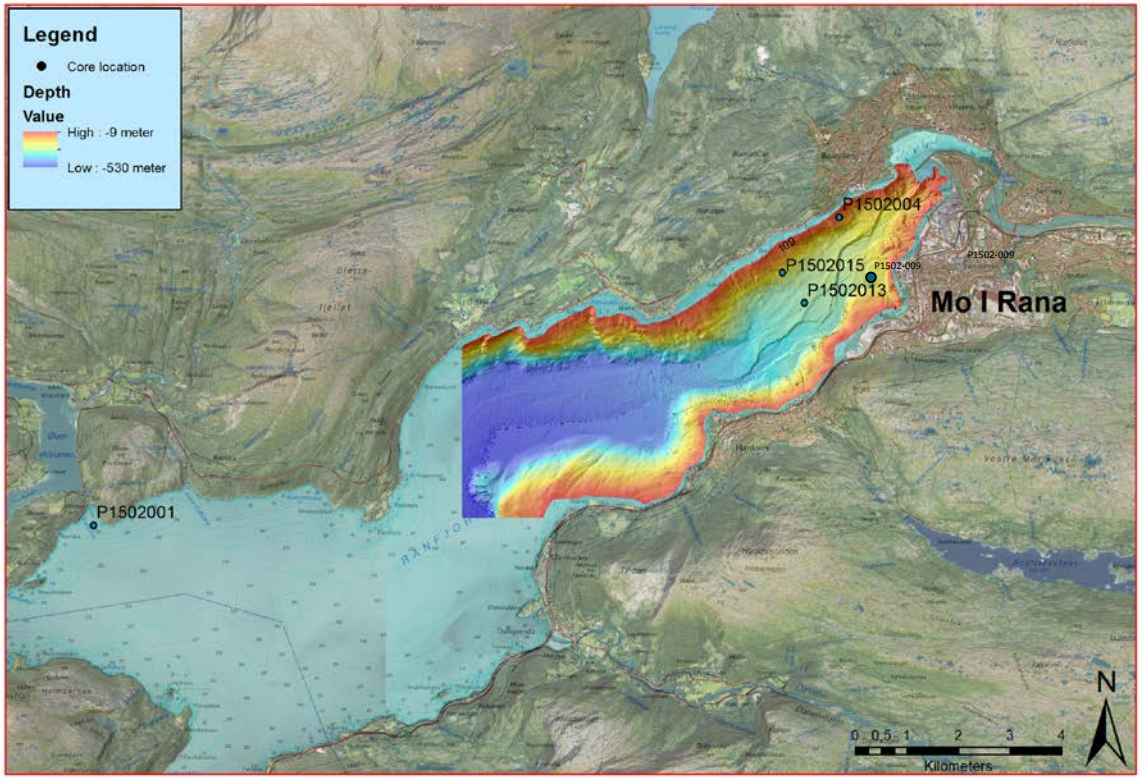




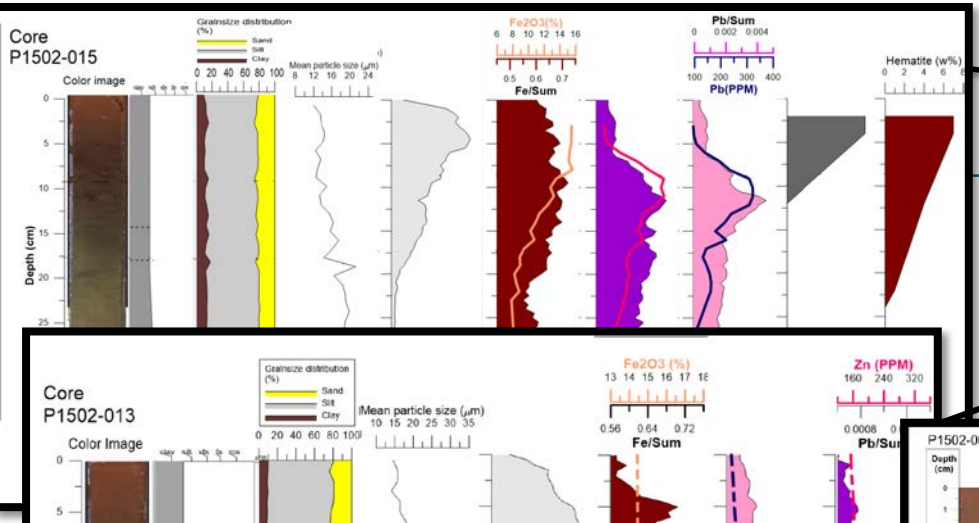
Sediment cores - Ranfjorden

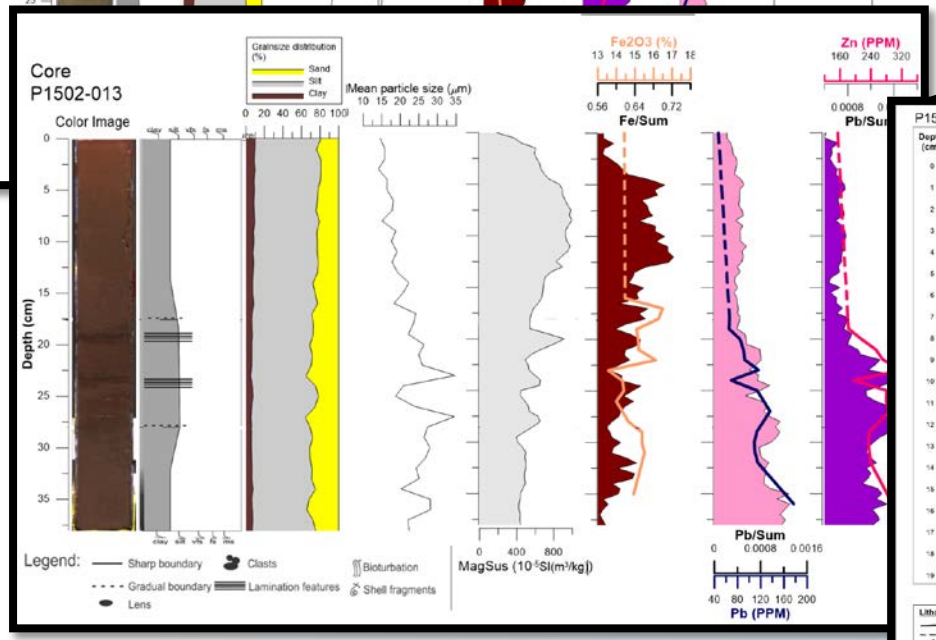
Core
P1502-015

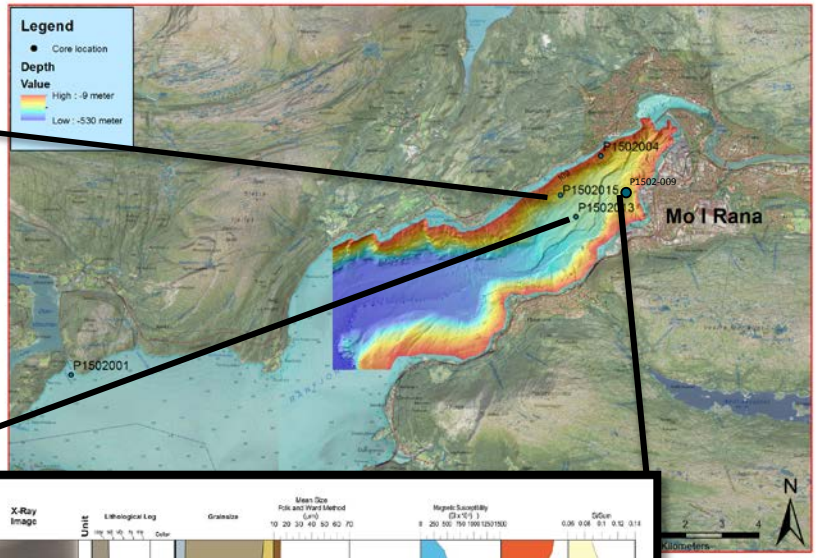


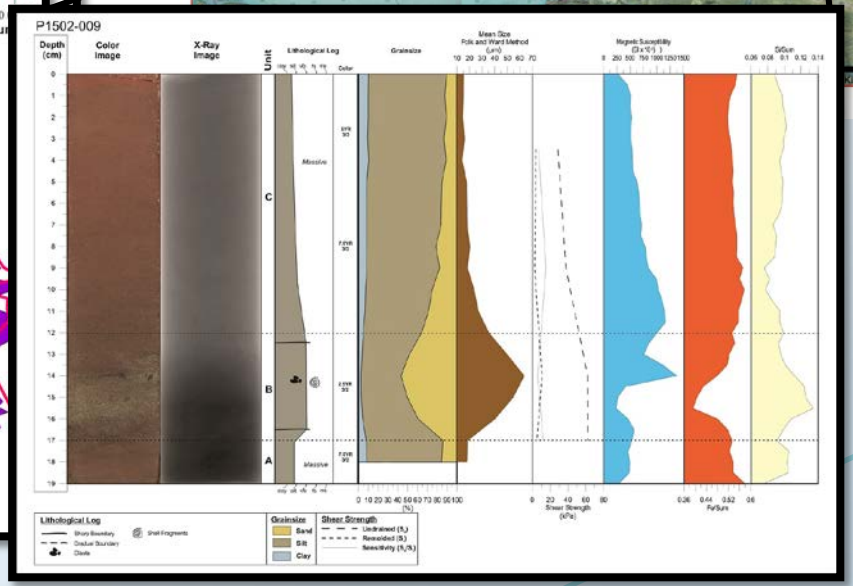


Sediment cores - Ranfjorden



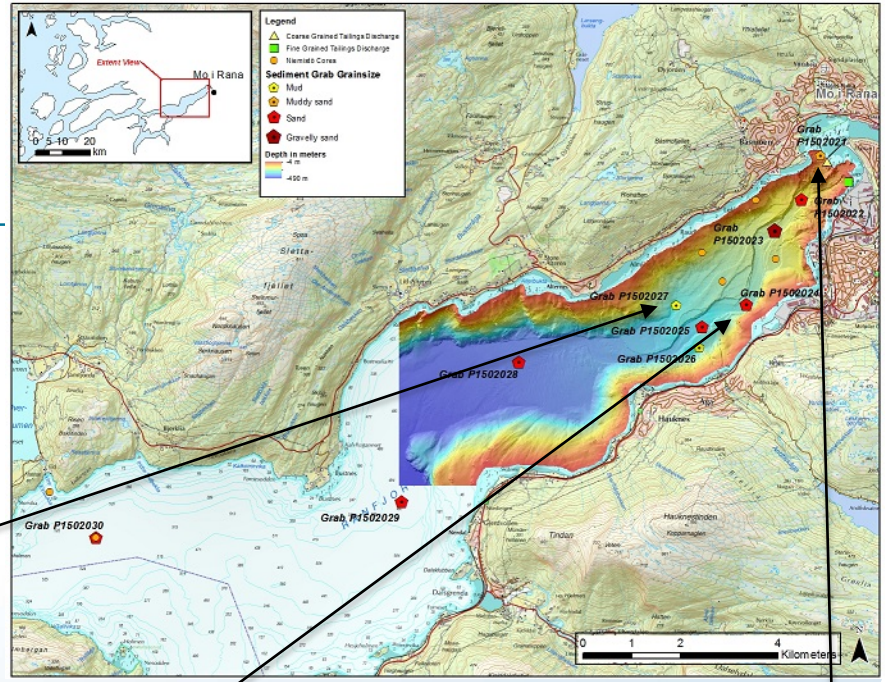






Sediment Grabs
(Haugen, 2018)

- Varying sediment-content
  - Outside vs inside the channel

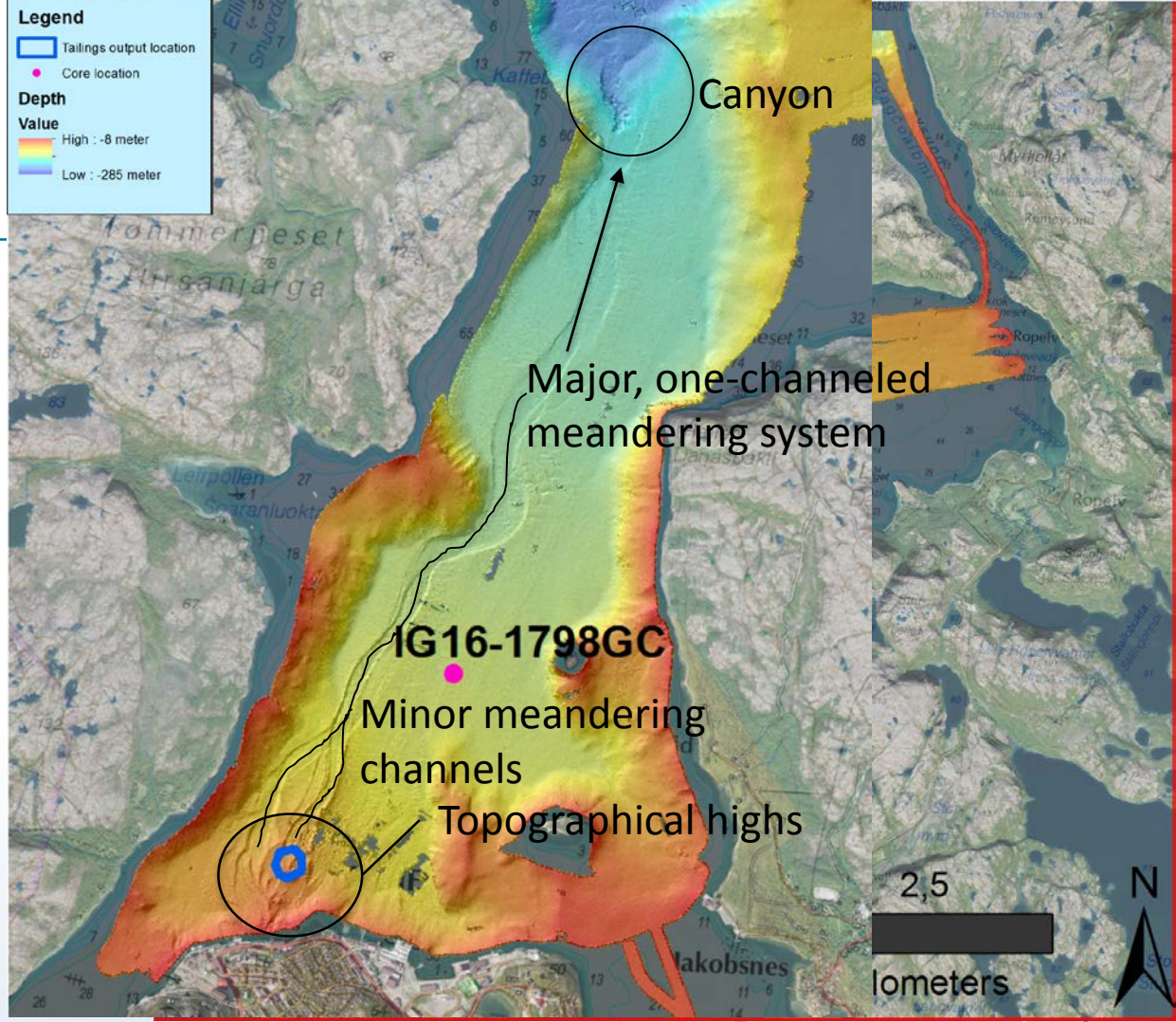


P1502-027

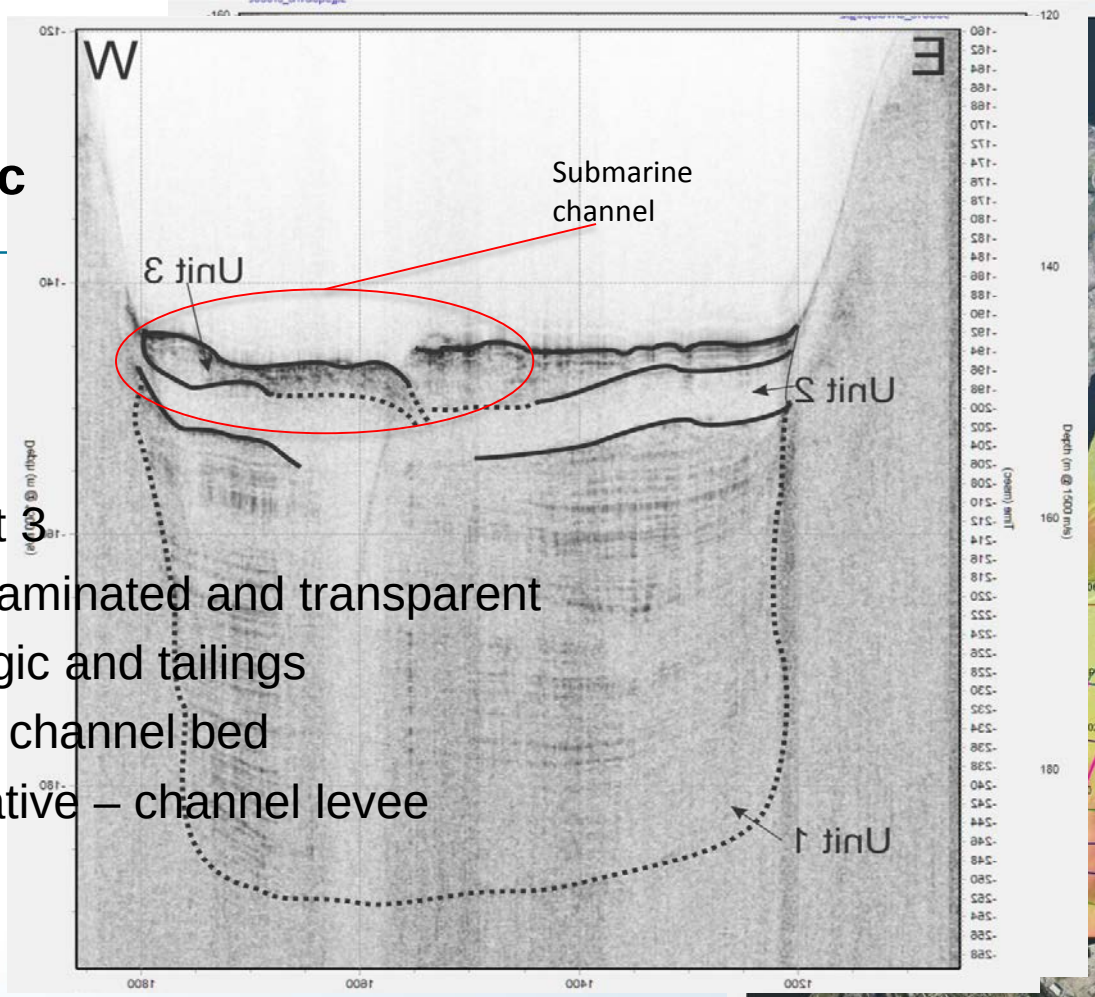

P1502-024

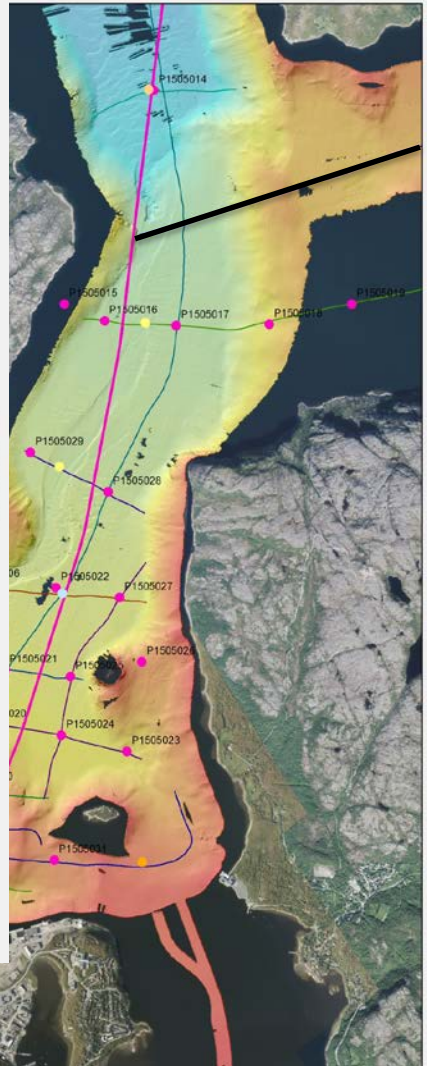

P1502-021

Bathymetry, Bøkfjorden



Topas Seismic



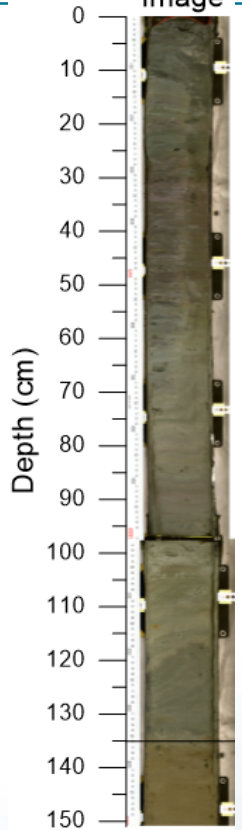


- Focus on Unit 3
  - acoustic laminated and transparent
  - hemipelagic and tailings
  - Erosive – channel bed
  - Accumulative – channel levee

Results - Bøkfjorden

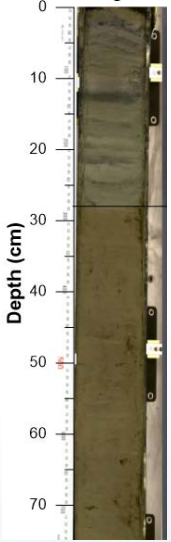
Core
IG16-179

Color
Image



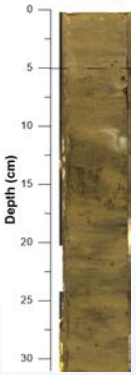
Core
IG16-181

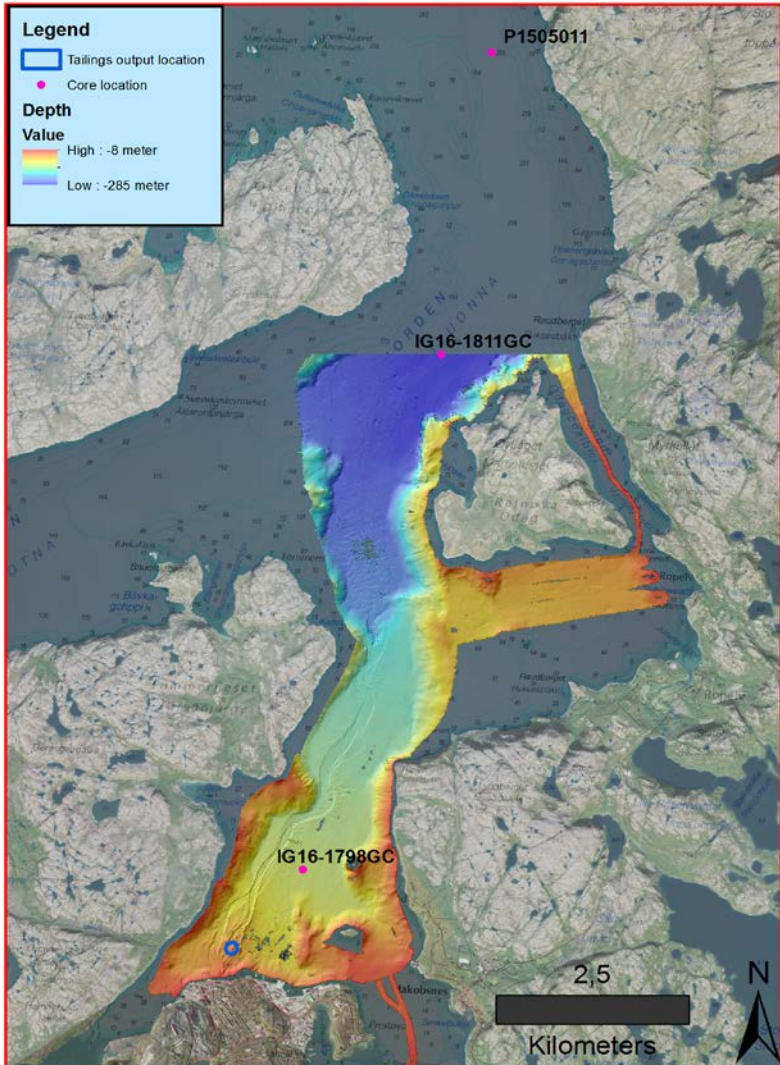
Color
Image



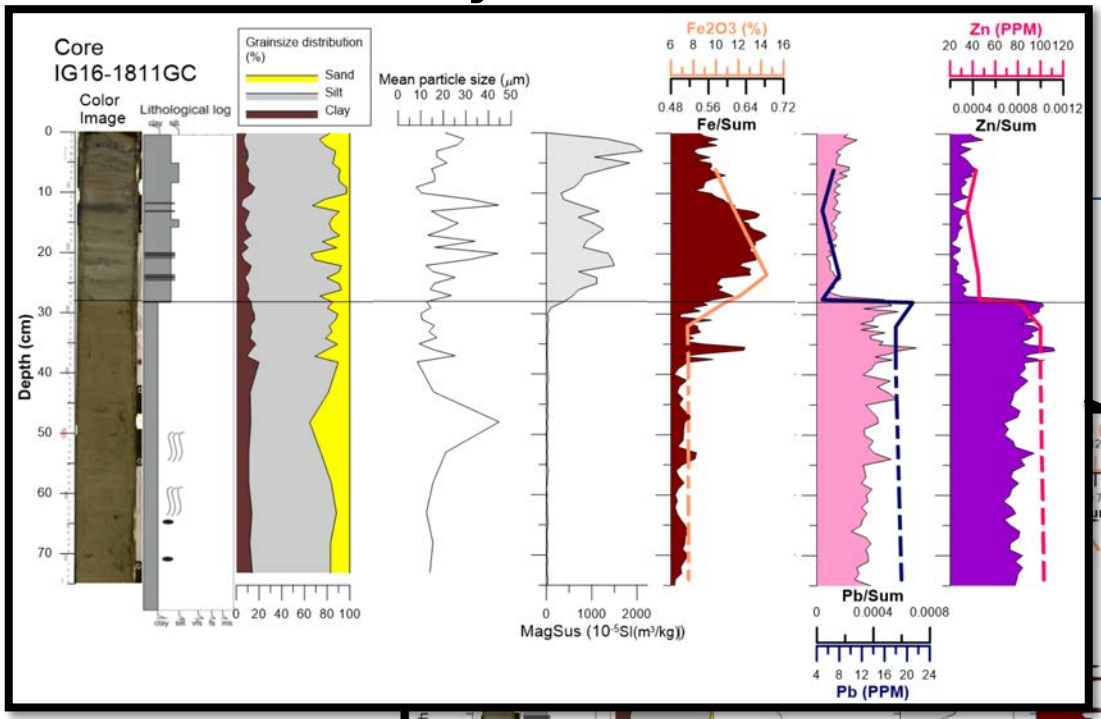
Core
P1505-011

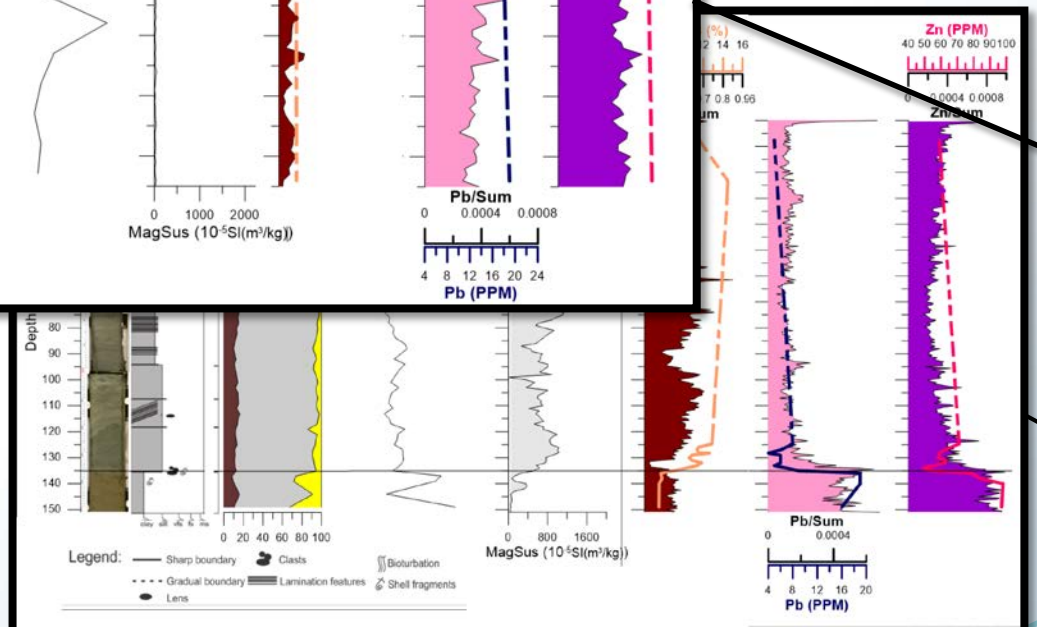
Color Image

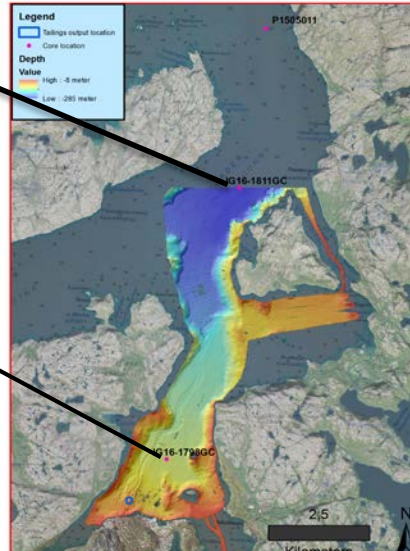




Results - Bøkfjorden

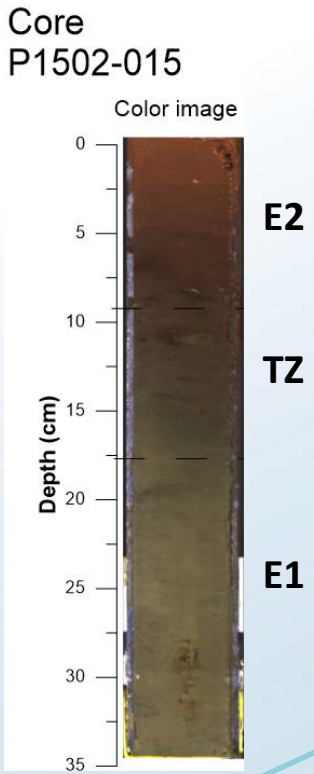


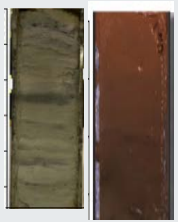




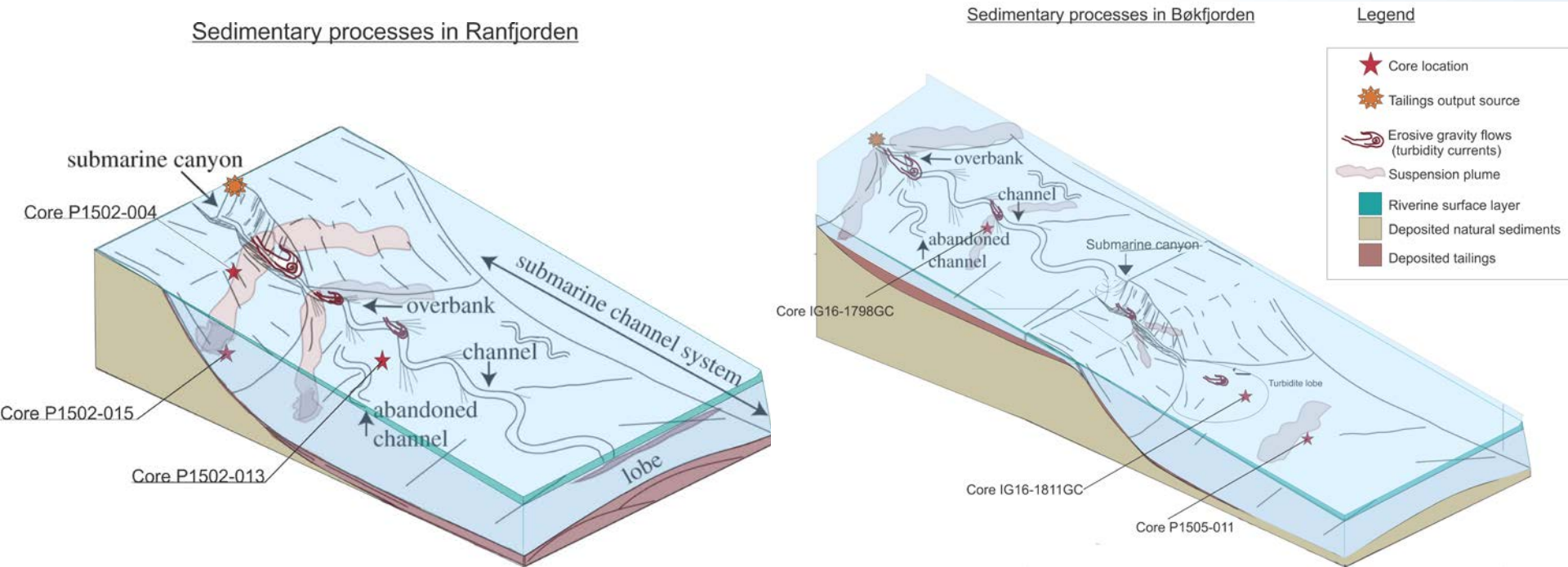
Three depositional environments

- Endmember 1 – Natural deposition (E1)
- Endmember 2 – Tailings deposition (E2)
- Transitional zone (TZ)



	Bøkfjorden	Ranfjorden
Endmember 1 	-Yellow-greyish -Massive -Fluctuating grainsize -Low magnetic susceptibility -Stable element ratios -Low Fe_2O_3 & SiO_2	-Yellow-greyish -Massive -Relatively coarse-grained sediments -Low magnetic susceptibility -Low tailings-content (Low Fe_2O_3) -Elevated Pb and Zn-levels
Endmember 2 	-Alternating grey and dark, stratified/laminated sediment -Fine-grained -High, fluctuating magnetic susceptibility -Fluctuating element ratios -Very high SiO_2 -High Fe_2O_3	-Red colored -Mostly massive (also laminated) -Fine- and coarse-grained -High magnetic susceptibility -High tailings-content (High Fe_2O_3) (Lowered Pb and Zn)
Transitional zone 	No distinct transitional zones	-Dark grey to red color -Gradually decreasing grainsize -Increasing magnetic susceptibility -Increasing tailings content (Fe_2O_3, Pb and Zn)

Comparison between the fjords



Conclusions

- Transport mainly by bedload currents
  - Both continuous and episodic deposition
    - Settling of sediment plumes
    - Mass movement – turbidity currents
      - Triggered by high sed. rate
      - Slope failure
  - Mainly out-fjord, also lateral
  - Sharp contacts
    - Little to no physical mixing (capping effect)
  - Gradual transition
    - Physical mixing
    - Isolation (capping effect)

Summary

- Study of two STPs in northern Norway
- Two endmembers
  - Tailings
  - Natural sediments
  - Varying degree of transition
    - Abrupt vs Transitional
- Meandering channel controlled
  - Slope and topography
  - Coarse-grained sediments confined in channel
  - Fine-grained sediments outside channel
    - Either by spill-over events or sediment plumes