

# Michigan International Copper Analogue (MICA) project

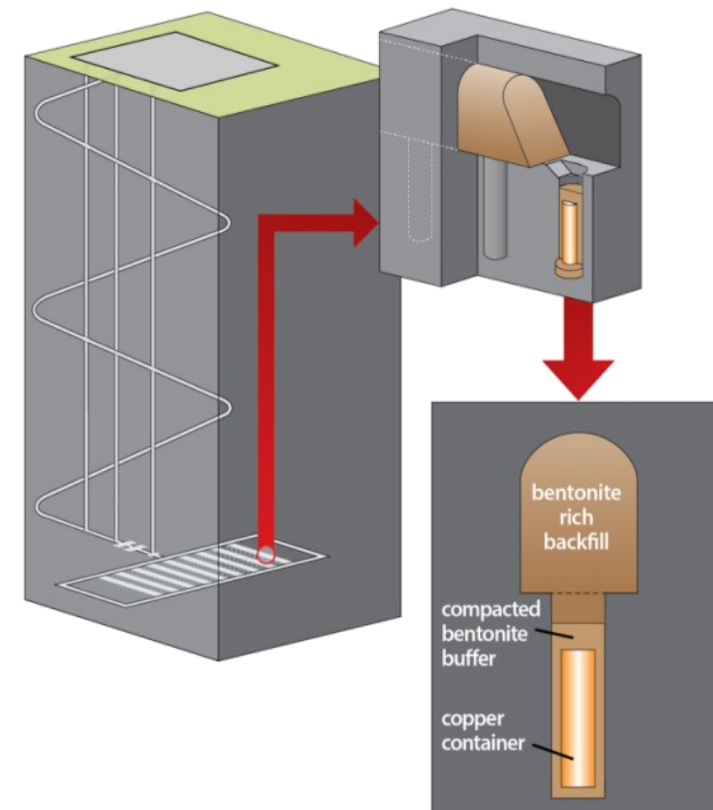
Ismo Aaltonen

17th NAWG Workshop, Zadar, Croatia  
May 8–12, 2023

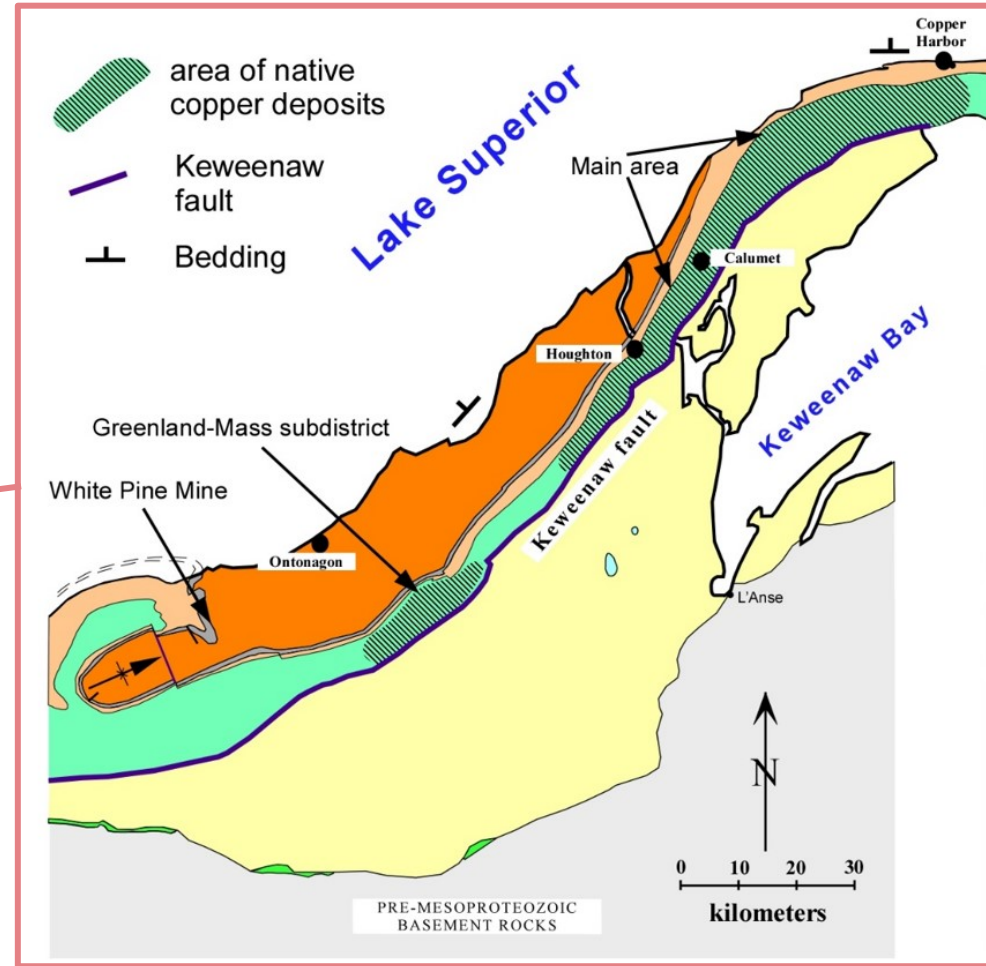
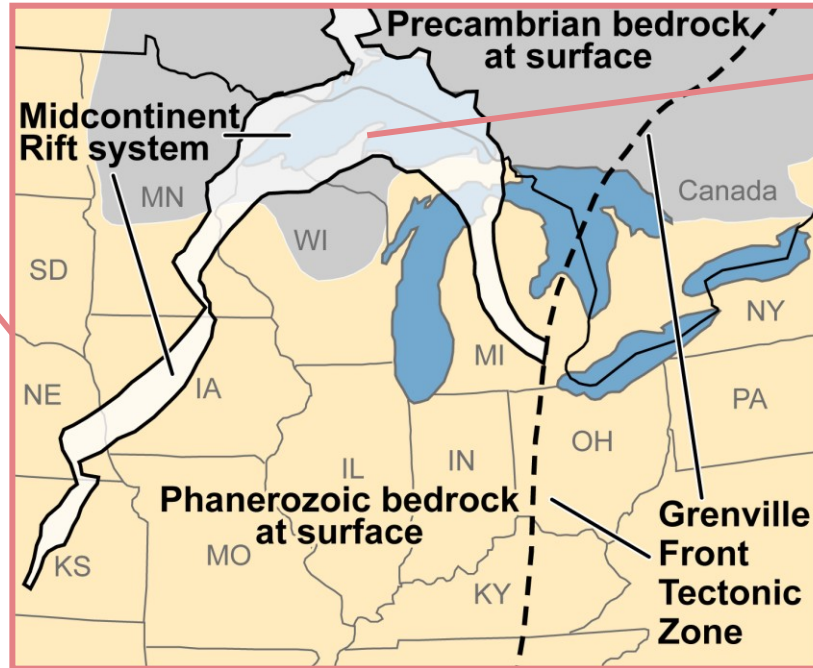
The MICA logo, featuring the word "MICA" in a stylized, teal-colored font. The letters are arranged in two rows: "MICA" on top and "MICA" on the bottom. The logo is enclosed within a thin red circular border.

# Background

- Copper is a component of several nuclear waste disposal concepts
- Copper stability is mainly studied in short-term investigations
- Radioactive waste management organisations have reviewed native copper analogues because of their potential to supplement and improve the understanding of copper corrosion
- The Michigan International Copper Analogue (MICA) project focuses on the stability of native copper in the world's largest native copper dominated deposits of the Keweenaw Peninsula, Michigan, USA
- MICA helps to understand long-term stability and corrosion issues of copper under real geologic boundary conditions



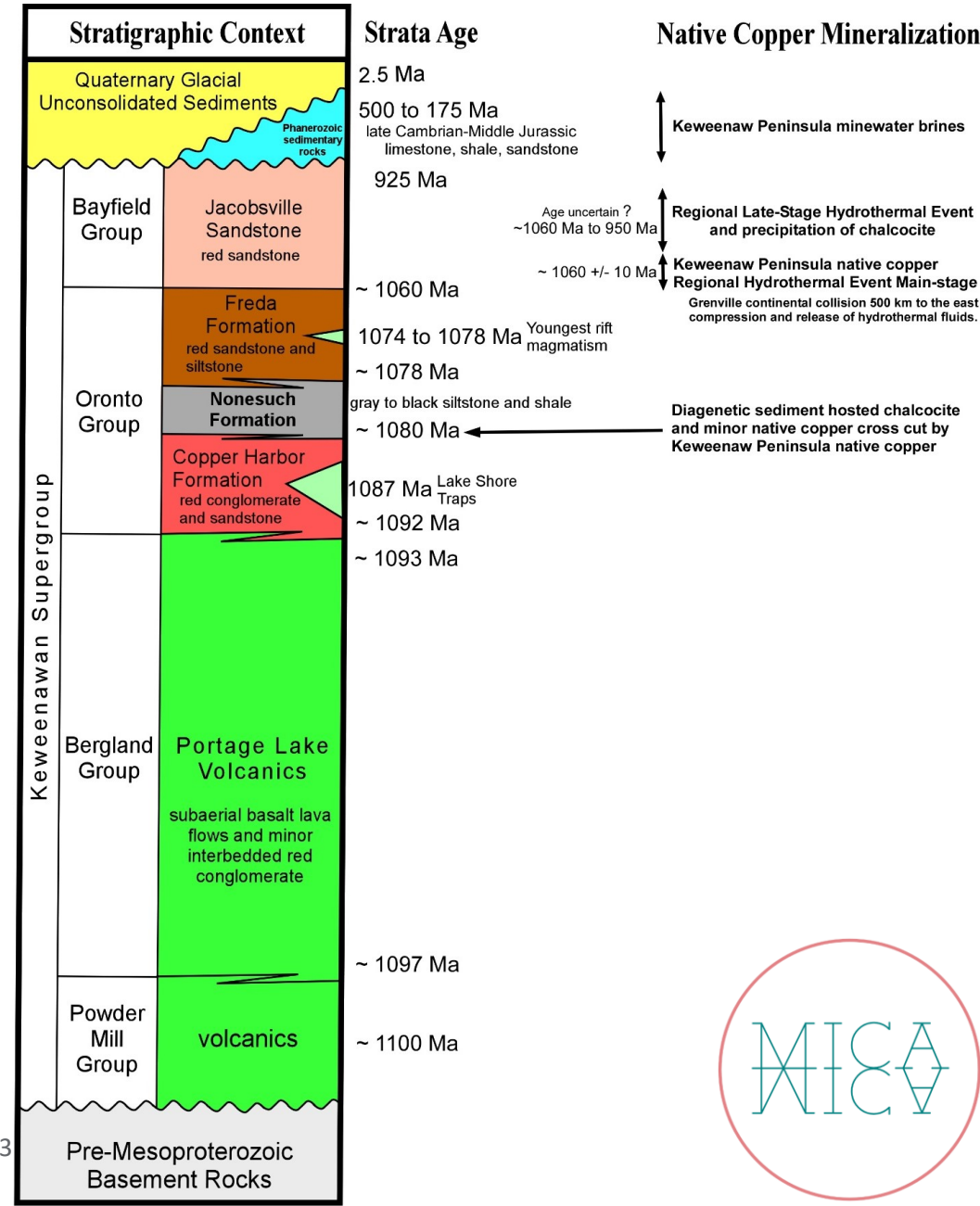
# Keweenaw Peninsula Geology





# Keweenaw Peninsula Native Copper

- A Precambrian continent rifted apart 1.1 Ga (Midcontinent Rift system)
- Volcanic and sedimentary material filled the rift
- Metamorphogenic hydrothermal fluids mineralized native Cu in the pore spaces of the rocks ca. 1.04–1.07 Ga
- Strong erosion ca. 1.0–0.5 Ga
- GW interaction and formation of a supergene mineral assemblage
- Buried by Phanerozoic sediments ca. 500–175 Ma
- Quaternary glacial processes exposed the copper deposits again
- 7 000 years ago, humans first exploited copper in Keweenaw
- Modern copper mining since 1845–1968
- Post-mining processes



# Native Copper Context



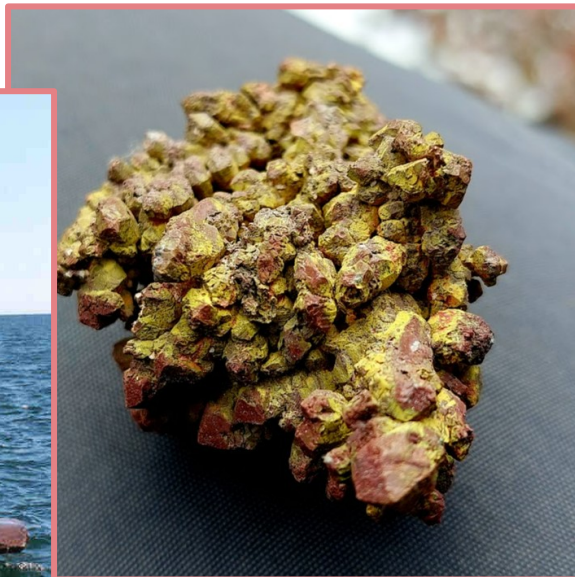
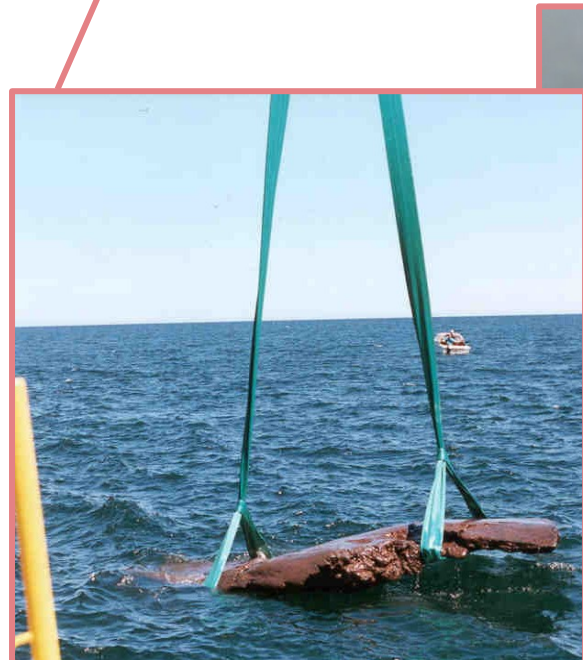
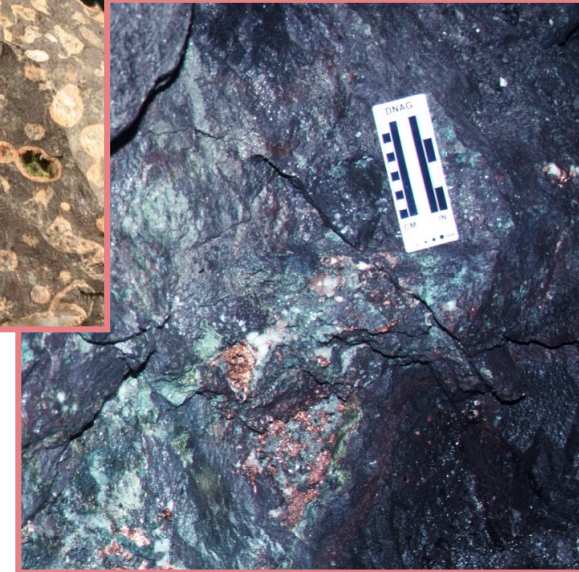
Bedrock native copper

Float copper

Lake copper

Chisel chips and fragments

Mining and post-mining processes



16.5.2023





# MICA Phase I findings

- The environmental conditions of a set of natural analogues were identified and described
- Sampling availability was demonstrated
- Preliminary scoring of the potential analogue types was carried based on their potential
  - *to provide data for supplementing the quantitative safety case;*
  - *to cover the most obvious gaps in safety case knowledge; and*
  - *to be relevant to the safety case and repository design optimization.*

Type	Description	Scoring (1-3)*
*1=RECOMMENDED FOR PHASE II, 2=POTENTIALLY RELEVANT, 3=NOT SAFETY CASE RELEVANT		
A	Long and Varied History of Keweenaw Peninsula Bedrock Native Copper in the Subsurface	1
B	Keweenaw Peninsula Deep Bedrock Native Copper – Long and Varied Native Copper History, Likely Less Exposed to Oxidic Conditions.	1
C	White Pine Mine Bedrock Native Copper – Long and Varied Native Copper History, Likely Less Exposed to Oxidic Conditions.	2
D	Keweenaw Peninsula Shallow Bedrock Native Copper - Long and Varied Native Copper History, Likely More Exposed to Oxidic Conditions.	1
E	Lake Superior Shallow Bedrock Native Copper	1
F	Keweenaw Peninsula Bedrock Native Copper Exposed to Supergene Weathering	3
G	Keweenaw Peninsula Bedrock Native Copper Exposed to Hydrothermal Sulfur	1
H	White Pine Mine – Bedrock Native Copper in Contact with Sulfide minerals	2
I	Lake Superior Shallow Native Copper with Glaciated Surface (Great Sand Bay Lake Copper)	3
J	Lake Superior Native Copper Gravel (Great Sand Bay Lake Copper Nuggets)	1
K	Glacial Native Copper (“Float Copper”)	1
L	Native Copper Chisel Chips	2
M	Native Copper in Clay	1

# Relevant analogues

- Bedrock copper
  - *Samples from various mines, different depths and degree of alteration, also less altered sampled for understanding the baseline*
- Cumulative corrosion
  - *Assessing the effects of the cumulative corrosion with samples from Lake Superior native copper gravel and float copper from glacial sediments*
- Clay and copper
  - *Native copper clasts found in fault clays. Opportunity for a copper canister + buffer analogue?*
- Copper and copper sulfide systems
  - *Corrosion processes in conditions where native copper and copper sulfide minerals co-exist*



# Project Status



- Project planning –2020
- Phase I 2021–2022
  - *Overview to the potential Keweenawan native copper analogues*
  - *Geologic history, environments, length of exposure, and uncertainties for all the analogue types*
  - *The feasibility of obtaining representative existing or new samples*
  - *Evaluating the potential analogue types for further studies*
  - *Test of analytical methods (mineralogy, chemistry, tomography, geochronology)*
  - *Excursion and field workshop in autumn 2022*
- Phase II 2023–
  - *Natural Analogue investigation phase*





Slide 3: Researcher: [Name] [Title] [Affiliation] [Date]  
Topic: [Title]  
Summary: [Text]  
Key Findings: [List]  
References: [List]

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