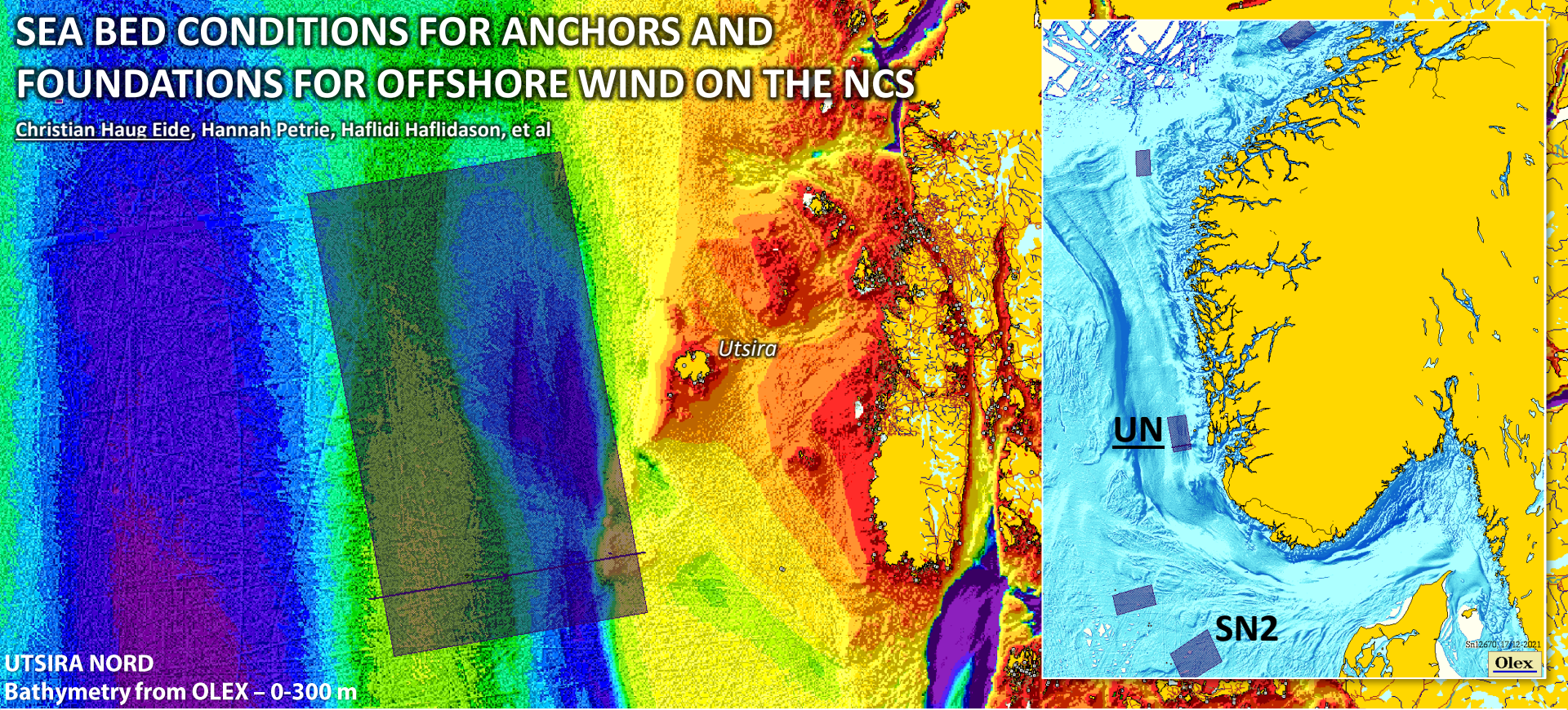
SEA BED CONDITIONS FOR ANCHORS AND FOUNDATIONS FOR OFFSHORE WIND ON THE NCS

Christian Haug Eide, Hannah Petrie, Haflidi Haflidason, et al



UTSIRA NORD
Bathymetry from OLEX – 0-300 m

@CH_Eide
UNIVERSITETET I BERGEN

AKADEMIA-AGREEMENT

equinor

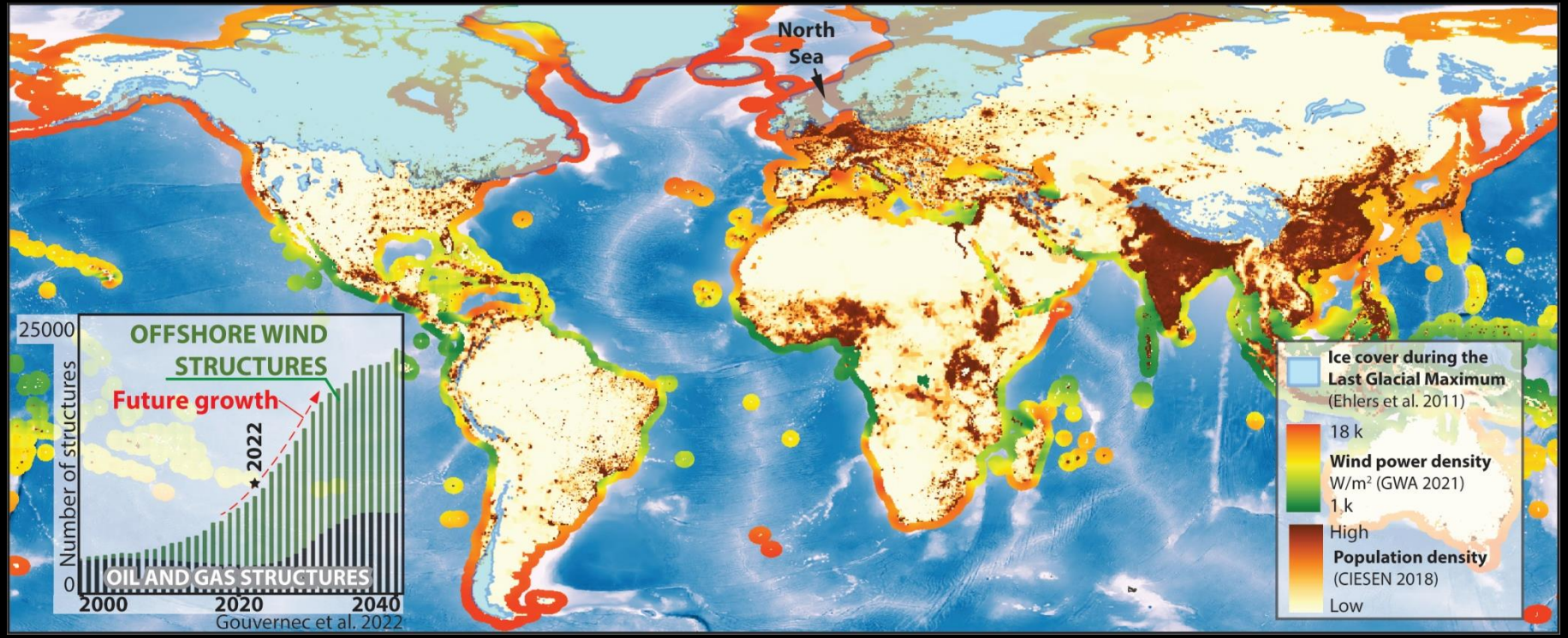
&

4SWIND

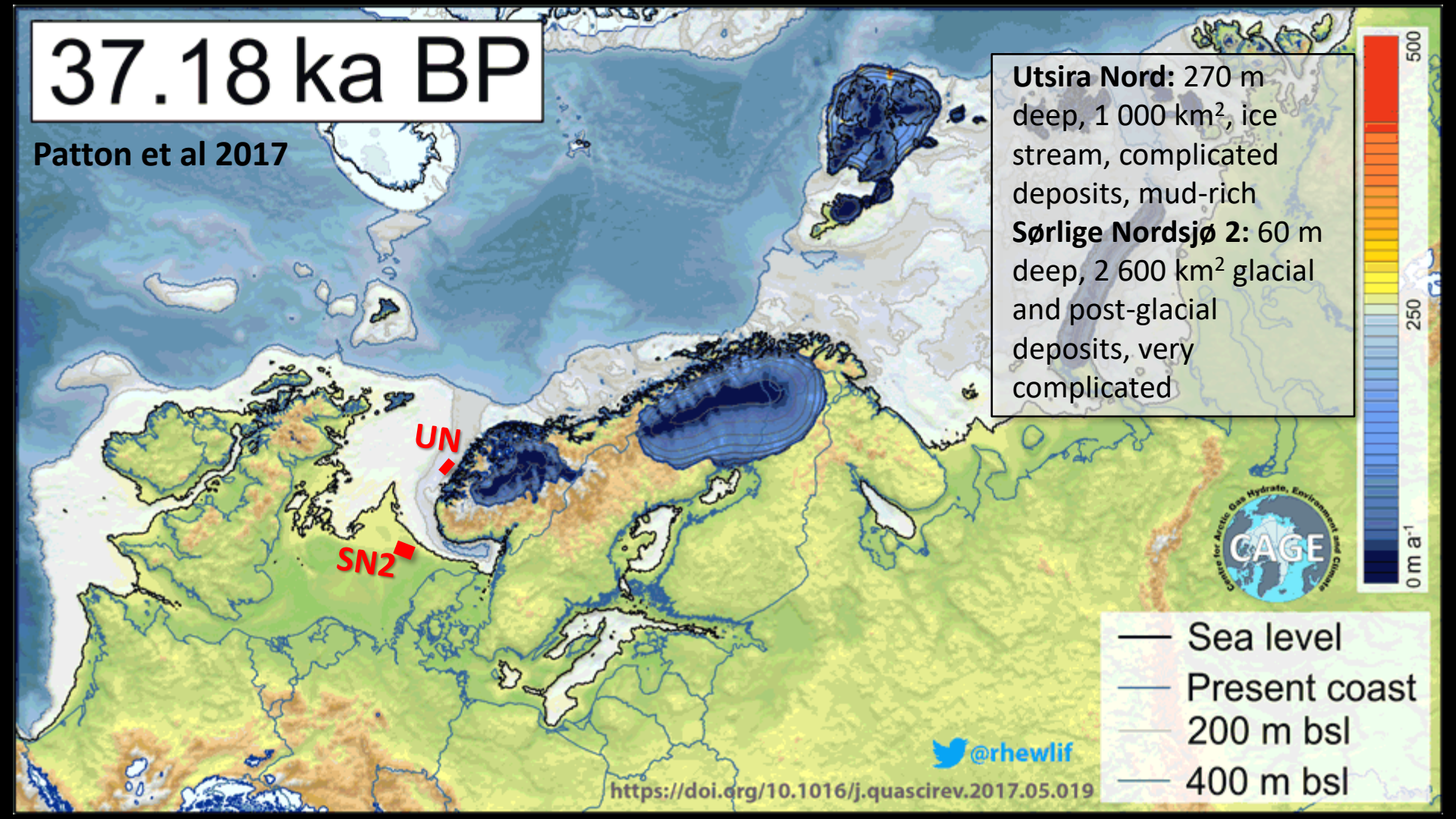
A 2022 KPN APPLICATION TO THE RCN

OPPORTUNITY

World wind resources, population and glaciated areas during last glacial maximum



- Offshore wind set to become a major **growth industry** (to meet **energy demand** & **reduce fossil fuel** dependency)
- **Large number of structures** per unit energy, **foundations** contribute significantly (10-25%) to **cost of wind farms**
- Require detailed **understanding of the soil and rock** exposed at and below the seabed
- **Complex formerly glaciated areas** present **challenges** for cost-efficient anchor & foundation design (and installation)


37.18 ka BP
Patton et al 2017
Utsira Nord: 270 m deep, 1 000 km², ice stream, complicated deposits, mud-rich
Sørlige Nordsjø 2: 60 m deep, 2 600 km² glacial and post-glacial deposits, very complicated
UN
SN2
500
250
0 m a⁻¹
CAGE
Sea level
Present coast
200 m bsl
400 m bsl
@rhewlif
https://doi.org/10.1016/j.quascirev.2017.05.019

Glaciers may erode or overconsollidate underlying sediments, or deposit new extremely heterogeneous deposits

Glacial till (‘boulder-clay’)

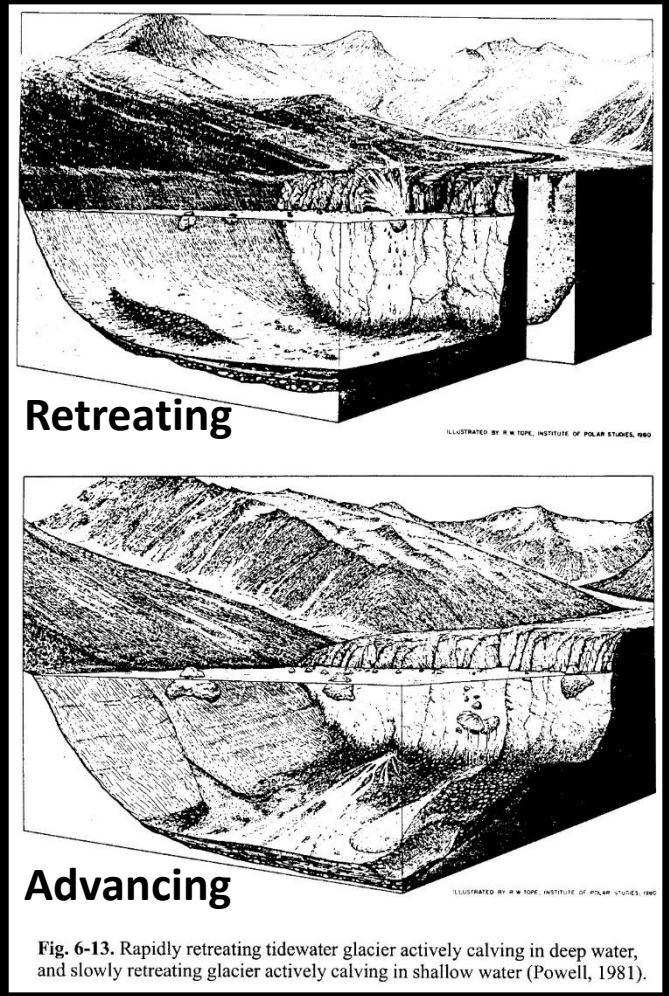
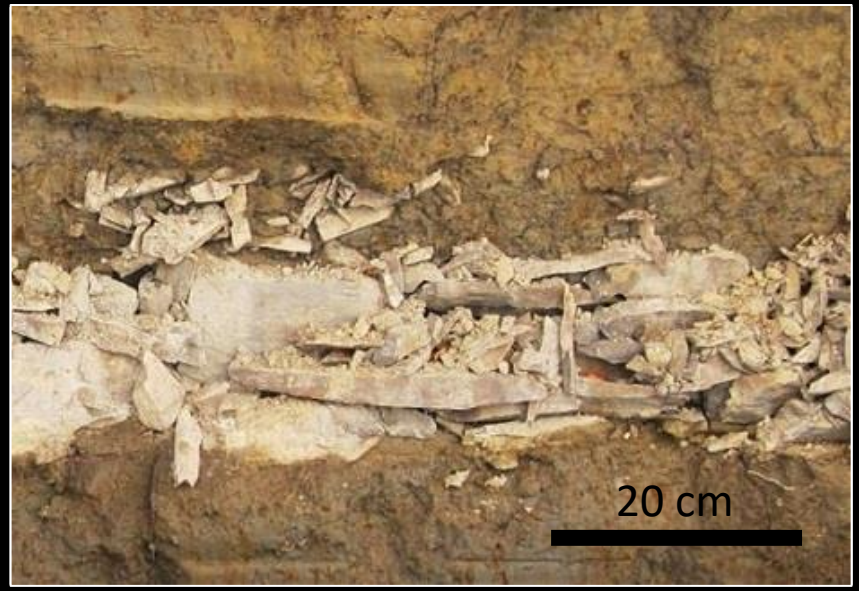


Fig. 6-13. Rapidly retreating tidewater glacier actively calving in deep water, and slowly retreating glacier actively calving in shallow water (Powell, 1981).

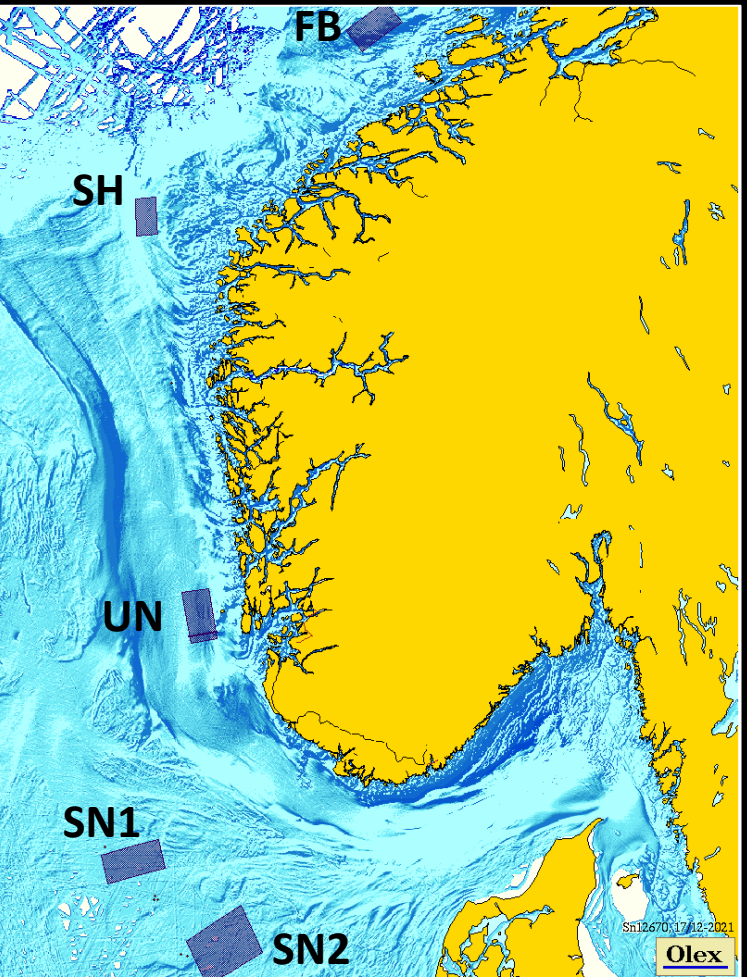
HIGHLY HETREOGENEOUS DEPOSITS



Eivind Bratlie – Glaciomarine deposits near Historisk Museum, Oslo
https://geoforskning.no/mysteriet-pa-tullinlokka-losningen-2019/

Suction anchor
www.aceton.com

MAIN QUESTIONS



HOW DO SOIL PROPERTIES VARY THROUGHOUT A PARTICULAR SITE?

CAN GEOTECHNICAL PROPERTIES BE PREDICTED FROM GEOLOGICAL DATA AND SEABED MORPHOLOGY?

WHICH AREAS ON NCS ARE MORE SUITABLE FOR FUTURE OFFSHORE WIND?

WHICH ANCHOR/FOUNDATION TYPES ARE SUITABLE FOR WHICH AREAS ON NCS?

HOW DO DIFFERENT GEOLOGICAL PROPERTIES REQUIRE DIFFERNENT GEOTECHNICAL SOLUTIONS, AND HOW DO THESE SOLUTIONS DRIVE COST?

PROJECTS AT UIB-GEO

Ongoing project

1: An integrated geological characterization of marine ground conditions for offshore wind foundations in the North Sea 2020-2023

5MNOK, Funded through AKADEMIA-agreement,
1 PhD (Hannah Petrie) >3 MSc's
1 10 day cruise to SN2 & UN – 800 km UHR 2D seismic, c 10 cores

equinor

AKADEMIA-AGREEMENT

Hannah Petrie
PhD Candidate
Geology for offshore wind

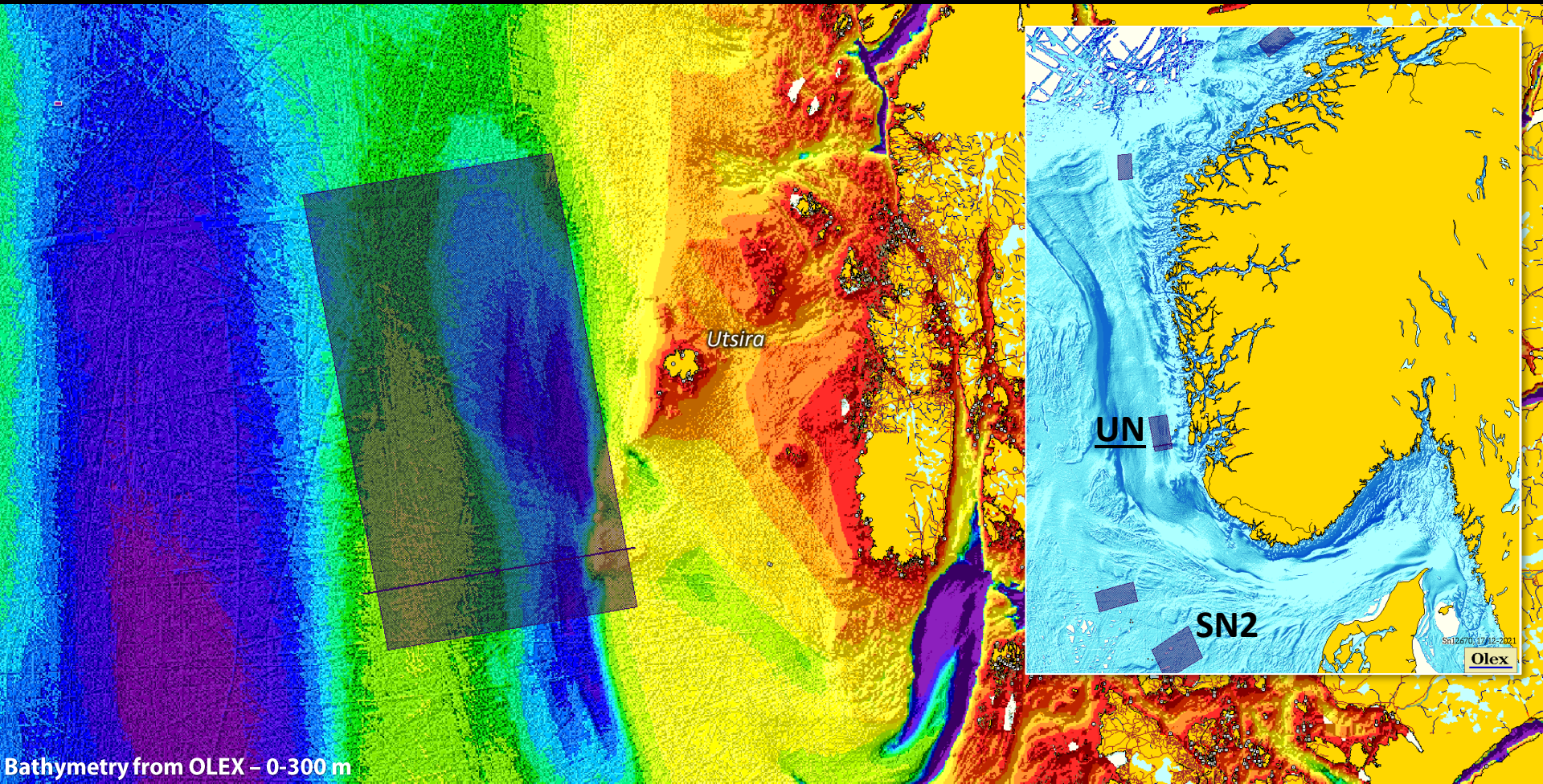
Application to RCN, currently being considered

2: 4SWIND: Advancing seismic sea-bed survey techniques and optimal site-selection for offshore wind farms
KPN Application 2022 (2022-2026)

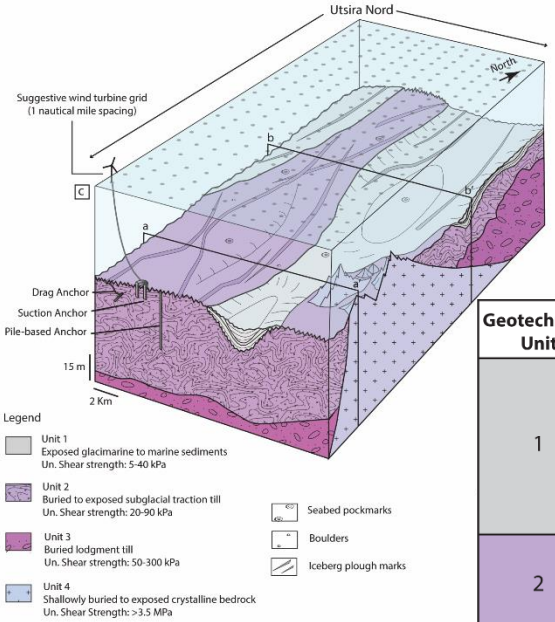
1 Postdoc, 1 researcher, 1 PhD
>15 MSc's
3 cruises each 15 days to UN & SN2 (UHR 3D seismic data, core data, geotechnical data, seismic P&S-wave tomography)

NTNU
The Arctic University of Norway – UiT
Volcanic Basin Petroleum Research
mareano
Norges Geologiske Undersøkelse
NGI
marum – Research Faculty, University of Bremen
GEOMAR
University of Stirling
University of Southampton
GEO PROVIDER
equinor

UTSIRA NORD SITE – HIGHLY ERODED ICE STREAM BED



UTSIRA NORD – HAZARDS, IMPACTS, MITIGATION

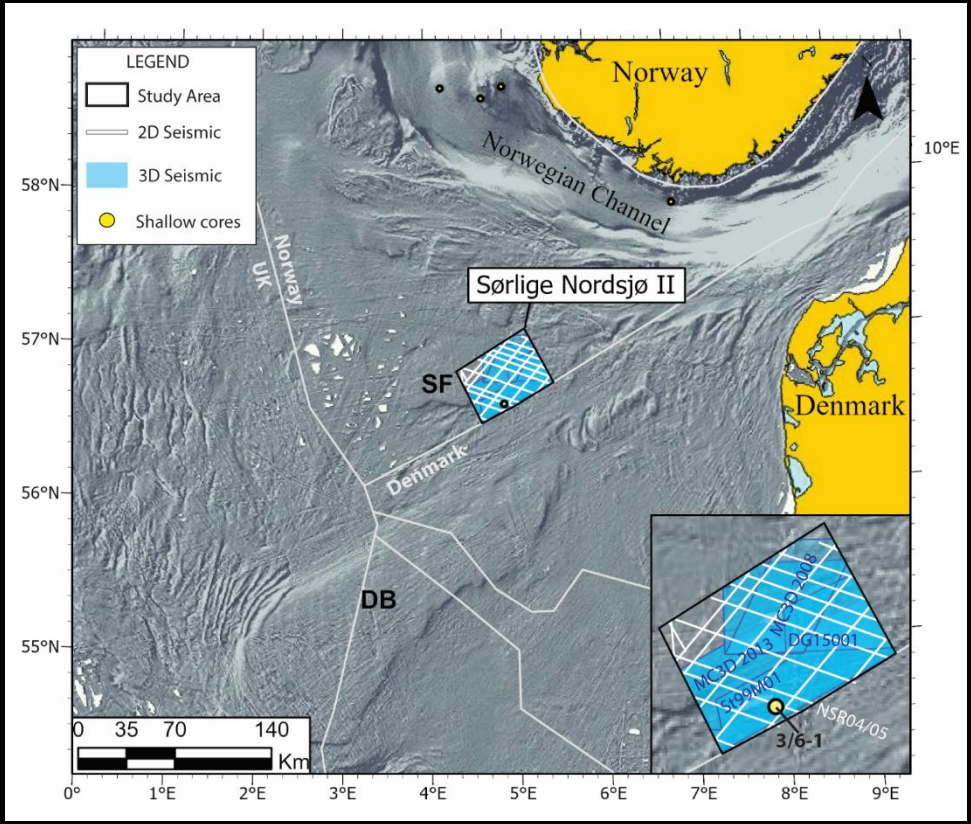


https://eartharxiv.org/repository/view/2915/

Geotechnical Unit	Description	Hazards	Causes	Potential Impact	Mitigation
1	Exposed glacimarine to marine sediments Un. Shear strength: 5-40 kPa (Gravity and piston cores)	Uneven seabed	Pockmarks Iceberg Scours	Variable anchor penetration	High resolution seabed mapping (sonar, 3D seismic)
			Boulders	Obstruction to anchor	
		Poorly consolidated sediment	Recent marine sediments deposited by currents	Seabed scour around anchors	In-situ testing across site to determine degree of consolidation of recent sediments
2	Buried to exposed subglacial traction till Un. Shear strength: 20-90 kPa (Gravity cores)	Sudden lateral variation in soil properties	Glacial troughs with softer sediment infill	Variable anchor penetration	Acquisition of 2D or 3D acoustic data to map filled glacial troughs on finer scale
3	Buried lodgment till Un. Shear strength: 50-300 kPa (Clarke et al., 1998)	Buried hard formation at varying depths	Overconsolidation of sediment by repeated ice activity	Obstruction to anchor Variable anchor/pile penetration *Potential impact increases northward as province closer to surface	Acquisition of 2D or 3D acoustic data to map Top Unit 3 on finer scale Acquisition of core and in-situ testing across site to determine variability in soil properties
		Highly variable soil properties	Poorly sorted mixture of clay, silt, sand, gravel, cobbles, boulders		
4	Shallowly buried to exposed crystalline bedrock Un. Shear Strength: >3.5 MPa (Singh and Murthy, 2016)	Uneven seabed	Rugged bedrock topography with exposed and buried peaks	Obstruction to anchor Shallow refusal Variable pile penetration Pile buckling	High resolution seabed mapping (sonar, 3D seismic) and sub-bottom profiling in south eastern part of the site
		Buried hard formation			

(Petrie et al., accepted 2022)

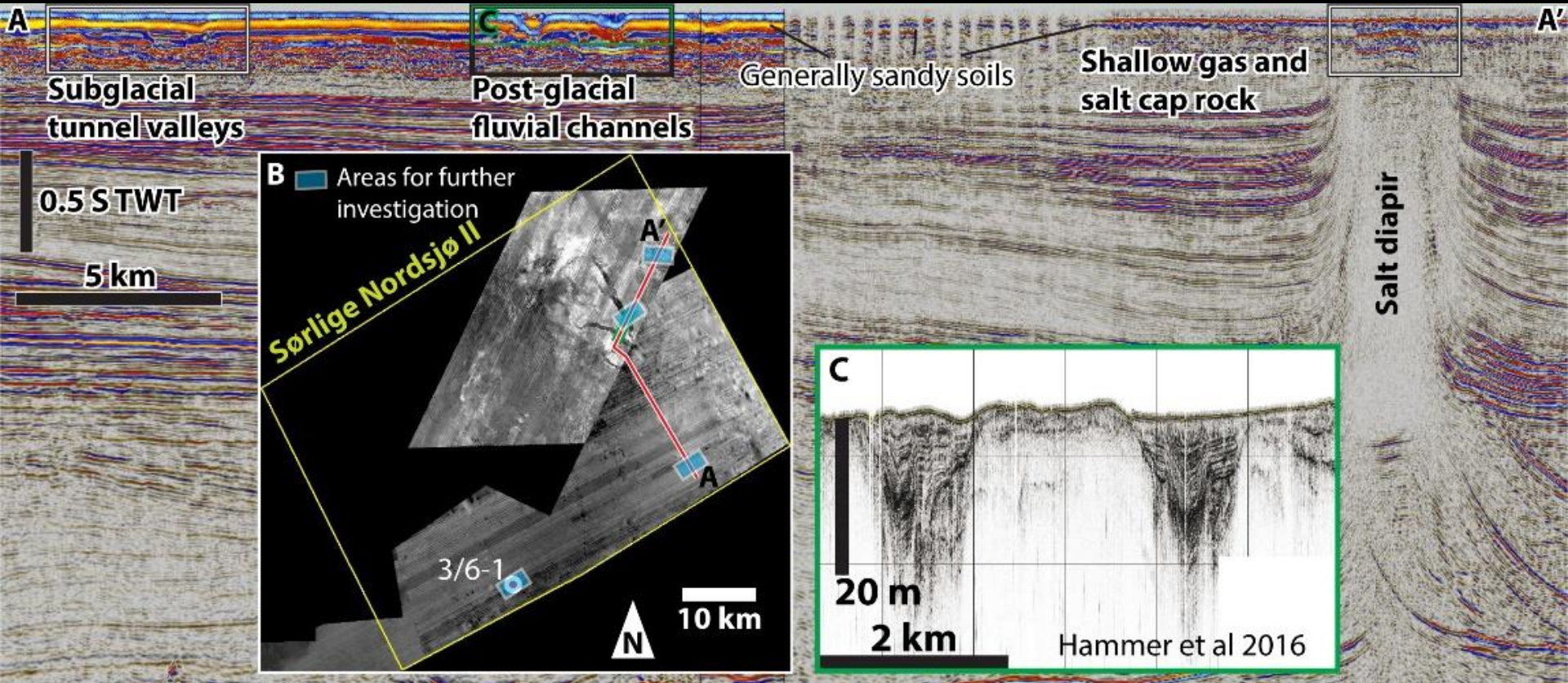
SØRLIGE NORDSJØ 2 SITE – CHANNELS, TUNNEL VALLEYS, SHALLOW GAS



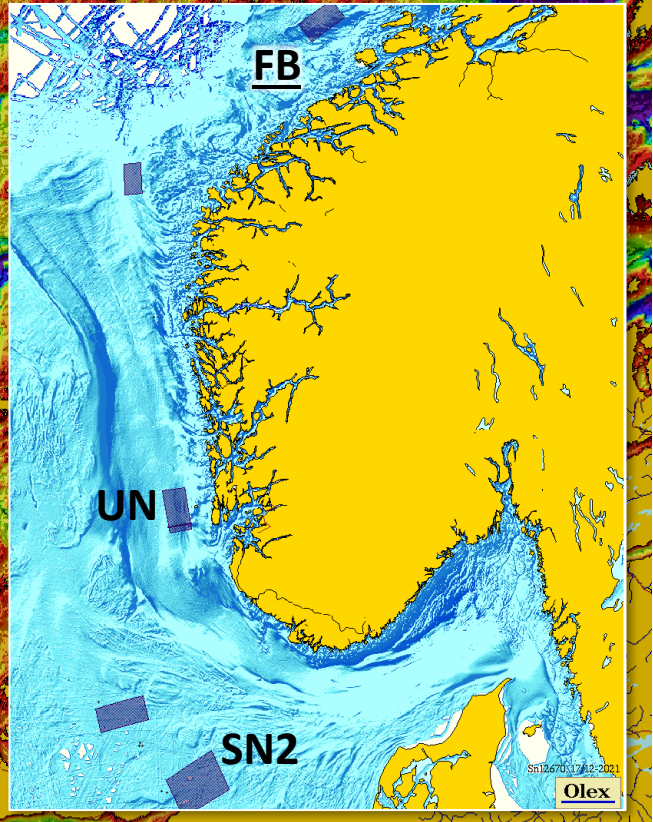
Average Depth: 60 m
Area: 2600 km^2

Petrie et al, in prep 2022

SØRLIGE NORDSJØ 2 SITE –CHANNELS, TUNNEL VALLEYS, SHALLOW GAS



FRØYBANKEN – STRONGLY DIFFERENT CONDITIONS IN S PART OF SITE



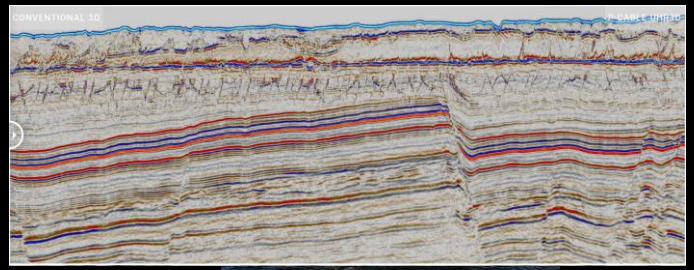
Bathymetry from OLEX

Grayscale | Left | Right | <<< | >>>

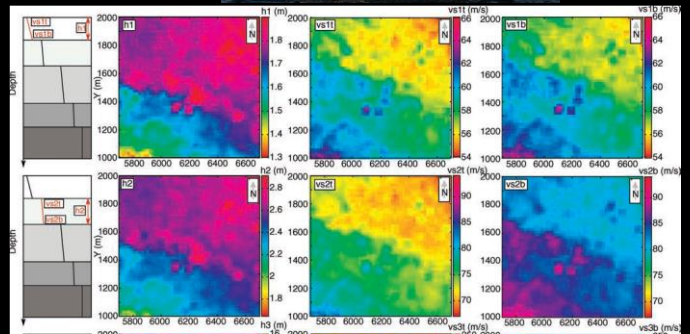
ayers | Chart selection | Norgeskart 20/7-2020 | NGU maps (rightmouse!) | Background | Chart files

FUTUTURE CRUISE PLANS

	2022 cruise, 10 days Funding: Akademia/Equinor				2023 cruise, 16 days Funding: Proposed 4SWIND project				2023/4 geotechnical cruise, 14 days Funding: Proposed 4SWIND project				2024 cruise, 16 days Funding: Proposed 4SWIND project			
	TOPAS	Core	UHR 3D	Tomog.	TOPAS	Core	UHR 3D	Tomog.	Core	CPTu			TOPAS	Core	UHR 3D	Tomog.
Sørlige Nordsjø 2																
Utsira Nord																



NCS-SUBSEA



Kugler et al 2007

CONCLUSIONS

- **GEOLOGICAL AND GEOTECHNICAL CONDITIONS ON NCS COMPLEX**
  - **MAINLY BECAUSE OF GLACIAL EROSION AND DEPOSITION**
  - **IMPORTANT TO ESTIMATE CONCEPT AND COST OF ANCHORS AND FOUNDATIONS**
  - **ANCHORS AND FOUNDATIONS C. 10-25% OF TOTAL COST OF OFFSHORE WIND FARMS**

- **STRONG VARIATIONS BOTH WITHIN AND BETWEEN SITES**
  - **MANY PROPOSED SITES (Trænabanken, Stadthavet, …) STRONGLY DIFFERENT FROM ANNOUNCED SITES (SN2, UN)**

- **NOT MUCH RESEARCH ON GEOLOGY OF OFFSHORE WIND IN NORWEGIAN ACADEMIA YET**
  - ***1 PhD at UiB***
  - ***KPN Project considered now by RCN***

- **UPCOMING CRUISES WILL ANSWER KEY UNKNOWNS, STUDENTS WILL BE TRAINED**

- **IMPORTANT TO CONSIDER GEOLOGY WHEN NEW SITES ARE PLANNED AND ANNOUNCED**