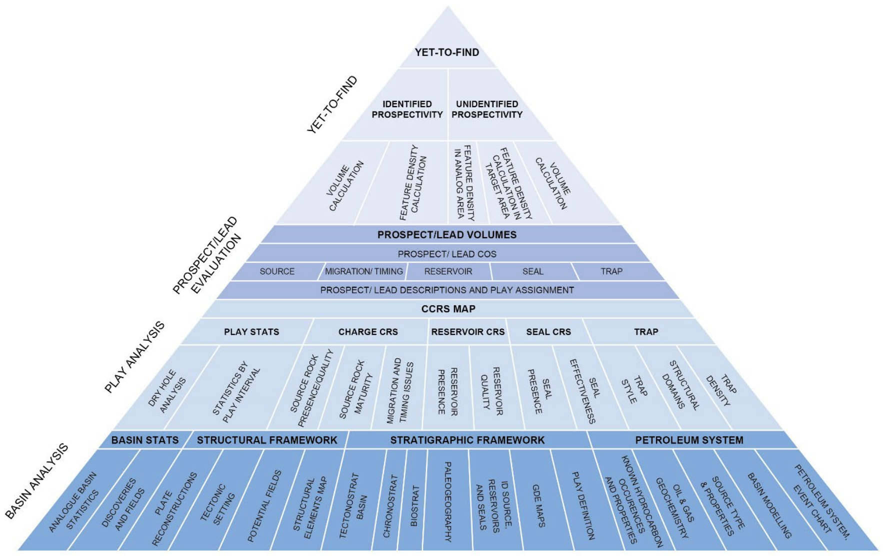
AU6 – South-East Greenland

1. Introduction



RESOURCE EVALUATION WORKFLOW

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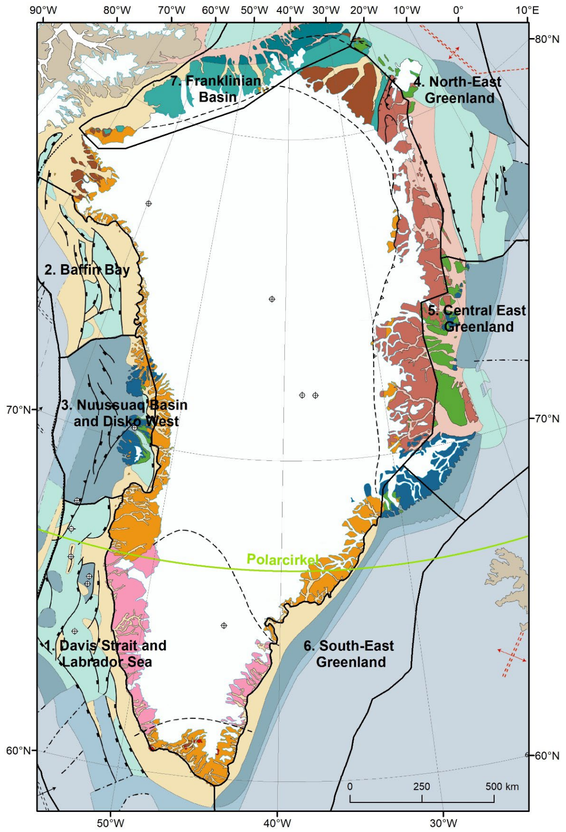
AU6: South East Greenland Introduction

1. Assessment Unit 6 covers offshore central East Greenland and part of the onshore Kangerlussuaq area
2. Offshore areas and the Blosseville Kyst region are covered by volcanic rocks of the North Atlantic Igneous Province
3. Very little data are available and no exploration licenses have ever been granted in AU6



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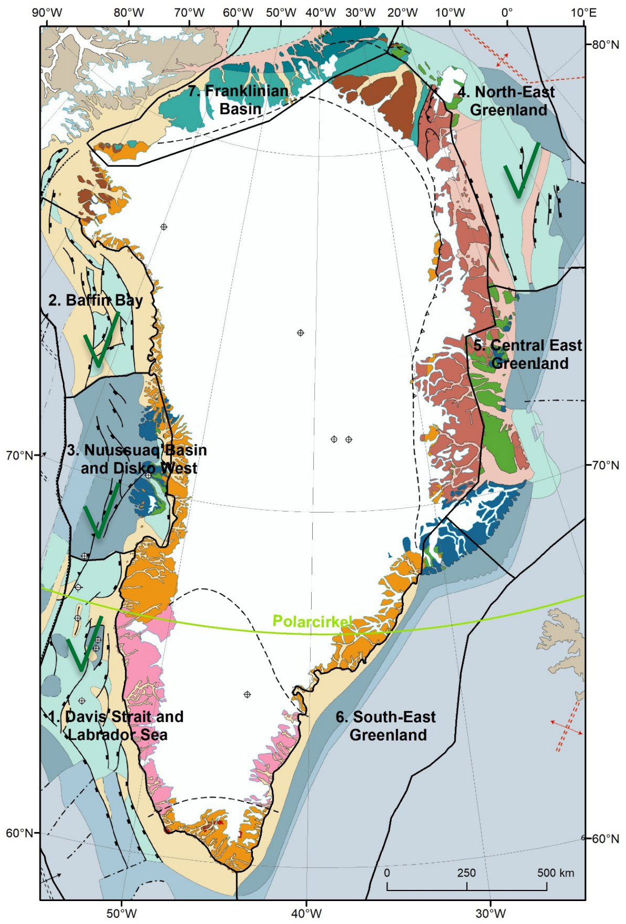
Contents

Introduction

Project area

- Seven assessment units have been established (AU1-AU7) covering 2.431.212 km^2
- Each assessment unit outline a larger geological province. This report is only dealing with AU6 – South East Greenland
- AU6 covers 369,042 km^2 of which large parts are covered by thick successions of basalts or oceanic crust

Assessments Units	Area km^2
AU1 – Davis Strait and Labrador Sea	470,865
AU2 – Baffin Bay	159,062
AU3 – Nuussuaq Basin and Disko West	175,430
AU4 – North-East Greenland	412,216
AU5 –Central East Greenland	369,042
AU6 – South-East Greenland	515,039
AU7 – North Greenland (Franklinian Basin)	329,558
TOTAL	2,431,212



Contributors to the AU6 Assessment

Geological Survey of Denmark and Greenland (GEUS)

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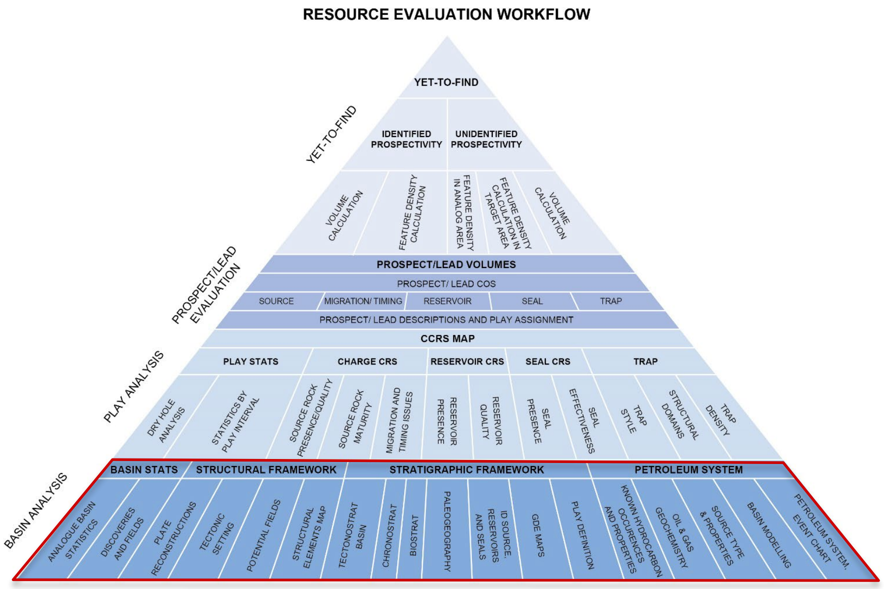
- Thomas Varming

Ministry of Mineral Resources (MMR)

- Martin Peter Brandt

AU6 – South-East Greenland
2. Database



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AU6: Database

2D seismic data

- Open grid
- DLC 1990s, TGS 2012
- Interpreted by GEUS

Other geophysical data

- TGS airborne grav/mag data

ODP Leg 163 boreholes drilled in 1998 and 1999

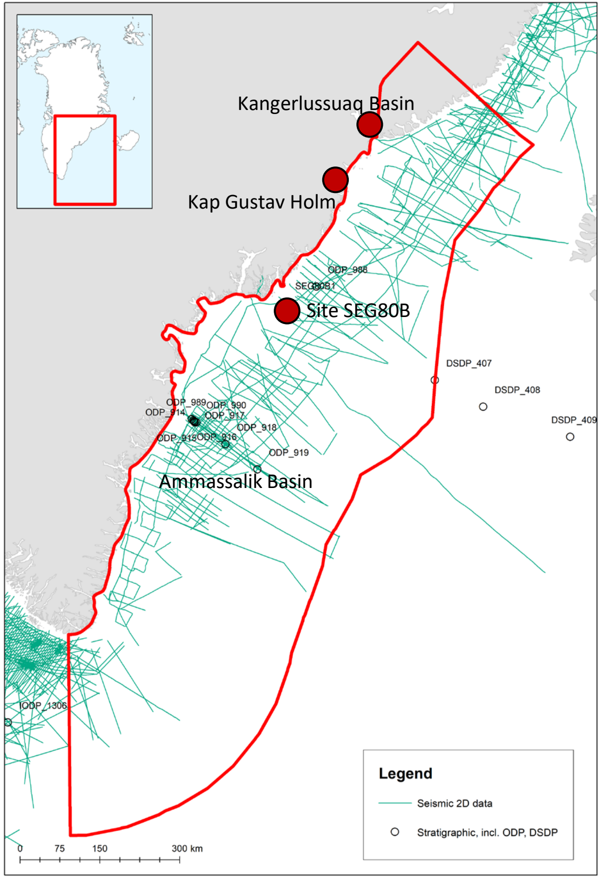
- Ten ODP boreholes mostly drilling the basaltic and post-break up section
- Ten shallow boreholes (each a couple of metres deep)
- Site SEG80B includes approximately 65 cm of sediments

Outcrops

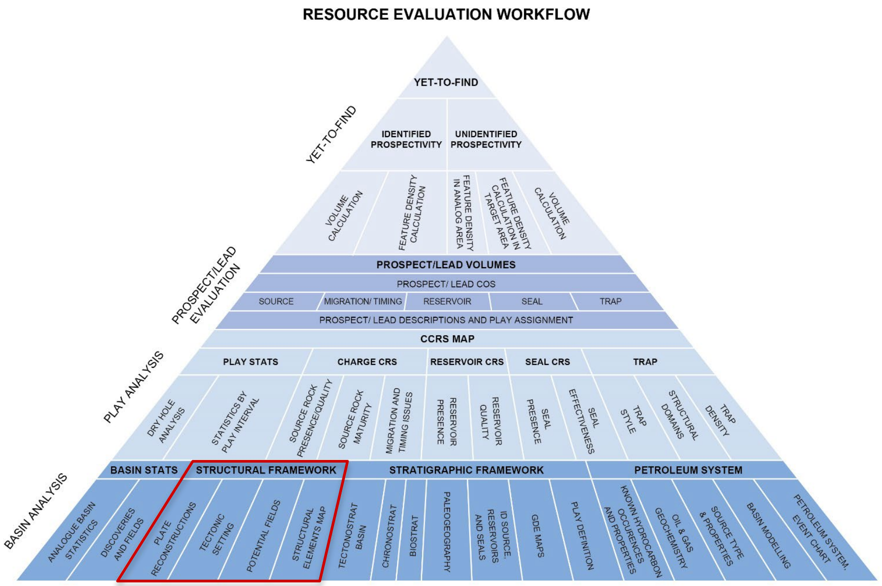
- Cretaceous-Eocene sediments and basalts in the Kangerlussuaq Basin
- Contact metamorphosed Cretaceous sediments at Kap Gustav Holm

Publications

- A number of academic publications



AU6 – South-East Greenland
3. Structural and Stratigraphic Framework



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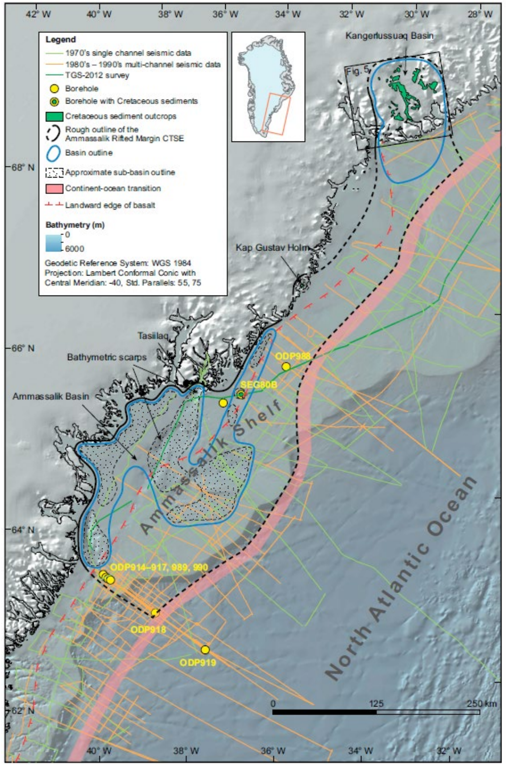
AU06 03: Structural and Stratigraphic Framework

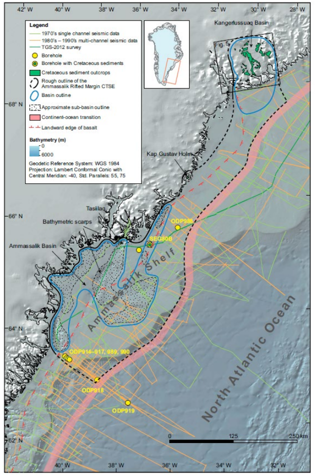
- Rifted volcanic margin
- Three Cretaceous-Paleocene basins have been recognized in AU6:
  - Kangerlussuaq Basin (onshore)
  - Kap Gustav Holm (onshore)
  - Ammassalik Basin (offshore)
  - Larger extension may exist underneath volcanics
- Basins formed during Cretaceous-Paleocene Rifting and are comparable with other rift basins along the NE Atlantic margins
- Notice that COB is located very close to the SE Greenland coastline, apart from at the Ammassalik Shelf, and the continental shelf very narrow



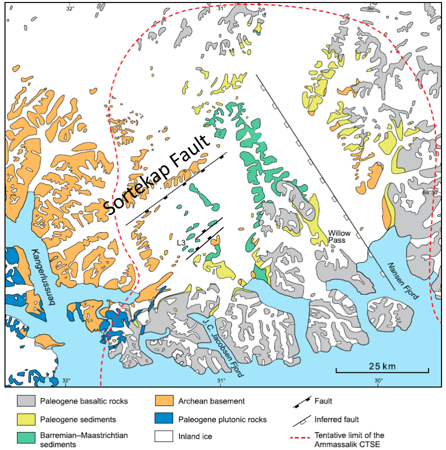
From Fyhn et al. 2021

Kangerlussuaq Basin

- Onshore sub-basalt basin, bounded by NE- and NW-striking faults
- Exposed over an area of 5 000 km^2, however, the basin margin to the NE is not exposed and the basin may continue below the Paleogene flood basalts along the Blosseville Coast
- The continuation of the basin into the offshore areas to the south and southeast is unknown
- The basin consists of predominantly NW-dipping fault blocks bounded by SW–NE–striking normal faults.
- The Sortekap Fault probably controlled the position of the NW basin margin during mid-Cretaceous (Aptian) and mid-Paleocene sea level lowstands.
- In areas south of the Sortekap Fault, crystalline basement locally crops out in windows between a cover of Cretaceous(?) sediments. These basement windows probably are related to exhumed crests of tilted fault blocks
- Paleogene continental breakup was accompanied by the development of a large-scale, coast-parallel flexure with dykes and normal faults (Nielsen, 1975, 1978; Nielsen and Brooks, 1981). Faulting occurred in a system of coast-parallel antithetic faults related to the Sortekap Fault and the bedding strike NE-SW, parallel to these tectonic lineaments



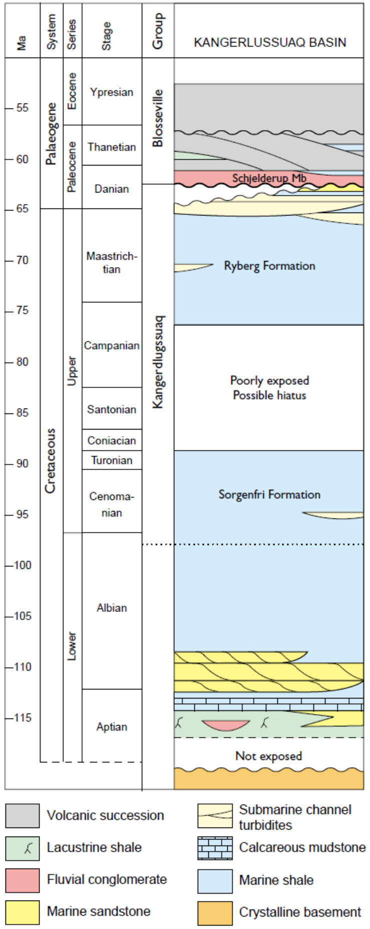
Fyhn et al. (2021)



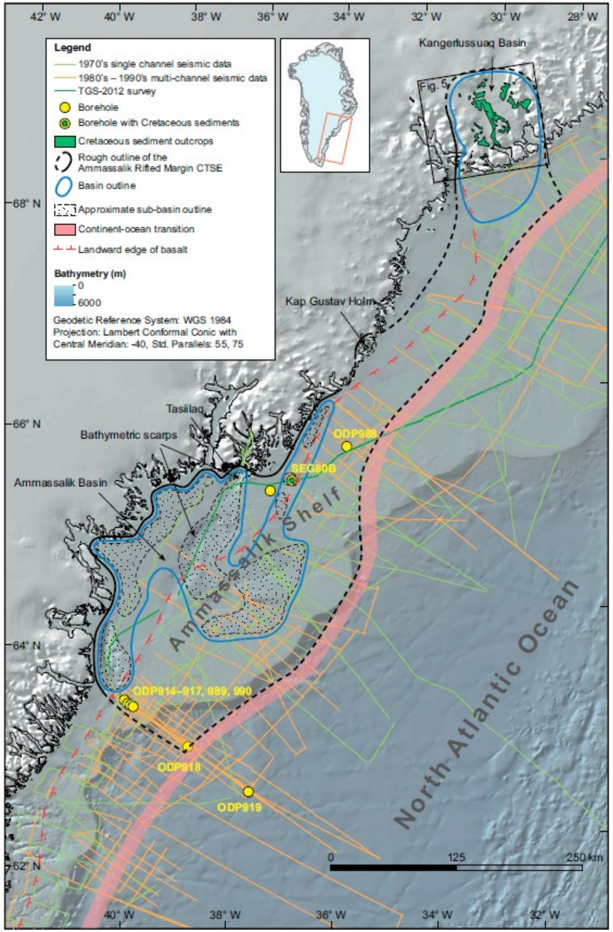
Based on Larsen et al. (2005)

Kangerlussuaq Basin

- Succession is ~1 km thick
- Oldest sediments are of Early Cretaceous age (Barremian?, Aptian – Early Albian) resting on crystalline basement
- Lower Albian-Aptian (Barremian?) succession composed of fluvial and estuarine sandstones and lacustrine mudstones
- Overlain by Albian and Upper Cretaceous succession dominated by monotonous silty mudstones and fine-grained sandstones reaching several hundred meters in thickness with a rich fauna of ammonites, echinoderms and bivalves. Increasing number of fan/channel turbidites sandstones in the Maastrichtian – Lower Danian succession
- Unconformity separates turbidites from overlying fluvial sandstones and conglomerates, immediately underlying the first volcanics
- The sedimentary succession has been deeply buried, potentially reaching a depth of more than 5 km (Brooks 1979) and is locally affected by intense heating from magmatic intrusions

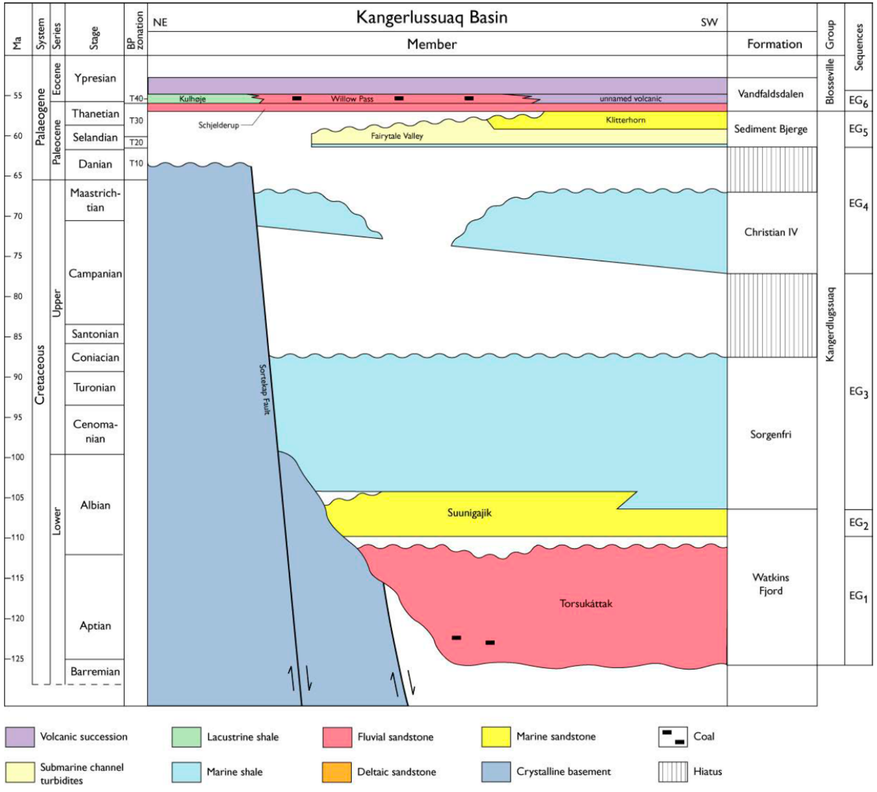


From Larsen et al. (2001)

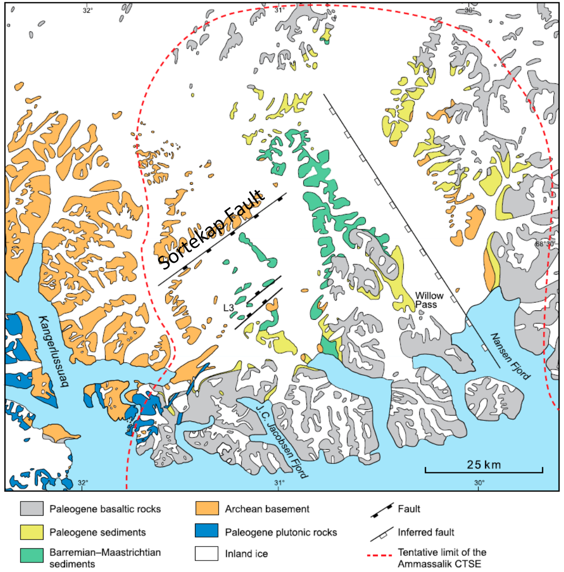


From Fyhn et al. 2021

Kangerlussuaq Basin



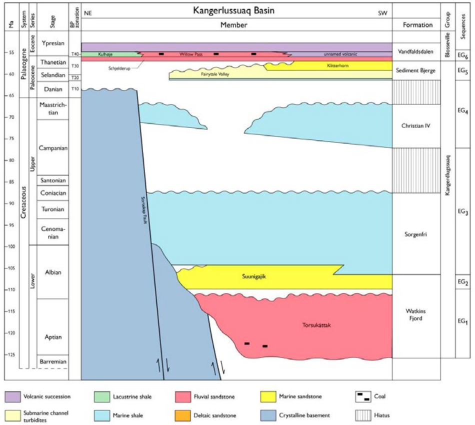
From Larsen et al. (2005)

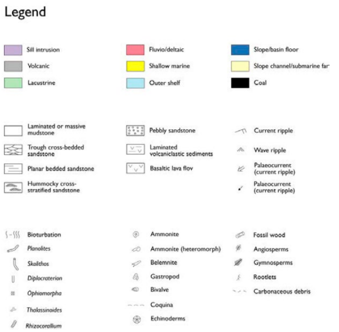


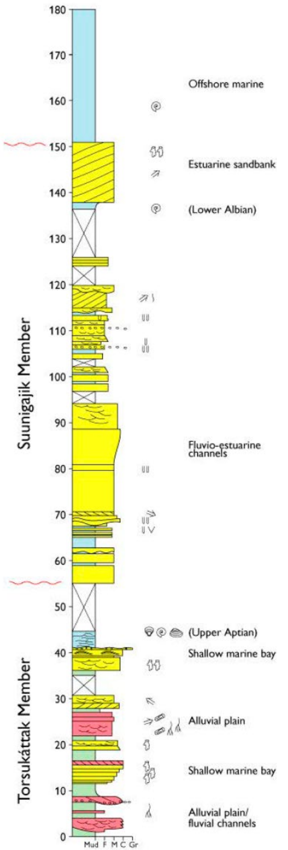
- The Sortekap Fault probably controlled the position of the NW basin margin during mid-Cretaceous (Aptian) and mid-Paleocene sea level lowstands

Kangerlussuaq Basin

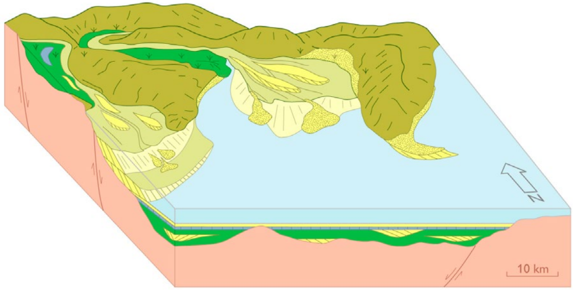
(Barremian?) Aptian-Albian Alluvial and Shallow Marine Sandstones







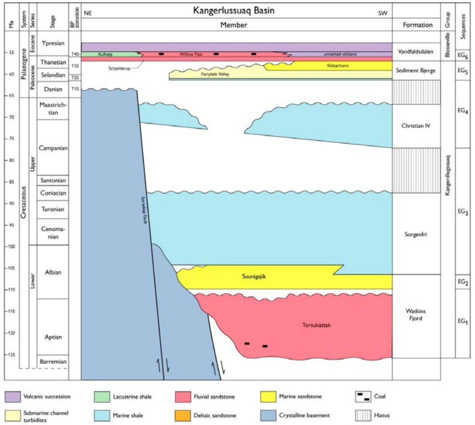
- Albian-Aptian fluvio-lacustrine sandstones and mudstones overlain by shallow marine sandstones. Palaeocurrents towards east

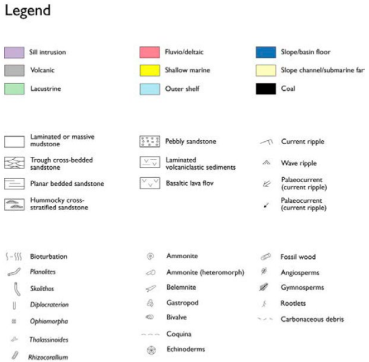


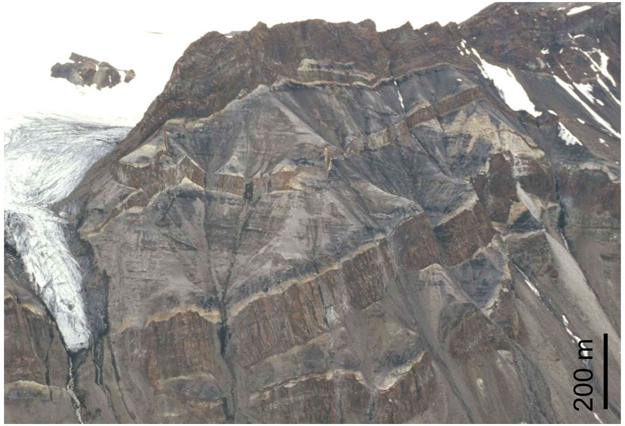
From Larsen et al. (2005)

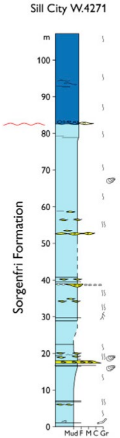
Kangerlussuaq Basin

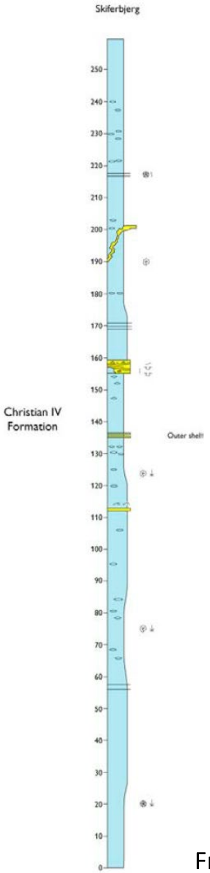
Aptian - Maastrichtian Alluvial and Shallow Marine Sandstones







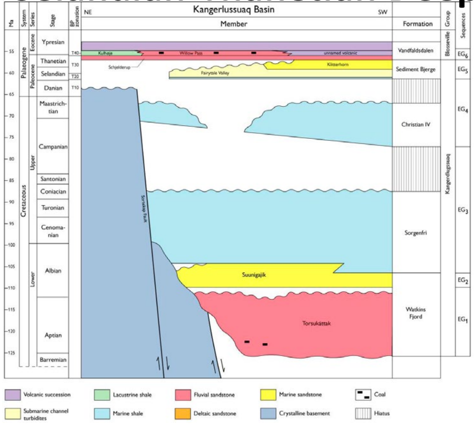


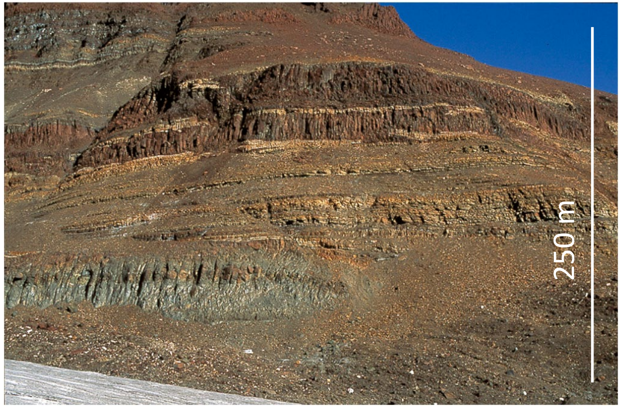


- Overlain by a thick succession of Albian-Coniacian and Campanian Maastrichtian succession dominated by monotonous silty mudstones and fine-grained sandstones, deposited in an outer shelf setting, reaching several hundred meters in thickness with a rich fauna of ammonites, echinoderms and bivalves
- An angular unconformity is developed between the two mudstone units in the western part of the basin and becomes conformably in the towards east

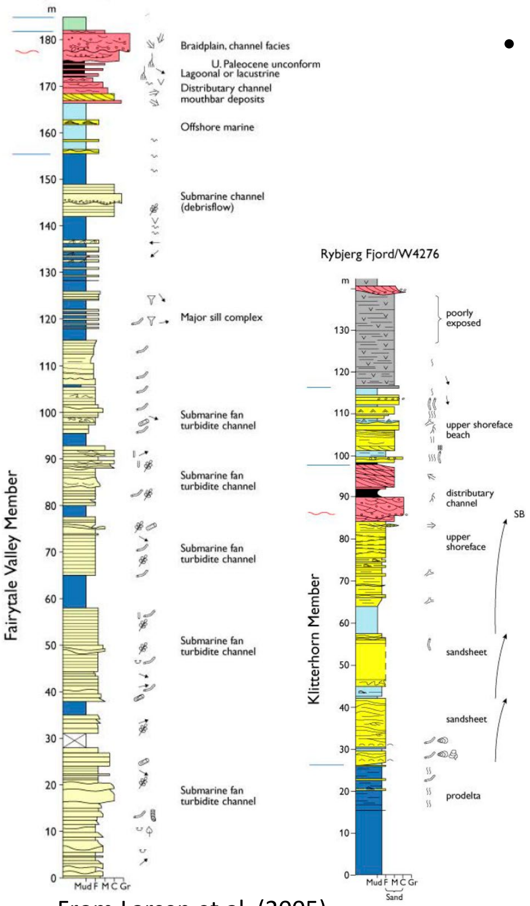
From Larsen et al. (2005)

Kangerlussuaq Basin
Selandian-Thanetian Deep and Shallow Marine Sandstones





Turbidite channel sst of the Fairytale Valley Mb



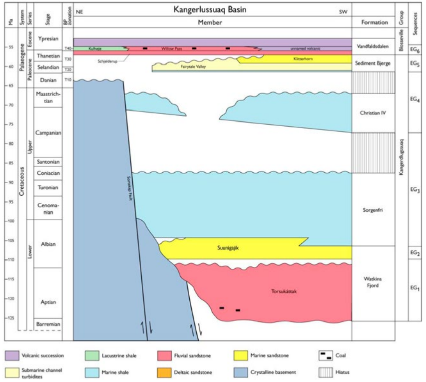
From Larsen et al. (2005)

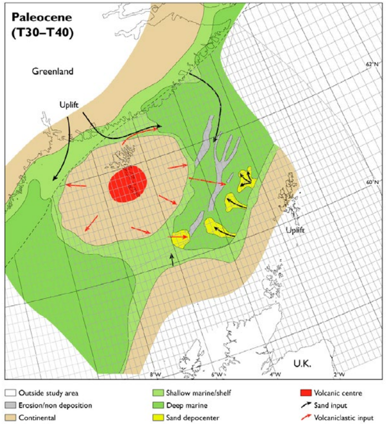
- Selandian turbidite channel sandstones unconformably overlying outer shelf mudstones and followed by shoreface and distributary channel sandstones

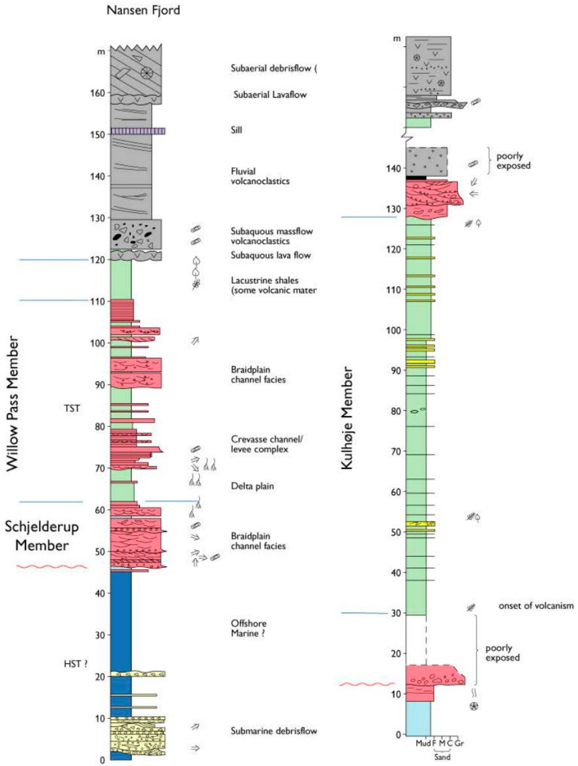
Cross-bedded shallow marine sst of the Klitterhorn Mb

Kangerlussuaq Basin

Thanetian-Ypresian Lacustrine Mudstones and Fluvial Sandstones







From Larsen et al. (2005)

- Major unconformity overlain by braid-plain river conglomerates and coarse-grained sandstones, delta plain and lacustrine mudstones

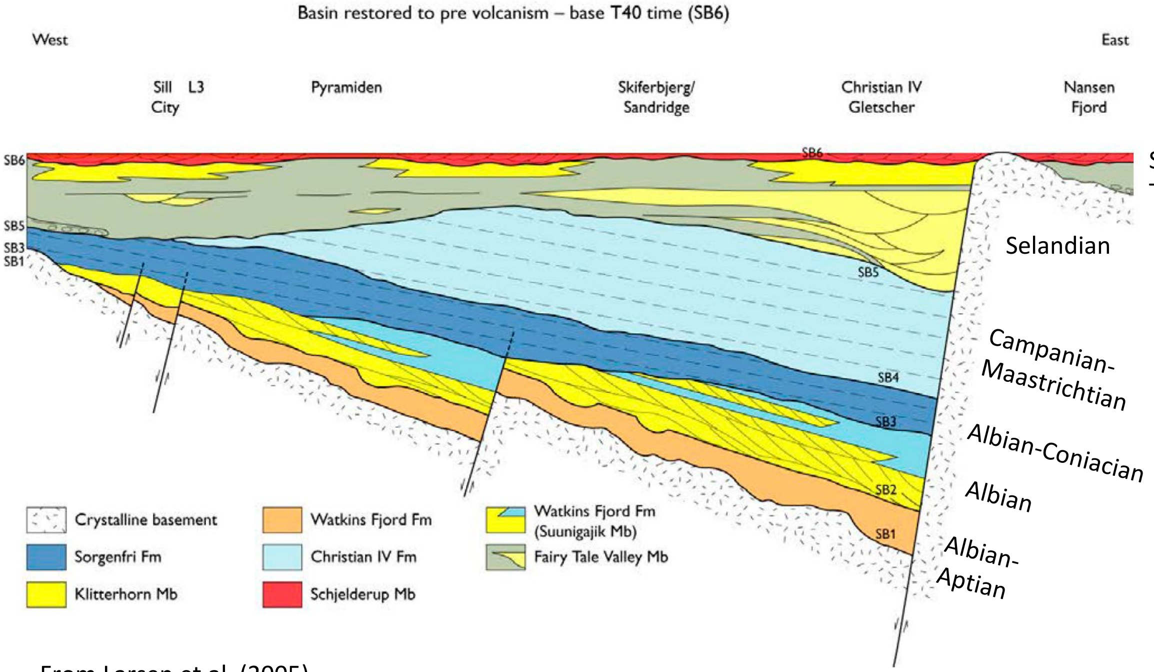
Amalgamated fluvial channels sadstones of the Schjelderup Mb

Kangerlussuaq Basin

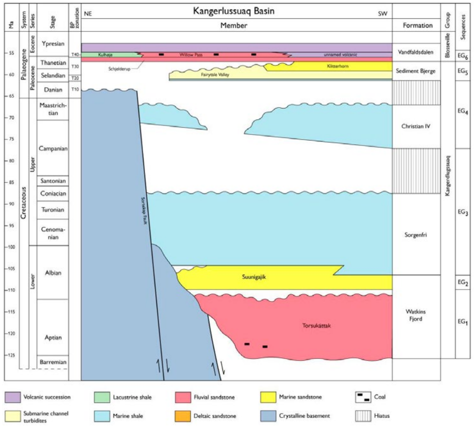
Early Eocene Intra-basaltic Siliciclastic Sandstones

- In the lower part of the volcanic succession two siliciclastic sandstone beds, up to 5 m thick, are present

Kangerlussuaq Basin
Sequence Stratigraphy



From Larsen et al. (2005)



SB6 – Fall in relative sea-level

SB5 – Angular unconformity, Tectonic

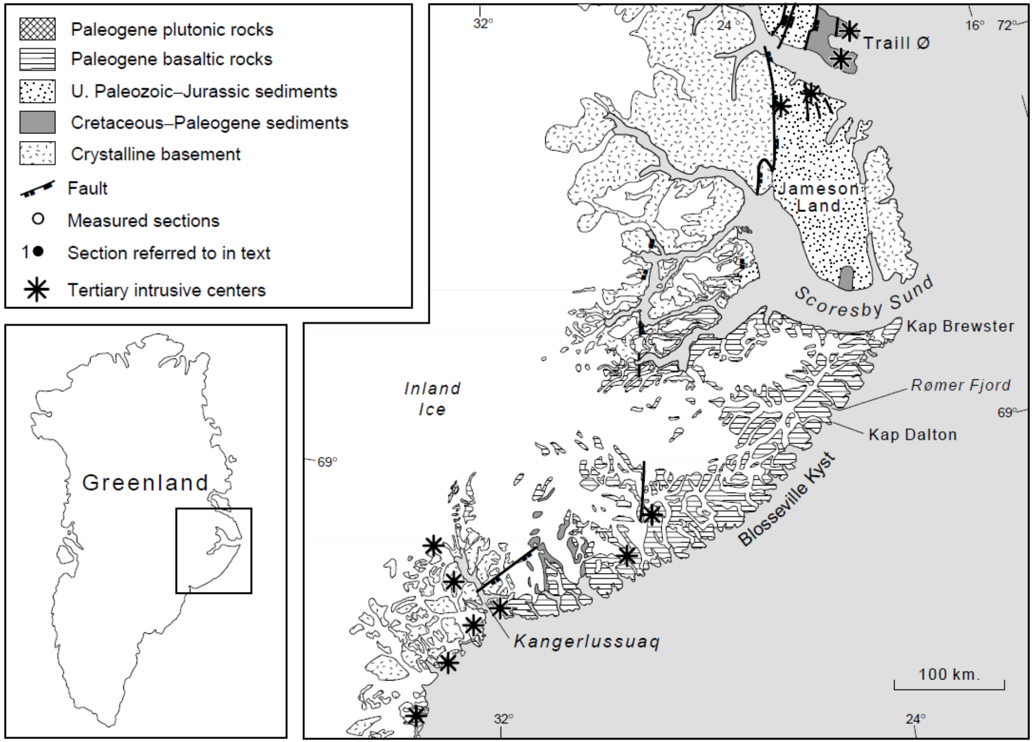
SB4 – Hiatus

SB3 – Angular unconformity, tectonic

SB2 – Fall in relative sea-level and river incision

SB1 – Basal onlap

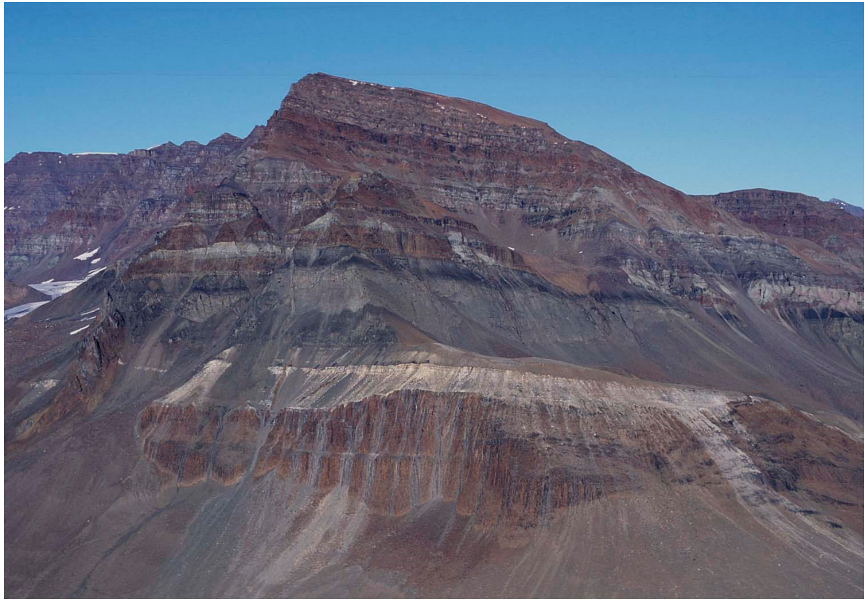
Kangerlussuaq Basin



From Larsen et al. (1999)

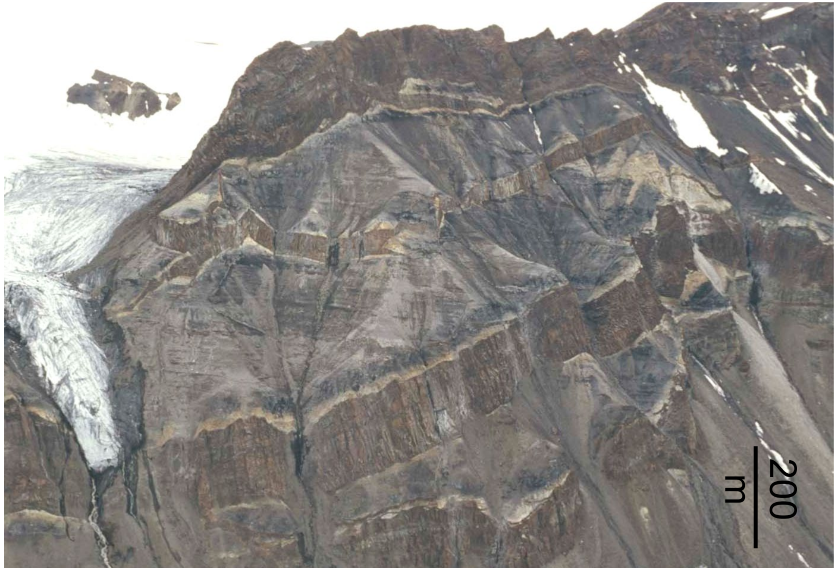
- The coast-parallel structural trend of the region is also reflected in the position of a number of large early Eocene–Oligocene intrusive centers formed along a southwest–northeast line (Wager, 1947; Nielsen, 1975, 1978; Tegner et al., 1998)

Kangerlussuaq Basin
Burial Depth



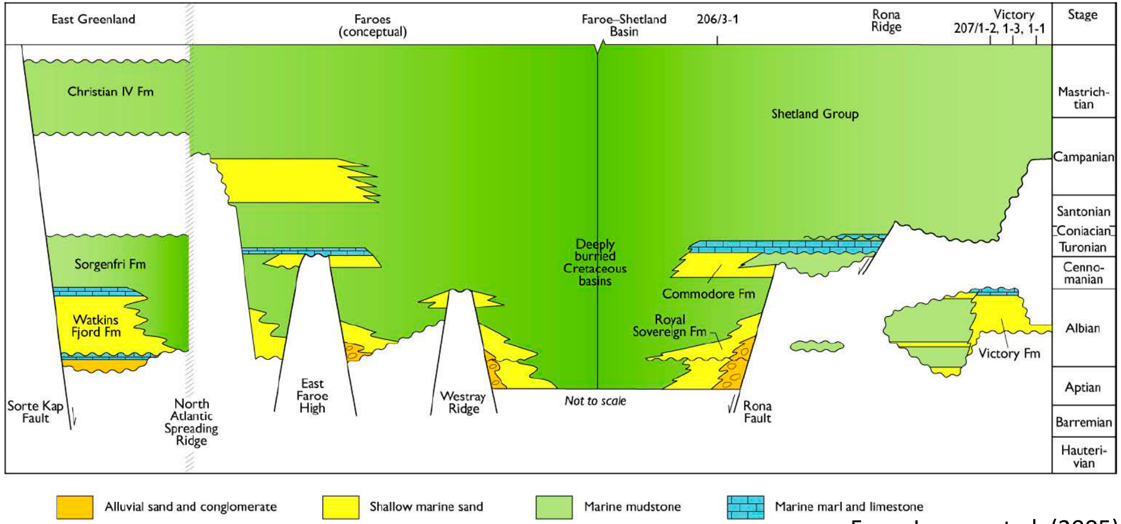
- The sedimentary succession has been deeply buried, potentially reaching a depth of more than 5 km (Brooks 1979) and is locally affected by intense heating from magmatic intrusions

Fluid inclusions suggest uplift of 3 km

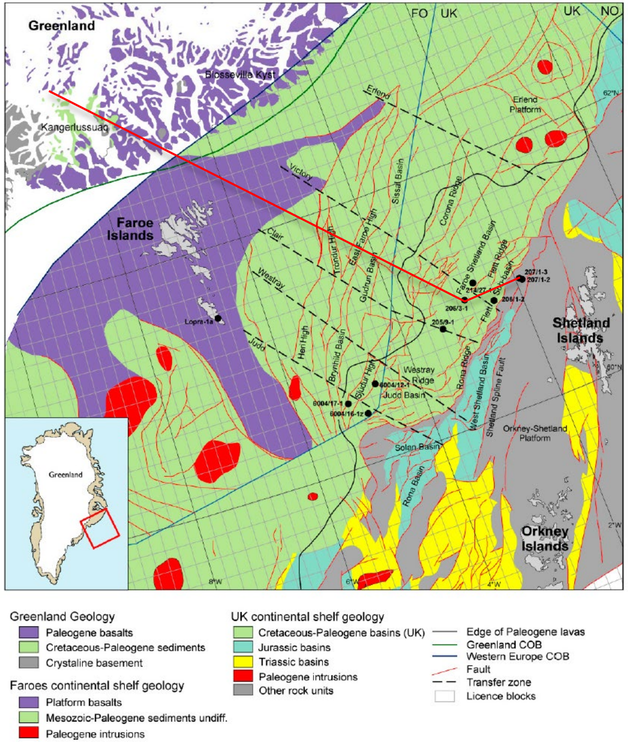


Kangerlussuaq Basin

Correlation of the Cretaceous Succession to the Conjugate Margin, WoS



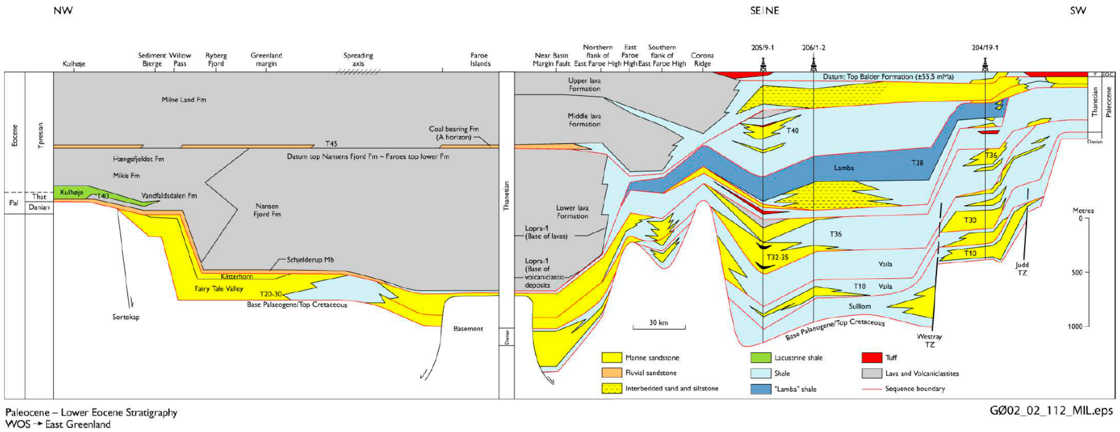
From Larsen et al. (2005)



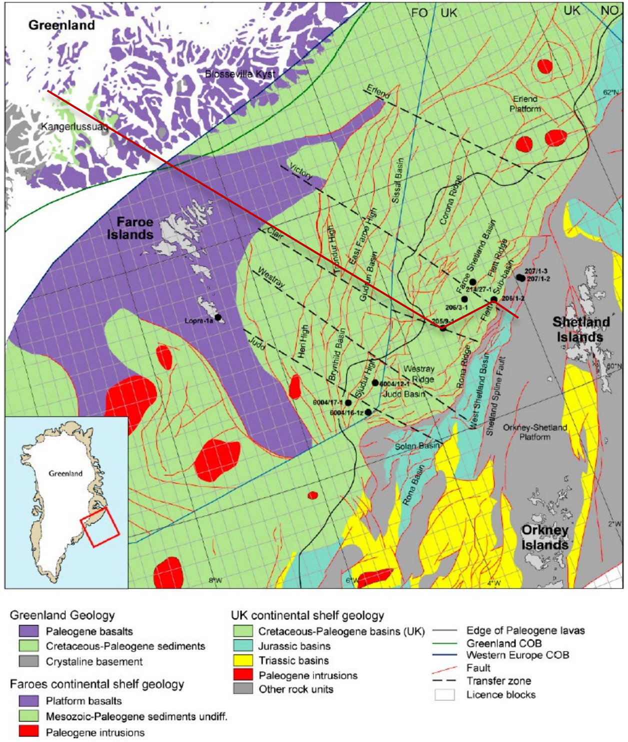
- Very similar Cretaceous evolution in of the Kangerlussuaq Basin and WOS apart from the presence of a Late Jurassic source rock in WoS

Kangerlussuaq Basin

Correlation of the Paleocene-Eocene Succession to the Conjugate Margin, WoS



From Larsen et al. (2005)



- Correlation of the Paleocene-Eocene successions in the Kangerlussuaq Basin and WoS
- Paleocene successions are very similar developed on the two conjugate margins with development of large turbidite channels and basin-floor fans
- Thick Eocene volcanic succession in East Greenland and Faroes island. Intra-basaltic siliciclastic sandstone present in both East Greenland, Faroe Islands, and UK (Rosebank Discovery, Paleocene-Eocene Flett Formation)

Kap Gustav Holm

- Isolated exposure covering a few km^2
- Succession approximately 150 m thick resting on basement
- Locally contact metamorphosed along Eocene intrusion

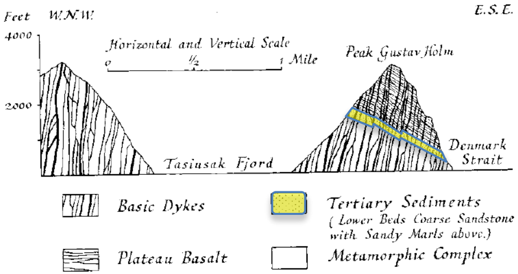
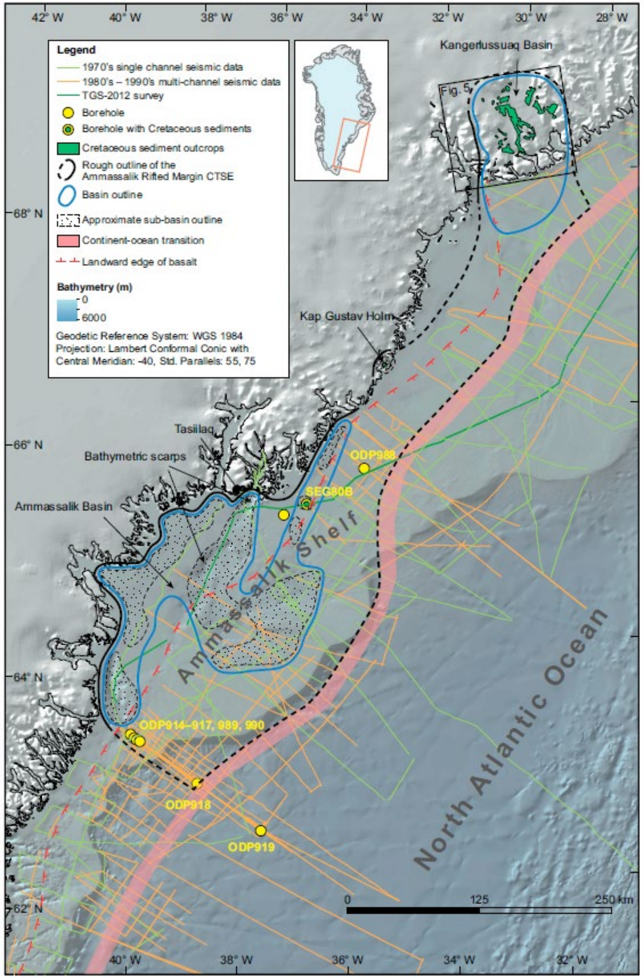


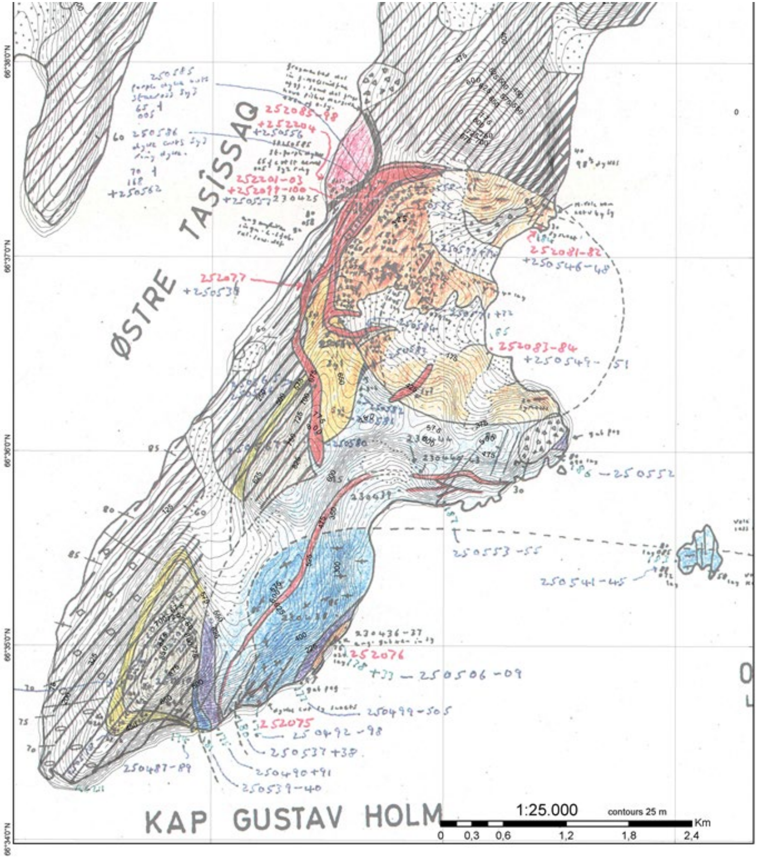
Fig. 4. Cross-section showing Peak Gustav Holm and the mountain to the west, both rising to the general level of the former peneplain, with Tasiusak Fjord cut along the former line of junction between the sediments and the Metamorphic Complex. The thickness of the sediments and the individual lava flows is exaggerated. (Reproduced by permission from the Geographical Journal).

From Wager 1934



Fyhn et al. (2021)

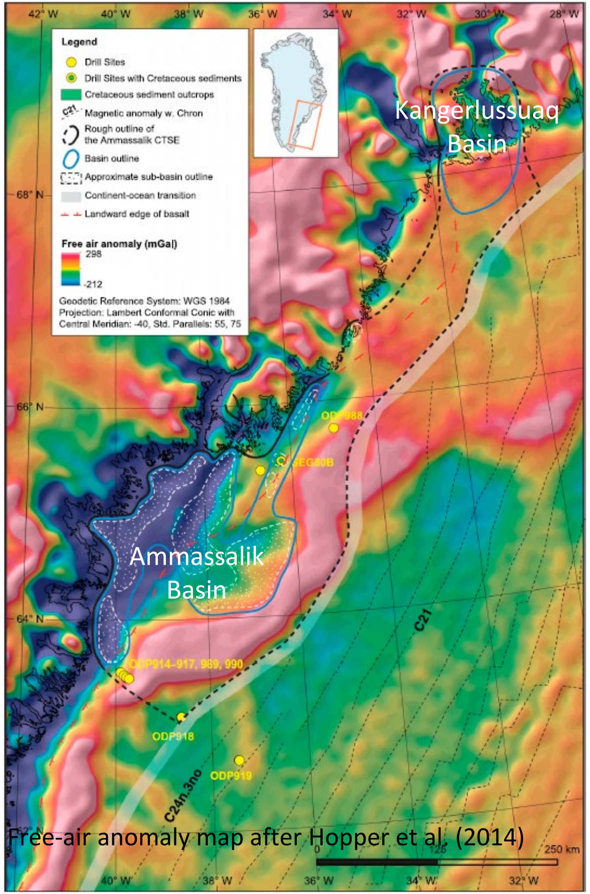
Kap Gustav Holm

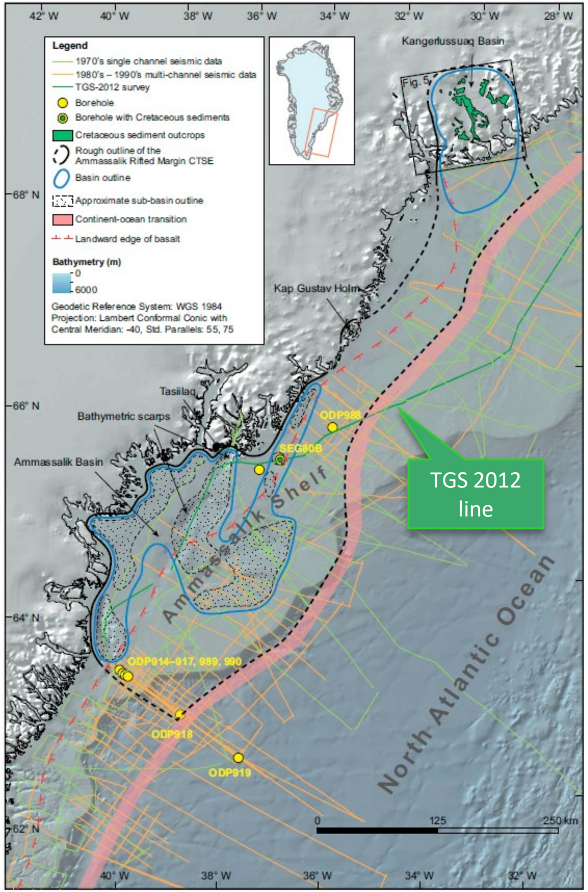


- Conglomerates, gravels, metamorphosed shales and fossiliferous sandstones
- Accessible part is 25-30 m thick with two submarine lava flows in the lower part
- Bivalves indicate a Late Cretaceous – Early Palaeogene age of the succession
- Room for an older ?Cretaceous succession underneath

Ammassalik Basin

- Offshore basin only covered by very few seismic lines
- Outline of basin is poorly defined due to limited seismic coverage. Expected to be in the order of a few thousand km^2
- Divided into a number of sub-basins separated by basement highs
- NNE-trending glacial-erosion-induced seafloor relief along the edge of the Ammassalik Basin and most likely reflect the prevailing structural orientation



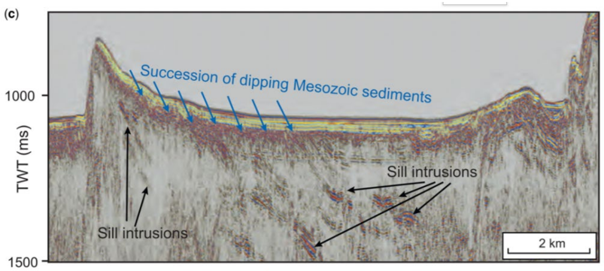


From Fyhn et al. (2021)

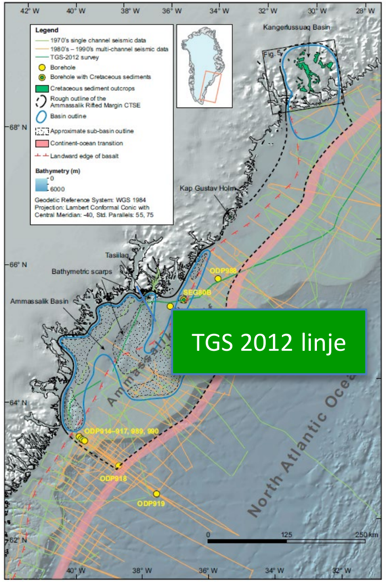
Ammassalik Basin
Geosection

- Seismic data suggest sediment thicknesses in excess of *c*. 4 km
- Gravity modelling suggests sediment thicknessess in the order of up to 7-10 km
- Possibly have been folded and experienced late Cenozoic inversion

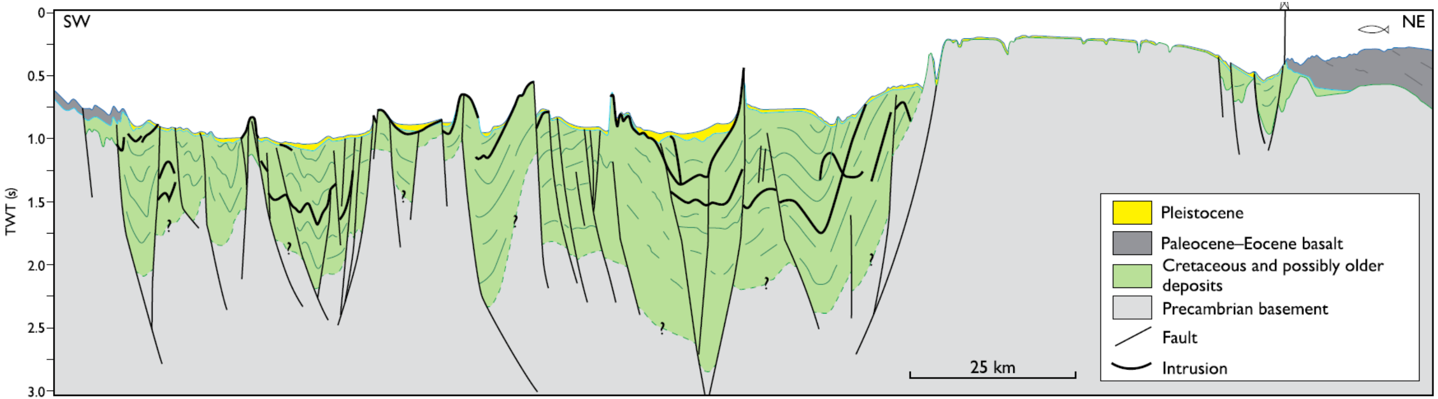
- Uplifted and eroded sometime after Eocene magmatism
- Several volcanic intrusions present in the sedimentary succession



From Gerlings et al. (2018)



From Fyhn et al. (2021)

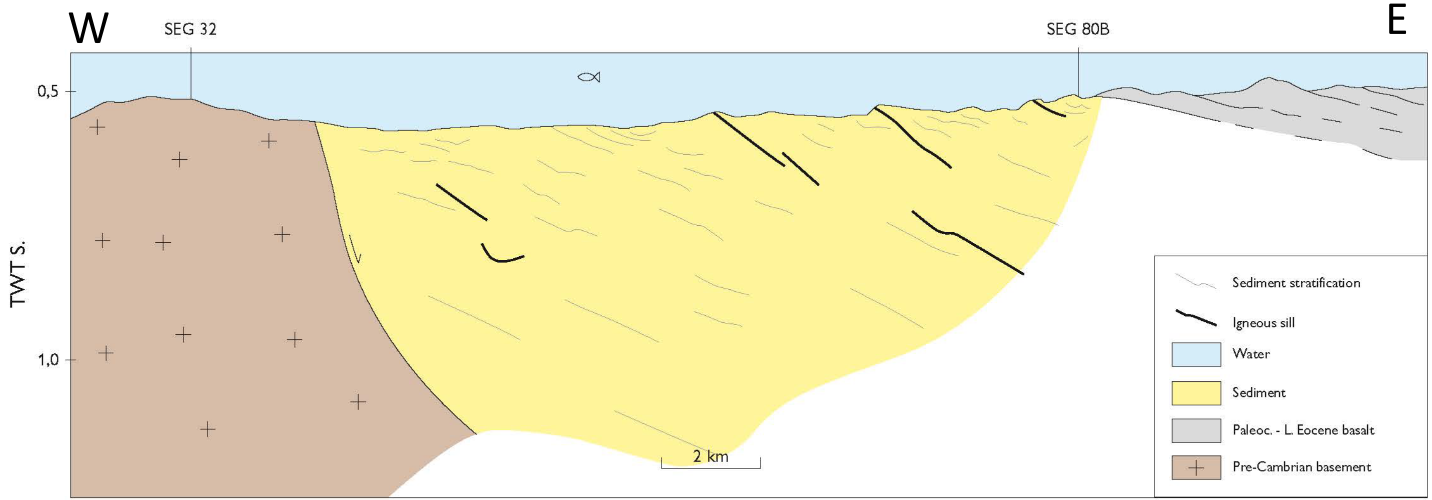


Geosection based on TGS 2012-10 seismic line. From Gerlings et al. (2018)

Ammassalik Basin

Site SEG80B core

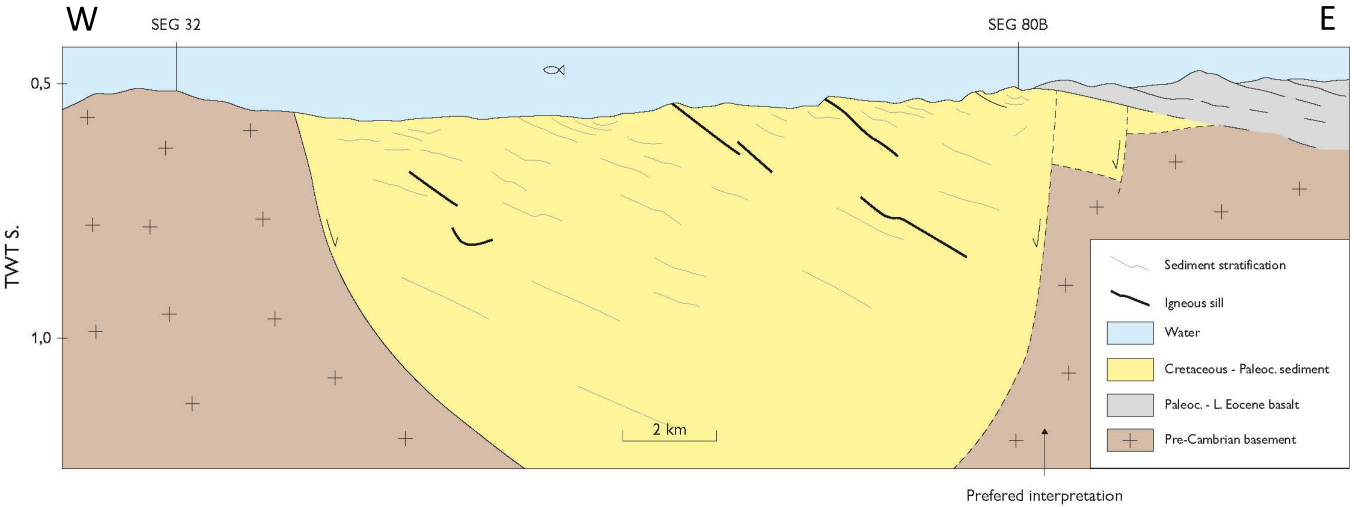
- Drillcore from site SEG80B (transect EG65) recovered poorly lithified sandstone with scattered organic fragments (65 cm)
- The site is inboard of the seaward dipping lava sequence and was probably never significantly affected by heating from the extrusives
- The bedding orientation recorded by seismic data indicates that the cored section represents some of the youngest parts of the basin fill
- Core recovery was low



Site SEG80B core

Ammassalik Basin
Site SEG 80B core

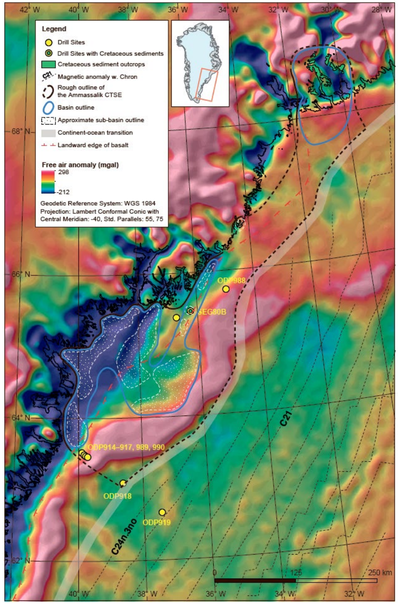
- Dinoflagellage cysts assemblage is dominated by an Albian flora, but dating is ambiguous since a few specimens of Maastrichtian to Danian and of Eocene and younger age occurs in the core
- The cored part of the basin was intruded by basalt sills suggesting an age older than the Eocene
- The youngest dinocyst of Eocene or younger age is therefore difficult to reconsile with the general interpretation of the basin. The youngest dinocysts are tentatively considered to reflect extant flora and are not age diagnostic
- TAI values of the Albian assemblage at Site SEG80B is 1-2 suggesting an uplift in the order of 1-2 km in the offshore areas. Eocene to recent dinocyst display no signs of burial
- The geotransect below depicts the preferred geological model for the basin and SEG 80B



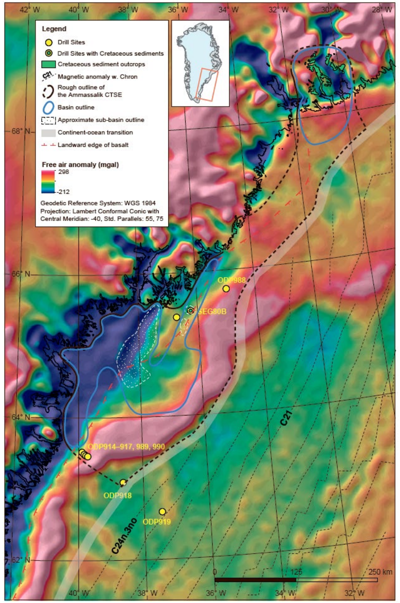
Basin Extent

- The extent of the Ammassalik Basin is very uncertain due to seismic coverage and overlying thick succession of Palaeogene basalts
- Below is shown three ”possible” outlines of the basin

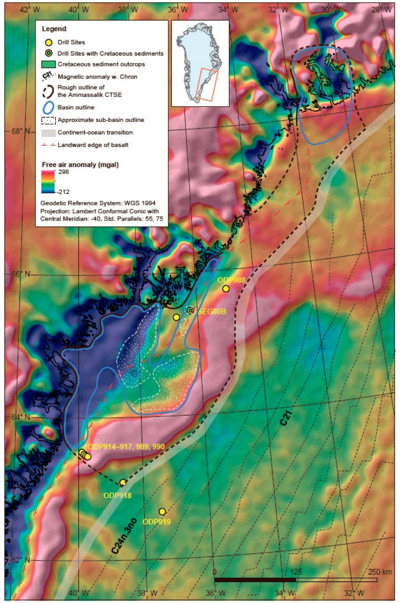
”Maxixmum” extent



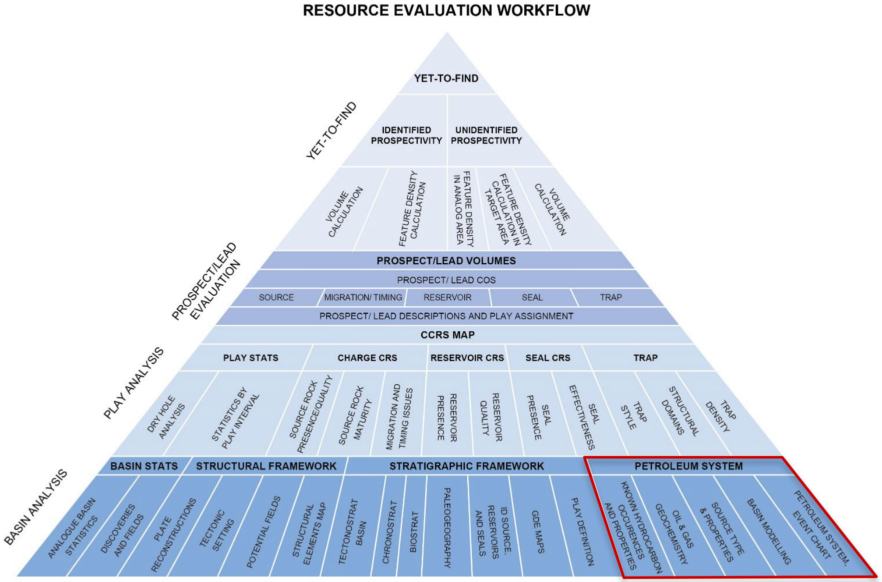
”Minimum” extent



”Most-likely” extent



AU6 – South-East Greenland
4. Petroleum Systems – Source Rock Assessment



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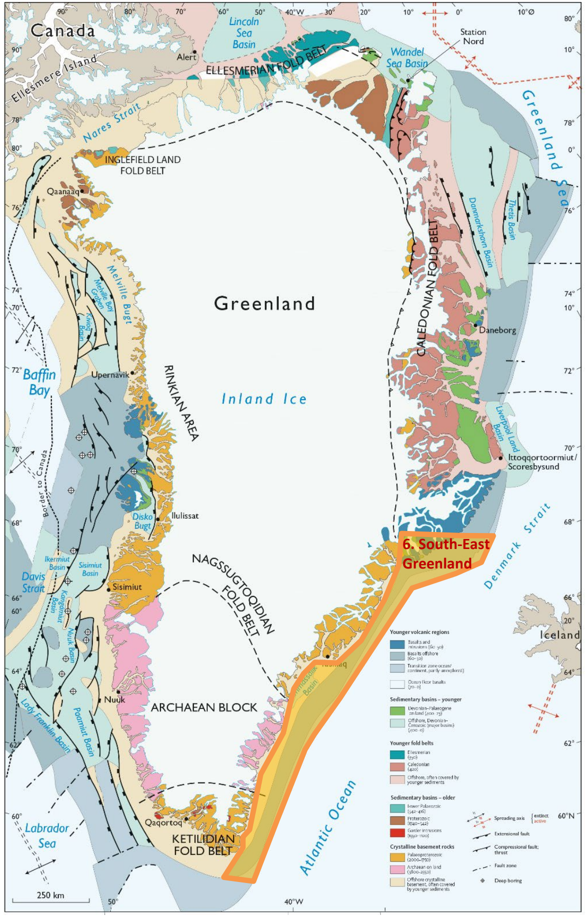
Regional Indications of Petroleum Systems

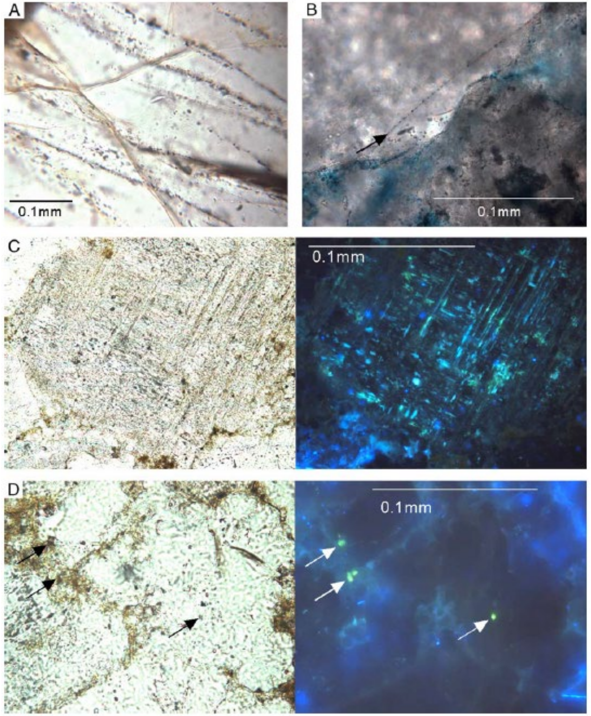


Petroleum seepage indicators:

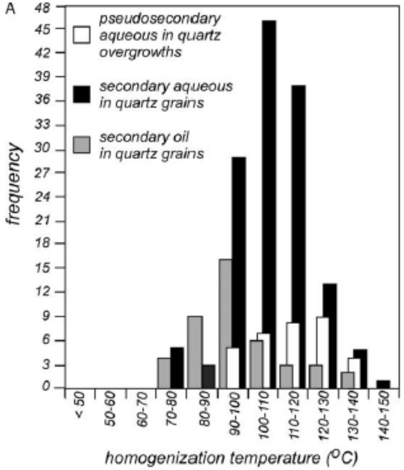
- No surface indications of petroleum seepage are known from the onshore areas of Assessment Unit 6 (AU6) (Christiansen & Bojesen-Koefoed 2021).
- Jonk et al. (2005) reports petroleum-bearing fluid inclusion in 3 samples collected from the Cretaceous-Palaeogene succession of the Kangerlussuaq Basin
- In 2011 Terraquest Ltd. carried out a combined magnetic, gravity and oil-seepage survey in part of the offshore area using a King Air 90 fixed-wing aircraft (Terraquest 2011).
  - The survey was solicited by TGS-NOPEC, which was itself responsible for reporting of the data collected.
  - It has not been possible to locate any report on oil seepage data from the survey. It is assumed that no useful data were collected.
- VBPR & TGS (2012, proprietary report) carried out a seabed sampling programme in the Ammassalik Basin:
  - Several gravity cores are held to show evidence of petroleum seepage
  - The presence of seepage can neither be unambiguously confirmed, nor ruled out.
- Synthetic Aperture Radar data suggest the presence of oil slicks in one offshore area within AU6 (Vis 2017)

Onshore Kangerlussuaq Basin

- Jonk et al. (2005) report petroleum-bearing fluid inclusions from three sandstone samples of the Cretaceous – Palaeogene succession of the Kangerlussuaq Basin.
- The samples include 2 fluvial sandstones (Aptian-Albian) and 1 injective sandstone intruded into the Palaeogene succession.
- Source inknown, suspected Aptian-age estuarine mudstones.
- Burial depth >3 km, temperature >108°C
- The data suggest that the sandstones may serve as migration conduits if adequately charged

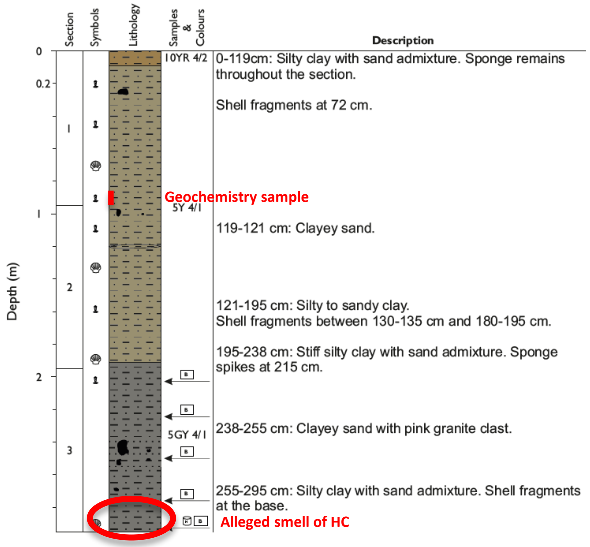


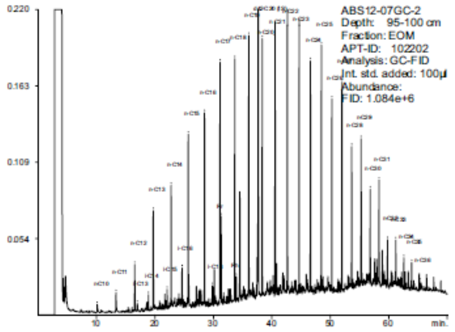
- Photomicrographs from Jonk et al. 2005:
  - A, B: aqueous fluid inclusions
  - C, D: petroleum-bearing fluid inclusions



VBPR – TGS Ammassalik seabed sampling

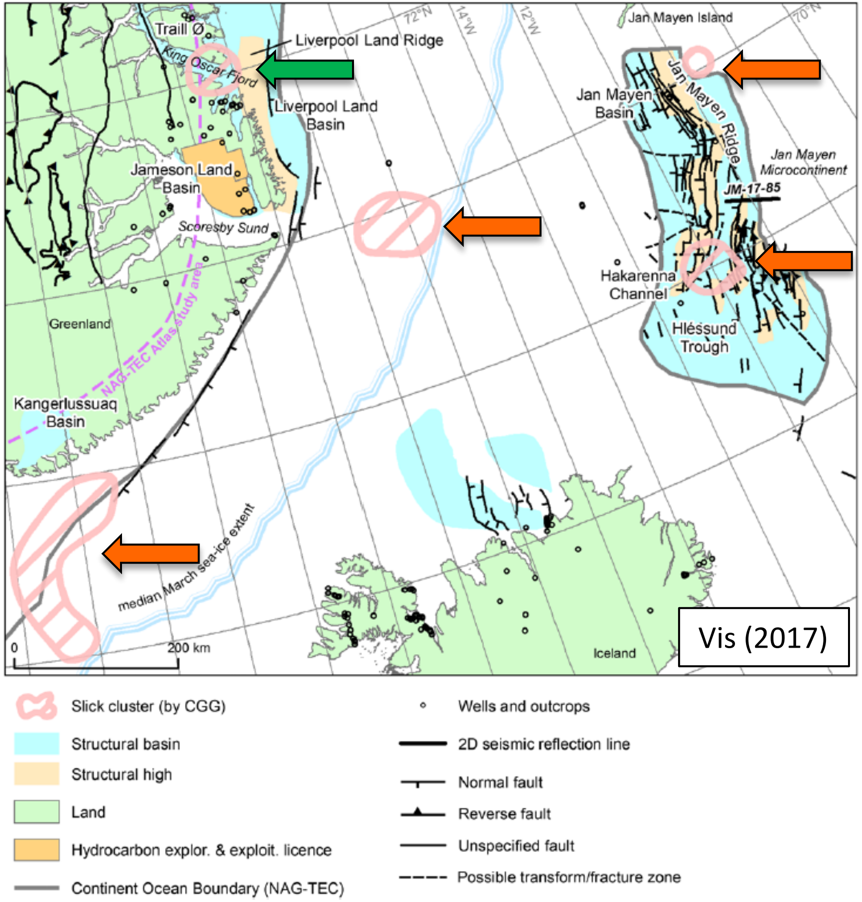
- Seabed sampling using gravity corer 2012
- 8 samples are held to show indications of petroleum seepage.
- One sample 07GC3 stands out by showing a well-developed distribution of n-alkanes
- Age-diagnostic NDR-data point to a Jurassic age
- This is interpreted to indicate seepage of Jurassic-age petroleum.





- Analytical quality is impeccable
- Interpretations may appear somewhat copious and would benefit from supporting evidence.
- The presence of seepage of thermogenic petroleum can neither be unambiguously confirmed, nor ruled out.
- If confirmed, the observations are important for assessment of the prospectivity of the region

Regional Offshore Indications of Petroleum System



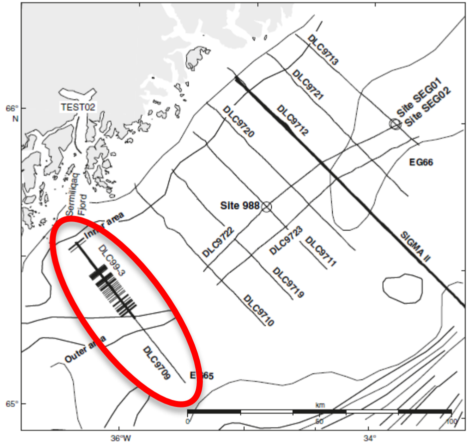
- SAR-data (Synthetic Aperture Radar) suggest the presence of oil slicks in 3 areas off East Greenland (Vis, 2017)

- Seepage in the King Oscar Fjord is inferred to originate from source rocks of Late Permian, Late Triassic–Early Jurassic and Late Jurassic age, as found in outcrops and boreholes in Jameson Land

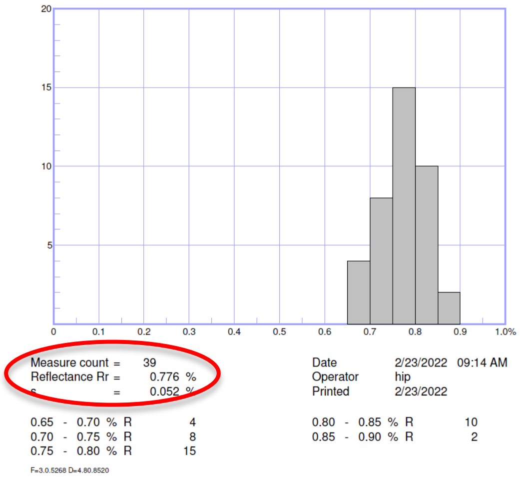
- Oil slicks observed seawards of the COB in East Greenland and the north of the Jan Mayen microcontinent may indicate the presence of yet unknown basins or Cenozoic source rocks

AODP leg 163X 1998: Site SEG80 core

- Drillcore from site SEG80 (transect EG65) recovered poorly lithified sandstone with scattered organic fragments.
- The site is outboard of the seaward dipping lava sequence and was probably never significantly affected by heating from the extrusives.
- Core recovery was low
- Dinoflagellage cysts indicate Albian age, but this dating is ambiguous since some younger palynomorphs seem to be present as well.
- Recent redating of existing and new palynological preparations suggest a Palaeocene or even Eocene age (Nøhr- Hansen 2022, written GEUS-internal communication)

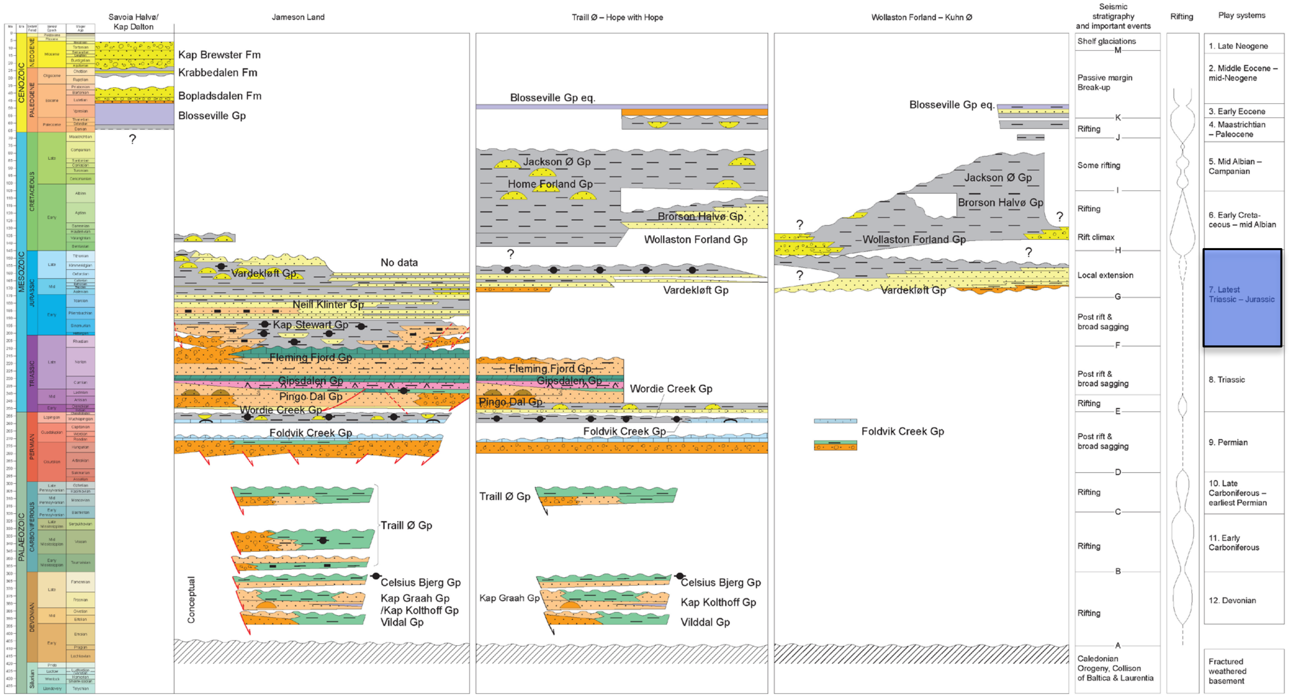


Site SEG80 core



- Vitrinite reflectance data indicate R_o=0.78%.
- Probably too high due to the highly oxidized nature of the organic particles
- TAI-values 1-2: thermally immature

Source Rocks



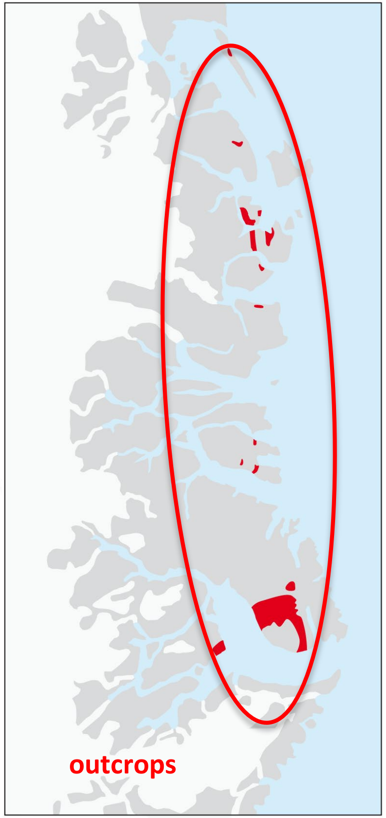
- **Play 7 Upper Jurassic-Lower Cretaceous** marine shale source rocks, Hareelv, Kap Leslie, Bernbjerg and Lindemans Bugt Formations

Play 7 Upper Jurassic – Lower Cretaceous

- Hareelv, Kap Leslie, Bernbjerg and Lindemans Bugt Formations
- Upper Jurassic, Oxfordian – Ryazanian
- Equivalents of the Kimmeridge Clay Formation *sensu lato*
- Dark-grey to black marine mudstones, often with gravity-flow sandstones, thickness 200–600 m
- Chemical characteristics very similar to those of various KCF-equivalents in NW-Europe
- TOC up to +10% Hydrogen Index variable, up to +400

Parametres for modelling:

- **TOC: 5%**
- **HI: 300**
- **Thickness: 15 0m**

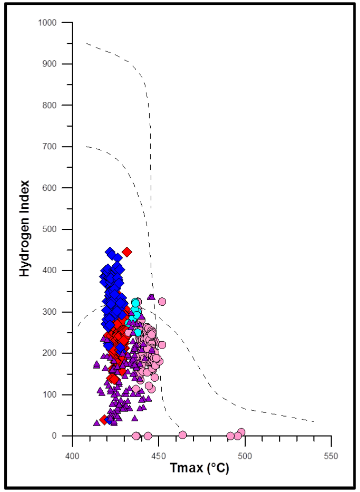


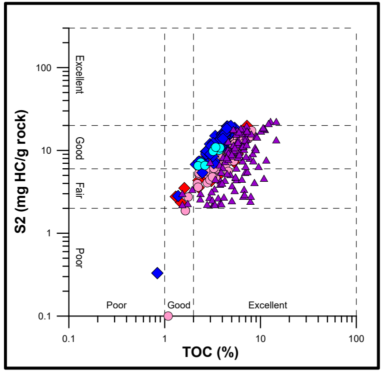
Pros

- **Excellent source rock, thick**
- **Rich, oilprone, well documented**
- **Widely distributed in the North Atlantic realm in general**

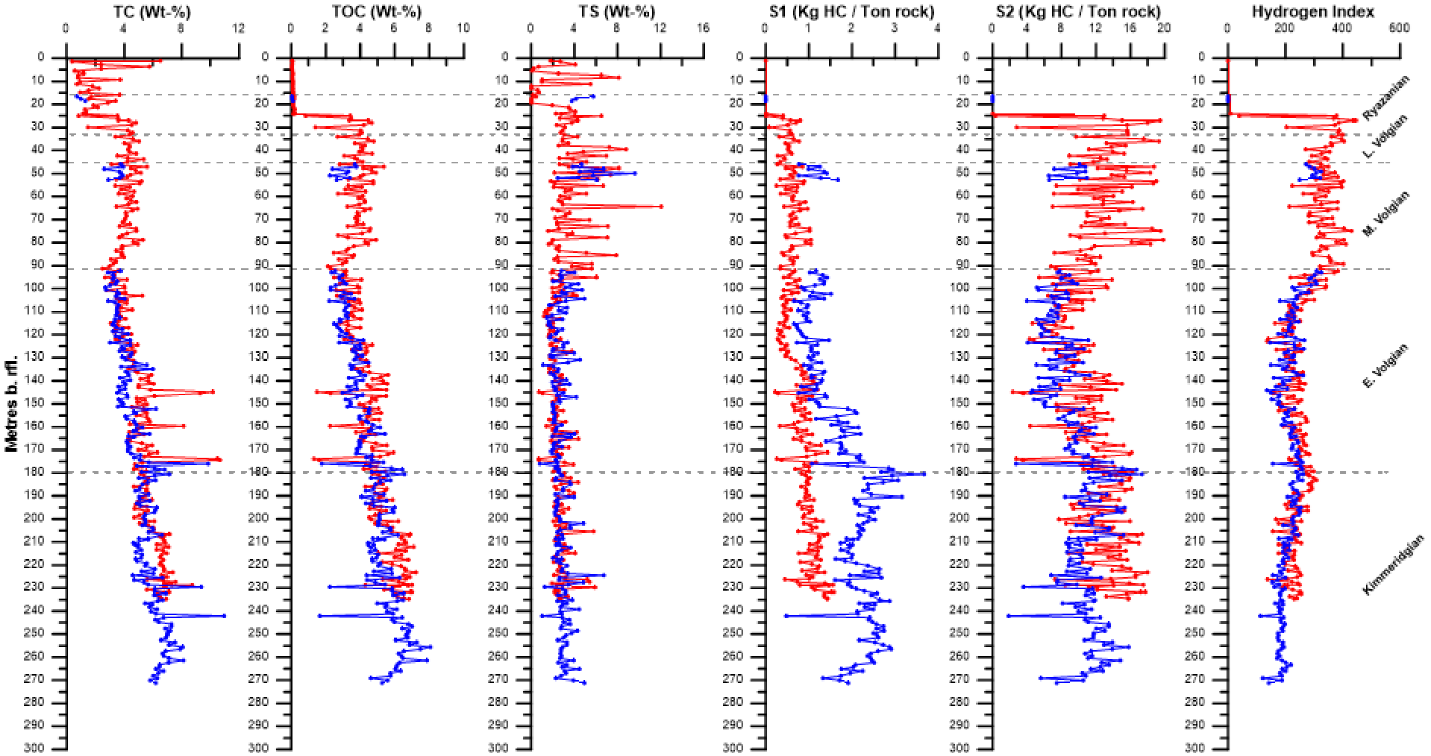
Cons

- **Unknown/not documented in AU6**





Play 7 Upper Jurassic – Lower Cretaceous: organic geochemistry in two fully cored boreholes

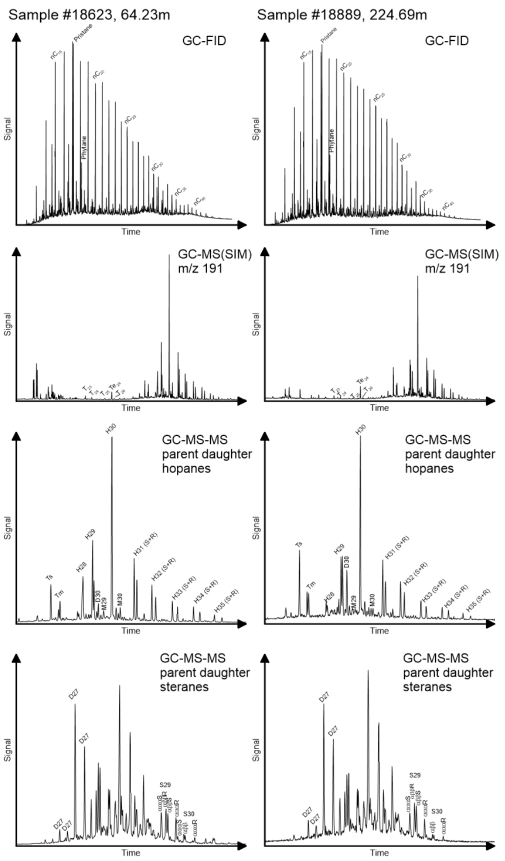


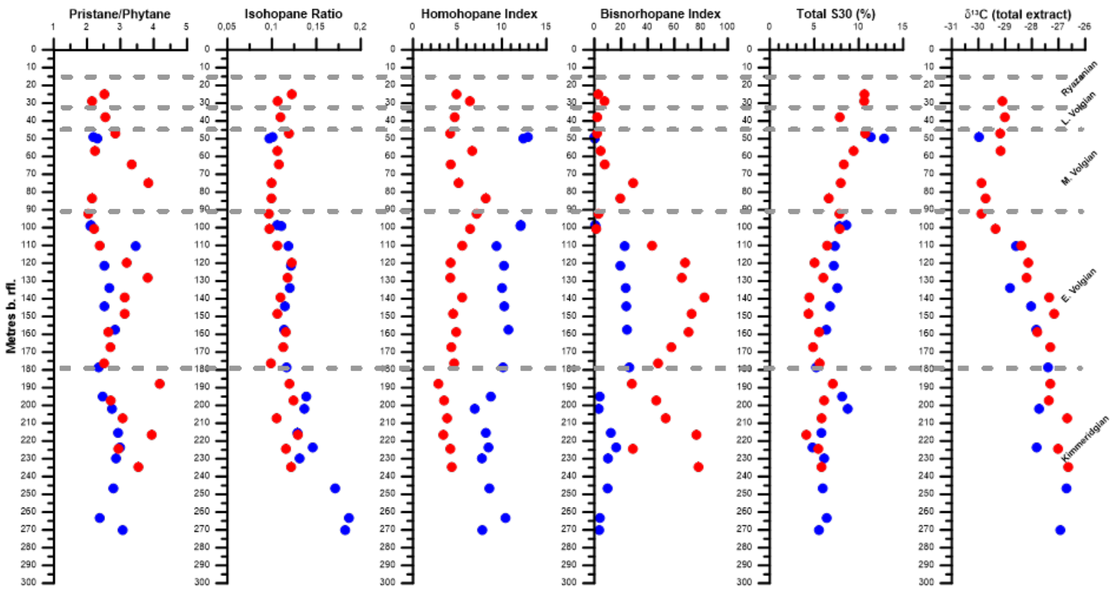
Red: Rødryggen-1
Blue: Brorson Halvø-1
Bojesen-Koefoed et al. *in press*

Key references:

Christiansen et al. (1992)
Requejo et al. (1989)
Surlyk (1987, 2003),
Surlyk & Noe-Nygaard (2001)
Strogen et al. (2005)
Bojesen-Koefoed et al. (2018)
Ineson & Bojesen-Koefoed (2018)

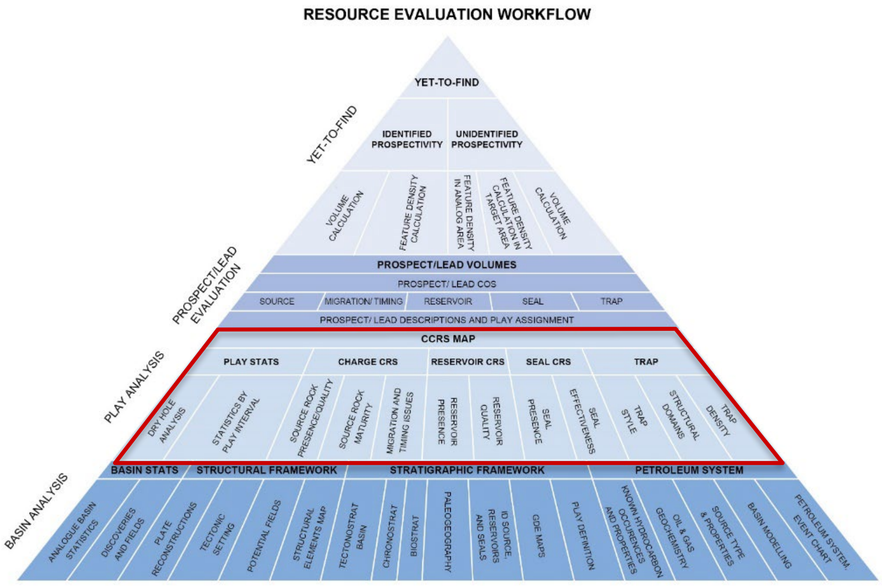
Play 7 Upper Jurassic – Lower Cretaceous: biomarker data





- Pristane/phytane <3 (mostly <2)
- Tricyclic triterpanes moderate
- Slight predominance of C27 steranes, presence of C30 steranes
- Occasionally high levels of 28,30-bisnorhopane

AU6 – South-East Greenland
5. Play Analysis



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Standardised risking schemes

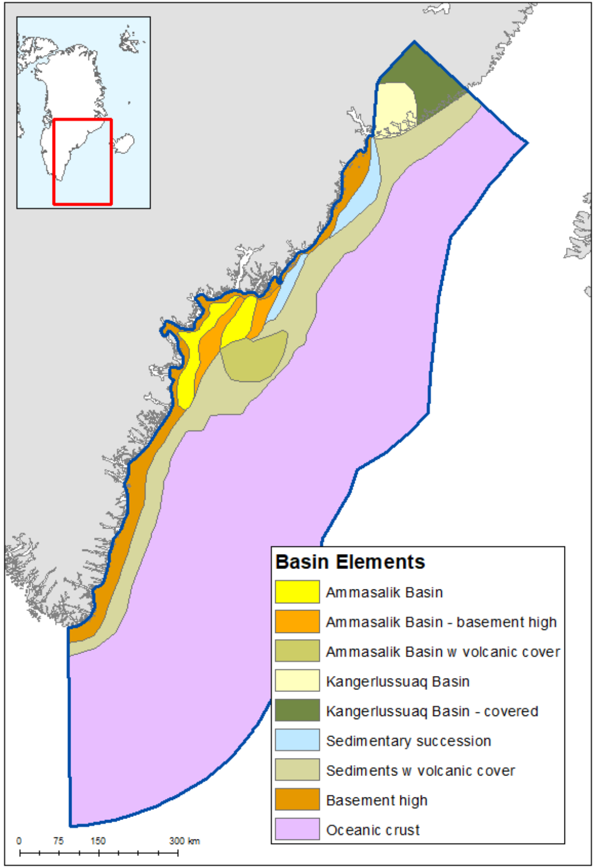
- The risking schemes used in Assessment Units 1–5 cannot be used in AU6 (southern East Greenland) due to the very low data density. Risking therefore heavily relies on knowledge from the conjugate margin, i.e. West of Shetland area, where exploration activity has been intense.

- **Risking is not carried out on individual plays but only on general, overall level.**

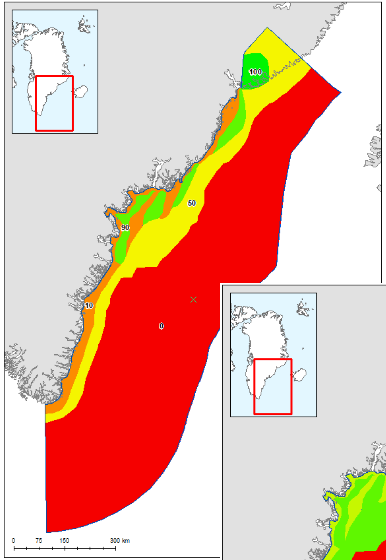
- Risking is based on the following assumptions:
  - Reservoir presence: Presence of at least one effective reservoir unit in the subsurface with a possible connection to source
  - Reservoir effectiveness: Anticipated burial of possible reservoir unit corrected for uplift and possibility of degrading intrusions
  - Top seal effectiveness : Overburden thickness, modified in areas with large amount of uplift
  - Trap presence: Possibility to acquire high-quality data
  - Charge: Outcrop data or knowledge from conjugate margin (possible presence of uppermost Jurassic source)

- Total risk is defined by Reservoir Presence, Reservoir Effectiveness, Top Seal, Trap Presence and Charge.
  Phase Risk and Timing are NOT assessed

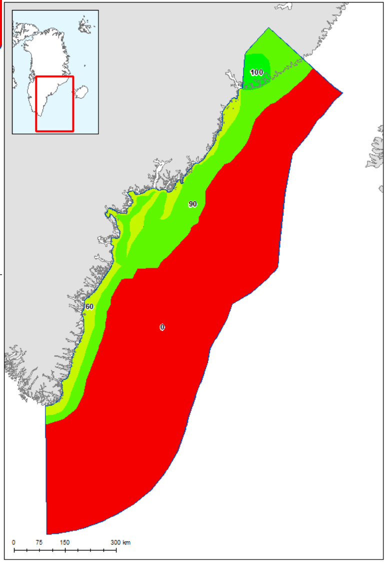
Basin Elements



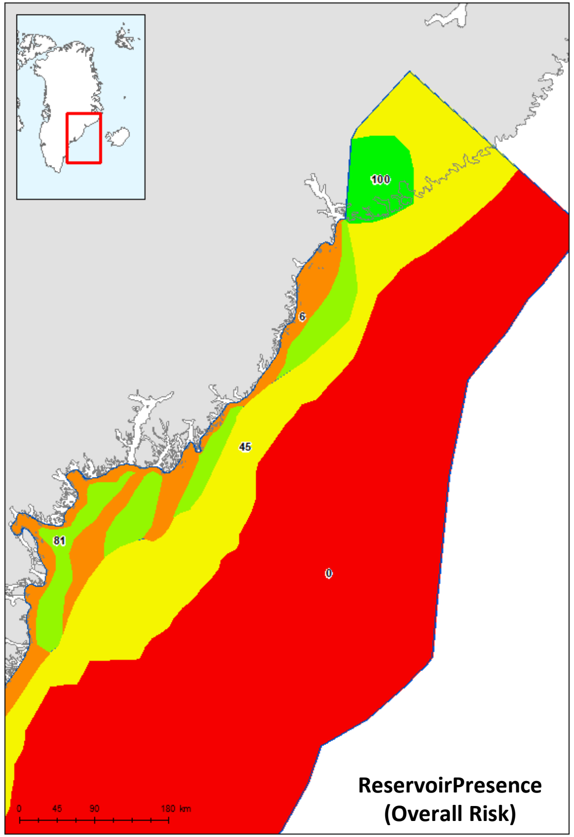
AU6 – Reservoir Presence



ReservoirPresence
(Play Risk)



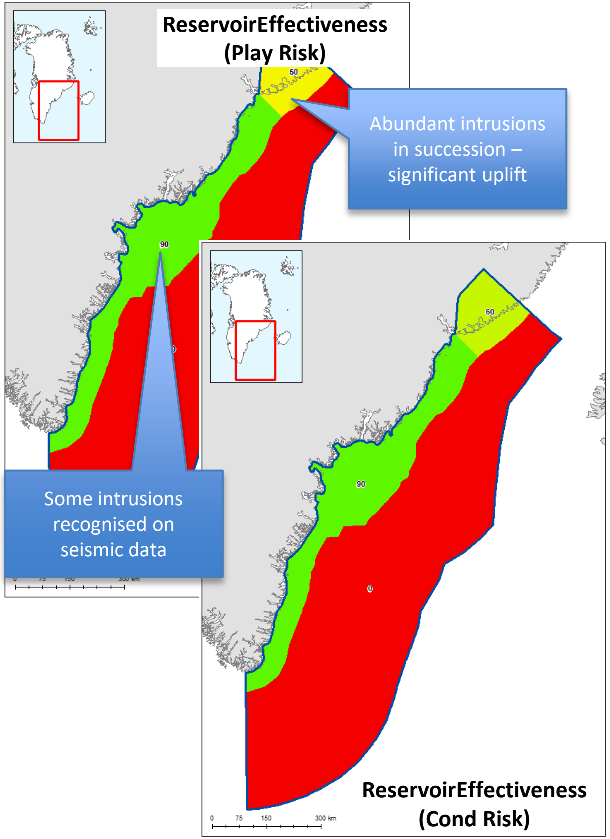
ReservoirPresence
(Cond Risk)

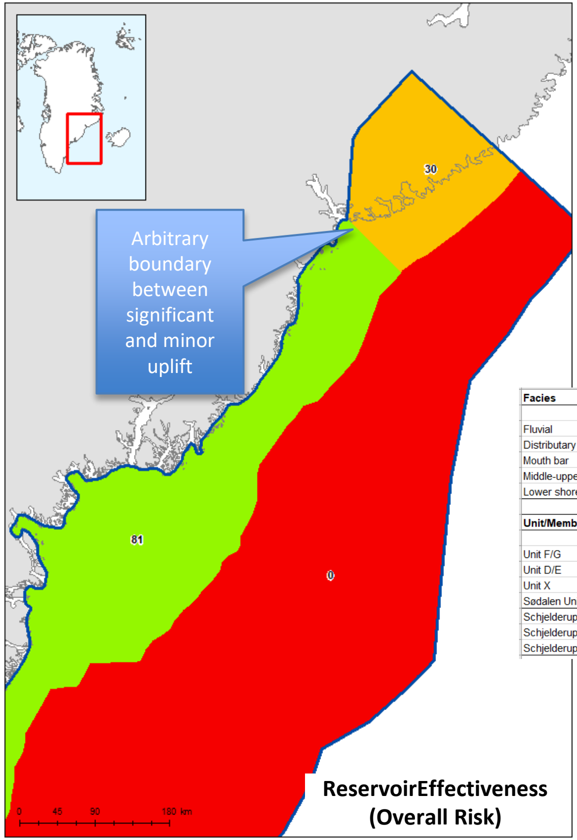


ReservoirPresence
(Overall Risk)

	Play	Cond	Overall
Documented in outcrop	100	100	100
Thick succession mapped on seismic data or proximity to outcrop	90	90	81
Unknown – lack of data	70	90	63
No data – below thick volcanic cover	50	90	45
Assumed eroded on highs or otherwise unlikely	10	60	6
Not present (Eroded/Oceanic crust)	0	0	0

AU6 – Reservoir Effectiveness



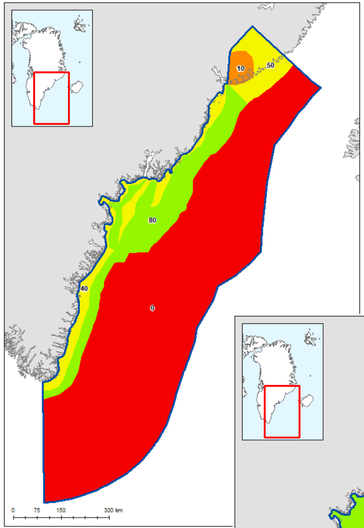


Depth	Play Risk	Cond Risk
<3km (<90°C)	100	90
3-4 km (90-120°C) or documented by outcrop studies	90	90
4-5 km (120-150°C)	60	70
5-6 km (>150°C and documented diagenesis)	50	60
>6 km (>150°C)	10	50
Areas with intrusions in play	50	60

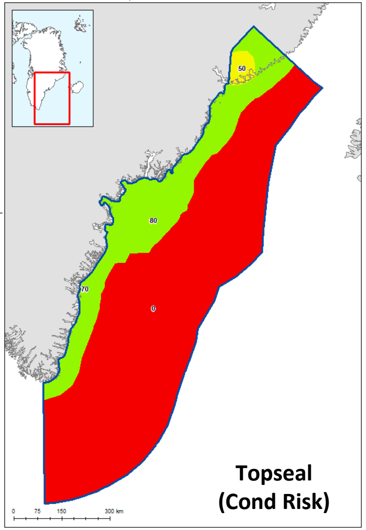
Facies	n	Porosity (%)			Permeability (mD)		
		Average	min	max	Average	min	max
Fluvial	34	6,62	2,65	16,17	9,23	0,02	81,67
Distributary channel	9	3,82	0,95	7,32	1,15	0,01	6,98
Mouth bar	1	6,49	6,49	6,49	0,08	0,08	0,08
Middle-upper shoreface	17	4,61	0,84	8,68	0,38	0,02	2,53
Lower shoreface	8	4,42	1,63	11,65	0,84	0,02	6,96

Unit/Member	n	Porosity (%)			Permeability (mD)		
		Average	Min	Max	Average	Min	Max
Unit F/G	11	0,79	0,22	1,96	0,04	0,01	0,34
Unit D/E	7	0,95	0,21	1,76	0,01	2,83	1,06
Unit X	12	4,42	0,84	8,68	0,02	2,73	2,53
Sødalen Unit	25	4,23	0,95	11,65	0,01	2,71	6,98
Schjelderup Mb.	34	6,62	2,65	16,17	0,02	2,66	81,67
Schjelderup Mb. Basin centre	13	4,07	2,65	5,79	0,02	2,67	19,23
Schjelderup Mb. Basin margin	21	8,24	2,68	16,17	0,04	2,66	81,67

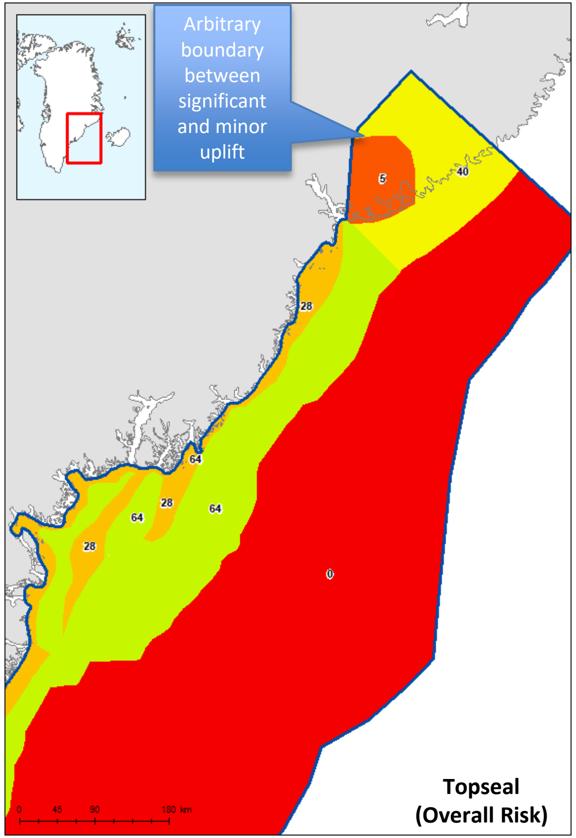
AU6 –Top Seal Risk



Topseal (Play Risk)



Topseal (Cond Risk)



Topseal (Overall Risk)

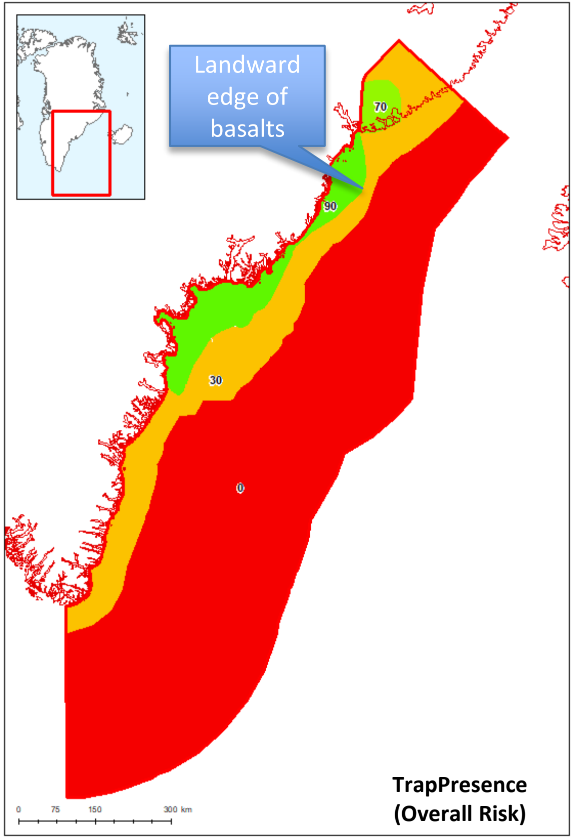
Thickness of overburden	Play Risk	Cond Risk	Overall Risk
Areas with >800 m overburden, proven	100	80	80
Areas with >800 m overburden, unproven	80	80	64
Areas with >2 km uplift*	50	80	40
Areas with <800 m overburden, unproven **	40	70	28
Only internal seal present (no seal towards overlying play)	30	50	15
Topographic risk ***	10	50	5
Outside play presence area	0	0	0

* Top seal breach in Barents Sea is caused mainly by tectonic reactivation of faults and fault dilation associated with deglaciation processes and is likely to have facilitated widespread hydrocarbon leakage from structural traps (Edmundsen *et al*. 2020, Petroleum Geoscience).

** Onshore AU5, all play areas with present overburden <800 m have been uplifted more than approximately 2000 m. Original overburden thickness is everywhere >800 m, and top seal risk is therefore entirely governed by uplift.

*** Onshore areas where the play is cut by topography

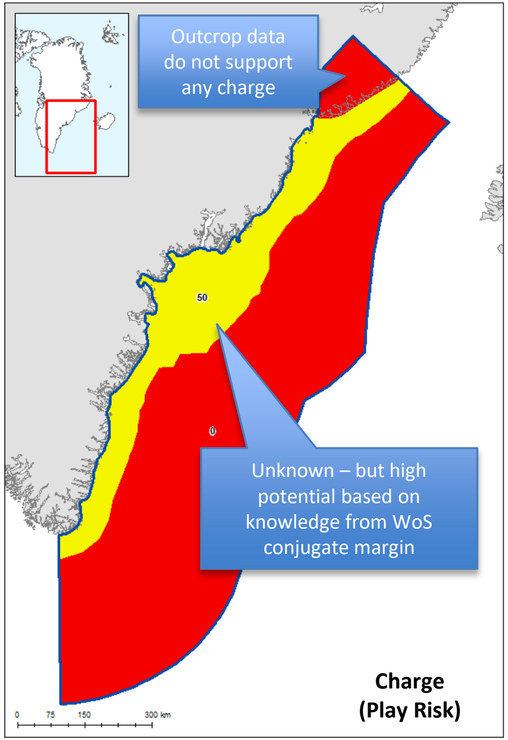
AU6 – Trap Presence

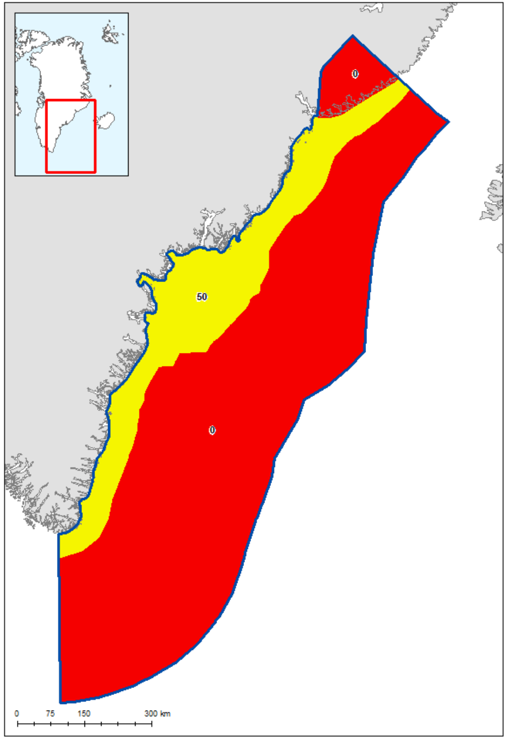


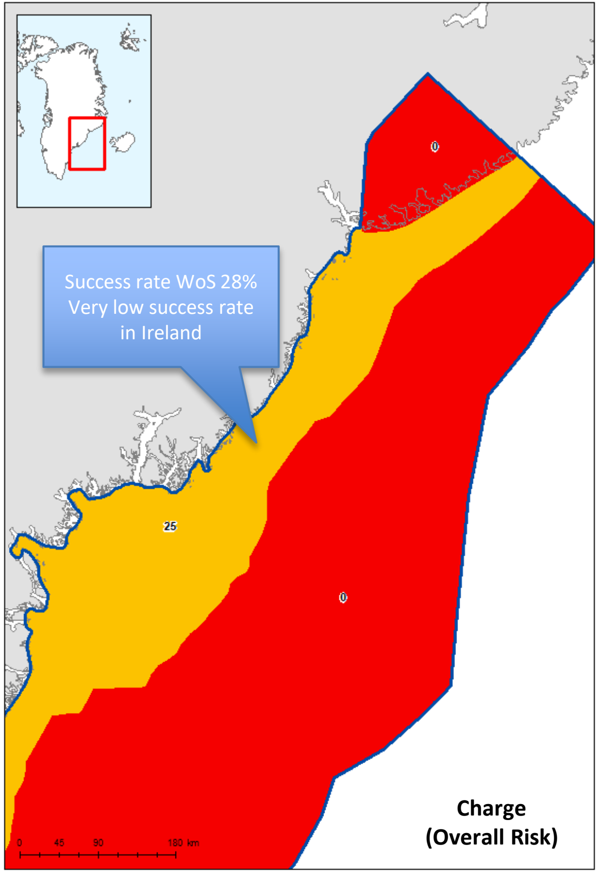
- The geological and structural evolution of the region indicates that viable exploration opportunities will exist independently of their present recognition that to a large extent reflects seismic density and quality
- The present seismic density and quality reflects the historic opportunities to acquire seismic (and other geophysical) data in the region. New data and mapping could result in significantly higher quality of data and thus better recognition of traps
- Trap is only risked on repeatability (Conditional Risk)

Trap Presence	Play Risk	Conditional Risk	Overall Risk
Areas where seismic acquisition could produce high-quality data	100	90	90
Areas where 2D seismic acquisition or mapping could provide sufficient data	100	70	70
Areas covered by a thick volcanic succession preventing imaging of deeper successions	100	30	30
Oceanic crust or play not present	0	0	0

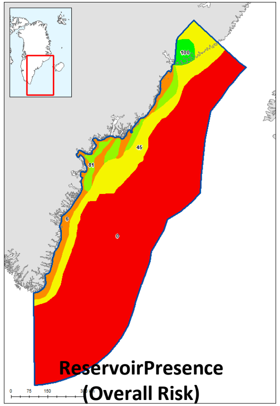
AU6 – Charge

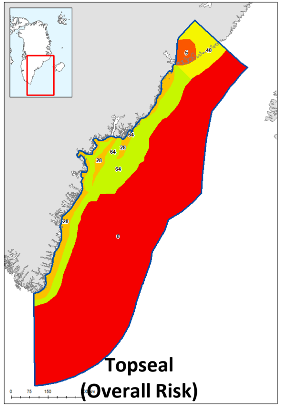

Outcrop data do not support any charge
50
0
Unknown – but high potential based on knowledge from WoS conjugate margin
0 75 150 300 km
Charge (Play Risk)

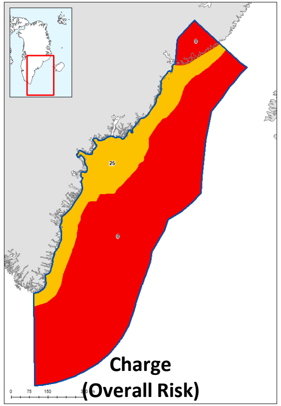

0
50
0
0 75 150 300 km

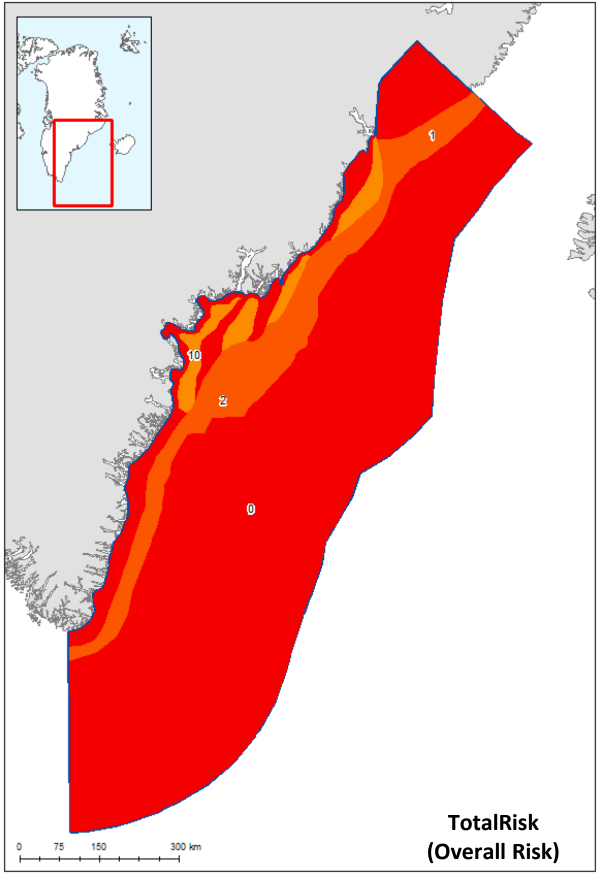

0
Success rate WoS 28% Very low success rate in Ireland
25
0
0 45 90 180 km
Charge (Overall Risk)

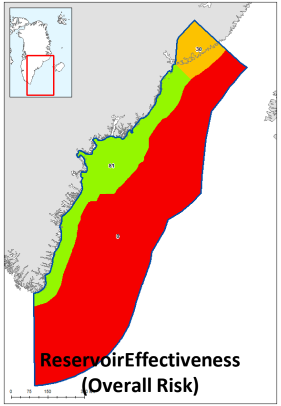
AU6 – Overall Risk Maps – Total Risk

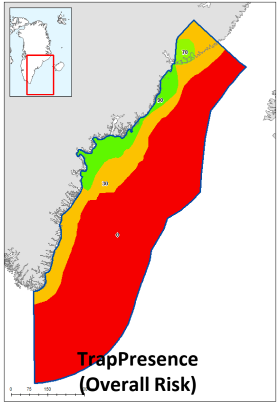












AU6 – South-East Greenland
6. Analogue Petroleum Basins

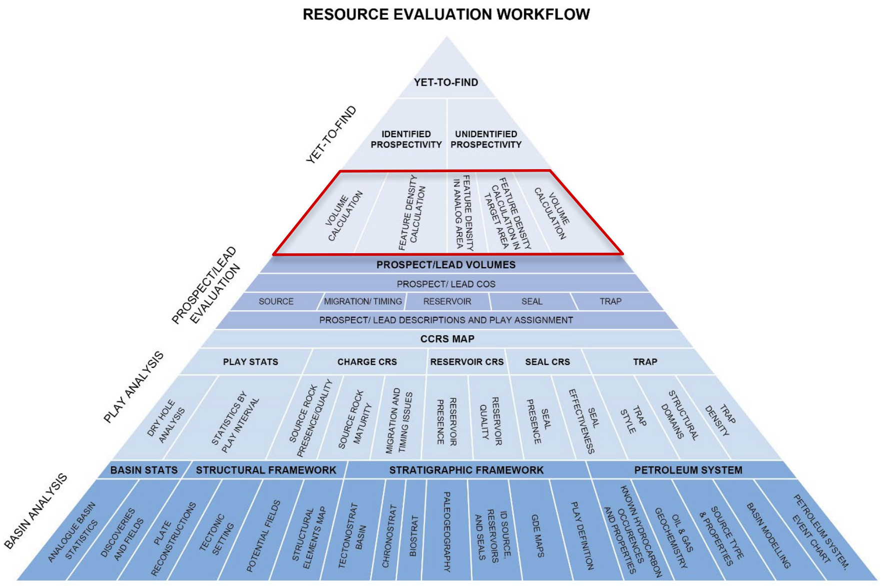


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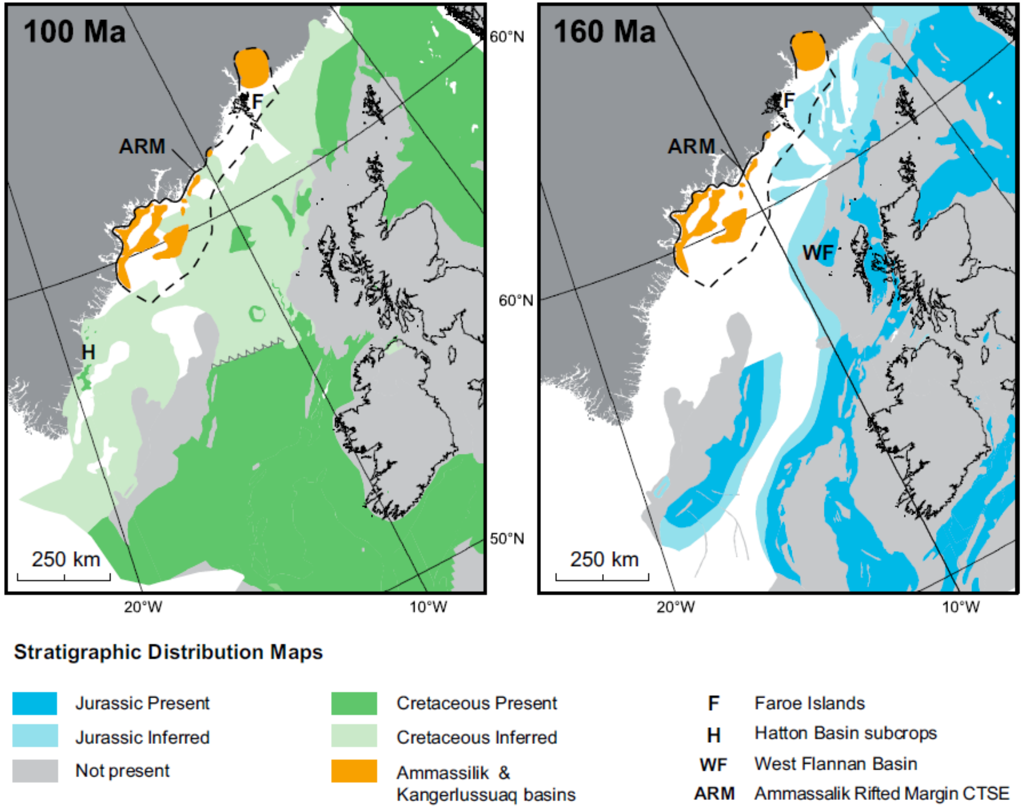
Plate Reconstructions

- No access to IHS or similar databases so evaluation is based on publications and www
- Most obvious analogs are West of Shetland Basin and offshore Ireland basins

Late Cretaceous and Late Jurassic plate reconstructions showing inferred and proven sedimentary basins

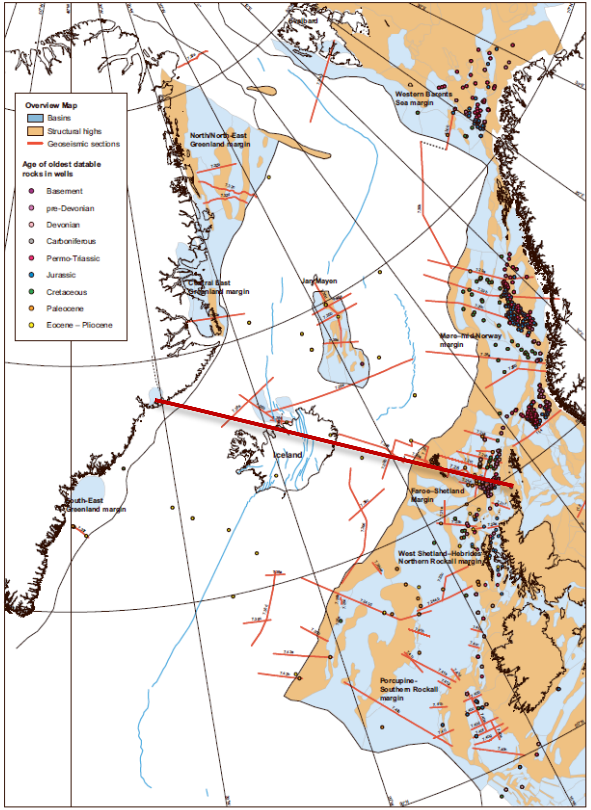


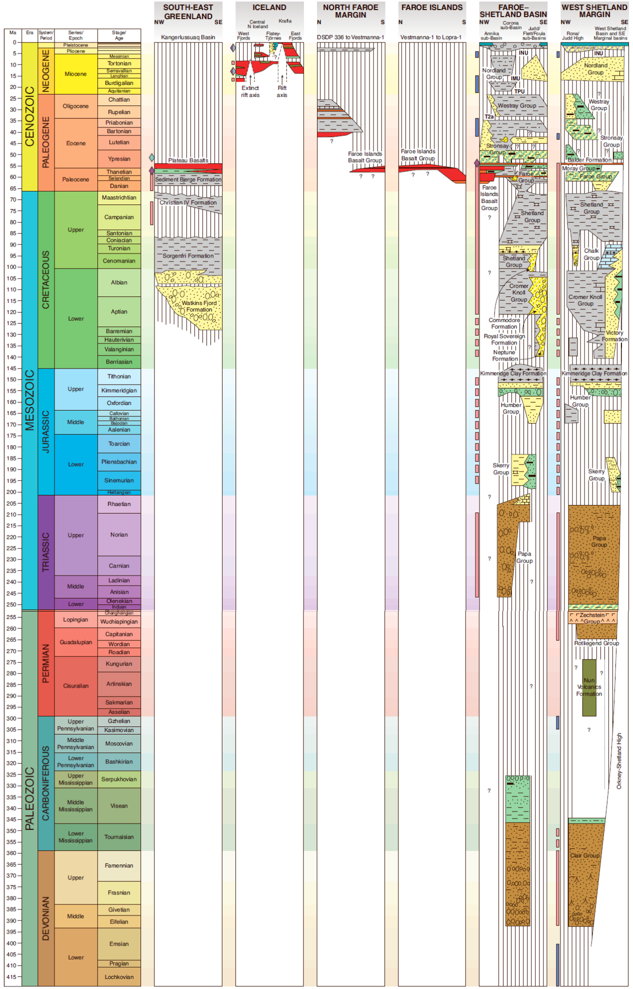
From Gerlings et al. 2018

Analogue Basins on the Conjugate Margin

West of Shetland Basin

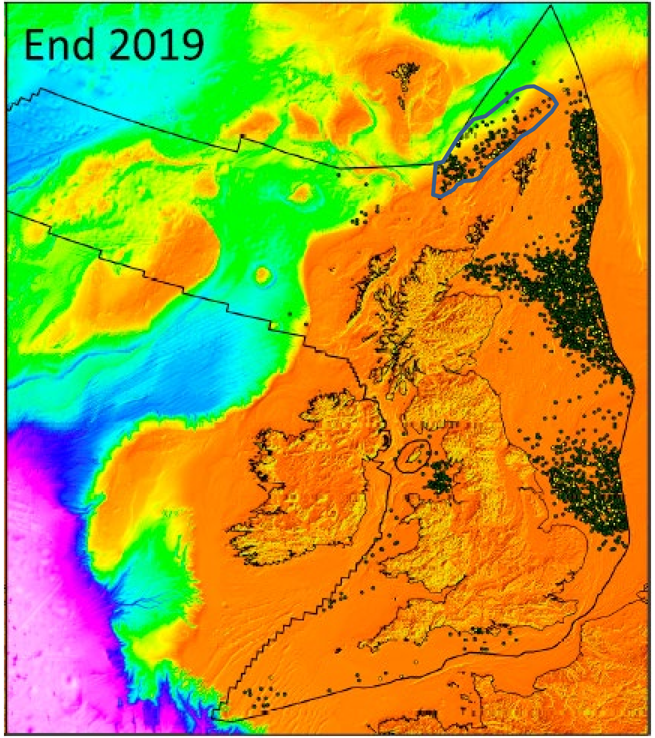
- No indications for Jurassic or older basins in SE Greenland, but cannot be excluded
- Devonian – Cenozoic stratigraphy on conjugate margin in Faroe-Shetland Basin and West Shetland Margin





From Stoker et al, 2014

West of Shetland Analogue

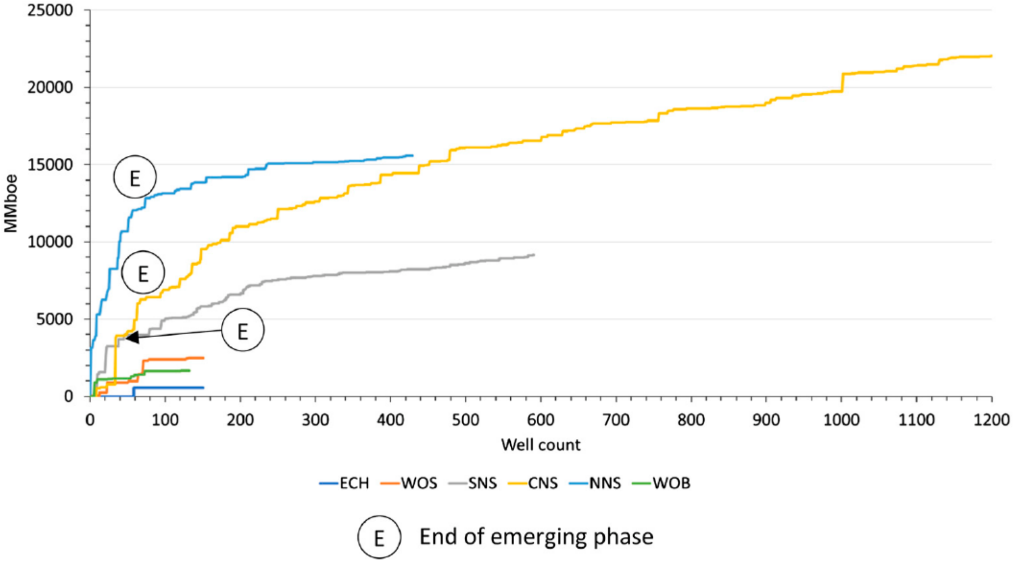


Exploration and appraisal wells on the UKCS by the end of 2019. Exploration wells are shown in green, appraisal wells in yellow. Coloured bathymetry. From Goffey et al 2020

- Total commercial resources: 2.6 Bboe
- Gross commercial discoveries: 13 wells
- Total technical resources: 2.4 Bboe
- Gross technical discoveries: 29 wells
- No of exploration wells: 151
- Commercial success rate: 8.6%
- Technical success rate: 28%
- Average discovery size: 119 MMboe recoverable
- Size of basin: ~30,000km^2
- 5 wells/1000 km^2
- Area yield: 0.167 Mboe/km^2

From Rouillard et al., 2020

West of Shetland Analogue



Cumulative commercial resource discovered by well count for each of the UKCS areas. The approximate ends of the emerging phase has been annotated for the Central North Sea (CNS), Northern North Sea (NNS) and Southern North Sea (SNS). ECH, English Channel; **WOS, West of Shetland**; WOB, West of Britain. Source: Westwood Global Energy, Atlas Service. From Rouillard et al. (2020)

- An almost flat creaming curve for WoS (commercial discoveries)
- The first commercial oil production from fractured basement at the Lancaster Field commenced in 2019 through an early production scheme (EPS), developing 37 MMbbl of reserves. Should the EPS be successful, this could unlock substantial further resources from discoveries in the play

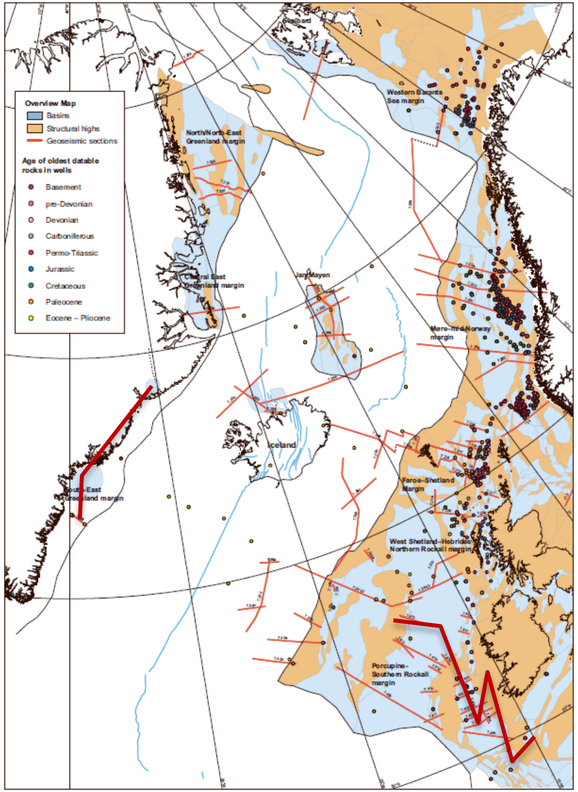
West of Shetland Analogue

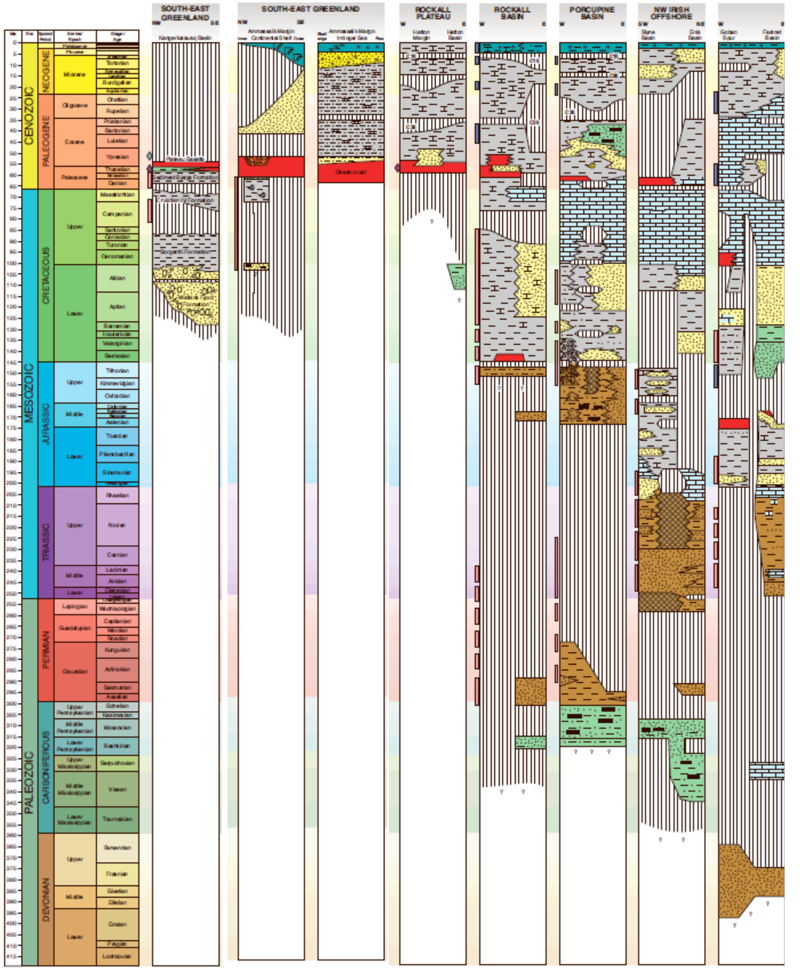
- The Greater **Clair** accumulation (1977: **870 MMboe**) is the largest field in the basin
- No commercial discoveries above 100 MMboe have been made since **Schiehallion** (well 204/20-1: c. **800 MMboe**) in 1993
- 80 wells have been drilled since Schiehallion but only five small commercial discoveries have been made, at **Loyal** (well 204/20-3: **7 MMboe**), **Tormore** (well 205/5a-1: **14 MMboe**), **Glenlivet** (well 204/30a-2: **48 MMboe**), **Alligin** (well 204/ 19-6**: 20 MMboe**) and **Edradour** (well 206/4-2: **38 MMboe**), leading to an average commercial success rate of 5% and an almost flat creaming curve for the area
- The first commercial oil production from fractured basement at the **Lancaster Field** is scheduled to commence in 2019 through an early production scheme (EPS), developing **37 MMbbl** of reserves. Should the EPS be successful, this could unlock substantial further resources from discoveries in the play
- There are c**. 2.4 Bboe in 29 undeveloped discoveries**, of which around **74% or 1.8 Bboe is in just nine discoveries**. These include Hurricane Energy's basement discoveries, **Lancaster, Halifax** (205/23-3A), **Lincoln** (205/26b-12) and **Whirlwind** (205/21a-5) (**992 MMboe, 41%**), the two Eocene–Paleocene accumulations of **Rosebank** (213/27-1Z) and **Cambo** (204/10-1) (**514 MMboe, 21%**), and the northern gas discoveries **Cragganmore** (208/17-3), **Bunnehaven** (214/9-1) and **Tobermory** (214/4-1) (**292 MMboe, 12%**)

Analogue Basins on the Conjugate Margin

NE Irish Offshore basins

- No indications for Jurassic or older basins in SE Greenland, but cannot be excluded
- Devonian – Cenozoic stratigraphy on conjugate margin in Rockall Basin, Porcupine Basin and NE Irish offshore basins



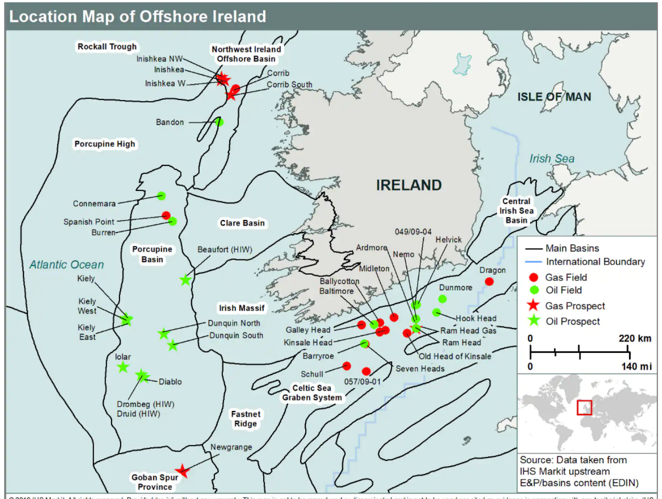


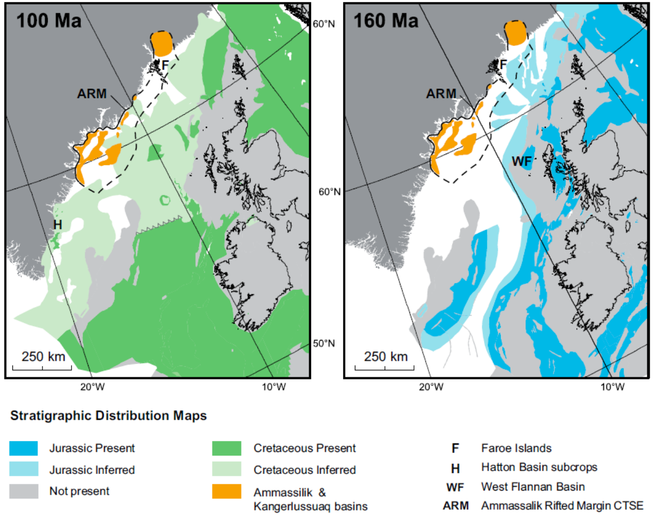
From Stoker et al, 2014

Offshore Ireland Analogue

- Irish basins are only partly explored
- 160 exploration wells have been completed successfully
- Four commercial gas discoveries all in the Celtic Sea Basin
- First discovery as Kinsale Head in the Celtic Sea in 1971 (recoverable reserves 1.65 TCF (270 MMboe)
- One commercial gas discovery in offshore NW Ireland (Corrib, reserves ~ 1 TCF (172 Mmboe))
- Three uncommercial discoveries in the Porcupine Basin
- In addition, there is have been approximately 11 oil, gas and condensate discoveries but none have yet led to commercial developments
- That is 5 commercial and 14 uncommercial discoveries, total of 19 discoveries
- Commercial success rate: 3%
- Technical success rate: 12%

- No info on size of basins, total discovered and commercial volumes, area yield, plays, ect



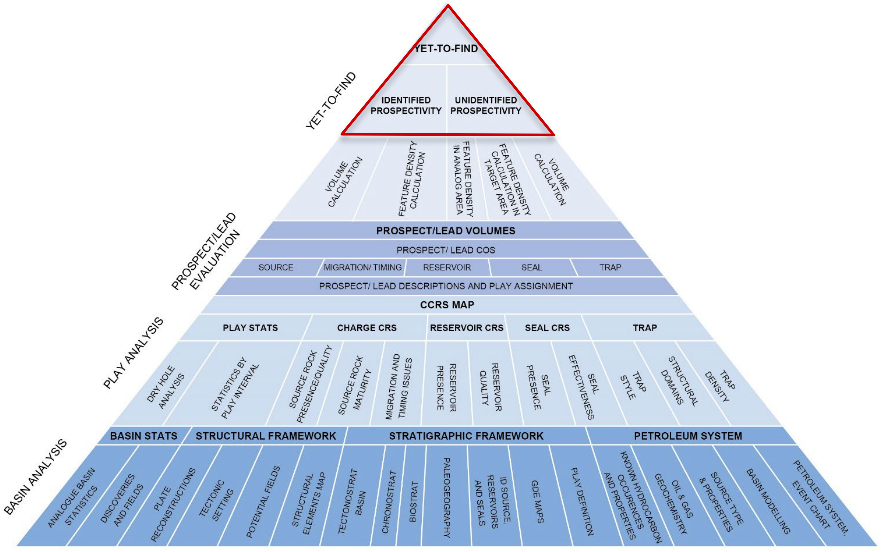


From Gerlings et al. 2018

AU6 – South-East Greenland

7. Yet-to-Find Assessment

RESOURCE EVALUATION WORKFLOW



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GOVERNMENT OF GREENLAND

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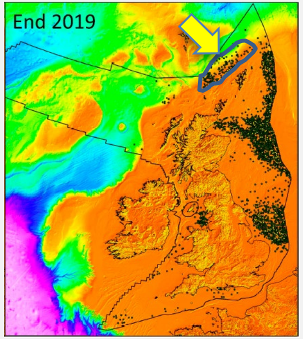
AU6 – Mean Risked Recoverable

West of Shetland



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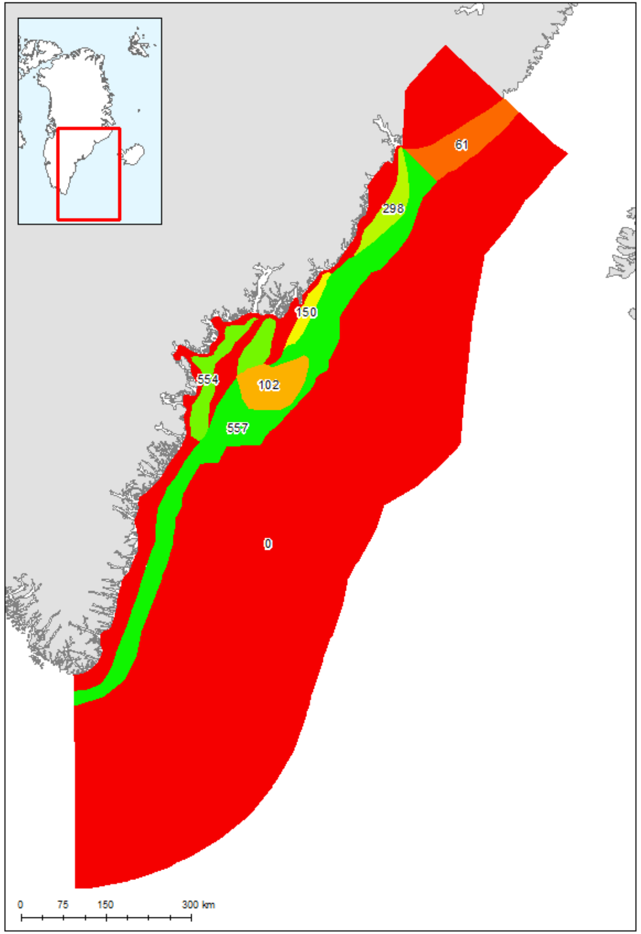
- **Average unrisked discovery size: 119 MMBOE recoverable**
- Size of basin: ~30,000 km^2
- **5 wells/1000 km^2**
- Area yield: 0.167 MMBOE/km^2

Due to the scarcity of data and thus mapped features in Assessment Unit 6 the Yet-to-Find assessment relies on analogue data from the closest exploration areas on the North-East Atlantic conjugate margin, i.e. West of Shetland and the Irish offshore basins (see presentation on Analogue Petroleum Basins).

West of Shetland region (~30,000 km^2) is regarded to be almost fully explored by now.

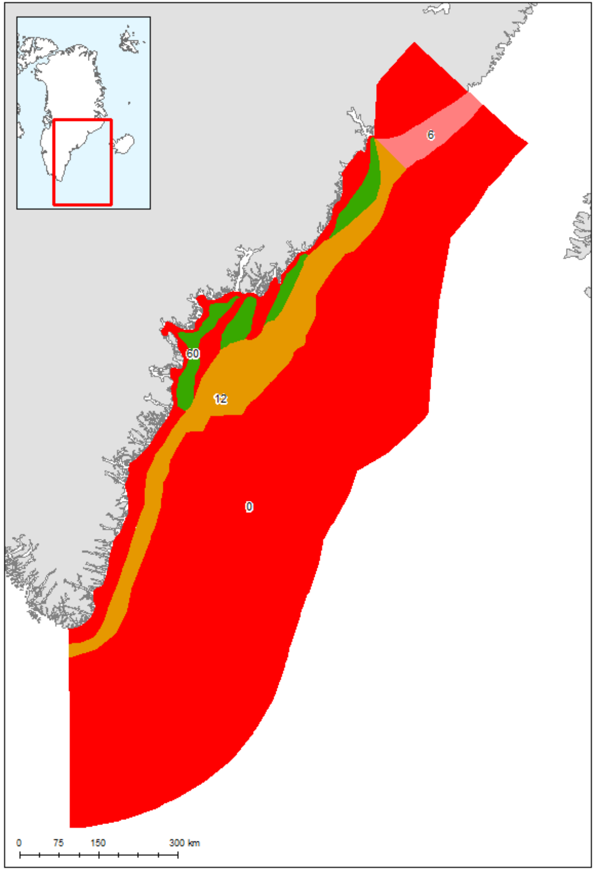
AU6 – Mean Risked Recoverable Yet-to-Find



- Feature Density: 151 exploration wells (features) drilled corresponding to a feature density (FD) of 5/1000 km^2.
- The total amount of resources (commercial and technical) amounts to 5.0 BBOE from 42 wells corresponding to an average **unrisked** discovery size (mean feature volume - MFV) of 119 MMBOE.
- The Mean Risked Recoverable of AU6 based on these analogue values is therefore:
  Sum of:
  [SegmentArea*FD*MFV*AU6TotalRiskOverall(per area)] = **1700 MMBOE**

SegmentComment	OverallSegmentRisk	FD	AreaSqKm	MeanFVol	FDRiskedRecov
Oceanic crust	0	5	383739	119	0
Kangerlussuaq Basin covered	0	5	11146	119	0
Kangerlussuaq Basin outcrop	0	5	7299	119	0
Basement highs	0	5	30261	119	0
Sediments with volcanic cover	1	5	10256	119	61
Sediments with volcanic cover	2	5	46843	119	557
Sediments with volcanic cover	2	5	8566	119	102
Ammasalik Basin	10	5	9308	119	554
Offshore sedimentary basin	10	5	5016	119	298
Offshore sedimentary basin	10	5	2519	119	150
Sum					1722

AU 6 – Mean Risked Recoverables per 1000 sqkm (MMBOE) Yet-to-Find



SegmentComment	FDRiskedRecov	RiskedRecovKscKm
Oceanic crust	0	0
Kangerlussuaq Basin covered	0	0
Kangerlussuaq Basin outcrop	0	0
Basement highs	0	0
Sediments with volcanic cover	61	6
Sediments with volcanic cover	557	12
Sediments with volcanic cover	102	12
Ammasalik Basin	554	60
Offshore sedimentary basin	298	60
Offshore sedimentary basin	150	60