Influence of ARD Drainage Characteristics on the Composition of Neutralization Sludges

Skya Fawcett, Lorax Environmental Services Ltd.

Alan J. Martin, Lorax Environmental Services Ltd.

Andrew Rollo, Canadian Environmental Assessment Agency

Diana Loomer, University of New Brunswick

Tom Al, University of New Brunswick

ACKNOWLEDGEMENTS

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  - Xstrata Zinc
  - EPCOR Utilities Inc.
  - Teck
  - Hudson Bay Mining and Smelting
  - Inmet

BACKGROUND

- The composition of ARD between mine sites is highly variable with respect to acidity, major ion content (e.g., S, Fe, Ca, Mg, Si, Na, K, Al), and trace element content (Cu, Pb, Ni, Zn, As).

- Variations in ARD drainage chemistry relate to several site-specific variables including:
  - Composition and abundance of S-bearing minerals
  - Composition and abundance of neutralizing minerals (carbonates, silicates, etc.)
  - Particle size distribution
  - Climate variables (water balance, temperature, etc.)
  - Mine waste management (segregation, blending, layering, compaction, etc.).

BACKGROUND

- At many mine sites the management of ARD involves neutralization with lime to reduce levels of acidity and trace elements prior to discharge to the environment.
- In general, treatment is achieved by raising the pH to values greater than 8.5 and separating the resulting precipitates (sludge) from the treated water prior to discharge.
- Given inherent variations in ARD composition, variations can be expected in the metal-bearing phases that are produced through lime neutralization.

Variability with respect to long-term chemical stability in a given depositional setting (Eh, pH dependence).

OBJECTIVES

- To assess how variations in ARD drainage chemistry influence the nature of metal-hosting phases in lime-neutralization sludges;
- To assess how such variation may influence the long-term chemical stability of sludge materials in various depositional settings.

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Provide basis from which to develop best management practices for neutralization sludges.

SAMPLE TYPES AND MINE SITES

Sample Types:

- ARD influent
- Treated effluent
- Lime-treatment sludges (high-density process)

1. Equity Mine (B.C.) - Goldcorp Canada
2. Geco Mine (Ontario) – Xstrata Zinc
3. Britannia Mine (BC) - EPCOR
4. Brunswick Mine (New Brunswick) – Xstrata Zinc
5. Samatosum Mine (BC) - Inmet
6. Sullivan Mine (BC) - Teck
7. Chisel North Mine (Manitoba)- Hudson Bay Mining and Smelting

STUDY SITES


Equity
Houston
Samatosum Mine
Chisel North Mine
Flin Flon
Sullivan Mine
Kamloops
Britannia
Vancouver
Kimberley
Britannia Mine
Geco
Thunder Bay
Bathurst
Brunswick Mine
Halifax

GEOLOGY AND TREATMENT PROCESS

	Equity	Geco	Britannia	Brunswick	Chisel North	Samatosum	Sullivan
Commodities	Au-Ag-Cu	Cu-Zn	Cu (Zn-Pb-Ag)	Pb-Zn-Cu-Ag	Cu-Zn	Ag-Cu-Pb-Zn-Au	Pb-Zn-Ag-Fe
Deposit Type	Intrusion-related hydrothermal	VMS	Massive Sulfide	VMS	VMS	Stockwork system	Sedex
Treatment Process	LDS/ HDS	HDS	HDS	HDS	HDS	HDS	HDS

HDS: typically 20-30% solids

METHODS

<u>Aqueous Phase</u>:

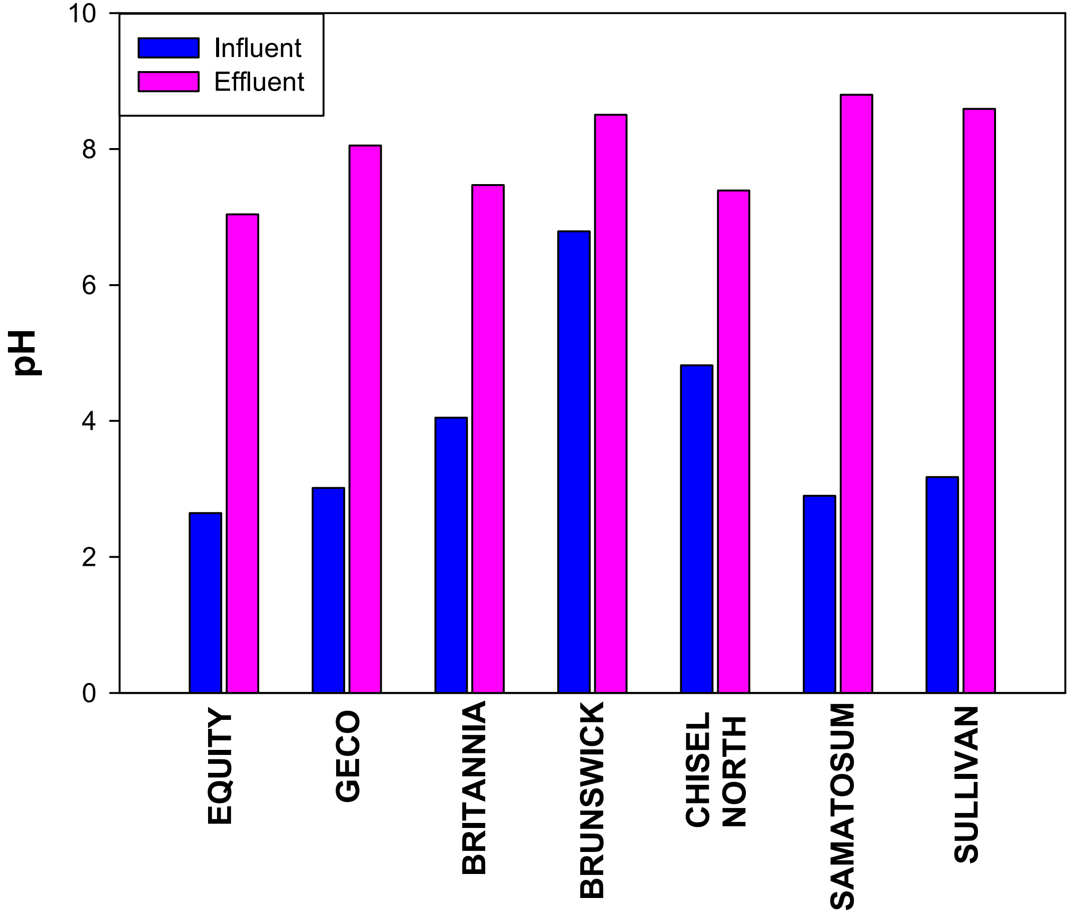
- ARD influent
- Treated effluent

} Full suite of major ions, trace elements, nutrient parameters

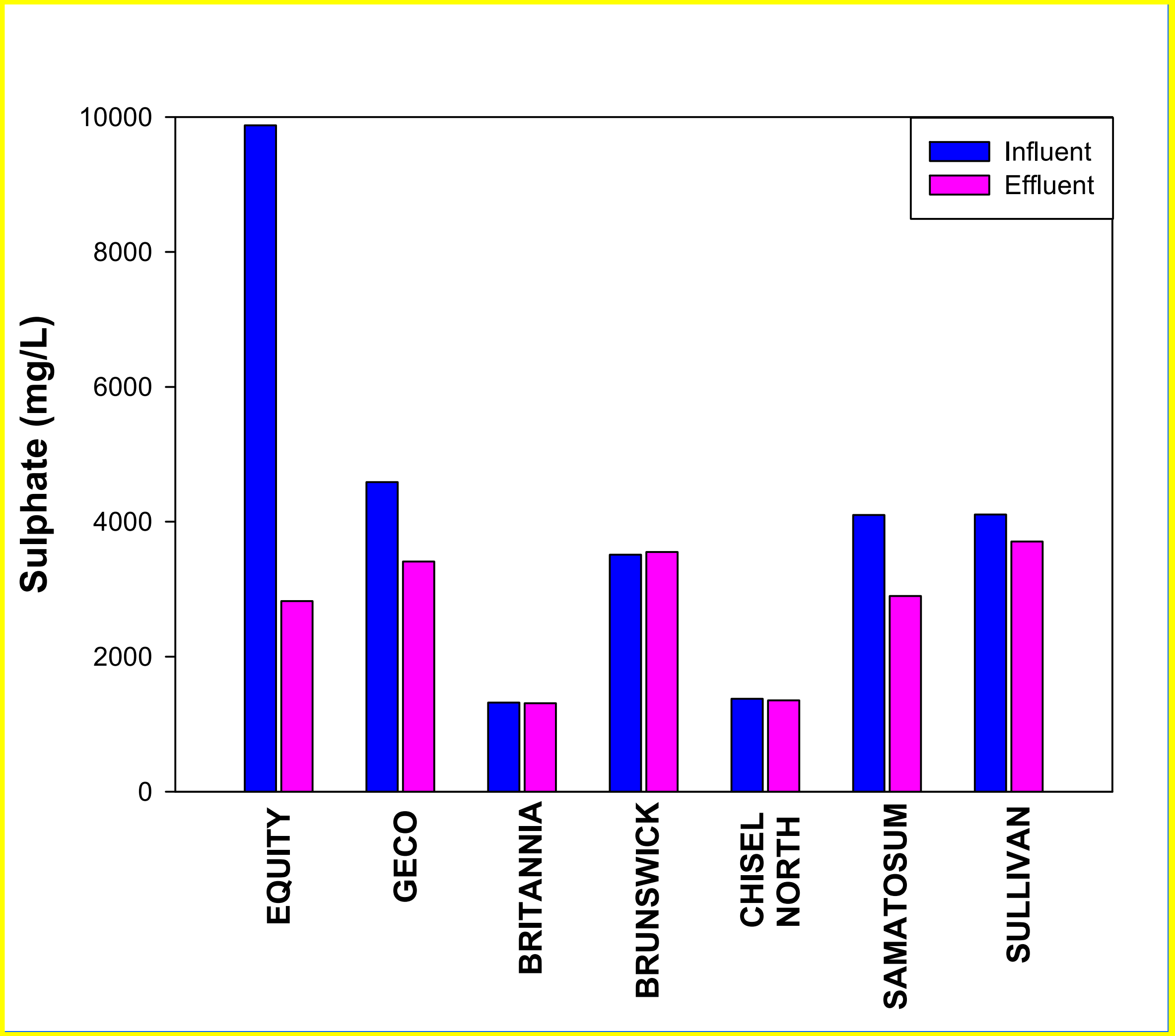
<u>Solid Phase</u>:

- Elemental Abundance
- X-Ray Diffraction
- High-resolution microscopy
  - Optical Microscopy
  - Scanning Electron Microscopy (SEM)
  - (Scanning) Transmission Electron Microscopy ((S)TEM).
  - X-ray absorption spectroscopy (XAS): synchrotron accelerator at Canadian Light Source – Saskatoon)

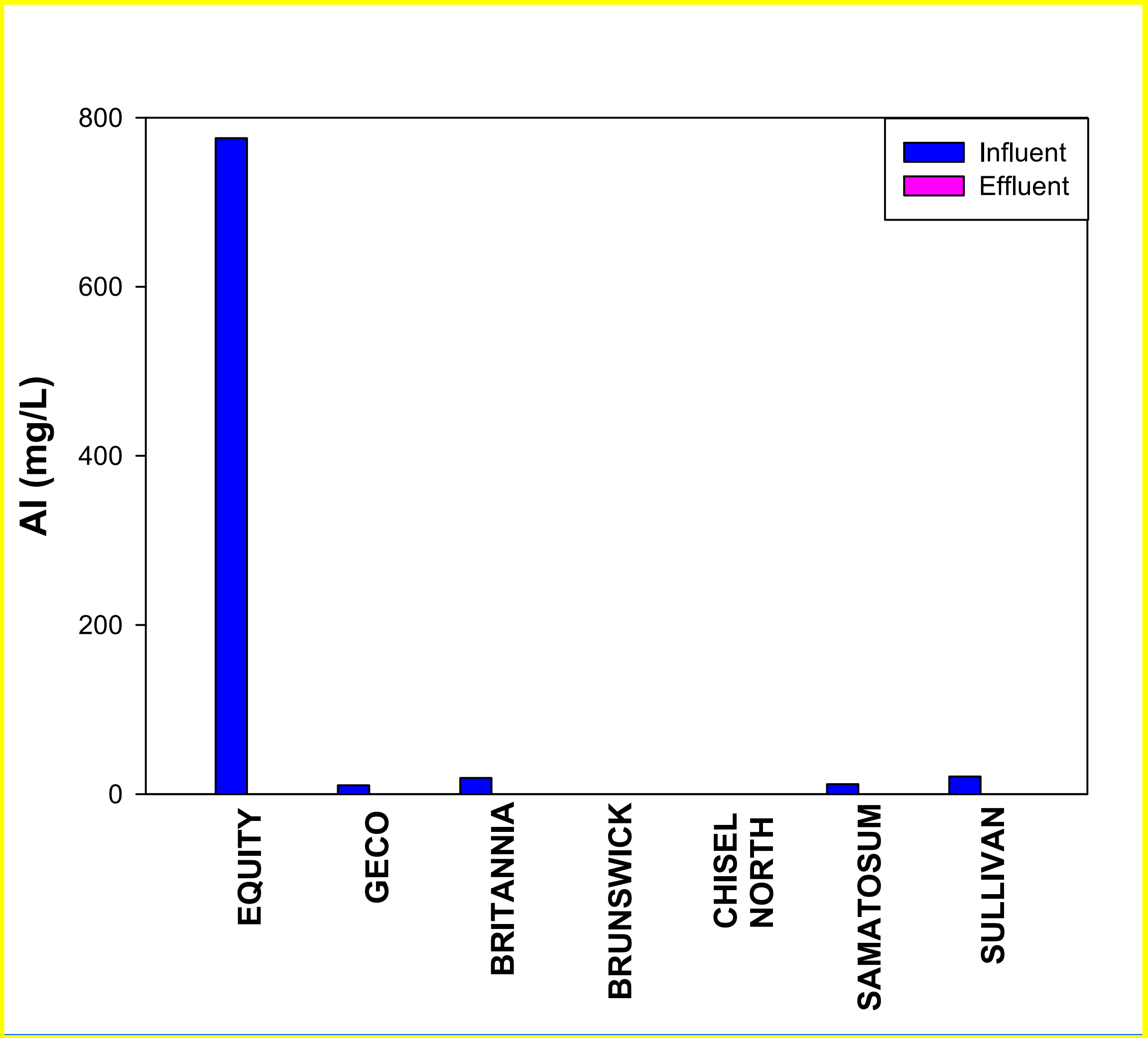
ARD CHEMISTRY: pH



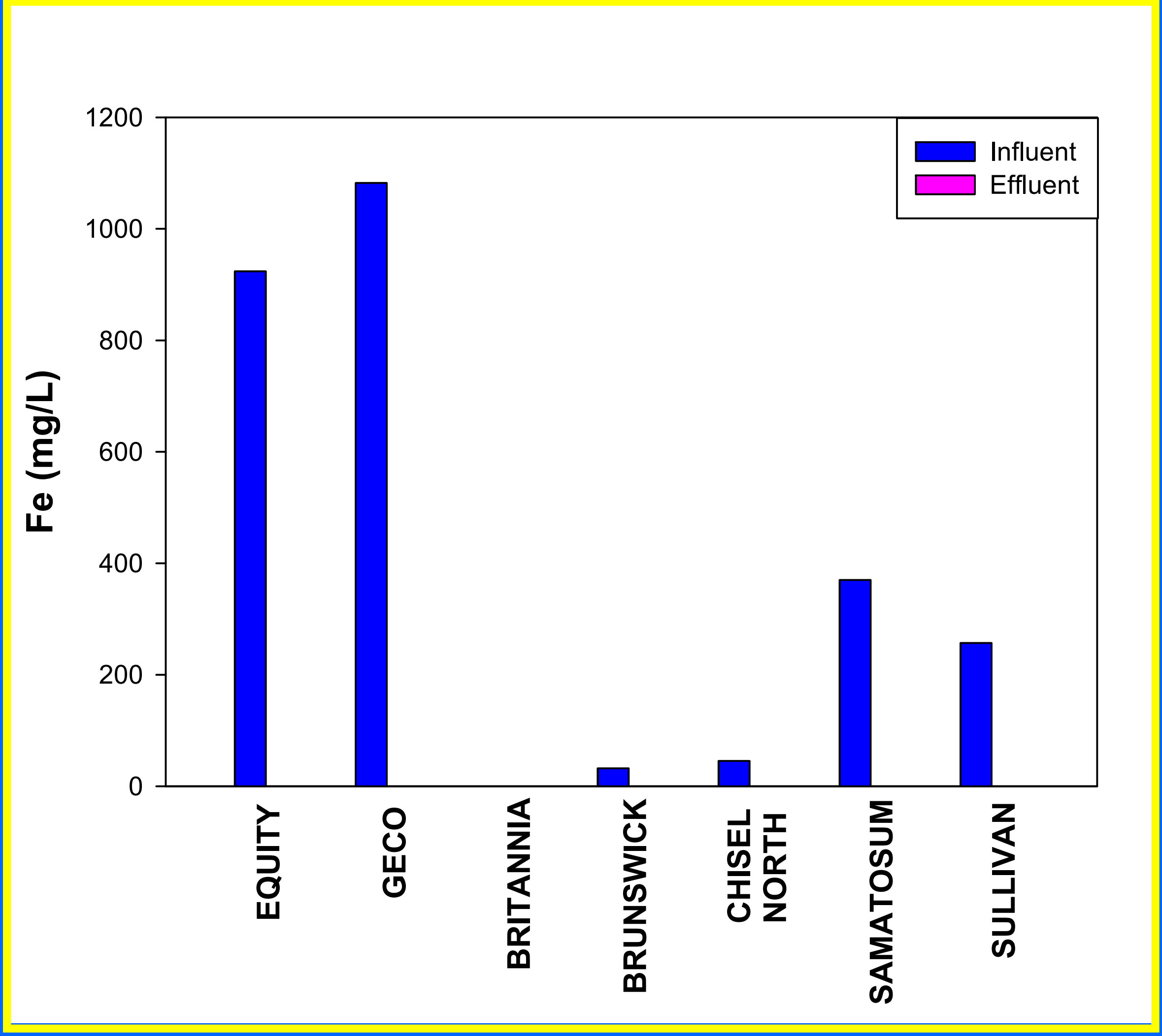
ARD CHEMISTRY: Sulphate



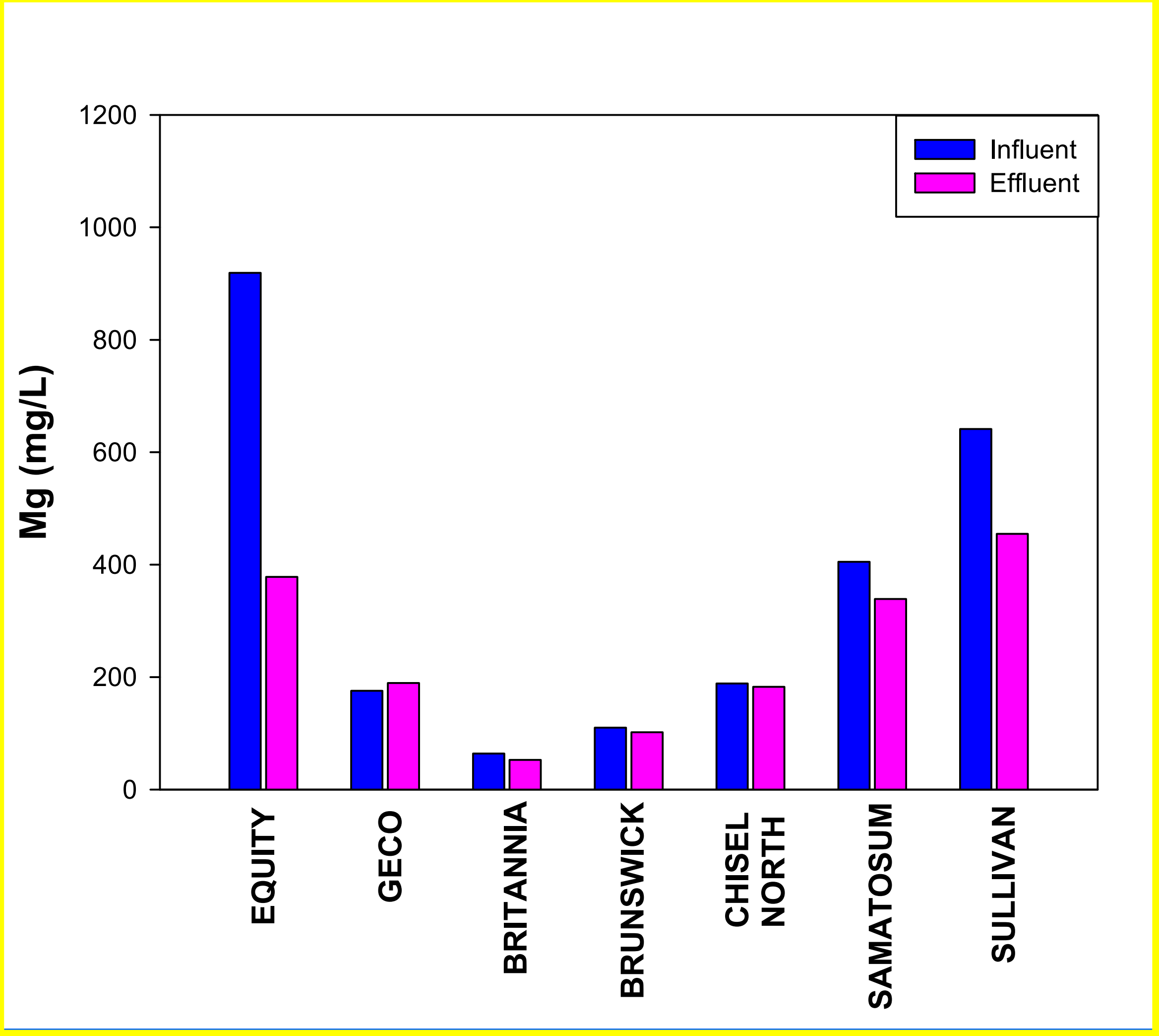
ARD CHEMISTRY: Aluminum



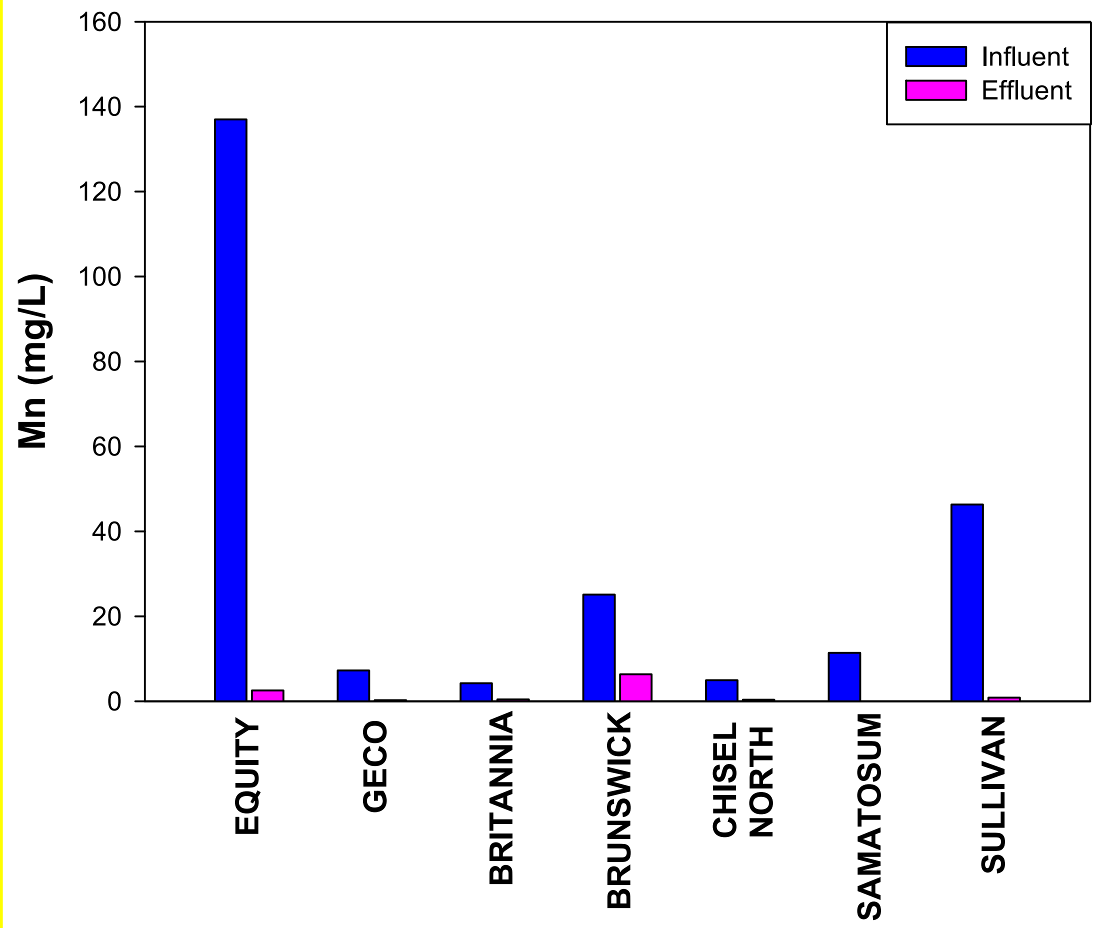
ARD CHEMISTRY: Iron



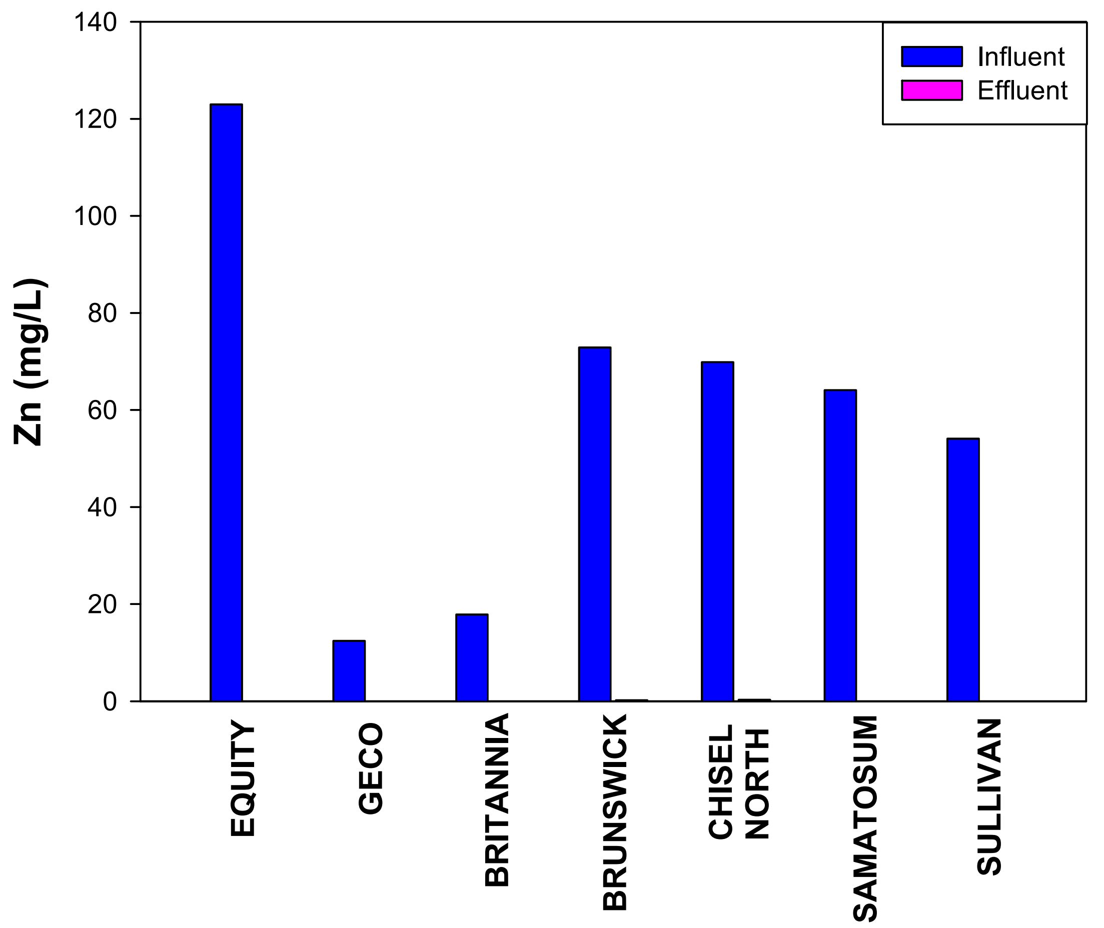
ARD CHEMISTRY: Magnesium



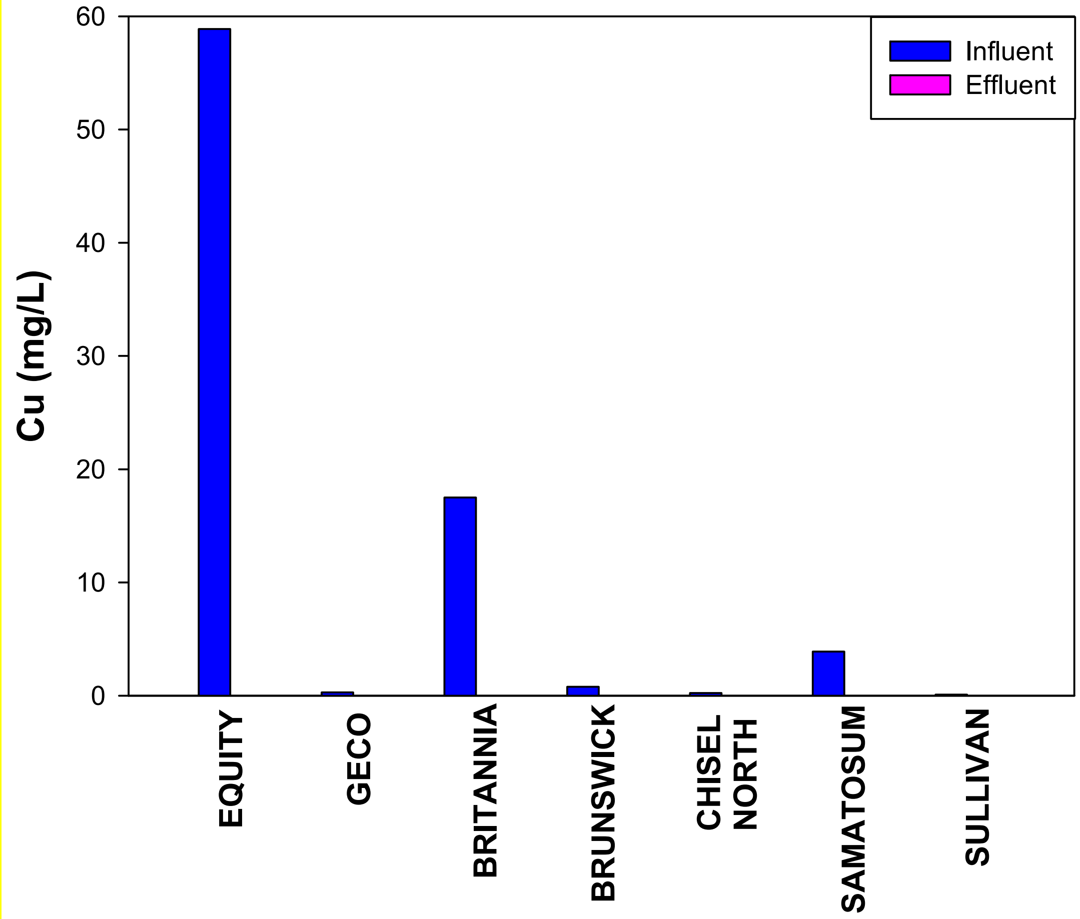
ARD CHEMISTRY: Manganese



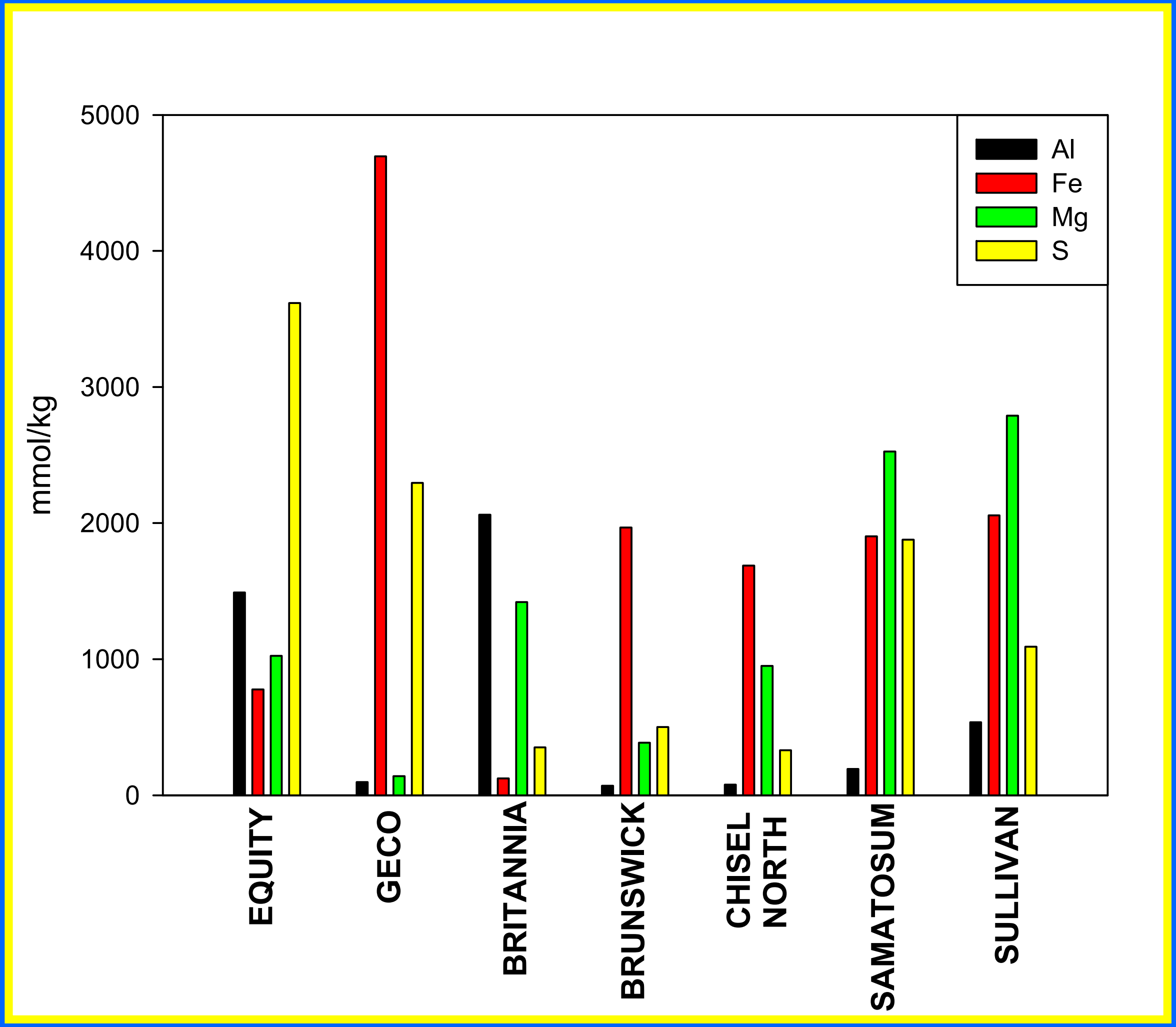
ARD CHEMISTRY: Zinc



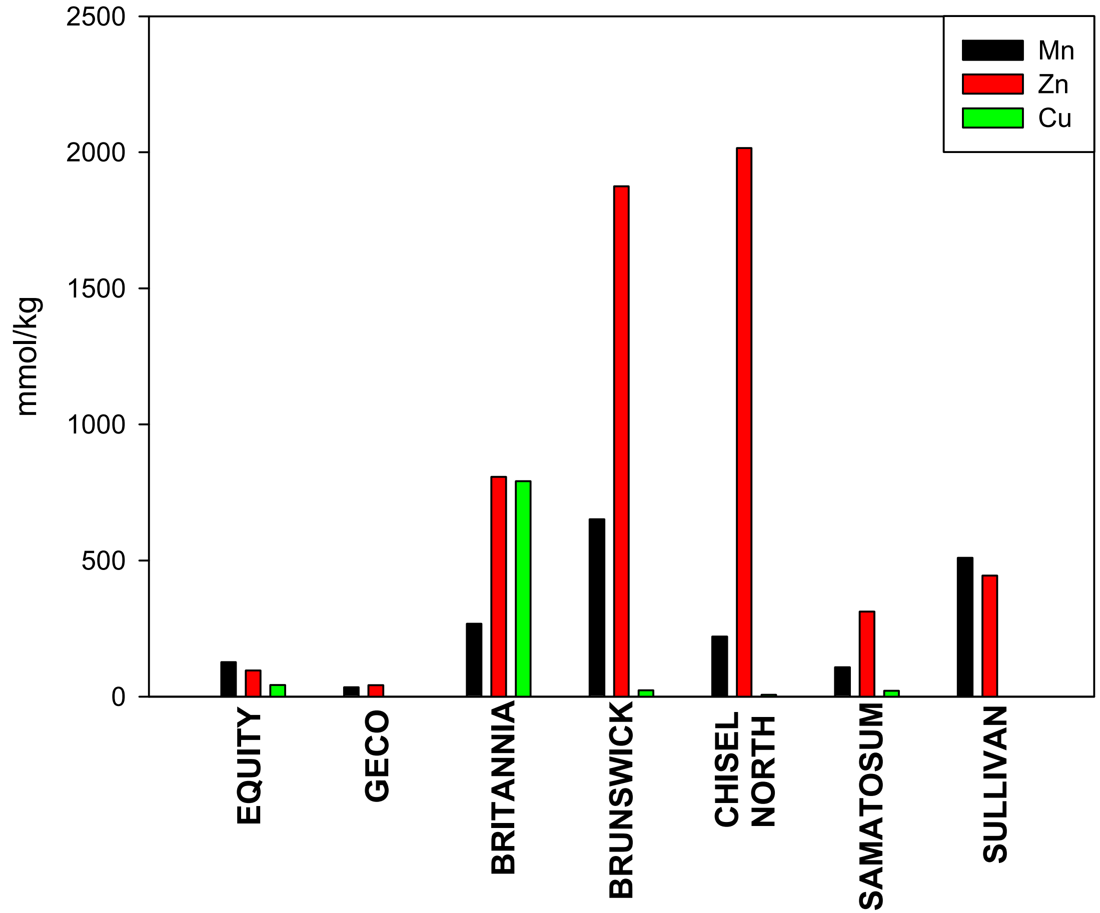
ARD CHEMISTRY: Copper



Solid Phase Chemistry – Al, Fe, Mg, S

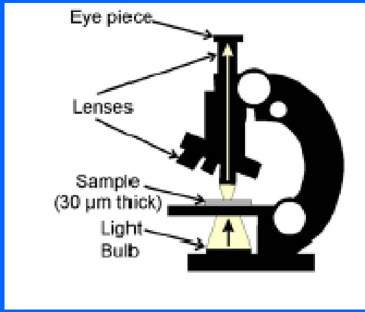


Solid Phase Chemistry – Mn, Zn, Cu

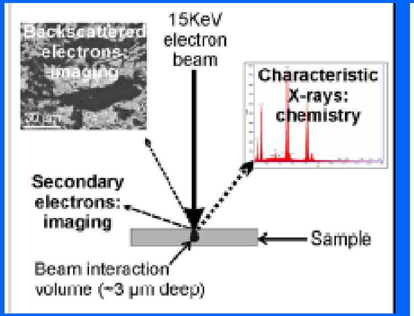


MICROSCOPY METHODS

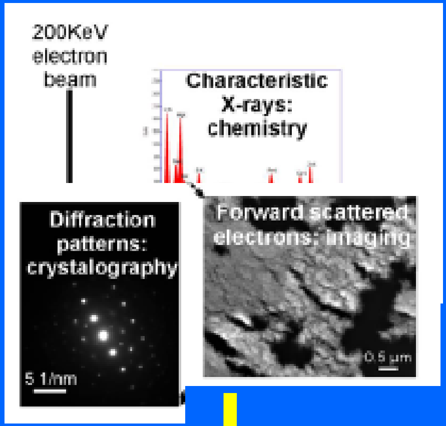
Optical



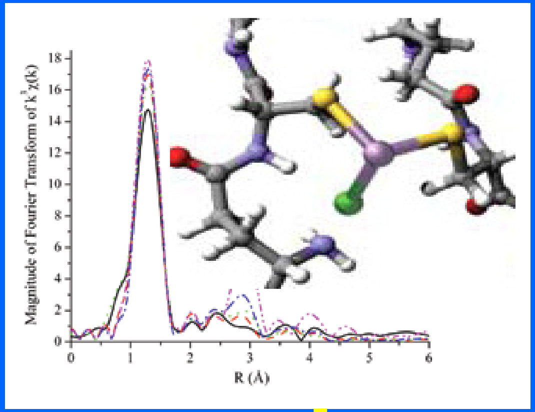
SEM



STEM



XAS



0.1 mm

Micrometres

Nanometres

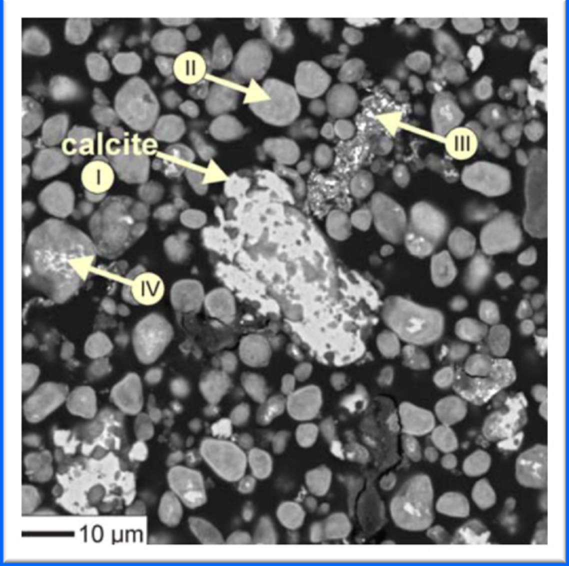
Atomic

Increasing Resolution

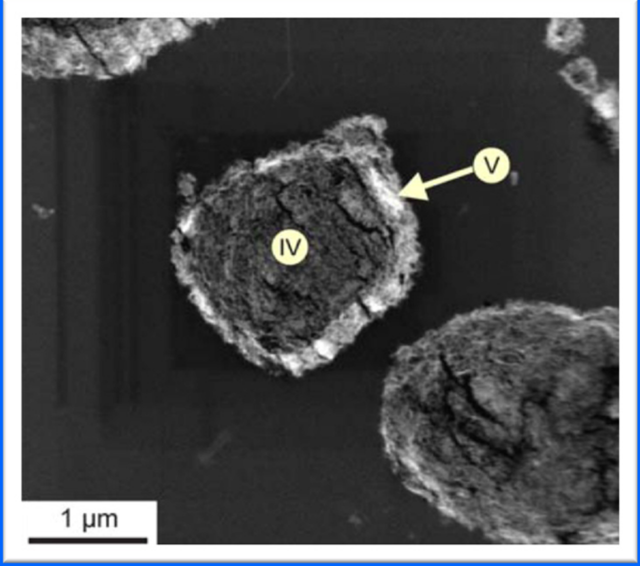
Comparative Methodologies

Methodology	Minerals and Phases Identified	Dominant Trace Element	Other
PHREEQC	Gypsum, fluorite, calcite, quartz, barite	-	-
Optical Microscopy	None	-	-
XRD	Mg-Calcite	-	-
SEM	Mg-Al-Si oxyhydroxide or hydroxycarbonate phase	Cu, Zn	S, Mn, Ca?, Fe?
STEM	Cu-oxyhydroxide	Zn, Mg, Al, Si	Ca, S, Cl, Mn and Fe
	Calcite	Cu	Zn

SEM



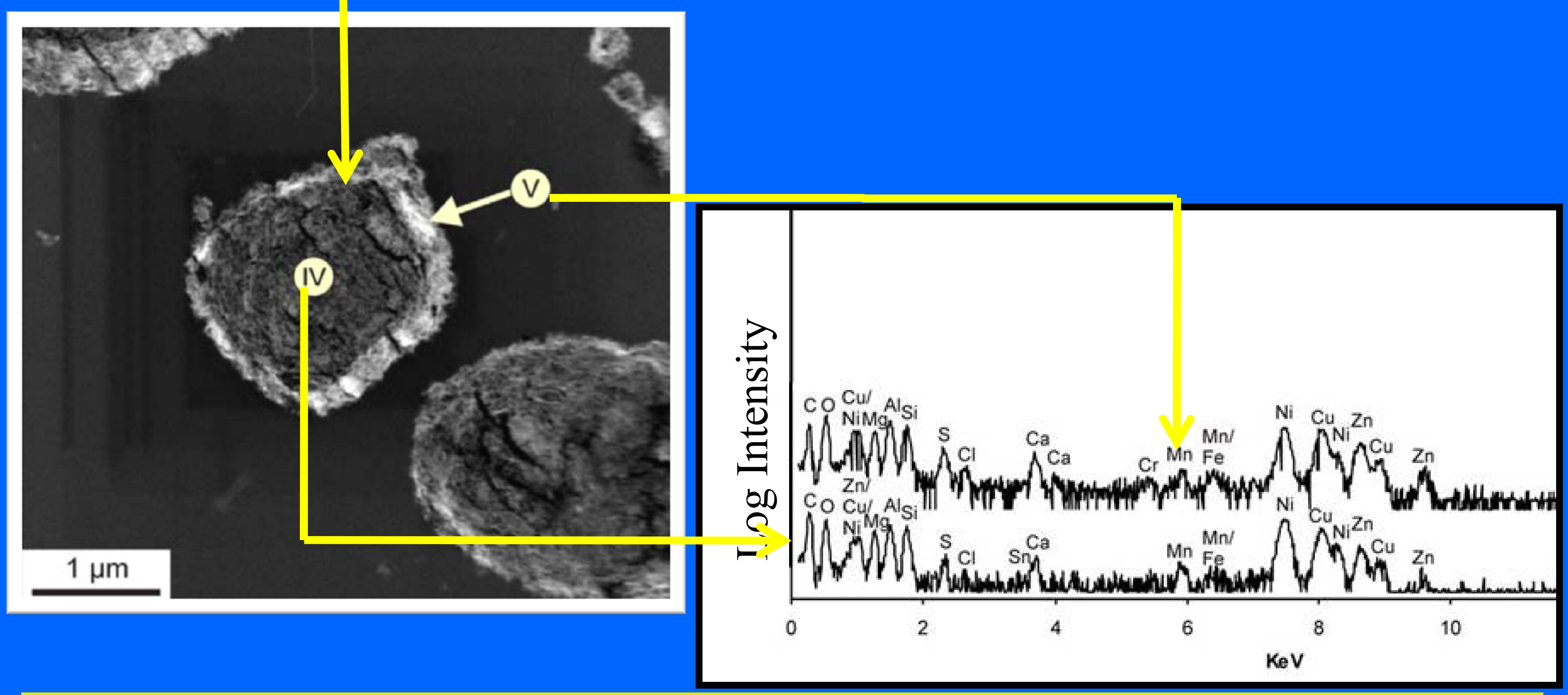
(S)TEM



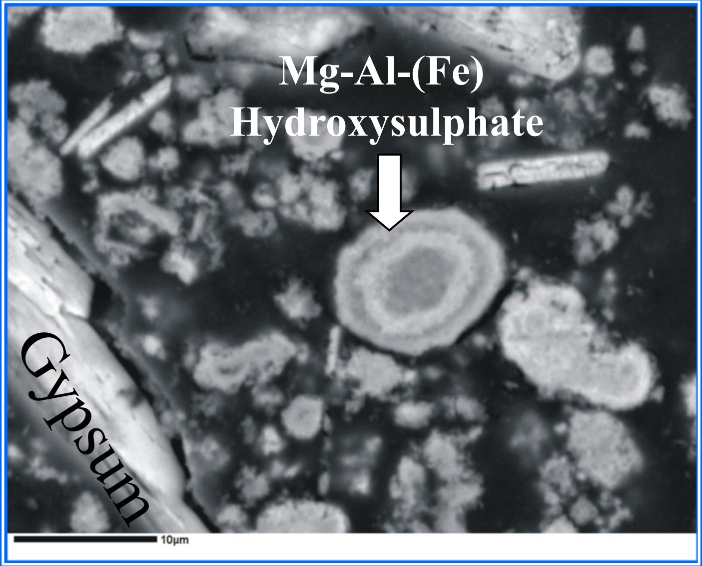
BRITANNIA HDS– Cu-Oxyhydroxide

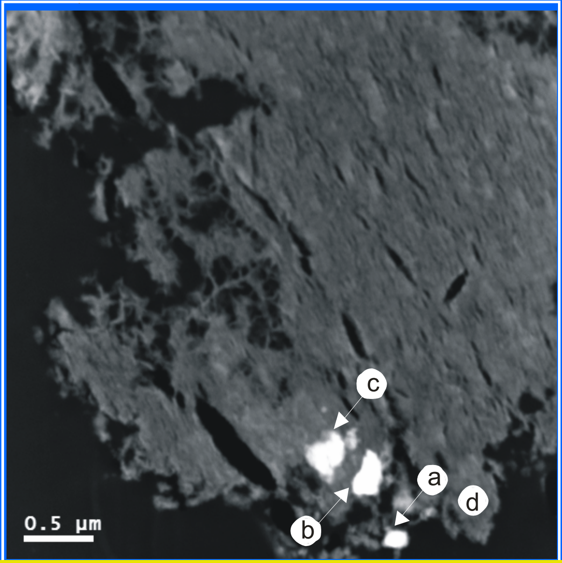
Zn and Mg-rich Cu-Oxyhydroxide

- Fibrous grains display compositional zoning
- SAED pattern consistent with amorphous or nanocrystalline material



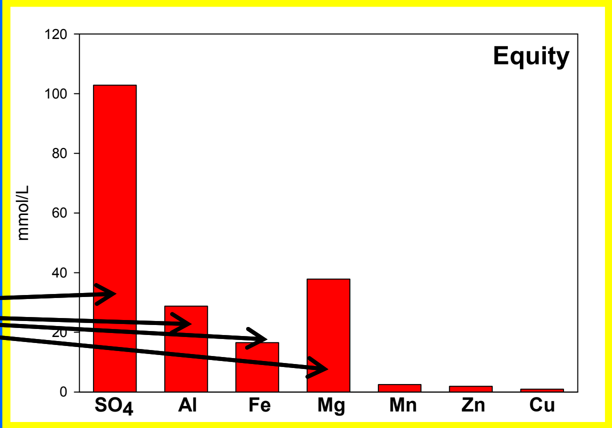
EQUITY HDS: Mg-Al-(Fe) hydroxysulphate



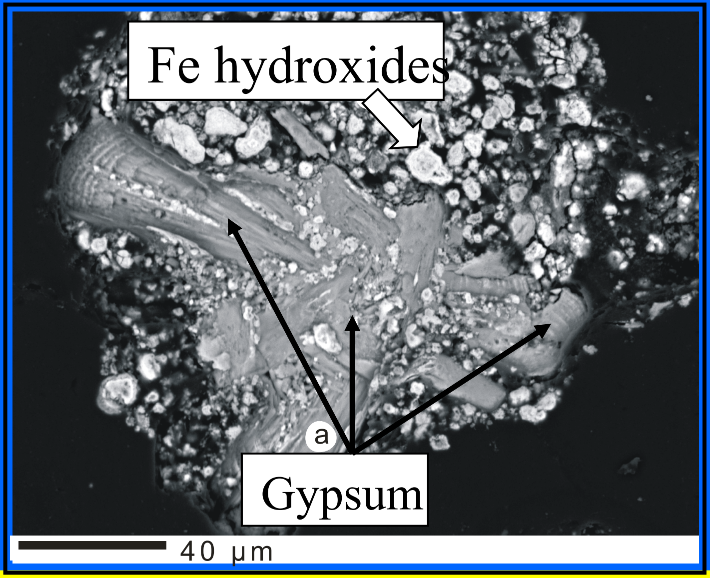


- Concentric layers alternating between Mg+Al-rich (Fe-poor) and Fe-rich; consistent with dissolution and re-precipitation reactions predicted to occur during sludge recycling in HDS process
- Zn is more strongly correlated with Mg/Al than Fe;
- SAED pattern suggests that this phase is amorphous.

Consistent with high sulphate, Al, Fe, and Mg in ARD influent water

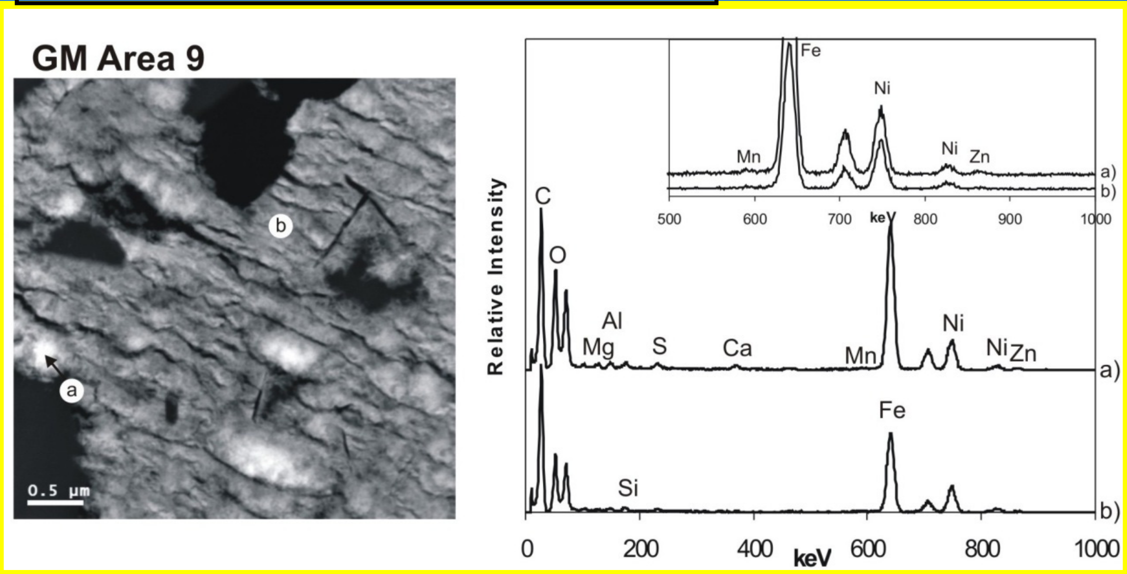


GECO HDS: Fe-Oxyhydroxide

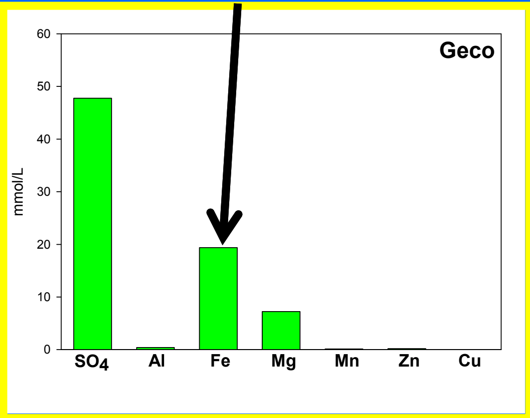


- Selected area electron diffraction (SAED) indicates the presence of broad diffuse rings, suggestive of poorly crystalline to amorphous Fe oxides.

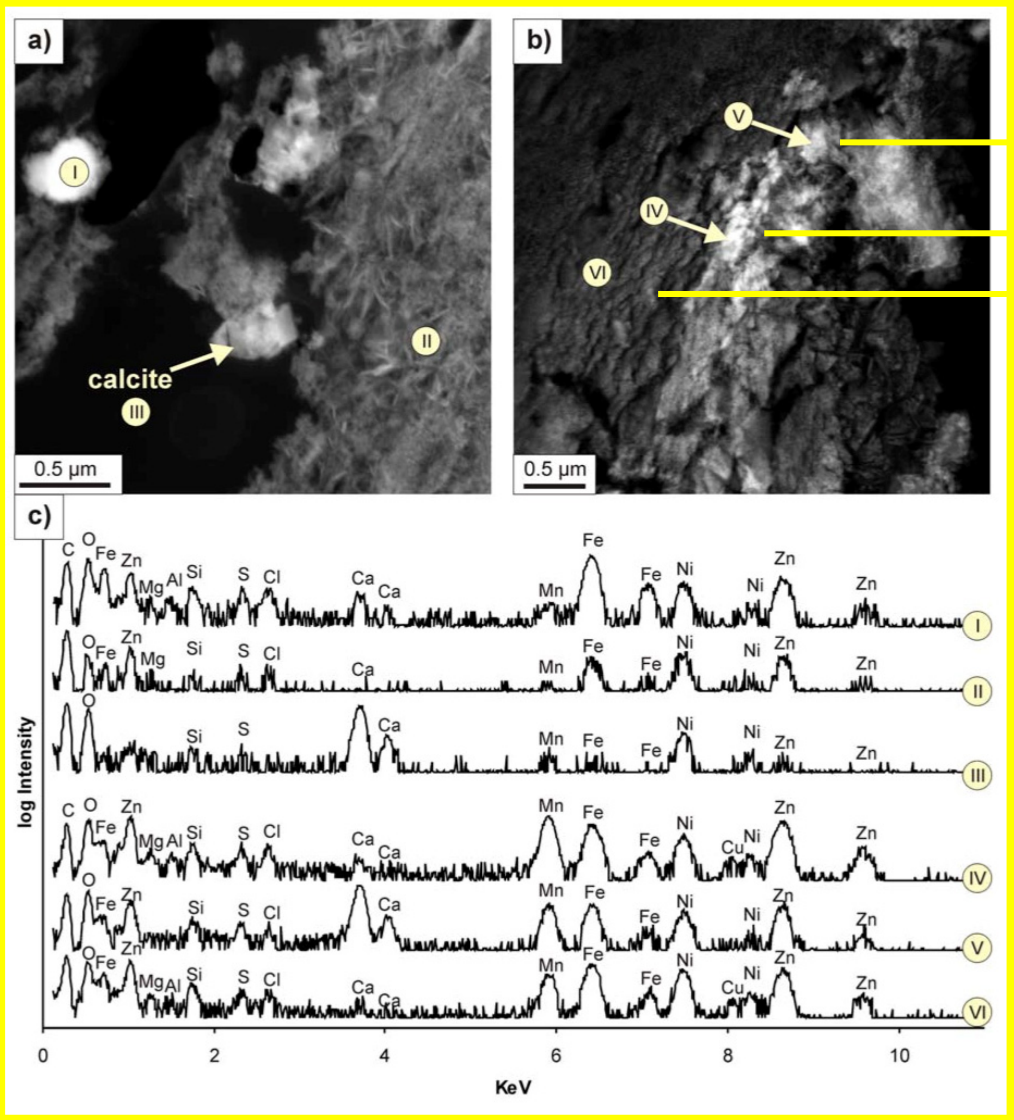
Relatively pure Zn-bearing Fe-hydroxide



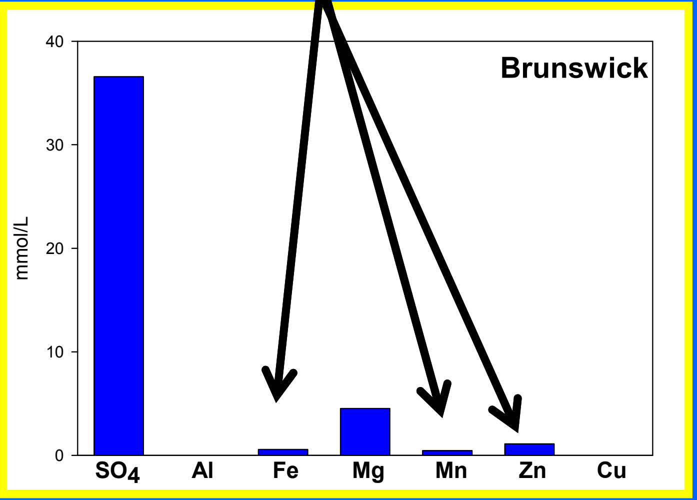
Consistent with high Fe and low Al in ARD influent water



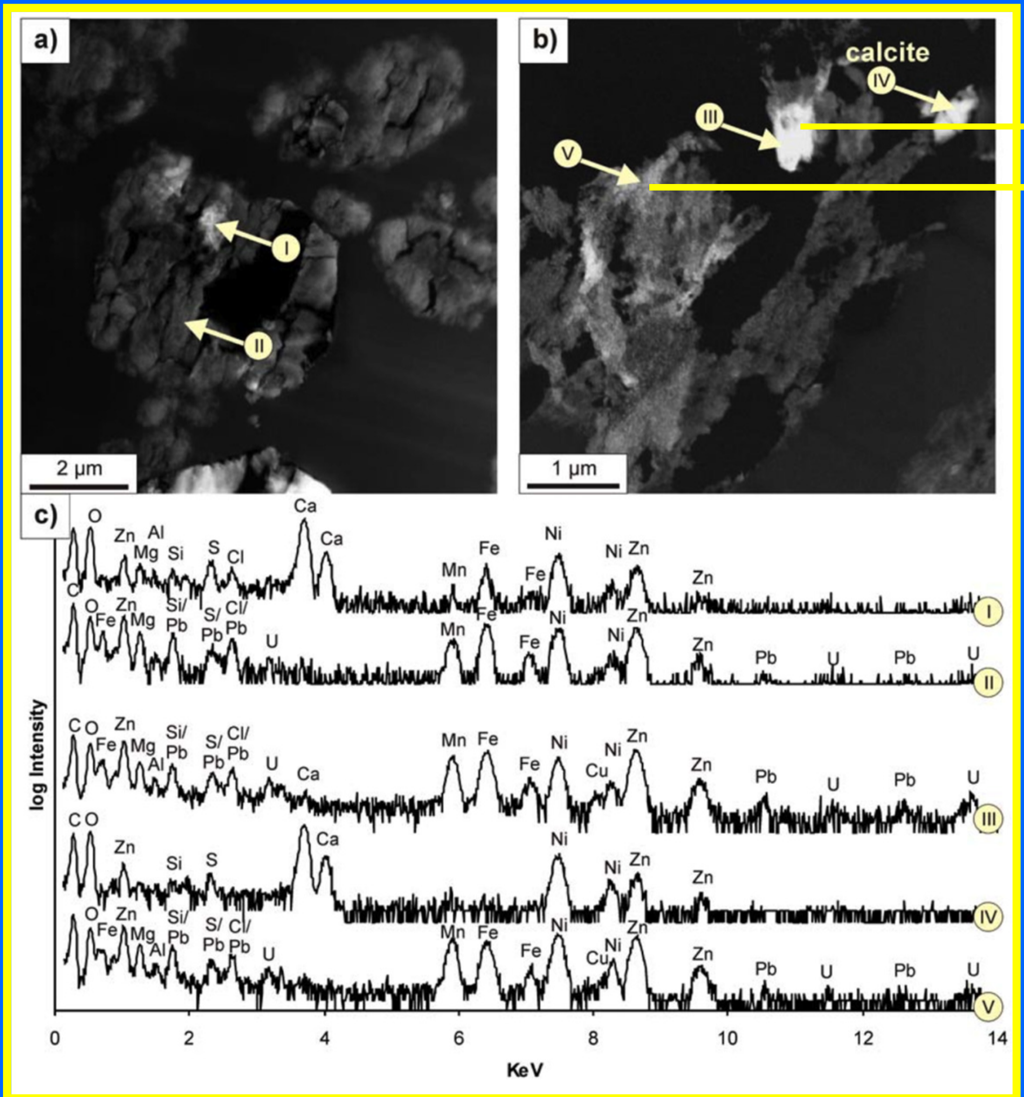
BRUNSWICK HDS: Zn-Fe-Mn Oxyhydroxide



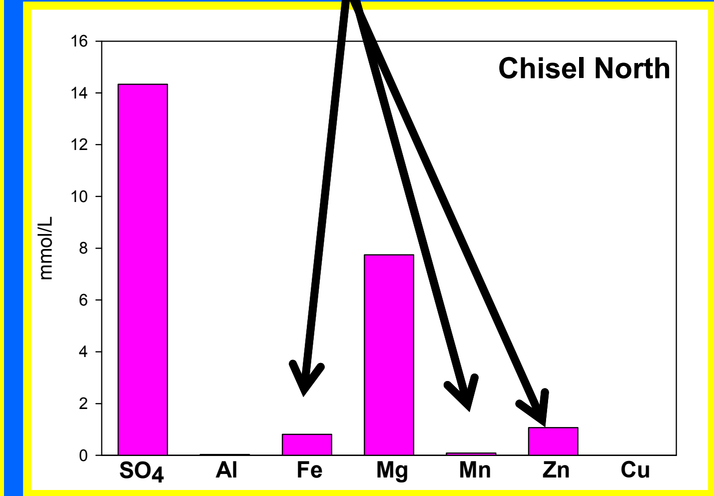
Consistent with relatively high Zn, Fe, Mn in ARD influent water, Mg<200mg/L



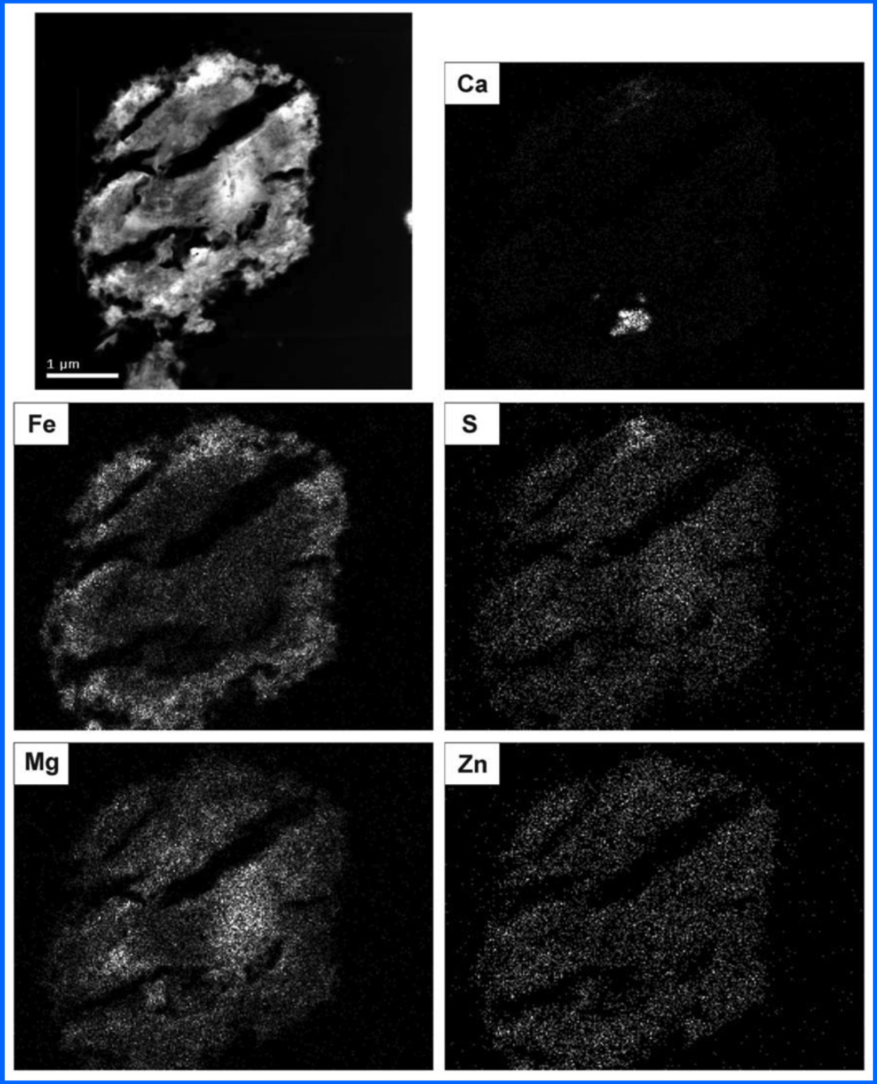
CHISEL NORTH HDS: Zn-Fe-Mn Oxyhydroxide

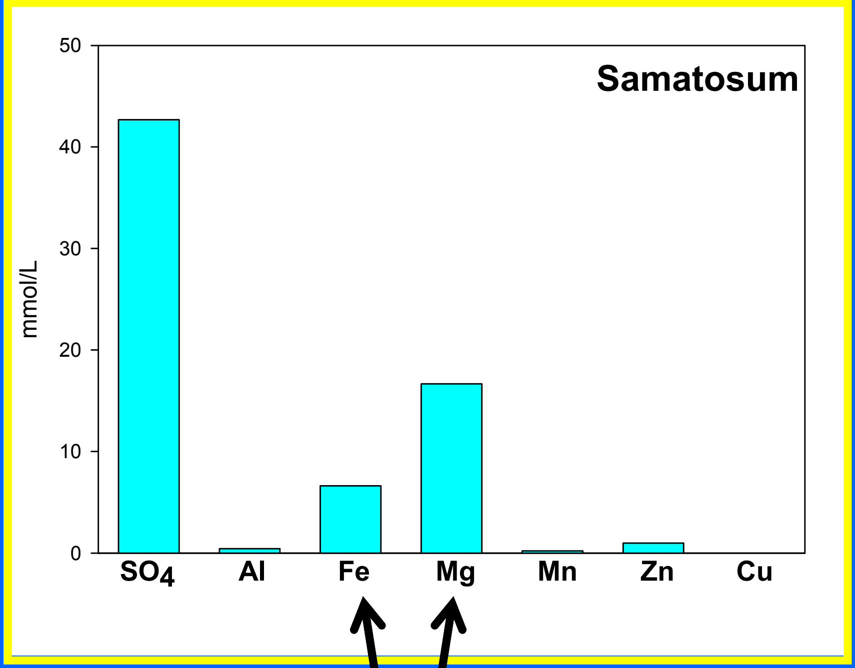


Consistent with relatively high Zn, Fe, Mn in ARD influent water, Mg<200 mg/L



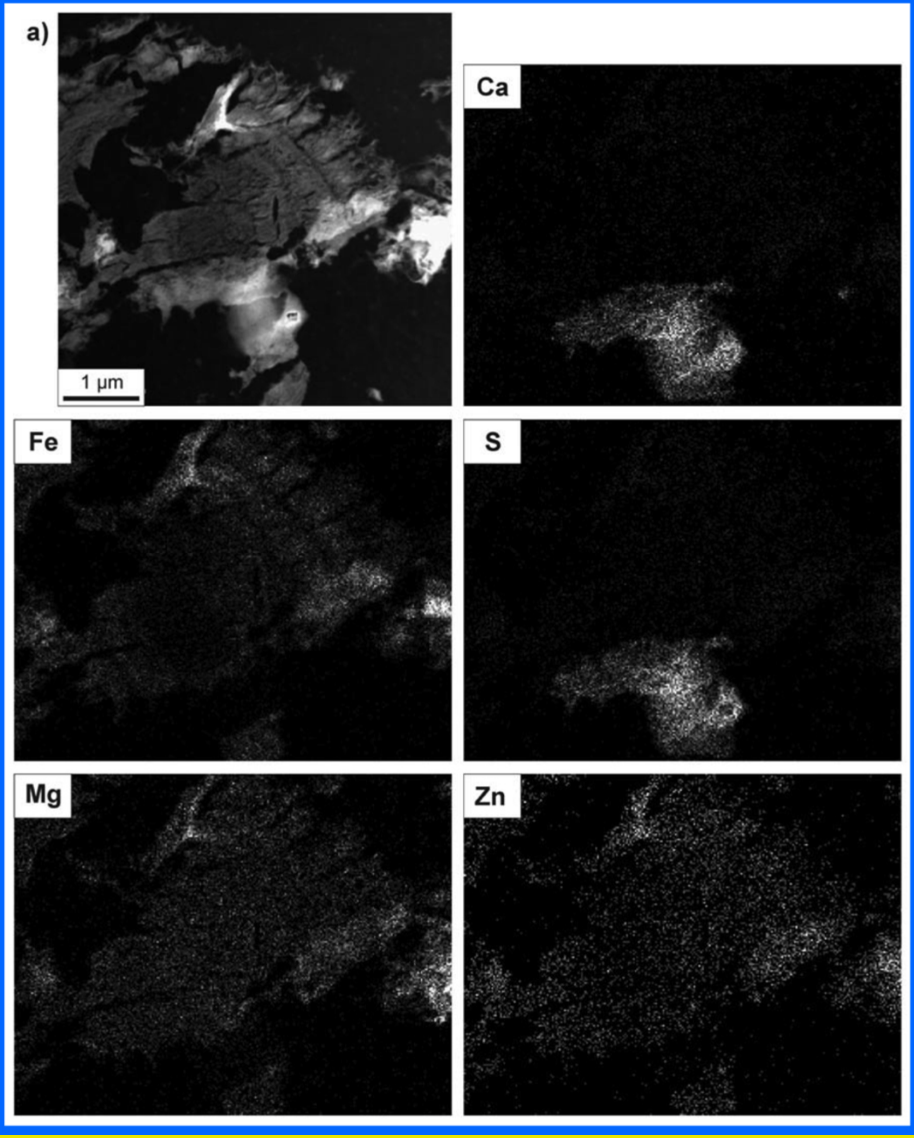
SAMATOSUM HDS: Fe-Mg Oxyhydroxide

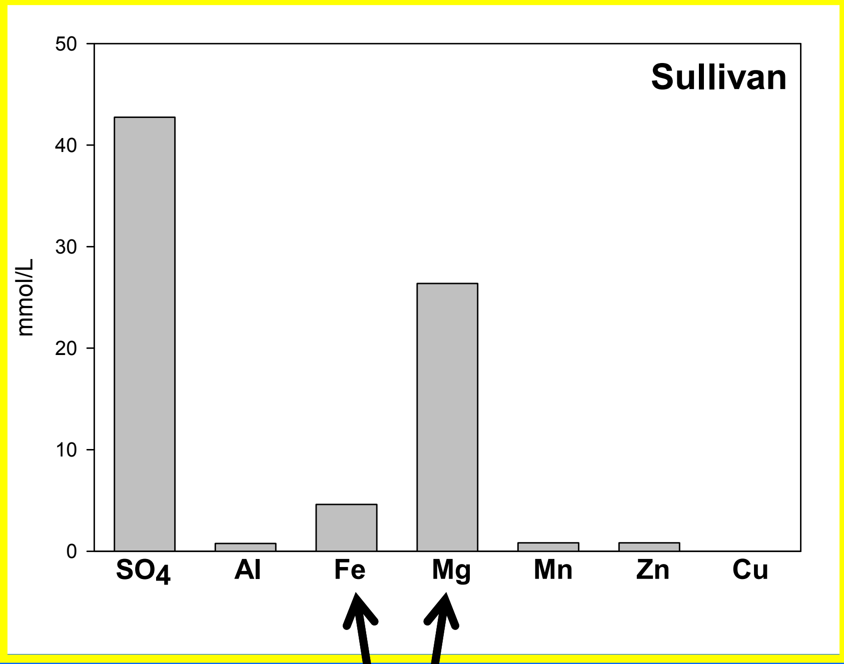




Consistent with relatively high Fe and Mg in ARD influent water

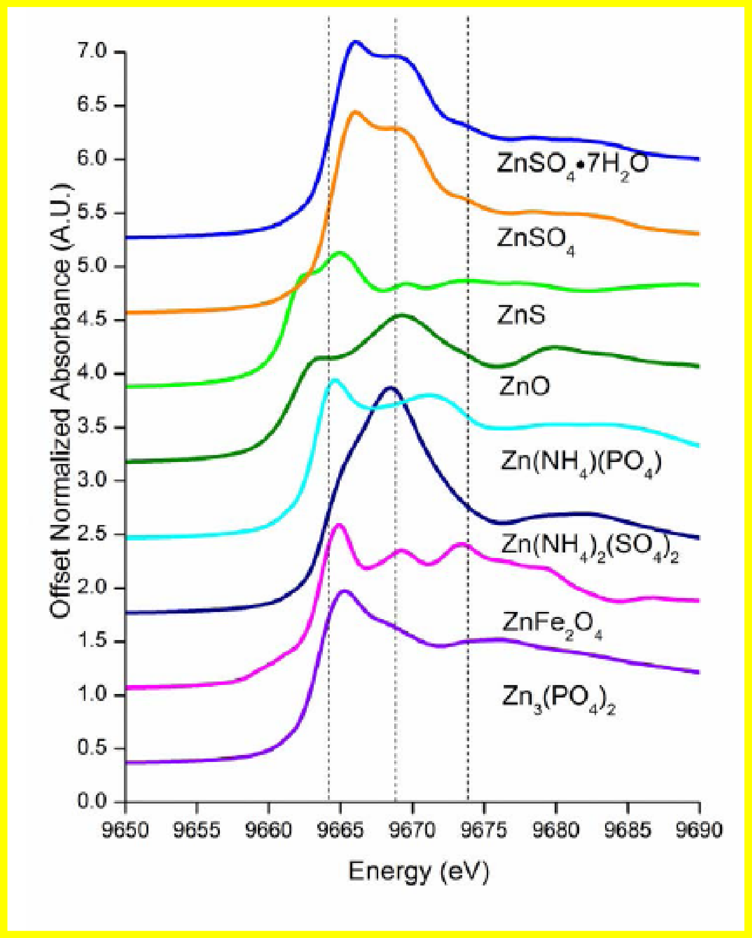
SULLIVAN HDS: Fe-Mg Oxyhydroxide



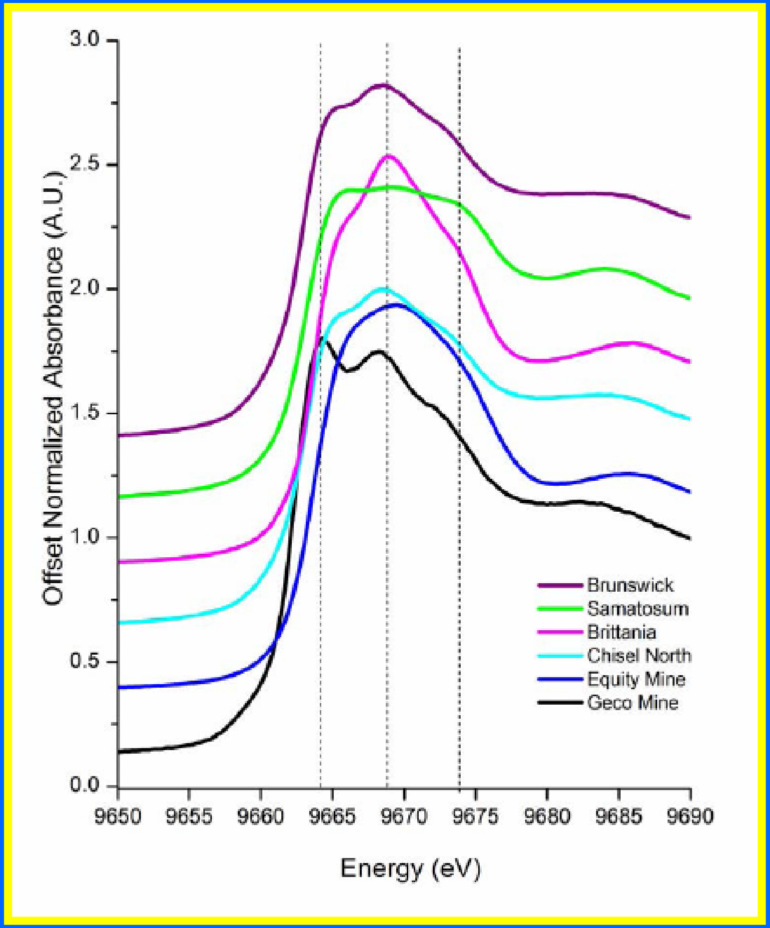


Consistent with relatively high Fe and Mg in ARD influent water

XAS



Model Compounds

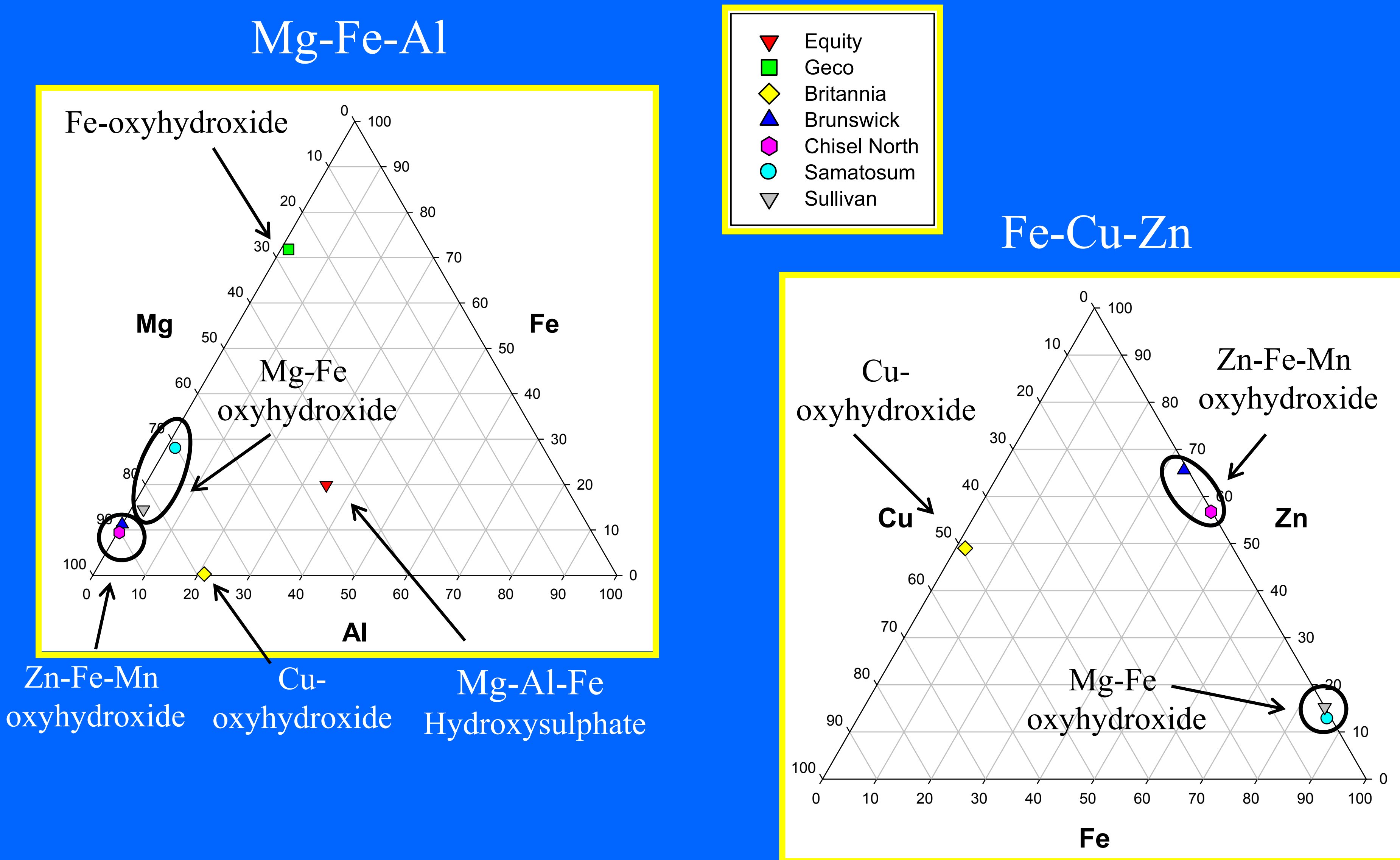


Sludge Samples

Summary

	Equity	Geco	Britannia	Brunswick	Chisel North	Samatosum	Sullivan
Dominant Solid-phase elements	Ca, S, Fe, Al, Mg	Fe, Ca, S	Ca, Al, Mg	Ca, Fe	Ca, Fe, Mg	Ca, Fe, Mg, S	Fe, Ca, Mg
Dominant elements in Influent	SO_4^{2-}, Al, Mg, Fe	SO_4^{2-}, Fe, Mg	SO_4^{2-}, Mg, Zn, Cu	SO_4^{2-}, Mg, Zn	SO_4^{2-}, Mg, Zn	SO_4^{2-}, Mg, Fe	SO_4^{2-}, Mg, Fe
Zn-hosting phase	Mg-Al-(Fe) hydroxysulphate	Fe-hydroxide	Cu-hydroxide	Zn-Fe-Mn hydroxide	Zn-Fe-Mn hydroxide	Fe-Mg hydroxide	Fe-Mg hydroxide

Predicting “Sludge Type”



SUMMARY

- In all sludges, metal-bearing phases were amorphous (or poorly crystalline) and variable in composition (relatively pure to heterogeneous).

- Metal-bearing phases largely governed by composition of ARD. Proportions of Fe, Mg, Al and S important. Textures and concentric zoning reflective of HDS process.

- Varied spectrum in metal-bearing phases observed, including:
  - Mg-Al-(Fe) hydroxysulphate;
  - Fe hydroxide;
  - Cu-Zn hydroxide;
  - Zn-Fe-Mn hydroxide;
  - Fe-Mg hydroxide

- Different metal-hosting phases can be expected to show contrasting chemical stabilities with respect to pH and Eh conditions. Results highlight need to understand controls governing long-term chemical stability of various sludge phases.

Predictive Tool

ARD Chemistry

↓

"Sludge type"
(metal-bearing phases)

↓

In situ chemical stability, depending on depositional environment

} Further investigation required

Thank you

Questions?