The interconnected uplift history and structural development of the Jan Mayen Micro-Continent and Iceland during the Cenozoic.

Anett Blischke, Iceland GeoSurvey
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Bryndis Brandsdottir, University of Iceland

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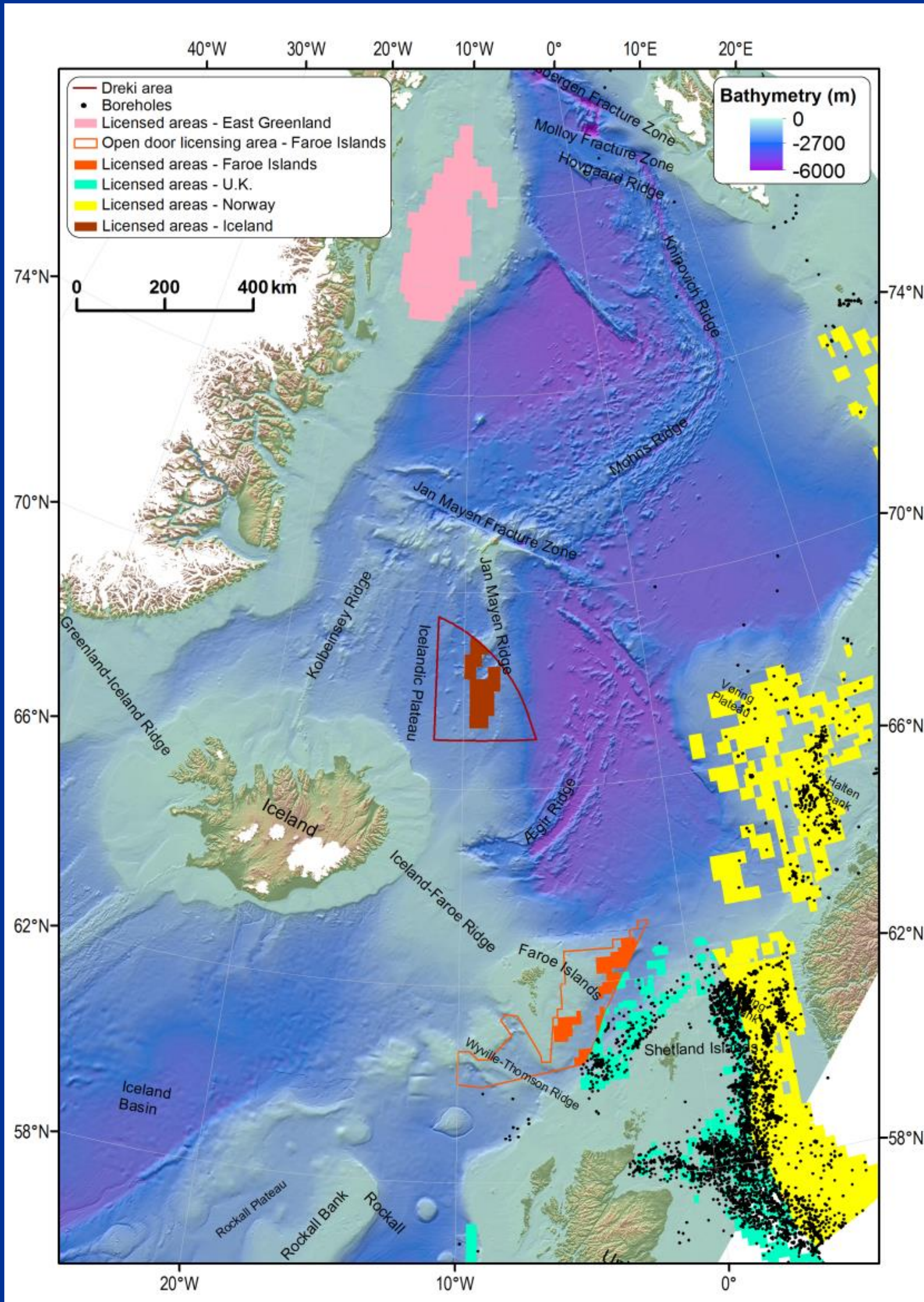
Research project of the Jan Mayen Micro-Continent

Stage 1. Known facts and data of the JMMC, regional setting of the JMMC and its conjugate margins.

Stage 2. Seismic volcano-stratigraphic characteristics of the Jan Mayen Micro-Continent area and distribution of volcanic intrusion complexes and hydrothermal vents.

Stage 3. Seismic sequence stratigraphic analysis of the Jan Mayen Micro-Continent and distribution of major sediment fairways.

Stage 4. Basin and hydrocarbon prospect analysis and description.



Location & Licences

- North Dreki is part of the Jan Mayen Micro-Continent (JMMC) with indications of continental strata and suitable structures

- Similarities to the middle East Greenland coast that is part of Greenland Licensing areas, the Møre- and Vøring Basins at the Norwegian coast, which are proven hydrocarbon provinces.

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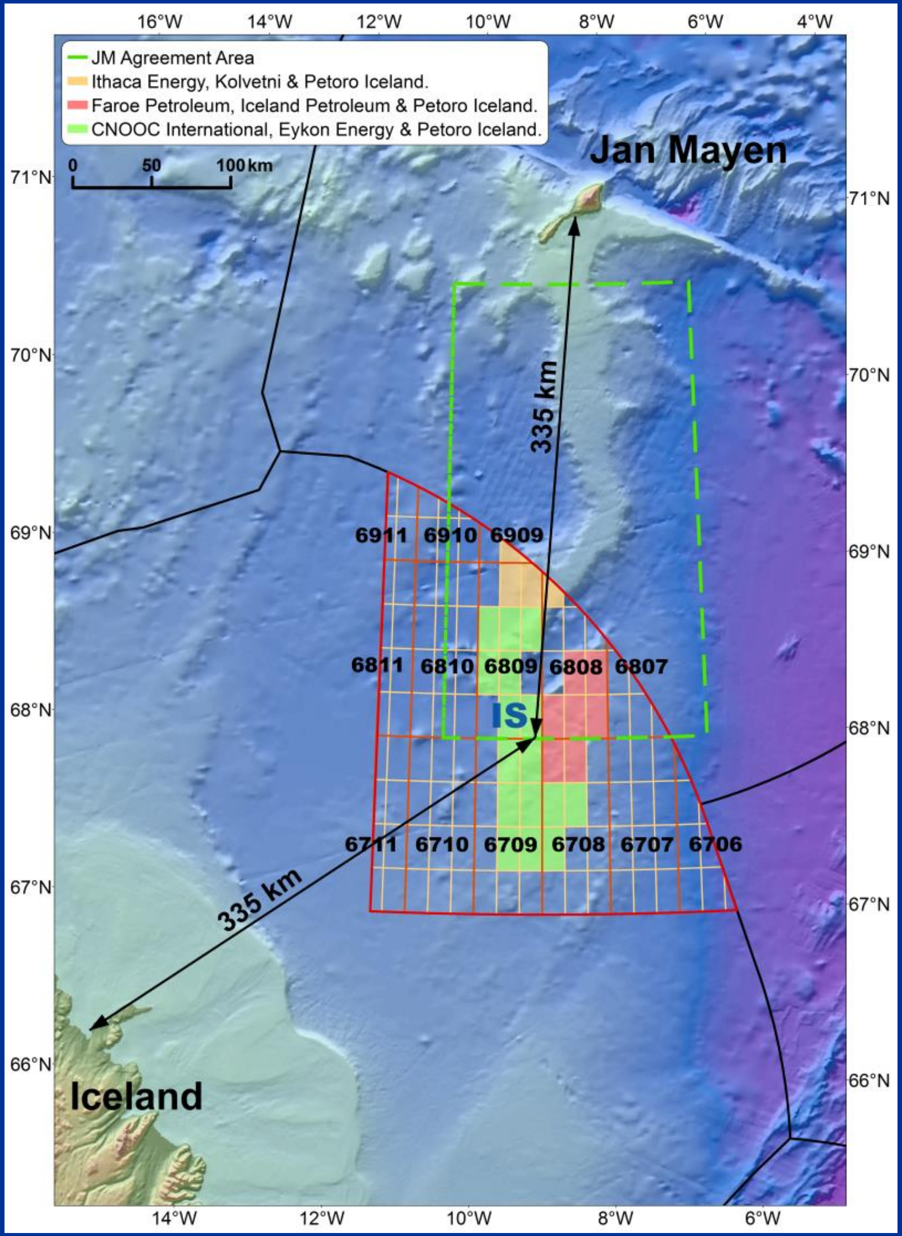
Icelandic Licenses

Second Icelandic Licensing Round

- January 2014, three licenses granted
- Petoro decided to participate in both licenses for the Jan Mayen Agreement area (green) for Norway
- Faroe Petroleum 67.5% (op.), Iceland Petroleum 7.5%, Petoro Iceland AS 25% (red)
- Faroe Petroleum 67.5% (op.), Iceland Petroleum 7.5%, Petoro Iceland AS 25% (blue)
- CNOOC Iceland ehf60% (op.), EykonEnergy ehf. 15%, Petoro Iceland AS 25% (light green)



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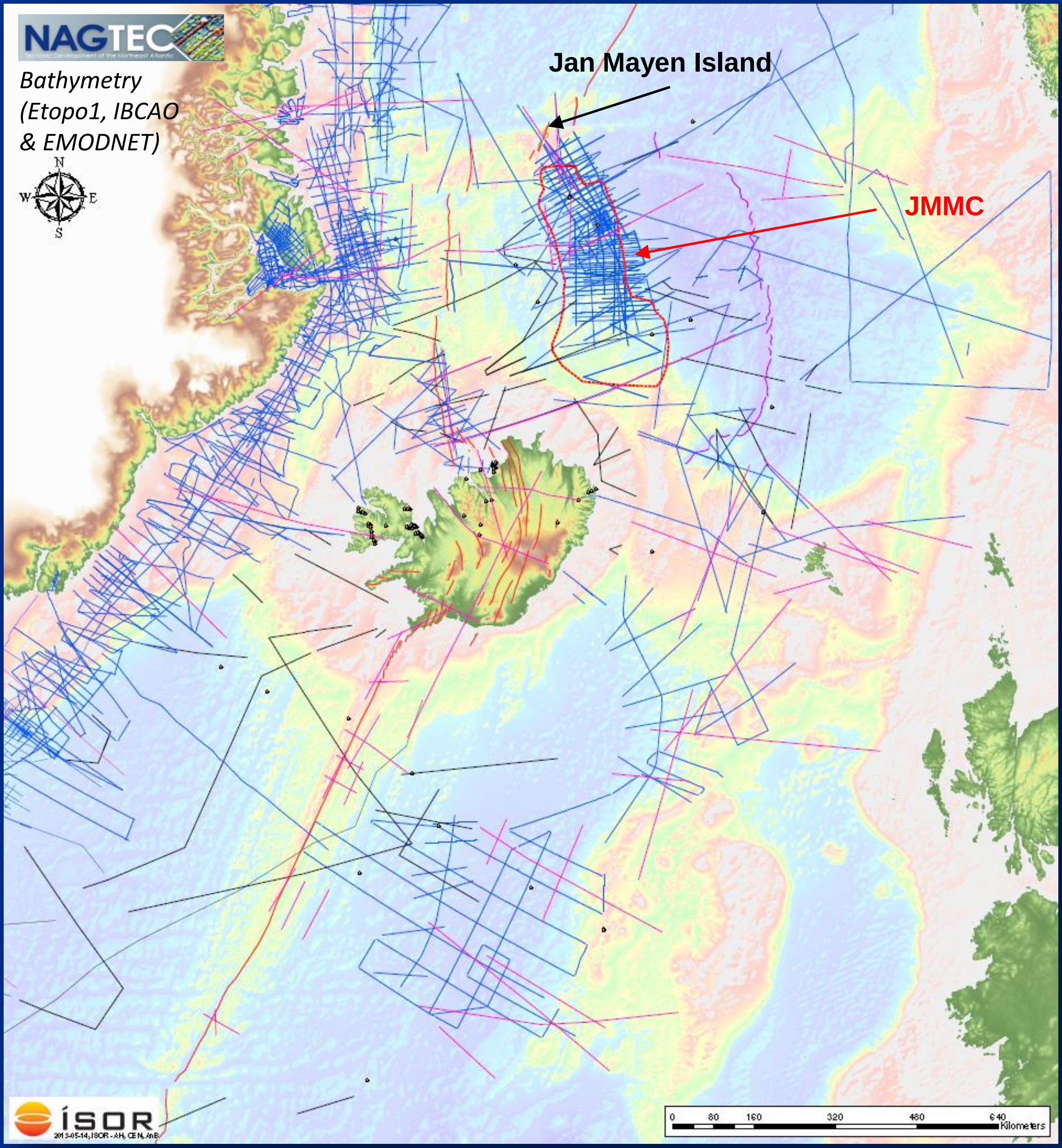
Data

The JMMC Project

Location & Data Coverage

- Analogue seismic data
- 2D MC reflection seismic data
- Refraction seismic data
- Boreholes and onshore site data
- Bathymetry data (NAG-TEC)
- JMMC outline



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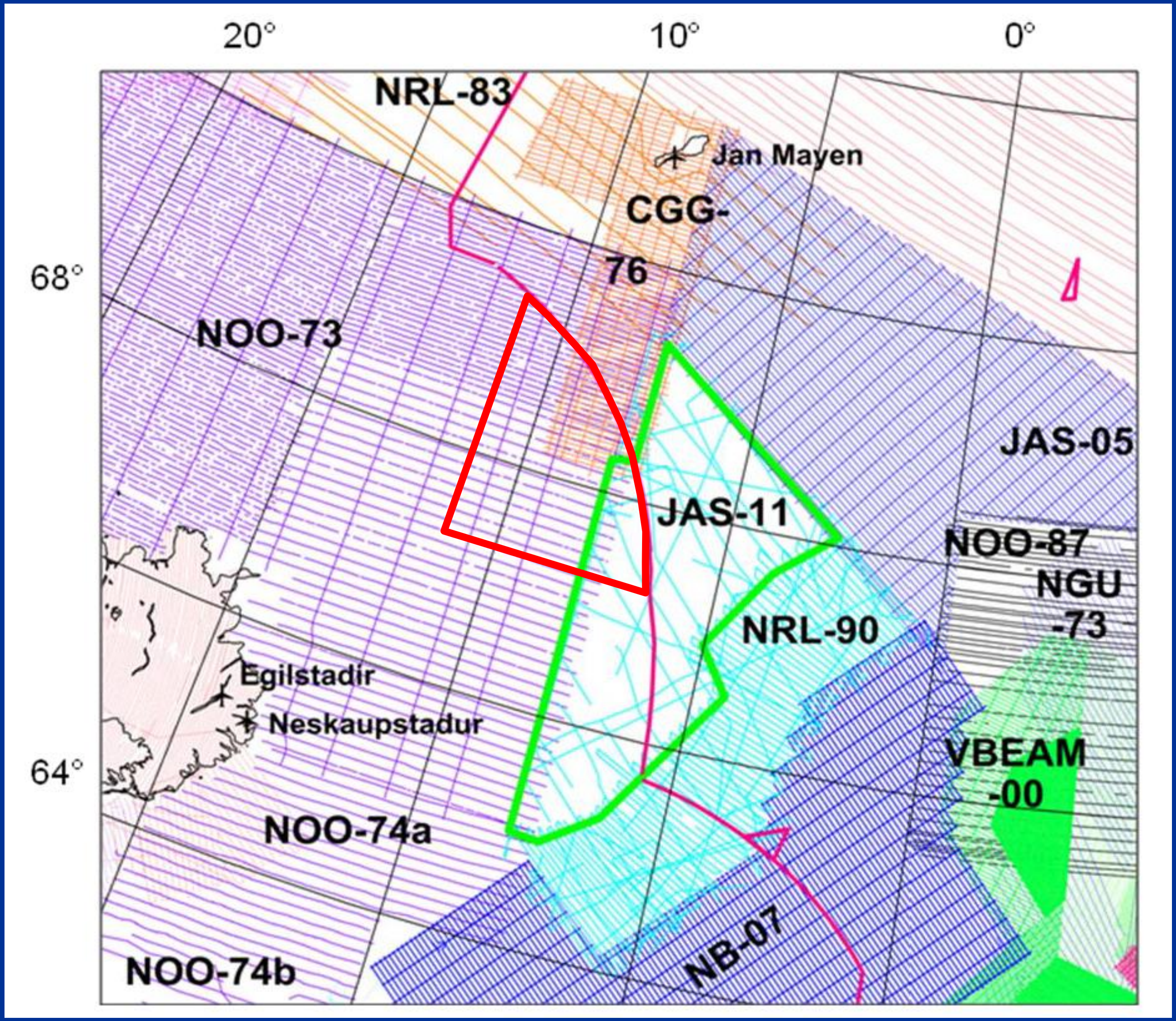
Magnetic Surveys

after Laurent Gernigon, 2011, NGU

Collaboration project NGU, NPD & NEA - Preliminary outline of the aeromagnetic survey

JAS-12

in the western Norwegian Sea (green frame)



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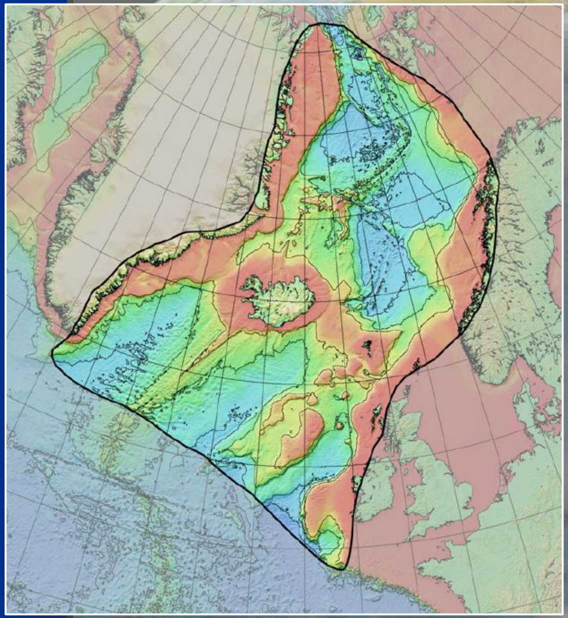
Release in September 2014 !!!

Northeast Atlantic Geoscience

Tectonic Development Theme

(NAG-TEC)



Tectonostratigraphic Atlas

of the Northeast Atlantic

A Northern European Geological Survey Initiative

GEUS

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

NGU

GSI

JARÐFEINGI

TNO innovation for life

Geological Survey of Northern Ireland

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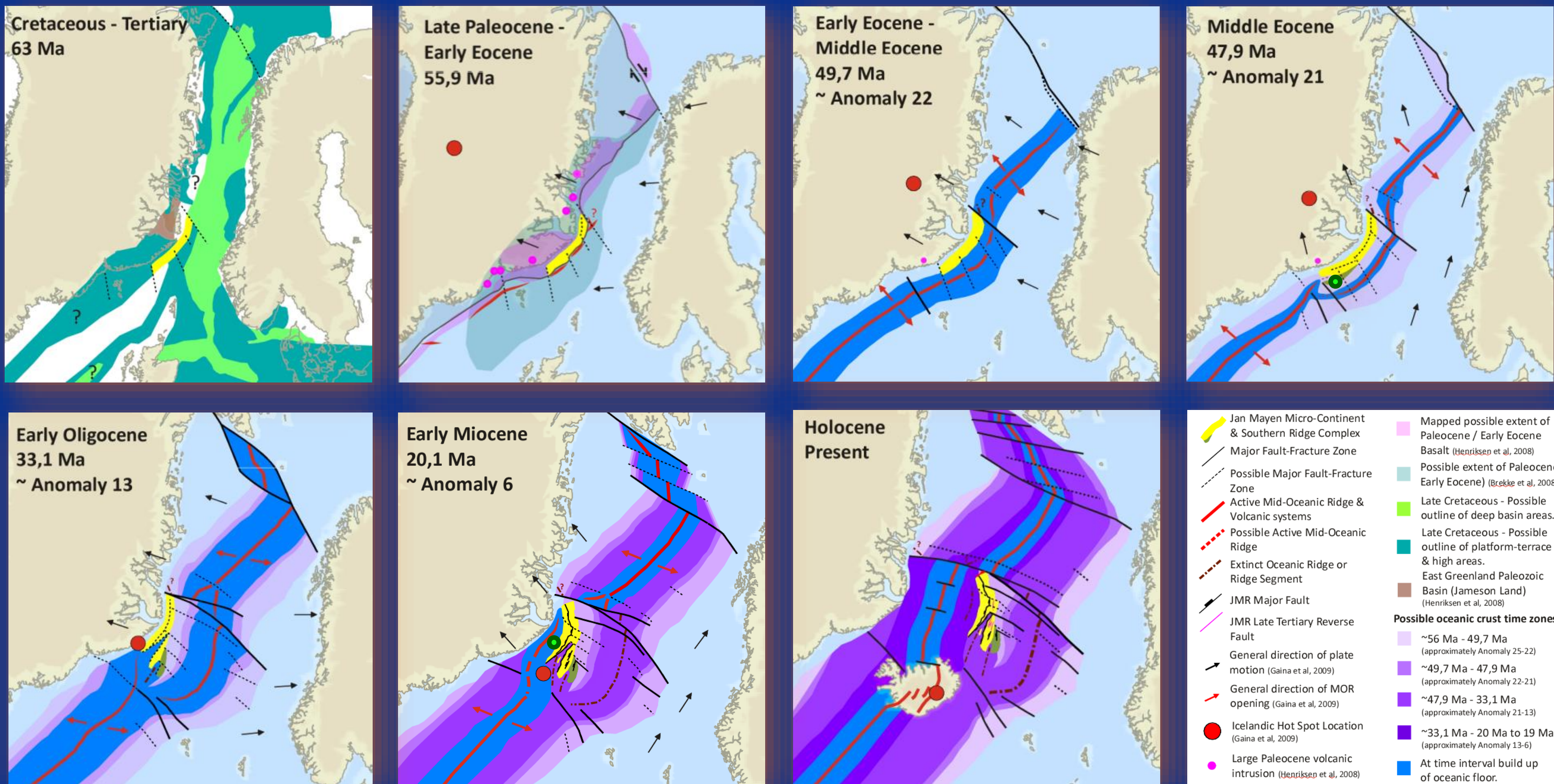
REGIONAL SETTINGS

- TECTONIC MODELS
- STRATIGRAPHY
- ANALOGUES

Tectonic History of the JMMC

Collage based on results of recent research publications and observations at the JMMC & Iceland



Data Source Reference List:

Dinkelman M.G. et al (2010): The NE Greenland Continental Margin. GeoExpro, No. 6. **Gaina, C. et al (2009):** Palaeocene-Recent plate boundaries in the NE Atlantic and the formation of the Jan Mayen microcontinent. Journal of the Geological Society, London, Vol. 166, pp. 1-16. **Gernigon L. et al (2009):** Geophysical insights and early spreading history in the vicinity of the Jan Mayen Fracture Zone, Norwegian-Greenland Sea. Journal of Tectonophysics, Vol. 468, pp. 185-205. **Roberts, A.M. et al (2009):** Mapping palaeostructure and palaeobathymetry along the Norwegian Atlantic continental margin: Møre and Vøring basins. Petroleum Geoscience, Vol. 15, pp. 27-43. **Brekke H. et al (2008):** The Geology of the Norwegian Sea Continental Margin and Probable Similarities with the Jan Mayen Ridge. 1st Petroleum Exploration Conference in Iceland. **Henriksen, N. et al (2008):** Geological History of Greenland - Four billion years of Earth evolution. Geological Survey of Denmark and Greenland (GEUS), Ministry of Climate and Energy, Copenhagen. **Mjelde, R. et al (2008):** Crustal transect across the North Atlanti., Marine Geophysical Researches, Vo. 29, pp. 73-87. **Mueller, R.D. et al (2008):** Palaeo-age, depth-to-basement and bathymetry grids of the world's ocean basins from 140-1 Ma. Science, 319, 1357 (data used in GPlates 1.0 http://www.gplates.org/index.html). **Mosar, J. et al (2002):** North Atlanti sea-floor spreading rates: implications for the Tertiary development of inversion structures of the Norwegian-Greenland Sea, Journal of the Geological Society, London, Vol. 159, pp. 503-515. **Gunnarsson, K. (1990):** Olíuleit á Jan Mayen-Hrygg, Erindi á ársfundi Orkustofnunar. **Gunnarsson, K. et al (1989):** Geology and hydrocarbon potential of the Jan Mayen Ridge. Oljedirektoratet, OD-89-91 and Orkustofnun OS-89036/JHD-07, report, pp. 143.Talwani et al (1976) : Series publications of the DSDP Leg 38 project … http://www.deepseadrilling.org/38/dsdp_toc.htm ; specifically the paper: http://www.deepseadrilling.org/38/volume/dsdp38_34.pdf. Scott, R.A., Lucy A. Ramsey, Steve M. Jones, Stewart Sinclair, Caroline S. Pickles (2005): Development of the Jan Mayen microcontinent by linked propagation and retreat of spreading ridges Original Research Article Norwegian Petroleum Society Special Publications, Volume 12, 2005, Pages 69-82.

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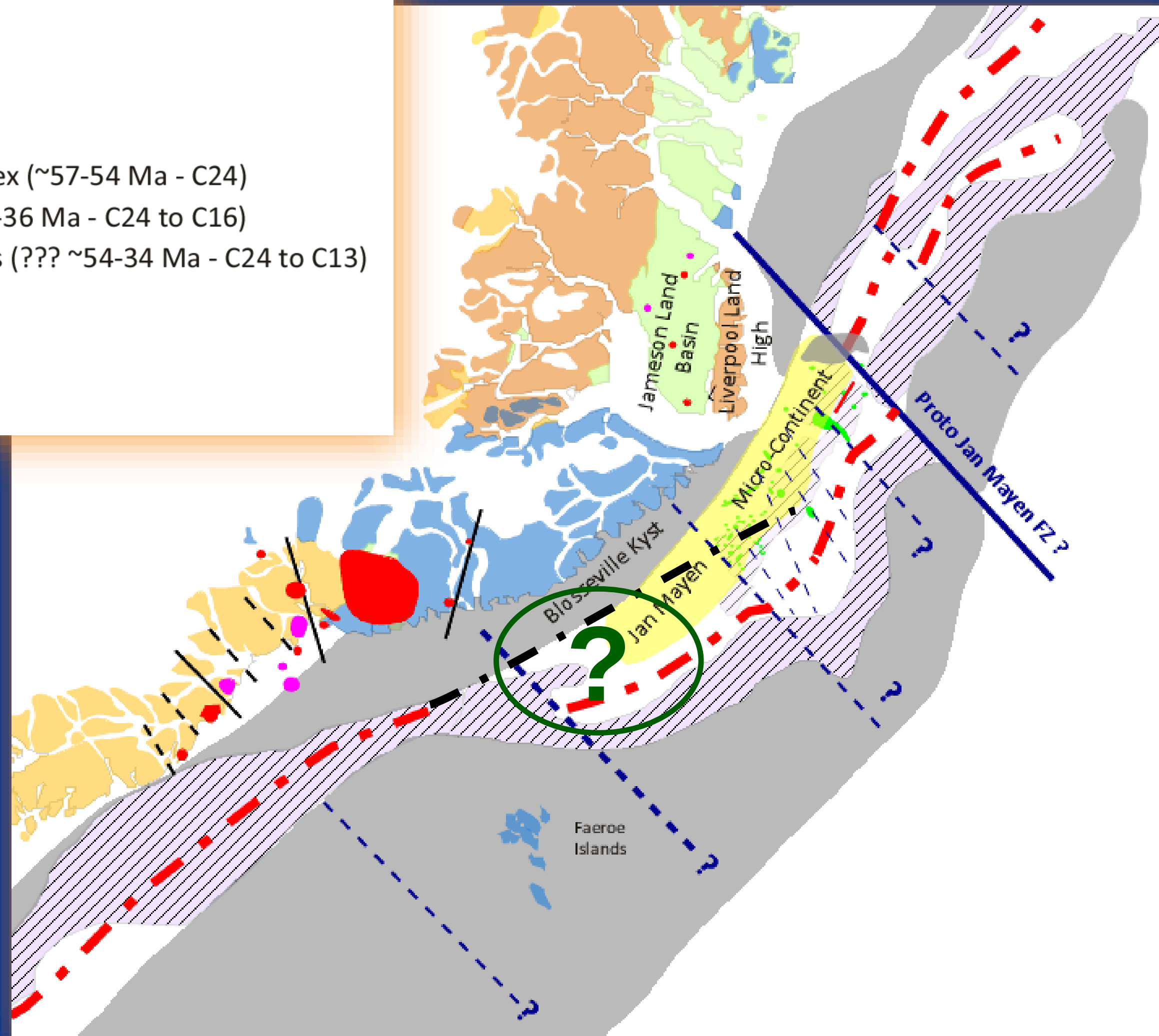

Central East Greenland Coast Break-up

(57-54 Ma; ~C24) magmatic centers / complexes, and post break-up intrusions (~53-36; C23-C16)

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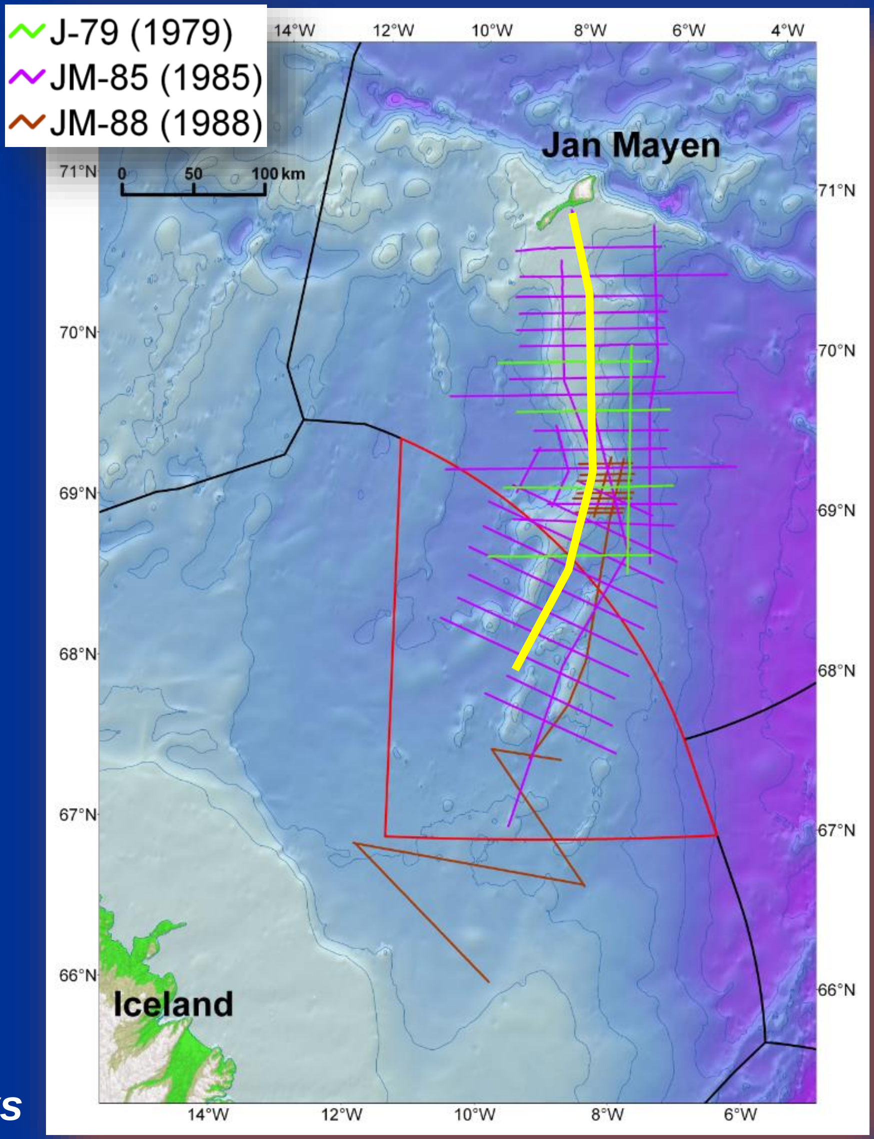
Conceptual model – seismic data comparison

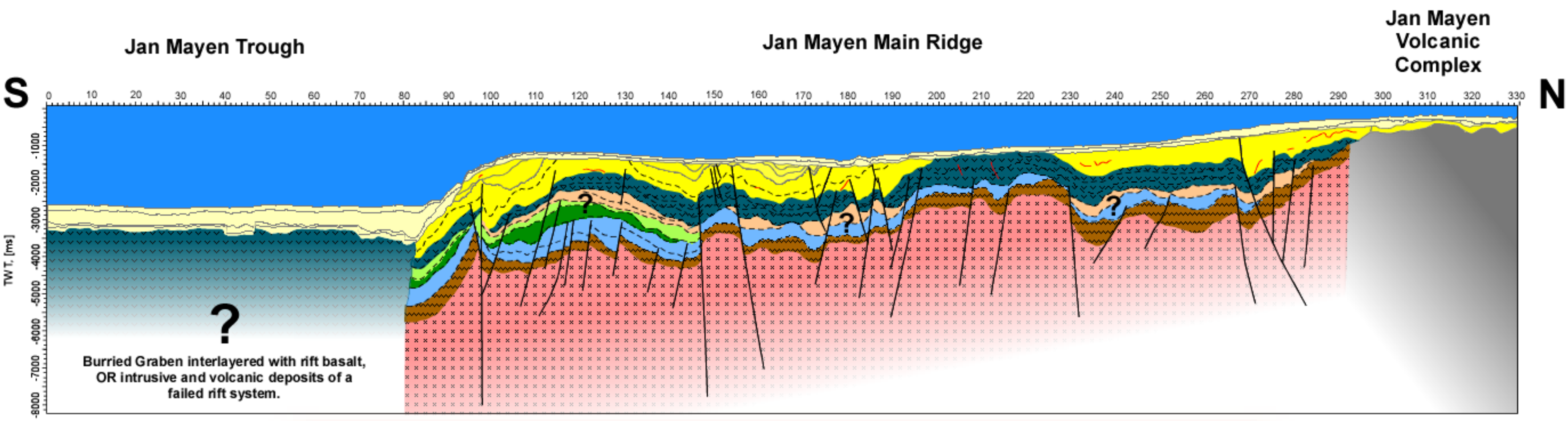
Key line interpretation at the JMMC



NPD-NEA Surveys

Conceptual model – seismic data comparison

Northern edge of the Dreki Licensing Area



Legend:

- Intra Quaternary
- Intra Quaternary to Middle Miocene (Mid Tertiary Unconformity)
- Middle Miocene (Mid Tertiary) to Top Paleocene (Early Tertiary)
- Middle Paleocene (Early Tertiary - Floodplain Sediments)
- Lower Paleocene
- Upper Cretaceous
- Mid Cretaceous
- Lower Cretaceous - BCU, Cretaceous undiff.
- Jurassic & Triassic
- Permian - Devonian, Paleozoic undiff.
- Paleozoic Basement
- Caledonian Crystalline Basement
- Volcanics / Basalts
- Seaward-Dipping Reflectors (SDR)
- Oceanic crust
- COB (Continental-Ocean Boundary)
- Sills and dykes
- Fault Zones
- Unit subdivision, general formation dip direction
- Unconformity

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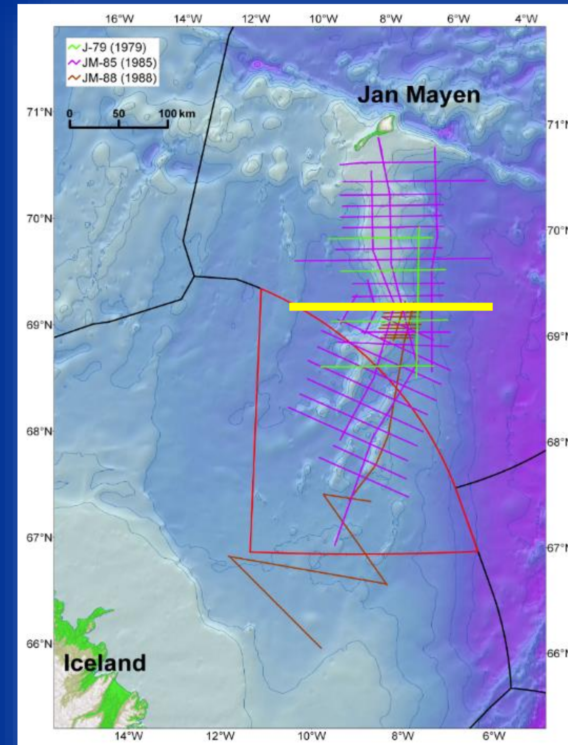
Regional Stratigraphy

Sediments & Igneous

Jan Mayen Micro-Continent – Main Ridge

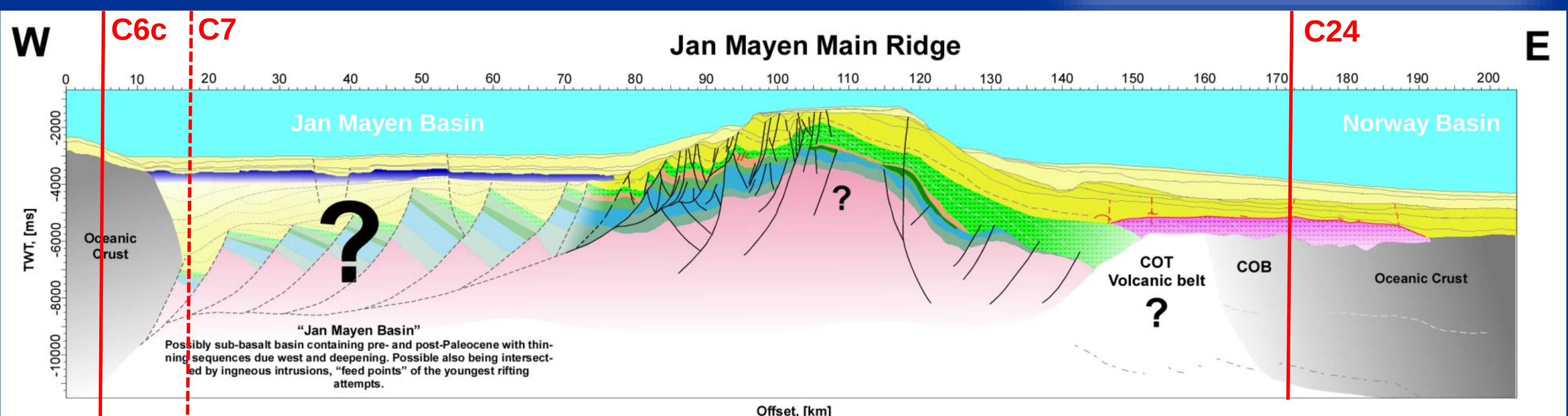
West-East geo-seismic section
Reaching across the micro-continent, the Iceland Plateau to the West, and to the Norway Basin and its Møre Basin as the conjugate margin to the East.
Sub-Paleocene strata & the Jan Mayen basin fills and structures are inferred.

The Jan Mayen Basin is possibly a sub-basalt basin containing pre- and post-Paleocene with thinning sequences due west and deepening. Probably also intersected by volcanic intrusions during the second break up.



Legend:

- Late Quaternary - Late Oligocene
- Early Oligocene - Paleocene
- Lower Paleocene
- Paleocene - SDR/Volcanics/Basalt
- Volcanic belt - Post-Paleocene
- Oligocene - poss. basalt flows
- Poss. Low Cretaceous
- Poss. Jurassic/Triassic
- Poss. Paleozoic
- Poss. Caledonian Basement
- Oceanic crust



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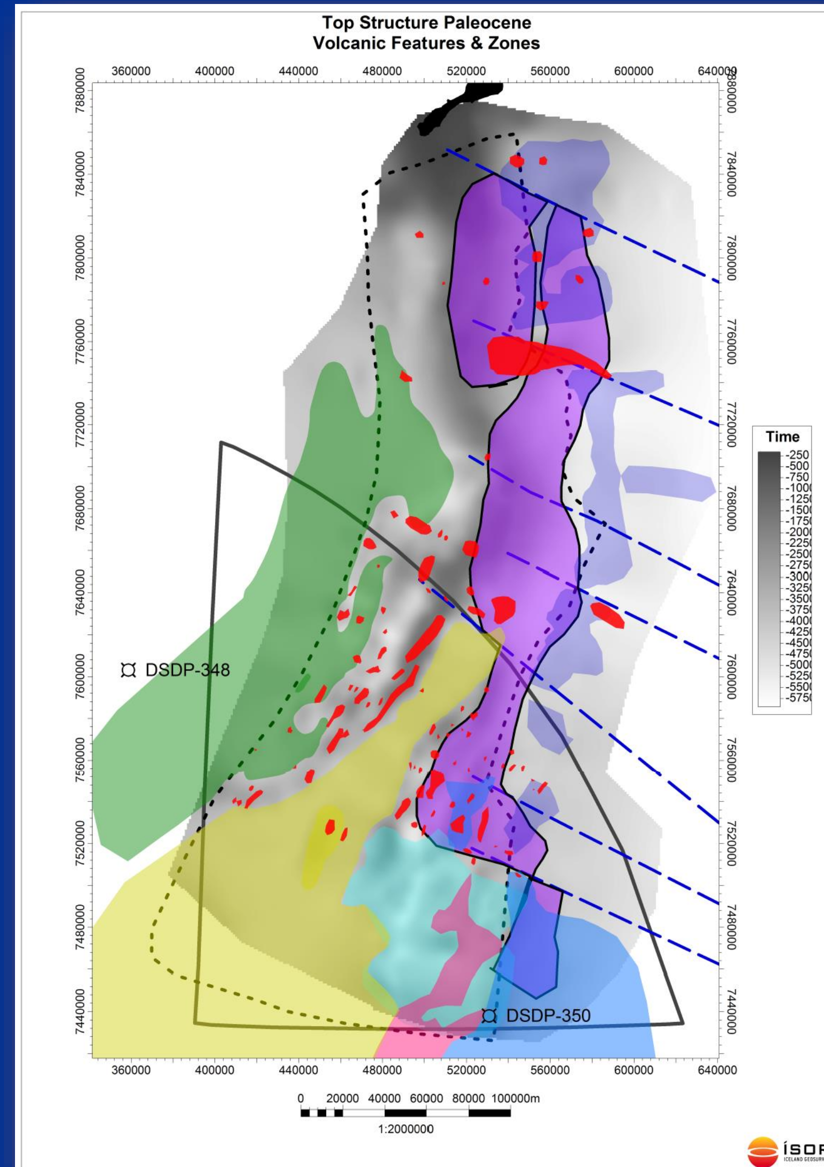
Volcanic Zones of JMMC

Possible scenario

- SDR (Seaward Dipping Reflectors)
- Poss. post break-up, larger intrusions
- Volcanic complexes poss. just above the top Paleocene marker
- 44-40Ma Anomaly 19-20 Basalt province
- Probably oceanic ridges / transition area
- Possible Rift area between Anomalies 20 & 13
- Jan Mayen Trough shallow intrusions
- Early to Late Oligocene composite sheet of flat-lying intrusive (Anomalies >6)
- Important Fault / Fractures Zones that influence and subdivide the JMR.



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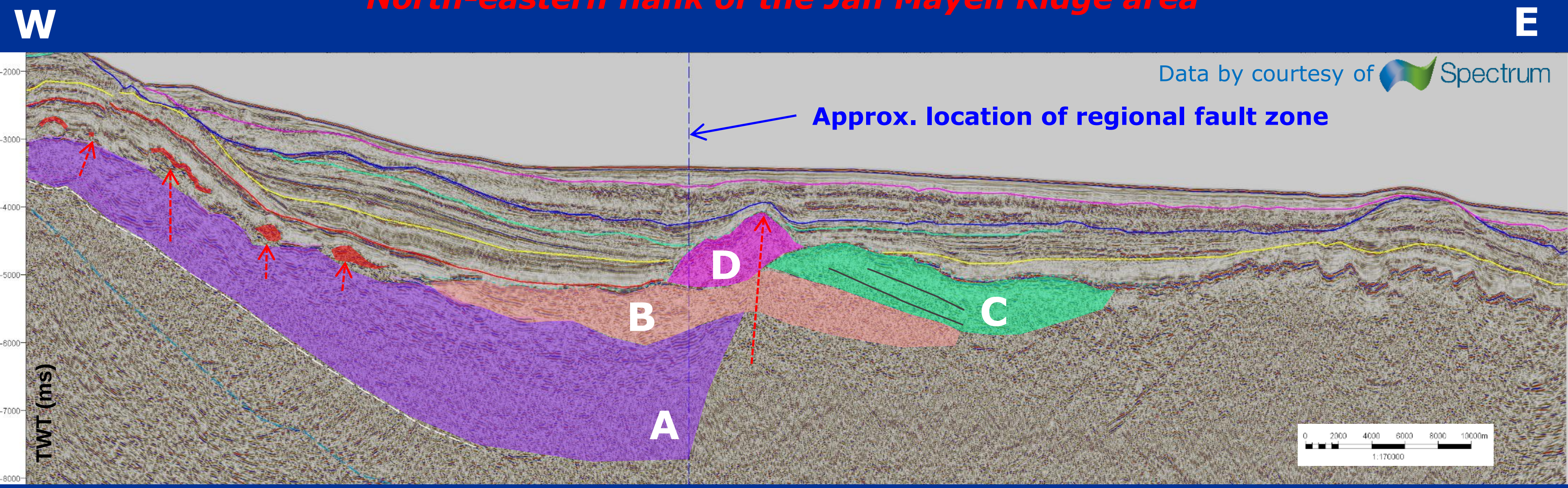
Volcano-stratigraphic characteristics

North-eastern flank of the Jan Mayen Ridge area



- **UC Early-Middle Miocene**
- **UC Late Oligocene - Miocene**
- **Early-Middle Oligocene**
- **UC Early Oligocene**
- **UC Eocene**
- **UC Top Paleocene**
- **Top Paleozoic poss.**
- **Top Basement poss.**

(A) Paleocene Volcanics (Plateau basalts ? & SDR´s)

(B) - (D) Igneous complexes / Sill intrusives on the main ridge during the Eocene to Early Oligocene

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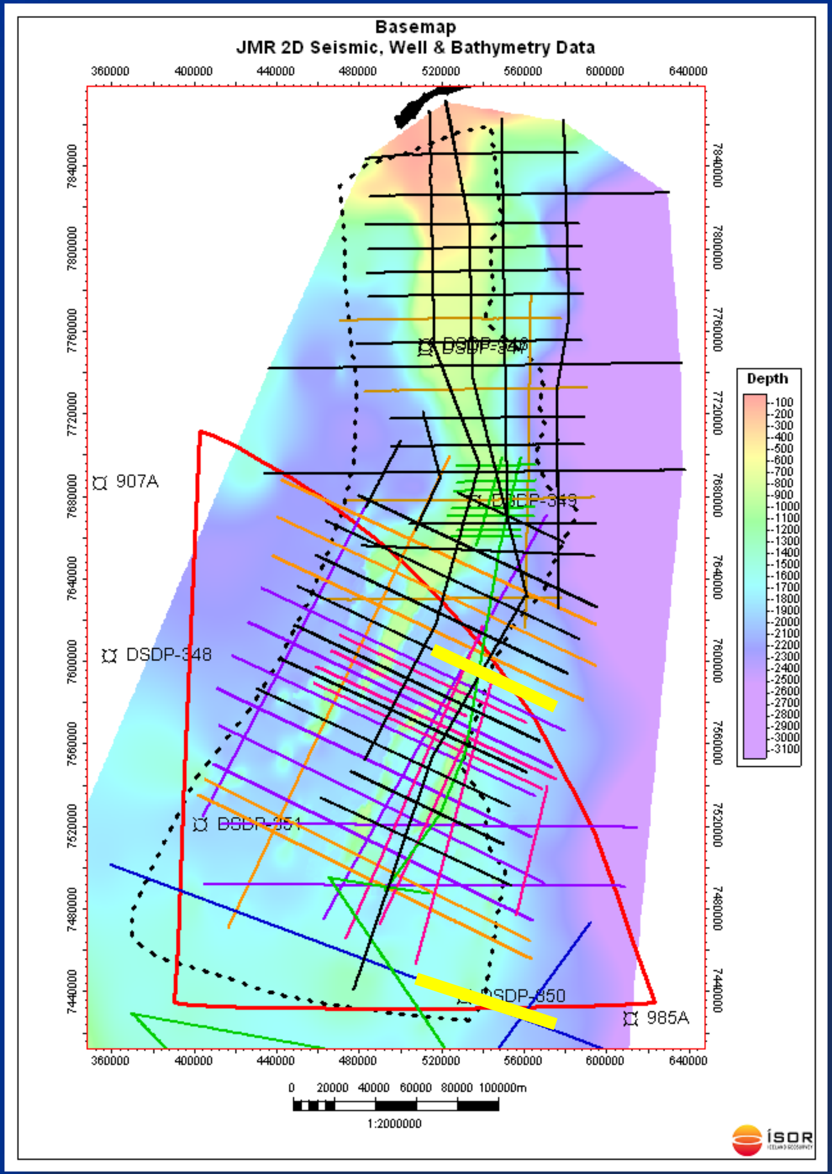
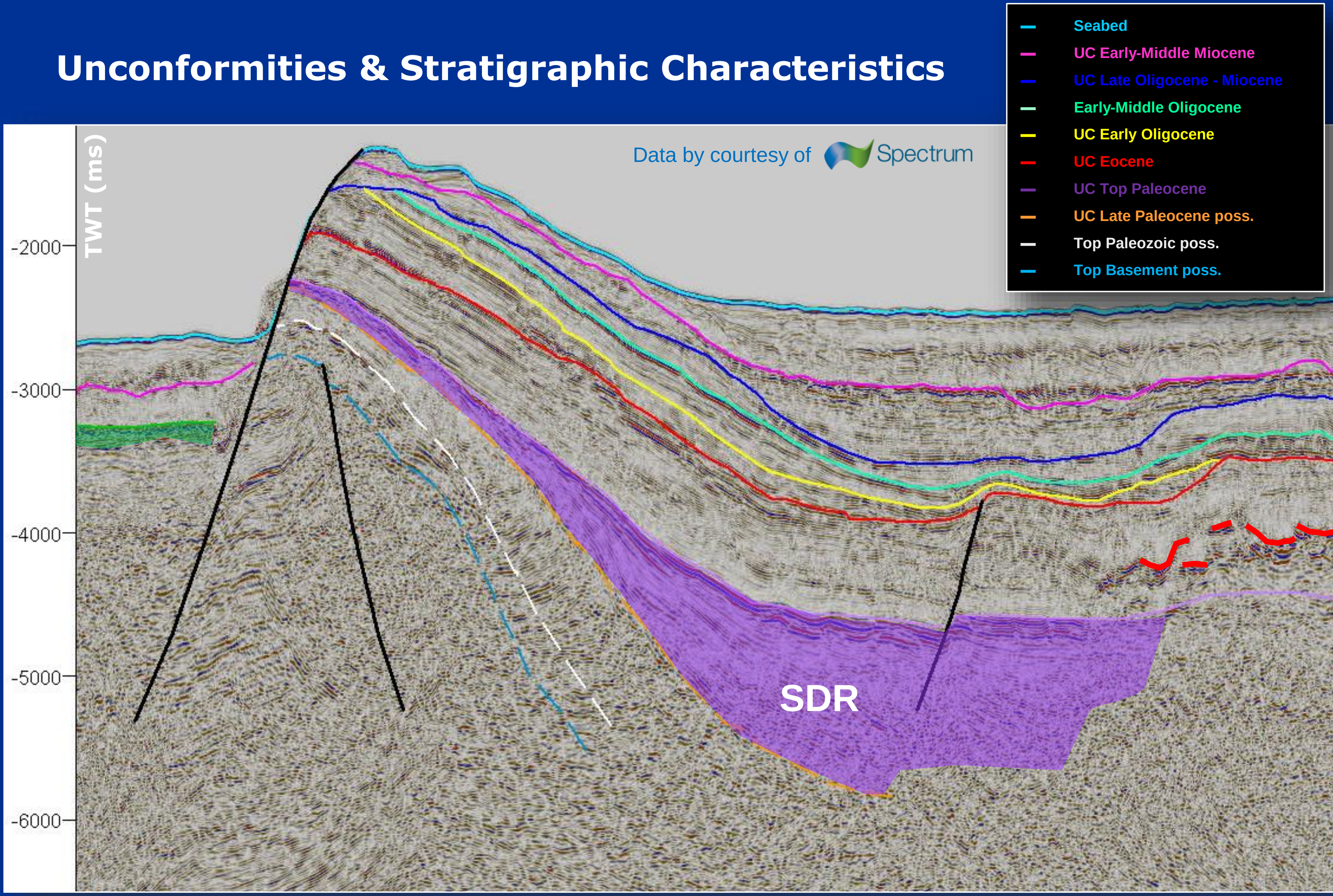
Conceptual model seismic data comparison

Key line interpretations of the Southern Ridge Complex



Unconformities & Stratigraphic Characteristics



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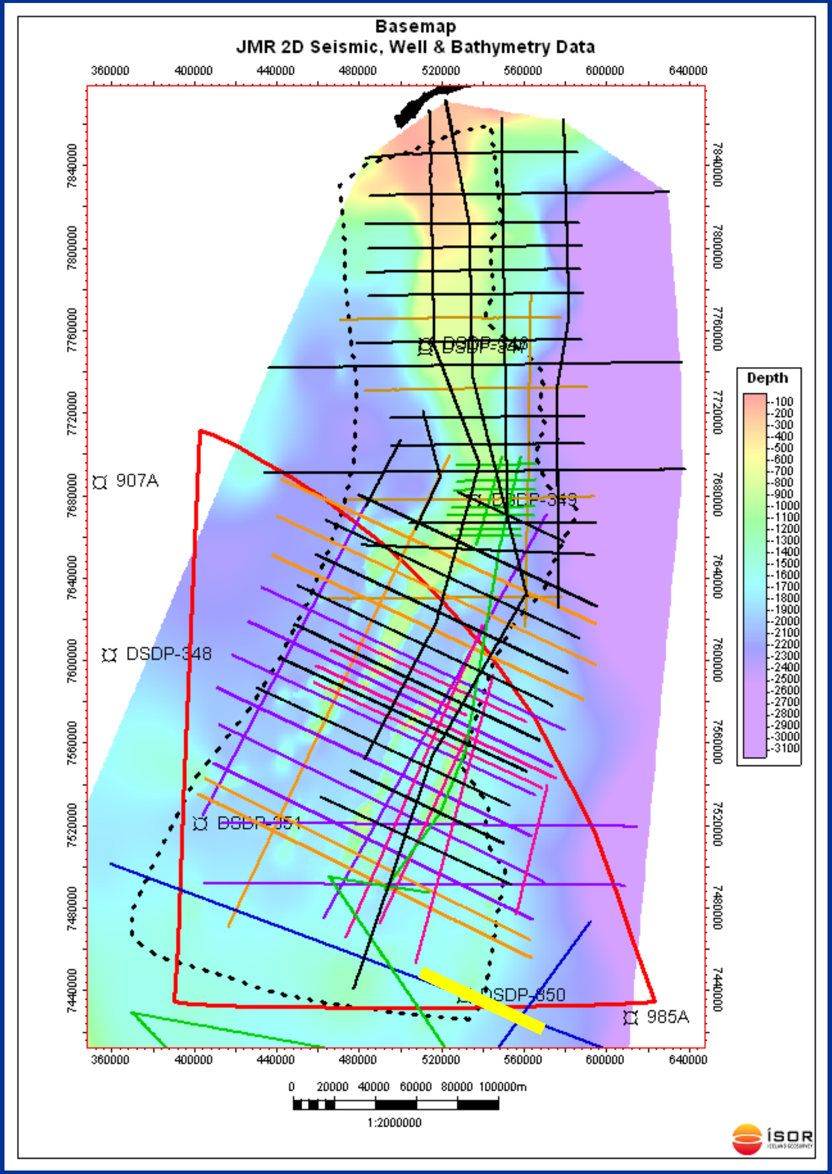
Stratigraphic / Volcano-stratigraphic Characteristics

Key line interpretation at the southern edge of the Southern Ridge Complex



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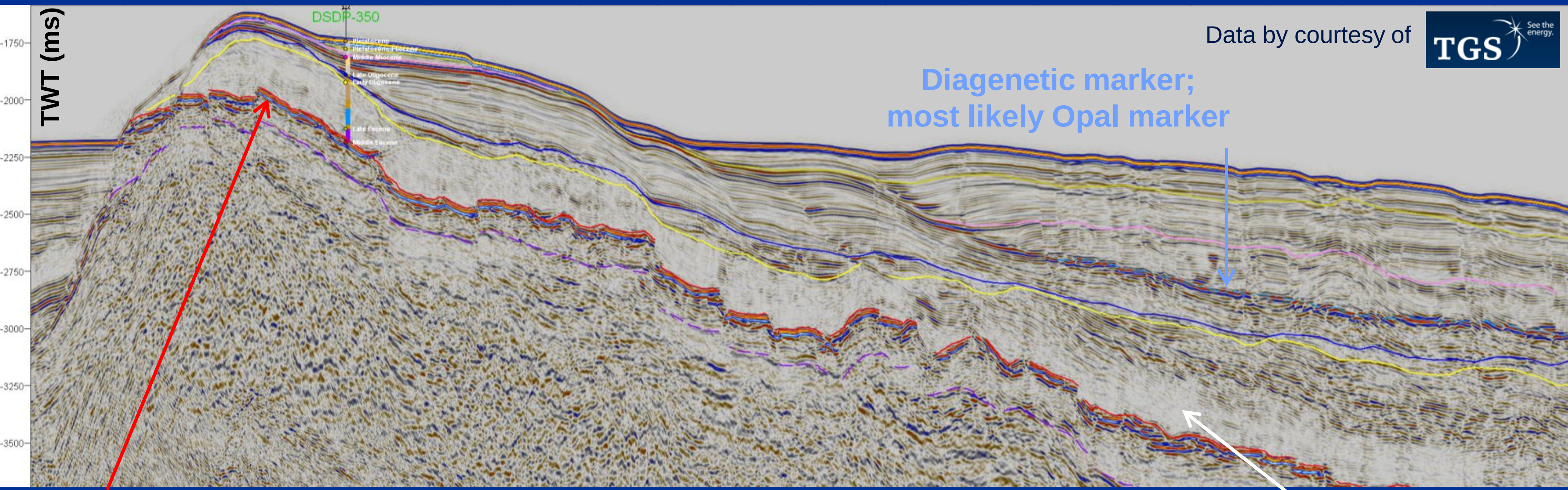
Volcano-stratigraphic Characteristics

Southeastern most edge of the Dreki Licensing Area



Seismic basement top Mid-Late Eocene basalts not Paleocene

Change in amplitude above igneous events reflect diagenetic changes of the "contact"-stratigraphy.

Sandy muds an muds, volcanic ash and foraminiferal oozes	
Alternating layers of unconsolidated and indurated to lithified sediments, silty sand	
Predominantly claystone	
Lithified sediments, particularly mudstone	
Limestone & sediment breccia	
Turbidites & breccias	
Basalt & igneous breccia	

- UC Plio-Pleistocene
- UC Early-Middle Miocene
- UC Late Oligocene - Miocene
- UC Early Oligocene
- UC Eocene
- UC Top Paleocene

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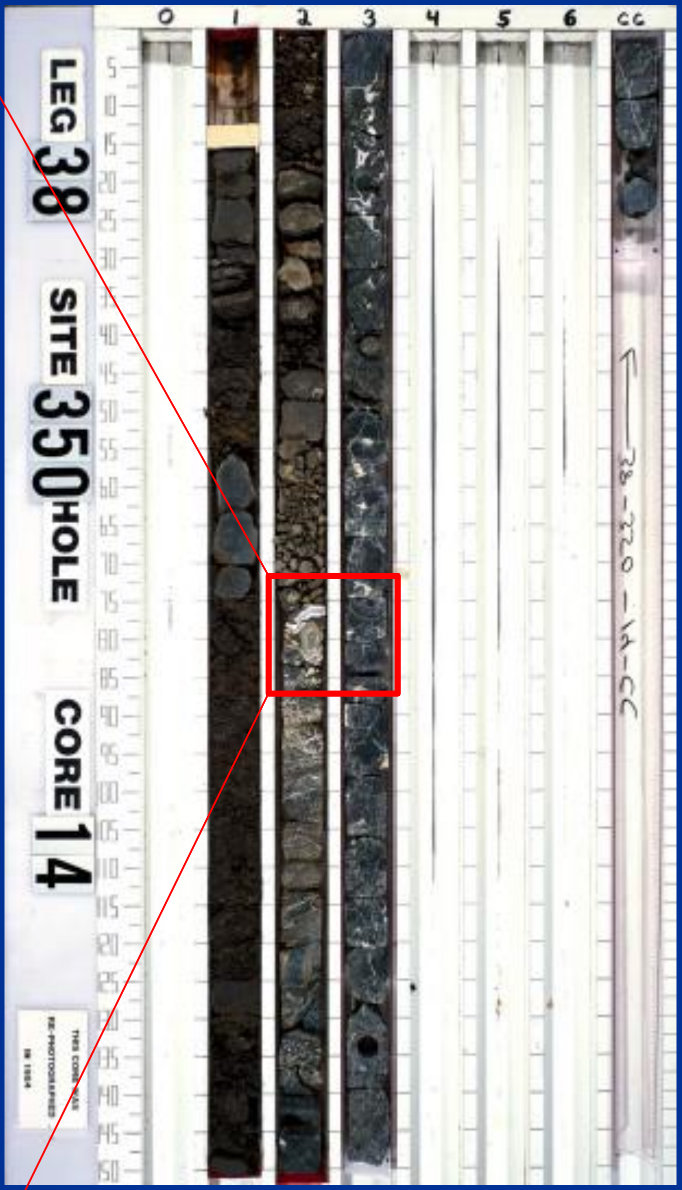
Photo Source: IODP / TAMU

By intrusive altered basalt breccia and sediment contact.



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Time determination uncertainties

K/Ar Dating:
33.5-50.5 Ma ???

Trace element sampling
(Nb, Zr, Y, Sr, Rb, Zn, Cu, Ni, Cr, V, Ba, Sc)

Godfrey Fitton (UoE)

Possibly glassy contact of younger Middle Eocene intrusion into an older basalt breccia formation.

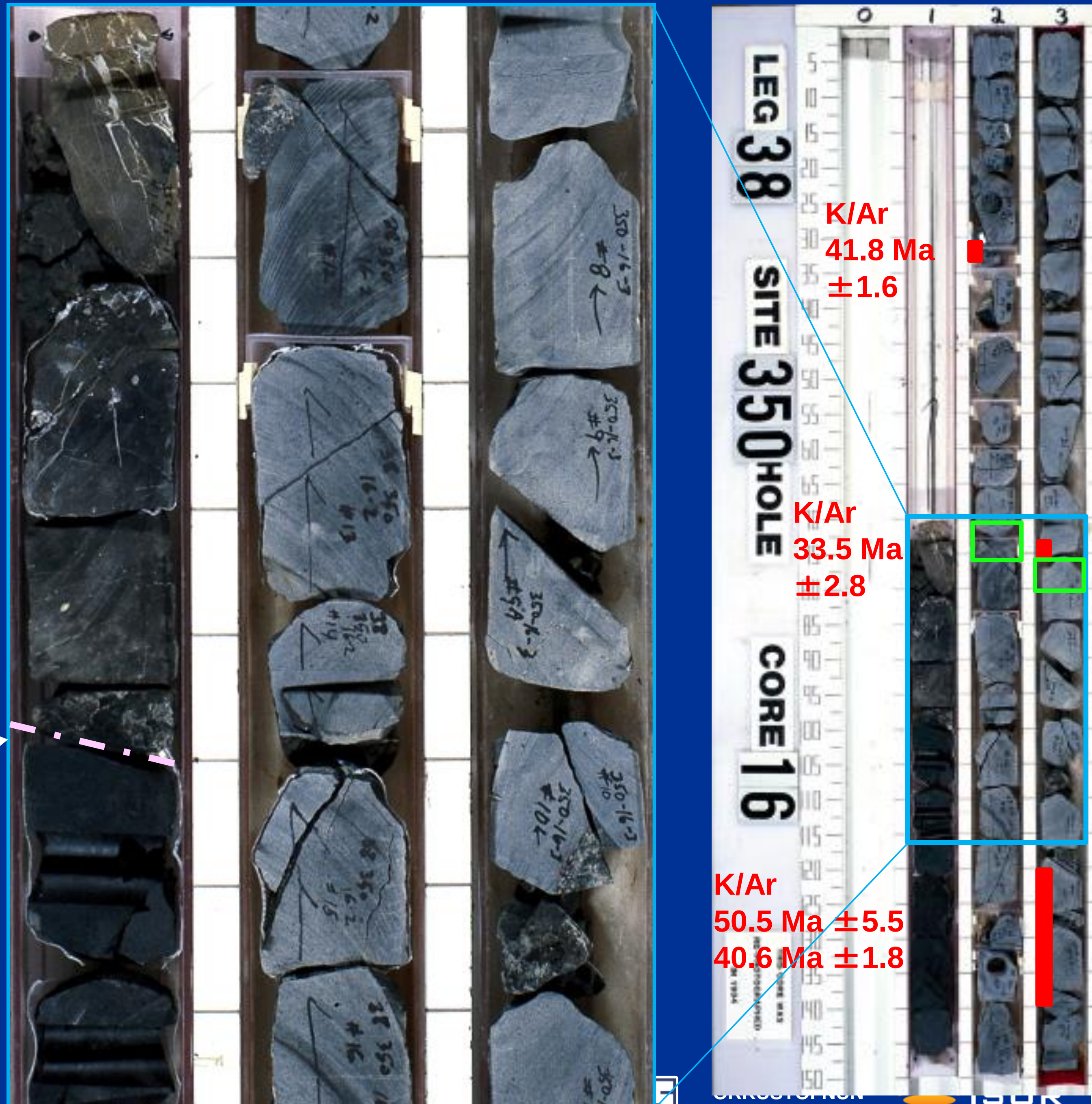

Photo Source: IODP / TAMU

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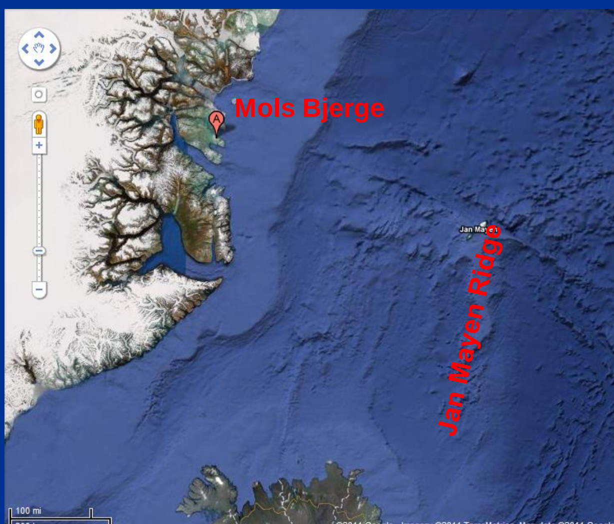
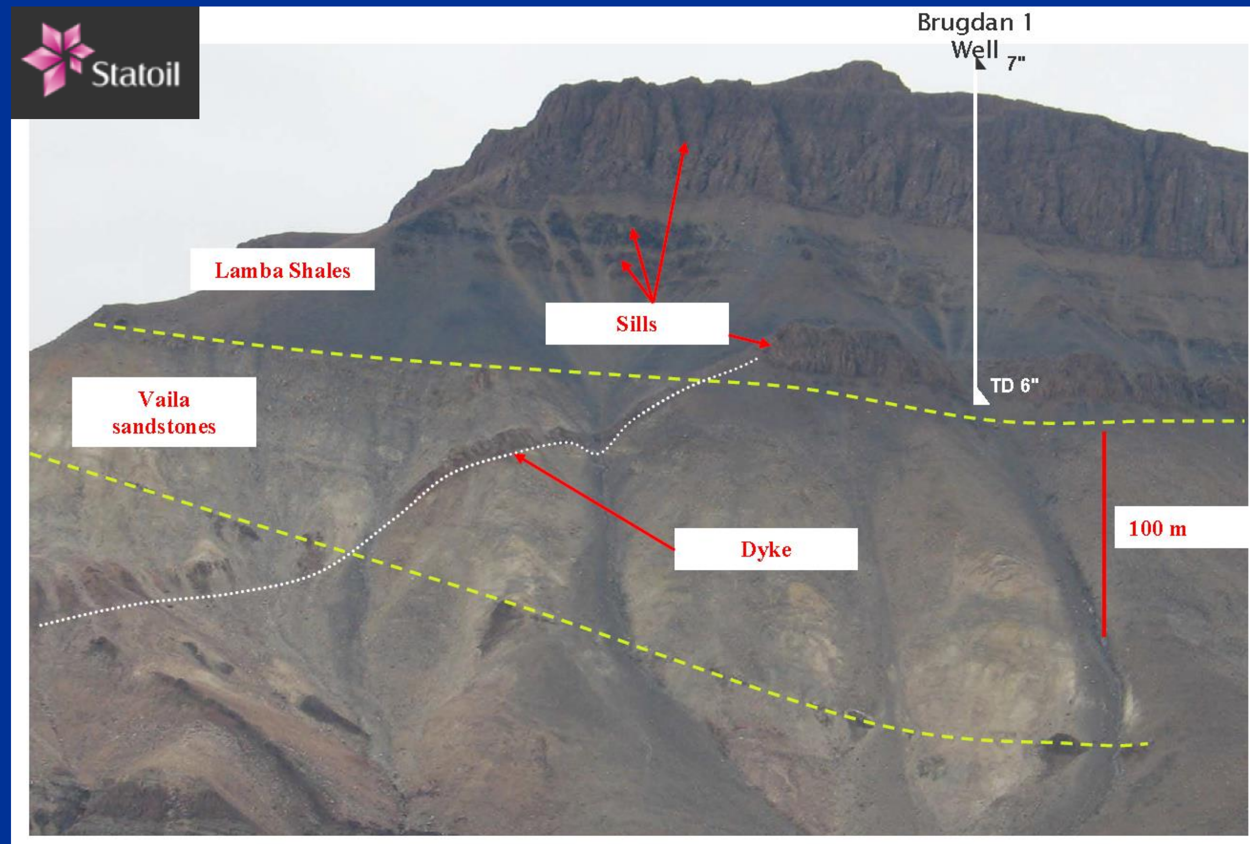
Analogue comparisons

Finding Analogues

Correlation criteria below Top Paleocene

Intrusions tend to pass through (***Dykes***) harder sediment sections, such as sandstones, but intrude more laterally (***Sills***) in soft- / not very much consolidated sediments, such as shale's - or along existing and open fracture zones or boundaries.

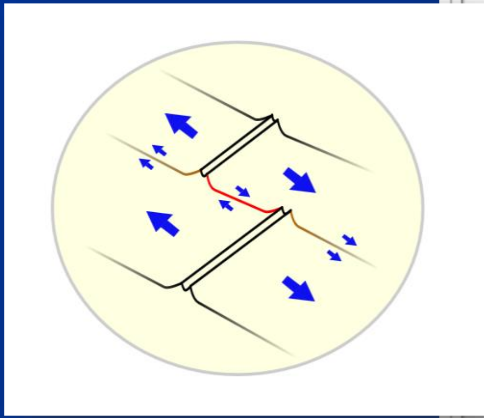


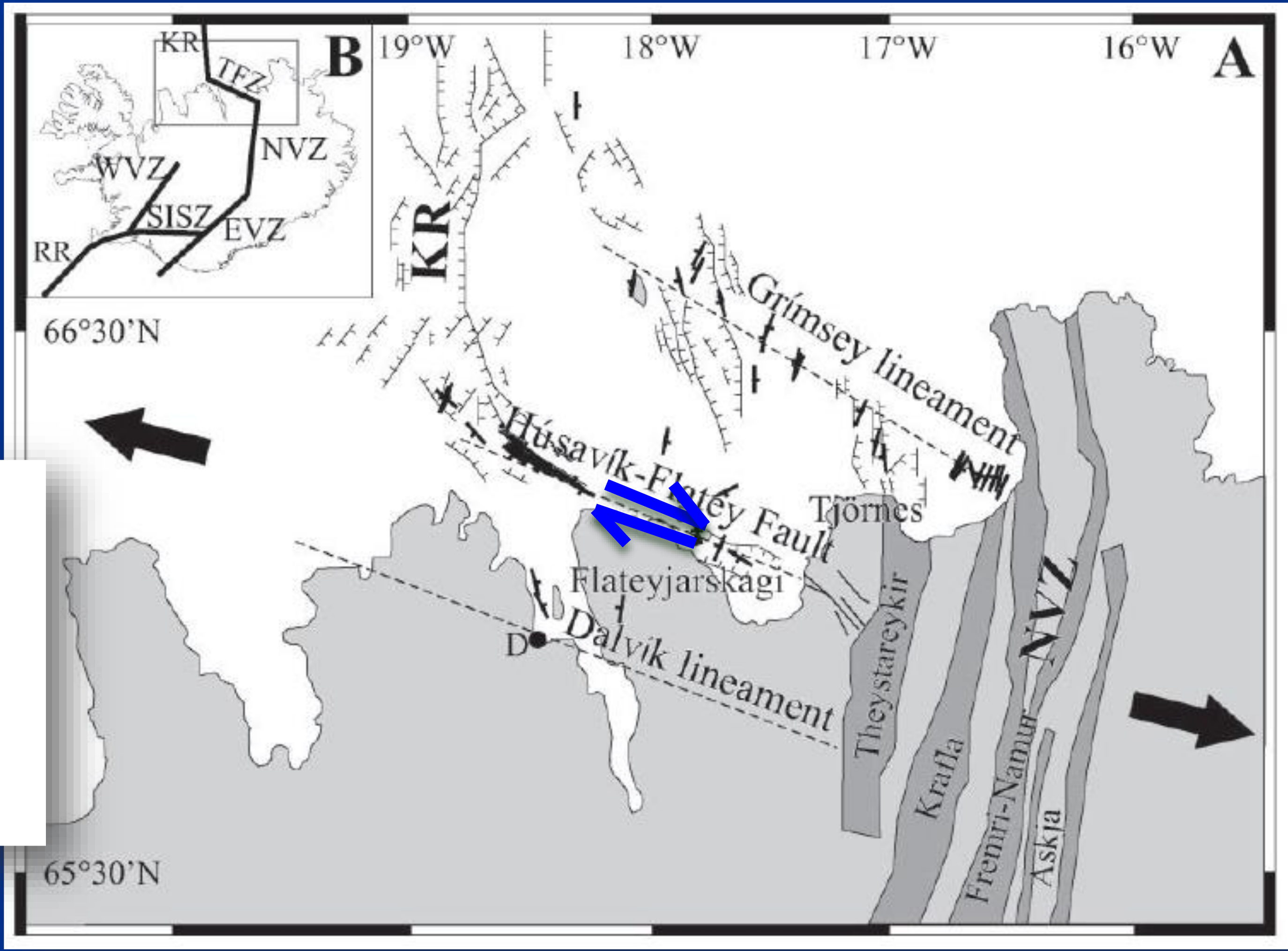


Ref.: APPEX 2011 Talk, StatOil

Tjoernes Fracture Zone – Husavik-Flatey Fault

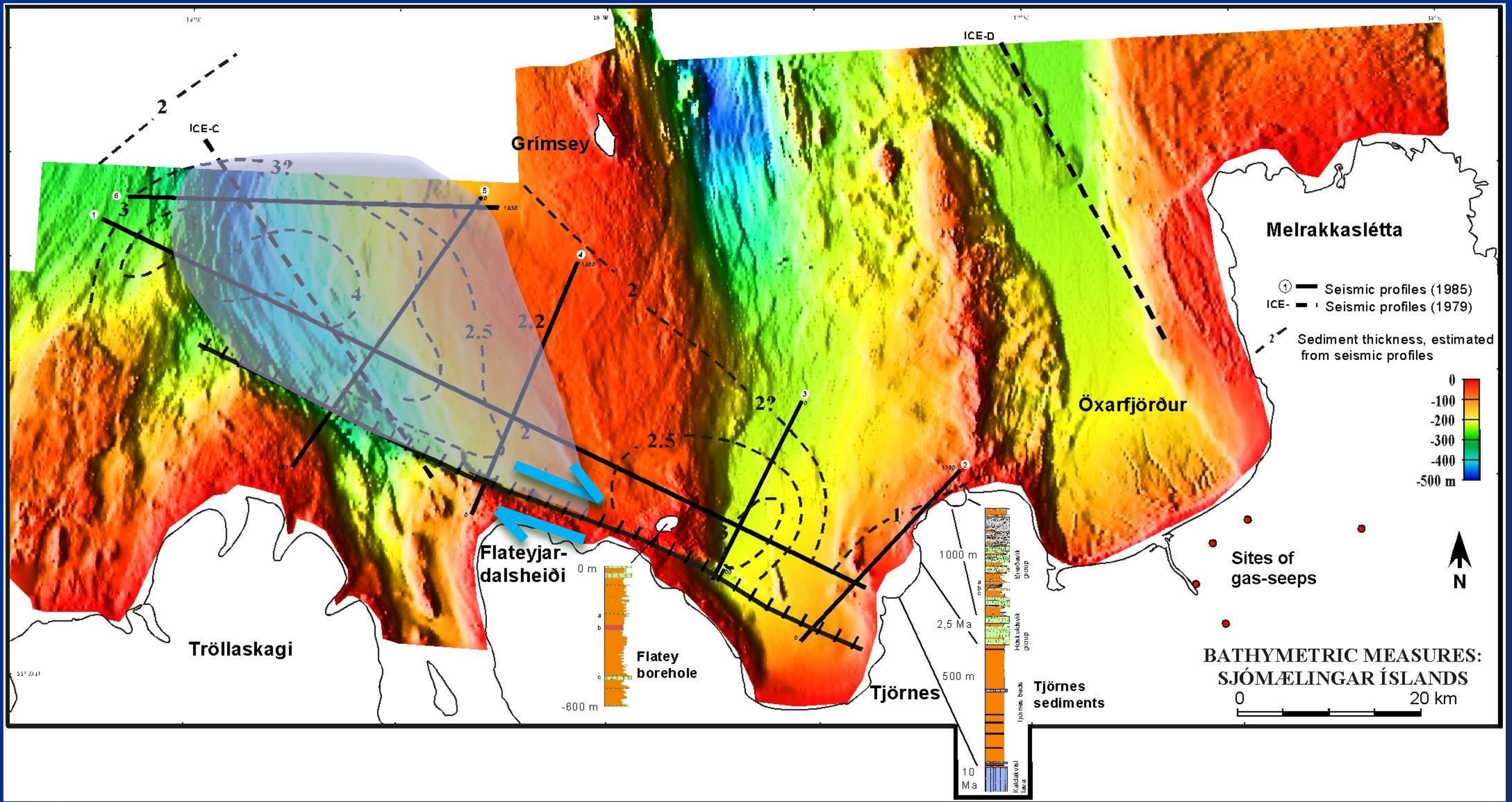
S. Garcia et al., 2002





Tjoernes Fracture Zone – Husavik-Flatey Fault

B. Richter, K. Gunnarsson, B. Brandsdóttir, et al., 2002; K. Gunnarsson, 1998



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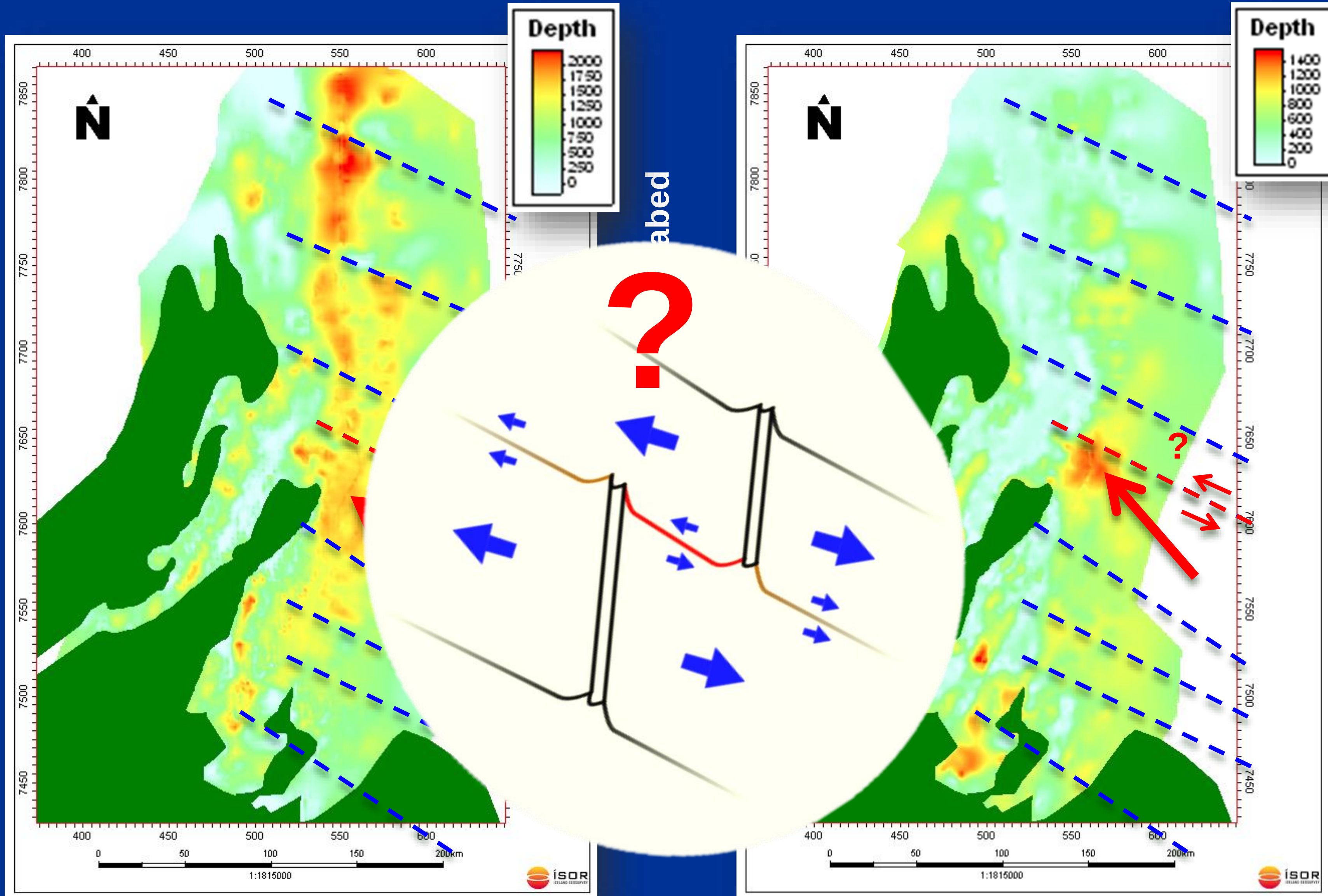
Top Paleocene - UC Late Oligocene-Miocene Isopach Map (m)



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What do we know?

- Best analogue comparison with East Greenland exploration examples and Møre Basin for the Norwegian side. Direct indications of pre-opening sedimentary strata of possibly Paleozoic, Triassic-Jurassic and maybe Cretaceous age – especially underneath the west flank areas of the ridge, i.e. Jan Mayen Basin.

- Post Paleocene sedimentary rocks of sufficient thickness and age, especially along the ridge flank areas, but are relatively thin towards the northern and southern edge of the ridge, and nearly completely eroded across the highest section of the Main Ridge, a small rim just West along the Jan Mayen Trough.

- Potential reservoir rocks possibly are locally terrigenous to shallow marine, but in general marine deposits, especially submarine fans / turbidite deposits for post Paleocene especially Eocene deposits, covered by deep marine and semi-pelagic sediments along the ridge flanks during the Miocene to present.

- Complex sub-division and structures along the JMMC, especially within the Southern Ridge Complex and along the western flank of the Main Ridge, presenting potential traps, both structural and stratigraphic.

- A detailed investigation of local structures in relation to sediment influx sediment systems areal distribution, or influence of ocean currents remains to be studied.

- Potential evidence of Jurassic source rock has been recorded. Hydrocarbon maturation variation is probably high, more gas prone in areas with influence of igneous activity, which needs to be investigated.

Future steps in mind short & long term

- Include all the available regional seismic data around Jan Mayen and North of Iceland.
- Specify oceanic crust types across the Greenland-Iceland-JMMC-Norway basin corridor.
- Focus on the Iceland-Faroe Ridge area to also be able to describe the transition between the south JMMC and NE-Iceland.
- Revise the onshore Iceland geo-chrone time and structure model.
- More data needed across those areas with very sparsely populated data coverage (magnetic, gravity, refraction and reflection seismic, etc.).

Thank you very much for your attention !

Acknowledgements:

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NAG-TEC Group

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