Soil Covers in the Canadian North

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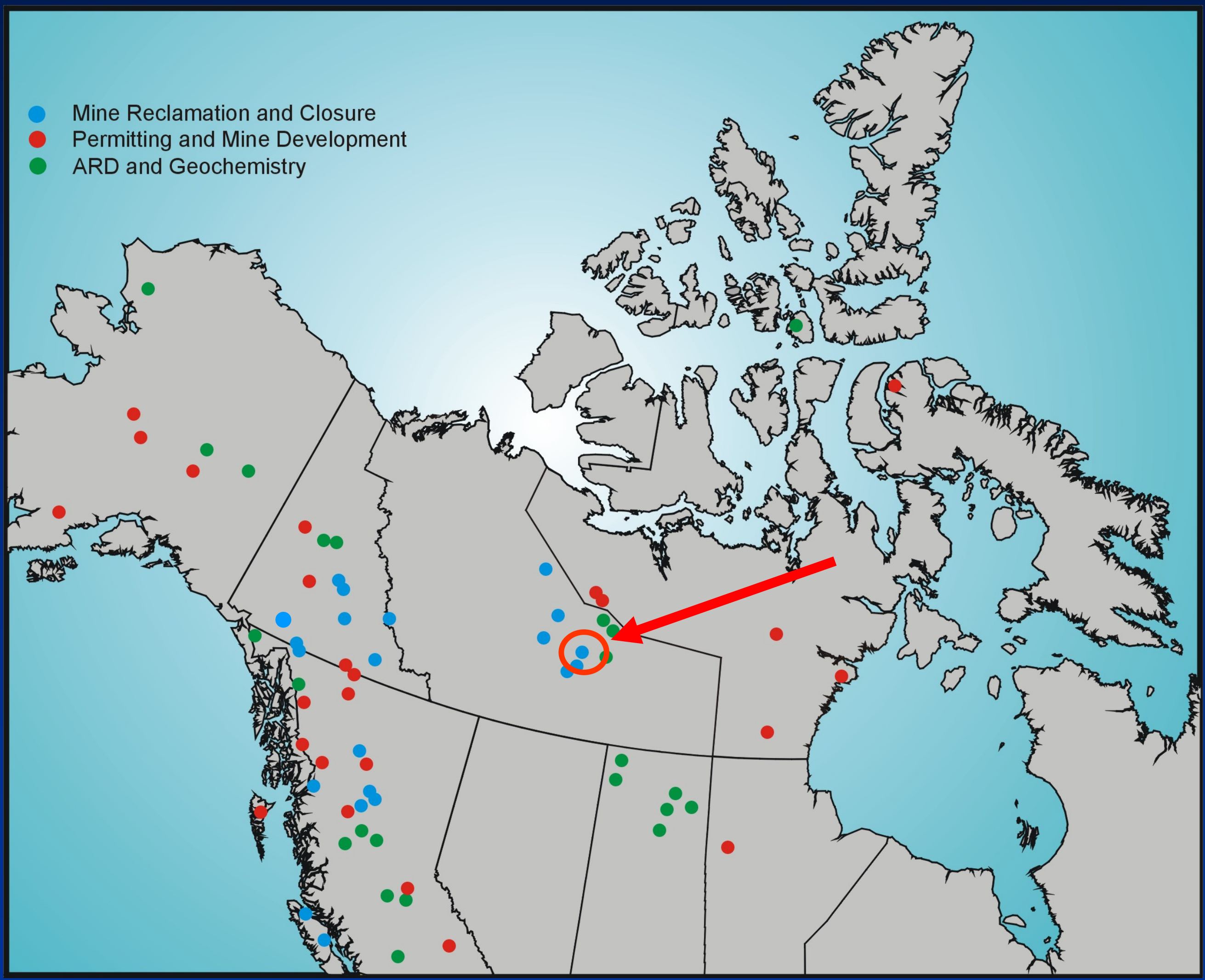
Overview

- Case histories
  - Discovery Mine, NWT
  - Beaverlodge Mine, Saskatchewan
  - Arctic Gold & Silver Tailings, Yukon
  - Venus Tailings, Yukon
  - Faro Mine, Yukon
  - Colomac Mine, NWT
  - Giant Mine, NWT
- Unique features of northern soil cover projects
- Requirements for “rational design”

Discovery Mine



1949-1969

85 km north of Yellowknife

1.1 million tonnes of tailings

Mercury contamination in Giauque Lake

Discovery Mine

Discovery Mine

3 ha tailings delta in Giauque Lake

Discovery Mine

- Delta tailings covered with GCL overlain by 20 cm crushed rock in 1997
  - Site accessible only by ice road
  - GCL best for winter application
  - Rock layer provides confinement for GCL swelling
- Inspections in 1998
  - Significant settling due to ice lenses melting
  - Repairs needed
  - Performing well since then

Discovery Mine

30 ha tailings on land

No containment

Discovery Mine

- Upland tailings covered in 1998 and 1999
  - Re-grading and surface compaction
  - Borrow source development and wind-rowing of clayey silt
  - Place 30 cm of clayey silt
  - Topped with 30 cm of 100 mm crushed rock

Discovery Mine

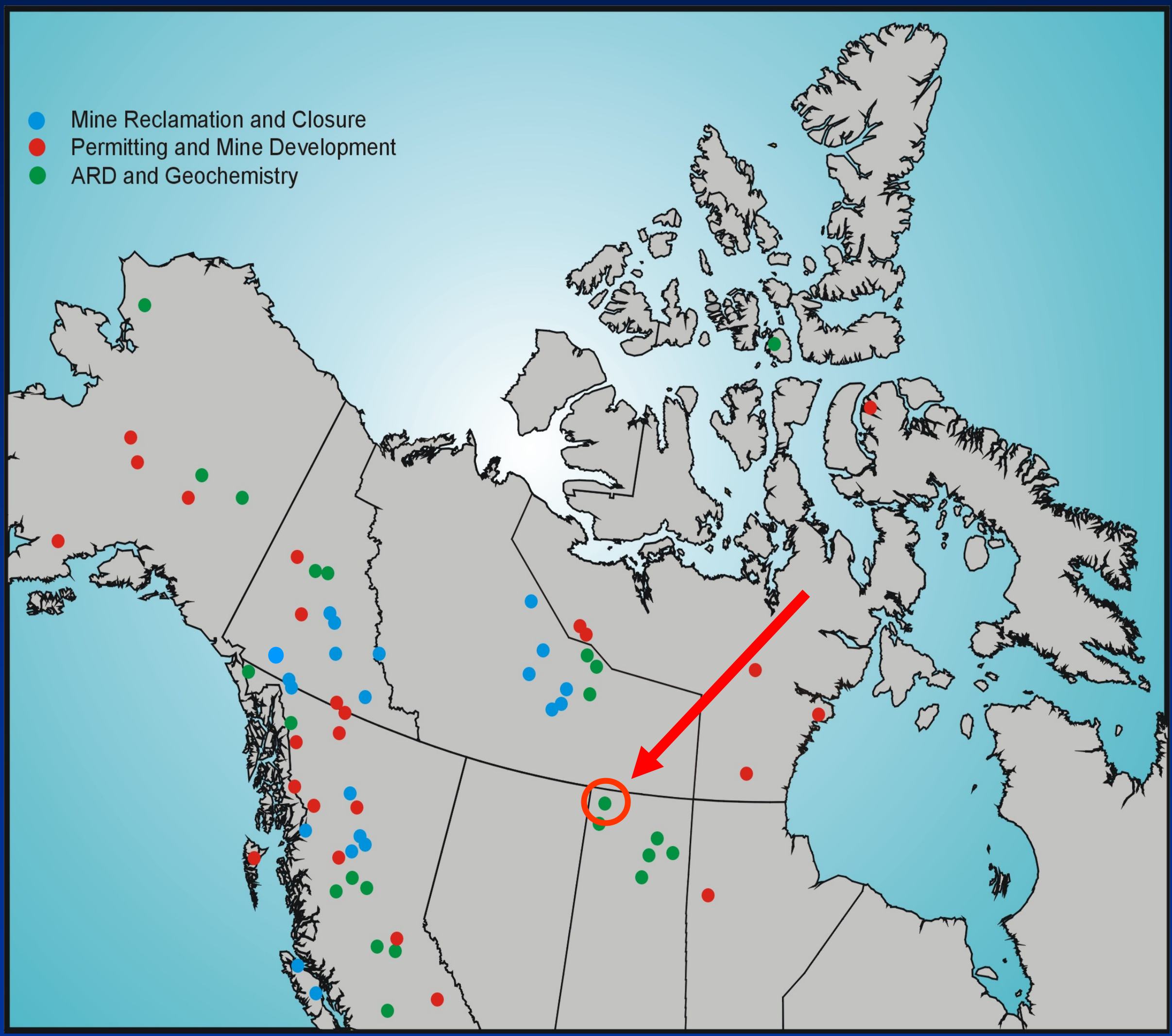
Inspections in 2003

Boils on surface of crushed rock

Mechanisms similar to patterned ground?

Also permafrost degradation in borrow pit

Beaverlodge Mine



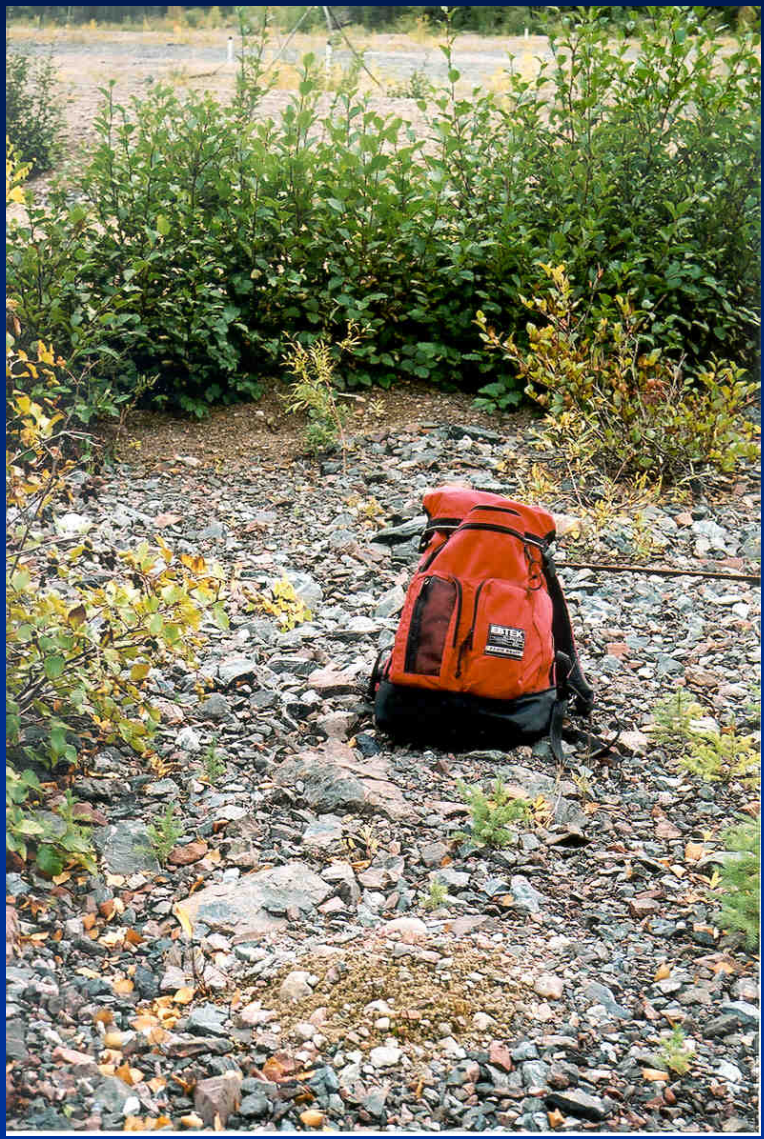
Uranium mine in northern Saskatchewan

Closed in 1980's

Beaverlodge Mine

- Tailings delta in Fookes Lake covered by coarse rock to prevent radiation release

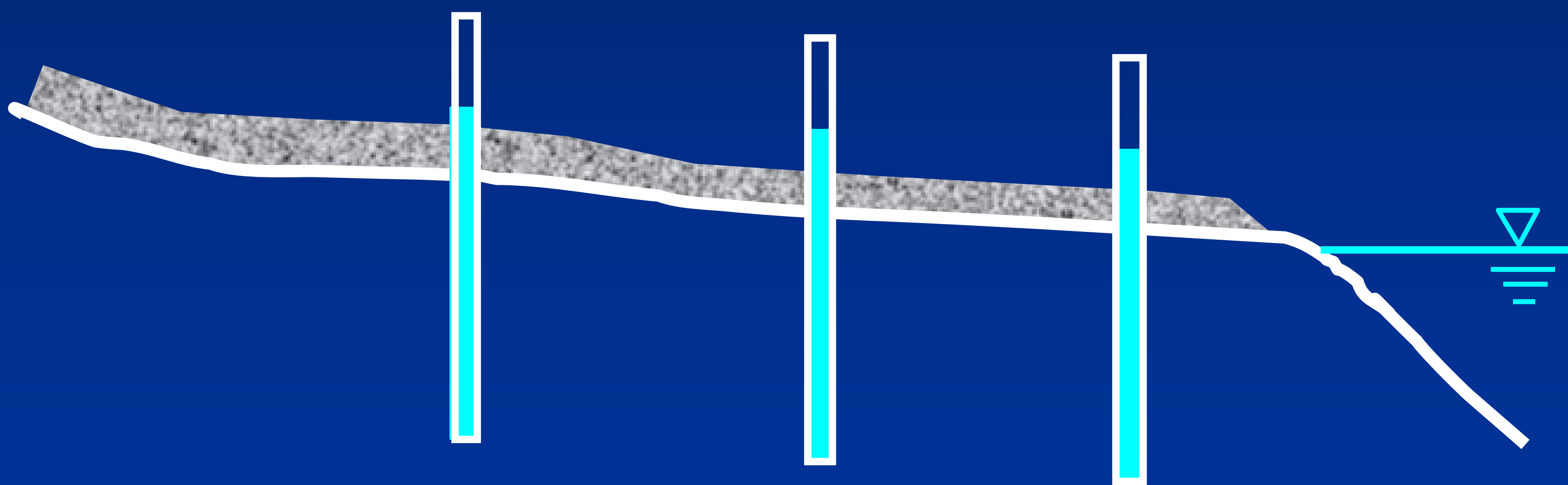
Beaverlodge Mine



- Inspections in early 1990's found tailings boils on surface
- Initially proposed "frost boils" as explanation
- Other cryoturbation phenomena also suspected

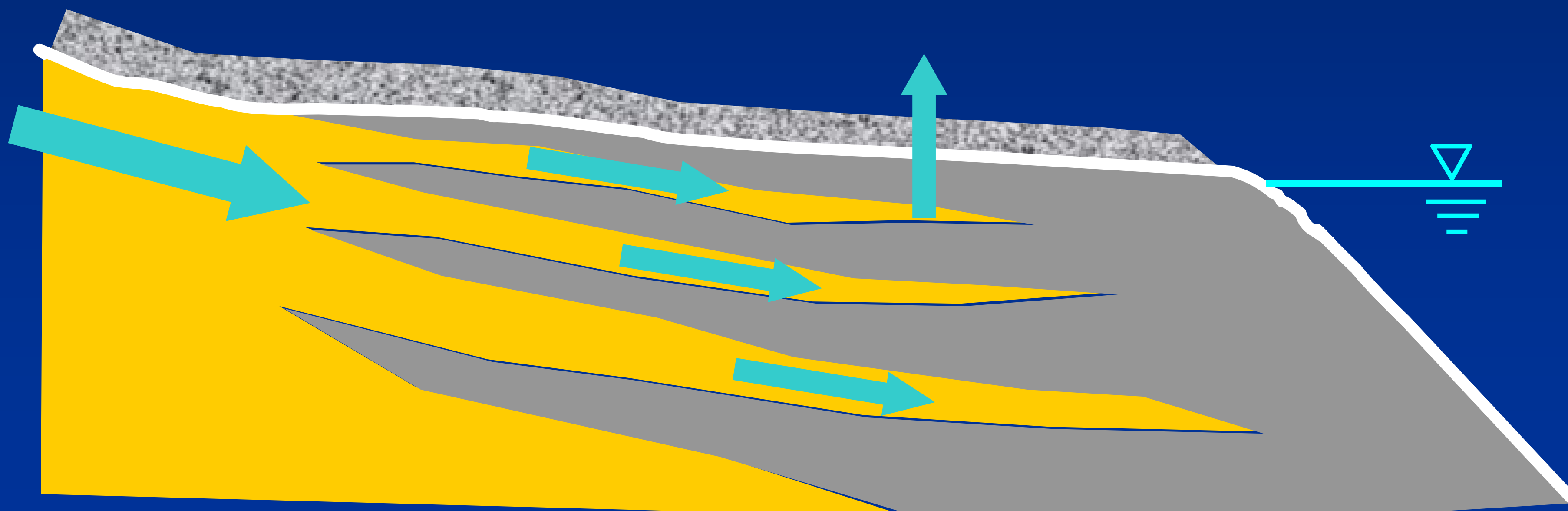
Beaverlodge Mine

- Further investigations in 1994-95 included three lines of piezometers and thermistors
- Piezometric levels above cover surface, even in summer



Beaverlodge Mine

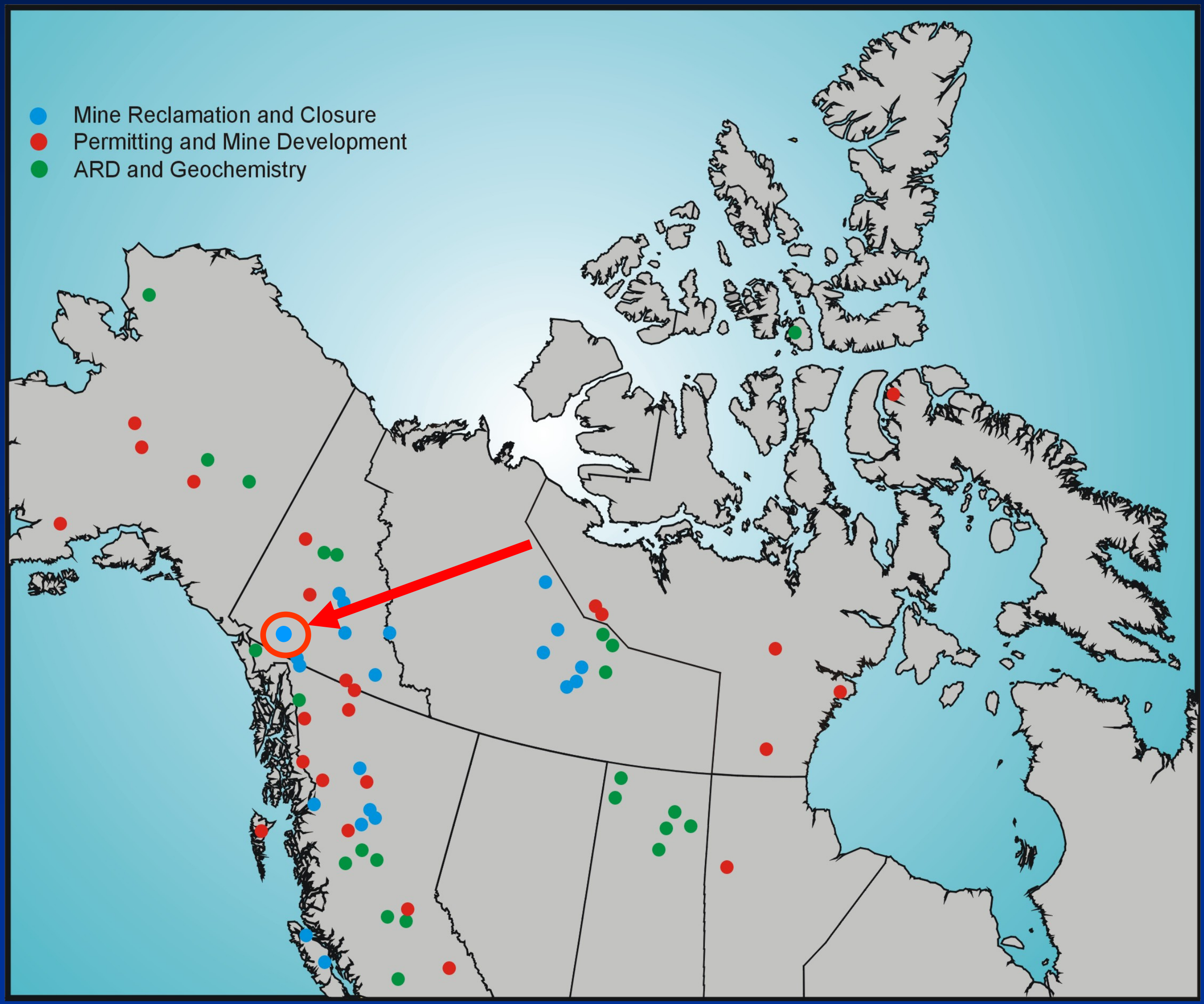
- Recharge from above delta travels via coarse layers and then boil to surface
- Can be exacerbated by surface freezing but cold is not the cause



Beaverlodge Mine

- Solution to problem has to been to place additional cover material that is properly graded to prevent upwards piping of tailings

Arctic Gold & Silver Tailings



Near Carcross, Yukon

1968-69 operation

Mill + tailings only

About 30,000 m^3

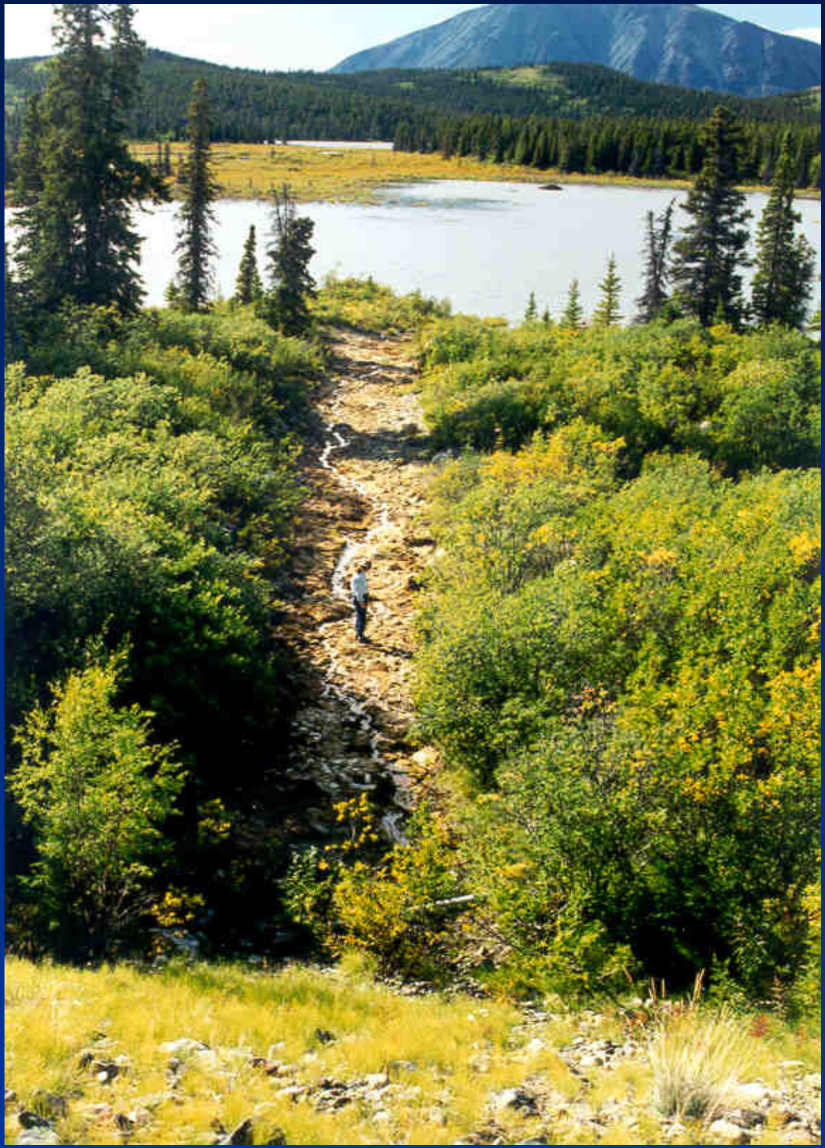
Arctic Gold & Silver Tailings

Tailings contain several % arsenic

Paste pH 1.8 - 3.0

Arctic Gold & Silver Tailings

Arctic Gold & Silver Tailings



Arsenic in seepage up to 28 mg/L

Tailings plume in lake

Arctic Gold & Silver Tailings

- Consultation with Carcross First Nation
  - Selected soil cover option
- Soil cover design considerations
  - High evaporation and upland location
    - Dry cover
  - Ease of construction
    - Simple two-layer profile

Arctic Gold & Silver Tailings

- Soil cover profile
  - 0.5m of sand and gravel
  - 0.3 m of clayey silt
- Constructed 1999
- Monitored since 2001

Arctic Gold & Silver Tailings

Healthy growth of vegetation in most areas

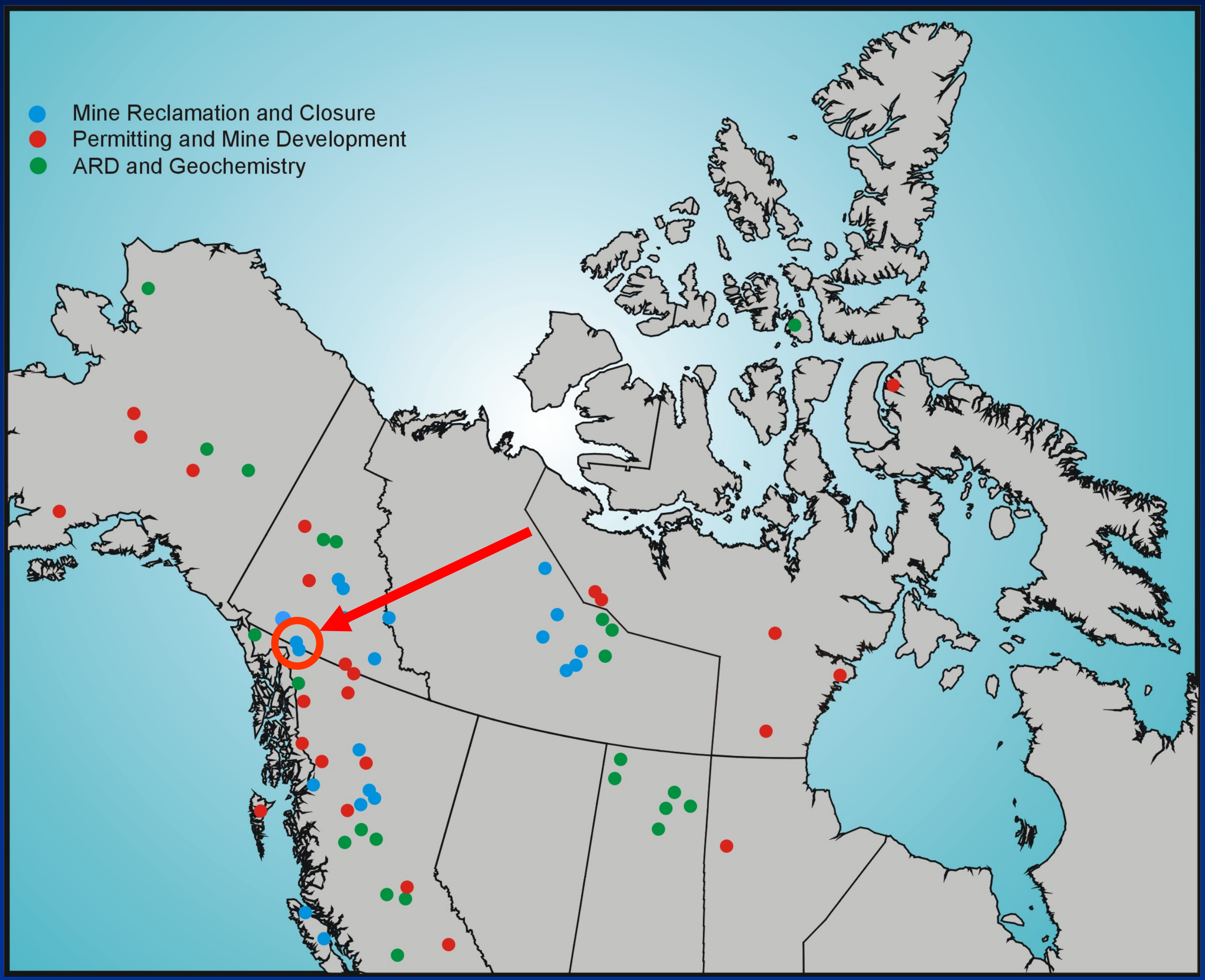
Some evaporite crystals in one low-lying area

Dessication cracks

Arctic Gold & Silver Tailings

Tailings and arsenic inputs to lake eliminated

Venus Tailings



Only 30 km from Arctic Gold & Silver

Similar gold + arsenopyrite ore and geochemistry

Similar history

Venus Tailings

Located along shore of Windy Arm

Next to highway from Whitehorse to Skagway

Venus Tailings

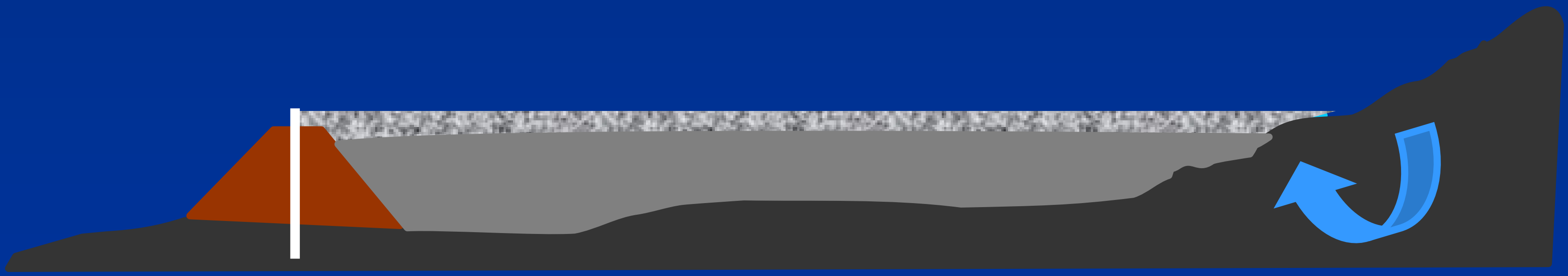
Groundwater from slopes to north discharges just uphill of tailings

Probably also through the tailings

Venus Tailings

- Design considerations
  - Dry cover very difficult
  - Wet cover more sensible
  - But concern about exposure of contaminated water and uptake of arsenic by berries
- Selected wet cover
  - Constructed Waterloo Barrier sheet pile wall on downhill side to manage water level
  - Placed geosynthetic and inert gravel on top of tailings

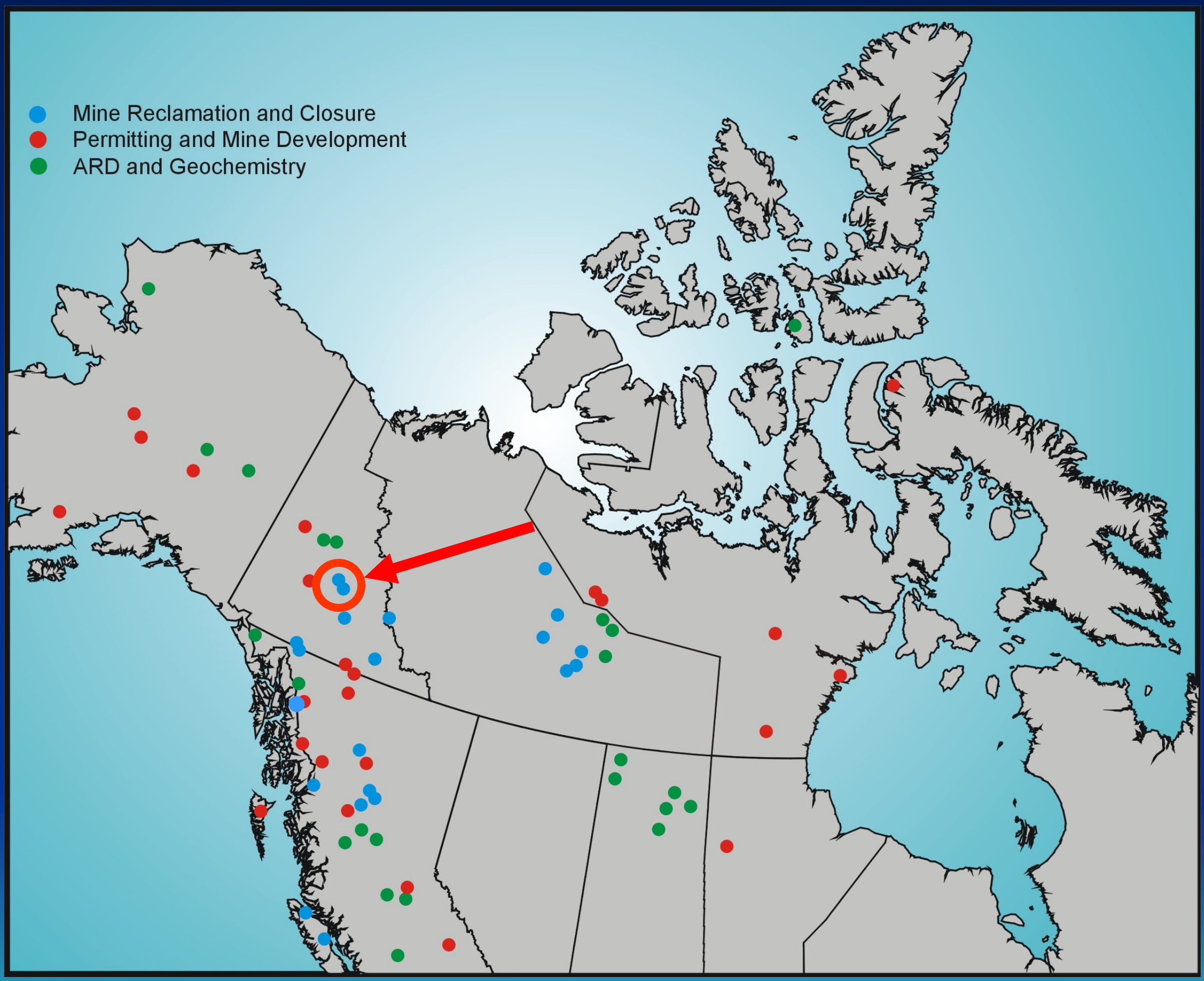
Venus Tailings



Venus Tailings

- Two years later
  - Extensive settlement of gravel cover
  - Contaminated water and tailings on surface
  - Placed additional 30-50 cm of gravel
  - Unique design requirement
    - Gravel must be same colour as previous!

Anvil Range Mining Complex



Largest mine in Yukon

Zinc and lead, massive sulphide

30 years of mining

Severe ARD

Anvil Range Mining Complex

- **Rose Creek tailings**
  - **196 ha**

- **Three mining areas, with ARD waste rock**
  - **Faro – 335 ha**
  - **Grum – 148 ha**
  - **Vangorda – 59 ha**

Rose Creek Tailings

Rose Creek Tailings

Original Impoundment completed in 1970's

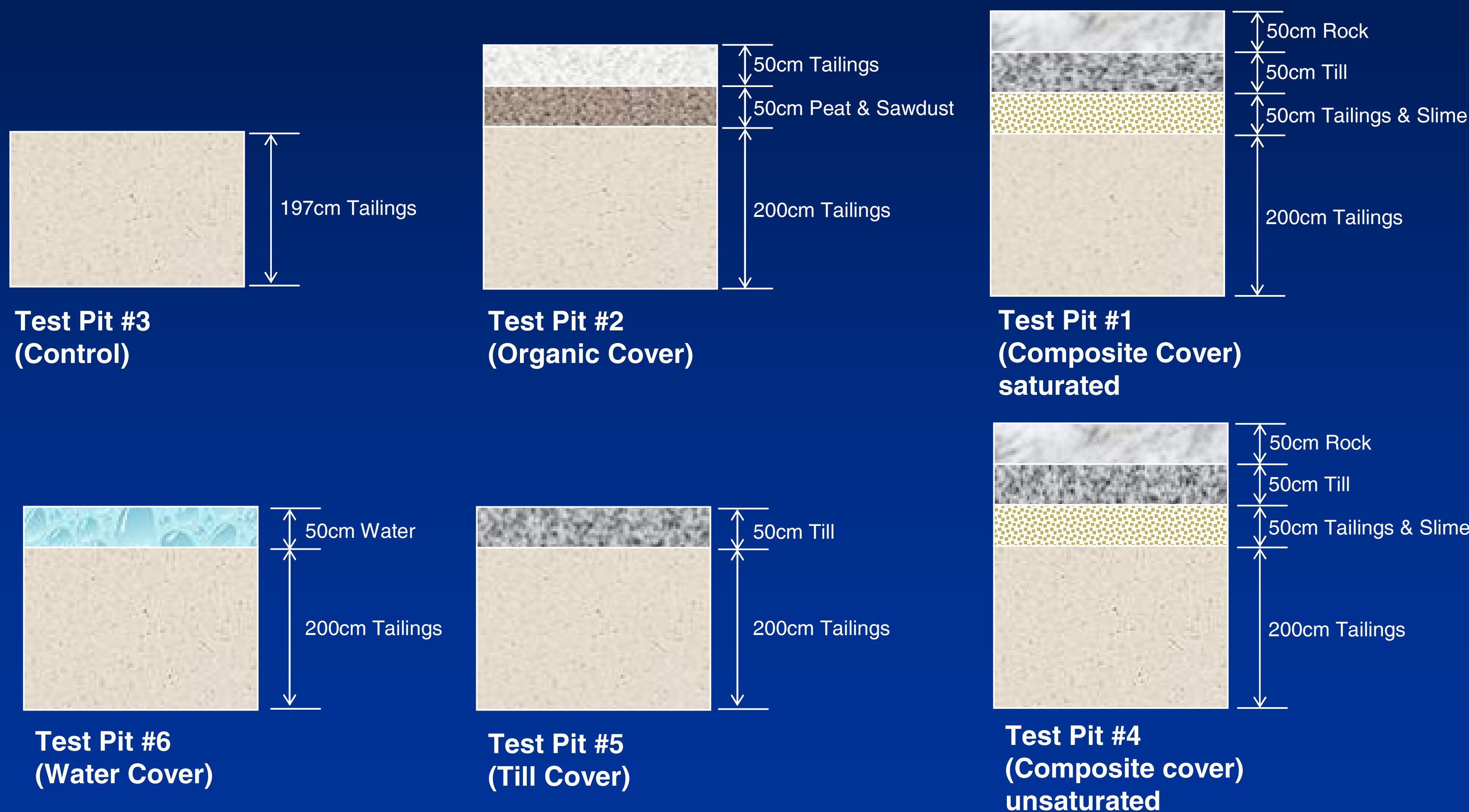
Estimated sulphate concentrations of 100,000 mg/L

Estimated zinc at 10,000 mg/L

Rose Creek Tailings

- Original Impoundment cover test area
  - Constructed 1992 – operated 5 years
  - Significant damage from freeze-thaw and poor maintenance

Rose Creek Tailings



Rose Creek Tailings

- Highly oxidized tailings
  - Oxygen barrier would have little benefit
- Tailings too flat for runoff covers
- Limited low permeability material in immediate area
- Most likely to build simple barrier covers or capillary break covers

Rose Creek Tailings

New trial areas initiated in 2003

Construction limitations only

Rose Creek Tailings

With & without geotextile filter layer

Settlement monitoring

Test pits to examine piping


CAT
Anvil Range


Anvil Rang

Vangorda Waste Rock

Vangorda Waste Rock

Cover test area built in 1994

Resloped to 2.5:1

Cover profile

- 1 m loosely compacted till
- 1 m highly compacted till

Not vegetated

Vangorda Waste Rock

Till cover material

- Low-plasticity clayey silt
- Prone to erosion
- Frost sensitive

Vangorda Waste Rock

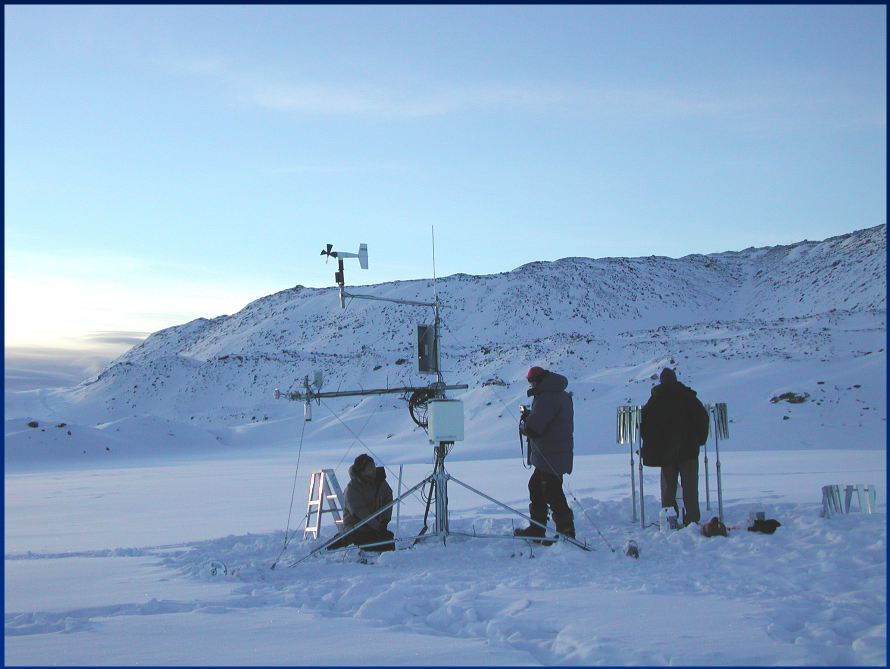
Vangorda Waste Rock

- Construction QA samples showed density of 95-100% standard proctor
- Field tests in 2003 showed density of 90% standard proctor
- Difference in density means 1-2 order of magnitude increase in permeability

Vangorda Waste Rock

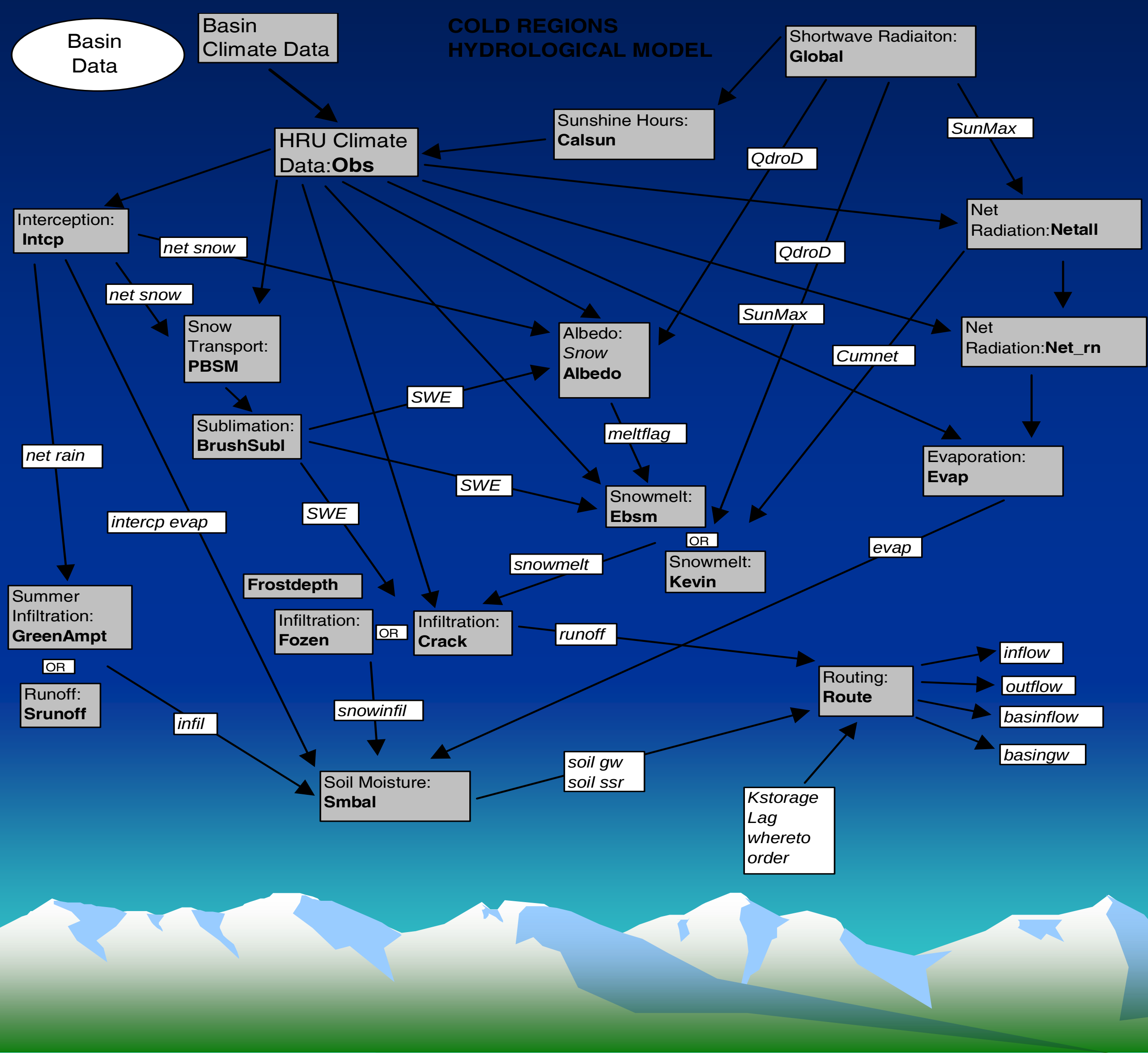
- Field tests in 2003 showed permeability of 10^{-4} to 10^{-5} cm/s

Vangorda Waste Rock



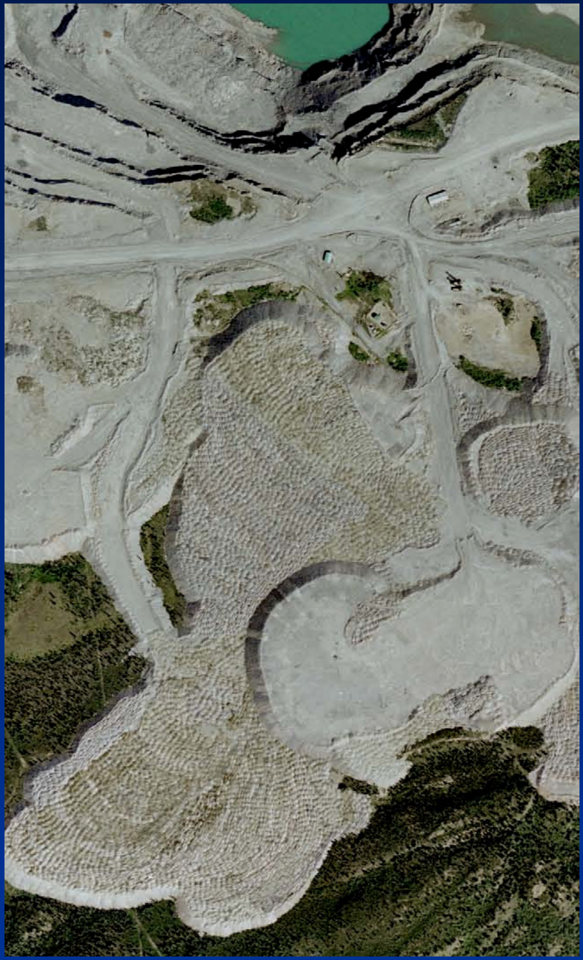
- Meteorological stations established in Dec 2003
- Cover trials in Sept 2004

Vangorda Waste Rock



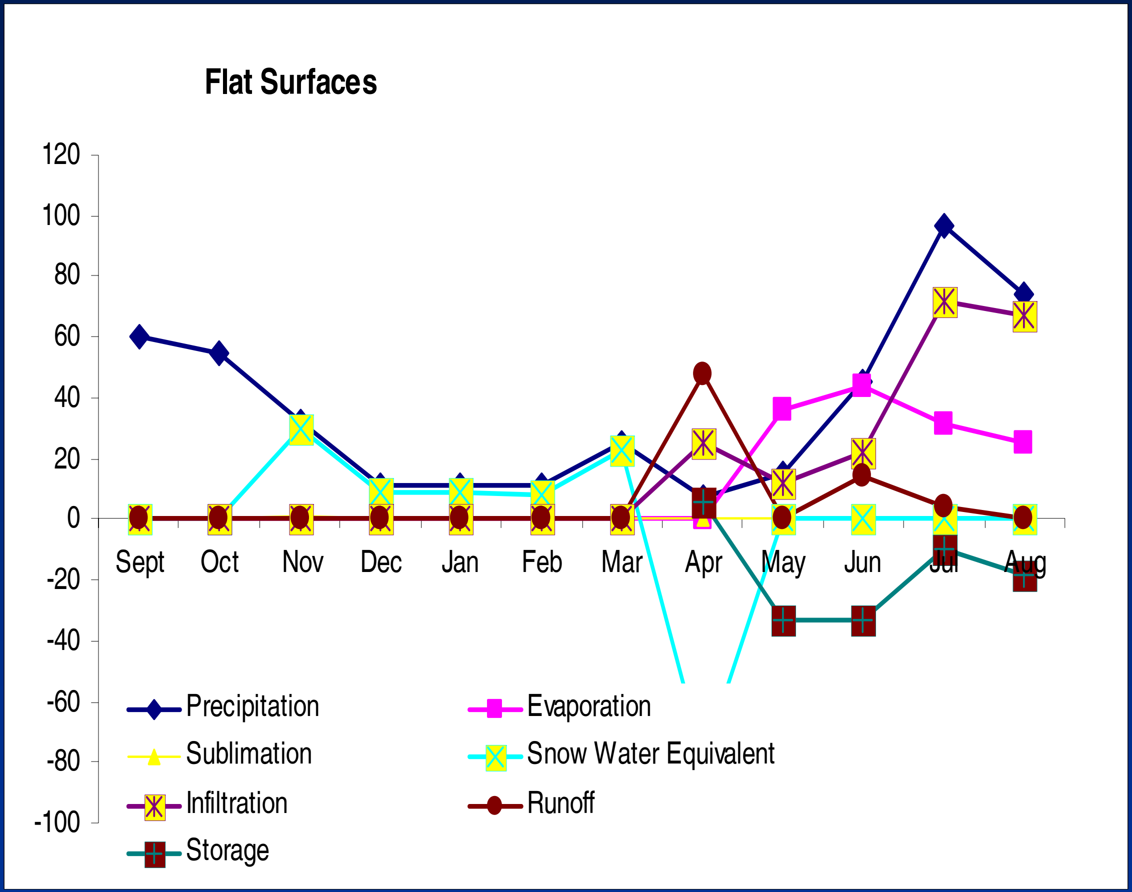
- Water balance modeling using Cold Regions Hydrologic Model
- Joint effort with YTG and NHRI

Vangorda Waste Rock



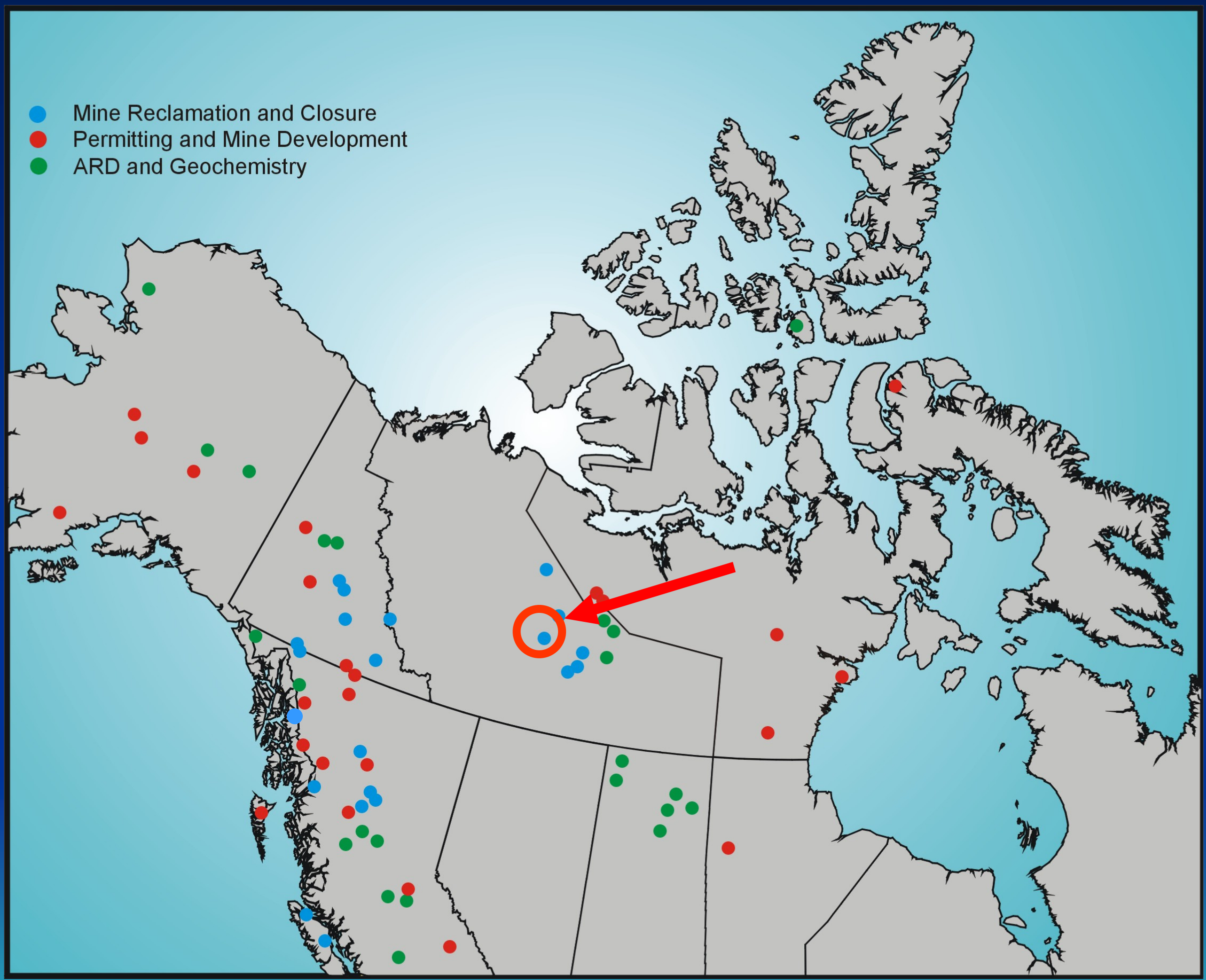
- Flat surfaces
- Slopes
  - North, East, South, West
- Bubble dumps

Vangorda Waste Rock



- Results to date very different than predictions based on SoilCover
- Both models need to be re-calibrated this winter

Colomac Mine



Former Royal Oak gold mine

220 km N of Yellowknife

Operated from 1990-1997

Tli Cho area

Colomac Mine

11.2 million tonnes of tailings

No ARD but very high cyanide, thiocyanate and ammonia

Colomac Mine

- Decision making
  - Results of technical studies presented to Tli Cho elders for input and feedback
  - Final decisions by owner, taking Tli Cho input into account

Colomac Mine

- Technical studies of cover options

Method	Difficulty	Certainty	Cost
Wet Covers	Low	Poor	\$3 – 4 M
Water Cover	Mod	Poor	\$3.5 M
Dry Covers			
Rockfill	Low	Good	\$3 M
Composite Soil	Low	Good	\$6.5 M
~~Low Infiltration~~	~~Mod~~	~~Mod~~	~~\$5 – 7 M~~
Direct Revegetation	Low	Poor	\$1 M
~~Freeze-back Covers~~	~~High~~	~~Low~~	~~\$3 – 4 M~~

Colomac Mine

- Results of Tli Cho evaluations

Method	Conclusion
Wet Covers	Acceptable
Water Cover	No. Too much risk of failure and might encourage moose to eat plants.
Rockfill Cover	Preferred, because it would discourage caribou feeding.
Composite Soil	No. Too much damage to area where soil would come from
Direct Reveg.	No. Caribou might eat plants.

Colomac Mine

- Rock fill cover
  - Use waste rock from mine area
- Concern about rough surface being an obstacle to caribou
  - Run-of-mine for 80 cm
  - Sorted to 4” minus for top 20 cm
- No revegetation
- Questions as to constructibility and whether geotextile separation layer is required

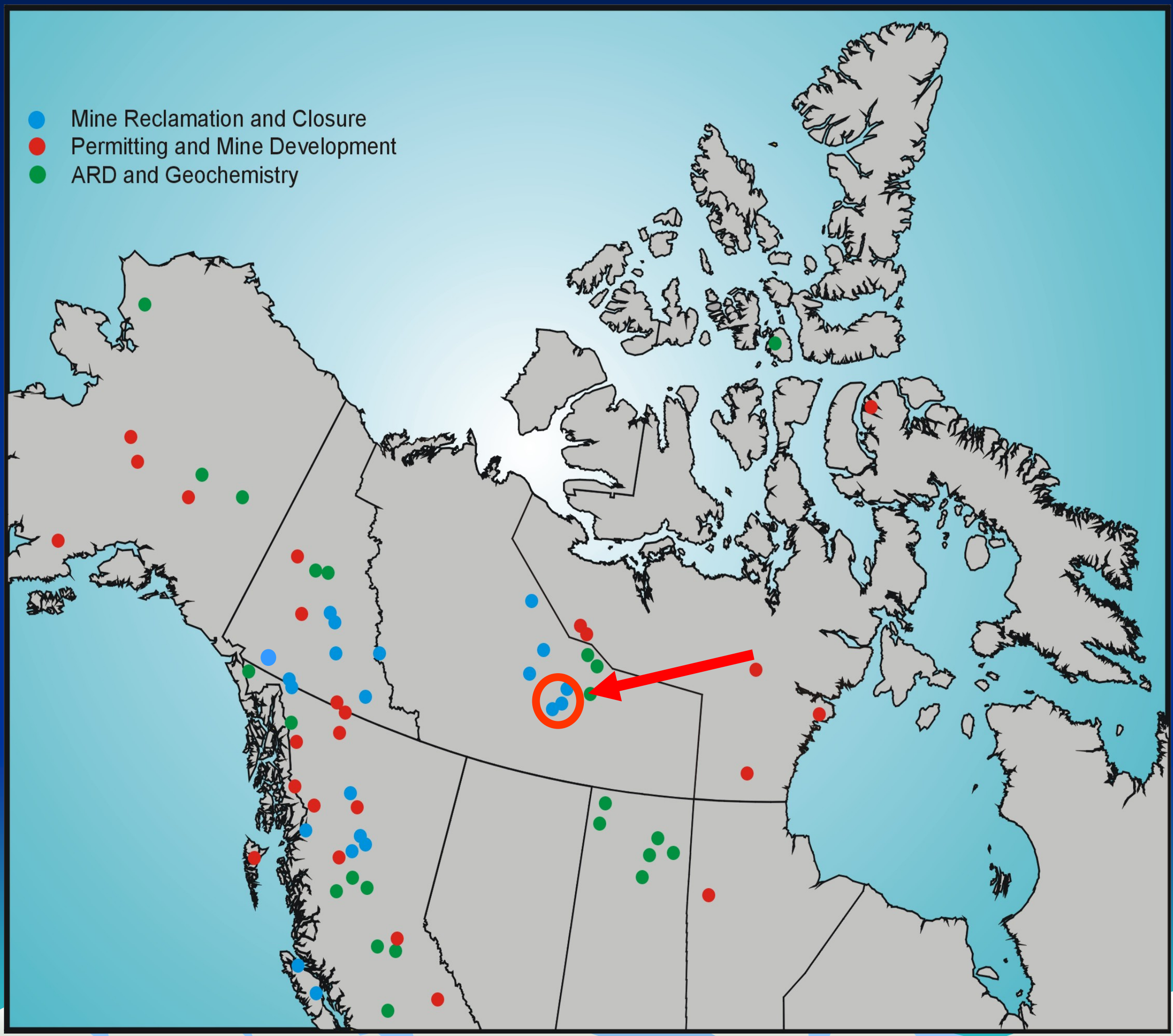
Colomac Mine

Test of winter construction in 2003

Colomac Mine

Monitoring test areas for settlement and upwards migration of tailings

Giant Mine



Former Royal Oak gold mine

Immediately north of Yellowknife

Operated from 1949-2004

Giant Mine

Tailings areas cover about 95 ha

High arsenic levels

Dust

Giant Mine

Sludge pond covers another 10 ha

Consolidation problem

Giant Mine

- Design objectives for tailings covers:
  - Stop dust and direct exposure
  - Minimize contaminated surface water
    - Need to prevent upwards flux of contaminants by evaporation
    - Suggests two-layer cover with capillary break
  - Allow future recreational use of surface
    - Local concerns about ATV users
    - Need one of the layers to be coarse material

Giant Mine

Test program in planning for 2005

Water storage

Integrity of capillary break

Need for geotextile seperation layers

Northern Cover Projects

- How do they differ from other cover projects?
  – Objectives
  – Phenomena
- What are the priorities for advancing the state of the art?

Northern Cover Objectives

- Objectives
  - – Inert covers as common as revegetated covers
    - No need to worry about animals eating contaminated vegetation
  - – Low maintenance
    - Surface water management important
    - If revegetated, allow natural succession
  - – Ease of construction by local forces

Northern Cover Phenomena

- Harmful
  - Degradation of compacted layers by freeze thaw
  - Frost heave effects
    - Tailings to surface
    - Degradation of capillary layers
  - Cryoturbation processes disrupting cover
    - Or not

Northern Cover Phenomena

- Beneficial
  - Soil remaining frozen while snow melts
  - Snow re-distribution off of exposed flat surfaces
  - Freeze back of reactive waste

Northern Cover Phenomena

- Unknown effect
  - – Snow-soil heat exchange
  - – Soil moisture movement to ice front
  - – Snow capture by plants, furrows or other surface roughness
  - – Slope and aspect effects

Northern Cover Priorities

- Many individual projects dealing with local issues:
  - Appropriate for “Objectives”
  - Dangerous for “Phenomena”
    - Could be emphasizing wrong deleterious processes
    - Could be overlooking potentially beneficial processes

Northern Cover Priorities

- Need overview to identify which processes are of general importance
  - Northern hydrology research
  - Ongoing testing and monitoring programs
  - Other research
- Coordination among projects to ensure processes are sufficiently studied

End