NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

GEUS

Conference on Exploration and Exploitation of Critical Raw Materials

Review of the critical raw material resource potential in Greenland

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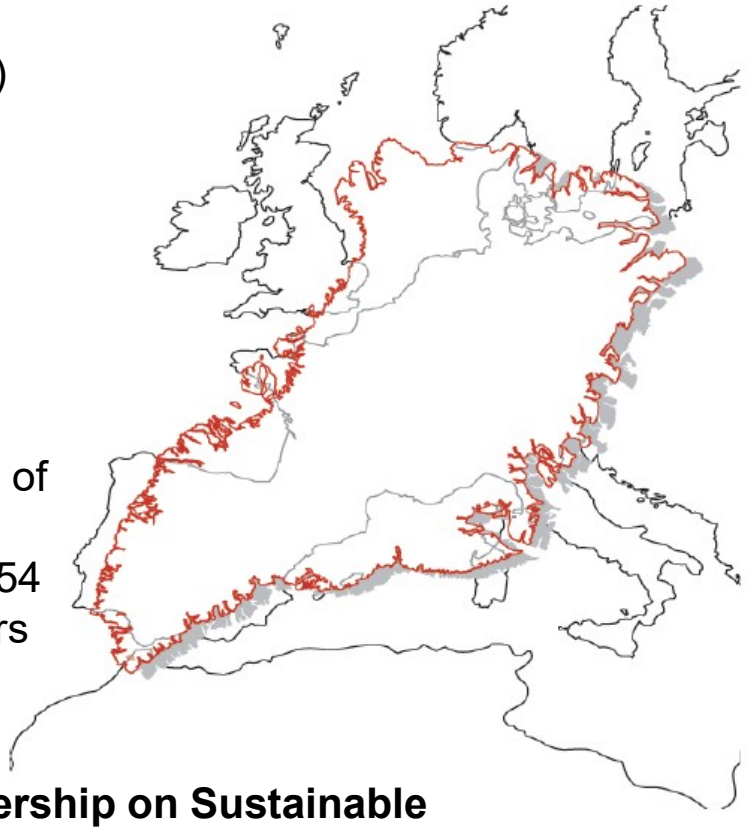
EGT-TWINN

Funded by the European Union

Background

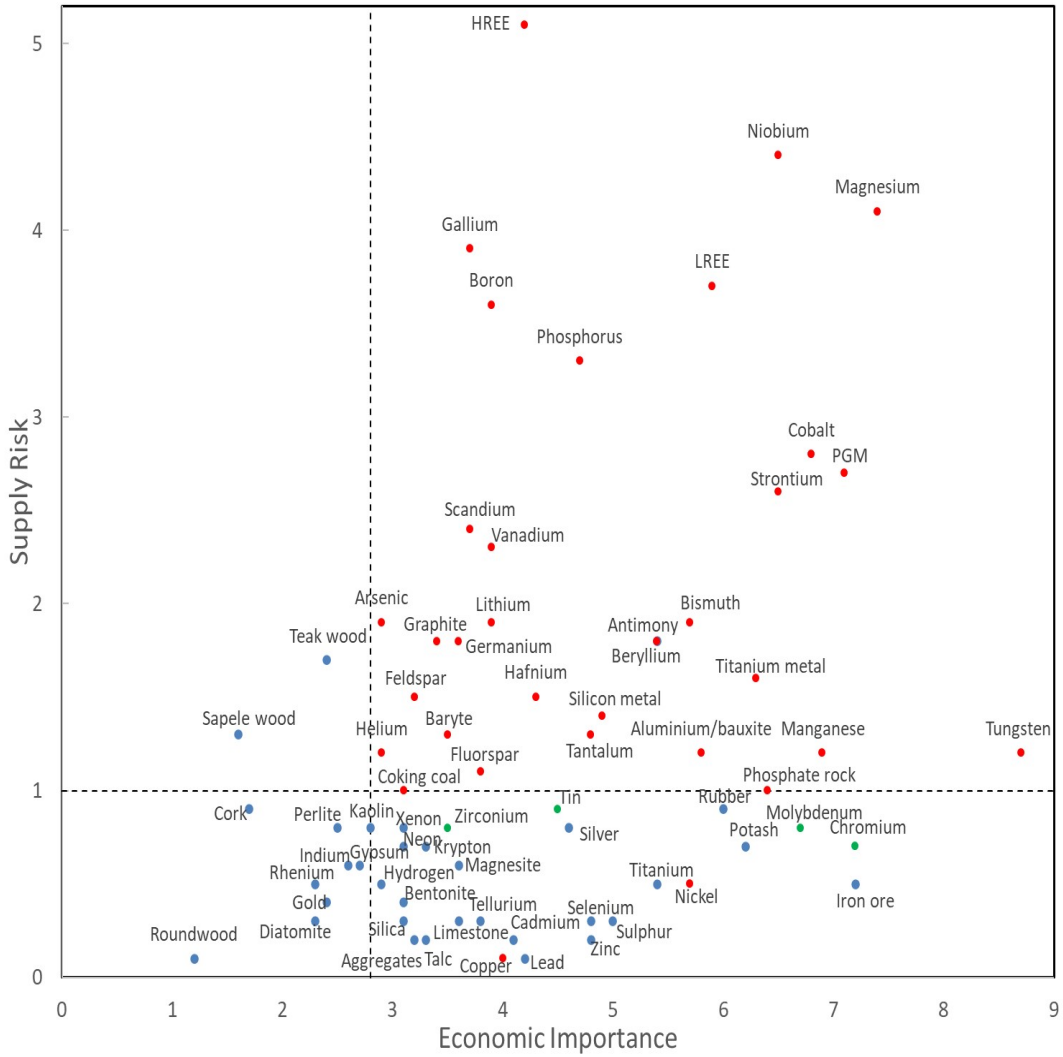
Greenland the facts:

- World's largest island (2,166,000 km^2)
- 410,000 km^2 exposed area
- N-S: 2675 km, W-E: < 1250 km
- Self-rule in the Danish Kingdom
- 57,000 residents
- Arctic climate
- 76 settlements, limited infrastructure
- Complex geological terranes
- Covering almost four billion years of geological history
- Long mining history dating back to 1854
- Limited mining acitivites in recent years



In 2023 EU formed a Strategic Partnership on Sustainable Raw Materials Value Chains with Greenland – but what is the critical raw material potential in Greenland?

Which raw materials?



Those defined as critical (CRM) by the EC (2023), based on:

-meeting EI and SR thresholds

-considered strategic (Cu, Ni)

Considered near-critical by virtue of their high EI and relative high SR (Zr, Sn, Mo, Cr).

Non-critical raw materials were not assessed in this review.

How were CRM resources assessed?

Known

Compiled from published estimates carried out by exploration companies or by the survey

Modern standards (NI43, JORC, etc)
or
Historic, less accurate, estimates

+

Unknown

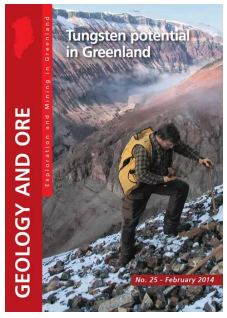
Estimated at yearly Mineral Resource Assessment workshops

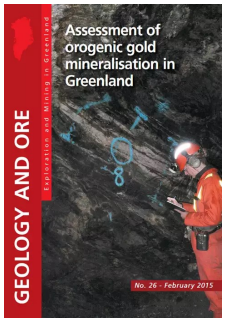
USGS 3-part approach:
1-delineation of permissive tracts
2-estimate of number of undiscovered deposits by expert panel (bidding)
3-deposit models tonnage/grade frequency distributions used for quantitative estimates

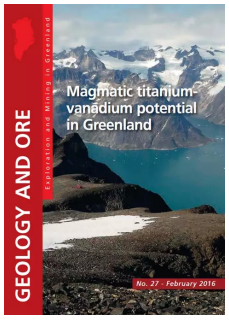
Known CRM resources in Greenland

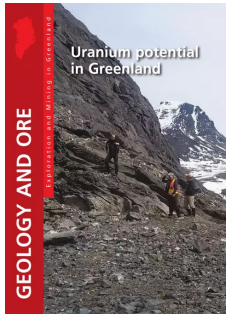
Results of MRAP workshops published:

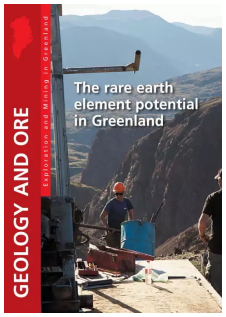
2017: Graphite (Geology & Ore No. 32, 2019)
2016: Uranium (Geology & Ore No. 28, 2018)
2015: Vanadium/titanium; magmatic (Geology & Ore No. 27, 2016)
2014: Gold (Geology & Ore No. 26, 2015)
2013: Tungsten (Geology & Ore No. 25, 2014)
2012: Nickel; magmatic (Geology & Ore No. 24, 2013, No. 31, 2018)
2011: Zinc (Geology & Ore No. 21, 2012; No. 30, 2018)
2010: REE (Geology & Ore No. 20, 2011; No. 29, 2018)
2009: Copper; sediment hosted (Geology & Ore No. 18, 2011; No. 33, 2019)

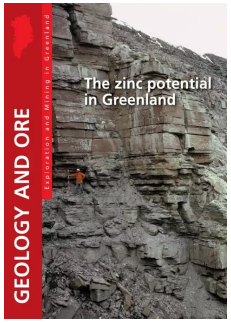


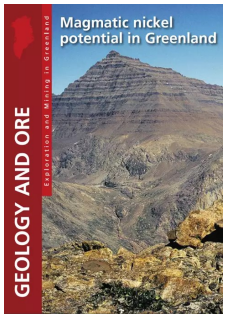


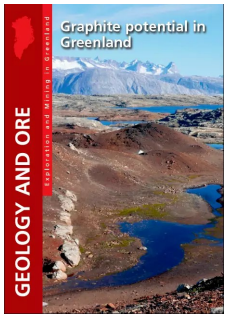


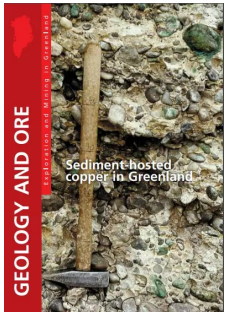




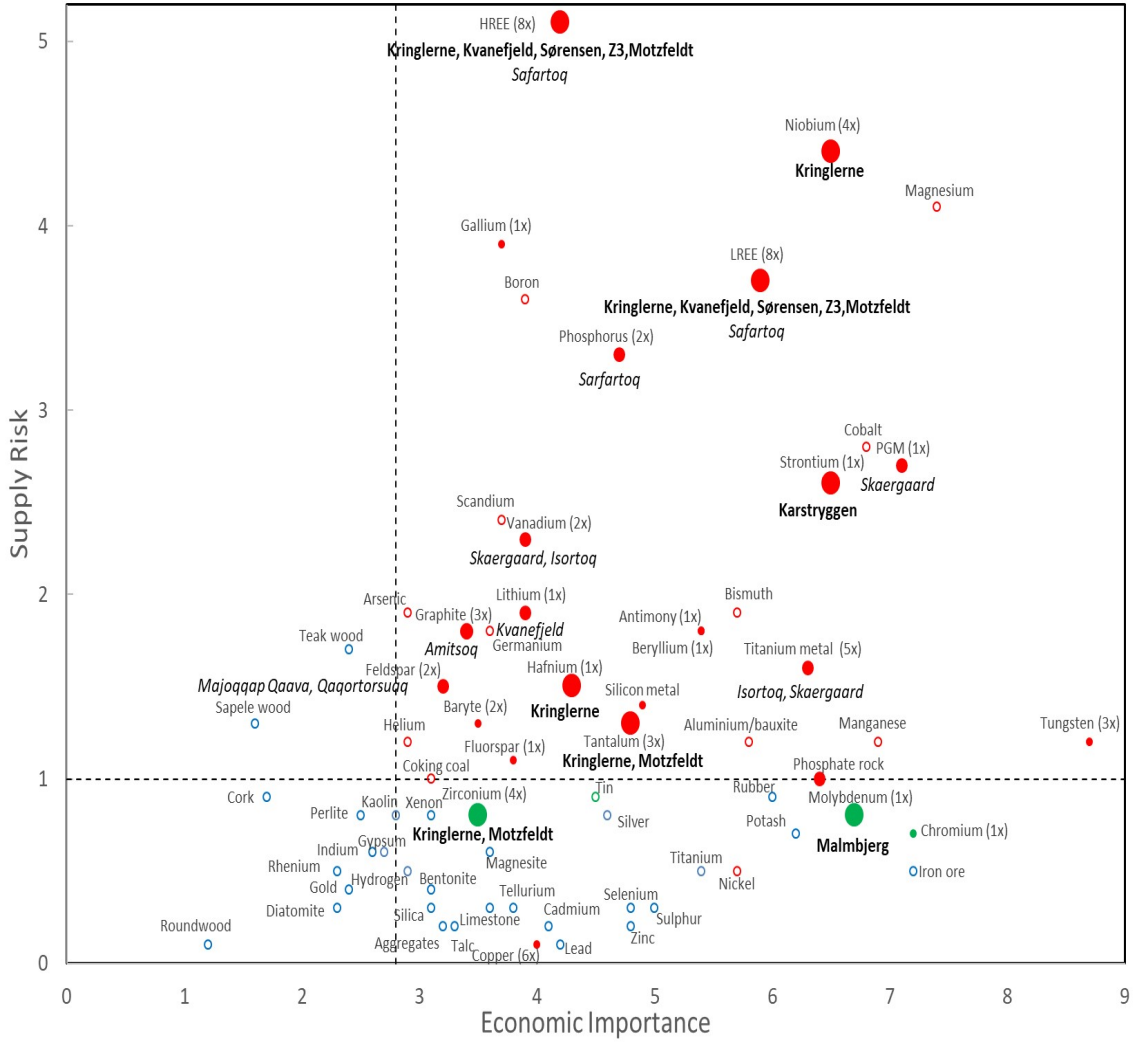








Known CRM resources in Greenland



Inspire size categories

- unknown
- very small to medium
- *large*
- **very large**

7 large deposits

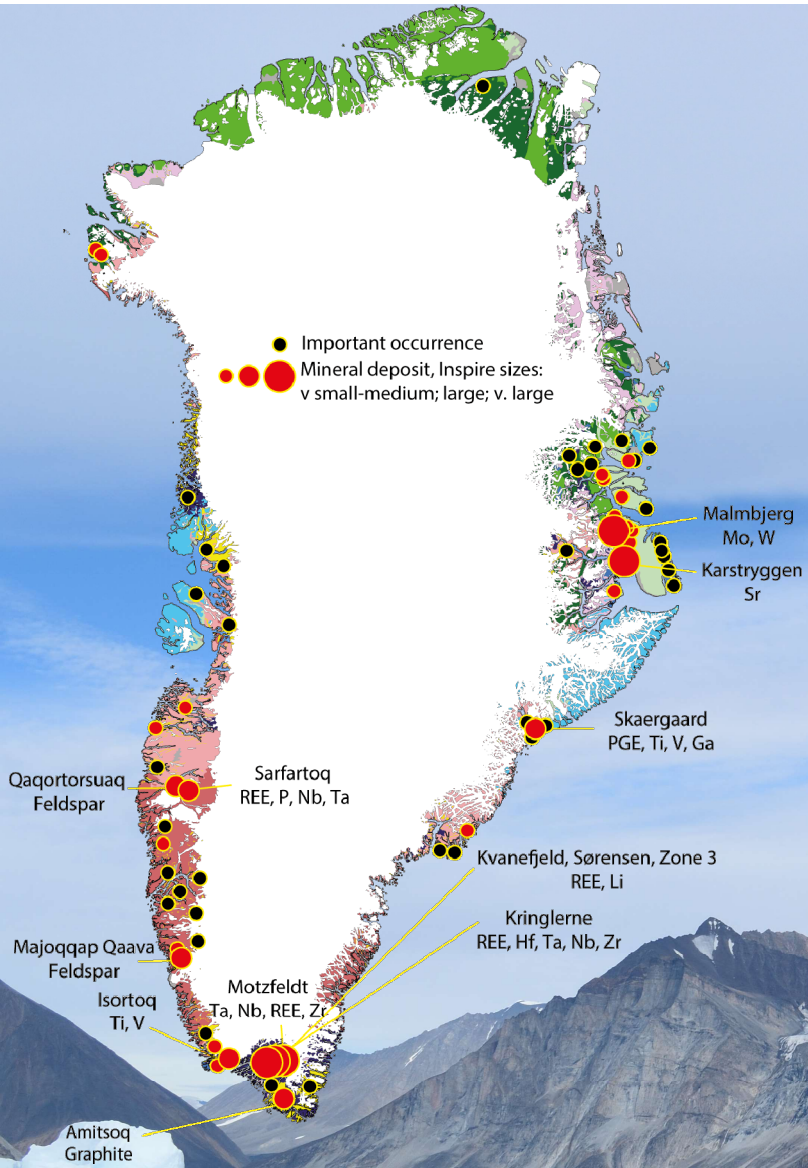
7 very large deposits

Deposits

Very large, REE deposits, some also hosting very significant Li, Ta, Nb, Hf and/or Zr resources, at Kringlerne, Kvanefjeld, Sørensen, Zone 3 (of the Illímaussaq intrusion) and Motzfeldt, in South Greenland.

East Greenland stands out by hosting the **very large** Malmbjerg Mo deposit, the **very large** Karstryggen Sr deposit, and the *large* Skaergaard PGM-Ti-V deposit.

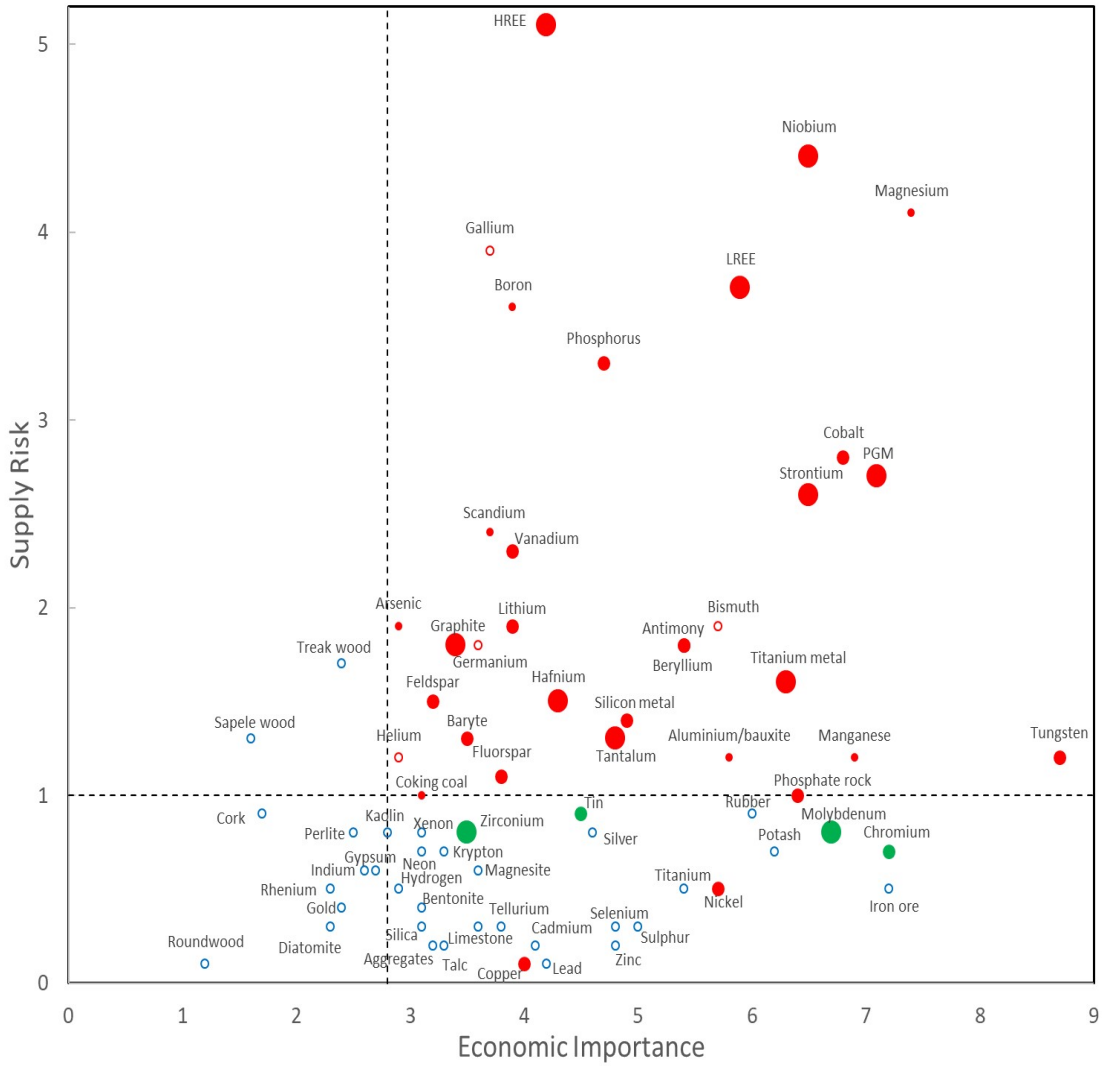
Also significant are the *large:*
-feldspar deposits at Majoqqap Qaava and Qaqortorsuaq (southern West Greenland);
-Sarfartoq REE-P deposit (southern West Greenland)
-Amitsoq graphite deposit (South Greenland);
-Isortoq Ti-V deposits (South Greenland);



Known CRM resources in Greenland

Commodity	Contained resource (t)	Commodity	Contained resource (t)
Antimony (Sb)	3,780	Niobium (Nb)	5,900,000
Baryte (Ba)	480,000	Phosphorus (P)	11,500,000
Beryllium (Be)	65	Platinum group metals (PGM)	576
Chromium (Cr)	560,000	Rare earth elements (REE)	36,100,000
Copper (Cr)	75,200	Silicon metal (Si)	2,800,000
Feldspar	81,000,000	Strontium (Sr)	9,800,000
Fluorite ($CaFl_2$)	250,000	Tantalum (Ta)	916,000
Gallium (Ga)	152,000 (?)	Titanium (Ti)	11,500,000
Graphite (C)	6,000,000	Tungsten (W)	26,200
Hafnium (Hf)	108,000	Vanadium (V)	179,000
Lithium (Li)	235,000	Zirconium (Cr)	57,100,000

CRM resources in Greenland



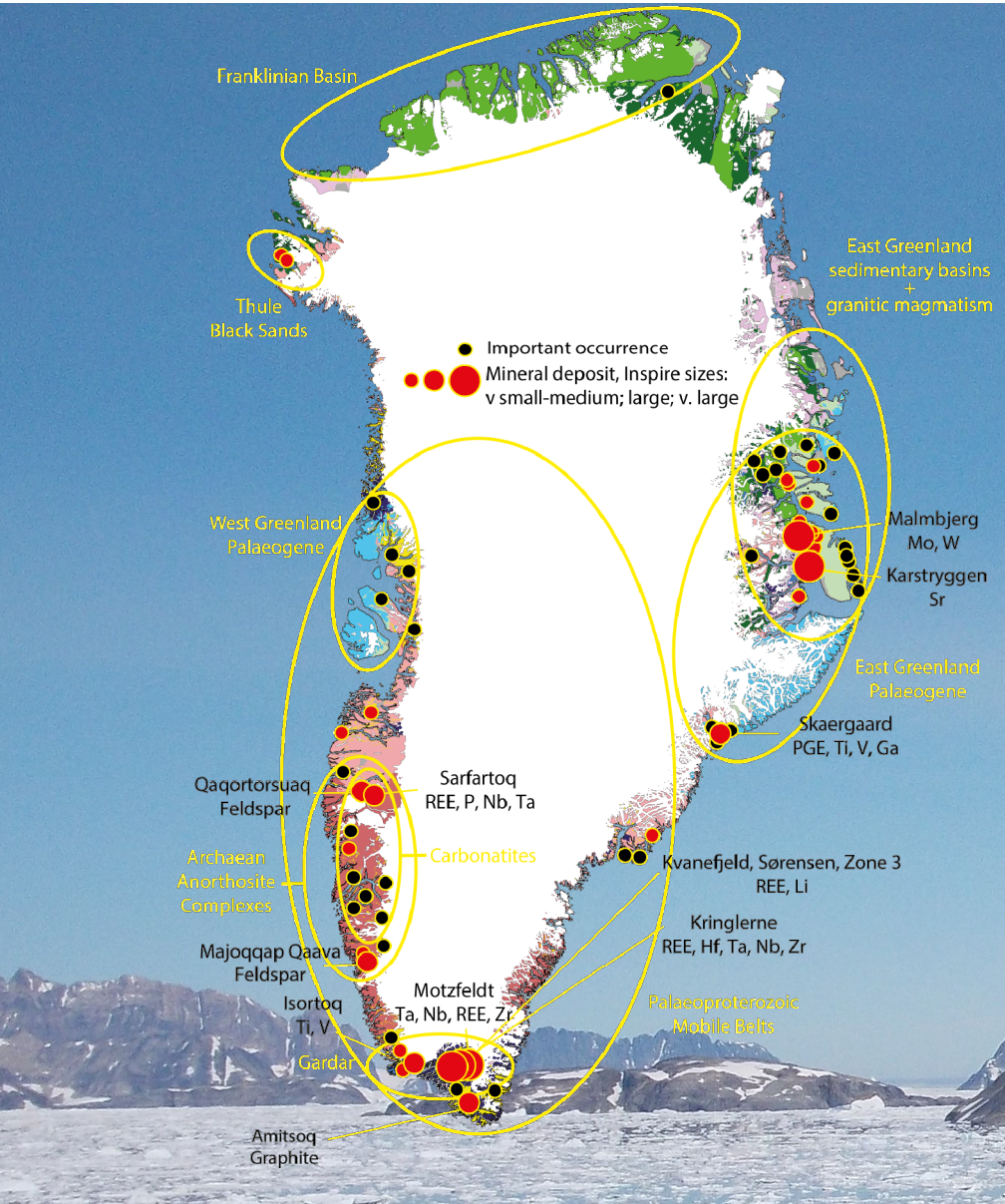
Resource potential

- unknown
- low
- moderate
- high

Low potential: 7

Moderate potential: 15

High potential: 11



Deposits and Provinces

Potential for undiscovered deposits can also be extended to:

-W, Sn, and Sb in veins, skarns and greisens, or sedimentary Cu in East Greenland.

-Ni, Cu and Co in magmatic deposits is expected in Western Greenland

-Zn and Pb deposits, from which Ge and Ga can be possible by-products, are predicted in North Greenland.

-graphite in Palaeoproterozoic terranes (West, South and East Greenland).

Mesoproterozoic Gardar rift, South Greenland

Extreme magmatic differentiation of alkaline magmas resulted in extraordinary accumulation of specialty metals:

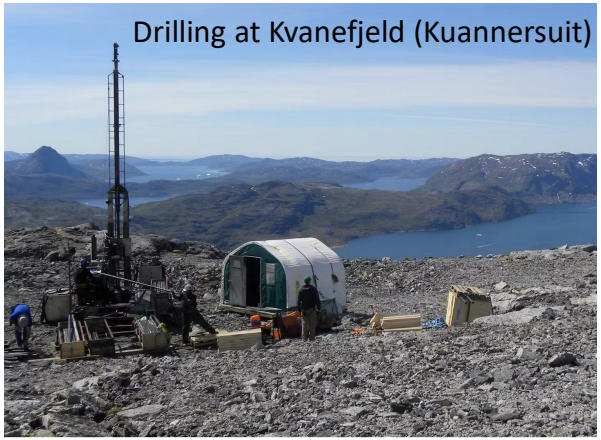
-Ilímaussaq intrusion: Kvanefjeld lujavrites: 9 Mt REE.

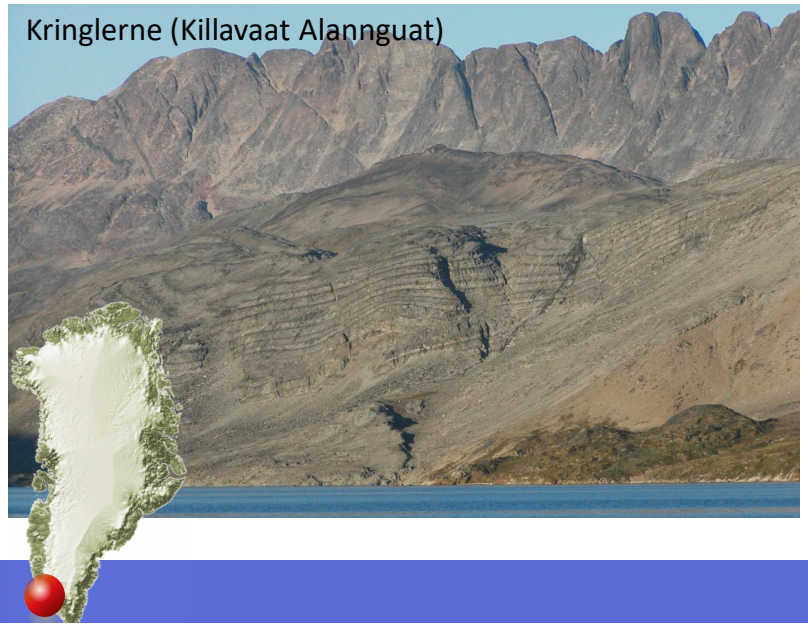
Kringlerne kakortokites: 24 Mt REE, 5 Mt Nb, 1 Mt Ta, Zr, Hf

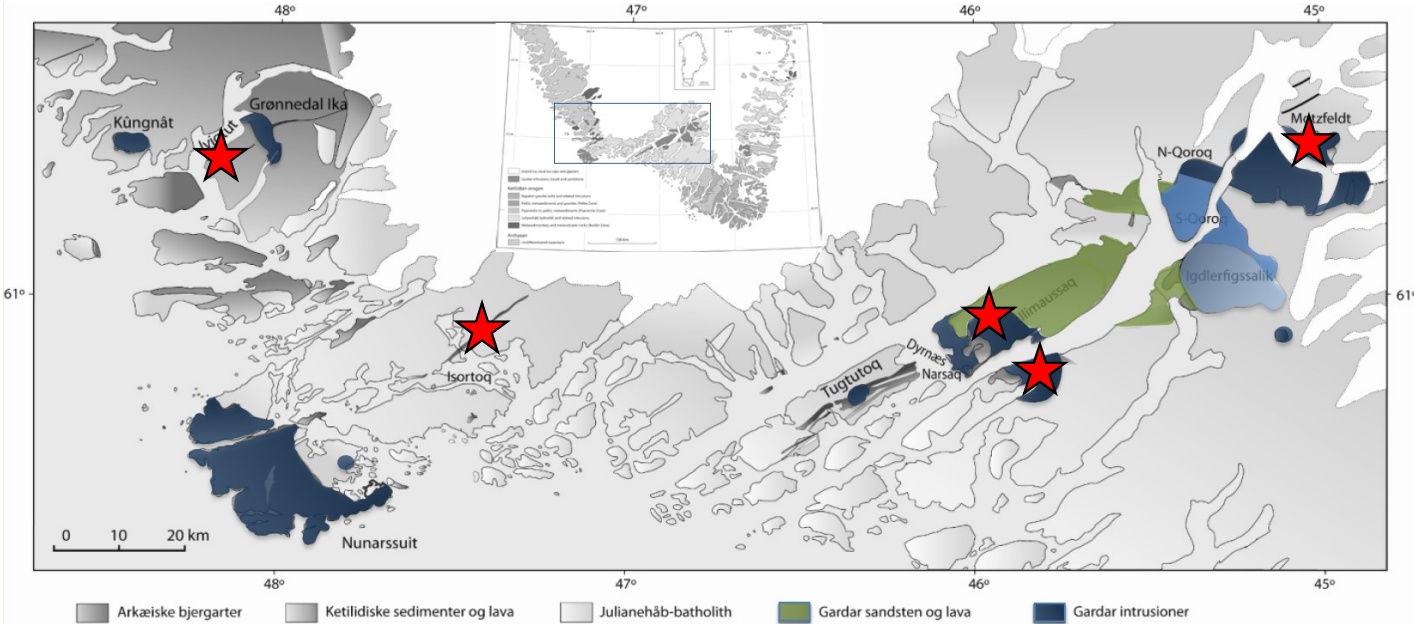
-Igaliko complex: Motzfeldt Ta-Nb-REE deposit;

-Ivittuut: cryolite (Na_3AlF_6), mined 1854-1987, resources high-quality quartz;

-Isortoq mafic dykes with Ti-V(-Fe) mineralization: 70.3 Mt grading 10.9 wt.% TiO_2 and 0.144 wt.% V_2O_5.





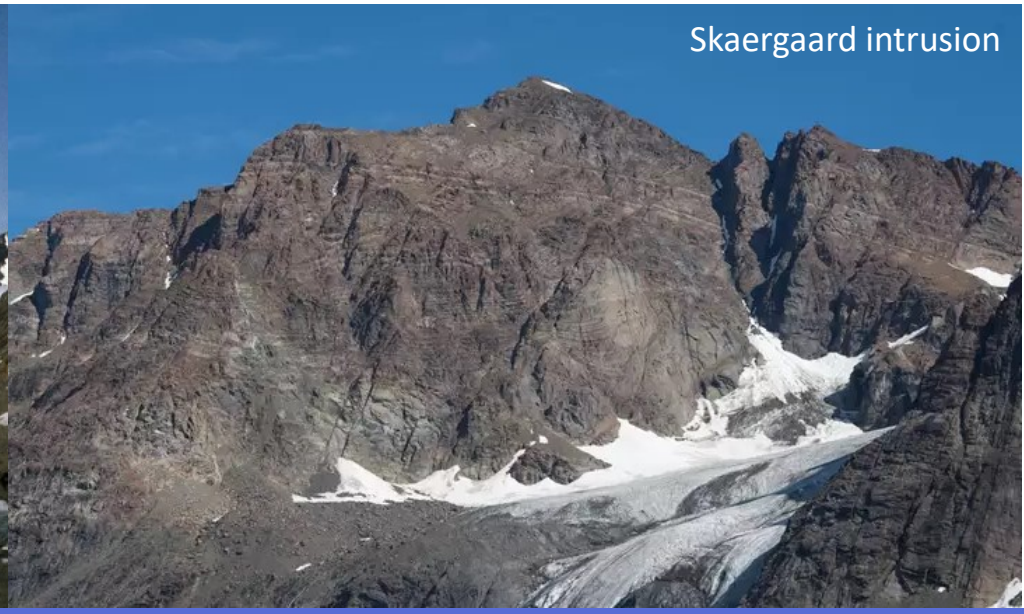


Palaeogene Intrusions, East Greenland

Rifted margin with voluminous flood basalts, dyke-sill complexes and intrusions:

-Skaergaard tholeiitic layered gabbroic intrusion (55 Ma) with spectacular magmatic layering, hosts a significant orthomagmatic stratiform PGE-Au deposit with a resource of more than 364 Mt @ 1.46 g/t Pd and 0.11 g/t Pt, and significant Ti, V and Ga.

-Malmbjerg alkali granite, and related Mo porphyry deposit with a resource of 315 Mt grading 0.18 wt.% MoS_2, also W and Sn endowment.



Archean anorthosite complexes, southern West Greenland

The highest concentration of anorthosite complexes in Greenland is found in the core of the North Atlantic Craton:

-Majoqqap Qaava deposit: 59 Mt

-Qaqortorsuaq deposit: 22 Mt

-other complexes found in Akia, Innajuattoq, Qarliit Nunaat, Buksefjorden.

Qaqortorsuaq (Fiskenæsset) deposit

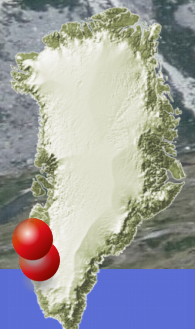
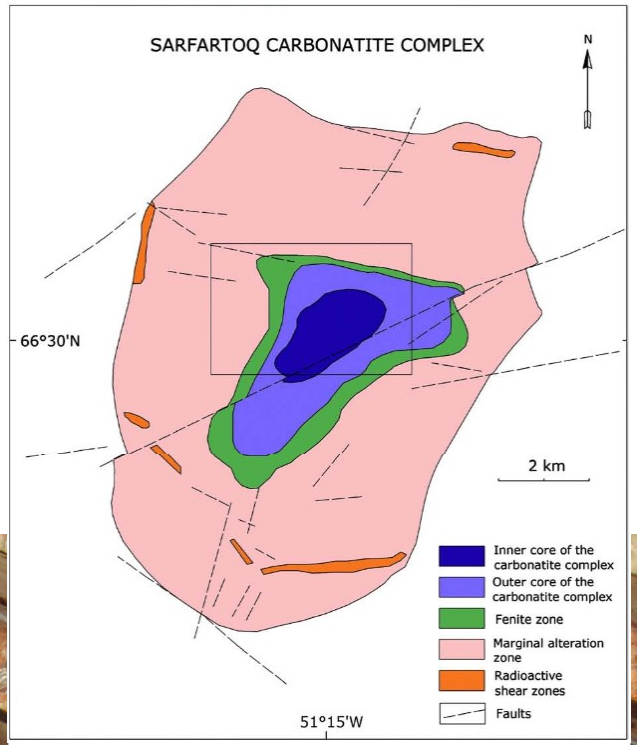


Photo: Greenland Anorthosite Mining

Carbonatites, southern West Greenland

Carbonatites, emplaced between the Archean and the Jurassic, can hold a potential for CRMs, typically hosted in pyrochlore (REE, Nb, Ta) or apatite (P):
-Sarfartoq (565 Ma), consisting of a dolomite-rich core zone of carbonatites surrounded by a fenitized aureole zone that is cut by carbonatite veins, breccias and agglomerates.
-Qaqarssuk (170 Ma), with a central unit of olivine søvite, and rauhaugite ring dykes and a late-state outer suite of fine-grained rauhaugite and søvite sheets.

Other mineralised carbonatites, without resource estimates, include the Tikiussaq and the Grønnedal-Ika complexes.



Modified after Secher and Larsen (2009)


Photo: Hudson Resources

Palaeoproterozoic terranes S, W and E Greenland

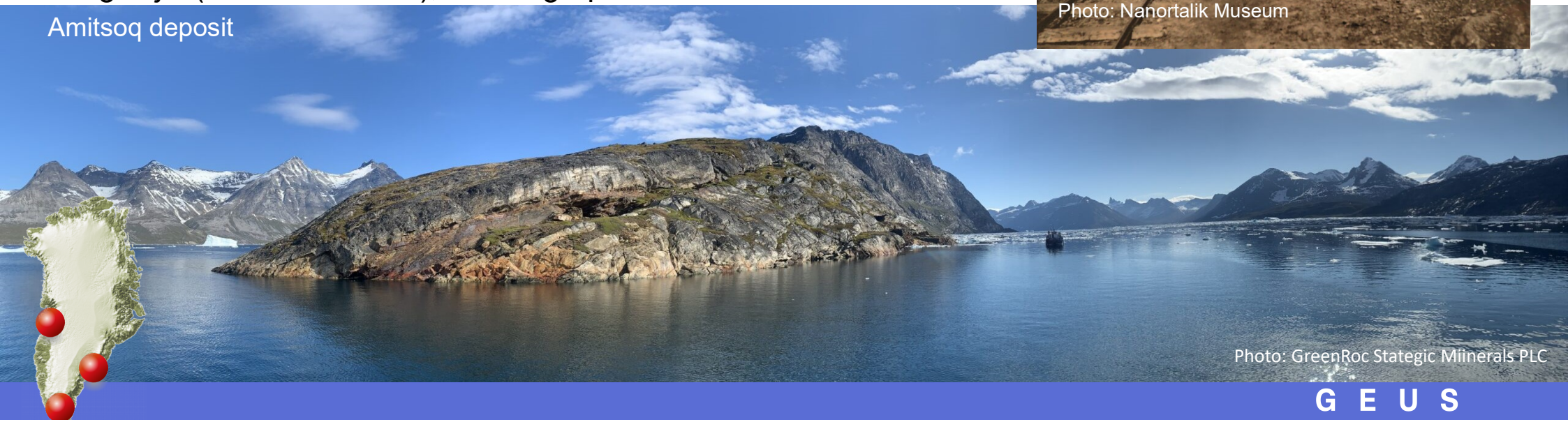
The reworked, deformed, and metamorphosed Palaeo-proterozoic Mobile Belts of Greenland can locally have relatively high abundance of carbonaceous material hosted in supracrustal rocks. This material, under appropriate metamorphic conditions, has been transformed into graphite:

-Amitsoq (South Grenland), with 4.7 Mt graphite

-Akuliaruseq (West Greenland), with 0.8 Mt graphite

-Kangikajik (East Greenland); 0.5 Mt graphite

Amitsoq graphite mine (1915-1924)
Photo: Nanortalik Museum



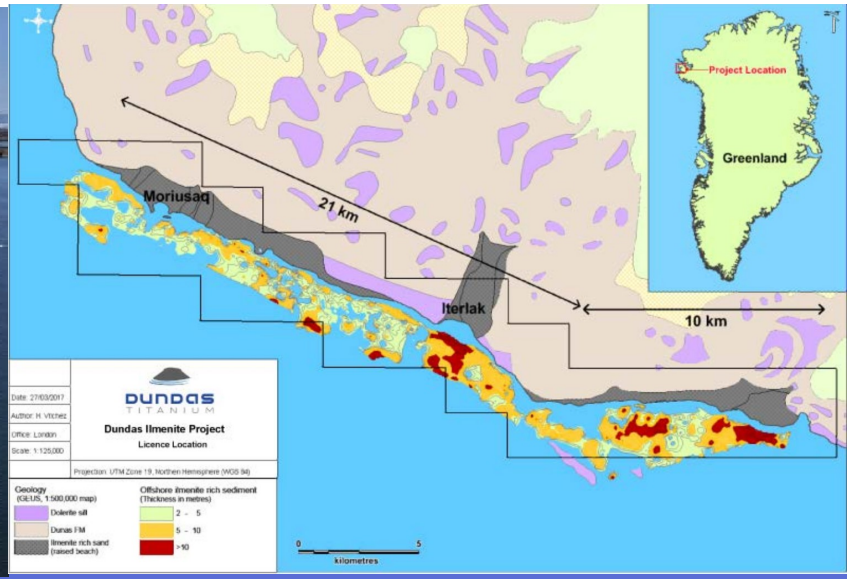
Thule Black Sands, North-West Greenland

Ilmenite-rich placers, related to active, raised, and drowned beaches, are known from along the coast of North-West Greenland. The ilmenite is derived from Neoproterozoic titanium-rich dolerite sills and dykes in the immediate hinterland of the beaches.

Two deposits:

Morisuaq; resource of 117.3 Mt grading 1.7 % Ti (2019 estimate).

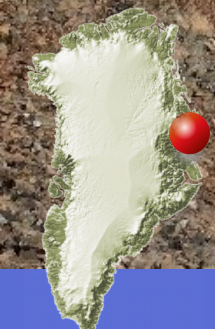
Thule Black sands; 19 Mt resource with 2.8 % Ti.



East Greenland Caledonides

Reduced Silurian and Devonian granitic intrusions are considered fertile and to hold a potential for W, Sn, Sb, Bi, Be, Mo, in pegmatites, skarns, greisens and veins.

Several small occurrences are known, but no significant deposits have yet been identified.

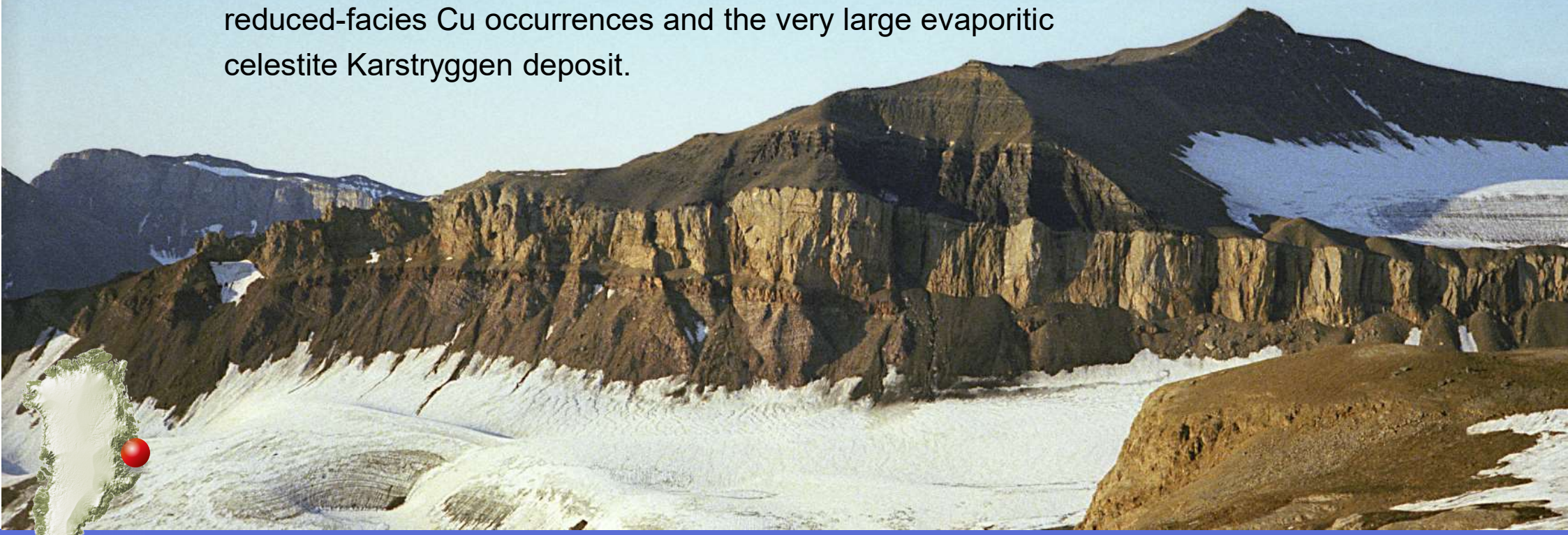


Mineralised veins

East Greenland sedimentary basins

The Neoproterozoic Eleonore Bay Supergroup comprises a thick succession of shallow-water sedimentary rocks, with stratabound Cu occurrences in 8 stratigraphic levels found along more than 300 km.

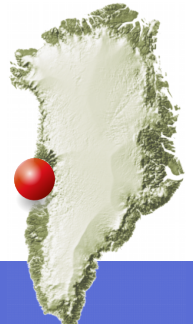
The Permo-Triassic Jameson Land Basin, related to continental break-up, consists of conglomerates, sandstones, shales, carbonates, and evaporites, with reduced-facies Cu occurrences and the very large evaporitic celestite Karstryggen deposit.

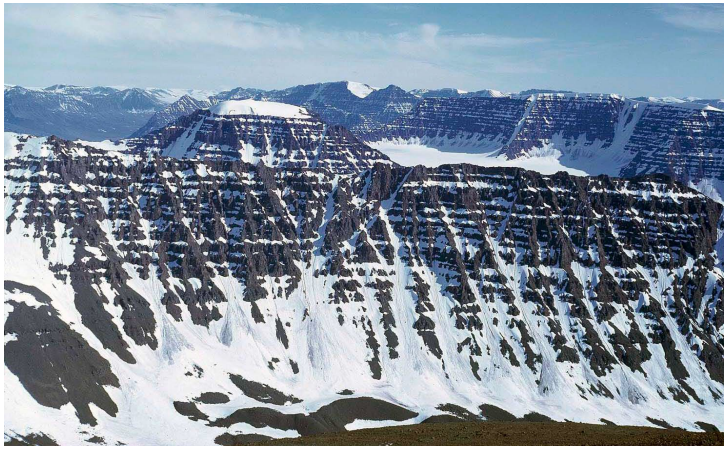


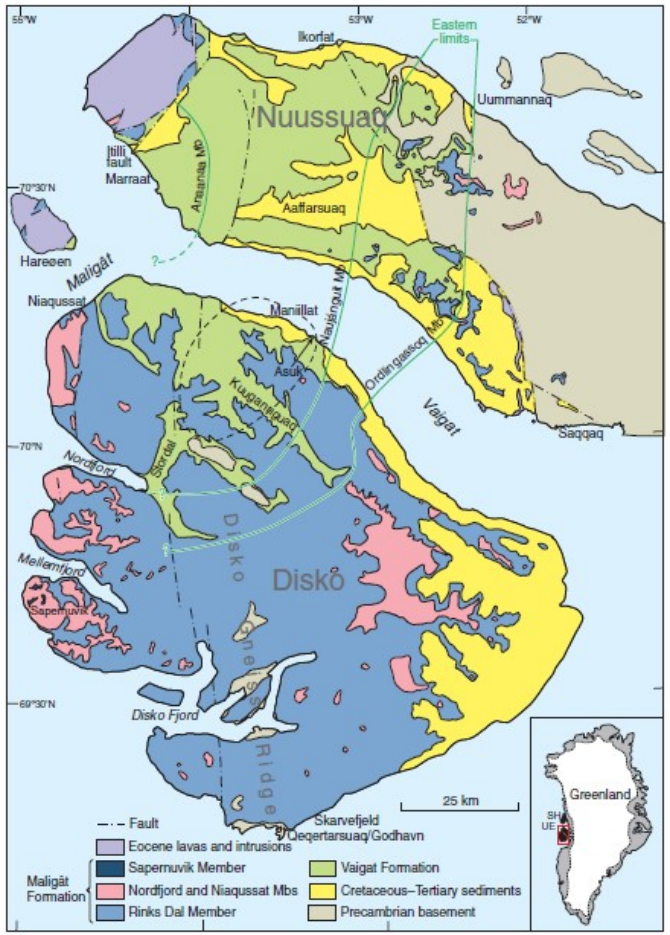
West Greenland Palaeogene Province

Potential for conduit-type (Norilsk type) Ni-Cu-PGM mineralisation related to picrite and/or tholeiitic basalt dyke-sill complexes.

Low contents of these elements in some crustally contaminated lavas suggest sulfide saturation took place. However, this saturation has taken place at shallower crustal levels than at Norilsk.



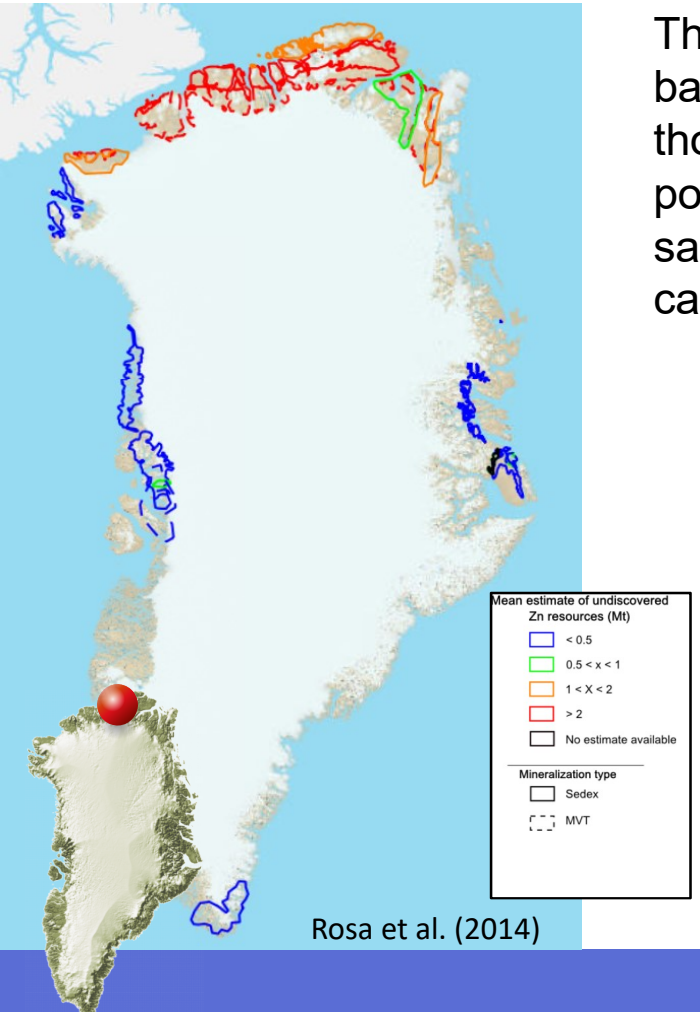




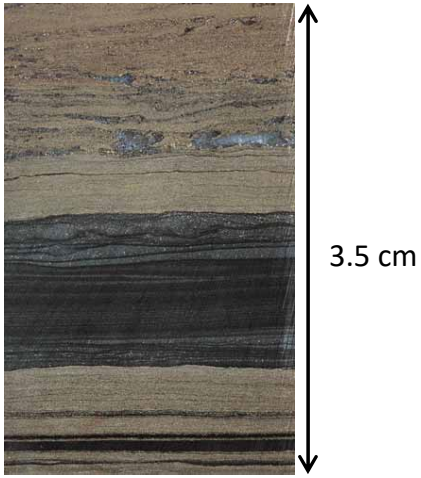
Larsen and Pedersen (2009)

Franklinian Basin, North Greenland

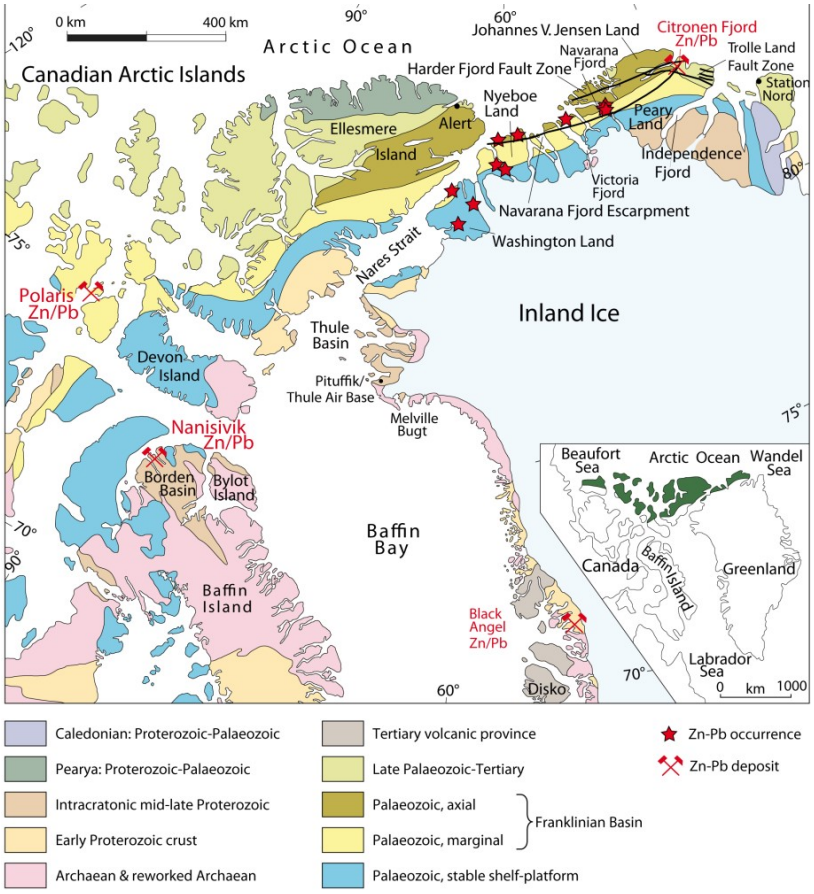
The Phanerozoic Franklinian basin in North Greenland is thought to host a significant potential for Zn-Pb mineralisation, from which Ge and Ga can be possible by-products.



Rosa et al. (2014)



Drill core, Citronen Fjord



After Dawes (1994)

Conclusions

The CRM endowment of Greenland considered plentiful and, in many cases, comparable to that found in well-established mining regions.

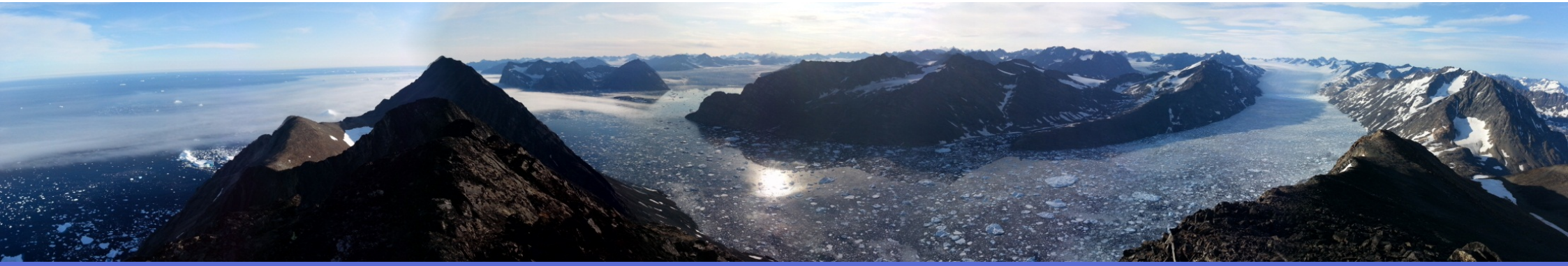
Whereas better quantification of resource numbers is desirable, it is already possible to point out some deposits that are particularly interesting:

- the **very large** rare earth element (REE) deposits, some also hosting very significant Li, F, Ta, Nb, Hf and/or Zr resources, at Kringlerne, Kvanefjeld, Sørensen, Zone 3 (of the Illímaussaq intrusion) and Motzfeldt, in the Gardar Province of South Greenland;
- the **very large** Malmbjerg Mo deposit, the **very large** Karstryggen Sr deposit, and the *large* PGM-Ti-V Skaergaard deposit (East Greenland);
- the *large* feldspar deposits at Majoqqap Qaava and Qaqortorsuaq, and the *large* REE-P Sarfartoq deposit (southern West Greenland), as well as the *large* Amitsoq graphite deposit and the *large* Isortoq Ti-V deposit (South Greenland).

Conclusions

Due to its relatively underexplored status, Greenland still holds a very significant potential for yet undiscovered deposits. Naturally, such potential extends beyond the CRMs and the areas for which resources have already been established, and extends to:

- W, Sn, and Sb in veins, skarns and greisens in Eastern Greenland;
- sedimentary Cu in Eastern Greenland;
- Ni, Cu and Co in magmatic deposits is expected in Western Greenland;
- Zn and Pb deposits, from which Ge and Ga can be possible by-products, are predicted in North Greenland;
- graphite deposits are thought to exist in Palaeoproterozoic terranes (West, South and East Greenland).



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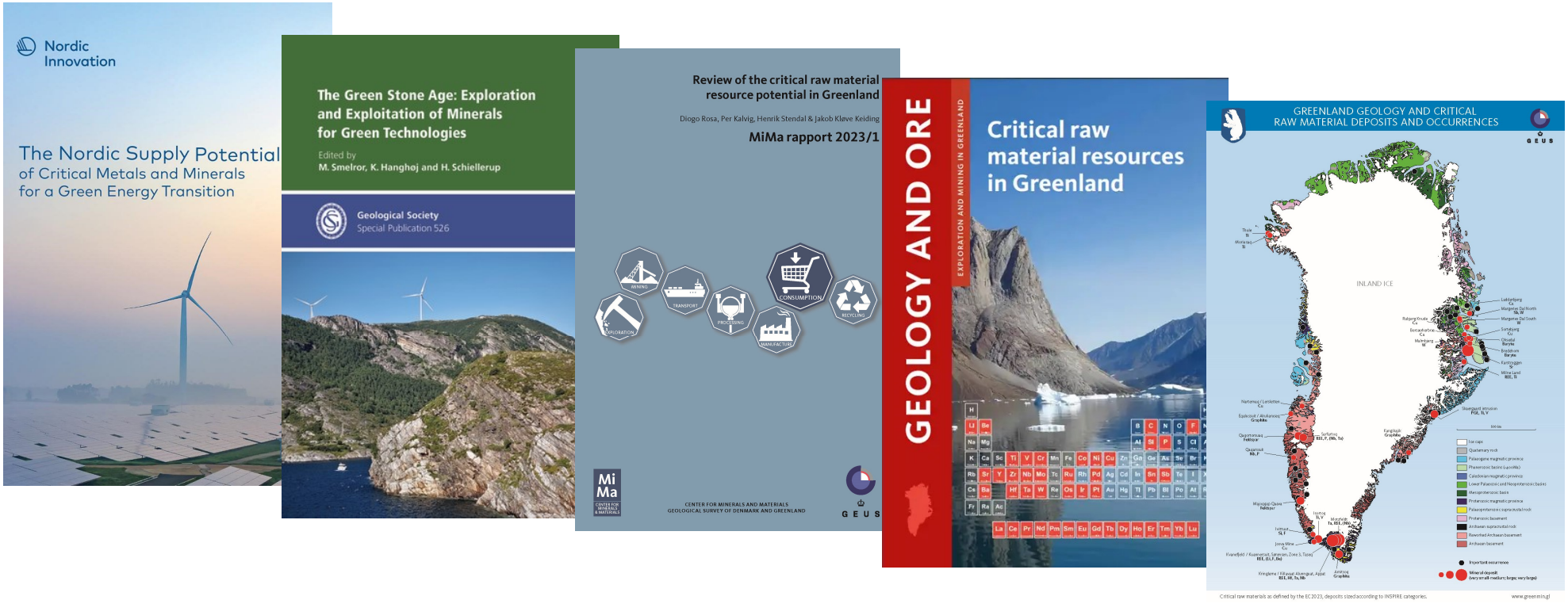

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