C.4. Pyrite Reactivity Study and Geochemical Stability of Paste Backfill

by
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Pyrite Reactivity Study
and
Geochemical Stability of Paste Backfill

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Pyrite Reactivity Study

Inconclusive ARD Predictions

- **ABA tests:**
  - **procedure dependent**
  - **NPR values in "uncertain" range**
- **Humidity cell tests:**
  - **ill-defined oxidation rates (gypsum)**
  - **rate changes with time**

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Objectives - Pyrite Study

- **Usefulness of Cyclic Voltamperometry**
  - **characterisation of pyrite reactivity**
  - **effect of leaching on reactivity**
  - **refinement of prediction data**

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Cyclic Voltamperometry (CV)

- **Electro-chemical Cell:**
  - **Pyrite-graphite "paste" anode**
  - **Graphite rod cathode**
  - **Hg/HgSO4 reference electrode**
- **Process:**
  - **Voltage applied to C-Py electrode**
  - **Average Py surface response**

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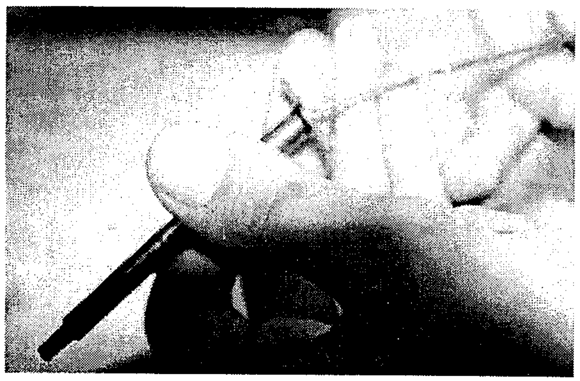
Pyrite-Graphite “paste” Electrode



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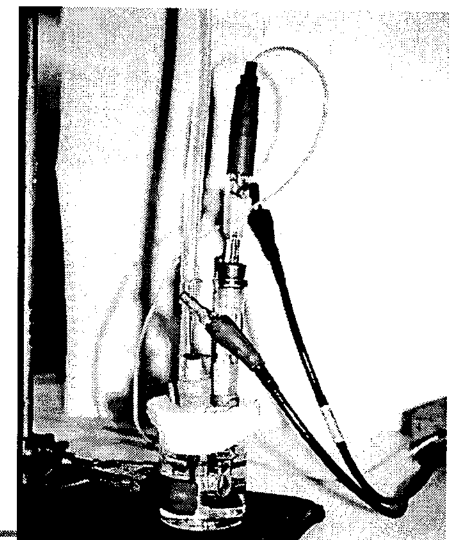
Cell Set up:



Methodology

- **Comparative study: 6 pyrite samples**
- **Pyrite Characterization:**
  - **leachate chemistry, stoichiometry, XRD, mineralogy, cv**
- **Leaching: 40 cycles, water pH 5.5**
- **Evolution of reactivity of pyrite surface**
  - **leachate chemistry, XRD, mineralogy, cv**

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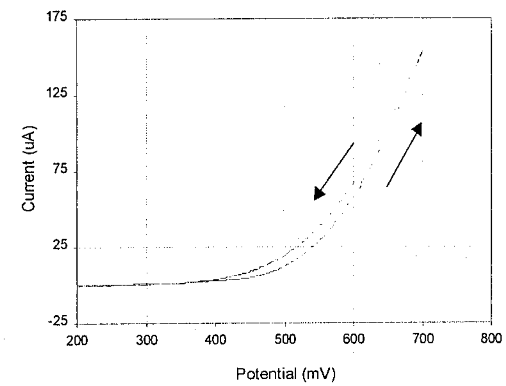
Typical CV Output



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Results: Effect of Mineral Inclusions

- Lowest impurities - Highest reactivity
  - Zn , Pb, Cu: 0.01% range
- Highest impurities - Lowest reactivity
  - Zn, Pb, Cu: 1-10% range

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Galvanic Effect of Sphalerite

- Initial relative "passivation" of pyrite
- High leachate Zn = ZnS oxidation
- Increased pyrite reactivity with time

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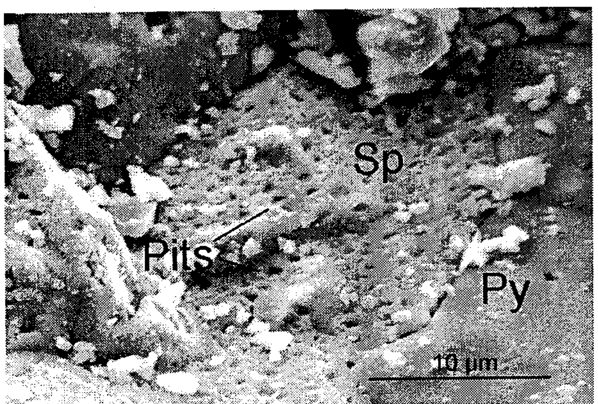
Preferential Oxidation of Sphalerite



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Secondary Precipitate Coatings

Overall decreased reactivity with time

- **"pure" pyrite sample:**
  - **early, continued passivation**
- **pyrite sample with sphalerite:**
  - **Passivation initiated after sphalerite oxidation**

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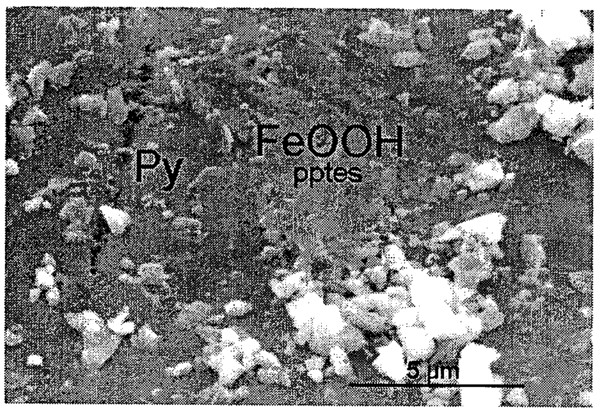
Secondary Precipitate Coatings



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Conclusion - Pyrite Reactivity

- Important Factors in py reactivity:
  - 1° Mineral Impurities (type, occurrence)
  - 2° Precipitate coatings
- Cyclic voltamperometry useful for reactivity characterization

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Use of Cyclic Voltamperometry

- **Identification of factors affecting reactivity of pyrite - or other S-minerals**
- **ARD Prediction**
  - **Field scale: megascopic influences on reactivity of waste, effluent quality**

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Geochemical Stability of Paste Backfill

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Cemented Paste Backfill

- **Waste management of reactive wastes**
- **Added buffering capacity to waste**

Potential Stability Problems:

- **Sulfate attack**
- **Water dissolution of binder**

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Objectives - CPB Leach Study

- **Verify geochemical stability**
- **Document chemical, mineralogical changes**
- **Identify possible impacts on:**
  - oxidation of pyritic tailings
  - physical strength of CPB

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Study Methodology

- CPB samples: 4 formulations
- Humid curing period: 14-days
- Leaching of CPB samples:
  - 20 weeks, 3 leaching conditions (water, ARD)
- Analyses:
  - Leachate/solid phase chemistry, mineralogy, ABA, UCS

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Moulding of CPB

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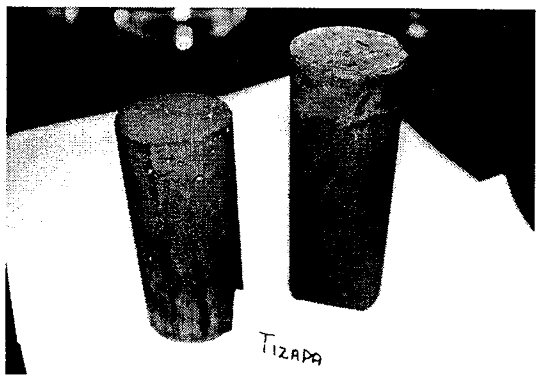
CPB After 14-day Cure



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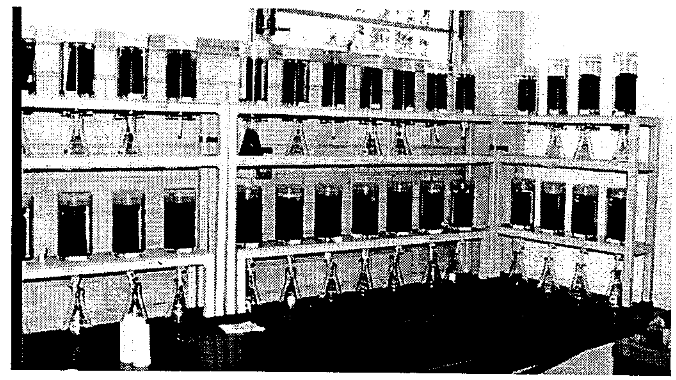
CPB Leaching Cells



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Results

- Leachate chemistry
- Solid phase chemistry of altered layers
- Acid-base accounting (ABA)
- Scanning Electron Microscopy (SEM)
- Unconfined compressive strength (ucs)

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Leachate Chemistry

- High, early buffering capacity of CPB
- Mineral coating in ARD environments
- Low metals in leachate
- Ca, K, Mg (cement components) depletion in all environments (ARD and water)

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Solid Phase Chemistry

- Little or no oxidation of sulfide minerals
- Depletion of Ca on outer edges
- Alteration layer thickness:
  - ∝ Portland cement content, solution pH

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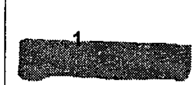
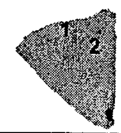
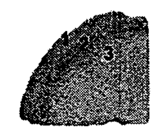
Solid Phase Chemistry

		Water - flooded		Water - cycled		$Fe_2(SO_4)_3$ (flooded)		
Paste X-section Scales Flooded: 1:2 Cycled: 3:2 Fe-sol.: 3:2								
Layers		1	Core (of cylinder)	1	2	1	2	3
Thickness		0.75 mm	-	4 mm	2 mm	2 mm	4 mm	2 mm
% concentration difference from core	S_{total}	I	I	I	I		I	I
			I					I
	S as S^{2-}	I	I	I	I		I	I
			I					
	Mg	I	I	I	I			
	Al	I	I	I	I	I	I	I
	Zn	I	I	n.a.	I		I	I
	Cu	I	I	I	I	I	I	I
	Pb	I	I	I	I		I	I

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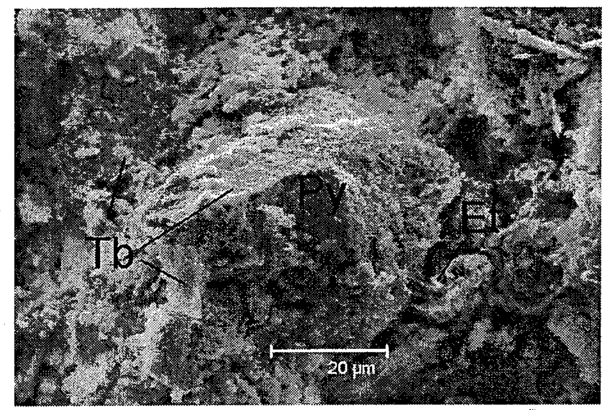
Acid-Base Accounting

Sample		NP $\frac{kg\ CaCO_3}{ton}$	AP $\frac{kg\ CaCO_3}{ton}$	NP/AP
Tailings		42	278.1	**0.15**
Paste		73	265.9	**0.27**
Paste, 20 wk Leached:				
Flooded	Layer 1	60	271	**0.22**
Cycled	Layer 1	45	268	**0.17**
$Fe_2(SO_4)_3$	Layer 1	-14	insuf.	**--**
	Layer 2	-2	299	**-0.01**
	Layer 3	-1	insuf.	**--**

Well-developed tobermorite in core



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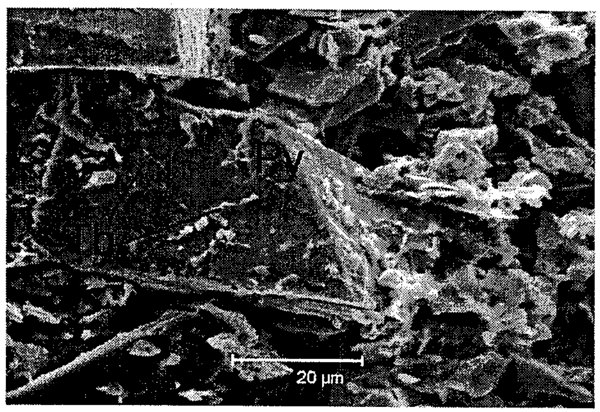
Degraded tobermorite, ARD-leached



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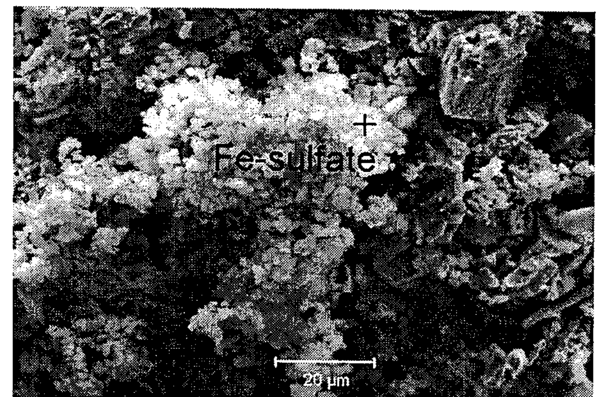
ARD - 2^{ry} precipitates



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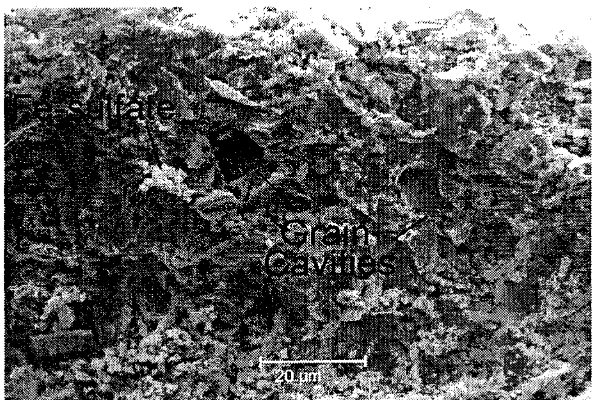
Loss of binder strength



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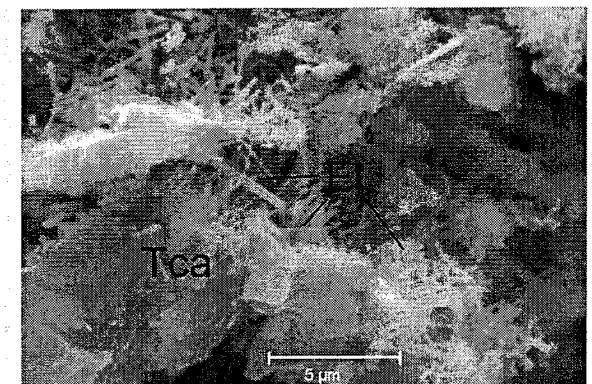
Incomplete Binder Development



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Conclusion - CPB Study

- Binder phases dissolve in aqueous solutions
- Alteration occurs as a penetrating front
- Depth of penetration front:
  - $\propto$ water regime, binder content / type
- No apparent UCS change (20 weeks)

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CPB and Acidic Drainage

- Binder addition may not continually buffer existing ARD
- Highly reactive pyritic tailings in CPB oxidize in moist air
- Low metal in leachate in 20 weeks
- No immediate effect of external SO_4 aggressivity

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Implications

- Loss of cement material will occur unless in <u>dry</u> mine

But:

- Impact of binder loss depends on planned use of CPB

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Recommendations

- Perform leaching tests in expected conditions for sensitive uses
- Longer-term CPB leaching study
  - Rate of CPB alteration
  - Oxidation of sulfides - time frame?
  - 2^{ry} mineral growths

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Acknowledgement

UBC - MMPE	R. Lawrence, M. Monroy,
UASLP - Met. Inst.	I. Gonzalez, G. Poling,
UAM-I Electrochem.	M. Raudsepp, L. St-Arnaud,
Noranda Inc.	M. Li, B. Ruiz, R. Espinoza
Peñoles	R. Cruz, I. Chavira,
N.S.E.R.C.	R. Verburg
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