Arsenic discharge from an historic gold mine site, Waiuta, Westland

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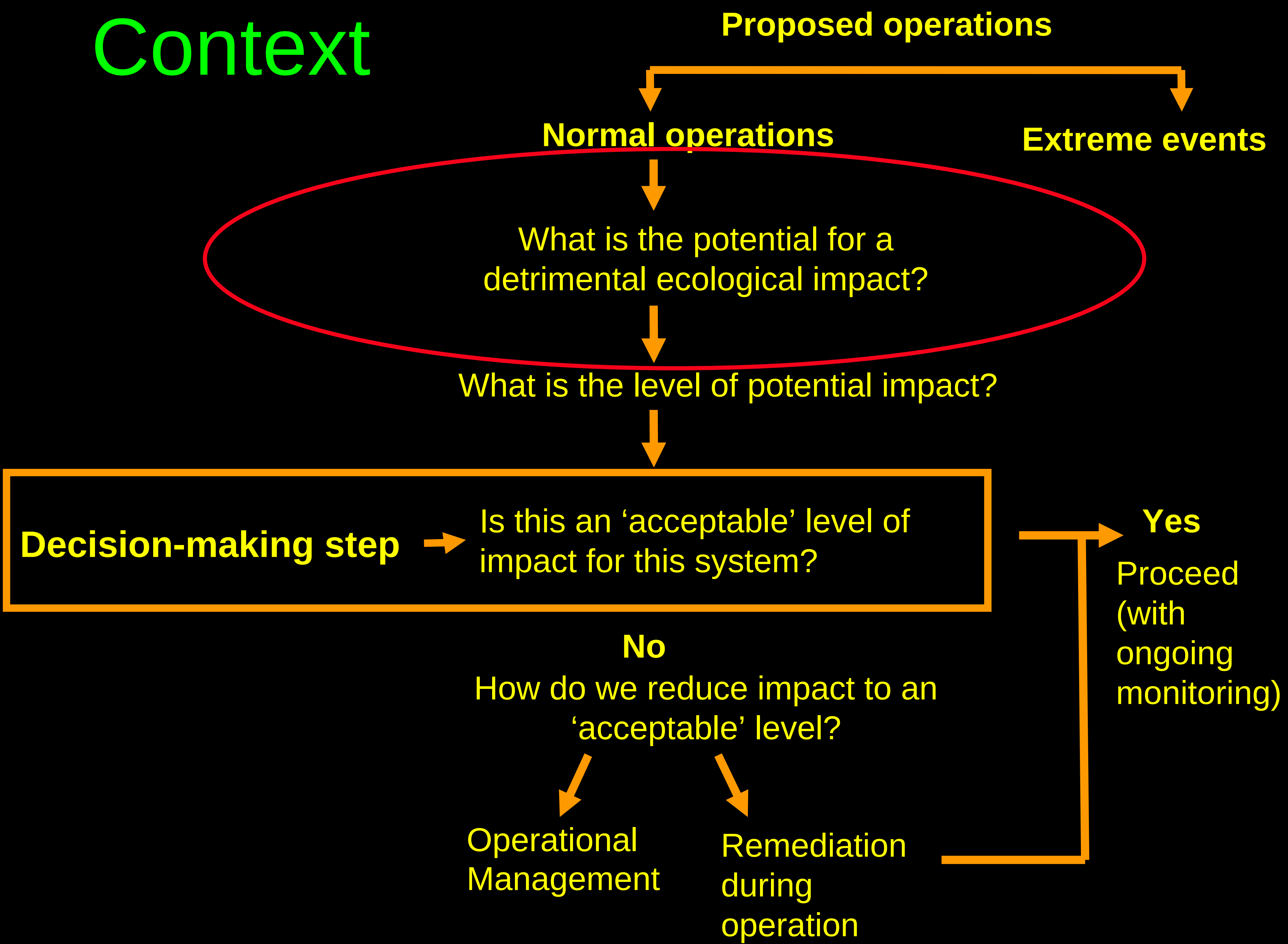
Mine drainage framework

Context



Proposed operations
Normal operations
Extreme events
What is the potential for a detrimental ecological impact?
What is the level of potential impact?
Decision-making step
Is this an 'acceptable' level of impact for this system?
Yes
Proceed (with ongoing monitoring)
No
How do we reduce impact to an 'acceptable' level?
Operational Management
Remediation during operation

Introduction

- Part of a PhD project
- Focus: Arsenic mobility at historic mine sites

→ Close association of the arsenic and gold
concentrating gold = concentrating arsenic

→ Arsenic-rich processing residues
unrestricted disposal at historic sites

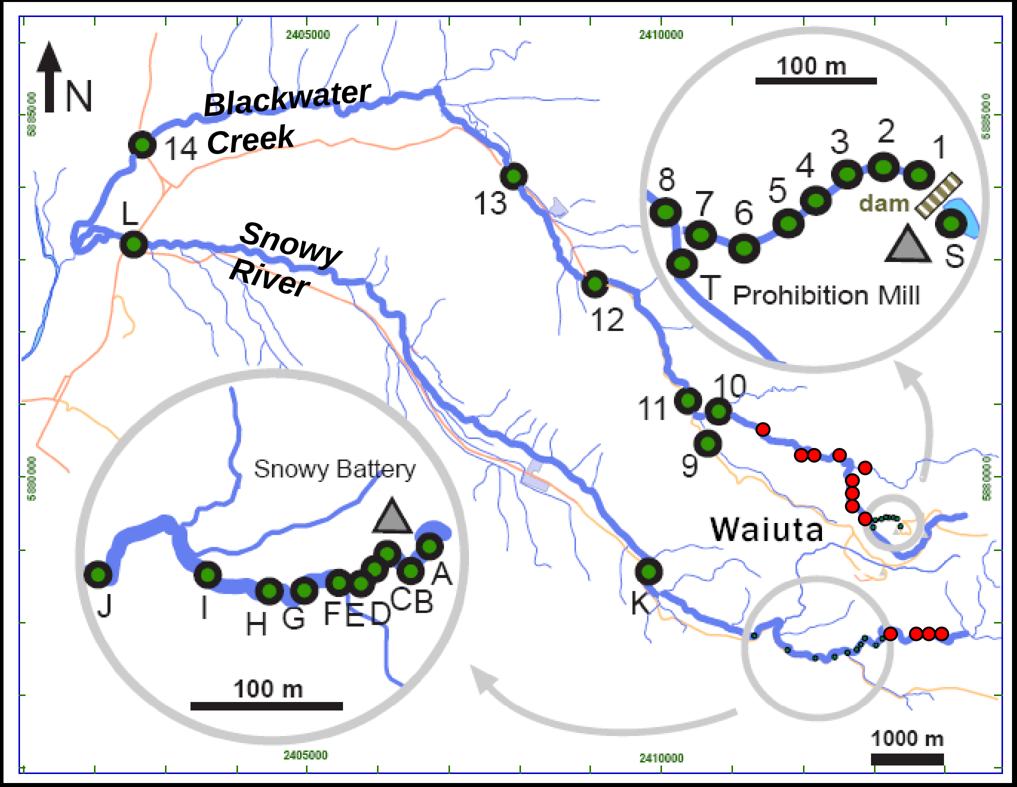
Introduction

- Hard rock gold deposits
- Host rock: Greenland Group metasediments (contain carbonates)

- Prohibition Mill site: 1938 – 1951
- Arsenopyrite-rich ore

Methodology - sampling

- A range of solid samples from processing plant, substrate and wetland
- Water samples:

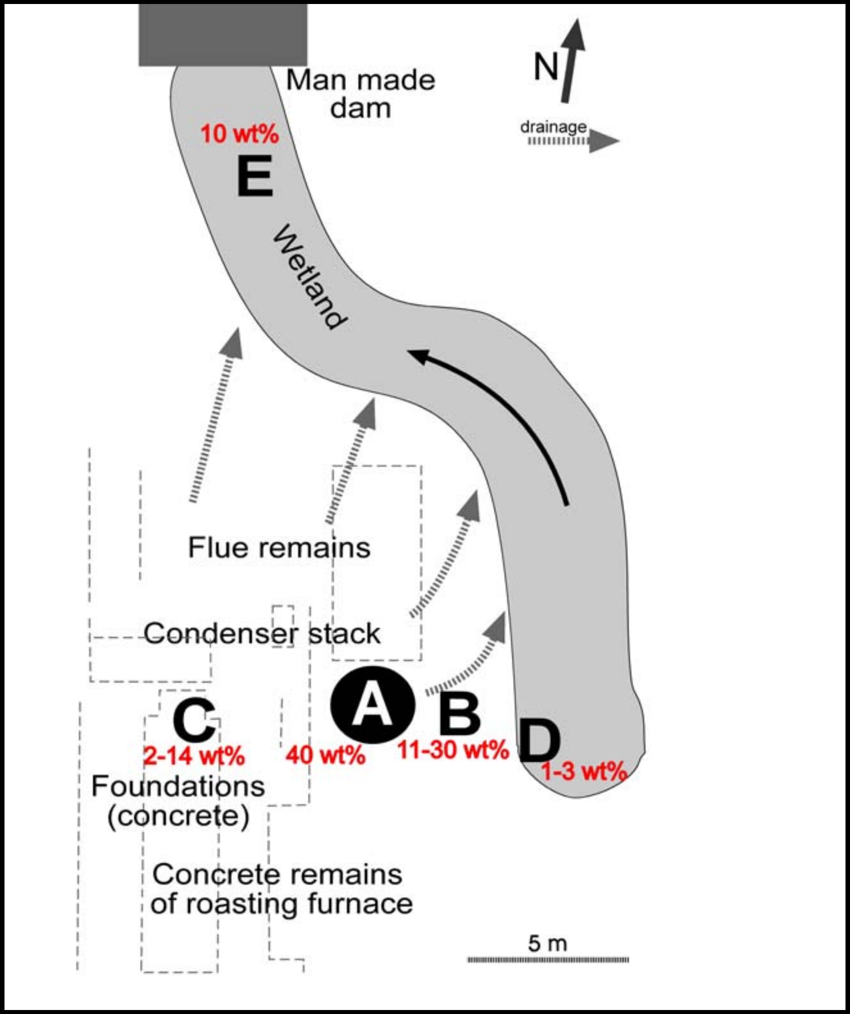


Methodology - analysis

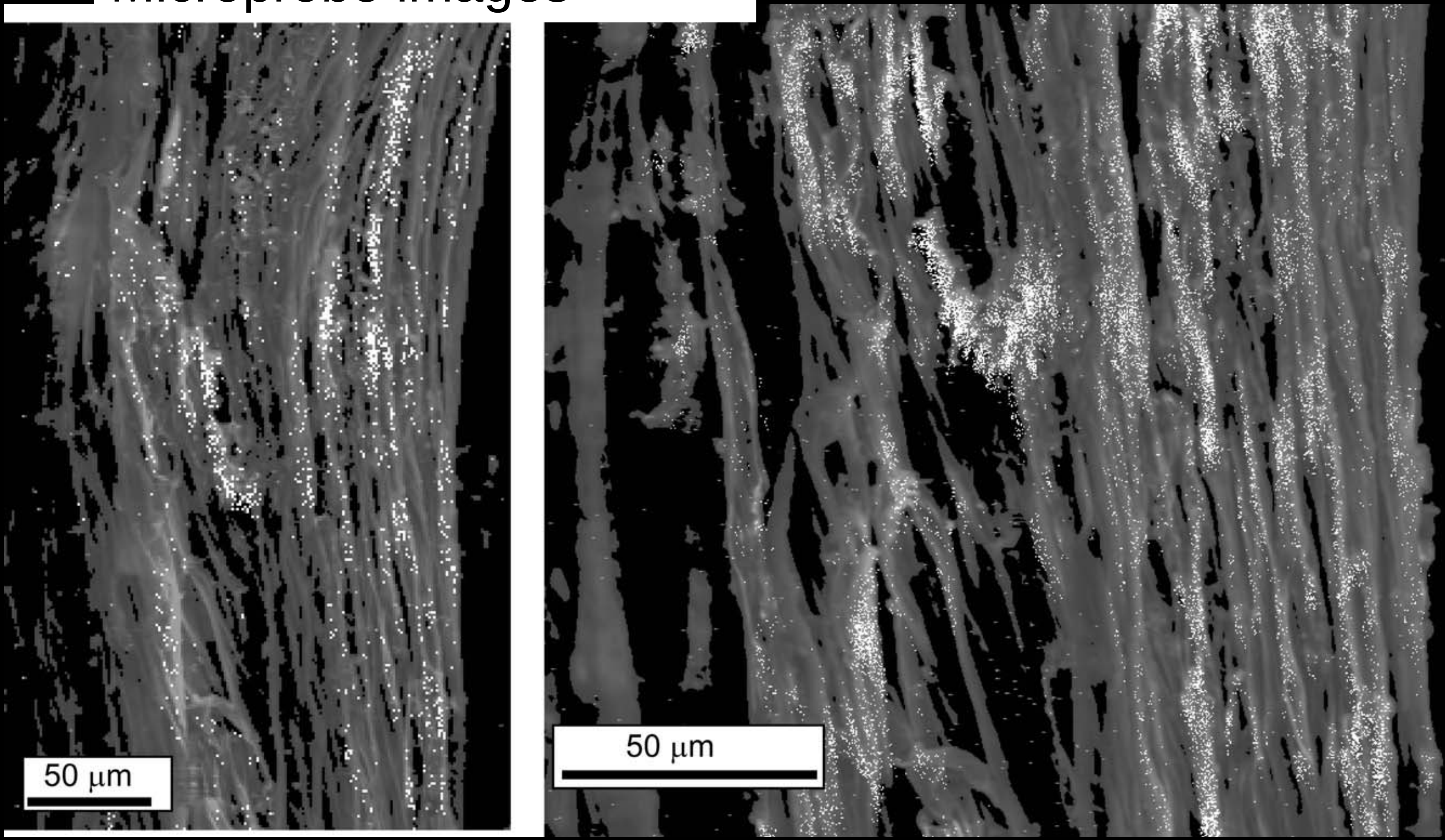
Method	Purpose
Solid samples	
- ICP-MS	Total arsenic concentration
- XRD	Mineral identification
- Microprobe	Micro-scale imaging for arsenic phase characterisation
- Handheld XRF	Arsenic distribution and extent in substrate
Water samples	
- Filtering (< 0.45 μm)	Separation of solid from dissolved arsenic
- ICP-MS analysis	Dissolved arsenic concentration
- Major ion profile	General water quality
- pH (in situ)	

Selected results

Arsenic in solids: *concentrations*



Moss, *Pohlia wahlenbergii*
Microprobe images



Moss As:
0.8-3.1 wt%

Water As:
50-77 mg/L

Substrate As:
3-16 wt%

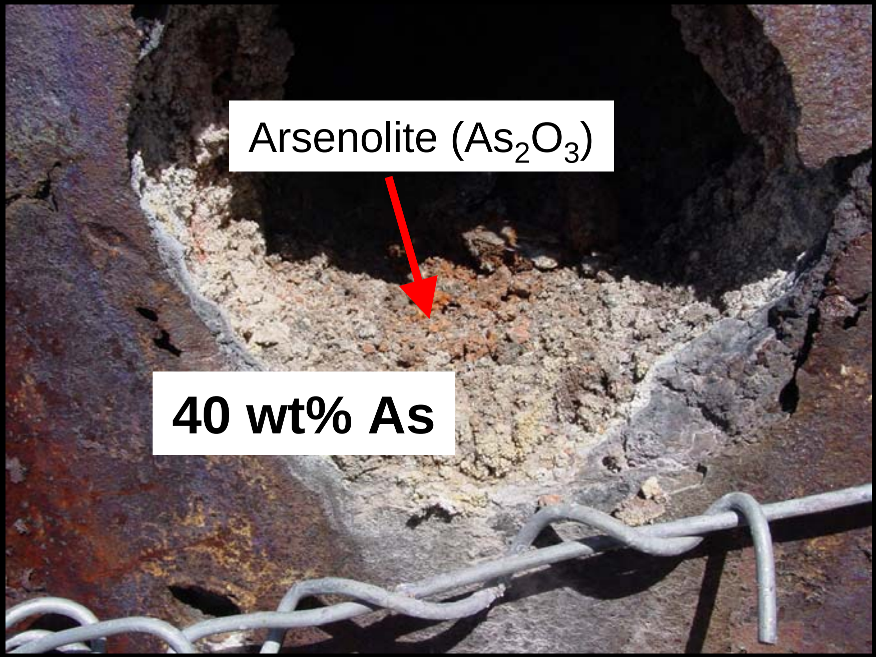
Intake of ca. 0.2 g of this material could be fatal

→ Human access has to be prevented

Selected results

Arsenic in solids: *mineralogy*

Roaster



Substrate

Arsenolite - roasting by-product

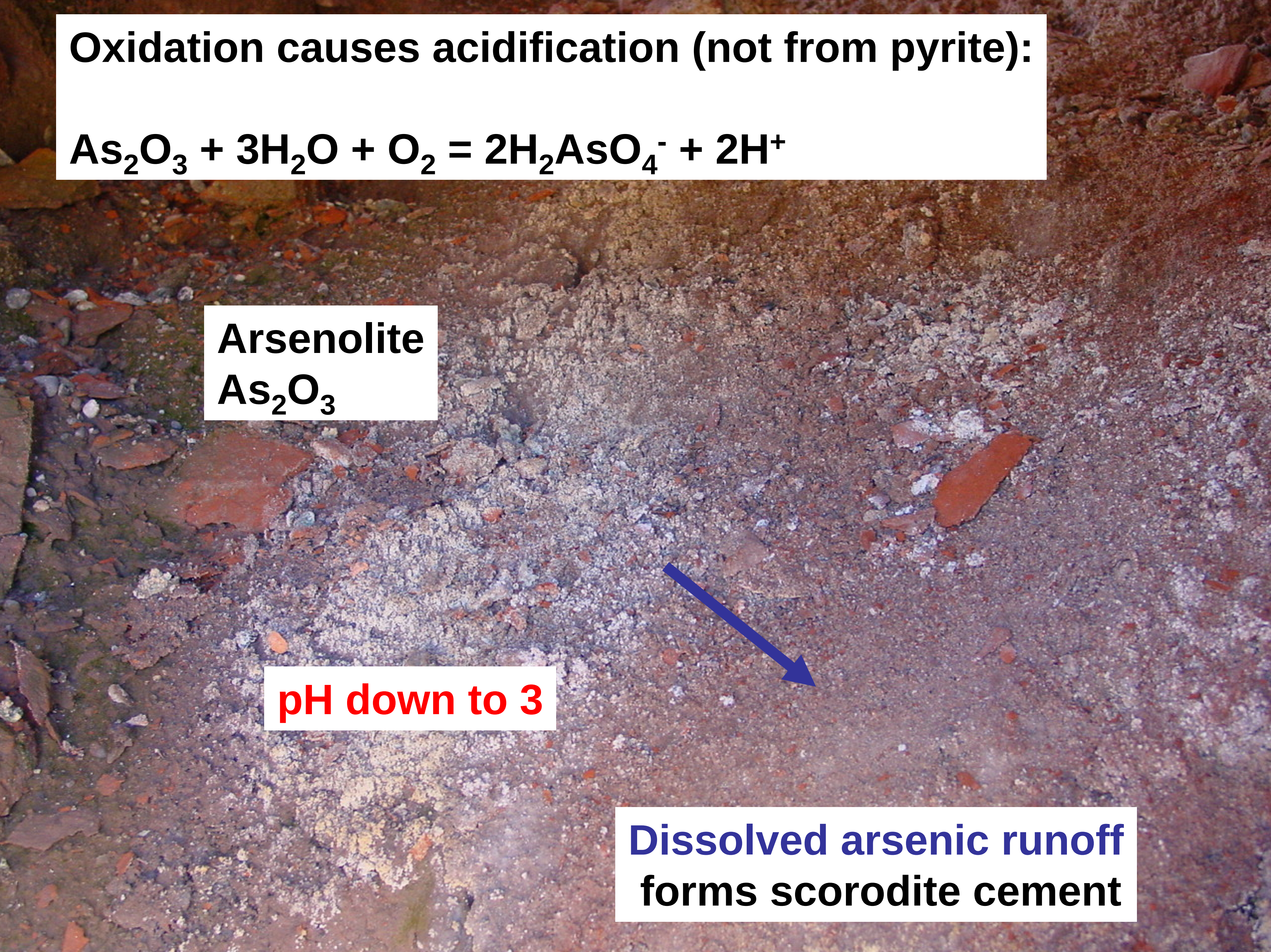
Occurrence: roaster and its vicinity, wetland (below surface layer)

Scorodite - common secondary arsenic mineral

Occurrence: mainly as substrate cement

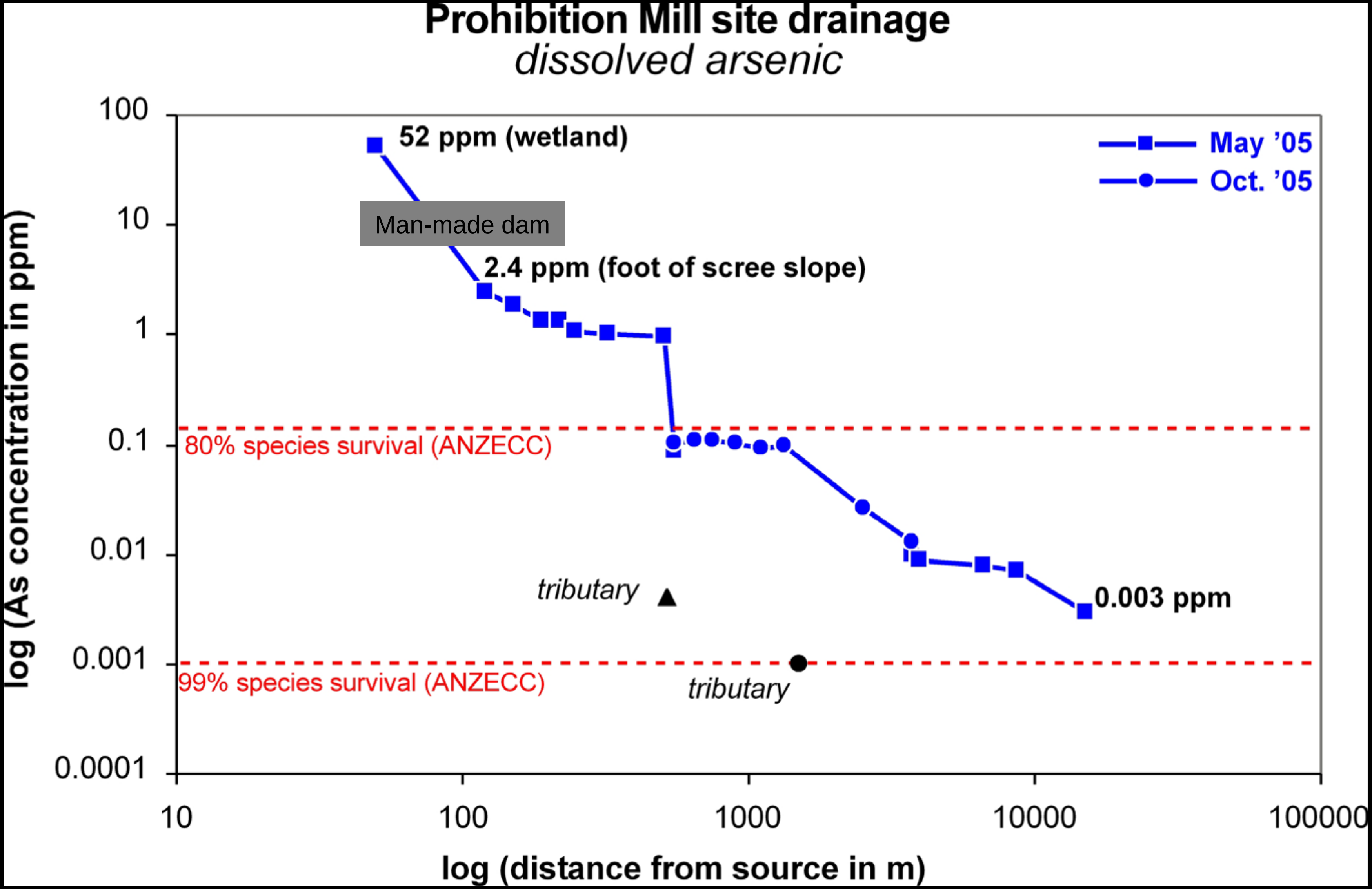
Oxidation causes acidification (not from pyrite):

$$As_2O_3 + 3H_2O + O_2 = 2H_2AsO_4^- + 2H^+$$



Selected results

Arsenic in water:



Local controls on site impact

<u>Controls</u>

Arsenopyrite-rich ore

↓ *Roasting of ore* — *Processing techniques*

Arsenolite (As_2O_3)

↓ *Dissolution* — *Exposure*

Dissolved arsenic

↓ *Precipitation* — *High dissolved arsenic, acidity*

Scorodite ($FeAsO_4 \cdot 2H_2O$)

Large volume of arsenic temporarily immobilised as scorodite

Management perspective: Removal of arsenolite lowers dissolved arsenic concentrations and increases pH
→ Scorodite becomes unstable → remobilisation of arsenic

Local controls on site impact

Processes in the man-made dam

Wetland

- High dissolved arsenic (52 mg/L)
- Acidic (pH 3-4, from arsenolite oxidation)
- Carbonate defficient

Man-made dam: Greenland Group boulders

- Dissolution of Fe-bearing carbonates:
  → Dissolved Fe
  → Neutralisation
- Precipitation of Fe (insoluble at circum-neutral pH) as iron oxyhydroxide (HFO)
  → Adsorption of arsenic onto HFO (passive treatment)

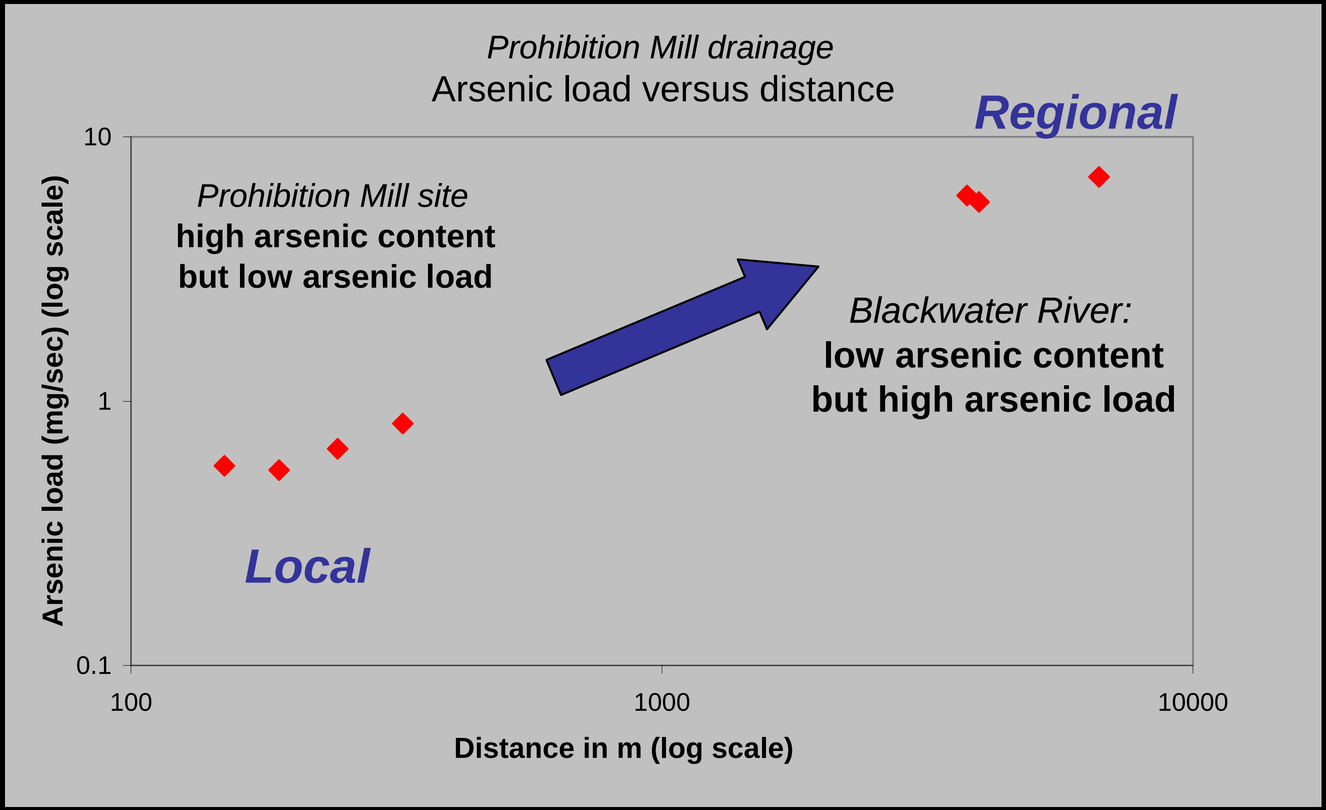
Creek

- An order of magnitude less arsenic than in wetland (2 mg/L)

Management perspective: No addition of lime or local rocks!
- Increased pH increases solubility of scorodite
- Increased dissolved carbonate

Regional controls on site impact

- Regional attenuation is via dilution (less effective)
- Prohibition mill site contributions - regional background contributions (natural):
  Arsenic load (mg/sec) = flow rate (L/sec) x arsenic concentration (mg/L)



Management perspective: site clean up will not have a significant influence on downstream arsenic concentrations

Conclusions

Site impact

Local:

- Prohibition mill site one of the most toxic sites in South Island:

  very arsenic-rich residues (up to 40 wt%), some in the form of very soluble arsenolite

  → site unsuitable for human access

  → very disrupted site ecosystem

  High dissolved arsenic in wetland (50 mg/L) and creek (2 mg/l)

  → Strongly disrupted stream biota several hundred metres downstream

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Regional:

- Site impact is negligible on a regional scale

Conclusions

Controls on site impact

Local:

- Arsenic mineralogy and their stabilities (dynamic system)
- Effective attenuation in man-made dam
  (sensitive to water quality and pH)

Regional:

- Dilution to elevated natural background

Conclusion

Management perspective:

- presently the site is acidic, carbonate deficient with very high dissolved arsenic concentrations from arsenolite dissolution.

  Changes of any of these parameters can result in :

  → Remobilisation of arsenic through scorodite dissolution

  → Reduction or prevention of efficient attenuation in dam

⇨ Site remediation options should be based on a geochemical understanding of the site!

- Site remediation will not change water quality of the downstream environment on a regional scale

Acknowledgements

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