SECTION B.17

PREDICTION OF PIT LAKE DRAINAGE CHEMISTRY

Andy Davis
Geomega

A Method to Predict Evolving Post-Closure Pit Lake Chemistry

by:

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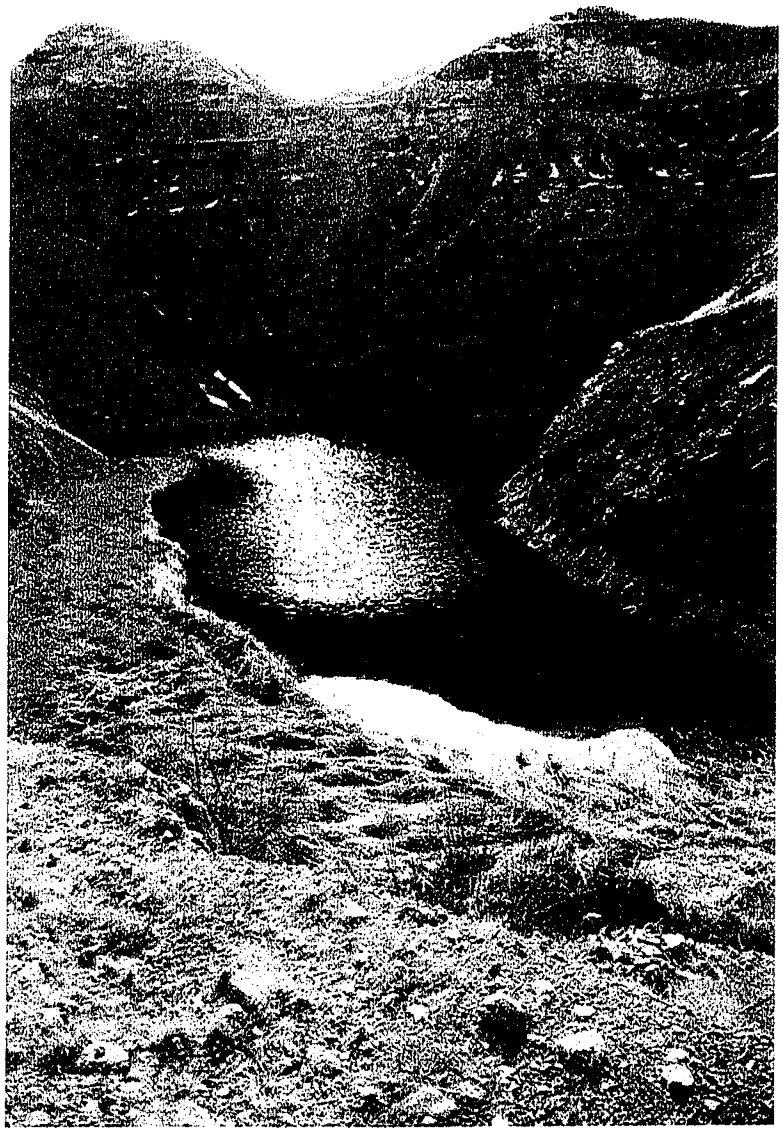
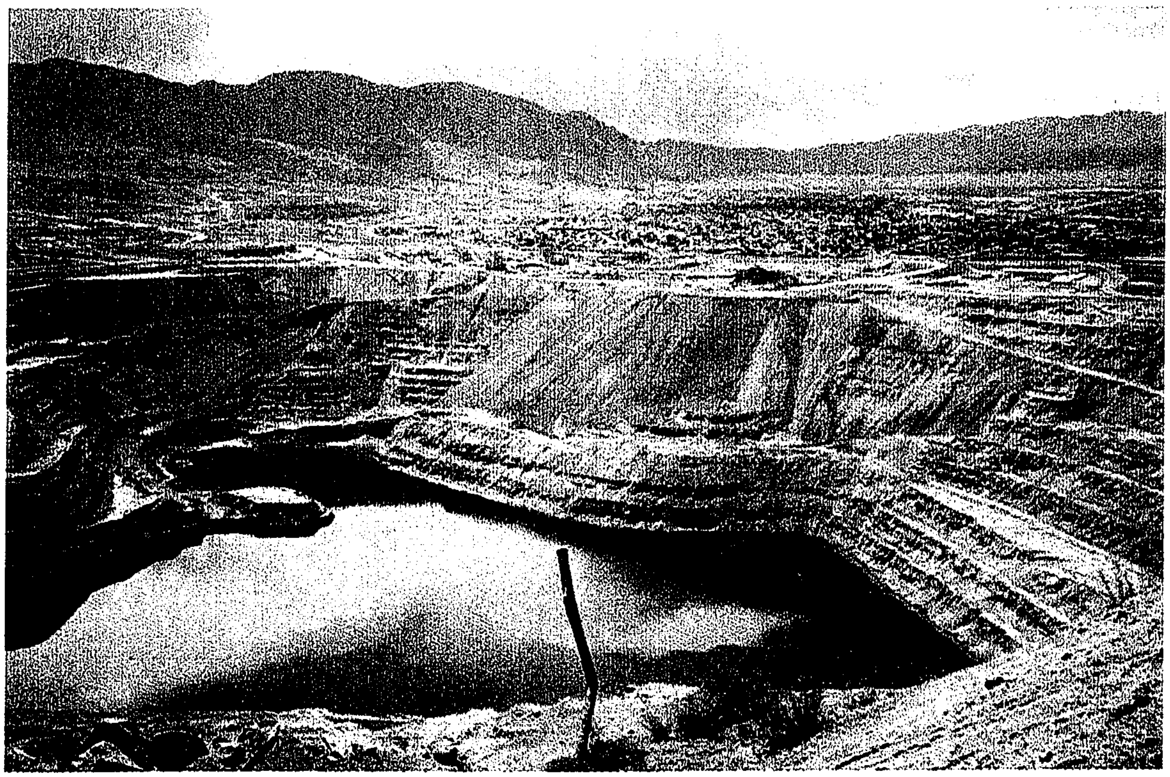


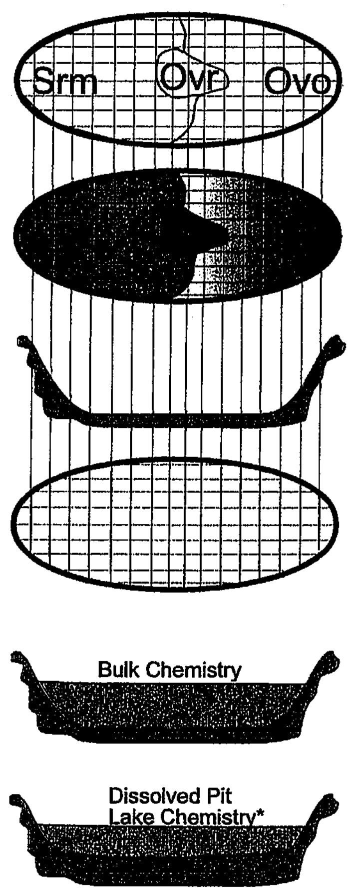


The Ying and the Yang of Pit Lake Chemistry (mg/L)

	Berkeley Pit	Cortez Pit
pH	2.8	8.1
As	0.05	0.038
Fe	386	0.134
Mn	95	0.002
Zn	280	0.002
Cl	9	24
SO_4	5740	90

Flow Chart Describing Progress and Integration of Pit Lake Chemical Prediction

Objective		Tool
Ultimate Pit Surface Geologic Block Model		Pipeline/South Pipeline Geology
Ultimate Pit Surface Oxidation Potential		NCV 15 0 -15
Weathering Rind Thickness		
Post Closure Groundwater Discharge to Pit		
		Chemical Release Functions
Geochemical Constraints		Regional Groundwater Model Elemental Discharge
		Solute Mass Discharge Pit Lake Volume
	Limnology Chemogenesis* Evapoconcentration* Attenuation Region*	PHREEQC
		CE-QUAL-W2



*Requires Field Specific Data

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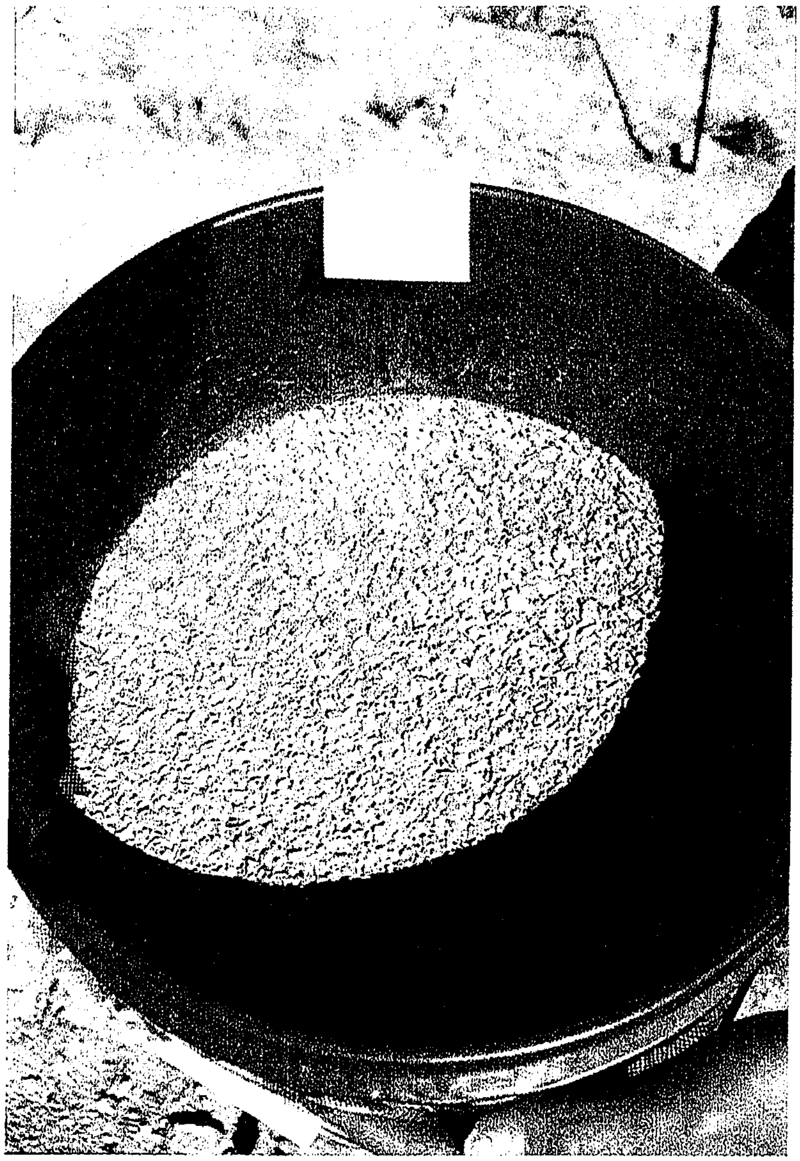
Leaching Tests

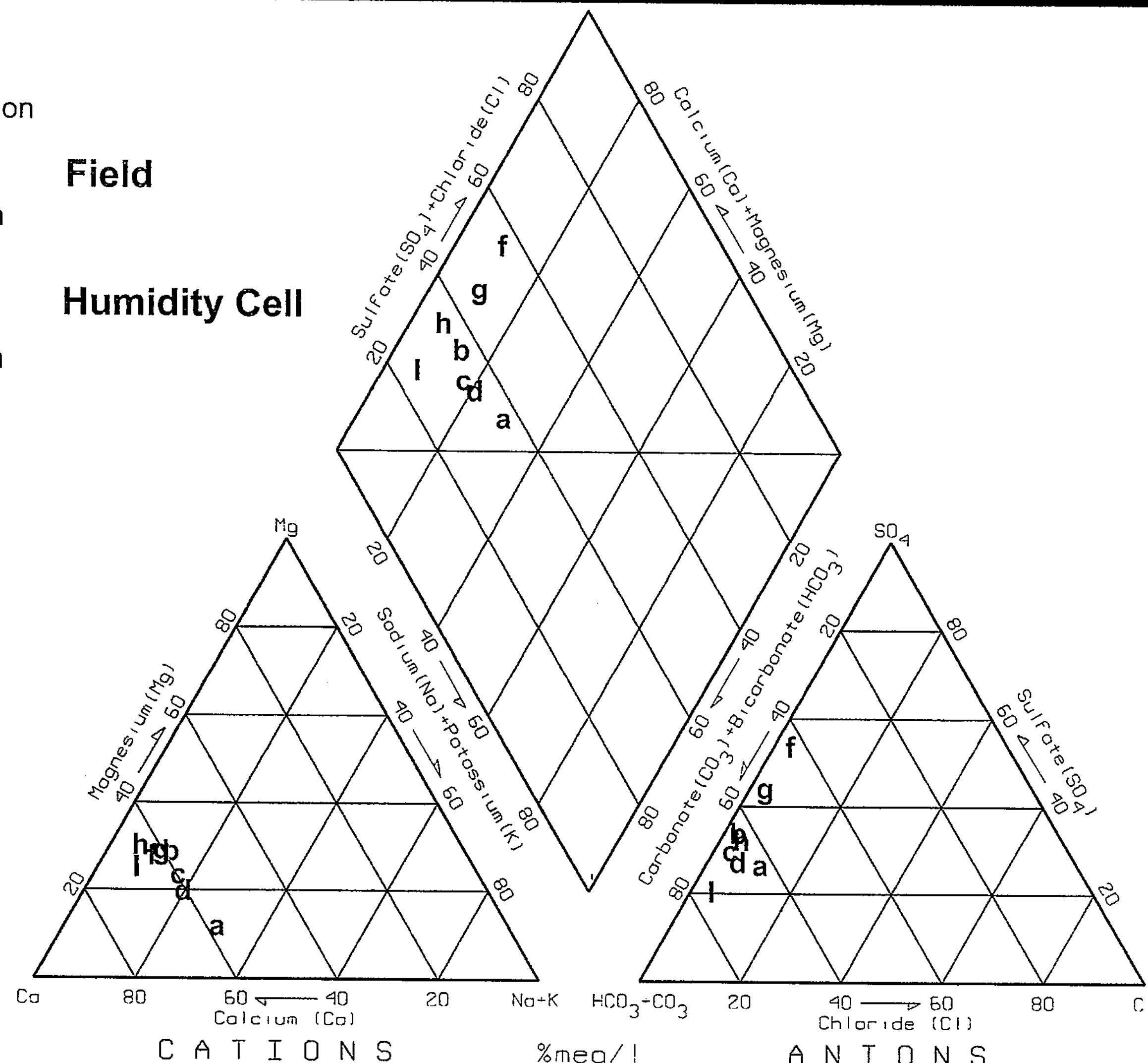
Methods
- Meteoric Water Mobility Tests
- Column Tests
- Humidity Cell Tests
- Field Oxidation and Leaching Tests

Issues
- Acid Generating/Neutralizing Potential
- Reactive Surface Area (particle size)



Comparison of Precipitation, Field Oxidation, Leachate, and Humidity Cell Leachate

a	Precipitation	
b	2-4 mm	Field
c	4-16 mm	
d	16-64 mm	
f	<2 mm	
g	2-4 mm	Humidity Cell
h	4-16 mm	
l	16-64 mm	



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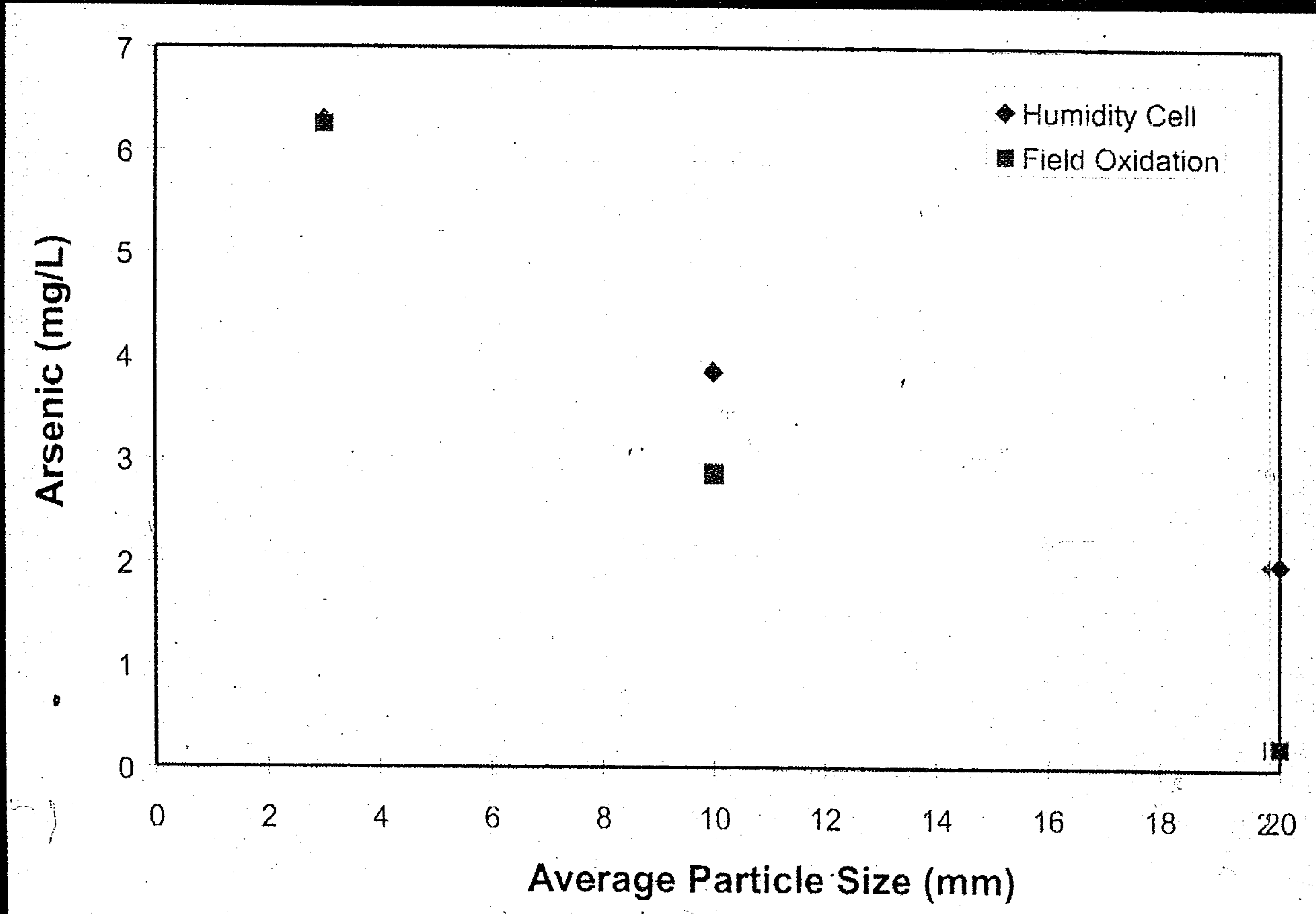
Average SSR3 Arsenic Concentrations



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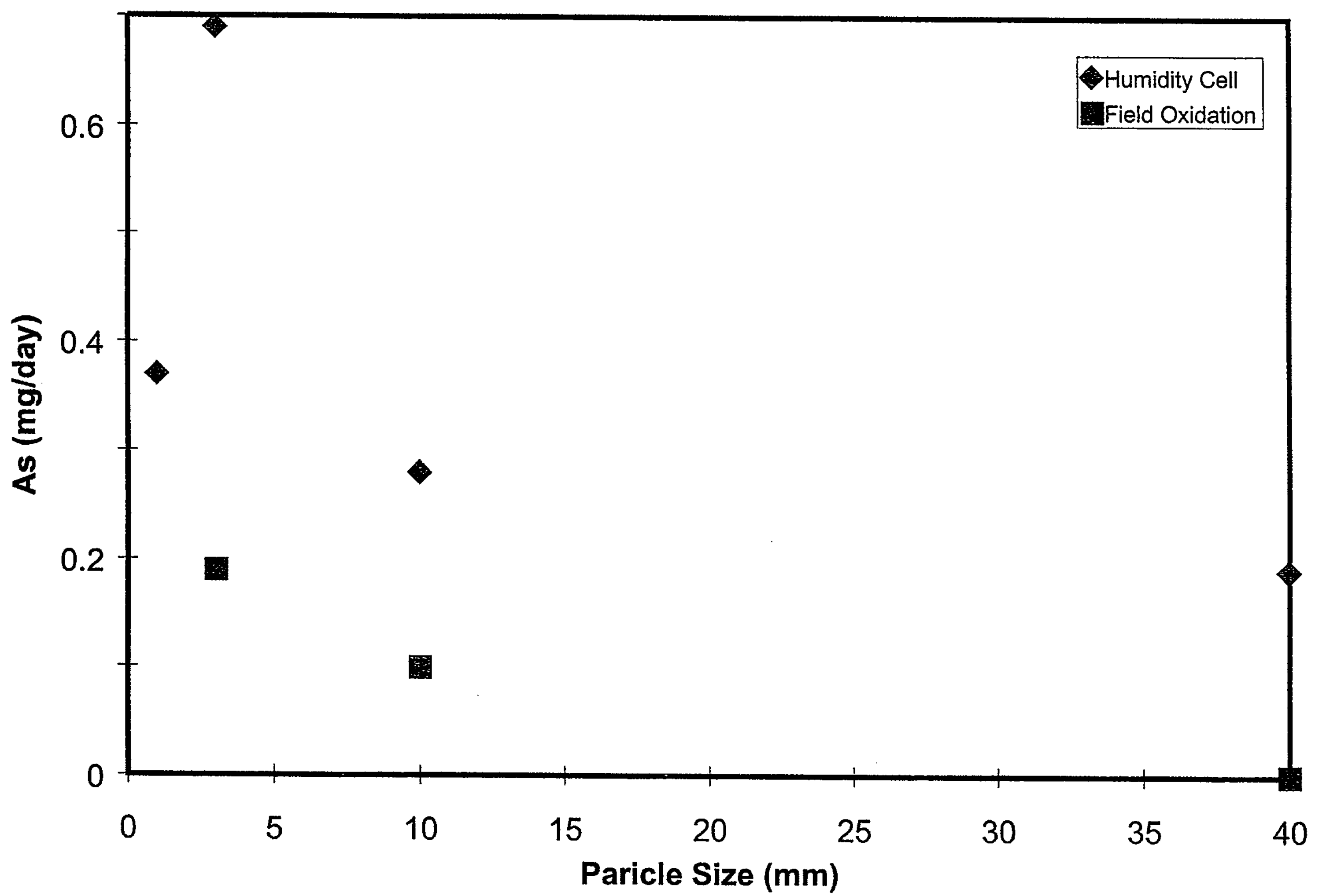
Arsenic in Field Oxidation and Humidity Cell Leachates



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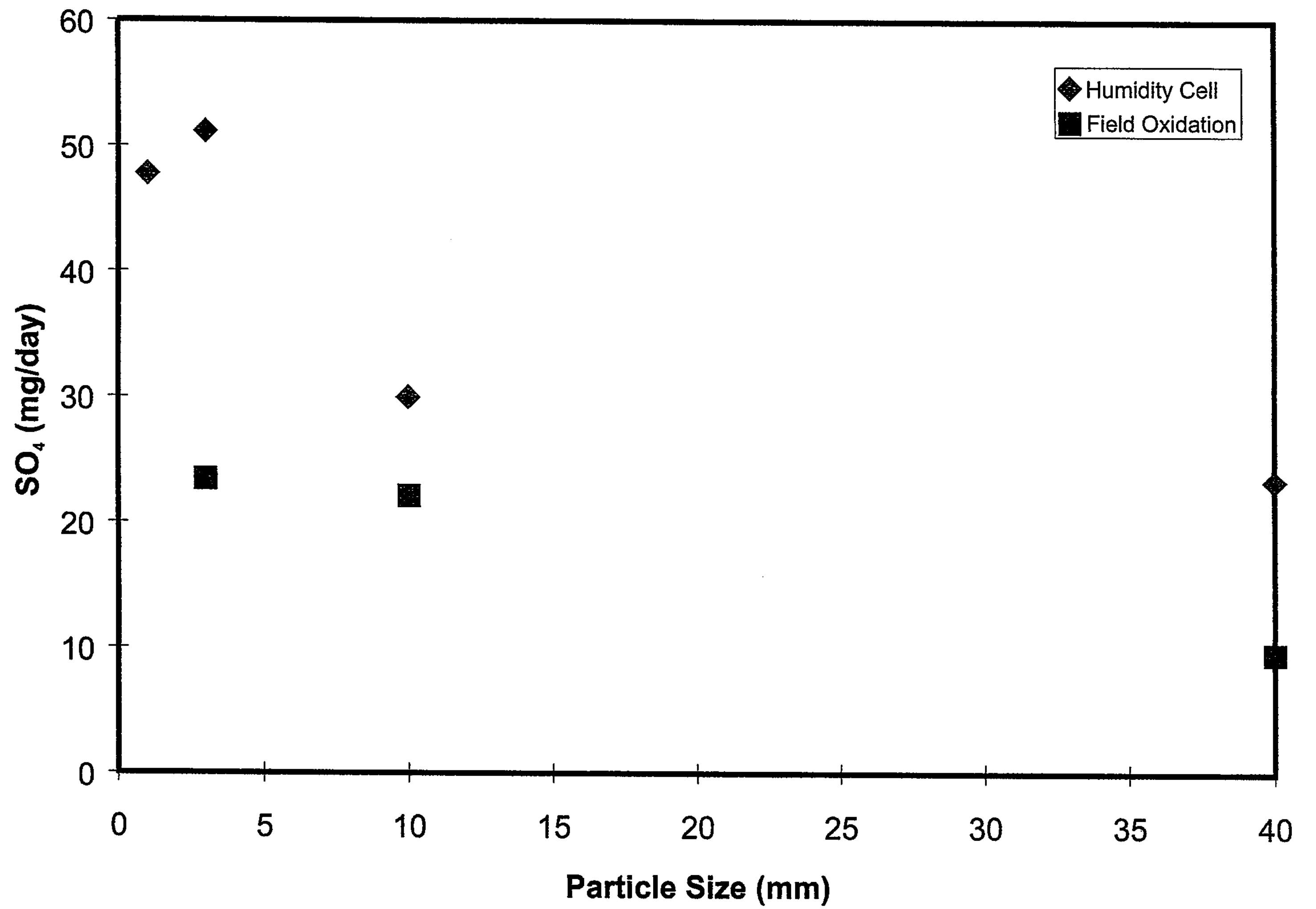
Sulfate in Field Oxidation and Humidity Cell Leachates



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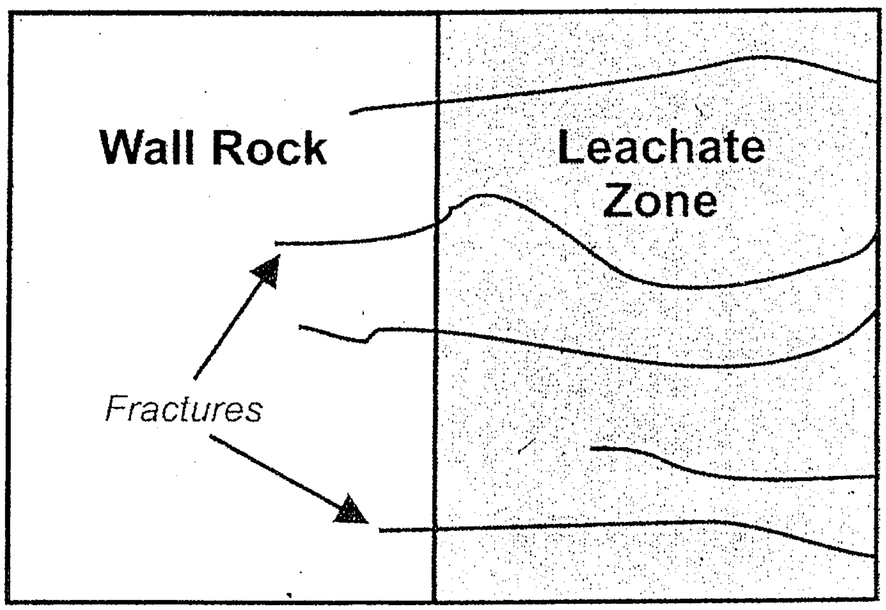
Pyrite Oxidation Model

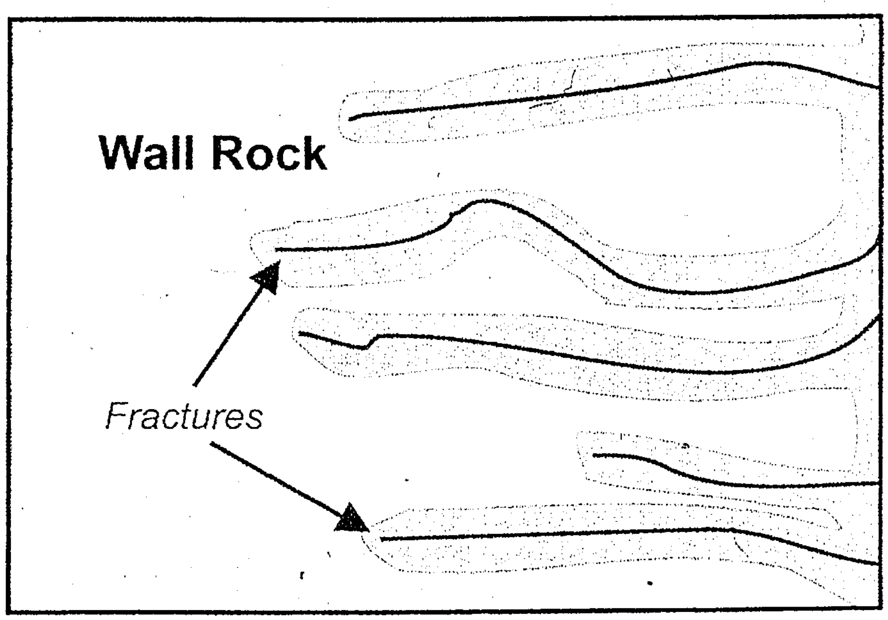
Based on the Davis-Ritchie Approach

- Modifications
  - Wall Rock Geometry – Fractures versus Porous Media
  - Water Content Oxidation Rate Limitation
- Other Features
  - Variable Air-Filled Porosity
  - Variable Particle Size

Bulk vs. Fracture Based Pyrite Oxidation



Planar Approach



Layered Approach

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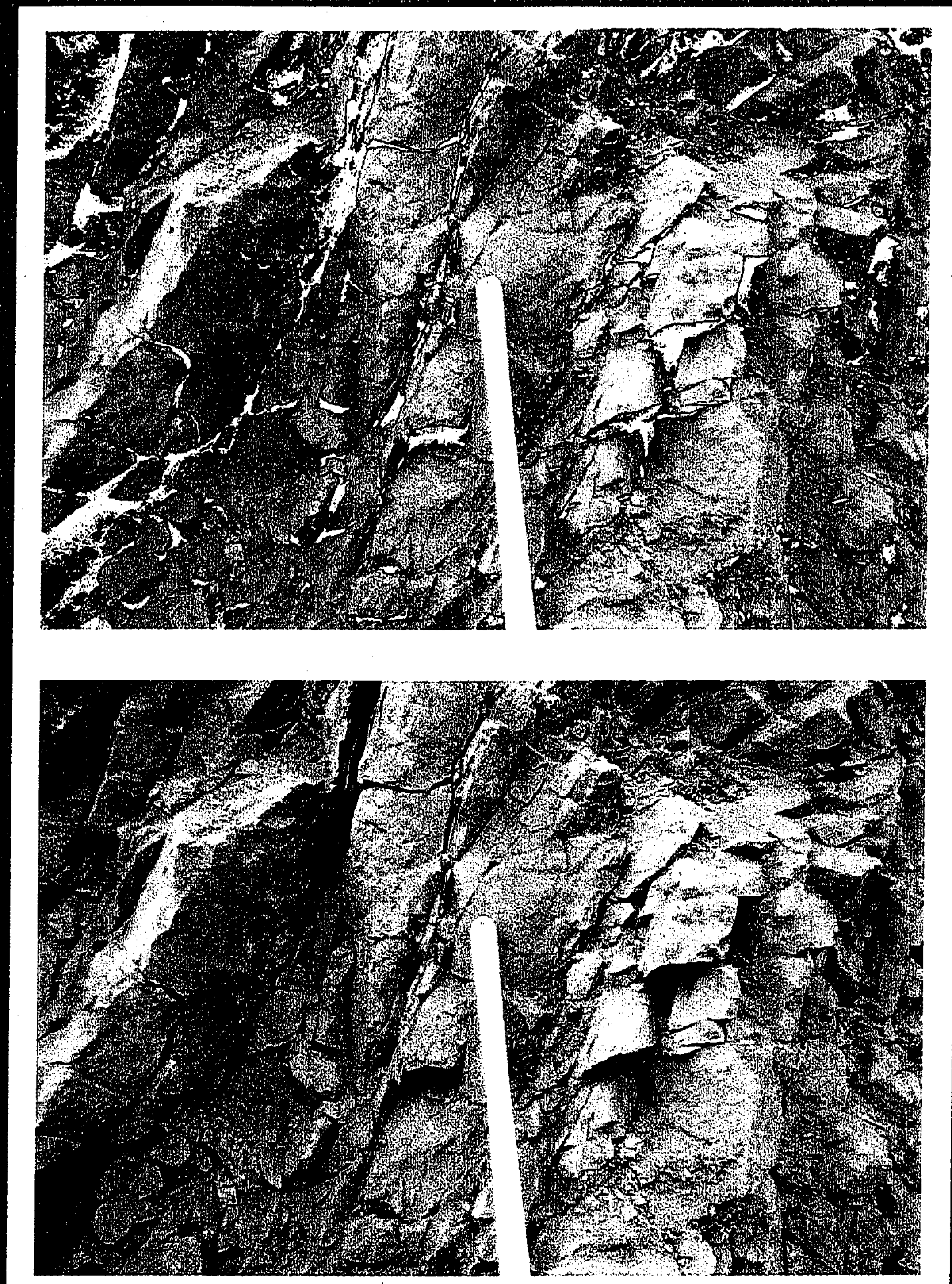
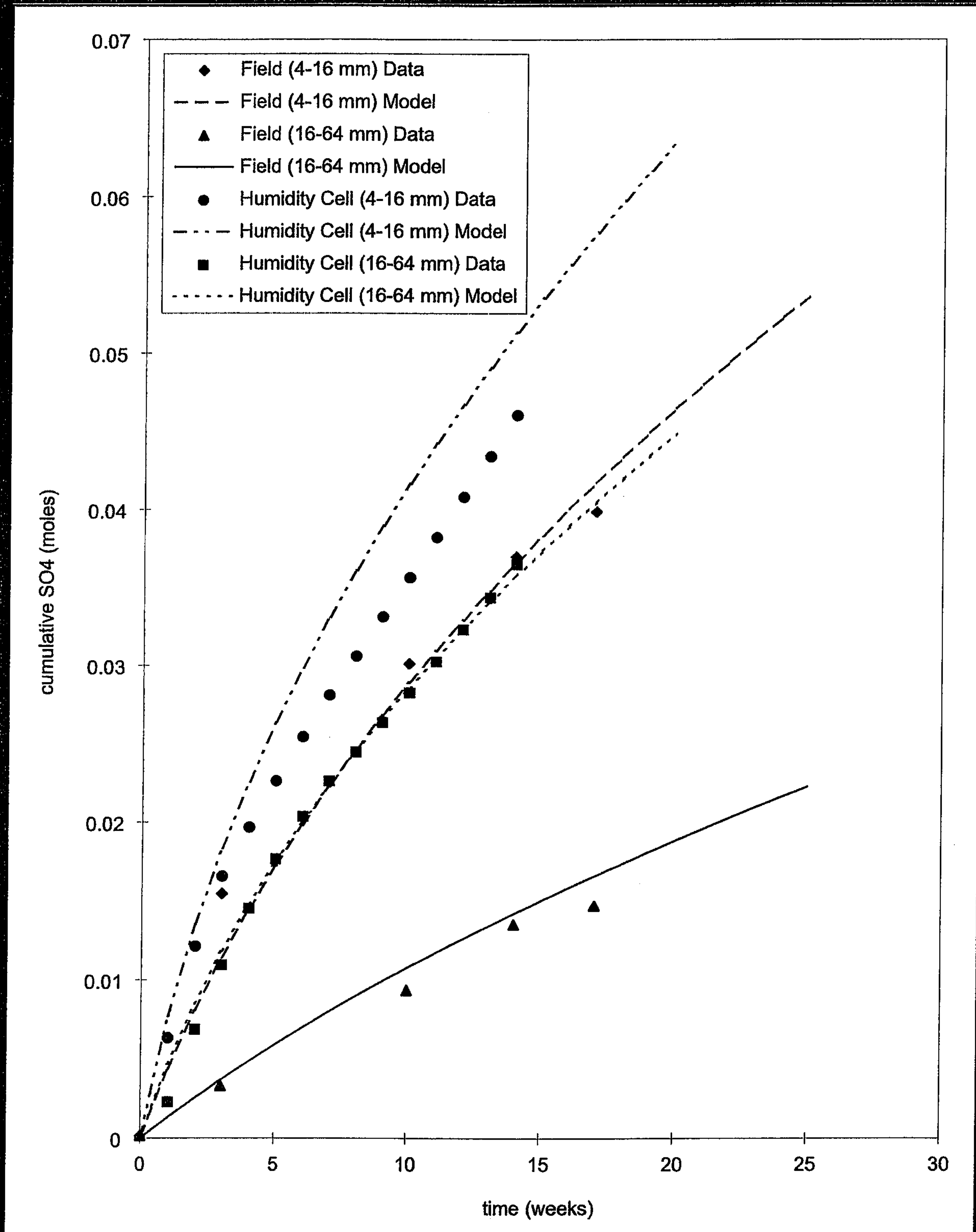
Photogrammetric Analysis of Macro-Fracture Density in the SOAP-GQ Pit Wall Rock



Observed Rate Limitation in Pyride Oxidation



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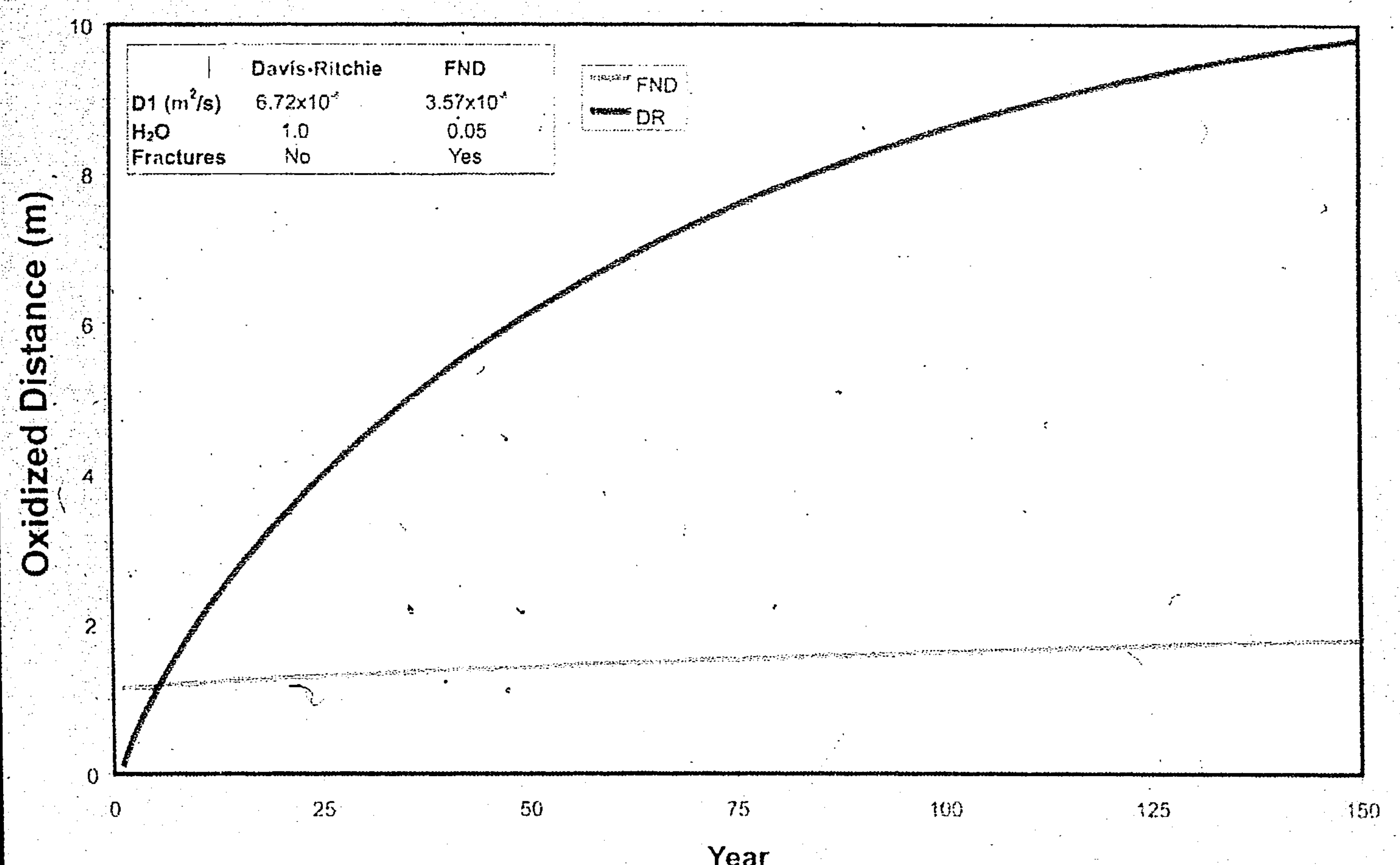
Comparison Between Davis-Ritchie and FND Models for SSR2 Rock (NCV<-1)



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Bulk Chemistry

Total mass of solutes contributed by:

Wall Rock Leaching
Groundwater Inflow
Surface Runoff
Precipitation
Groundwater Outflow

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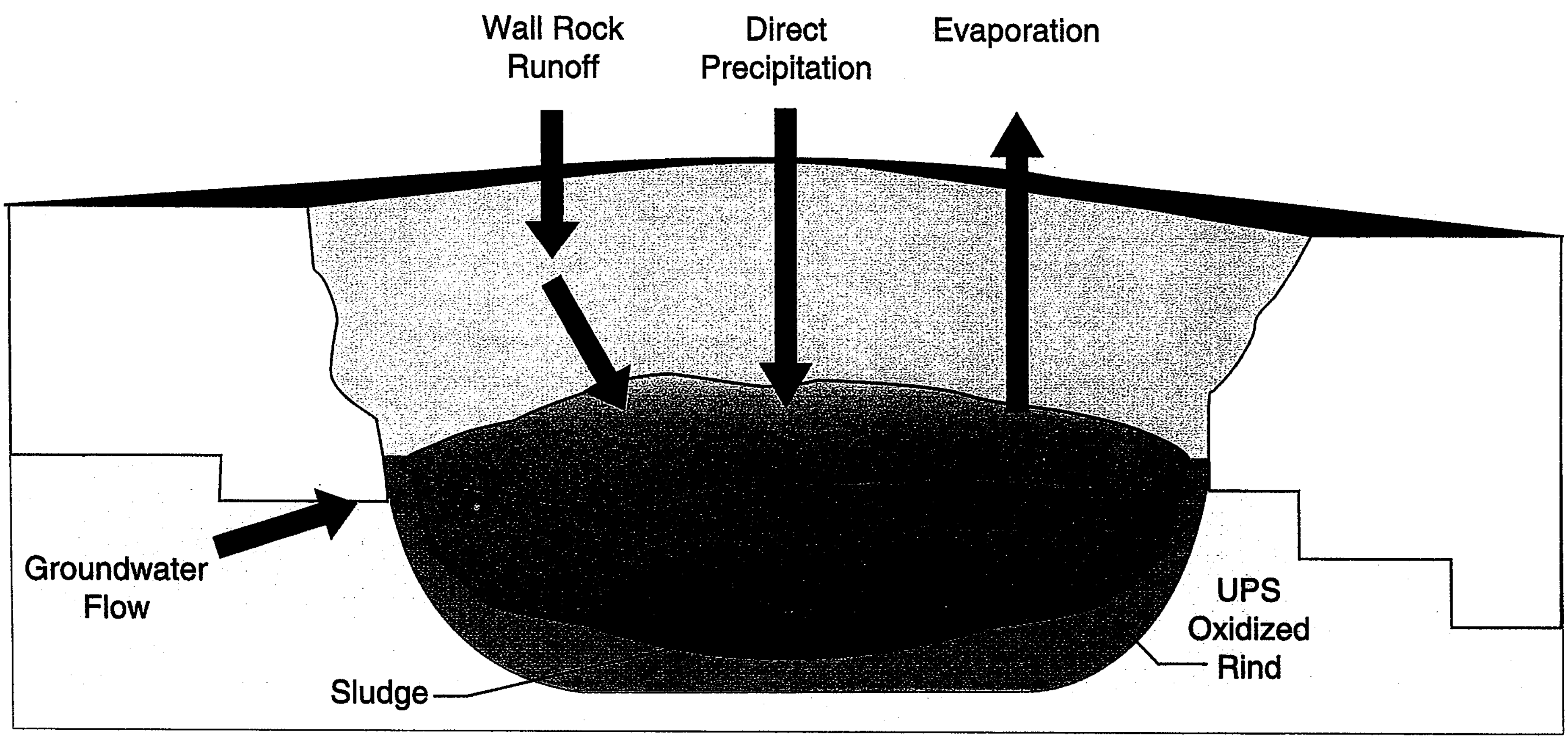
Schematic of Hydrologic Cycle for a Refilling Pit



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Dissolved Chemistry

1. Mix various solutions
2. Evapoconcentration
3. Solid and Gas Phase Equilibrium
4. Sorption to AFH
5. Charge Balancing
6. Analog Test

Equilibrium Phases

Gases

- **Carbon Dioxide**
- **Oxygen**

Solids

- **Amorphous Ferric Hydroxide**
- **Calcite**
- **Gibbsite**
- **Barite**

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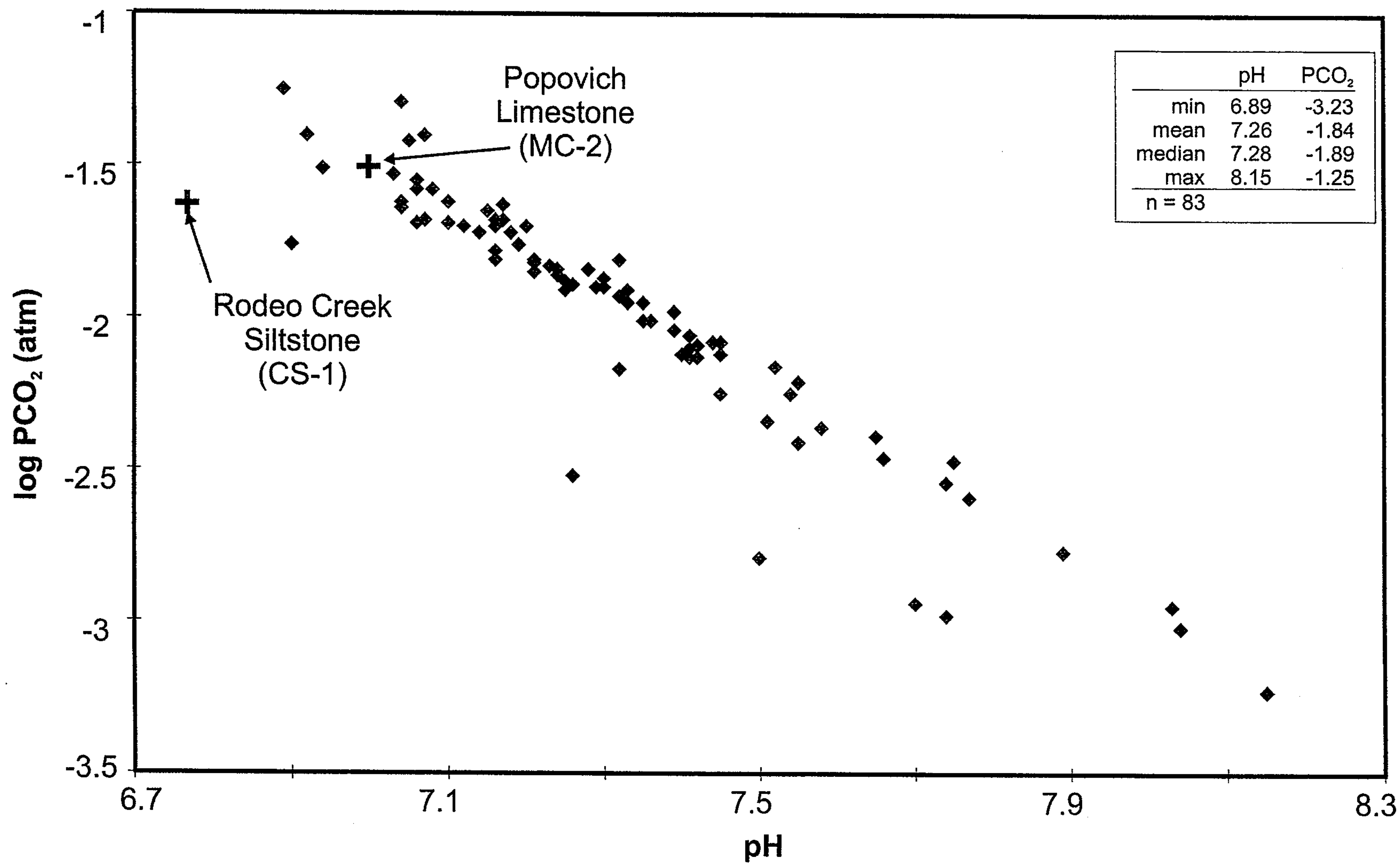
PCO_2 as a Function of pH in Carbonate Aquifers



	pH	PCO_2
min	6.89	-3.23
mean	7.26	-1.84
median	7.28	-1.89
max	8.15	-1.25
n = 83		

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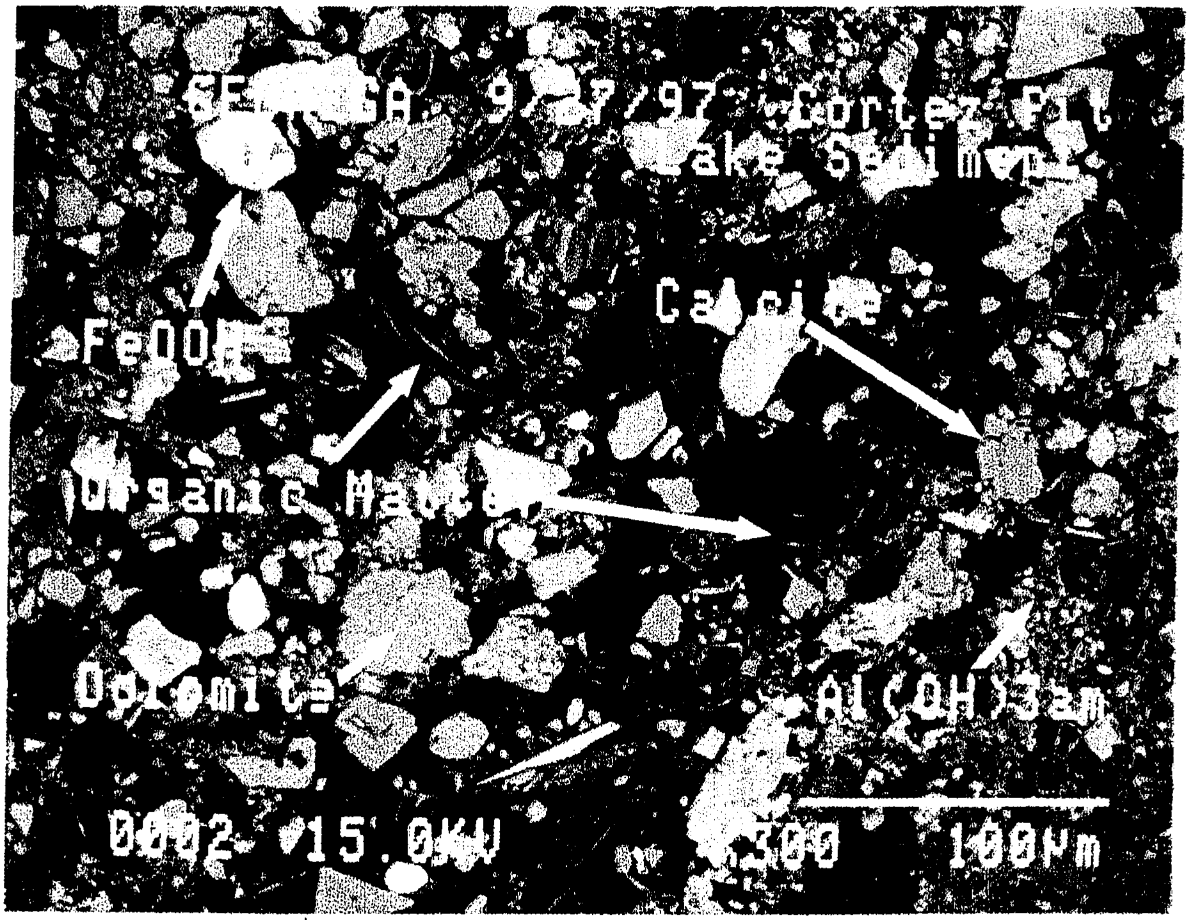
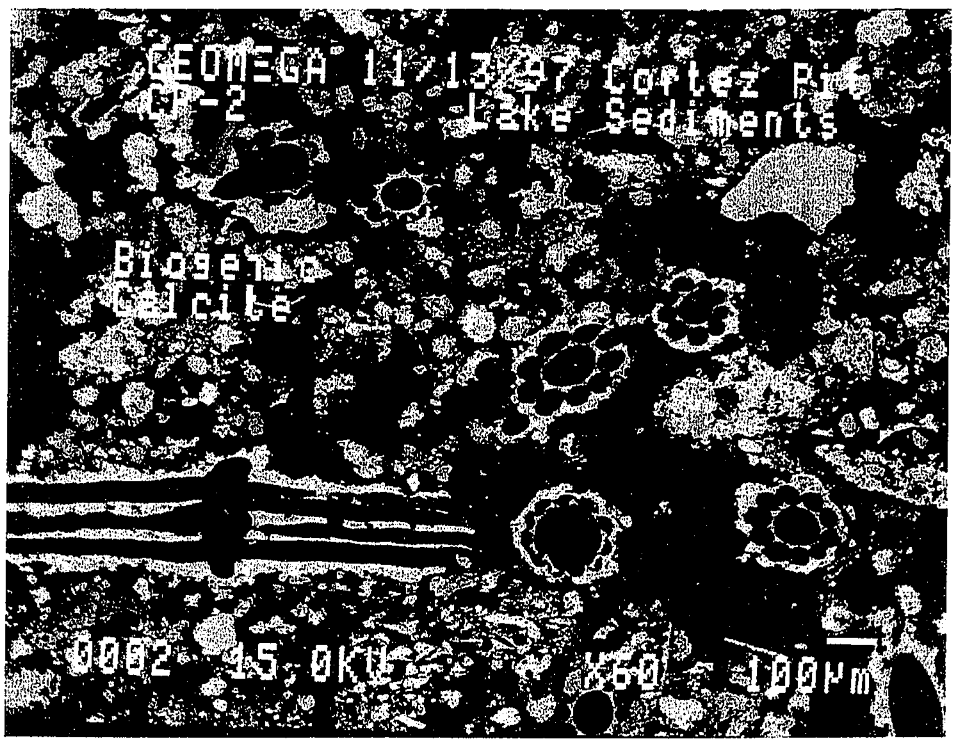
(source: Plummer et al. 1976; Langmuir 1971)


FeOOH
Dolomite
Al(OH)3am
0002 15.0KV
100μm


GEOMEGA 11/13/97 Cortez
Lake Sediments
Biogenic
Calcite
0002 15.0KV
X60 100µm

Evapoconcentration

Theory of Geochemical Divides

Field Tests

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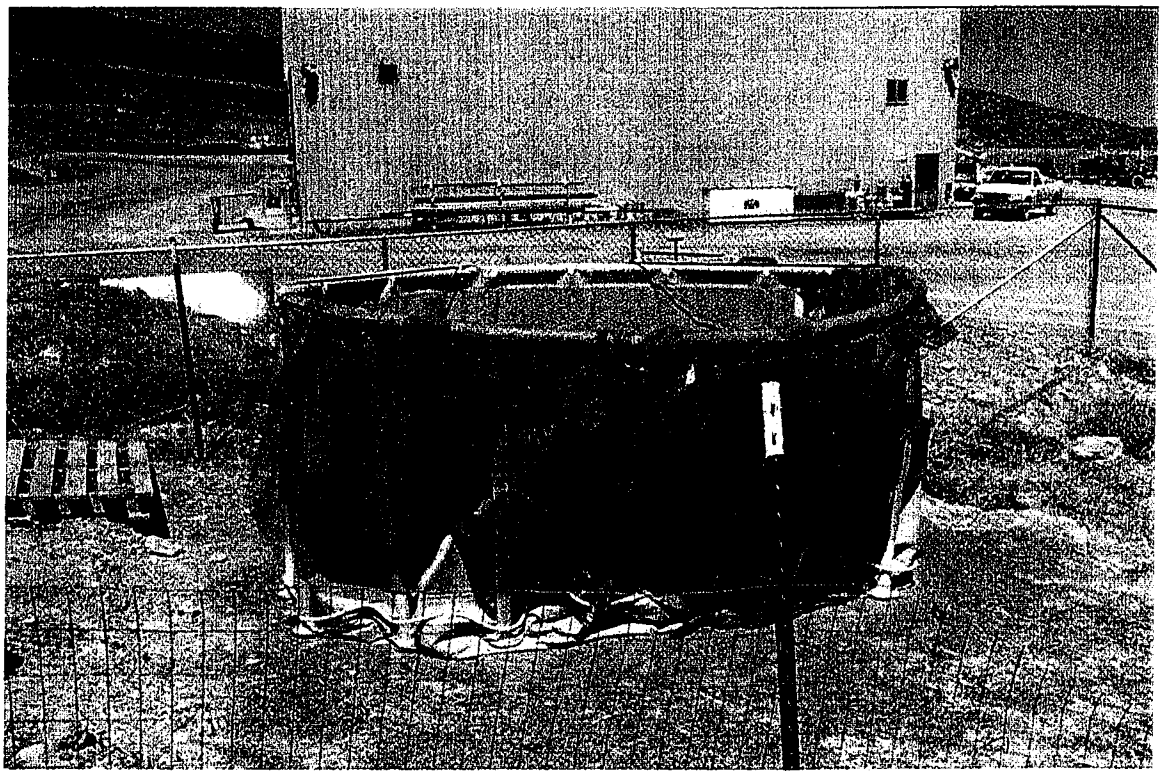
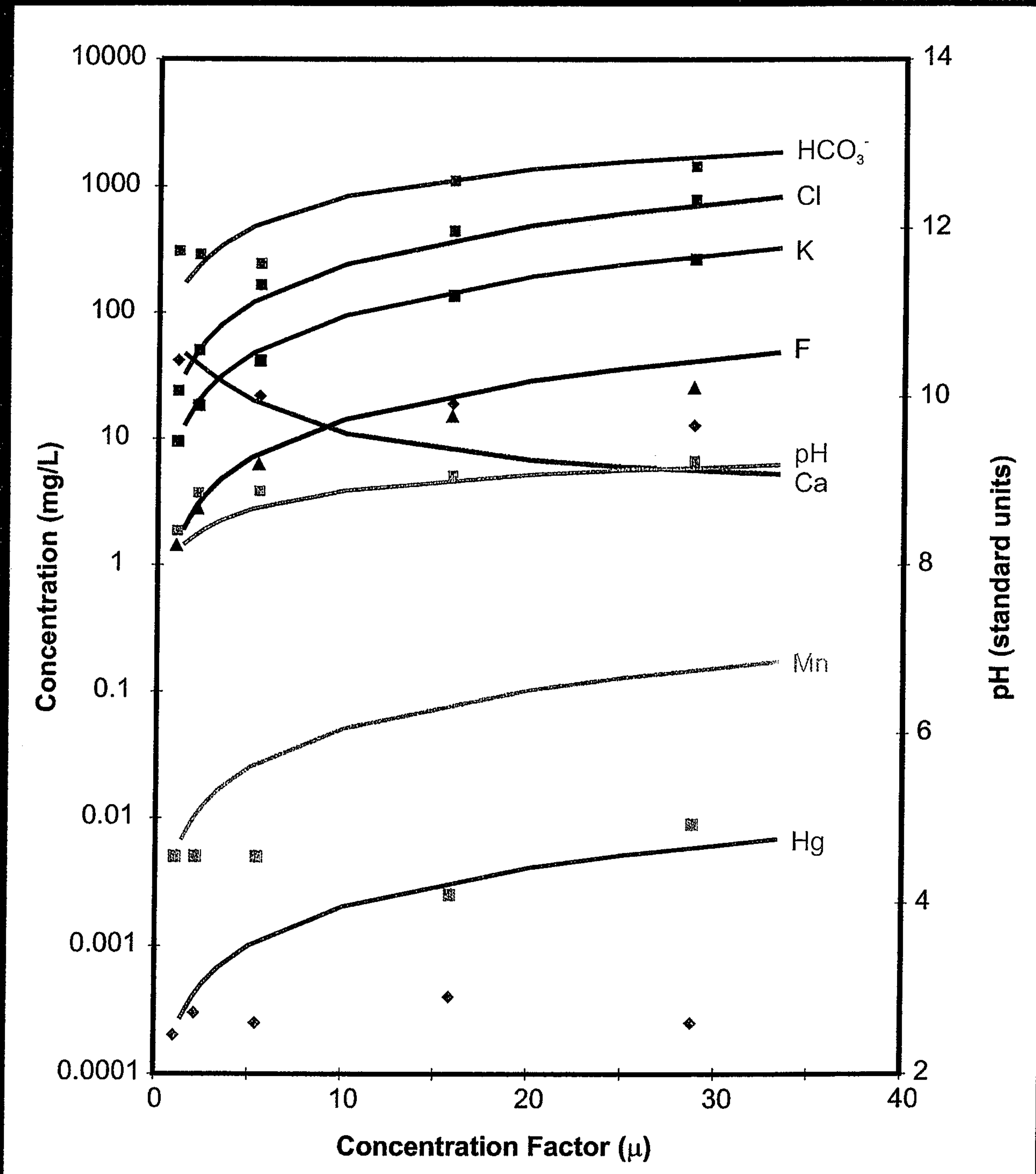


Pipeline/South Pipeline Evapoconcentration Experiment: Predicted (—) and Experimental (■)Data



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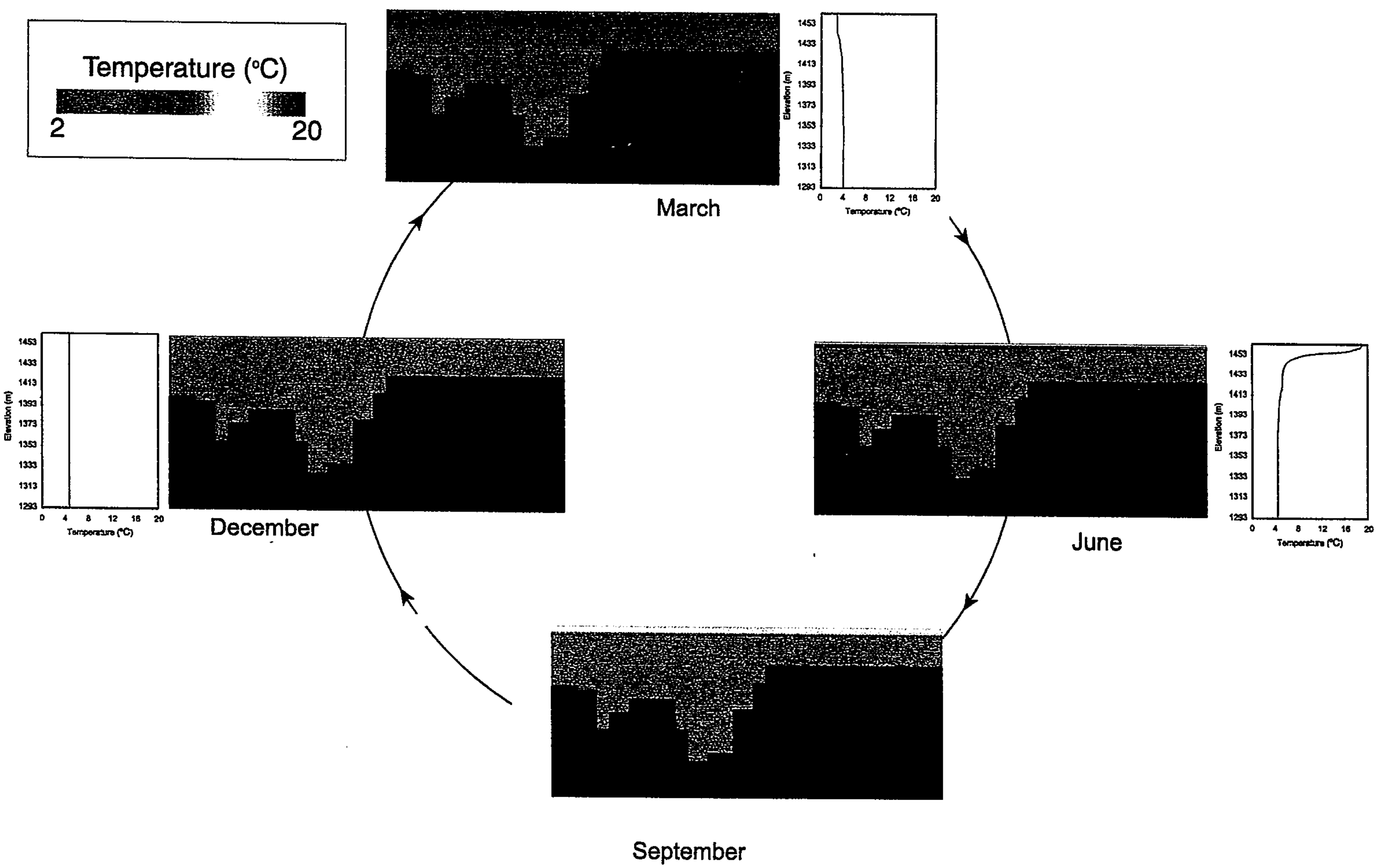
Hydrodynamic Model

Does the pit lake mix and turn over?

Does the pit lake become anoxic?

Temperature Profiles for the Dual Pit Lakes with Waste Rock Scenario



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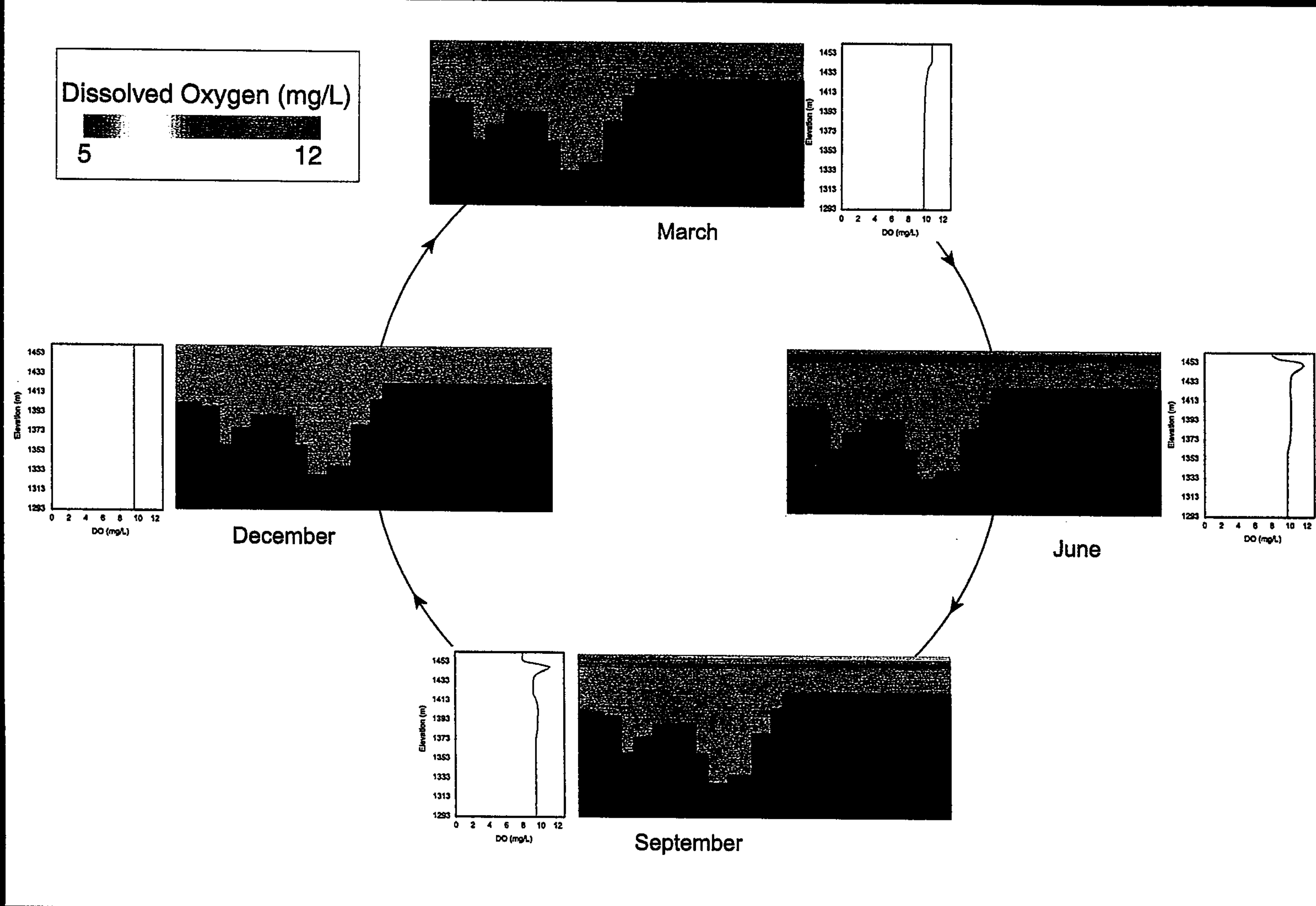
Dissolved Oxygen Profiles for the Dual Pit Lakes with Waste Rock Scenario



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Comparison of Predicted Pit Lake Water Quality to an Analog Pit Lake

Analyte	Cortez Pit Lake (20 years after refilling)	Predicted South Pipeline Pit Lake (20 years after refilling)
pH	8.07	8.19
alkalinity	282	265
arsenic	0.038	0.020
calcium	45	66
chloride	24	85
fluoride	2.4	2.9
iron	<0.01	0.0004
sodium	69	123
sulfate	90	219
TDS	432	810

Conclusions

This methodology for predicting pit lake water quality is proposed for fulfillment of the technical requirements for an Environmental Impact Statement, or as part of permitted facility closure.

- Improved definition of constraints on pyrite oxidation in arid environments
- More accurate representation of leaching characteristics of wall rock

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Comments

Issue	Remedy
Determination of background water quality	monitoring well samples, appropriate detection limits
Wall rock leachate quality	laboratory/field testing, leaching of representative samples
Oxidation modeling	results of the leaching tests, characterization of rock fractures and porosity
Bulk chemistry	water balance, groundwater flow model
Dissolved chemistry	identification of equilibrium phases, evapoconcentration tests, analog tests
Hydrodynamic modeling	comparison to existing lakes
Other influences	microbial activity