



**Arsenic Mobility from
Arsenopyrite-rich
Gold Mine Waste,
Snow Lake, Manitoba**

Barbara L. Sherriff

*Department of Geological Sciences,
University of Manitoba*

ACKNOWLEDGEMENTS



Kristin Salzsauler, Stephanie Simpson

Nikolay Sidenko, Jamie VanGulck,

Elena Khozhina, Kathleen Londry.

NSERC

Manitoba Sustainable Innovation Fund

New Britannia Mine

Manitoba Mines Branch

Many field and laboratory assistants

Nor - Acme Mine, Snow Lake (1949 – 1958)



© CGC-GSC
1994-530

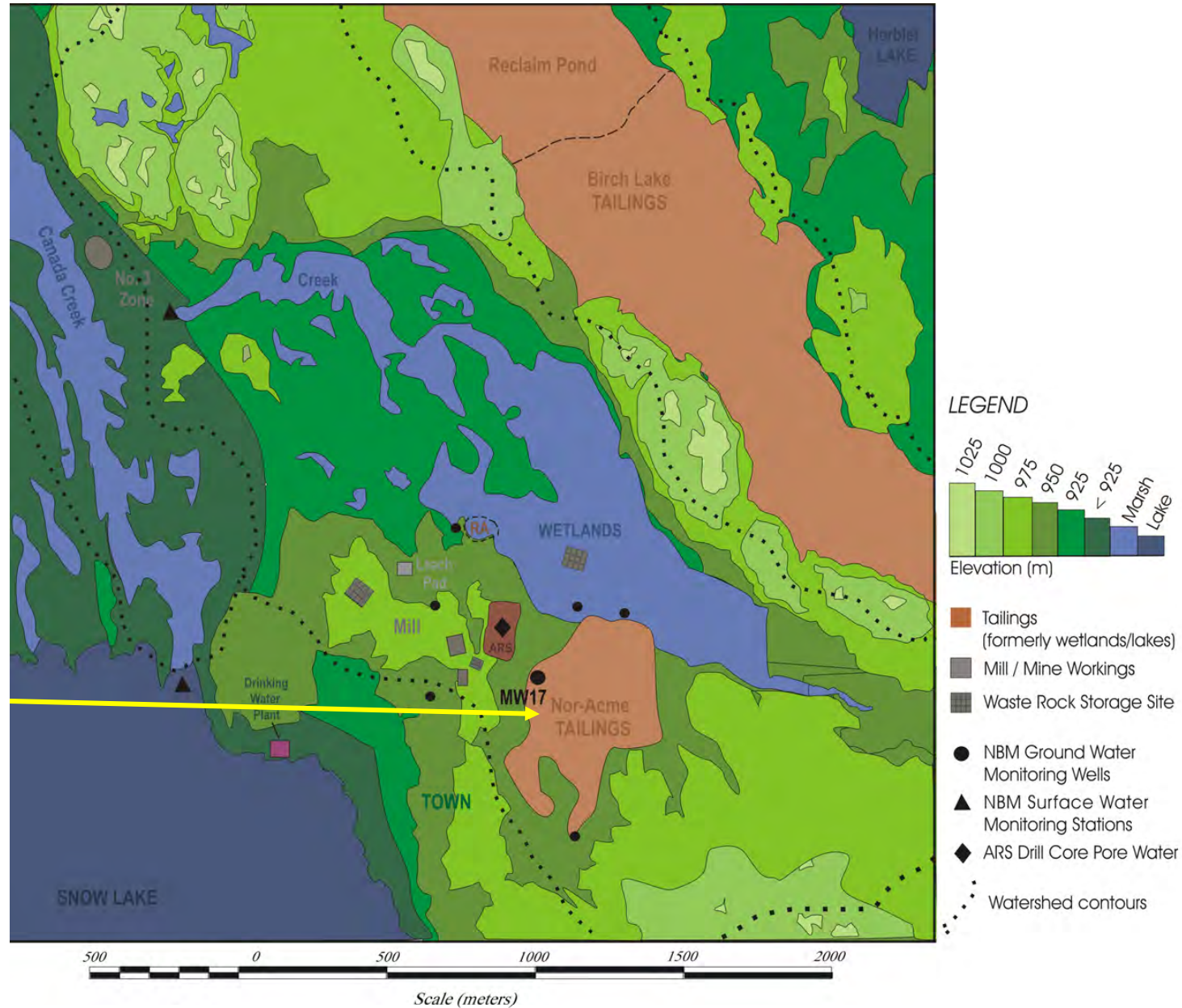


Reopened as New
Britannia Mine 1995
Arsenopyrite Residue
Stockpile (ARS) and the
Nor Acme Emergency
Tailings (NATA) were
designated as orphaned
sites

New Britannia Mine
closed in 2002

Arsenic Contamination of Mine Watershed

MW 17
< 20 ppm As

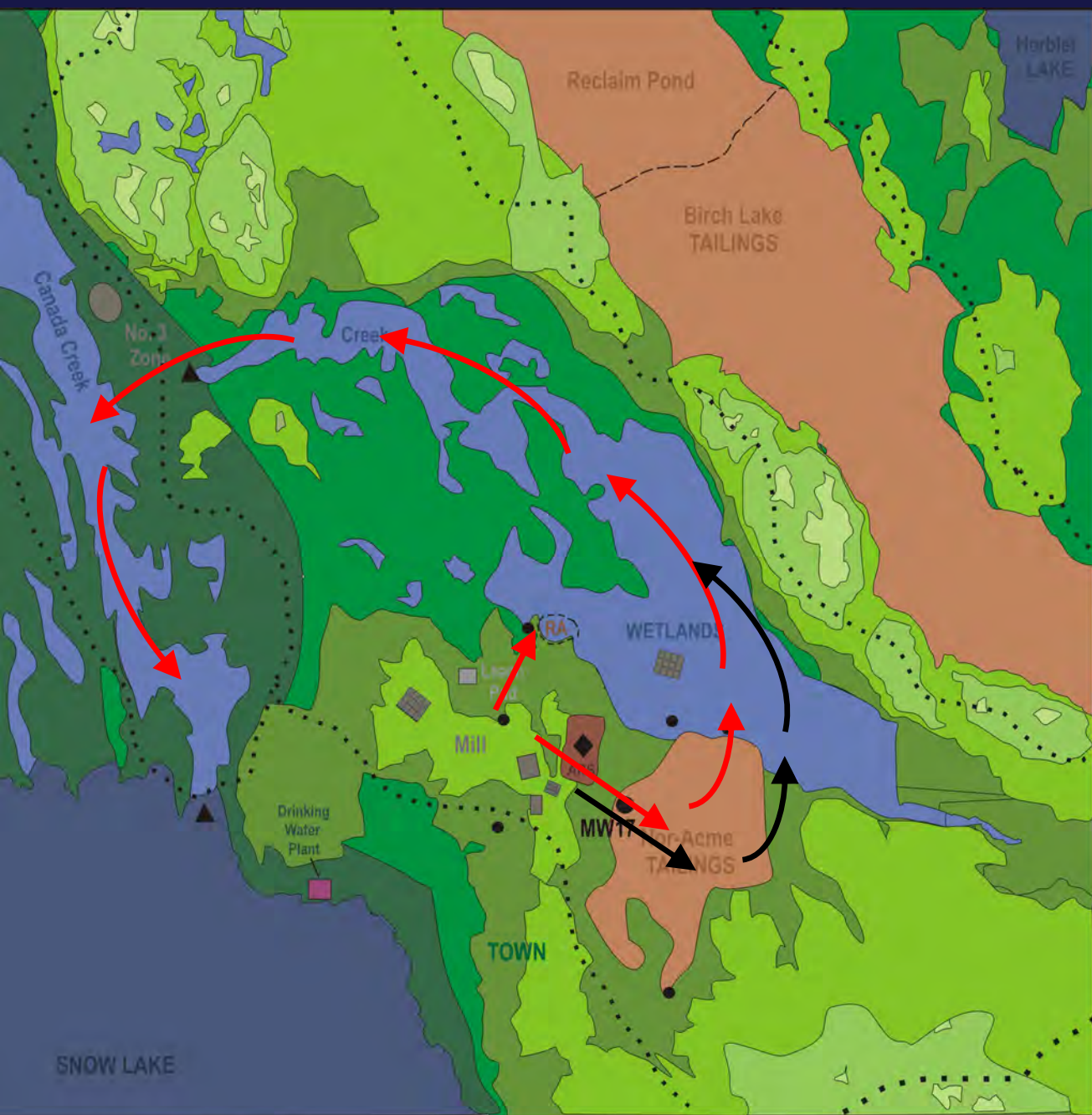


Objectives of Research

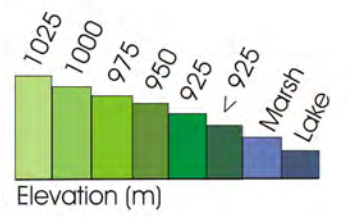
- To determine the cause of the high arsenic in MW 17
- To determine the flow path of ground and surface water to predict the possibility of contamination of Snow Lake
- To determine the geochemical and mineralogical processes controlling the mobility and attenuation of arsenic in the mine watershed

→ **Surface and**
 → **Ground water**
Flow Path

from Elevations
and Water Table
in Wells



LEGEND

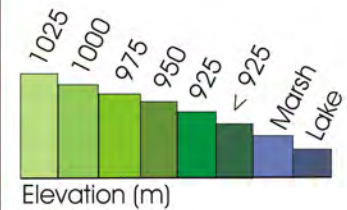
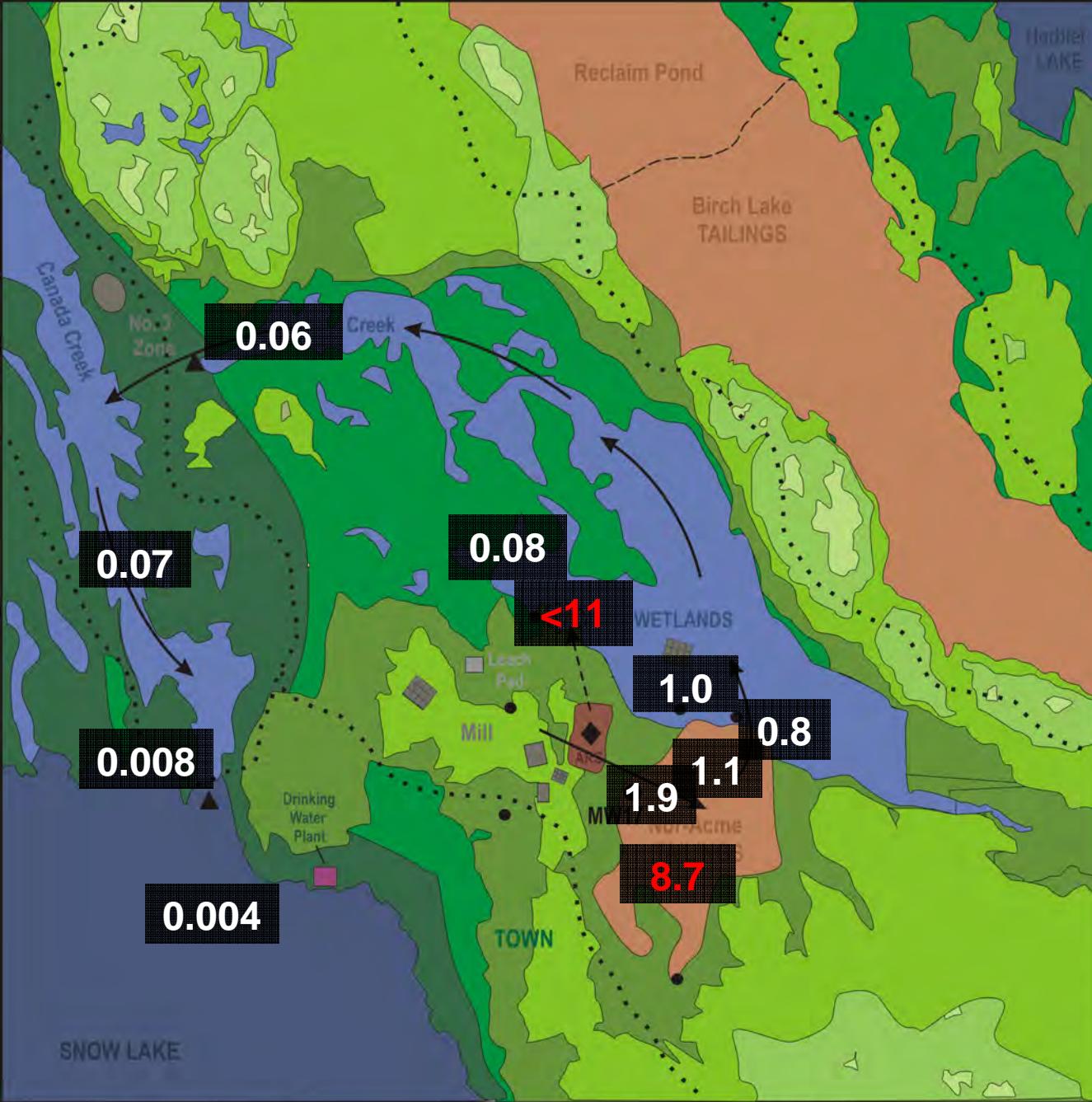


- Tailings (formerly wetlands/lakes)
- Mill / Mine Workings
- Waste Rock Storage Site
- NBM Ground Water Monitoring Wells
- NBM Surface Water Monitoring Stations
- ARS Drill Core Pore Water
- Watershed contours



Scale (meters)

Surface Water As (ppm)



- Tailings (formerly wetlands/lakes)
- Mill / Mine Workings
- Waste Rock Storage Site
- NBM Ground Water Monitoring Wells
- NBM Surface Water Monitoring Stations
- ARS Drill Core Pore Water
- Watershed contours
- Predicted surface and ground water flow path
- Runoff from ARS

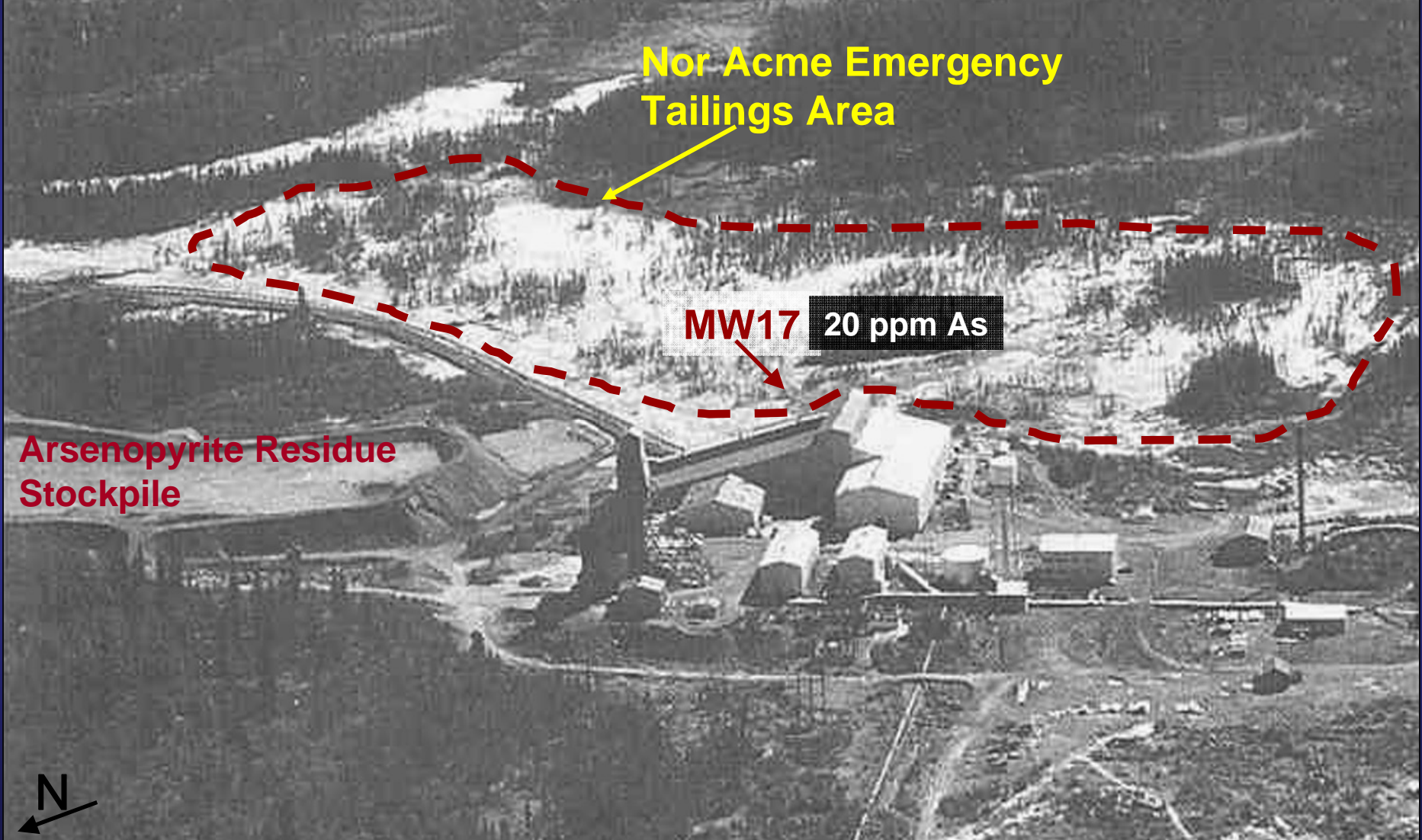


Scale (meters)

Standards and Regulations

- Canadian natural background of As in soils: 5–14 ppm
 - ★ARS solid: **23 wt%**
- Canadian standard for As in drinking water: 0.025 ppm
 - ★ARS pore water: **100 ppm**
 - ★MW17: **20 ppm**
 - ★Snow Lake: **0.004 ppm**
- Standard for As in mining environments: 0.5 ppm
 - ★RA: **<11 ppm**
 - ★NATA: **<9 ppm**

Two Possible Sources of As Contamination



Nor-Acme Mine site (1954)

THE ARSENOPYRITE STOCKPILE



Ore: Free gold overgrowing arsenopyrite & refractory gold *in* arsenopyrite.
Beneficiation: Crushing and grinding, flotation and cyanidation.
Recovery of gold only 81%

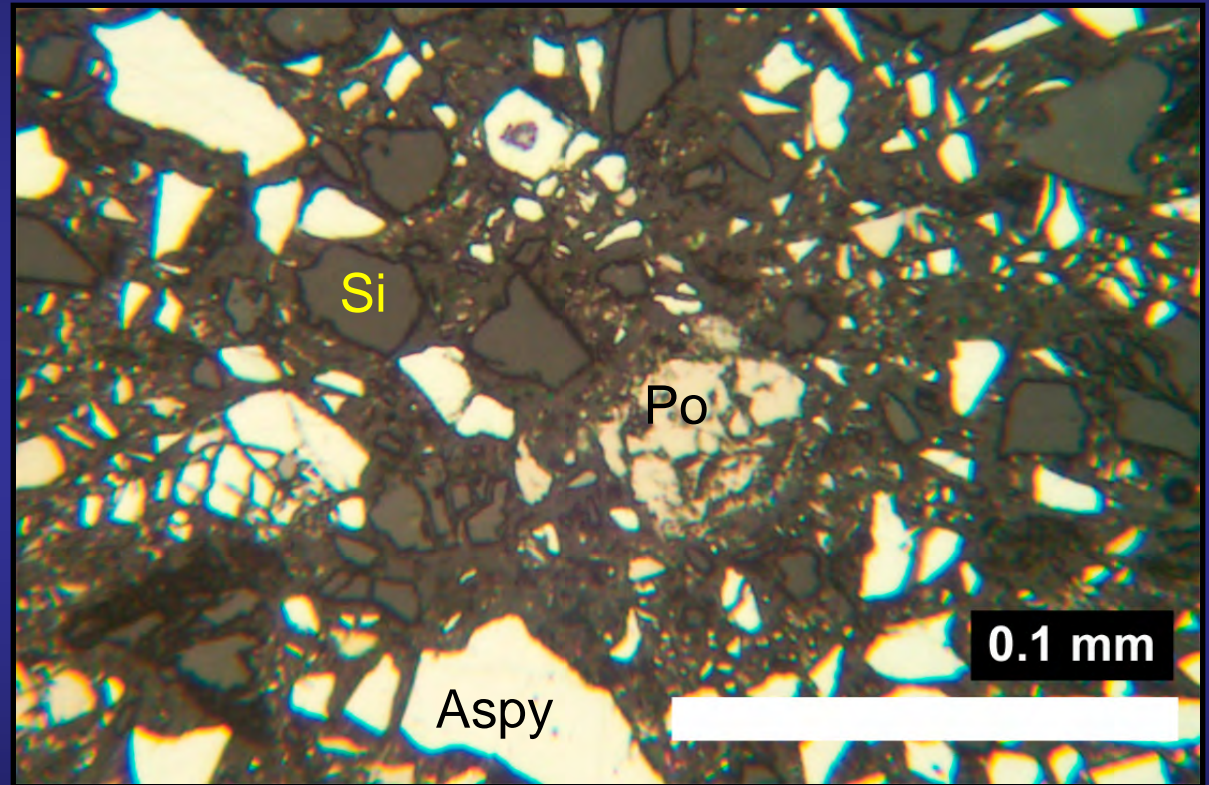
Cyanide treated residue stored in the 200 m x 100 m Stockpile 1949-1958
Covered by New Britannia Mine in 2000
Drilled and sampled in 2003

Extensive alteration of sulphides in top 1m released As from arsenopyrite
Solid Residue: 18% As
Pore water: 100 ppm As

Primary Mineralogy

SULFIDES
Arsenopyrite
Pyrrhotite
Pyrite
Chalcopyrite

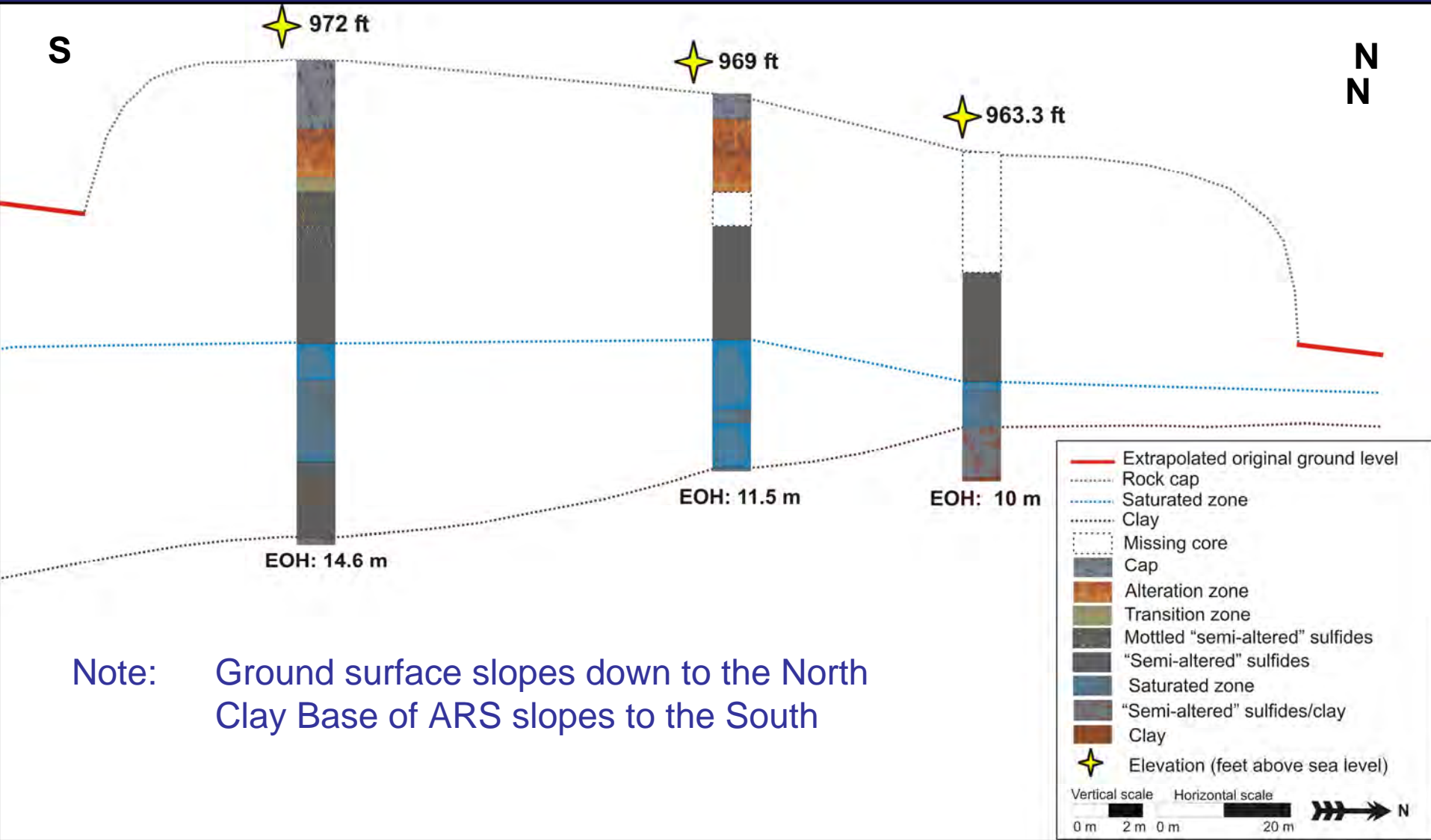
NON-SULFIDES
Quartz
Plagioclase
Orthoclase
Amphibole
Hydrobiotite
Calcite



Gold: Free gold overgrowing arsenopyrite & “invisible” refractory gold in arsenopyrite

Extensive alteration of sulphides in upper 1 m released As from arsenopyrite

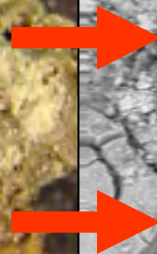
Solid Residue: 23% As, Pore water: 100 ppm As



Note: Ground surface slopes down to the North
Clay Base of ARS slopes to the South

Alteration Minerals in the top 1 m of ARS from sample collected prior to capping Amorphous iron sulfoarsenates (AISA)

22 - 26 wt % As



200UM

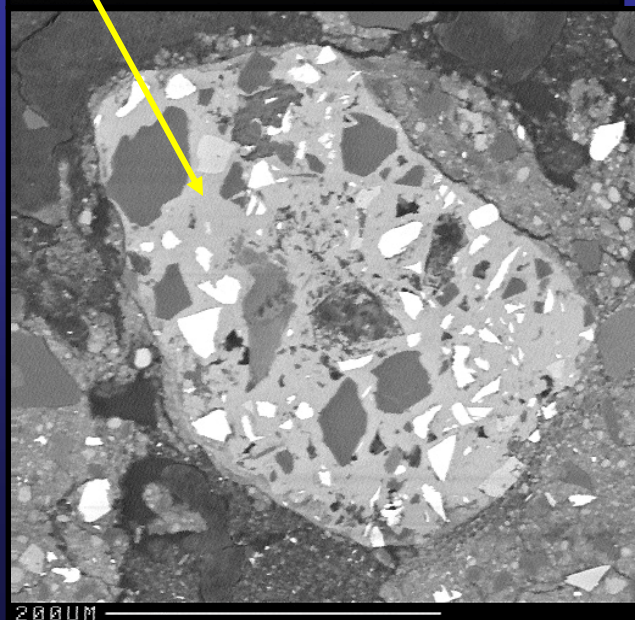
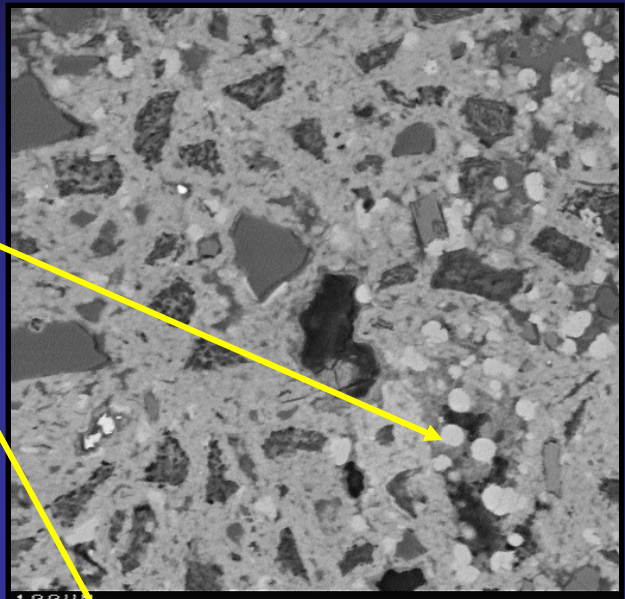
SCORODITE



Inclusions in
AISA cement
and forming
cement

35 wt % As

Precipitation
produces acid

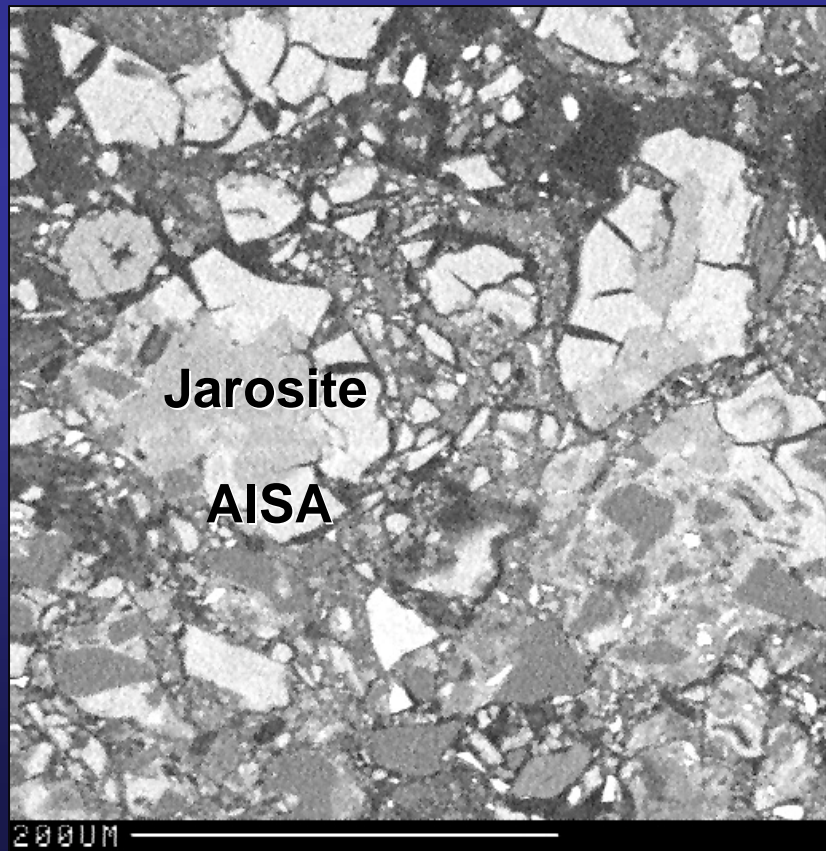


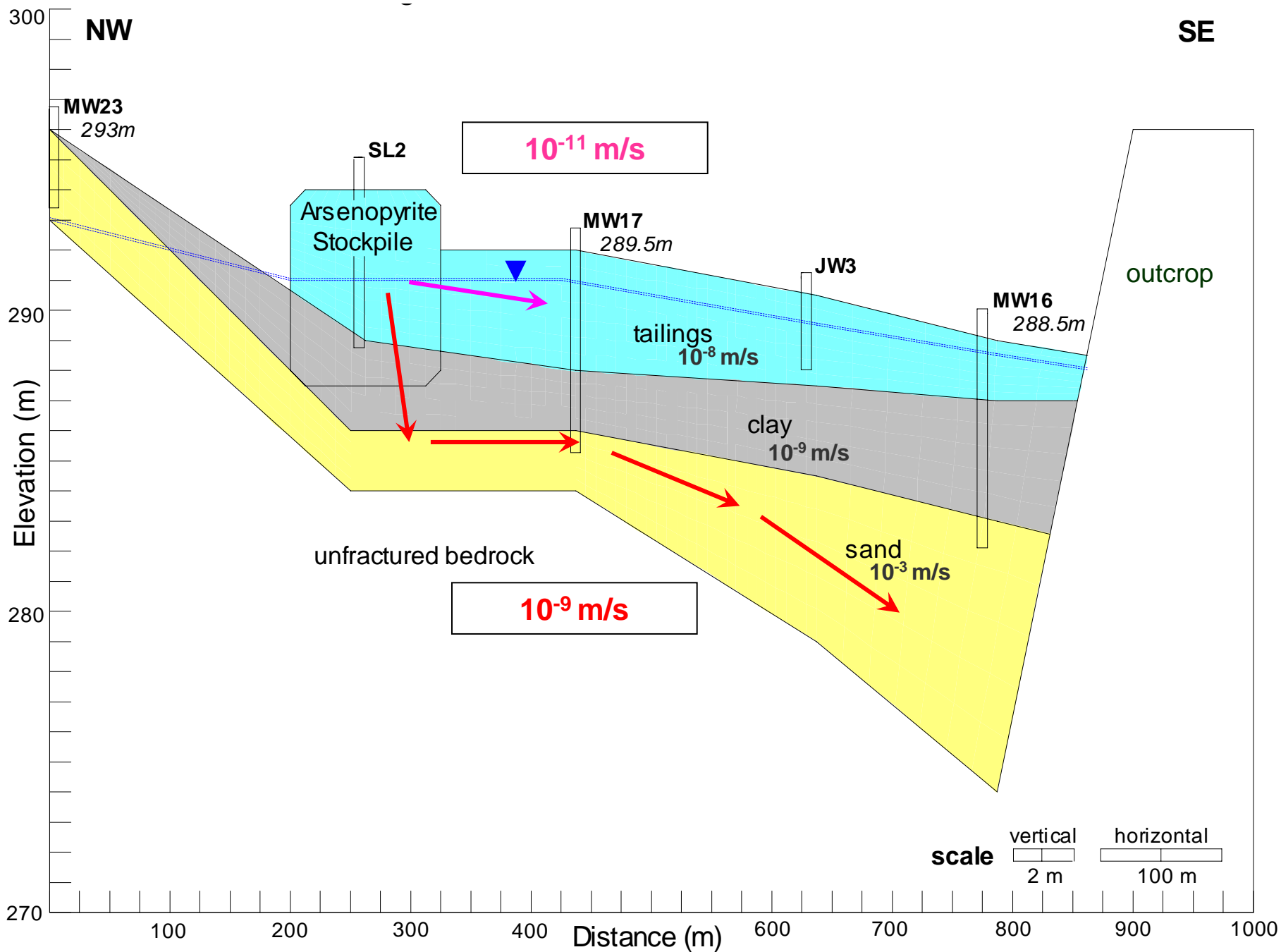
JAROSITE



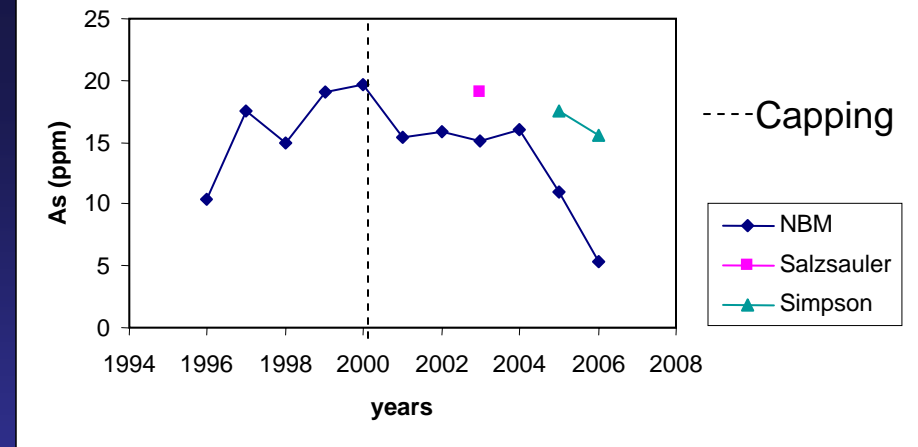
Incorporates < 5.6 wt % As.

Forms in acidic oxidizing conditions





Arsenic in the Arsenopyrite Residue Pile



Before Capping in 2000:

Arsenopyrite oxidized producing acid (pH ~ 2)

Arsenic accumulated in secondary AISA, jarosite, scorodite

Infiltration through pile from rain and snow

Arsenic-rich acidic runoff to NE

Increasing As in MW 17

2000: Cap limits water and oxygen infiltration

Reducing conditions in pore water and now neutral pH prevent the production of stable secondary phases

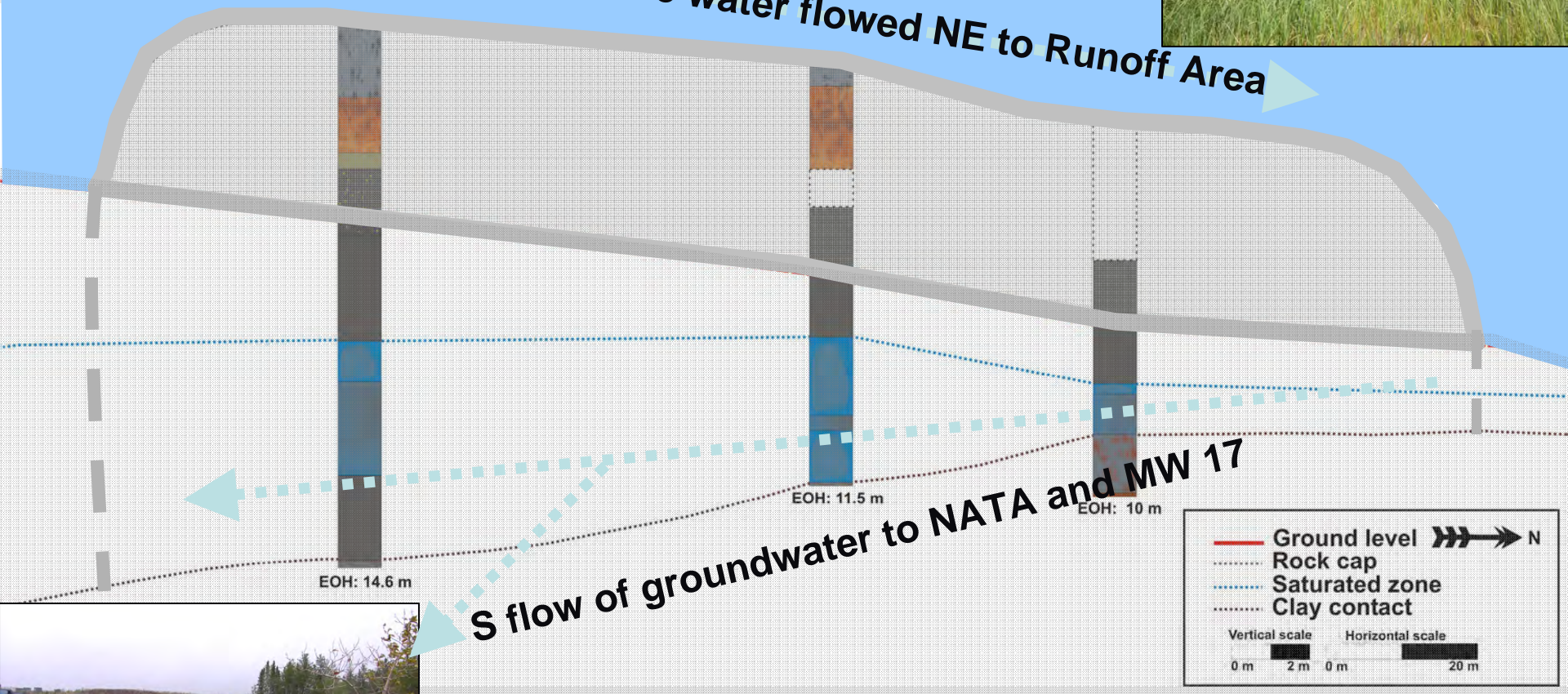
Arsenic released in drainage water (100 ppm)

Infiltration has been eliminated but groundwater still flows through the base of the pile

Slight reduction in As in MW 17

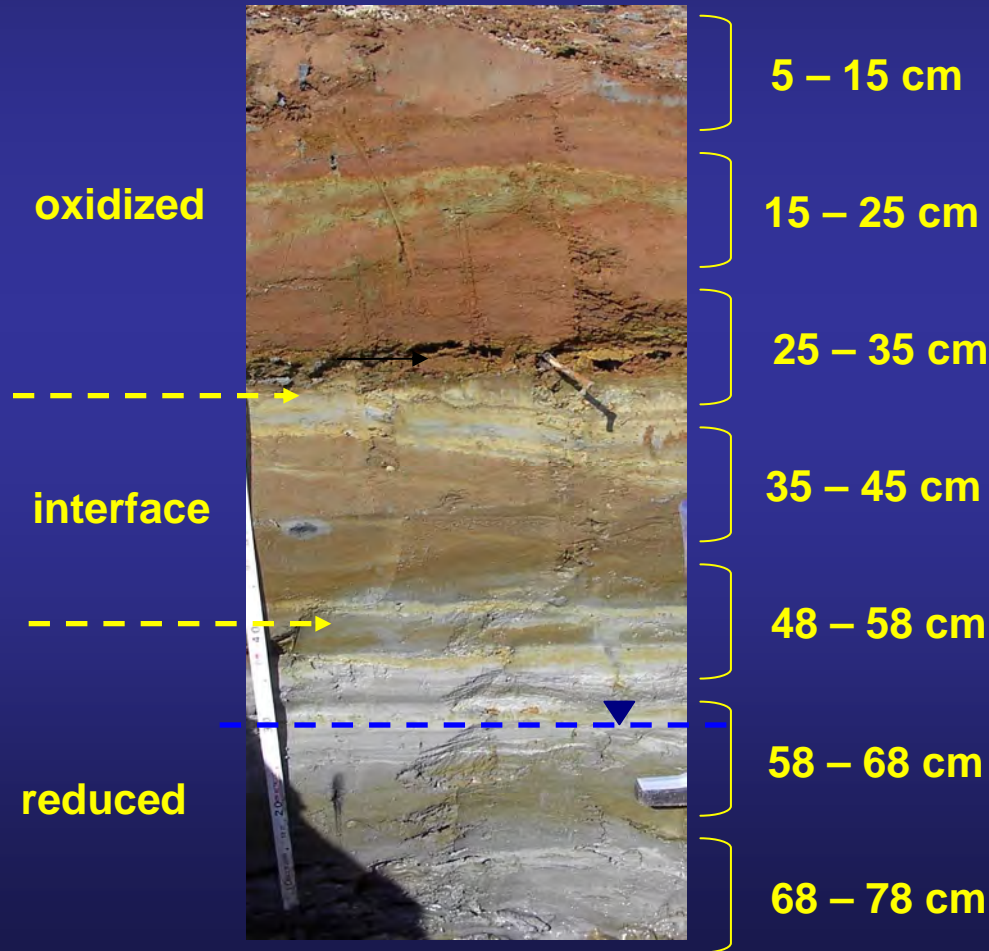
Note: the difference in total As from NBM and my group

Prior to capping surface water flowed NE to Runoff Area



Underlying clay contains 0.9 wt % As in arsenopyrite

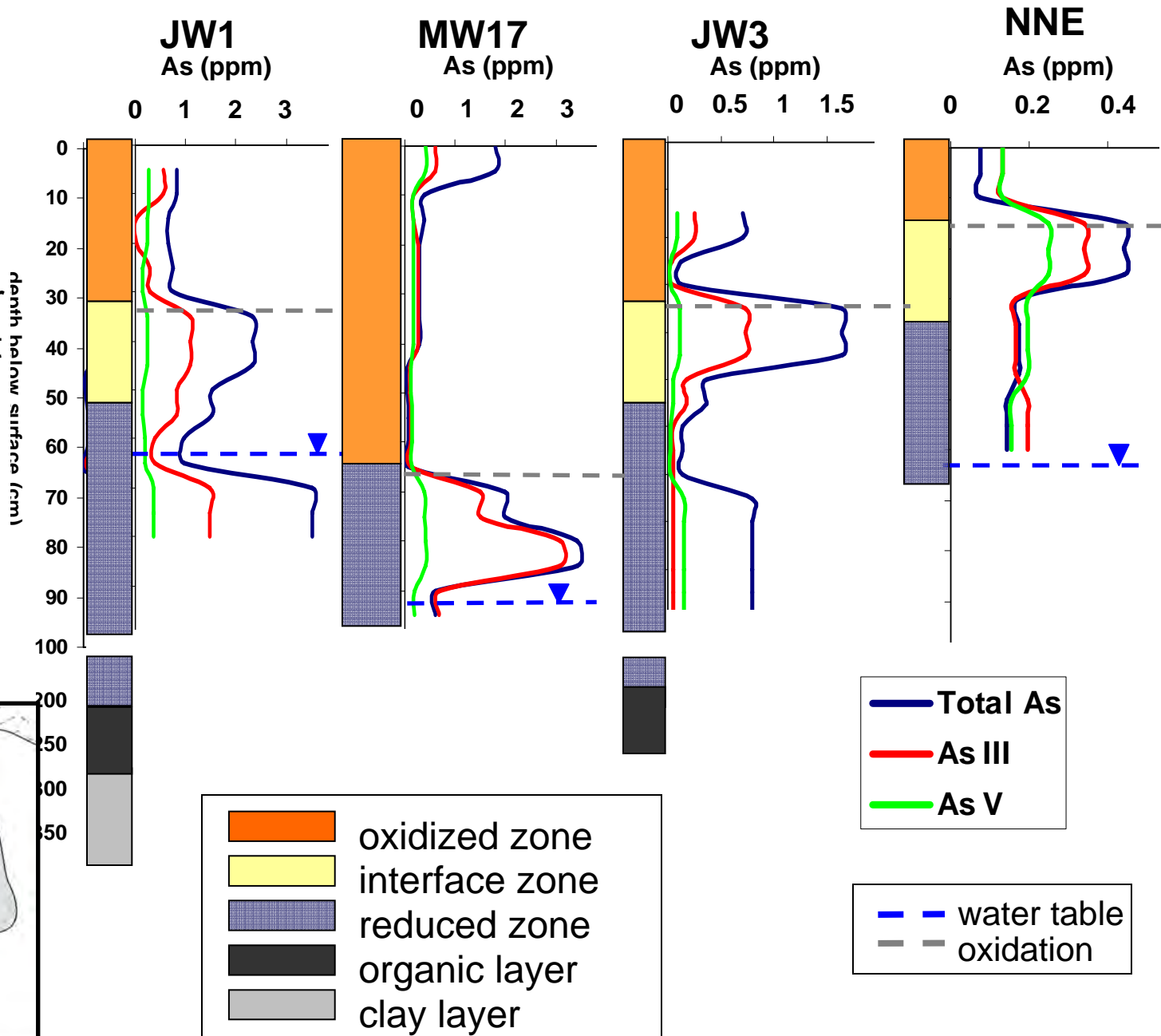
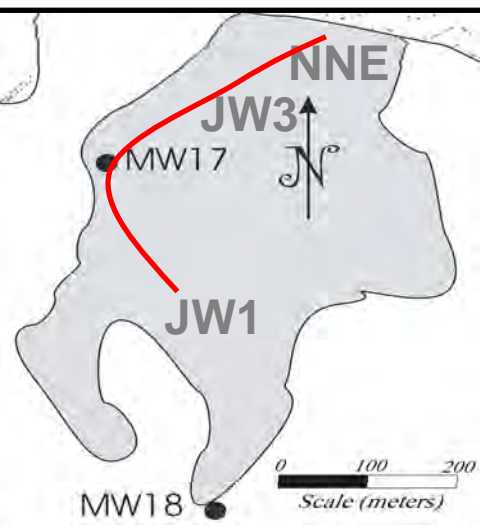
Nor Acme Emergency Tailings (NATA)



Arsenic in pore water of NATA

Concentration low, NATA not the major source of arsenic at MW17.

Higher As in the interface zone. Removed by adsorption to FeOOH in oxidized zone



Runoff Area

Boggy area

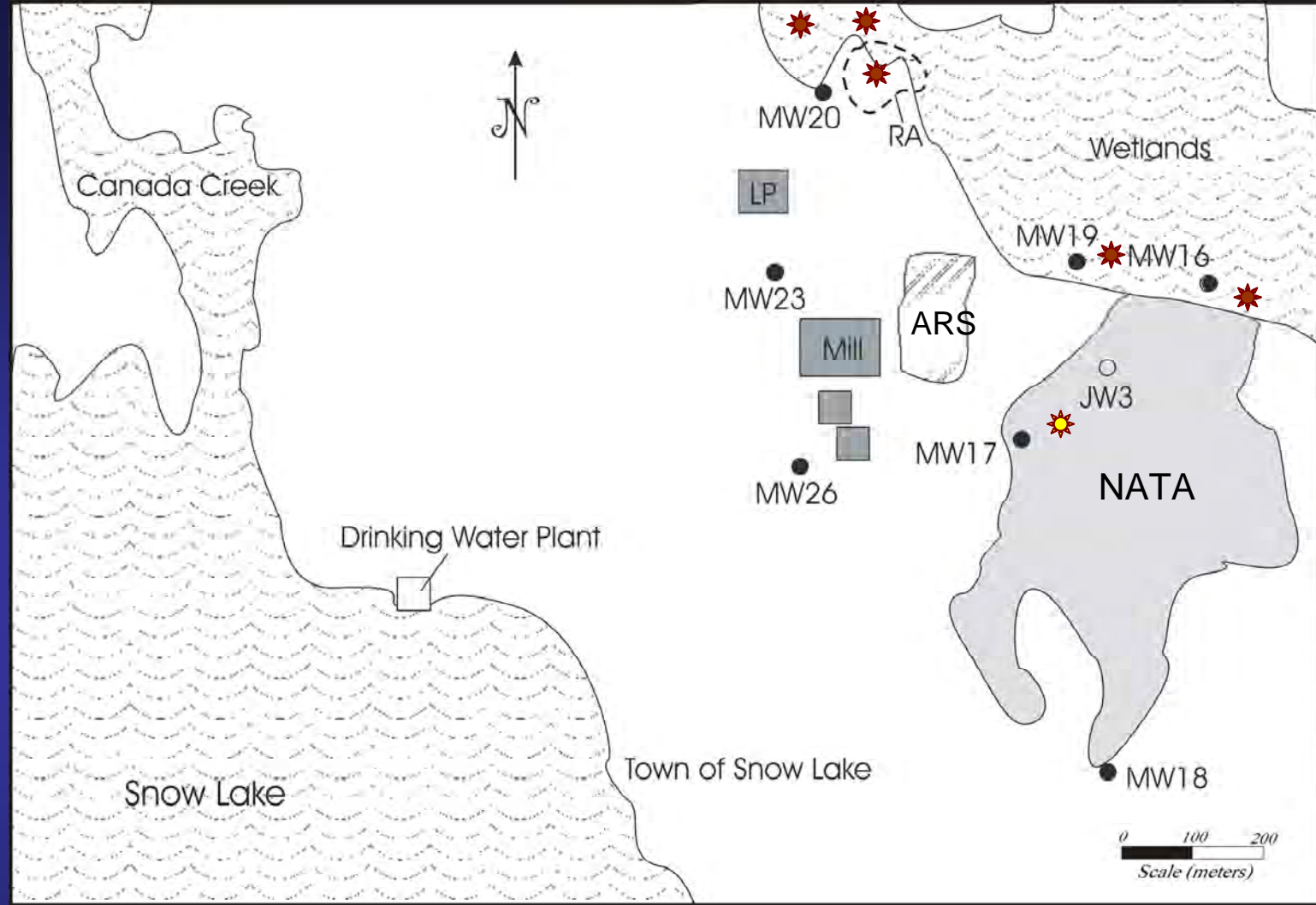
Runoff from ARS prior to capping and from mine area and old leach pad



Surface Water

pH 7.2
SO₄ 340 ppm
Fe 0.5 ppm
As (III) 3.5 ppm
As (V) 6.9 ppm

Sample Sites for Plants



LEGEND

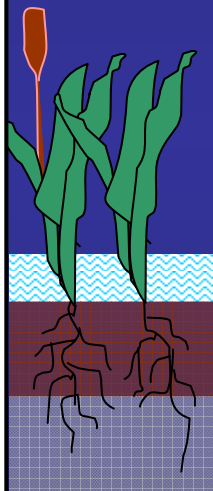
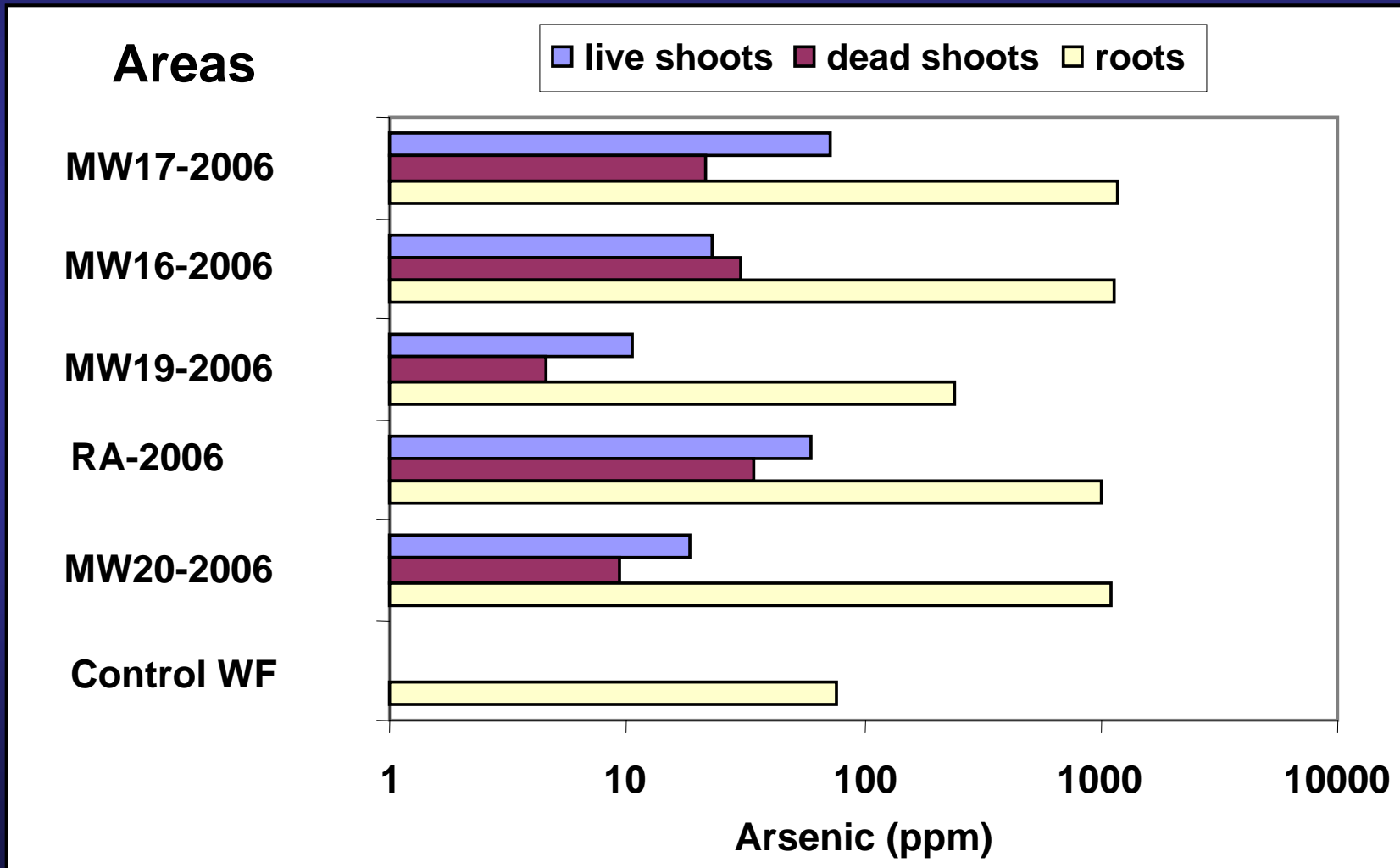
-  Nor-Acme tailings area (NATA)
-  Arsenopyrite Residue Stockpile (ARS)
-  Wetlands / Lake / Creek
-  New Britannia Monitoring Wells (MW)

-  **Aquatic plants**
-  **Positive control**

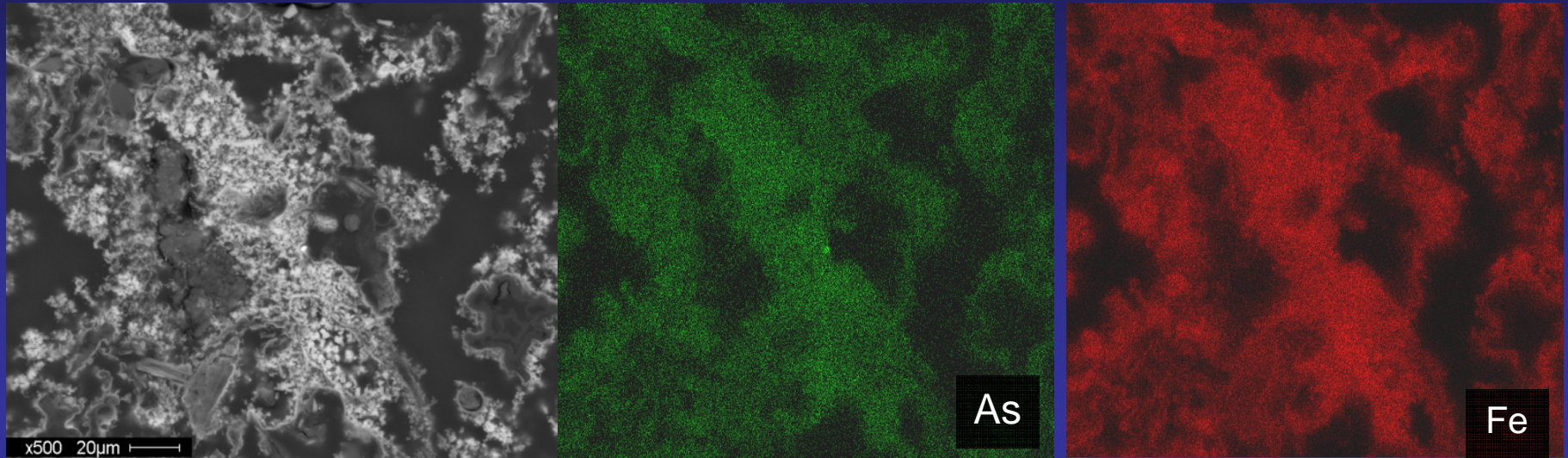
Negative control samples collected near Wekusko Lodge (WL) camp ground 40 km SW.

Accumulation of Arsenic in Cattails

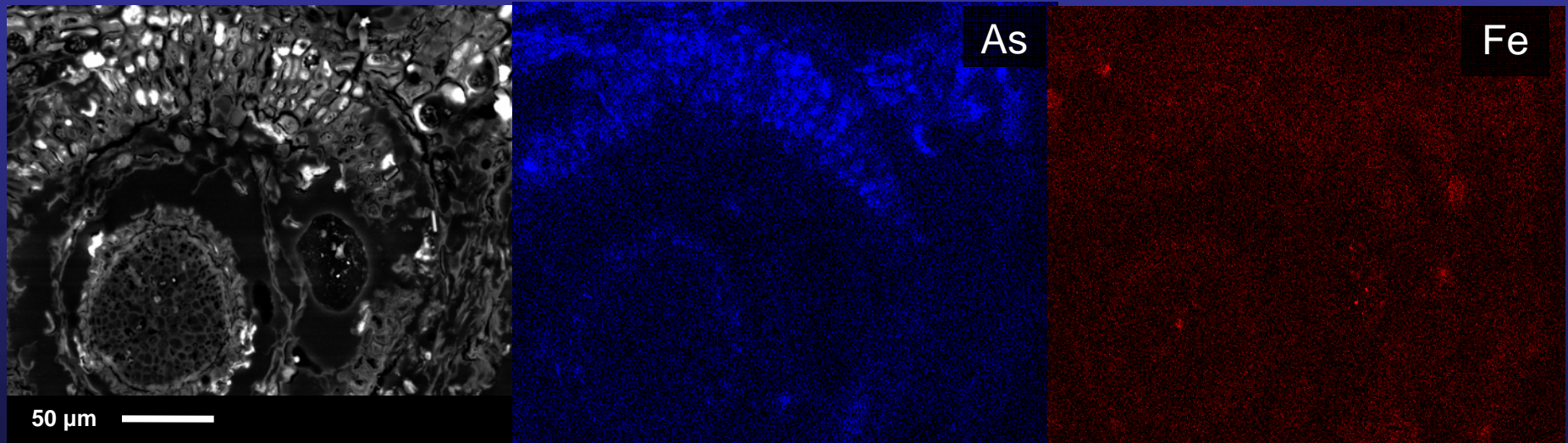
Higher As content in roots (<1000 ppm) than shoots (< 90 ppm)



Arsenic accumulates in roots of plants both with Fe oxy-hydroxides and alone



SEM backscatter images with EDX element scans





The Source of Arsenic at Snow Lake Mine

1949-2000: Surface runoff from the Arsenopyrite Residue Pile, the Leach Pad and the Nor Acme Tailings area

2000: Leach Pad remediated and ARS capped preventing infiltration.

Arsenic still leaching through the base of the ARS to MW17 joins runoff from Nor Acme tailings area in the runoff area

Mechanisms of Attenuation of Arsenic

- In ARS, the formation of scorodite, jarosite, ALSA in the oxidized residue prior to 2000
- Adsorption of arsenic to Fe oxy-hydroxide minerals in oxidized regions of soil and tailings
- Adsorption in the roots and shoots of plants with Fe or alone



Possible Future Contamination of New Britannia Mine Site

- Possibility for mobilization of As in groundwater if environment becomes reducing and Fe oxyhydroxides become unstable
- Plants in wetlands may release As
- Plants may be a passage of As into the food chain
- Arsenic in surface water will be attenuated by Fe-oxyhydroxides in oxygenated water before reaching Snow Lake