Geophysical survey results from Bjørnafjorden E39 project (West Norway) – an attempt to summarize 770 km of sub-bottom data

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Project Intro

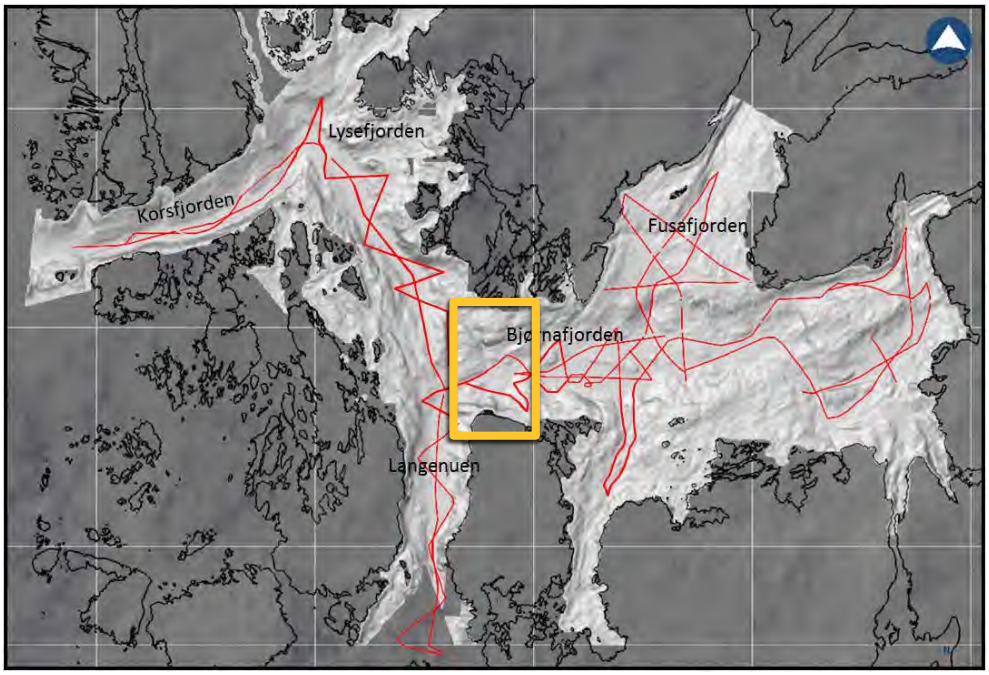
As part of the «ferry free E39» project (Norwegian Road Administration, https://www.vegvesen.no/Vegprosjekter/ferjefriE39/English) details of the seabed in Bjørnafjorden was required for the area that is planned to be crossed by bridge.

DOF Subsea Norway was tasked to perform detailed seabed mapping of bathymetry (dualhead multibeam) and sediments (sub bottom profiler). This survey work was performed in 2016 by using the vessel MV Geosund and Geocat.

DOF Subsea

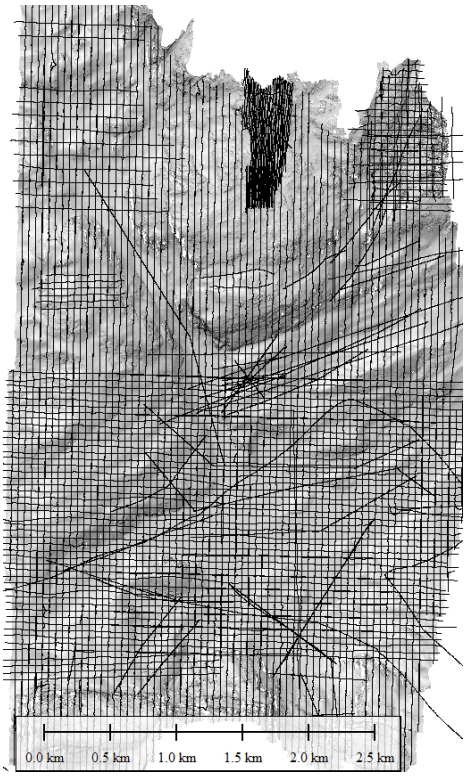
Statens vegvesen

Survey Overview
Sediments and geology
Slides
Visualisation
Summary



In addition to survey in main area (orange box), approx **250 km** of Sub-Bottom Data was aquired in surrounding area – for a regional overview of sediment

Sub-bottom Profiler Data



770 km of Sub-Bottom Data in a 18 km² Area

MBE 0.5 m resolution (50m line spacing North – South)

Black lines = SBP Survey lines

Survey – SBP Main objective

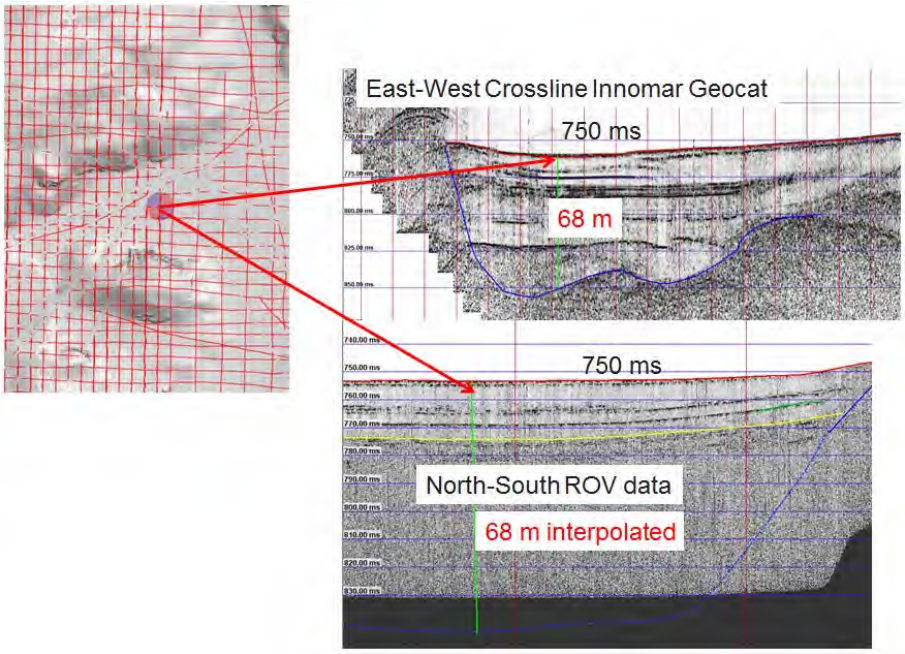
Sediment **amount**

Sediment **depositional process**

Sediment **distribution**

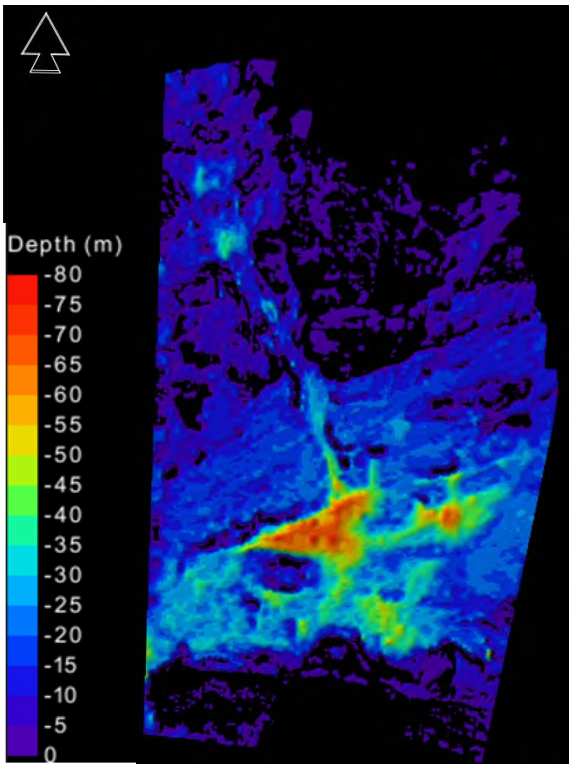
Sediment - Amount

For some areas with thick sediment deposits, the interpretation had to be done by interpolating between Hullmounted SBP and ROV SBP data



Interpretation using iXBlue Delph

Sediment - Amount



Geocap for creating isopach

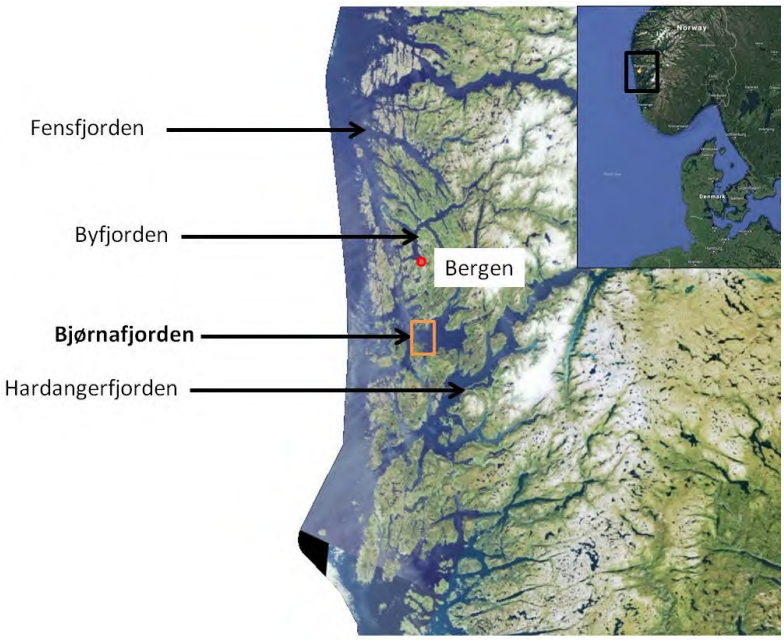
Sediment velocity of 1500 m/s

Up to 80 m of sediment infill

Sediment – Depositional Processes

In order to discuss depositional prossessess in Bjørnafjorden, we first need to look at studies done in nearby fjords – as no groundtruthing was available for Bjørnafjorden.

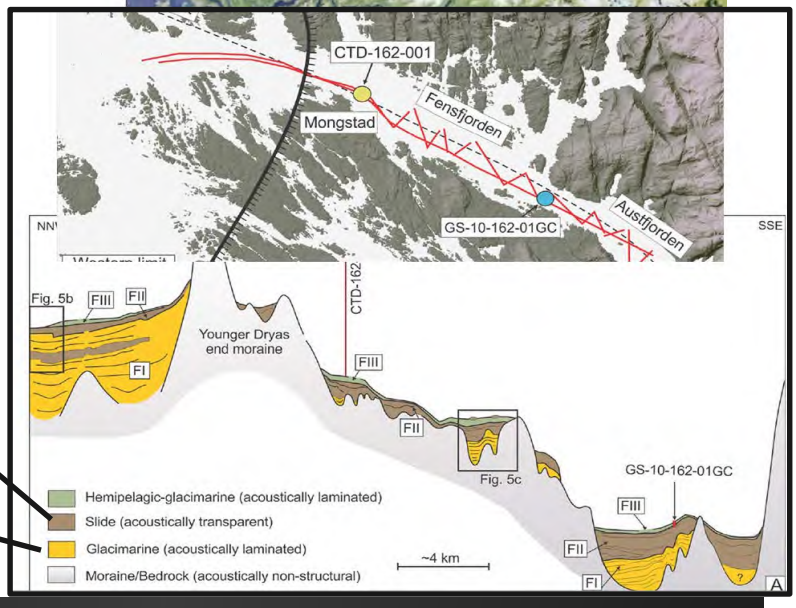
Will focus on conclusions only, for full reference please see last page



Hjelstuen et al. (2013)

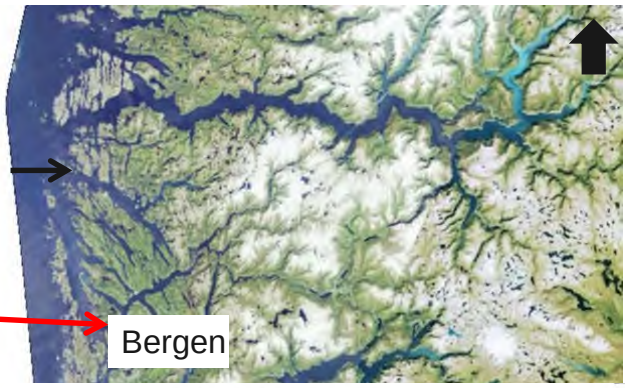
Fensfjorden

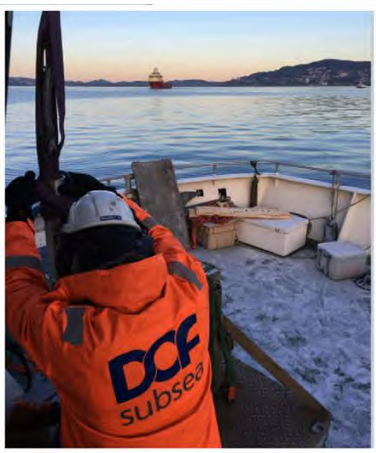
- Turbidites dated to 2040 and 1190 cal. Yrs BP
- Slide debrites (maybe related to rapid glaci-isostatic adjustments (earthquake)
- Glacimarine sediments, suggested Allerød age (ca 13 500 – 12 300 cal. Yrs BP)

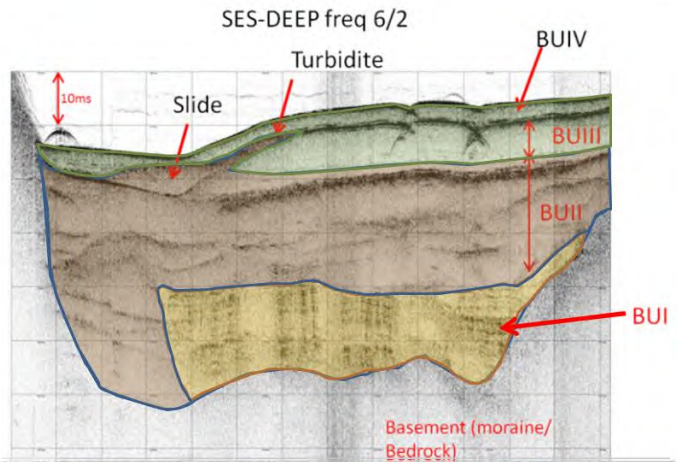


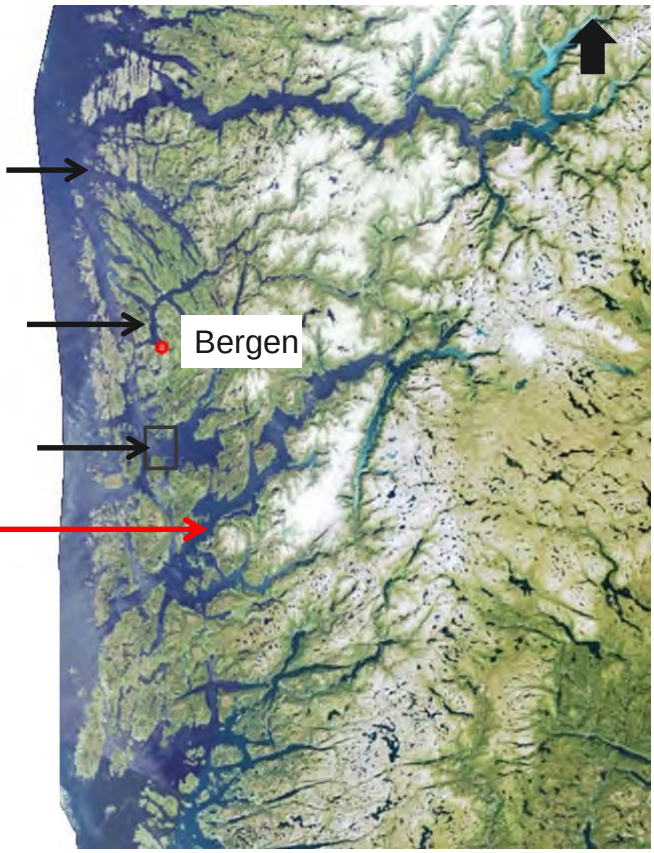
Hjelstuen et al. (2014)

- Youngest turbidite same age as the youngest in Fensfjorden (Earthquake)
- Earthquakes of M7 is inferred to occur every 1100 year in the Bergen area, M5 earthquakes every 10 year.









Bellwald et al. (2016)

Hardangerfjorden Bellwald et al. (2016)

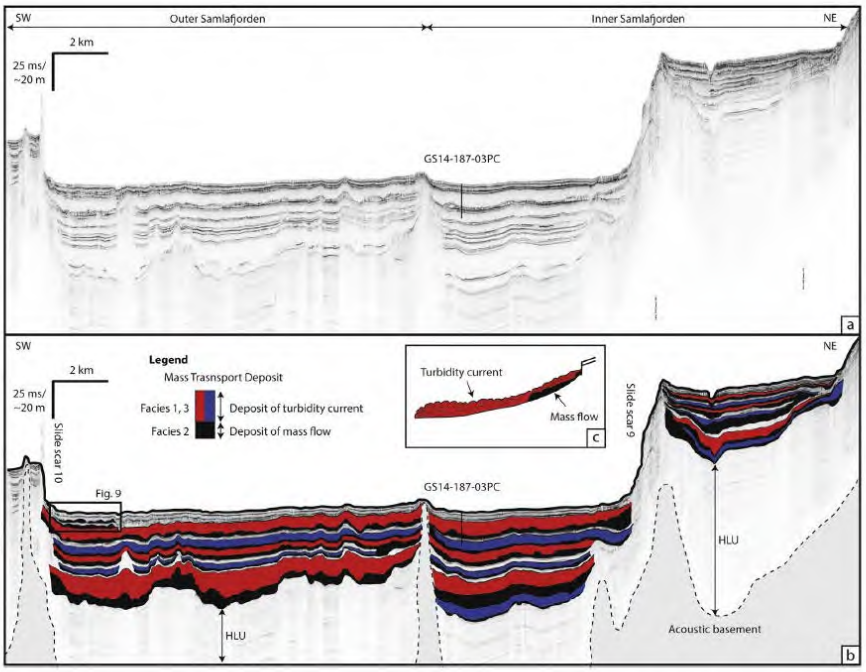
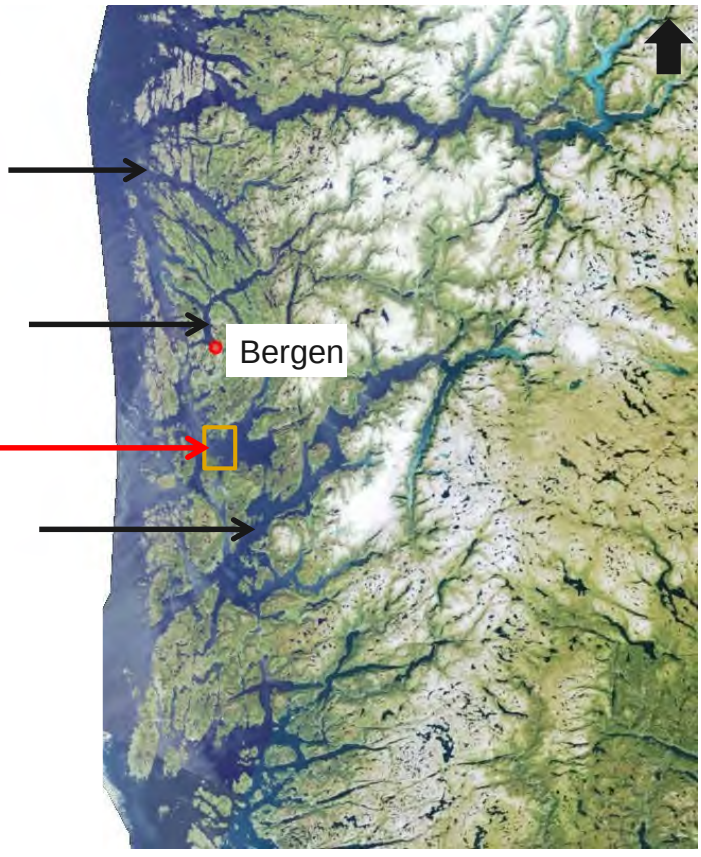


Fig. 6. (a) Seismic profile from Samlafjorden. Profile location in Fig. 5. (b) Interpretation of seismic profile from Samlafjorden showing the character of the Hardangerfjorden Lower Unit (HLU) and Hardangerfjorden Upper Unit (HUU). (c) Schematic model of suggested mass wasting process.

- Two main units described (lower unit: mainly glacimarine, upper unit: slide deposits mainly)
- 19 Mass flow slide events observed
- Schematic mass flow slide model

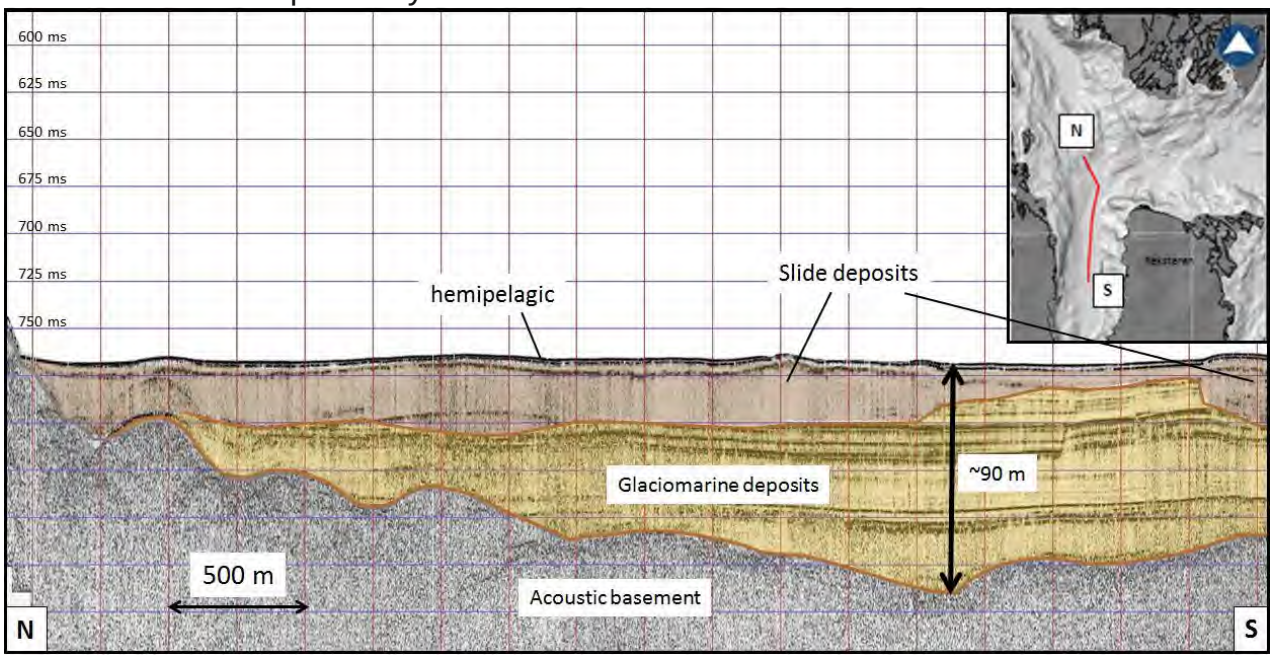
Bjørnafjorden

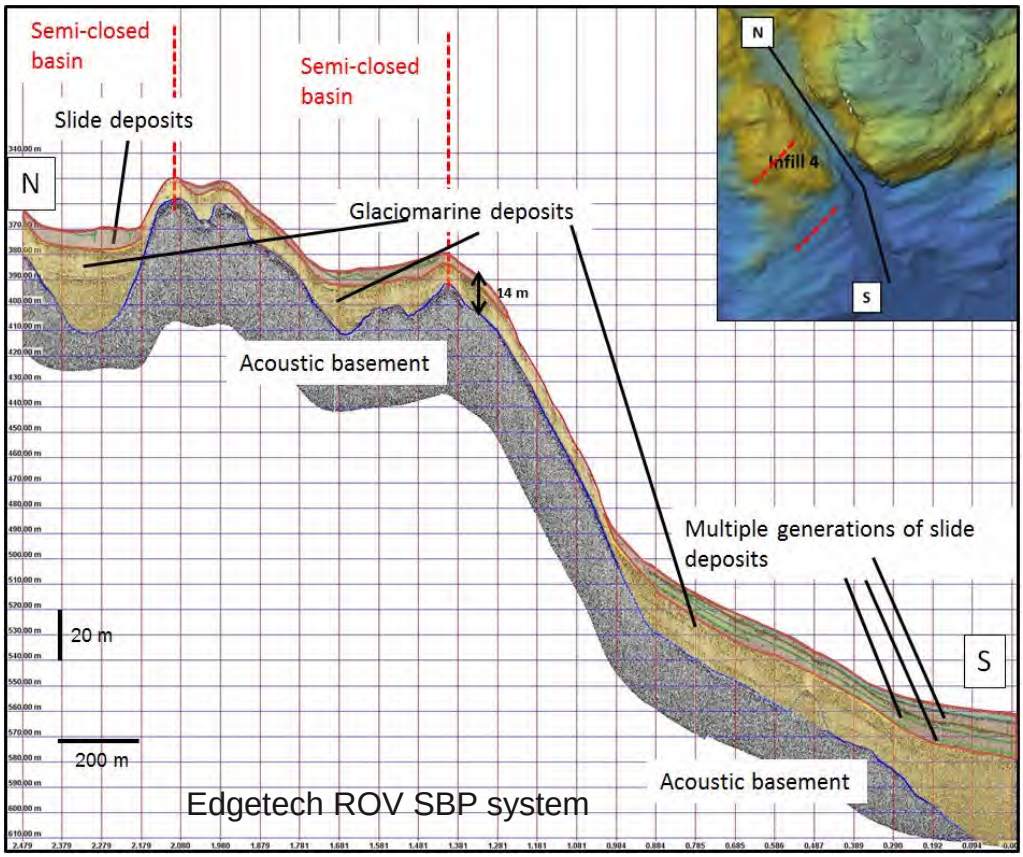
And then Bjørnafjorden and DOF Subsea results from the survey campaign done 2016 for the Norwegian Road Administration



Bjørnafjorden SBP Examples

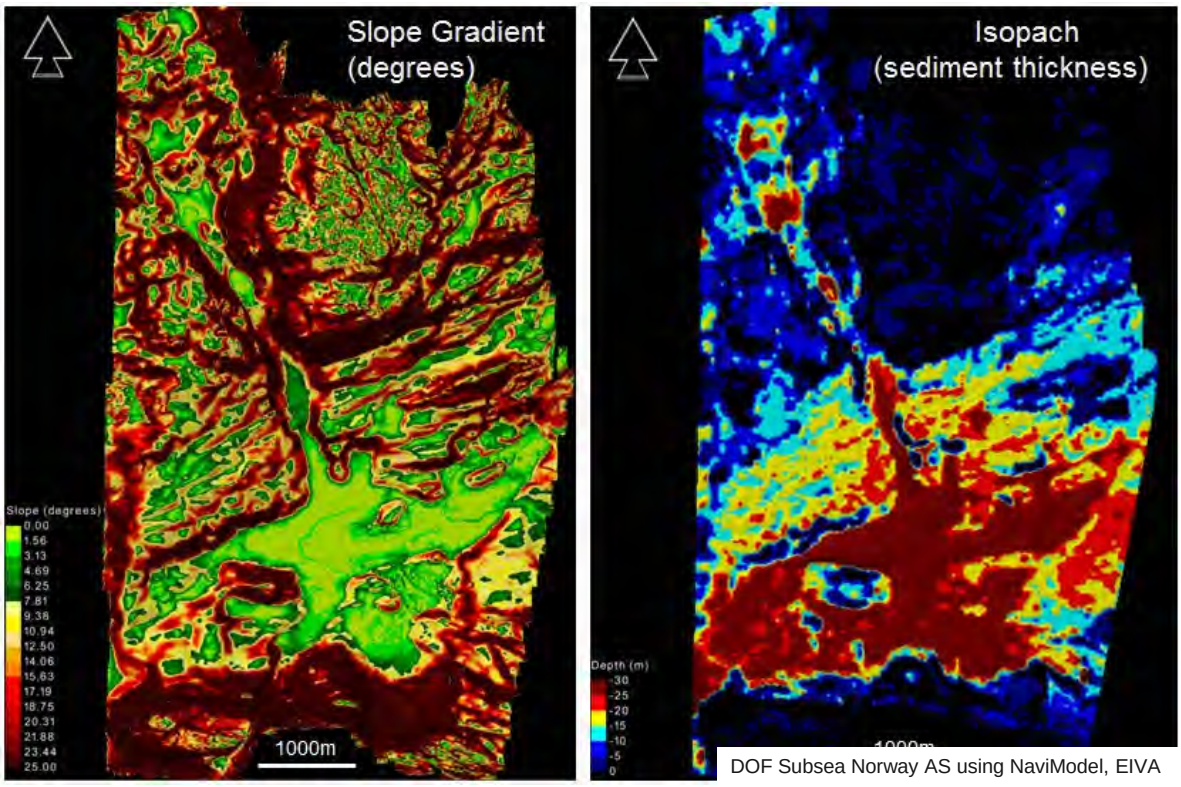
Innomar Deep SBP system





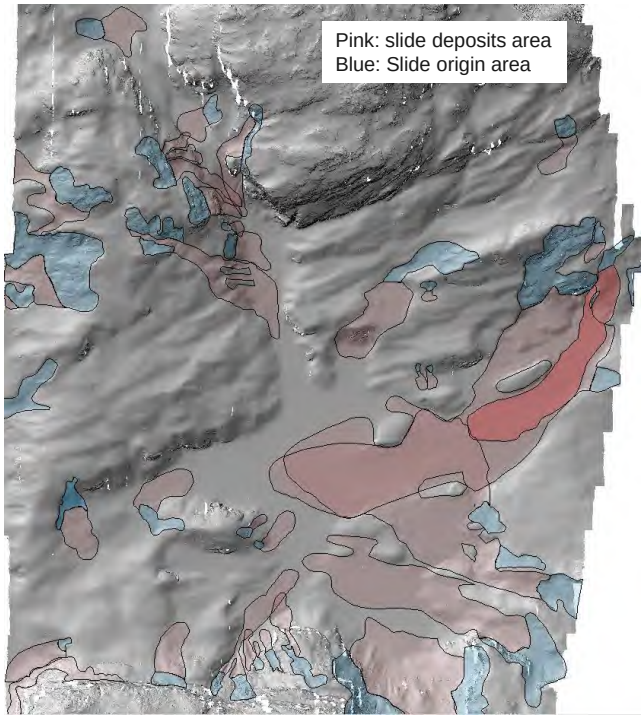
Download: www.innomar.com/seabed-acoustics-2017.php

Sediment - Distribution



DOF Subsea Norway AS using NaviModel, EIVA

Slides (mass flow)



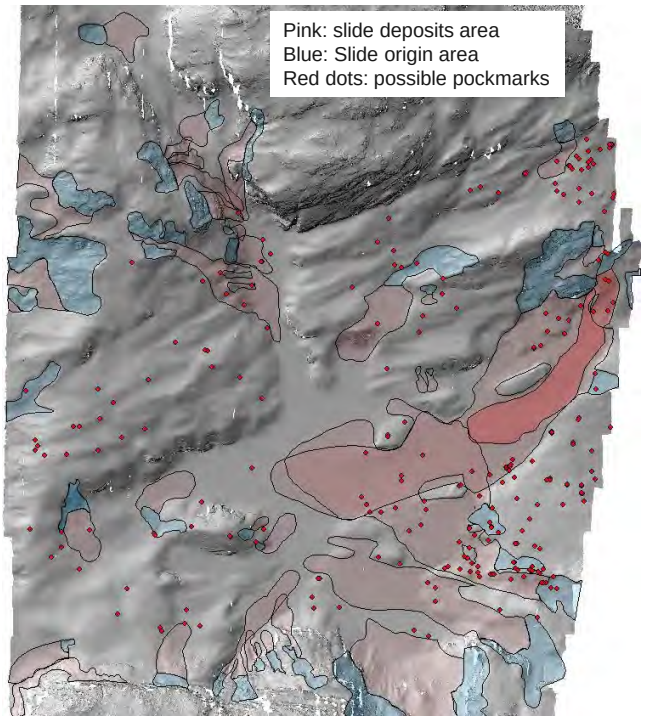
Bridge anchoring:

- Slope stability
- Future slides?

Observations:

- > 40 individual surficial slide events from MBE
- Mainly from localities with gradient slopes >20°
- Affected the entire sediment succession

Slides



Trigger mechanism?

General pre-conditional factors for slides to occur:

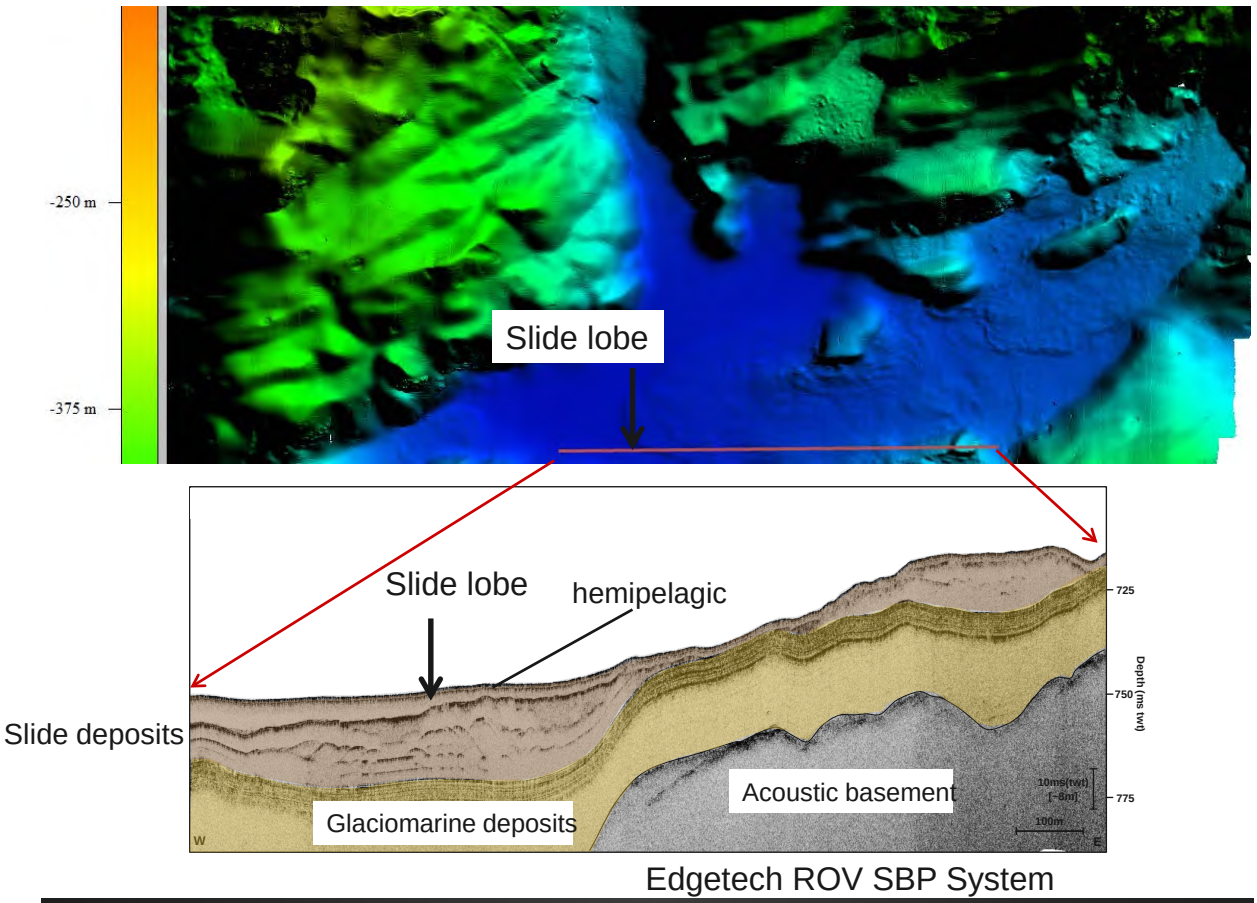
- **High sedimentation rate**
- Unfavorable soil layering
- «Weak layers»/ slip plane
- Over-steepening
- **Artesian pressure**
- **Fluid-flow/ Fluid escape**

Slides – trigger mechanism?

High sedimentation rate probably during deglaciation (Bellwald et al, 2016), and possible pockmarks observed in the area (porewater from groundwater/ fluid escape?) – however not observed any clear direct link between pockmarks and slide.

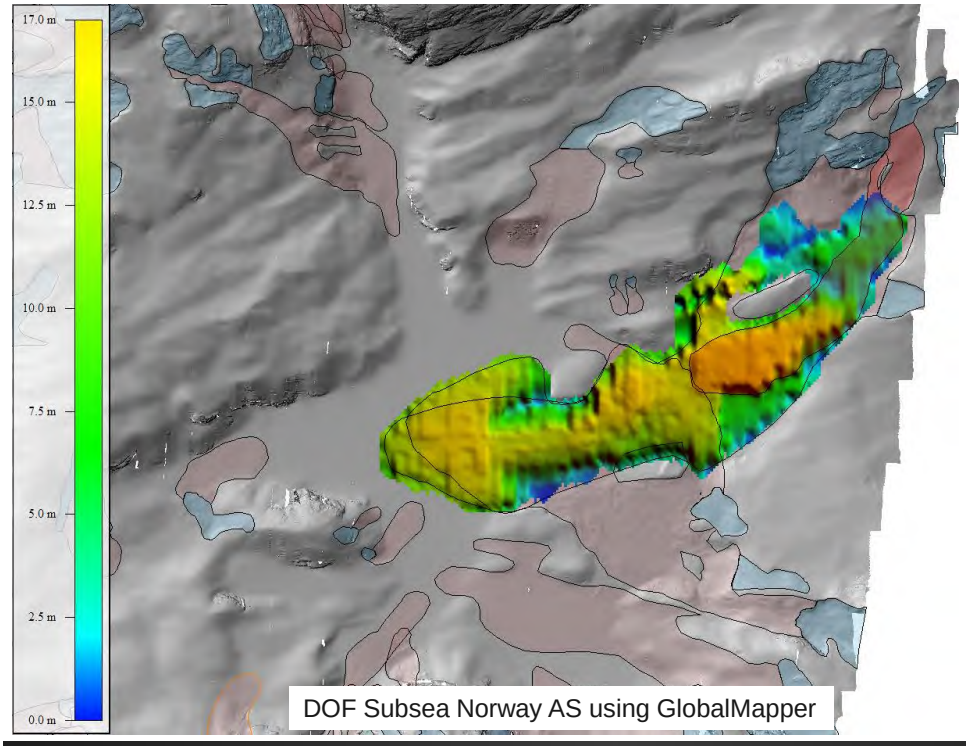
Further no over-steepening observed, nor «weak layers» observed either – hence earthquake is suggested to be most significant trigger mechanism

Slope angles versus thickness of deposits are suggested as main focus for any future slide events.

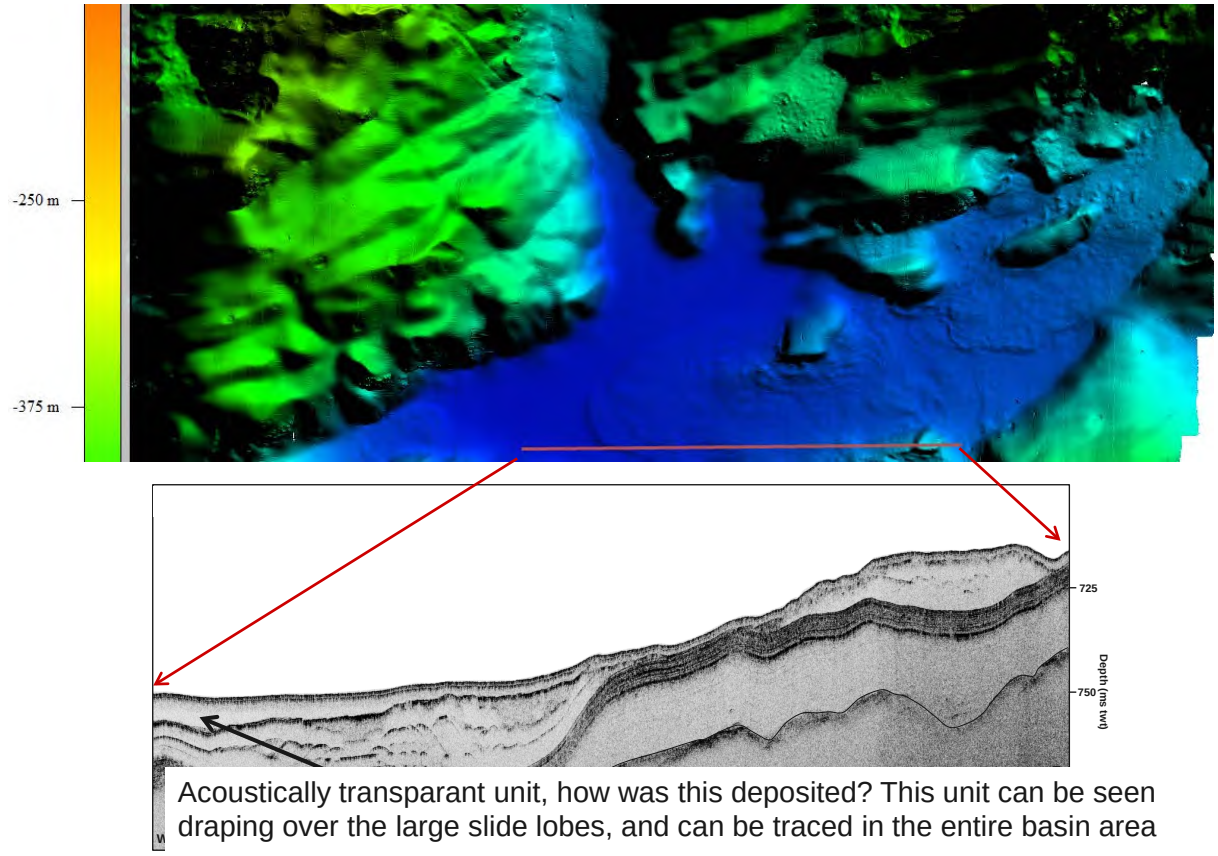


Edgetech ROV SBP System

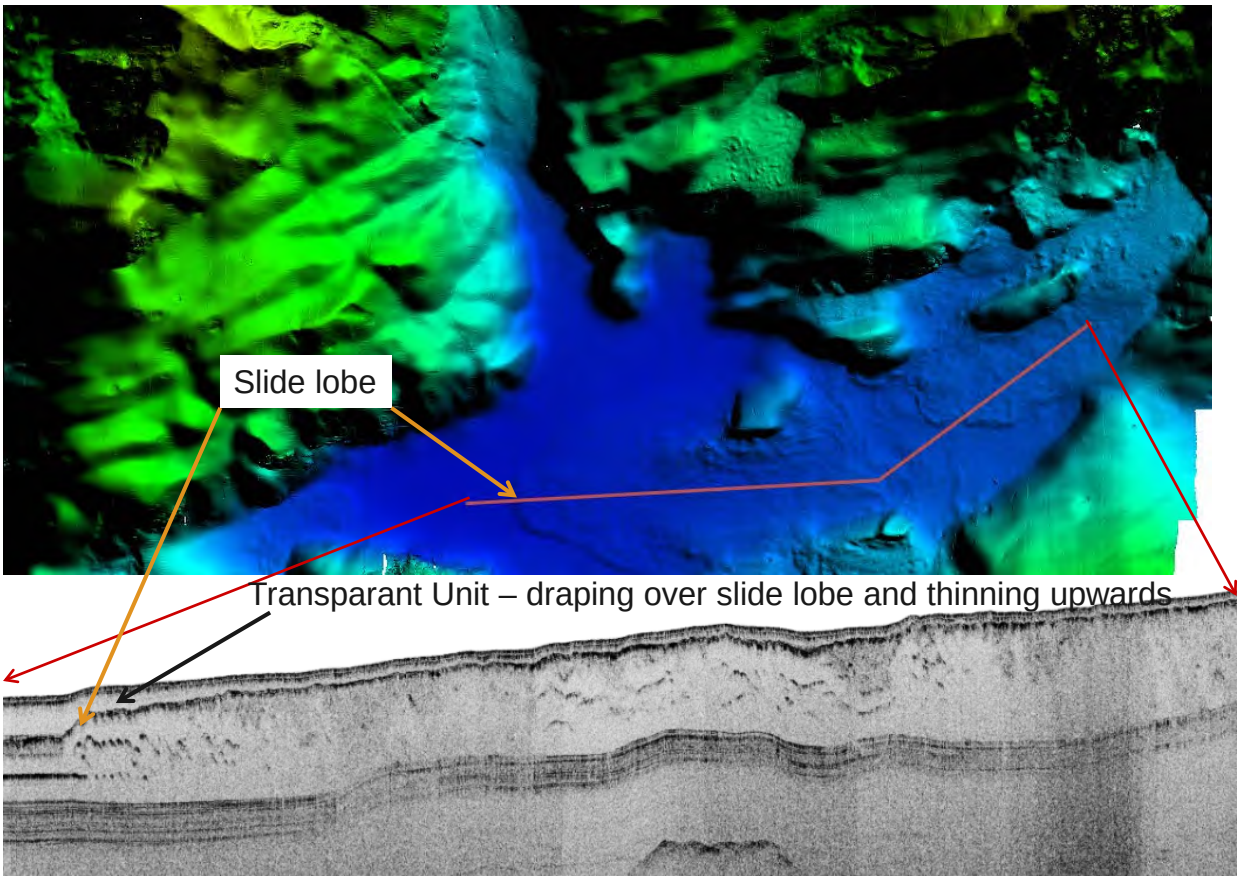
Visualisation – thickness model as a tool to visualize/ understand deposition



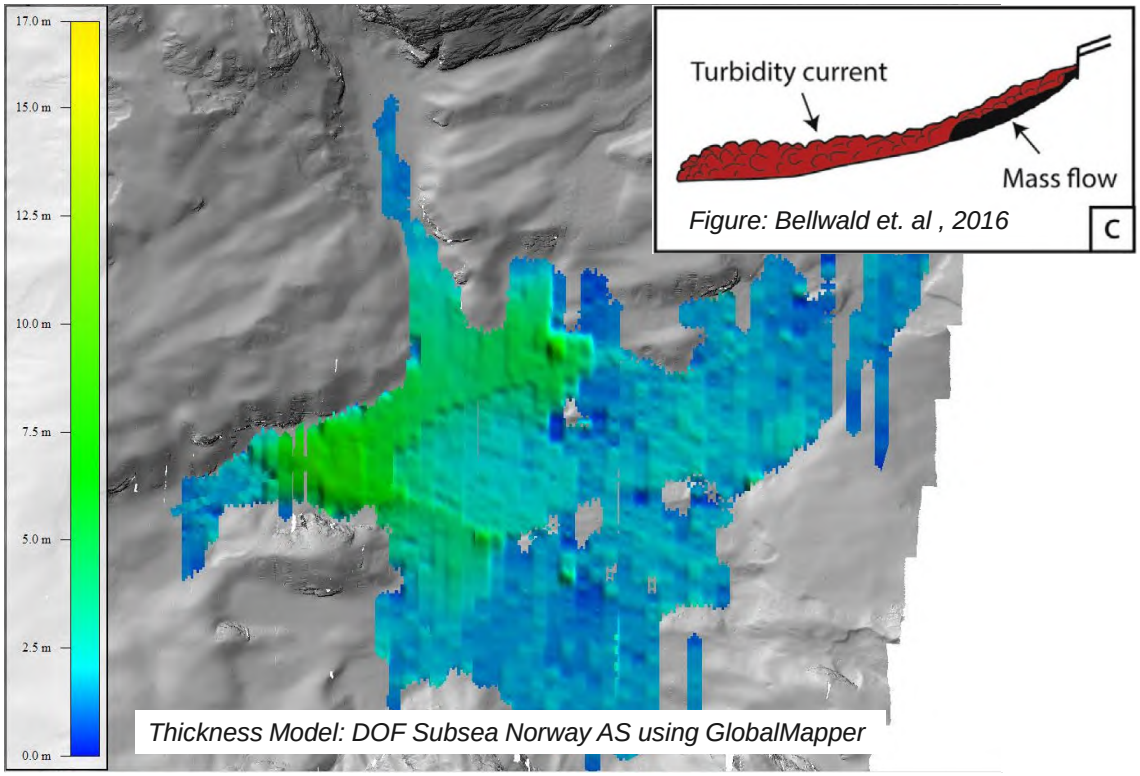
Thickness model of slide deposits



Acoustically transparant unit, how was this deposited? This unit can be seen draping over the large slide lobes, and can be traced in the entire basin area



Thickness model of transparant unit in the basin area (ref. previous example). Possible turbidite?



Conclusions – Bjørnafjorden Main Area

- Up to 80 m thick sediment package deposited during and after withdrawal of the Late Glacial Maximum ice sheet in survey area
- Sediment deposition history within Bjørnafjorden is consistent with observation from other nearby West Norwegian fjord systems
- > 40 individual slide events are located within the survey area, and significant amount of sediments still preserved on the slopes
- Earthquake is considered to represent the most dominant trigger mechanism for the slide events in Bjørnafjorden
- The result of this project comprise an unique high-resolution dataset (MBE/ SBP) in terms of study of fjord stratigraphy (history of sediment deposition/ deglaciation history)
- Scientific article based on the survey results were published June 2017: Solli et al., 2017: Detailed site survey examining the postglacial sediment succession and depositional processes within a Norwegian fjord system, Bjørnafjorden (West Norway), NORWEGIAN JOURNAL OF GEOLOGY Vol 97 Nr. 2, https://dx.doi.org/10.17850/njg97-2-02

THANK YOU!!

Reference:

- Bellwald B, Hjelstuen BO, Sejrup HP, Haflidason H. 2016. Postglacial Mass Failures in the Inner Hardangerfjorden System, Western Norway. In *Submarine mass movements and their Consequenses,* Lamarche G et al. (eds). Advances in Natural and Technological Hazards Research 41.
- Hjelstuen BO, Kjennbakken H, Bleikli V, *et al.* 2013. Fjord stratigraphy and processes – evidence from the NE Atlantic Fensfjorden system. *Journal of quarternary Science* **28** (4): 421-432.
- Hjelstuen BO and Brendryen J, 2014. Submarine Mass Movements and Trigger Mechanisms in Byfjorden, Western Norway. In *Submarine Mass Movements and Their Consequences,* Krastel S et al. (eds). Advances in Natural and Technological Hazards Research 37.