Post-Closure Mobility of Arsenic in Mine-Impacted Lake Sediments

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Introduction

- Collaborative research project with the University of British Columbia (Tom F. Pedersen)
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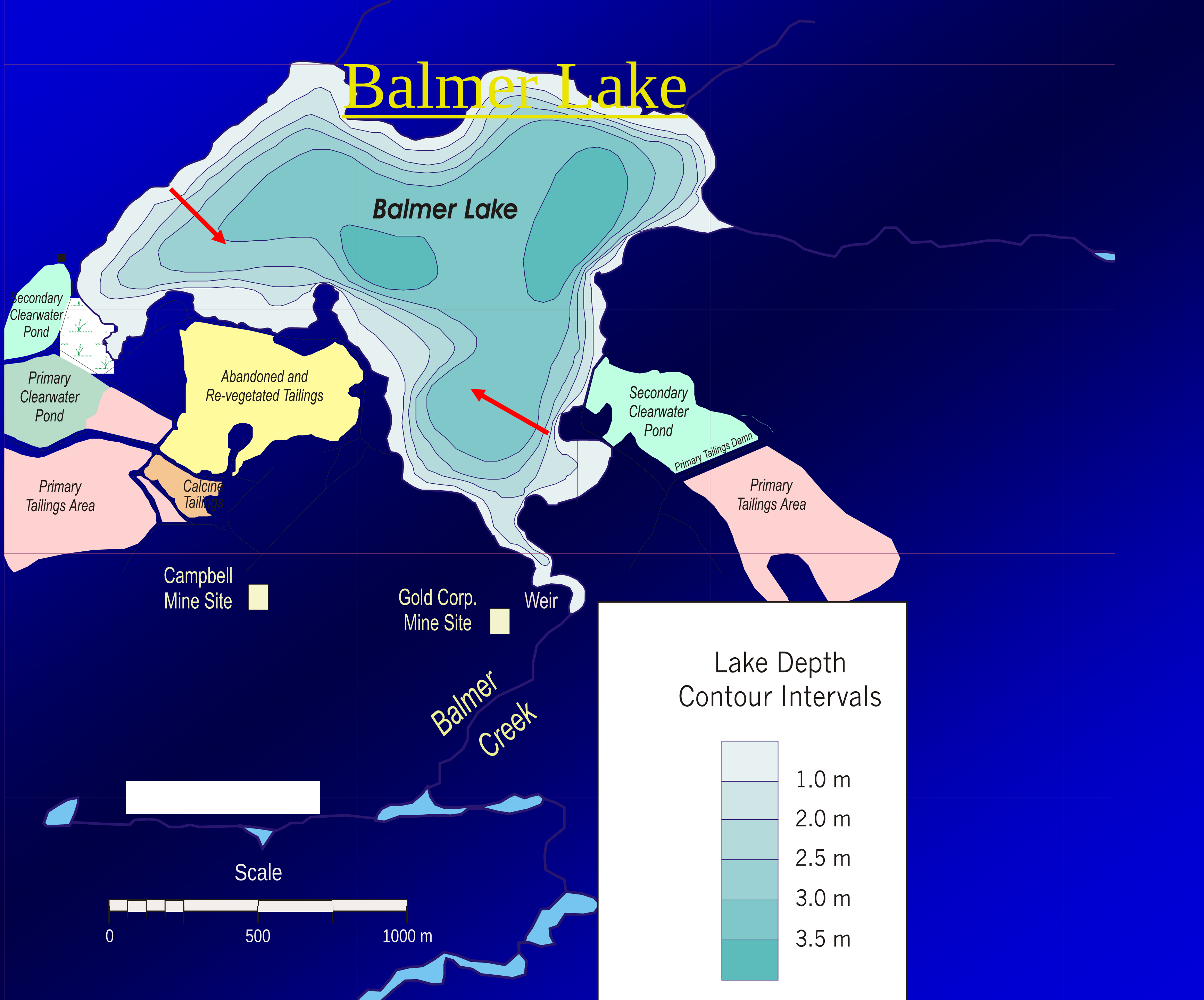
John Jambor (LRC)

Figure 2-1

Study Location Map

Source: Calvin Price, PDI

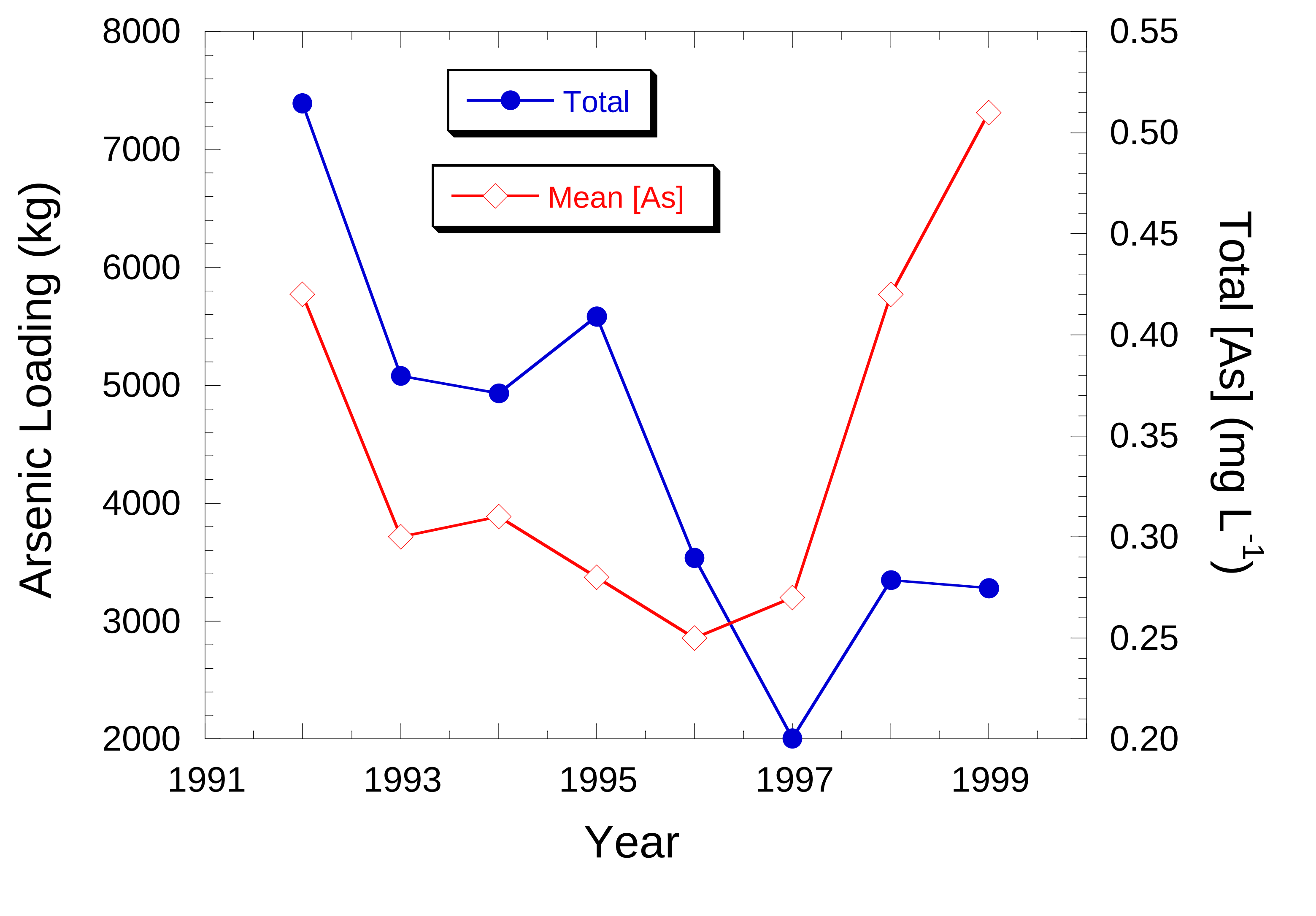
Balmer Lake


Balmer Lake
Secondary Clearwater Pond
Primary Clearwater Pond
Abandoned and Re-vegetated Tailings
Primary Tailings Area
Calcine Tailings
Secondary Clearwater Pond
Primary Tailings Damn
Primary Tailings Area
Campbell Mine Site
Gold Corp. Mine Site
Weir
Balmer Creek
Lake Depth Contour Intervals
1.0 m
2.0 m
2.5 m
3.0 m
3.5 m
Scale
0
500
1000 m

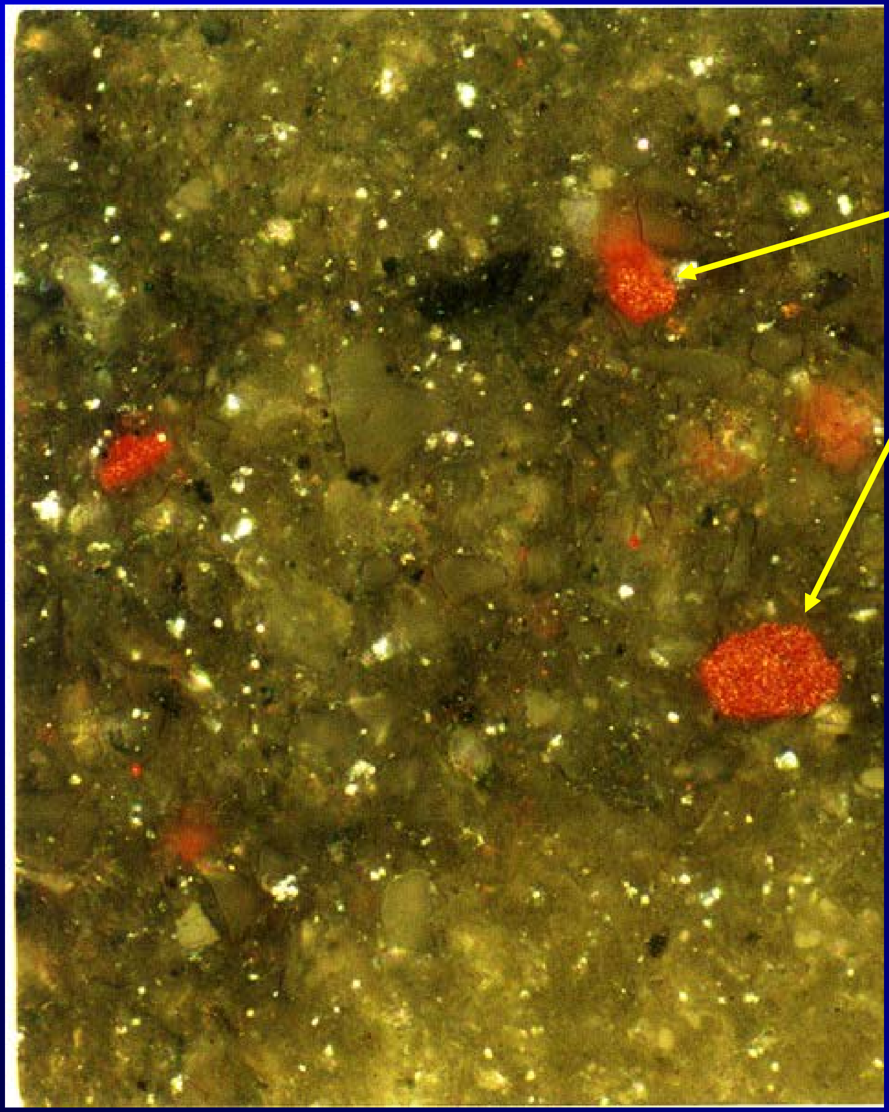
History of Mining-Related Inputs

- Direct tailings deposition prior to 1970
- Tailings pond overflow
- Treatment products (INCO-SO_2 processing)
- Blasting reagents
- Domestic greywaters and sewage
- Groundwater inputs from perched tailings deposits

Water Column Evolution



Mineralogy

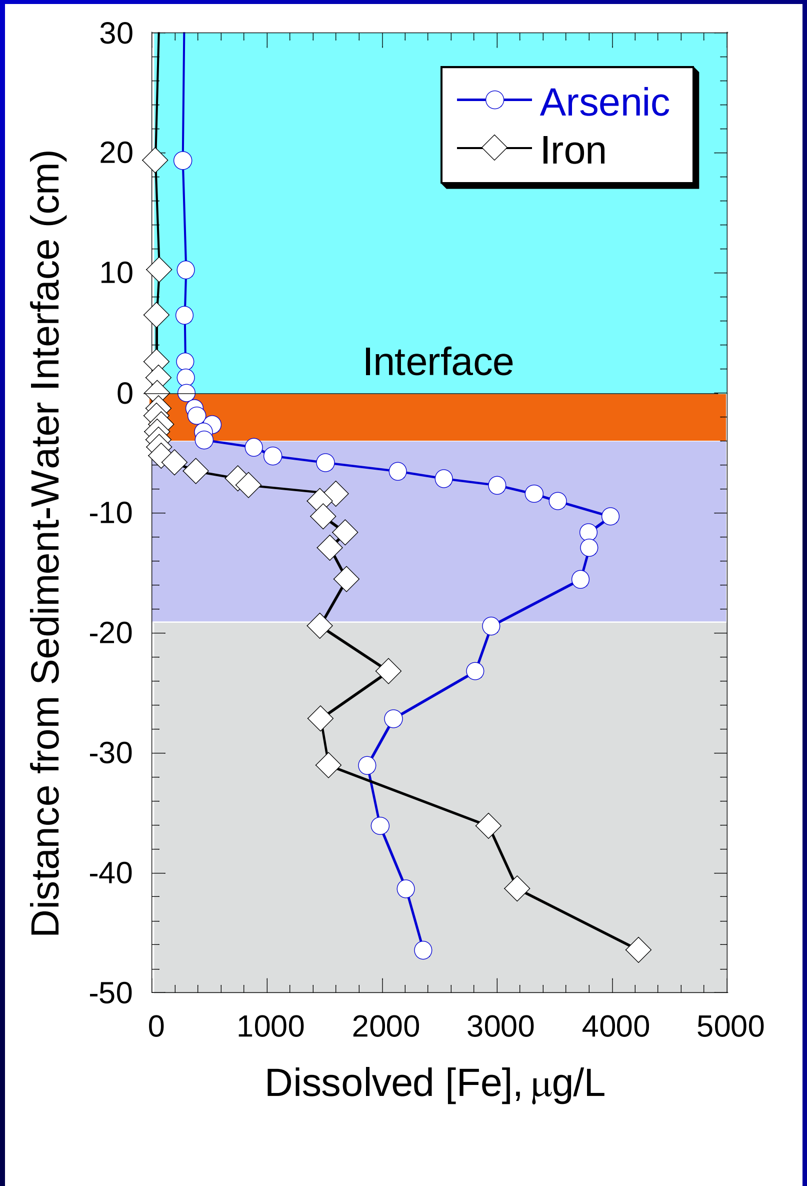


Sponge-texture hematite, hosting between 0.6 to 6.4 wt.% arsenic

- Arsenic concentrations in surface sediments ranging from 2,500 to 5,000 ppm

- Organic-rich sediments ~10 wt.% organic carbon

Arsenic Behaviour

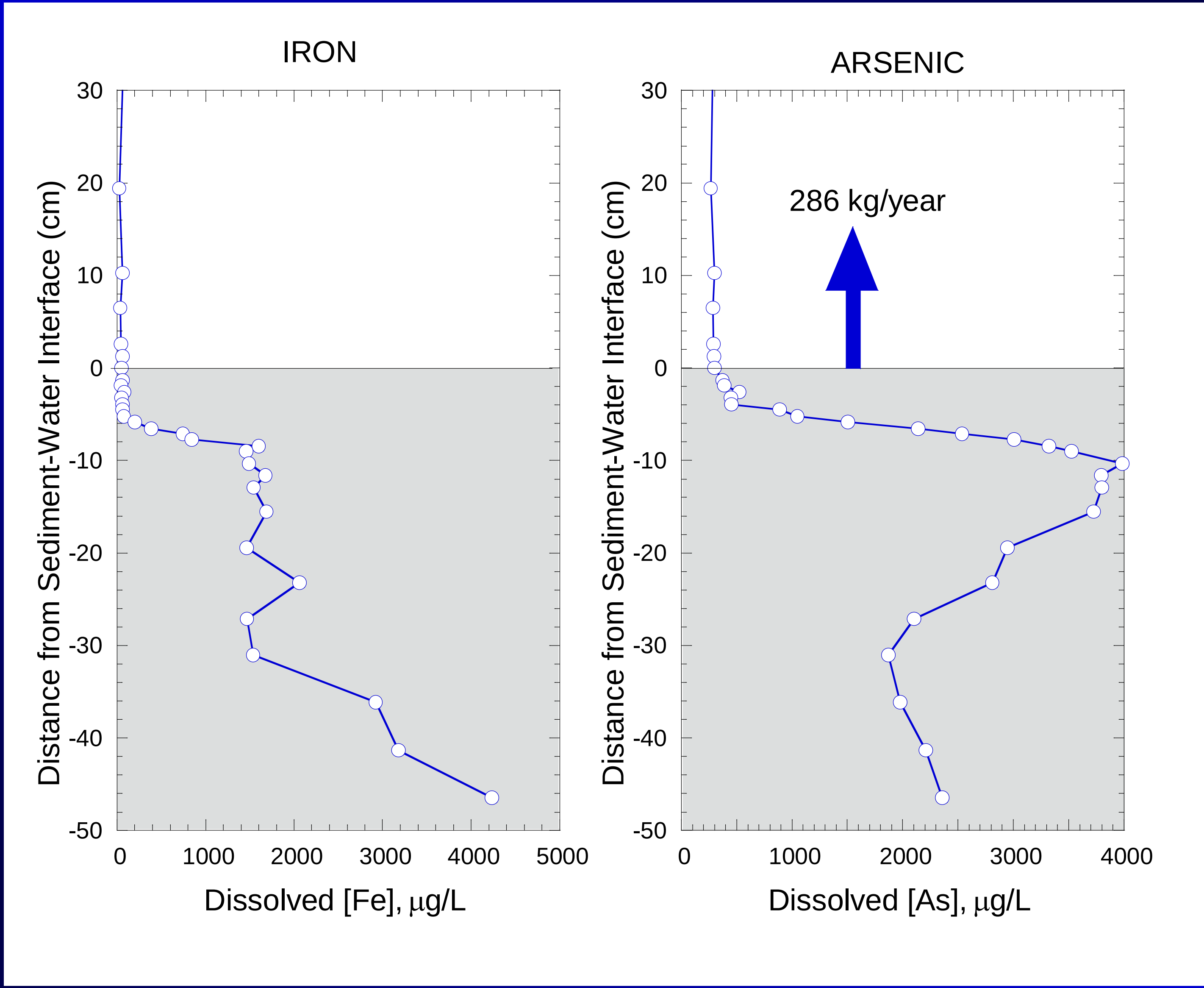


Re-precipitation in oxic interfacial horizons

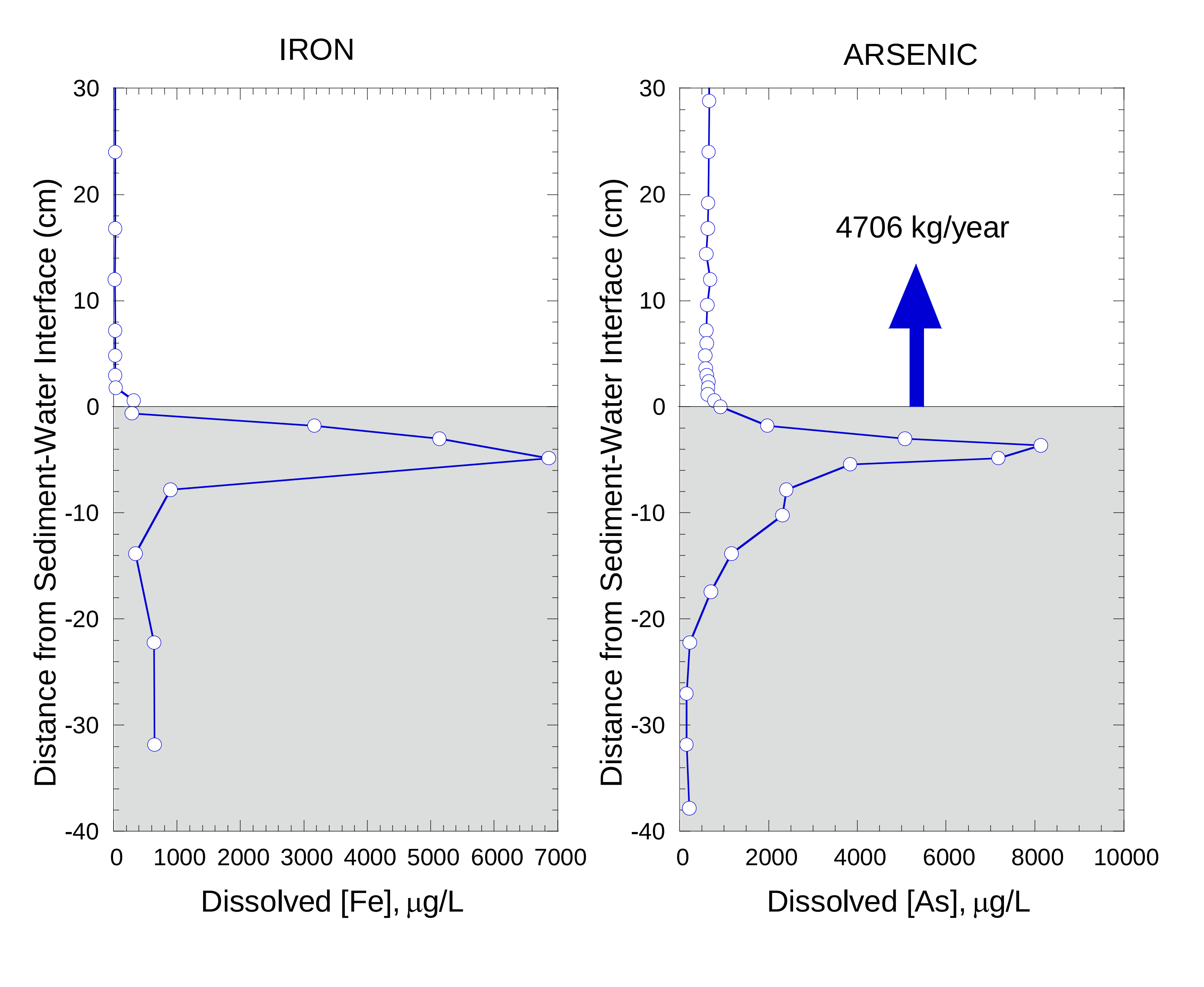
Remobilization via the reductive Dissolution of hydrous Fe-oxides

Removal from pore solution via precipitation of As-sulphide phases

Porewater Profiles 1993-94



Porewater Profiles 1999



Flux Calculations

Rates of diffusive transfer to the water column were calculated using Fick's Law of Diffusion:

Where the rate of diffusive transport (flux) =

$$\text{Flux} = \frac{D^o_j}{F}\,\phi\,\frac{dc}{dz}$$

D^o_j = temperature corrected *in situ* diffusion coefficient

$\bar{F}$ = formation factor (tortuosity) for silty clay

ϕ= sediment porosity

$\frac{Dc}{dz}$ = concentration gradient across the sediment-water interface

Water Column Impact

- 1993-94: Arsenic flux could contribute approximately 2-15% of water column inventory.
- 1999: Arsenic flux could contribute at least 60% of water column inventory

Therefore:

Although *rates* of As remobilization have not changed considerably since 1993, the data suggest that diffusive *fluxes* to the water column have increased in recent years.

Consistent with observations of decreased inputs of effluent-derived arsenic over the 1993-99 period.

Alteration to Redox Conditions

It is postulated that a shift in redox conditions occurred as a result of increased productivity in the water column.

Increased primary production

↓

Increased accumulation of organic matter

↓

Increased sediment oxygen demand

↓

Decreased thickness of oxic sediments

↓

Decreased sorptive capacity for upward diffusing arsenic

↓

Increased As flux to water column

Trophic Status

Classification of Lakes into Trophic State Based on Summer Surface Averages (Yeasted and Morel, 1978)

	Oligotrophic	**Mesotrophic**	**Eutrophic**	**Balmer Lake**
TP (µg/L)	<10	10-20	>20	30
TN (µg/L)	<350	350-650	>650	2,000
Chl (µg/L)	<4	4-10	>10	18

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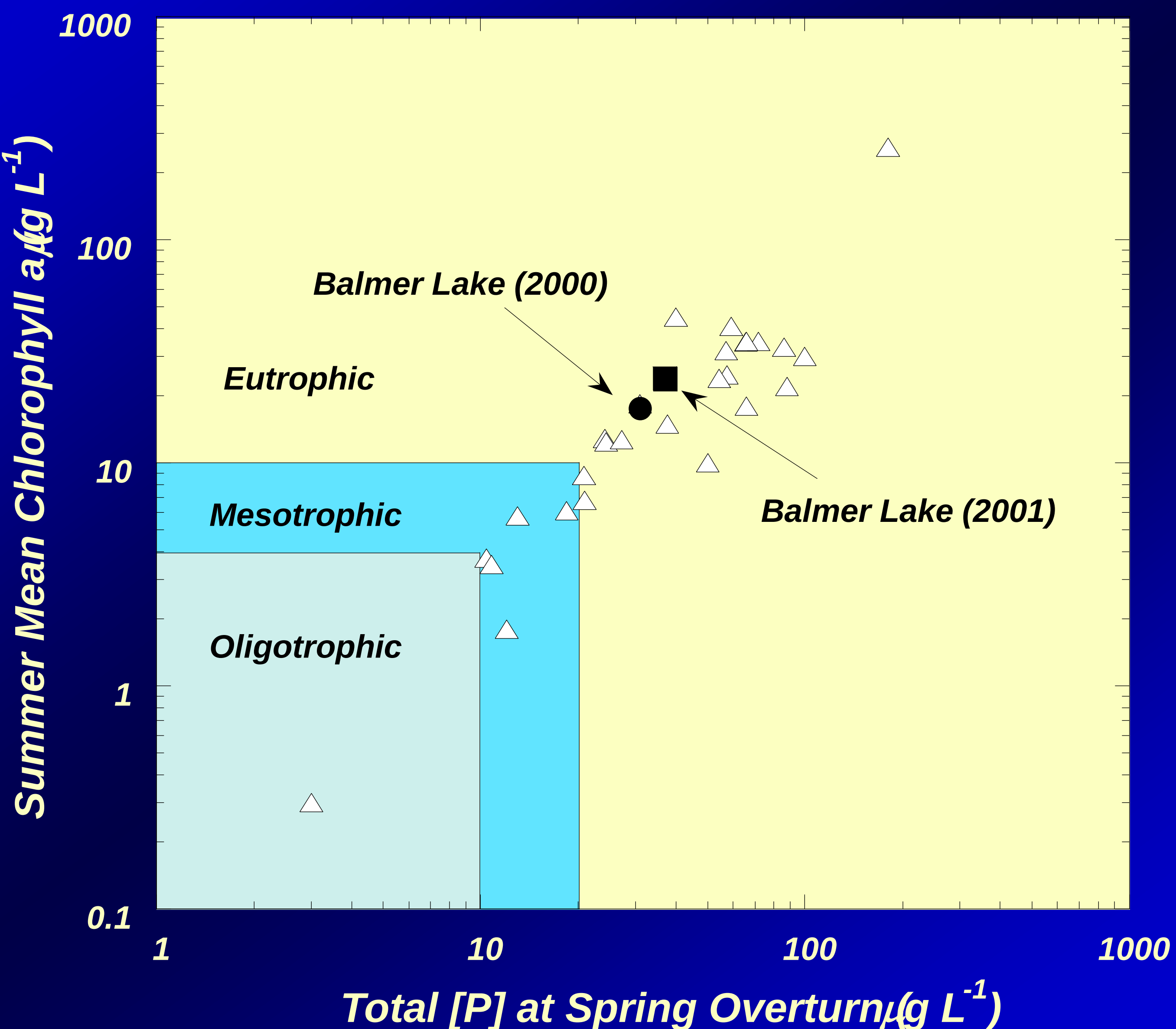
Role of Phosphorus in Lake Eutrophication



Phosphorus Budget

Natural Loading: Direct precipitation Run-off	~200 kg per year
Mine-Related Loading: Placer Dome Inc. Goldcorp Inc.	150 to 300 kg per year

Therefore, mining-related inputs have profoundly altered the phosphorus budget in Balmer Lake

Water Column Trace Metals

Parameter	May, 1994	August, 1999
Dissolved Metals (μg/L)		
Cu	195	12
Ni	395	29
Zn	60	2

Lake Remediation

- Reduce P-loadings (*i.e.*, *sewage)* to the system

- Suggest to reduce P loadings to within 10% of estimated background

  - This implies reducing the collective P loadings from the two adjacent mine sites from ~150 kg y^{-1} to <20 kg y^{-1}

- A push towards more reducing conditions (i.*e*., enhanced sulphide precipitation is not recommended.

Conclusions

- The release of sediment-derived As appears to have increased in recent years in response to alterations to redox conditions.
- More reducing conditions (i.*e*., higher SOD) are suggested to have resulted from increased primary productivity in the water column.
- The changes represent an ironic consequence of improved water quality in Balmer Lake

What have we learned?

- Biological and geochemical processes are intimately linked in mining impacted systems (e.g., Balmer Lake, Quirke Management Area).
- Alterations in to the receiving environment post closure can result in enhanced metal mobility.
- The geochemical sensitivities of elements and phases of concern must be carefully examined in relation to potential changes which may occur in the receiving environment.
- Monitoring programs must be tailored to address site-specific conditions in order to anticipate contaminant behaviour.