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Minerals and
Metals Sector

Secteur des minéraux
et des métaux

Metal Mobility under A Water Cover - Observations from Laboratory Studies

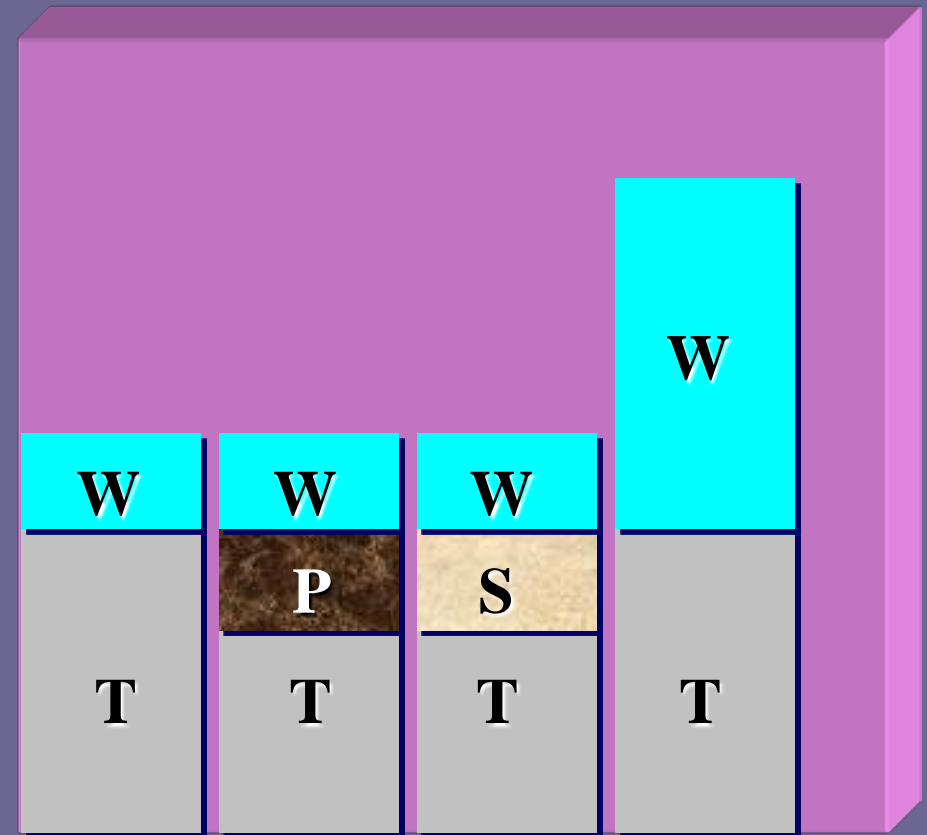
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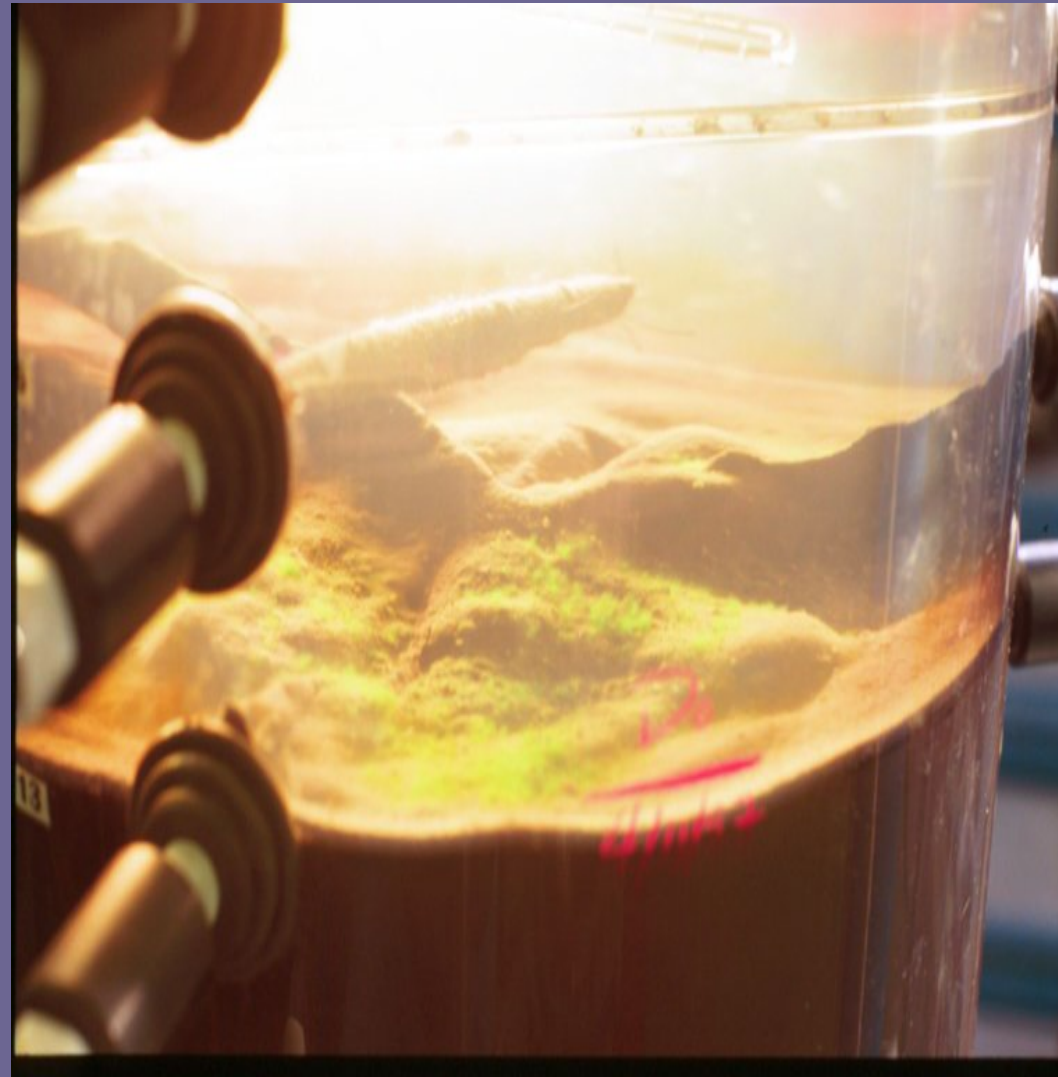
Scope of Presentation

- Provide an overview of metal mobility under water with reference to three laboratory studies:
 - Louvicourt column study of four disposal scenarios
 - Lysimeter testing of massive sulfide tailings from two Newfoundland sites
 - Investigation of galvanic effects under a shallow water cover
- Comment on relevance of laboratory observations to field applications

Louvicourt Column Study: Scenarios

- 0.3 m water over tailings
- 0.3 m intermediate peat layer over tailings under a 0.3 m water cover
- 0.3 m intermediate sand layer over the tailings under a 0.3 m water
- 1.0 m water over tailings
- All scenarios run in triplicate





Two Study Phases for Each Scenario

- Phase I, Mixed Water Cover
 - 100 days water circulated without aeration
 - 100 days water circulated and aerated
- Phase II, Mixed Water Cover with Runoff and Drawdown
 - duration: 343 days
 - removal of 70 mL/day to simulate a drawdown of 0.36 m/yr
 - precipitation event simulated by adding 4L every 9 weeks; overflow collected after 24-36 hr residence time

Quality of Overlying Water

Phase I

Phase II

0.3 m

pH ~7
[SO₄, Ca, Mg, Zn]
[Cu]↓

pH ~5
[SO₄, Ca, Cu, Mg, Mn, Zn]

Peat

pH ~4
Efflux of Al, Mn±Zn
[Cu]↓

pH ~ 6.5 - 7
reduced efflux of Al, Mn±Zn
[Cu]↓

Sand

pH ≤ 6
[Al, Cu, Zn]
Efflux of Mn

pH 6.8 → 7.6
[Al, Cu]↓

1.0 m

pH ≥ 7
[Cu]↓
Efflux of Zn

pH 7 → 8
[Cu]↓
Efflux of Zn__

Comparison of Loadings in Phases I and II

	<u>Units</u>	<u>0.3 m</u>	<u>peat</u>	<u>sand</u>	<u>1.0 m</u>
Phase I					
SO ₄ - Day 100	g	4.85	0.76	0.97	4.57
SO ₄ - Day 200	g	8.86	0.78	1.40	7.51
Zn - Day 100	mg	2.33	1.80	4.73	0.00
Zn - Day 200	mg	7.13	0.71	7.86	2.26
Ca - Day 200	g	1.83	0.05	0.31	2.07
Cu - Day 200	mg	-0.35	-0.32	3.12	-0.57
Mn - Day 200	mg	0.00	1.76	6.23	0.00
Phase II					
SO ₄ - Day 217	g	3.49	0.08	0.13	1.16
Zn - Day 217	mg	10.82	0.21	0.11	1.77
Ca - Day 217	g	0.64	-0.06	0.01	0.55
Cu - Day 217	mg	0.34	-0.34	-0.41	-0.50
Mn - Day 217	mg	28.3	0.39	-0.03	-0.03

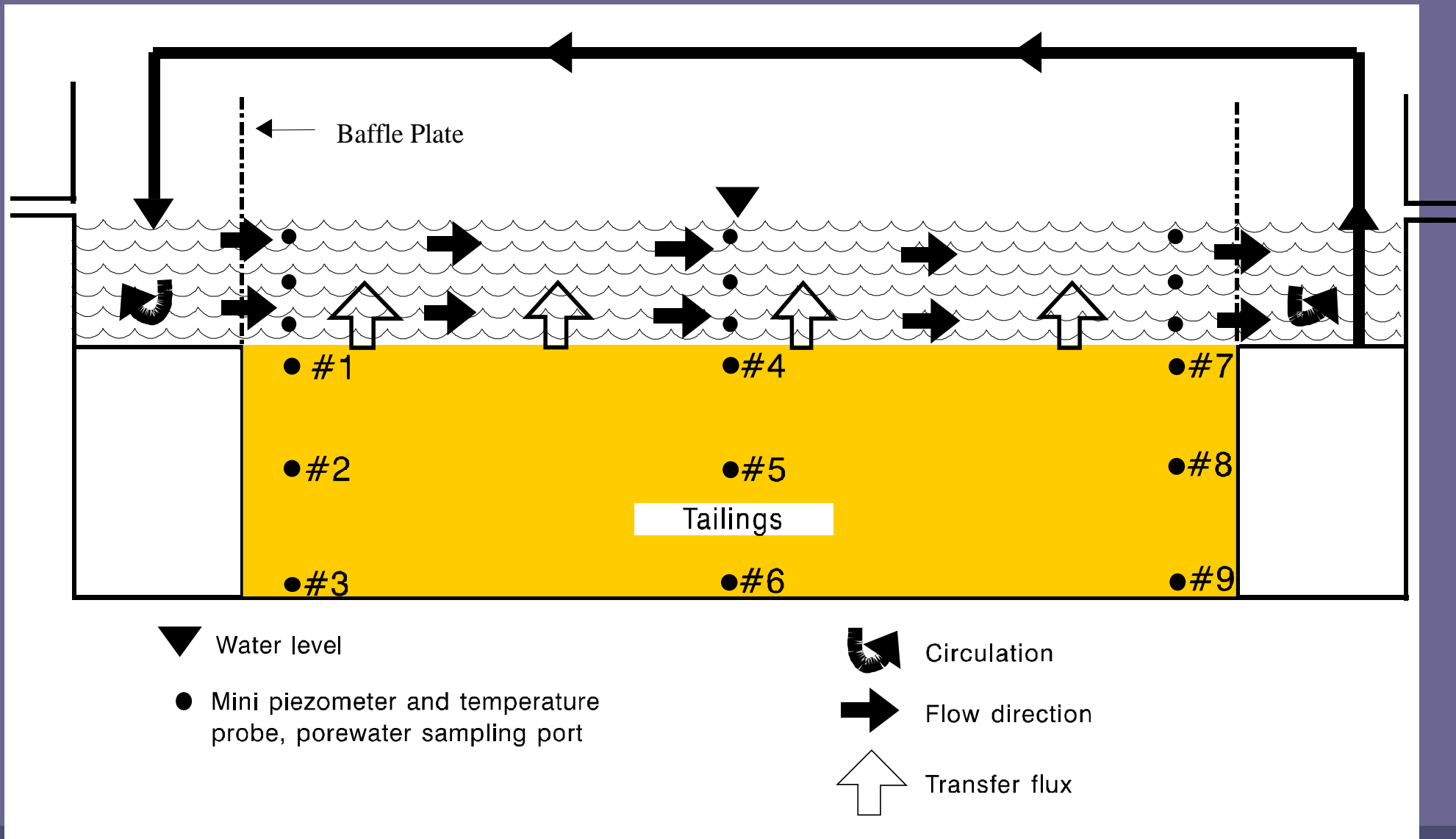
Observations - Louvicourt Study

- Both sulfide oxidation and sulfate dissolution contributed to increasing sulfate concentrations in the water covers directly over tailings
- Hydrolysis of dissolved Fe and Mn could be responsible for acidification near the water-solids interface in the peat and sand columns during Phase I
- Precipitation of oxyhydroxides at the water-solids interface and drawdown limited the efflux of undesirable metals to the overlying water column

Louvicourt Column Study - Conclusions

- The 0.3 m water cover directly on tailings seems to be least effective in arresting sulfide oxidation and metal leaching
- The alkalinity balance and drawdown rate critically control the long-term performance of a deeper water cover. If the replenishing water contains little alkalinity, a 1.0 m water cover may not be more effective than a 0.3 m cover
- After the initial flushing of stored weathering products, both peat and sand can provide an effective diffusion layer to suppress chemical weathering of the underlying tailings in the long run

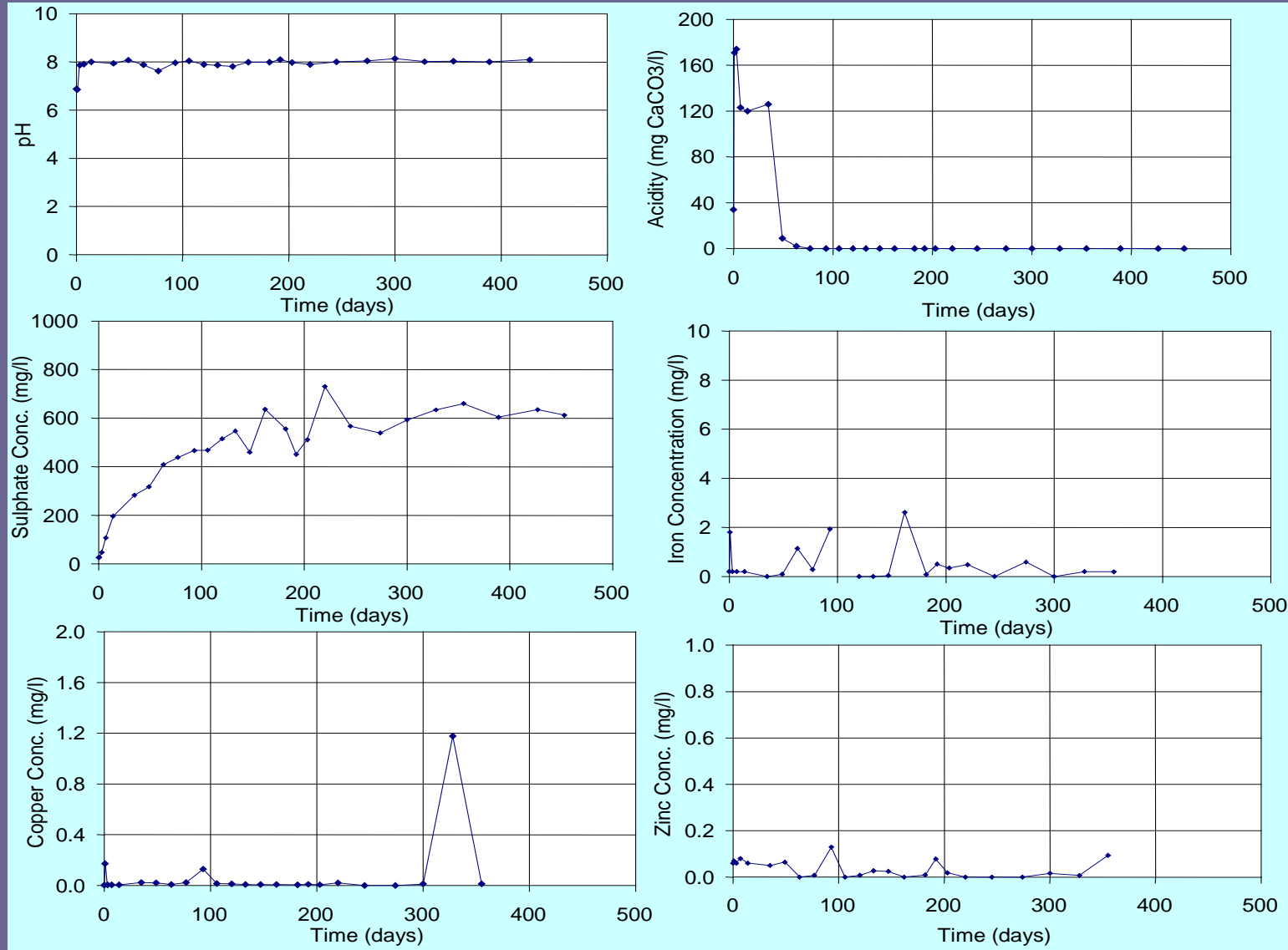
Lysimeter Setup for Newfoundland Tailings



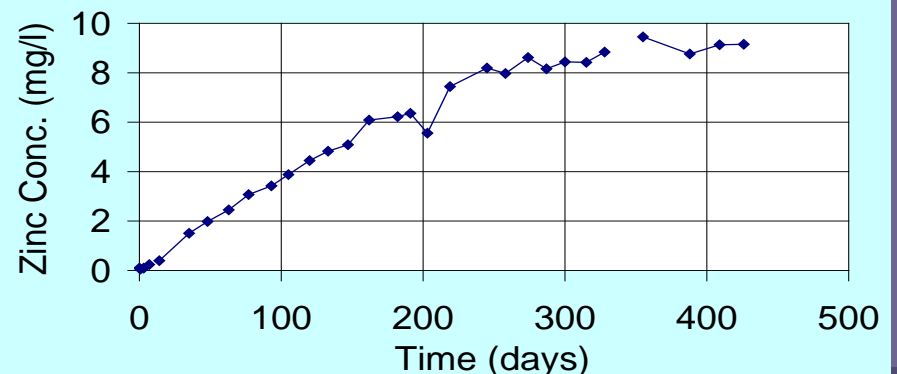
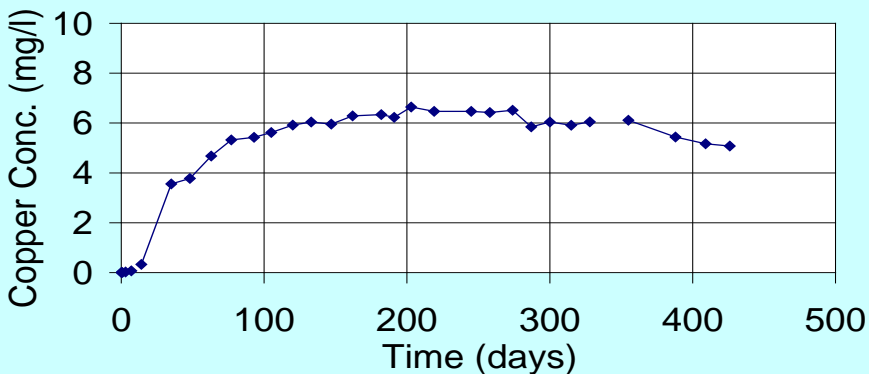
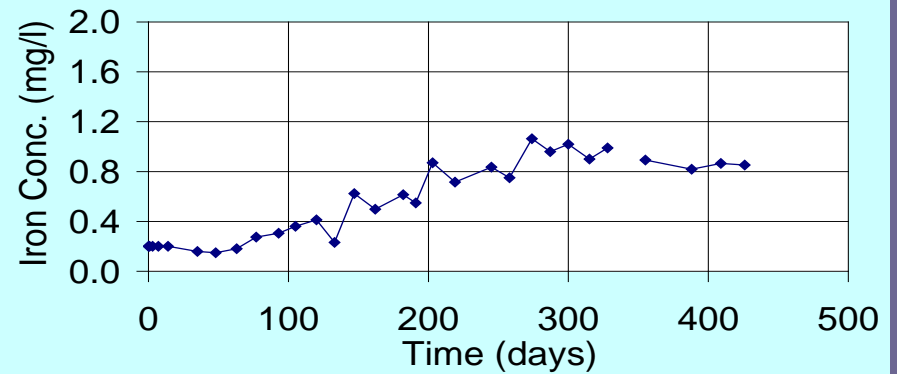
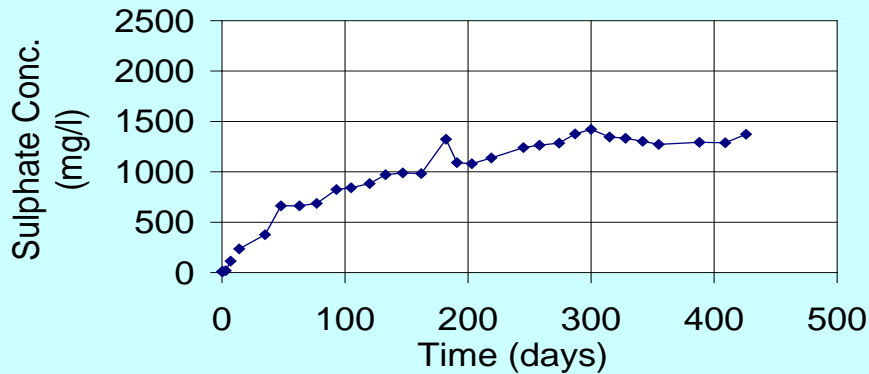
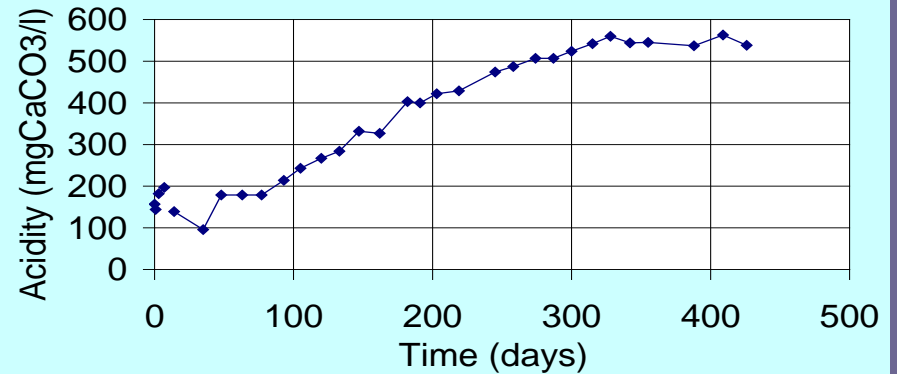
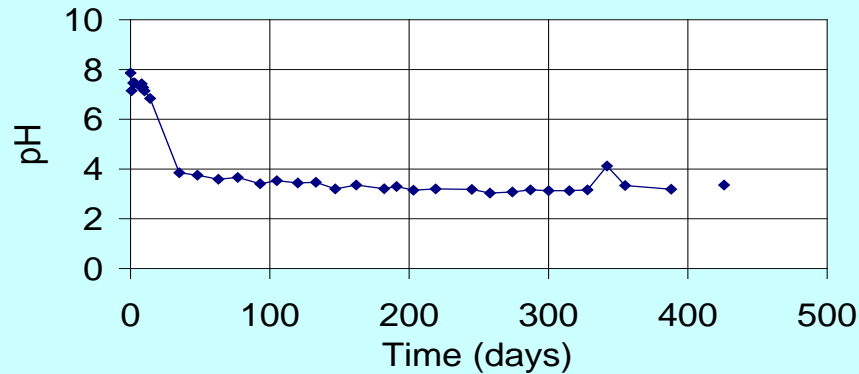
Comparison of Two Massive Sulfide Tailings from Newfoundland

	Little Bay	Tilt Cove
%Al	6.1	5.6
% C	0.17	0.12
% Ca	1.9	1.3
% Cu	0.04	0.4
% Fe	13.8	30.1
% Mg	3.7	3.2
% S (tot)	1.73	18.7
% SO ₄	0.31	3.18
% Si	23.5	8.16
% Zn	0.01	0.39
Pyrite morphology	granular	framboidal to very fine-grained

Little Bay Tailings - Non Reactive



Tilt cove Tailings - Reactive



Observations from Lysimeter Testing of Massive Sulfide Tailings

- Sulfide morphology is often more important than chemistry in acid generation and metal leaching
- Secondary iron sulfates represent a temporary storage of acidity
- Subaqueous disposal is generally effective in suppressing sulfide oxidation; however, alkalinity balance determines if net acid generation occurs

Electrochemical Series of Common Sulfides

Assorted Literature

Sato (1992)

Mineral (rest potential)

Pyrite (0.63)

Chalcopyrite (0.52)

Chalcocite (0.44)

Covellite (0.42)

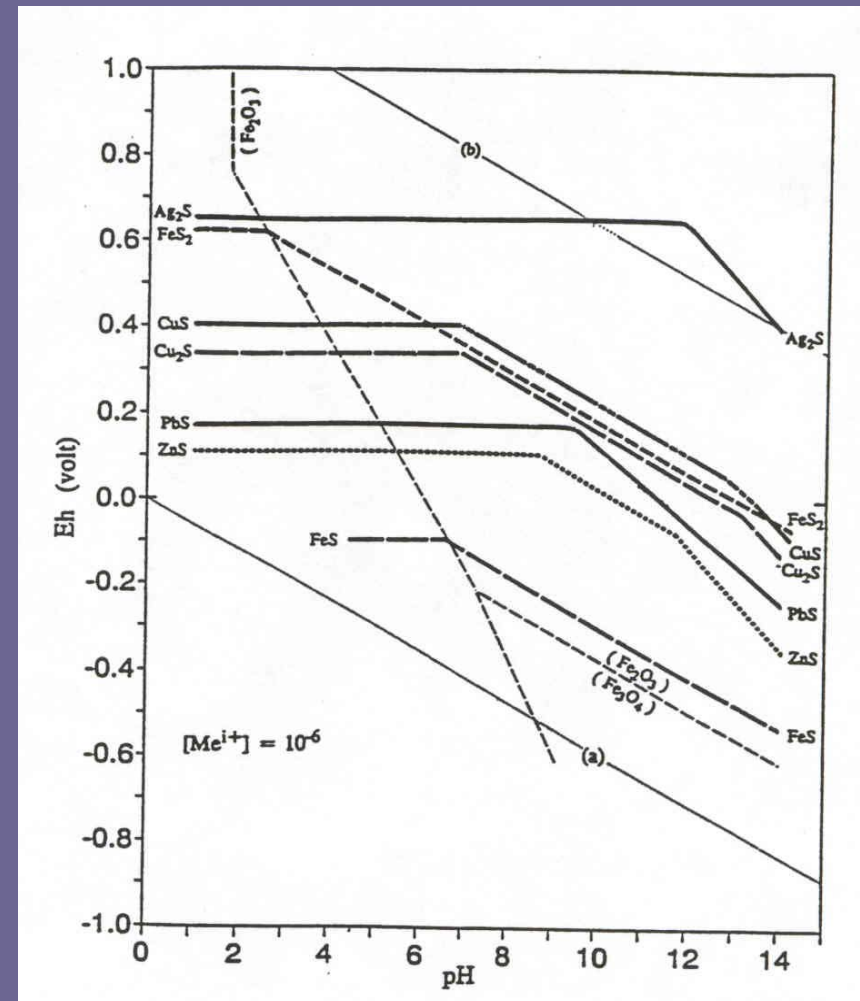
Molybdenite (?)

Galena (0.28)

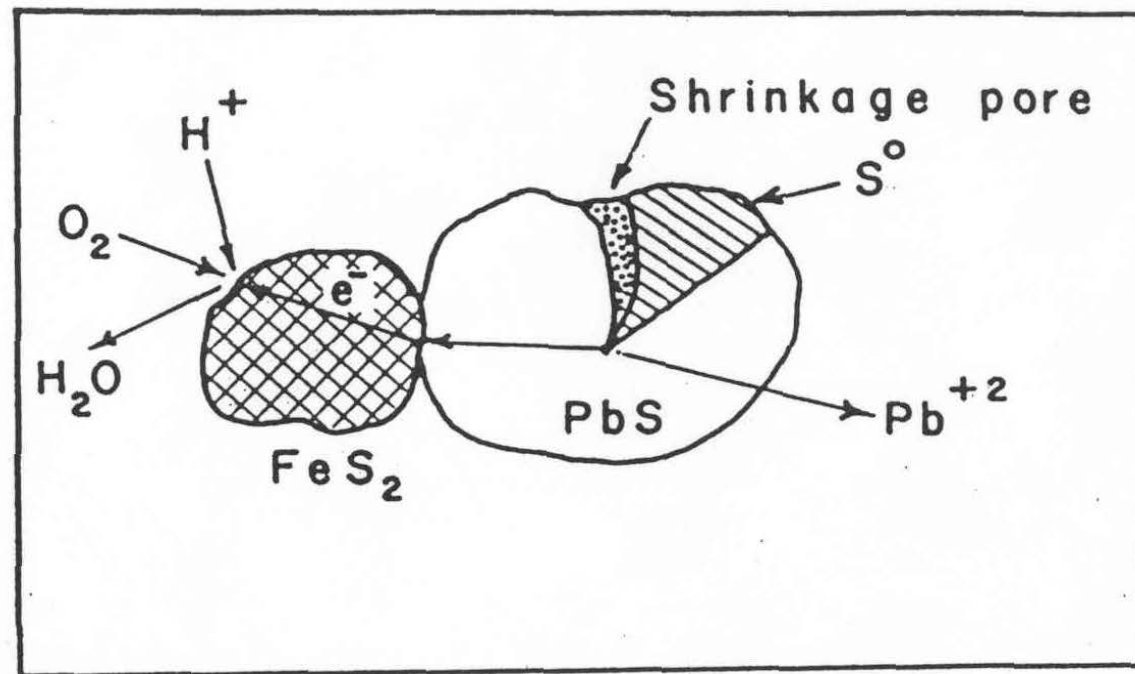
Sphalerite (-0.24)

Pyrrhotite (-0.28)

Arsenides(?), Antimonides(?)



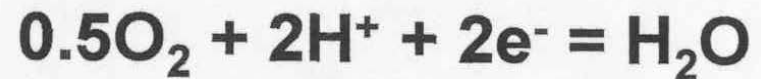
Galvanic Interaction between Pyrite and Galena



Anodic reaction:

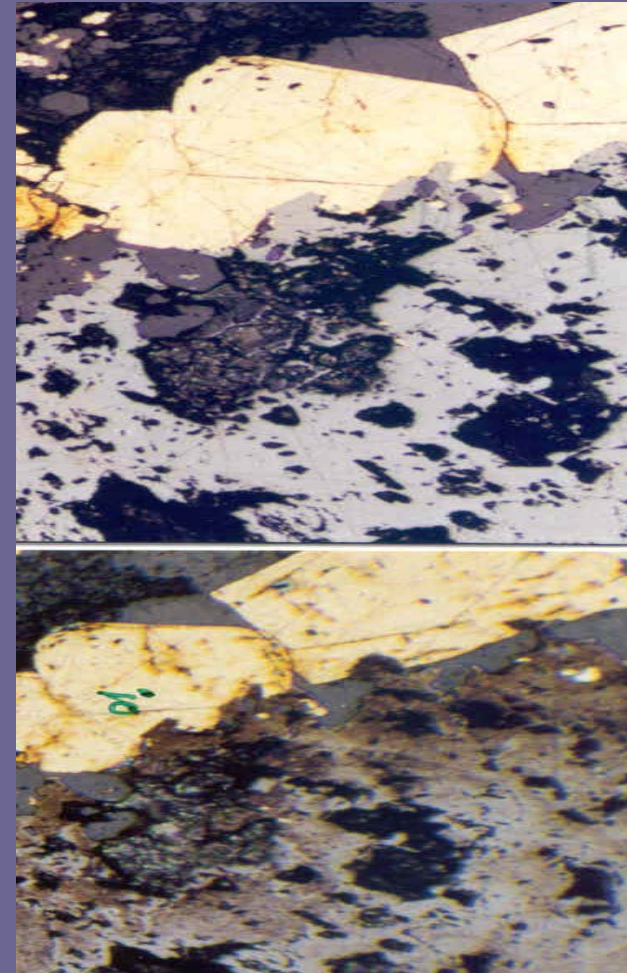
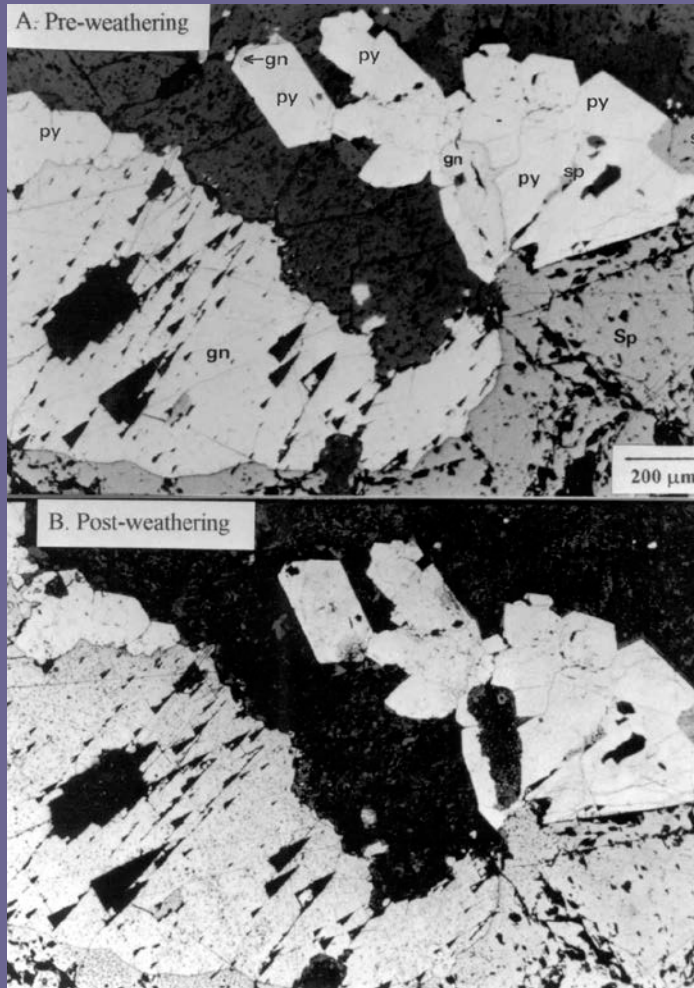


Cathodic reaction:

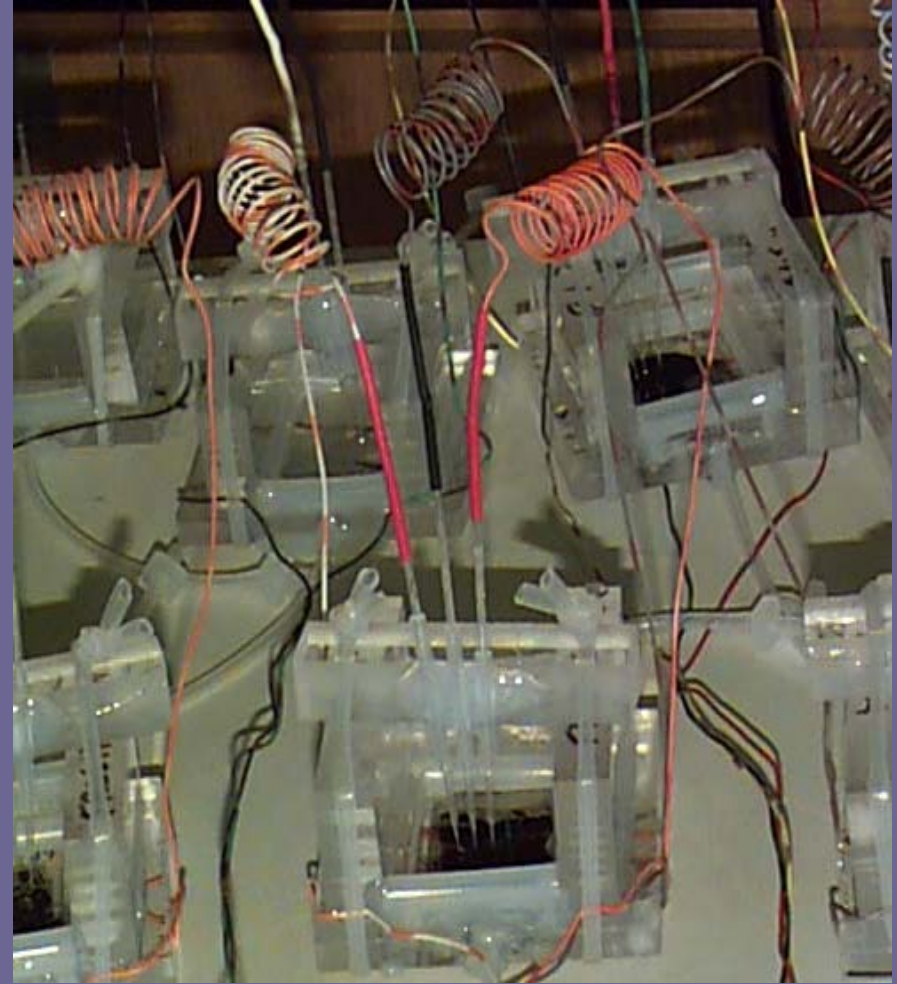
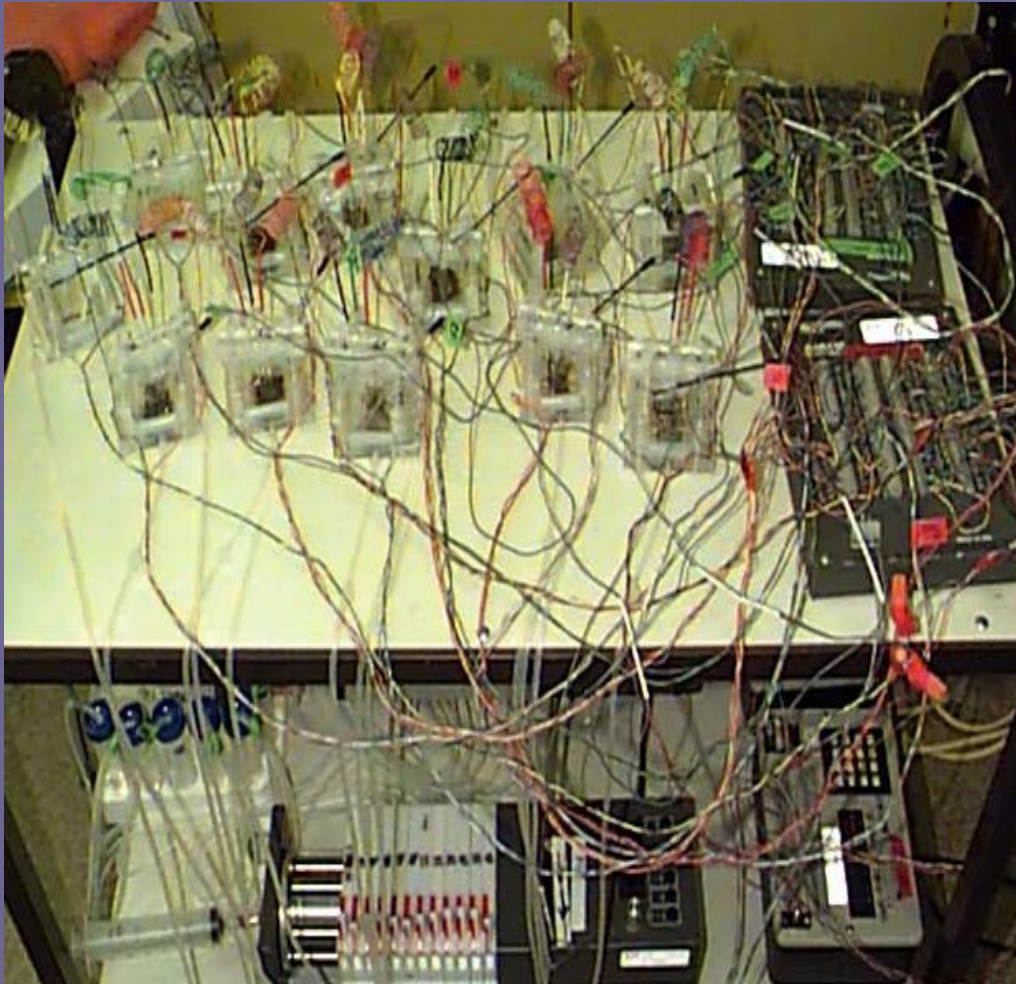


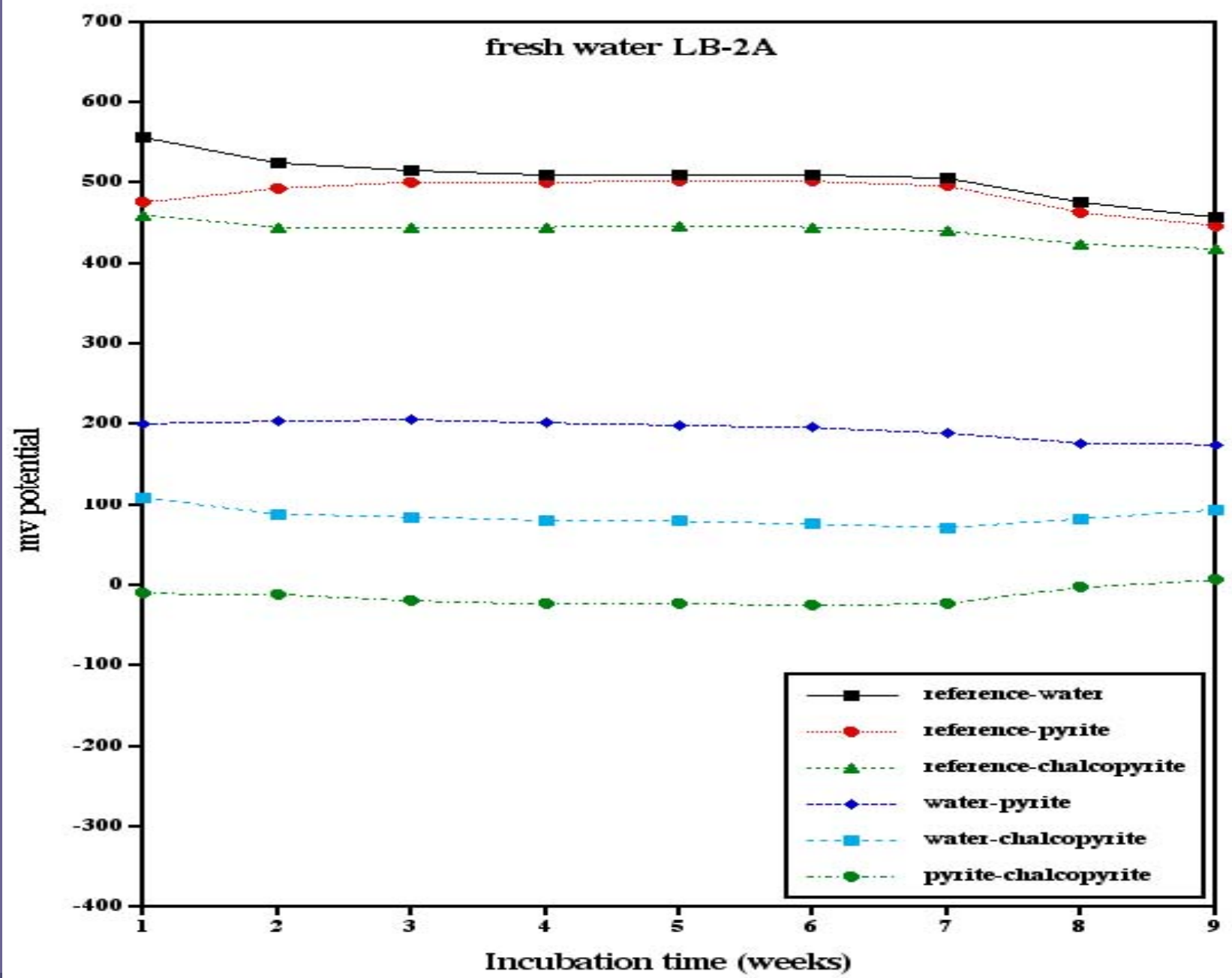
(i.e. Pyrite acts as inert electrode discharging oxygen adsorbed on its surface)

Rate of oxidative dissolution of an anode mineral depends on its area relative to the cathodic species



Study of Galvanic Effects under Water Experimental Setup





Galvanic Interaction - metal releases from a specimen with pyrite-sphalerite-galena

Cu $\mu\text{g/L}$	<0.5
Ni $\mu\text{g/L}$	0.09
Pb $\mu\text{g/L}$	62
Zn $\mu\text{g/L}$	29

*pH remained near neutral
throughout the experiment

When does galvanic sulfide oxidation become insignificant?

- In the absence of a strong electrolyte solution
- In the presence of a more effective oxygen scavenger than the sulfide galvanic couple
- Under highly reducing conditions such that sulfides become the stable phases

Conclusions

- Water covers represent a dynamic system
 - many reactions can occur especially at the water-solids interface to affect the water quality of both the water cover and the porewater in mine waste
 - alkalinity balance determines if net acid generation occurs
- Under favorable conditions, galvanic interaction may lead to metal mobilization even under a water cover