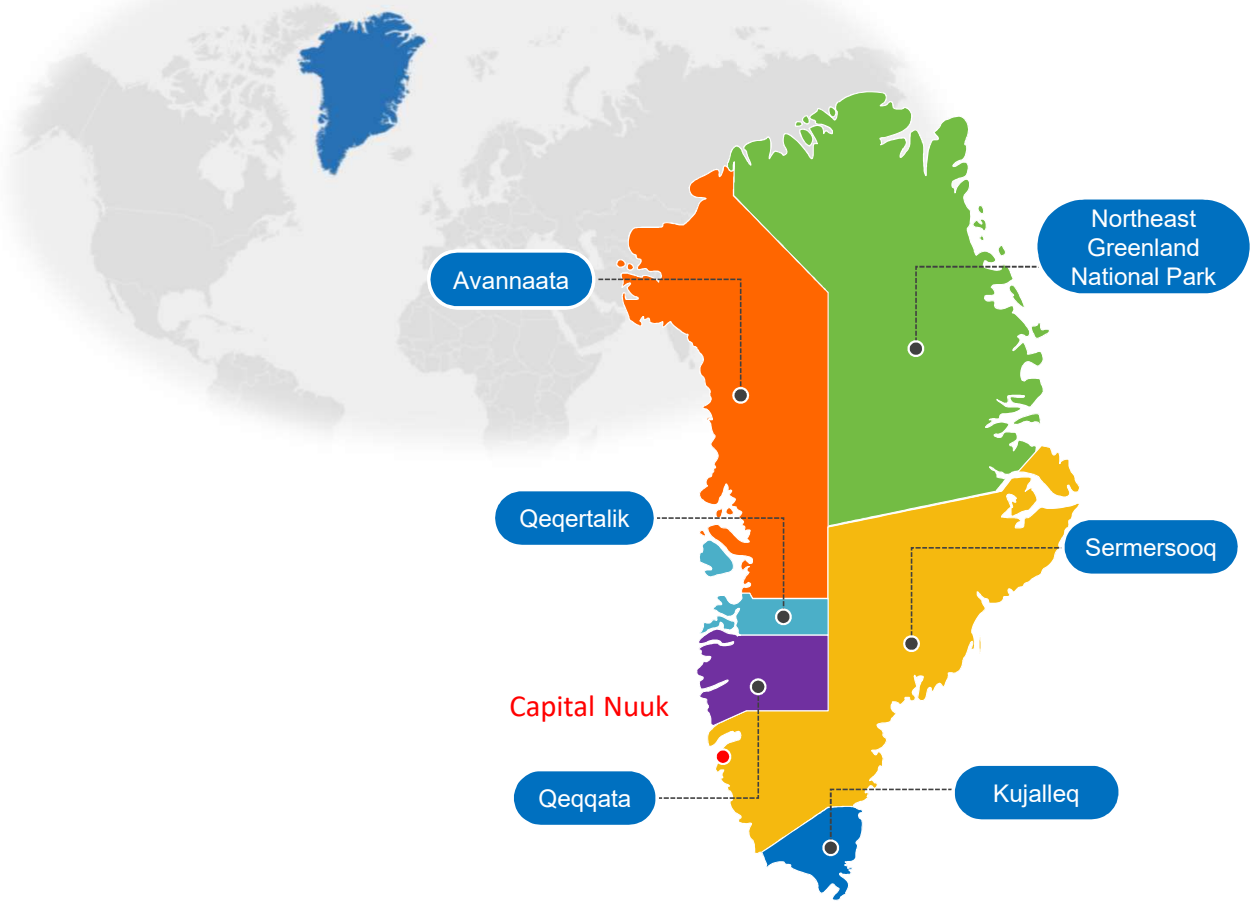
NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

Greenland
– New Exploration Opportunities
– Competitive Licensing policy

Greenland

NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

- Part of the Kingdom of Denmark.
- Home rule since 1979.
- Self-Government since June 2009.
- Population: approx. 57,000.
- 5 municipalities.
- Latitudes 59˚46’ N to 83˚39’ N.
- North-South 2,670 km.
- East-West 1,050 km.



Greenland Self-Goverment

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- Greenland Parliament (Greenlandic: Inatsisartut)
  - 31 members, including 1 chairperson.
  - Passes acts of law which apply to all public authorities and private parties.
- Courts of law with jurisdiction in Greenland: Supreme Court of Denmark, High Court of Greenland, Court of Greenland and 4 district courts.
- Greenland is an overseas country and territory (OCT) in relation to the EU under the Treaty on the Functioning of the EU (TFEU) and has a cooperation agreement with the EU.

Parliament of Greenland

Greenland Self-Goverment

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- Ministry of Industry, Energy and Research of the Greenland Self-Government is the licensing authority
- The Geological Survey of Denmark and Greenland (GEUS) advises on all geological matters

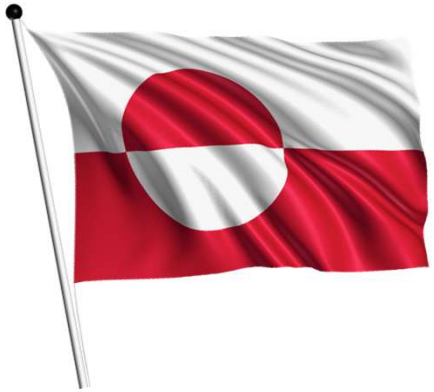

Photo: Filip Gielda, Visit Greenland

USGS Assessment Circum-Arctic appraisal (2007)

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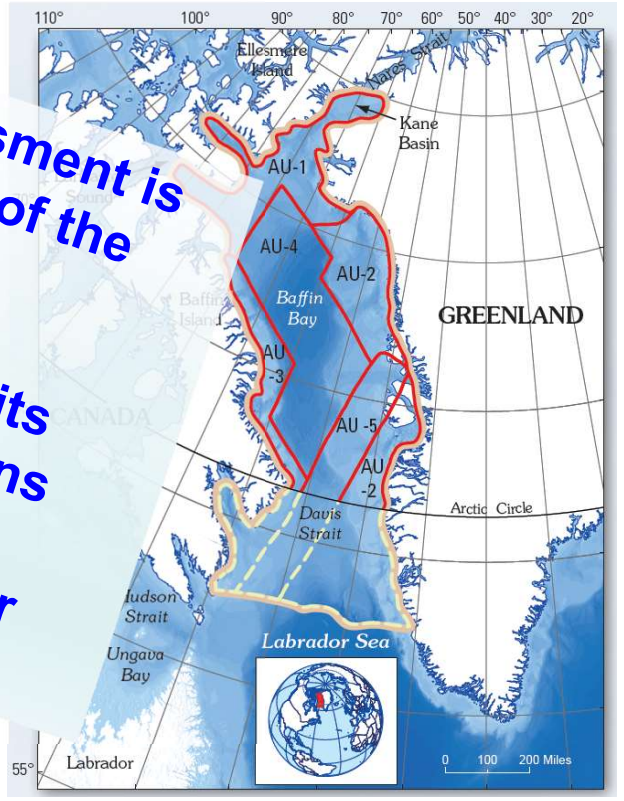
GOVERNMENT OF GREENLAND

- Greenland ap… between GE… systems, str… types.
- The asses… CARA tea… analogu…
- United … followi…
  - 31 BBOE offshore in …
  - 17 BBOE offshore West Greenl…
  - 3.3 BBOE offshore North Greenland

- **New play-based resource assessment is currently being conducted for all of the Greenlandic continental shelf**
- **The assessment consists of sub-units comprising unique geographic regions**
- **Licensing rounds will be conducted for each assessment unit**



From:
Gautier D L (2007) U.S. Geological Survey Fact Sheet FS-2007-3077, 4 p.
Schenk, C J et al. (2008) U.S. Geological Survey Fact Sheet FS-2008-3014, 2 p.

Focus of Presentation

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GOVERNMENT OF GREENLAND

1. Exploration potential of on- and offshore West Greenland
2. Resource assessment
3. Licensing policy
4. Environment
5. Physical conditions
6. Infrastructure

GEUS

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Exploration Potential On- and Offshore West Greenland

Outline

- Database
- Regional Geology
- Stratigraphic Framework
- Tectono-Stratigraphic Evolution
- The Nuussuaq Basin and exploration possibilities
- Source rocks
- Reservoirs
- Seals
- New Resource Assessment
- Post Well Analysis
- USGS 2007 Assessment
- Concluding remarks

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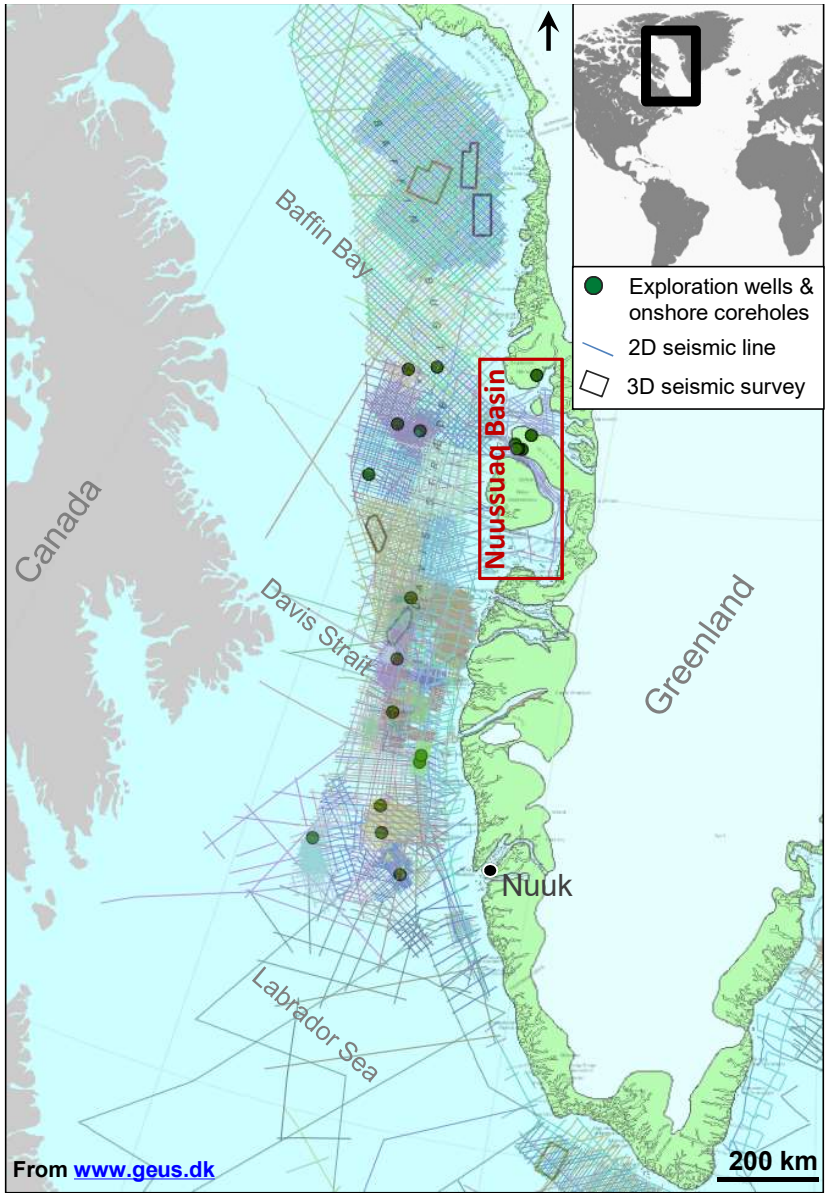
West Greenland Database

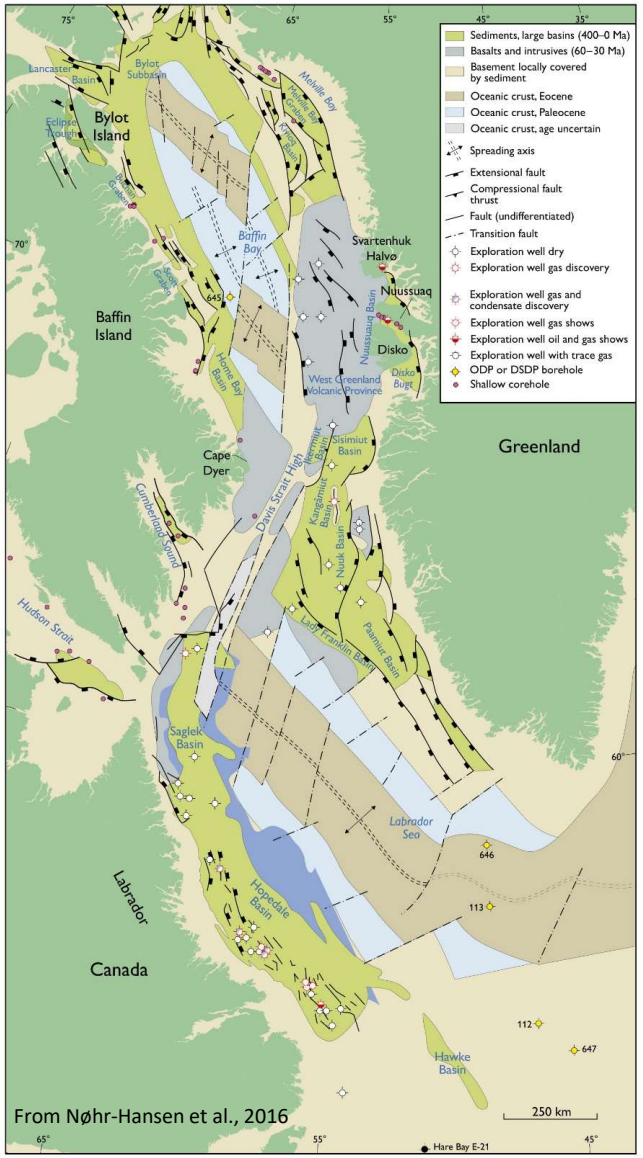
Huge database including:

- >200,000 line km 2D seismic data
- Six 3D seismic surveys
- Magnetic and gravity surveys
- Fifteen exploration wells (fourteen offshore)
- Numerous boreholes
- Excellent outcrop analogs in the Nuussuaq Basin



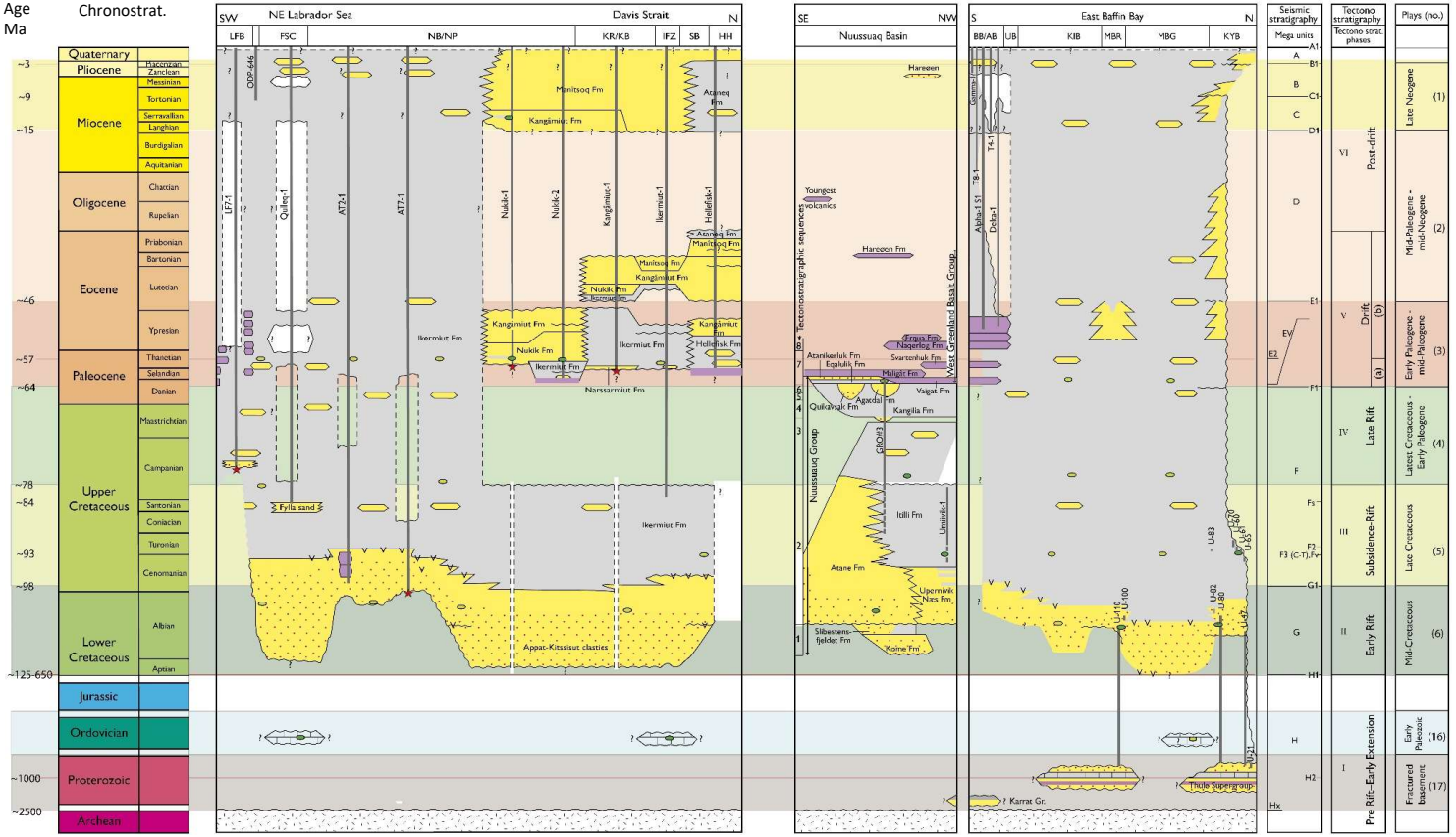
Regional Geology

- **Early Cretaceous – Paleocene rift basins** from Labrador Sea in the south to Baffin Bay in the north, more than 2000 km of continental margin
- Area covers **+800,000 km^2** (~1 well/50,000 km^2)
- **15 exploration wells** have been drilled in West Greenland; one possible gas discovery and a few wells with oil and gas shows and inclusions
- 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**

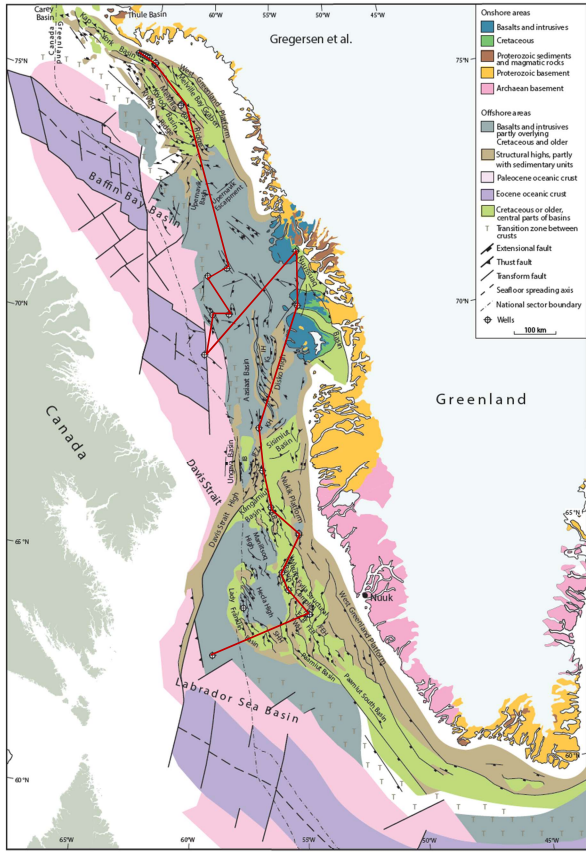


Stratigraphic Framework

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

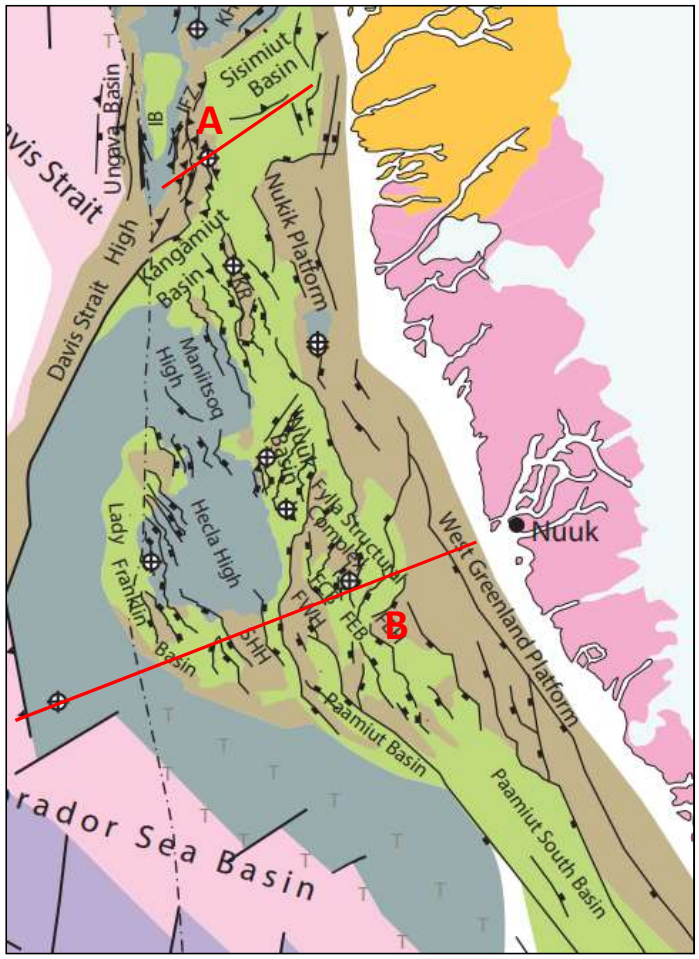


From Gregersen et al., 2019

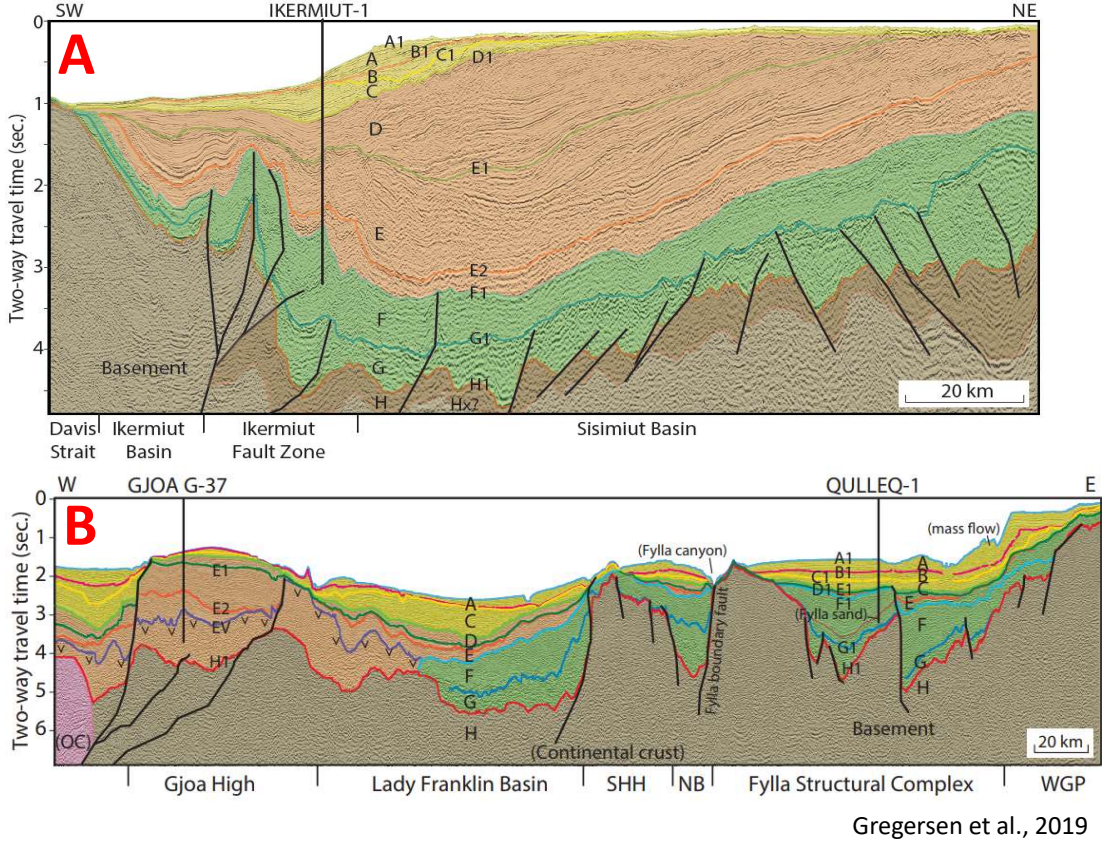


From Gregersen et al., 2019

Regional Geology, Tectonic Setting and Structural Elements



Gregersen et al., 2019



Gregersen et al., 2019

- **Nine super-regional seismic horizons** have been mapped along the West Greenland margin by Gregersen et al. (2019)

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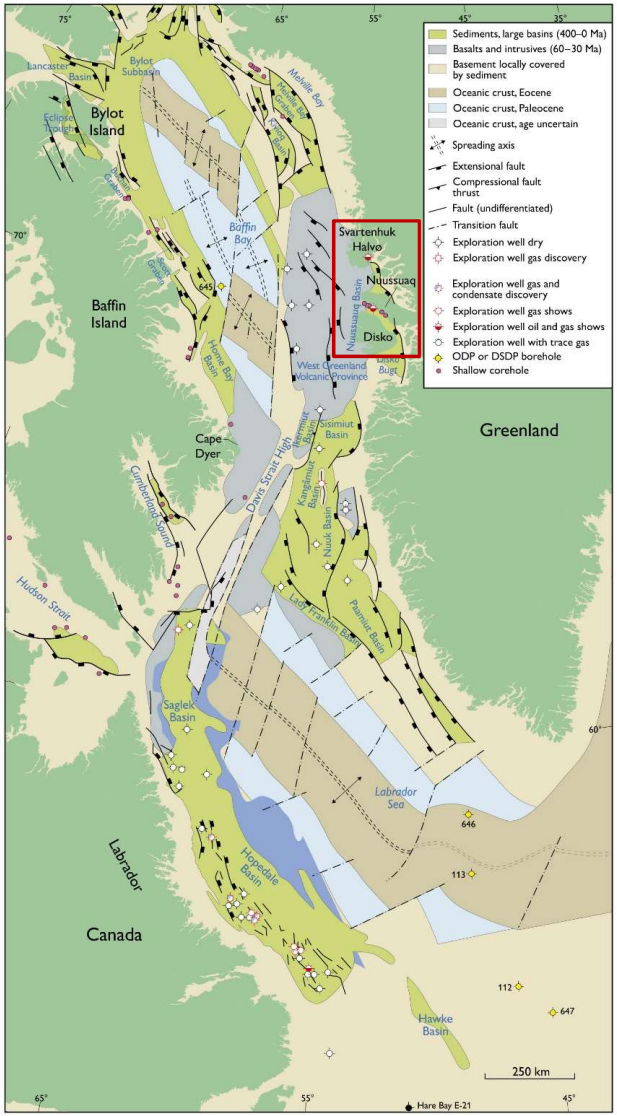
Nuussuaq Basin

- Onshore exposure of the Early Cretaceous – Paleocene rift basins
- Full syn-rift section preserved
- Sediment thicknesses up to 10 km
- Several oil seeps and shallow boreholes with gas and oil shows indicating working petroleum system
- Analogue for the offshore basin, with its own exploration potential

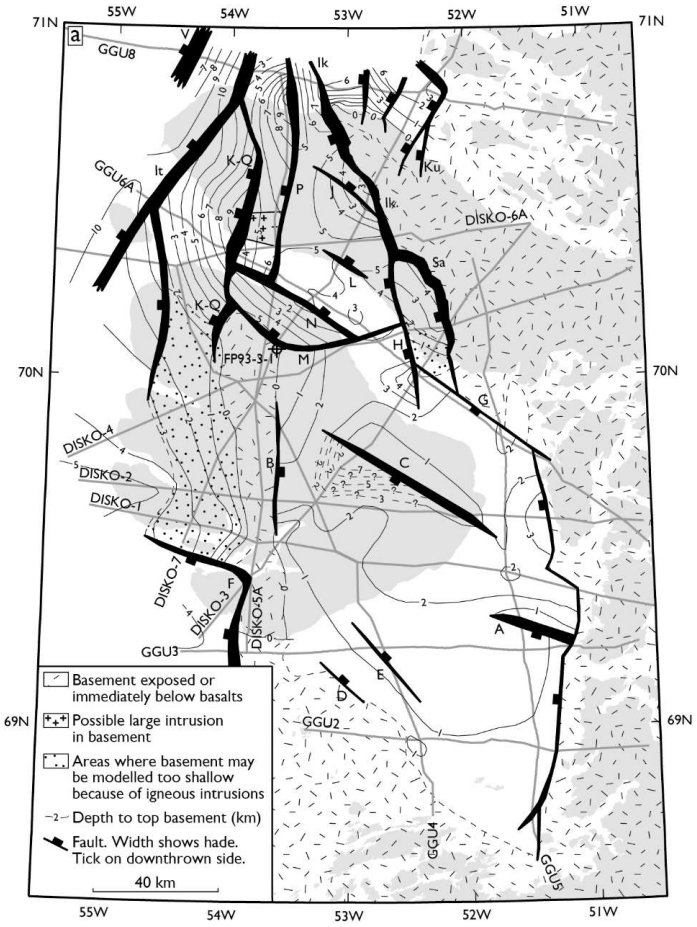


From Nøhr-Hansen et al., 2016

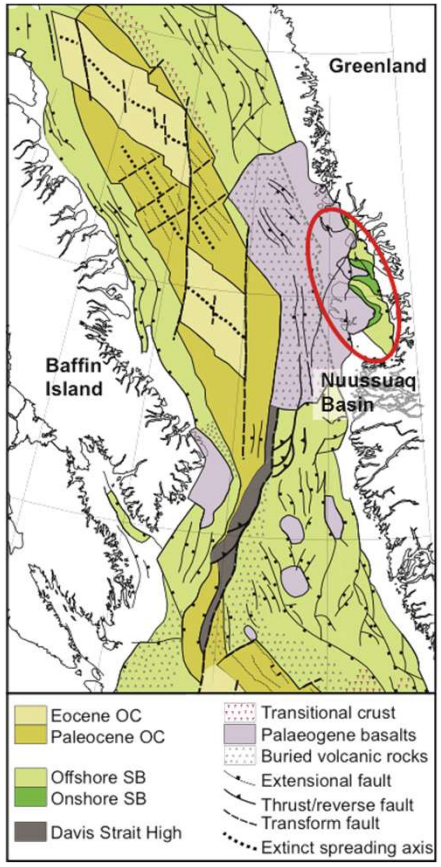
GEUS

Nuussuaq Basin
Structures

- Gravity modelling indicates sediments thickness in the Nuussuaq Basin up to 10 km



From Chalmers et al., 1999

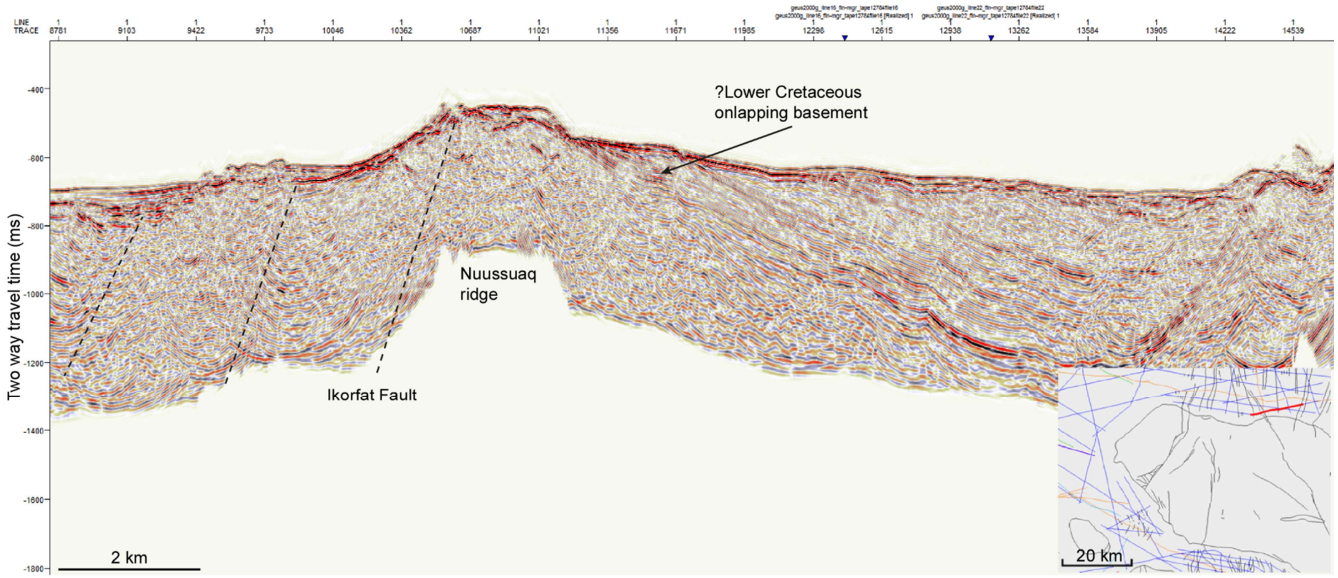


Modified from Nøhr-Hansen et al. 2016

GEUS

Nuussuaq Basin
Structures

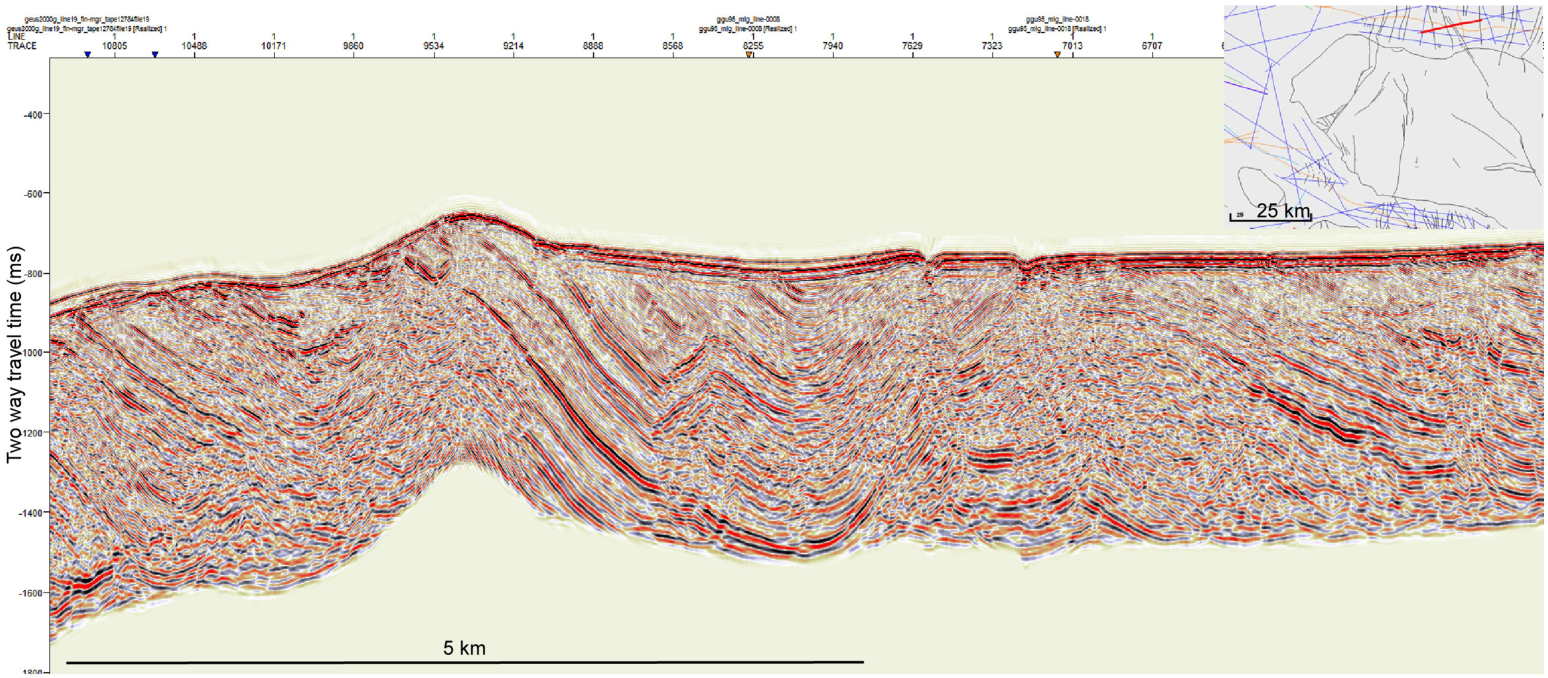
- Large Early Cretaceous rotated fault blocks along the north coast of Nuussuaq. These are likely to extend into the onshore areas



GEUS

Nuussuaq Basin

Structures



- Large Early Cretaceous rotated fault blocks along the north coast of Nuussuaq that are likely to extend into the onshore areas
- Notice the syncline formed during latest Paleocene – Early Eocene compression

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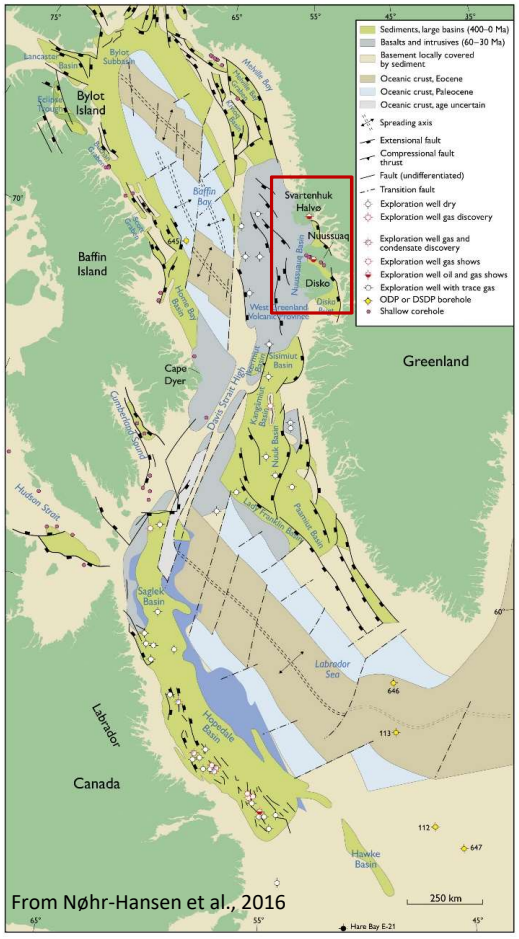
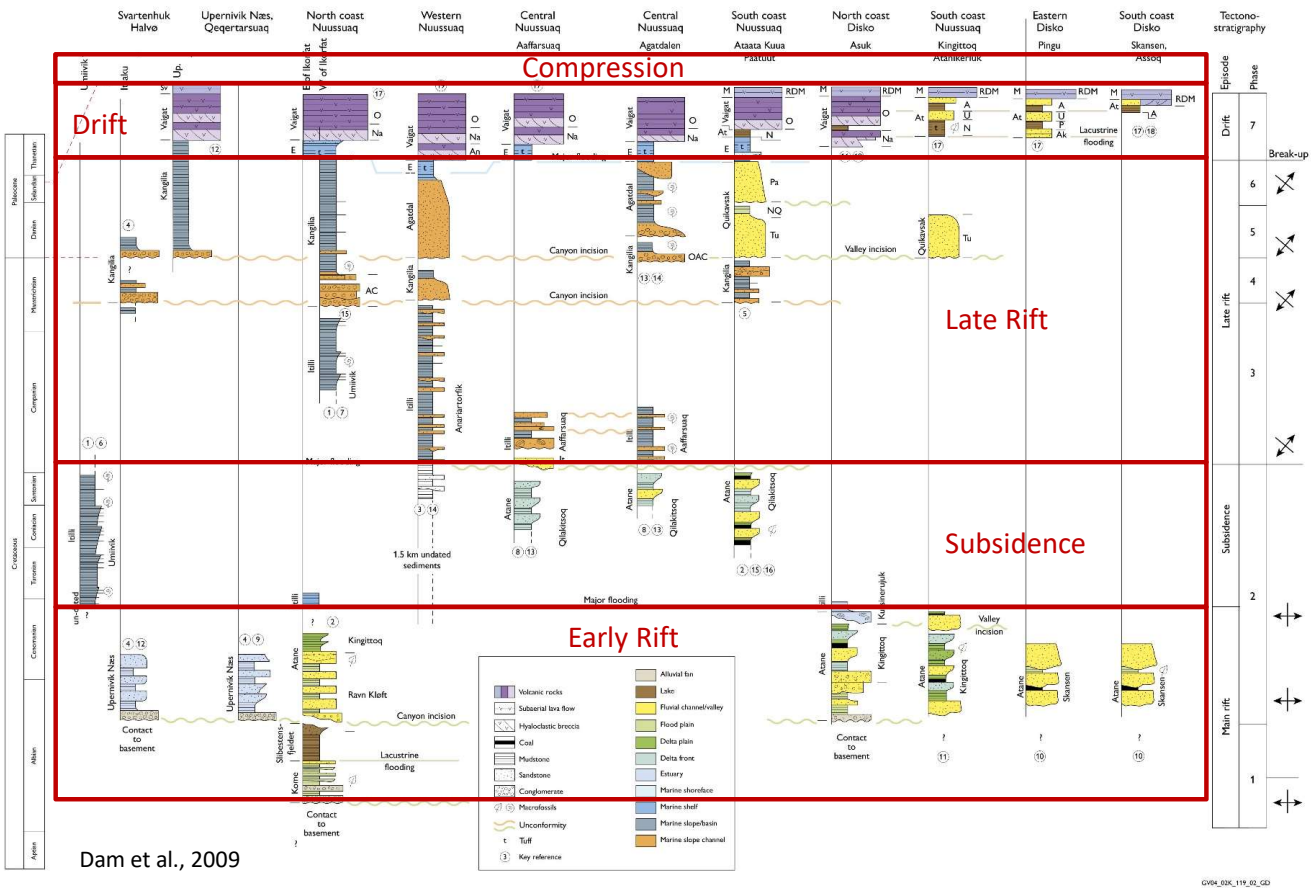
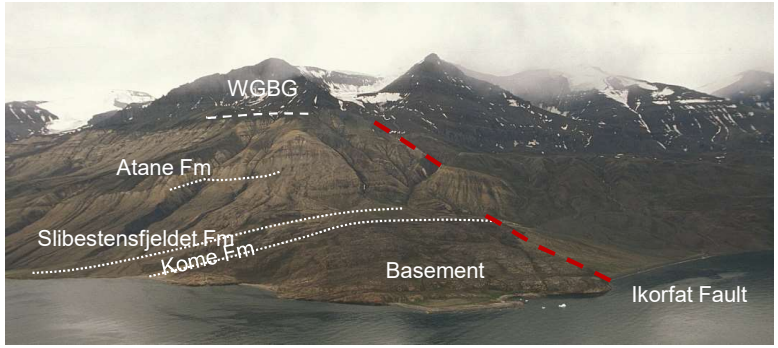
Regional Geology
Nuussuaq Basin

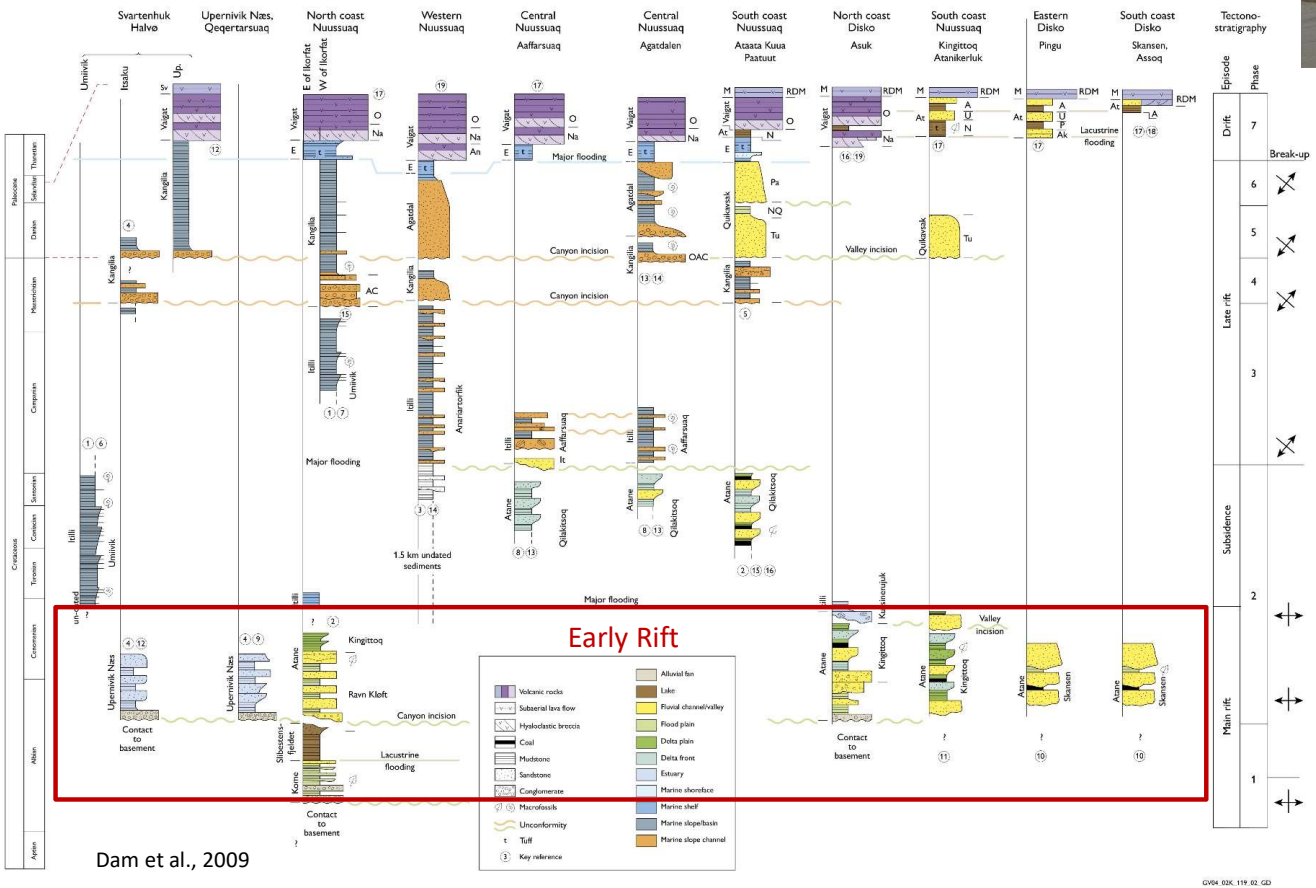




Dam et al., 2009

Regional Geology
Nuussuaq Basin



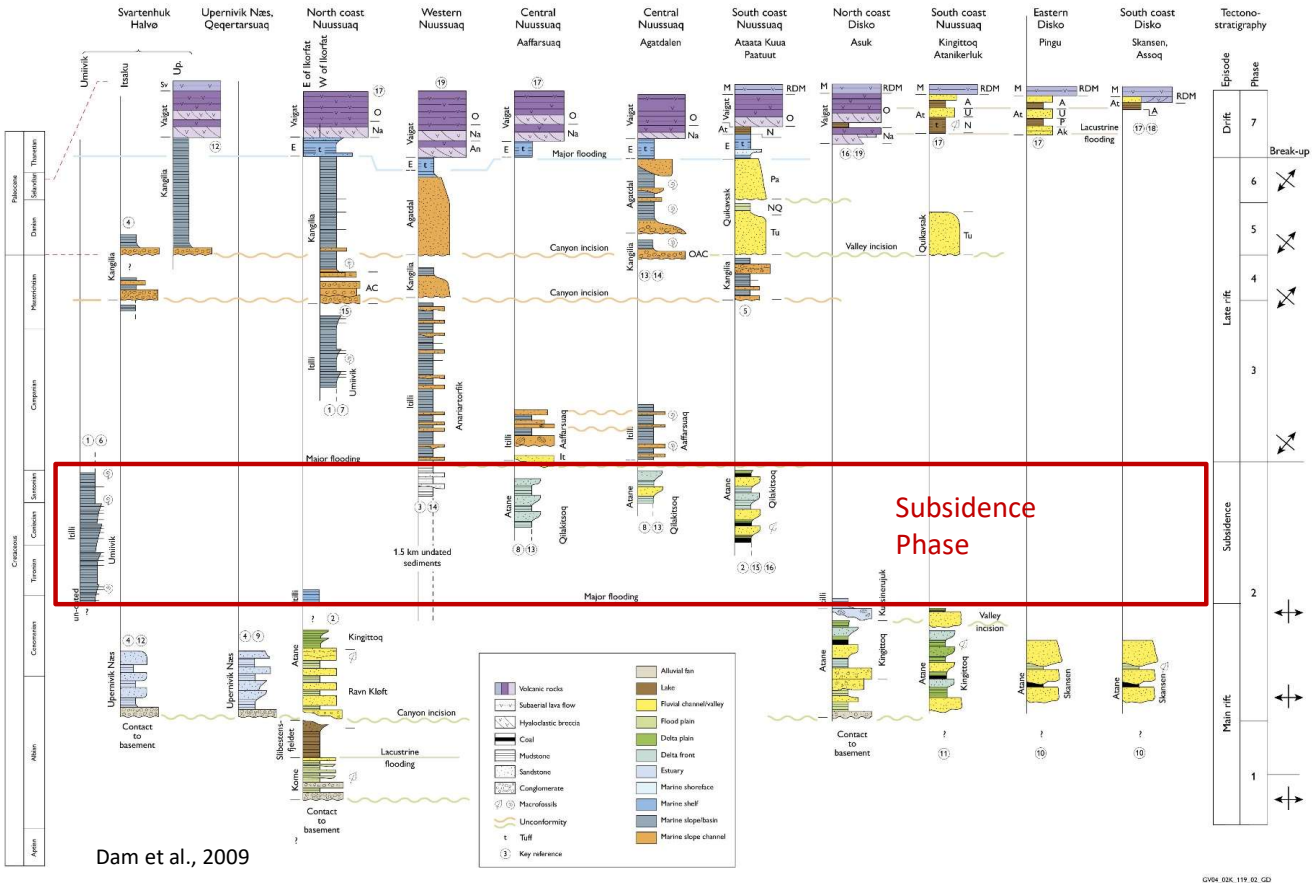


Dam et al., 2009

- Albian – Cenomanian **early rift phase**
- **Deposition of SR in** Baffin Bay
- **Syn-rift sediments** composed of alluvial fan and fan-delta and lacustrine deposited in grabens and onlapping weathered basement highs

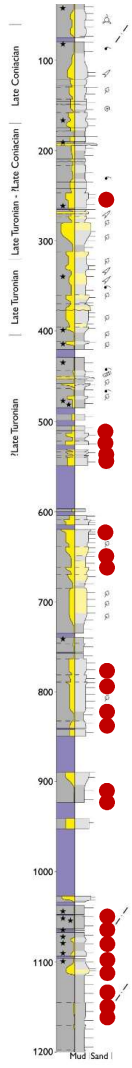
Regional Geology
Nuussuaq Basin

- A thick succession mudstones and fine-grained heterothic sediments in Umiivik- borehole
- Deposition of **Cenomanian-Turonian SR**
- Likely source for the **Itilli oil**
- **Paleocene volcanism** has caused thermal degradation of the organic matter
- **Wet gasses** were common in the core
- Back-calculation of the source rock potential suggests presence of **excellent SR in** Svartenhuk area



Dam et al., 2009

Umiivik-1 borehole



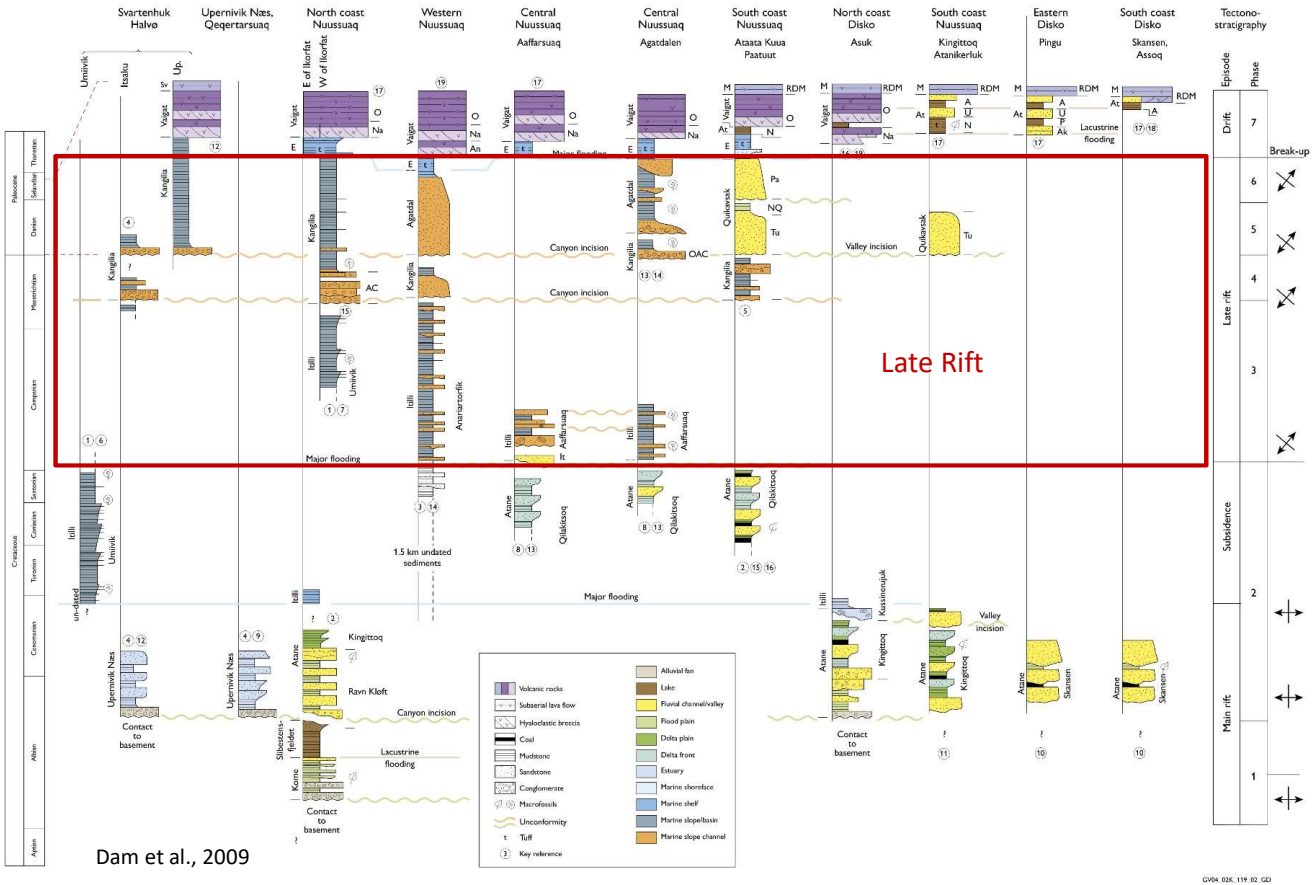
Wet gas

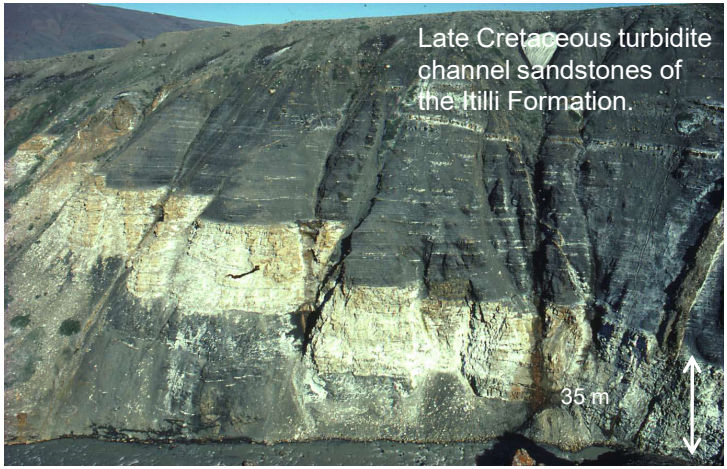
Dam et al., 2009

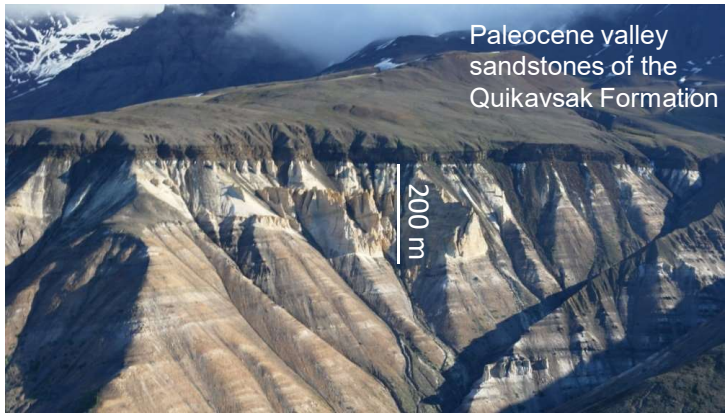
GEUS

Regional Geology
Nuussuaq Basin

- Earliest Campanian - Paleocene **late rift phase**
- Establishment of a **major turbidite system**
- **Uplift of basin**, formation of major unconformities, valley and submarine canyon incision
- **Major sand input** to the offshore areas
- Deposition of **Paleocene SR**, the source for the **Marraat oil**

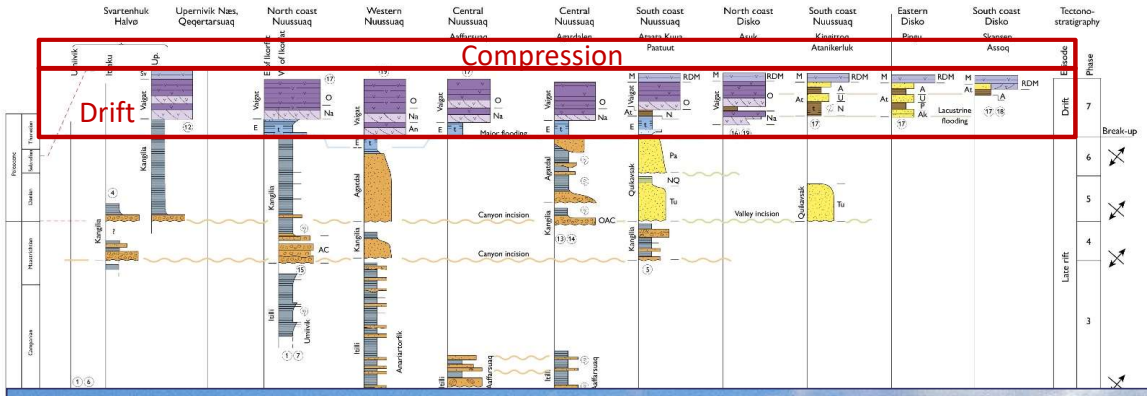






Regional Geology
Nuussuaq Basin

- **Paleocene volcanism** and establishment of the North Atlantic Igneous Province
- **Major subsidence** due to loading of volcanics and emptying of magma chambers
- **Hyaloclastite foreset beds** indicate water depth of ~700 m
- **Oil seeps** in the Marraat area



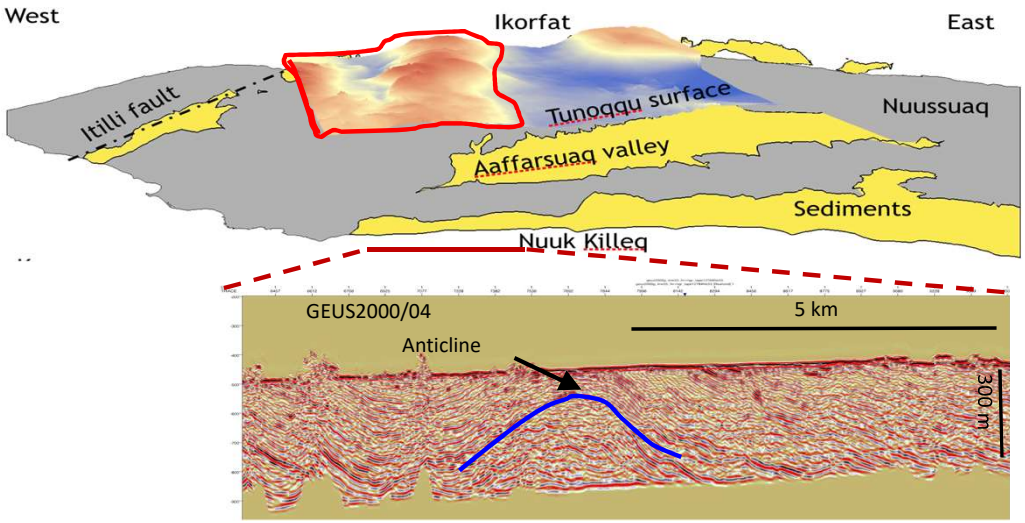
Dam et al 2009

GEUS

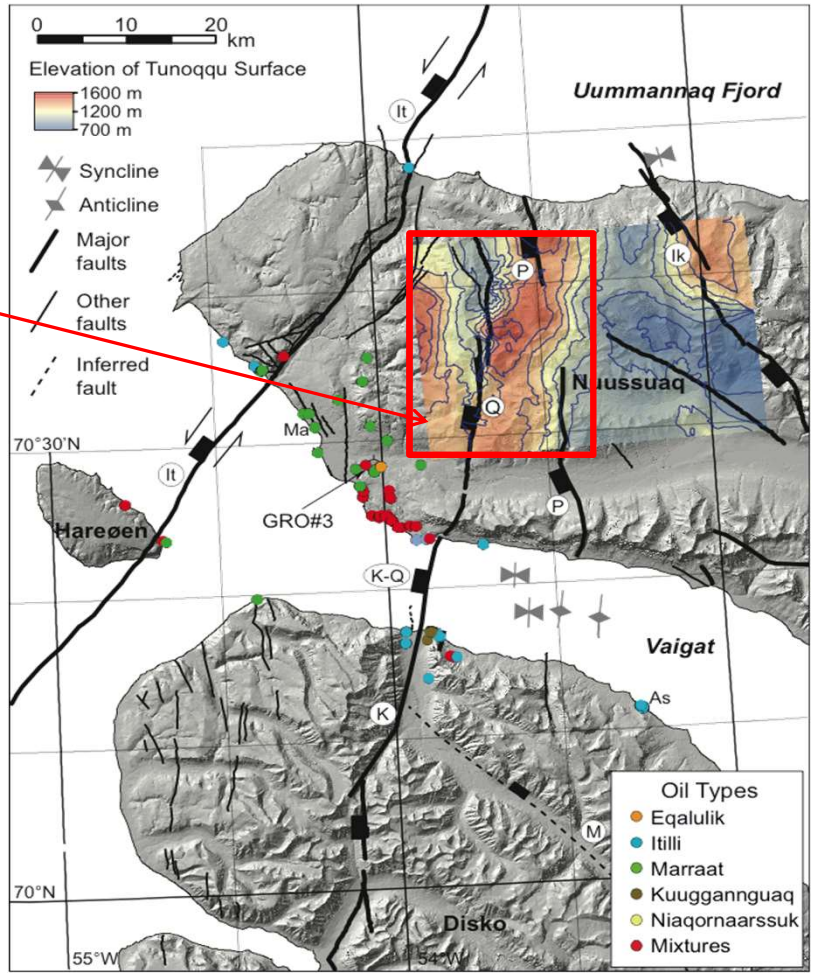
Latest Paleocene – Early Eocene Compression

Nuussuaq Basin

- Formation of compressional structures



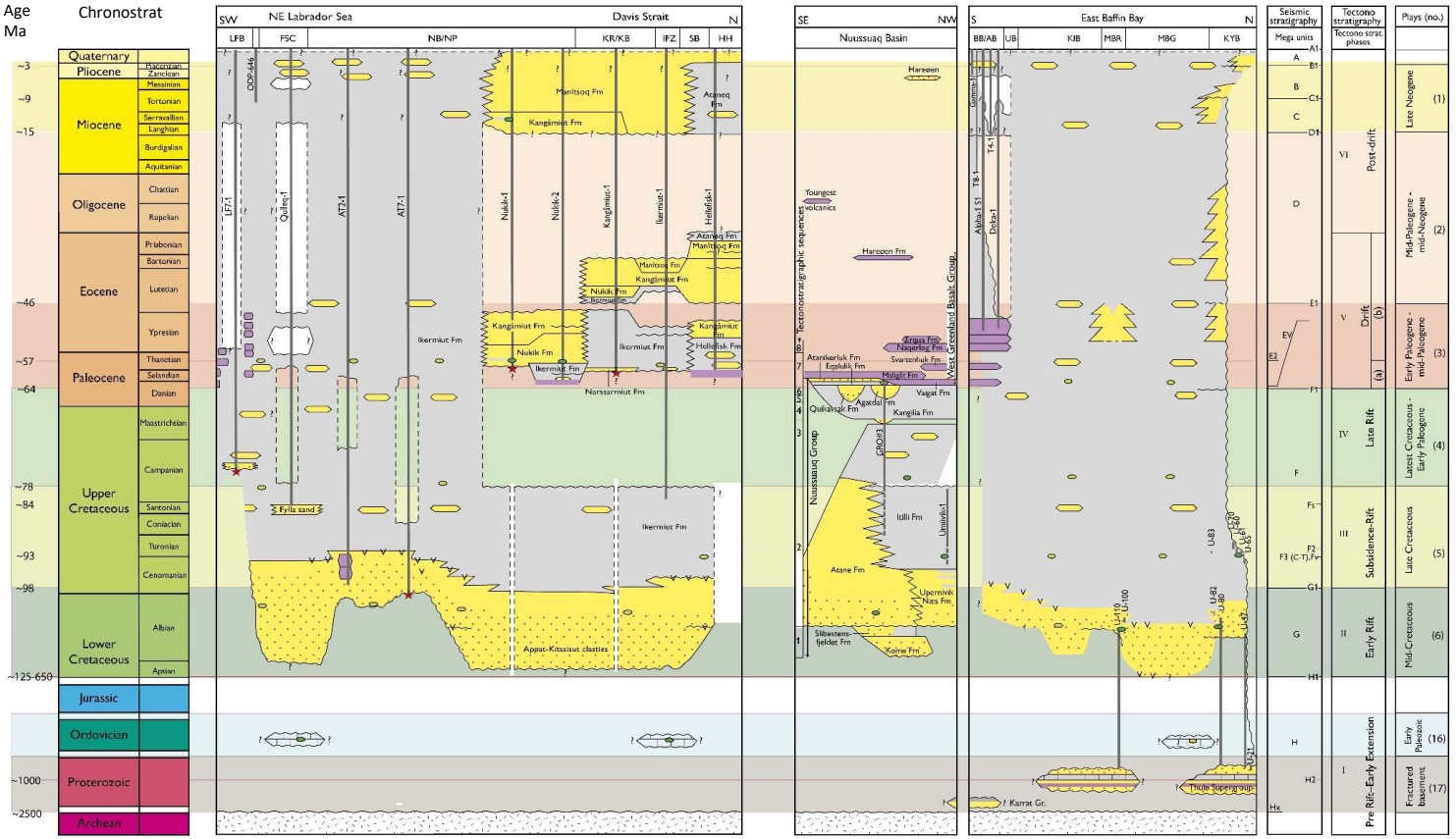
GEUS 2016



Offshore seismic data from Vaigat

GEUS

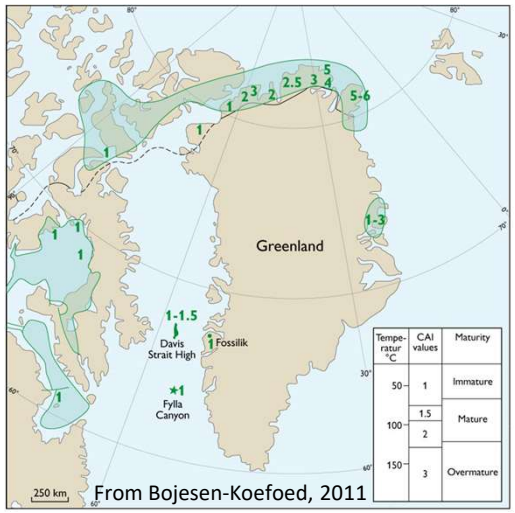
Source Rocks West Greenland



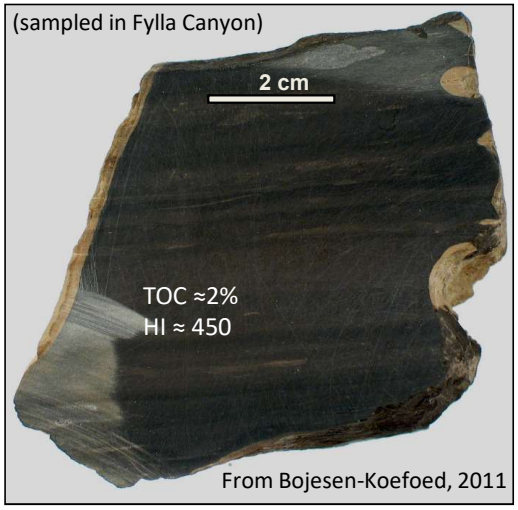
Gregersen et al., 2019

- Several potential petroleum source rocks have been documented or are assumed present at different levels of confidence
- The level of confidence is critical for charge risking
- 6 potential source rocks in West Greenland:
  - **Ordovician** marine shales
  - **Albian** deltaic/terrigenous shale
  - **Cenomanian – Turonian** marine shale
  - **Campanian** Deltaic/ terrigenous shale
  - **Paleocene/Eocene** (several levels) deltaic/terrigenous shale
  - **Miocene** deltaic/terrigenous shale

Ordovician Source Rocks



From Bojesen-Koefoed, 2011



From Bojesen-Koefoed, 2011

Presence

- Fossilik inlier: intraformational oil stains in Ordovician carbonate: fall-back breccia in diatreme (?)
- Marine shale source rock from the Fylla Canyon (offshore): dredge sample
- Franklinian Basin, North Greenland and Canada: marine shale source rock from Aleqatsiaq Fjord Fm (North Greenland)
- Oil stain in Ordovician limestone, Davis Strait High (offshore): dredge sample
- Hudson Bay – Foxe Basin (Canada), outcrops widespread, Boas River Fm: well documented

Character/quality

- Variable: carbonate/marine shale/oil shale
- Type II kerogen, predominantly oil-prone with gas potential
- TOC up to 16% (Boas River Fm)
- Hydrogen Index up to 600 (Boas River Fm)
- Thickness up to 35m (Boas River Fm)

Pros

- Widely distributed
- Rich, oil-prone
- Probably easy to recognize in oils due to characteristic biological marker distribution

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Albian Source Rocks and Seepages

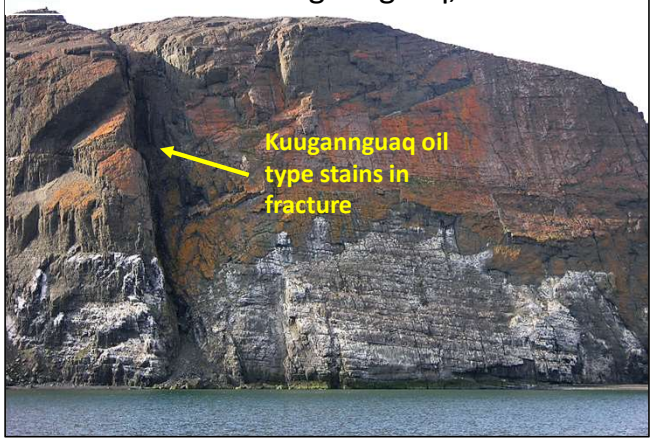
Presence

- Hassel Formation, Ellesmere Island, Nunavut, Canada (data in Núñez-Betulu (1993))
- Atane Formation, Nuussuaq Basin, Greenland
- Baffin Bay, Kap York Basin boreholes U110 and U80
- Kuugannguaq oil type seepages, Nuussuaq Basin, Greenland
- Labrador Sea South Hopedale L-39 well, Bjarni Fm

Character/quality

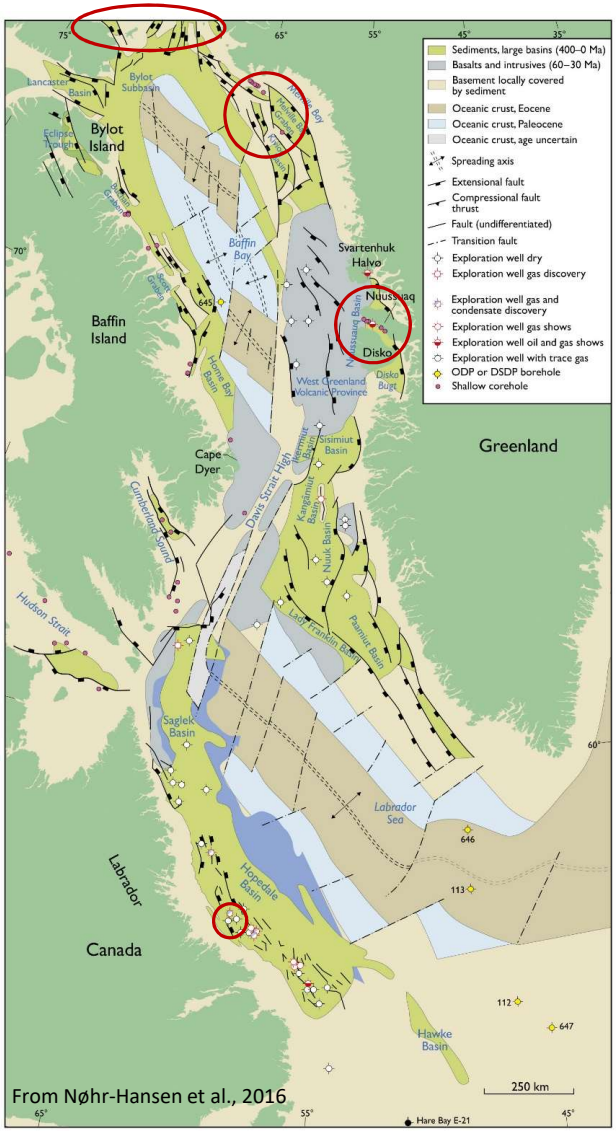
- Type II/III kerogen, oil and gas potential
- TOC up to 18% (carb. shale); 62% (coal)
- HI up to 375 (carb. shale); 150 (coal)
- Thickness: Atane Fm: 3000m or more Bjarni Fm: 500m

Bird-cliff East of Kuugannguaq, Disko



Pros

- Thick, easily drained source
- Mature over large areas if present
- Accumulations sourced from the Albian in the South Hopedale L-39 well, Labrador Sea



Cenomanian – Turonian Source Rocks and Seepages

Presence

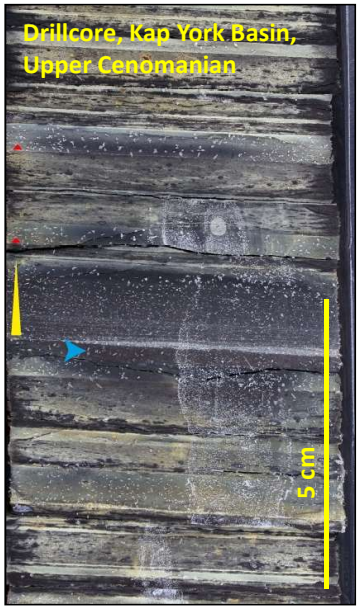
- Bituminous Mb, Kanguk Fm, Ellesmere Island (Núñez-Betulu, 1993))
- Baffin Bay, boreholes U0065, U0083, U0060, U0061 and U0070
- Umiivik-1 fully cored borehole, Nuussuaq Basin: overmature Turonian (?) shales with wet HC gas
- Itilli oil (and Asuk oil) type seepages, Nuussuaq Basin
- Scott Inlet seepage (Fowler et al. 2005)
- More info in Bojesen-Koefoed (2011) and references therein

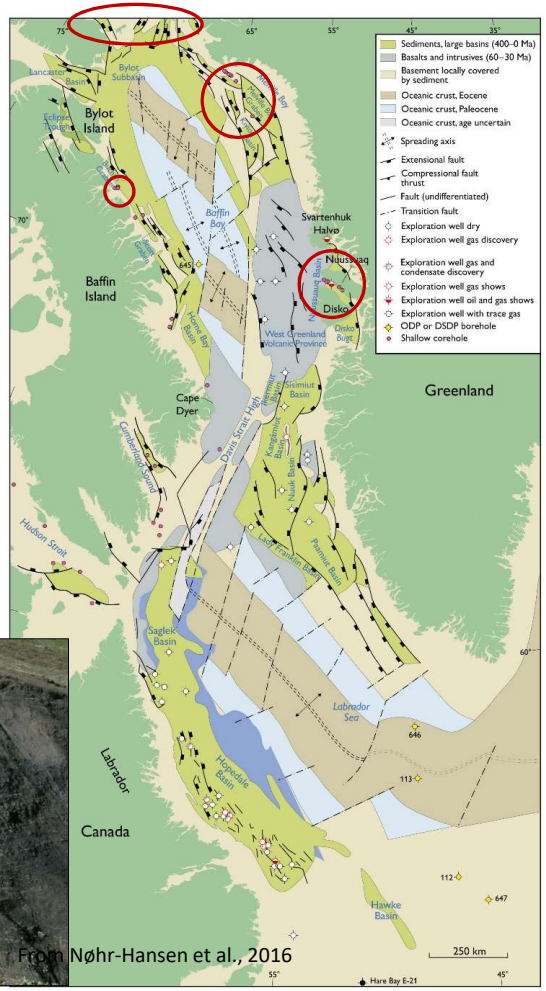
Character/quality

- Marine shale source rock
- Type II kerogen, predominantly oil-prone with gas potential
- TOC up to 10% (Ellesmere Island); up to 6% (Kap York Basin)
- Hydrogen Index up to 550 (Ellesmere Island); up to 375 (Kap York Basin)
- Thickness up to 80m (Ellesmere Island); 335m (Kap York Basin)

Pros

- Thick, widespread, can be expected to blanket vast areas
- Oil-gas prone
- Mature over large areas in Baffin Bay





From Nøhr-Hansen et al., 2016

Paleocene and Eocene Source Rocks and Seepages

Presence

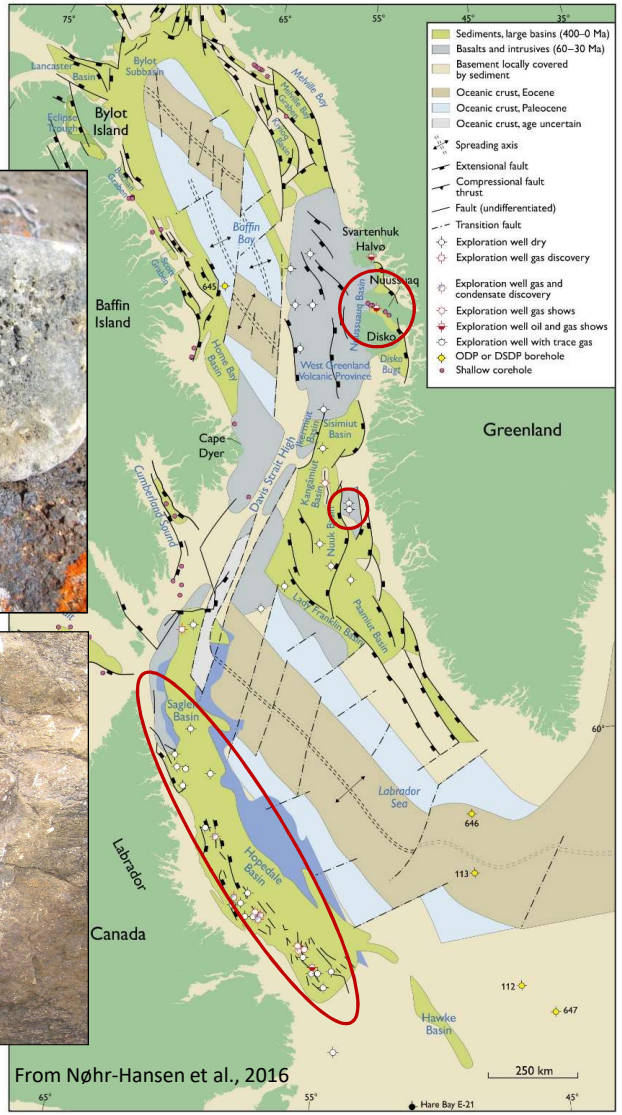
- GRO#3 well Nuussuaq Basin
- Nukik-1 well
- Cartwrigth Fm, Gudrid Mb, Labrador Sea
- Marraat oil type seepages, Nuussuaq Basin, Greenland
- Hekja O-71, Ralegh N-18 wells
- Several Danian through Ypresian intervals depending on location
- More information in Bojesen-Koefoed (2010) and references therein.

Character/quality

- Deltaic shales
- Type II/III kerogen, gas/oil-prone
- TOC up to 10% (Cartwrigth Fm); 4% (GRO#3 well)
- HI up to 400 (Gudrid Mb); 290 (Nukik-1 well)
- Thickness 100m (Gudrid Mb, Cartwrigth Fm, Nukik-1 well)

Pros

- Marraat oil widespread, suggesting that the regional climatic conditions were conducive for the development of deltaic source rocks,
- Source potential in Nukik-1 good,
- Gudrid Mb of the Cartwrigth Fm recognized as a petroleum source in the Labrador Sea



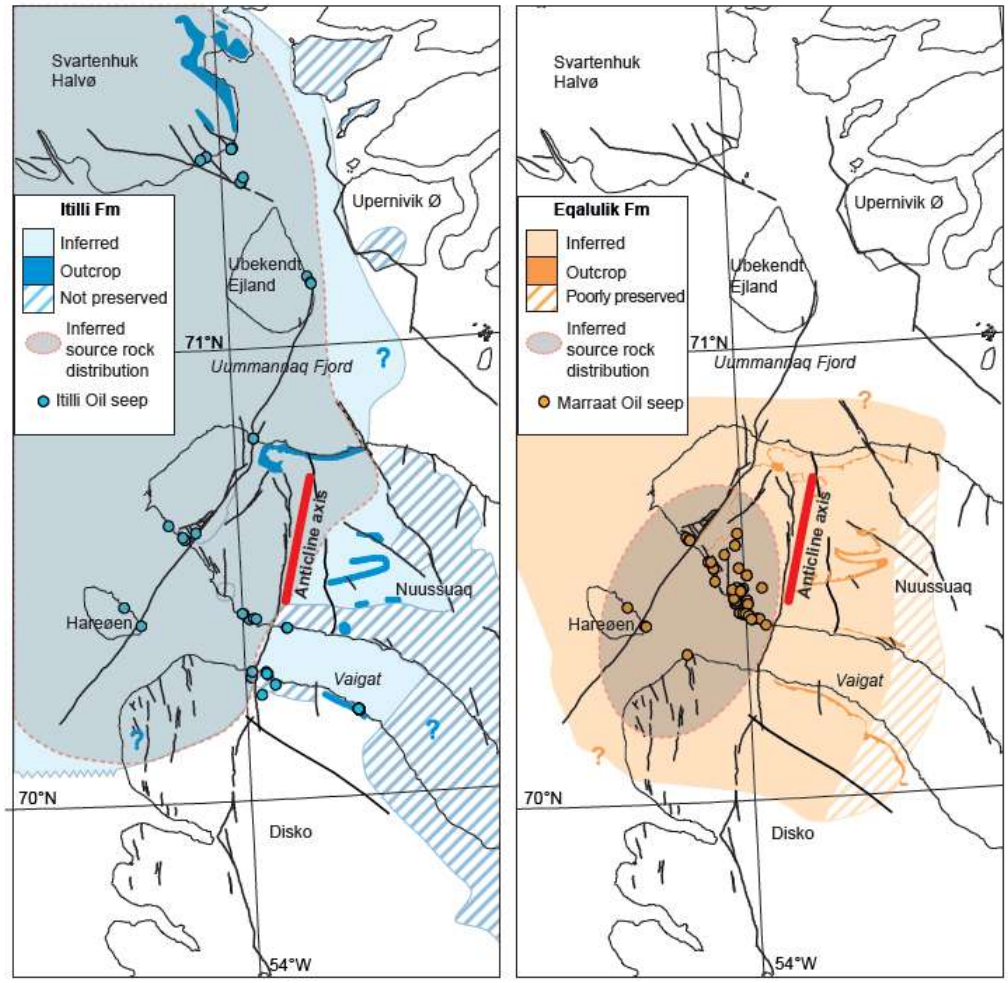
Nuussuaq Basin

Oil Seeps and source rocks

- Expected distribution of Cenomanian and Paleocene source rocks

Cenomanian SR distribution

Paleocene SR distribution



From Sørensen et al. 2017

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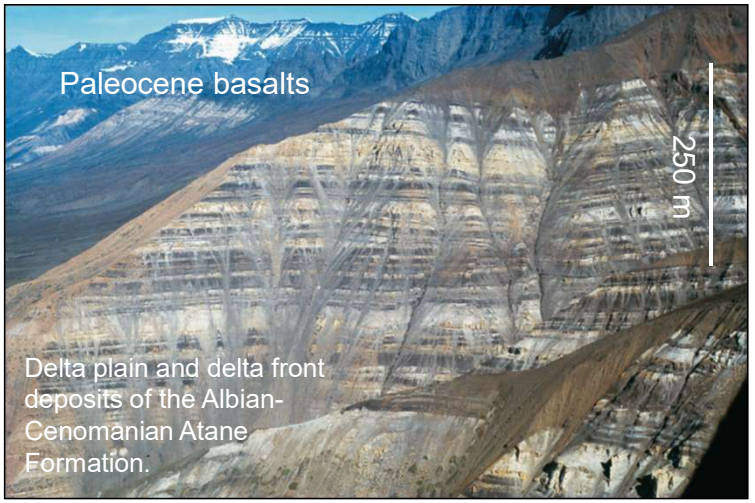
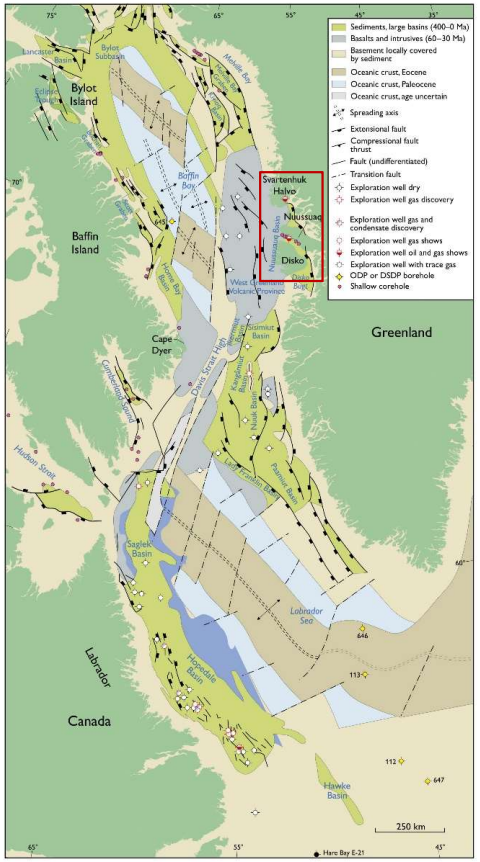
Reservoirs

- The Nuussuaq Basin provides **excellent reservoirs** on several stratigrafic levels

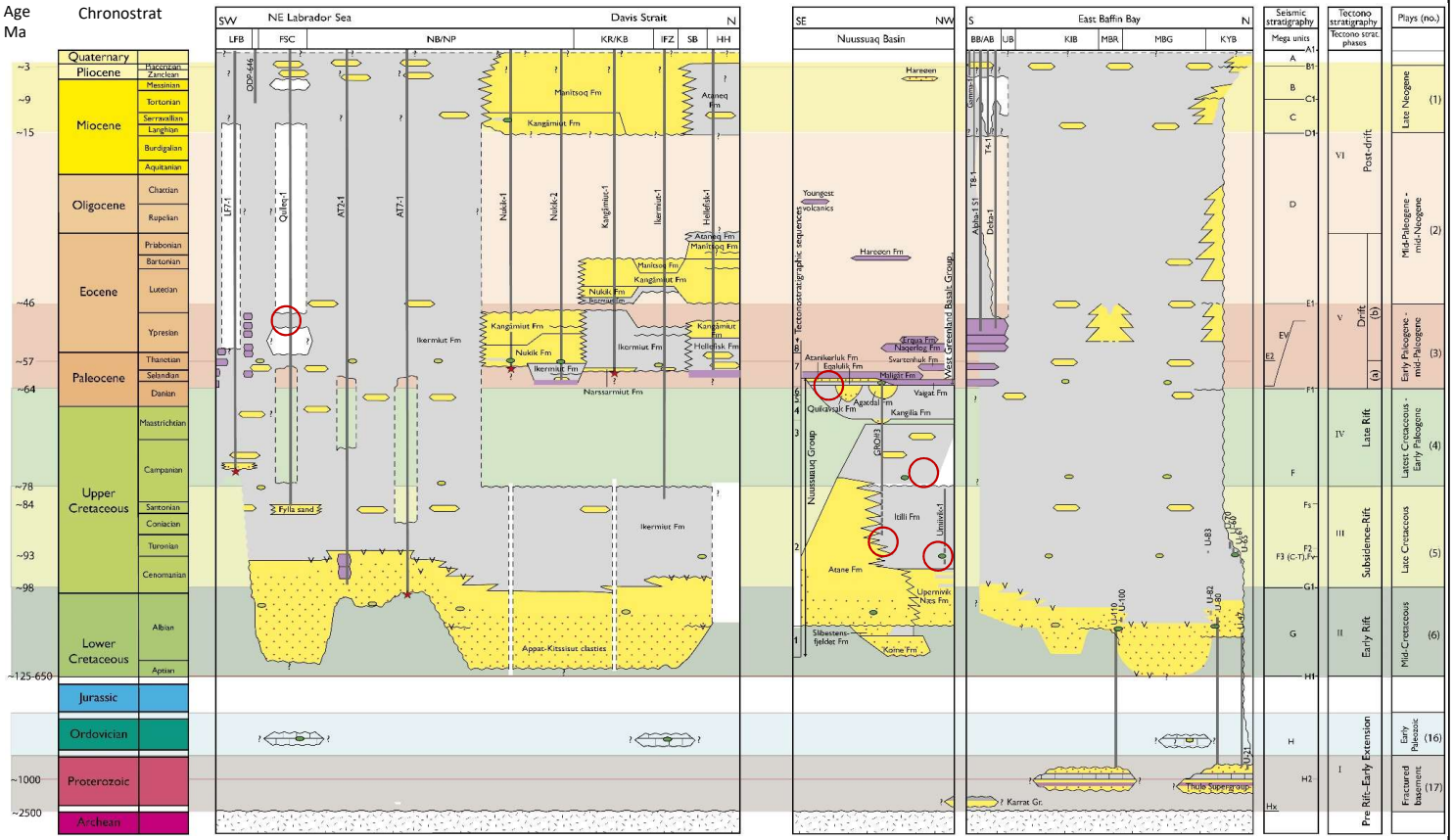




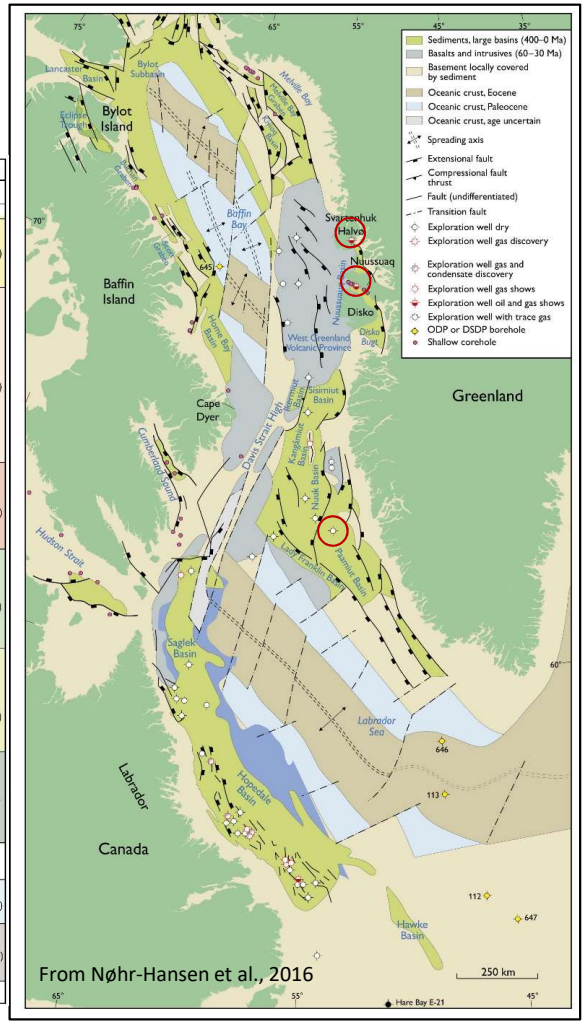
Dam et al. 2009

Seals

- Sealing studies (**mercury injection capillary pressure data**) have been performed on potential regional seals in the Nuussuaq Basin (outcrops and boreholes) and in the Qulleq-1 well, Paamiut Basin, SW Greenland

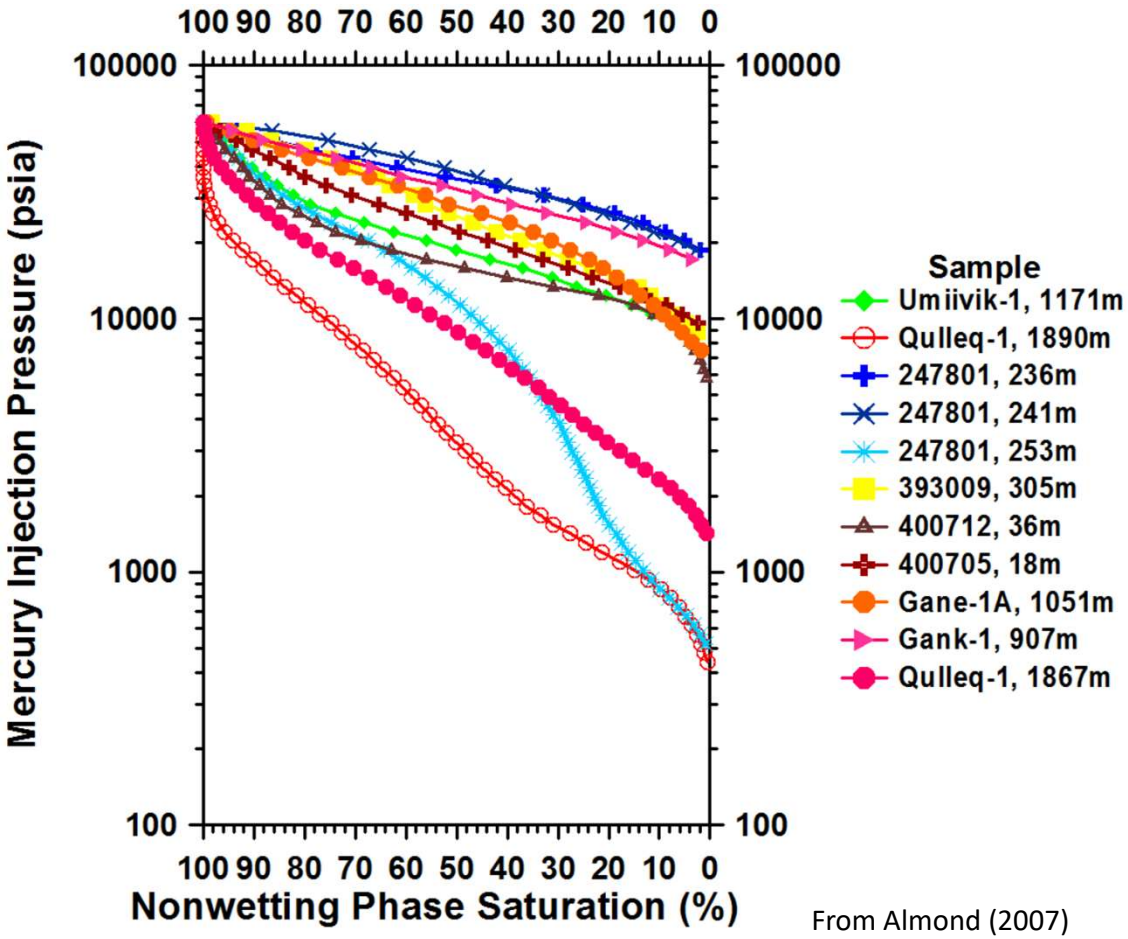


From Gregersen et al., 2019



From Nøhr-Hansen et al., 2016

Seals

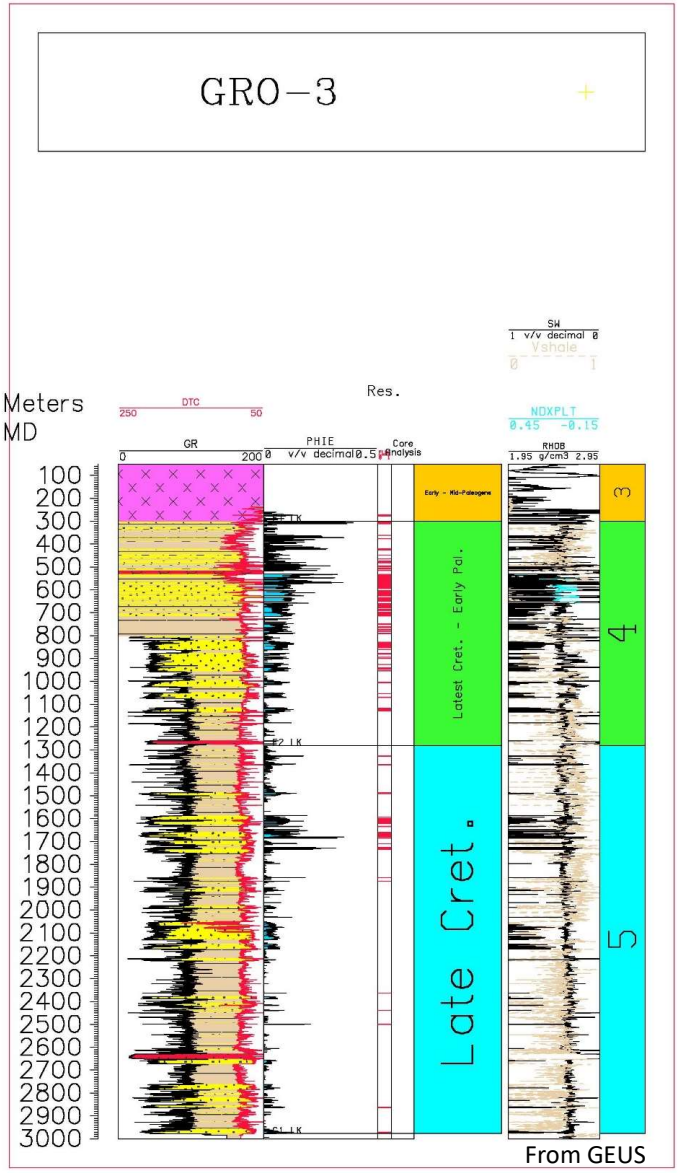


From Almond (2007)

- The seal study has confirmed that **high-quality seals** occur in Cenomanian–Coniacian, Campanian and Danian mudstone successions in the Nuussuaq Basin
- High-quality seals are also **regionally documented** from Svartenhuk Halvø in the north to south coast of Nuussuaq
- Measured capillary pressure data indicate that the seals in this area are capable of:
  - Retaining a **P50 oil column of 100 m to 1500 m**
  - The **P90 oil column can be as high as 1160 m** while the **P10 oil column can be as much as 2014 m**
  - The **P50 gas column could be between 148 m and 2164 m**

Nuussuaq Basin
GRO#3 exploration well

- Drilled early Paleocene – Late Cretaceous succession
- Proved Paleocene source rock and Late Cretaceous – Paleocene reservoir rocks
- Oil and gas shows
- **Drilled off structure**
- TD'ed at 3 km



From GEUS

Exploration Possibilities

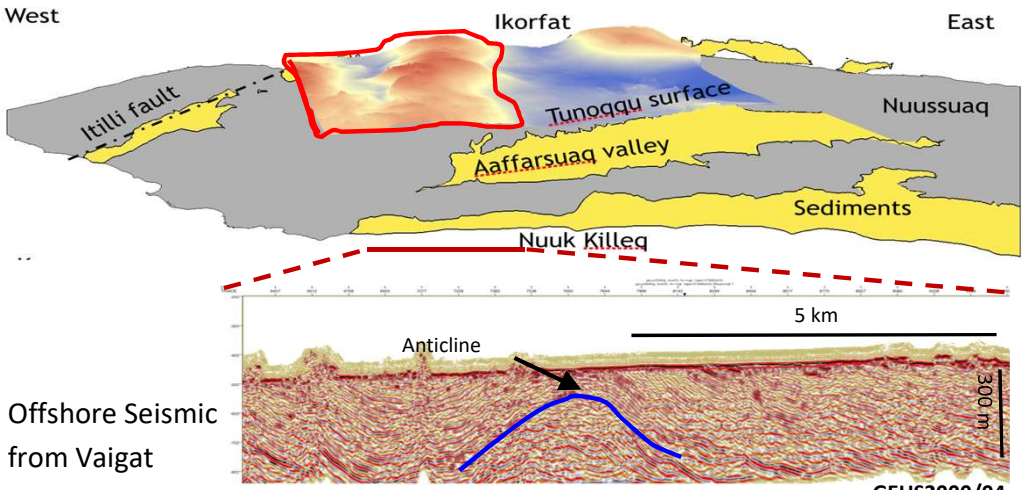
NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

GEUS

Onshore Exploration Possibilities

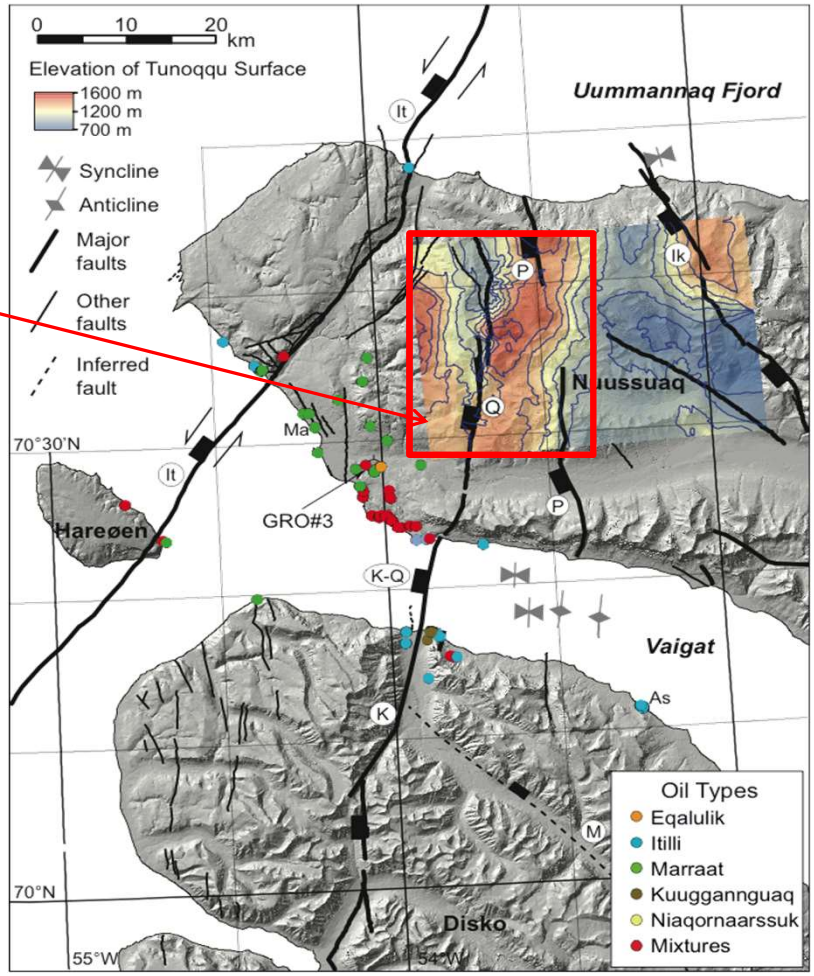
Nuussuaq Basin

- A large domal structure is present in the western part of Nuussuaq covering >60km^2
- Oil seeps are surrounding this structure
- Oils have been sourced from Cenomanian-Turonian marine and Paleocene deltaic source rocks



Offshore Seismic from Vaigat

From GEUS 2016



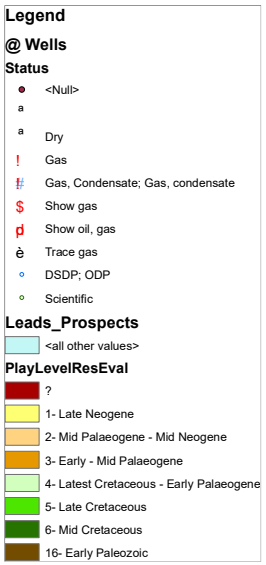
From Sørensen et al., 2017

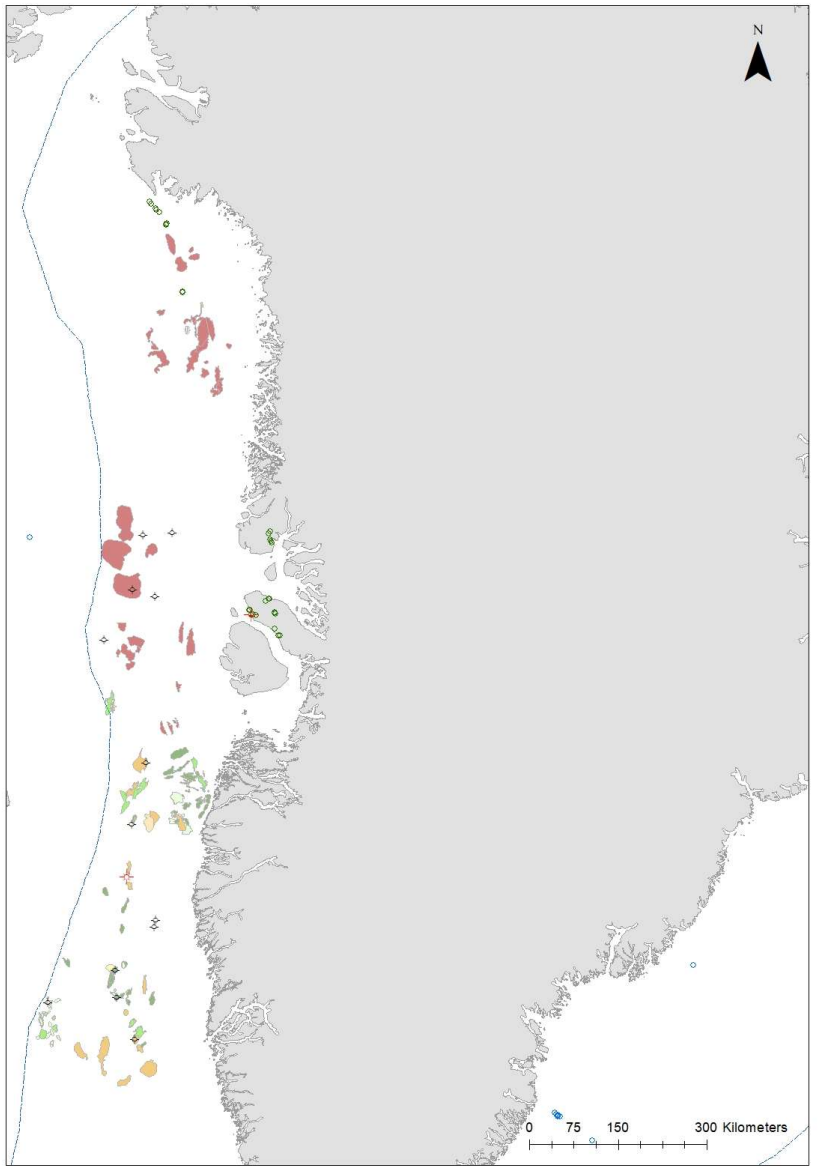
GEUS

Exploration Possibilities offshore West Greenland

Lead Portfolio

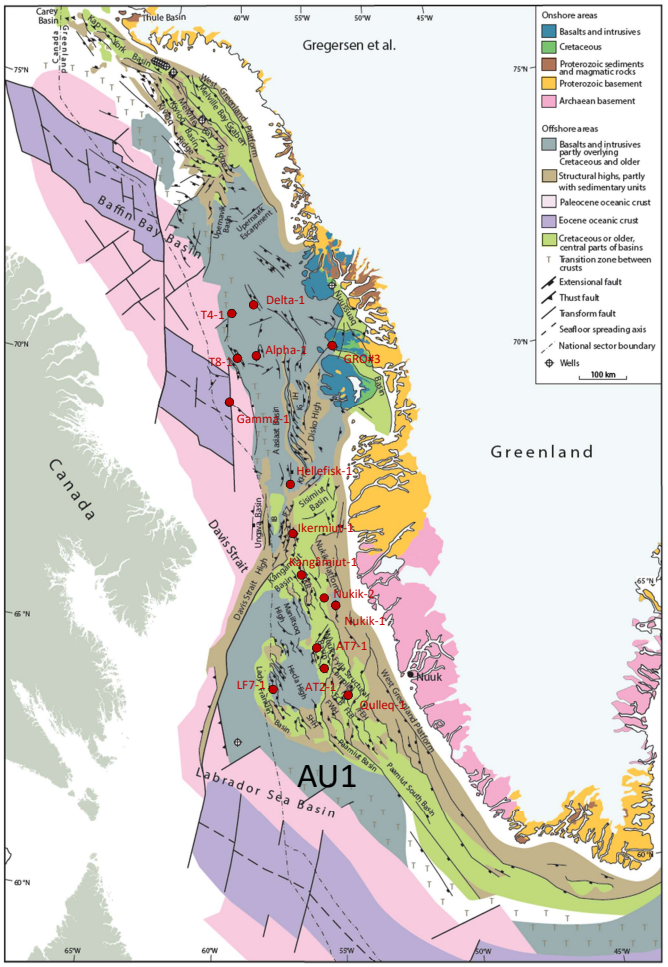
- Large portfolio currently including 194 structural leads (including only large structural closures),
- Leads on Paleozoic, Cretaceous, Palaeogene, Neogene and Pleistocene level,
- We are currently calculating volumes and assigning risks to individual leads in SW Greenland,
- Over the summer the leads in Baffin Bay will be evaluated.





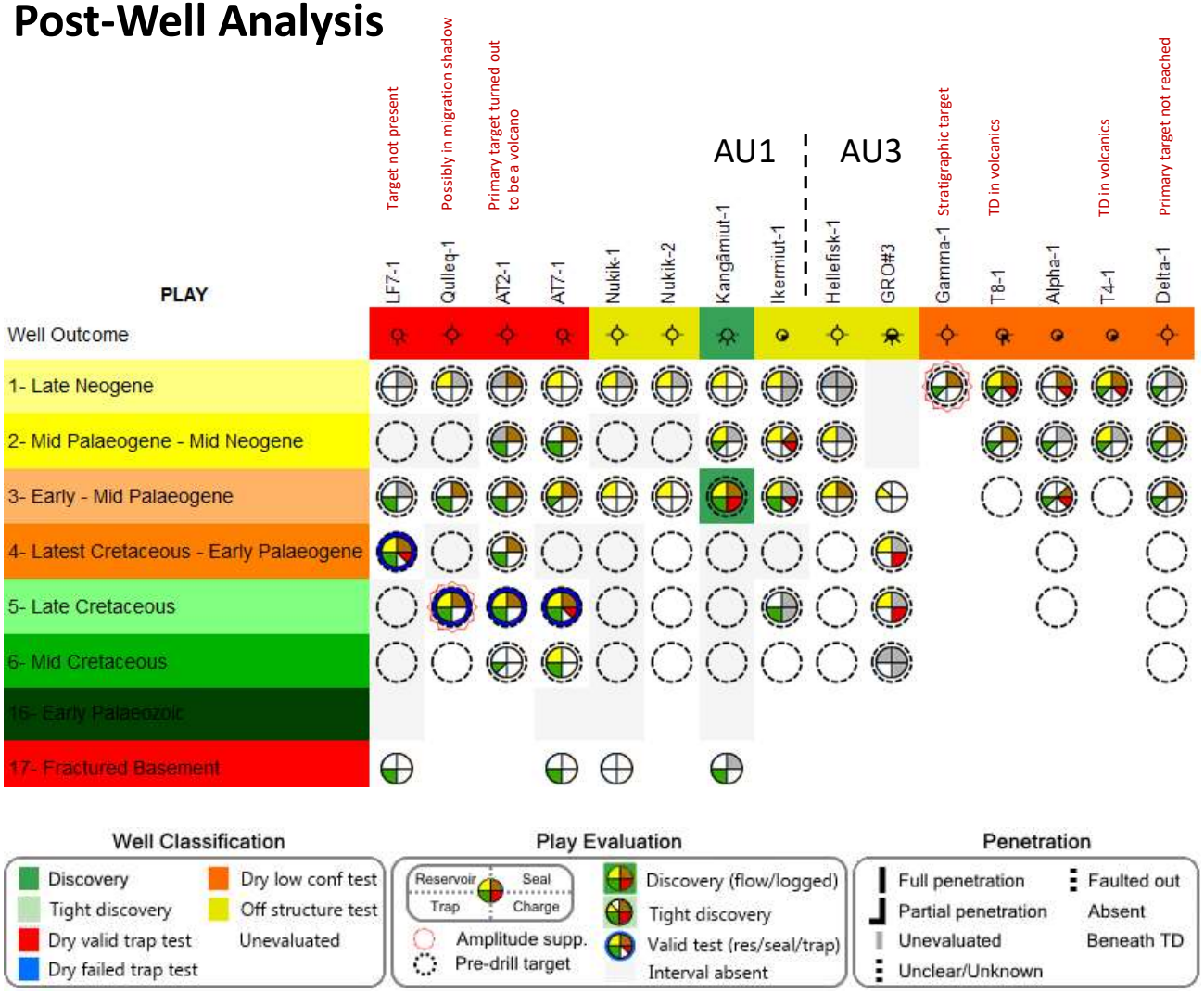
Post-Well Analysis

- As part of the Resource assessment project a post-well analysis has been performed
- 15 exploration wells have been drilled in West Greenland;
  - 8 exploration wells in SW Greenland (AU1)
  - 6 exploration wells in the basalt area (West of Disko area, AU3)
  - 1 exploration well in the Nuussuaq Basin (AU3)
  - No exploration wells have been drilled in the Baffin Bay area



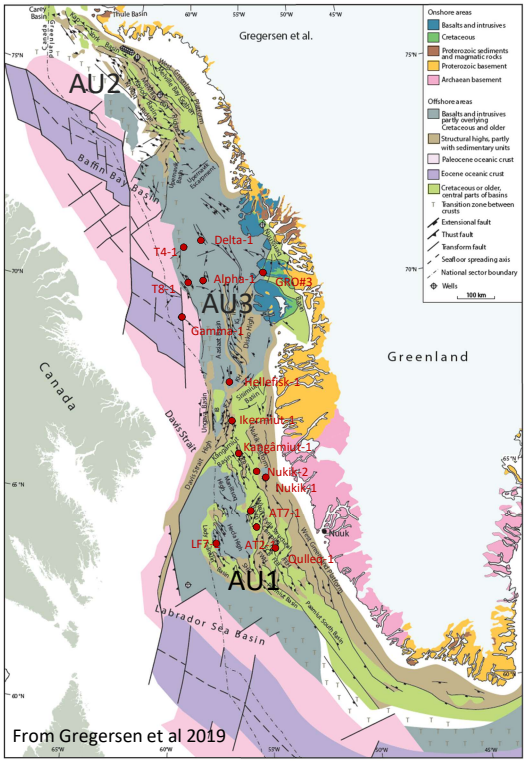
From Gregersen et al 2019

Post-Well Analysis



From the Greenland Resource Assessment Project (2019)

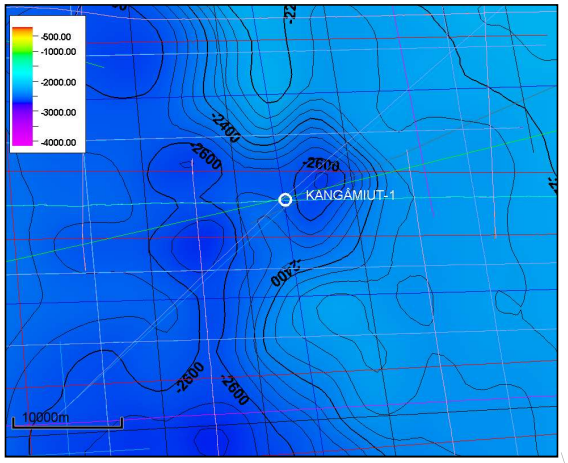
- 1 “gas discovery”
- 4 dry valid trap tests
- 5 low confidence tests
- 5 off structure tests
- “Successful play” is Play 3 – Early – Mid Paleogene Play
- Several wells with fluid inclusions



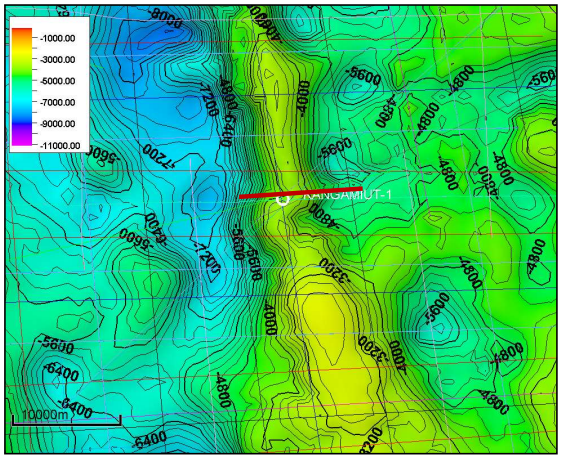
From Gregersen et al 2019

Kangâmiut-1 “Discovery”

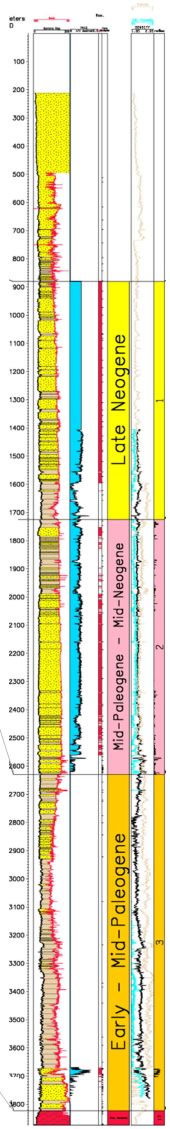
Top Early-Mid Paleogene Play – Play 3



Top Basement – Play 17

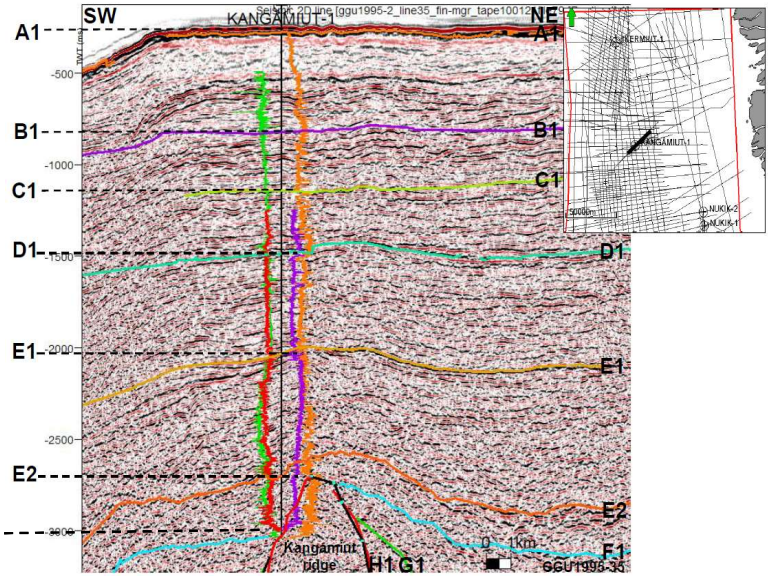


From the Greenland Resource Assessment Project (2019)



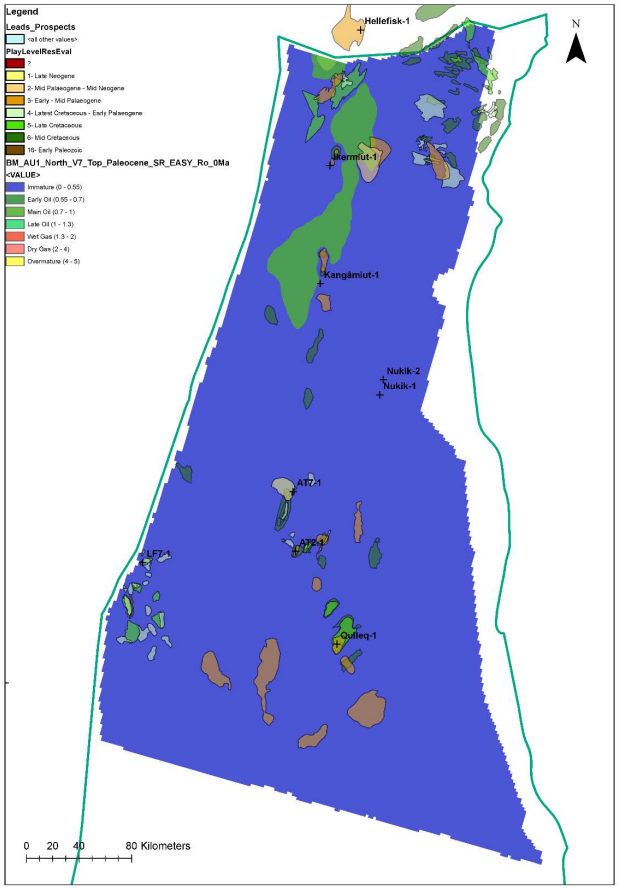
- The Kangâmiut-1 well may have drilled into hydrocarbon field, but technical difficulties related to pressure caused the well to be incompletely tested
- The reservoir appears to be a fan on the west flank of the Kangâmiut Ridge
- Drilled in a saddle with two large structures sitting North and South of the well
- Paleocene reservoir, net res ~ 40 m, Φ ~ 12%

Gas kick

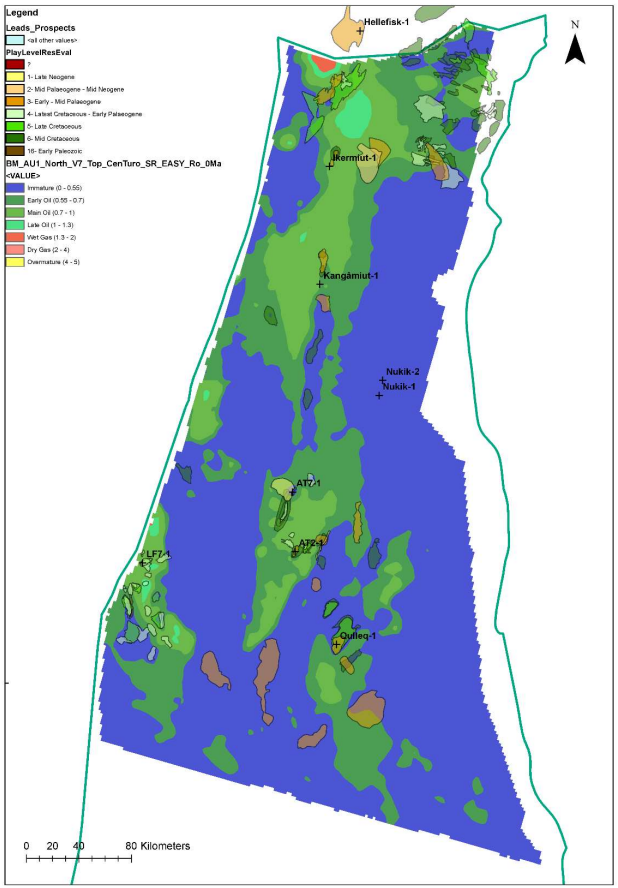


Kangâmiut-1 “Discovery”

Mature Paleocene SR (if present)



Mature Cenomanian-Turonian SR (if present)



From the Greenland Resource Assessment Project (2019)

- If present, hydrocarbons from the Kangâmiut-1 ”Discovery” could have been sourced from either a Cenomanian-Turonian or a Paleocene source rock
- Fluid inclusions in Ikermiut-1 suggest that they were sourced from a very poor, terrestrial Early Campanian source rock
- This is suggesting that a Cenomanian-Turonian source rock is not present in the area and that the Kangãmiut- hydrocarbons were most likely sourced from a Paleocene source rock

Resource Assessment for Greenland

Purpose

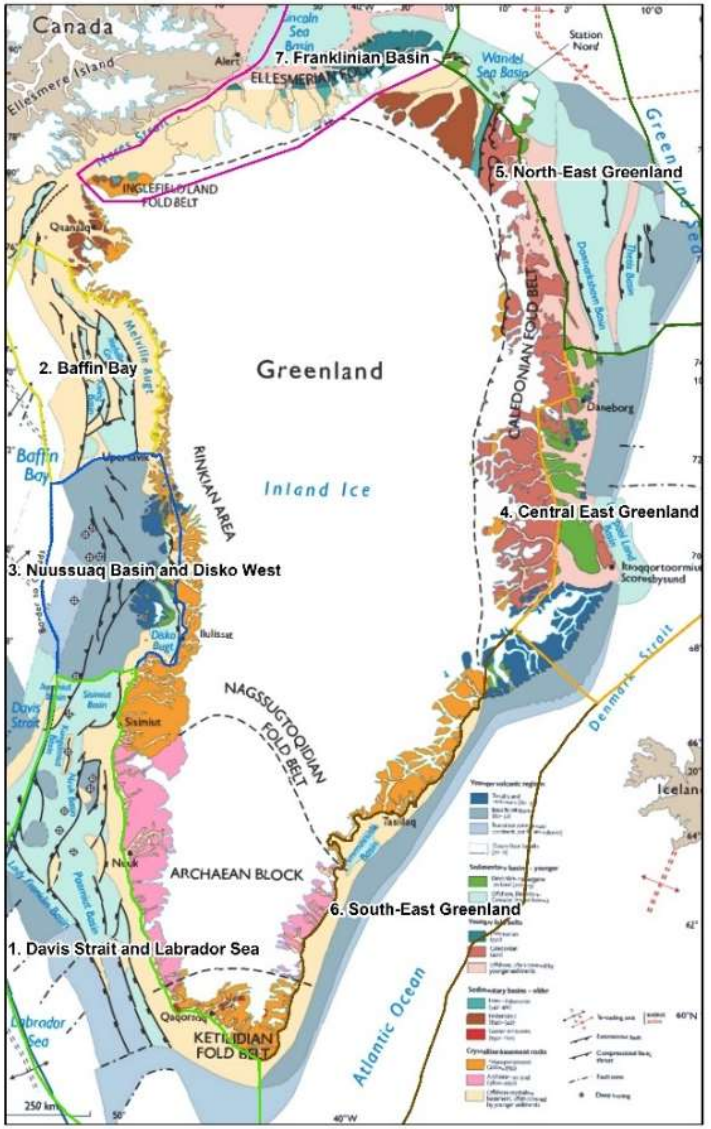
- Provide an estimate of the play-based, yet-to-find potential of conventional hydrocarbons on the Greenland continental shelf

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
- Help defining new G&G initiatives

Collaborators

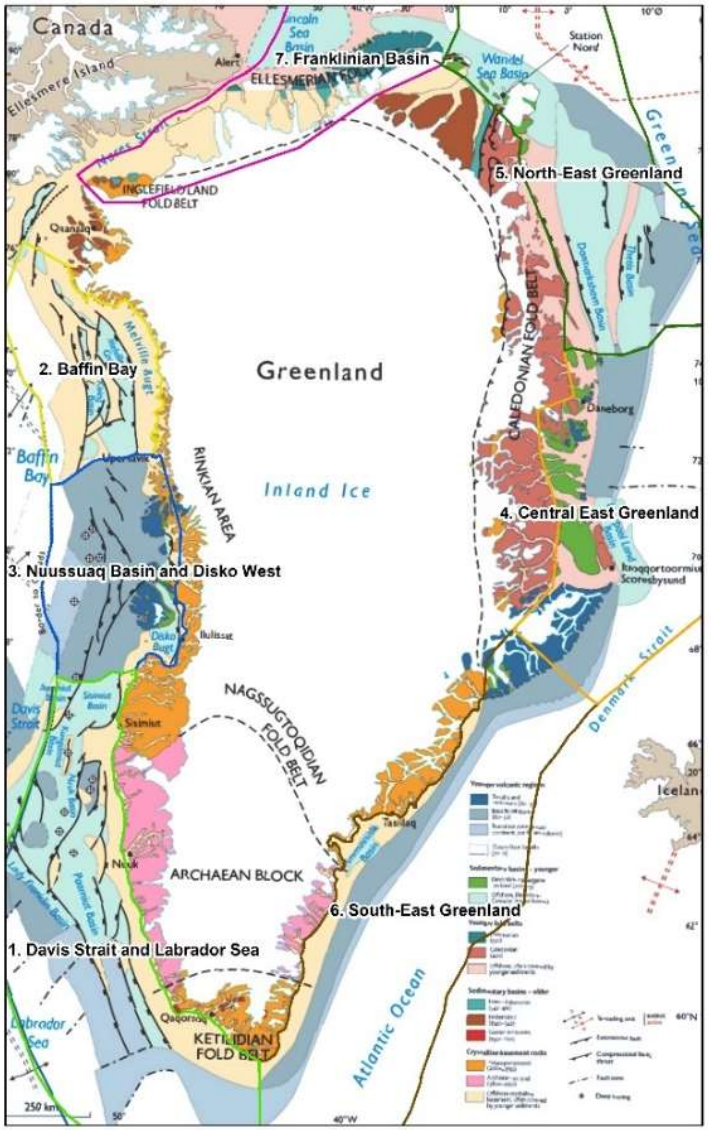
- Project is a collaboration between NUNAOIL, MIER, and GEUS
- Project is located at GEUS and most of the work is performed by GEUS



Assessment areas (1-7) of the Greenland Resource Assessment Project

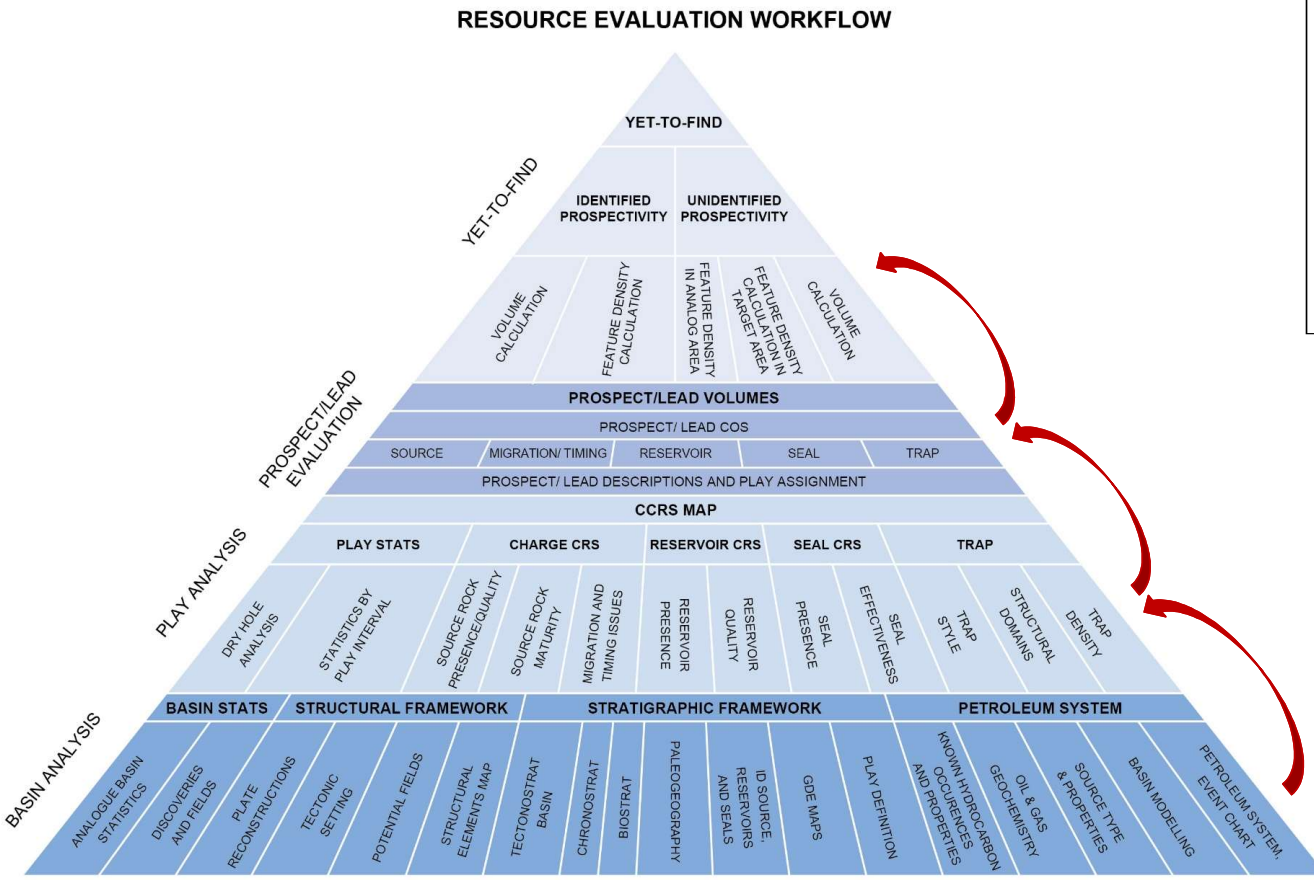
Resource Assessment for Greenland

- Huge area covering more than 2.431.212 km^2 - slightly larger than the Norwegian continental shelf
- Seven assessment units have been established. Assessment units outline larger geological provinces and were designed primarily for efficiency in carrying out the work and to facilitate regular reporting
- Existing data from industry, GEUS, NUNAOIL, and MIER are incorporated into a database that forms the basis for establishing play types and assessing each unit
- These data will be used for a new super regional basin modeling exercise
- The total work load is estimated to take 3 ½ year but individual assessment units will be reported as they are finalized
- The work will be finalized in due time for future licensing rounds

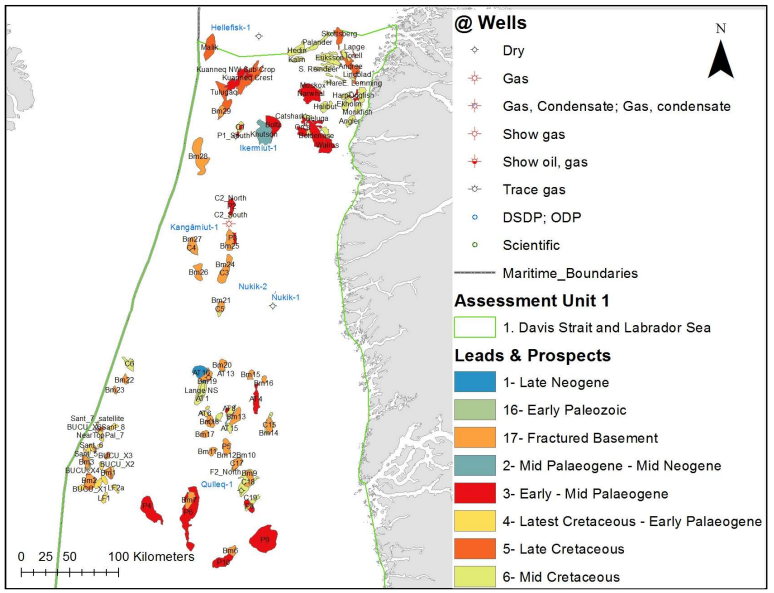


Assessment areas (1-7) of the Greenland Resource Assessment Project

Resource Assessment for Greenland Workflow

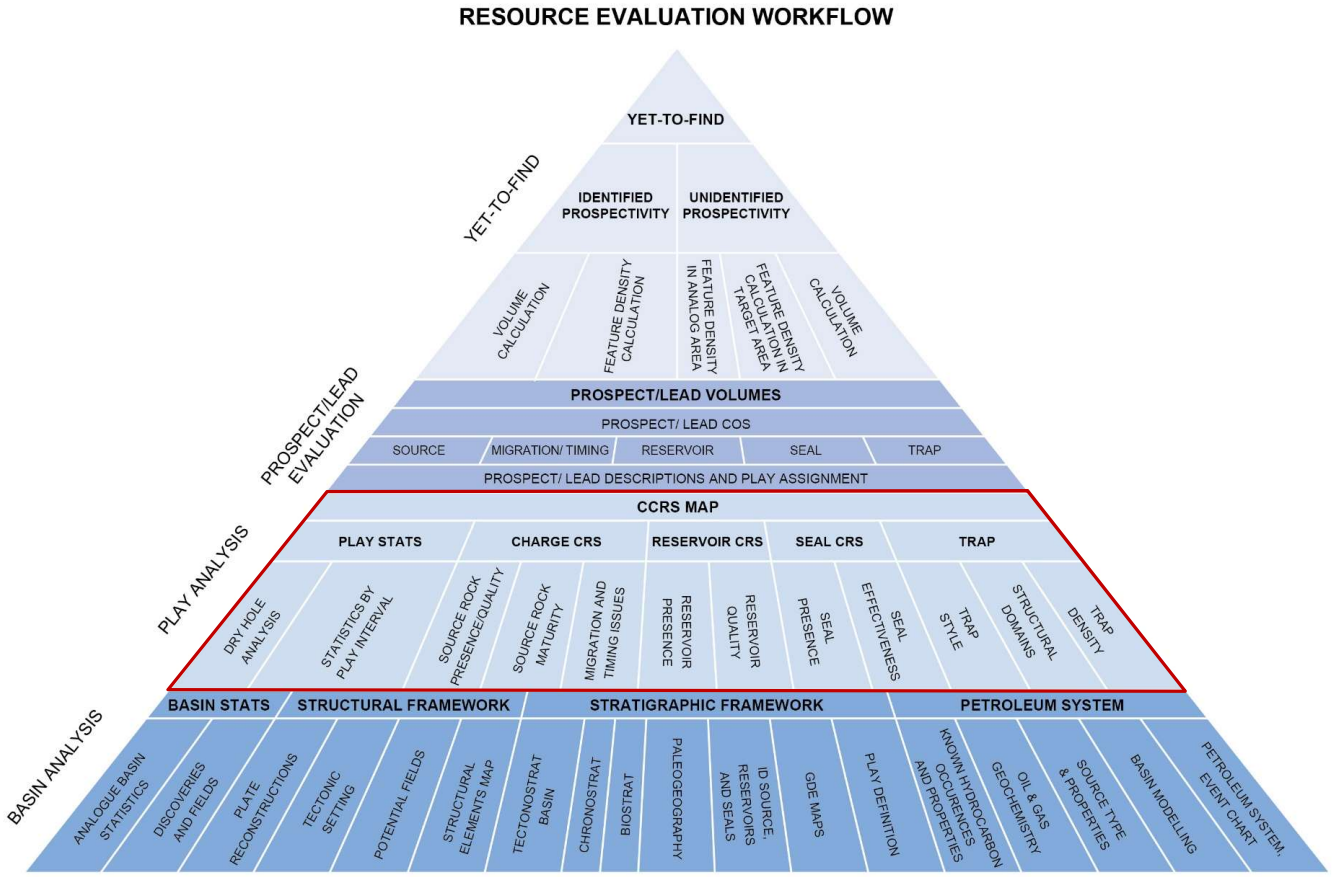


From the Greenland Resource Assessment Project (2019)



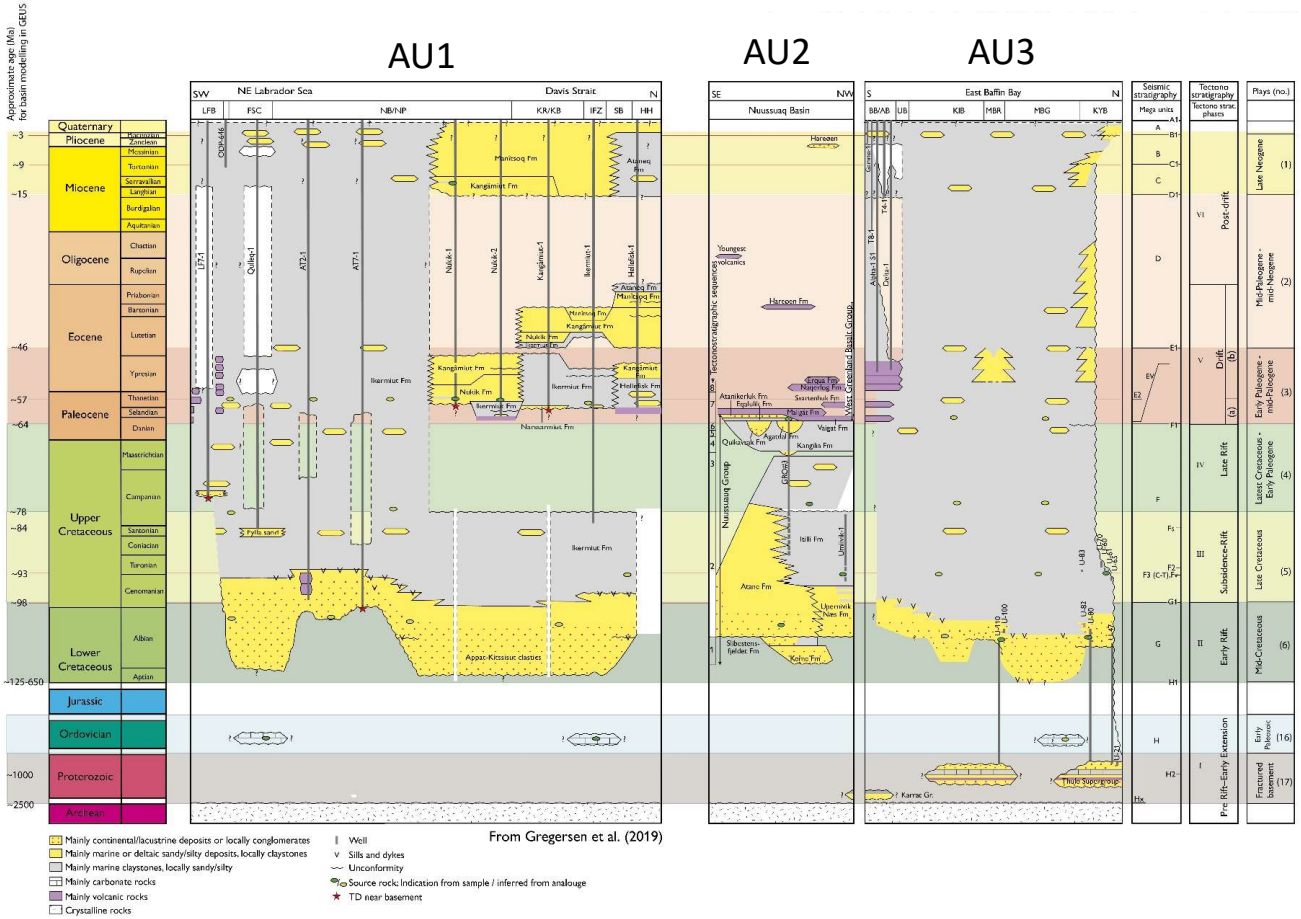
- Compile all available industry and GEUS/MIER/NUNAOIL data on regional geology and prospects
- Integrate regional seismic interpretations for production of regional depth and thickness maps
- Perform in-house basin evaluation and basin modelling
- Perform in-house play analysis
- QC all reported industry/GEUS/ MIE/NUNAOIL leads and prospects and assign them to play intervals
- Perform in-house lead/prospect volumes and risking
- Perform in-house play-based resource assessment

Resource Assessment for Greenland
Play Analysis



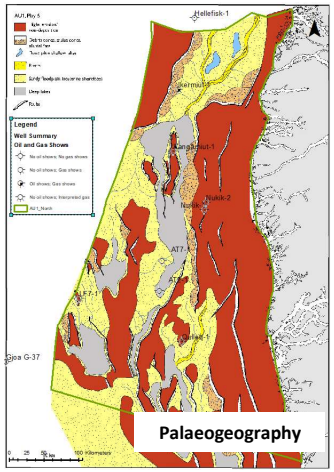
From the Greenland Resource Assessment Project (2019)

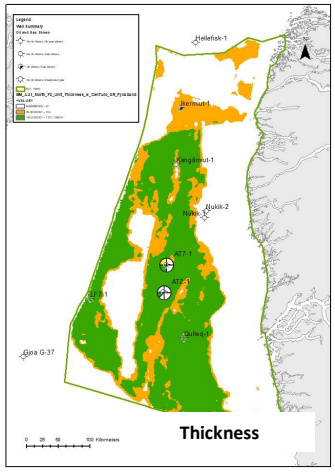
West Greenland Plays

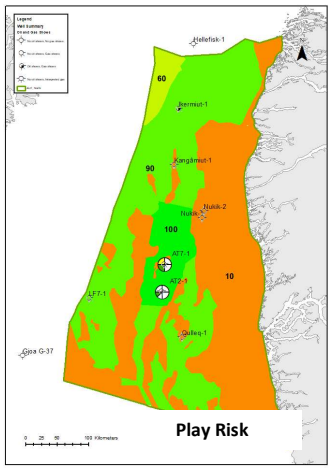


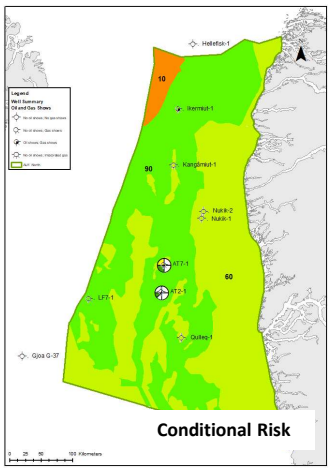
- 17 plays have been defined for all of Greenland, of which 8 are present in West Greenland
- They are:
  - Play 17 Fractured Basement
  - Play 16 Early Paleozoic
  - Play 6 Mid-Cretaceous (Early Rift)
  - Play 5 Late Cretaceous (Subsidence-Rift)
  - Play 4 Latest Cretaceous – Early Paleogene (Late Rift)
  - Play 3 Early Paleogene – mid-Paleogene (Drift)
  - Play 2 Mid-Paleogene – mid-Neogene (Drift- Post-drift)
  - Play 1 Late Neogene – Post-drift

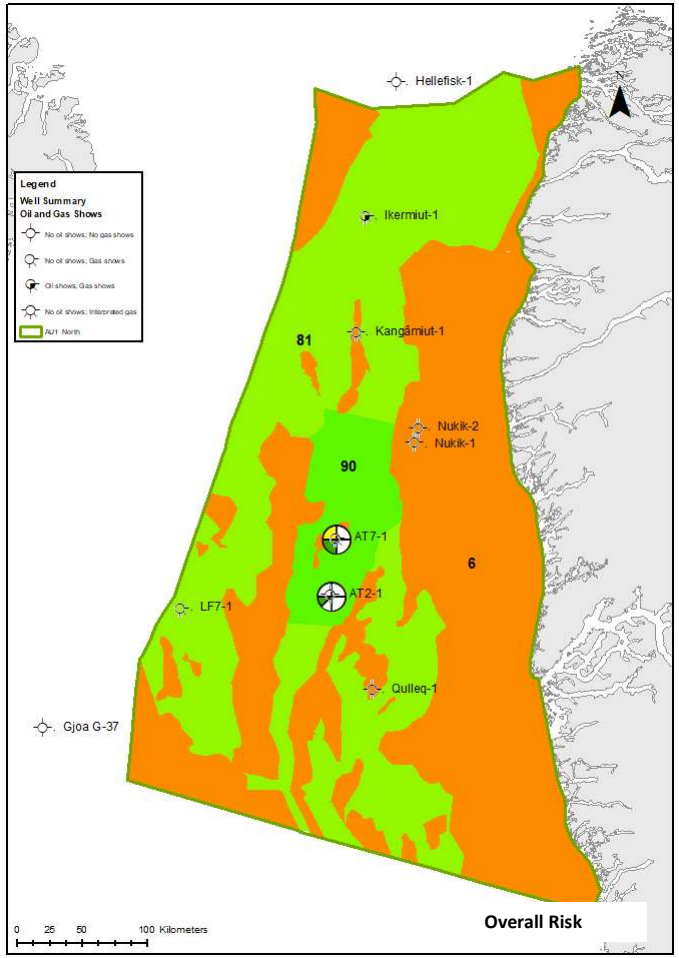
Resource Assessment for AU1, West Greenland
Play 6 – Reservoir Presence





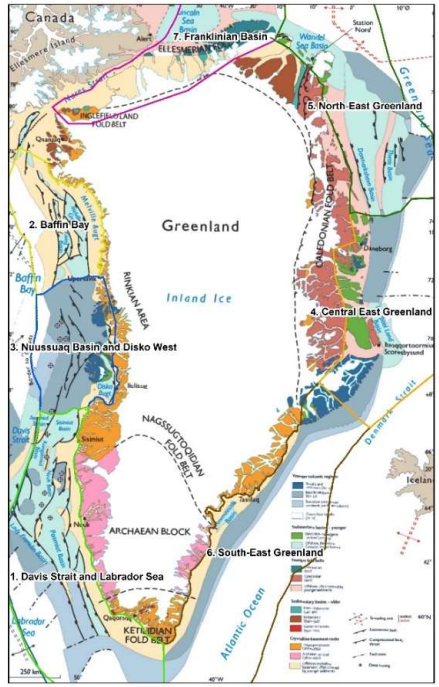




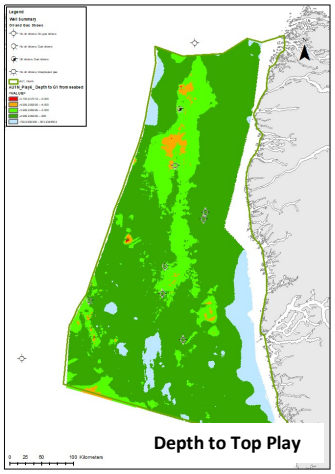


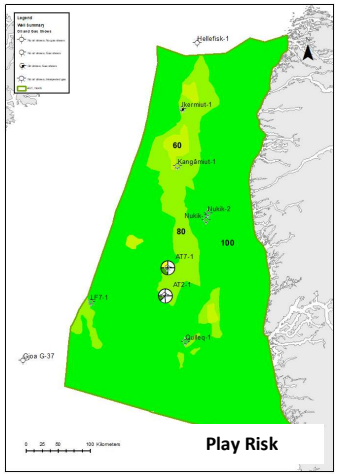
GDE	Comment	Play Risk
Syn-rift sst (alluvial fan, fluvial etc.)	Basinal areas where reservoir sst are proven by well penetrations	100
Syn-rift sst (alluvial fan, fluvial etc.)	Basinal areas without well penetrations	90
Syn-rift sst (alluvial fan, fluvial etc.)	Basement highs	10

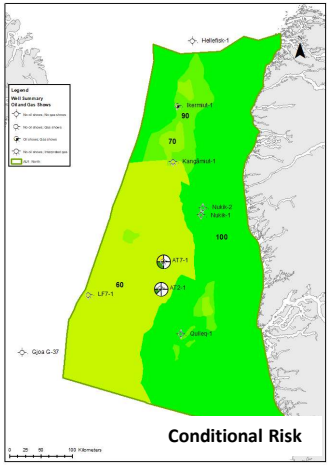
GDE	Comment	Cond Risk
Syn-rift sst (alluvial fan, fluvial etc.)	Basinal areas where reservoir sst are proven by well penetrations	90
Syn-rift sst (alluvial fan, fluvial etc.)	Basinal areas without well penetrations	90
Syn-rift sst (alluvial fan, fluvial etc.)	Basement highs	60

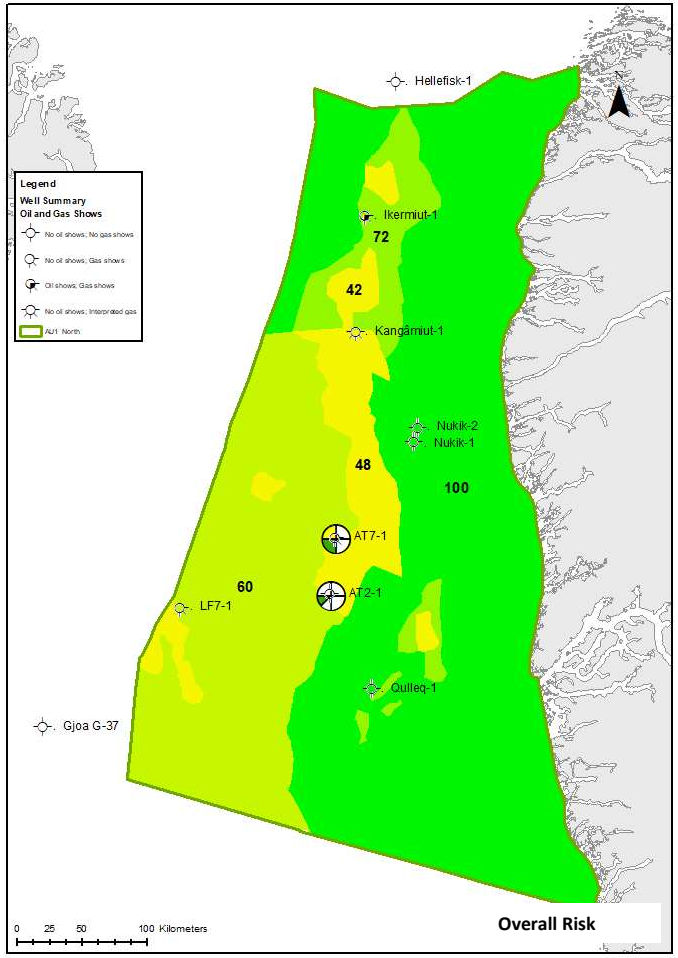


Resource Assessment for AU1, West Greenland
Play 6 – Reservoir Effectiveness





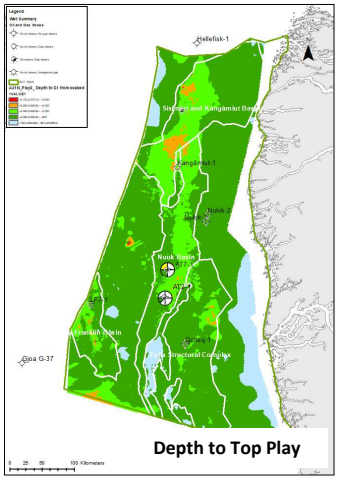


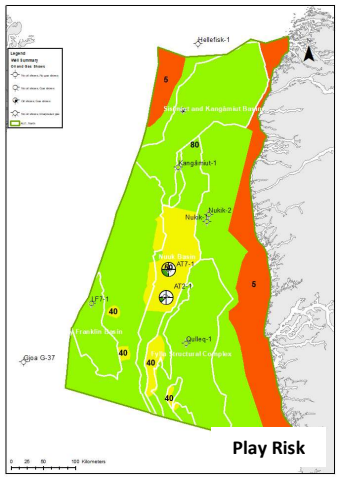


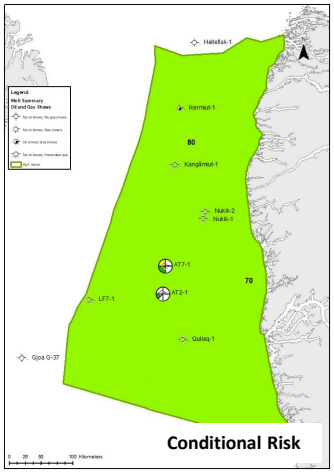
Depth	Play Risk
<3 km (<90°C)	100
3-4 km (90-120°C)	90
4-5 km (120-150°C)	60
> 5km (>150°C)	50

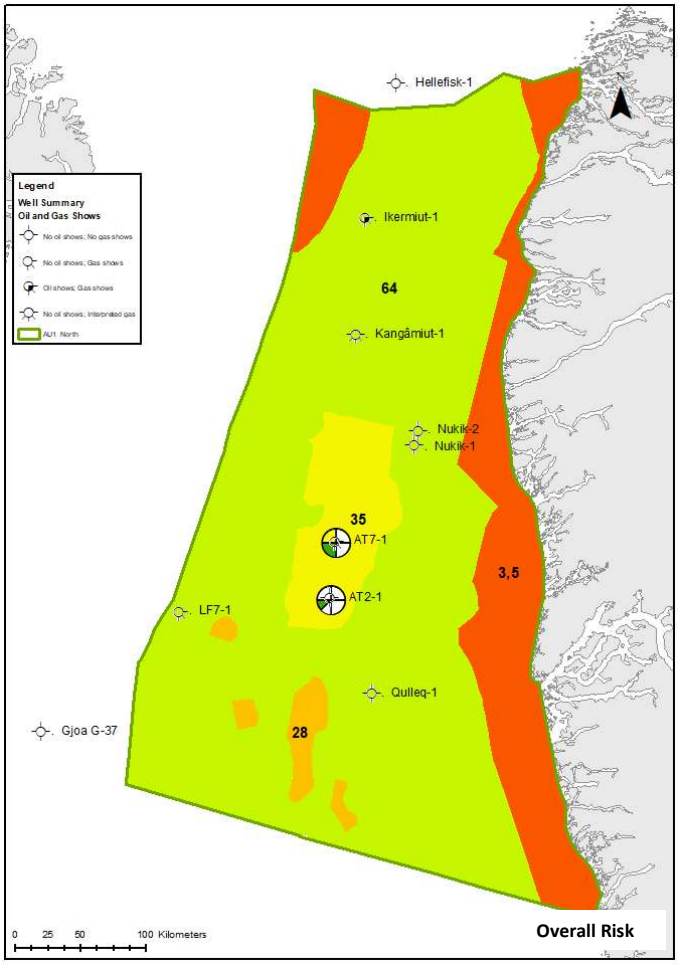
Depth	Cond Risk
<3 km (<90°C)	100
3-4 km (90-120°C)	90
4-5 km (120-150°C)	70
> 5km (>150°C)	60

Resource Assessment for AU1, West Greenland
Play 6 – Top Seal





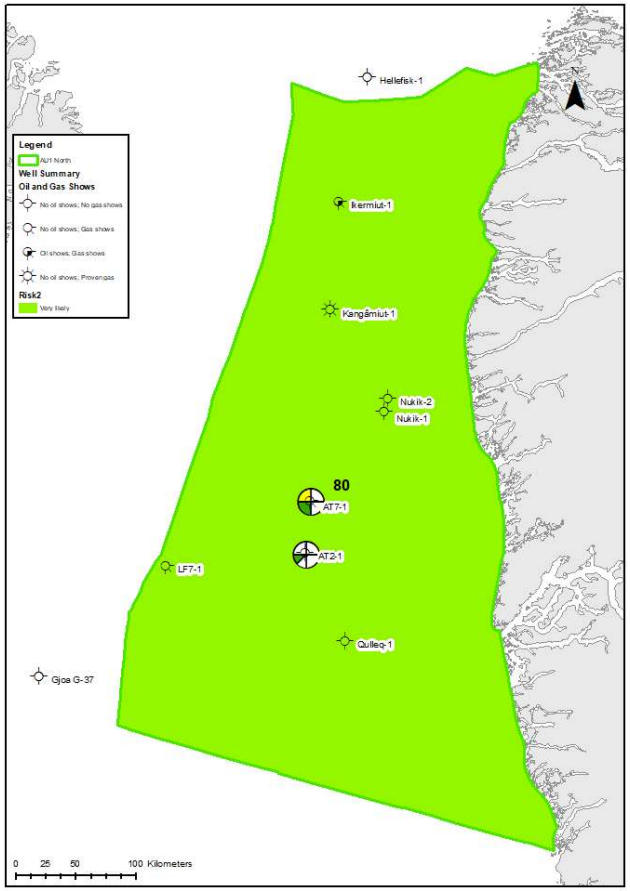




Thickness of Overburden	Play Risk
Areas with more than 800 m overburden, unproven	80
Areas with less than 800 m overburden, unproven	40
Areas where top seal is thin due to erosion or non-deposition	50
Basement areas along margin of basin with little chance of Paleocene section being present	5
Davis Strait High with little chance of seal section being present	5

Thickness of Overburden	Cond Risk
Areas with more than 800 m overburden, unproven	80
Areas with less than 800 m overburden, unproven	70
Areas where top seal is thin due to erosion or non-deposition	70
Basement areas along margin of basin with little chance of Paleocene section being present	70
Davis Strait High with little chance of seal section being present	70

Resource Assessment for AU1, West Greenland
Play 6 – Trap Effectiveness



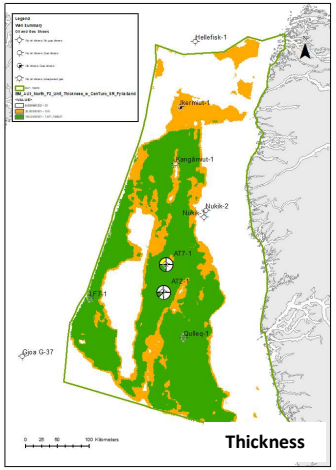
Known leads

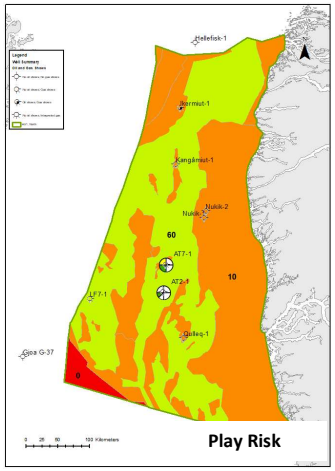
Trap Presence	Play Risk	Conditional Risk
4-way closures (C)	100	90
Fault-bounded 3-way closures (CT)	100	70

Unidentified leads

Play	# 3-way closures	# 4-way closures	Average Trap Risk (Conditional)
3	1	8	85
4	7	15	85
5	9	4	75
6	**28**	**17**	**80**
16	Not mapped – same as Play 6		80

Resource Assessment for AU1, West Greenland
Play 6 – Source Presence, Source Maturity

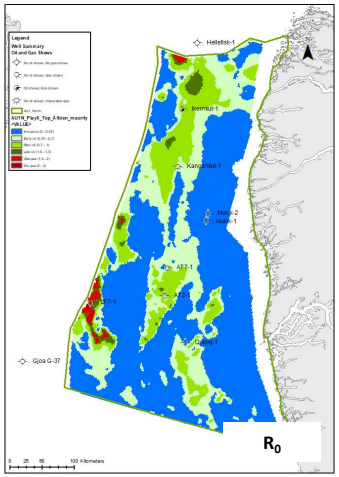


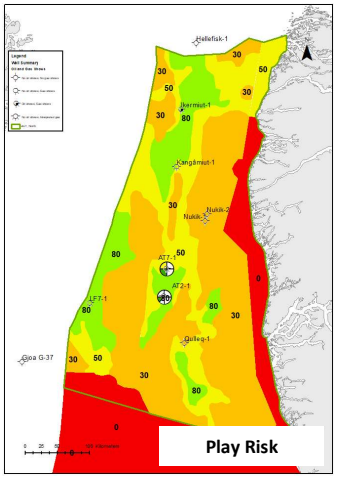


Source Presence

Source Presence	Play Risk
Proven by well data/oil seeps/oil and gas shows,	100
Regional data suggests presence of a source rock but without well calibration	50-70
Untested basement highs	30
Tested basement highs without presence in well	10

NB Play 6
SR presence over highs are assigned 10 (and not 30) as they formed as rift shoulders during main rifting, with very little chance of being covered by SR
All basins are assigned 60. Very little data and if source presence is differentiate the basin areas, it has large implications for definition of the kitchen areas

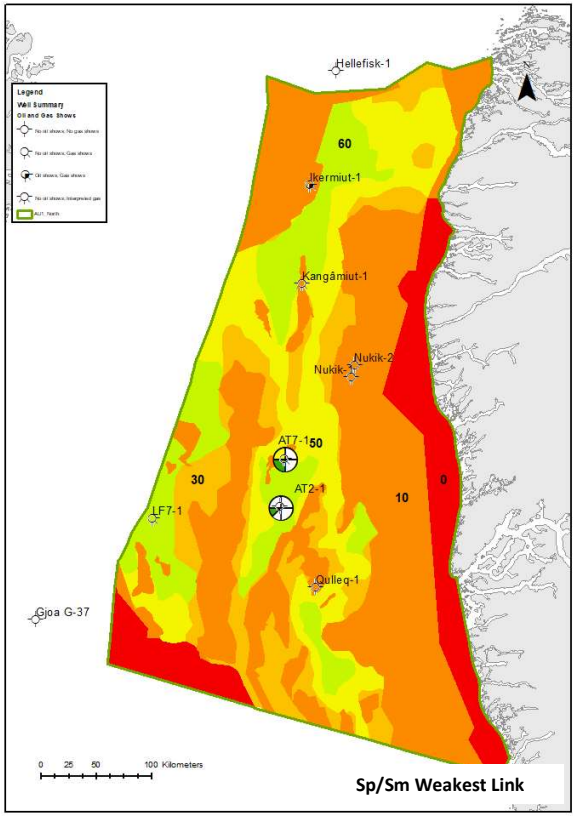




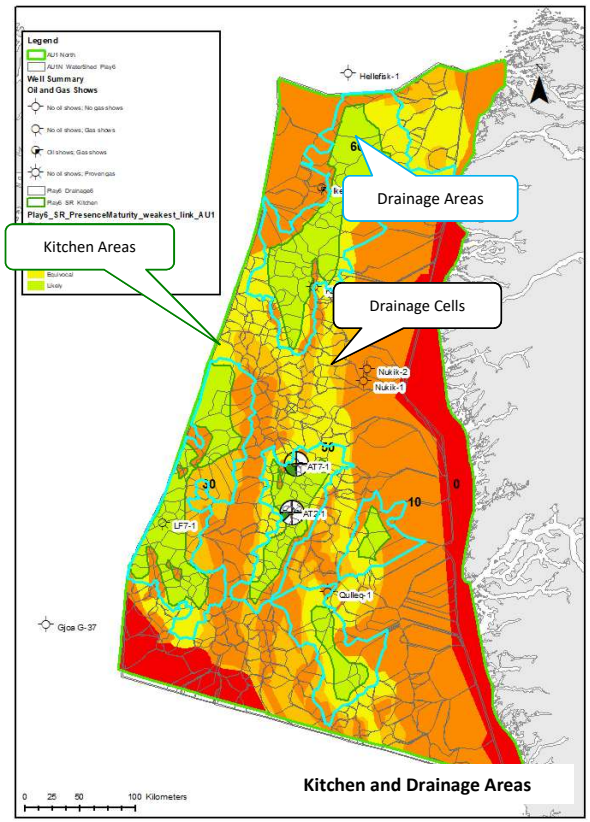
Source Maturity

Ro	Comment	Play Risk
0-0.55	Immature	30
0.55-0.7	Early oil mature	50
0.7-1.3	Oil Mature	80
1.3-4.0	Gas mature	80
4.0-5.0	Over mature	50

Resource Assessment for AU1, West Greenland
Play 6 – Kitchen



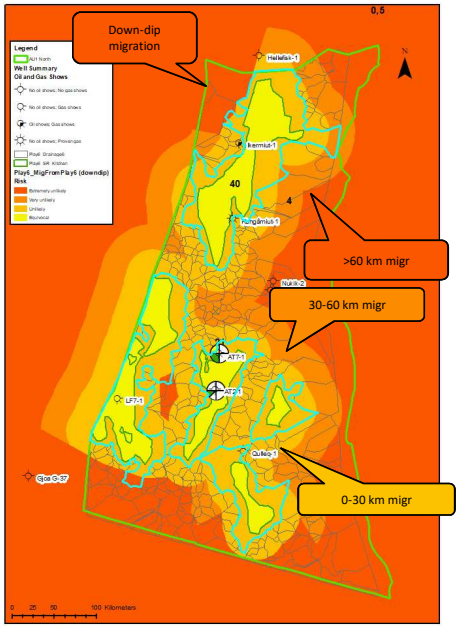
Sp/Sm Weakest Link



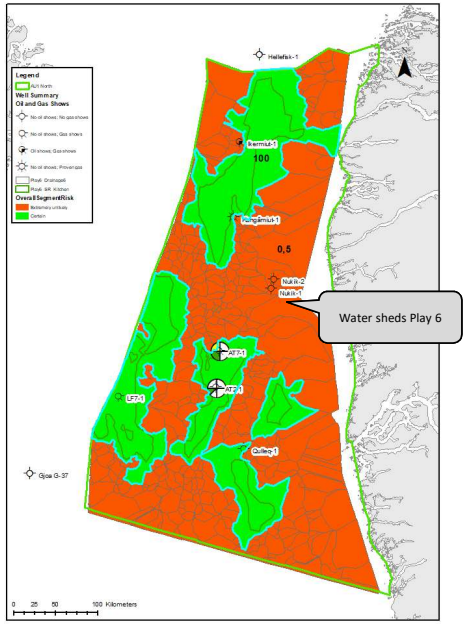
Kitchen and Drainage Areas

Kitchen Areas - Comments
Source kitchen defined by combining source presence and source maturity maps using a weakest link approach. Polygons with the smallest combined risks are defined as the kitchens. These polygons should represent areas where source rock temperatures are in the oil and gas windows.

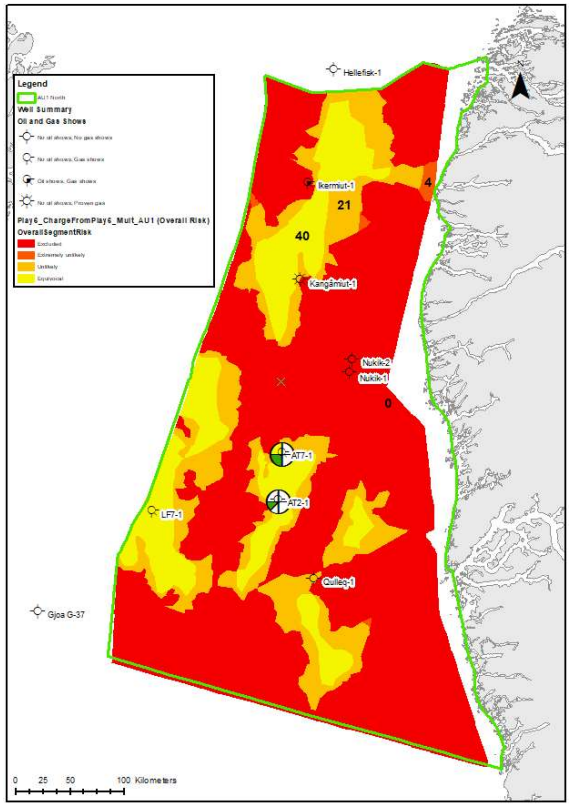
Resource Assessment for AU1, West Greenland
Play 6 – Charge/Migration From Play 6



Kitchen and Migration Zones (Overall)



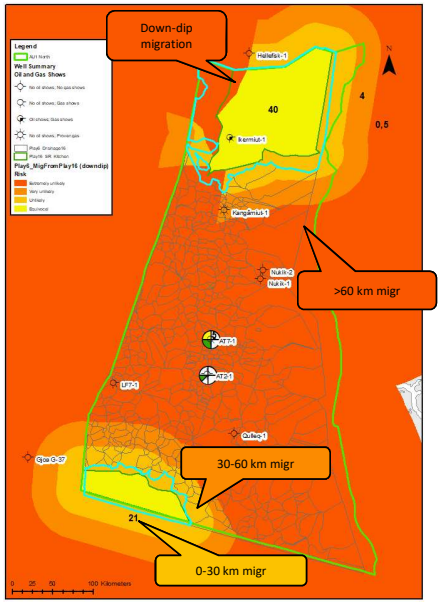
Migration Corrected Kitchen



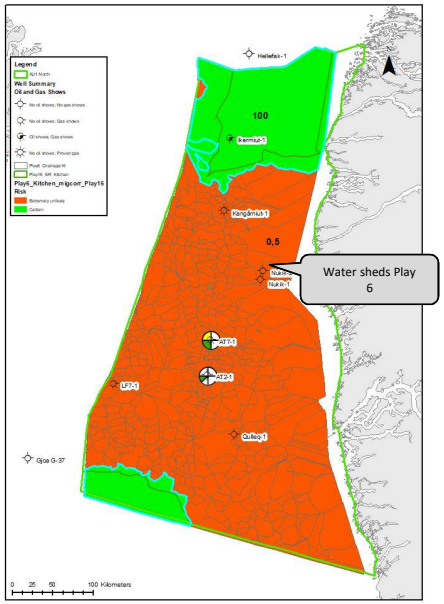
Charge From Play 6 Overall

Migration	Play Risk	Cond. Risk
Drainage cell vertically above kitchen area with proven charge at same play level	90	
Kitchen area with no vertical charge recorded at same play level	WL-10	80
Less than 30 km lateral migration from kitchen area required	WL-30	70
30-60 km lateral migration from kitchen area required	WL-50	40
60-90 km lateral migration from kitchen area required	WL-70	10
Note WL: Weakest Link Minimum Risk: 5		

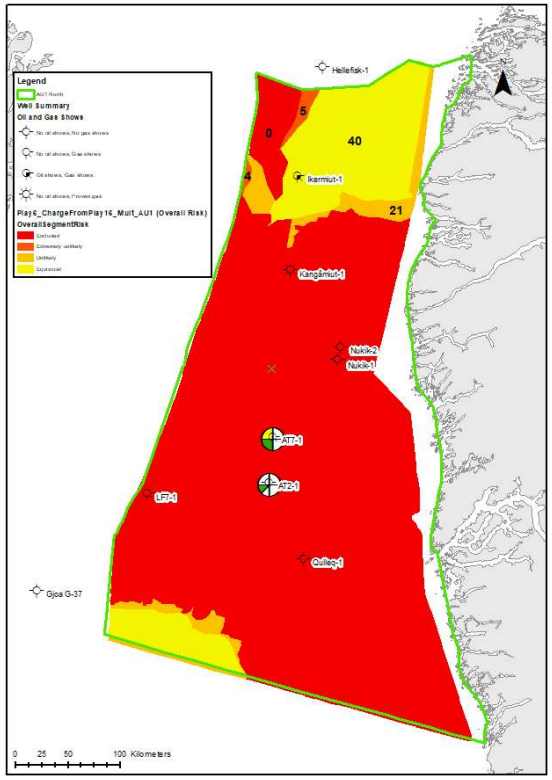
Resource Assessment for AU1, West Greenland
Play 6 – Charge/Migration From Play 16



Kitchen and Migration Zones (Overall)



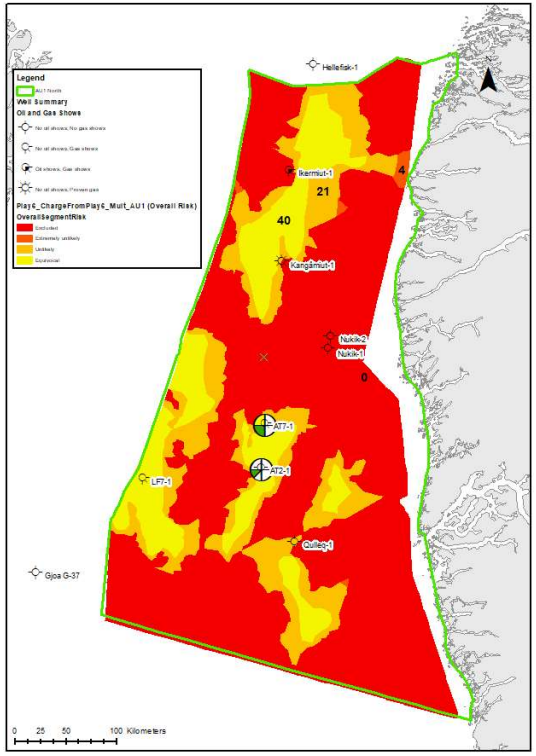
Migration Corrected Kitchen



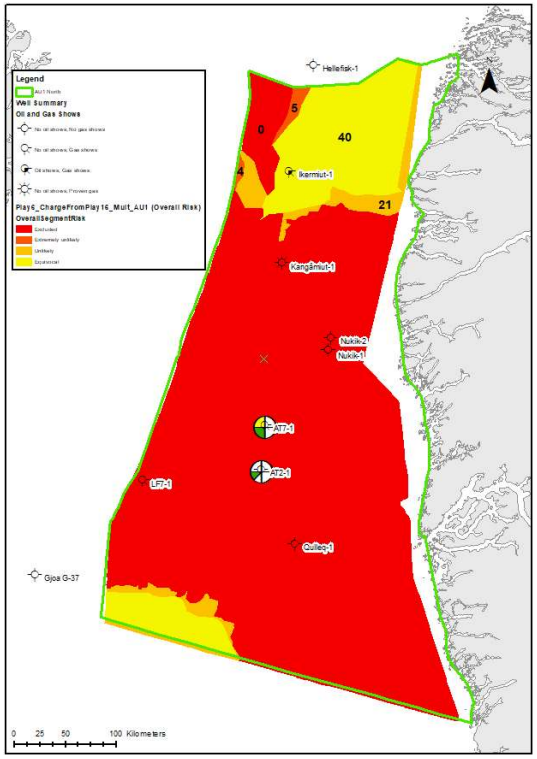
Charge From Play 16 Overall

Migration	Play Risk	Cond. Risk
Drainage cell vertically above kitchen area with proven charge at same play level	90	
Kitchen area with no vertical charge recorded at same play level	WL-10	80
Less than 30 km lateral migration from kitchen area required	WL-30	70
30-60 km lateral migration from kitchen area required	WL-50	40
60-90 km lateral migration from kitchen area required	WL-70	10
Note WL: Weakest Link Minimum Risk: 5		

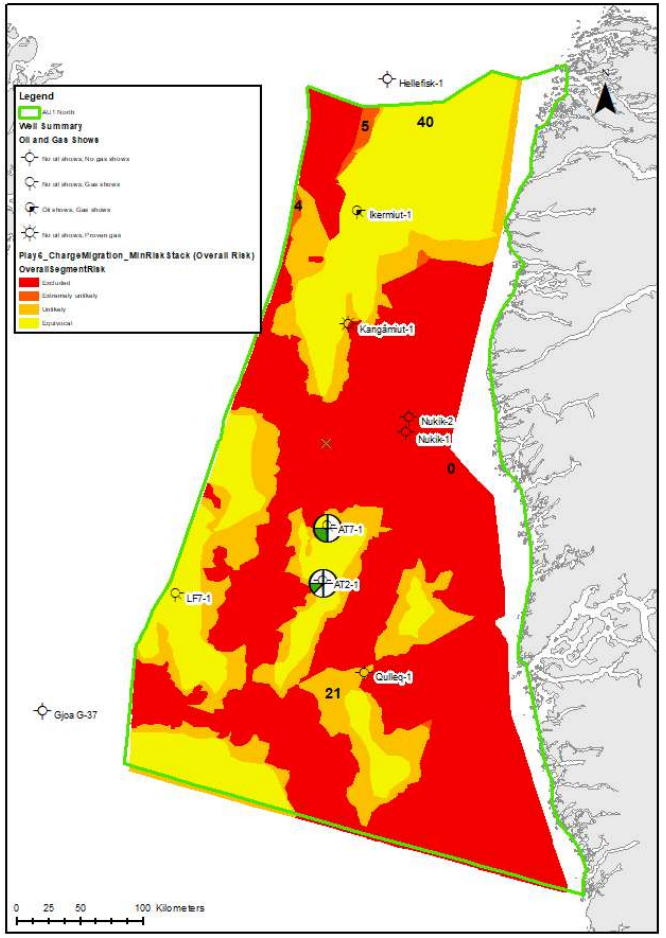
Resource Assessment for AU1, West Greenland
Play 6 – Charge/Migration Total



Charge From Play 6 Overall

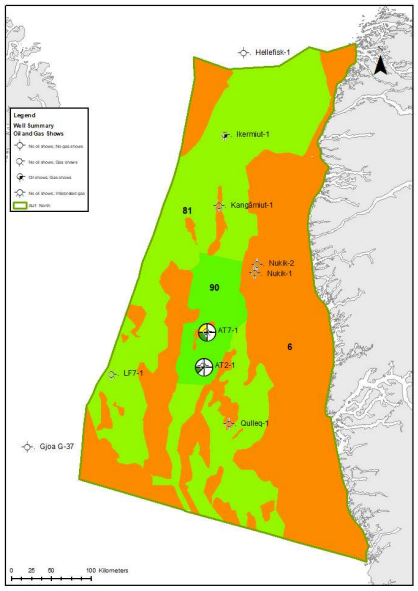


Charge From Play 16 Overall

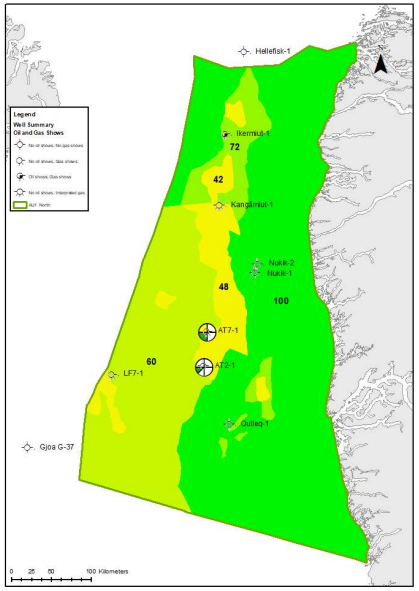


Charge/Migtation Stack Overall

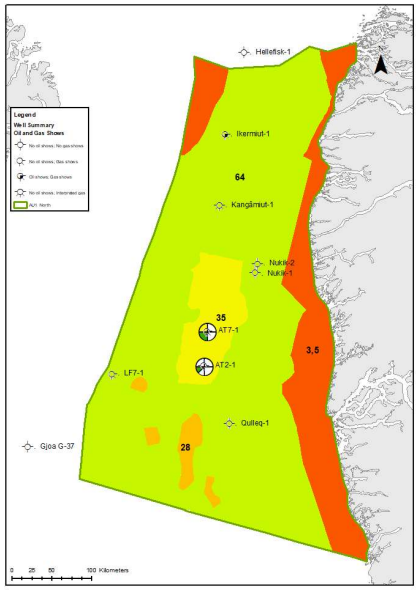
Resource Assessment for AU1, West Greenland
Play 6 – Overall Risk Maps



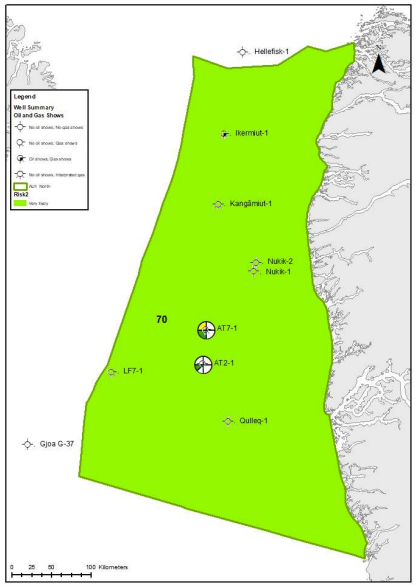
Reservoir Presence
Overall Risk



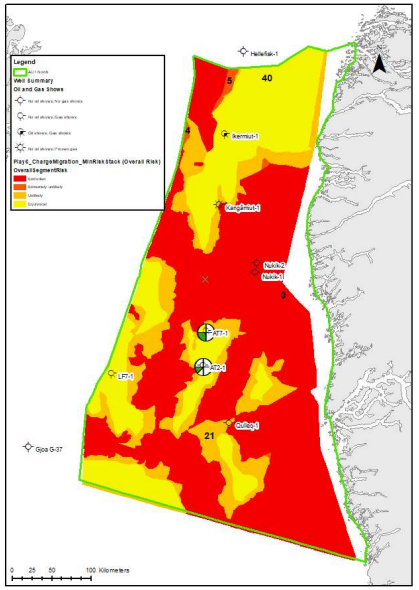
Reservoir Effectiveness
Overall Risk



Top Seal Presence
Overall Risk

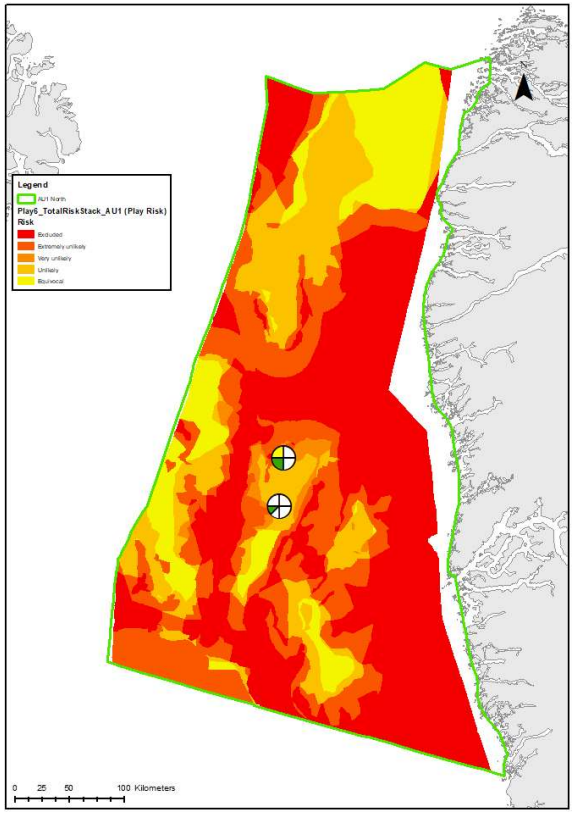


Trap Effectiveness
Overall Risk

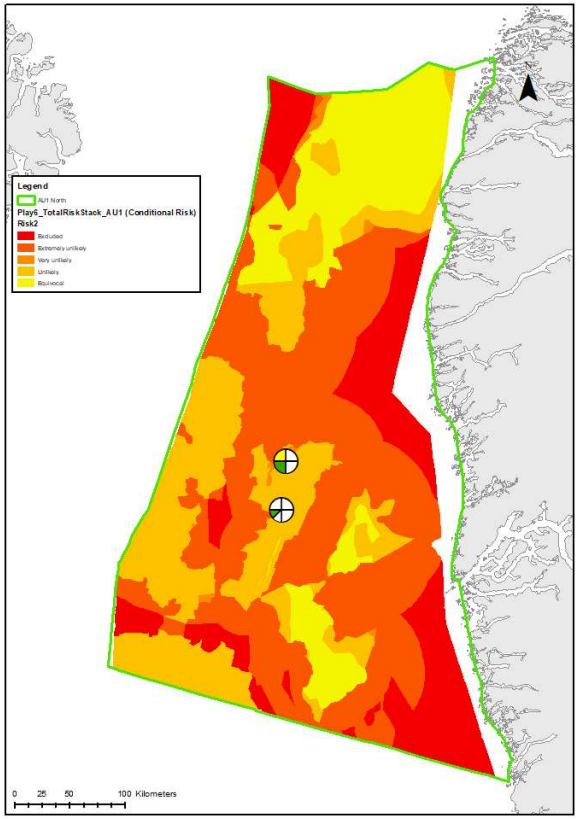


Charge/Migration
Overall Risk

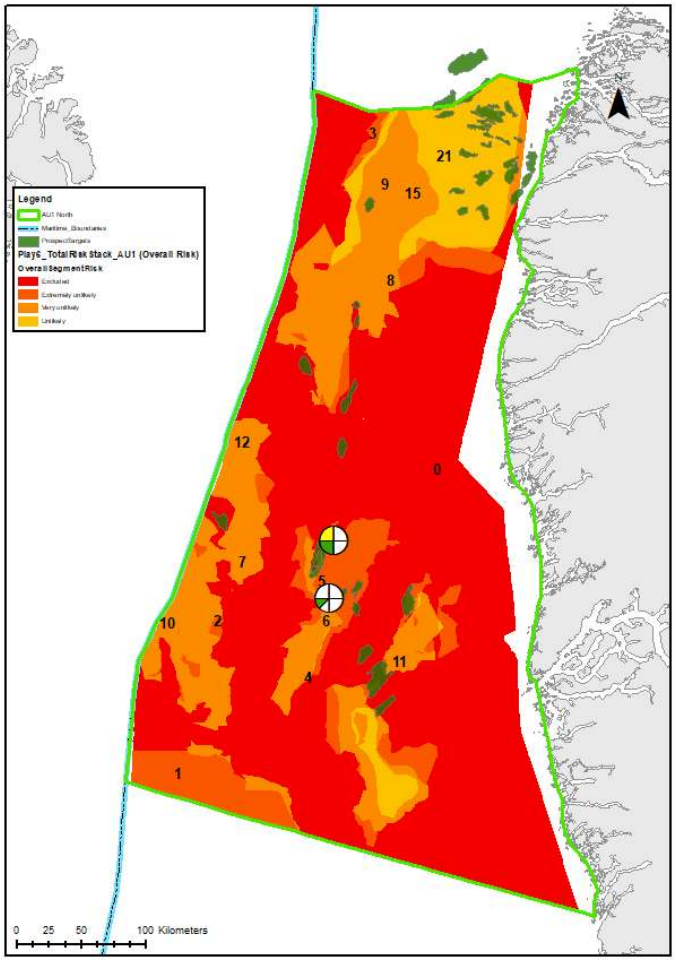
Resource Assessment for AU1, West Greenland
Play 6 – Total Risk Stacks



Total Play Risk

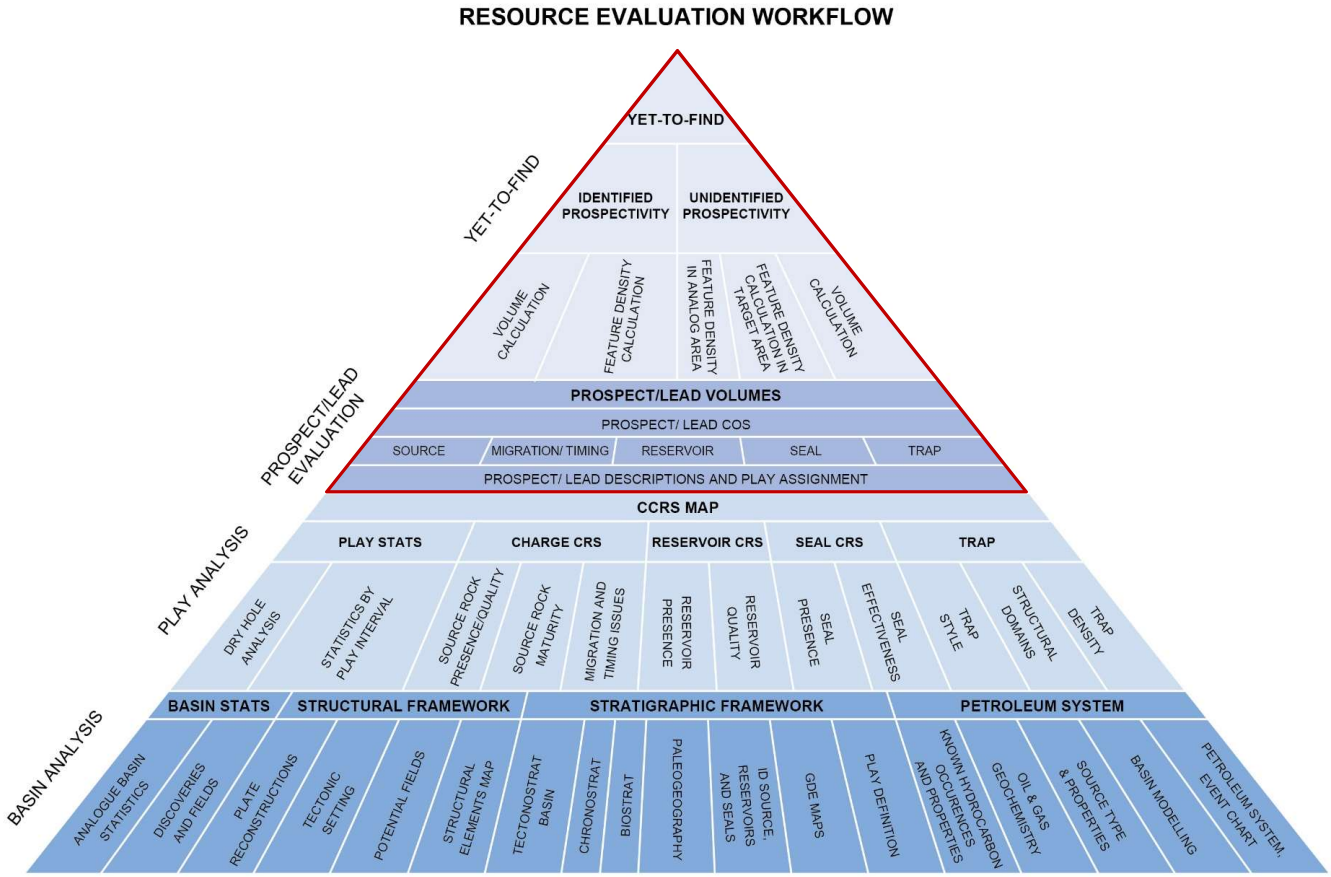


Total Conditional Risk



Total Overall Risk with Leads

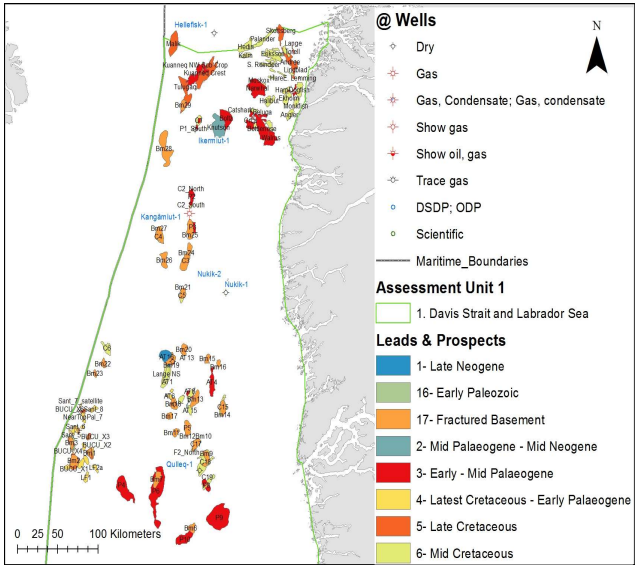
Resource Assessment for AU1, West Greenland
Prospect and Lead Volumes – Identified Prospectivity

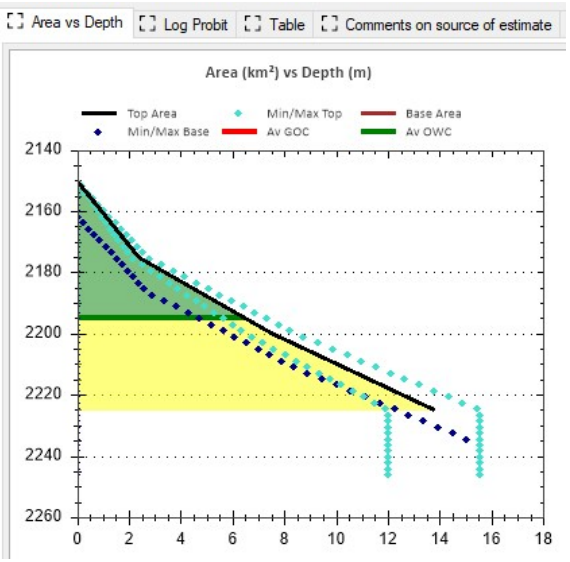


From the Greenland Resource Assessment Project (2019)

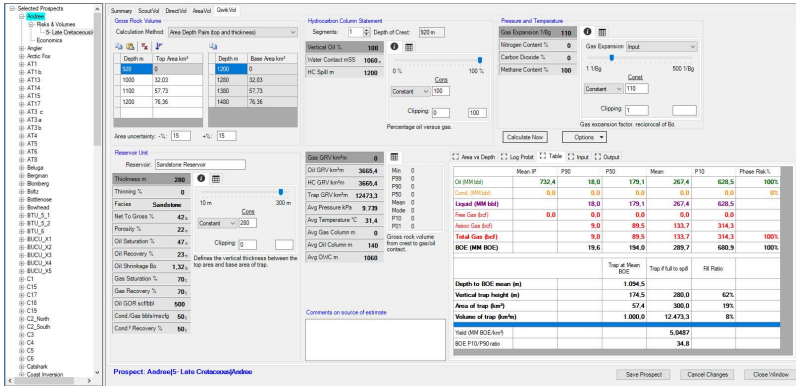
Resource Assessment for AU1, West Greenland
Prospect and Lead Volumes – Identified Prospectivity

- Total no of mapped leads in AU1 is 159 on all stratigraphic levels
- Volume calculations for individual leads are based on a normal ”top-to-base fill” distribution (see section on Volume Calculations for details), since Source Rock quality analysis does not support a fill-to-spill scenario



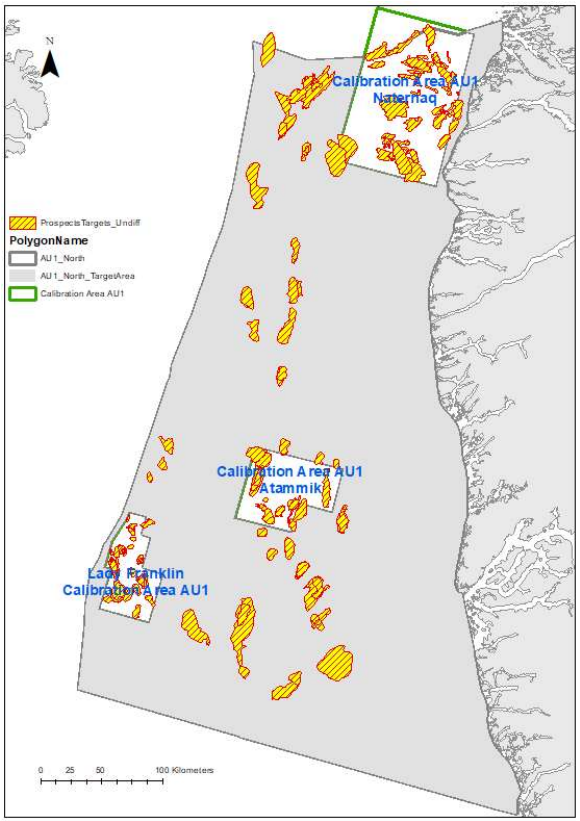


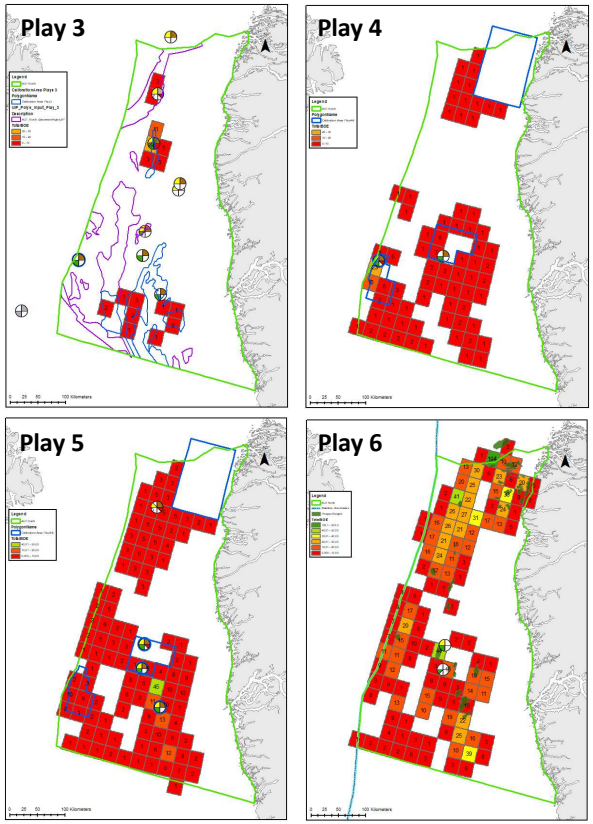
Volume calculation

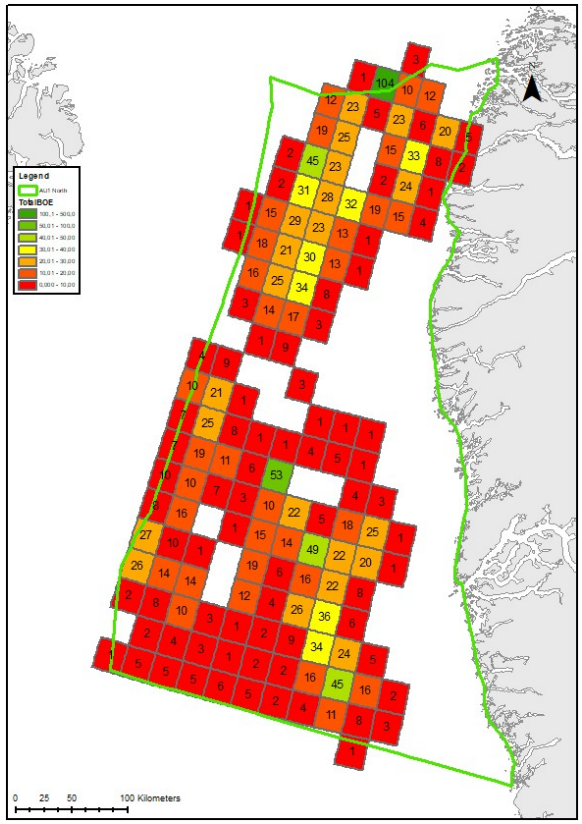


Resource Assessment for AU1
Unidentified Prospectivity and Risk Mean Recoverable (MMBOE) per Block

Block size approx. 650 km^2







Calibration and Target areas for Yet-to-Find analysis for Plays 4-6.

Risked mean recoverable (MMBOE) per block, northern part of assessment unit AU1. A: Individual plays, B: Total roll-up for plays 3-6.

Summary of Identified and Unidentified Prospectivity in Northern Part of AU1

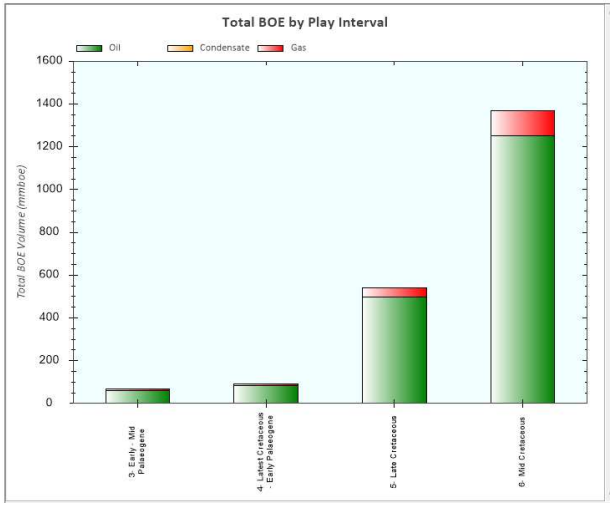
Summary of Results by Play Interval (Identified Prospects)

Play Interval	Number of Prospect Targets	Unrisked BOE (mmboe)	Risked BOE (mmboe)	EMV (M$)
3- Early - Mid Palaeogene	10,00	3.468,19	67,10	0,00
4- Latest Cretaceous - Early Palaeogene	16,00	363,87	68,26	0,00
5- Late Cretaceous	10,00	2.209,99	74,70	0,00
6- Mid Cretaceous	45,00	6.185,84	382,68	0,00
Totals:	81,0	12.227,9	592,7	0,0

Summary of Results by Play Interval (Unidentified Prospectivity)

Play Interval	Number of Unidentified Features	Unrisked BOE (mmboe)	Risked BOE (mmboe)	EMV (M$)
3- Early - Mid Palaeogene	0,00	0,00	0,00	0,00
4- Latest Cretaceous - Early Palaeogene	90,07	2.071,63	23,01	0,00
5- Late Cretaceous	55,55	12.277,08	467,21	0,00
6- Mid Cretaceous	259,30	32.671,78	987,05	0,00
Totals:	404,9	47.020,5	1.477,3	0,0

- The Total Risked Recoverable (Mean Case) for the northern part of AU1 is 2,070 MMBOE
- The total un-risked Recoverable (Mean Case) for the northern part of AU1 is 59,247 MMBOE
- Average area yield~15 MMBOE/1000 km^2
- The Total Risked Recoverable (Mean Case) for the southern part of AU1 is 700 MMBOE
- The total un-risked Recoverable (Mean Case) for the northern part of AU1 is 20,000 MMBOE
- **The Total Risked Recoverable (Mean Case) AU1 is 2,770 MMBOE**
- **The total un-risked Recoverable (Mean Case) for of AU1 is 79,247 MMBOE**
- **Average risk of leads is <5%**



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 — restricted data access
- The assessment is probabilistic and made by the USGS CARA team based on geological synthesis and analogue modelling

Pmean Total Conventional Resources in West Greenland and East Canada (Sum of 5 AUs)

Commodity	Mean
Liquids + NGL	**8 BBO**
Gas	**51 TCF**
Total	**17 BBOE**

Assessment is covering both Canada and Greenland

From:

Gautier D L (2007) U.S. Geological Survey Fact Sheet FS-2007-3077, 4 p.

Schenk, C J et al. (2008) U.S. Geological Survey Fact Sheet FS-2008-3014, 2 p.

Concluding Remarks

- Continental shelf off West Greenland is a huge frontier area
- Good seismic coverage and ties to wells
- Oil seeps and source rocks penetrated in boreholes provide expectations for regionally distributed source rocks of Cenomanian-Turonian and Paleocene age
- Oil seeps and oil and gas shows/inclusions indicate working petroleum systems
- Sandstones at all stratigraphic levels provide models for reservoir distribution and quality
- Seal study indicates presence of mudstones with excellent sealing capacity
- Onshore Nuussuaq Basin has its own exploration potential including presence of a large domal feature
- Additional geophysical data is needed to understand the full exploration potential of the Nuussuaq Basin
- Some 190 structural leads and prospects have been mapped and volumes and risks are being assigned in the Greenland Resource Assessment Project currently carried out by GEUS in collaboration with Nunaoil and MIER
- Leads at several stratigraphic levels and some with closures exceeding 100 km^2
- **The Total Risked Recoverable (Mean Case) of AU1 is 2,770 MMBOE**
- **The total un-risked Recoverable (Mean Case) of AU1 is 79,247 MMBOE**

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Project Initiatives

Disko-Nuussuaq

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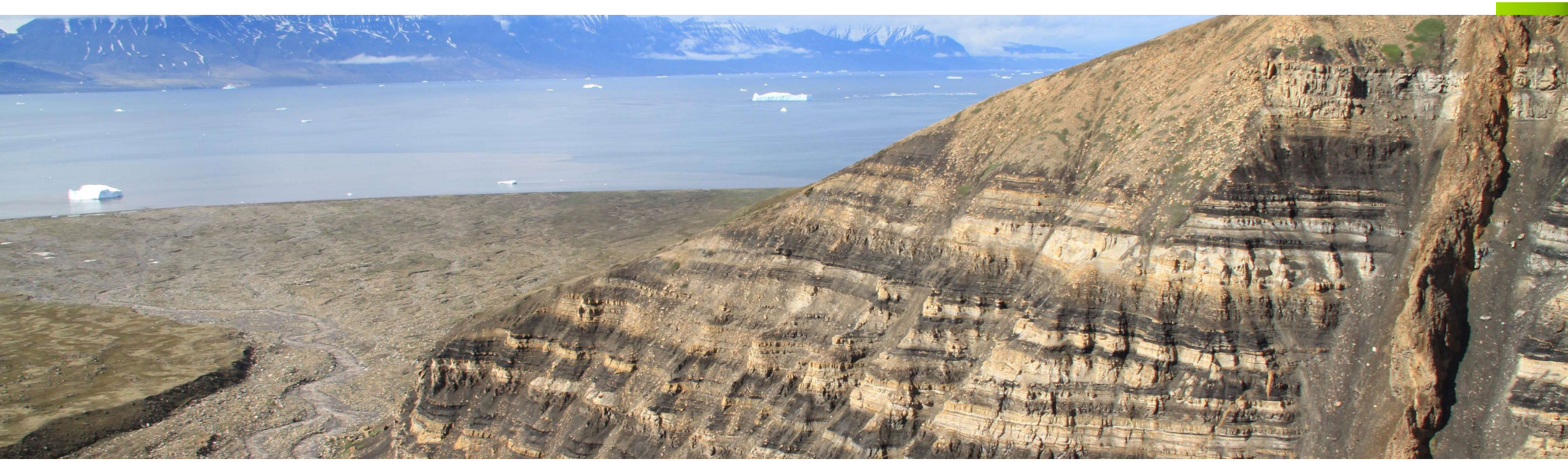
The Nuussuaq Peninsula

Greenland



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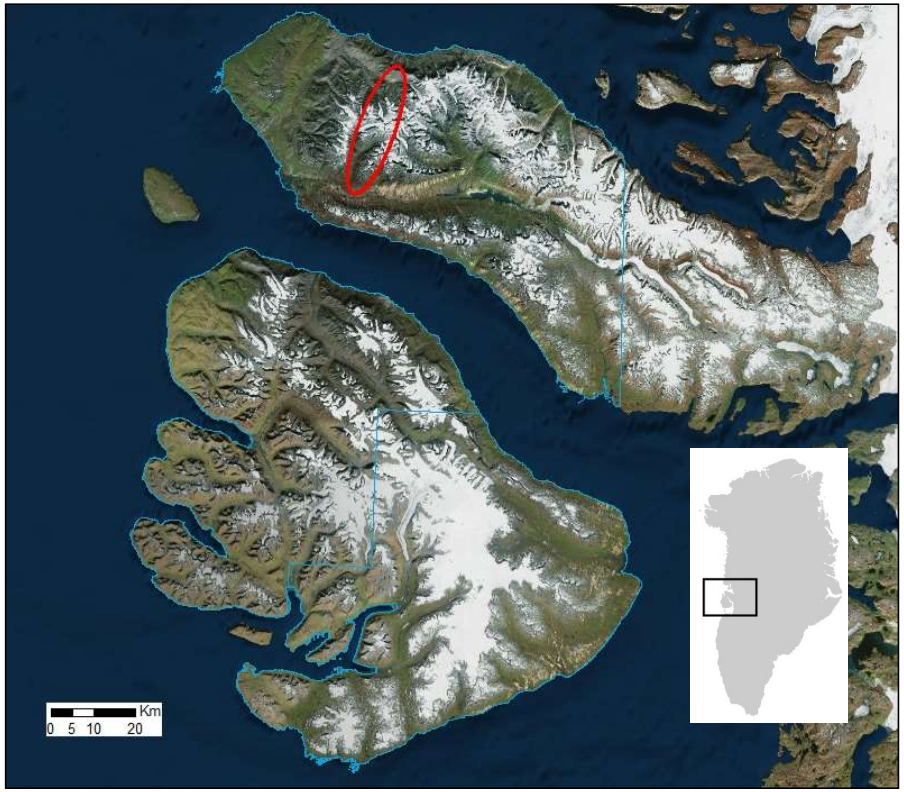
Nuussuaq Peninsula

Region info

- West Greenland
- Latitude 70^0 0’ - 70^0 50’
- Areal extent Nuussuaq appr. 7150km2
- Topography: mountainous (peaks above 2100m.a.s), major valley depression running E-W/ESE-WNW, Aaffarsuaq Valley
- Terrain formed by glacially induced processes
- Valley stretches characterized by glacier-meltwater transported deposits
- Tributaries draining from highlying topography feed rivers in valley floors
- Alluvial-/fluvial deposits in valley floors



Nuussuaq Basin

Petroleum Potential

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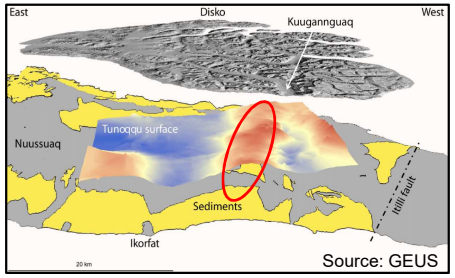

Petroleum

-Oil seeps onshore
-Oil & gas in sl.c wells
-200 oil samples acquired
-5 distinct oil types

Reservoir

-Prodelt./deltaic/fluv. sands
-Slope turbidites
-Incised valley complexes

Seal

-Marine mudstones
-Intra Fm. Mudstones
-Local mudstones

Structure

-Anticline structure
-Photogramm. Ident.
-Supra level mapping
(Tunnoqu Mb)

Onshore observations, slimcores, mapping:	*5 oil types** -Itilli oil, type II -Marrat oil, type III -3 more local oil types, less sign. (Bojesen-Kofoed et al, 1999)	-Atane Fm -Itilli Fm. -Qikavsak Fm	-Kangilia Fm. -Atane Fm. (Intra) -Maligat Fm (Volc. Series) -Eqalulik Fm (local)	*-Seismics needed to confirm mapped structure*

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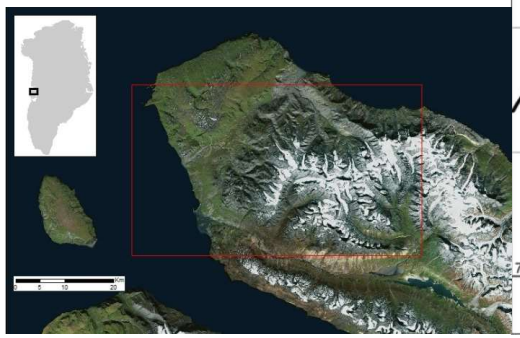
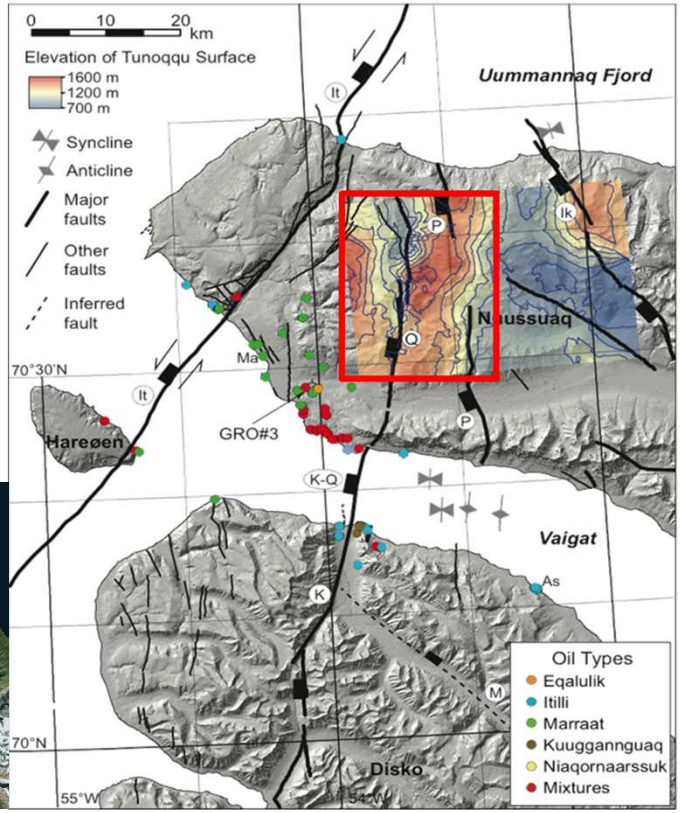
Nuussuaq

Opportunity

- The Nuussuaq peninsula is known for **abundant oil seeps**.
- **New structural lead** with great potential has been mapped by GEUS.
- Gross lease unrisked UPIIP of up to **1018 MMBBL** (GLJ Petroleum) in the Q1 structure.
- The geology on Nuussuaq has the potential to contain **other oil structures**.





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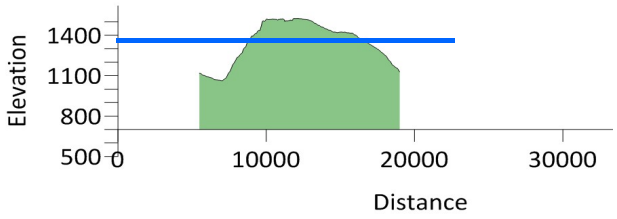
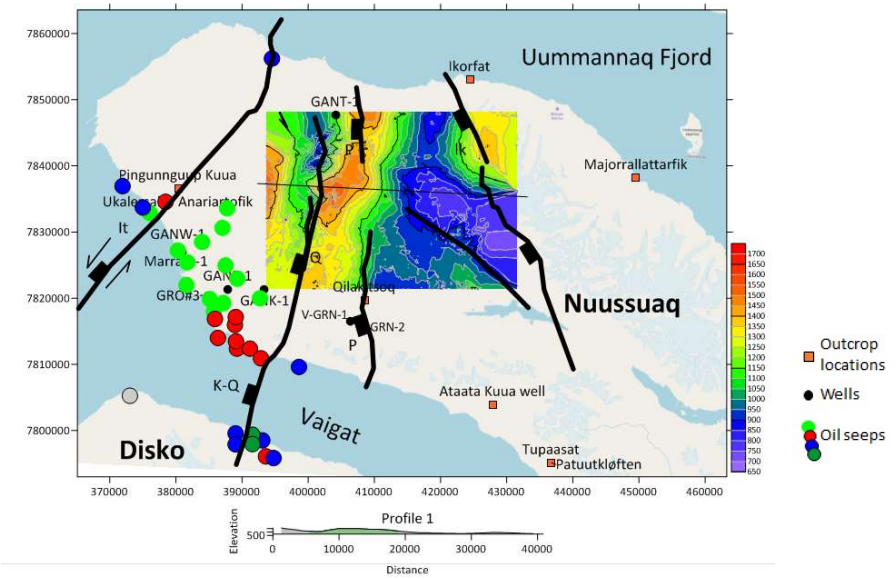
Nuussuaq

Significant potential

- Anticline of 250km2 mapped out by photogrammetry on Nuussuaq
- Domal elongate structure in central part of anticline identified with closure of ca 60km2
- Amplitude of structure 180m
- Preliminary first estimate of ressources: Gross lease unrisked UPIIP of up to 1018 MMBBL



10 X vertical exaggeration



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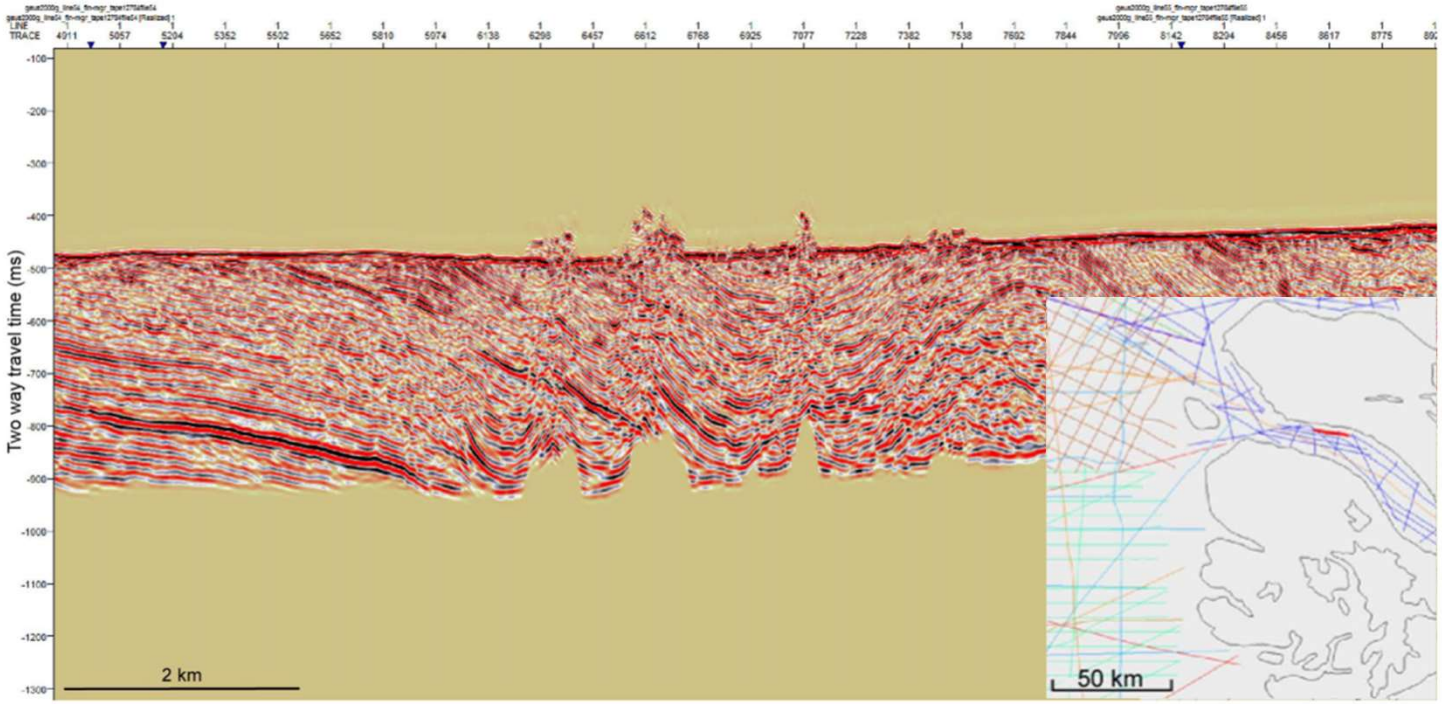
Nuussuaq

Offshore structure south of Nuussuaq

- Seismic reflection data from Vaigat showing folded Cretaceous sediments
- Red Line on map inset outlines location of profile



Disko-Nuussuaq Open Door 2019

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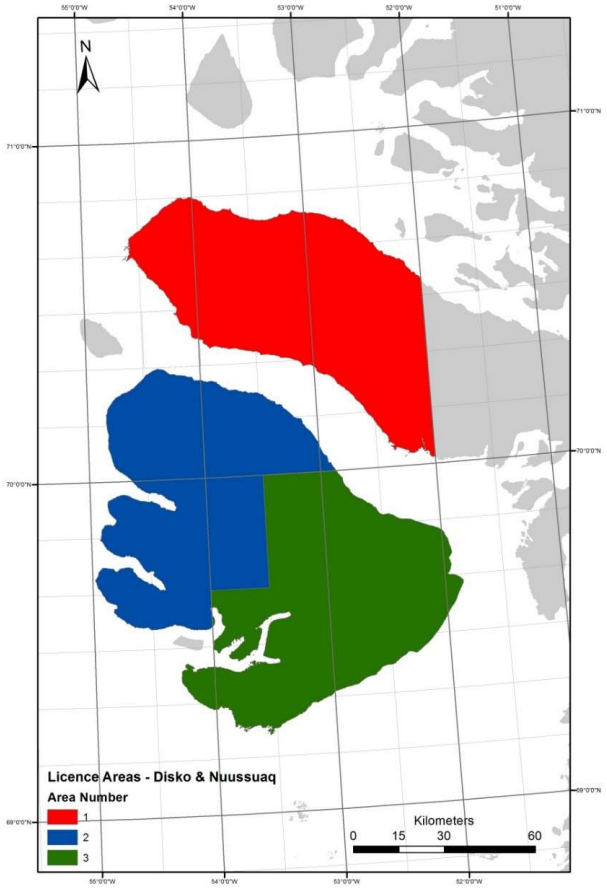
Onshore areas of Disko and the Nuussuaq Peninsula

Opens for applications:

- **1st of October 2019**
- First come - First served

Area sizes:

- Area 1, on the Nuussuaq peninsula covers 4,538 km2.
- Area 2, on the northern part of the Disko Island covers 4,126 km2.
- Area 3 on the southern part of the Disko Island covers 4,409 km2.



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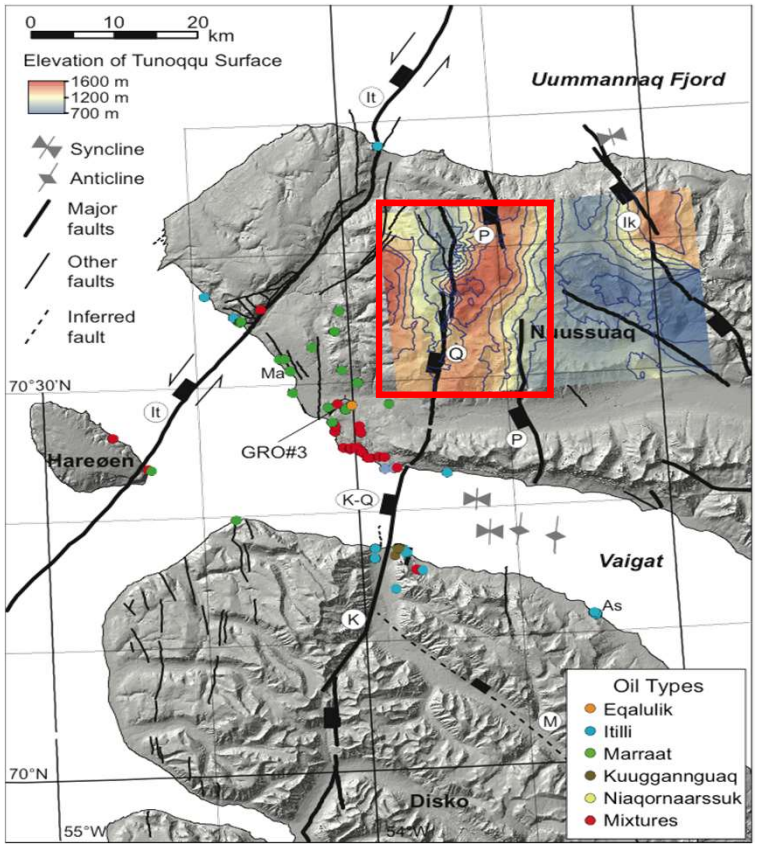
Nuussuaq licensing

Opens July 2019

- Exclusive licence covering the Nuussuaq peninsula, **with a mapped structure (Q1) and potentially other oil structures**.
- A **pre-designed work programme**.
- Favorable **fiscal terms**.
- **Small financial commitment**.
- **Publicly funded** FTG in 2019.
- **Public contribution** to seismic acquisition programme planned for 2020



Next Steps

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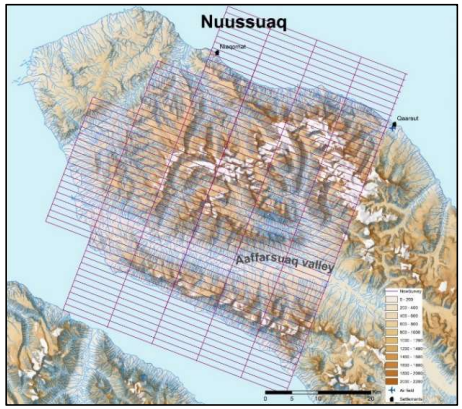
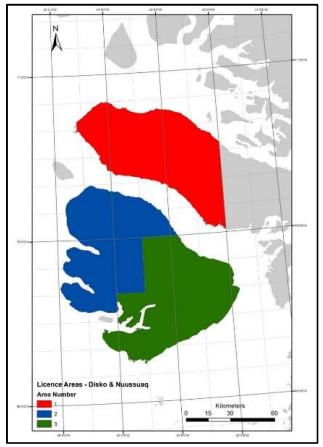
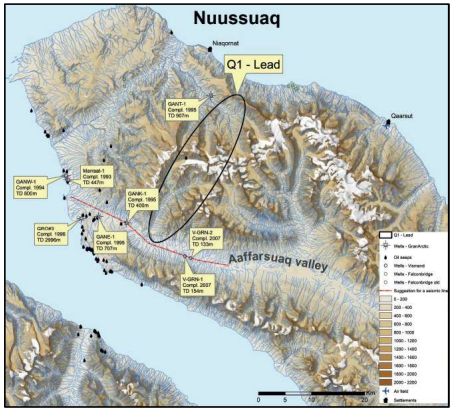
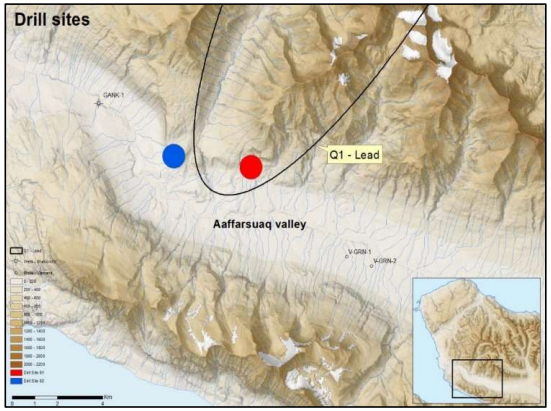
1. Enhanced full tensor gravity survey (eFTG) on Nuussuaq during fall of 2019.
2. Granting of licence to participants (2019).
3. Seismic acquisition planned for 2020 (optional use of pre-designed work programme)
4. Stratigraphic well in 2021









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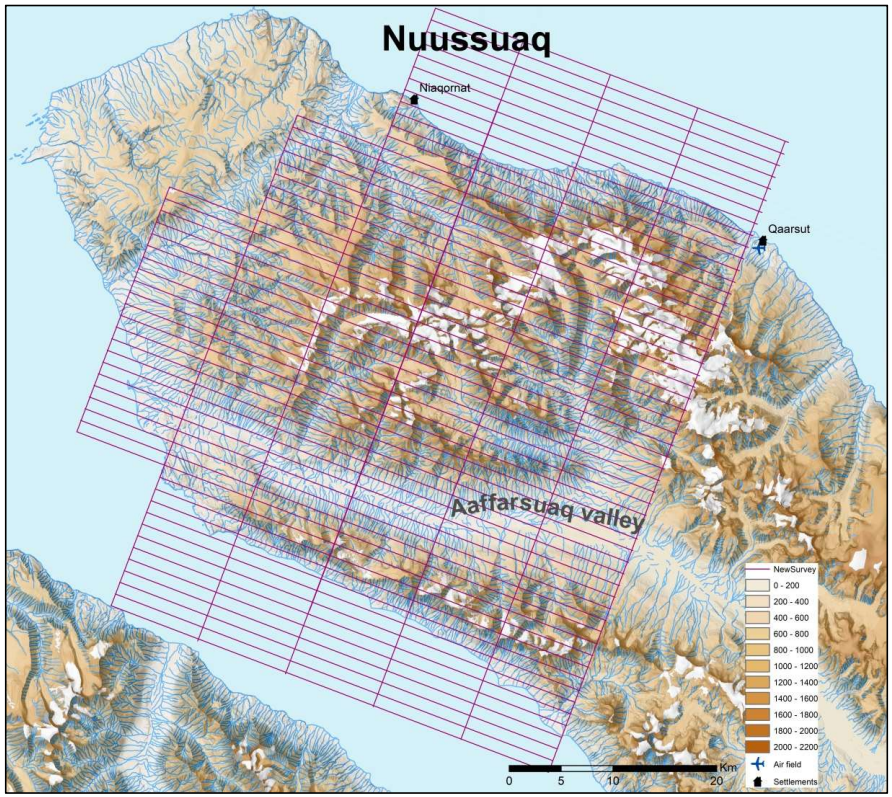
Step 1

Follow up to GEUS's work: eFTG* Survey

- Airborne gravity survey planned
- High resolution gravimetry & magnetics
- Acquisition period: Fall 2019
- AOI 3155,87km2
- Gridding 1200m by 9000m
- Aerial Survey time planned 14 days
- Processing time data planned 1 month
- Purpose is to provide better understanding of the structural configuration as basis for seismic acquistion
- Contractor: ABI Holdings Limited
- Financed by Gov't of Greenland but data and results will be made available free of charge



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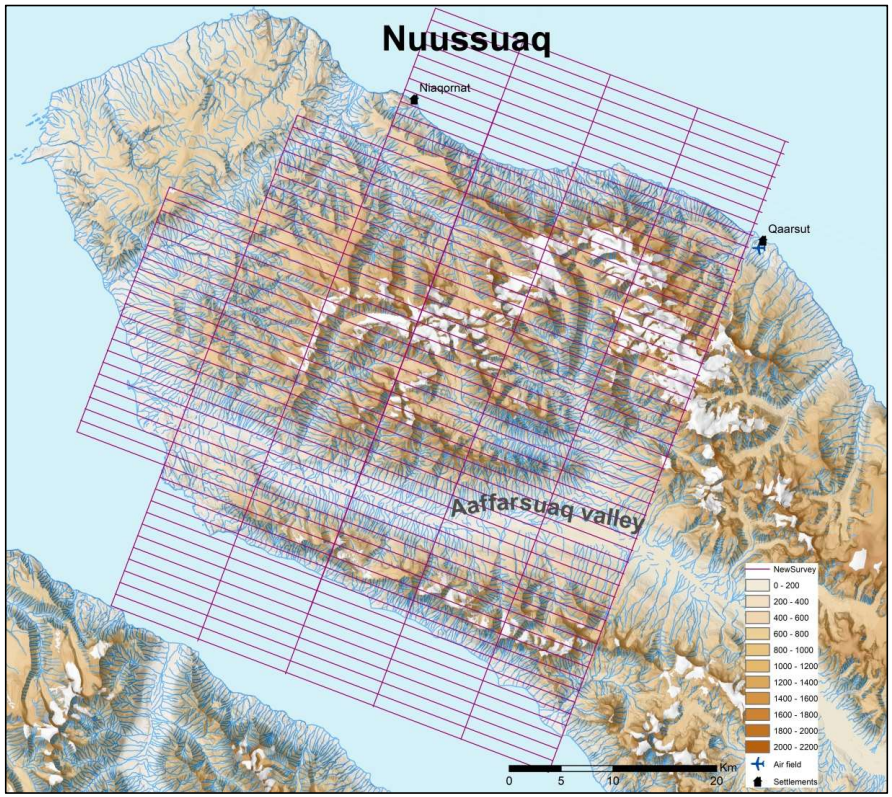
Step 1

Purpose of eFTG survey

By combining the offshore 2D seismic interpretation of the Vaigat Fjord and Ummannaq Fjord areas with a high resolution Full Tensor Gravity (FTG) survey covering Nuussuaq Peninsula, a better structural understanding will be provided of:

- The domal feature in Western Nuussuaq, the main exploration target
- The structural configuration of the onshore areas and the possible upside exploration potential
- Optimize the design of future onshore 2D seismic surveys



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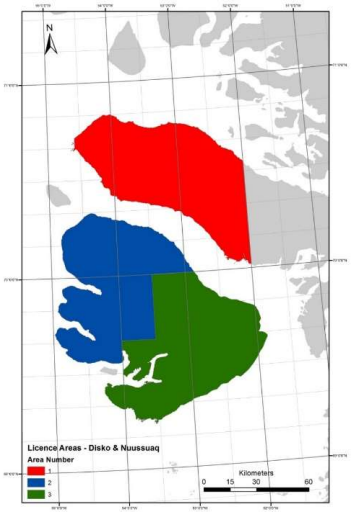
Step 2

Exclusive licence – Nuussuaq

- 1 exclusive licence to the entire Nuussuaq area.
- Licence may be shared by a consortium.
- Formal invitation letter to be published.



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Step 3

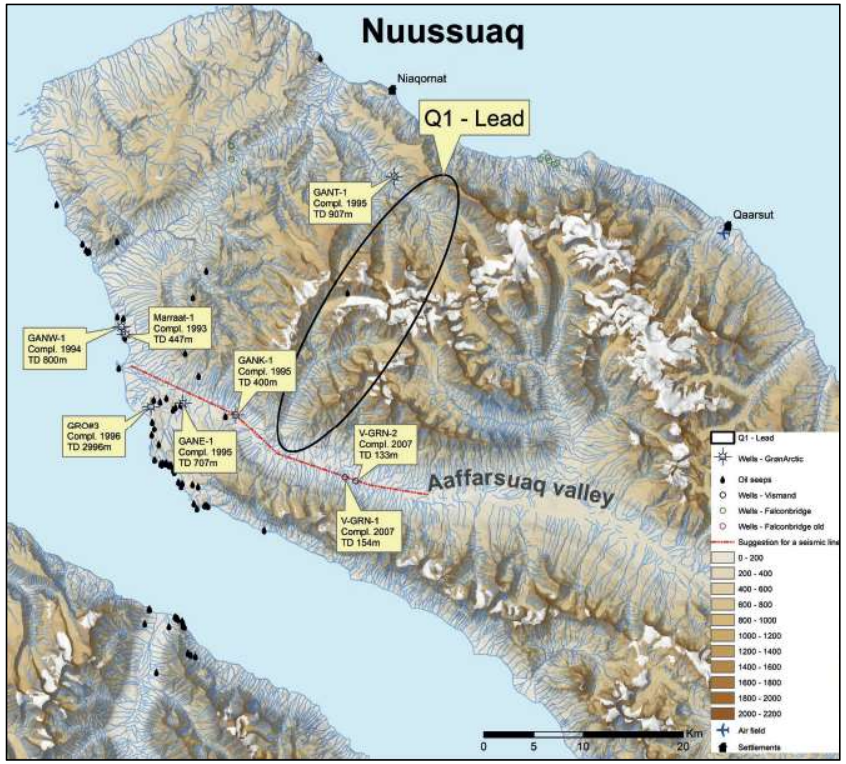
Seismic acquisition

Nuussuaq West onshore

- 2D-seismics acquisition
- Subsurface imaging of Q1 structure (NE-SW anticline)
- Outline basin configuration/depth
- Transect/image subsurface of drill site

Seismics Operation:

- Min. 30km NW-SE line Aaffarsuaq valley
- Acquisition period: Spring 2020
- Operational time: 6-6½ weeks
- Possible contractors.: MIE, GEUS, AU and EMJ
- Budget: 2.5 mill $ (public contribution)



Step 3

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Proposed partners (not binding)

University of Aarhus

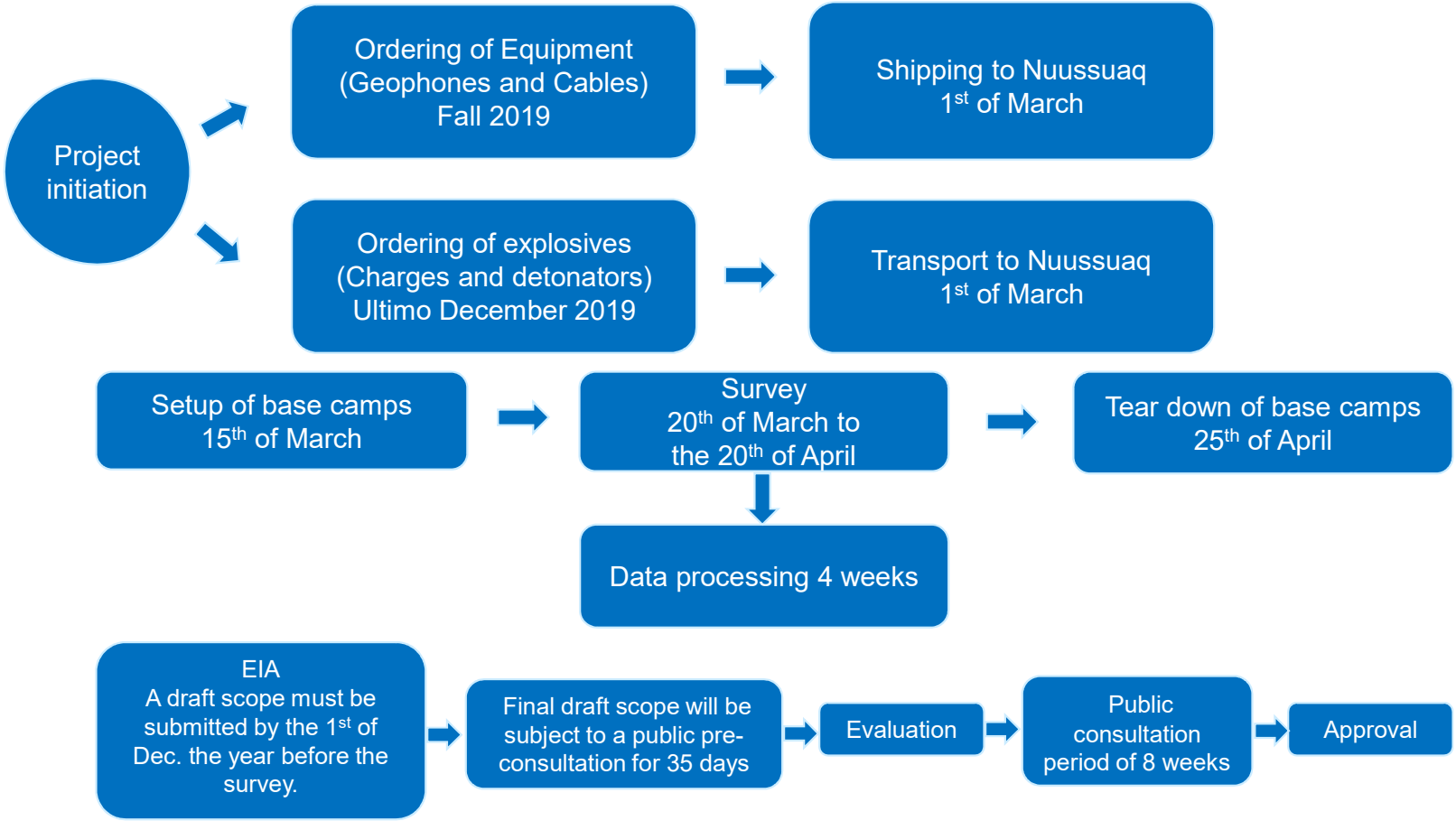
- Dep. of Geosciense
- 6 weeks of seismic survey
- Data processing 4 weeks
- Approx. USD500,000 (standing offer)

EMJ-Atcon A/S

- Logistics, purchase of explosives, camp management and drilling.
- 6 weeks of survey
- Approx. USD 2,000,000 (standing offer).

Step 3

Timeline for seismics acquisition



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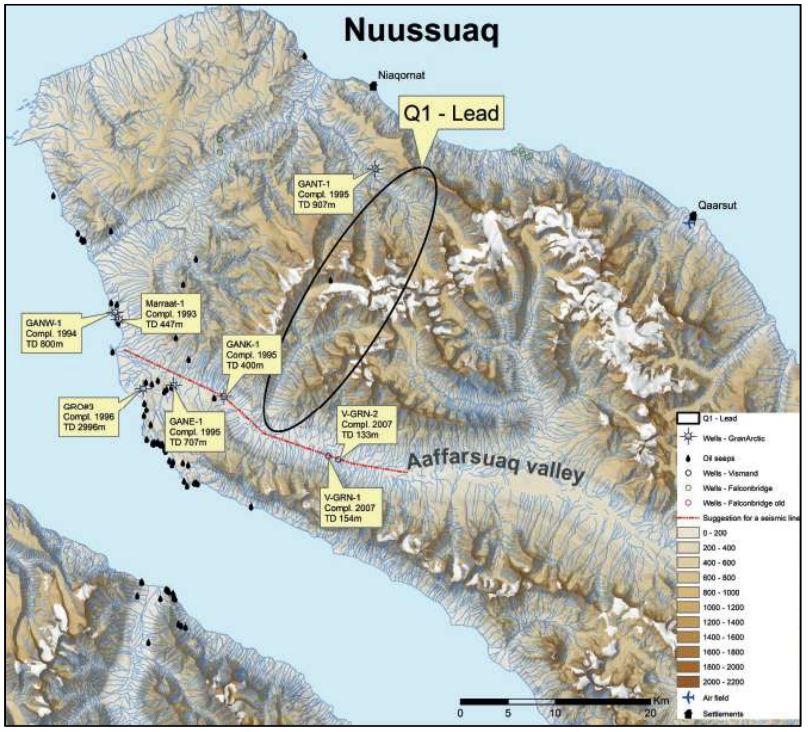
Step 3

Purpose of Aaffarsuaq 2D Seismic Line

Acquisition of a 30km seismic line in the Aaffarsuaq valley, located just south of the closure of the domal feature, will help:

- Constraining the structural configuration of the Nuussuaq Peninsula
- Establish to what extent the strata underlying the mapped domal feature have been affected by similar deformation
- Tie the GANW-1, GANE-1 and GANK-1 boreholes and the GRO#3 well into the area of interest
- Support interpretation of the FTG data
- Evaluate the possible upside exploration potential
- Optimize the design of future onshore 2D seismic surveys



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Step 4

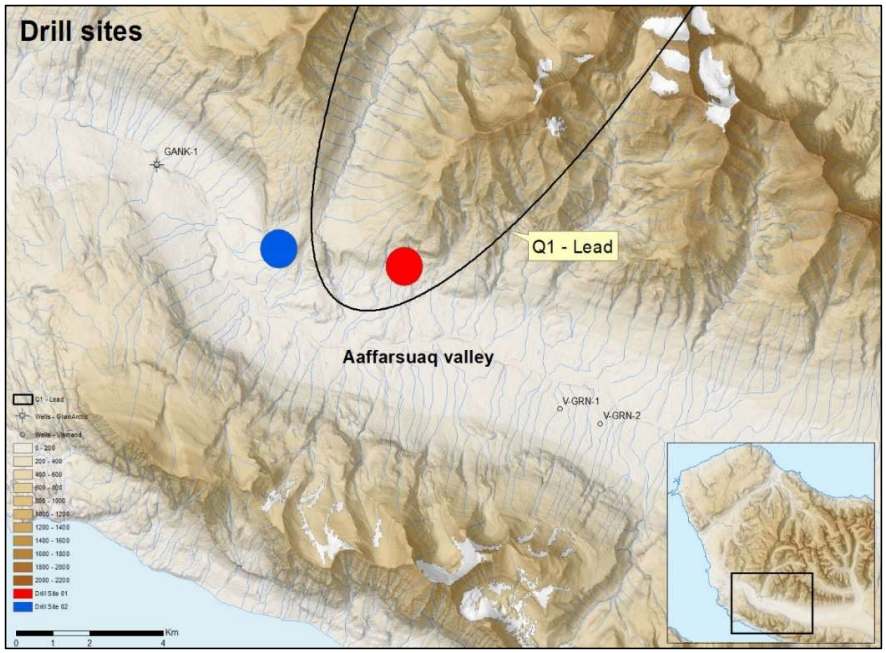
Stratigraphic Well – Nuussuaq West onshore

- Aim: obtain subsurface geol. data
- TD: at least 1200m preferably 1500m

- Targeting res./seal/SR rocks of Q1-lead
- Core retrieval for analyses
- Planned as cored wells, HQ min 96mm

Drilling operation

- Slimcore rig
- Duration min. 6-8 weeks pr well
- Cost 6 million USD
- Contractor: Potential external contractor identified



Step 4

Purpose of stratigraphic well

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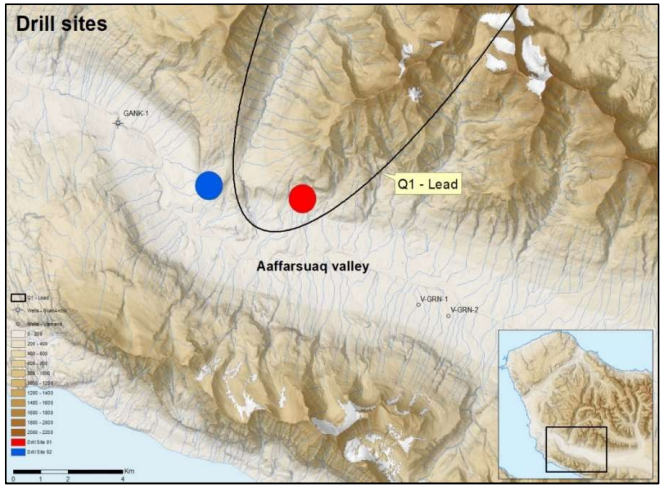
The purpose of drilling a stratigraphic well in the Aaffarsuaq valley is to provide information on:

- Play elements for a:
  - Paleocene Play
  - Late Cretaceous Play
  - Mid-Cretaceous Play
- Important stratigraphic, sedimentological and structural information on the evolution of the Nuussuaq Basin
  - subsurface sampling of reservoir/seal rocks for analyses:
    - Porosity/permeability studies
    - Seal capacity studies
  - source rock sampling (if drilled into/through):
    - Kerogen type, TOC and HI
    - Potential/Yield – RockEval type analysis
- Implications for the hydrocarbon potential in the on- and offshore areas
- The two wells together will provide information on the structural development of the K-Q Fault on Paleocene – Late Cretaceous facies and palaeogeographic evolution



Budget (est.) for Step 3 and 4

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Core elements of exploration commitments in the work programme of the exclusive licence

Contractor	USD (est.)
Seismic acquisition	
Aarhus University	500.000
EMJ-Atcon	2.000.000
Drilling	
Stratigraphic well (est.)	6.000.000
Buffer	500.000
Total	9.000.000

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Possible additional steps

Work Program for a 2nd Exploration Phase (Year 4 and onwards)

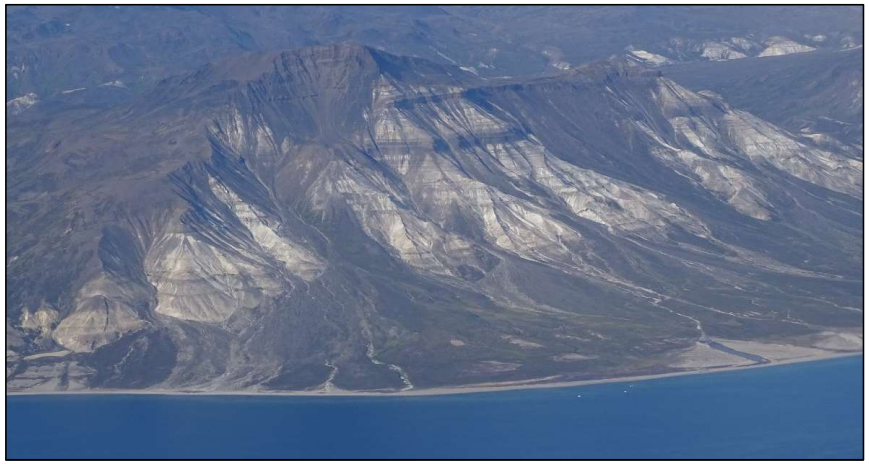
If the work program for the 1st exploration phase (year 1-3) has a successful outcome, a 2nd exploration phase work program could include:

- Acquisition of additional geophysical data (e.g. 2D seismic data) to delineate the trap and decide a location for an exploration well
- Additional geological studies for further de-risking of play elements

  -advanced reservoir rock studies (diagenetic/post-depositional development)

  -AFTA-studies

  -advanced thermal modeling studies of AOI
- Drilling of a full scale Exploration well



General Licence Terms

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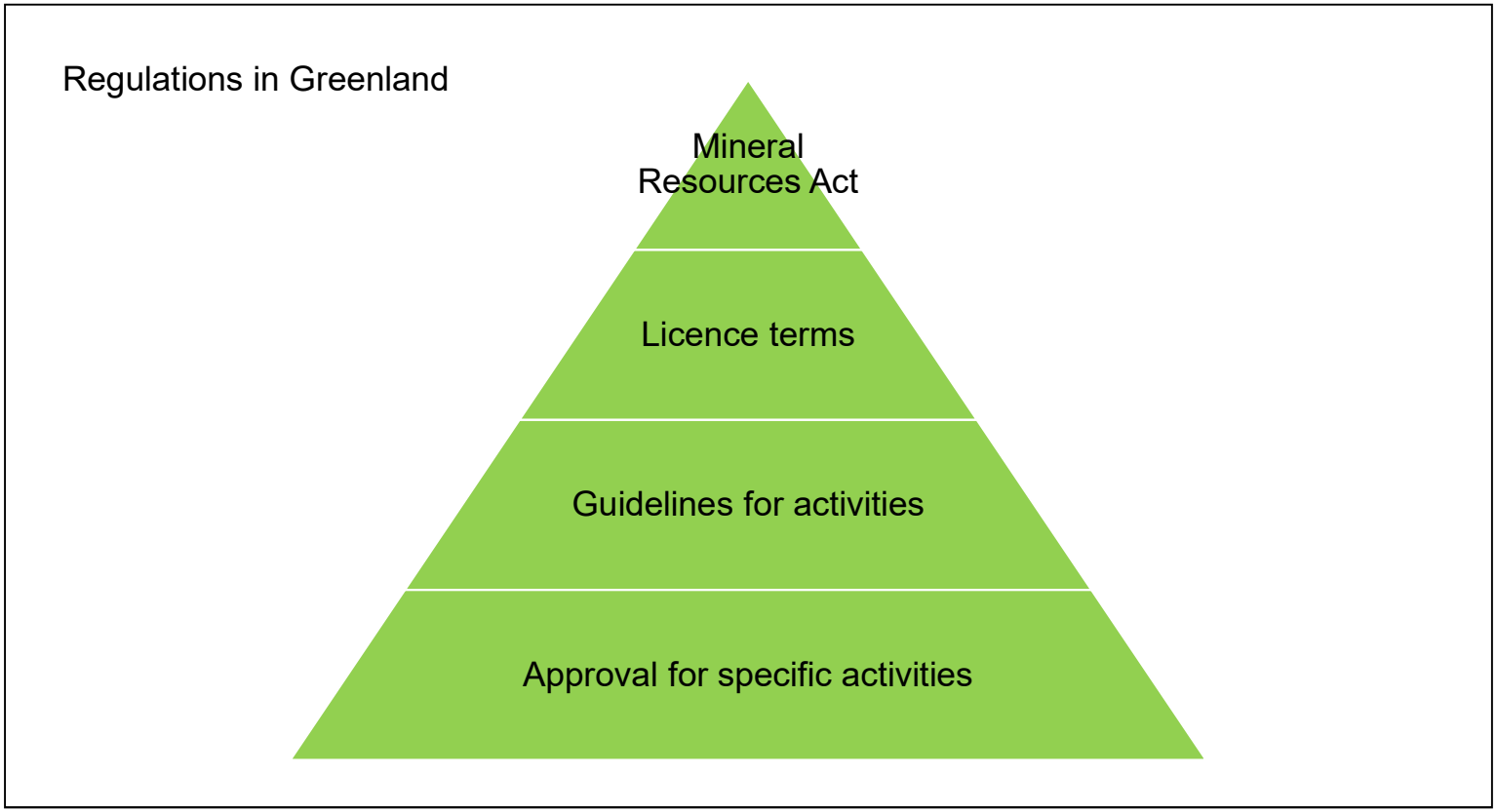

General Licence Terms

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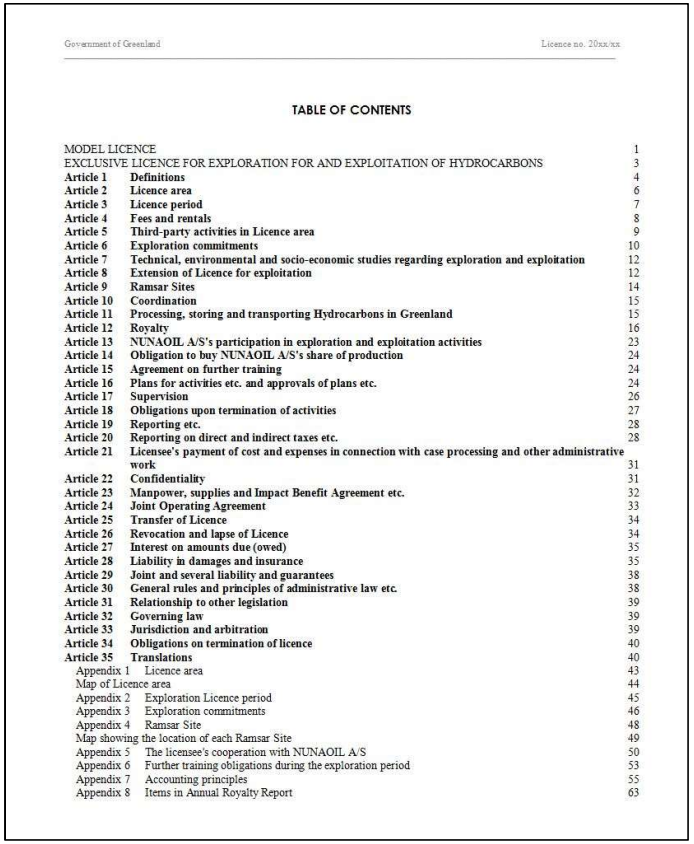
Model licences:

- Licence area and period
- Fiscal terms
- Extension of licence for exploitation
- Environment
- Activities and supervision
- Reporting
- Etc.

Model Joint Operating Agreement



Government of Greenland Licence no. 20xx/xx

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General Licence Terms

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- Licences are granted for an exploration period of up to 10 years
- Work programme has to be agreed upon before the Licence is granted
- Licensees have a right to a 30-year extension for areas where exploitation is intended

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Fiscal Terms

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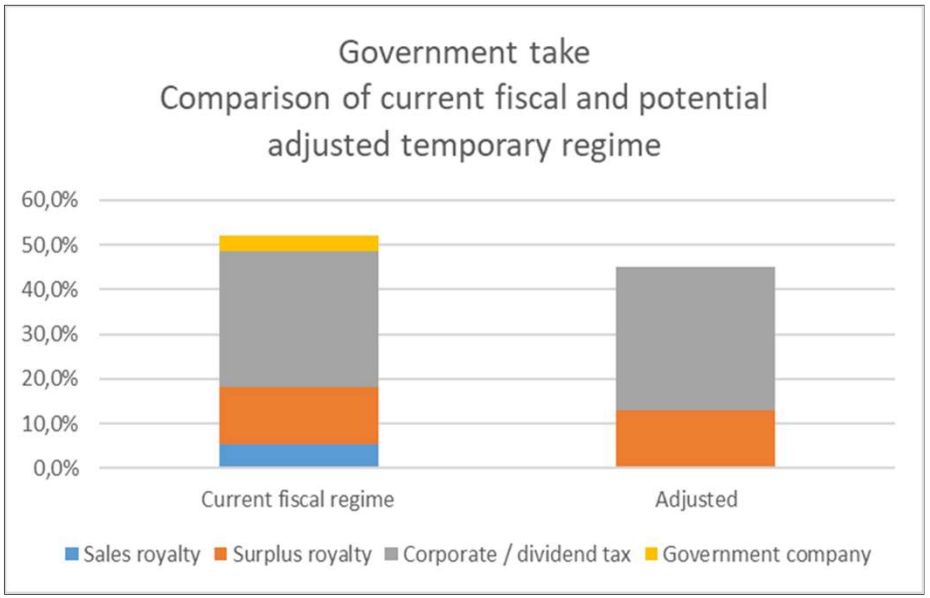
- First mover fiscal terms considered for Disko-Nuussuaq licenses:
  - No sales royalty
  - Only taxation of surplus



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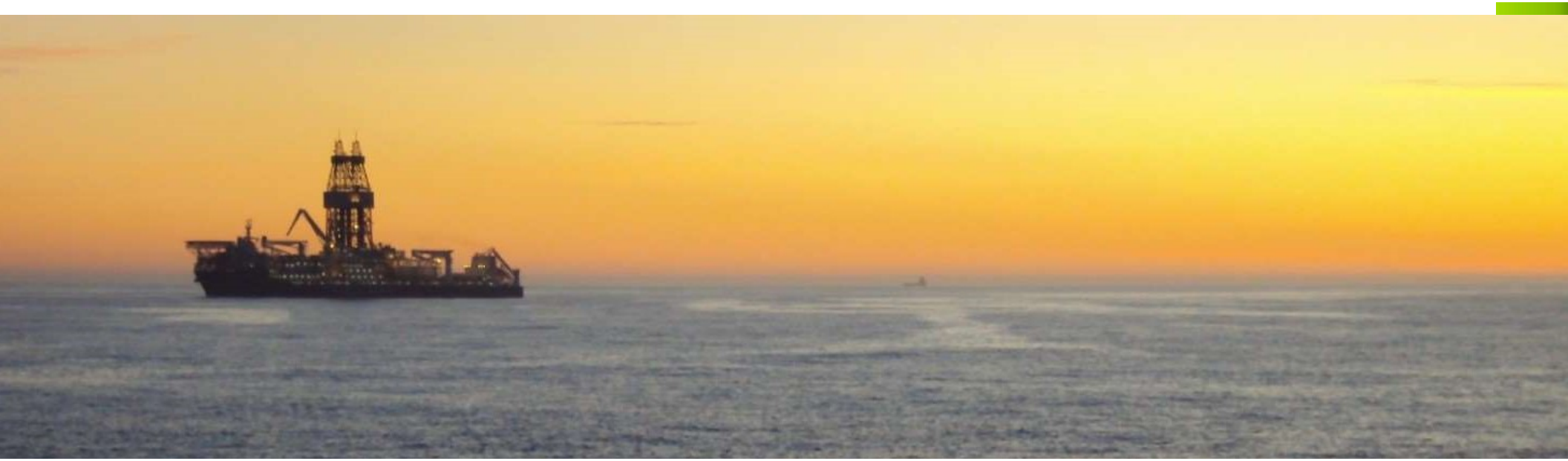
Offshore Licensing Policy

Long term strategy



Offshore Licensing Policy

Long term strategy

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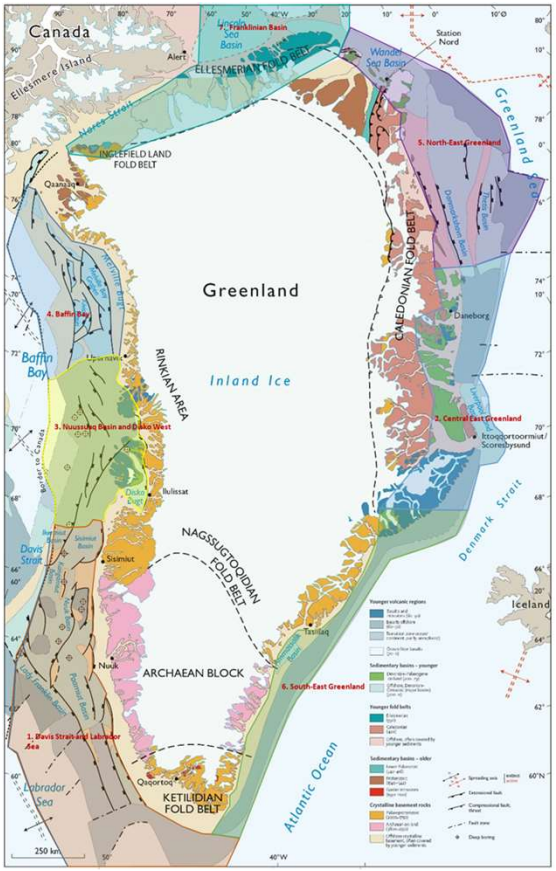

Ressource assessment

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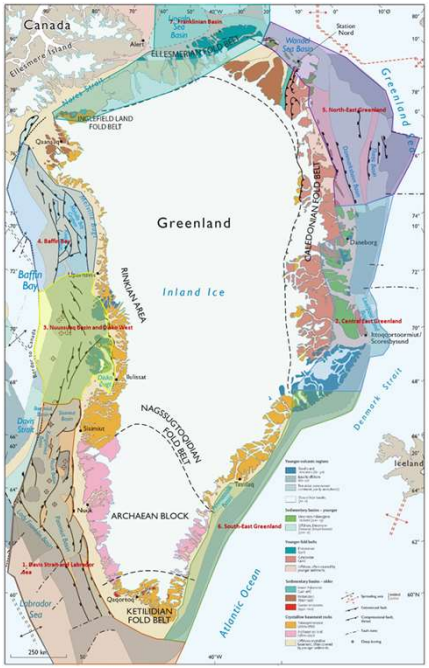
- The work is estimated to take 3½ year but individual assessment units will be reported as they are finalized,
- Offshore regions ready to be licensed:

Region (area)	Expected ready for opening for licensing
Nuussuaq Basin / Disko West (3)	October 2019 (onshore)
Davis Strait (1)	July 2020
Baffin Bay (2)	July 2020
Nuussuaq Basin / Disko West (3)	July 2020 (offshore)
Northeast Greenland (5)	July 2021
Central East Greenland (4)	January 2022

- The work will be finalized in due time for future offshore licensing rounds.



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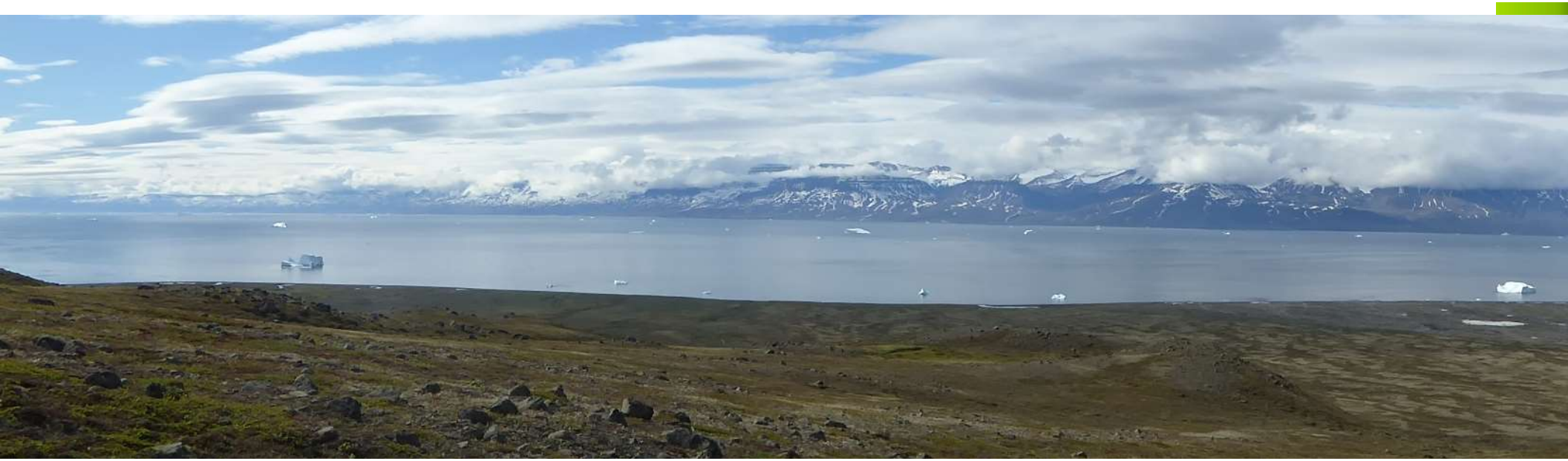
Strategic Environmental Impact Assessment

SEIA



Strategic Environmental Impact Assessment (SEIA)

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- Before the opening of areas for oil and gas exploration and exploitation a SEIA is being prepared.
- The SEIA is a vital part of the basis for the political approval of licence calls.
- The SEIA is made in co-operation between the Ministry of Environment, The Danish Centre for Environment and Energy (DCE) and the Greenland Institute of Natural Resources (GINR).

Strategic Environmental Impact Assessment (SEIA)

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Results of the assessment:

- identification of biological important, sensitive areas and periods
- identification of potential conflict between biology and human use in certain areas and periods
- identification and improvement of knowledge gabs
- oil spill drift models (modelled by DMI)
- assessment of environmental impacts

Strategic Environmental Impact Assessments (SEIA)

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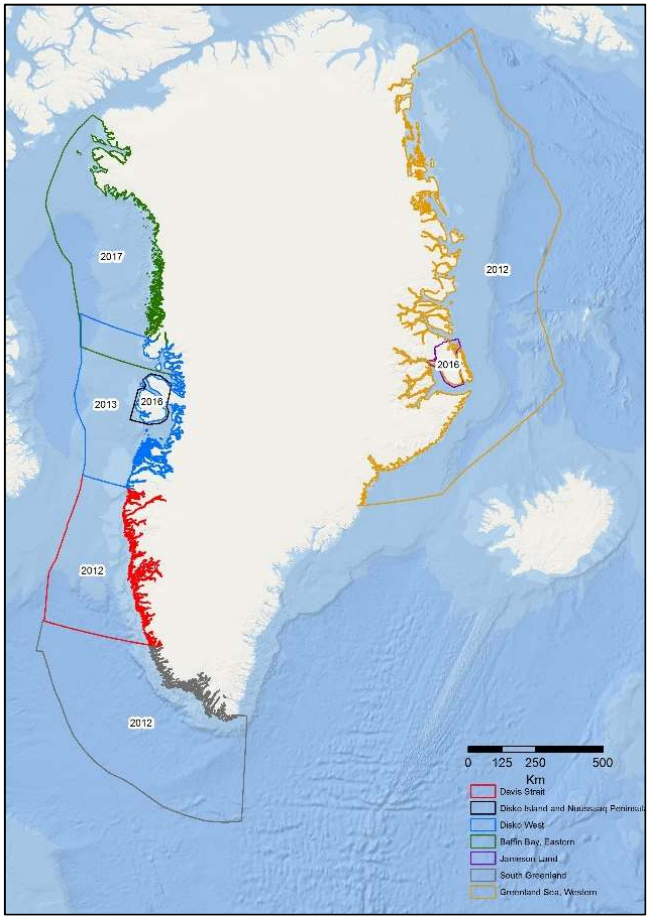
Greenland

Area	Published
1 South Greenland	2012
2 Davis Strait	2012
3 Disko West	2013
4 Jameson Land	2016
5 Disko-Nuussuaq	2016
6 Baffin Bay	2017
7 Greenland Sea	2018

Published year represent newest updated SEIA

Note: Environmental assessments have already been carried out for the most prospective areas.



Strategic Environmental Impact Assessments (SEIA)

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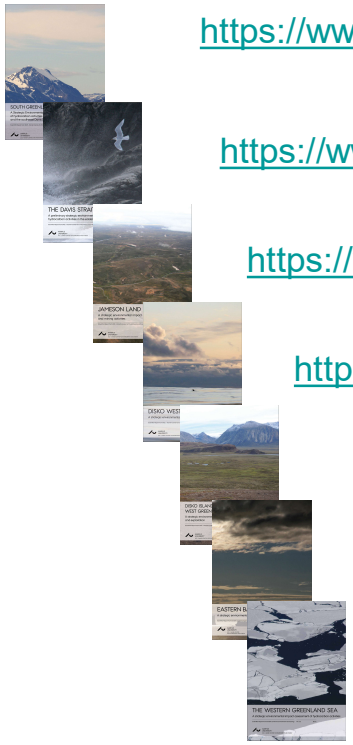
Greenland - links



https://www2.dmu.dk/Pub/SR23.pdf South Greenland 2012

https://www2.dmu.dk/Pub/SR15.pdf Davis Strait 2012

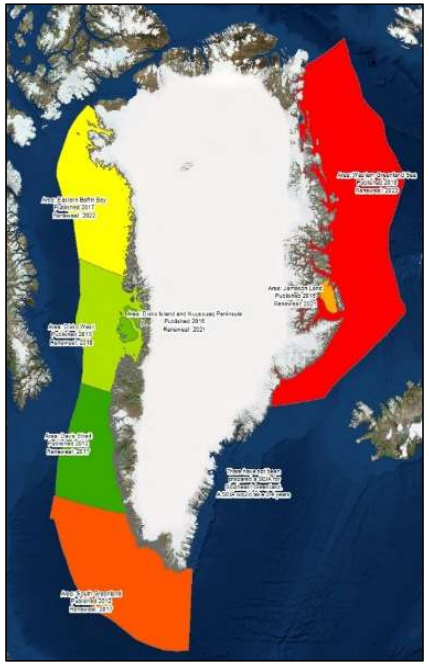
https://www2.dmu.dk/Pub/SR41.pdf Jameson Land 2012

https://dce2.au.dk/pub/SR71.pdf Disko West 2016

https://dce2.au.dk/pub/SR199.pdf Disko-Nuussuaq 2016

https://www2.dmu.dk/Pub/SR9.pdf Baffin Bay 2017

https://www2.dmu.dk/Pub/SR22.pdf Greenland Sea 2018



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Strategic Environmental Impact Assessment

Nuussuaq

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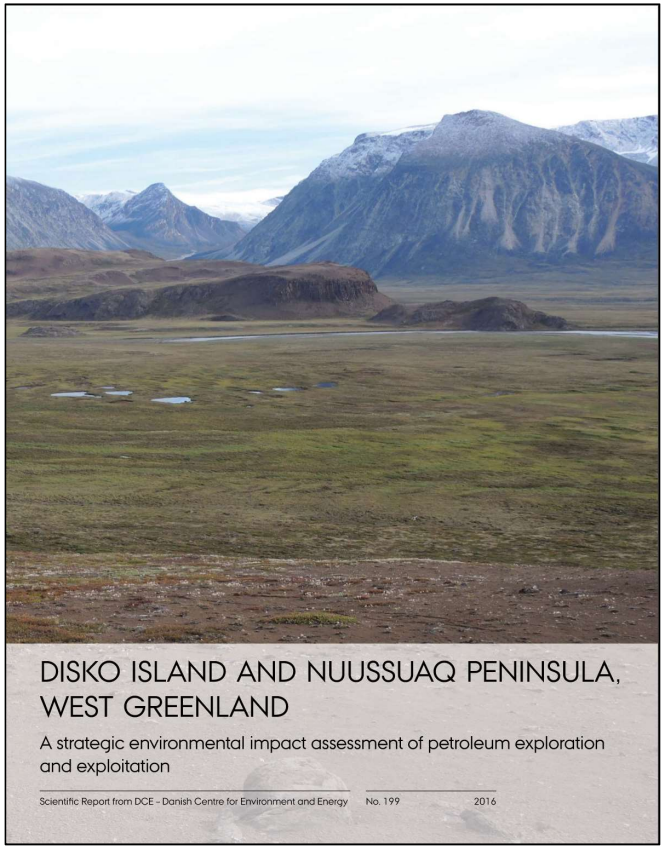
SEIA

Disko-Nuussuaq

SEIA report issued 2016:

- Published by Danish Centre for Environment and Energy (DCE)
- Greenland Institute of Natural Resources Available at:

  https://www.govmin.gl/environment/strategic-environmental-impact-assessment-seia



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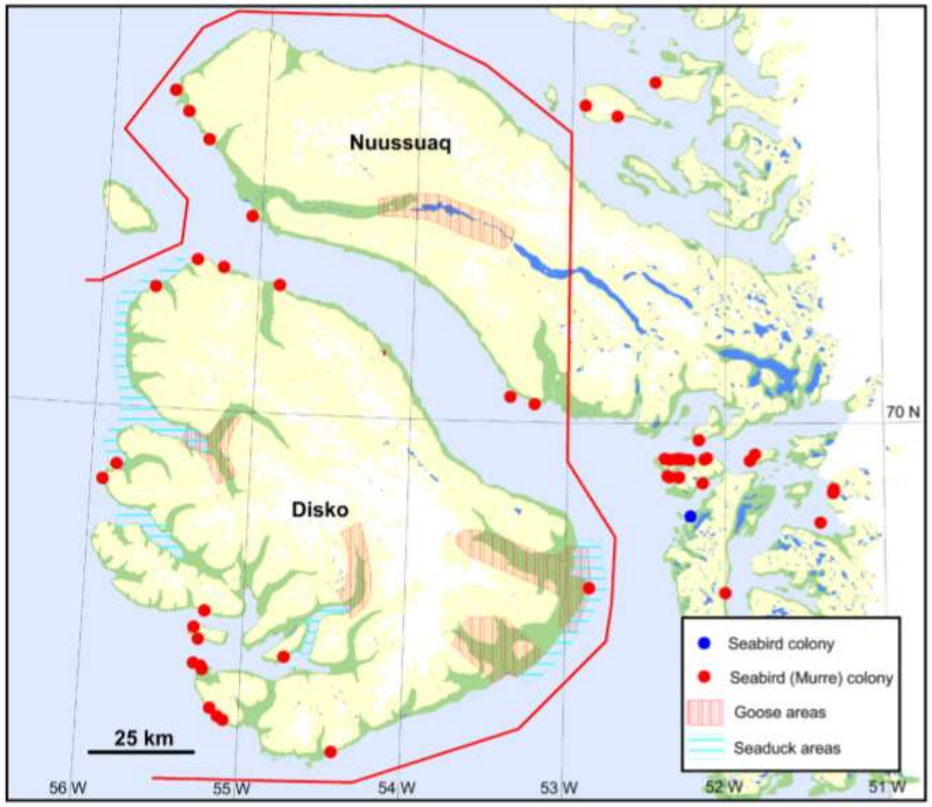
SEIA

Disko-Nuussuaq

SEIA 2016

- Important areas for wildlife
- Local areas in Nussuaq and Disko
- Consider and minimize operations and survey activies in most sensitive areas

Protected areas and conservation



Source: SEIA 2016

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Nuussuaq physical conditions

Ice Conditions

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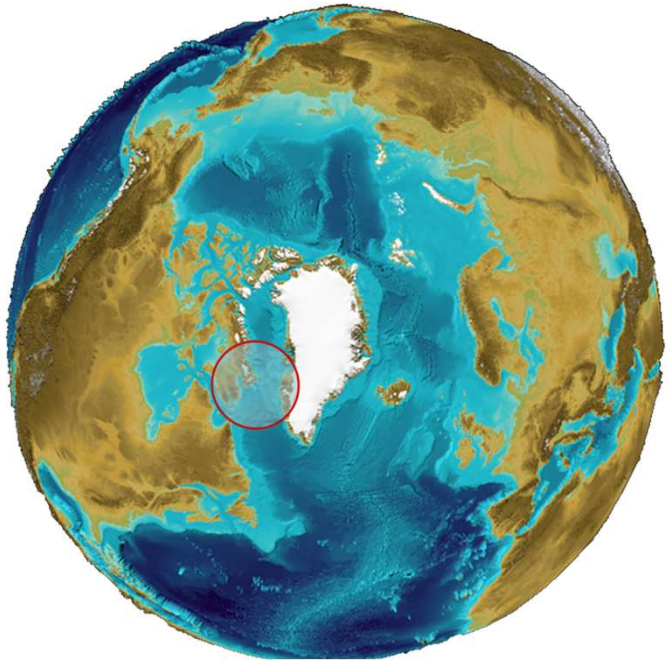

Sea ice conditions in the Arctic Ocean

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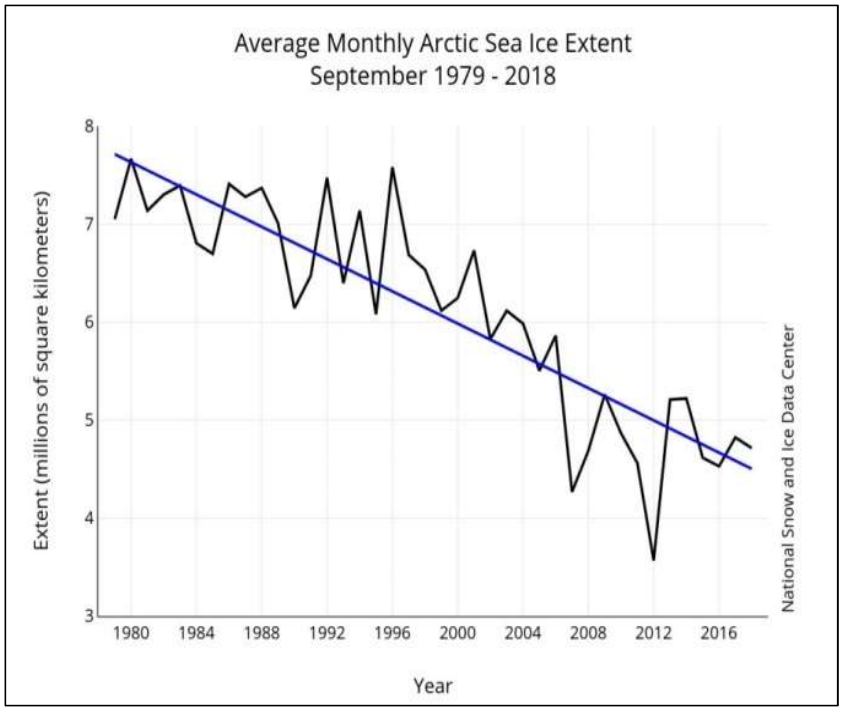
- If ship and aircraft records from before the satellite era are taken into account…
- …sea ice may have fallen by as much as 50 percent from the 1950s.



Source: National Snow And Ice Data Centre, Boulder Colorado

West Greenland offshore ice conditions

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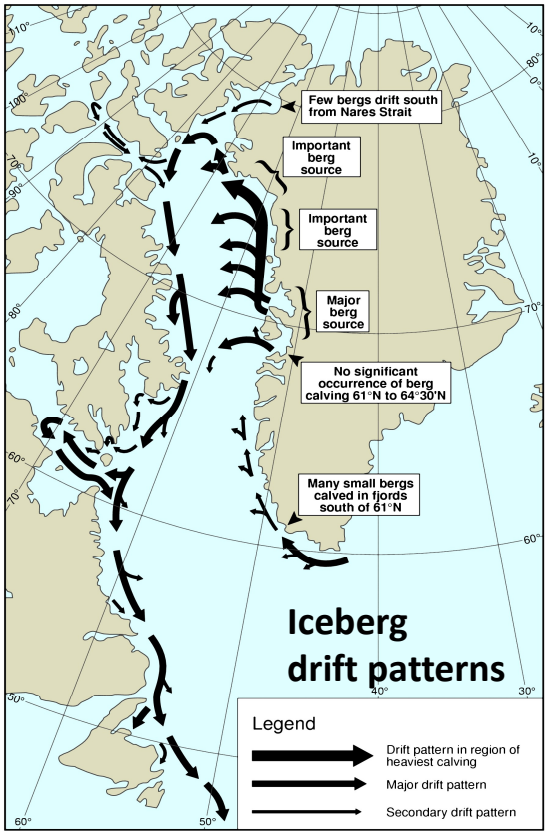

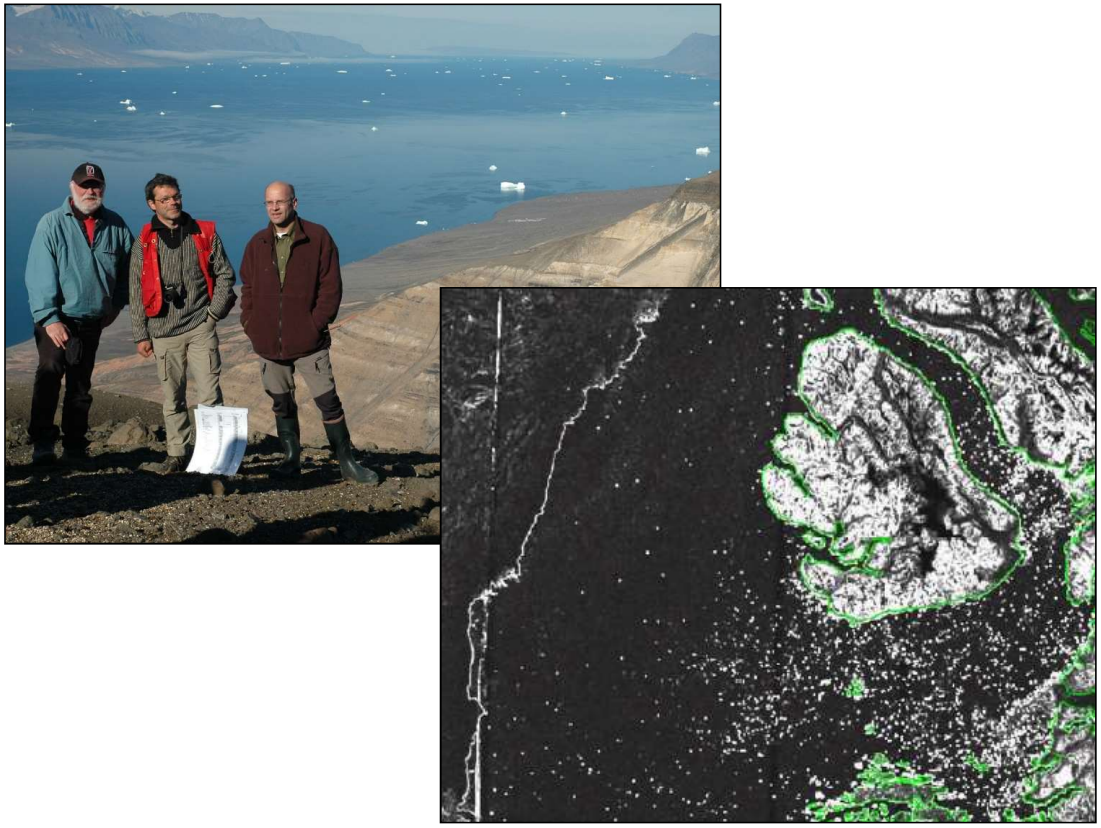

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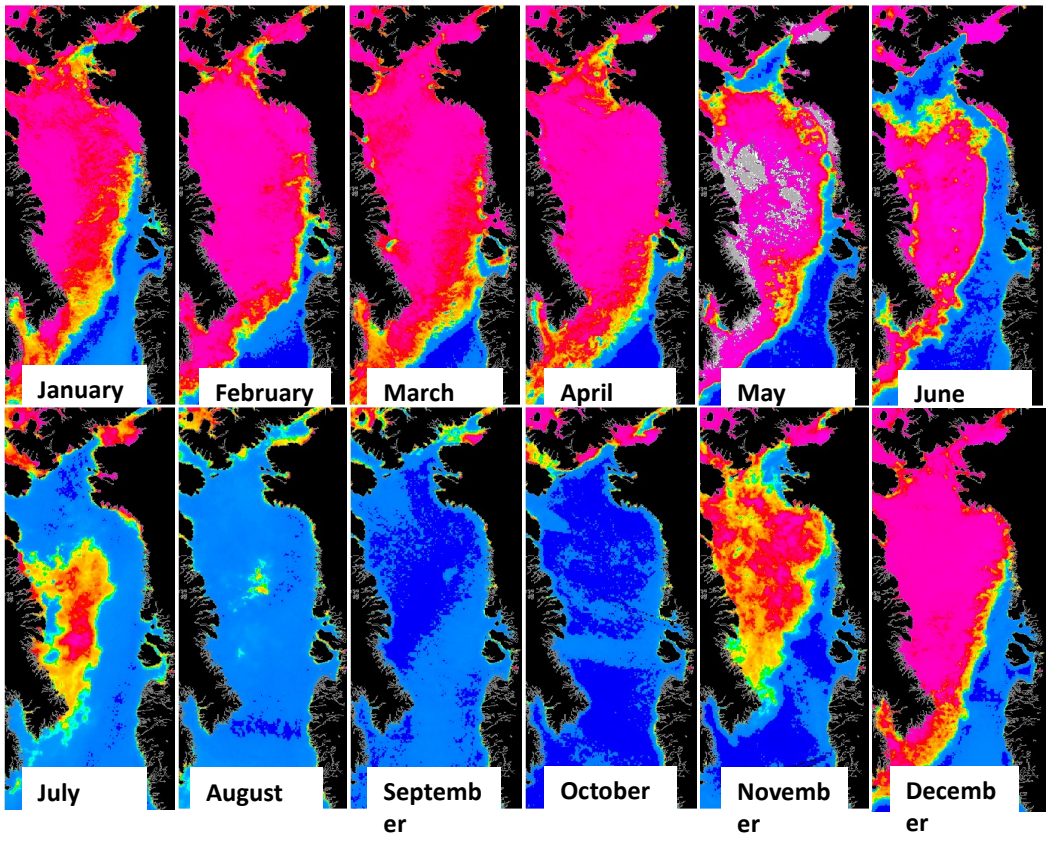
West Greenland offshore ice conditions

On a yearly basis



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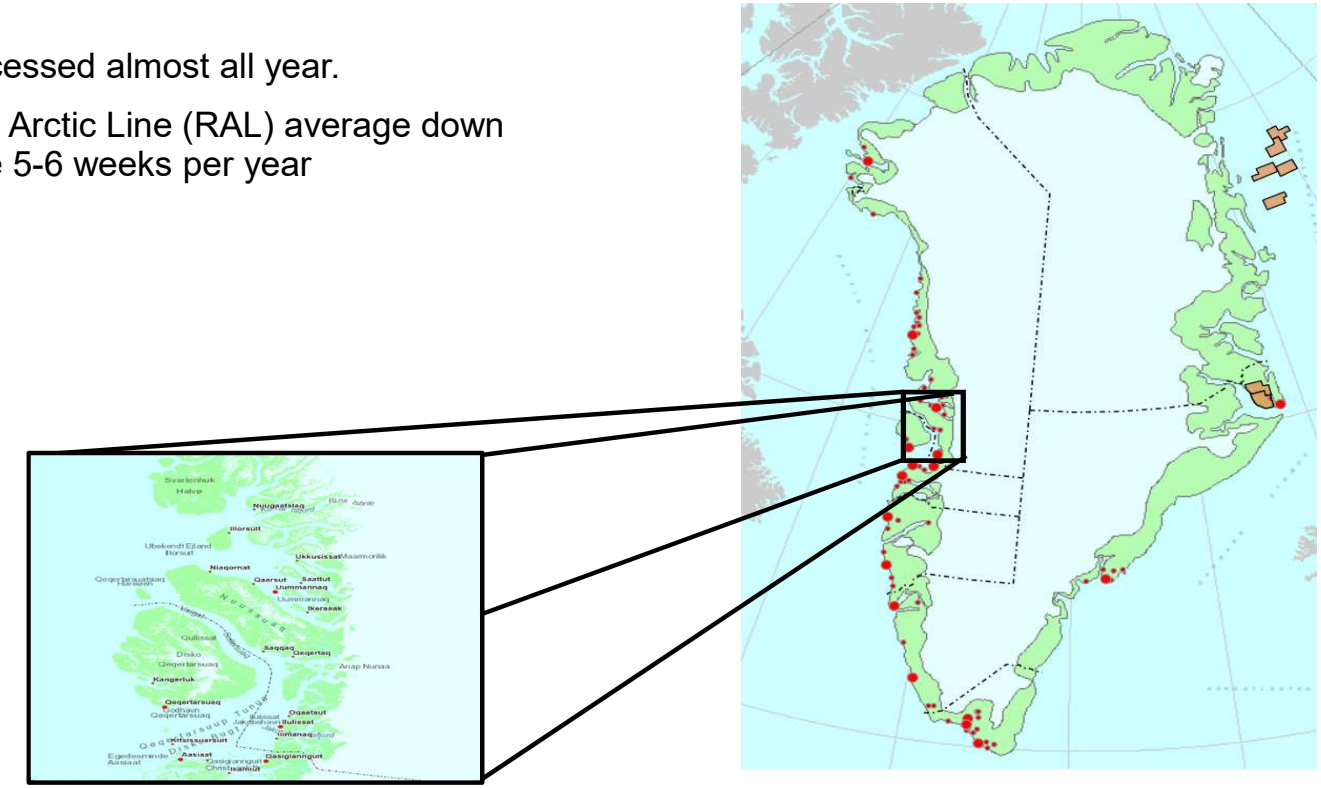
Accessibility

Ilulissat harbour

- Ilulissat can be accessed almost all year.
- According to Royal Arctic Line (RAL) average down days due to ice are 5-6 weeks per year



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Infrastructure


Photo: Rebecca Gustafsson

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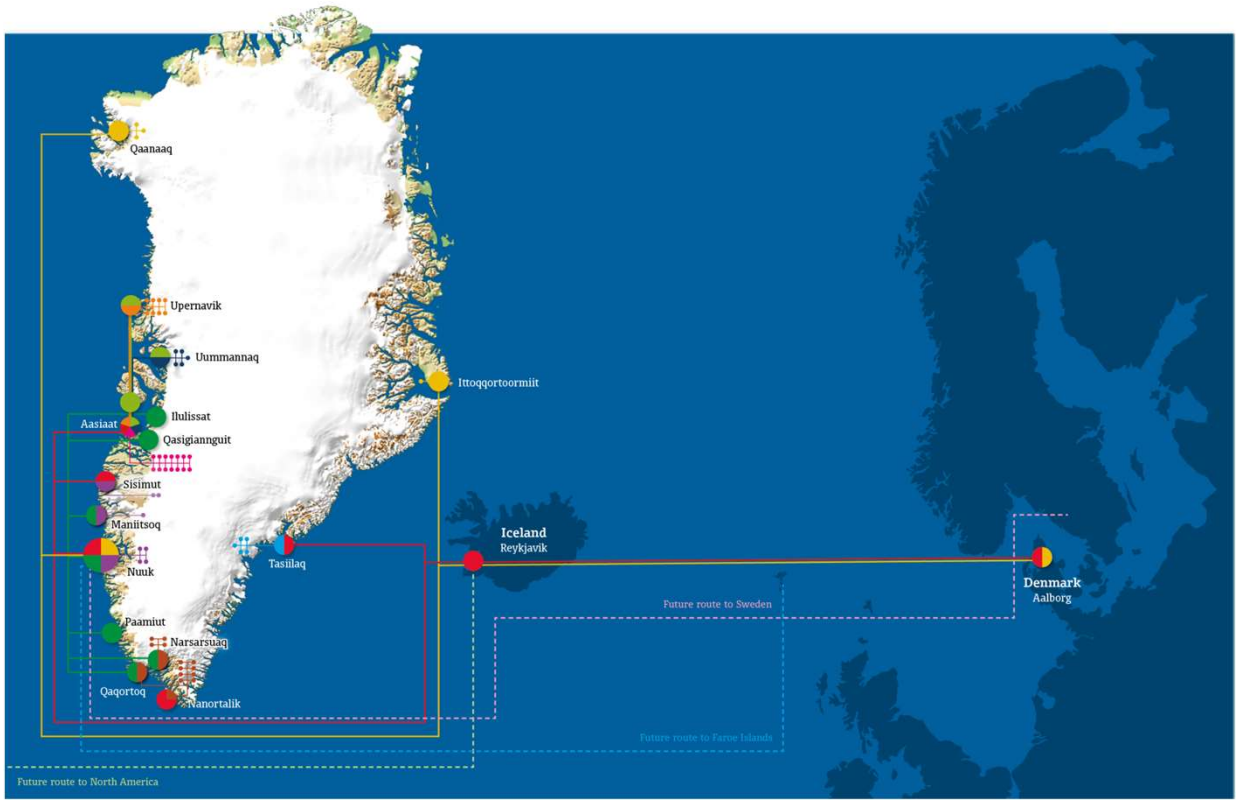
Infrastructure

Connections by sea

- Royal Arctic Line (RAL) has cargo routes connecting all cities in Greenland.
- RAL have connections to Reykjavik in Iceland and Aalborg in Denmark.
- RAL and the Icelandic shipping company Eimskip have entered into a Vessel Sharing Agreement with effect from 2019.
- The Vessel Sharing Agreement means that RAL in future will offer transportation to additional international destinations.



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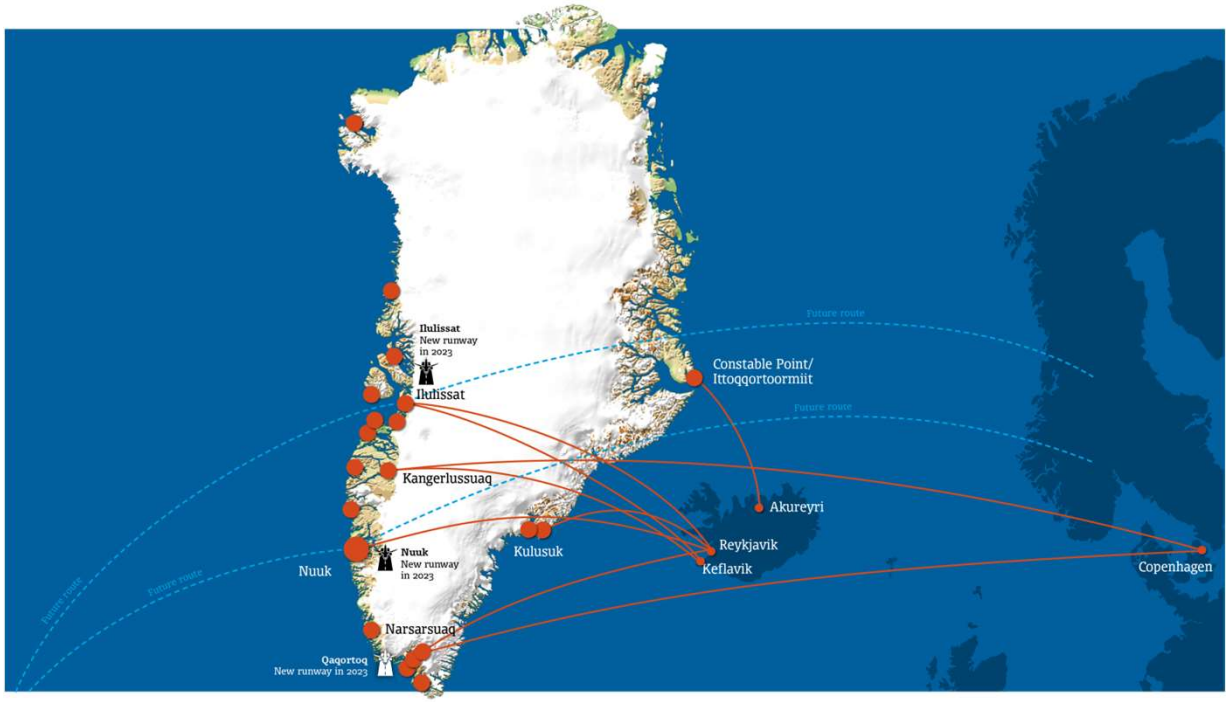
Infrastructure

Connections by air

- Greenland is well connected by air with 13 airports and 43 heliports.
- Greenland have international airportsin Kangerlussuaq and Narsarsuaq.
- New international airports are presently being constructed in the capital Nuuk and in the tourist center of the north – Ilulissat.
- The new international runways will be finalized in 2023.



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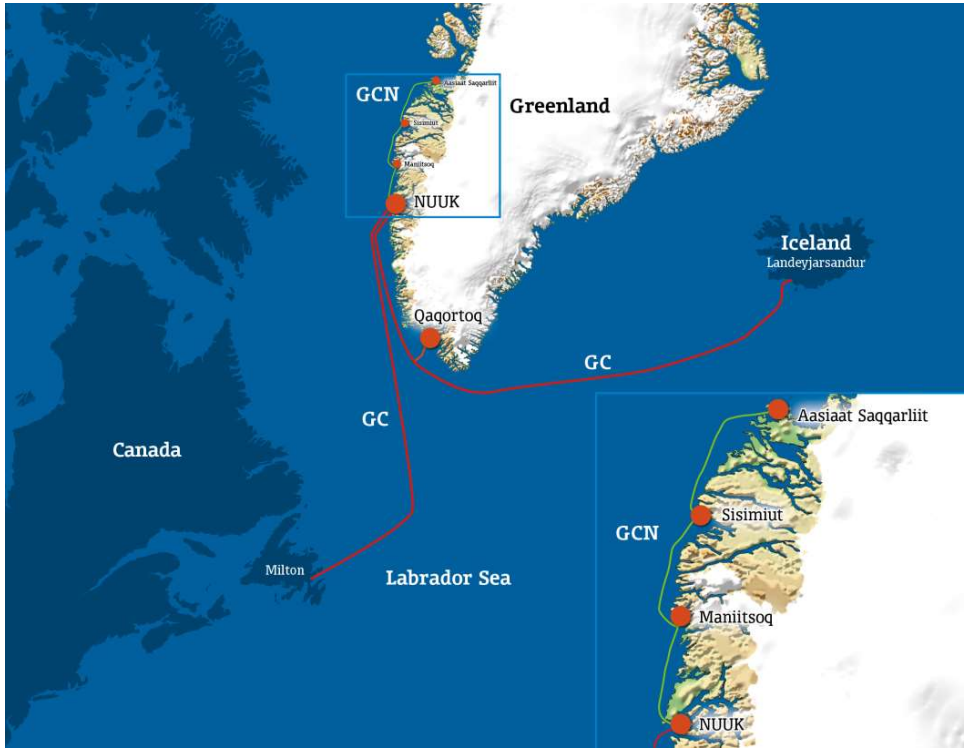
Infrastructure

Telecommunication

- Greenland is connected to the rest of the world by fiber cable.
- The marine cable connects South and West Greenland to the rest of the world, extending from Nuuk and Qaqortoq to Canada and Iceland and from there to the rest of the world.
- The international sea cable is extended along the west coast of Greenland from Nuuk to Aasiaat in North Greenland in a 680 km extension called Greenland Connect North.
- The telecommunication in other parts of Greenland is covered by a digital radio chain.
- All cities in Greenland has cell phone coverage, as well as the majority of the settlements. Large areas around the cities also has cell phone coverage.



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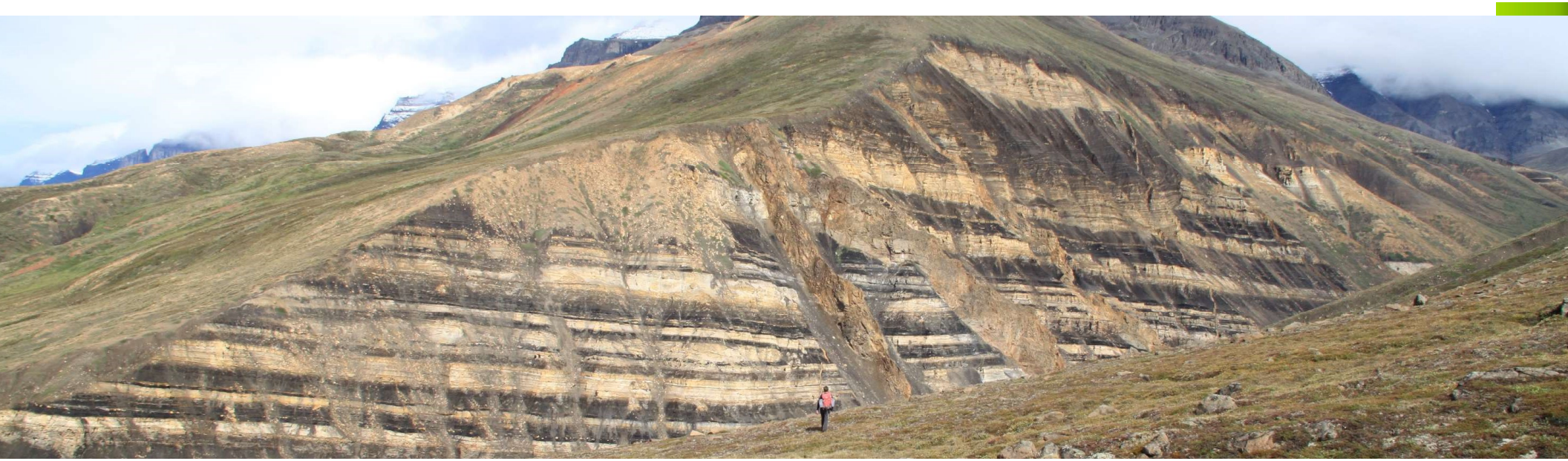
Additional Information



Content of USB

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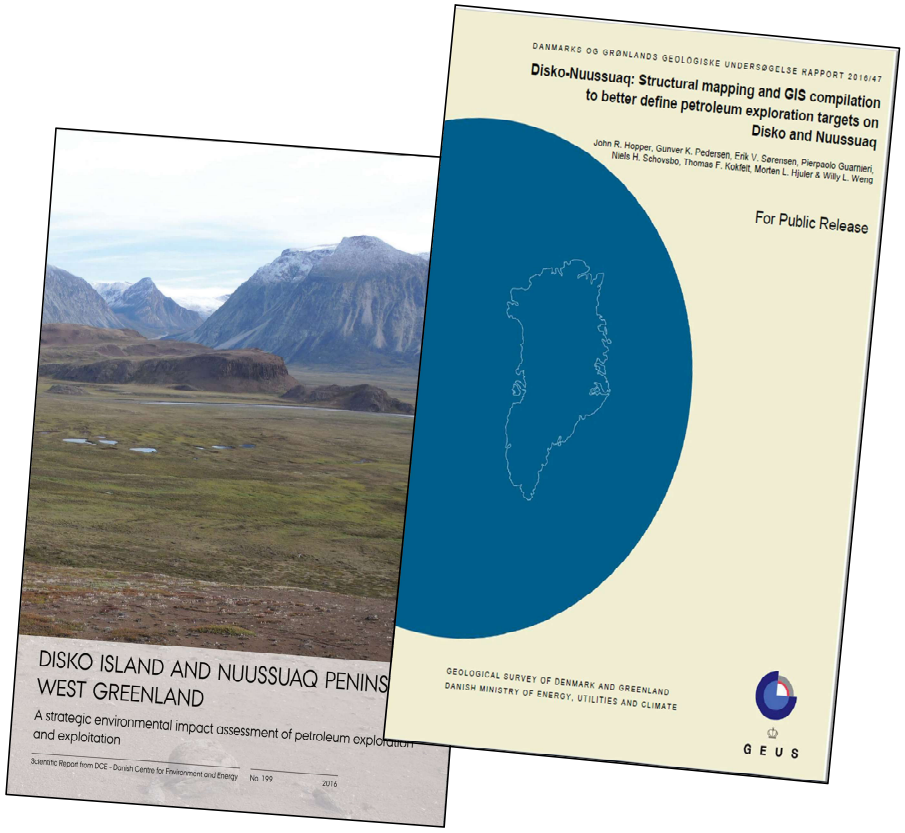
- Delegation list
- GEUS report 2016
- Model licence
- This presentation
- Exploring for oil in Greenland
- Doing business in Greenland
- How to get exploration data
- SEIA report Disko Island and Nuussuaq Peninsula
- 3D visualisation of the Aaffarsuaq Canyon
- Greenland in 6 minutes



Come visit us

At booth 004

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Thank you

Questions?

Photo: Mads Phil, Visit Greenland