



IAEA – Uranium from Unconventional Resources
November, 2009

***Agpaitic Nepheline Syenites of the Ilimaussaq Complex, Greenland:
An Important New Uranium Ore-Type***



GREENLAND
MINERALS AND ENERGY LTD
“Specialty Metals for a Greener World”



ACKNOWLEDGEMENTS

Material presented herein draws on many years work by numerous groups

Geology and resources:

Geological survey of Greenland and Denmark, researchers from the University of Copenhagen

Metallurgy and process development:

Danish Atomic Energy Commission (RISO)





Introduction

Uranium deposit types: *unconformity, sandstone, quartz-pebble conglomerate, IOCG-U, surficial calcrete, intrusive-hosted*

Intrusive deposit types:

Alaskite (leucogranite) – large bulk-tonnage, low grade deposits

Rossing Mine, Rossing South, Etango, Valencia

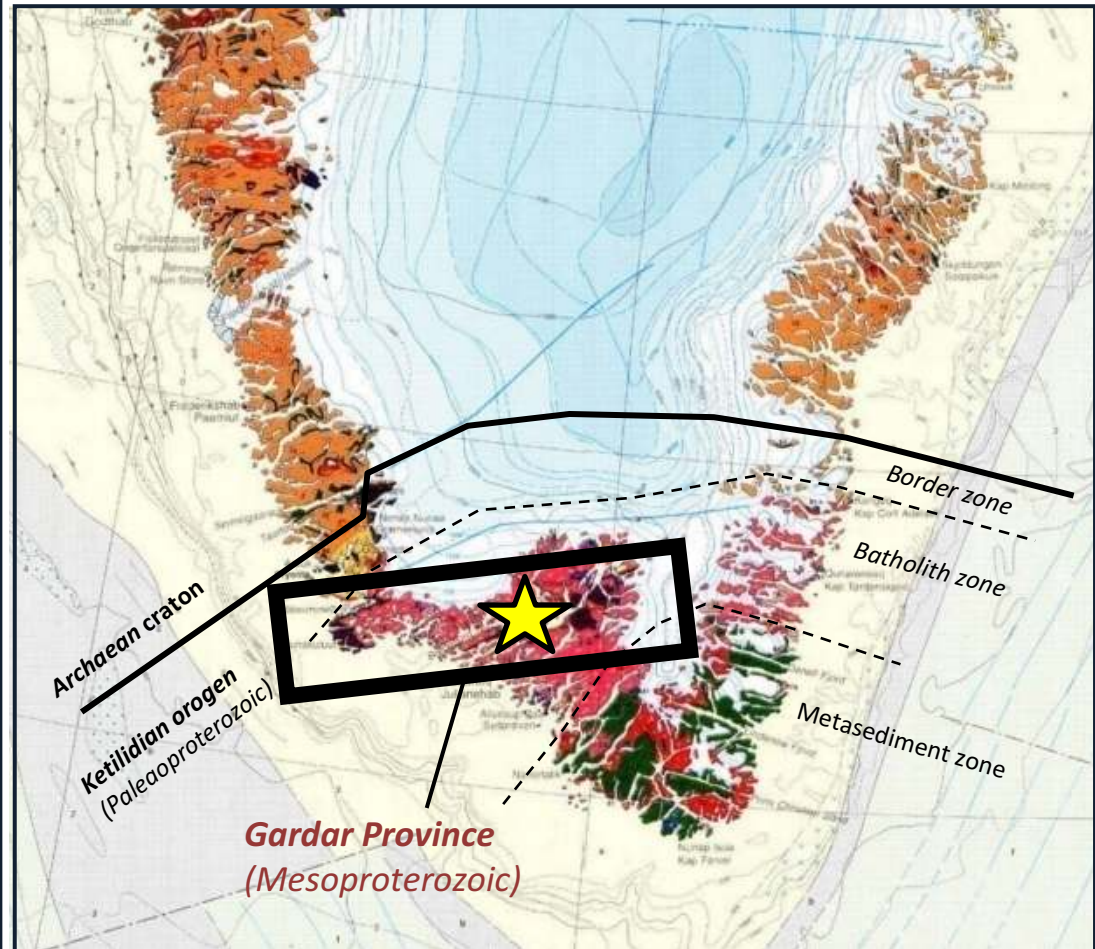
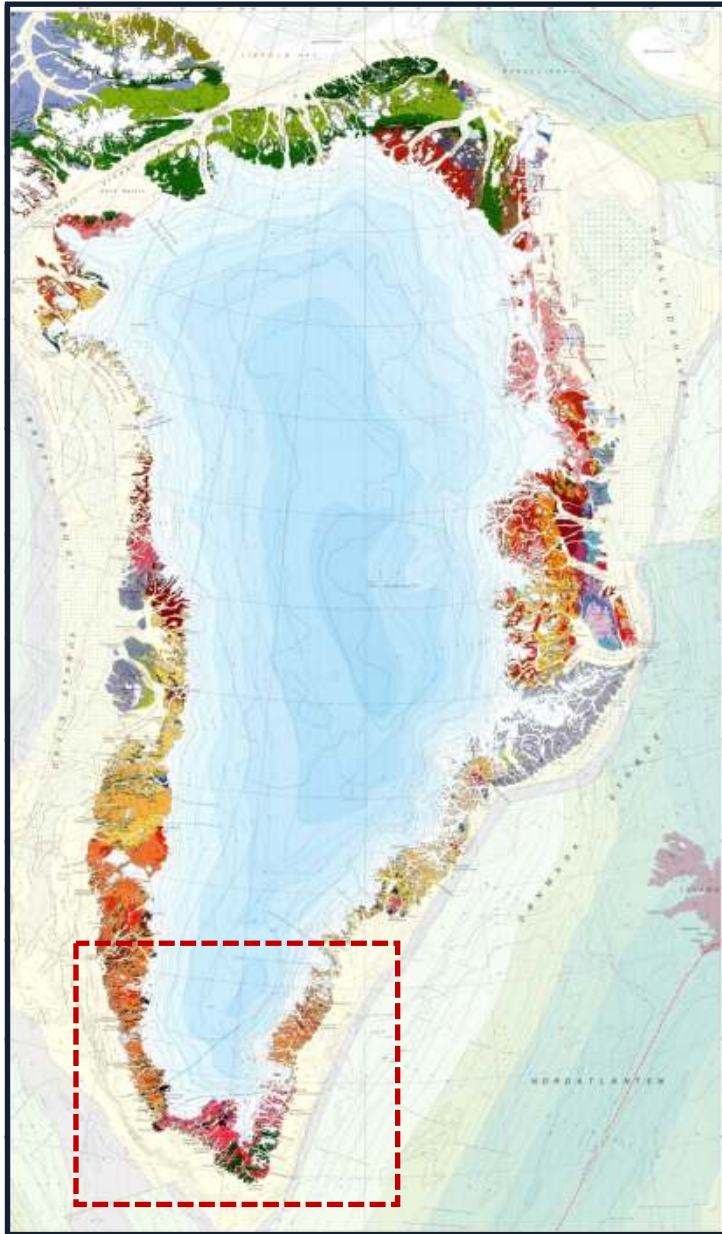
Agpaitic Nepheline Syenites: type locality – ***Ilimaussaq Complex***, south

Greenland

Inconventional rocks, unconventional minerals, extraordinary resource scale



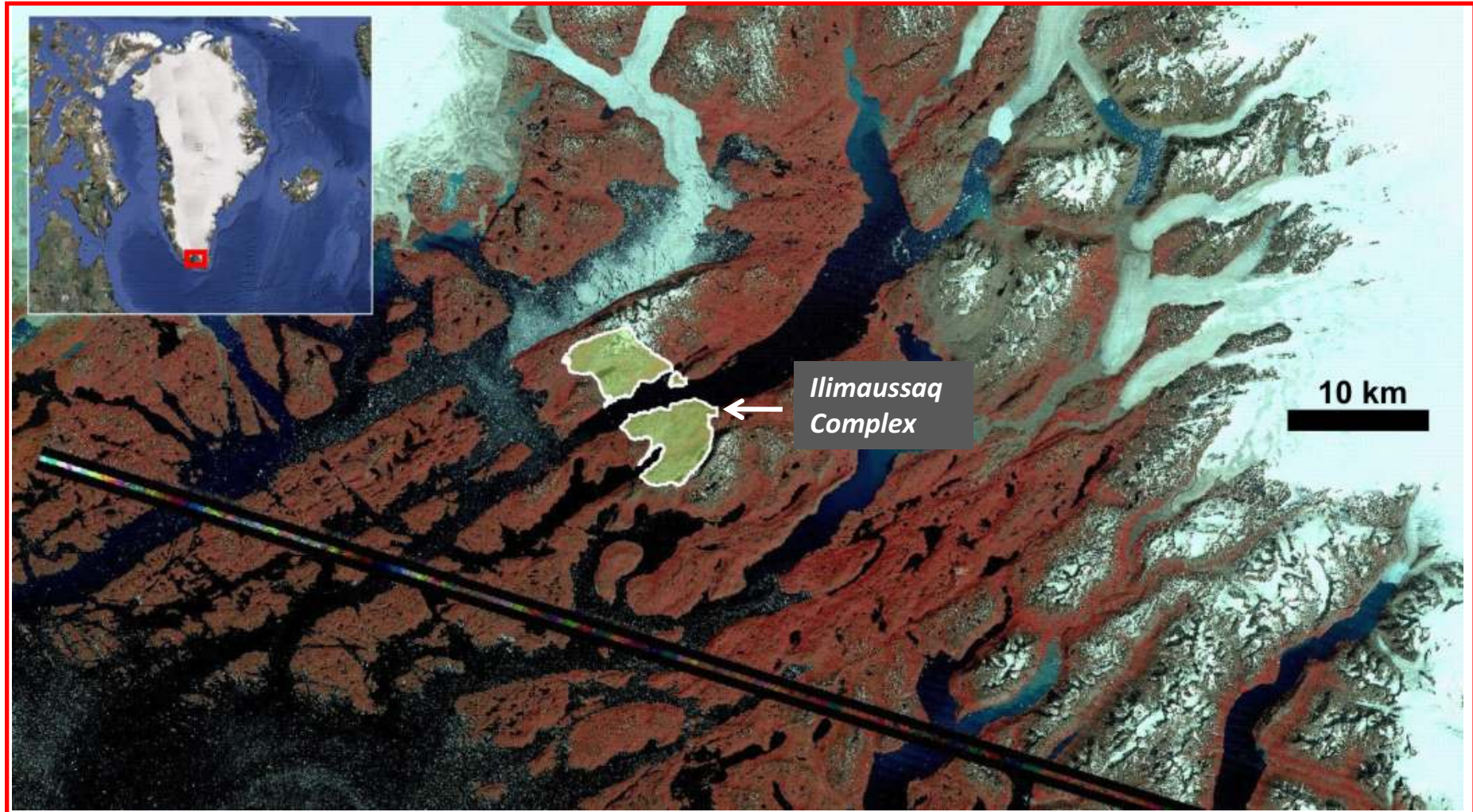
Greenland Geology



Gardar Province – Alkaline intrusions emplaced in a continental rift setting (*Ilimaussaq Intrusion*)



Ilimaussaq Intrusive Complex



False-colour image over south Greenland



Ilimaussaq Intrusive Complex



- Recognised as being geologically-unique since early 1800's
- Subject of more than 700 published scientific papers
- Uranium enrichment identified in the 1950's
- Work programs implemented by RISO and GEUS (state sponsored)
- Work programs ceased in 1983, project mothballed
- Work recommended in 2007 by *Greenland Minerals and Energy Limited*
- Taking a polymetallic, or multi-element approach



Ilimaussaq Complex: *layered alkaline intrusion, type-locality of agpaitic nepheline syenites*



Ilimaussaq Intrusive Complex

Geology and Genesis



1



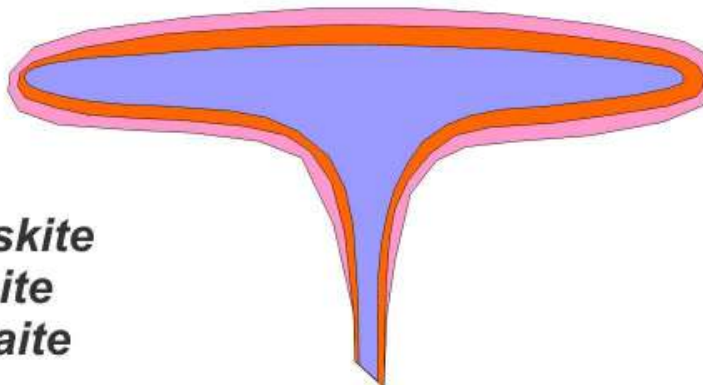
Augite Syenite

2



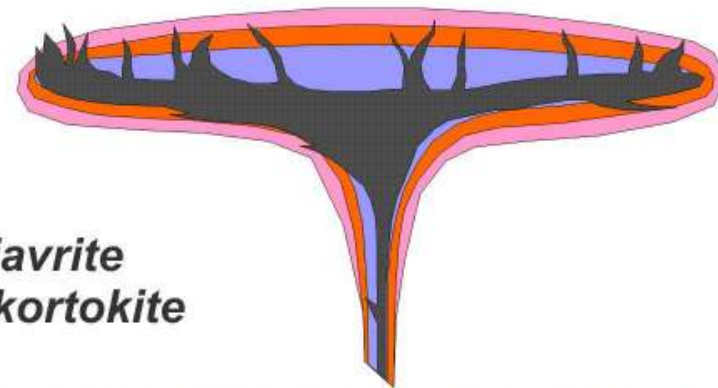
Peralkaline Granite

3



*Pulaskite
Foyaite
Naujaite*

4

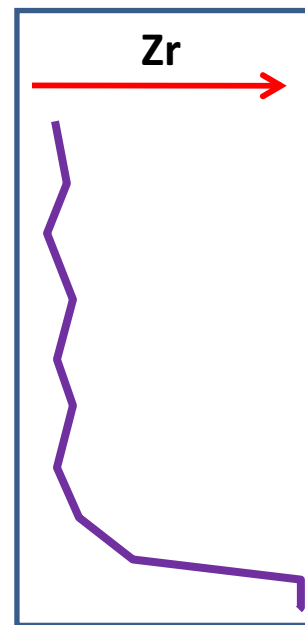
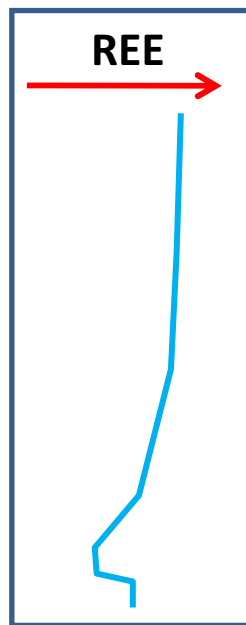
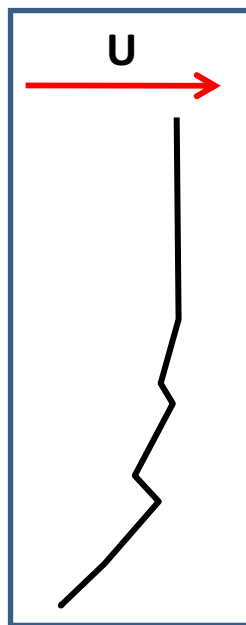
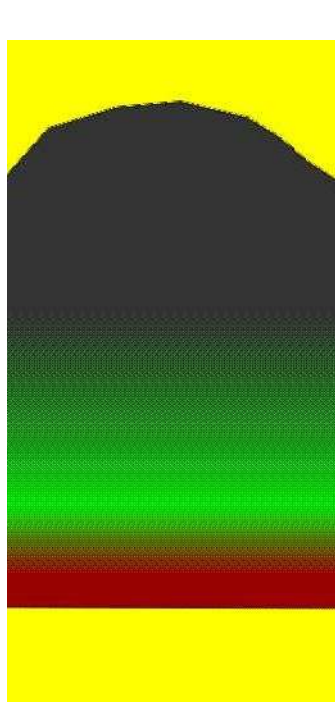
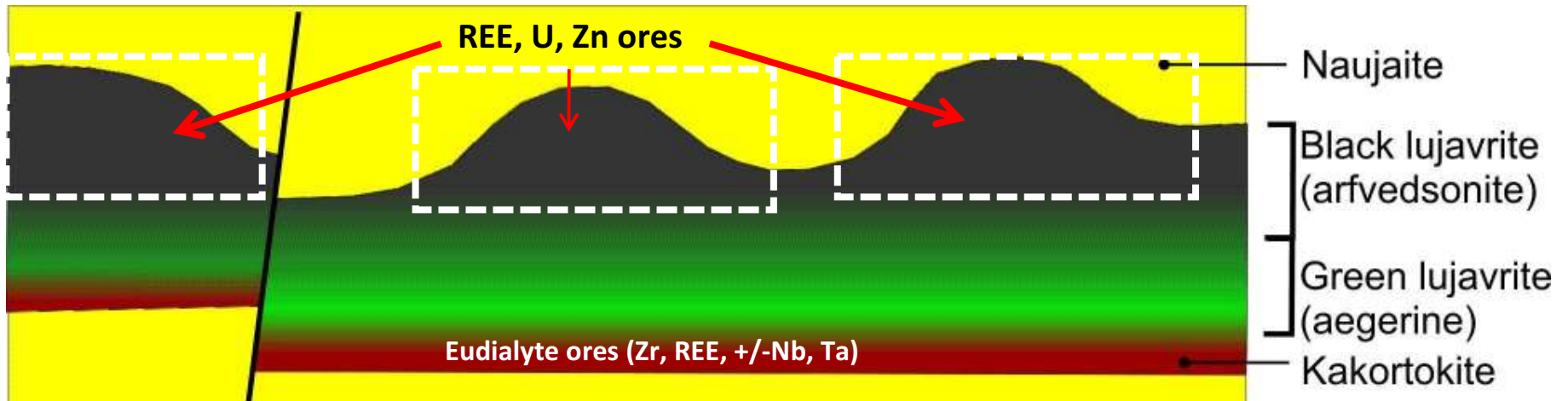


*Lujavrite
Kakortokite*

(host units to multi-element mineralisation)



MAJOR ORE TYPES OF THE ILIMAUSSAQ COMPLEX

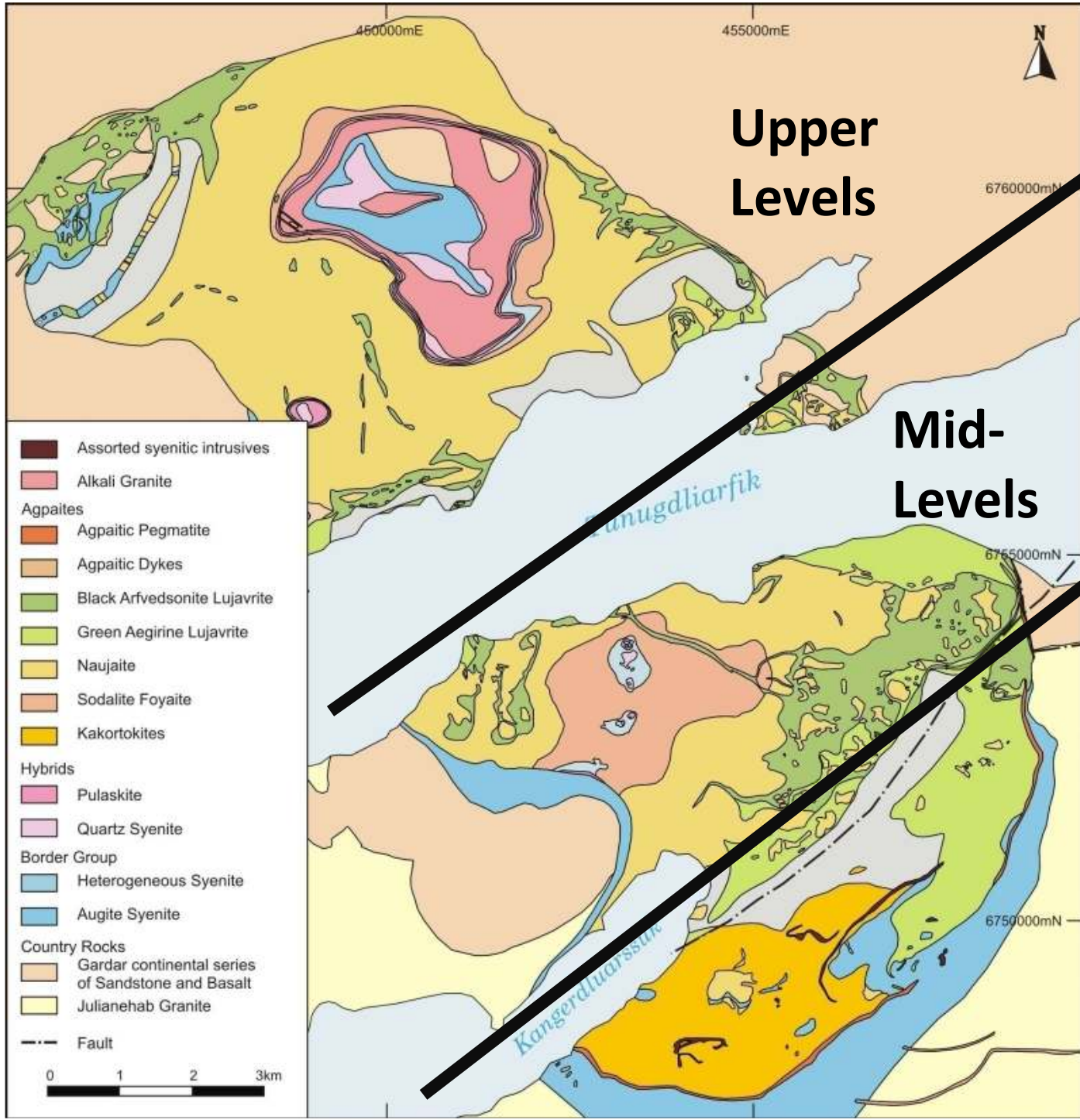


Key Minerals

- Steenstrupine* - U, REEs
- Na-Zr-U-silicates* - U, Y
- Cerite, Vitusite* - REEs
- Sphalerite* - Zinc

Eudialyte +/- monazite

Geochemical profiles

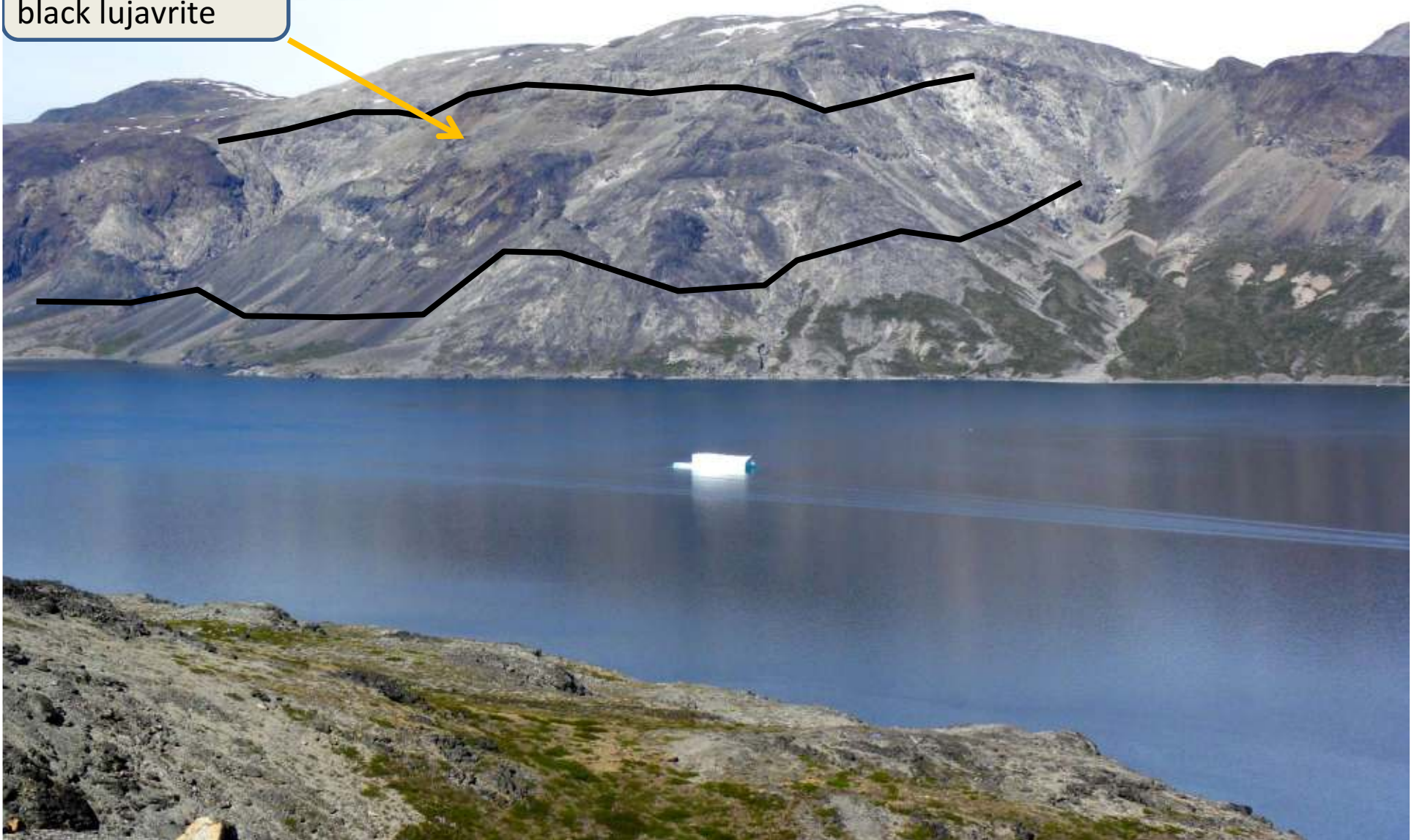


Block faulting has resulted in different levels of the complex being exposed with deeper levels exposed to the south

Basal Levels (Kakortokites)

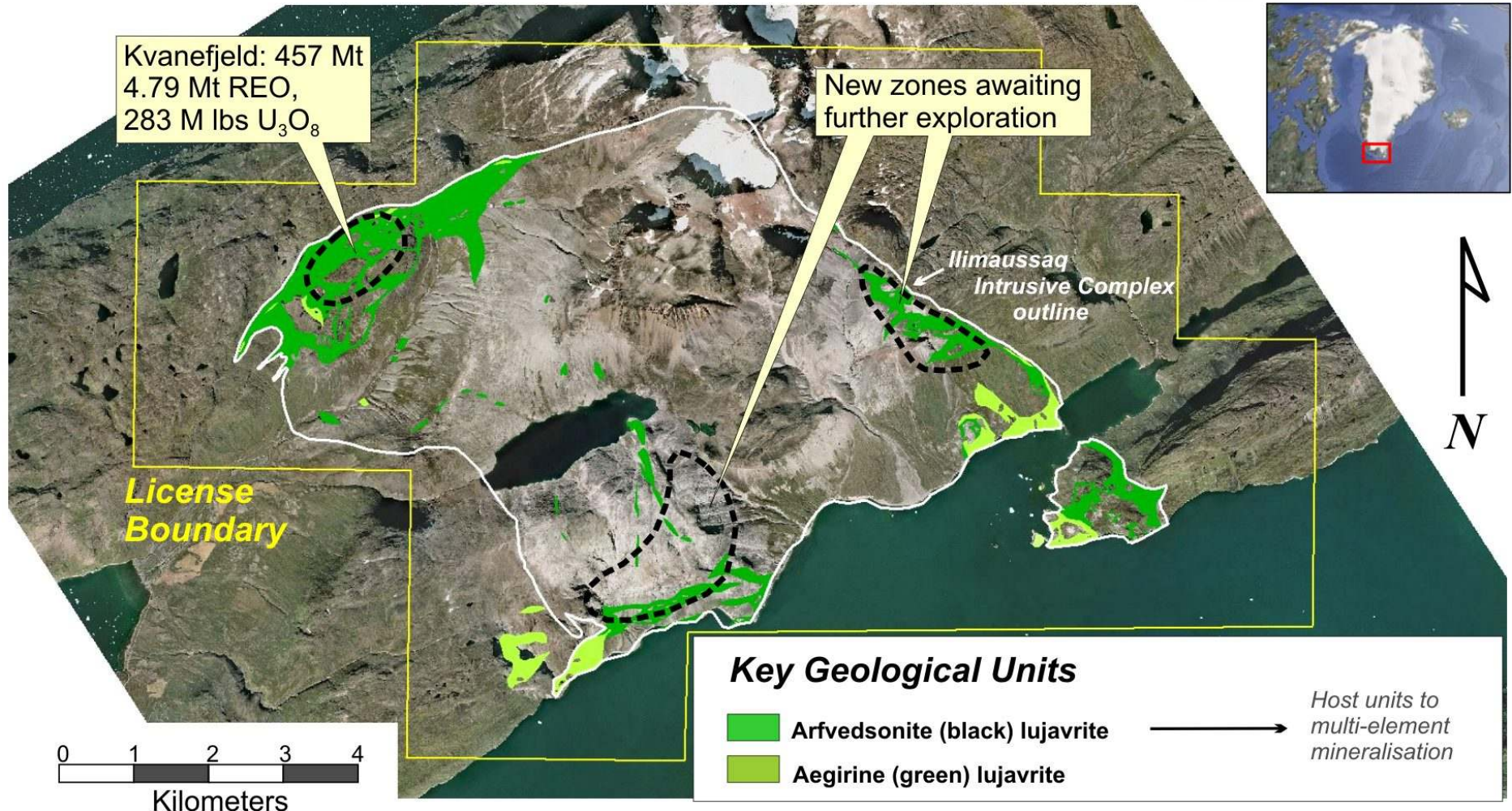
View toward northern half of the complex where highest levels are preserved

Think sequence of
black lujavrite



Ilimaussaq Intrusive Complex

Key Geological Units



Kvanefjeld - Resources

At U ₃ O ₈ % cutoff grades ¹	Tonnes (million)	U ₃ O ₈ %	U ₃ O ₈ lb/t	TREO% ²	Zn%	Resource category
0.015	365	0.028	0.62	1.06	0.22	Indicated
	92	0.027	0.59	1.12	0.22	Inferred
	457	0.028	0.62	1.07	0.22	TOTAL
0.020	276	0.032	0.70	1.13	0.23	Indicated
	63	0.031	0.69	1.21	0.24	Inferred
	339	0.032	0.70	1.14	0.23	TOTAL
0.025	207	0.035	0.77	1.20	0.23	Indicated
	43	0.036	0.78	1.31	0.25	Inferred
	250	0.035	0.77	1.22	0.24	TOTAL

1) Uranium cut-off grades used owing to greater assay coverage; 2) TREO = rare earth elements plus yttrium

457 Mt Resource containing:

4.9 Mt TREO @ 1.07%,

0.99 Mt Zn @ 0.22% Zn

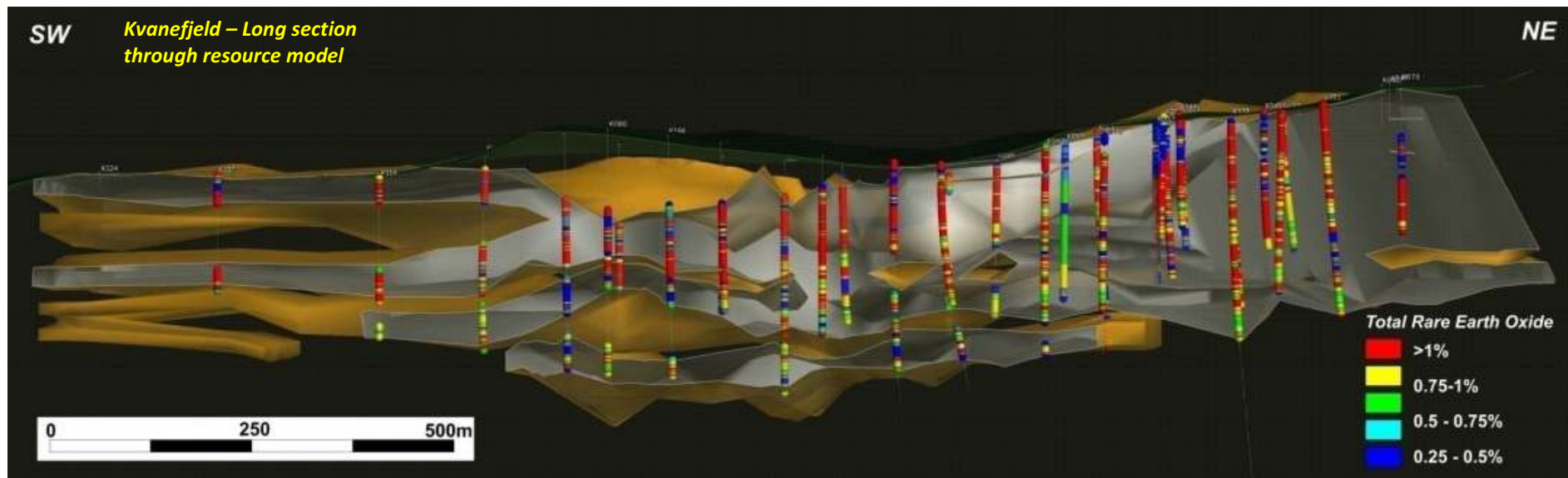
282 Mlbs U₃O₈ @ 280 ppm U₃O₈

JORC – Compliant, 79% Indicated, 21% Inferred



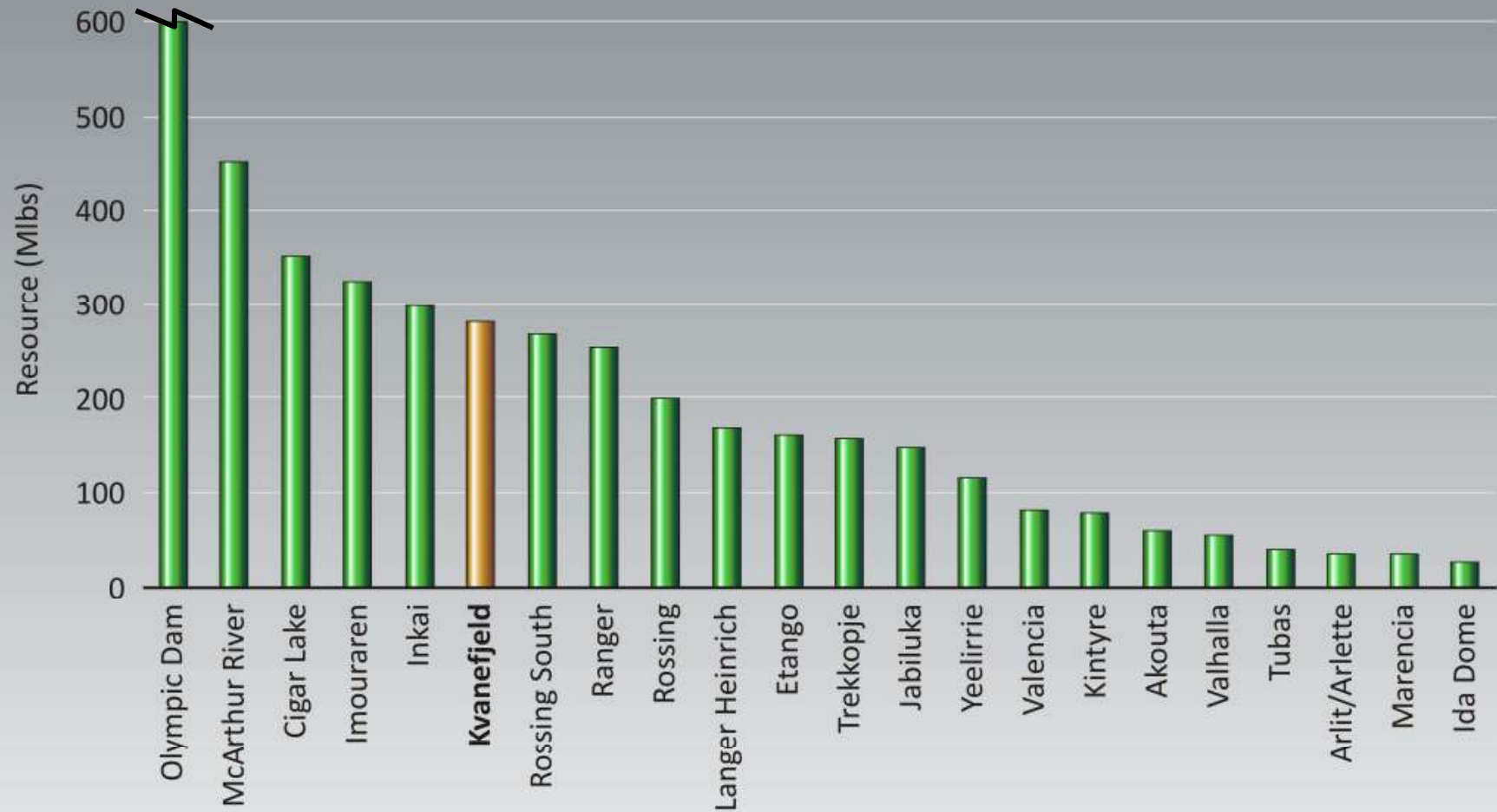
Kvanefjeld – Resource Details

- 457 Mt resource, mostly outcropping and within 300m of ground surface
- Low strip ratio
- Highest grades are in the near-surface environment:
 - Grades range from >350 ppm U₃O₈, 1.3% REO near surface, to 200 ppm U₃O₈ and 1% REO below 250 m depth
- Resource is located 7 km from tidewater, with deep water fjords running directly out to North Atlantic Ocean

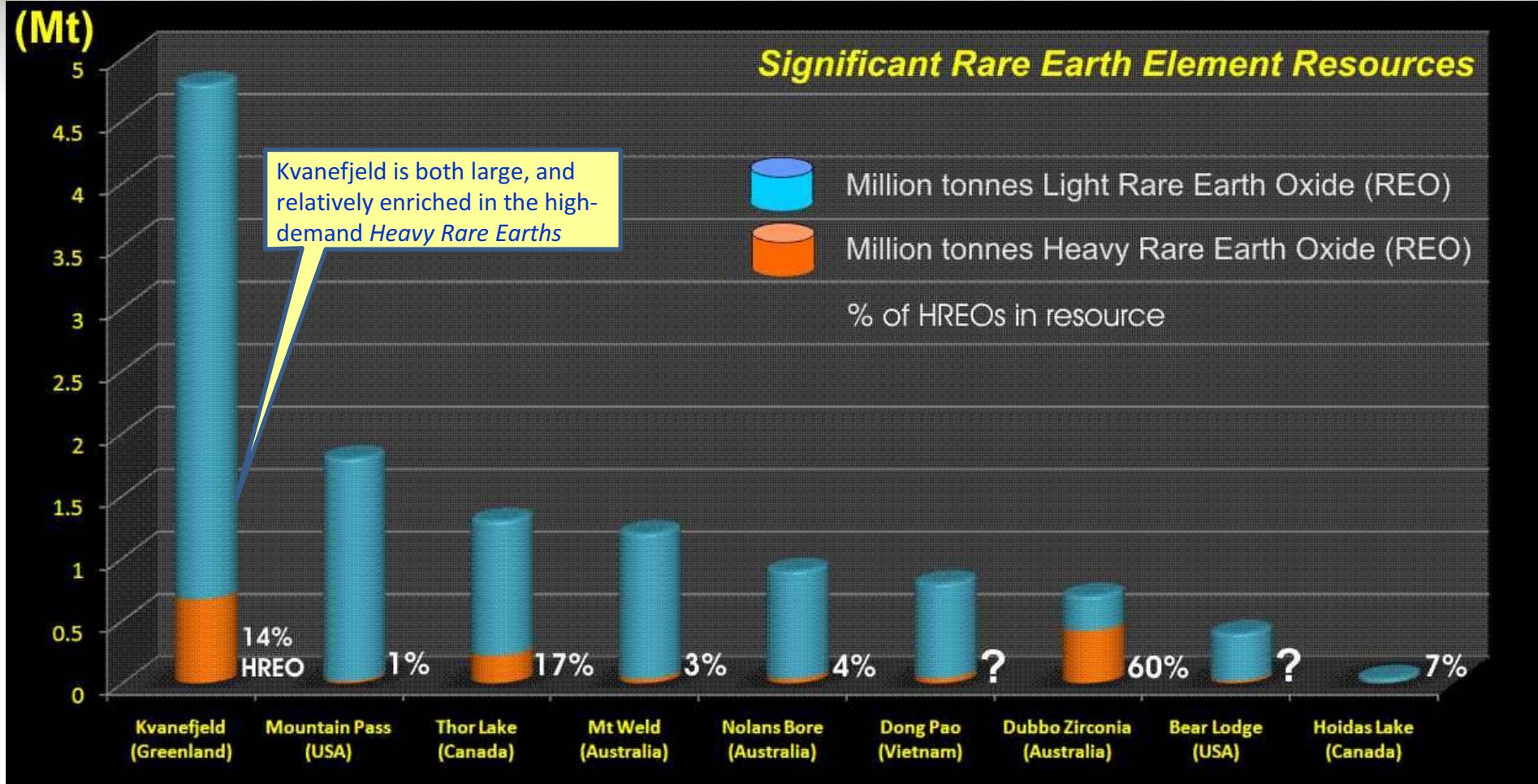


Uranium Deposits Ranked by Size

Resource rankings of major global uranium deposits



The Global Significance of the Kvanefjeld Resource



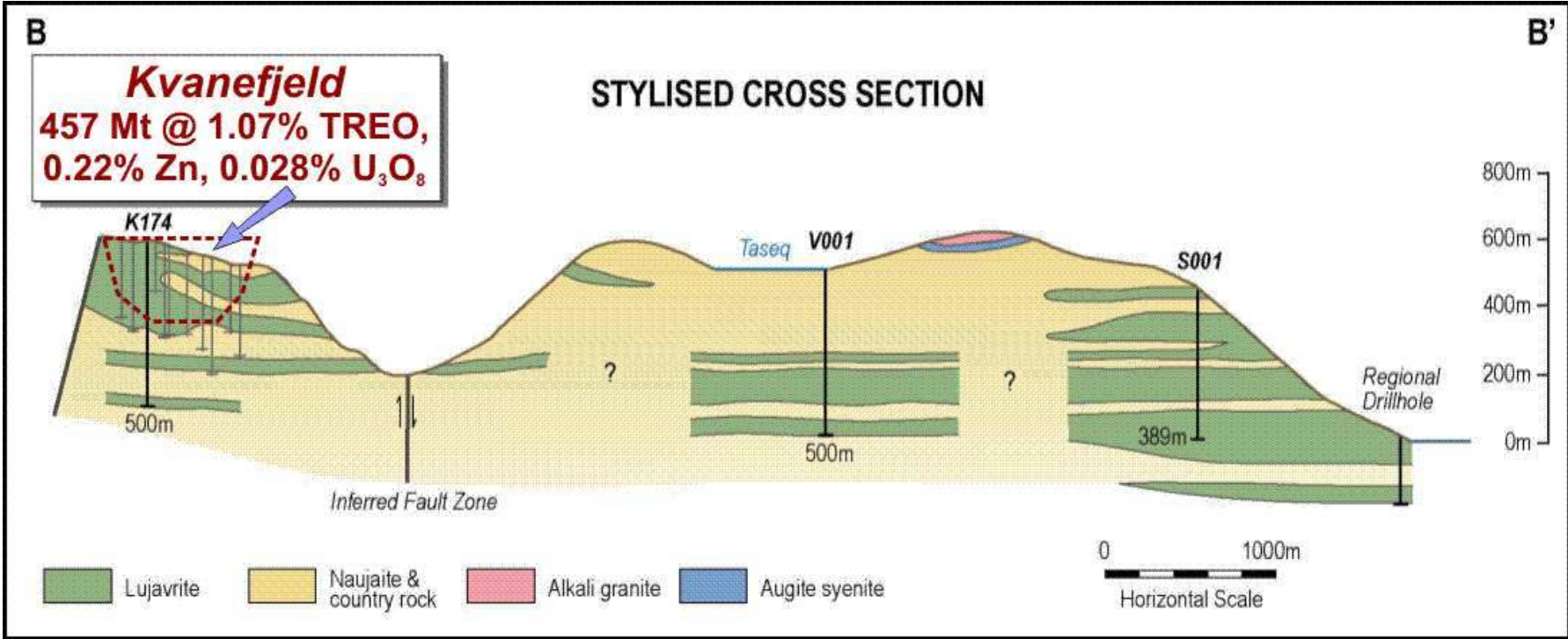
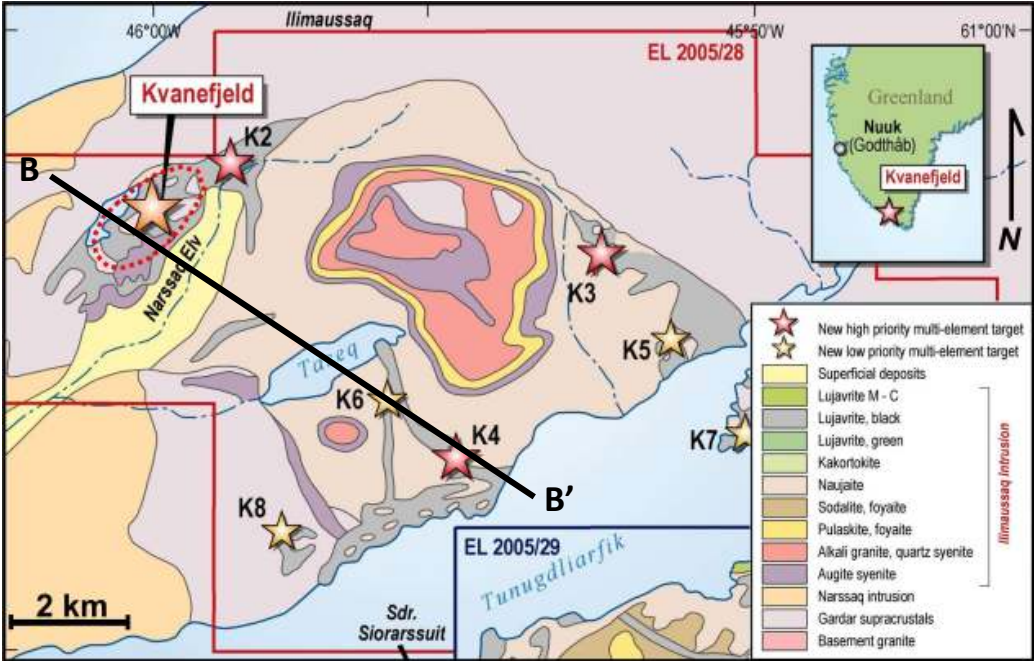
Known REE resources that are compliant by either the Australian JORC code, or Canadian National Instrument 43-101 standards. China also contains very significant REE resources but compliant figures are uncertain (Source IMCOA).



Ilimaussaq Complex Resource Potential

Regional drill holes demonstrate huge potential for new multi-element deposits

Lujavrite – host to multi-element ores, occurs throughout the northern Ilimaussaq Complex at varying depths

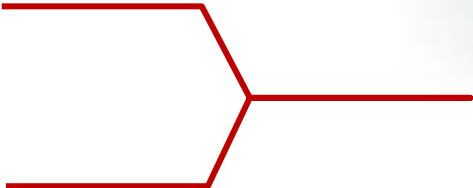


Kvanefjeld Ore

(Lujavrite Mineralogy)

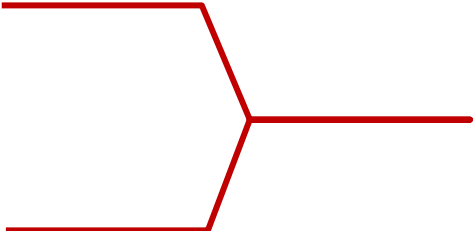


Aegirine
Arfvedsonite
Biotite



*Amphibole, pyroxene
(Fe silicates)*

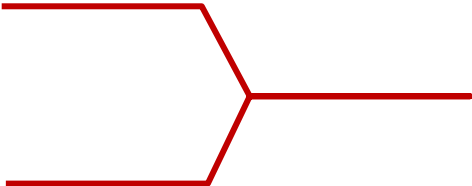
Albite
Microcline
Sodalite
Analcime



*Feldspars/Feldspathoids
(Silicates)*

Steenstrupine
Monazite
Vitusite

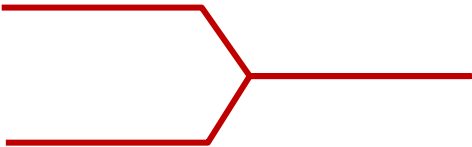
U, REE
REE, Th
REE



Phosphates

Cerite
Na-Zr-silicates

REE
U



Silicates

Sphalerite

Zn



Sulphide



Historical Metallurgical Developments

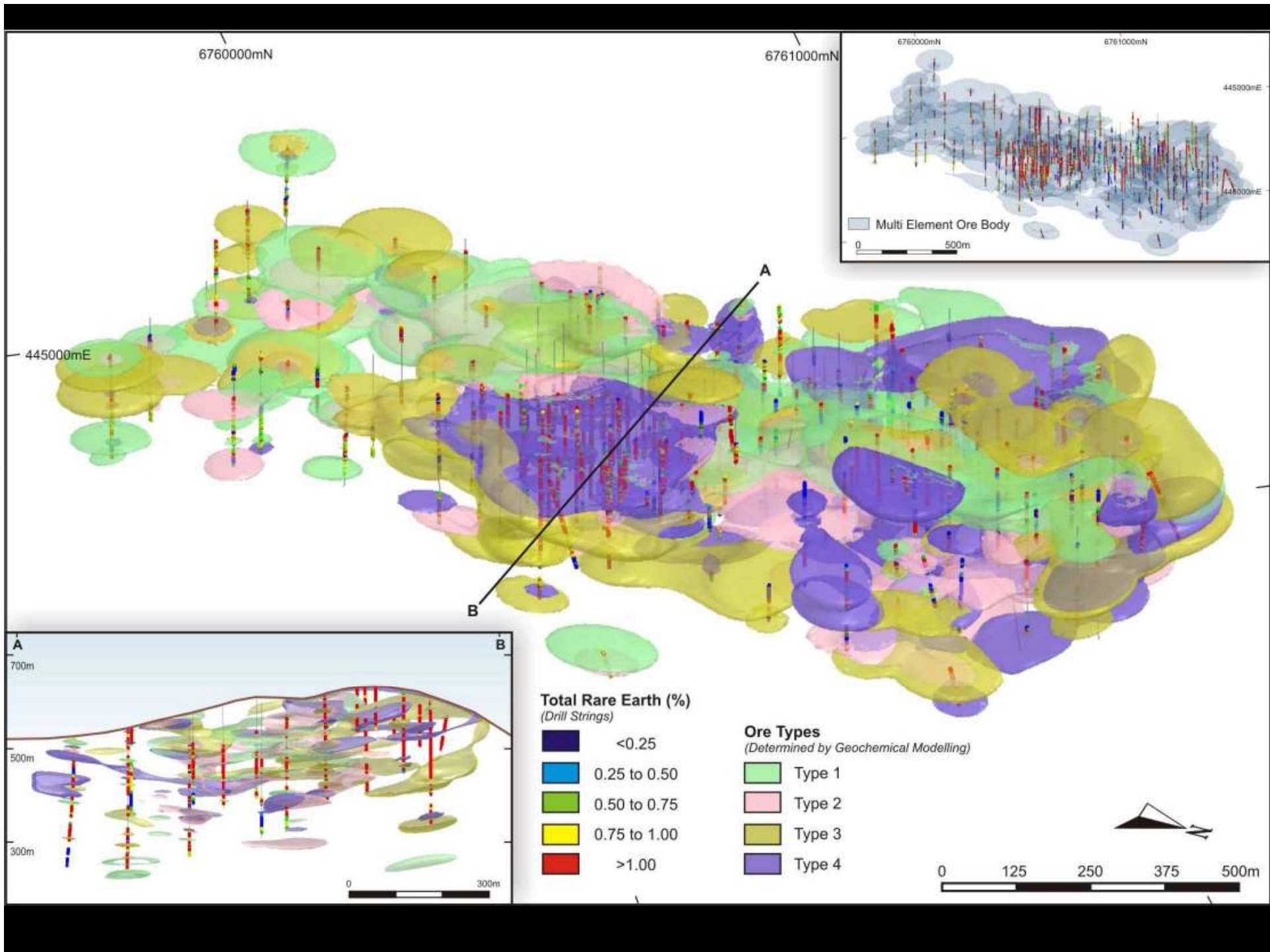
- Sulfuric acid leach, and sulfation roast both demonstrated to successfully leach uranium but acid consumption too high (*strongly alkaline ore*)
- Alkaline leaching evaluated, but unconventional approach required
 - *Unconventional mix of carbonate and bicarbonate*
 - *Temperatures > 250°C required to achieve good recoveries*
- Piloted successfully using pipe reactors
- Program considered a success but work ceased owing to a shift in political sentiment



Current Pre-Feasibility Study

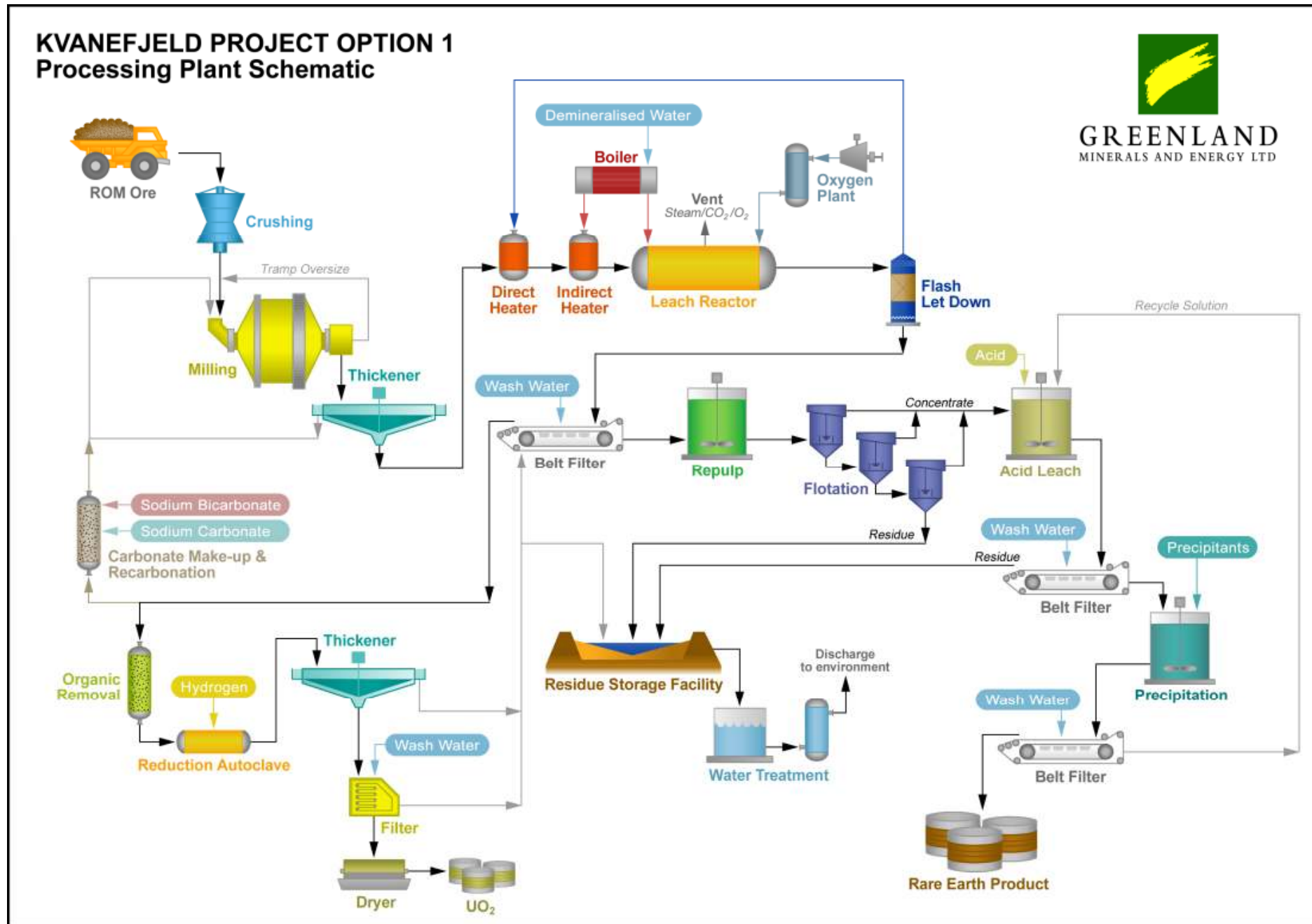
- Kvanefjeld resource is currently the subject of a pre-feasibility study
 - *Multi-element approach – looking to extract U, REEs, and Zn*
- Draws heavily on historic work, and integrates technological developments of the last 25 years
 - *Autoclave technology allows higher P-T operations*
- Ability to map ore-body to account for mineralogical variability





Conceptual process flow sheet – base case scenario:

1- alkaline pressure leach uranium extraction; 2 - concentrate REE minerals; 3 - extract REEs with dilute acid wash





- *Black lujavrites represent a new uranium ore-type yet to be mined*
- *Ores are considered polymetallic: uranium co-exists with REEs and zinc*
- *The Ilimaussaq complex already hosts the 6th largest uranium resource with potential for very significant increases*
- *Alkaline pressure leach under unique conditions can successfully extract uranium*
- *Unique rock-types and minerals lead to a unique process route, which may open up more opportunities for similar resources*

