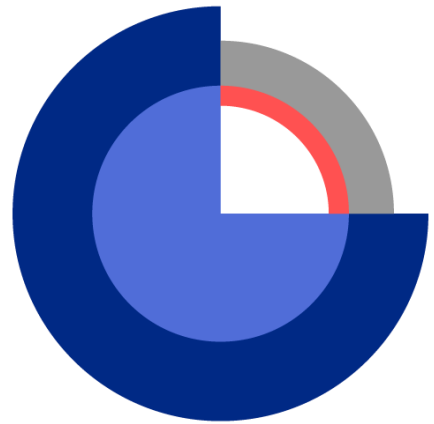


GEUS

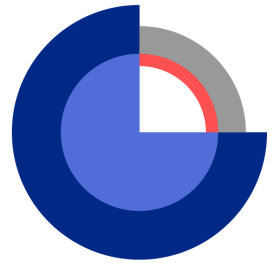
Geological screening for offshore wind in Danish waters

Thomas Vangkilde-Pedersen

Geological Survey of Denmark and Greenland,

Department of Near Surface Land and Marine Geology – SURFACE





Vietnam November 2025

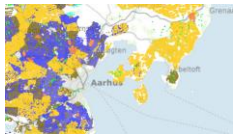
G E U S

GEUS is the geological memory of Denmark and Greenland

GEUS produce geological maps and geological 3D models and run national geological databases:



The Jupiter borehole database



The Gerda shallow geophysical database



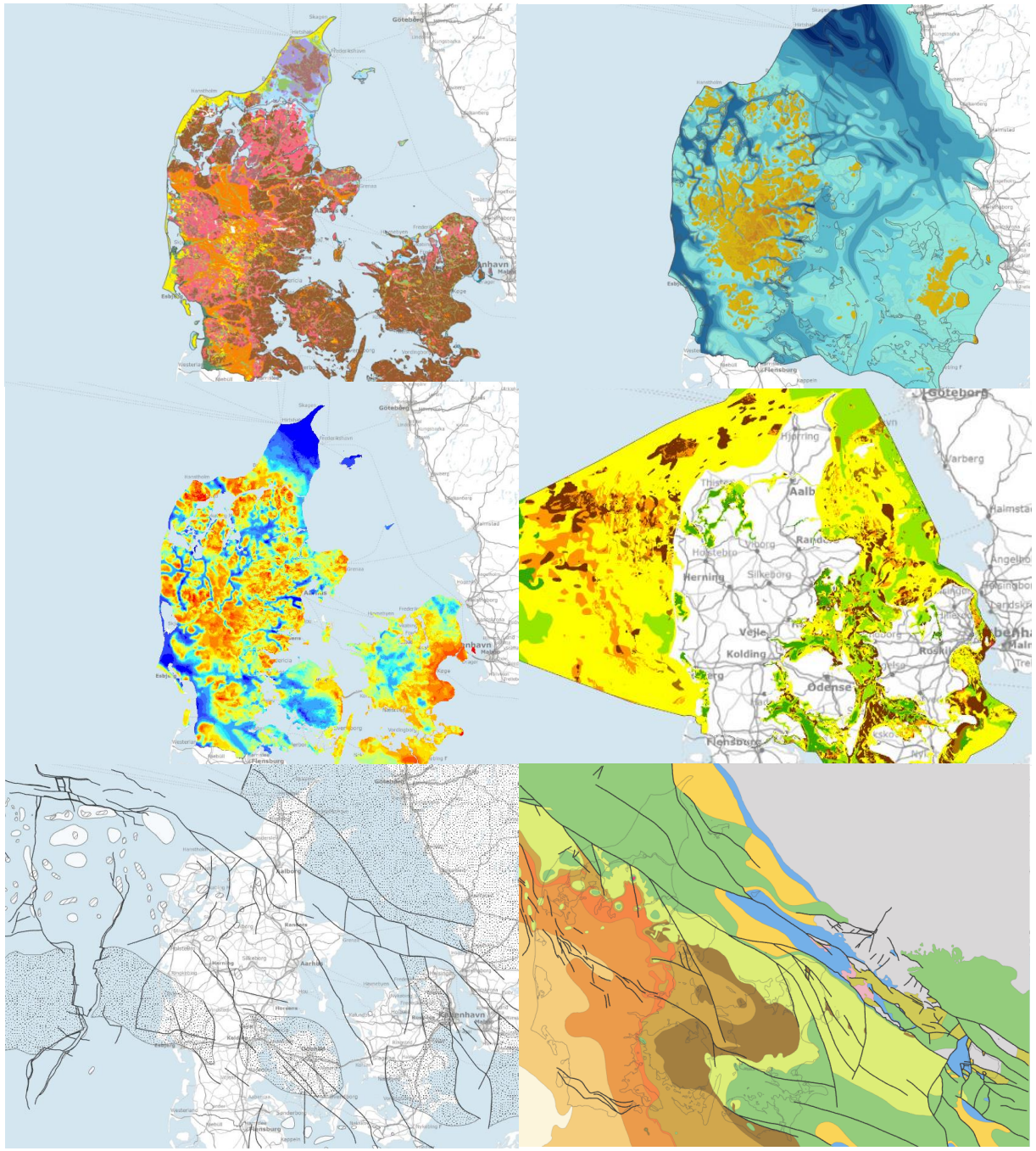
The Marta marine raw material database



The deep subsurface database for Danmark



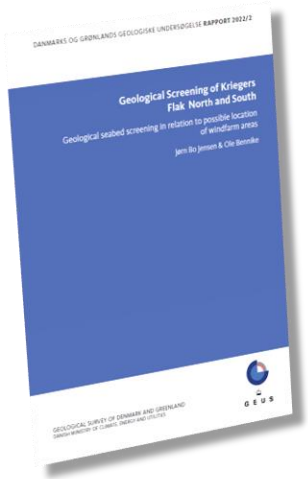
The Greenland subsurface database



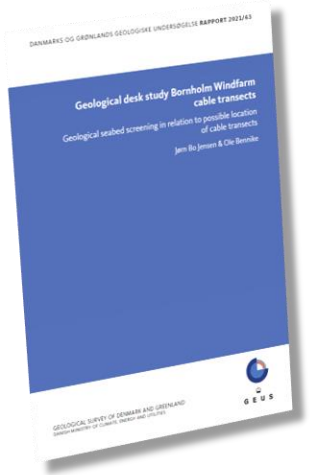
GEUS activities in offshore wind projects

- We carry out geophysical surveys for seabed geology and seabed environmental and habitat mapping
- We perform large scale overall geological screening and mapping programs
- We do geological desk studies of planned offshore wind farm locations
- The desk studies are successfully used as the geological framework for subsequent detailed site surveys and investigations



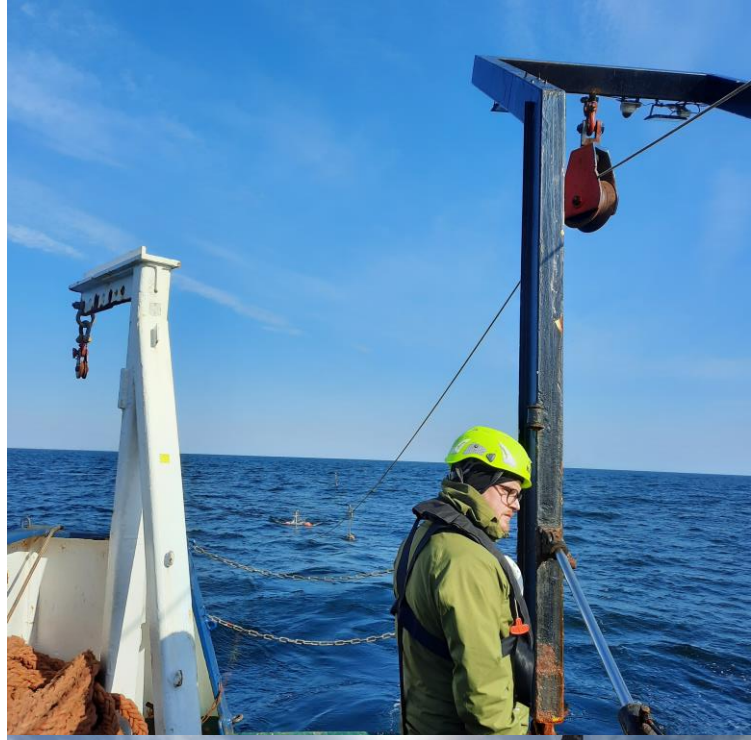














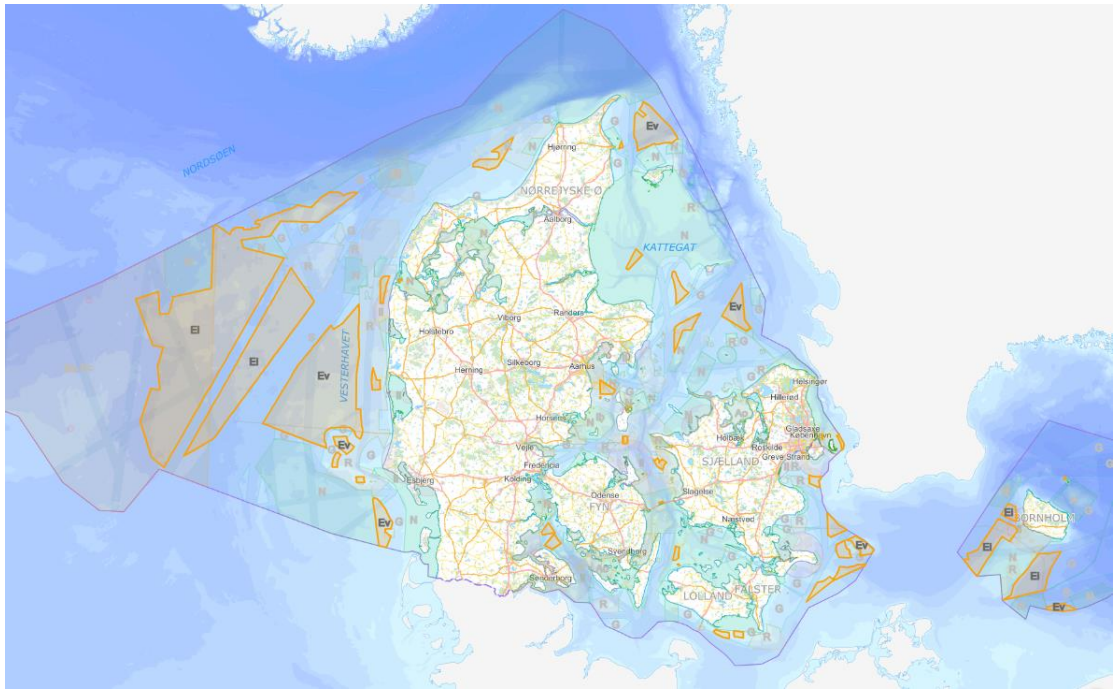
Denmark plans massive upscaling of offshore wind

Existing offshore wind is 2,3 GW

Already decided and tendered 1,35 GW



Source: Danish Energy Agency



Denmark's maritime spatial plan – offshore renewable energy areas

Source: Danish Maritime Authority

Plans for additional 9 GW by 2030

By 2030 approx. 12,5 GW offshore wind

Danish Energy Agency

GEUS

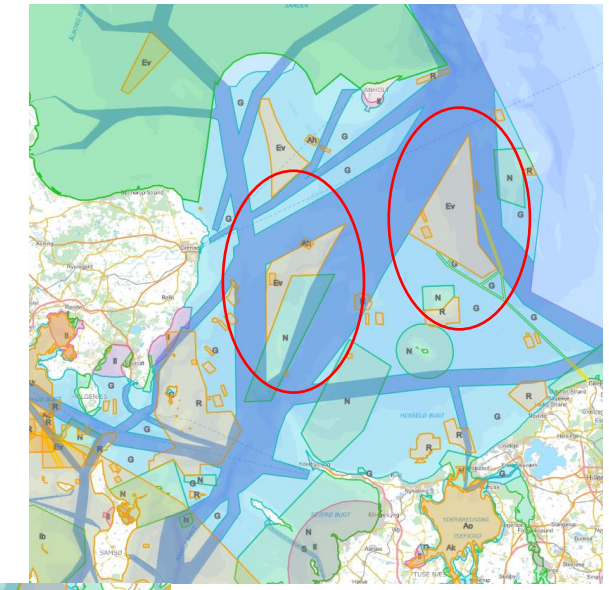
Massive upscaling and spatial planning

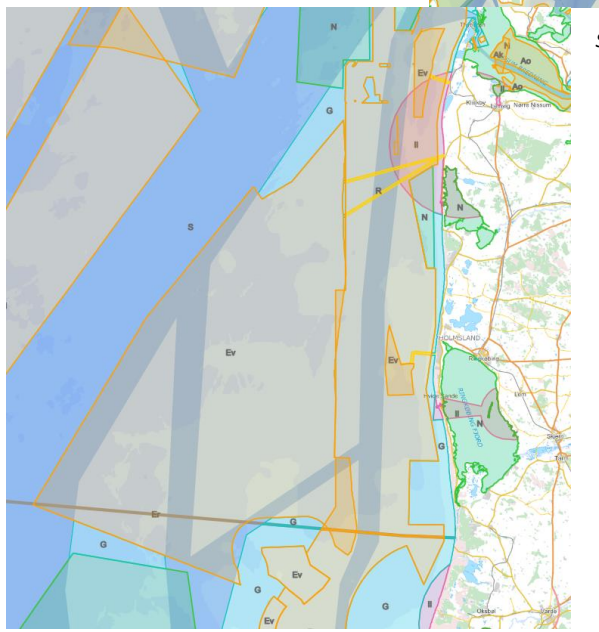
Planning for offshore wind – and fitting into all other spatial interests – is always challenging

Large scale offshore wind development multiplies the challenges

- Navigational safety and access
- Defense – military exercise areas and radar coverage
- Nature and environment
- Commercial fishing
- Raw material extraction
- Cables and pipelines

…… and geology!





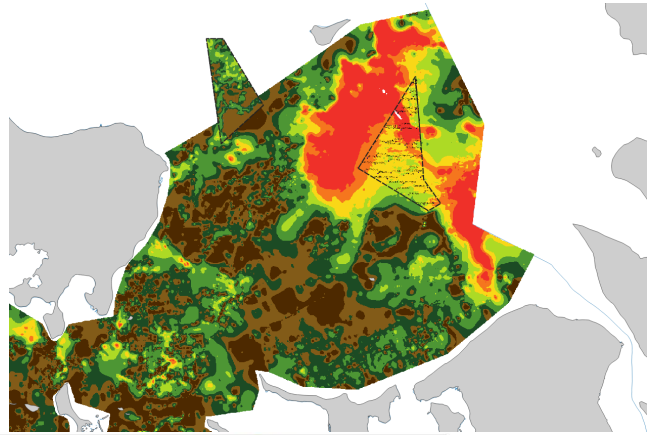
Source: Danish Maritime Authority

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Massive upscaling from a geological perspective

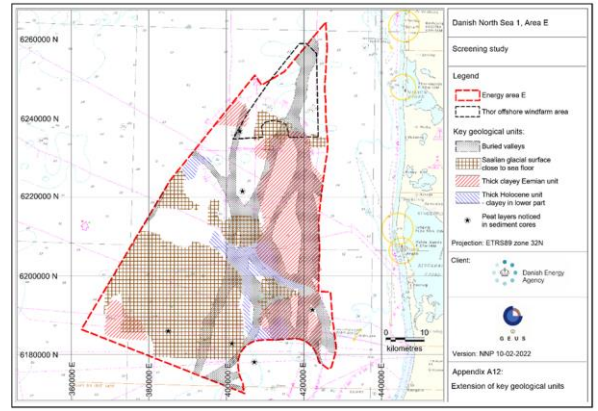
Overall geological screening to avoid designation of wind farm areas with unsuitable geology

- Important step in Maritime Spatial Planning
- Important to bring in early
- Few examples in the past with not so well-suited locations



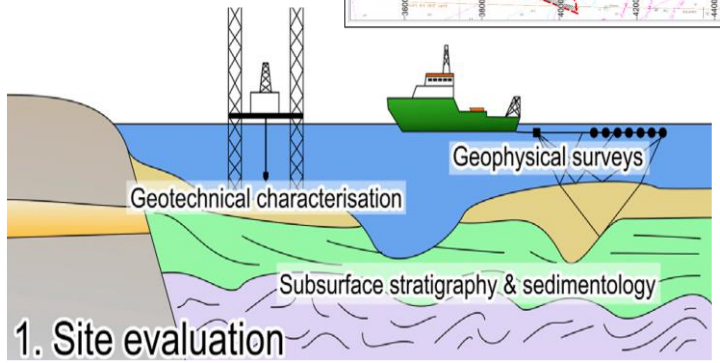
Detailed geological desk studies early in the planning phase

- Based on existing data
- Inexpensive, but very efficient
- Use geological framework from overall screening



Detailed site investigations before tendering

- Expensive, but important
- Use geological framework from overall screening
- Use results of geological desk study
- Important for developers to know complexity of geology
- Important for developers to know predictability of geology

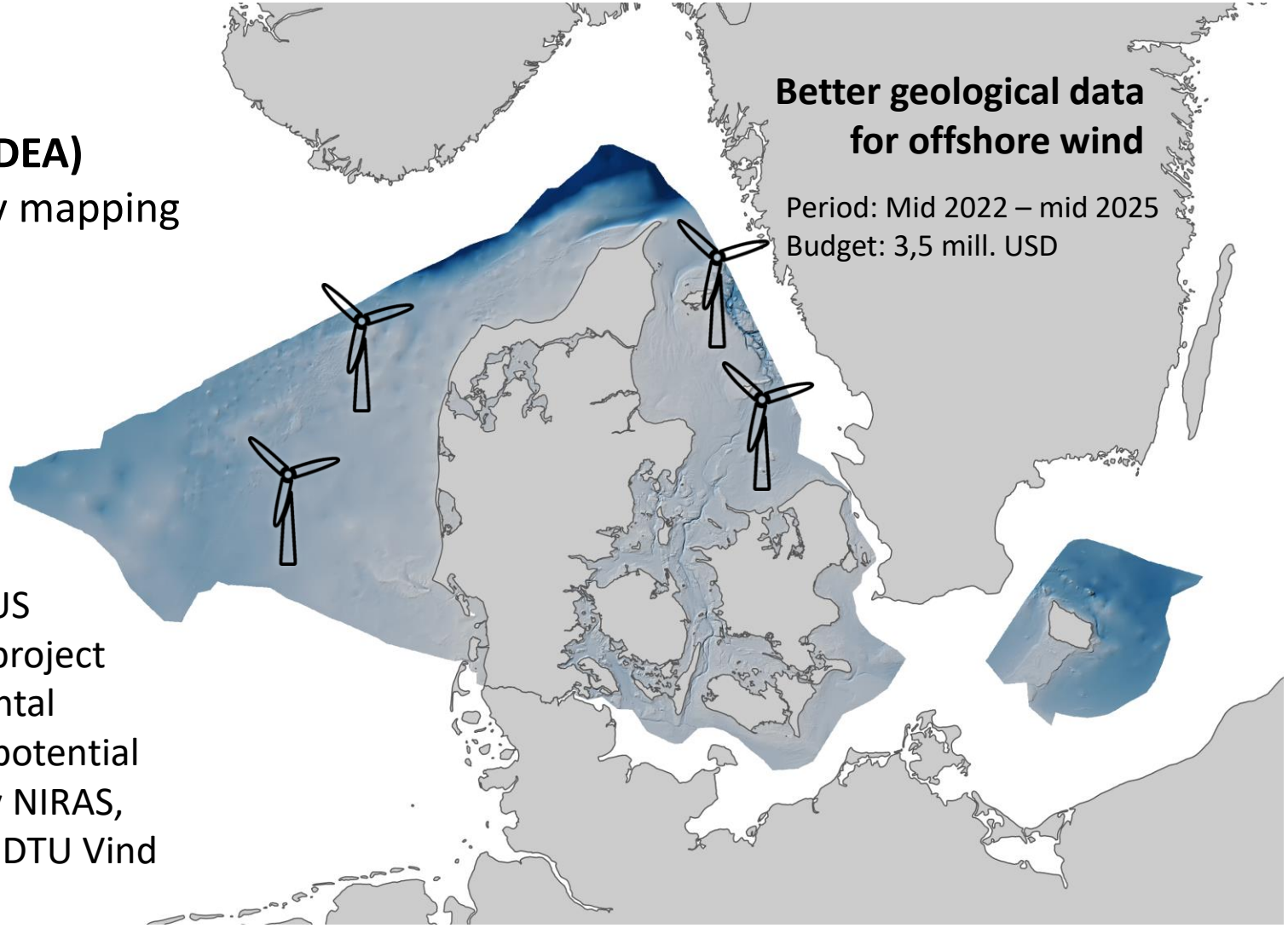


From Velenturf et al., 2021: Geoscience Solutions for Sustainable Offshore Wind Development. The Geological Society of London.

G E U S

Geological screening for offshore wind farms

Danish Energy Agency (DEA)
Screening and sensitivity mapping



Geological mapping by GEUS provides input to the DEA project ”Screening and environmental mapping of offshore wind potential in Denmark” carried out by NIRAS, DCE Aarhus University and DTU Vind

Thomas Vangkilde-Pedersen, Niels Nørgaard-Pedersen, Nicklas Christensen, Lara F. Perez, Lis Allaart, Jørgen Overgaard Leth, Luna Holland Winther, Sunny Singhroha, Rasmus Ørnekoll Stenshøj, Ole Bennike, Henrik Jønsson Granat, Lars-Georg Rödel, Sigurd Bøgelund Andersen, Lisbeth Lyngkjær Pedersen, Lars Øbro Hansen, Mikkel Skovgaard Andersen, Katrine Elnegaard Hansen, Jørn Bo Jensen

Geological Survey of Denmark and Greenland, Department of Near Surface Land and Marine Geology - SURFACE

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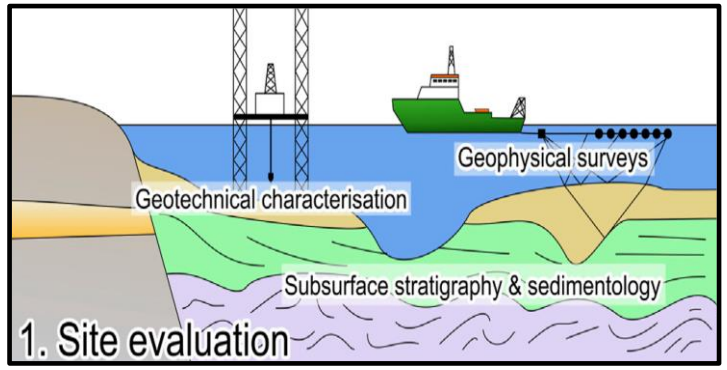
Aim and objectives

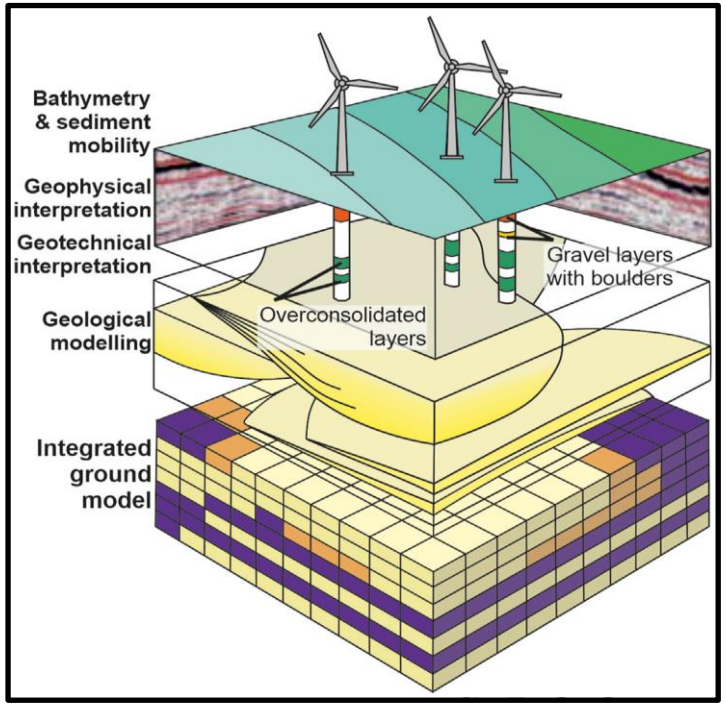
The geology and bathymetry of the seabed are the most important factors for the total construction costs of offshore wind farms

The aim of the project is to produce maps of geological units with potential impact on the construction of offshore windfarms to point out areas that are geologically well-suited/not suited

The project objectives are to:

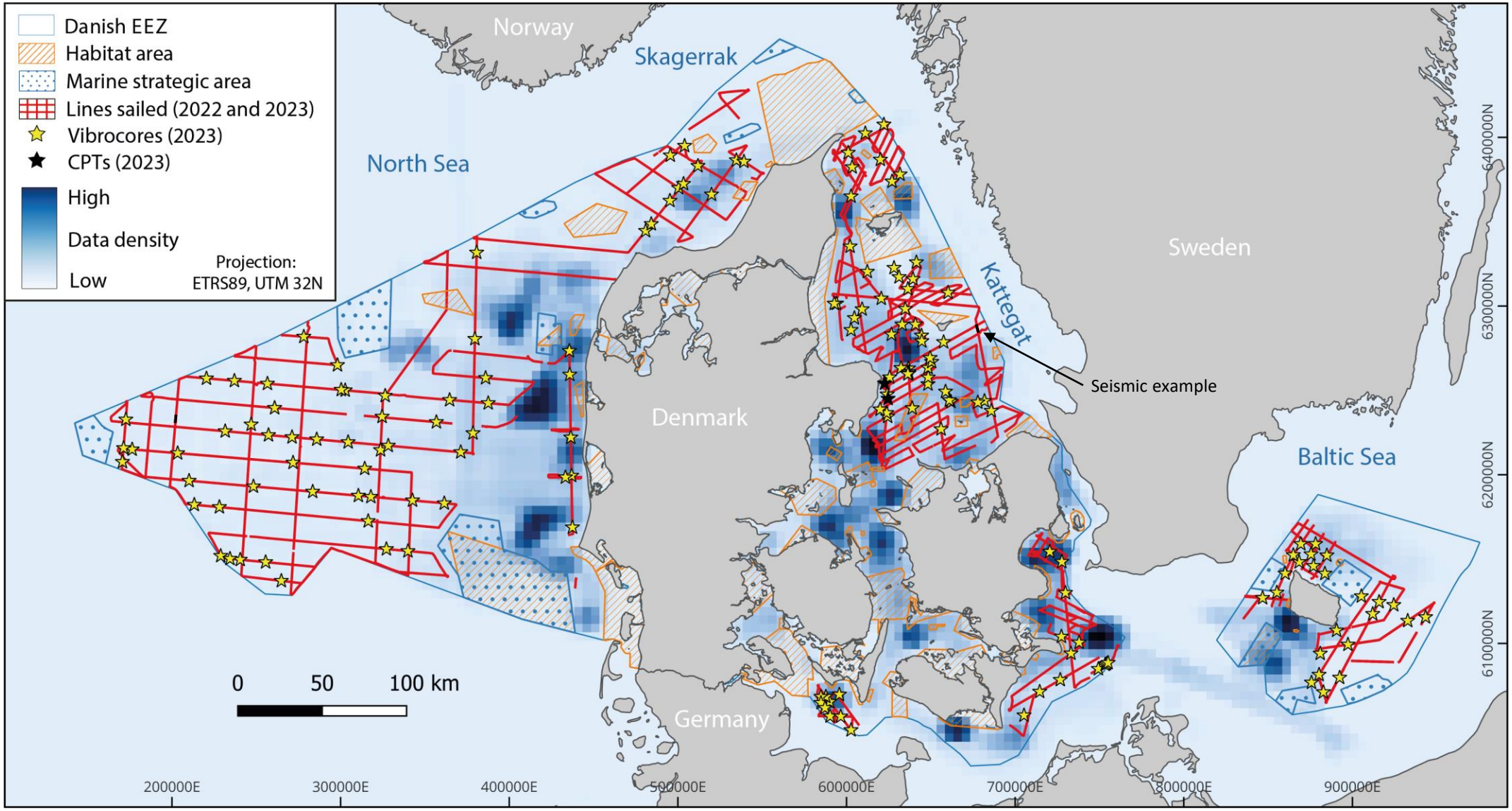
- ✓ **Perform a desk study** of existing geological data to assess the need for new (and better) data
- ✓ **Acquire new seismic data** for mapping of geological units with potential geotechnical implications for offshore wind farm constructions
- ✓ **Acquire new vibrocore boreholes (and CPT)** to support the geological interpretation of the seismic data
- ✓ Establis**h conceptual geological models** based on existing knowledge for the different mapping areas as a basis for the geological screening/mapping
- ✓ **Produce maps of geological units** important for offshore wind farm constructions
- ✓ **Identify areas** that are geologically well-suited/not well-suited
- ✓ **Identify areas** with potential marine-archeological interests





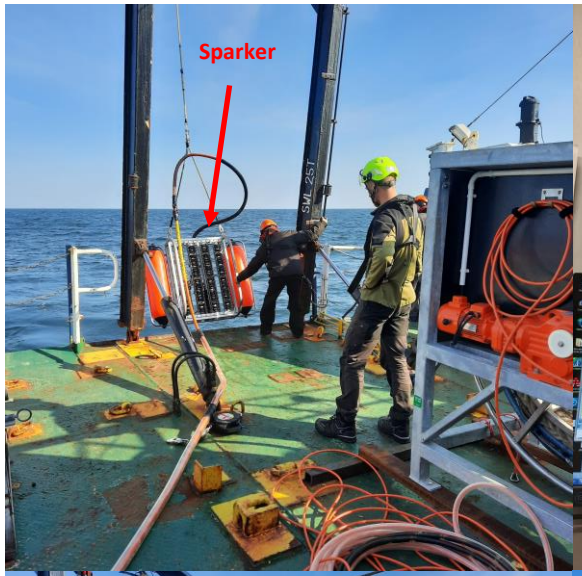
From Velenturf et al., 2021: Geoscience Solutions for Sustainable Offshore Wind Development. The Geological Society of London.

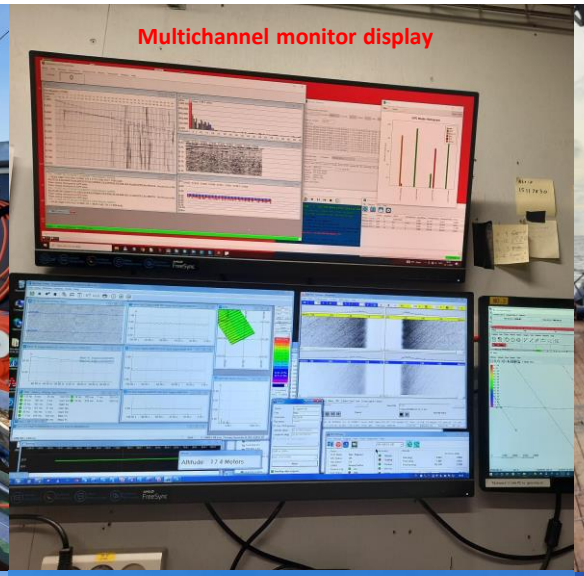
Density of existing data and acquisition of new data



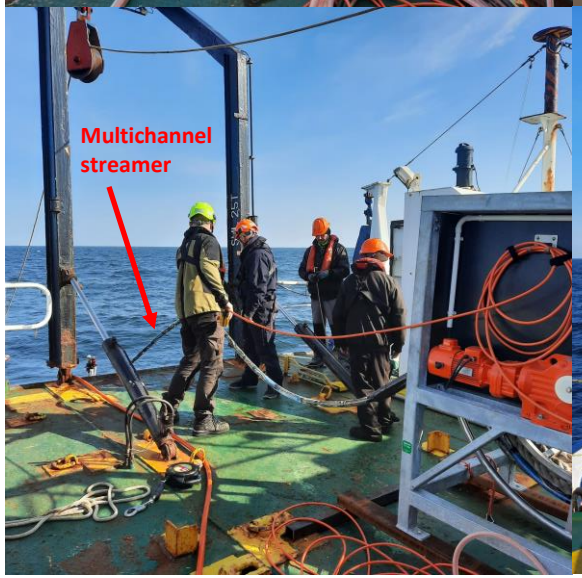
GEUS

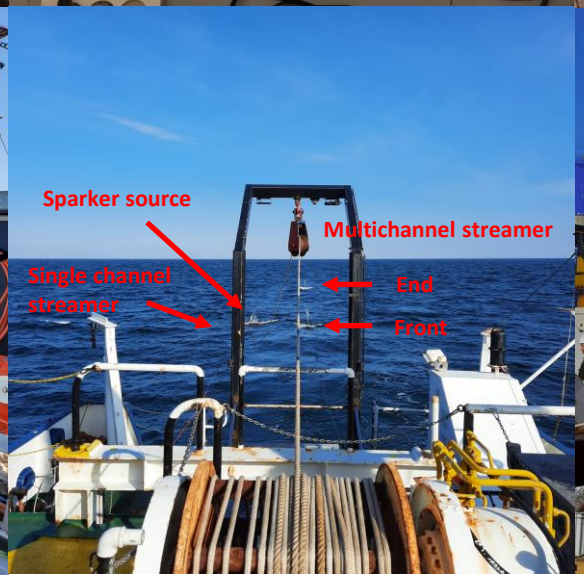
Ultra-High Resolution Seismic (UHRS) - Equipment setup













- Geo-Source 200 sparker at 400 J
- Geo-Sense 8 element single channel streamer
- Geo-Eel LH 16 multichannel streamer
  (100 m, 96 ch. In 2022 / 50 m, 48 ch. In 2023)

- Innomar SES 2000 Medium sub-bottom profiler
- EdgeTech 6205 sidescan sonar and multibeam

- 6 m Vibracorer MED-C VC(VKG)-6
- Geo-Engineering GOST CPT unit



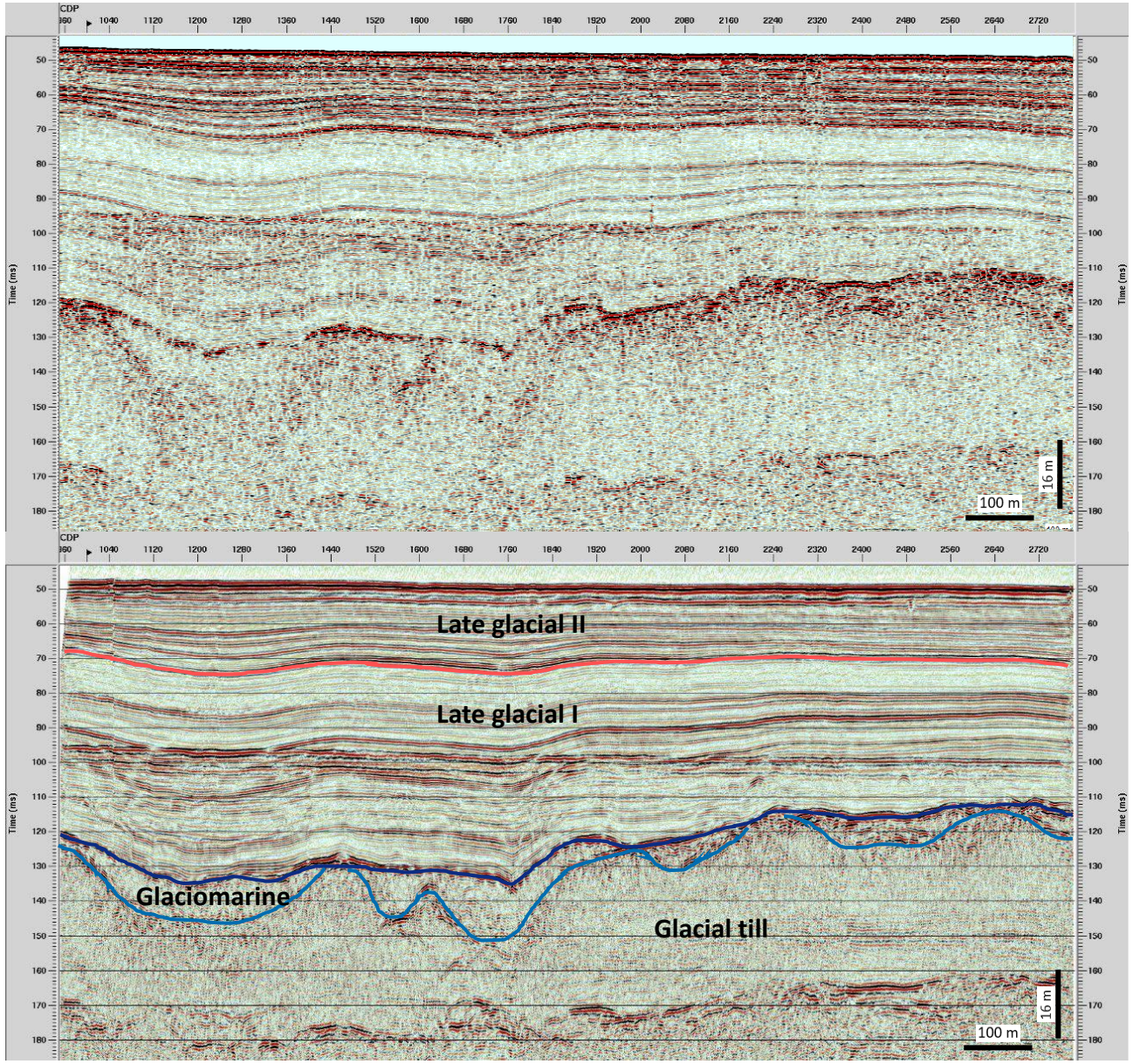
Survey vessels provided by FOGA

- Signal frequencies 200 – 1200 Hz
- Dominant frequencies 600 - 700 Hz
- Vertical resolution <30 cm
- Penetration up to 100 - 300 m

GEUS

7780 km seismic data, 168 vibrocores and 2 CPT

Single channel vs multichannel sparker data (Kattegat)

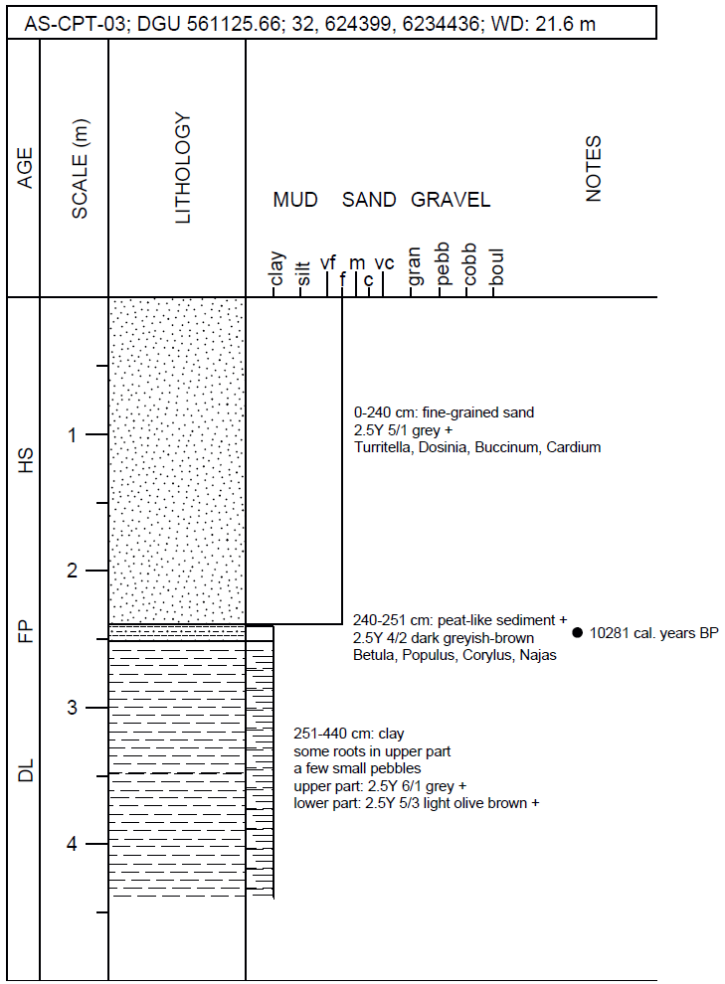


Processed single channel sparker data

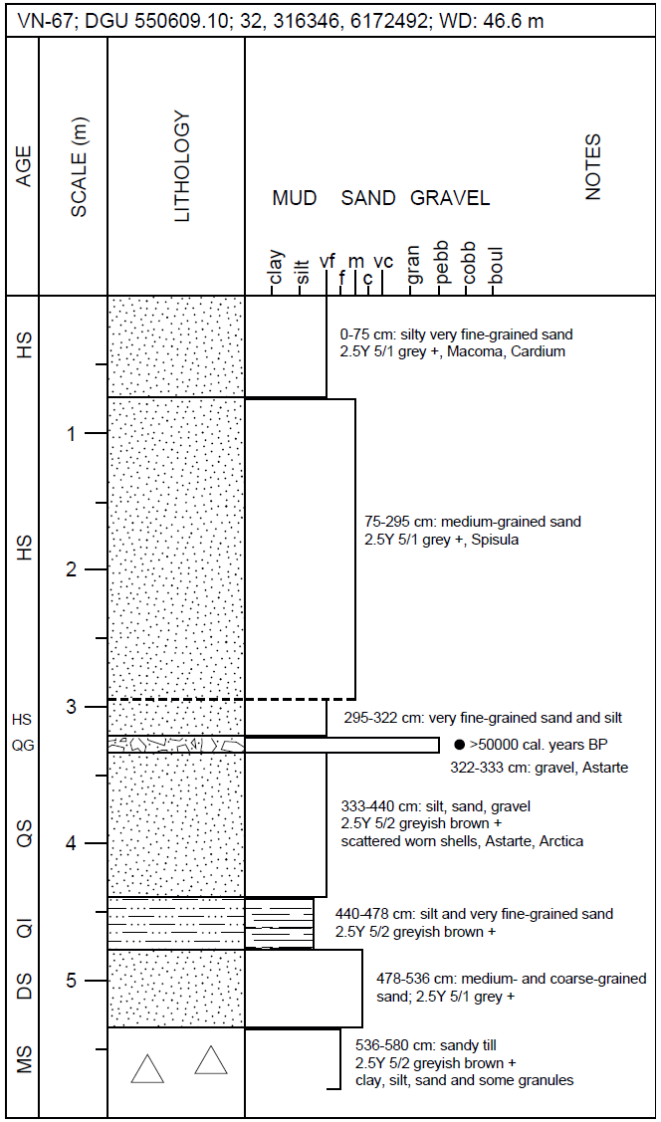
Processed multichannel sparker data with interpretation

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Examples of vibrocore data



Kattegat



North Sea

GEUS

Sediment types and geotechnical implications

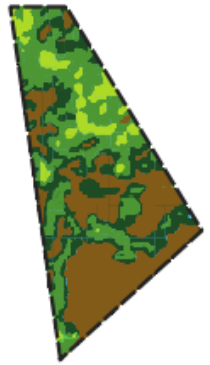
Sediment type	Critical geotechnical conditions/challenges	Foundation suitability
Marine sand	n.a.	Well suited
Marine clay/soft mud	Low geotechnical strength	Not well suited if thick
Peat	High compressibility, low geotechnical strength	Not well suited
Glaciofluvial sand	n.a.	Well suited
Glaciolacustrine clay	Low geotechnical strength if not overconsolidated by ice sheet loading	Not well suited if thick
Moraine clay/till	Often, but not always, overconsolidated, potentially heterogeneous, can contain coarse lag deposits, boulder stones and dislocated slabs of older sediments	Potentially problematic
Buried valley sediments	Potentially heterogeneous with both glacial and non- glacial deposits, sharp variations in sediment composition across flanks and internally with abrupt changes in geotechnical properties	Potentially problematic
Glaciotectonic deformations	Often steeply dipping layers and very alternating layering, dislocated slabs of older sediments may occur and potentially abrupt changes in geotechnical properties	Potentially problematic
Gas or fluids in the sediments	Can lead to blow outs when drilling for sediment sampling and infrastructure construction, can cause acoustic blanking of seismic reflection data, preventing interpretation of units below	Potentially problematic
Overconsolidated sediments	Ice sheet loading or subaerial exposure and desiccation, can lead to overconsolidation of sediments and difficult testing and construction conditions	Potentially problematic
Shallow bedrock	Typically, high geotechnical strength that potentially may be problematic, can also be weathered with lower strengths at the interface with Quaternary sediments	Potentially problematic

Partly based on Velenturf et al., 2021

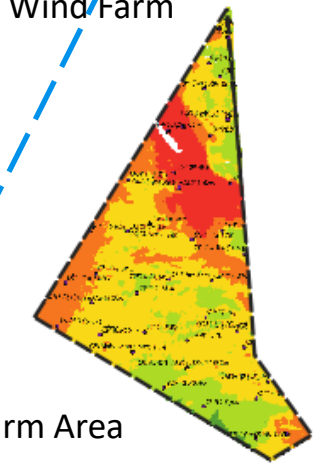
GEUS

Southern Kattegat



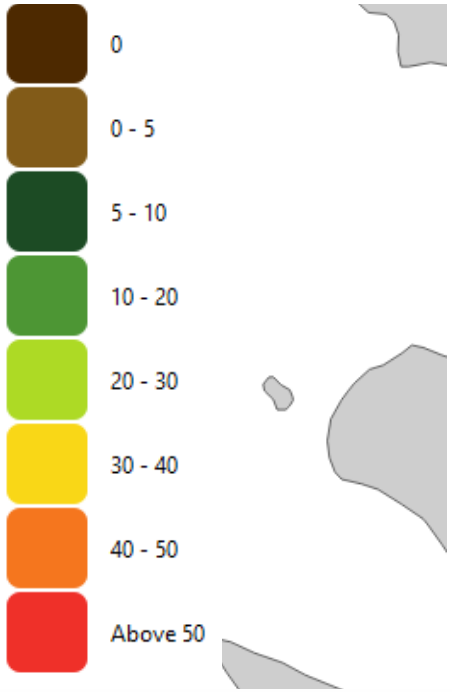


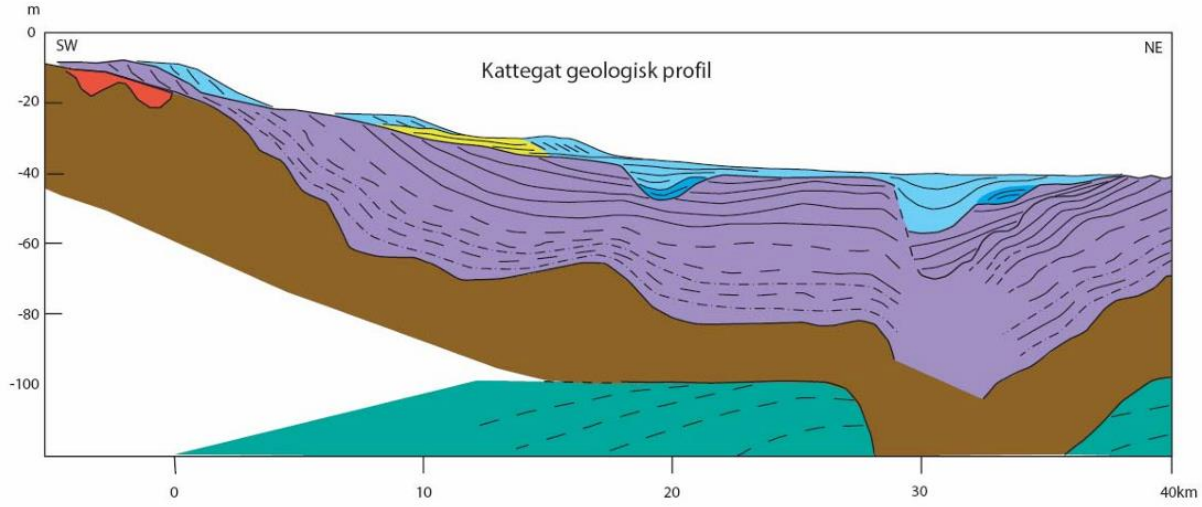
Anholt Offshore Wind Farm



Previous Hesselø Wind Farm Area

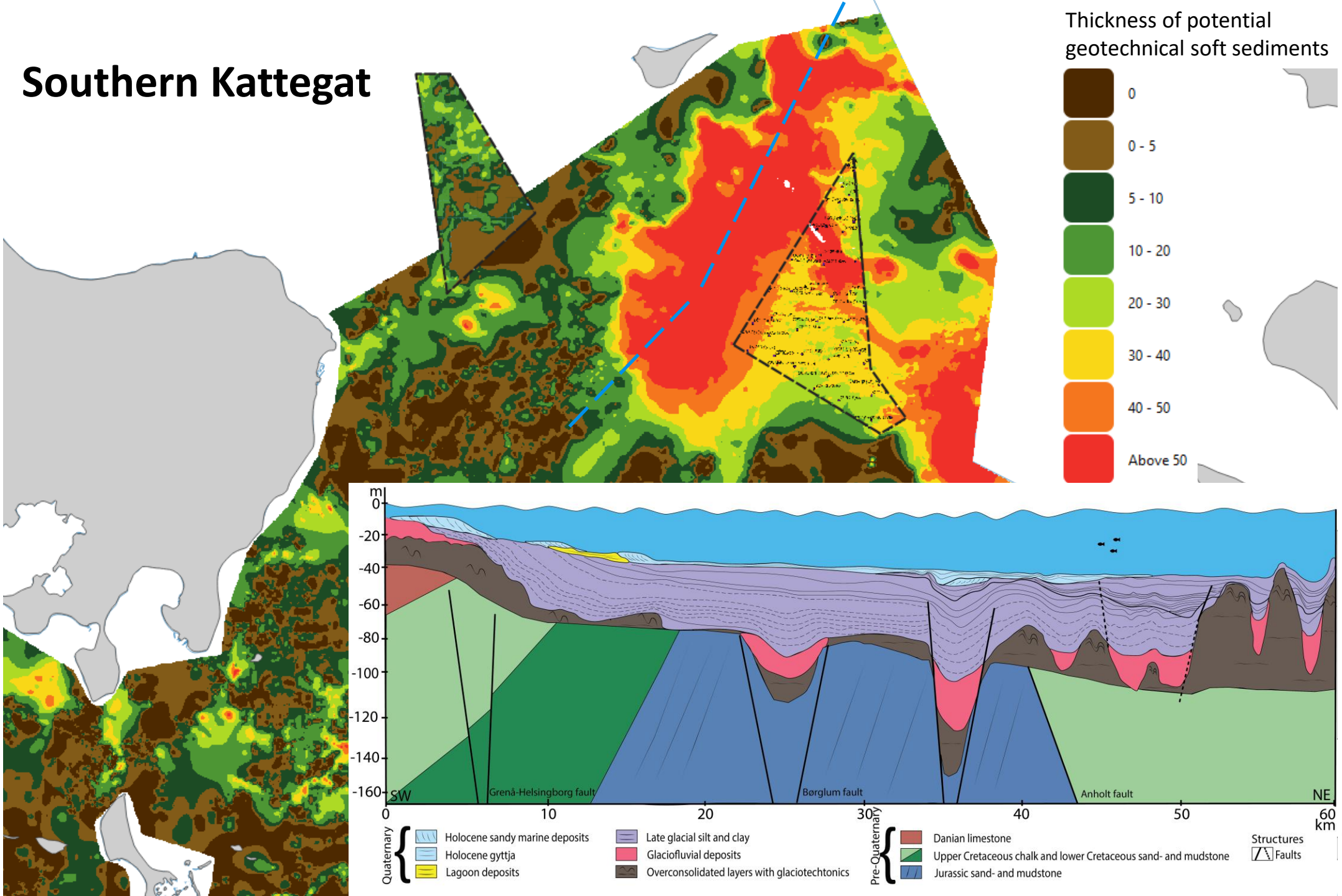
Thickness of potential geotechnical soft sediments



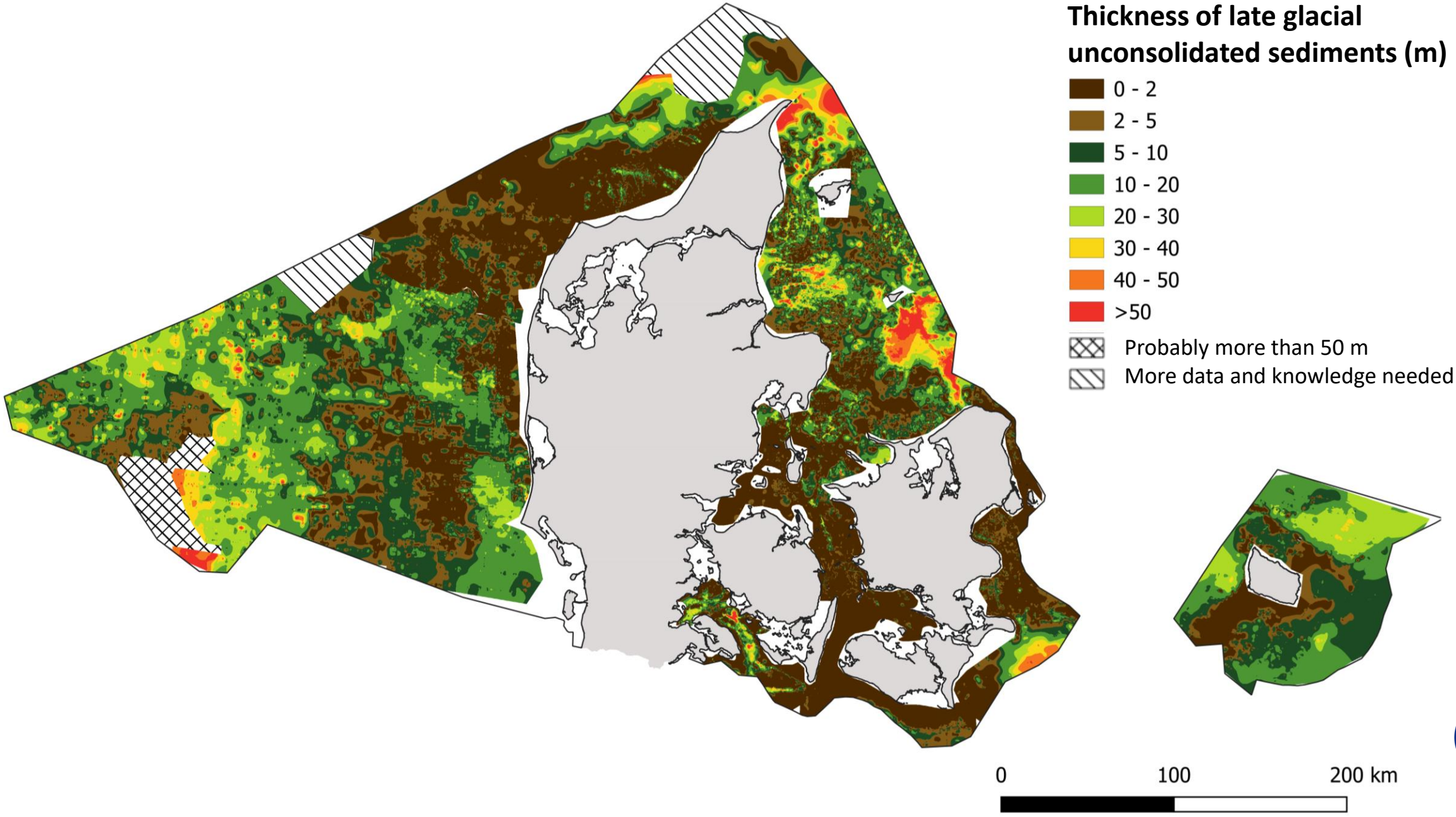


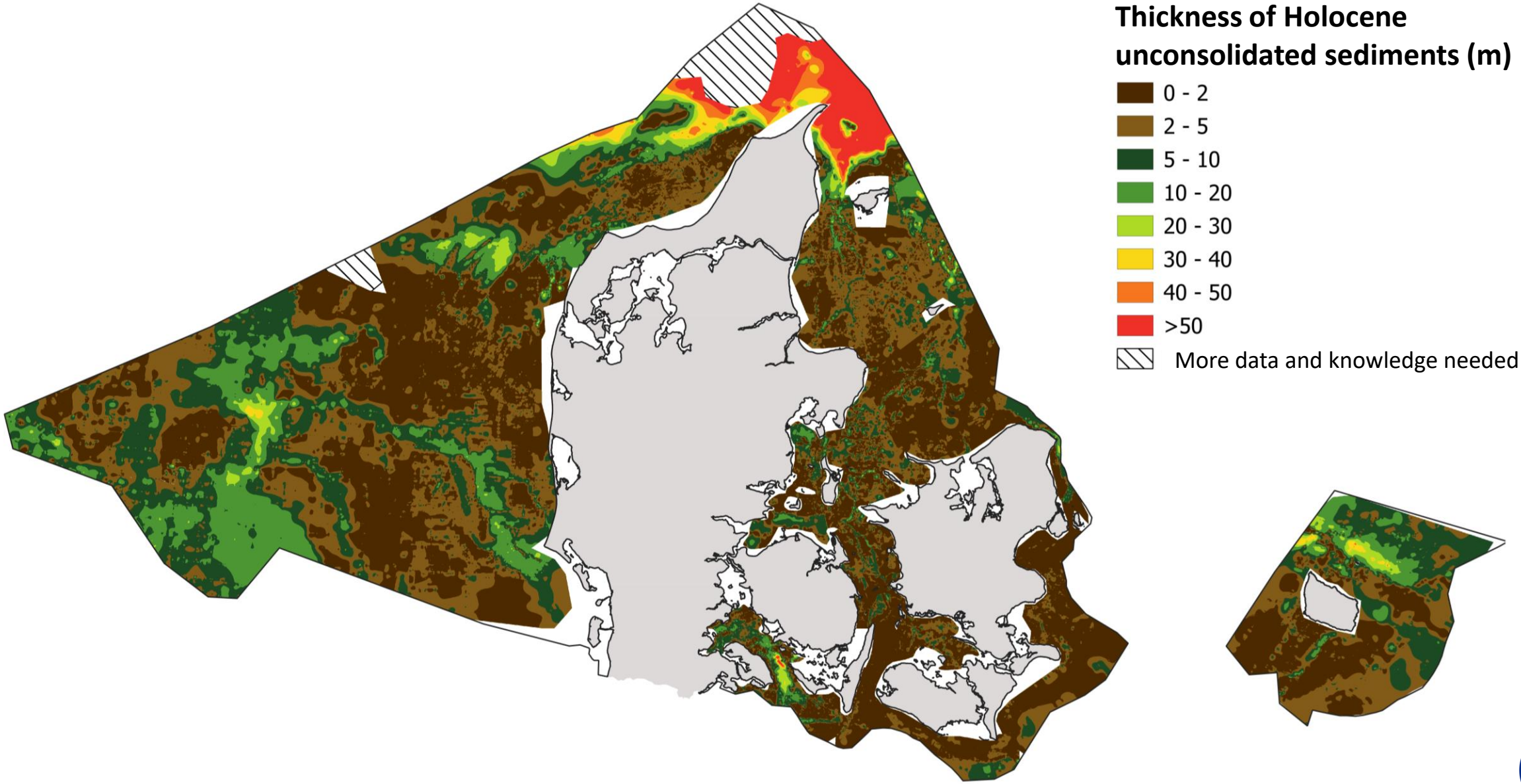
GEUS

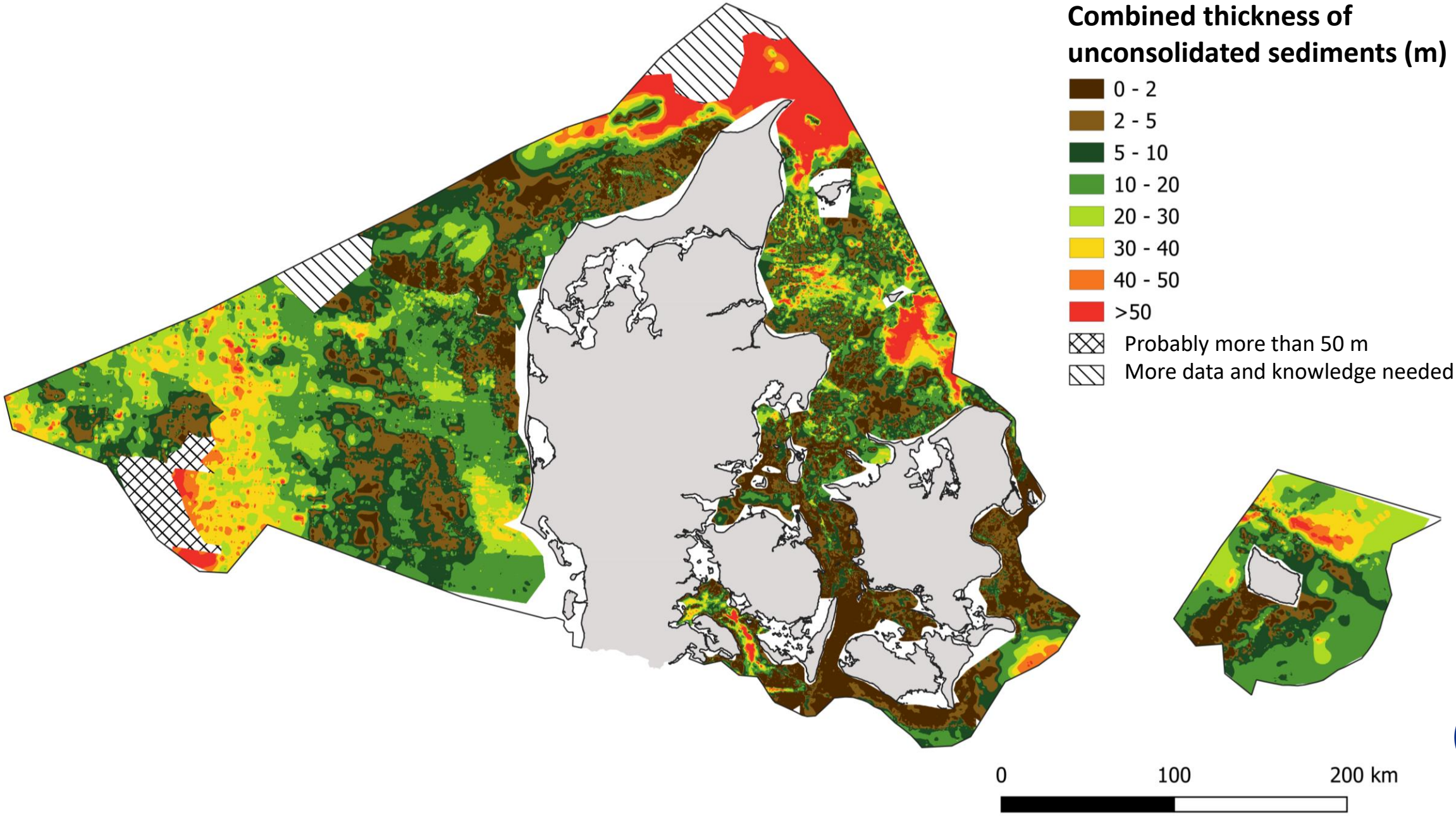
Southern Kattegat

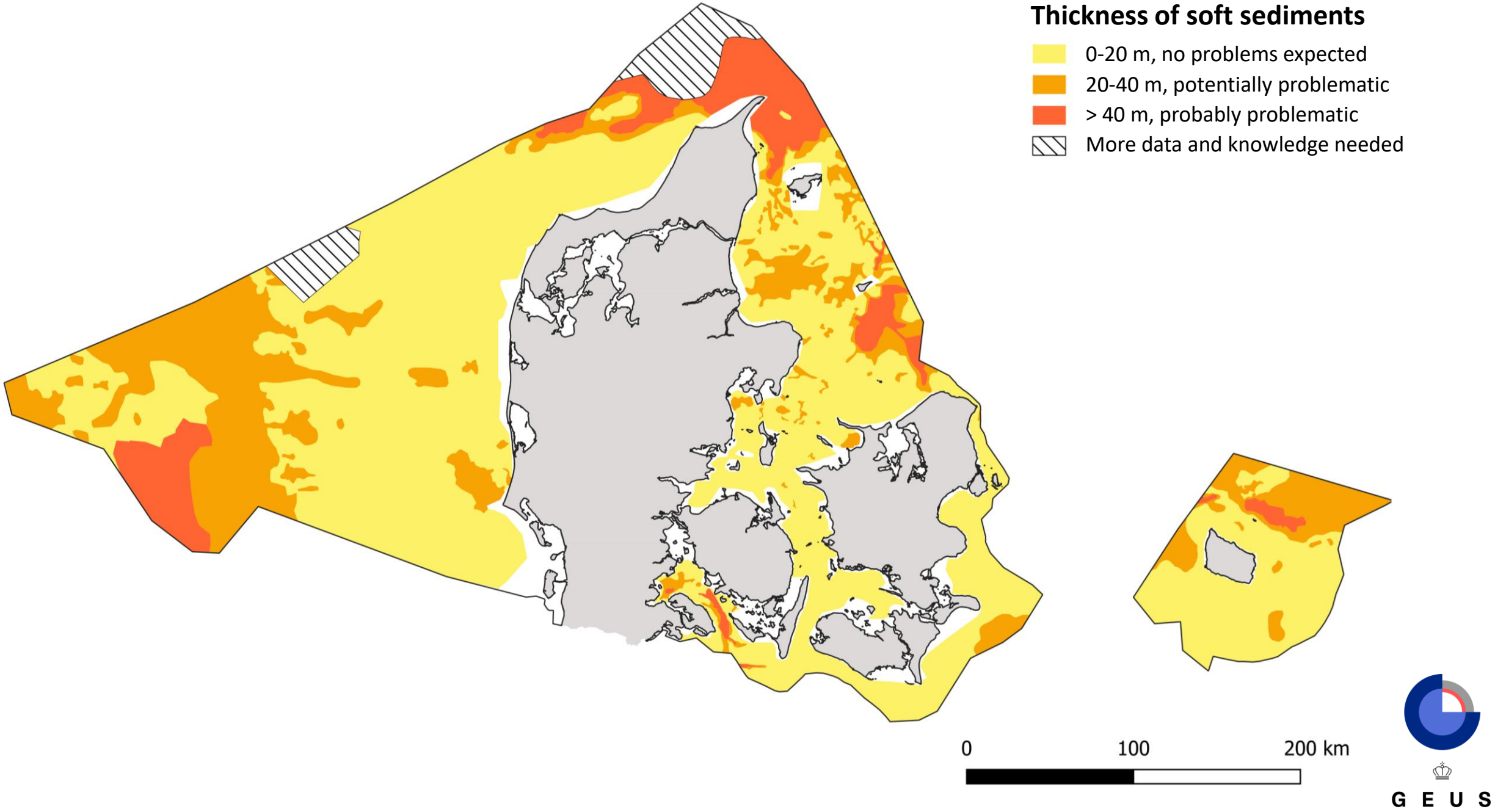


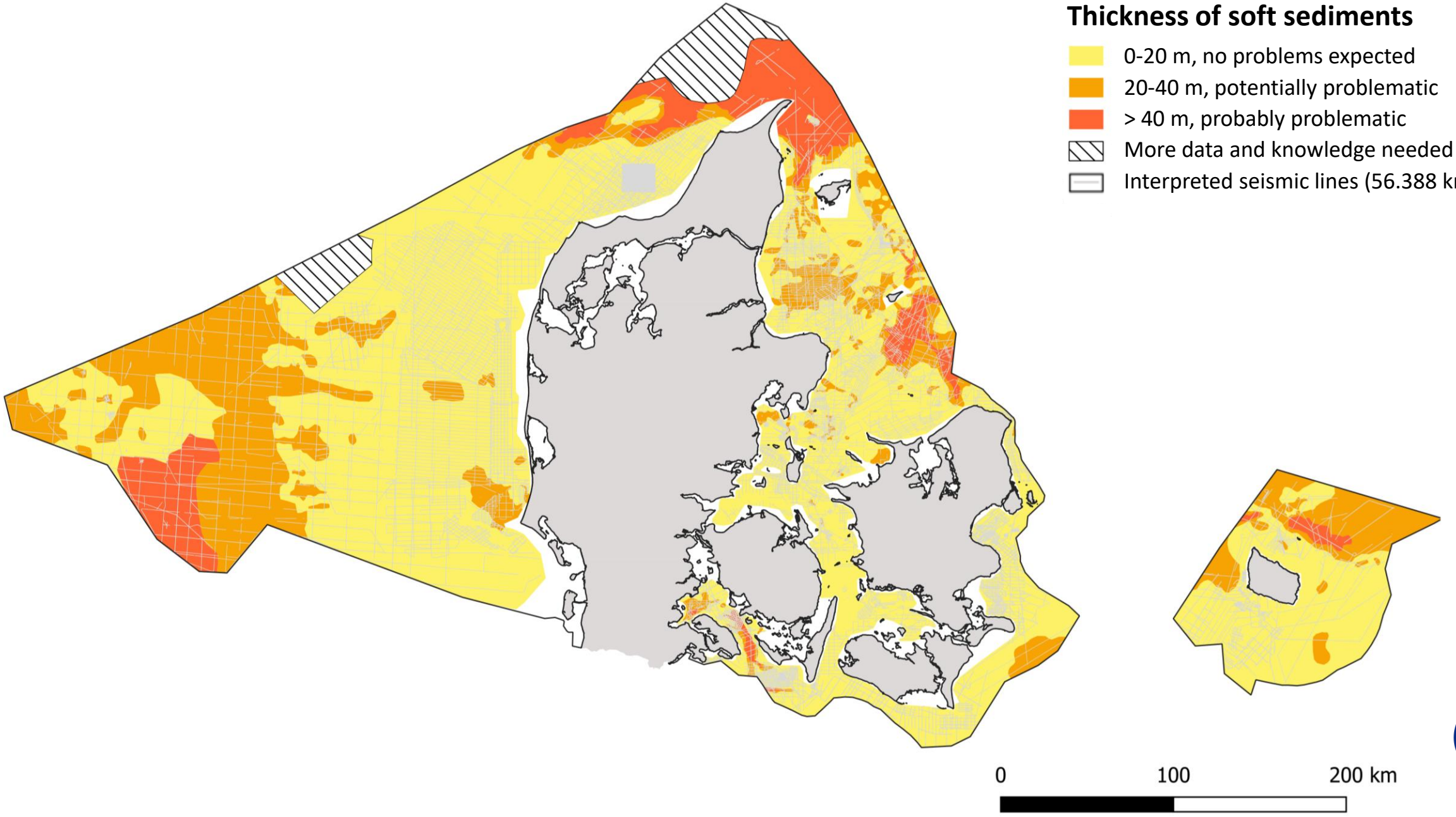
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Thickness of late glacial unconsolidated sediments (m)
0 - 2
2 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
>50
Probably more than 50 m
More data and knowledge needed
0
100
200 km
G E U S


Thickness of Holocene unconsolidated sediments (m)
0 - 2
2 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
>50
More data and knowledge needed
0
100
200 km
G E U S


Combined thickness of unconsolidated sediments (m)
0 - 2
2 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
>50
Probably more than 50 m
More data and knowledge needed
0
100
200 km
G E U S


Thickness of soft sediments
0-20 m, no problems expected
20-40 m, potentially problematic
> 40 m, probably problematic
More data and knowledge needed
0
100
200 km
G E U S


Thickness of soft sediments
0-20 m, no problems expected
20-40 m, potentially problematic
> 40 m, probably problematic
More data and knowledge needed
Interpreted seismic lines (56.388 km)
0
100
200 km
G E U S

Added value - Conclusions

The geological screenings provides:

- New and better seismic data
- Focus on overall mapping of geological units important for offshore wind development
- Focus on geological age (stratigraphy) and depositional history and environment, being important parameters for the initial evaluation of geotechnical properties and for later detailed investigations
- A solid (and necessary) basis for more detailed desk top screening studies prior to designation of wind farm areas
- Together with more detailed screening studies, a basis and geological framework for later detailed site investigations prior to tendering (successful approach on several occassions)
- Overview of areas not so well-suited for offshore wind from a geological perspective or more complex geology (important for developers to know geological complexity and predictability!)

The geological screening does not provide:

- With 5-10 km between seismic lines in some areas, it is a very overall and coarse geological mapping
- There are still areas with low, or no data coverage, e.g. in habitat areas
- No detailed mapping of geotechnical units and properties

Synergy with research projects:

- NOARG (North Sea tunnel valleys - Architecture, genesis, and prediction, Geocenter Danmark)
- WINDFARM (Wind infrastructure planning support, EUDP)

GEUS


Thank you for the attention!
GEUS