

# Deeply weathered and fractured basement on the Norwegian shelf: What can we learn from onshore Norway?

Marco Brønner

Force seminar, Underexplored Plays III,  
Oct. 31st, Stavanger

Metamorphic Proterozoic saprolite

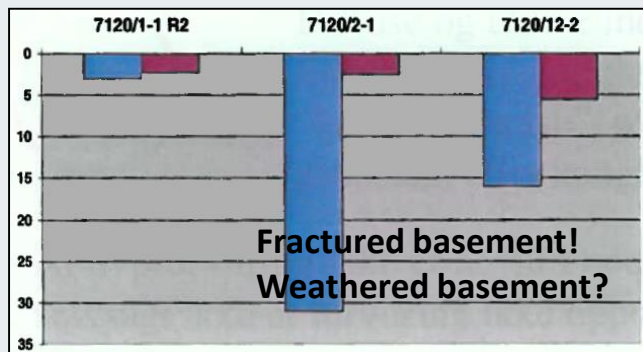
Foto: I. Lindahl

- **What can we gain from offshore observations and what are we missing?**
- **Onshore-offshore correlation:**
  - Type and age of weathering
  - Bedrock characterization
  - Basement fracturing
- **Onshore observation:**
  - Sub-seismic resolution fractures
  - Identify basement fracturing systems

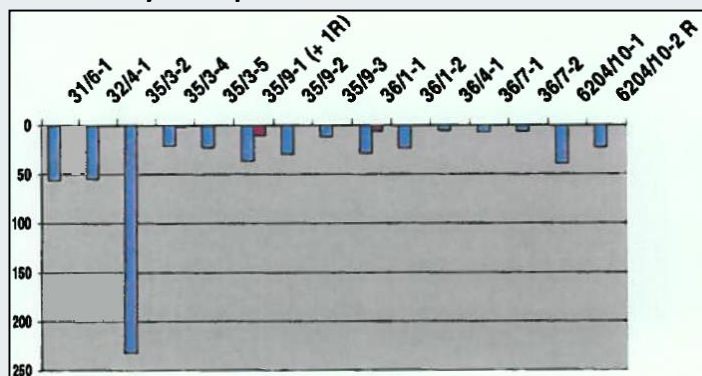


# Basement characterisation offshore

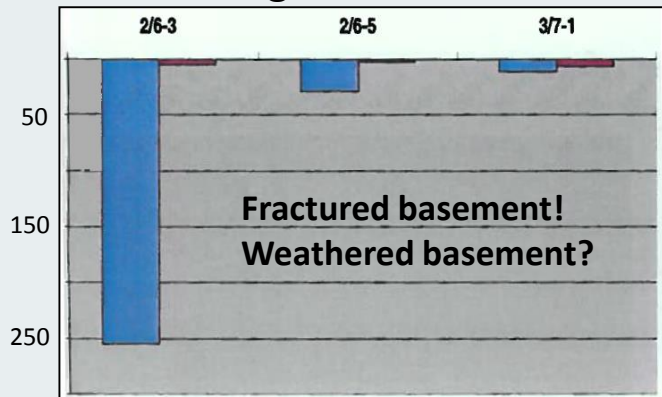
## Western Barents Sea



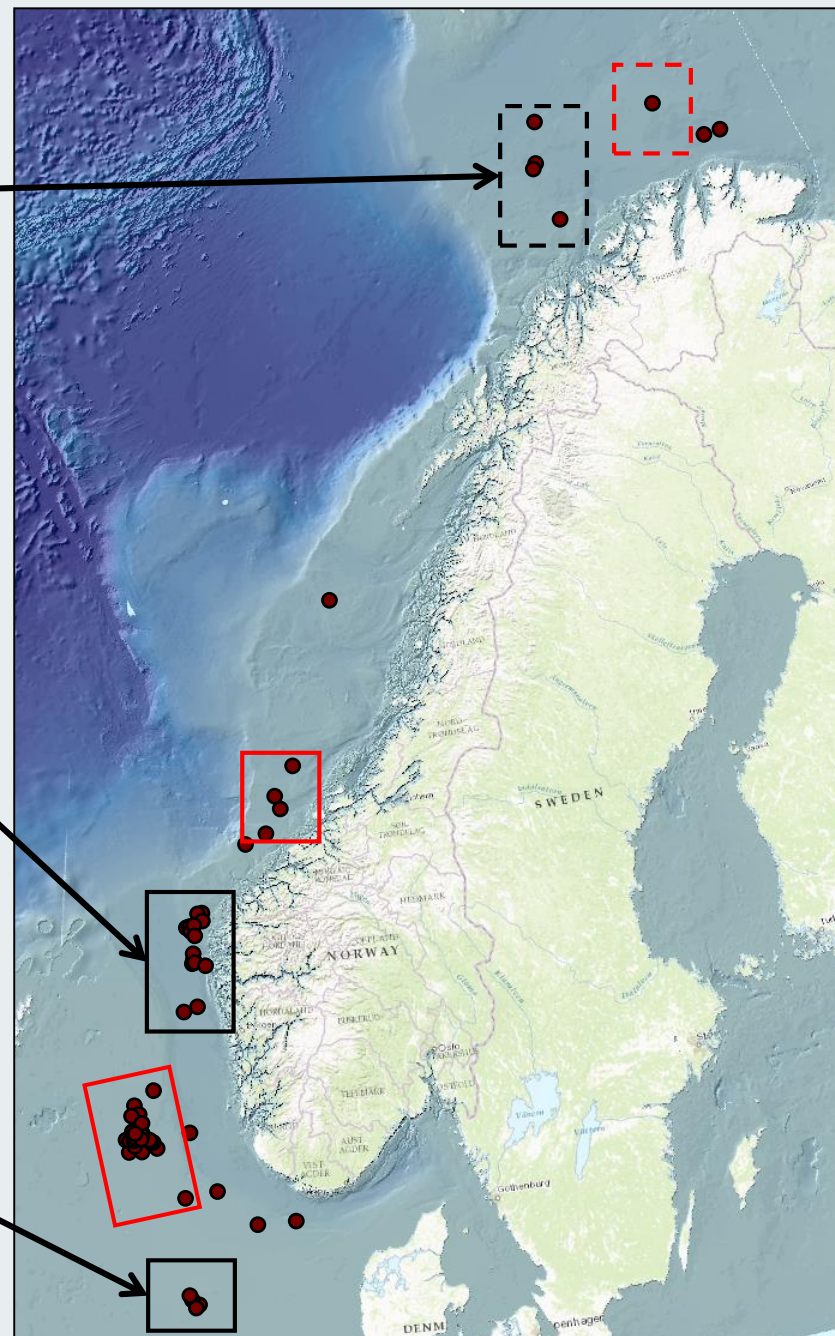
## Måløy Slope



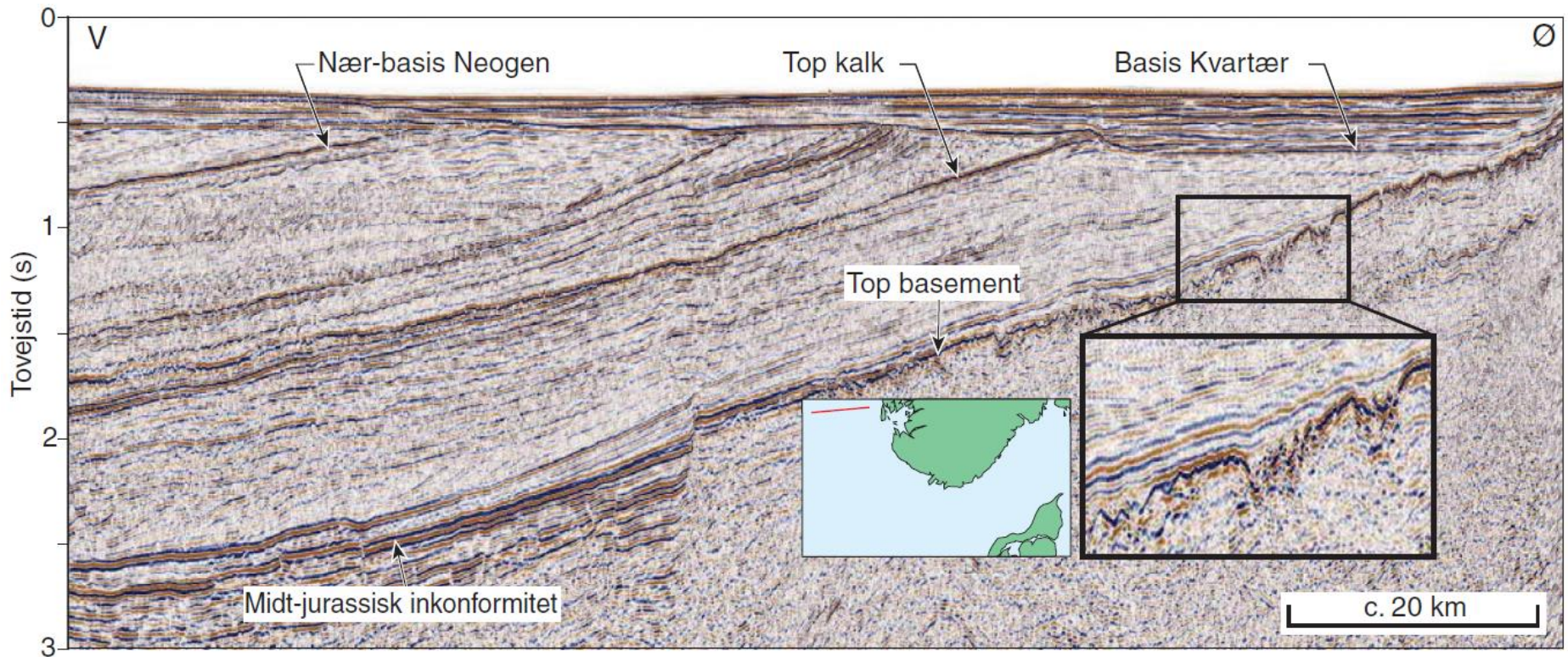
## Mandal High



Courtesy Jon-Arne Øverland

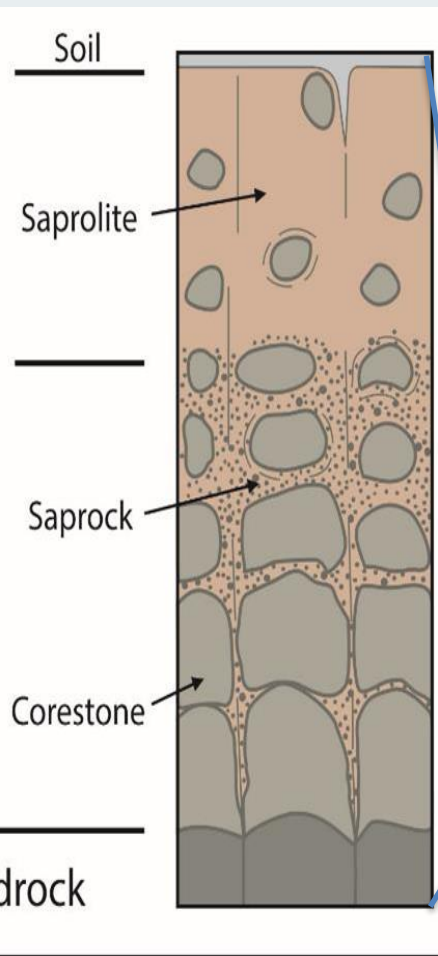


# Evidence of deep weathering on seismic data on the Stavanger Platform

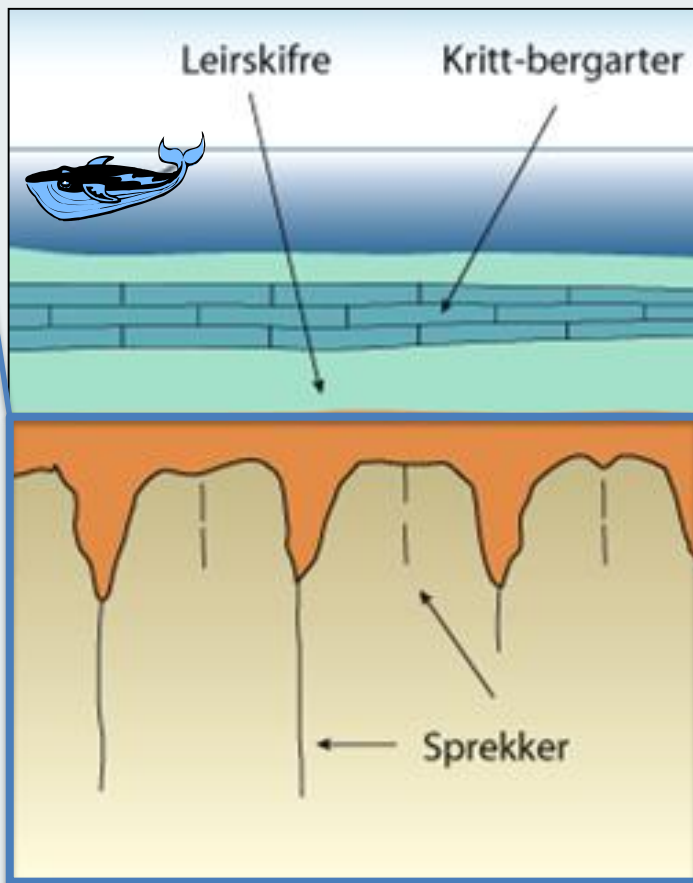


Lars Nørgaard Jensen (from Japsen et al. 2008)

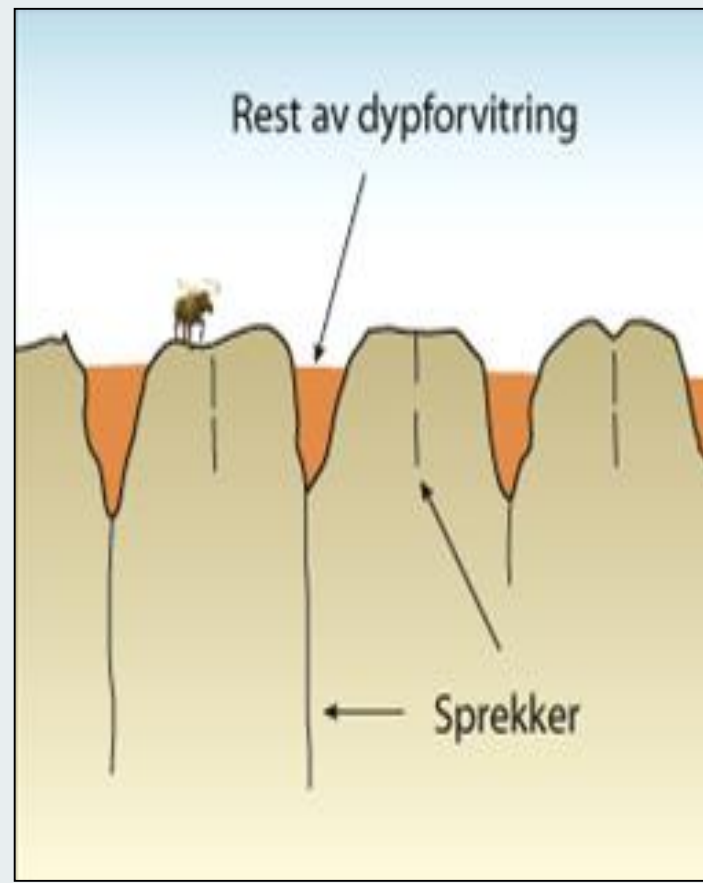
# Suggested concept



offshore



onshore



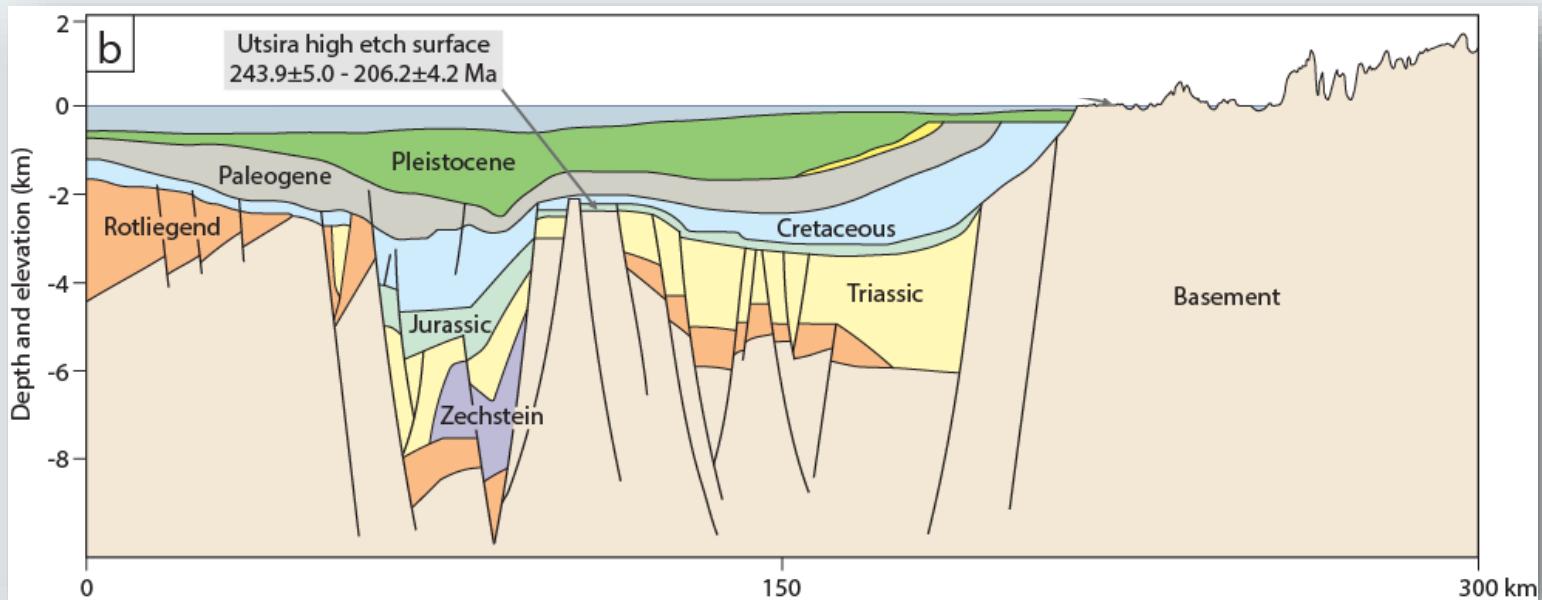
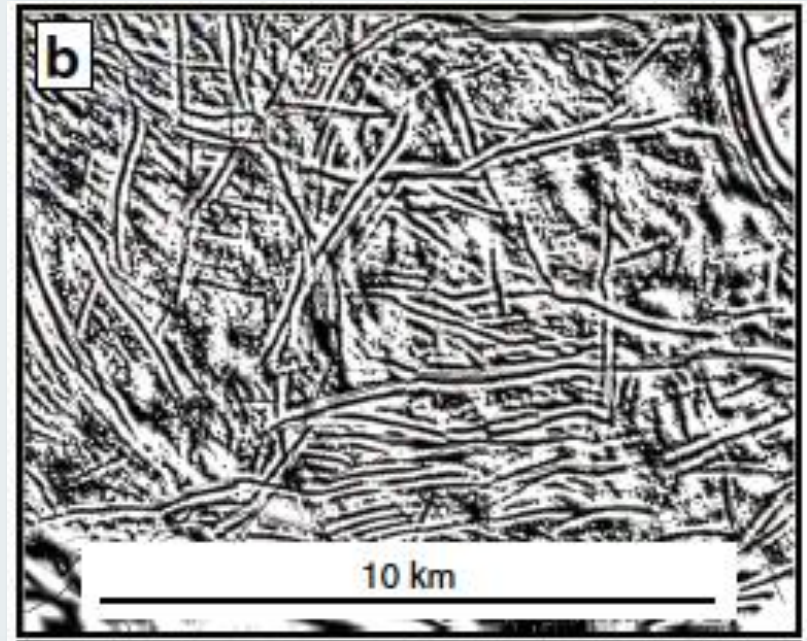
Modified from Lidmar-Bergström et al. 1999

Nesbitt 1979



Utsira Top basement interpretation (by Lundin)

# Offshore etch surface

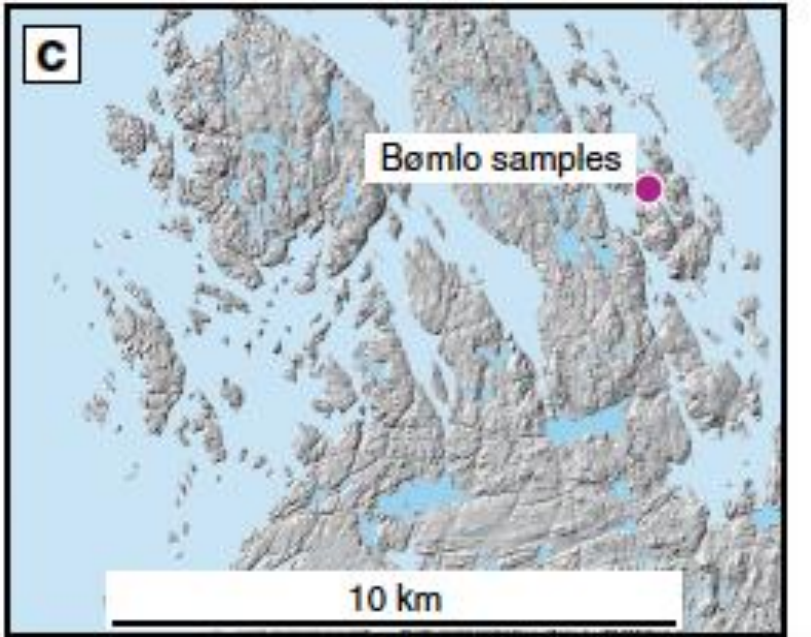


Modified after Fredin et al. (2017)

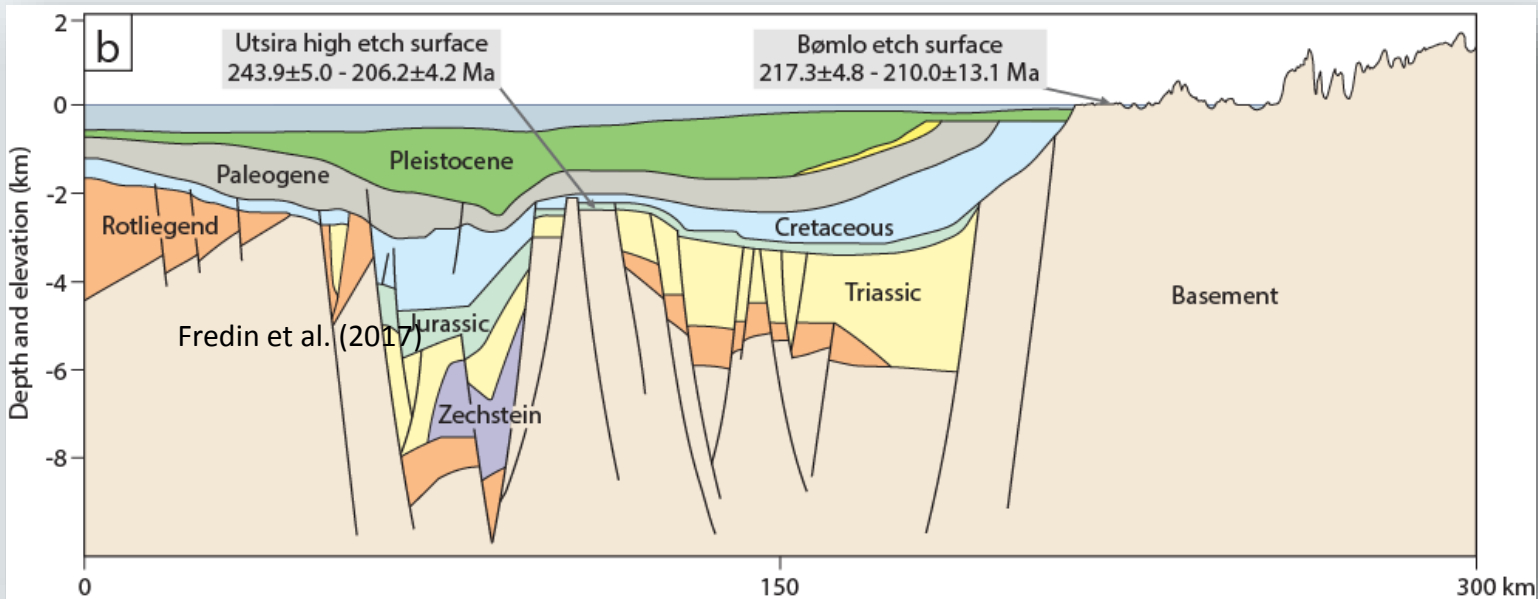
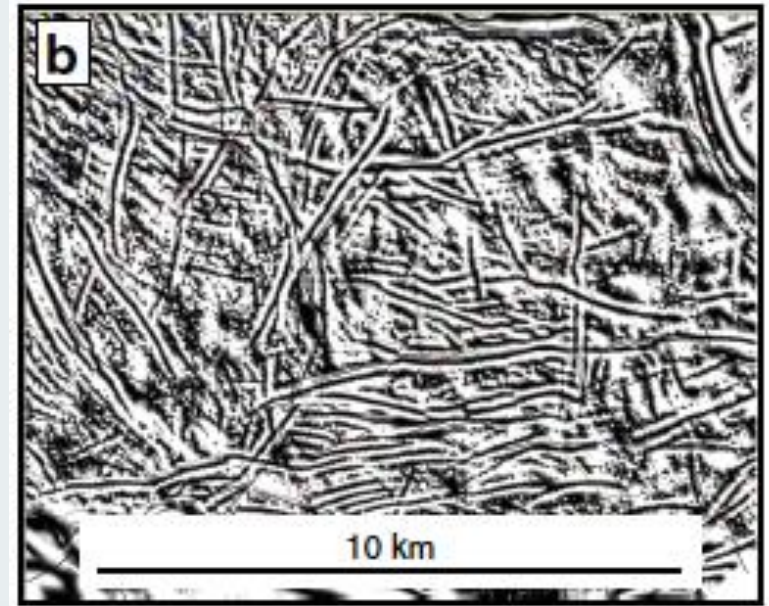


# Onshore-offshore correlation

Bømlo Etch surface



Utsira Top basement interpretation (by Lundin)

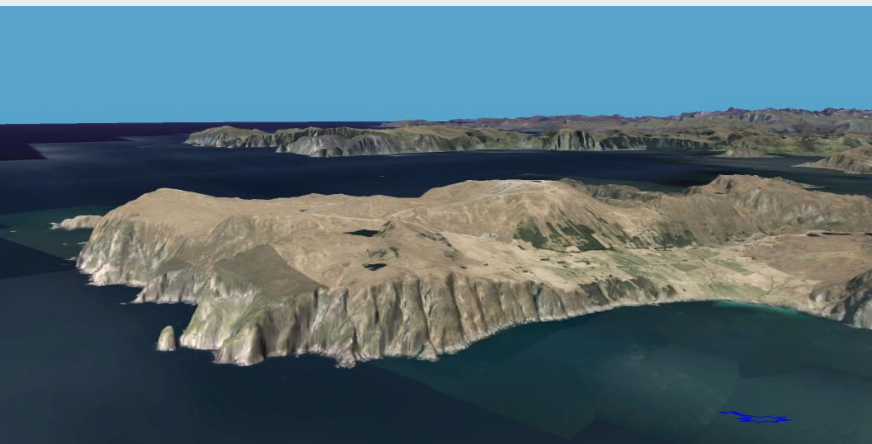


Modified after Fredin et al. (2017)

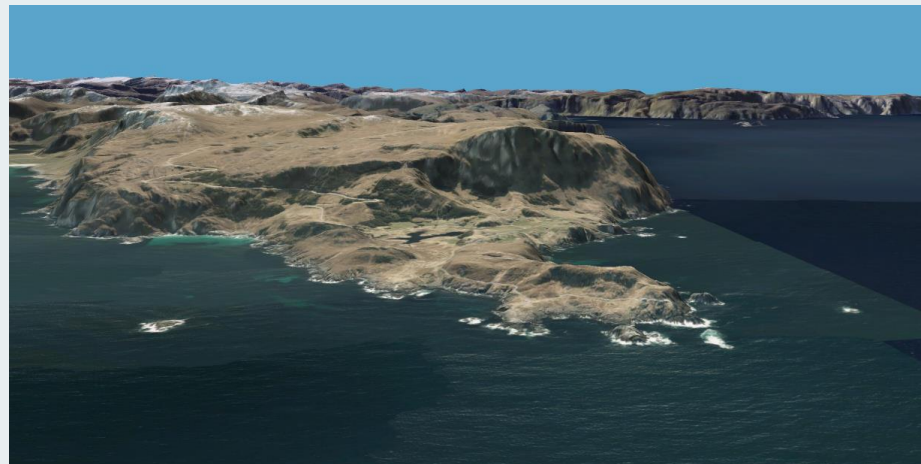


# Old erosion surfaces at Stadlandet and Vågsøy and on Frøya High

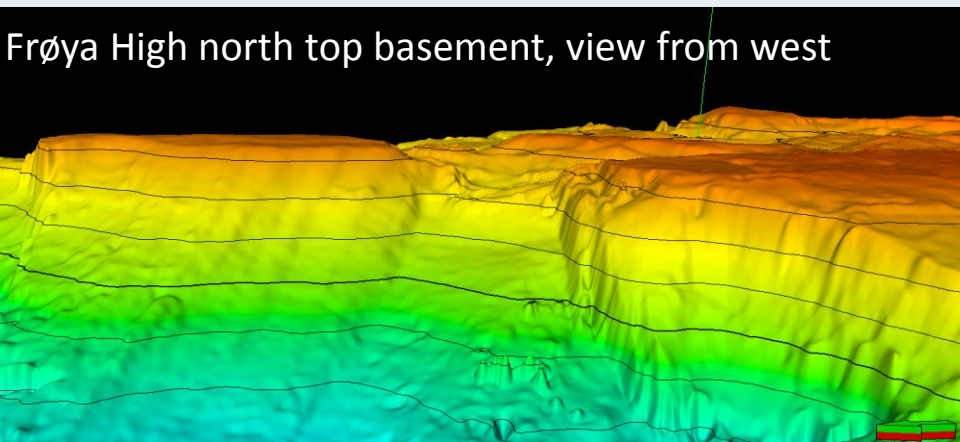
Peneplain Vagsøy, Stadlandet, view from west



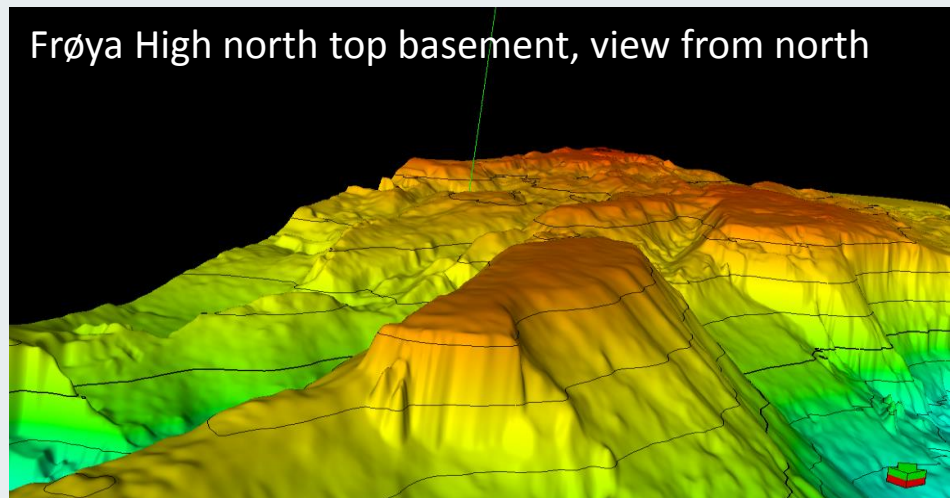
Peneplain Vagsøy, view from north



Frøya High north top basement, view from west

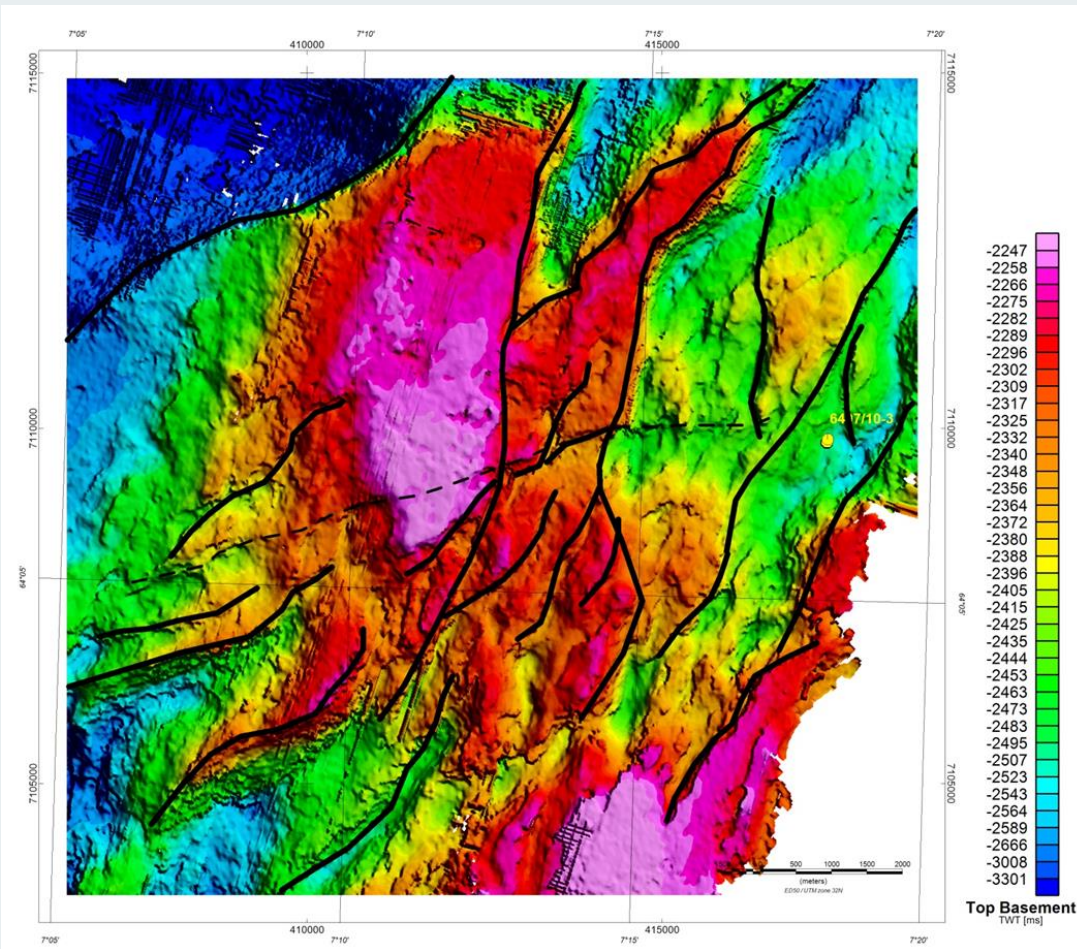


Frøya High north top basement, view from north

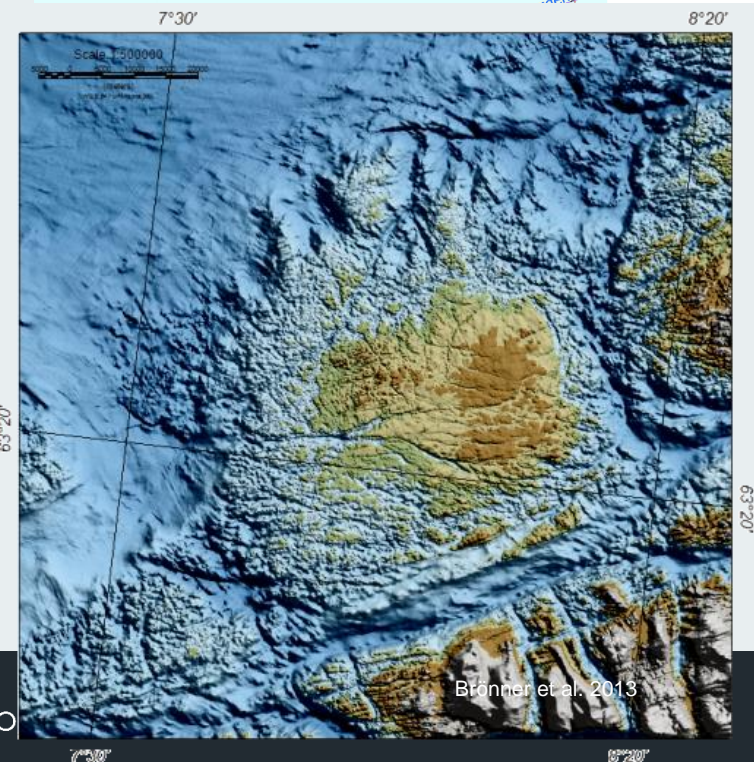
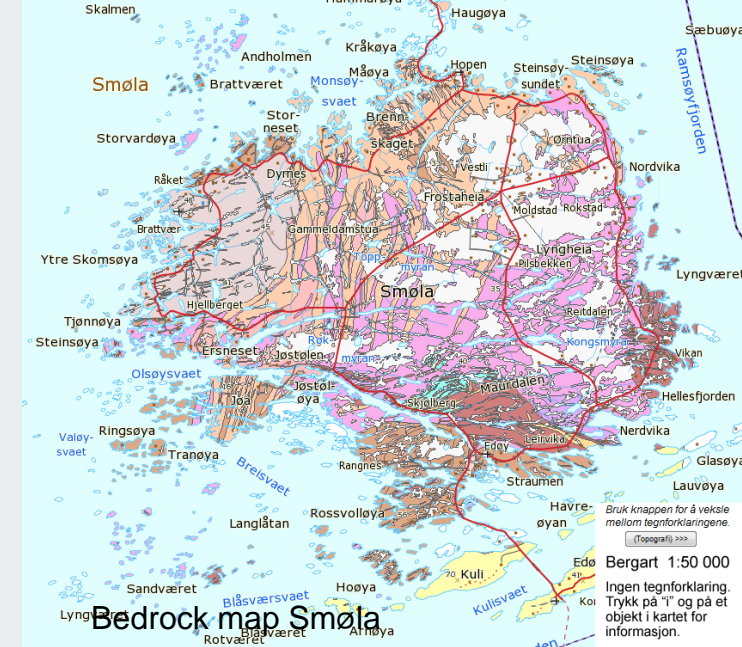




# Onshore-offshore correlation, Frøya High - Smøla



Top Basement map Frøya High north

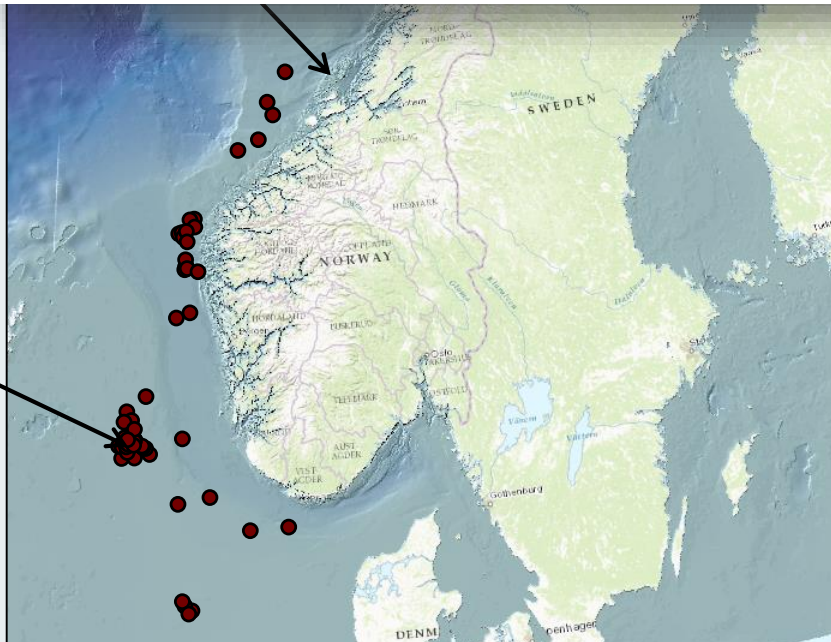
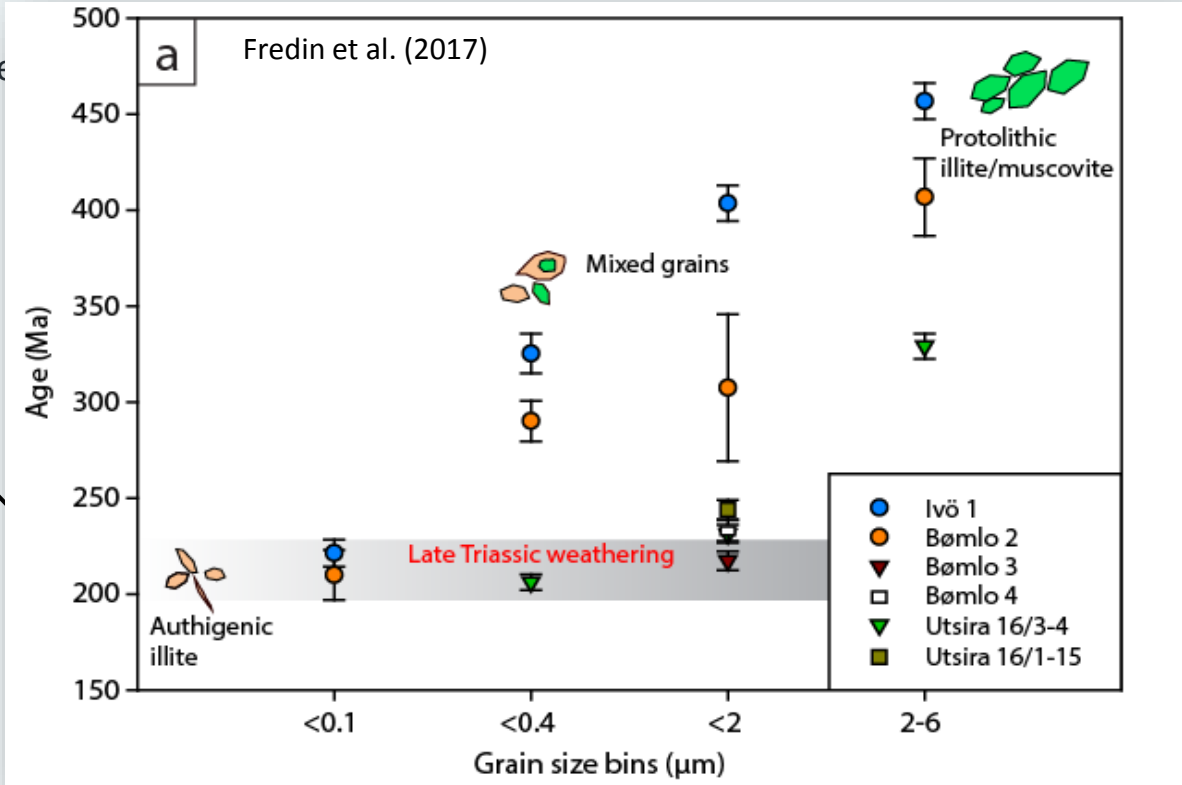


Frohavet 6408/12-U-01



Deep we

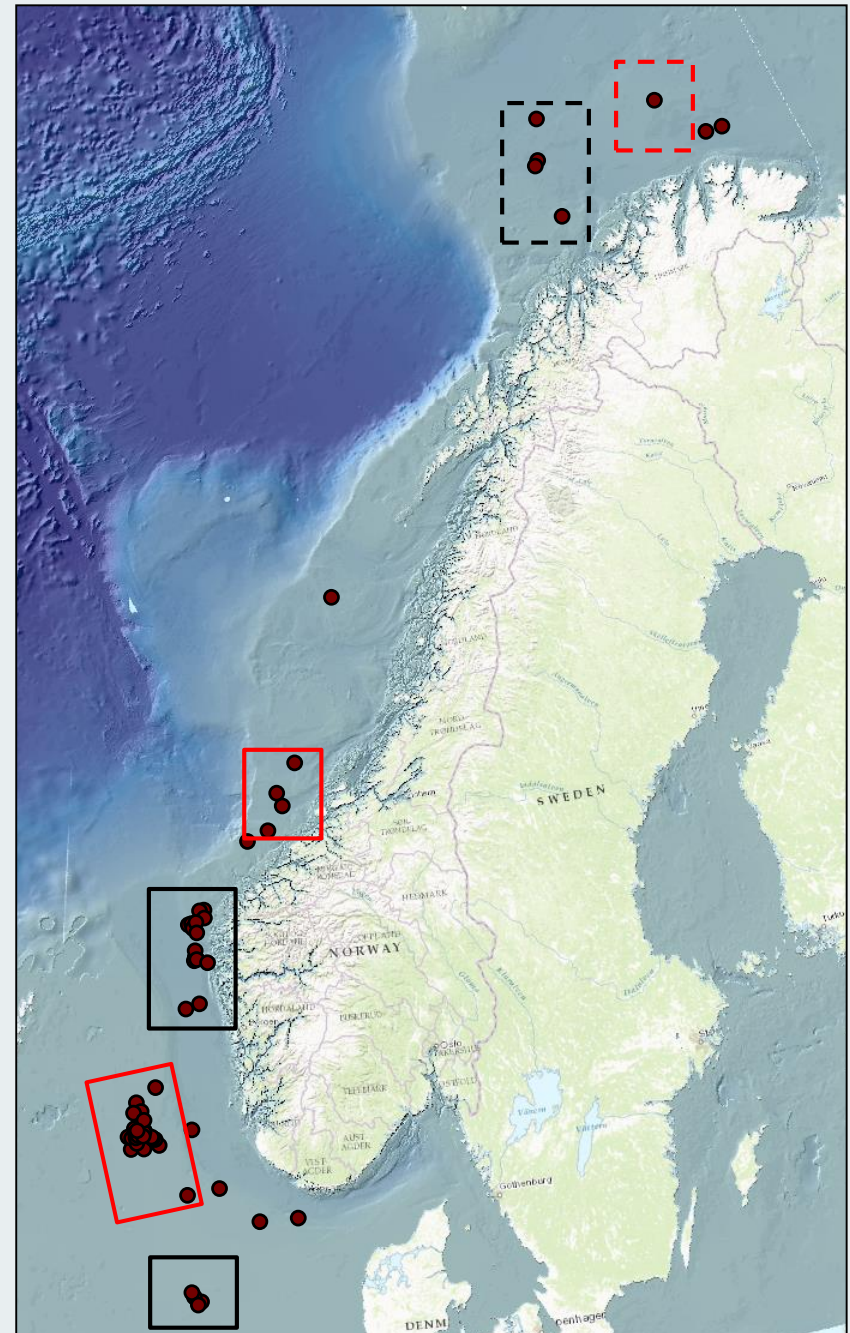
16/1-15



## Basement description from well reports

- *weathered basement*
- *weathering products*
- *regolith*
- *paleosol*
- *slightly kaolinized*
- *basement wash*
- *sandstone*
- *conglomerate*
- *chlorite shist*

“The absence of any description of weathering does not mean there is none” (Jon-Arne Øverland)



# Weathered basement remains onshore



Ivø, southern Sweden, clay rich



sandy



Andøya, Nordland  
quartz rich, porous



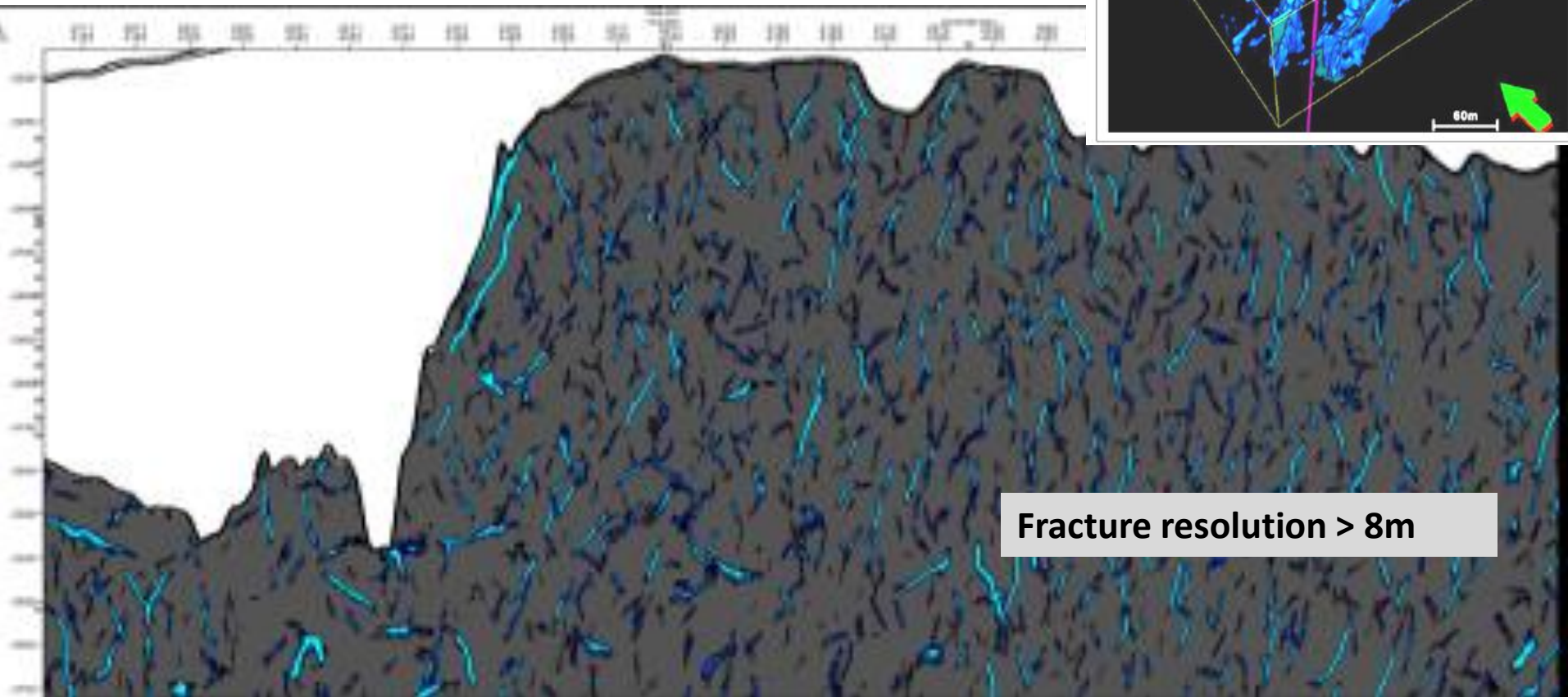
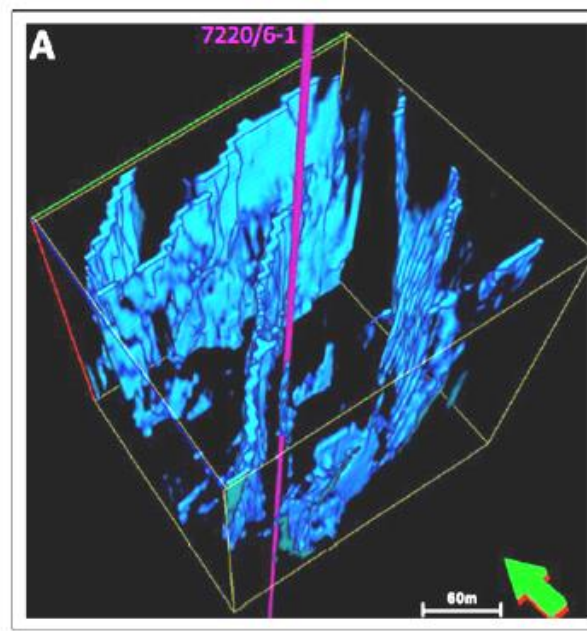
Andøya, Nordland, clay rich,  
micro-fractured



grussy

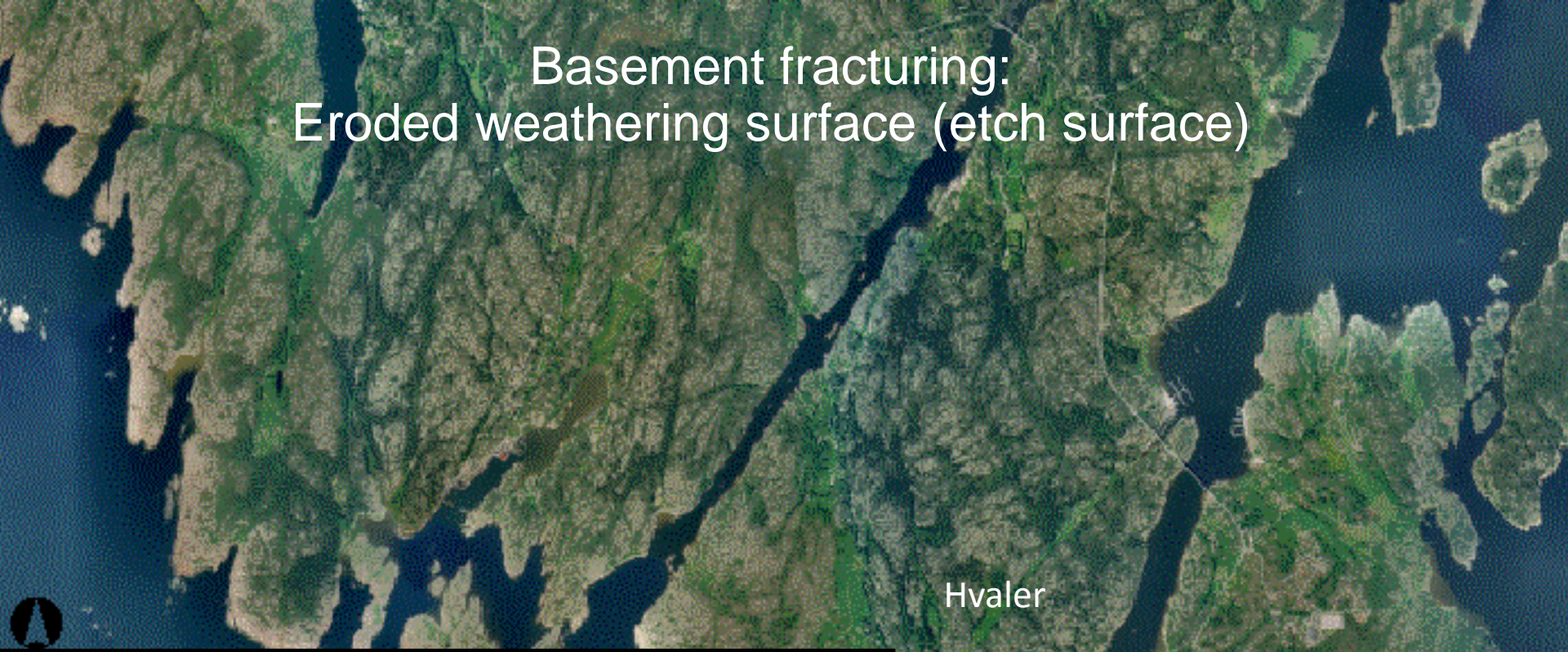


Display basement fractures from marine 3D seismic data

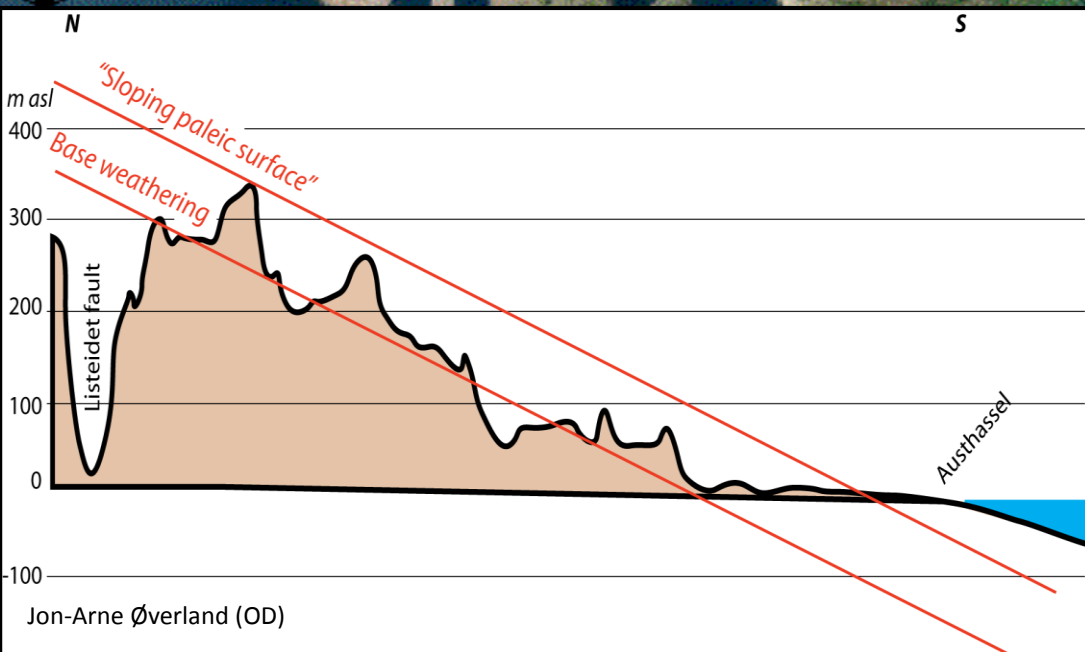


Fracture resolution > 8m

# Basement fracturing: Eroded weathering surface (etch surface)

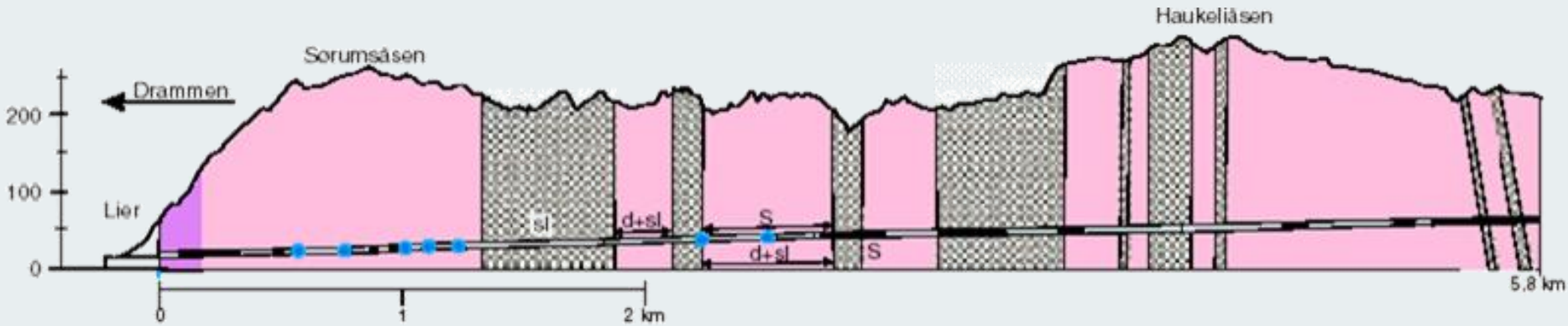


Hvaler



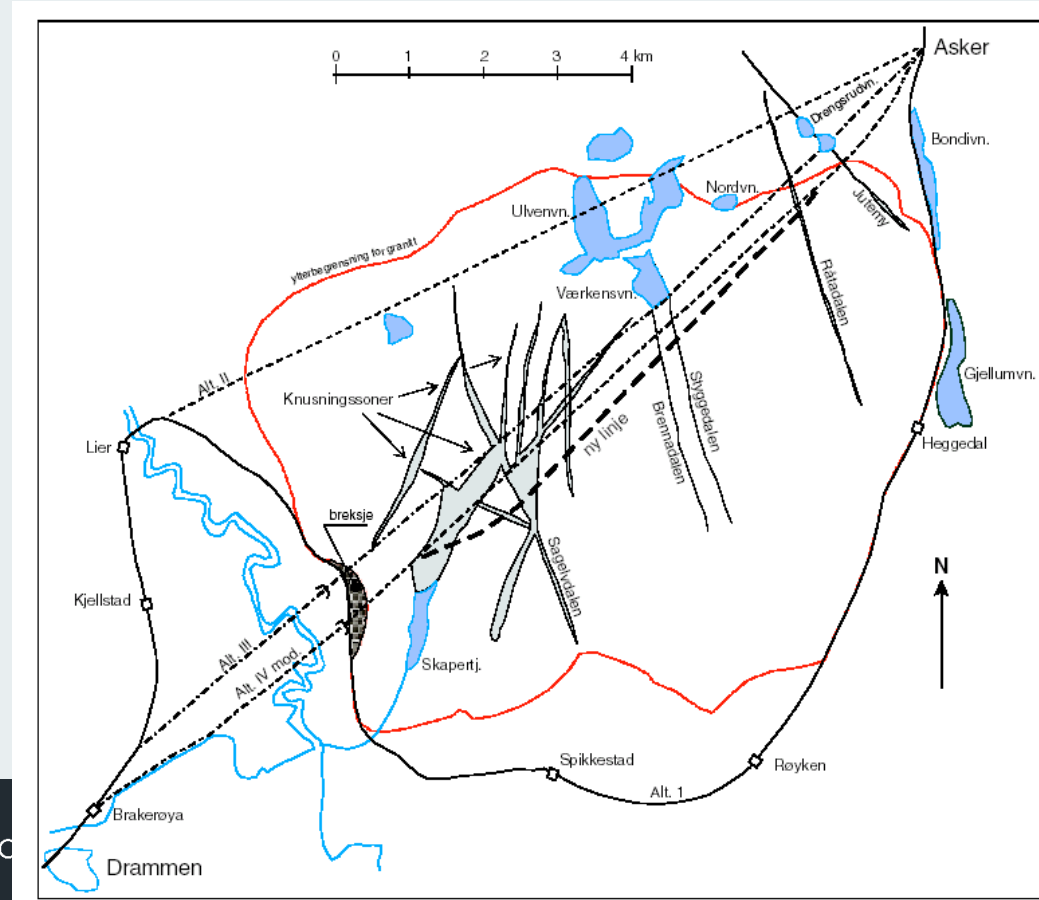
Sarpsborg





Lieråsen railroad-tunnel: Fractured basement  
 > 200m deep and  
 > 200 m wide

Huseby 1968, Palmstrøm et al. 2003



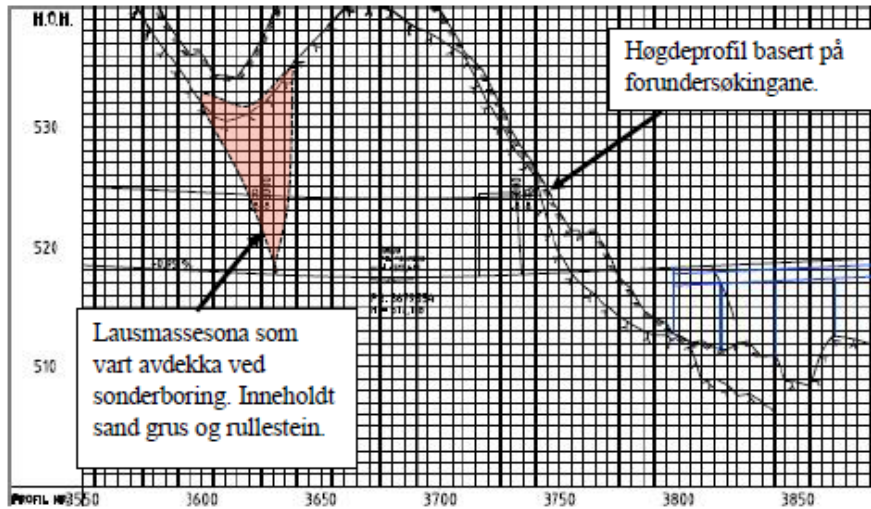
GEOL

- What can we gain from offshore observations and what are we missing?
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# Potential fractured and weathered basement western Norway



Weathering zone E16 Rådal

Folldalentunnel, E39 Øye – Eidsbru



Foto: Terje Kirkeby: Svakesone i Folldalentunnel



'Soil' fill collapse in an unpredicted fracture

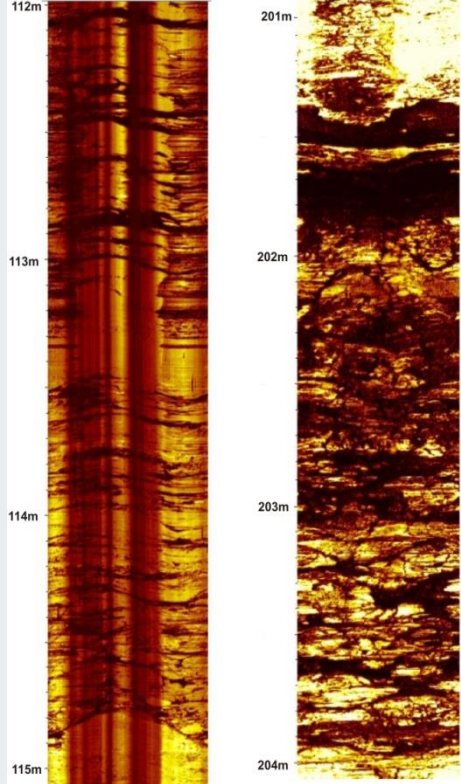


Fractured and weathered gabbro, Kråkenenes

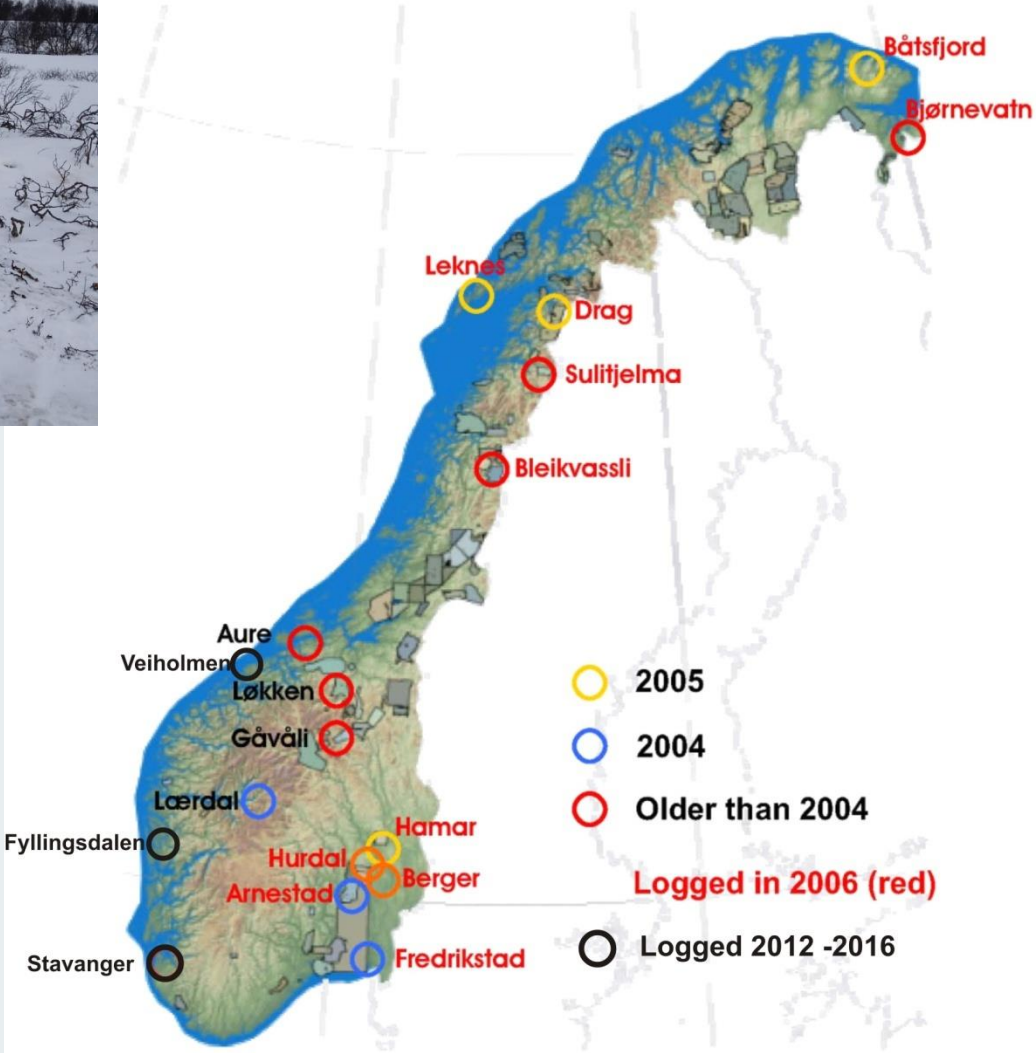
# BASE 2: Fracture mapping in boreholes



NGU borehole logging

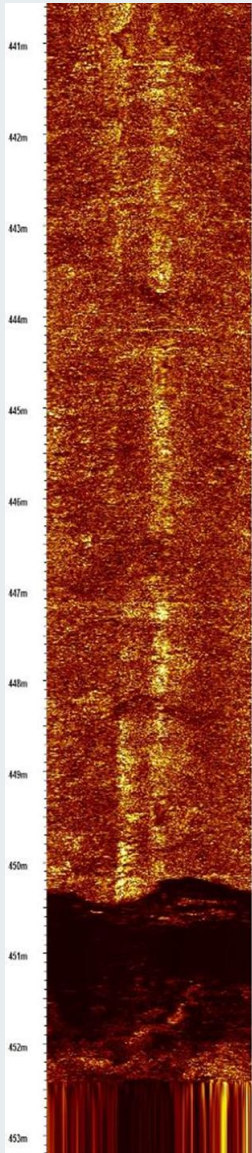


Bh 2, acoustic televiewer image, 112-115 m (left), 201-204 m (right).



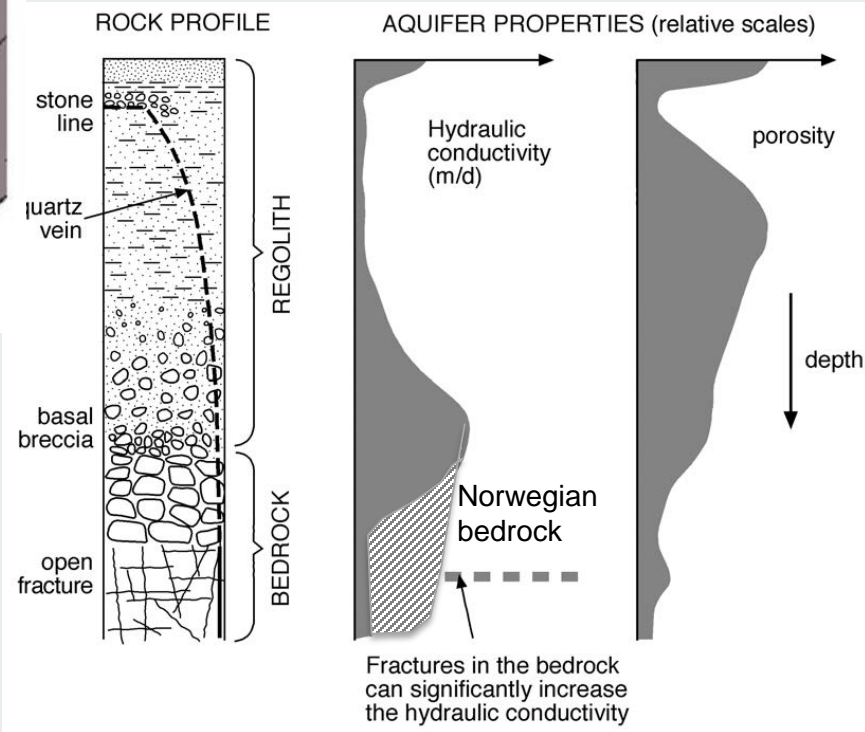
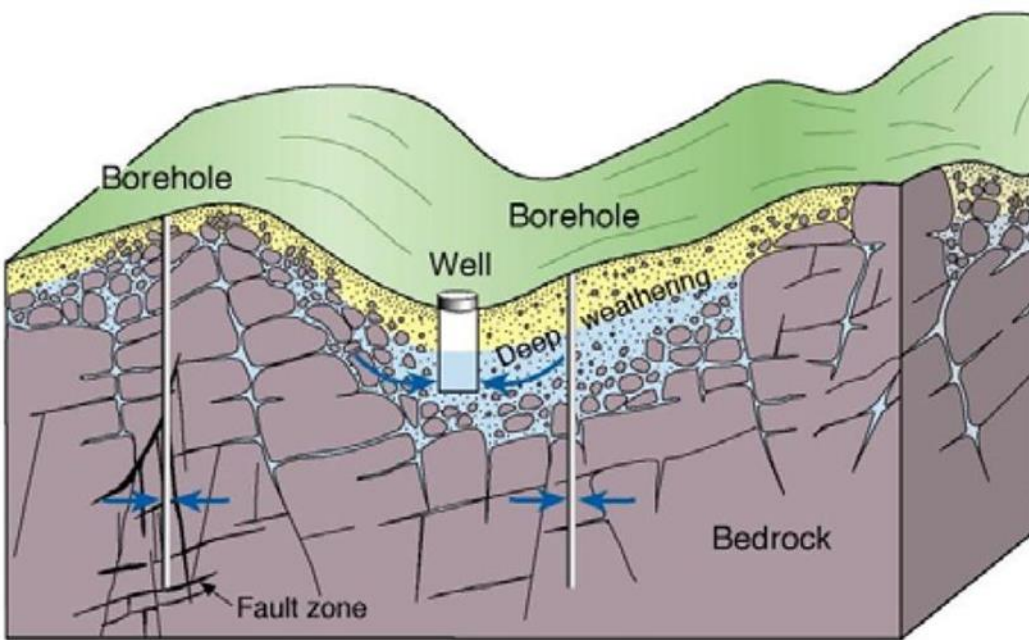
# Sub-seismic resolution fractures

Haytor Rocks, Dartmoor



Rennesøy (foto: C. Hiorth)

# Groundwater aquifer in weathered and fractures bedrock

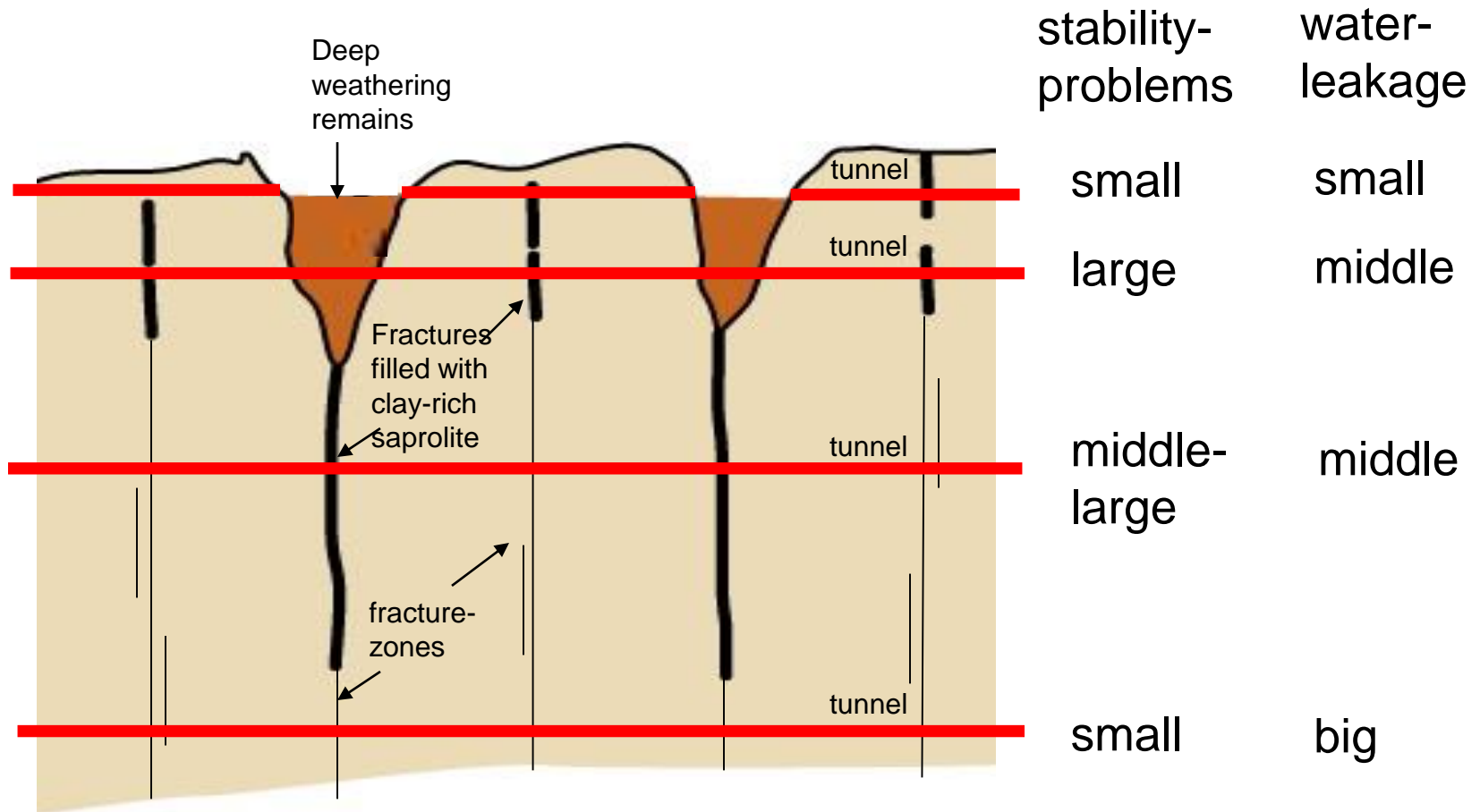


Chilton and Foster 1995



# Summarize

## Tunnel problems in Østlandet



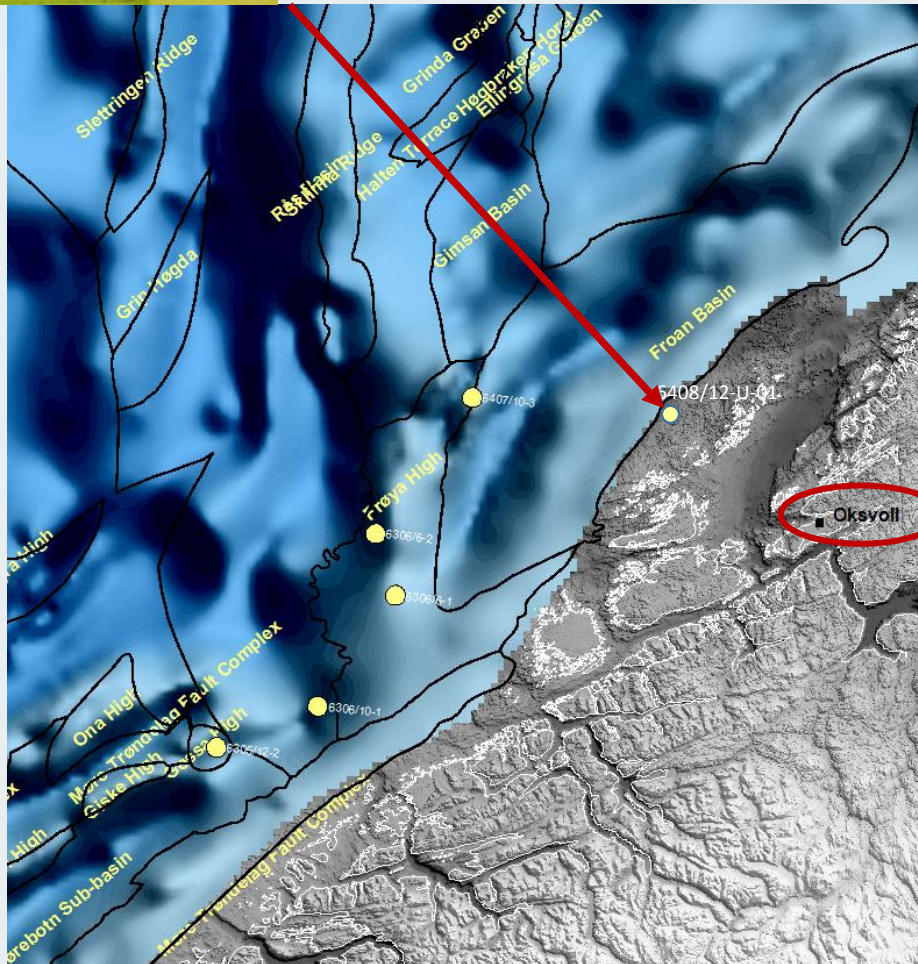
## Outside the box: Basement migration systems

(Adressavisen, October 18th, 1950)

### „OLJEFELTET” I FOSEN



Meldingen om olje-funnet på gården Oksvoll i Fosen i Sør-Trøndelag har vakt atskillig oppsikt. Her er et bilde fra arbeidet med grøften hvor oljen ble funnet. Den som er aller mest interessert i funnene er kanskje Einar Leth Olsen, som eier eiendommen. Som nevnt i morgennummeret i går er det også funnet oljeaktige forekomster andre steder på eiendommen. Einar Leth Olsen ses midt på bildet, med spaden i hendene.

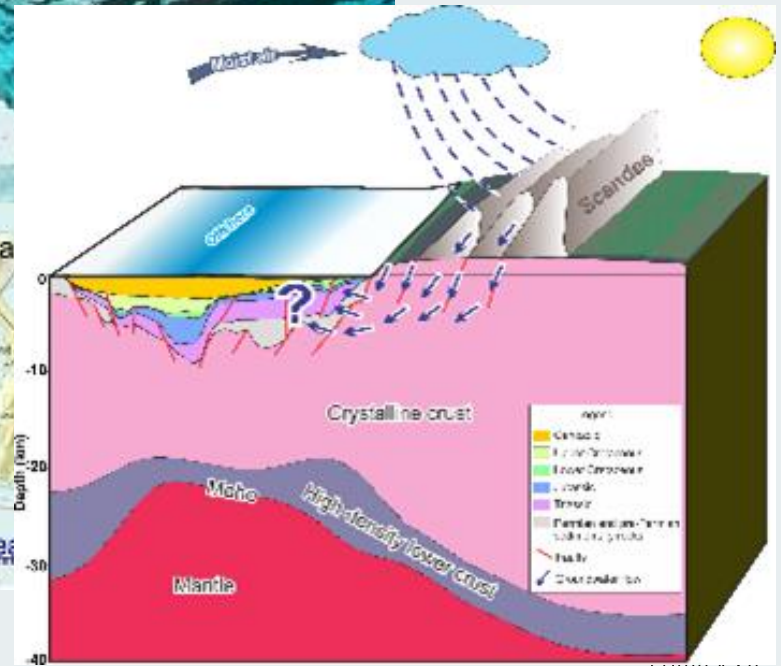
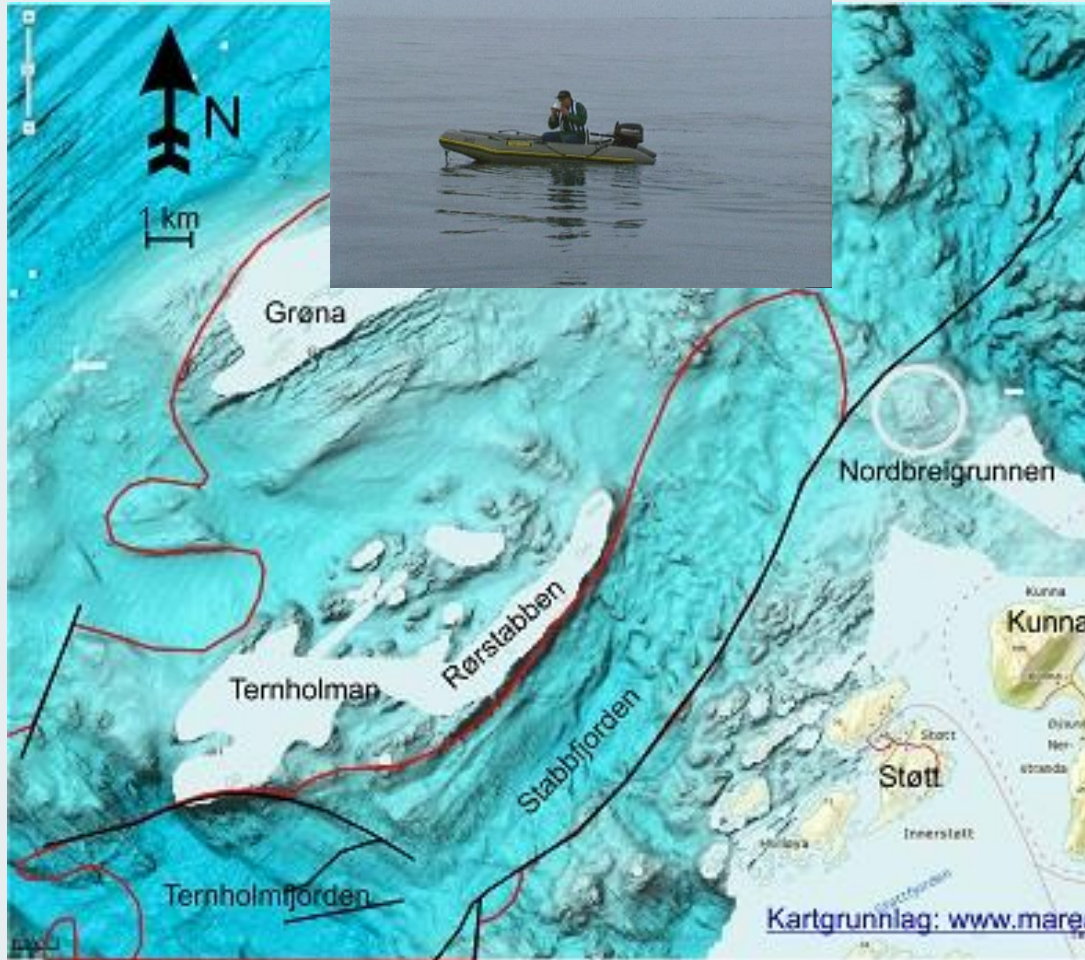


Top Basement map



# Outside the box: Basement migration systems

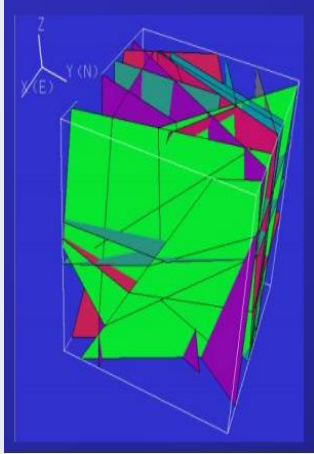
## Drinking water offshore Nordland on the marine strandflat



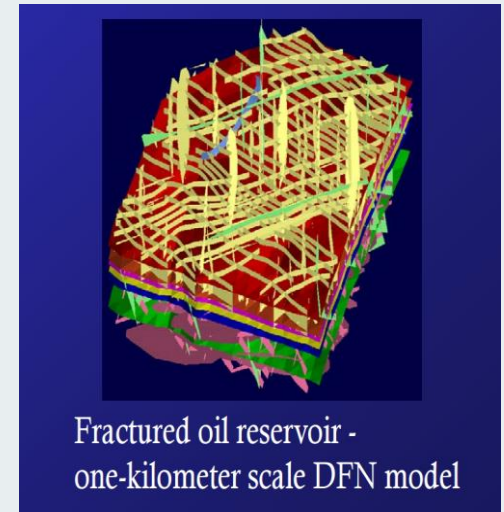
Solbakk, 2016

Maystrenko et al. (submitted)

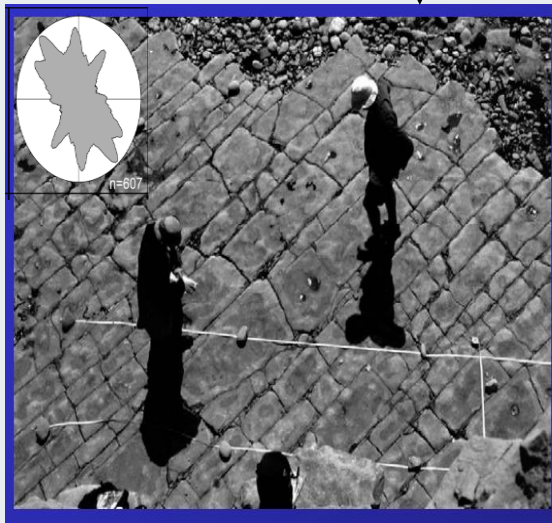
# BASE2 – Geomechanical-Structural approach



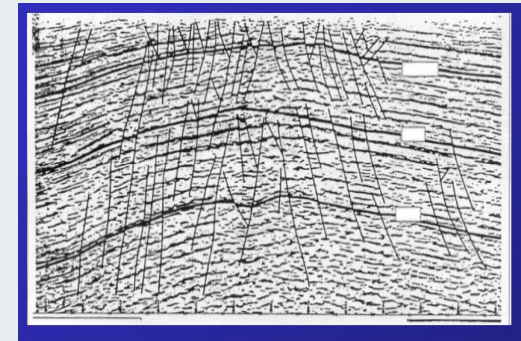
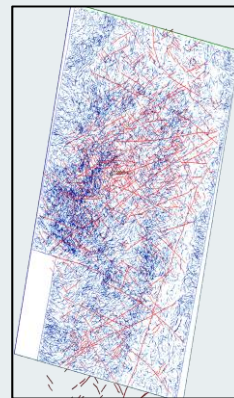
		Dimension of Feature				
		0	1	2	3	
Dimension of Sampling Region	0	$P_{00}$ Length <sup>0</sup> Number of Fractures Samples per Point Sample of Rock Mass				“ POINT MEASURES
	1	$P_{10}$ Length <sup>1</sup> Number of Fractures per Unit Length of Scalene (Frequency or Linear Intensity)	$P_{11}$ Length <sup>1</sup> Length of Fracture Intersections per Unit Length of Scalene (Linear Porosity)			“ LINEAR MEASURES
	2	$P_{20}$ Length <sup>2</sup> Number of Trace Centers per Unit Sampling Area (Area or Trace Density)	$P_{21}$ Length <sup>2</sup> Length of Fracture Traces per Unit Sampling Area (Linear or Trace Intensity)	$P_{22}$ Length <sup>2</sup> Area of Fractures per Unit Sampling Area (Areal Porosity)		“ AREAL MEASURES
	3	$P_{30}$ Length <sup>3</sup> Number of Fracture Centers per Unit Rock Volume (Volume Intensity)	$P_{31}$ Length <sup>3</sup> Area of Fractures per Unit Volume of Rock Mass (Volume Intensity)	$P_{32}$ Length <sup>3</sup> Area of Fractures per Unit Volume of Rock Mass (Fracture Porosity)	$P_{33}$ Length <sup>3</sup> Volume of Fractures per Unit Volume of Rock Mass (Fracture Porosity)	“ VOLUMETRIC MEASURES



...from the field, through the reservoir to DFN models... and back, to enhance recovery and production.



Courtesy G. Viola



Sub seismic-resolution faults: what is their impact??





- Click to edit background picture



**THANK YOU FOR YOUR ATTENTION**