Geological and Mineralogical Characterization of Taconite Dust Particles

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NRRI

- **The Institute was established in 1983 to encourage economic growth for Minnesota's natural resources-based industries while keeping watch over that growth's impact on the environment.**

This includes providing information to help Minnesota's decision-makers manage resources and the environment

NRRI Minerals Project Capabilities

- **The Duluth-based Economic Geology Group (EGG) focuses on the geology and mineralization characteristics of ferrous, non-ferrous, and industrial minerals of Minnesota; collectively, the Group has over 150 years of experience.**
- **Our Coleraine Lab is recognized worldwide for its capabilities in ferrous, non-ferrous, and industrial minerals, renewable energy and environmental remediation.**

Fundamental Question

- **Are mineral dust particles generated by taconite mining and processing responsible for negative health effects on the Iron Range?**

  What work needs to be done to make that determination from a geological and mineralogical perspective, and how should it be performed?

  What additional mineralogical data could be collected to benefit epidemiological studies?

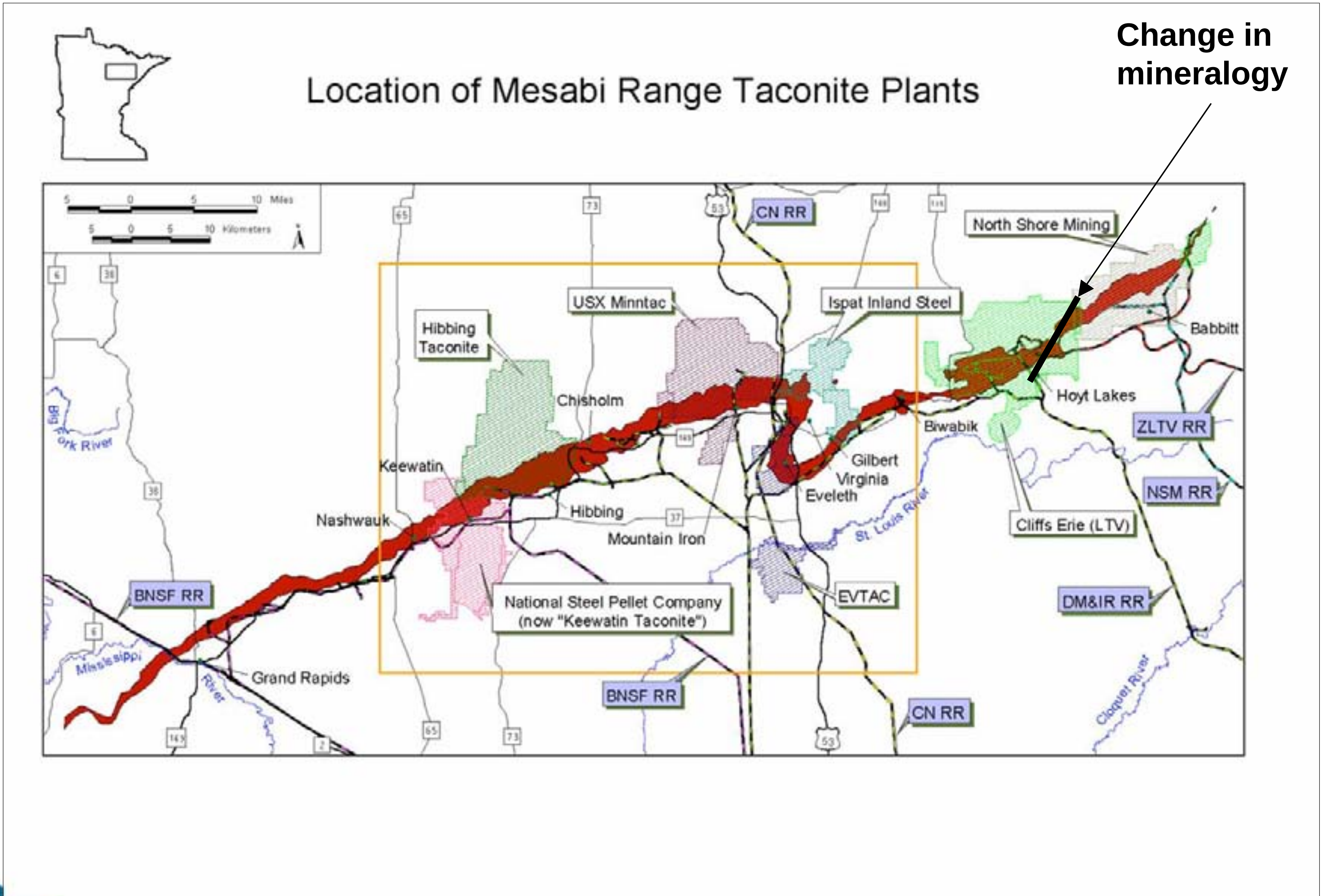
  Is there a geographic relationship?

Overview: What is known

- Geology of the Biwabik Iron Formation
- Mineralogical Changes
- Sampling and Testing
- Taconite Flow Sheet

Location of Mesabi Range Taconite Plants

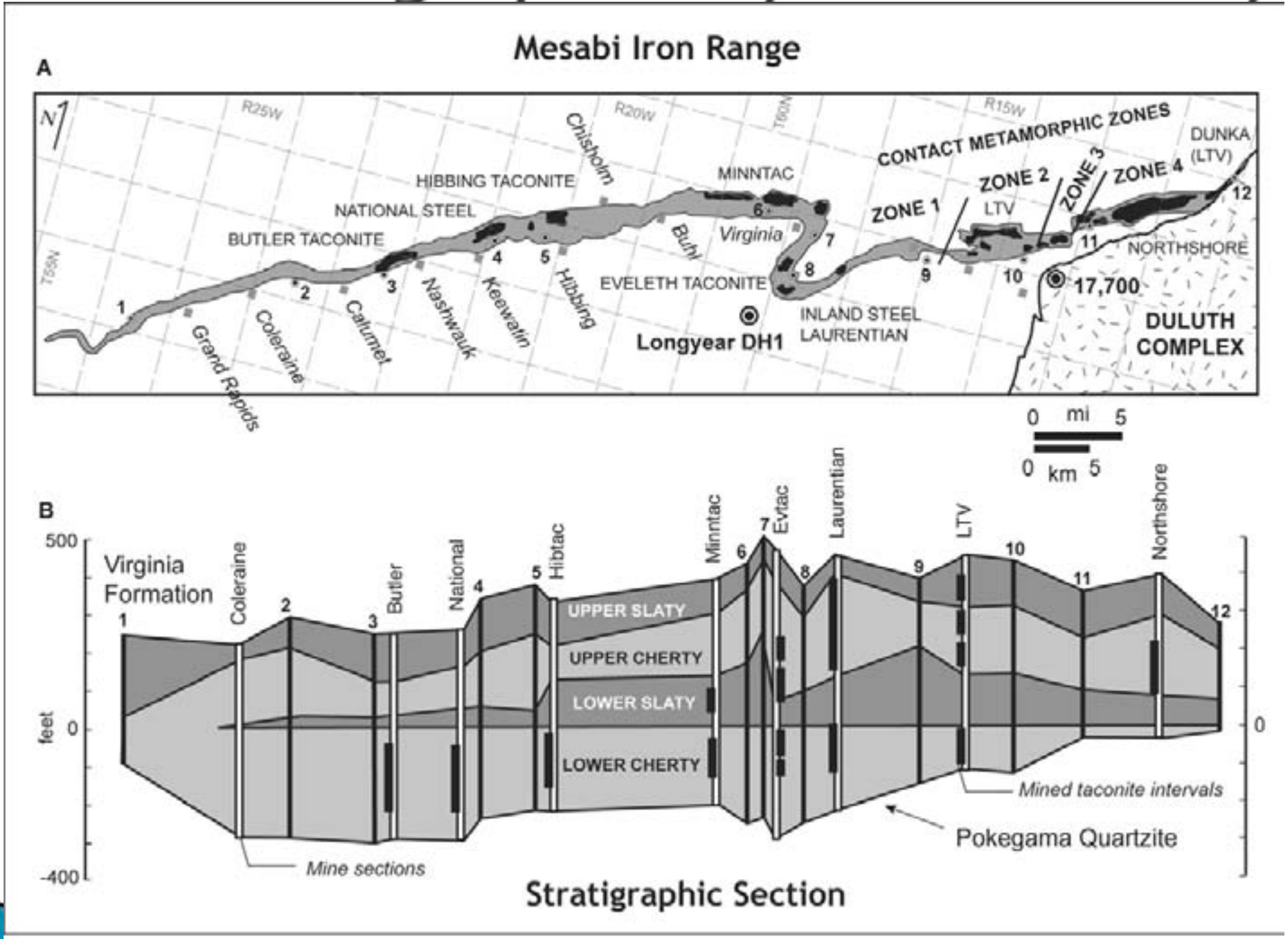
Change in mineralogy



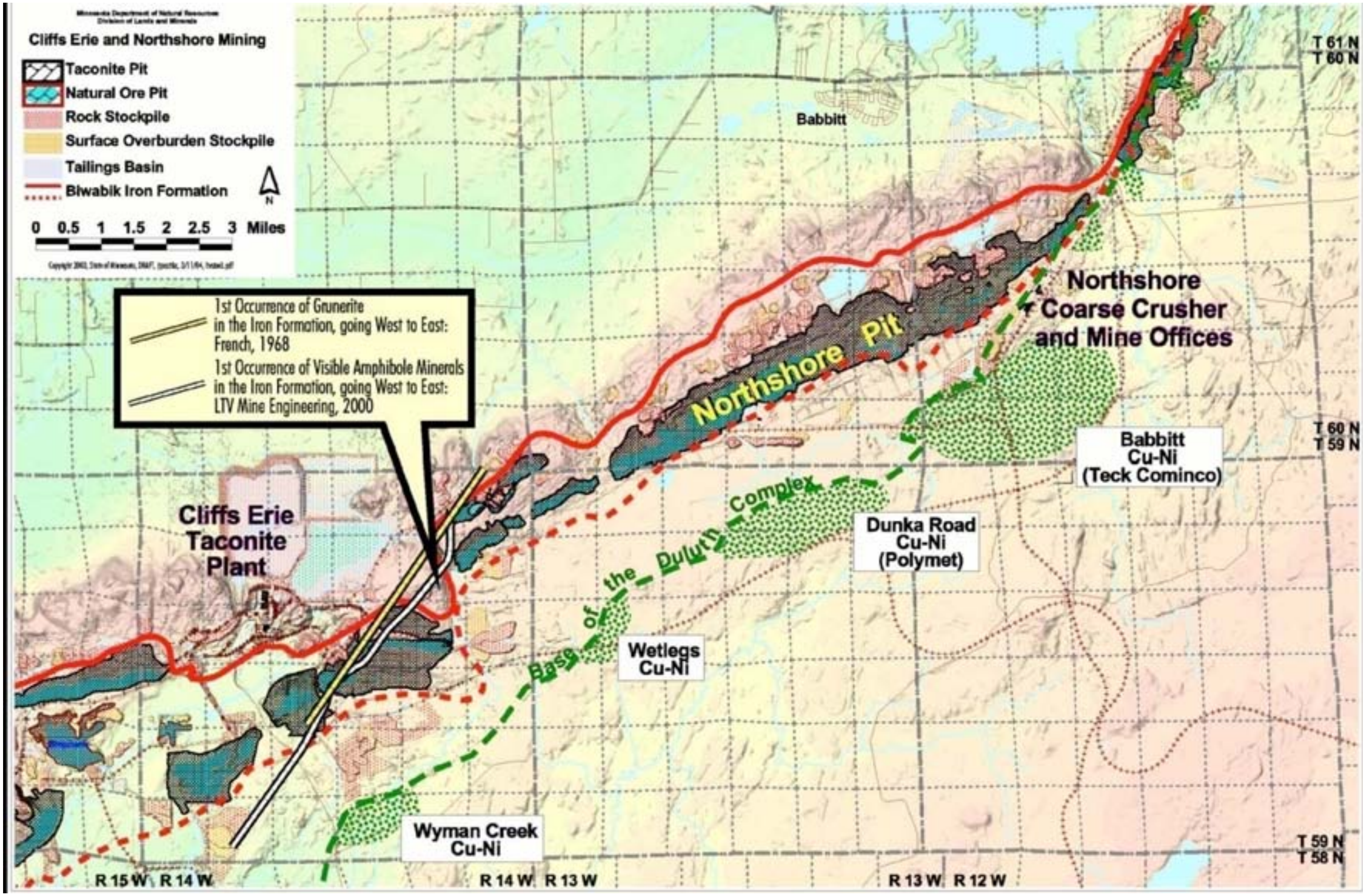
Information already available

Differences exist in geology and mineralogy from one end of Iron Range to the other, and has been studied and documented by several investigators.

Geology of Biwabik Iron Formation varies stratigraphically and laterally



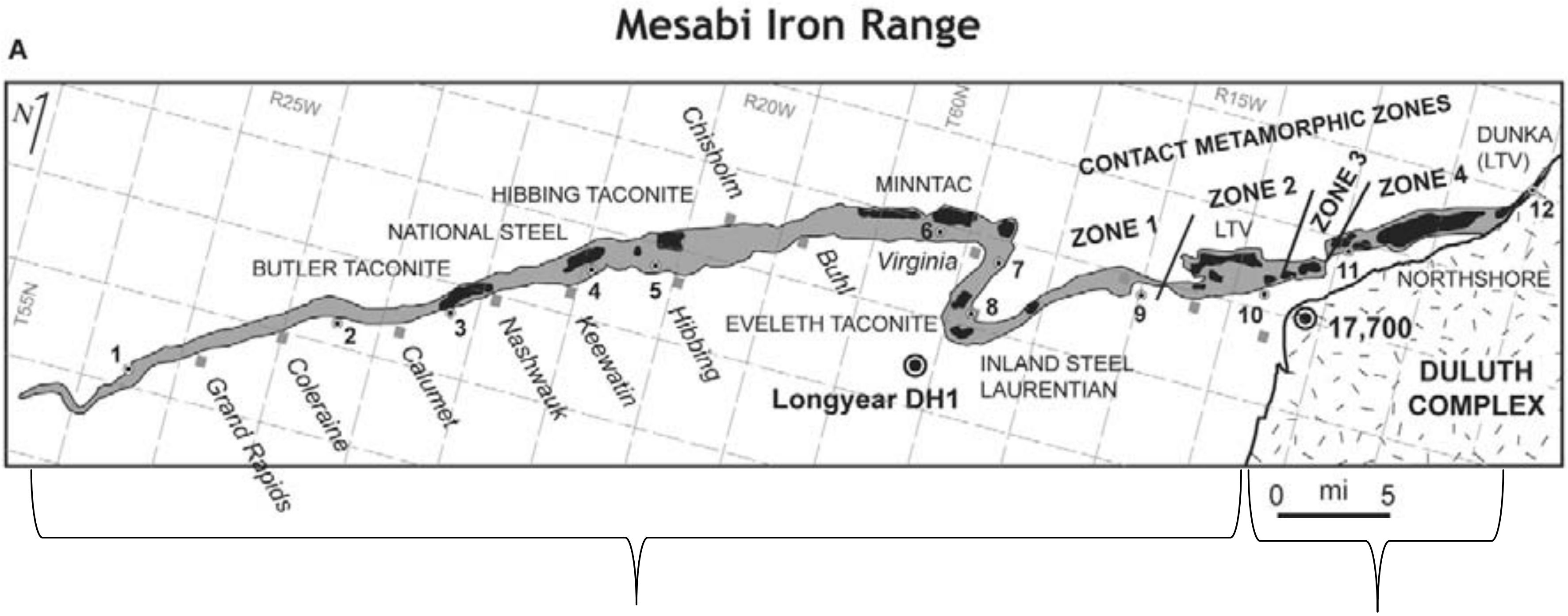
From: OVERVIEW OF THE MINERALOGY OF THE BIWABIK IRON FORMATION, MESABI IRON RANGE, NORTHERN MINNESOTA Peter L. McSwiggen and G.B. Morey (in press).



Map of Cliffs Erie (formerly LTV) and Northshore Mining Company properties showing line where grunerite and other amphibole minerals first appear at the eastern end of the BIF (map courtesy of Minnesota Department of Natural Resources, Division of Lands and Minerals, [illegible])

Taconite Mineralogy

West to East



quartz, magnetite, hematite, carbonates, talc, chamosite, greenalite, minnesotaite and stilpnomelane

grunerite, hornblende, hedenbergite, ferrohypersthene (ferrosilite), and fayalite

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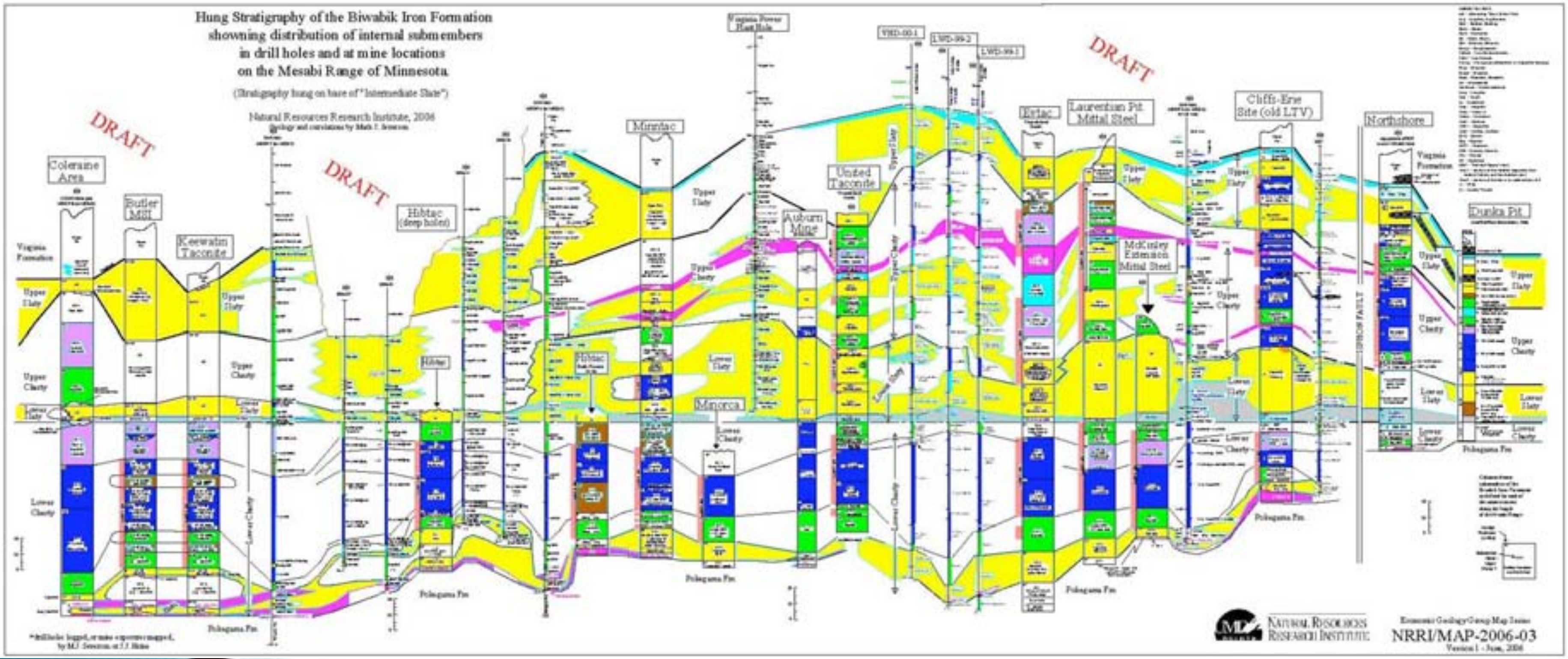
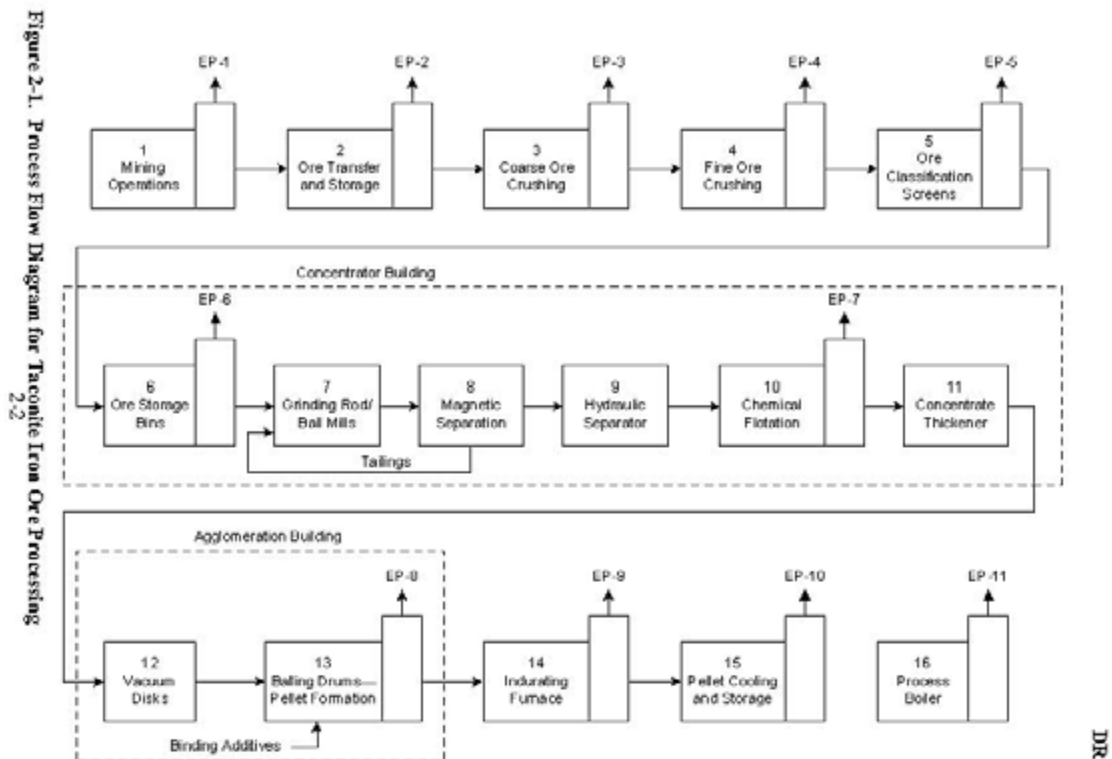
Developing the Geological Detail on the Iron Range

Current work is underway to understand the various rock types and horizons for the various active mining operations. This work can be utilized to better understand if mined rock is closely related to the particle types found in the investigation.

Ongoing work by NRRI geologists is showing how (and if) geologic horizons correlate from one mine to the next, across the entire Biwabik Iron Formation



Taconite operations provide several sampling opportunities



Source: Taconite Mining and Processing Industry Profile Draft Report, September 2001, Prepared for Bryan J. Hubbell, USEPA, EPA Contract Number 68-D-99-024 RTI Project Number 7647.002.142

Mining and coarse crushing

Fine grinding and concentrating

Agglomeration and pellet production

Tailings as a sample medium

- Contain the non-magnetic portion of the ore that is mined
- Represent a “run-of-mine” composite of the ore that is processed
- Silicates, amphiboles, and/or asbestos minerals are non-magnetic, and would most likely be found in the tailings
- Therefore, tailings will be the most “representative” sample medium for characterizing the fibrous particle potential of the iron-formation.

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Current research objectives and approach

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Objective of current study

Characterize fibrous minerals (length to width ratio greater than 3:1) in Biwabik Iron Formation-related materials:

- Tailings, ore, and pellet fines
- Air samples in plant
- Ambient air and dust in surrounding communities
- Biwabik Iron Formation (*in situ*)

Fibrous minerals of the Biwabik Iron Formation

- **Grunerite/Cummingtonite** $(Mg,Fe)_7Si_8O_{22}(OH)_2$
  - Amphibole
  - Common metamorphic mineral in iron-rich rocks
  - Mostly massive, also as "Amosite" asbestos
- **Actinolite** $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
  - Amphibole
  - Metamorphic mineral
  - May be restricted stratigraphically

Fibrous minerals of the Biwabik Iron Formation (cont.)

- **Minnesotaite** $(Fe,Mg)_3Si_4O_{10}(OH)_2$
  - Iron-rich talc
  - Occurs in unmetamorphosed Biwabik Iron Formation
- **Greenalite** $(Fe)_{2\text{-}3}Si_2O_5(OH)_4$
  - Iron serpentine
  - Occurs in unmetamorphosed Biwabik Iron Formation
- **Stilpnomelane** $K(Fe,Mg)_8(Si,Al)_{12}(O,OH)_{27}\cdot n(H_2O)$
  - Variable composition sheet silicate
  - Occurs in veins and in unmetamorphosed iron formation

Minerals that occur as fibers in the Biwabik Iron Formation:

- Some of these minerals are not currently associated with negative consequences to human health
- All of these minerals are more abundant in their non-fibrous form
- It is currently unclear what fraction of these minerals occur with fibrous (asbestiform) morphology

- Document for each 3:1 length to width ratio particle:
  - Mineralogy
  - Chemical composition
  - Dimension
  - Fiber/cleavage fragment
  - Additional (?)

Proposed sampling program

- Crushing, grinding, and dust generation sites at taconite operations
  - Done with cooperation of mines
  - MSHA collaboration on personal air sampling

- Surrounding communities and adjacent non-mining properties
  - Collaboration with state agencies on ambient air monitoring

Proposed sampling program (cont.)

- Where run of mine material warrants further investigation, thin sections will be prepared from drill core of iron-formation for *in situ* characterization

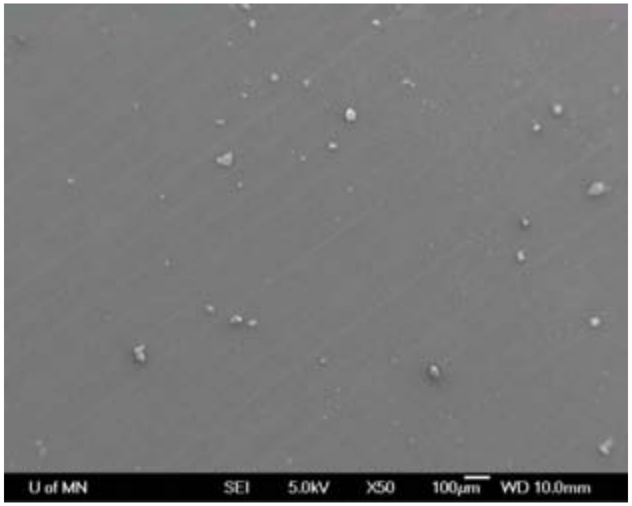
Sample analysis

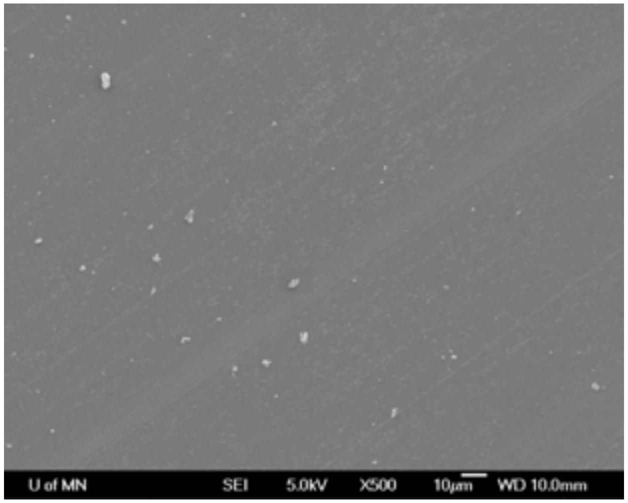
- Split samples
  - Send splits to >1 independent accredited asbestos labs for routine analysis
- Methodology for tailings, ore, and pellet fines based on USGS procedure for analysis of asbestos in soil from Libby, MT
  - SEM procedure
  - Disperse samples on filter
  - Identify particles with length to width ratio of 3:1
  - Energy dispersive X-ray spectra for chemical composition
  - Report results as mass fraction 3:1 particles; break down into subpopulations based on mineralogy, shape, etc.

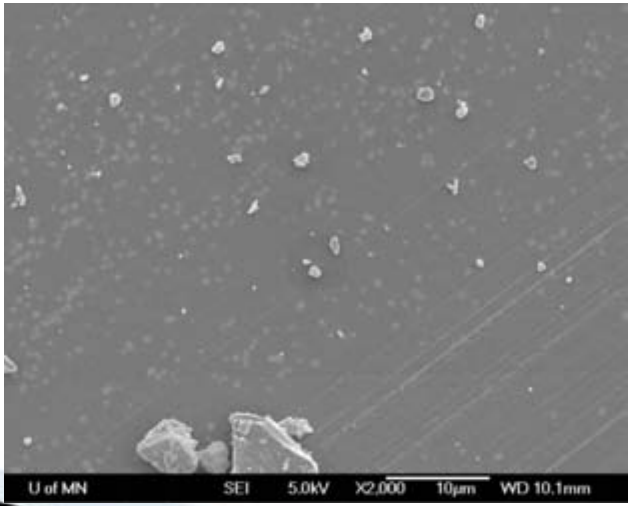
Sample analysis (cont.)

- Methodology for air samples modified from TEM-based procedure used by Dept. of Health
  - Report results as fibers/cm^3; break down into subpopulations based on mineralogy, shape, etc.

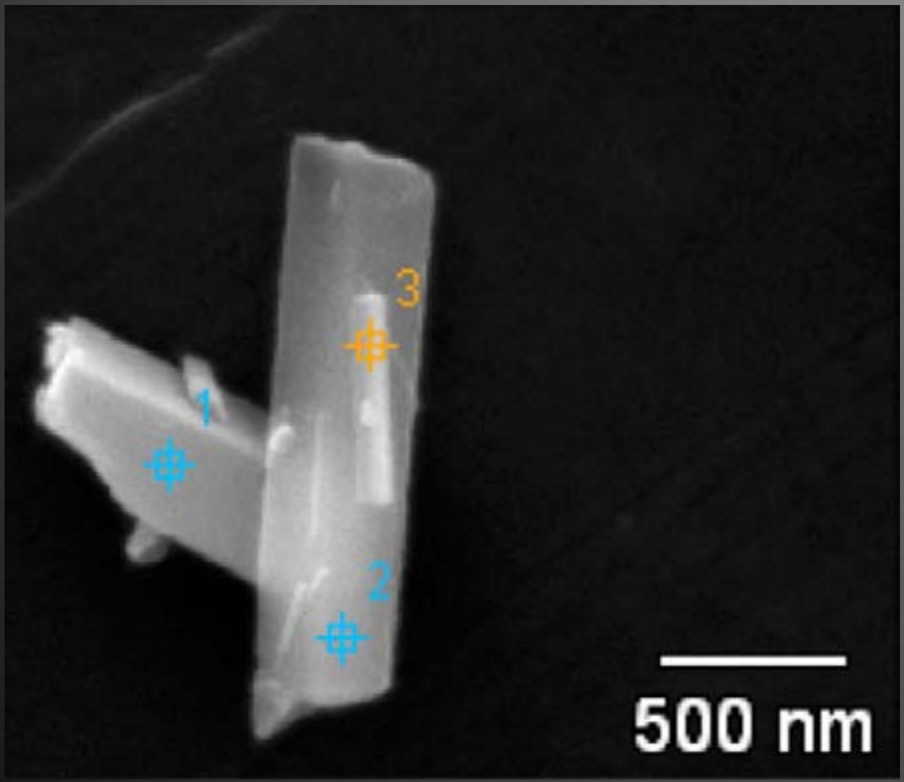
Example from preliminary work on west end tailing sample





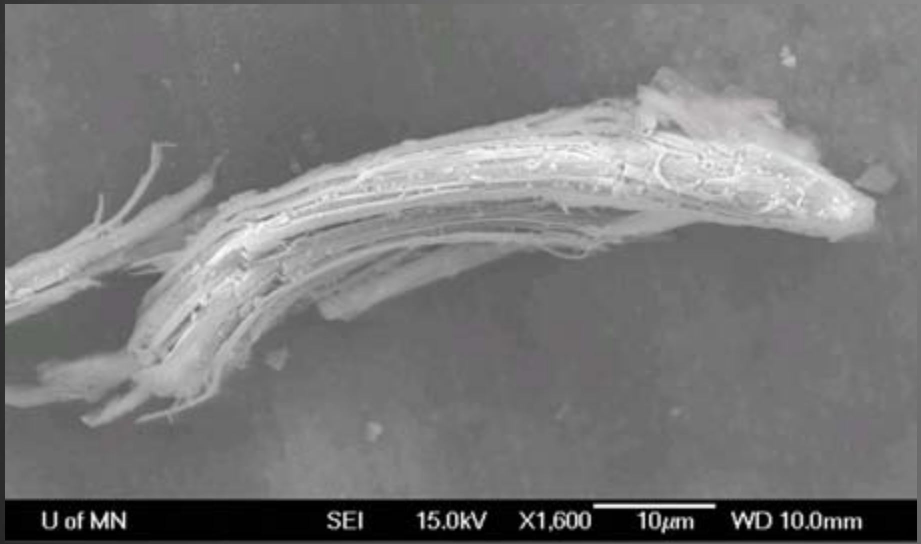


1µm= .00004”
1”=25,400 µm



Chemical composition from energy-dispersive spectroscopy (EDS) indicates probable carbonate

Fiber or cleavage fragment?



- Polycrystalline
- Flexible (displays curvature)
- Frayed ends
- Very high length to width ratios (can be greater than 100:1), width independent of length

- Single crystal
- Brittle
- Blocky
- Length to width ratios greater than 3:1, but width related to length
- Lower tensile strength than fiber
- Different dissolution kinetics and mechanisms

Fiber/cleavage fragment determination

- Characteristics other than shape can be used to make subjective determination
- Diffraction experiment in TEM and possibly SEM can distinguish between single crystals and bundles of fibrils
- Optical microscopy of thin sections can be used for corroboration

Conclusion

Characterize particles at taconite operations and in surrounding communities

Document: size, composition, mineralogy, fiber/cleavage fragment for particles with length to width ratio of 3:1

Work in collaboration with state and federal agencies for sample collection