Effect of Source Water Chemical Composition on the Mineralogical and Chemical Properties of Resulting Iron Oxide Precipitates in Coal and Hard-rock Mining Influenced Waters

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Background

Hypotheses

Methods

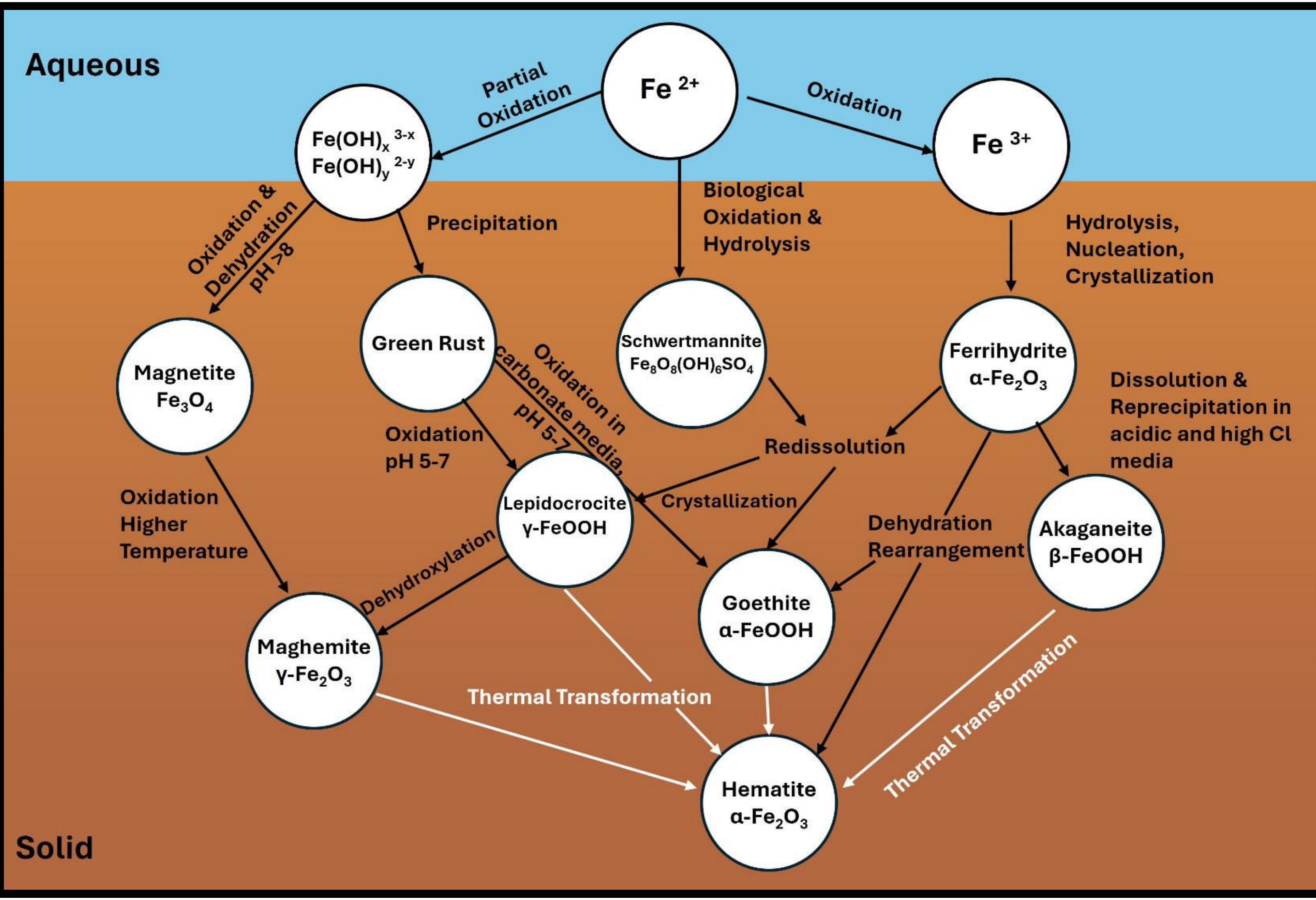
Results

Key Takeaways

Iron Oxidation and Retention

- Oxidation Ponds and Discharges
  1. Fe (II) → Fe (III)
  2. Hydrolysis of Fe (III)
  3. Precipitation of Fe (III) oxides
  4. Flocculation and settling of particulates

- Residual management


Aqueous
Fe 2+
Partial Oxidation
Oxidation
Fe(OH)x 3-x
Fe(OH)y 2-y
Fe 3+
Oxidation & Dehydration pH >8
Precipitation
Biological Oxidation & Hydrolysis
Hydrolysis, Nucleation, Crystallization
Magnetite
Fe3O4
Green Rust
Oxidation in carbonate media, pH 5-7
Schwertmannite
Fe8O8(OH)6SO4
Ferrihydrite
α-Fe2O3
Dissolution & Reprecipitation in acidic and high Cl media
Oxidation pH 5-7
Redissolution
Oxidation Higher Temperature
Lepidocrocite
γ-FeOOH
Crystallization
Dehydration Rearrangement
Akaganeite
β-FeOOH
Dehydroxylation
Goethite
α-FeOOH
Maghemite
γ-Fe2O3
Thermal Transformation
Thermal Transformation
Hematite
α-Fe2O3
Solid

Why It Matters

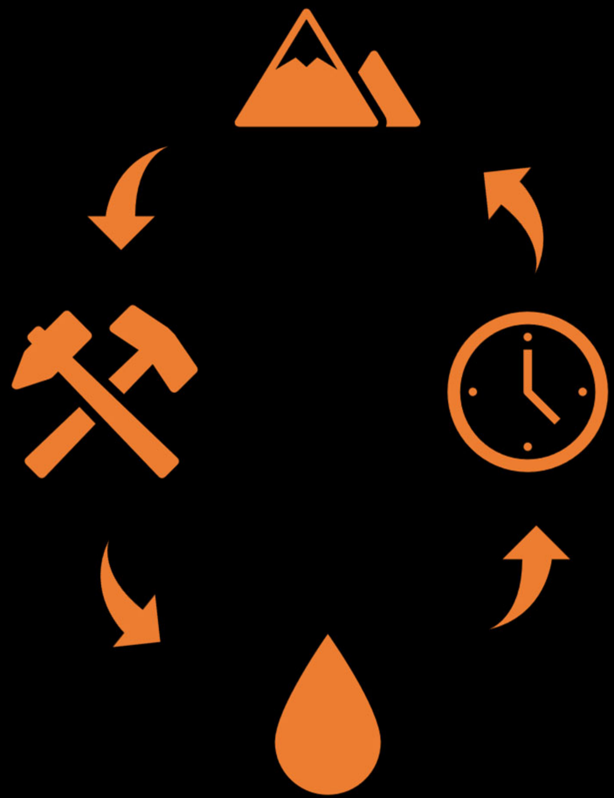
- Affects treatment performance
- Costly sludge disposal

Why It Matters

- Affects treatment performance
- Costly sludge disposal
- Turn “waste” into a resource
- Sustainable reuse

Challenges and Research Needs

- Most research performed in net-acidic coal mine drainage
  - Net-alkaline mine drainage → different mineralogy and transformation rates
  - Hard-rock mining drainage → elevated metal concentrations
- Limited evaluation of how these solids change over time
  - Age and become more crystalline
  - Decreased sorption capacity



Hypotheses

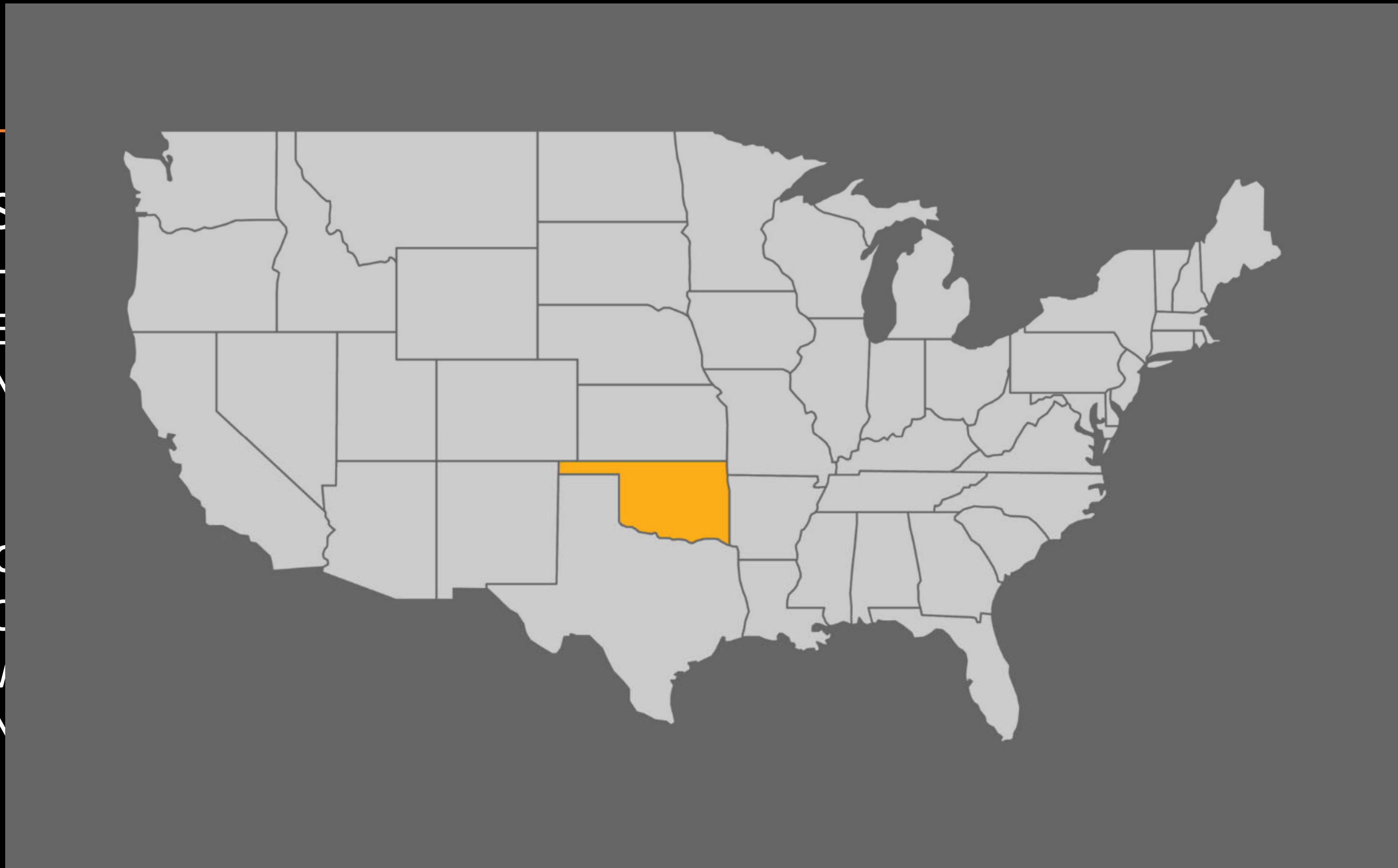
1. Chemical composition of mine drainage waters (e.g., pH, total alkalinity, metals concentrations, anions concentrations, etc.) has significant cumulative effects on resulting precipitate mineralogy

2. The resulting mineralogy of iron oxides formed from different mine drainage water compositions affects their sorption capacity

3. As the mine drainage-derived solids age, they become more crystalline and thus their sorption capacity decreases

Res

- Tri-S
  - H
  - E
  - N
- Arko
  - C
  - V
  - N



Characterization of Iron Oxides from Different Mine Water Chemistries

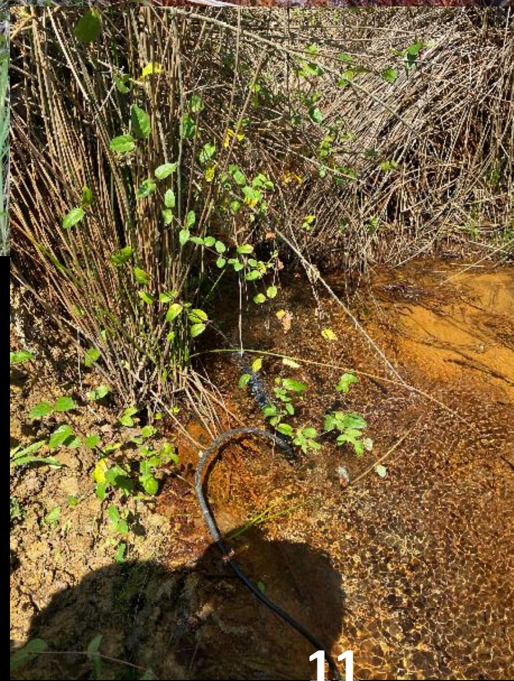
Water Quality Analyses

- Physicochemical Parameters (pH, ORP, DO, SC, etc.)
- Alkalinity
- Turbidity
- Anions (Cl^-, PO_4^{3-}, SO_4^{2-})
- Total and Dissolved Metals/Base Cations (Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Si, Zn)

Solids Characterization

- Moisture Content
- Organic Matter Content
- Specific Surface Area
- Percent Crystallinity
- Point of Zero Net Charge
- Total Metals Concentrations
- Mineralogy
  - X-ray Diffraction
  - Scanning Electron Microscopy

Site	pH	Net-Acidity (mg/L $CaCO_3$)	Ionic Strength (M)	Fe (mg/L)	SO_4 (mg/L)
GOWEN (n=10)	4.47 ± 0.35	309 ± 138	0.028 ± 0.003	124 ± 18	456 ± 129
HOWE (n=10)	4.46 ± 0.34	85 ± 37	0.011 ± 0.001	36 ± 10	165 ± 46
LEB (n=8)	6.63 ± 0.32	-125 ± 25	0.032 ± 0.05	31 ± 3.9	1010 ± 2472
RI7 (n=8)	6.41 ± 0.26	9.5 ± 157	0.12 ± 0.11	169 ± 102	3359 ± 5165
MRPTS (n=86)	5.97 ± 1.13	-84± 53	0.11 ± 0.2	165 ± 34	2241 ± 616
SECPTS (n=71)	6.15 ± 0.17	-114 ± 59	0.10 ±0.02	124 ± 31	1930± 343

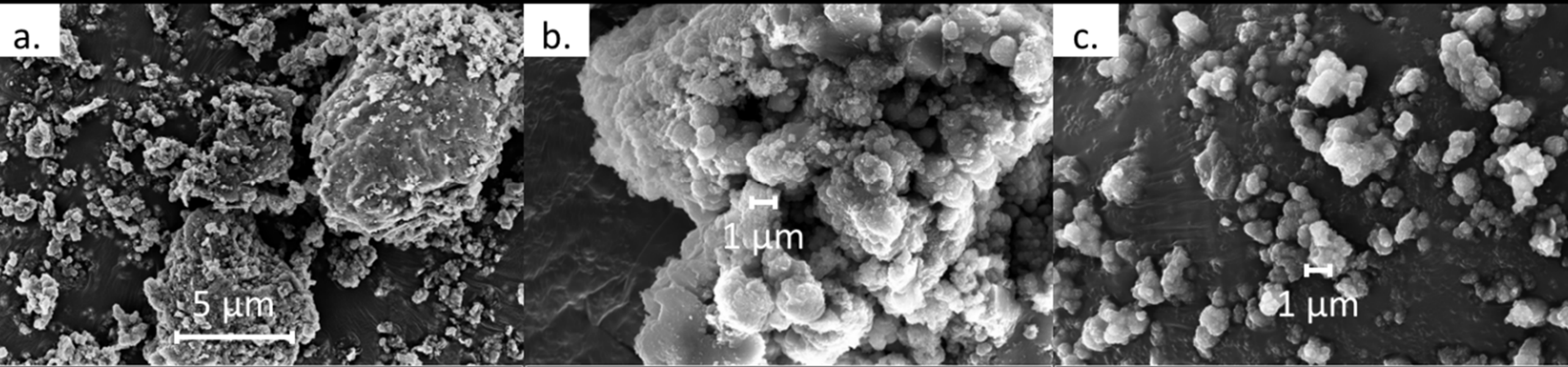


Site	Fe (mg/kg)	Specific Surface Area (m^2/g)	Crystallinity %	PZNC
GOWEN	411000 ± 2400	18 ± 0.13	64 ± 5.2	5.55
HOWE	333000 ± 9400	40 ± 0.10	69 ± 4.1	4.24
LEB	382000 ± 15000	135 ± 0.58	52 ± 3.9	5.64
RI7	524000 ± 42000	167 ± 0.35	55 ± 8.4	5.76
MRPTS	489000 ± 21000	115 ± 0.25	56 ± 0.4	7.11
SECPTS	406000 ± 20000	99 ± 0.13	56 ± 12	5.94

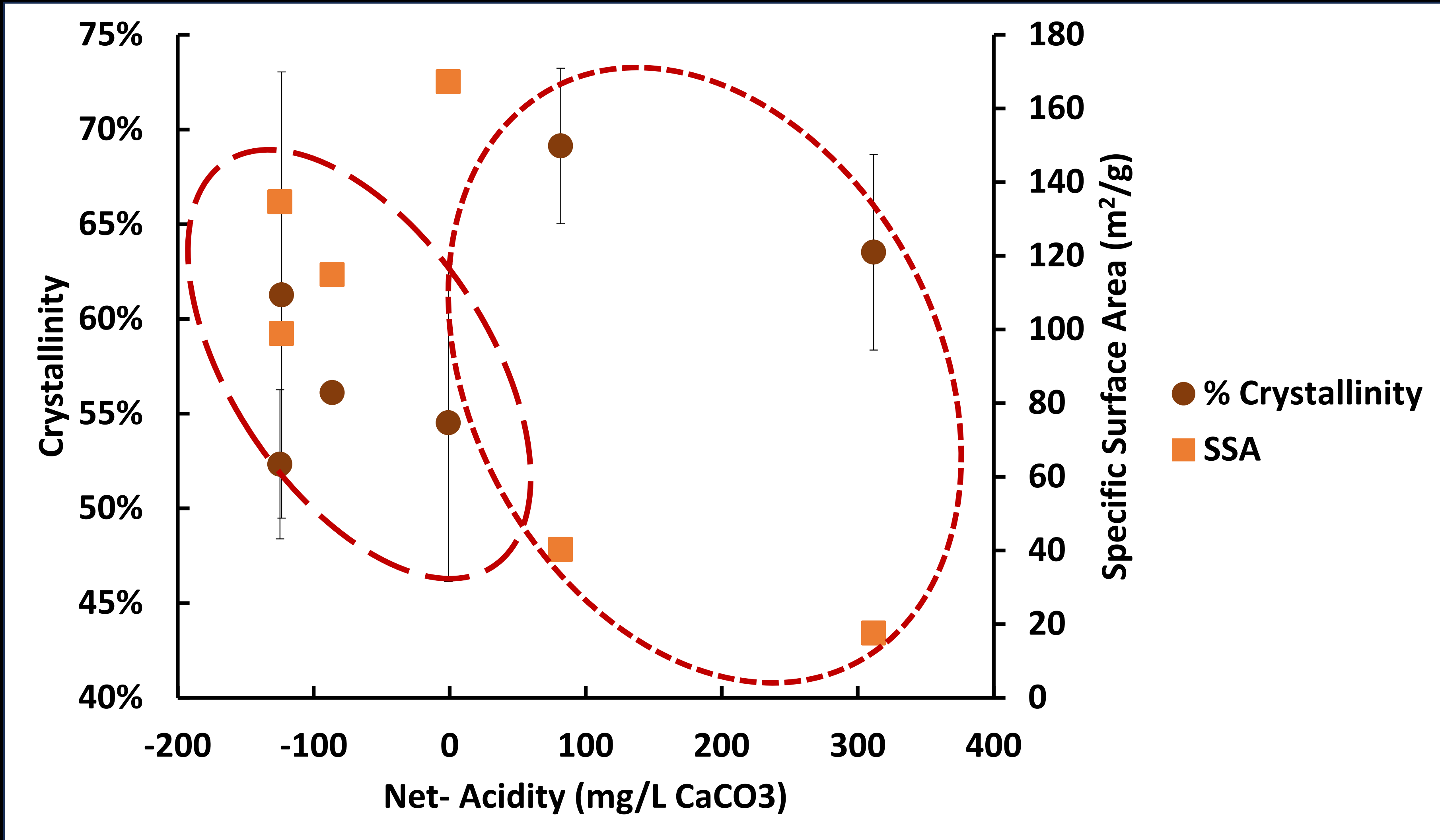
All precipitate samples:

- **Mostly mineral (<20% organic)**
- **Primarily goethite**

More amorphous goethite and ferrihydrite phases present

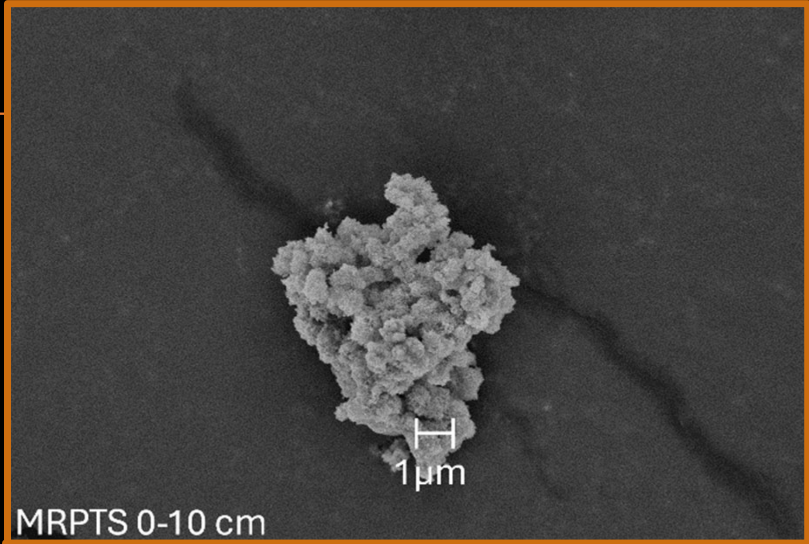


LEB RI7 MRPTS

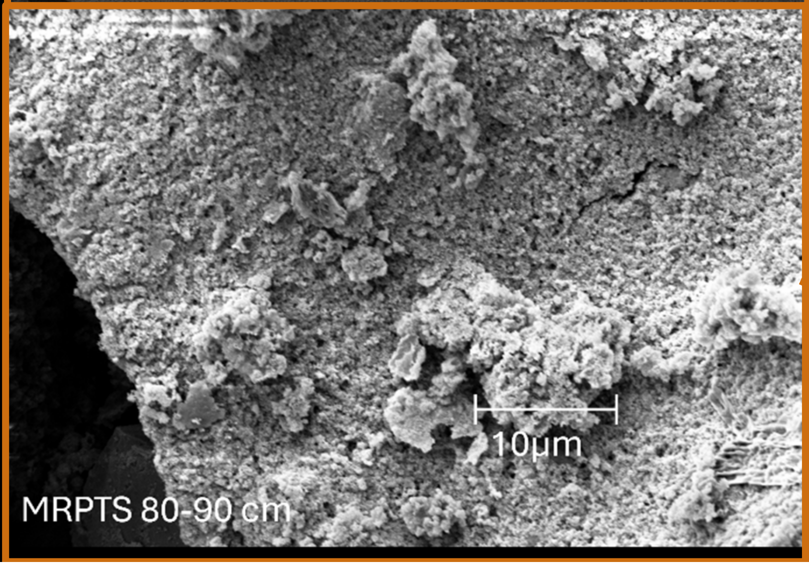

75%
70%
65%
60%
55%
50%
45%
40%
Crystallinity
-200
-100
0
100
200
300
400
Net- Acidity (mg/L CaCO3)
180
160
140
120
100
80
60
40
20
0
Specific Surface Area (m2/g)
% Crystallinity
SSA

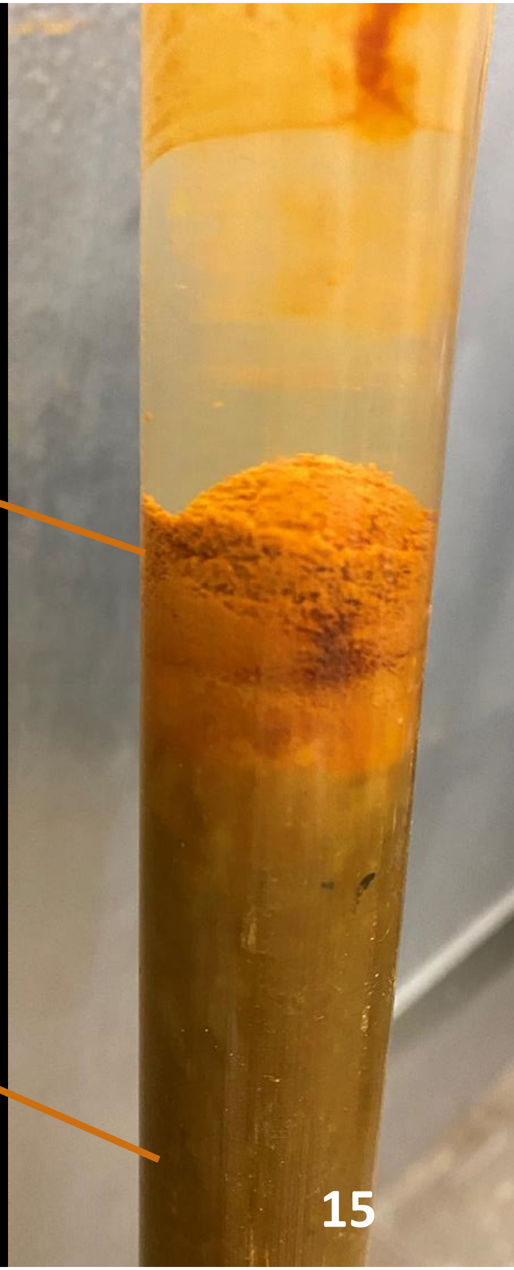
Iron Oxides Heterogenous with Depth

0-2 years old
SSA: 157 ± 0.26 m^2/g



13-15 years old
SSA: 95 ± 0.13 m^2/g





Key Takeaways

- Source mine drainage water quality influences the properties of iron oxide precipitates
  - Net-acidic pH → lower PZNC → higher crystallinity → lower SSA
  - Lower PZNC makes less favorable for anion sorption
  - Less metals sorbed less likely to release metals

- Oxidation ponds not static systems
  - Iron oxides continue to mineralize over time

Waste into Resource

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Thank You!!

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Ongoing Work

- Phosphorus sorption capacity experiments
  - 35,000 to 100,000 mg P/kg
  - Minimal metals desorption
- Analysis of new vs aged iron oxides
  - Mineralogical and physical differences
  - Effect on sorption capacity
- Cost analysis
  - Traditional disposal vs beneficial reuse (AMDTreat)
  - Comparison to industrial Fe sorbents