



Greenland Frontier Opportunities

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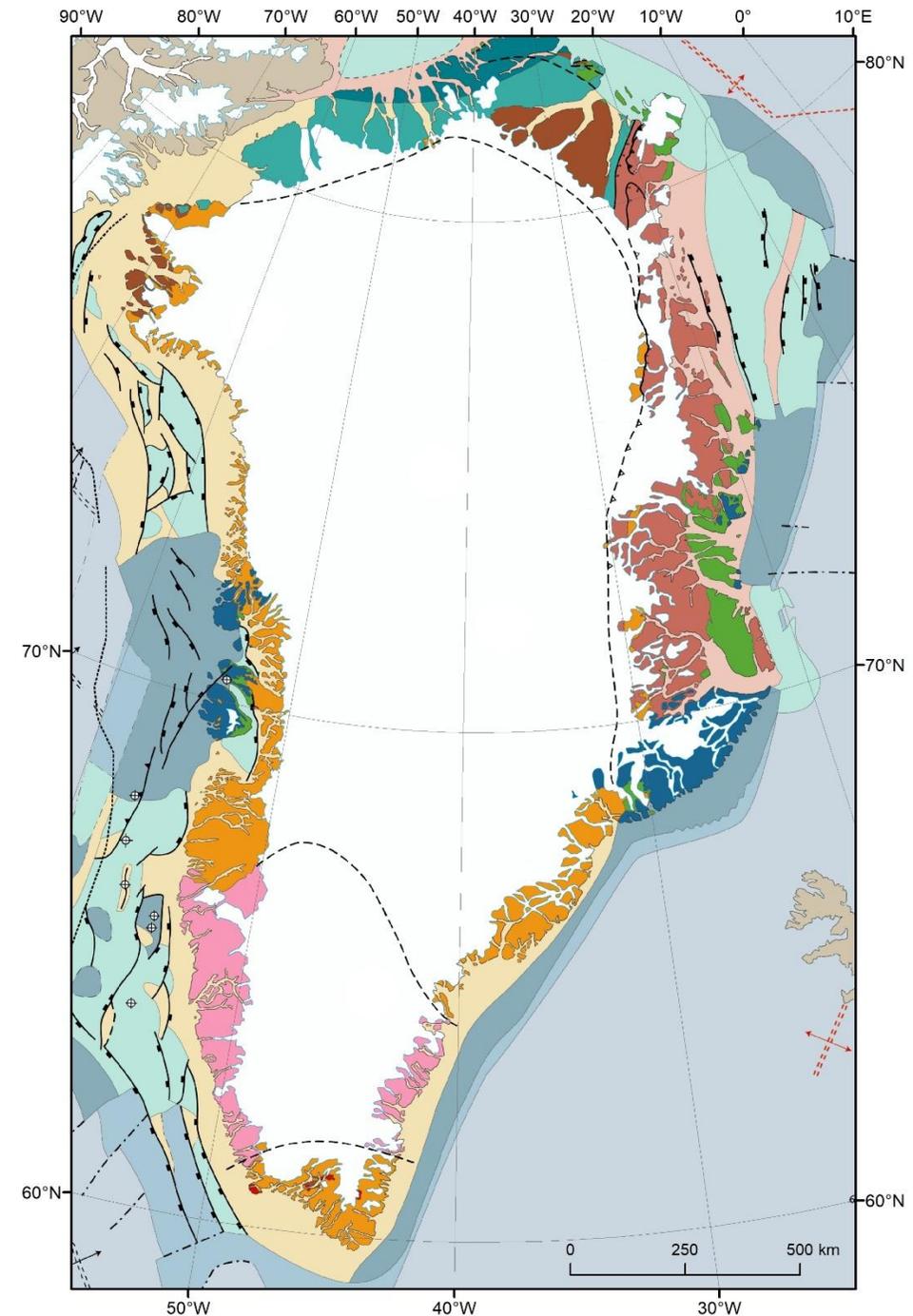
²Government of Greenland, Ministry of Industry, Energy, Research and Labour



GEUS

Introduction to Greenland Geology

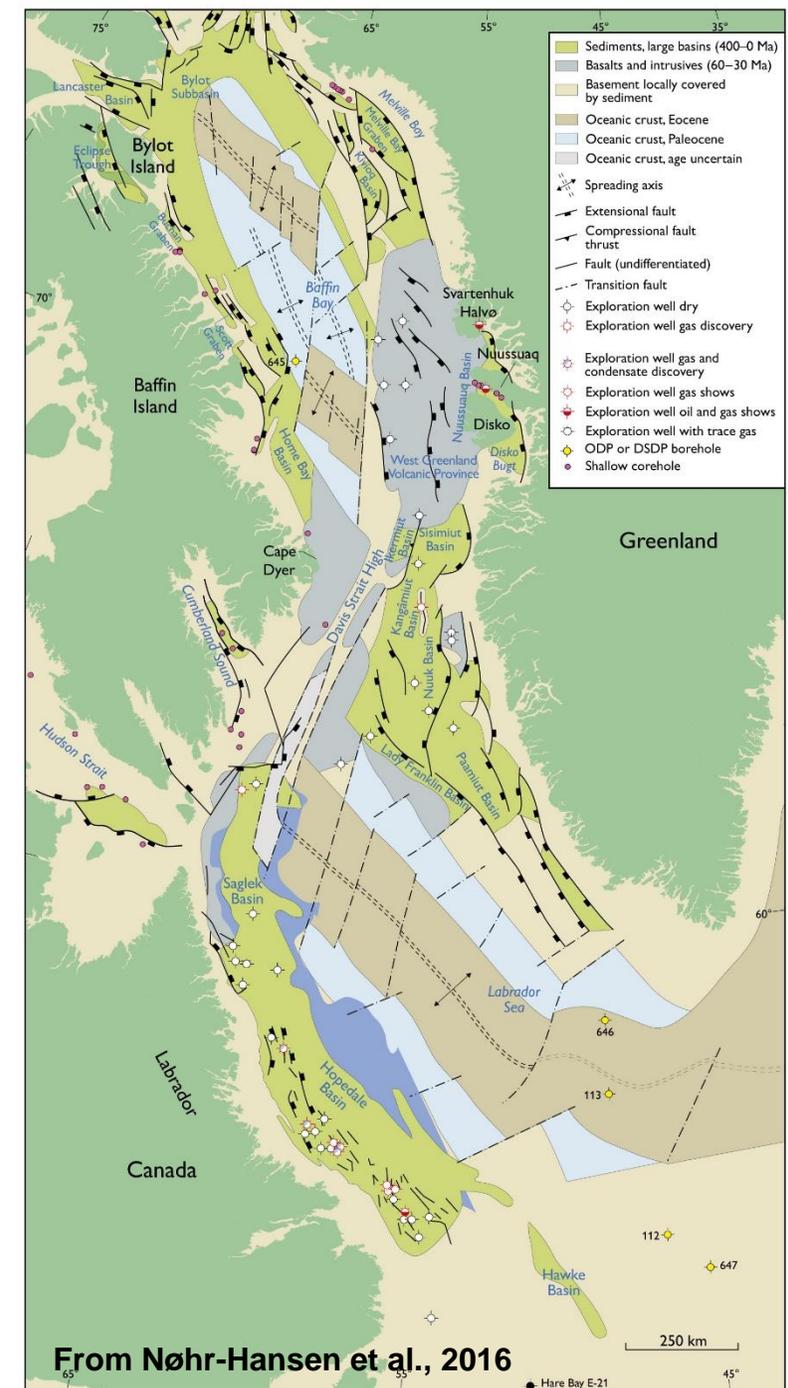
- The Greenland continental shelf covers some **2.4 million km²** and constitutes **one of the largest frontier regions in the World**
- In **West Greenland** the exploration potential is associated with **Albian – mid-Neogene rift and passive margin basins**
- In **Central and Northeast Greenland** exploration potential is associated with on- and offshore **Carboniferous – mid-Neogene rift and passive margin basins**
- Exploration potential is also associated with offshore Cretaceous–Jurassic basins in **Southeast Greenland** and the onshore Cambrian–Silurian Franklinian Basin in **North Greenland**
- **Focus** in this presentation will be on **West Greenland** and **East and Northeast Greenland**



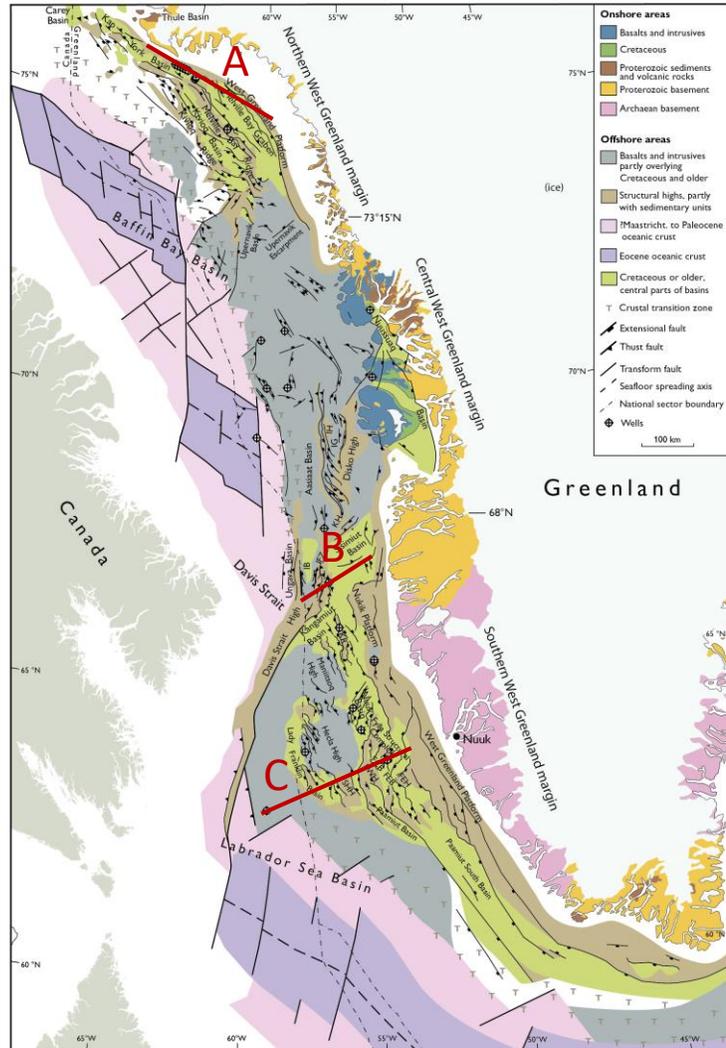
West Greenland

Regional Geology

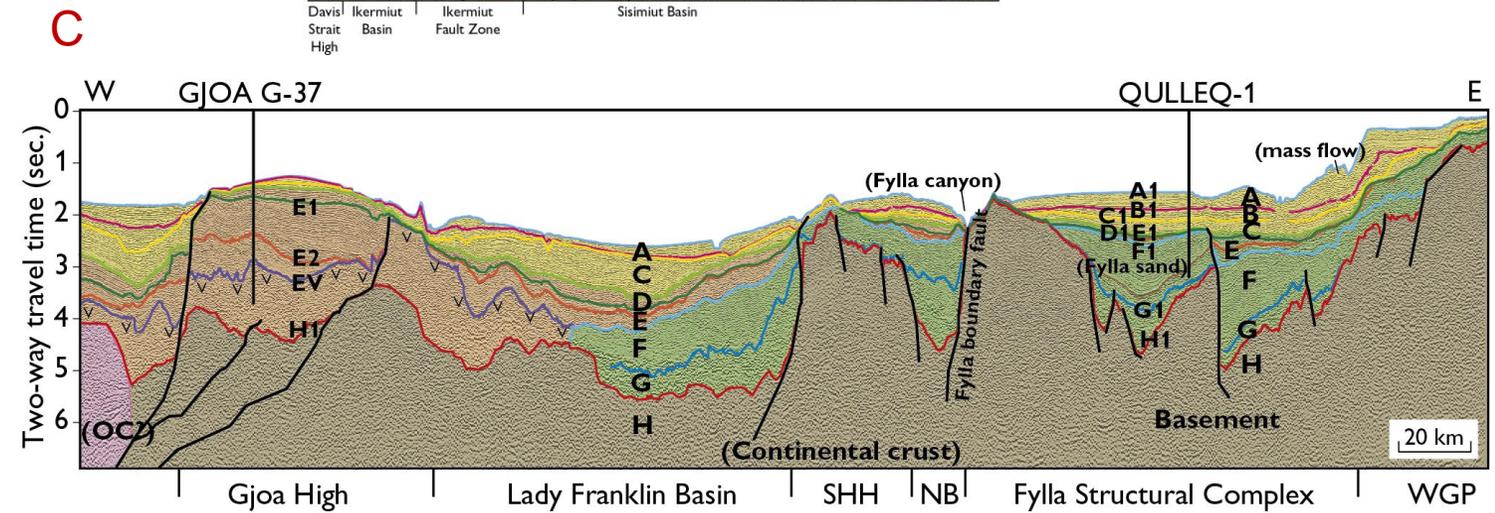
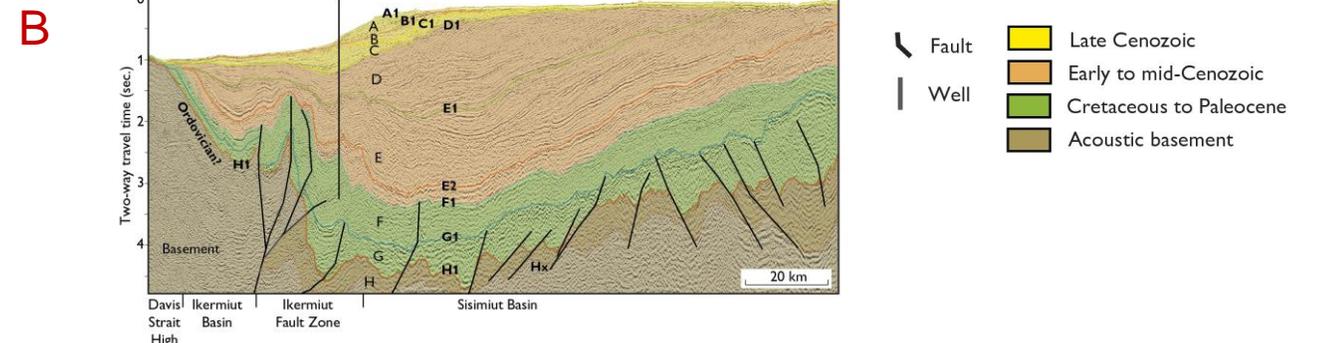
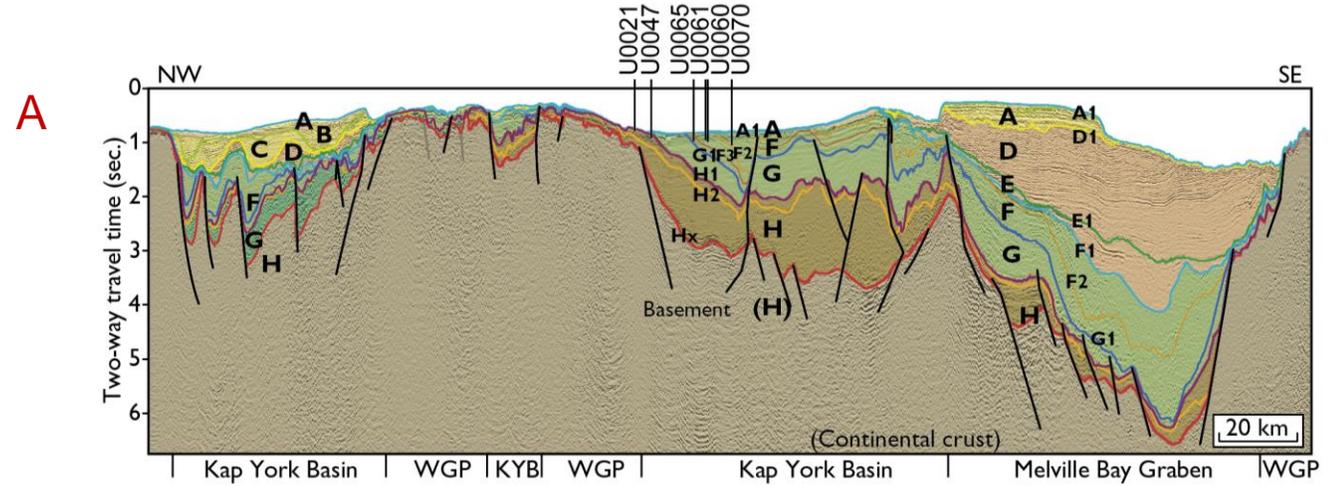
- **Early Cretaceous – Paleocene rift basins** from Labrador Sea in the south to Baffin Bay in the north, more than 2000 km of continental margin
- **15 exploration wells** have been drilled in West Greenland; one possible gas discovery and a few with oil and gas shows and inclusions
- Area covers **+800,000 km²** (~1 well/50,000 km²)
- Several **oil seeps** and shallow boreholes with **gas and oil shows** indicating a working petroleum system
- On the conjugate Canadian margin, nine gas, condensate, and oil discoveries
- Still considered as a **huge prospective frontier region**



Greenland Regional Geology



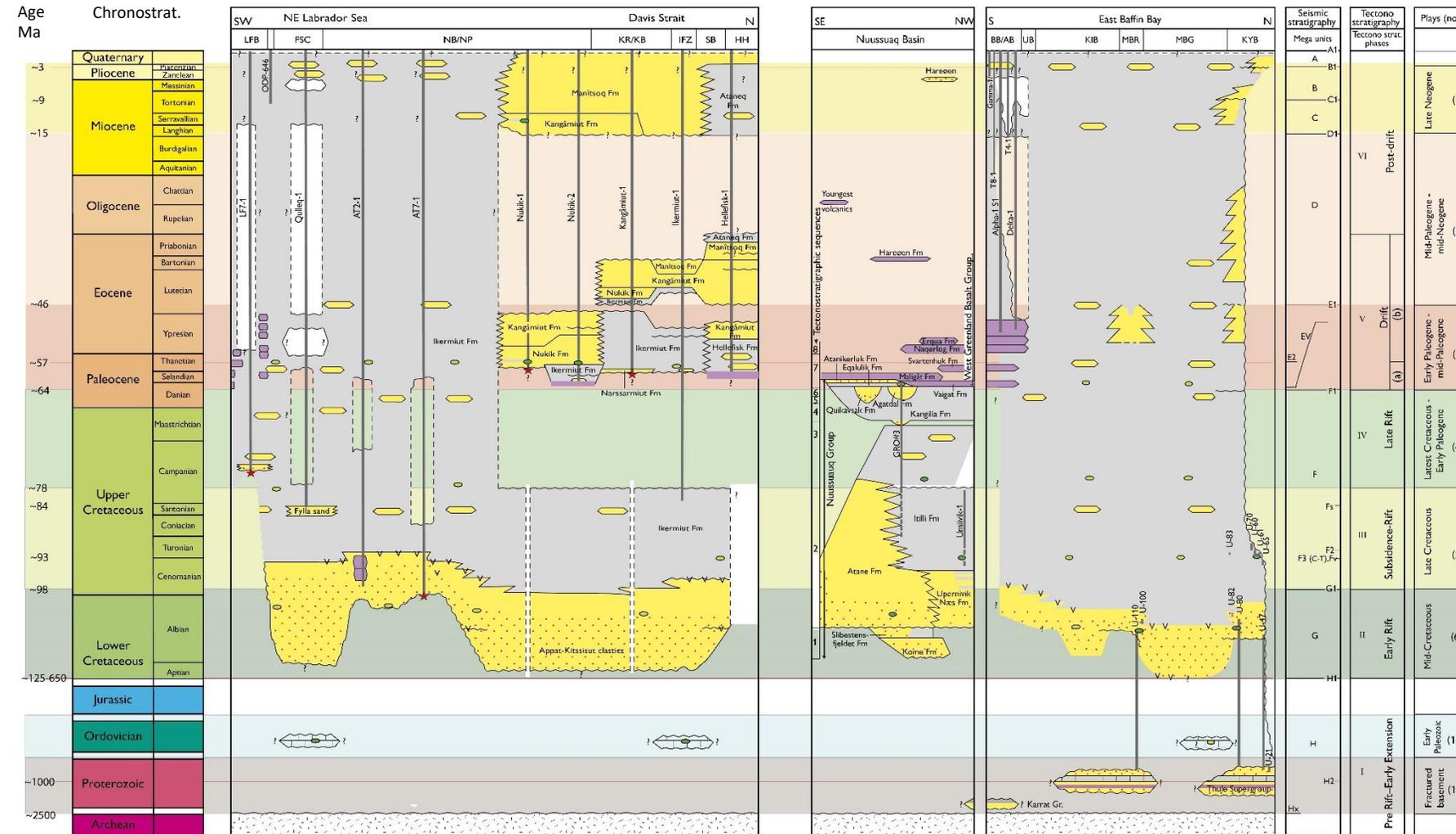
From Gregersen et al., 2019



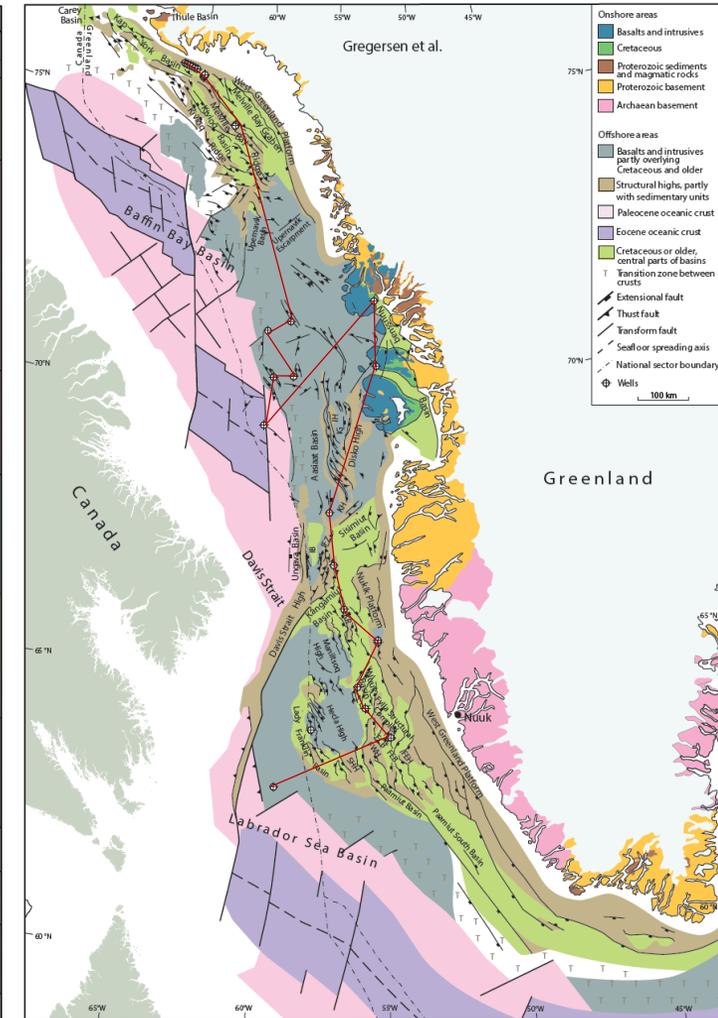
- Fault
- Well
- Late Cenozoic
- Early to mid-Cenozoic
- Cretaceous to Paleocene
- Acoustic basement

Greenland Regional Geology

- Same tectono-stratigraphic evolution along the entire West Greenland margin
- The sedimentary basin evolution can be divided into **six tectono-stratigraphic phases**
- 5 potential source rock intervals**
- Reservoirs** at several stratigraphic levels
- High quality regional **seals**



From Gregersen et al., 2019

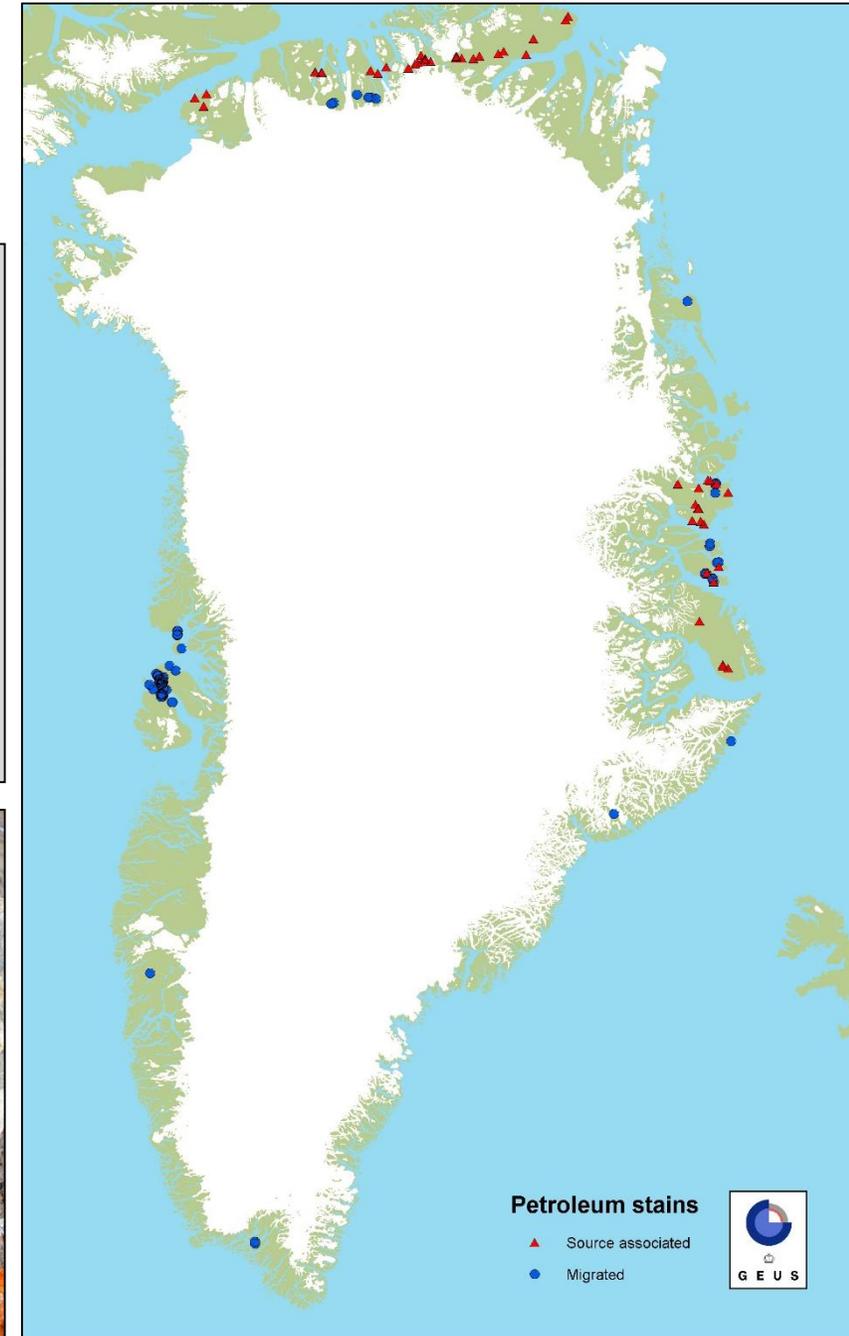
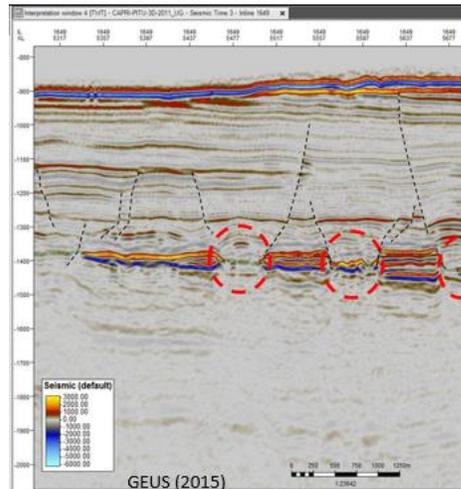
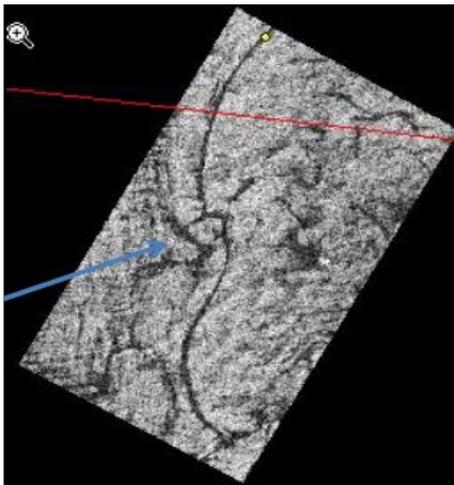
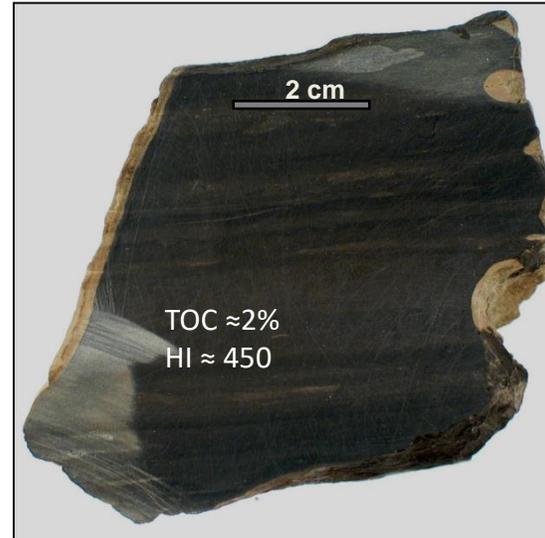


From Gregersen et al., 2019

West Greenland

Source Rocks

- Five **potential petroleum source rocks** have been documented from outcrops, cores and oil seeps, including:
 - Miocene** Type marine, deltaic II-III shale
 - Paleocene/Eocene** marine, deltaic Type II-III shale
 - Cenomanian – Turonian** marine Type II-III shale
 - Albian** deltaic/terrigenous Type I-III shale
 - Ordovician** marine Type II shale

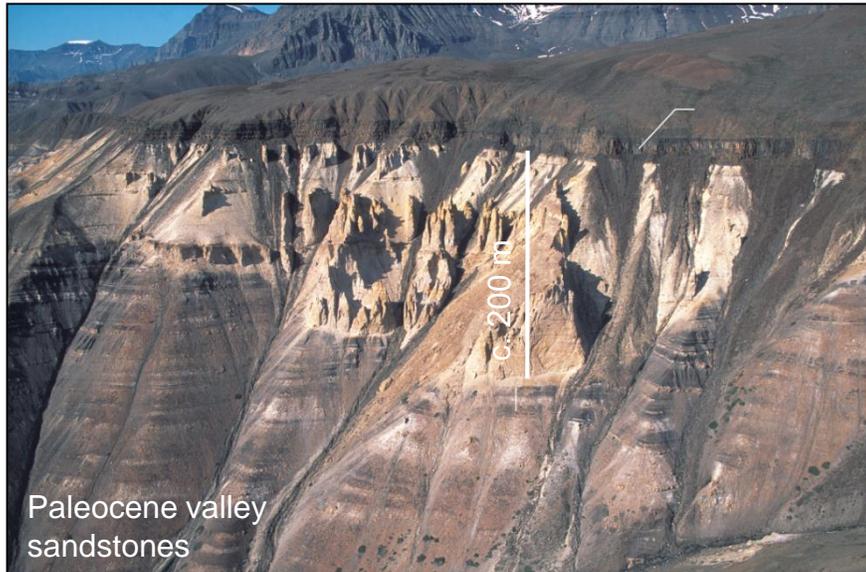


West Greenland Reservoirs

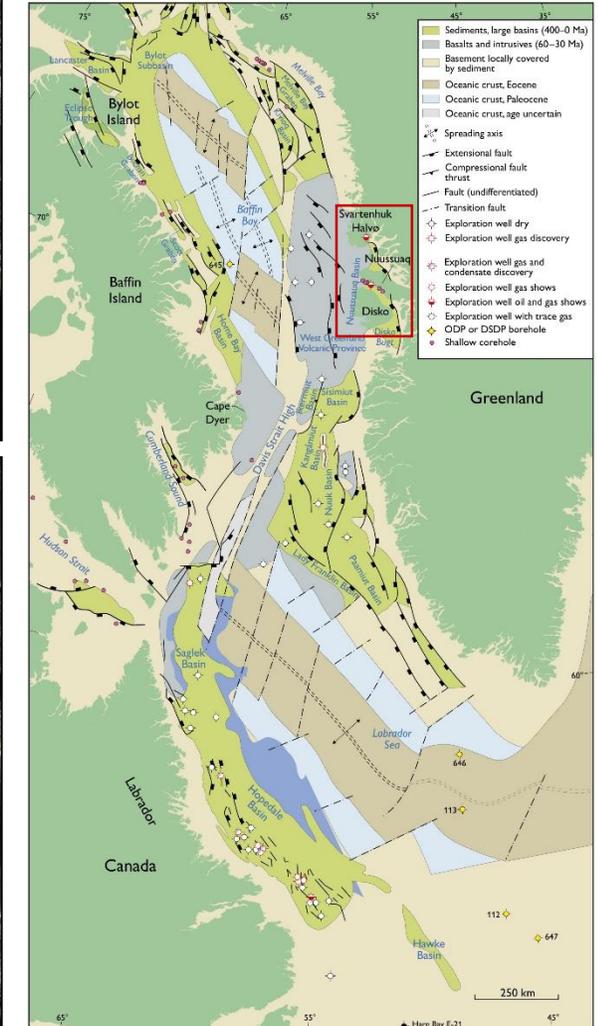
- **Excellent reservoirs proven at several stratigraphic levels from exploration wells, stratigraphic wells and onshore analogues (Nuussuaq Basin)**



From Dam et al., 2009



From Nøhr-Hansen et al., 2016



West Greenland Seals



	Mean critical capillary pressure	P50 Maximum Static Capillary Column		
Group 1	798 psia	208 ft	63 m	Shale types 2 and 5 with indications of alteration
Group 2	2,166 psia	561 ft	171 m	Shale type 3 with possible indications of alteration
Group 3	10,998 psia	2964 ft	903 m	Group 3 is comparable to seals offshore GOM
Group 4	21,238 psia	5729 ft	1746 m	Group 4 is comparable to seals offshore Nigeria

From Almond, 2007



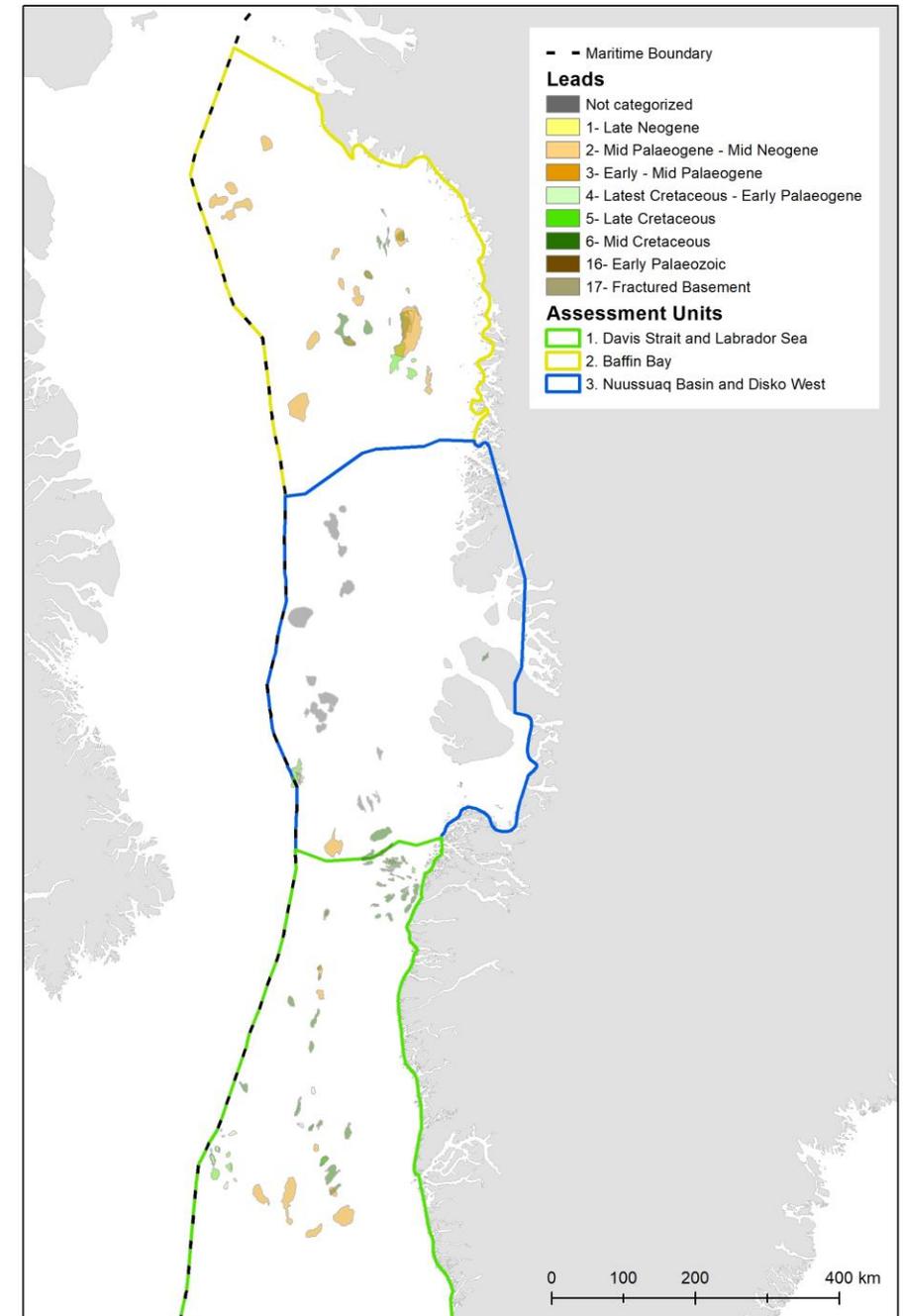
- A **seal study** has been conducted and confirmed that **high-quality seals** occur in Cenomanian–Coniacian, Campanian and Danian mudstone successions in the Nuussuaq Basin



West Greenland

Exploration Possibilities

- Large portfolio including **136 structural leads** (including only large structural closures)
- Leads on Paleozoic, Cretaceous, Palaeogene, Neogene and Pleistocene level

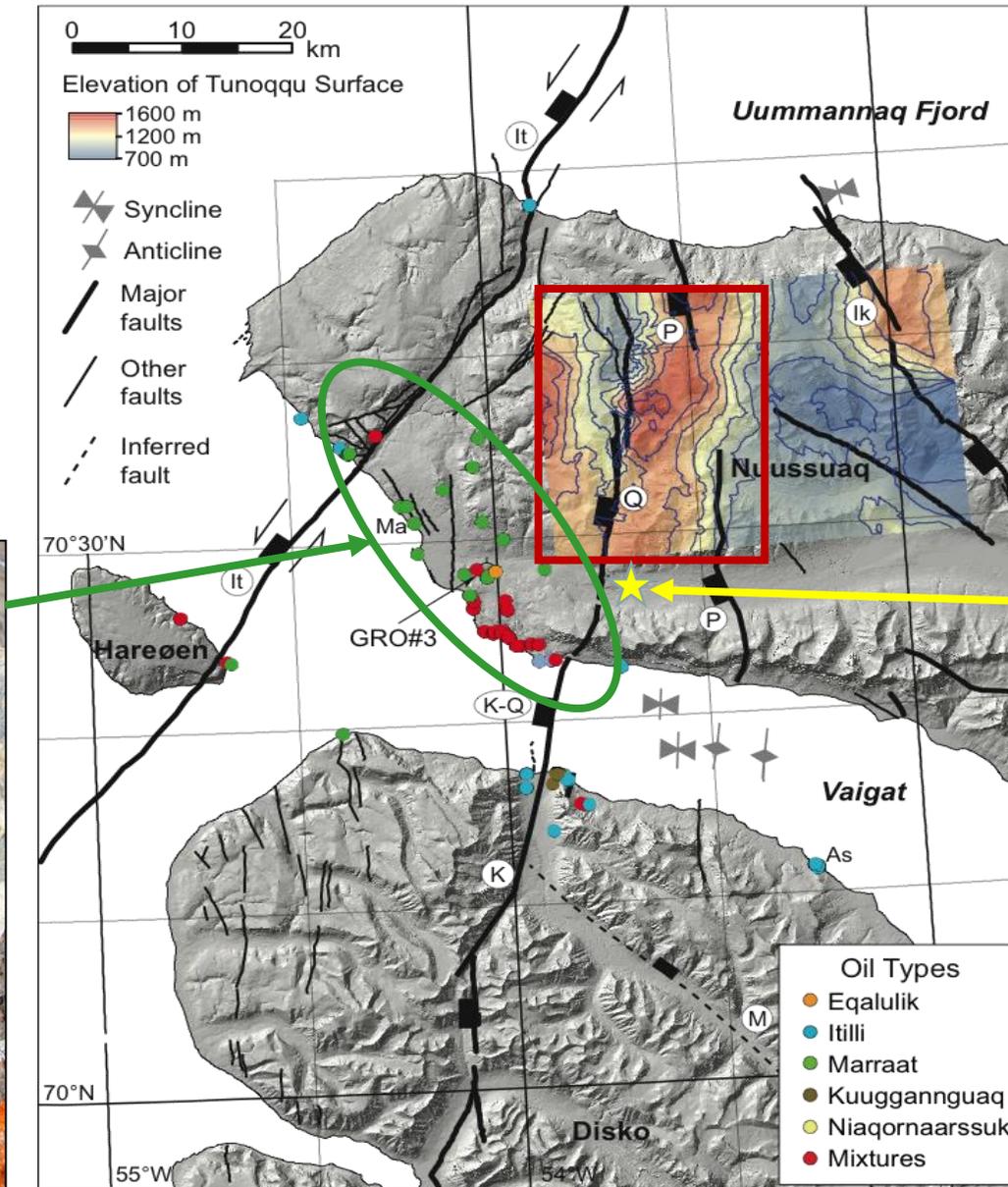


From the Greenland Resource Assessment Project

West Greenland

Selected Leads

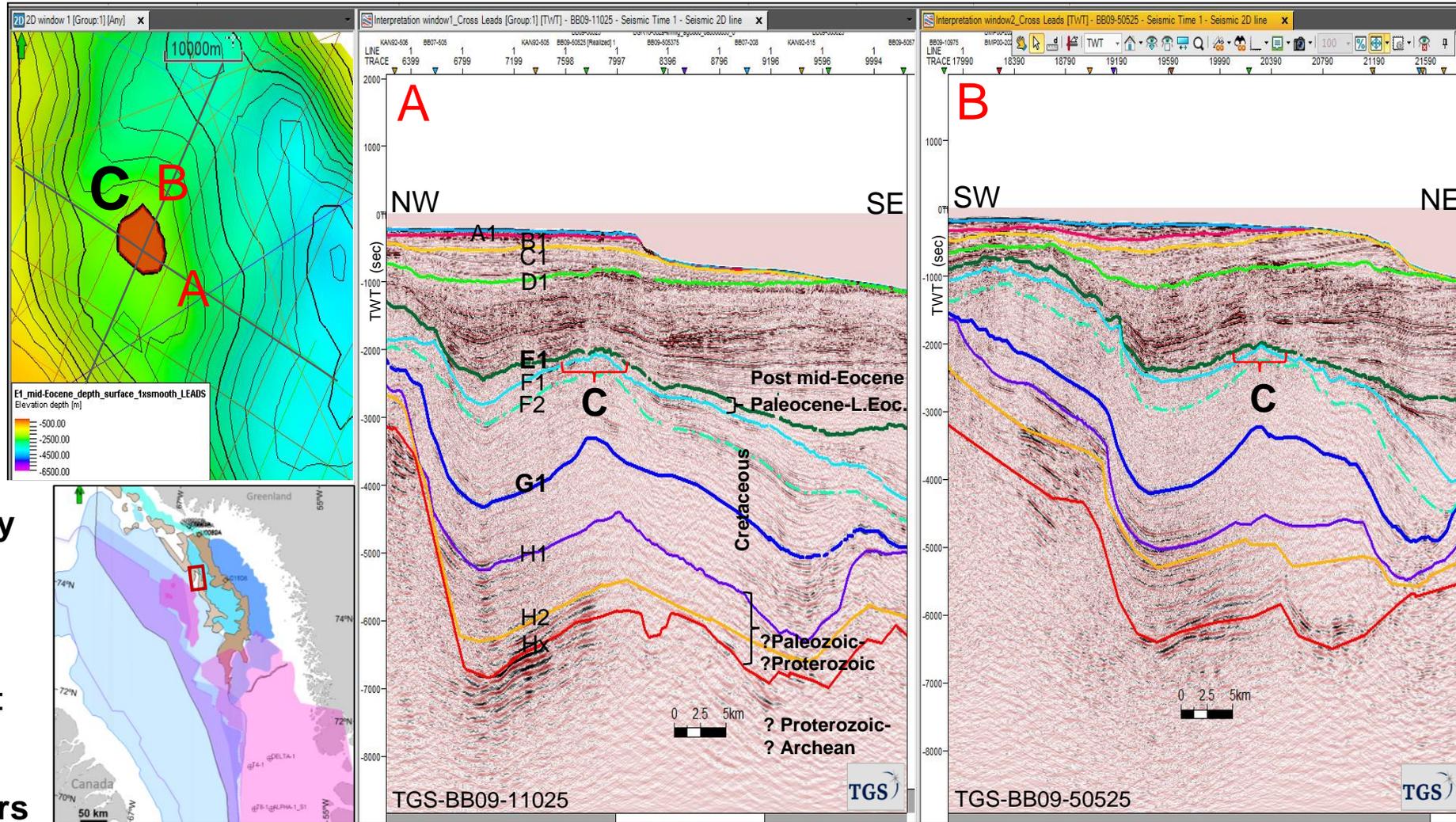
- Major **earliest Eocene 4-way closure** (60 km²) mapped with photogrammetry
- Amplitude** of structure 180 m
- In-place, un-risked volumes up to **1018 MMBBL** (GLJ Petroleum)



West Greenland

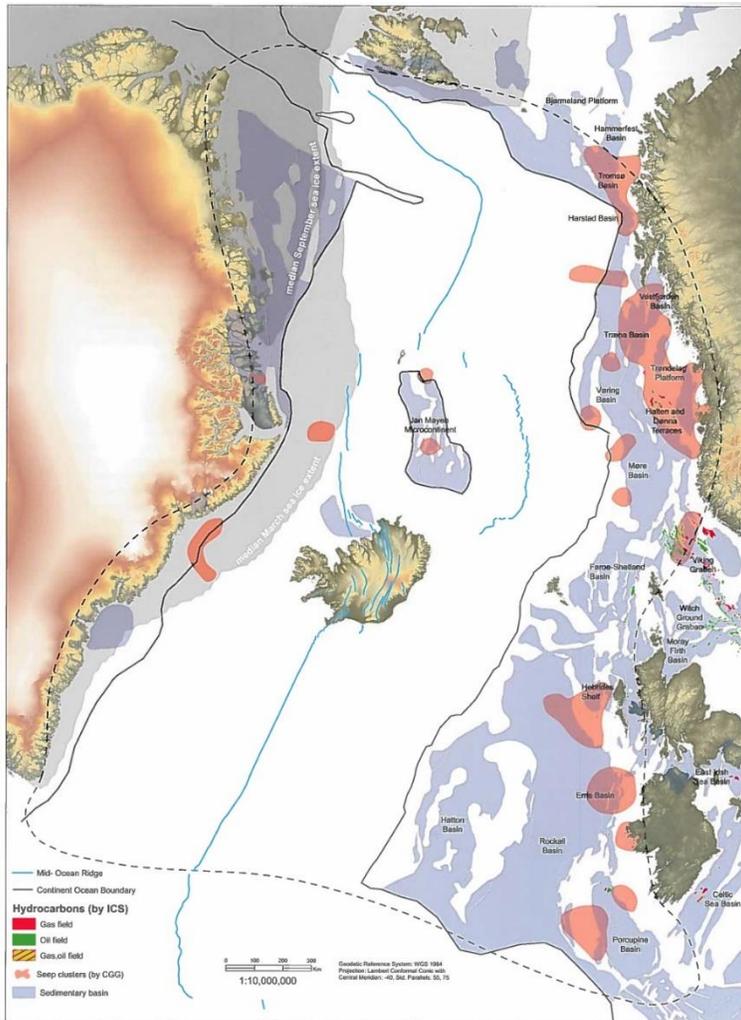
Selected Leads

- C Lead Melville Bay
- Early to mid-Palaeogene 4-way closure
- Area 250 km²
- Unrisked, recoverable, P_{mean}: **545 MMBOE**
- Potential for **stacked reservoirs**



East Greenland

Exploration Potential On- and Offshore East and Northeast Greenland

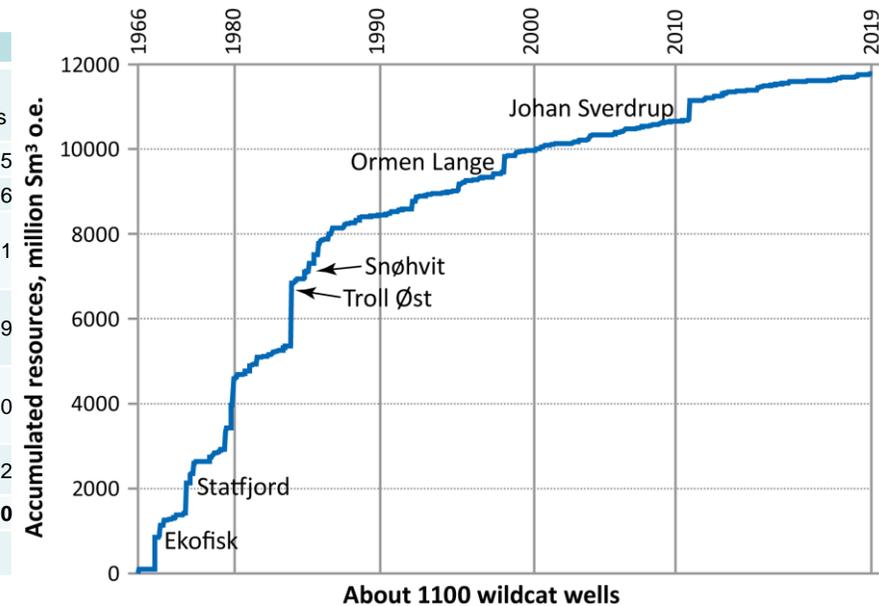


- **Carboniferous – Paleocene** rift basins
- Area covers **+780,000 km²**
- **No exploration wells** have been drilled in East Greenland
- **Conjugate margin to the NCM**
- Accumulated resources NCM are some **100 Bboe** (NPD, 2017)
- East and NE Greenland considered as a **huge prospective frontier region**

Petroleum resources on the Norwegian Continental shelf per 31 Dec 2017

	Oil mill. Sm ³	Gas bill. Sm ³	NGL mill. tonn	Condensate mill. Sm ³	Sum o.e. mill. Sm ³	Sum Boe Mill. barrels
Produced	4261.4	2341.1	200.3	117.3	7100.3	44659.5
Reserves*	1131.1	1729.1	109.5	20.7	3088.9	19428.6
Contingent resources in fields	338.5	241.3	20.8	2.4	621.5	3909.1
Contingent resources in discoveries	275.0	293.4	15.2	1.9	599.2	3768.9
Production not evaluated	130.0	70.0			200.0	1258.0
Undiscovered resources	1995.0	1870.0		135.0	4000.0	25159.2
Total	8130.7	6544.9	345.8	277.4	15610.0	98184.0

* Includes resource classes 1, 2 and 3



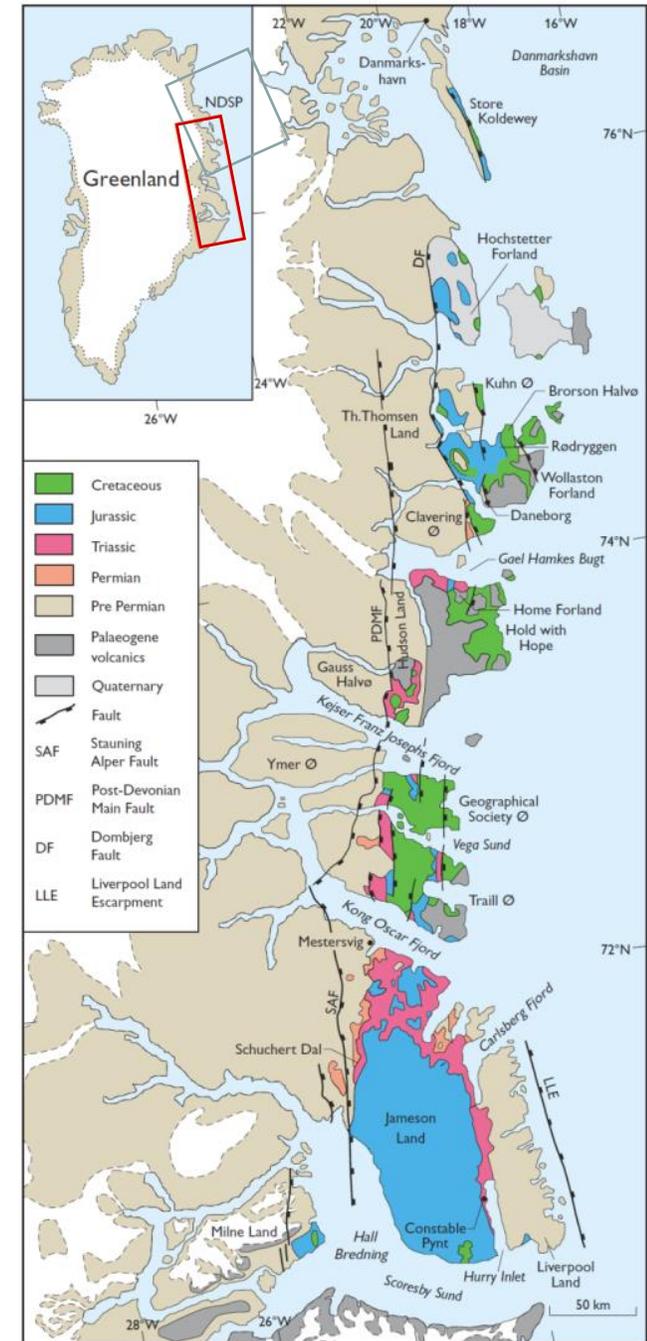
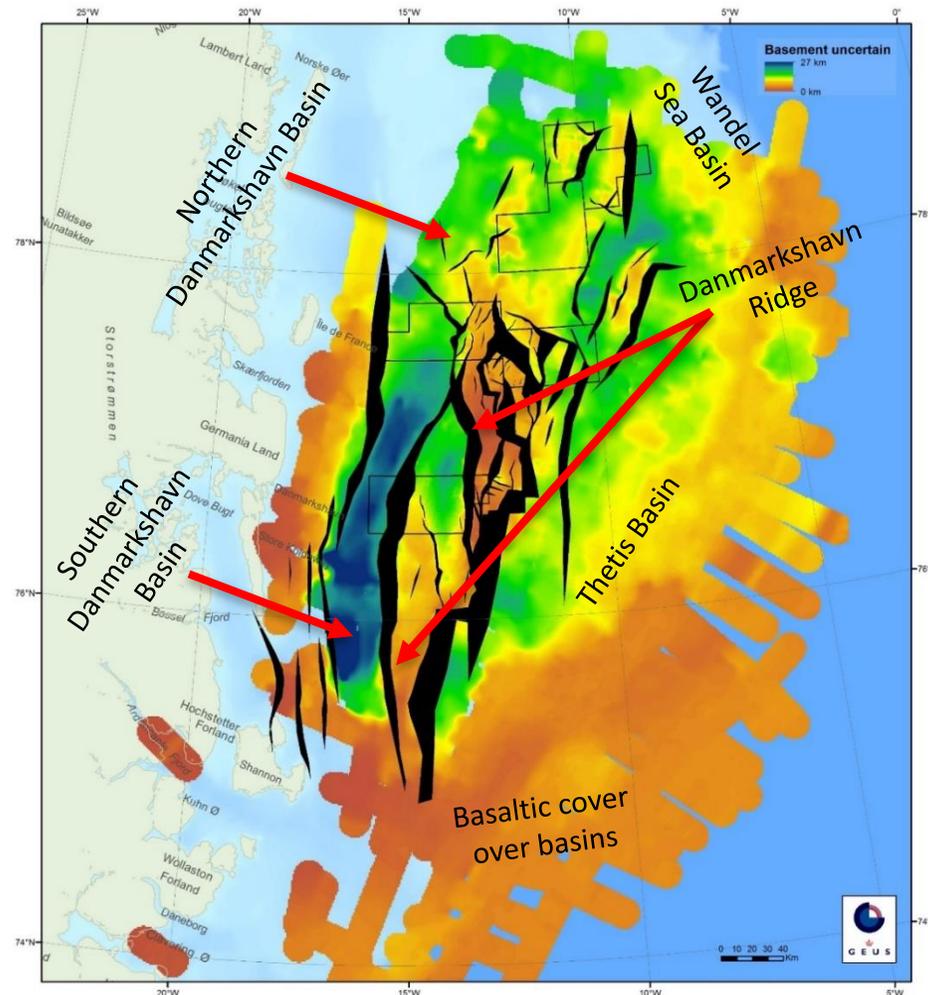
About 1100 wildcat wells

East Greenland

Exploration Potential On- and Offshore East and Northeast Greenland

- **Exploration potential** associated with the **onshore Jameson Land Basin** and offshore NE Greenland
- **World-class outcrops** of the East Greenland Rift System, that **serve as analogue** for the offshore area

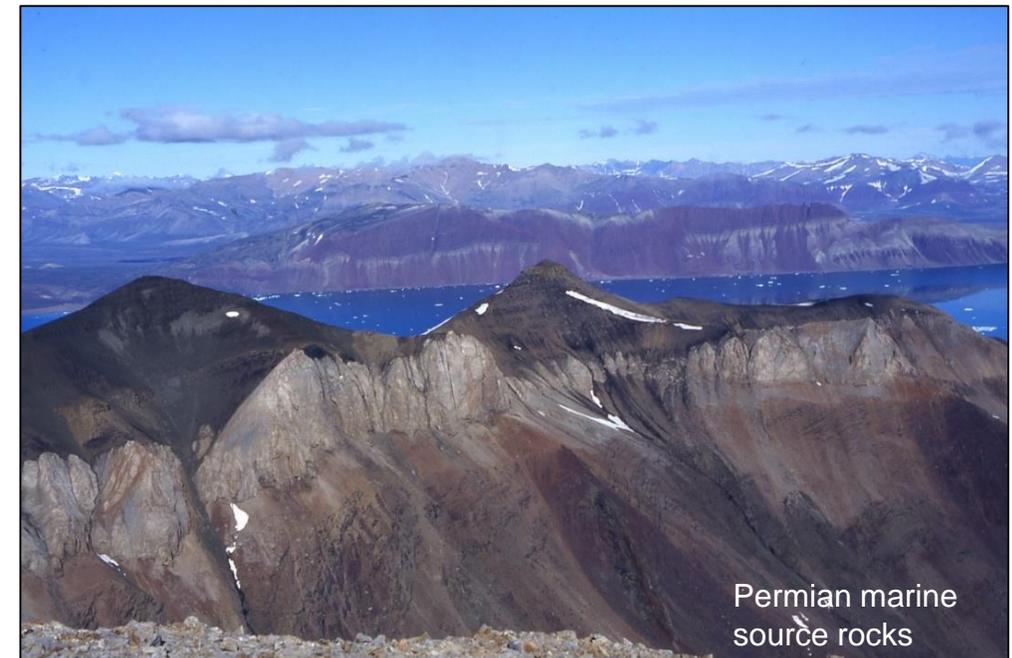
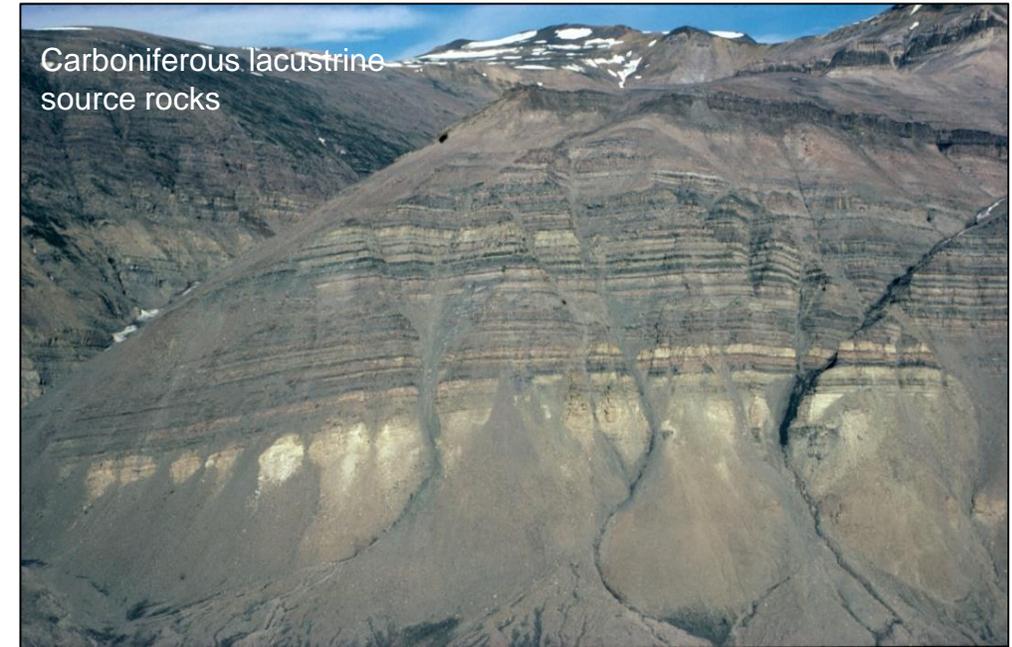
Depth to basement map From Fyhn et al., 2018



East Greenland

Source Rocks

- **Several potential petroleum source rocks** have been documented from outcrops, cores and oil seeps:
 - **Oxfordian-Ryazanian** marine Type II-III shales
 - **Lower – Middle Jurassic** marine Type II-III shales and coals
 - **Late Triassic – Lower Jurassic** lacustrine Type I shales
 - **Middle Triassic** lacustrine Type I shales
 - **Permian** marine Type II shales
 - **Carboniferous** lacustrine Type I shales and coals
 - **Devonian** lacustrine Type I shales
- **Oxfordian-Ryazanian (KCF equivalent)** marine shales are considered the **primary SR in the region**



East Greenland

Petroleum Stains

- Petroleum **staining** is common **onshore**

East Greenland

- **Stains** of hydrocarbons are present as both source associated and migrated

Oil bleeding out of an belemnite. Blokelyv core, Jameson Land



Carbonate-filled fracture with oil stains. Blokelyv core, Jameson Land

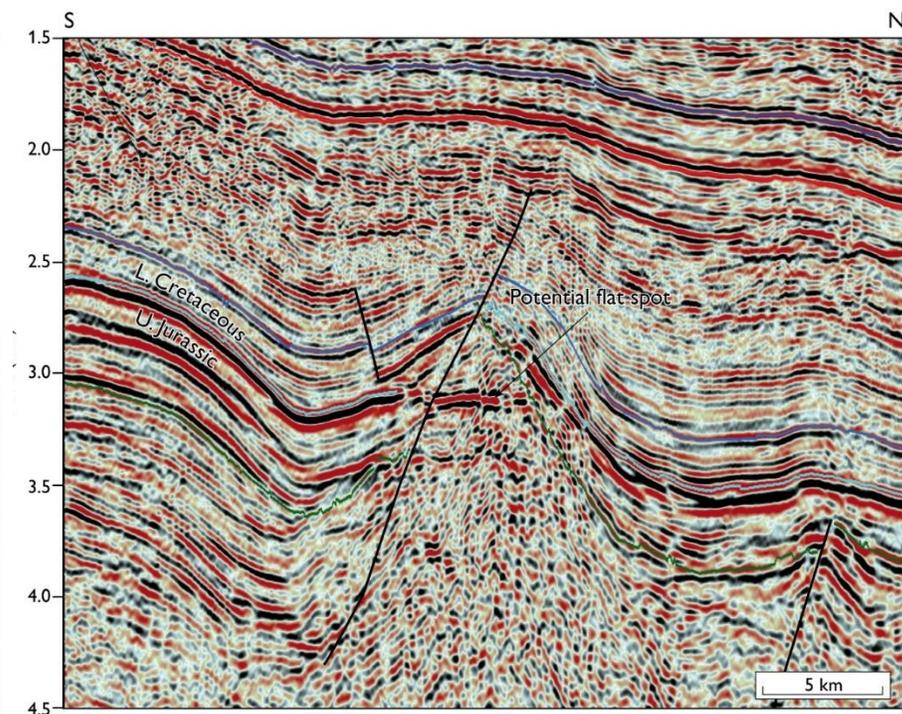
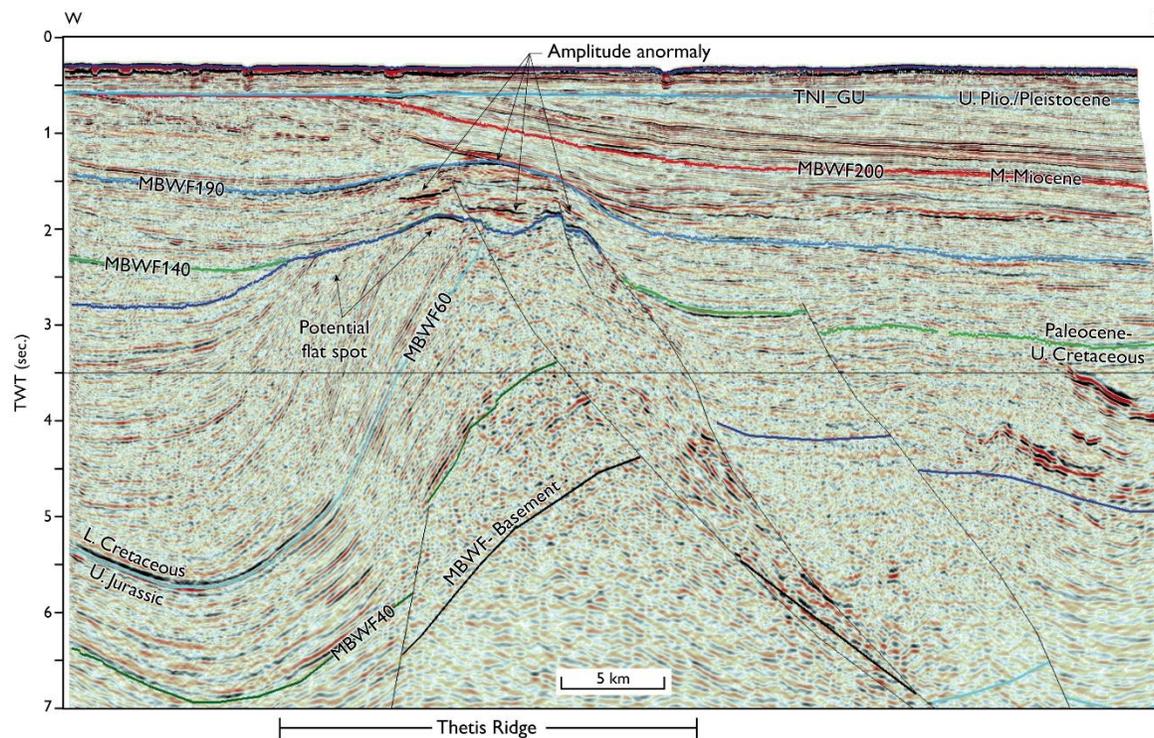


Northeast Greenland

DHIs



- **Major DHIs** are common offshore Northeast Greenland
- The DHIs are concentrated in specific areas, possibly indicating areas with **working petroleum systems**
- **Amplitude anomalies** are the most common DHI-type and are often accompanied by underlying chimney-like features



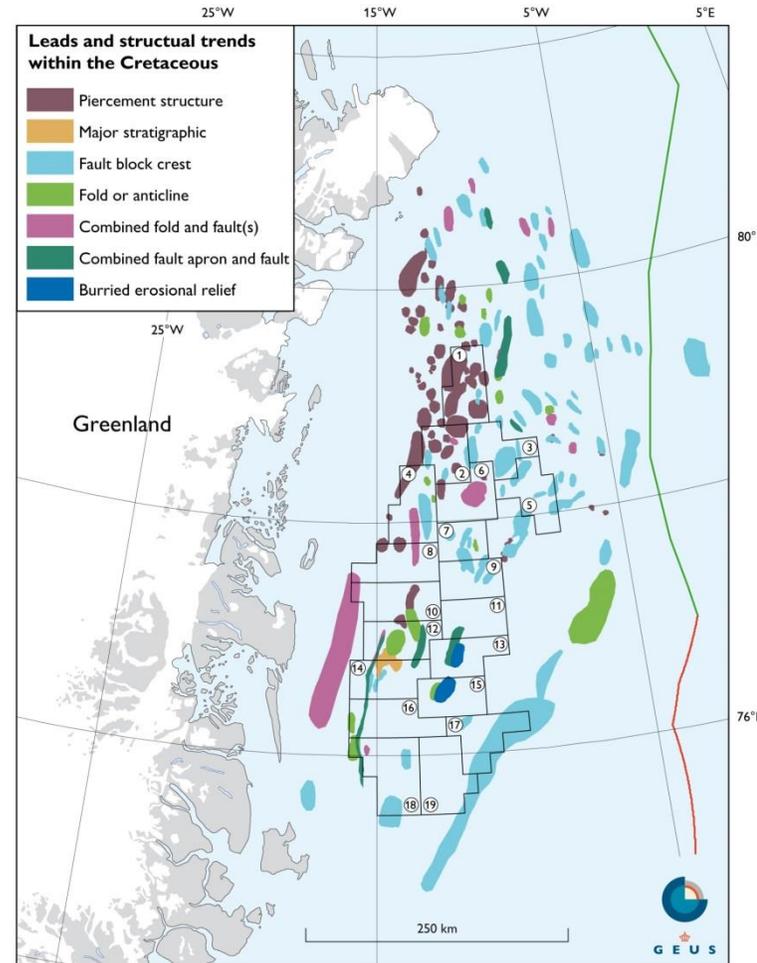
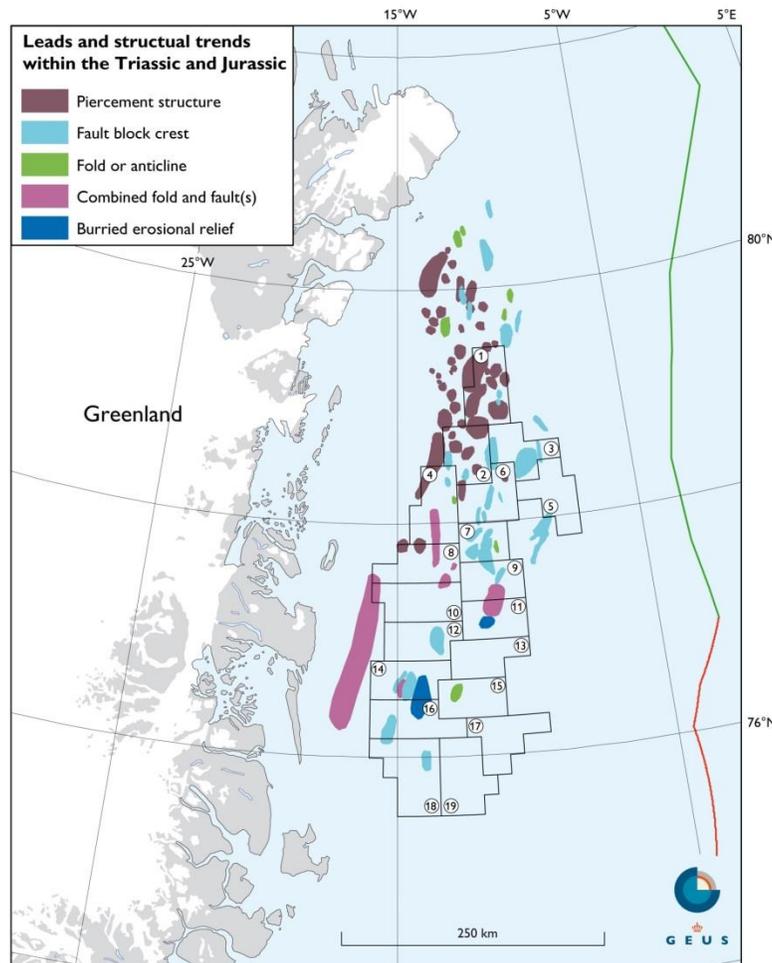
From Fyhn et al.,
2018



GEUS

Northeast Greenland

Proven Prospectivity



- **169 leads** have been mapped at several stratigraphic levels
- **Volumes** will be calculated as part of the ongoing **Greenland Resource Assessment Project**

From Fyhn et al., 2018





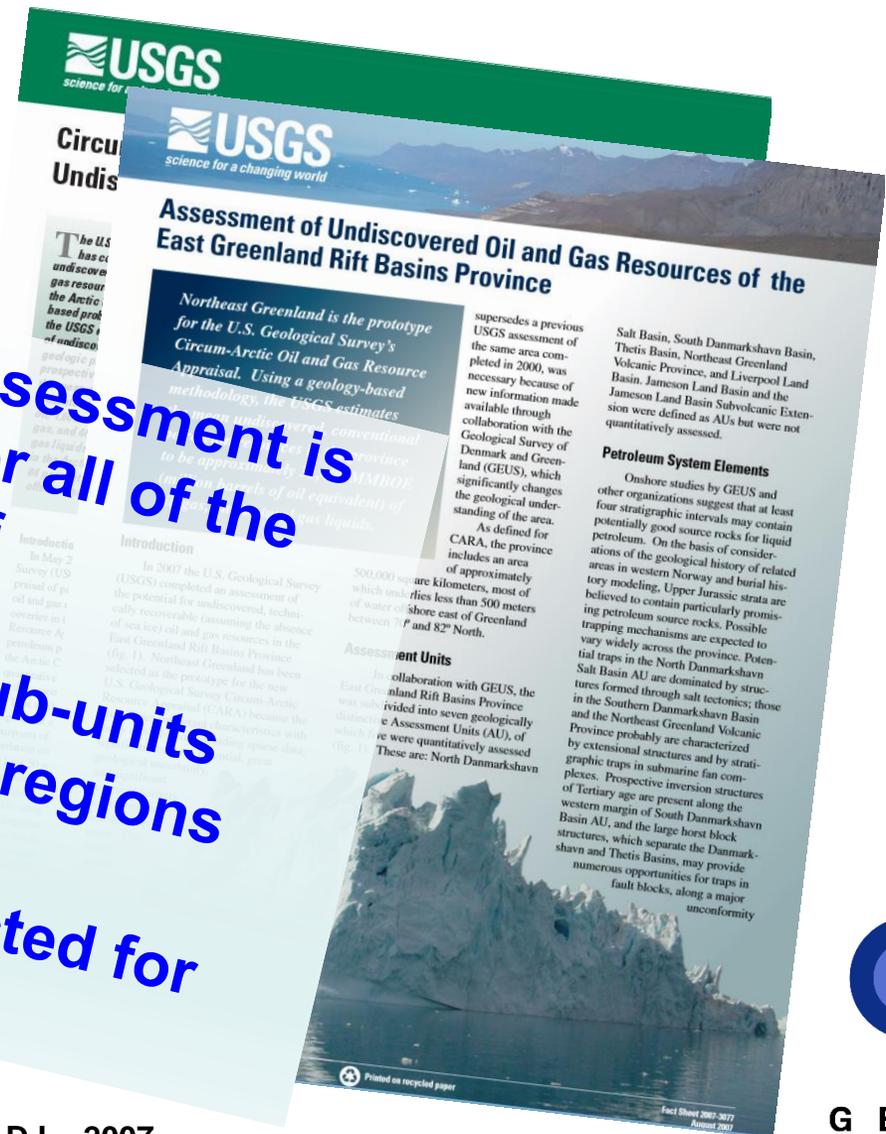
Greenland's Oil Potential

USGS Assessment Circum-Arctic appraisal (2007)

- Greenland appraisal was made in close collaboration between **GEUS** and **USGS** on discussions of petroleum systems, stratigraphy, thermal maturity, uplift, play types
- The assessment is probably the most advanced and made with the **USGS CARA team** based on geological synthesis and analogue modelling
- United States following means:
 - 31 BBOE
 - 17 BB
 - 3.3 BBOE OTS

New play-based resource assessment is currently being conducted for all of the Greenlandic continental shelf comprising unique geographic regions each assessment unit

The assessment consists of sub-units comprising unique geographic regions



From:
Gautier D L , 2007
Schenk, C J et al., 2008



New Resource Assessment for Greenland

Purpose

- Provide an **estimate of the play-based, yet-to-find potential** of conventional hydrocarbons on the Greenland continental shelf

Why?

- Facilitate company business decisions and **guide the industry toward the most prospective areas**
- Help the Greenland authorities and politicians in **strategic decisions and in planning for future licensing rounds**

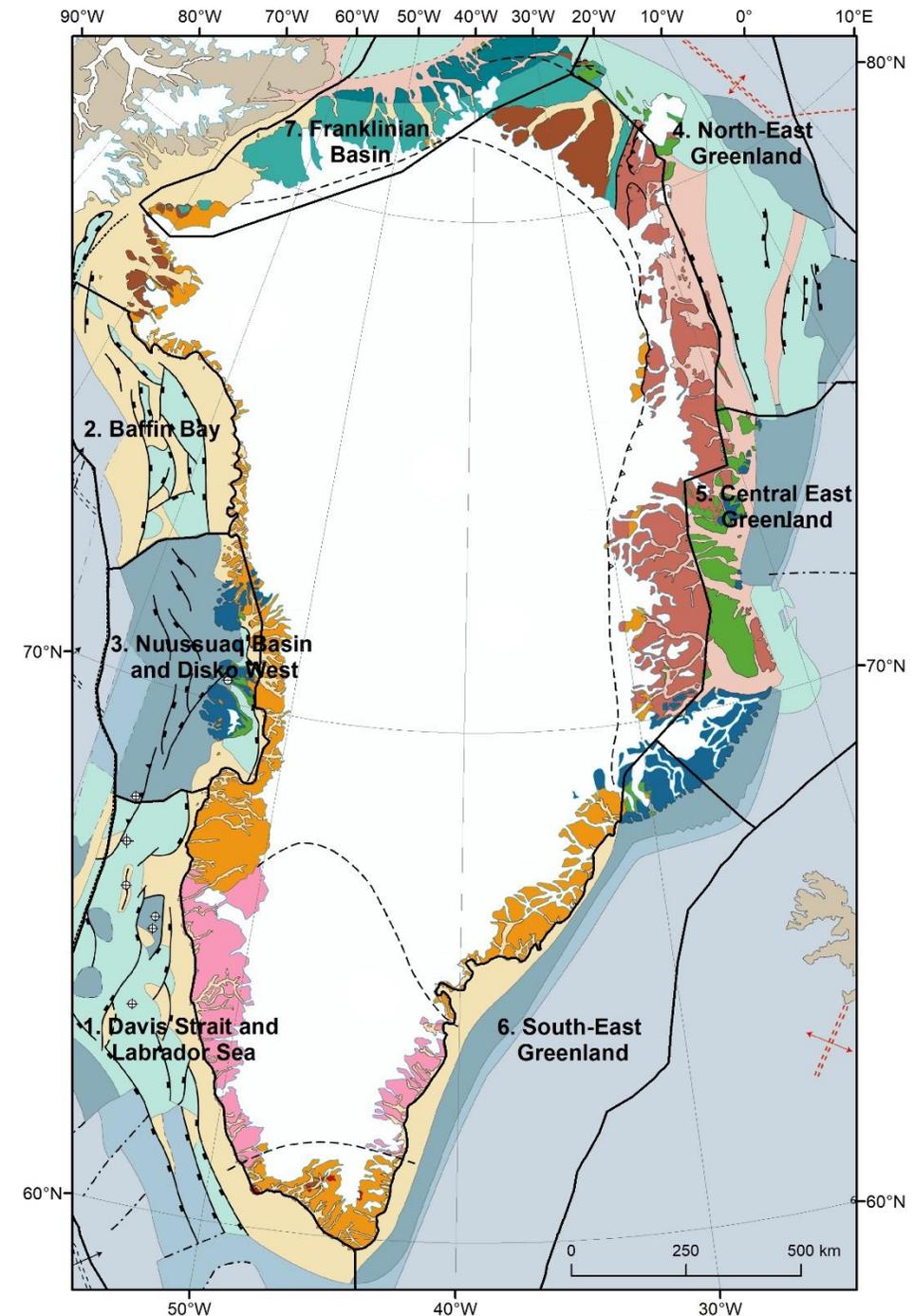
Collaborators

- Project is a collaboration between **NUNAOIL, MIERL, and GEUS**
- Project is located at **GEUS** and most of the work is performed by GEUS

QC

- **Norwegian Petroleum Directorate (NPD)**
- **GIS-Pax**

Assessment units (1-7) of the Greenland Resource Assessment Project.



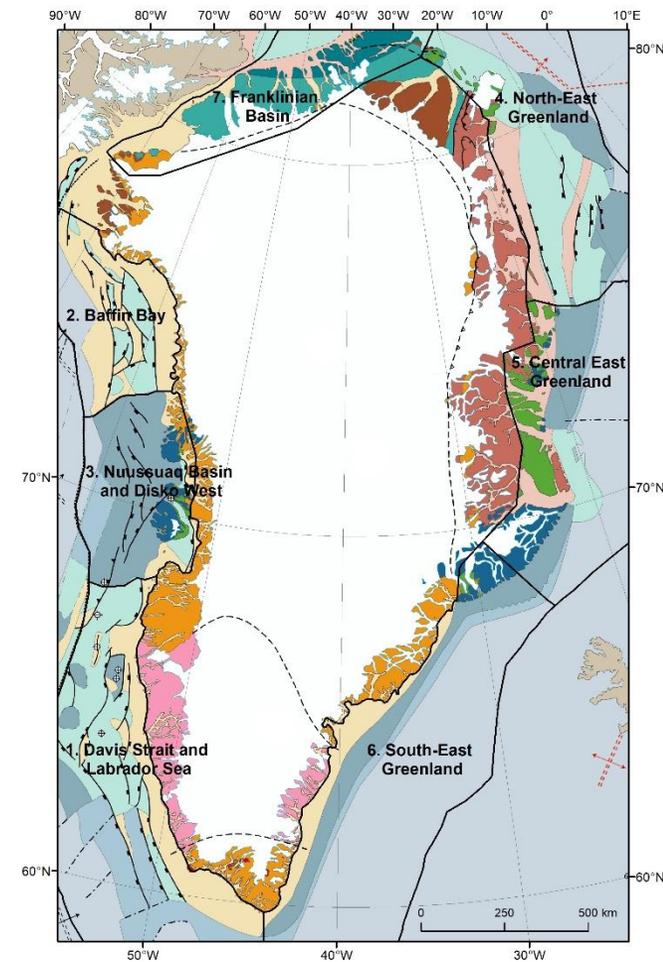
New Resource Assessment for Greenland

Results from AU1

- Total identified prospectivity (mean risked recoverable volumes): **1.1 Bboe**
- Total unidentified prospectivity (mean risked recoverable volumes): **4.5 Bboe**
- Total Risked Recoverable (Mean Case): **5.6 Bboe**

- The Total Un-risked Recoverable (Mean Case) of AU1: **77.0 Bboe**

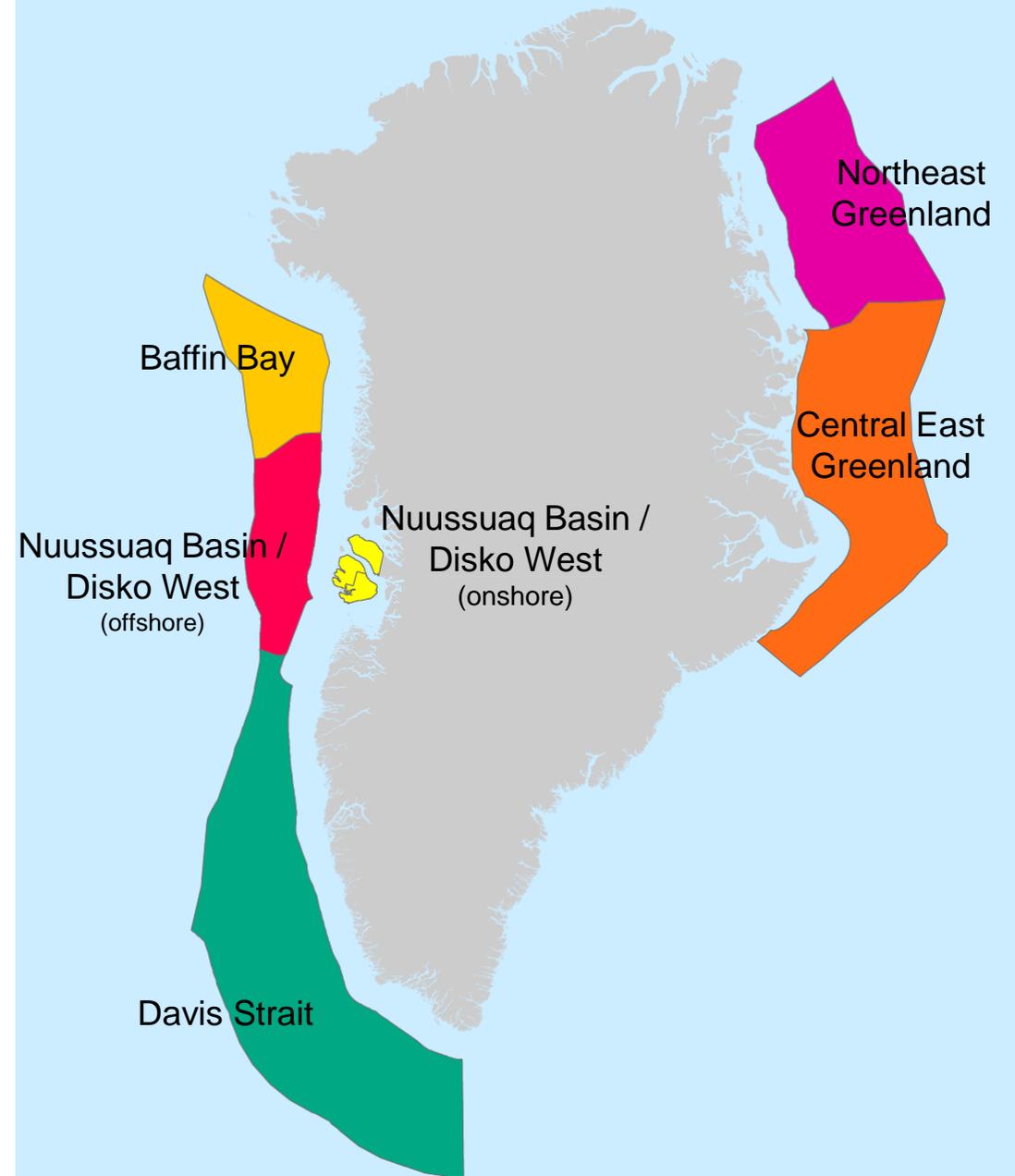
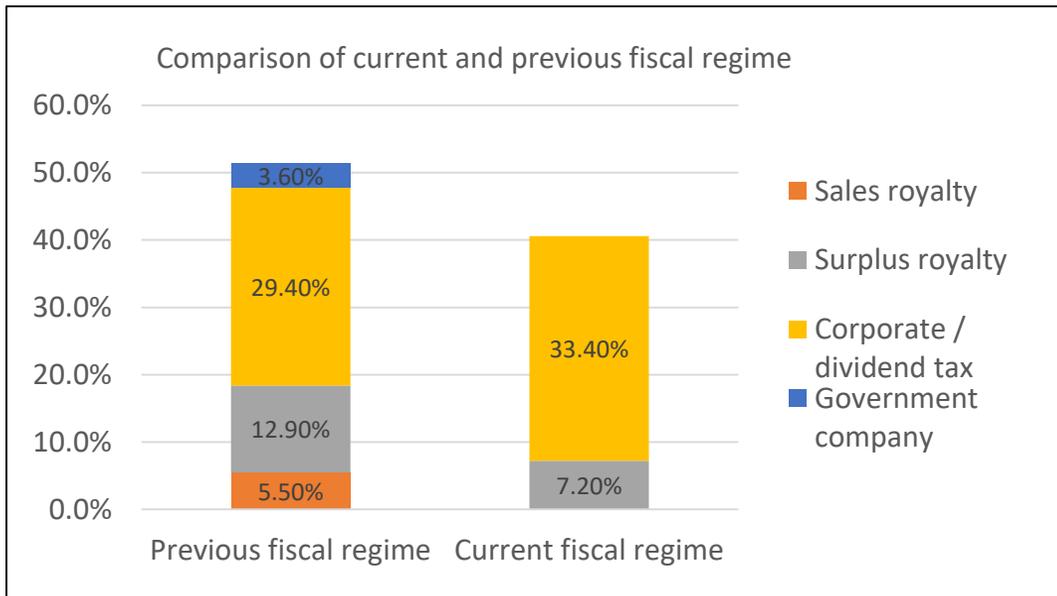
- The **Player** and **ArcGIS** projects together with the **slide pack** with full documentation are available for the petroleum exploration industry at **no cost** and can be downloaded from the **project website**: <https://greenland-resource-assessment.gl>
- Results from **AU2** will soon be available



The screenshot shows the 'Greenland Resource Assessment Data Portal' website. The header features the NUNAOIL logo and navigation links: Home, Assessment Units, Downloads, Contacts, Register, Login, Terms and Conditions. A dropdown menu is open under 'Assessment Units', listing AU1 through AU7 with their status: AU1: Southern West Greenland, AU2: Baffin Bay, AU3: Central West Greenland, AU4: Not finalized, AU5: Not finalized, AU6: Not finalized, AU7: Not finalized. The main content area includes a 'PROJECT DESCRIPTIO' section with an 'Aim of Project' and a 'NEWS' section dated 18 December 2019. A small map of Greenland is visible in the bottom right corner of the page.

Overview of Future Licensing Plans and New Competitive Fiscal regime

Region (area)	Opening for licensing
Nuussuaq Basin/Disko West (onshore)	February 2020
Davis Strait	September 2020
Baffin Bay	September 2020
Nuussuaq Basin / Disko West (offshore)	September 2020
Northeast Greenland	July 2021
Central East Greenland	January 2022





Thank you

Please meet us in Booth 18

