Post-Closure Metal Mobility in Subaqueous Tailings Deposits

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Two Case Studies

Theme: enhanced metal mobility in the post-closure period

I. *Equity Silver Tailings Pond*
pH-controlled release of copper from submerged tailings deposits

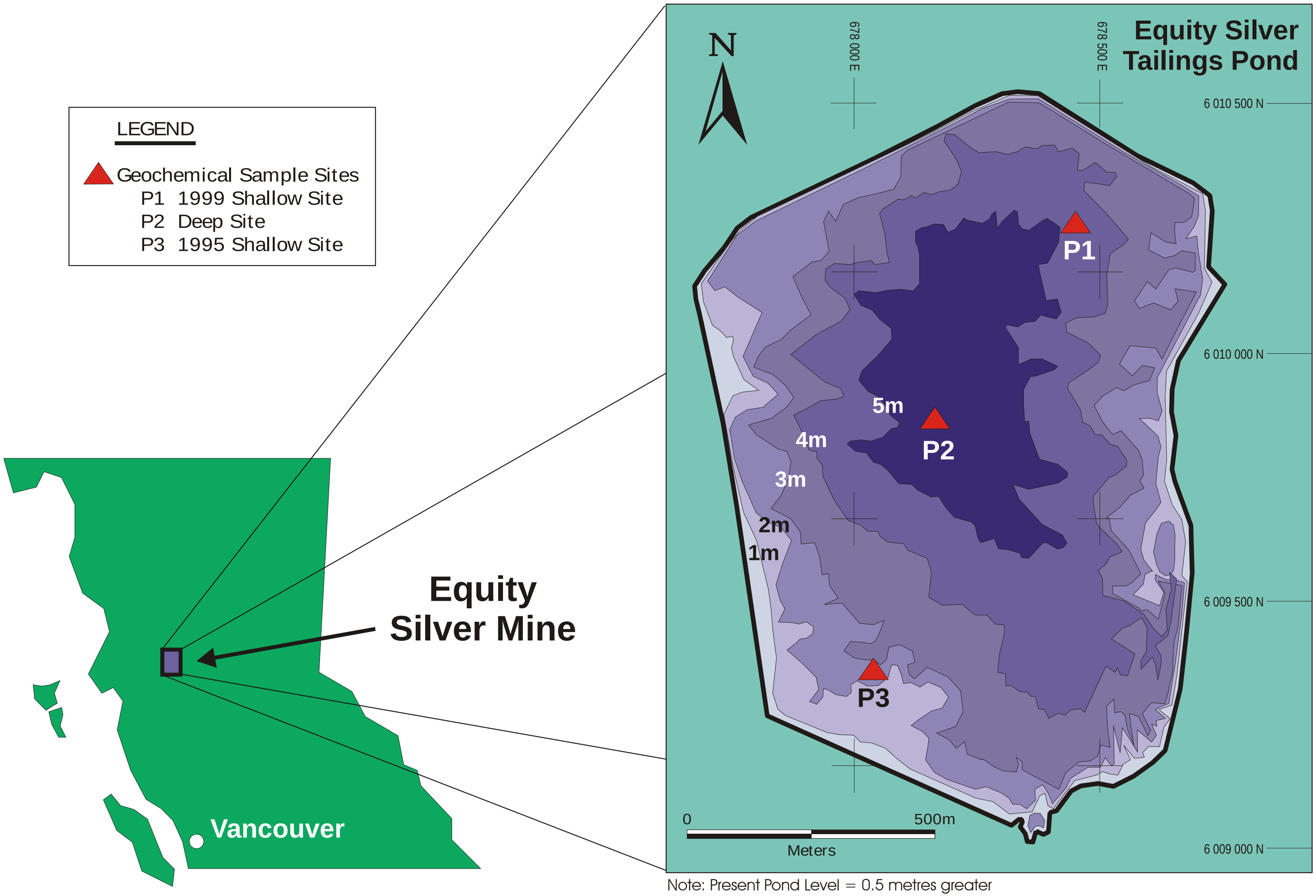
II. *Elliot Lake Waste Management Area*
Redox-controlled release of radium from subaqueous uranium mine tailings

I. The pH-controlled release of copper from subaqueous mine waste

- Equity Silver Tailings Pond (Placer Dome Inc.)

- Acknowledgements
Mike Aziz and Keith Ferguson (PDI)

Site Location



Note: Present Pond Level = 0.5 metres greater than indicated on depth contours

PLACER DOME NORTH AMERICA

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History and Environmental Setting

- Mine operated from 1980 to 1994

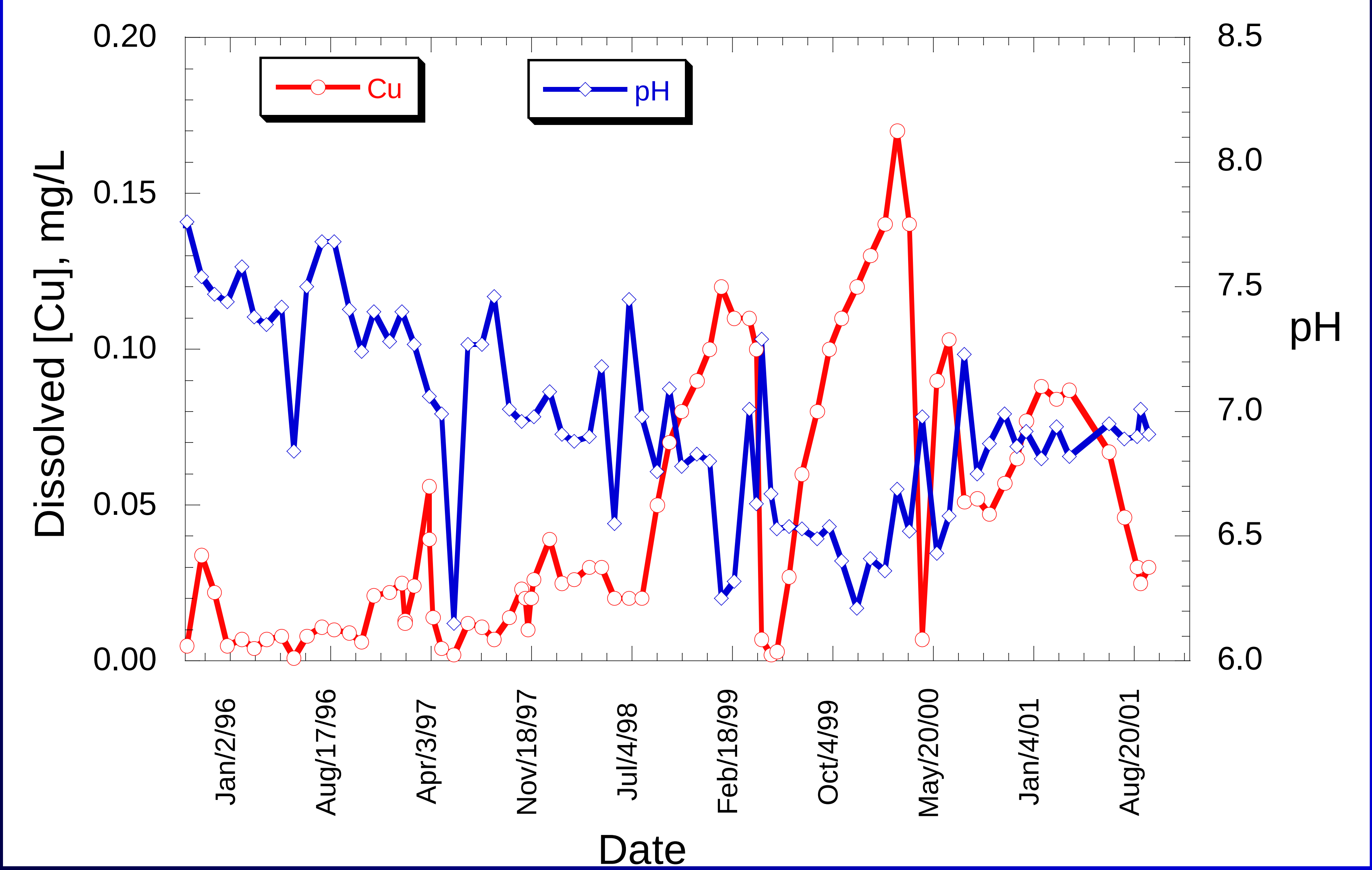
- Flotation tailings discharged subaqueously to Equity Silver Tailings Pond (ESTP)

Other inputs to ESTP:

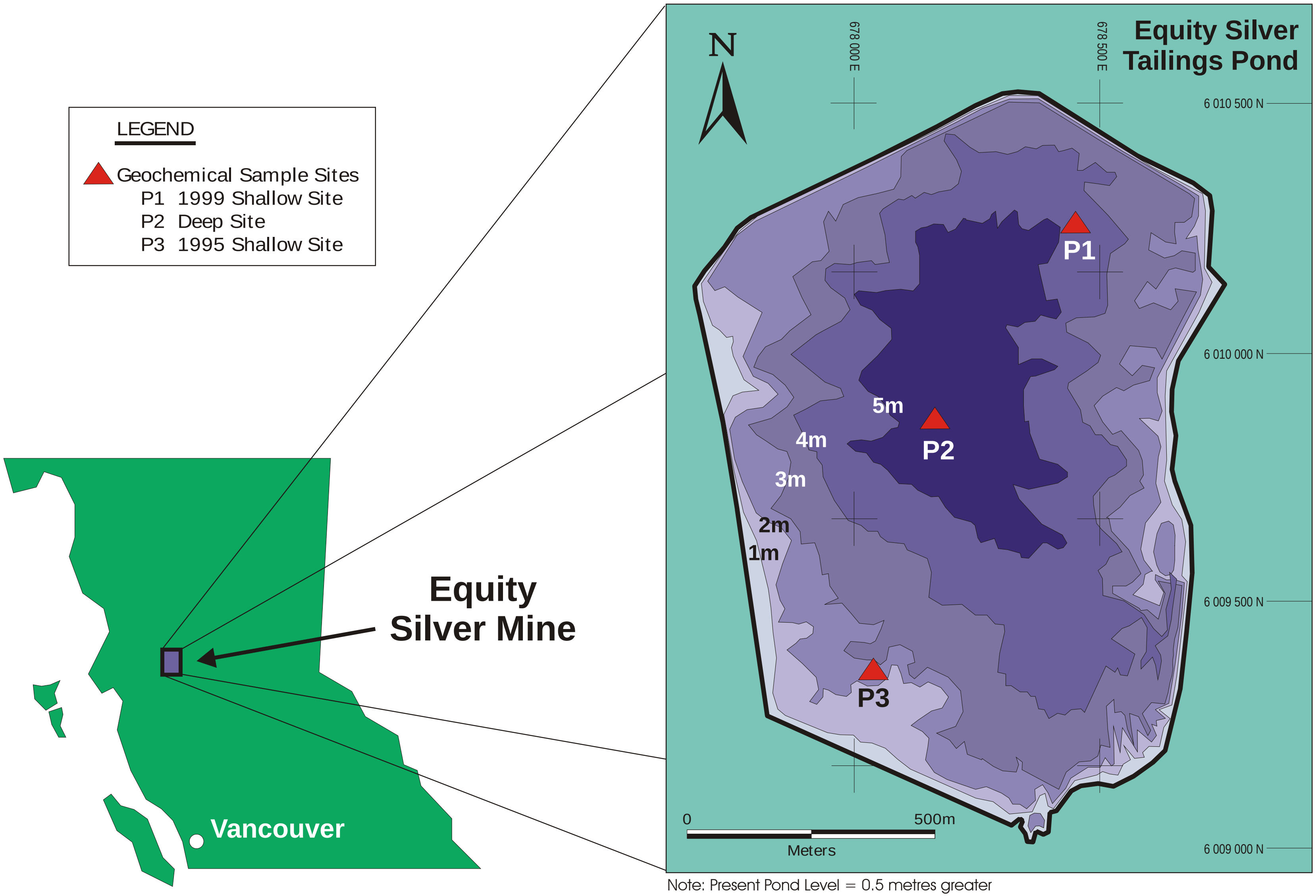
•Co-deposition of neutralization sludges derived from lime-treated ARD to southern zone of ESTP

•Direct discharge of ARD to northeast zone of ESTP

Water Column Evolution



Site Location



Note: Present Pond Level = 0.5 metres greater than indicated on depth contours

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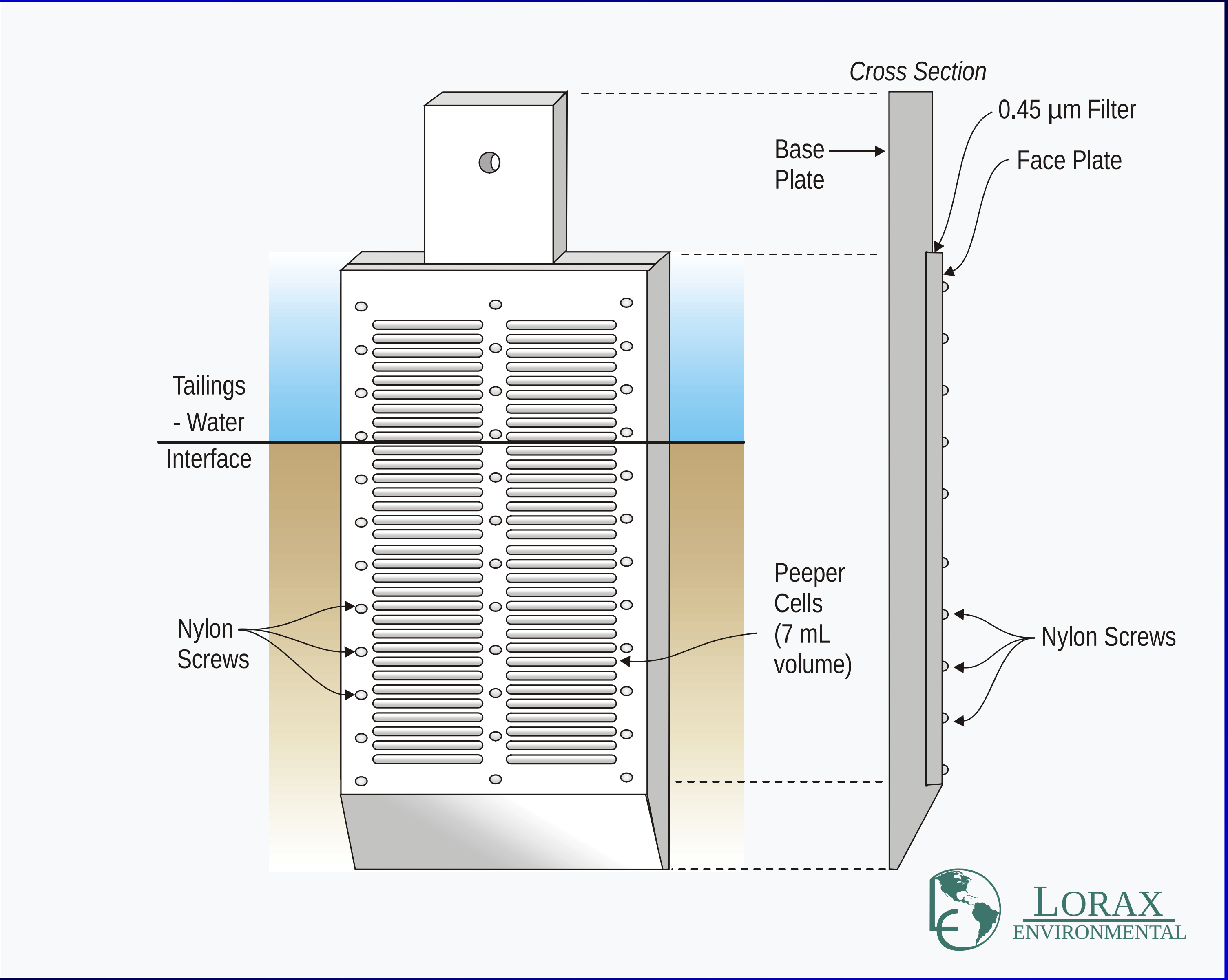
Freeze Coring: Area of direct ARD inputs

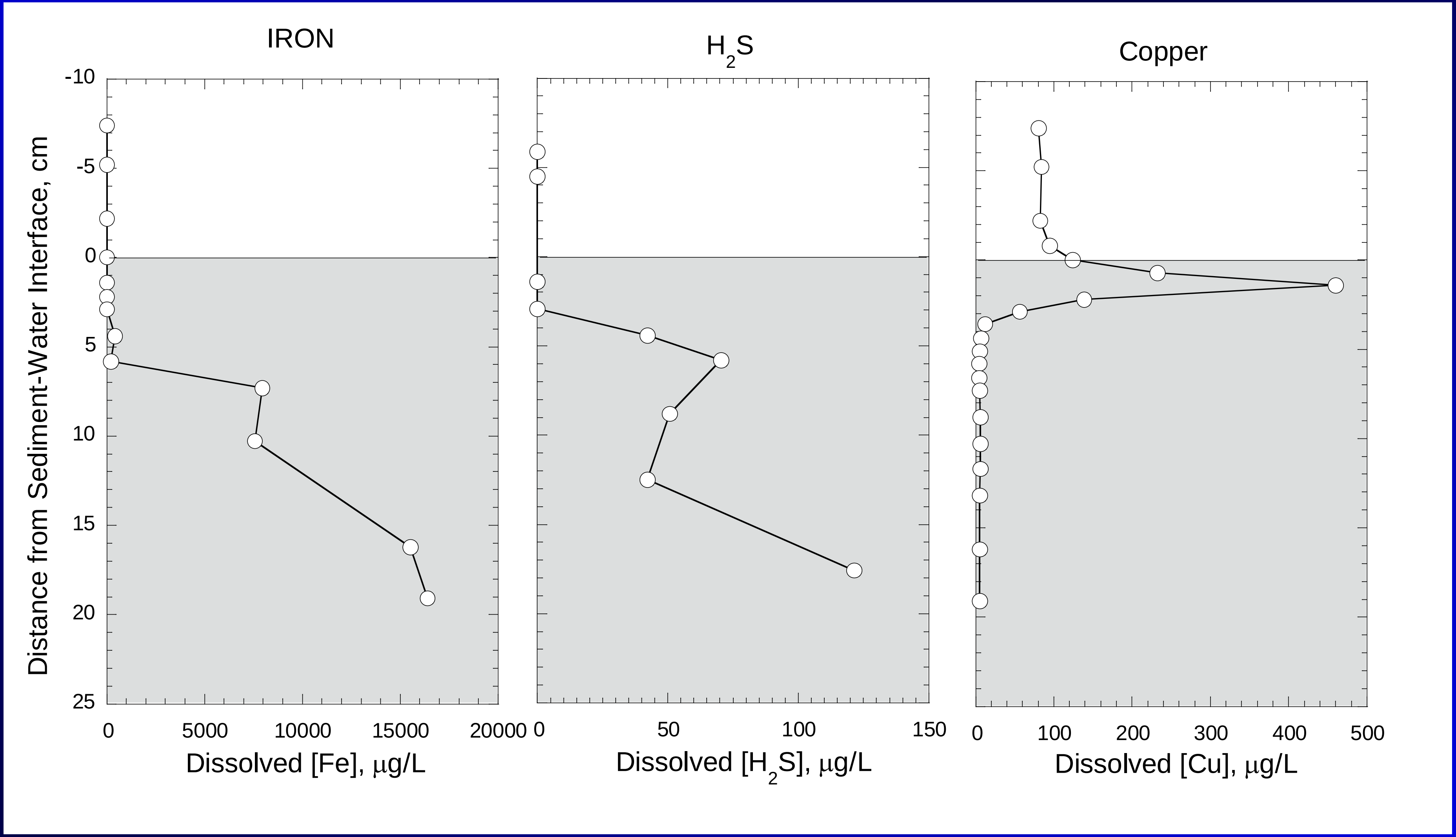
Orange silty/clay with discontinuous mm-scale grey laminations

Massive grey silty/clay tailings

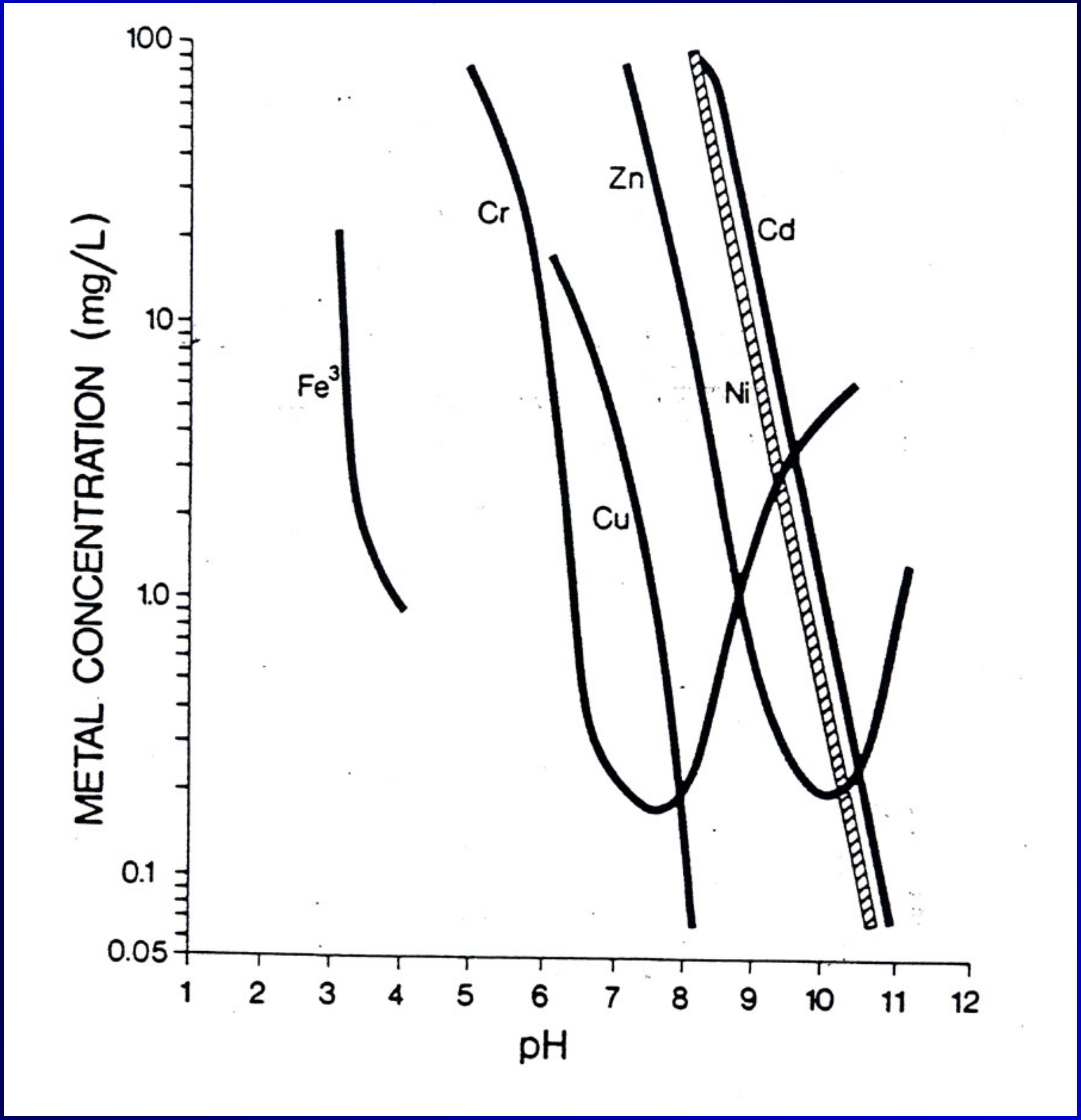
Dialysis Array Sampler (Peeper)



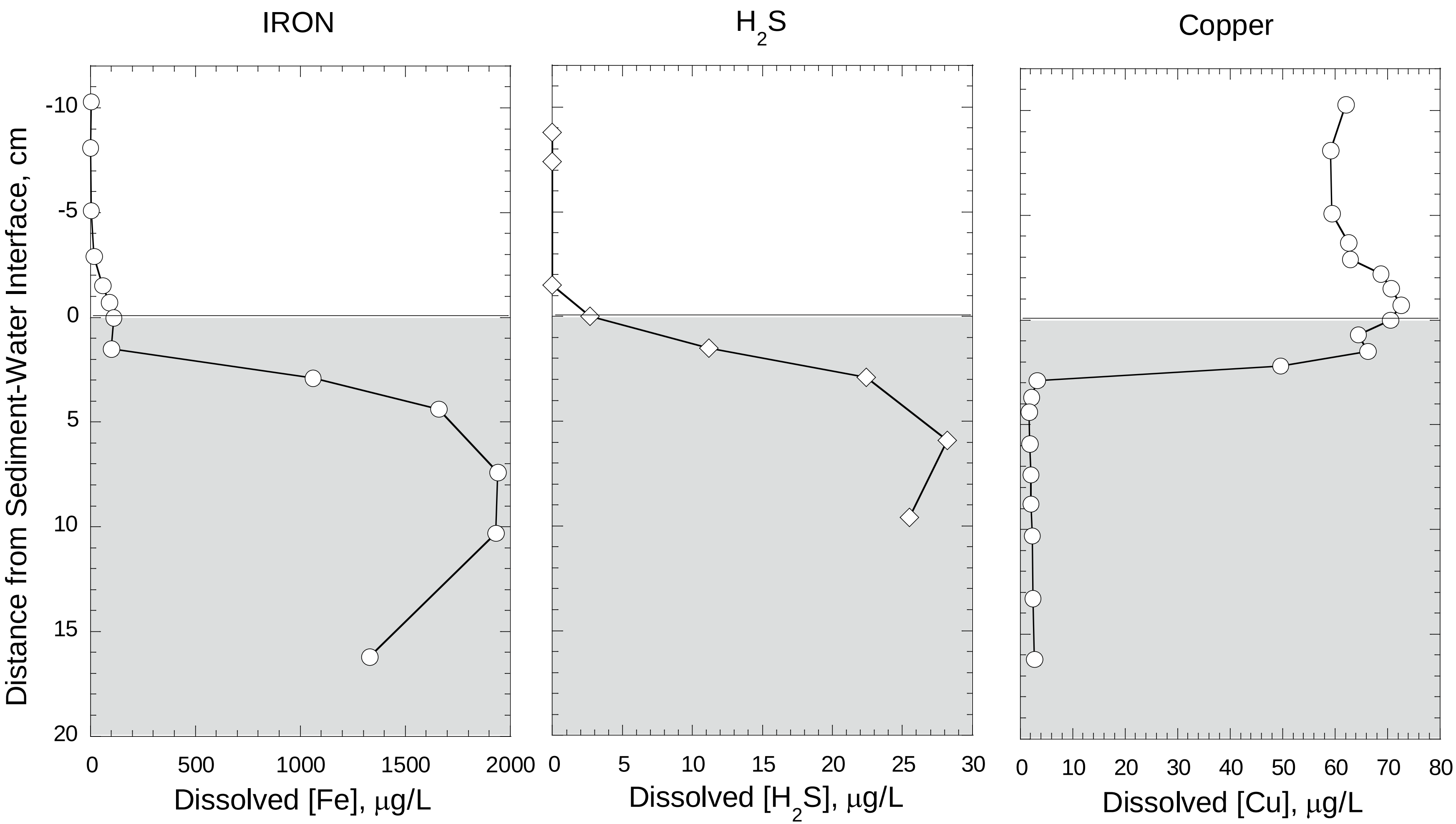
Porewater Profiles
Area proximal to direct ARD inputs



Metal Hydroxide Solubility



Porewater Profiles
Area of minimal sludge accumulation



Summary

- Continual inputs of relatively low pH meteoric waters have resulted in a pH drop during the closure period (from ~8 to 6.5 to 7).

- The pH drop has resulted in the destabilization of pH-sensitive solid phases at the tailings-water interface in areas which host metal hydroxides associated with ARD neutralization.

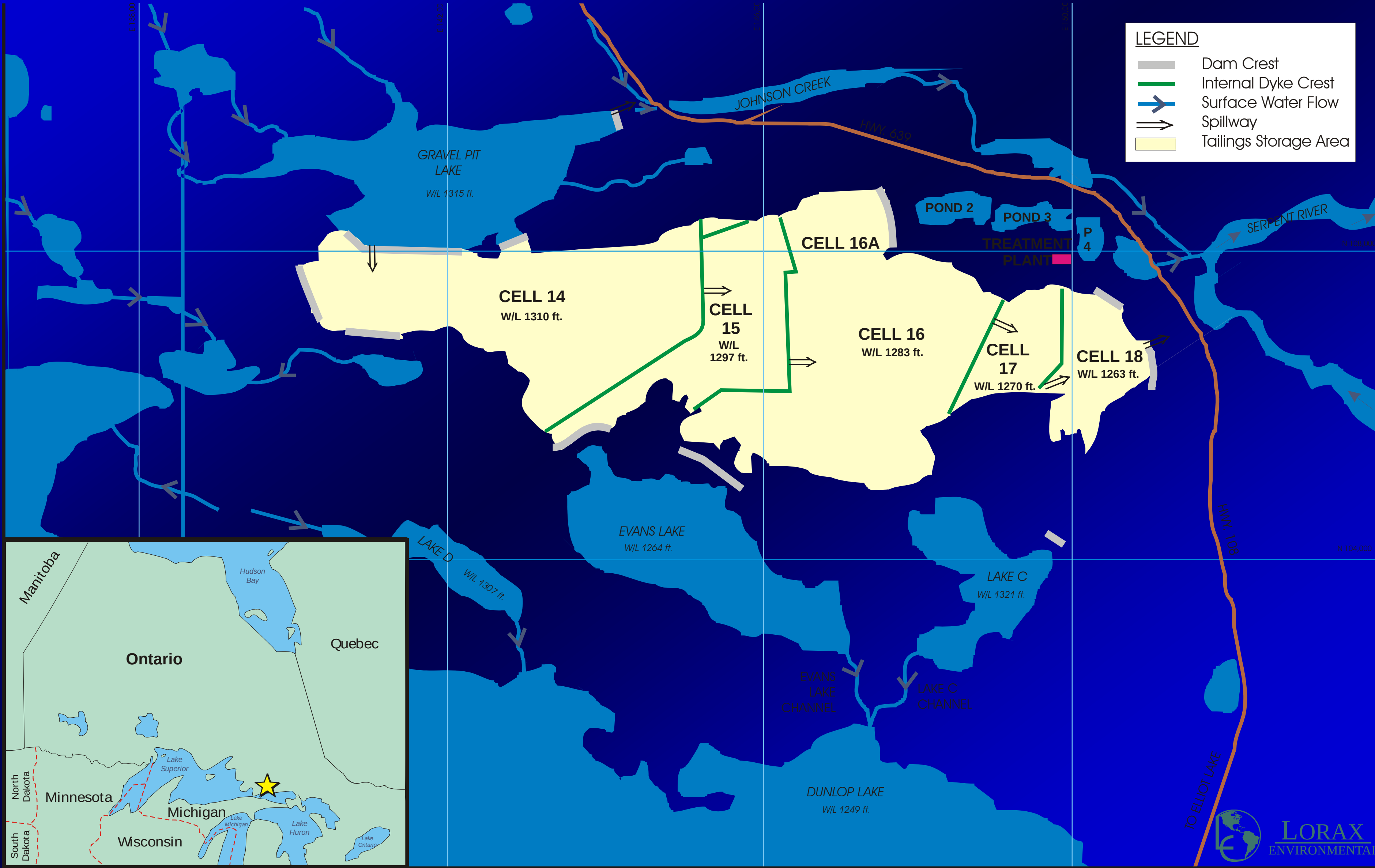
- These latter submerged deposits represent a significant and potentially long-term source of copper to the water column.

- To contrast, areas characterized by predominantly sulphide tailings with only minor sludge component are relatively stable.

I. Redox-controlled release of radium from subaqueous mine tailings

- Collaborative research project with the University of Western Ontario
- Facilitated by Dr. Ernest Yanful (Department of Civil Engineering)
- Funding provided by Rio Algom
- Acknowledgements: Art Cogan and Roger Payne (Rio Algom)

Quirke Waste Management Area



Objectives

- To determine the biogeochemical mechanisms governing the behaviour of radium in submerged uranium mill tailings
- To quantify the rate of radium transfer across the tailings water interface
- To develop remediation options if required

Background

- The Quirke Mine operated from 1956 to 1961, and again from 1968 to 1990

- Uranium ores were processed using conventional leaching with sulphuric acid and recovery via ion exchange

- Prior to discharge, the tailings stream was neutralized with lime to 8.5>pH<10.5

- In total, ~42 million tonnes of acid-generating tailings were discharged subaerially to the Quirke Waste Management Area.

- Considerable oxidation of the mine surficial tailings occurred prior to flooding

Tailings Geochemistry

- Tailings are dominated by:
  - quartz (65-95%)
  - muscovite (<1 to 8%)
  - K-feldspar (1 to 10%)
  - Calcite (<1 to 6%; from limestone applications)

- Other secondary minerals:
  - Gypsum (<1 to 17%)
  - Barite ($BaSO_4$)
  - Radiobarite (presumed to be radium source)

Environmental Setting – Cell 14

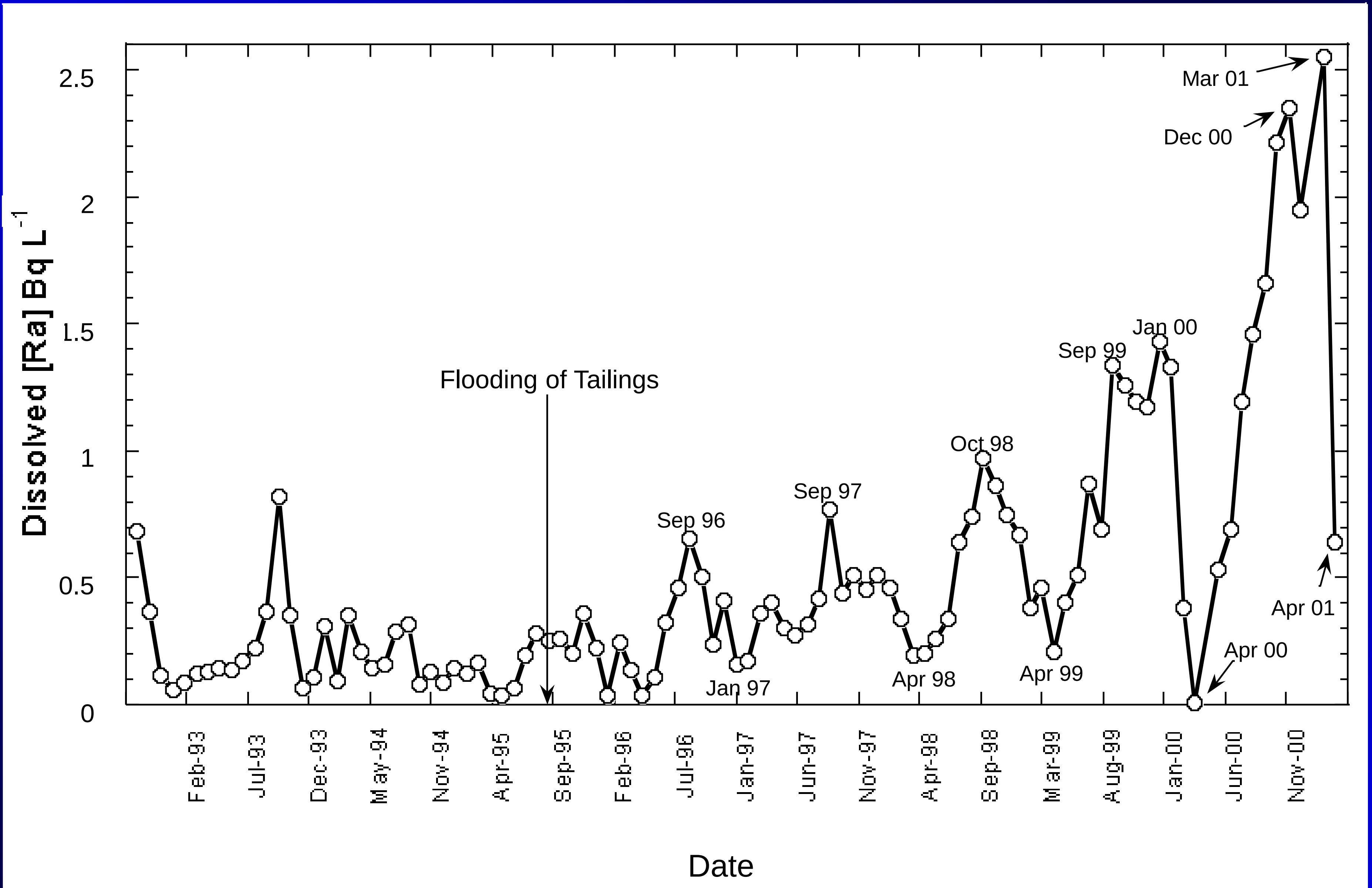
Shallow zones (<1.5 m deep):

- Sparsely vegetated sites
- Well-mixed water columns and fully oxygenated bottom waters
- Profiles of dissolved O_2, Fe and Mn indicate sub-oxic below tailings depths of ~3 cm.

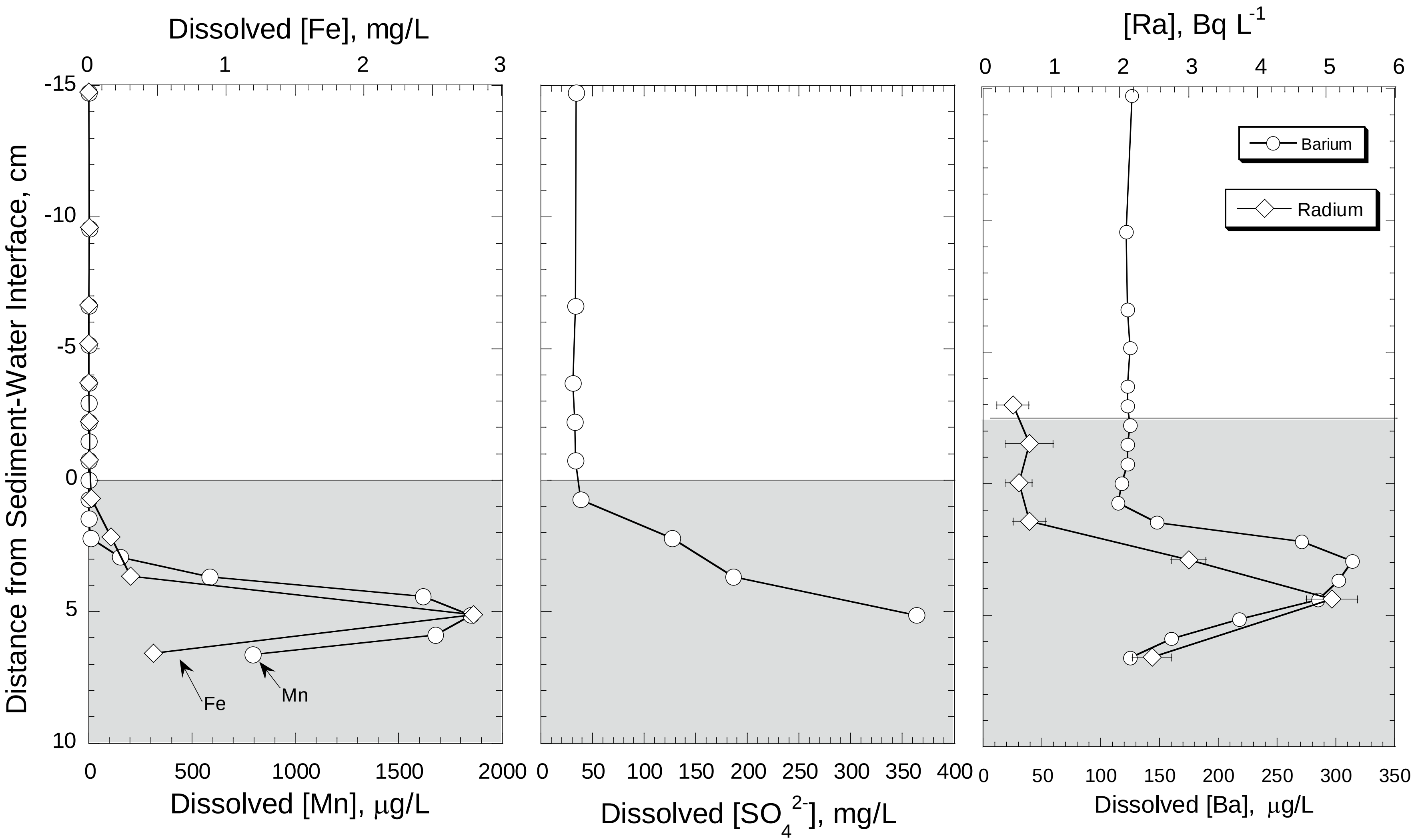
Deep zones (<1.5 m deep):

- Thick vegetation (*Chara sp.*)
- Stagnant bottom waters
- Profiles of dissolved Fe, H_2S and SO_4^{2-} demonstrated the presence of fully anoxic conditions above the tailings-water interface.

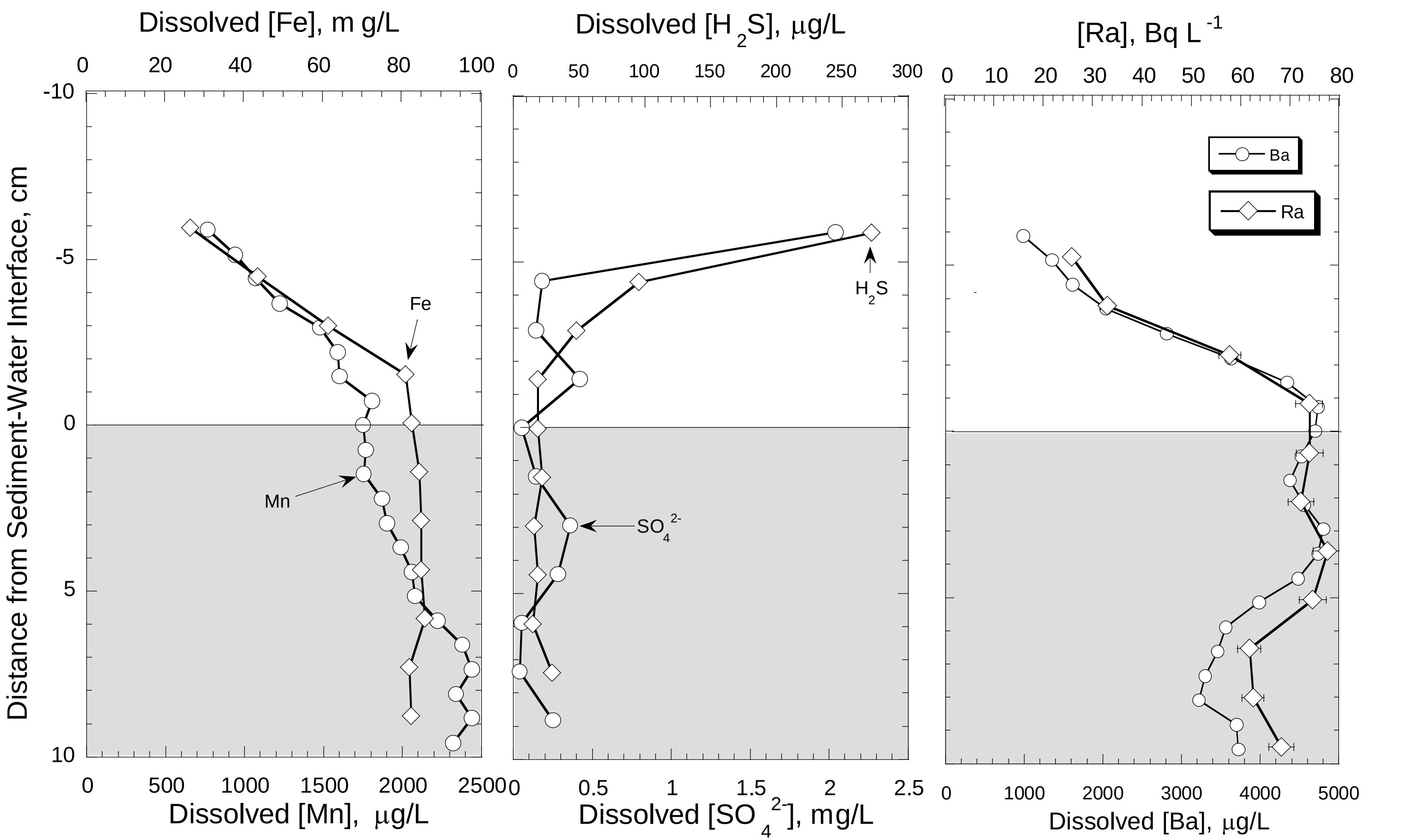
Water Column Evolution



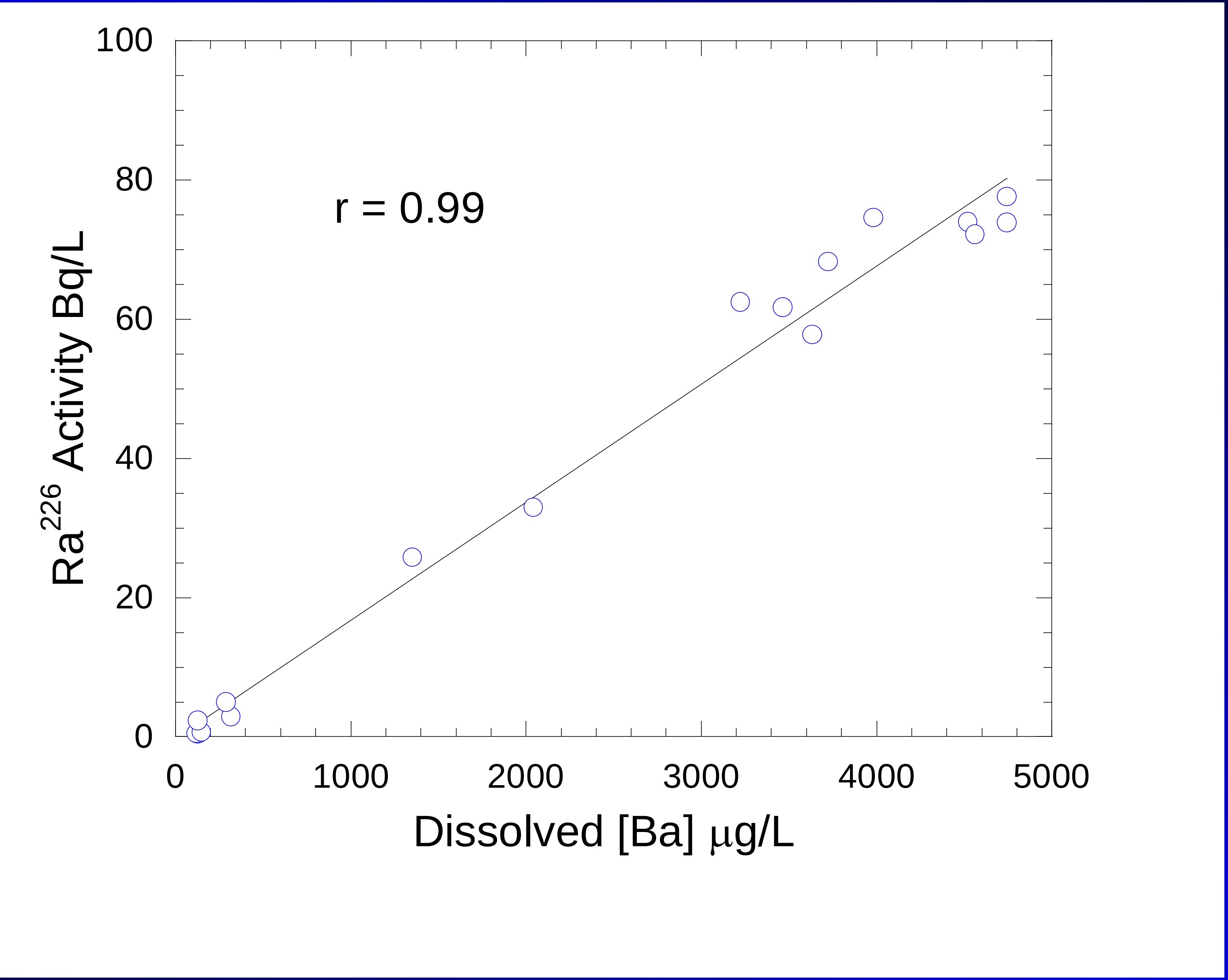
Porewater Profiles – Shallow, unvegetated area



Porewater Profiles – Deep, vegetated zones



Radium-Barium Relationship



Summary

- Two mechanisms lead to undersaturation with respect to barite, and radium mobility:

1) Diffusion of sulphate out of the porewaters at the shallow sites
2) Sulphate reduction in the deep, vegetated sites

The latter mechanism is quantitatively more significant, and contributes substantially more ^{226}Ra to the water column

- Flux calculations suggest that the rate of radium transfer from the vegetated tailings to the water column can account for the observed water column inventory:

Summary cont.

- The data suggest that the increase in radium mobility can be related to increases in the spatial extent and density of benthic flora.

- The spatial distribution and density of benthic flora appears to be limited by the formation of ice in the winter months

- The tailings represent a significant and potentially long-term source of Ra to the water column. Such conclusions have important ramifications with respect to waste water treatment and radiological exposure.

What Have We Learned?

- Profound shifts in the physical, chemical and biological environment can occur between operational and closure periods

- Highlights the need to conduct rigorous examination of both the waste material and the receiving environment.

- Highlights the dangers associated with lab-scale predictive testwork.

- The inherently complex nature of natural systems requires that *in situ* examinations be conducted when ever possible.

- Materials Balance Sheet: important to keep an accurate record of the types of materials discharged, and the area of placement