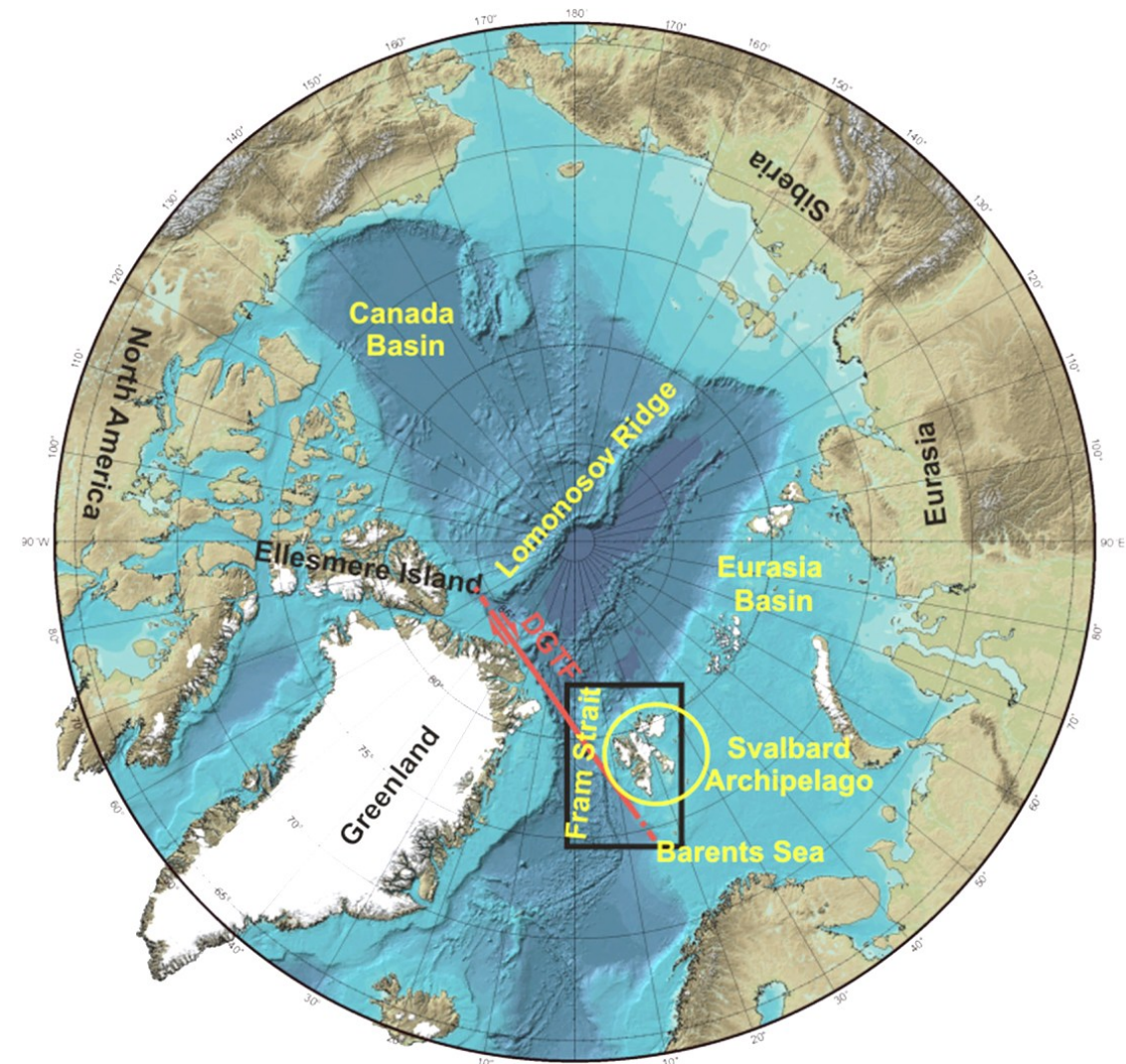


# The geology of Greenland and the Arctic

Pat Mills July 2026



Cianfarra(2014) De Geer Transform Fault in NW Spitsbergen DOI 10.1007/s00024-014-0869-9  
<https://www.cntraveler.com/gallery/photos-that-will-make-you-want-to-visit-greenland>

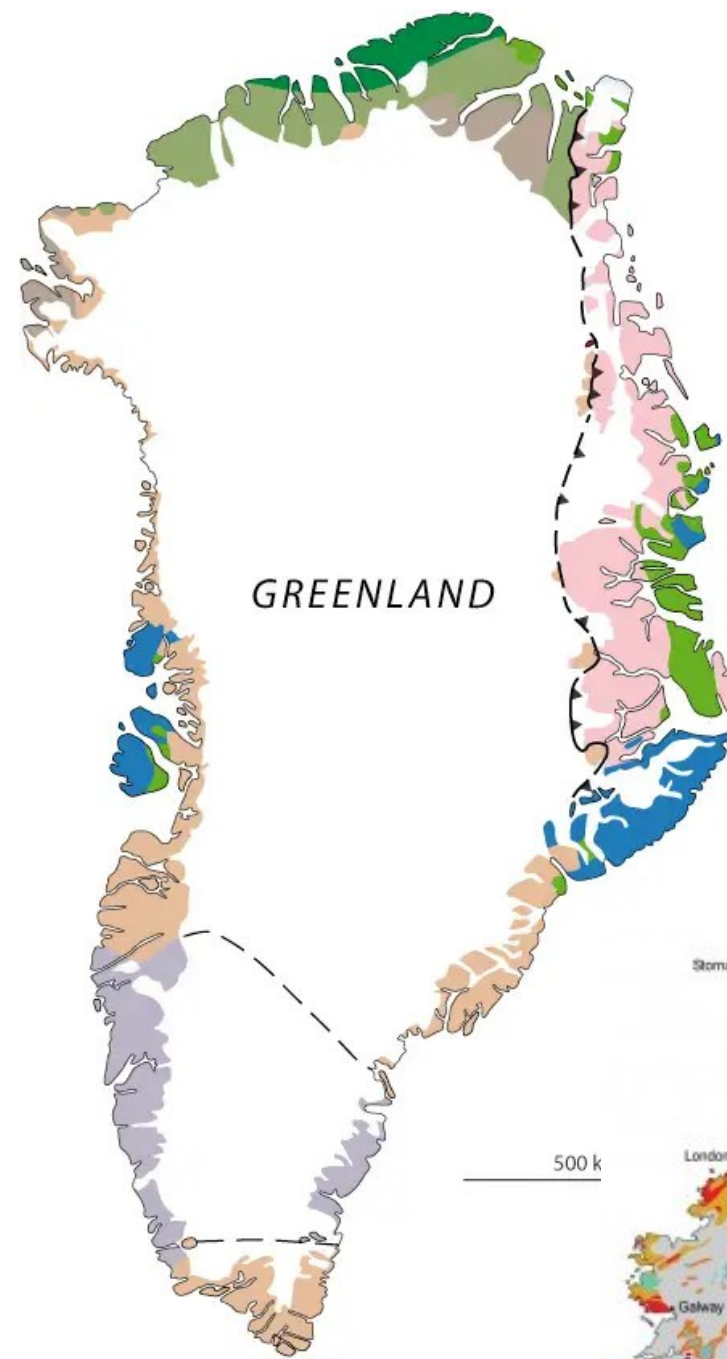
## Greenland is huge, cold and remote

- Extremely cold, even in summer
- Dark throughout winter
- Rugged coast

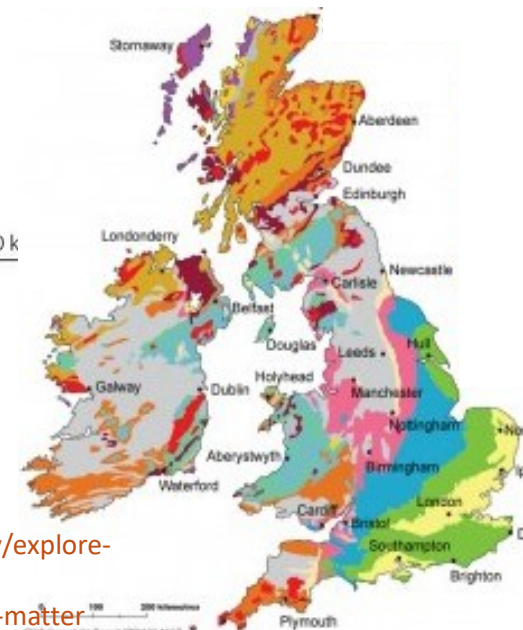
A lot of ice: if the ice were to melt, then global sea level would rise by **7.4m**

Governed by Denmark, supported by Norway. It has never produced any petroleum; there is a gold mine, but the attempt to mine iron ore ended in bankruptcy.

Only 1% of the land is considered accessible, nearly all the population live in just 16 towns along the rugged coastline.



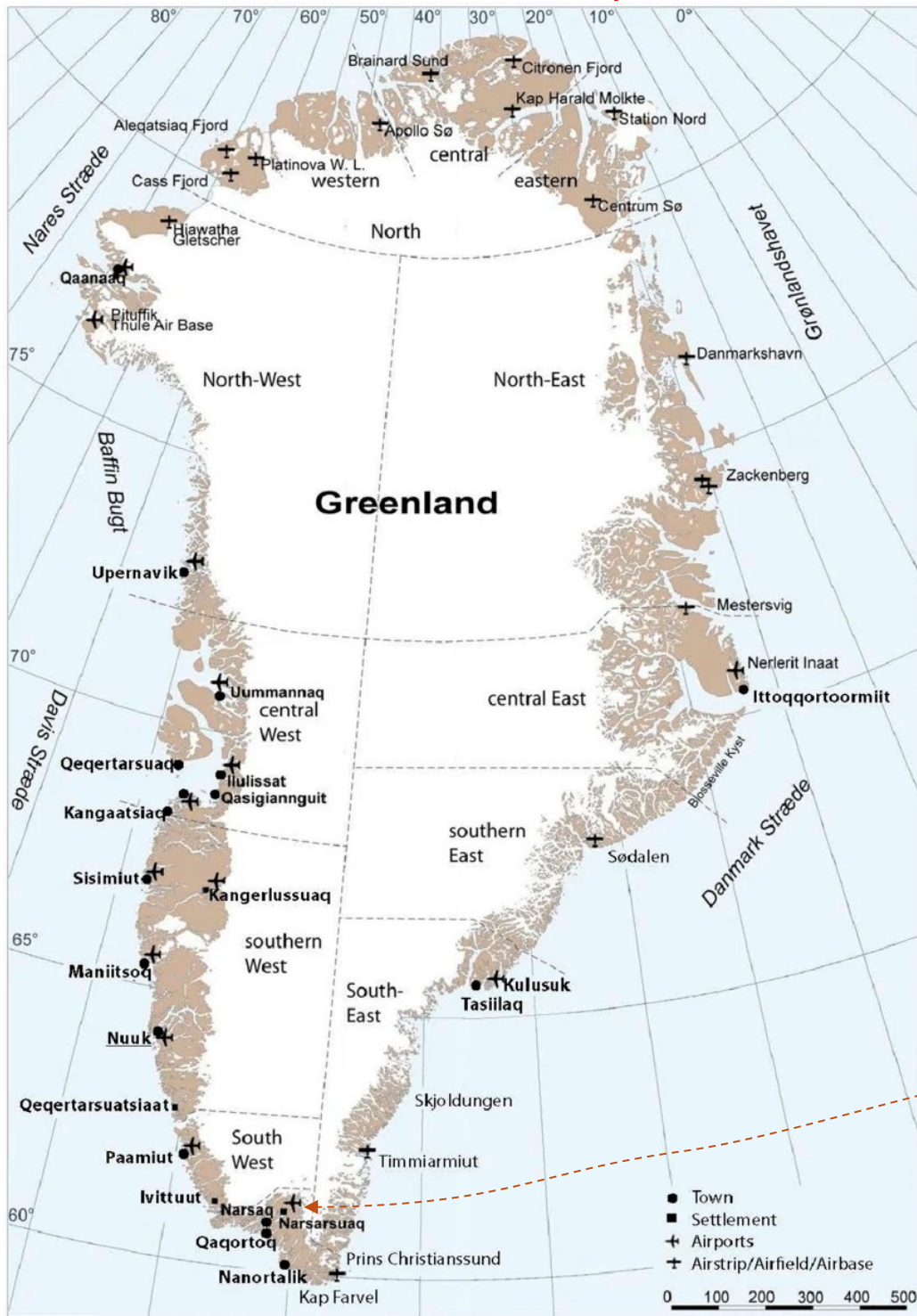
Great Britain to  
same scale



[www.thegeologytrusts.org/pub/wp-content/uploads/2010/03/GB-IPR\\_123-16CTGeologyMap.jpg](http://www.thegeologytrusts.org/pub/wp-content/uploads/2010/03/GB-IPR_123-16CTGeologyMap.jpg)  
<https://eng.geus.dk/explore-geology/learning-about-geology/explore-ilulissat-icefjord/the-land-below-and-around-the-ice>  
[nsidc.org/learn/parts-cryosphere/ice-sheets/why-ice-sheets-matter](http://nsidc.org/learn/parts-cryosphere/ice-sheets/why-ice-sheets-matter)



# Greenland towns and airstrips (2020)



## Greenland GDP by sector (2008)

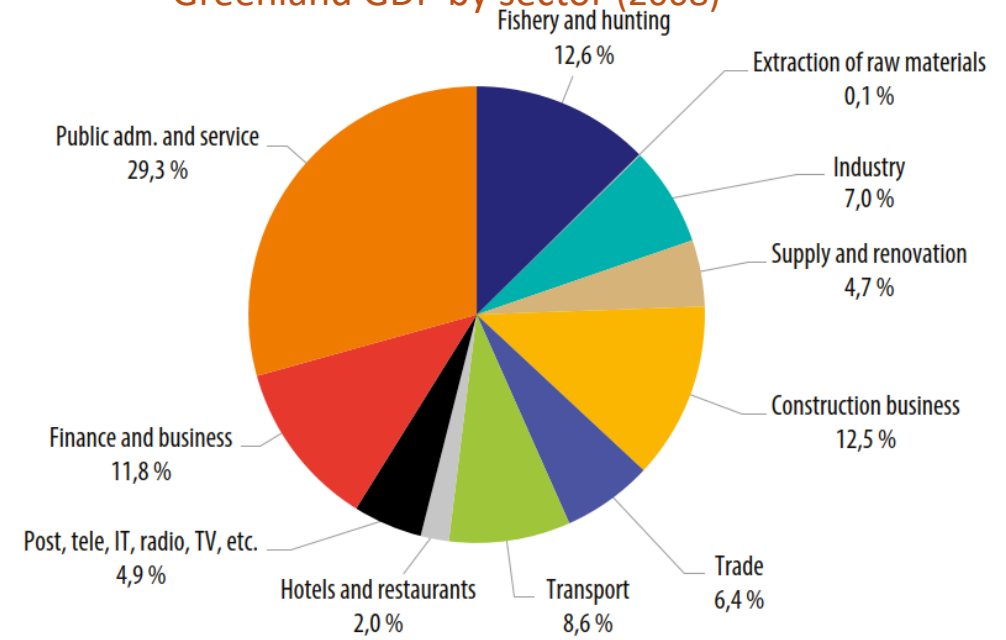


Figure 4. 2018 GDP by sector in 2010-values. Source: Statistics Greenland (2018).

## Nalunaq gold mine in South Greenland (2008)



[https://www.researchgate.net/publication/345627031\\_Study\\_on\\_Arctic\\_Mining\\_in\\_Greenland/download](https://www.researchgate.net/publication/345627031_Study_on_Arctic_Mining_in_Greenland/download)

# Geology around the coast – a mixed bag!

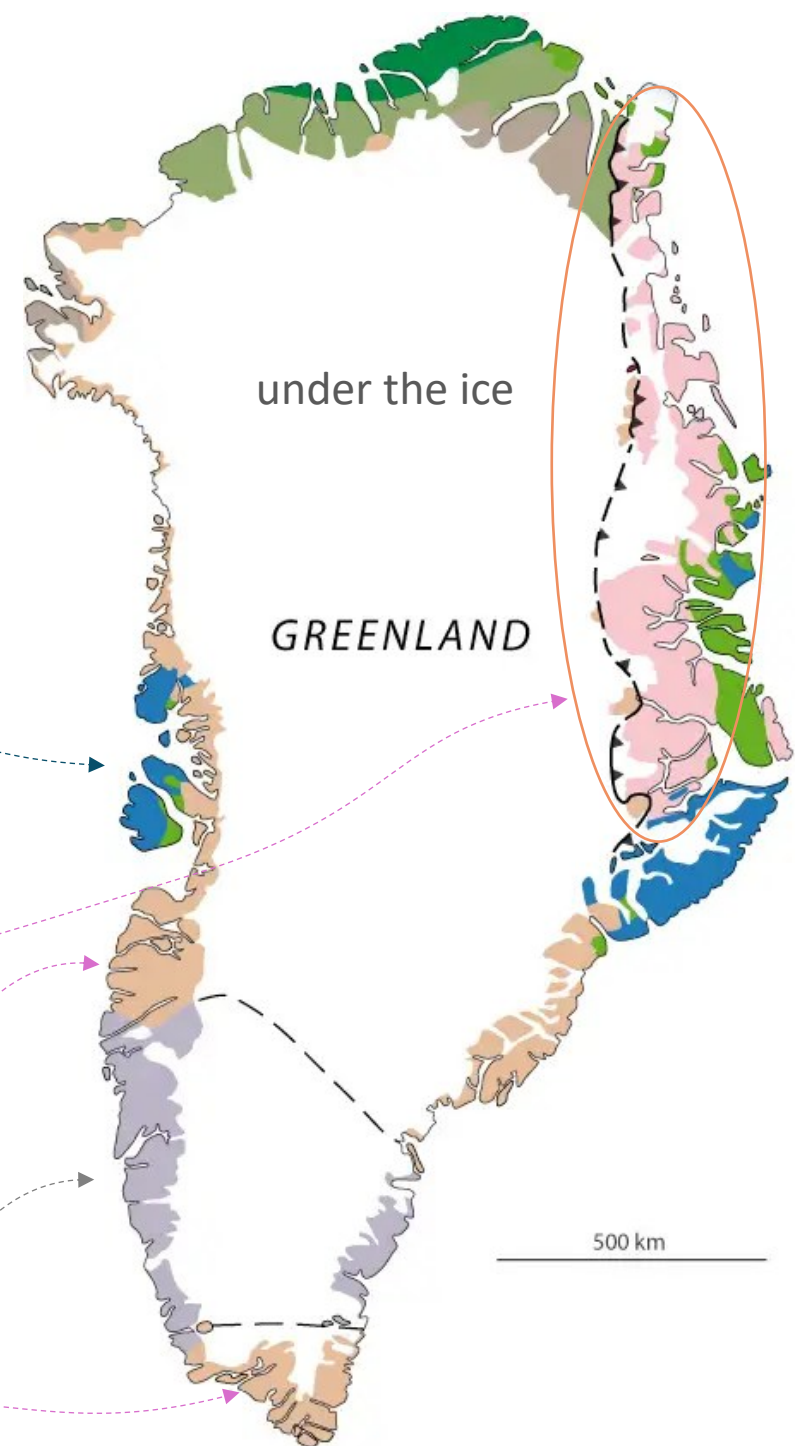
- Tertiary, basalts
- Devonian–Tertiary, sediments
- Cambrian–Silurian, sediments
- Proterozoic, sediments and volcanics
- North Greenland fold belt (Palaeozoic)
- Caledonian fold belt (Palaeozoic)
- Precambrian shield
- Precambrian shield

|     |               |
|-----|---------------|
| 0   | Neogene       |
| 23  | Paleogene     |
| 65  | Cretaceous    |
| 145 | Jurassic      |
| 200 | Triassic      |
| 251 | Permian       |
| 299 | Carboniferous |
| 359 | Devonian      |
| 417 | Silurian      |
| 444 | Ordovician    |
| 488 | Cambrian      |
| 541 |               |

Tertiary basalts

450-350Ma  
Caledonian fold belt  
(orogeny)

3.9 - 1.6 Ga formation of Precambrian shield



<https://simple.wikipedia.org/wiki/Laurentia>

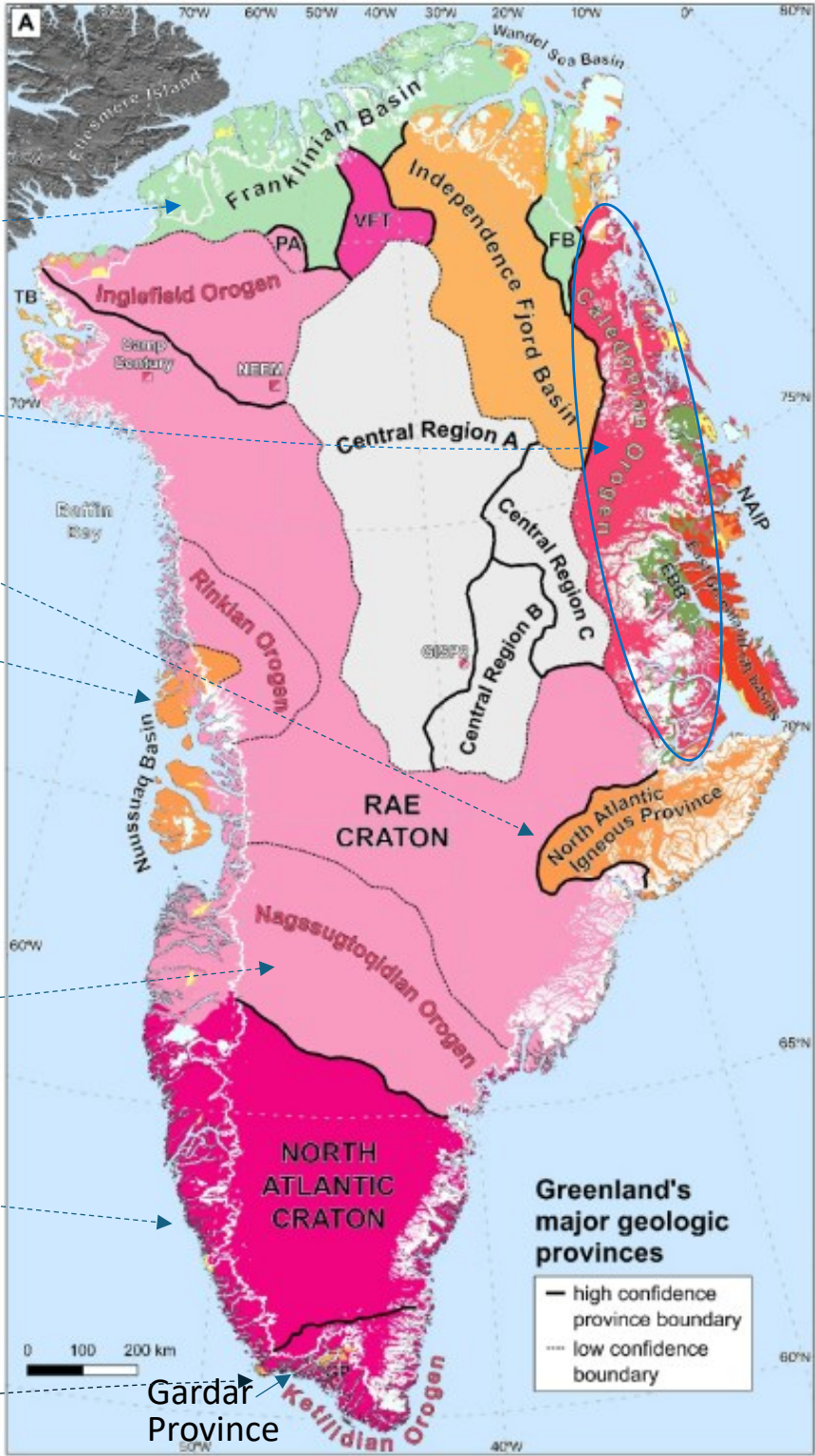
[https://en.wikipedia.org/wiki/File:Simplified\\_geological\\_map\\_of\\_Greenland\\_showing\\_baseament\\_terrains\\_and\\_sedimentary\\_basins.webp](https://en.wikipedia.org/wiki/File:Simplified_geological_map_of_Greenland_showing_baseament_terrains_and_sedimentary_basins.webp)

<https://eng.geus.dk/explore-geology/learning-about-geology/explore-ilulissat-icefjord/the-land-below-and-around-the-ice>

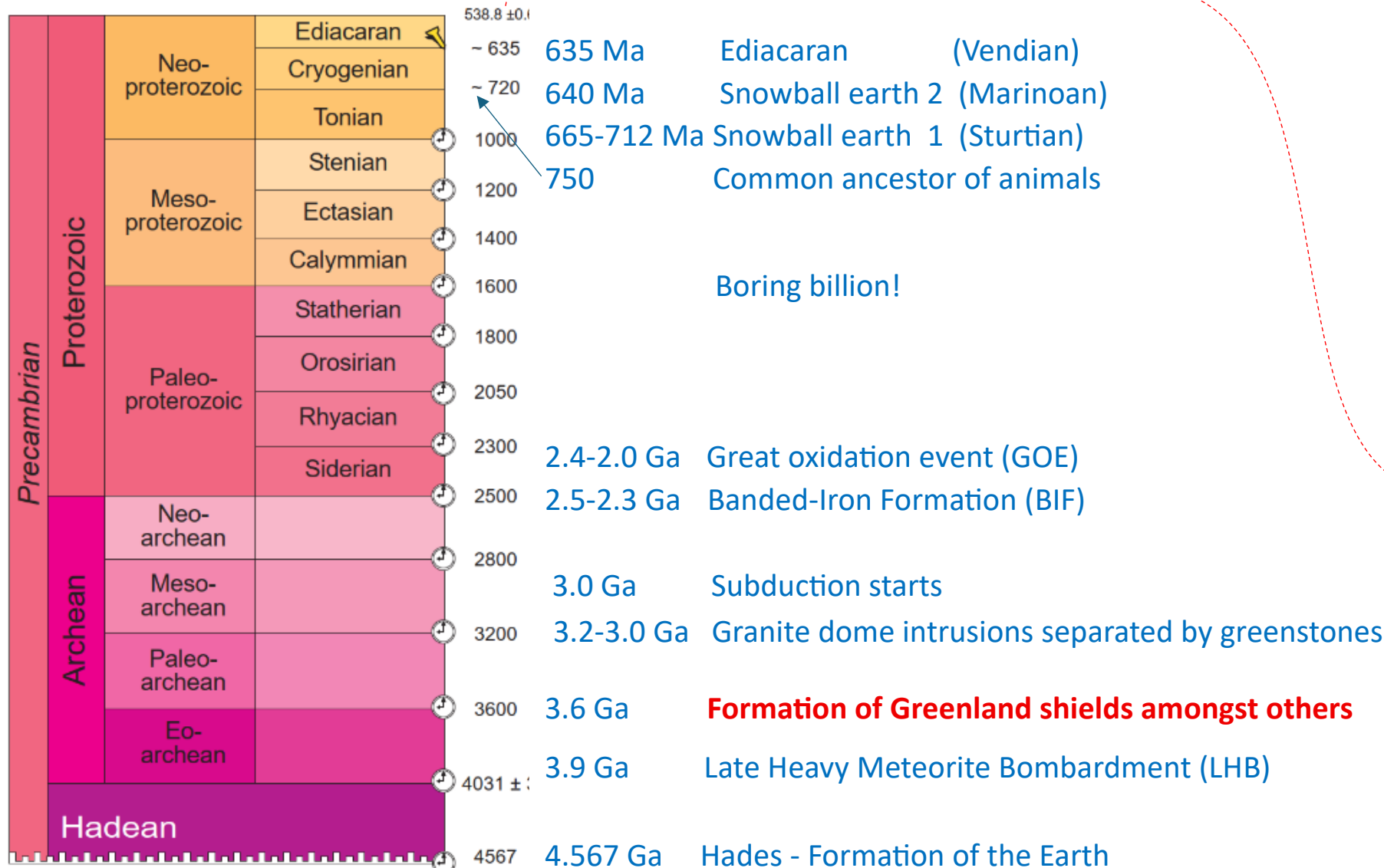
# Geological provinces (McGregor 2024)

A geological province is a spatial region defined by shared geological attributes, rock types, and structural evolution.

| from | to   | type    | name                            |
|------|------|---------|---------------------------------|
| 66   | 23   | igneous | North Atlantic Igneous Province |
| 145  | 23   | igneous | Nuussuaq basin                  |
| 359  | 23   | basin   | Wandel Sea Basin (youngest)     |
| 419  | 252  | basin   | East Greenland rift basins      |
| 490  | 390  | orogeny | Caledonian orogeny              |
| 1000 | 416  | basin   | Franklinian Basin               |
| 2500 | 539  | basin   | Eleonore Bay basin              |
| 1600 | 541  | basin   | Thule basin                     |
| 2500 | 1000 | basin   | Independence Fjord Basin        |
| 1600 | 1000 | igneous | Gardar province                 |
| 4031 | 1600 | orogen  | Ketilidian orogen               |
| 4031 | 1600 | orogen  | Nagssugtoqidian orogen          |
| 4031 | 1600 | orogen  | Rinkian Orogen                  |
| 4031 | 1600 | orogen  | Inglefield Orogen               |
| 4031 | 2500 | shield  | North atlantic craton           |
| 3200 | 2500 | shield  | RAE craton                      |
| 3600 | 3200 | shield  | Victoria fjord terrane (oldest) |



# Precambrian Shields - timescale



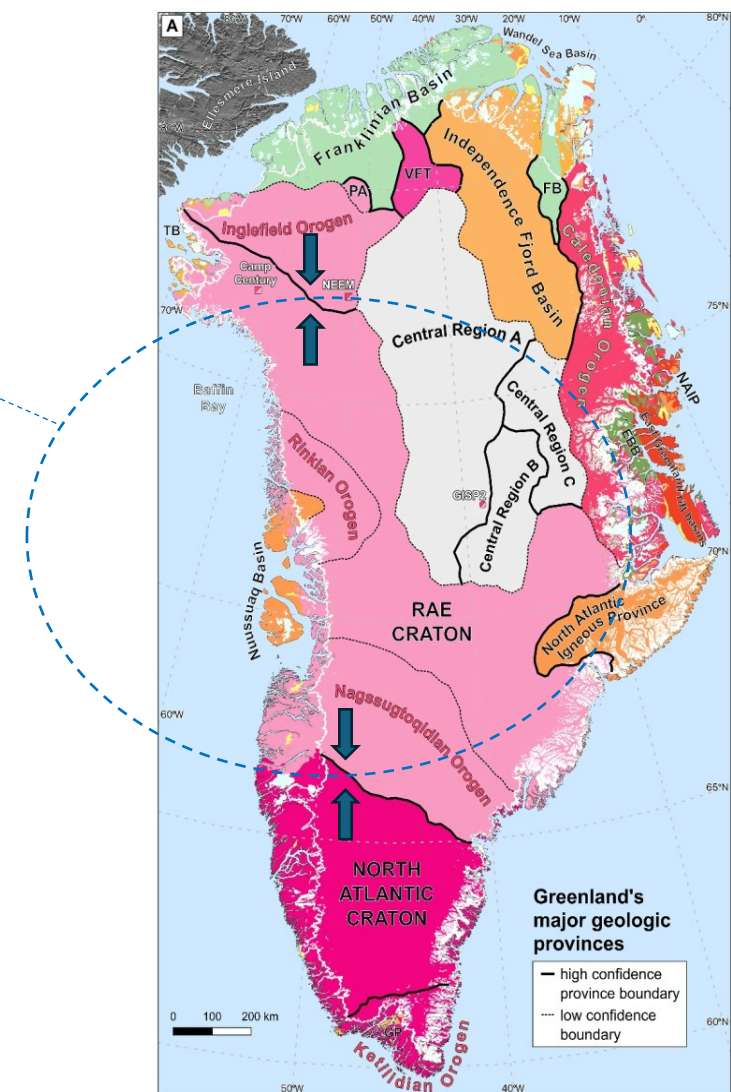
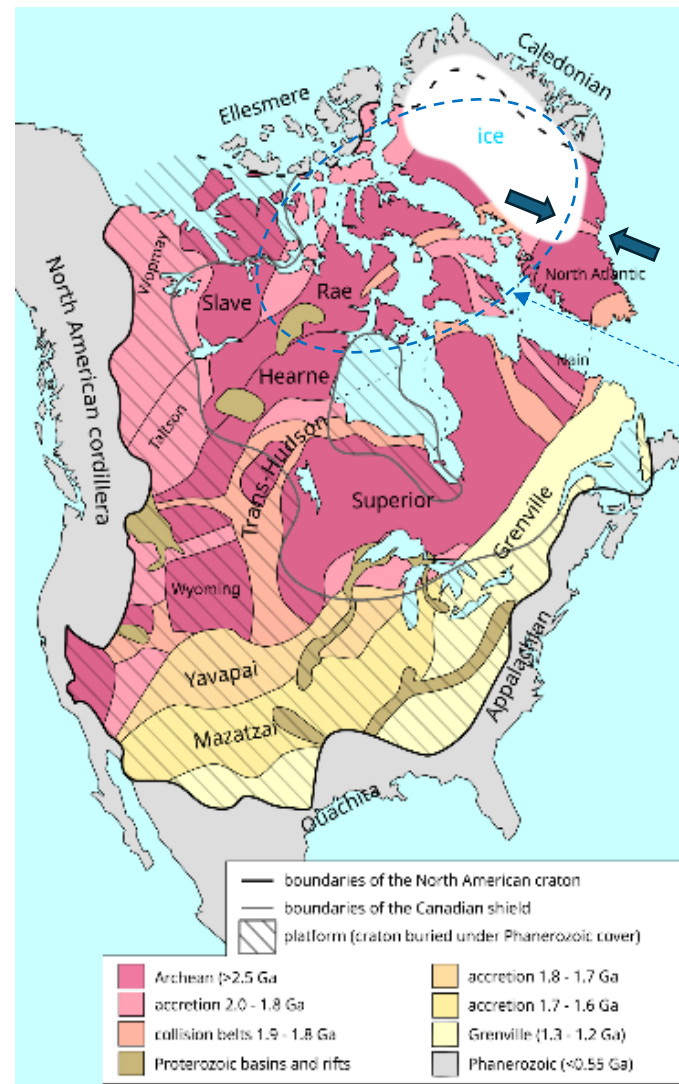
|     |               |
|-----|---------------|
| 0   | Neogene       |
| 23  | Paleogene     |
| 65  | Cretaceous    |
| 145 | Jurassic      |
| 200 | Triassic      |
| 251 | Permian       |
| 299 | Carboniferous |
| 359 | Devonian      |
| 417 | Silurian      |
| 444 | Ordovician    |
| 488 | Cambrian      |

# RAE Craton

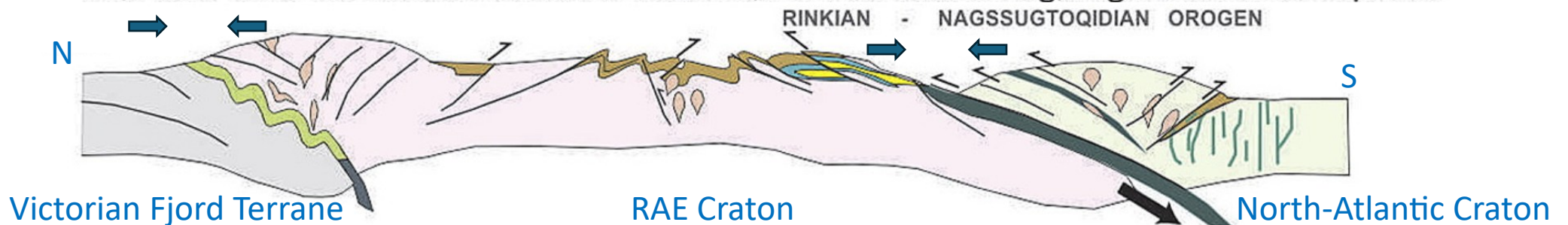
North-west reach of  
Canadian Shield

1873-1840 Ma collided N-S with  
North Atlantic Craton

MacGregor(2024) - Geologic Provinces Beneath the  
Greenland Ice Sheet  
[https://commons.wikimedia.org/wiki/Category:Hearne\\_Craton#/media/File:Tectonic\\_structure\\_North\\_American\\_craton.svg](https://commons.wikimedia.org/wiki/Category:Hearne_Craton#/media/File:Tectonic_structure_North_American_craton.svg)  
[https://ars.els-cdn.com/content/image/1-s2.0-S1342937X17300771-fx1\\_lrg.jpg](https://ars.els-cdn.com/content/image/1-s2.0-S1342937X17300771-fx1_lrg.jpg)

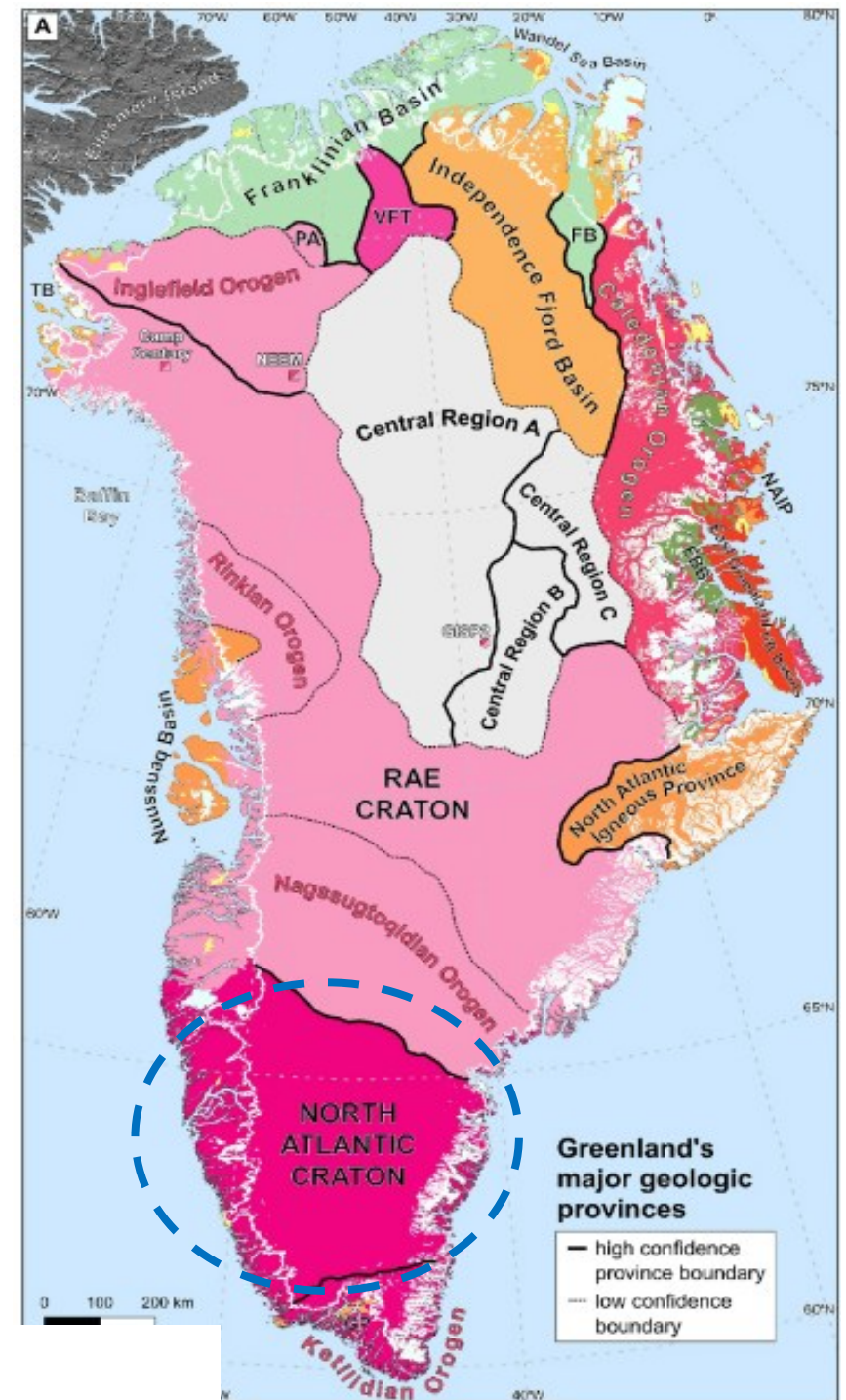


1840 Ma: Rae-North Atlantic craton collision, recumbent folding, regional metamorphism



## North Atlantic Craton (3.85Ga to 550Ma)

- exposed in Labrador, Greenland and Lewis, Scotland.
- best example of evolution of greenstone crust
- formed by horizontal accretion of plates
- example of early subduction at 2.55Ga in Majorqaaq belt
- abundant evidence of early crustal growth from 3.9-3.6Ga



Waterton(2024) Chondritic osmium isotope composition of early Earth mantle

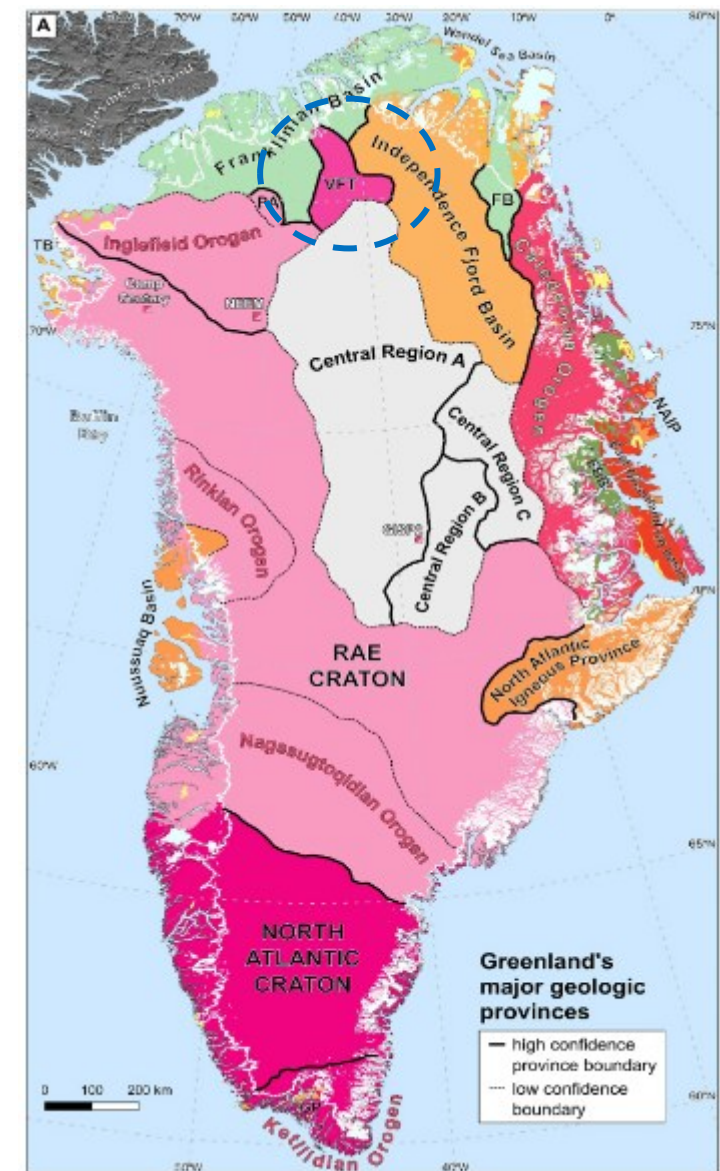
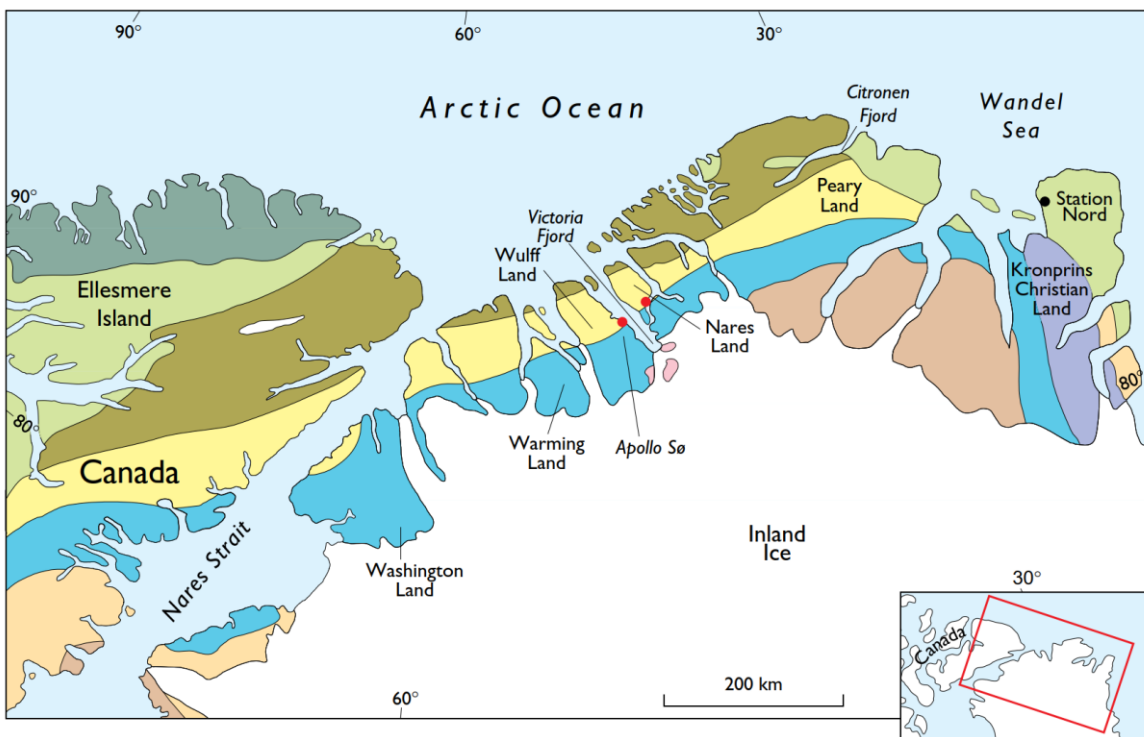
<https://doi.org/10.7185/geochemlet.2424> (~3.25 Ga)

<https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2020.540997/full>

<https://www.dailymail.co.uk/sciencetech/article-8135975/Geologists-diamond-bearing-rock-fragment-ancient->

# Victoria Fjord Terrane

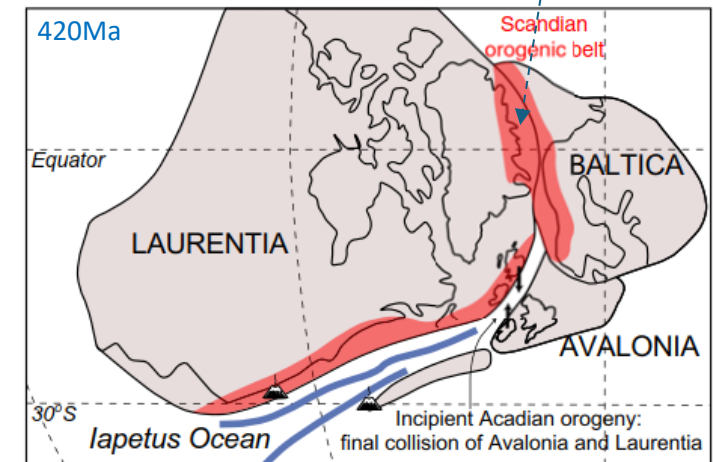
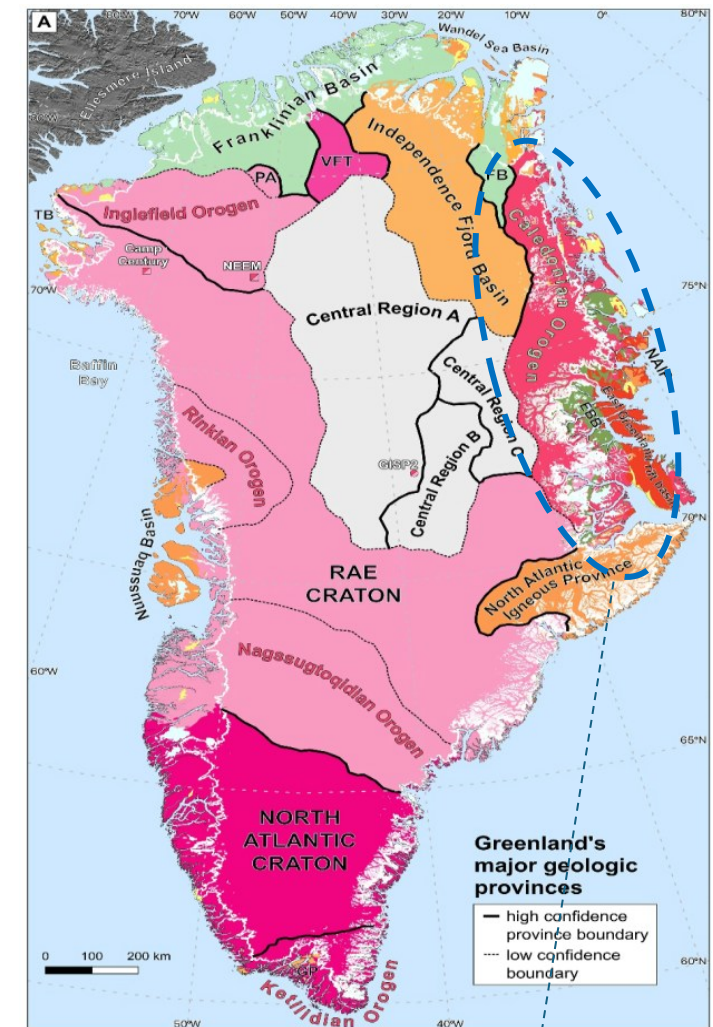
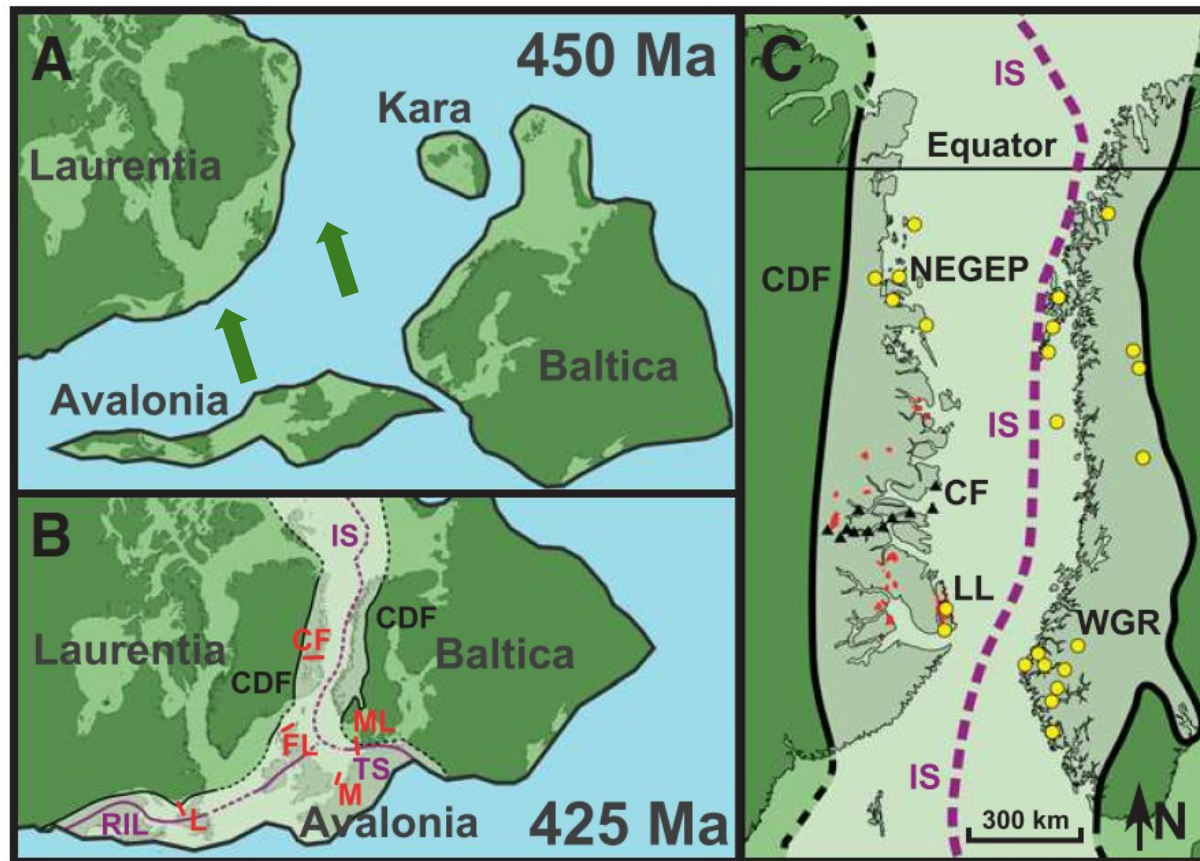
- Northern-most exposure of archaean crust
- Zircon dated to 3.50–3.26 Ga



nutman(2019) victoria\_fjord\_terrain\_dating\_smhpapers1\_798\_1  
[https://ro.uow.edu.au/articles/journal\\_contribution/The\\_Archaean\\_Victoria\\_Fjord\\_terrane\\_of\\_northernmost\\_Greenland\\_and\\_geodynamic\\_interpretation\\_of\\_Precambrian\\_crust\\_in\\_and\\_surrounding\\_the\\_Arctic\\_Ocean/27745719?file=50504601](https://ro.uow.edu.au/articles/journal_contribution/The_Archaean_Victoria_Fjord_terrane_of_northernmost_Greenland_and_geodynamic_interpretation_of_Precambrian_crust_in_and_surrounding_the_Arctic_Ocean/27745719?file=50504601)  
Sonderholm(1997) DOI:[10.34194/ggub.v176.5056](https://doi.org/10.34194/ggub.v176.5056)  
MacGregor(2024) - Geologic Provinces Beneath the Greenland Ice

## Caledonian Orogeny (490-390Ma)

- Mountain-building event following closure of Iapetus ocean
- Collision of three land masses: Laurentia, Baltica and Avalonia
- Left as evidence the Great Glen Fault in Scotland
- Greenland and Scandinavia re-opened as the Atlantic Ocean
- The average annual temperature in the area being -10 °C



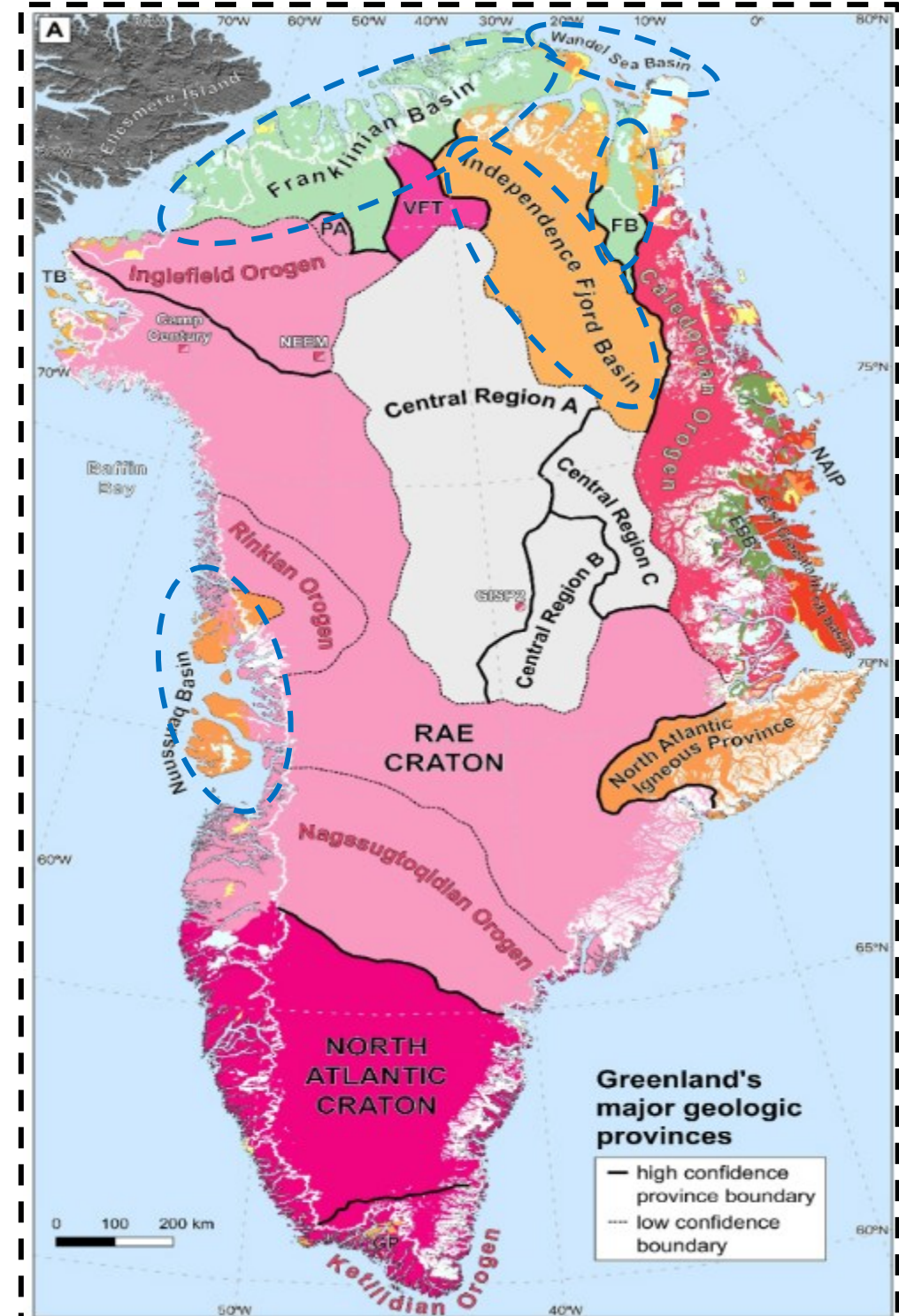
[https://en.wikipedia.org/wiki/Caledonian\\_orogeny](https://en.wikipedia.org/wiki/Caledonian_orogeny)

Schiffer(2014)Subduction zone in East Greenland Caledonids

Chew(2014)Scottish Caledonides MacGregor(2024) - Geologic Provinces Beneath the Greenland Ice

# Sedimentary Basins

- Wandel Sea Basin 23 Ma
- East Greenland rift basin 252 Ma
- Franklinian Basin 416 Ma
- Eleonore Bay basin 535 Ma
- Thule basin 541 Ma
- Independence Fjord Basin 1000 Ma



# Top of Greenland

McClelland(2023)Palaeozoic evolution of the

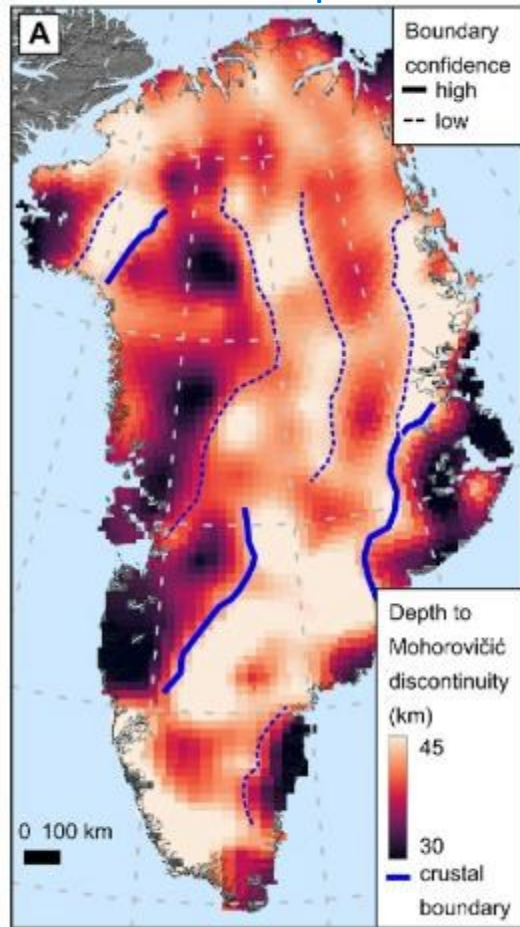
## CATS – The Canadian Arctic Transform System



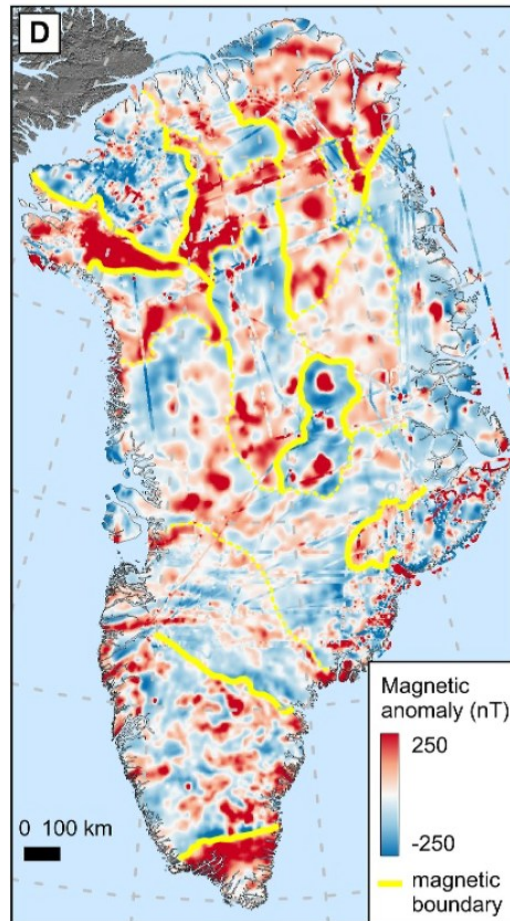
Figure 1. Generalized tectonic map of northern Laurentia showing the terrane distribution on the Arctic and Cordilleran margins of Laurentia and Paleozoic orogenic belts in the circum-Arctic region. AA—Arctic Alaska terrane; AT—Alexander terrane; F—Farewell terrane; YTn and YTs—northern and southern components of the Yukon-Tanana terrane.

# Geology inland by remote sensing

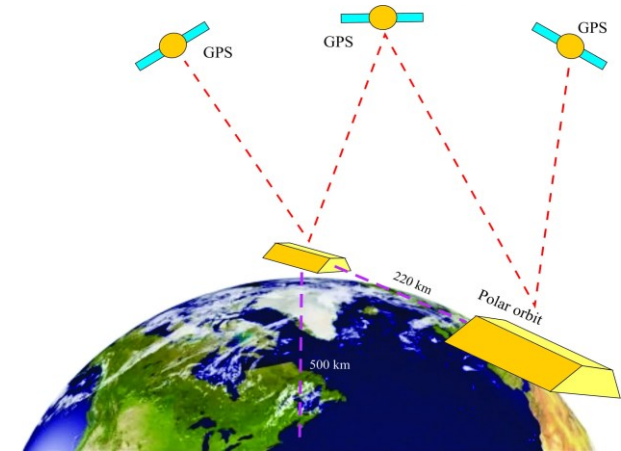
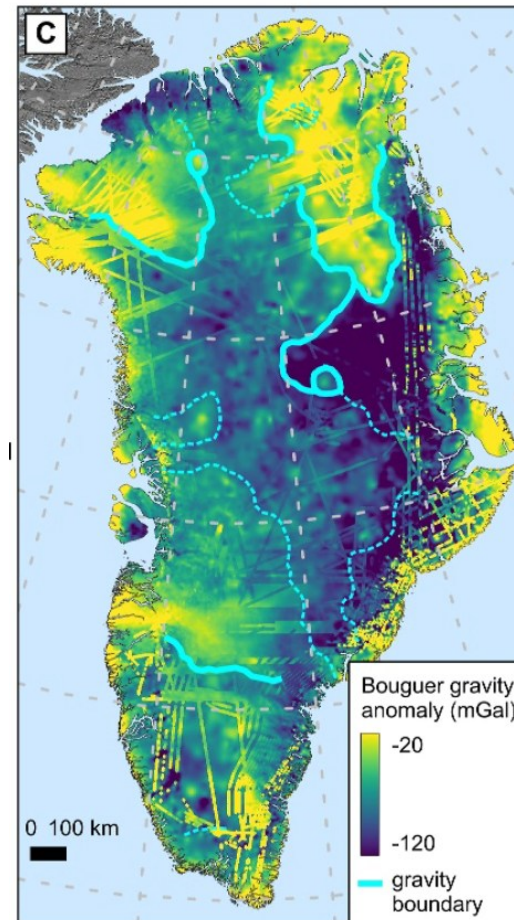
## Crust depth



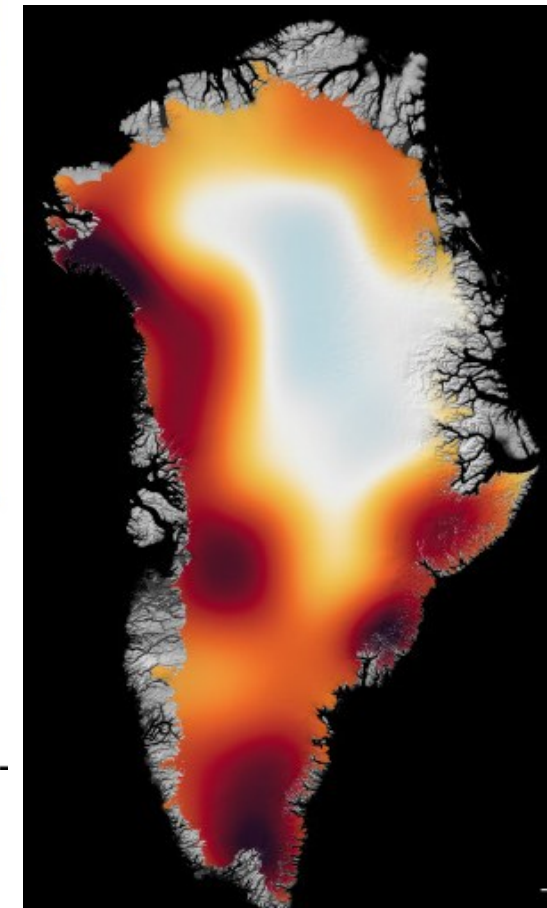
## Magnetic anomalies



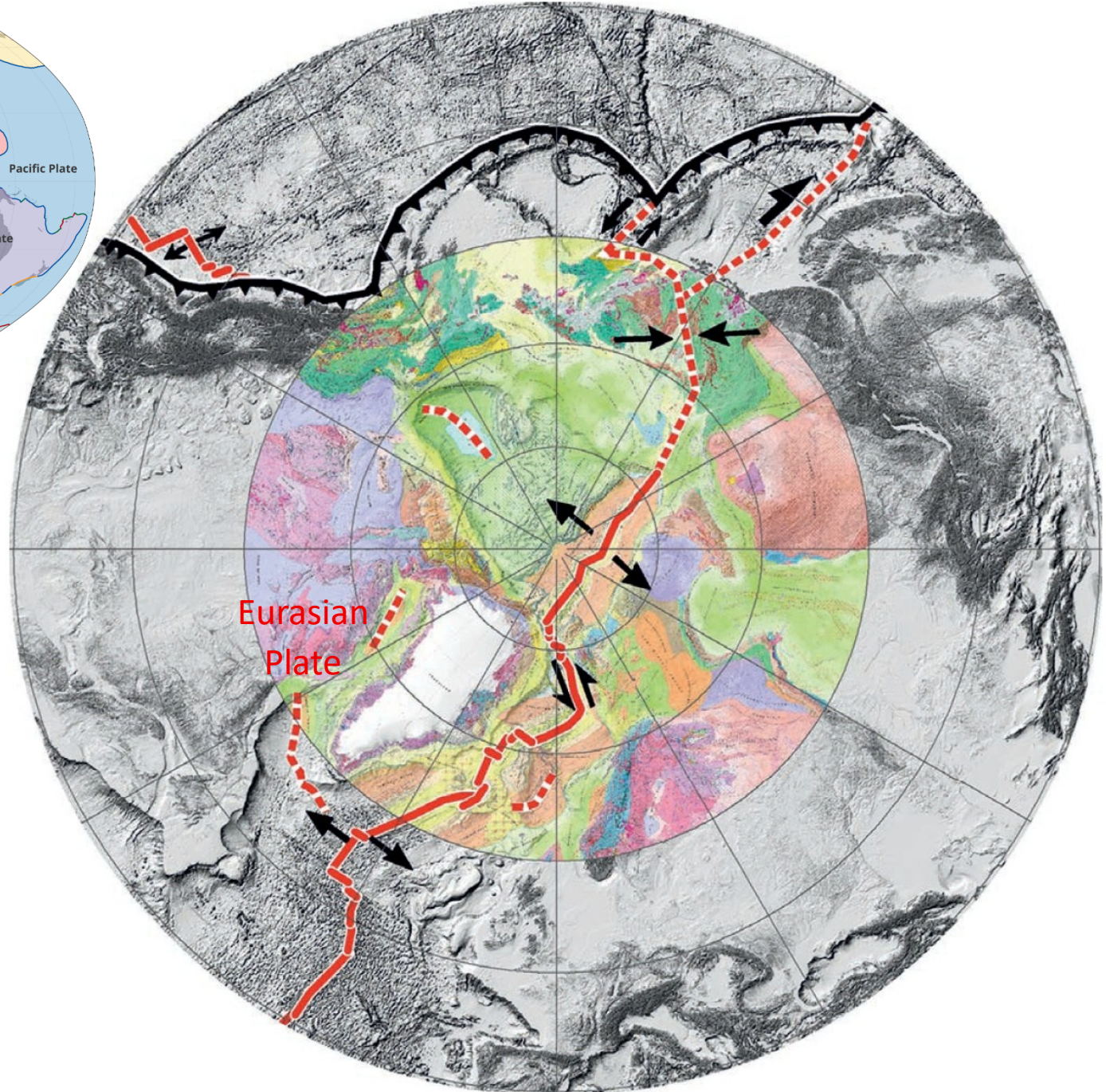
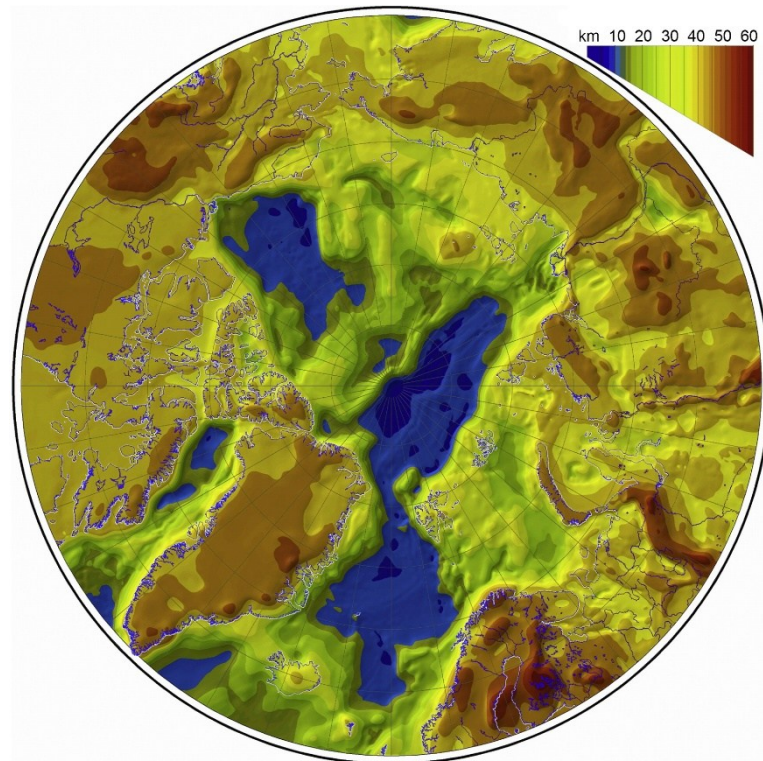
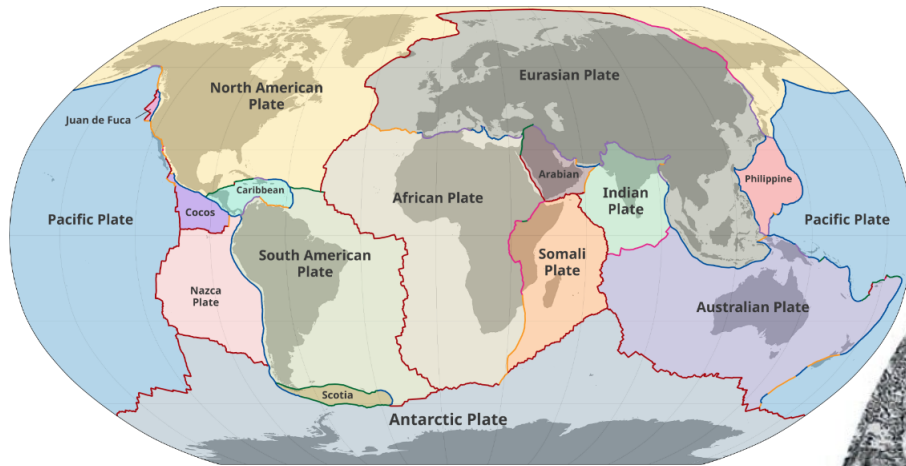
## Local gravity



## Ice melt 2002-2025



# Continental plates in the Arctic



# Large Igneous Provinces (LIP) in the Arctic

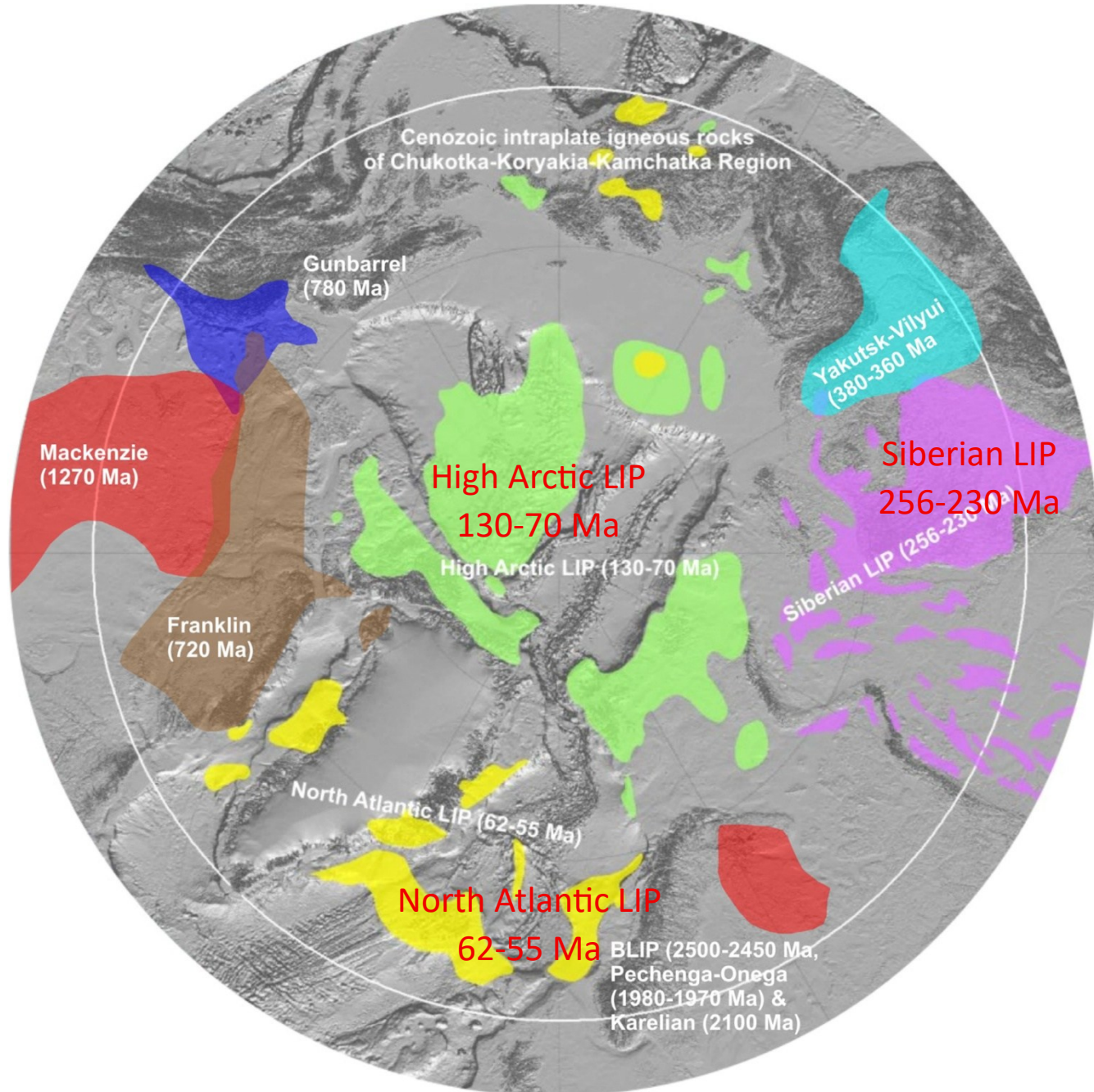
North Atlantic LIP (yellow)

High Arctic LIP (green)

Siberian LIP (mauve)

Yakutsk LIP (azure)

|     |               |
|-----|---------------|
| 0   | Neogene       |
| 23  | Paleogene     |
| 65  | Cretaceous    |
| 145 | Jurassic      |
| 200 | Triassic      |
| 251 | Permian       |
| 299 | Carboniferous |
| 359 | Devonian      |
| 417 | Silurian      |
| 444 | Ordovician    |
| 488 | Cambrian      |
| 541 |               |



# Svalbard towns

Population 2,600 (2024)

Longyearbyen 2,300

Barentsburg 450

Ny-Ålesund 50

## Activities

Whaling in 17<sup>th</sup> and 18<sup>th</sup> centuries

Coal mining in Barentsburg

Long-term seed vault (1.3m items at -18°C 2025)

## Birds and marine life

Massive numbers of plankton

Associated whales, fish and birds

Eider duck, terns, guillemots, puffins, skua, ptarmigan

Note: Svalbard is the whole archipelago including Spitsbergen, Nordaustlandet and Edgeøya.

Other major islands include Barentsøya, Prins Karls Forland, Kvitøya, Kong Karls Land,

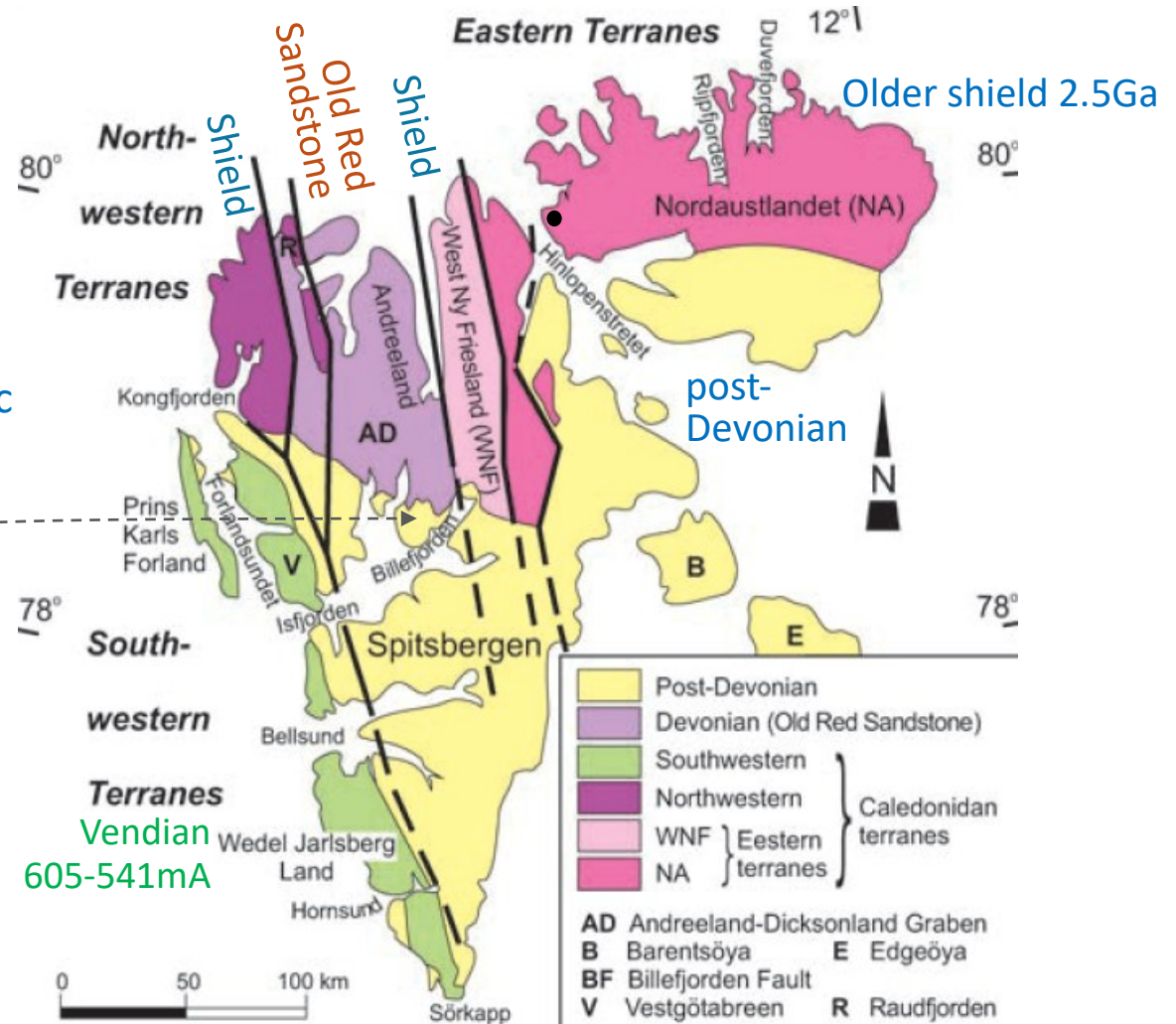
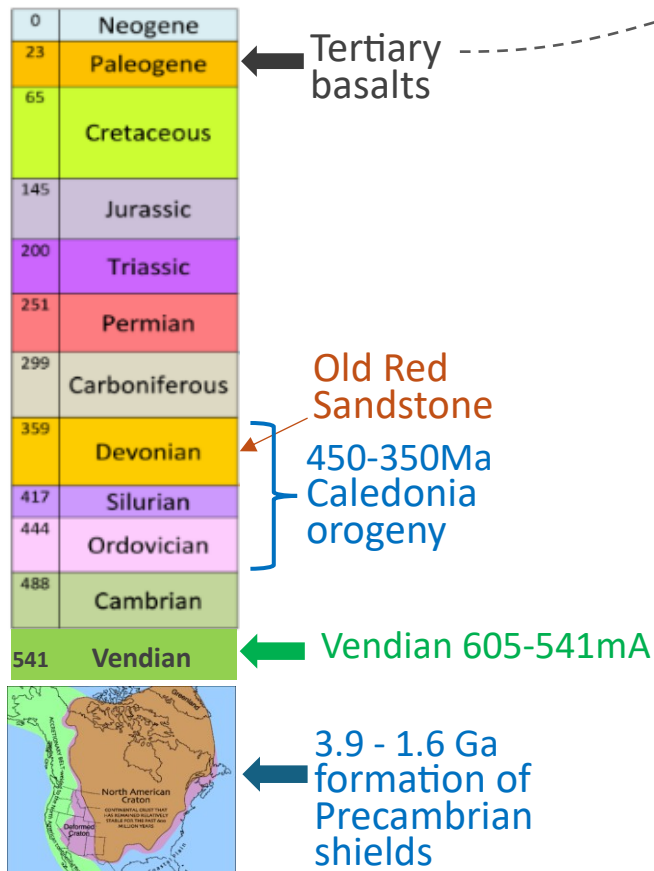
Bjørnøya (Bear Island), and Hopen.

80° north

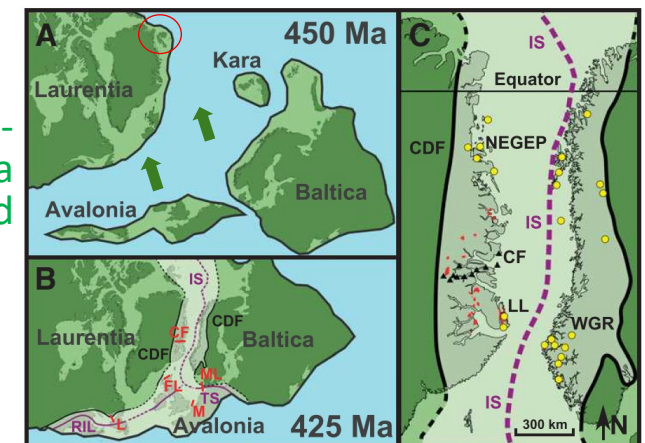


# Svalbard geology (2008)

- Shield terranes partially melted during Caledonian Orogeny (450-350Ma), so hard to interpret dates
- SW Vendian terranes similar to NE Greenland
- South Svalbard deposits all post-Devonian
- Some basalt intrusions during spreading of Atlantic



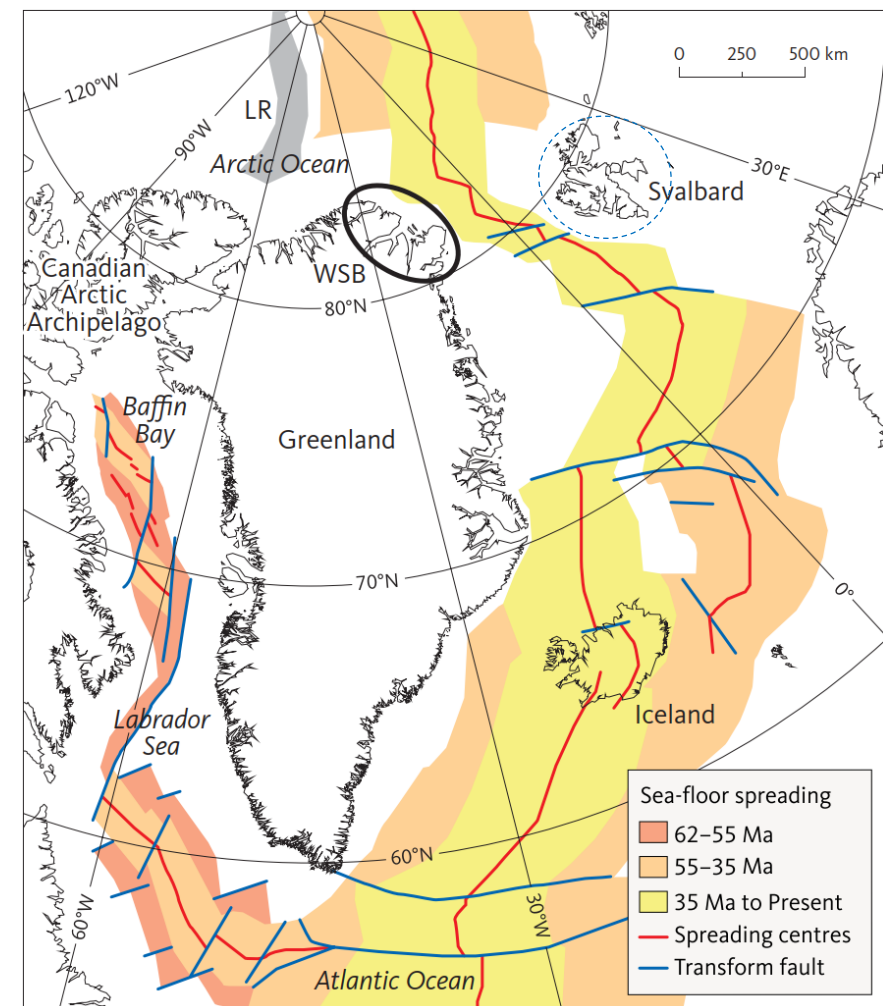
**Caledonian orogeny -** collision of Laurentia, Baltica and Avalonia metamorphosed the basement of Svalbard



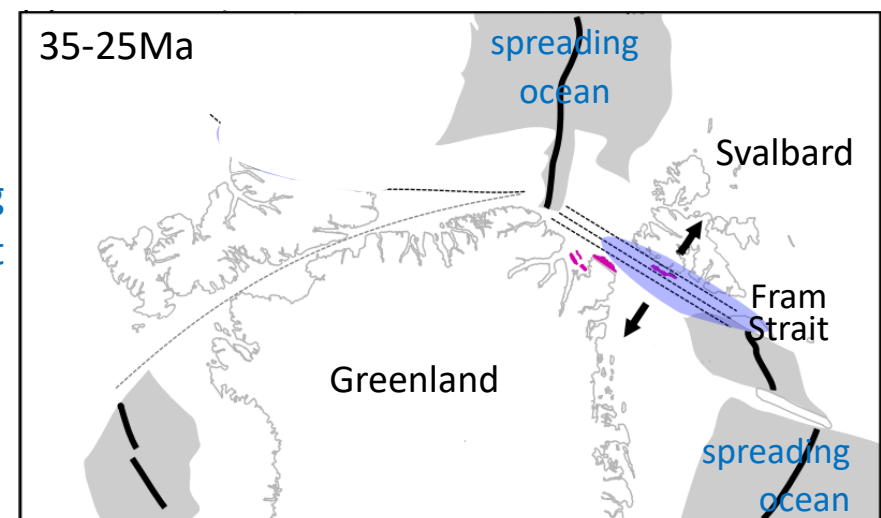
Harland(1997) Proto-basement in Svalbard  
 Schiffer(2014) Subduction zone in East Greenland Caledonids  
 Gee(2008) From early paleozoic platforms of Baltica and Laurentia to Caledonide Orogen

# A puzzle: did mid-Atlantic sea-floor spreading separate Svalbard from Greenland?

- Greenland and Svalbard are currently located on either side of the mid-Atlantic ridge.
- In the 1970's Harland identified the rocks of NW Svalbard had similar dates to those on the NE Greenland coast. Had they been part of same plate in the past? A puzzle!
- The model (top right) proposes that Svalbard & Greenland had been adjacent but spread apart when the Atlantic opened up.



Model for spreading of the Fram Strait



Cianfarra(2014) De Geer Transform Fault in NW Spitsbergen DOI 10.1007/s00024-014-0869-9  
japsen(2021)wandel\_sea\_basin <https://doi.org/10.34194/geusb.v45.5298>  
Meier(2025) Breakup of Fram Strait (Svalbard and Eastern North Greenland)  
<https://doi.org/10.1029/2023GC011074>

## CAMBRIDGE SPITSBERGEN EXPEDITION, 1967

[By R. H. Wallis and W. B. Harland, Department of Geology, University of Cambridge. Reports on previous expeditions in this series appeared in the *Polar Record*, Vol 13, No 85, 1967, and earlier issues.]

In continuation of the geological investigation of Spitsbergen, under the direction of W. B. Harland, Department of Geology, University of Cambridge, an expedition numbering nineteen led by R. H. Wallis left Newcastle on 22 June and returned on 13 September. The expedition divided into four field parties, the party leaders being responsible for separate scientific programmes. The organization of the expedition was carried out by R. H. Wallis and P. I. Maton.

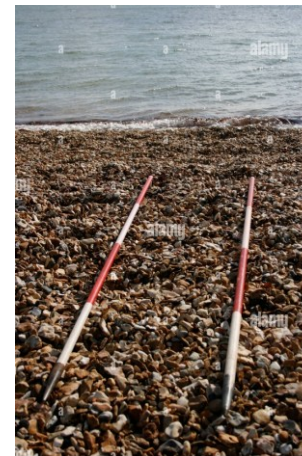
The expedition arrived in Longyearbyen on 1 July and commissioned the 8·8 m and 7·2 m diesel motor boats *Salterella II* and *Collenia*. *Salterella II* was captained by A. C. Davies (University of Newcastle) with engineer J. Newman (Guildford County Technical College), *Collenia* was captained by either P. I. Maton or R. H. Wallis with engineer R. B. Kendal (Guildford County Technical College).

Party C was transferred from Longyearbyen by *Salterella II* and *Collenia* to their preliminary base at Grønfjorden on 3 and 4 July, and then the two boats continued northwards to Ny Ålesund arriving on the fifth. During 6–8 July, Parties A and B were transferred from Ny Ålesund and Virgohamna to the northern base of Biskayerhuken. Ice conditions in the north and east were very favourable and the boating programme for Parties A and B were thus carried out as planned.

# Virgohamma June 1967



- 3 in geophysics party, Paul Maton, David and me
- Luminescence of plankton when disturbed with oar
- Virgohamner: invisible eider duck
- Millions of terns in terneries



Virgohamna  
remains of 1907 north-pole attempt in balloon

<https://cruise-handbook.npolar.no>  
<https://cruise-handbook.npolar.no/en/nordvesthjornet/virgohamna.html>

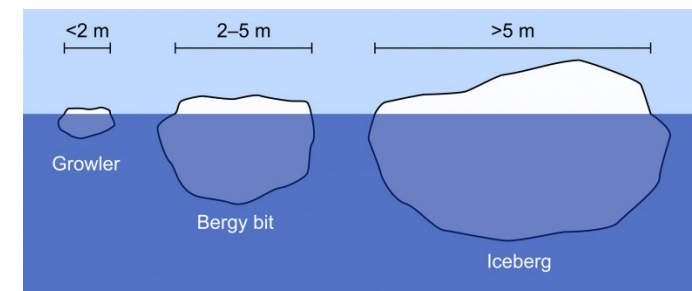
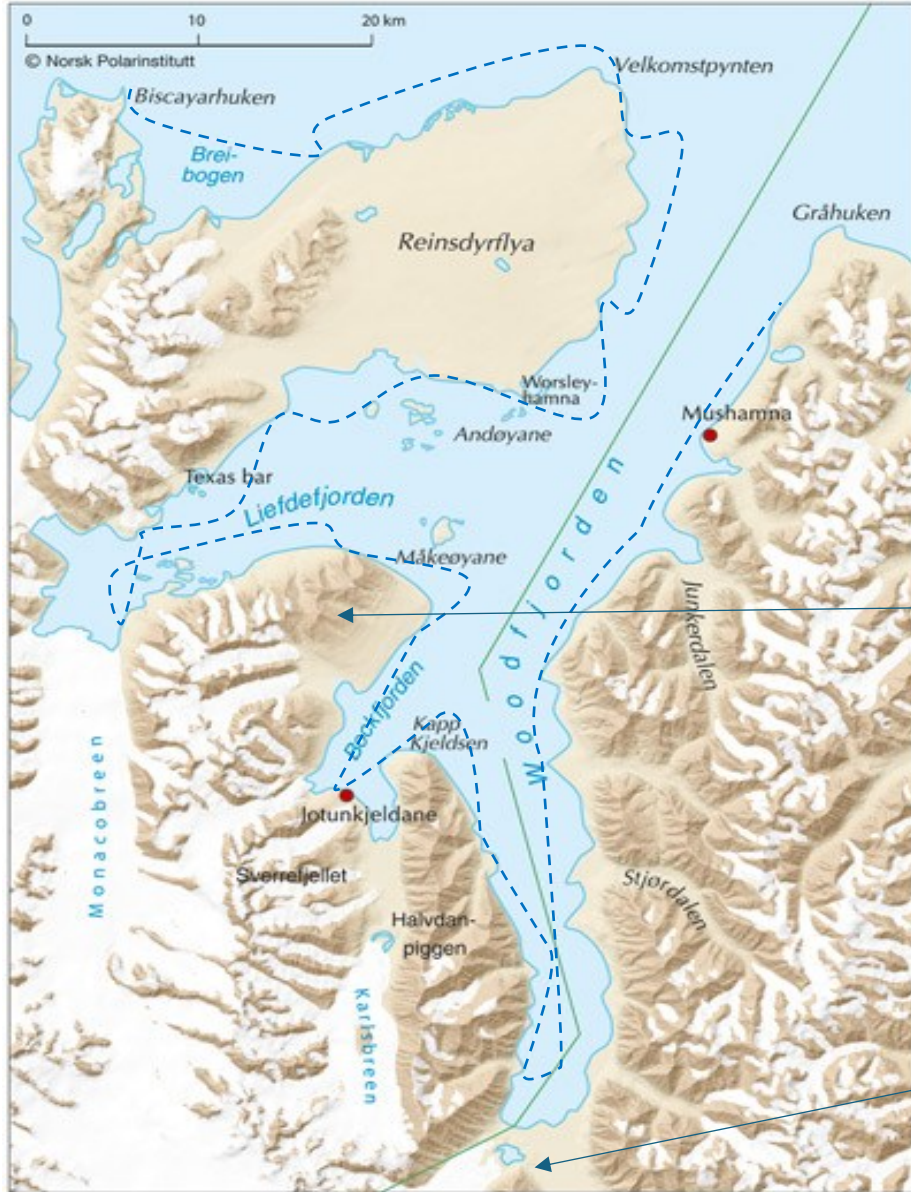
Worden Gravimeter, Smithsonian Museum

[https://www.si.edu/object/worden-gravimeter%3Aanmah\\_865076](https://www.si.edu/object/worden-gravimeter%3Aanmah_865076)



## Biscayarhuken – Woodfjorden

- Fuel drums left on storm beach from previous year's expedition
- Arctic foxes, guillimots having flying lessons
- "Bears run at 15mph and swim at 8 knots"
- Cushions of saxifrages on arctic tundra



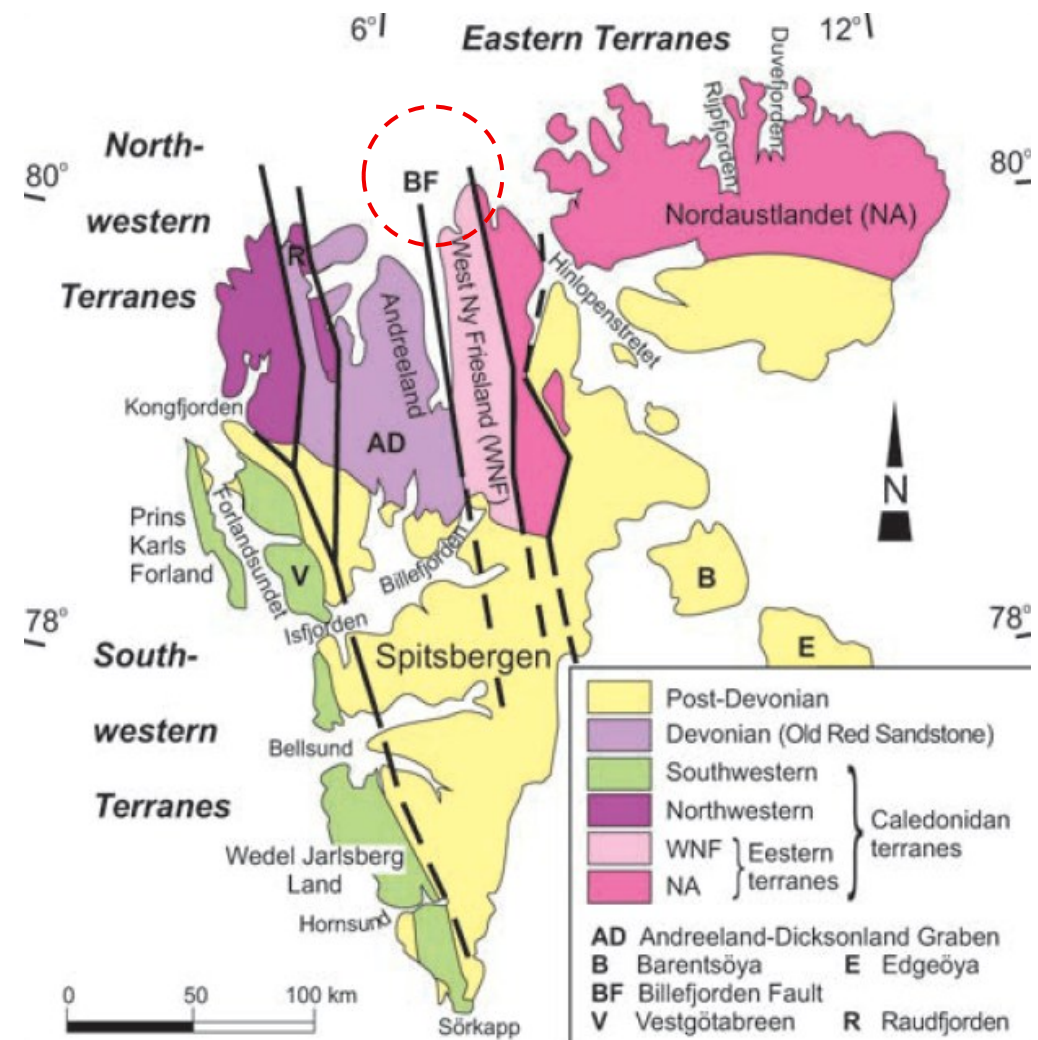
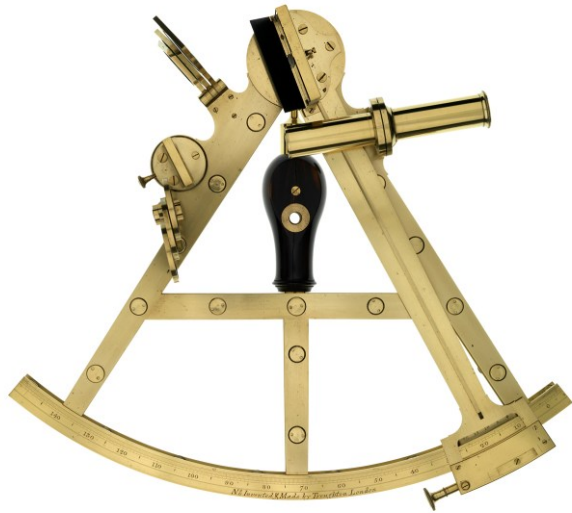
- Growlers!
- Telegraph poles!
- Sudden rocks!
- 90m to zero at shore
- Tide over ledges!

Devonian rock in graben sediments  
between Precambrian schists

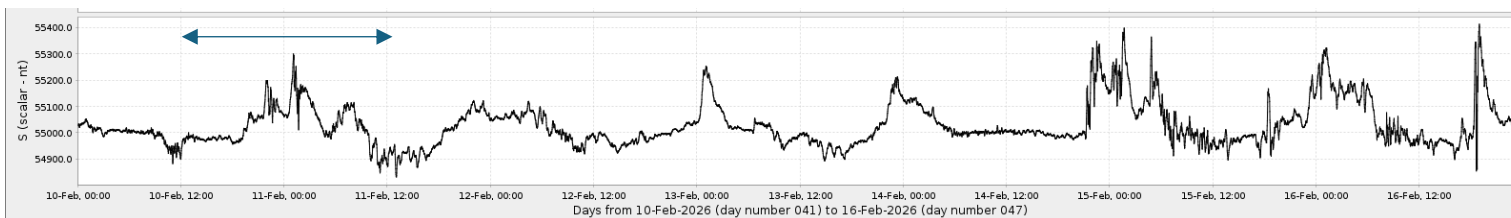


# North of West Ny Friesland

Plotting extent of edge of Devonian graben  
Position fixes and magnetic measurements  
No GPS!



## Magnetic variation 24-hours

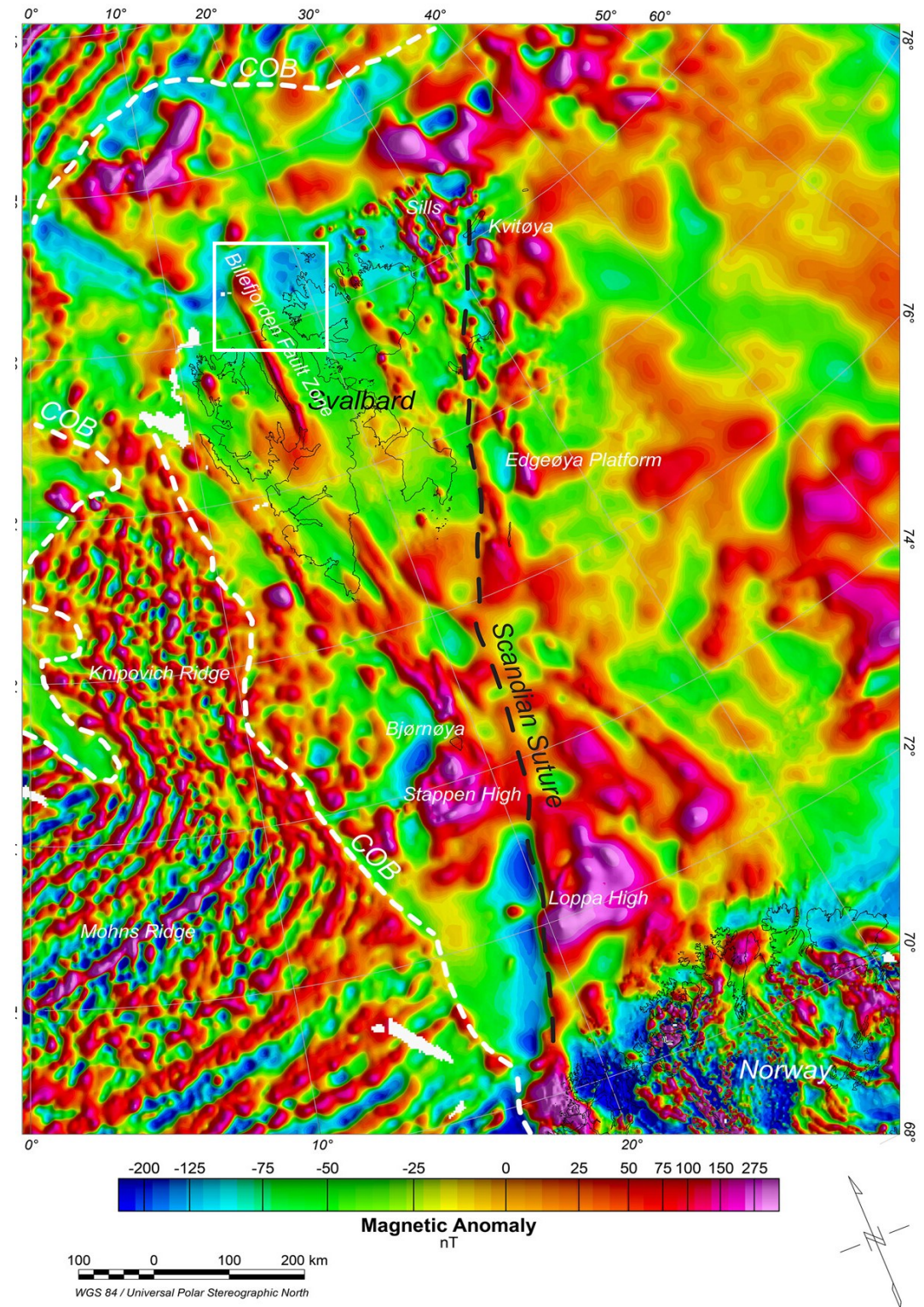


[https://intermagnet.org/data\\_download.html](https://intermagnet.org/data_download.html)

[https://imag-data.bgs.ac.uk/GIN\\_V1](https://imag-data.bgs.ac.uk/GIN_V1)

# 2024 Map of magnetic anomaly around Svalbard

White square shows  
where we were measuring



# Hinlopen Strait

3-days waiting for wind to calm down

## Guillimots at Hinlopen Strait

[https://en.wikipedia.org/wiki/Hinlopen\\_Strait](https://en.wikipedia.org/wiki/Hinlopen_Strait)



