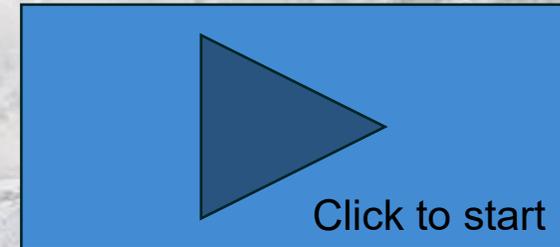


Grønland's mining history - Maarmorilik and Ivittuut

By the end of this session, you will know:

- Why men mined in Grønland despite arctic challenges
- What working in the mines was like
- How mining affected local environments and what can be learned from these impacts
- Why Grønland's resources still matter today

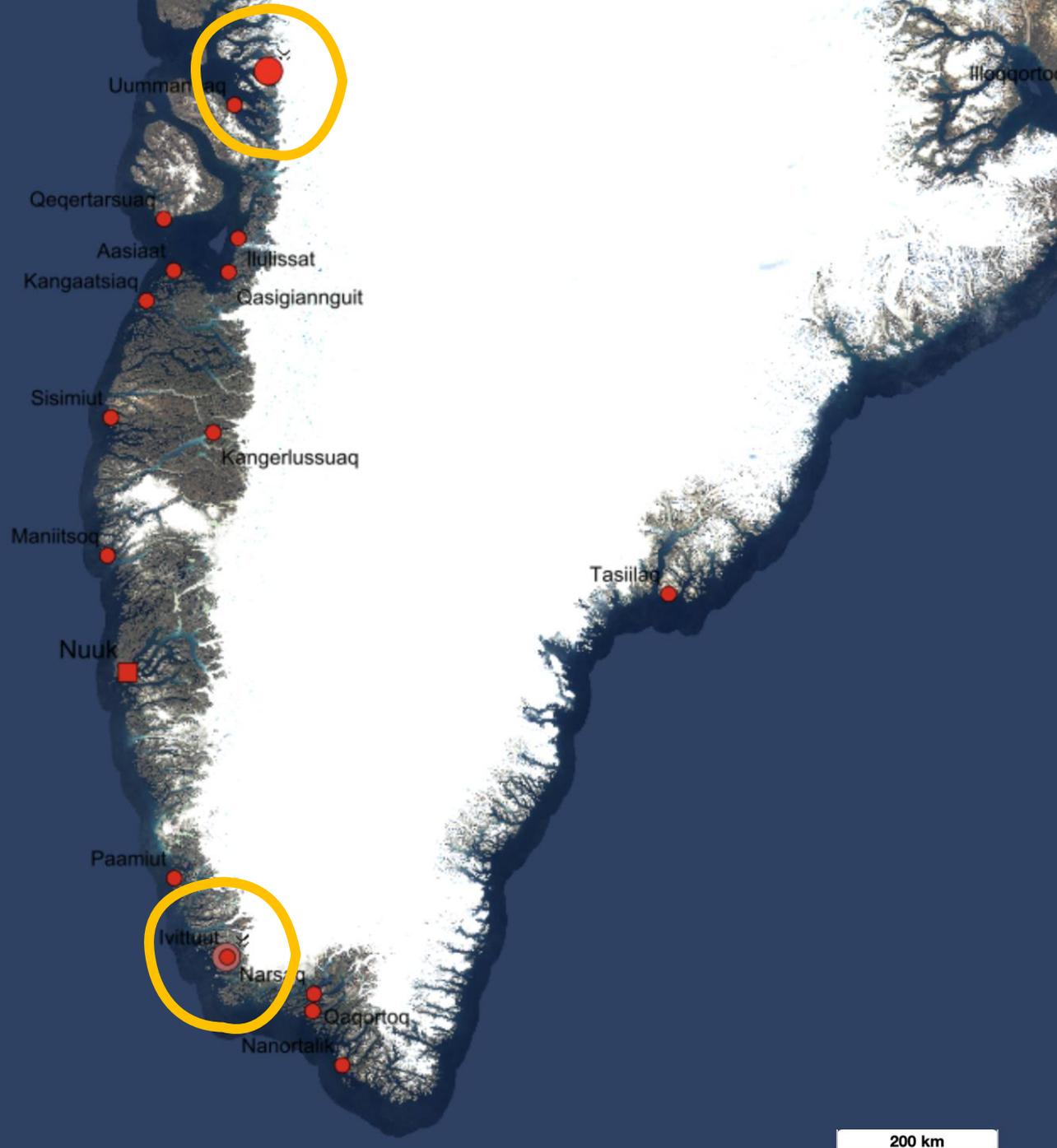


Geographic Overview

As most of Greenland's settlements, both the abandoned mining towns discussed in this slide show are situated on the west coast:

Maarmorilik and **Ivittuut**

Click the orange circles to find out more about Greenland's forgotten mining history!



Black Angel – Part of Greenland's Mining History



1960's



1975



1991



1973



1980's



2008 - now

Return to map



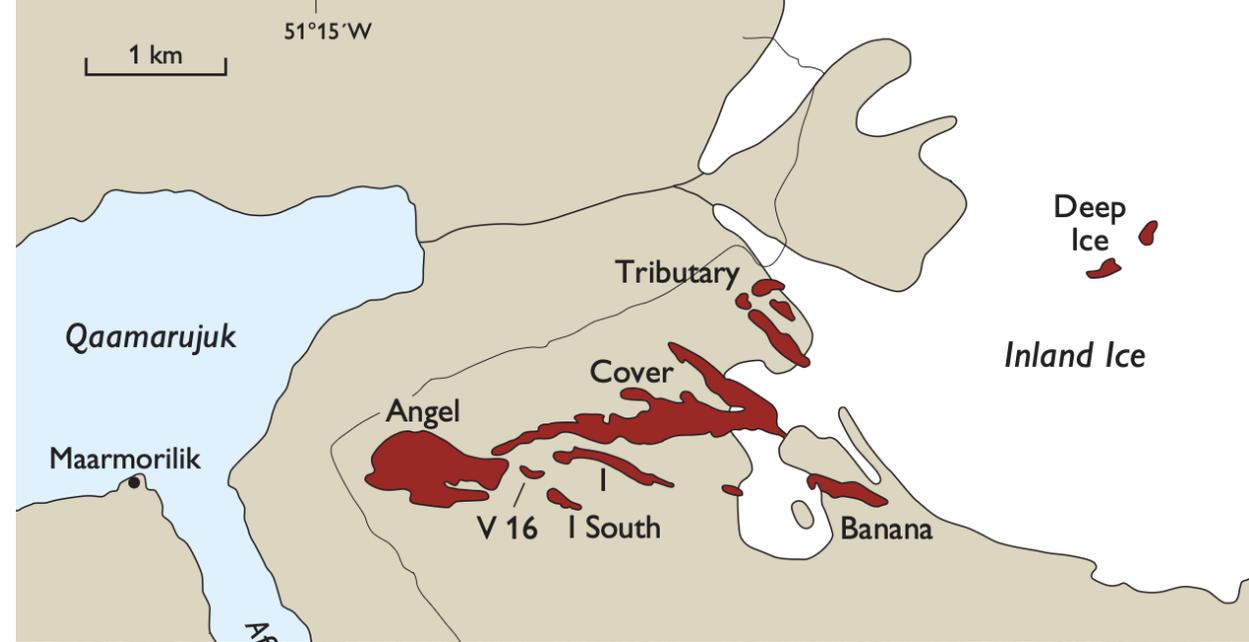
Maarmorilik, 1960's

Geological Exploration

After marble had been mined here for at least 30 years – giving the village its name – geological exploration in the 1960's finds a remarkable occurrence of Lead and Zink. The deposit is called Den Sorte Engel (Back Angel) after a characteristic outcrop of dark sediments in the cliffs.

Click the pictures on the right for more information about Black Angel's geology and ore.

Return to
timeline



Top: map of deposit zones (red). Bottom: Sulphidic ore minerals oxidize at outcrop, creating a characteristic red staining.

Maarmorilik, 1960's

Why mine here? - Black Angel's geology and ore

- Deposit was formed by limestone sediments and metal-enriched fluids in an ancient sea (ca. 2 Ba ago)
- Tectonics later folded and thickened metal-rich layers and turned the limestone into marble
- Ore now occurs as **lens-shaped bodies** inside the mountain
- The ore consists mainly of the minerals **sphalerite (zinc)** and **galena (lead)**, with silver as a valuable by-product
- Black Angel was exceptional because of **very high metal grades**



Galena (Pb)



Spahlerite (Zn)



Acanthite (Ag)

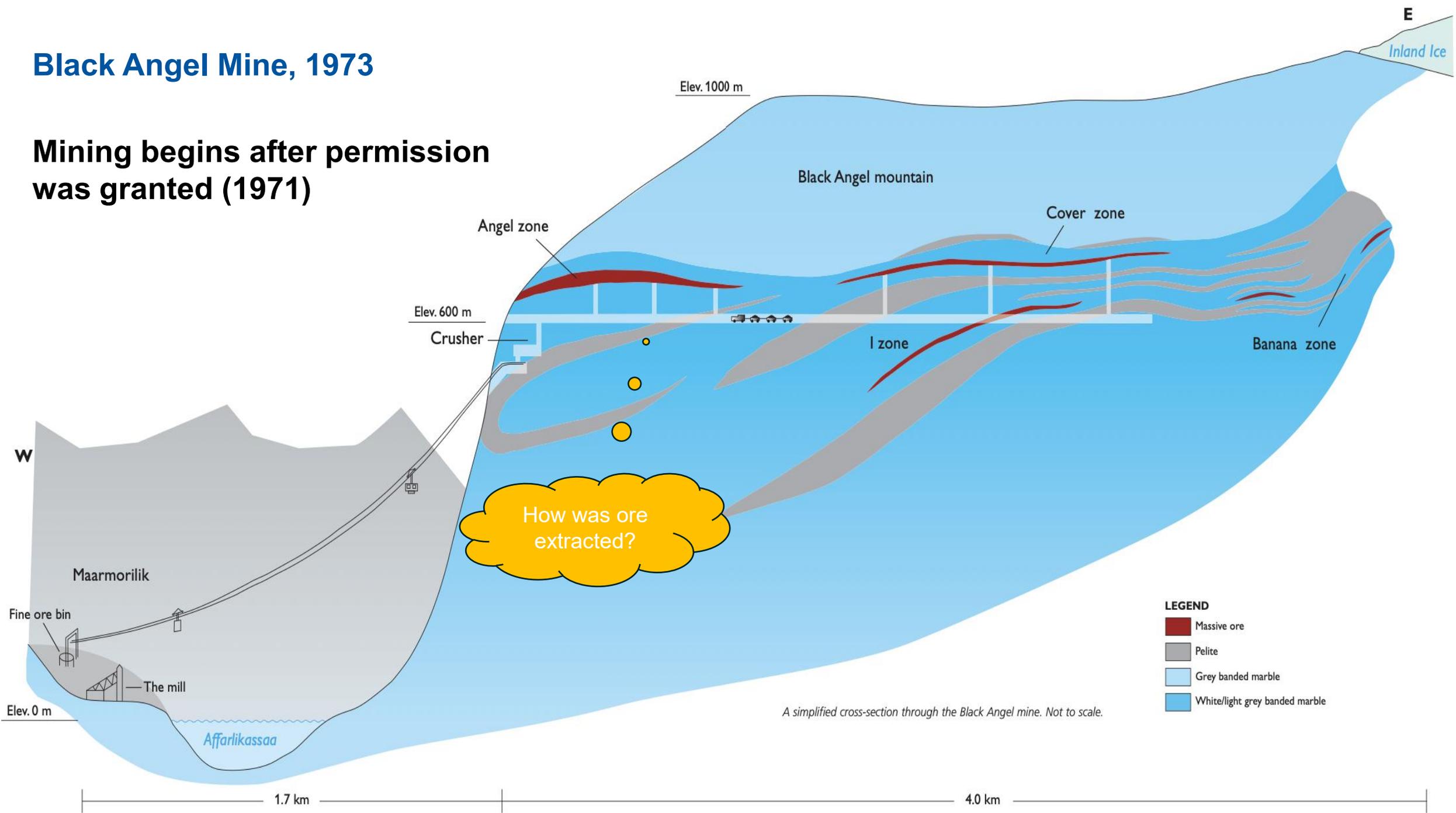
Click the minerals
for more info about
the valuable metals
contained

Return to
timeline



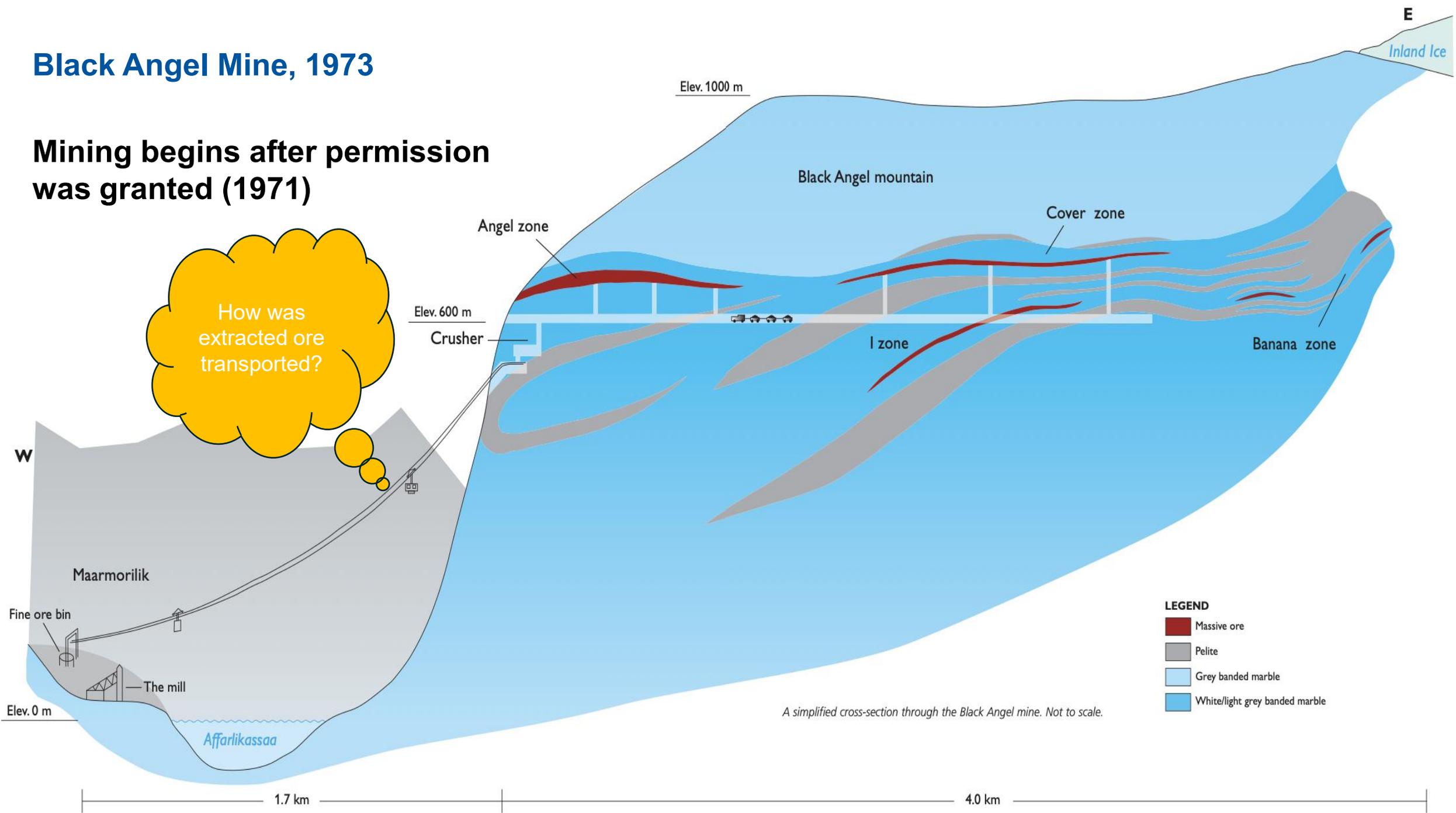
Black Angel Mine, 1973

Mining begins after permission was granted (1971)



Black Angel Mine, 1973

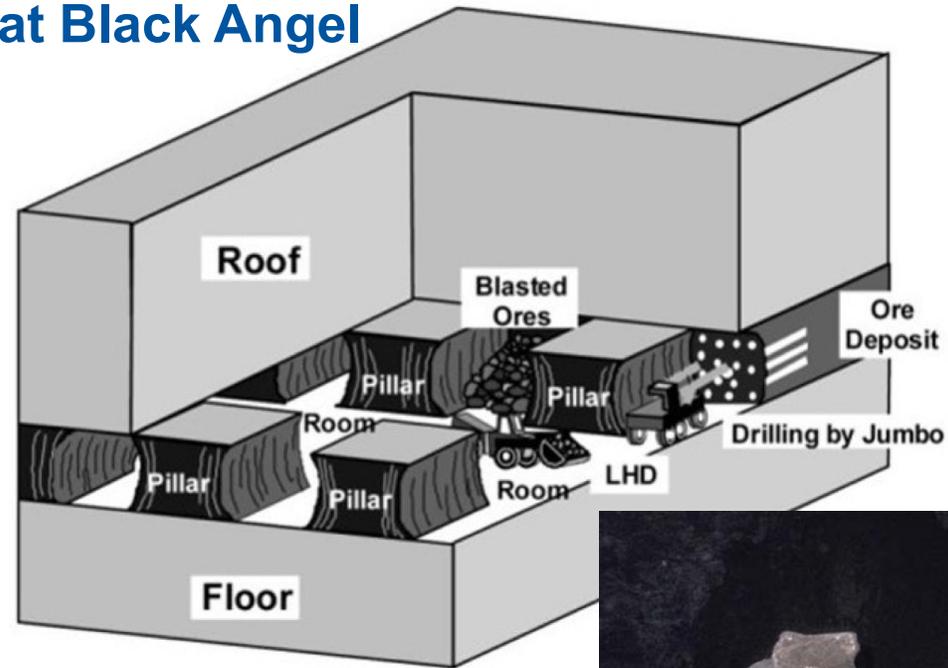
Mining begins after permission was granted (1971)



Mining methods, transport and logistics at Black Angel

Extraction

- Competent rock & permafrost enabled unsupported mining method: Room and Pillar
- Pillars = ore losses. Can be reduced with extensive rock mechanics and selective mining
- Late mining activities included pillar recovery, which maximized the extracted reserves using backfill to support the roof (overlying strata)



Simplified room & pillar design



LHD (load, haul, dump machine) in operation at black angel mine

Parameter	Deposit (Ore) ⓘ			Production ⓘ			Recovery ⓘ	
	Tonnage Mt	Pb %	Zn %	Tonnage Mt	Pb %	Zn %	Ore tonnage %	Metal content %
Value	13.557	4.0	12.3	11.196	4.1	12.6	82.6%	84.6%



Additional Info for table

Black angel deposit and production figures

Parameter	Deposit (Ore)			Production			Recovery	
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Value	13.557	4.0	12.3	11.196	4.1	12.6	82.6%	84.6%

- Deposit (Ore) – this addresses the orebody estimated prior to extraction
 - Tonnage – the weight of rock mass classified as ore in Mt
 - Pb %, Zn % – the ore grade of metal contained in ore in % for Lead and Zinc, respectively
- Production – this addresses the ore that was actually extracted from the mine site
- Recovery – the share of ore, respectively metal, that was actually extracted from the orebody
 - Ore tonnage % = $\text{Tonnage (Production)} / \text{Tonnage (Deposit)}$
 - Metal content % = $(\text{Tonnage} * (\text{Pb \%} + \text{Zn \%}) (\text{Production})) / (\text{Tonnage} * (\text{Pb\%} + \text{Zn \%}) (\text{Deposit}))$



Mining methods, transport and logistics at Black Angel

Transport and Logistics

- One of the least accessible mines worldwide
- Underground haulage by LHDs, trucks, and locomotive
- Primary crusher and intermediate storage at the portal
- 1500m aerial tramway to transport ore, staff and material
- Concentrator plant in Maarmorilik
- Shipment within a window of 6 months in summer due to frozen fjords



View from the cliff on the areal tramway and the village in winter, frozen fjord not passable.

Return to
timeline





Black Angel Mine, 1975

Working and living in Maarmorilik

A mix of 350 (at peak times) Grønlanders, Dens and Swedes worked in the Black Angel Mine. Despite long shifts of ten hours, six days a week, workers were proud of their locally-build know-how and skills. Additionally, they earned one month off after four months on site.

Return to
timeline



What went wrong? - Environmental pollution

- Mining caused lead and zinc contamination of the fjord, particularly in the first years of mining.
- Increased metal levels were found in water, sediments, seaweed, mussels, and fish.
- Main sources of contaminant were
 - Waste rock with low mineralization, disposed of on the cliff outside the mine.
 - Depleted sands from processing (tailings), disposed of in the fjord.
- In 1975, local seal hunters protested against pollution by blockading an ore ship.
- Elevated metal levels in biota (mussels) even in 2010.

Have there been any consequences?
What can we learn from this case?

Black Angel Mine, 1980's

What was learned? - Shift towards more sustainable mining

- Authorities demanded improvement of environmental situation
- Measures have been implemented:
 - Waste pile was moved away from tidal zone
 - Tailings metal content was significantly reduced
- Monitoring data shows that contaminant levels decreased during ongoing mining activities and particularly after mine closure.
- Water samples from 2010 show element concentrations below EU drinking water standards.
- Nowadays, land, water, and biota degradation by mine wastes, as well as rehabilitation issues, are increasingly addressed by the mining industry and authorities.
- However, mine wastes remain a major challenge for modern society.



Black Angel Mine closes after 17 years of operation



- Over its lifetime, the mine generated net earnings as high as 1,154 M DKK and taxes as high as 556 M DDK.
- These profits and the jobs were lost upon mine closure.
- Many buildings were dismantled and disposed of in old mine voids.
- Remains of the mining town fall into ruin

Return to
timeline



Maarmorilik, 2008 - now

Why do we still talk about Black Angel?

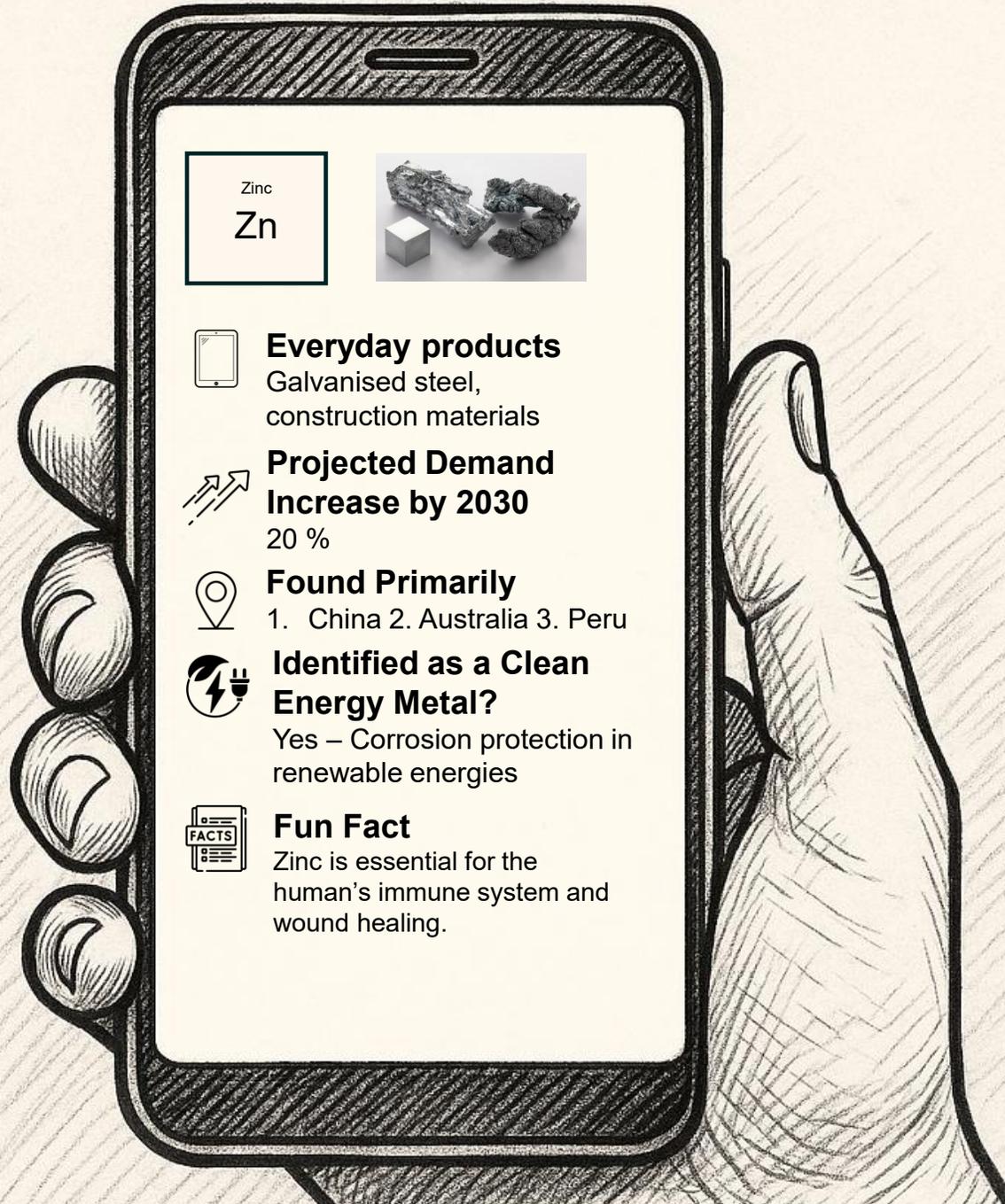
- In recent years, a number of companies aimed to bring black angel to a second life.
- Repeated exploration drilling in vicinity of the mine indicate ore zones (areas had been previously covered by the inland ice cap).
- Ore left in pillars that could be recovered.
- Most recent assays identify commercially relevant concentrations of critical raw materials:
 - [Germanium](#)
 - [Gallium](#)
 - [Cadmium](#)

Mineral Resources around Maarmorilik remain an important asset for Greenland and could potentially be exploited in the future, implementing modern technology and environmental safeguards.

Return to
timeline



Zinc in everyday products



Zinc
Zn



Everyday products

Galvanised steel,
construction materials



Projected Demand Increase by 2030

20 %



Found Primarily

1. China 2. Australia 3. Peru



Identified as a Clean Energy Metal?

Yes – Corrosion protection in
renewable energies



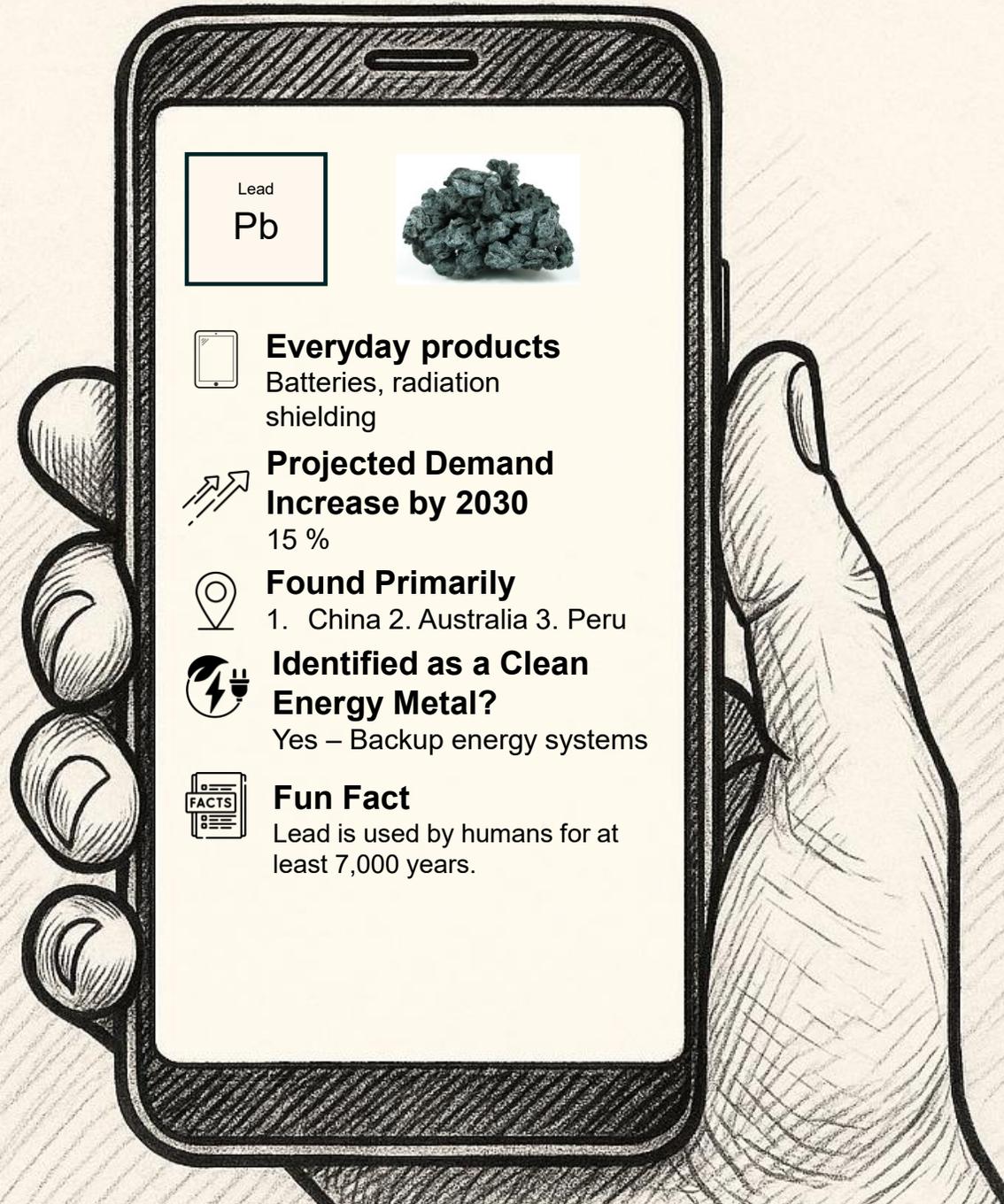
Fun Fact

Zinc is essential for the
human's immune system and
wound healing.

Return to
overview



Lead in everyday products



Lead
Pb



 **Everyday products**
Batteries, radiation shielding

 **Projected Demand Increase by 2030**
15 %

 **Found Primarily**
1. China 2. Australia 3. Peru

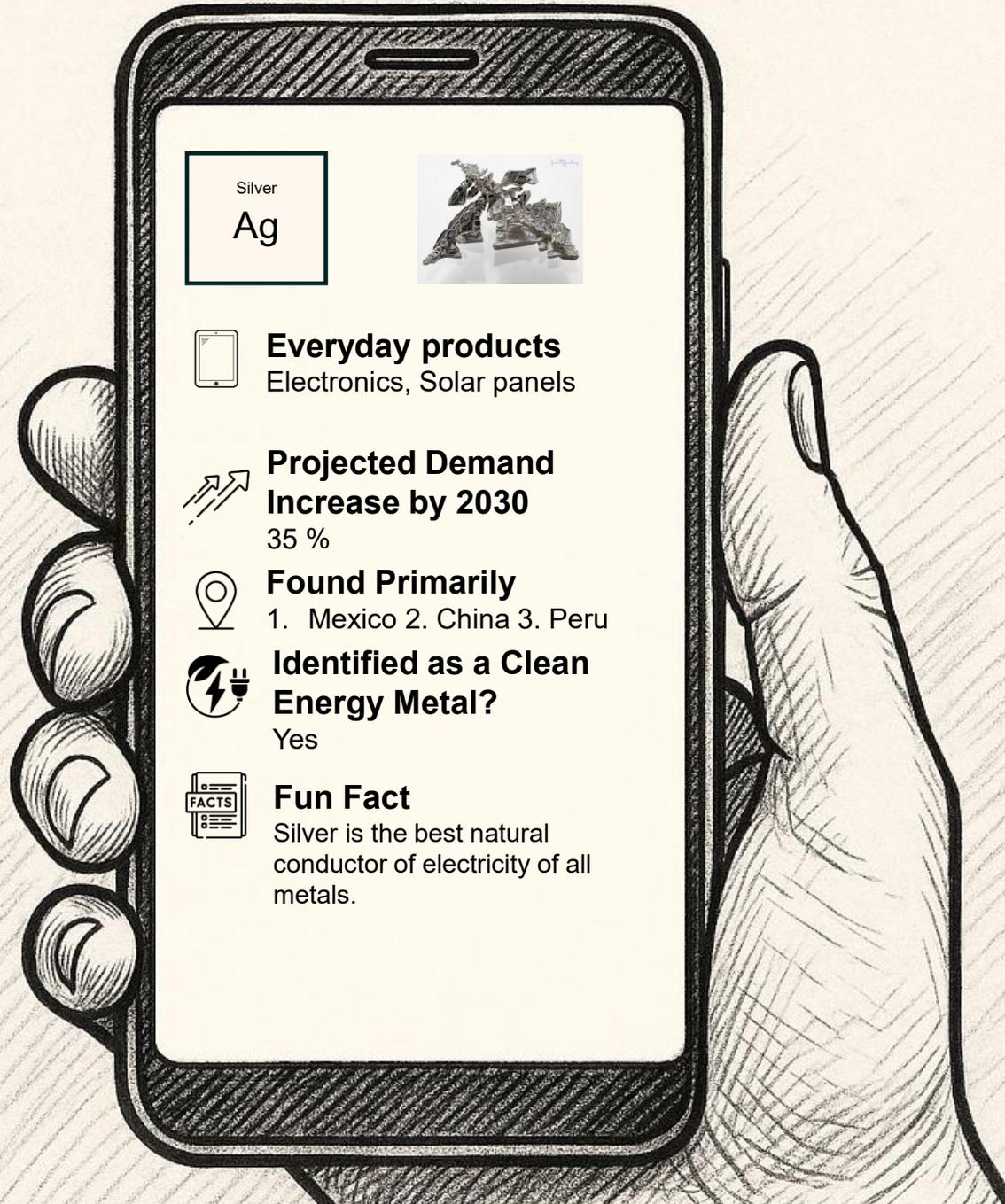
 **Identified as a Clean Energy Metal?**
Yes – Backup energy systems

 **Fun Fact**
Lead is used by humans for at least 7,000 years.

Return to
overview



Silver in everyday products



Silver
Ag



Everyday products
Electronics, Solar panels



Projected Demand Increase by 2030
35 %



Found Primarily
1. Mexico 2. China 3. Peru



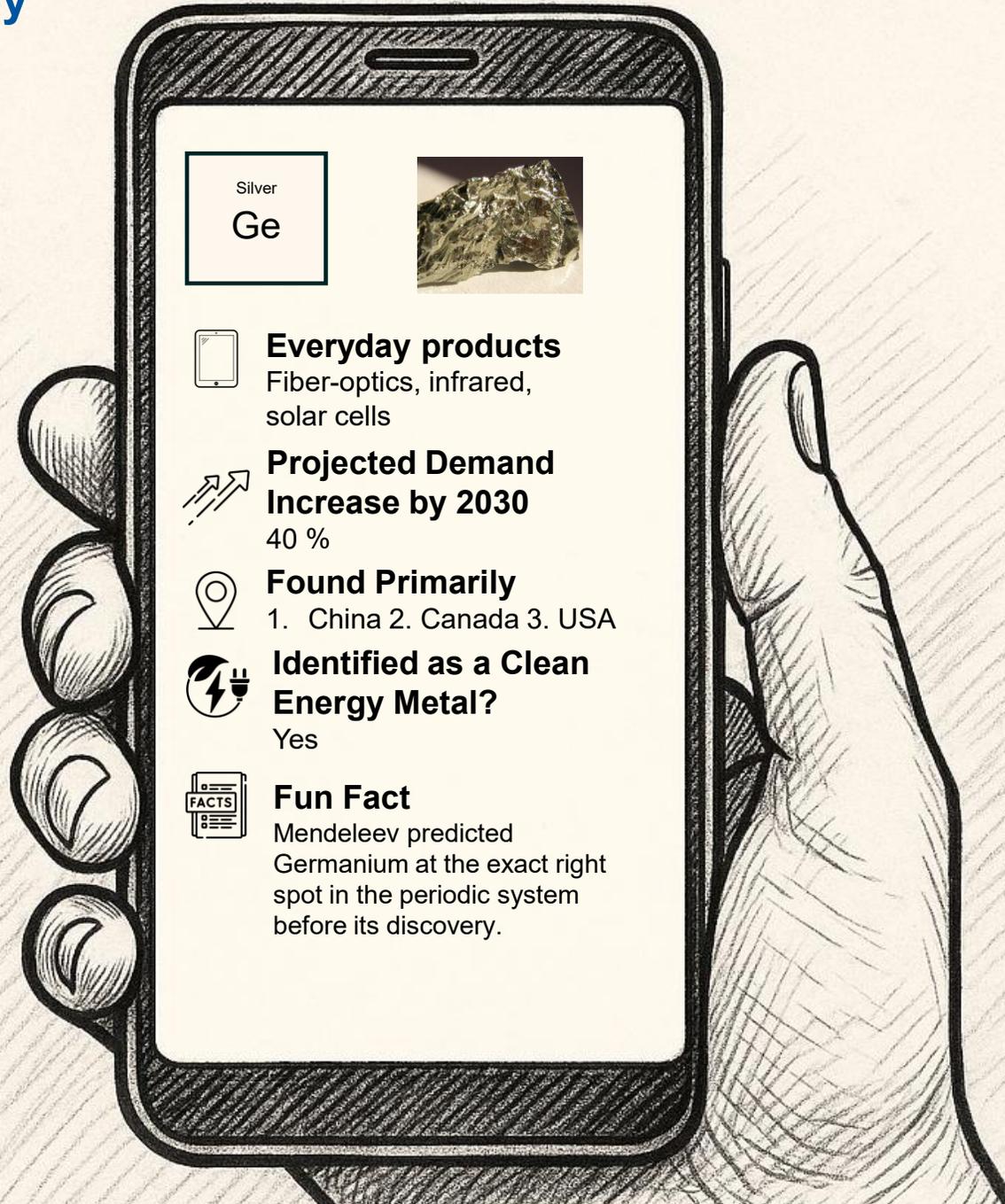
Identified as a Clean Energy Metal?
Yes



Fun Fact
Silver is the best natural conductor of electricity of all metals.

Return to overview 

Germanium in everyday products



Silver
Ge



Everyday products

Fiber-optics, infrared, solar cells



Projected Demand Increase by 2030

40 %



Found Primarily

1. China 2. Canada 3. USA



Identified as a Clean Energy Metal?

Yes

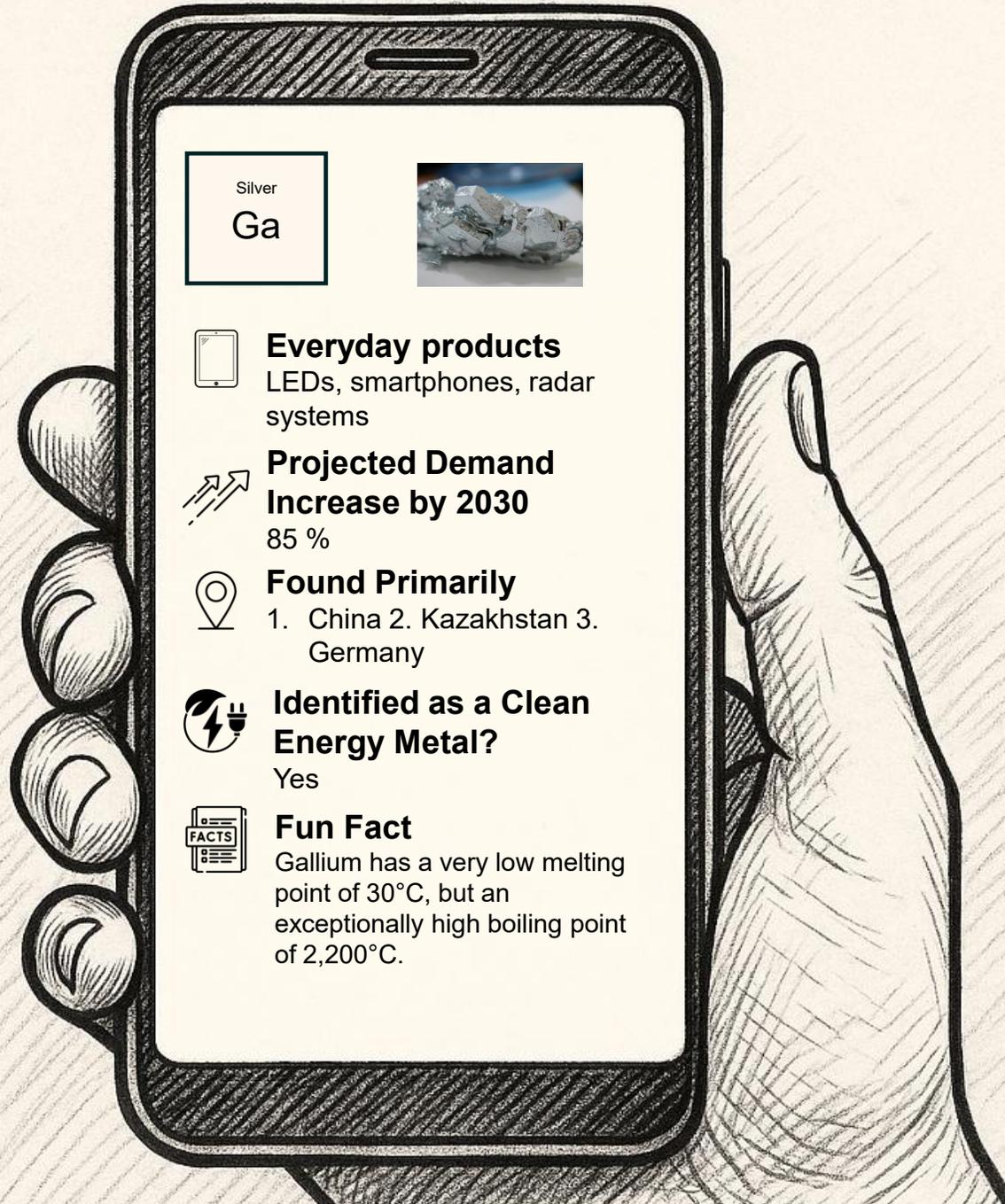


Fun Fact

Mendeleev predicted Germanium at the exact right spot in the periodic system before its discovery.

Return to overview 

Gallium in everyday products



Silver
Ga



Everyday products

LEDs, smartphones, radar systems



Projected Demand Increase by 2030

85 %



Found Primarily

1. China 2. Kazakhstan 3. Germany



Identified as a Clean Energy Metal?

Yes

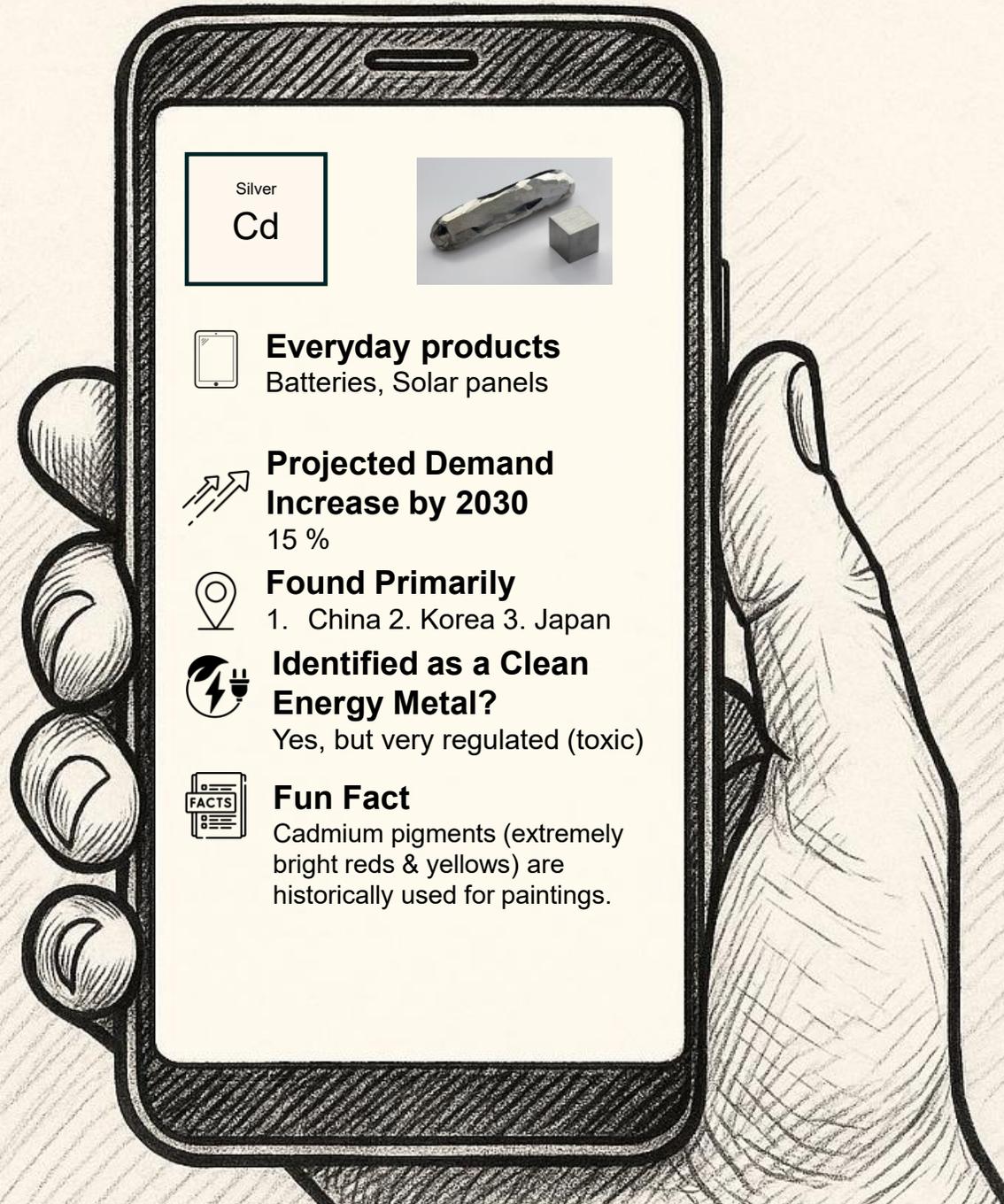


Fun Fact

Gallium has a very low melting point of 30°C, but an exceptionally high boiling point of 2,200°C.

Return to overview 

Cadmium in everyday products



Return to
overview



Ivittuut – national and global significance through mining



Geology and mine



and its purpose



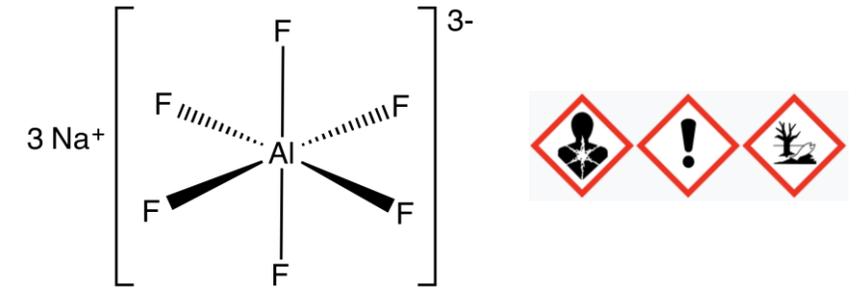
Return to map 

Past and current political importance

Cryolite

Sodium hexafluoroaluminate

- Discovered in 1799
- Naturally occurring as a mineral, but very rare
- Used as flux in the **Hall–Héroult process** to produce Aluminum from oxides (mostly Bauxite)
- Other uses: whitener for enamels, opacifier for glass
- Nowadays synthetically produced
→ cheaper, independent of natural occurrence



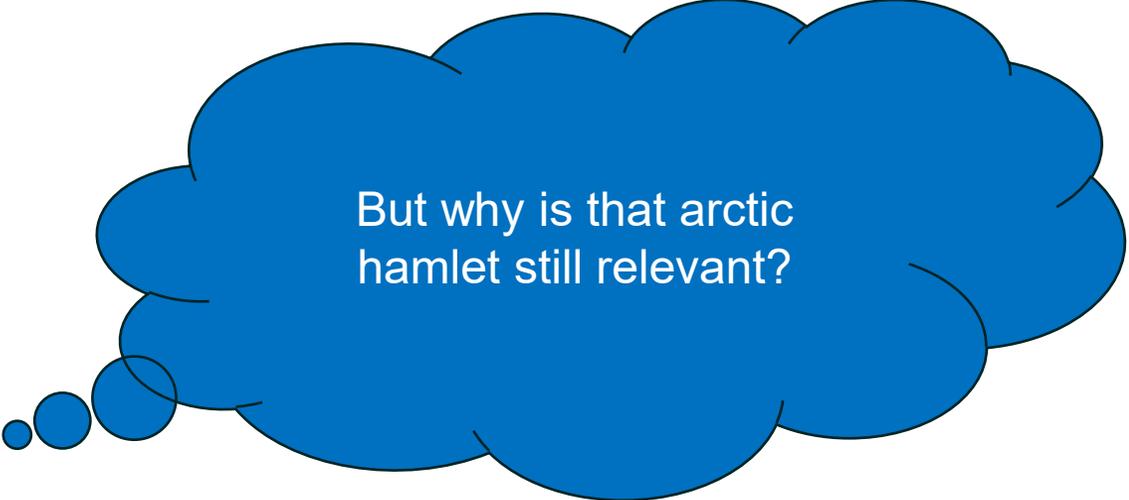
Return to
overview



Geopolitical significance of Ivittuut

Cryolite = “Critical Raw Material of the past”

- Deposit found around the time of first Cryolite discovery
 - Cryolite mining in Ivittuut started in 1859 by Danish miners
 - Before synthesis was invented: Monopoly on Cryolite
 - Strategic importance for:
 - Aluminum production
 - Greenland’s economy benefited
 - American occupation in WW II
- US Navy even built the Bluie West Seven Base, sent coast guards & weapons to protect the quarry!

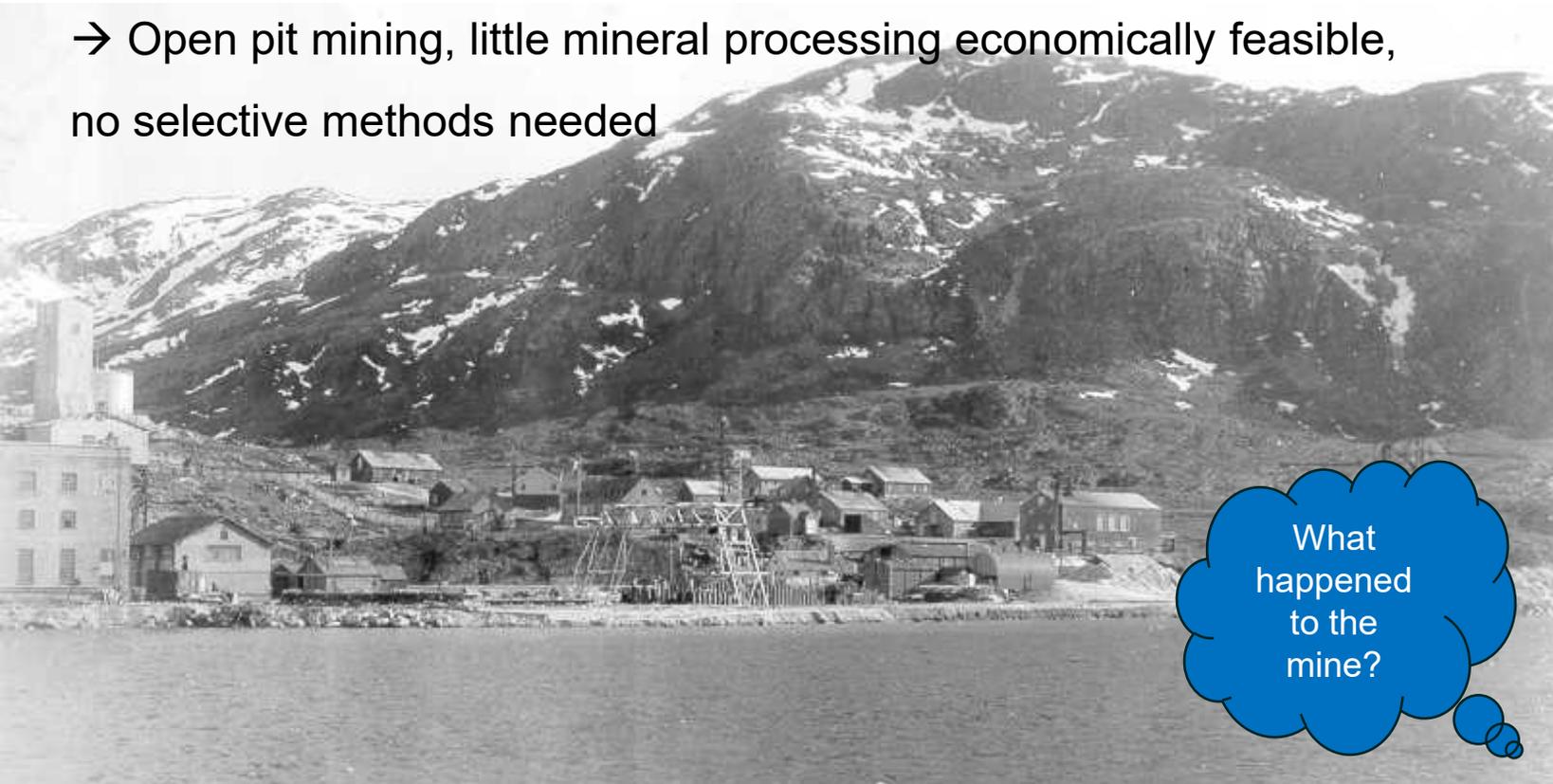


But why is that arctic hamlet still relevant?

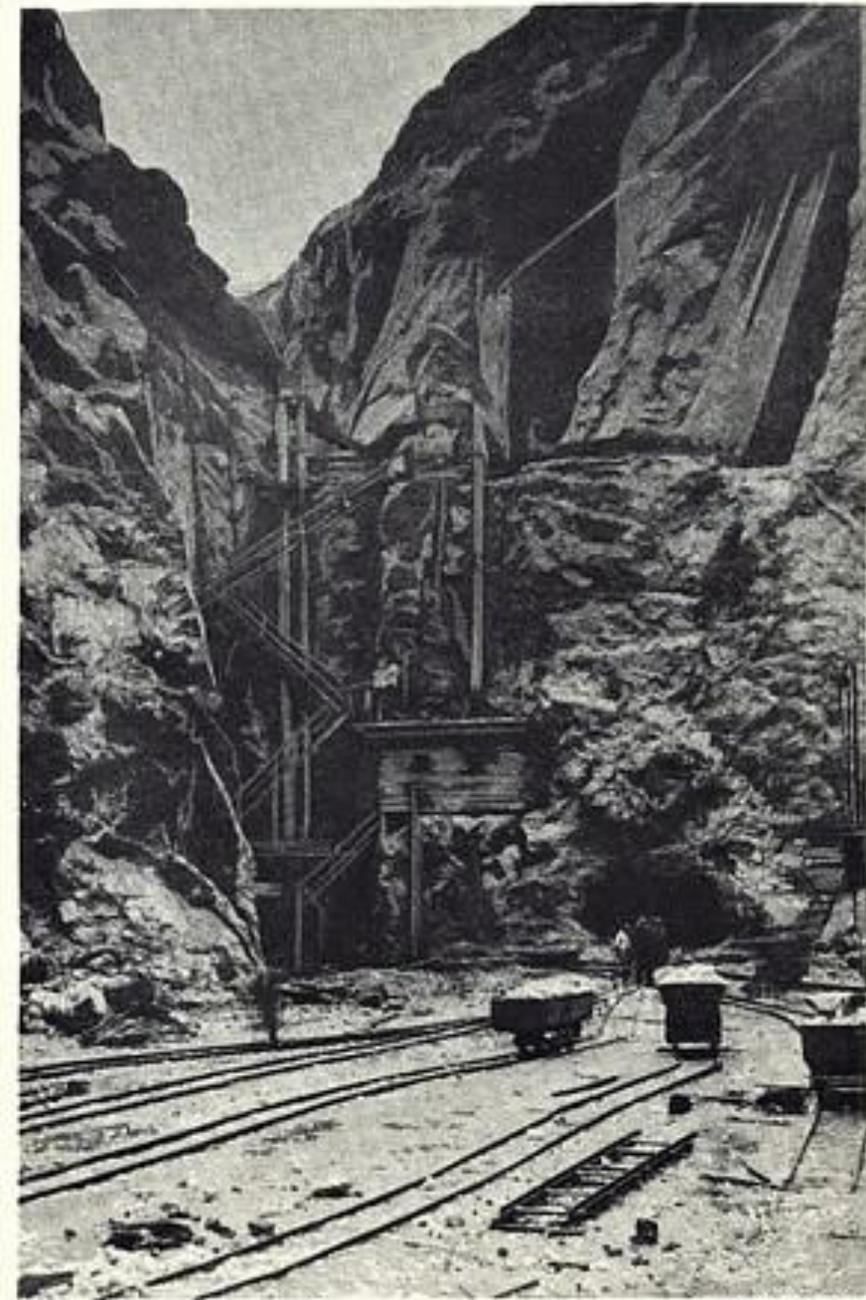
Why and how mine Cryolite in Ivittuut?

Governed by Geology

- Deposit formed by fluor- and sodium-rich magmatic intrusions into alkaline country rock (ca. 1.3 Ba ago)
 - Orebody is shallow, massive, pure, not finely disseminated
- Open pit mining, little mineral processing economically feasible, no selective methods needed



What happened to the mine?



KRYOLITHMINEN IVIGTÛT
DANS LA MINE DE CRYOLITHE D'IVIGTÛT
POUL HANSEN FOT.

Ivittuut, 1960's - now

Mine closure and the withdrawal of people

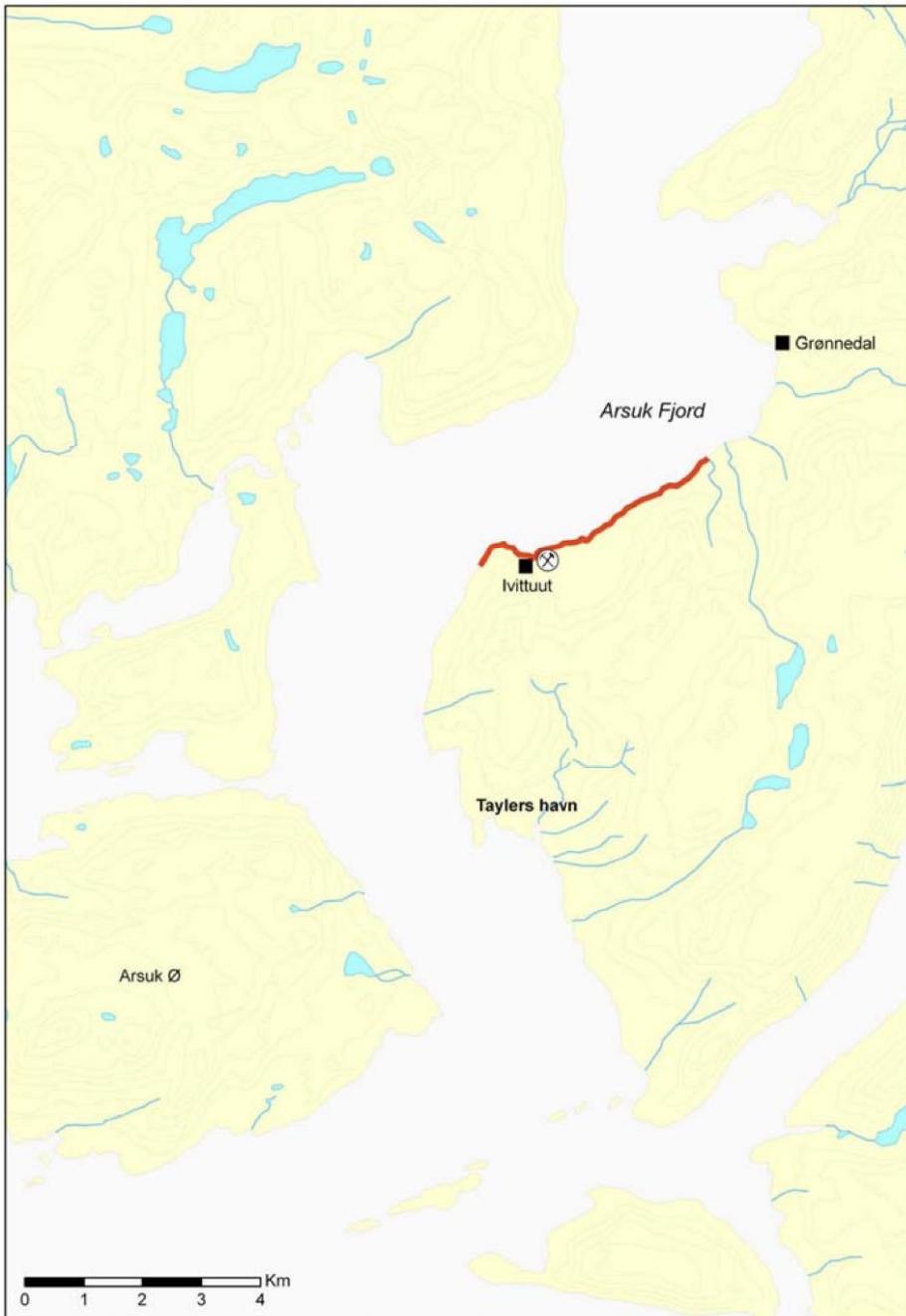
- Synthetic Cryolite reduced the mine's importance drastically
- Mining became uneconomic, sales from stockpiles continued
- 1987: final mine shutdown
- Settlement was abandoned soon after



What went wrong?

Environmental pollution from Ivittuut Mine

- Arsuq Fjord was polluted with Zinc and Lead
- Main pollution source: mineralized waste rock from Ivittuut (similar to pollution in Maarmorilik)
- Much higher metal contaminant concentrations observed
- Affected coastline 32 kilometers long
- Mussels in red area (figure on the left) may not be consumed
- As of 2014, these pollution-causing rocks still released Lead and Zinc into the fjord



Return to
overview



Why does Ivittuut still matter today?

Although abandoned, it remains a symbol:

- Greenland's mineral wealth influences the interest in the island
- Historical military alliances could crack
- Contemporary debates about
 - Resource governance
 - Autonomy
 - Economic partnershipsconcern Greenland more than ever



→ Natural resources can shape global power dynamics!

Return to
overview



Key takeaways



Greenland has already **shaped global power** in the past.



Critical Raw Materials (**CRMs**) are a present, **not a future issue**. The EU **depends** on imports for over **90%** of CRMs.



High-grade deposits matter disproportionately. Greenland is expected to have many of such.



Everyday choices influence global **resource pressure**. Extend item lifetimes!



Ivittuut and Black Angel ask a question that remains unanswered: Who decides about resources and who benefits when demand-, security- and community-interests intersect?