Overview of Mine Water Classification & its Genesis

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Outbursts of Water from the Slovenian Abandoned Mines

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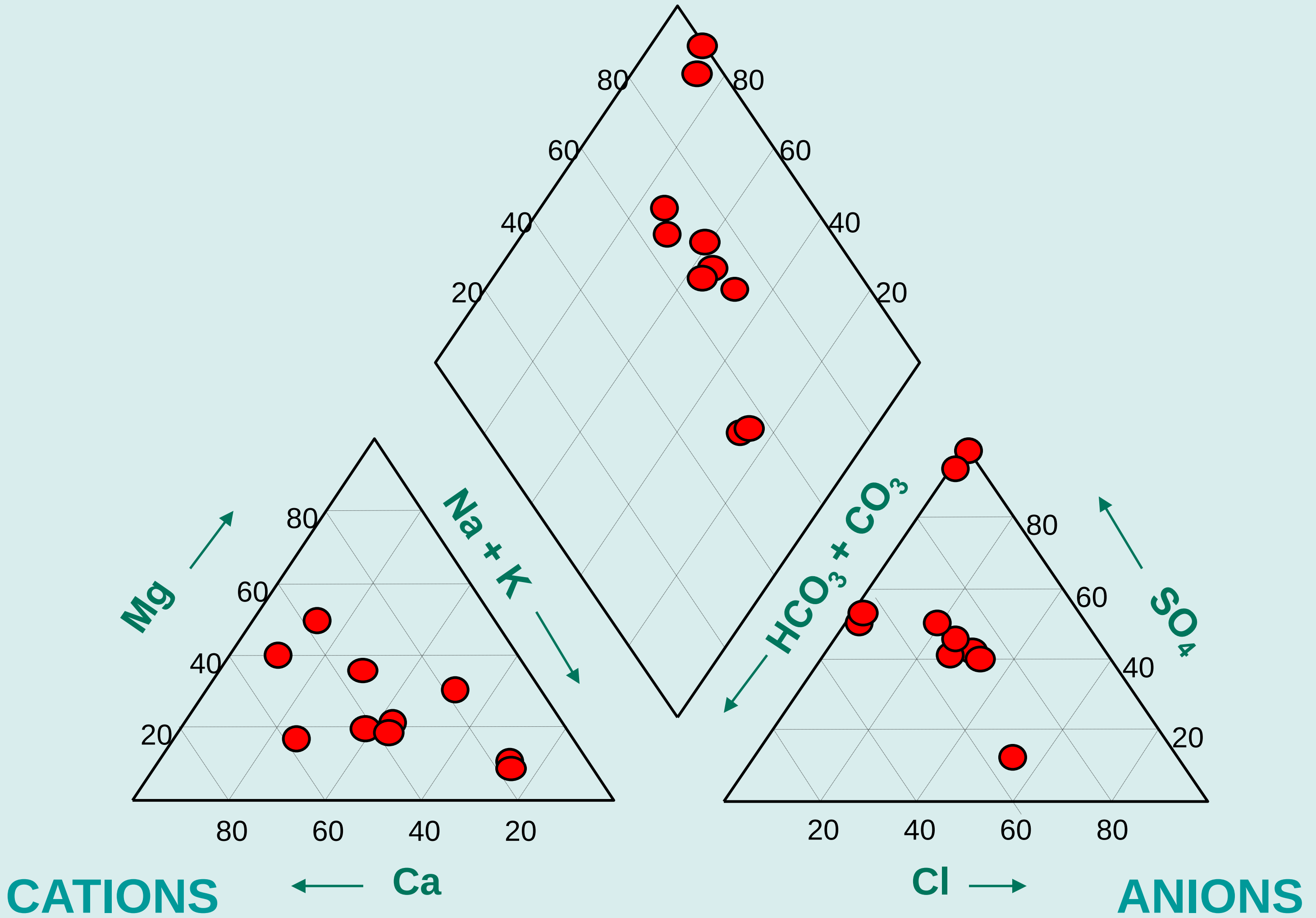
Existing Classifications

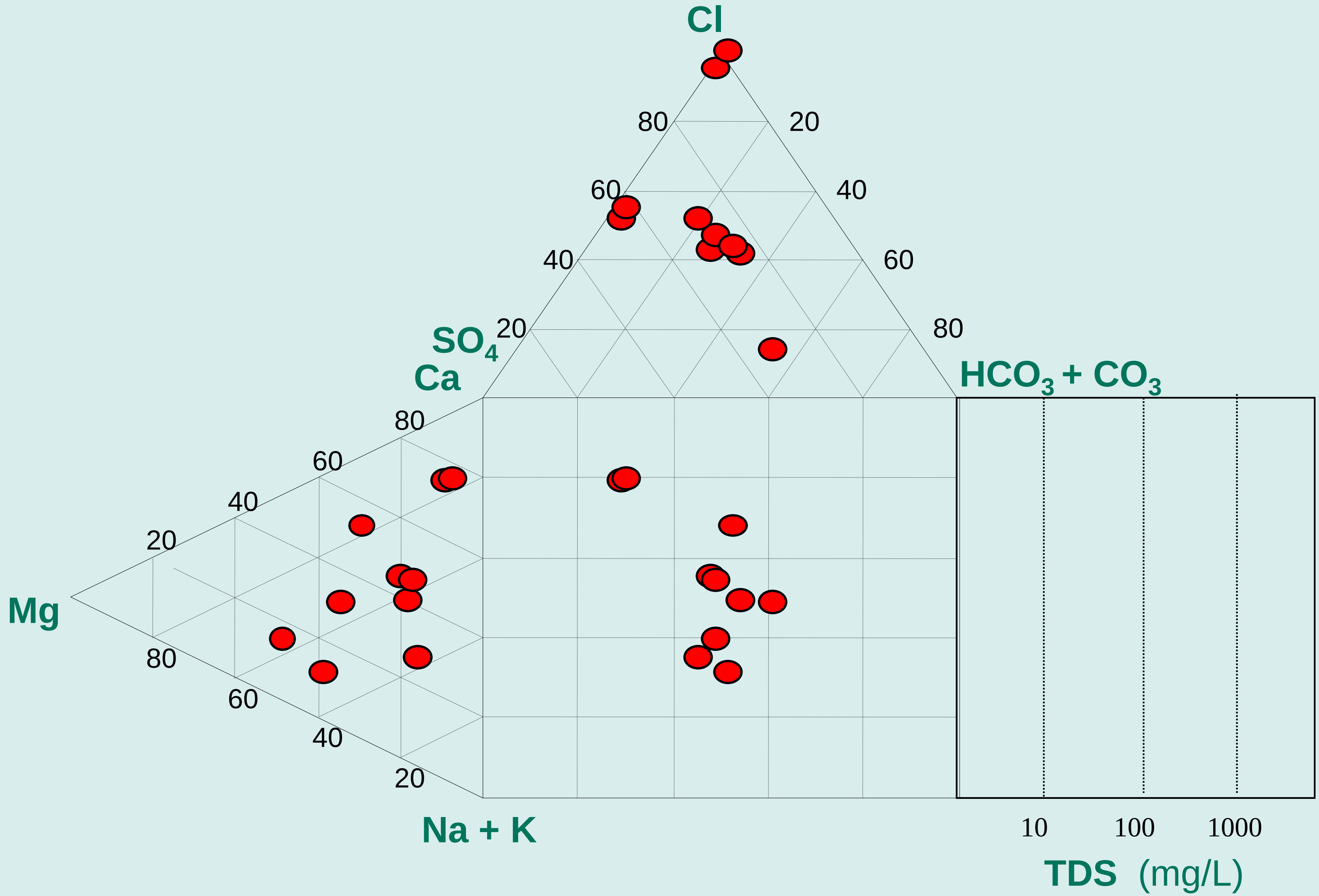
Six major schemes for classifying mine water exist:

- Facies diagrams (Piper 1944 & Durov 1948)
- Glover’s scheme (1975)
- Ficklin et al. (1992)
- US Bureau of Mines’ scheme (1994)
- Younger’s scheme (1995)
- Azzie’s scheme (2000)

Piper Diagram



Durov Diagram



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Glover's Scheme

1. Acidic with low Fe_{TOTAL} conc.

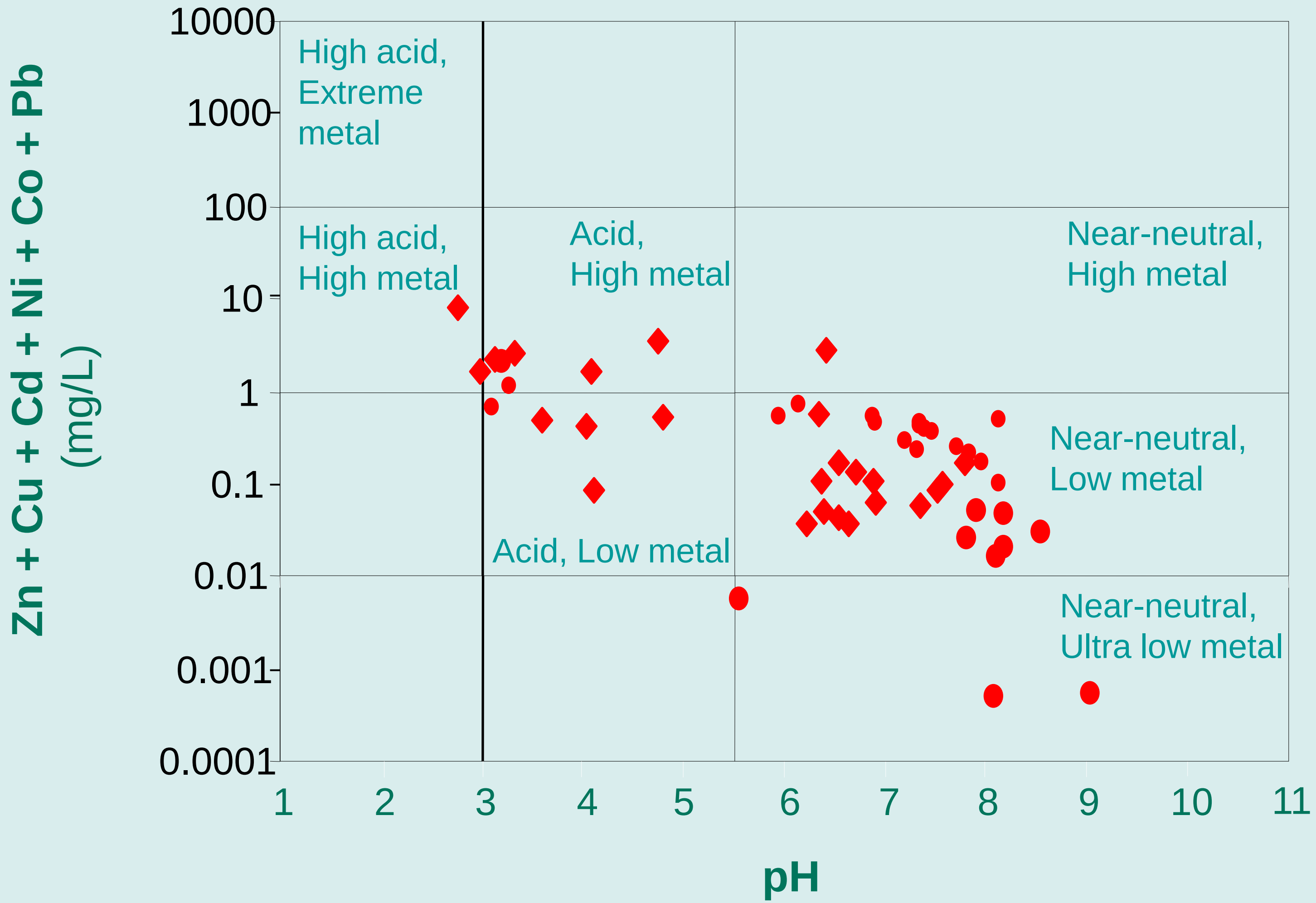
2. Acidic with high Fe^{3+} conc.

3. Acidic with high Fe^{2+} conc.

4. Neutral with high Fe^{2+} conc.

5. Suspended ferric hydroxide
   (combined with dissolved Fe^{2+} or Fe^{3+})

Ficklin, Plumlee, Smith & McHugh



US Bureau of Mines' Scheme

GROUP 1:

Net alkaline minewaters

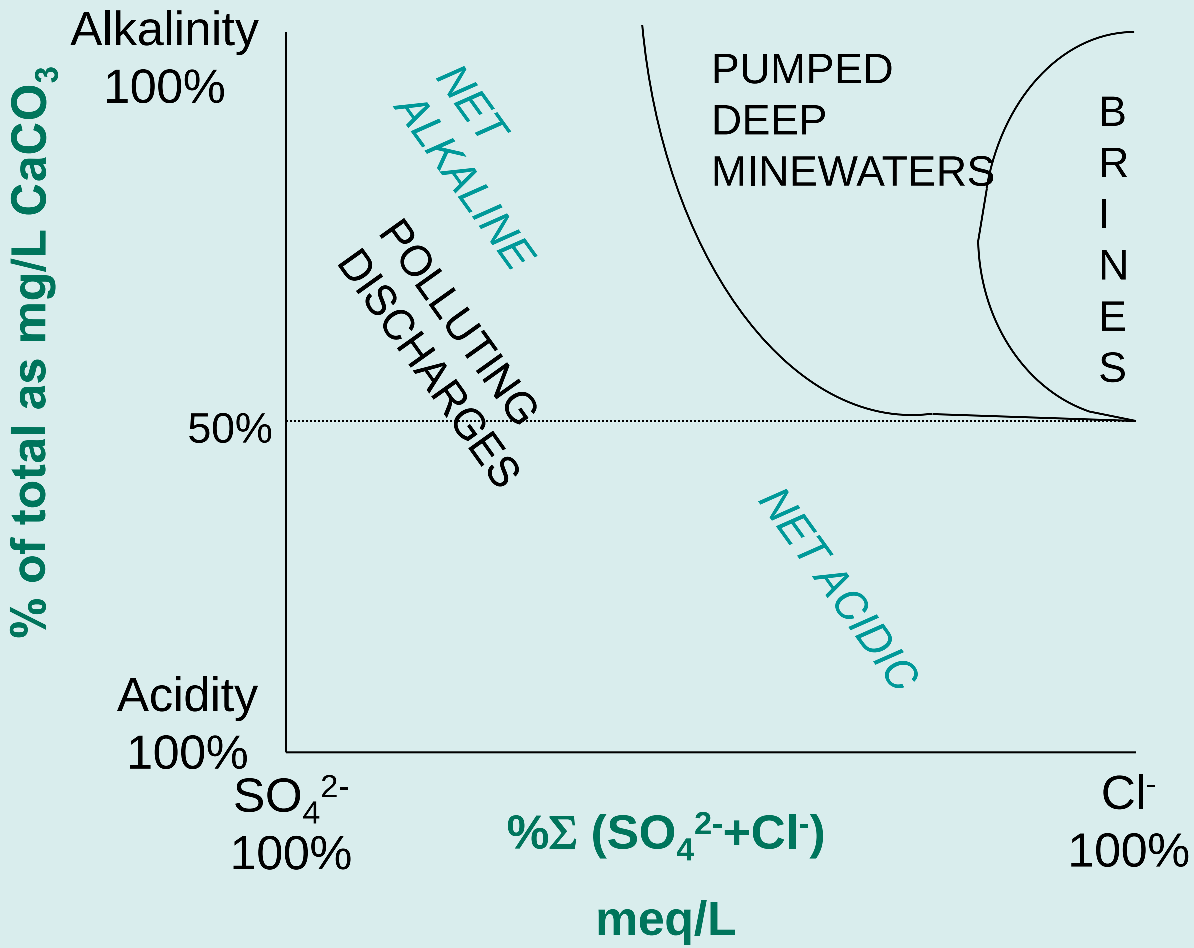
i.e. alkalinity > acidity

GROUP 2:

Net acidic mine waters

i.e. acidity > alkalinity

Younger’s Scheme



Azzie's Classification

Selection Criteria

- Alkalinity / acidity (Net)
- Salinity

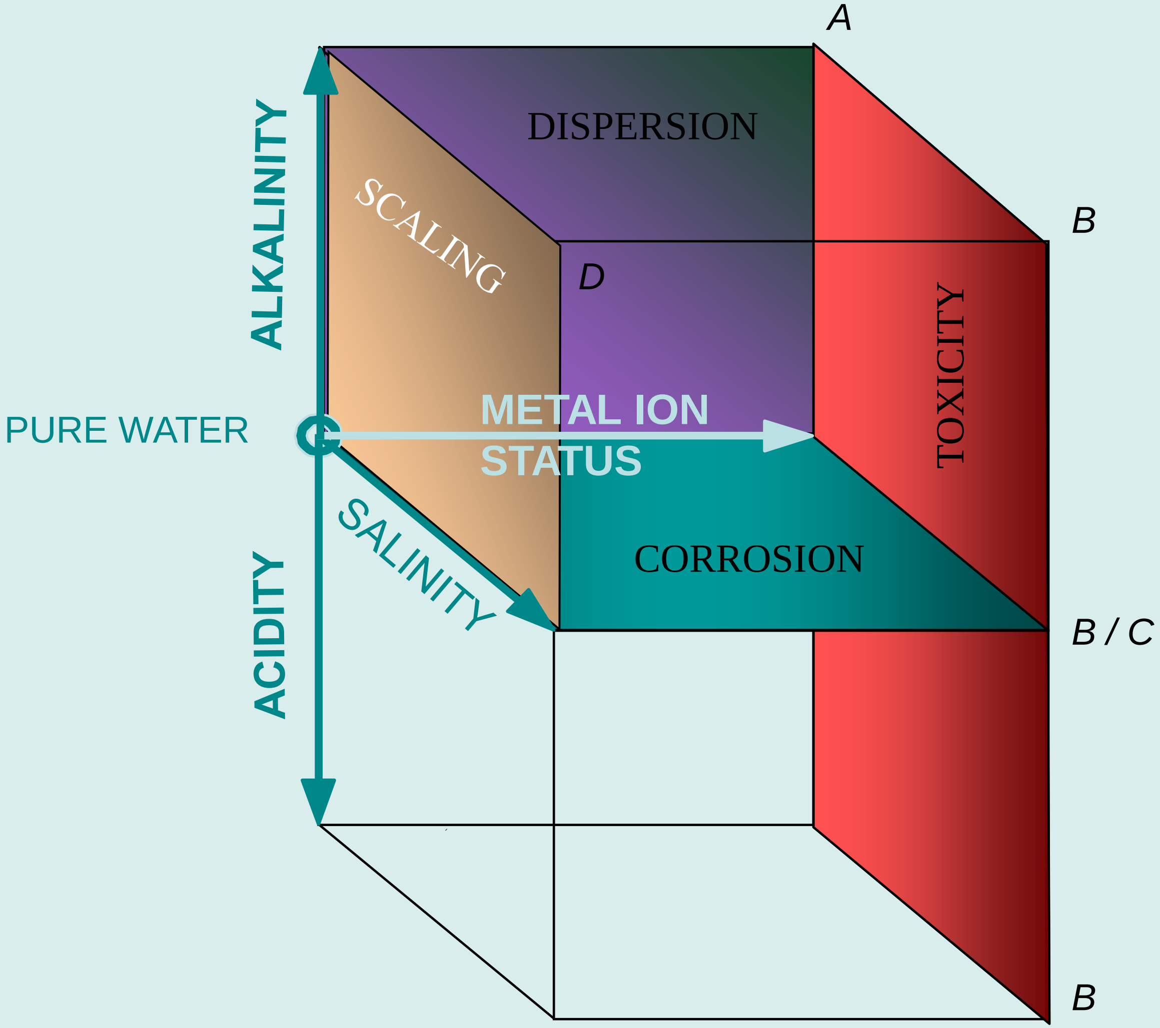
  $I = \frac{1}{2} \sum m_i z_i^2$
- Metal ion status

  $SAR = Na^+ / (Ca^{2+} + Mg^{2+})^{1/2}$

  or

  $AAR = (Al^{3+} + Fe_{TOTAL}) / (Ca^{2+} + Mg^{2+})^{1/2}$

Azzie's Classification



A = Highly dispersive

B = Highly toxic

C = Highly corrosive

D = Highly scaling

Types of Drainage

There are 3 types of drainage produced by sulphide mineral oxidation:

Acid Rock Drainage

- Acidic pH
- Moderate to elevated metals
- Elevated sulphate
- Treat for acid neutralization and metal & sulphate removal

Neutral Mine Drainage

- Near neutral to alkaline pH
- Low to moderate metals. May have elevated Zn, Cd, Mn, Sb, As, or Se
- Low to moderate sulphate
- Treat for metals & sometimes sulphate removal

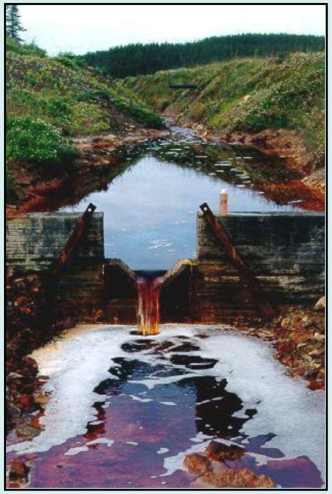
Saline Drainage

- Neutral to alkaline pH
- Low metals. May have moderate Fe
- Moderate sulphate, magnesium & calcium
- Treat for sulphate and sometimes metal removal

What is ML & ARD ?

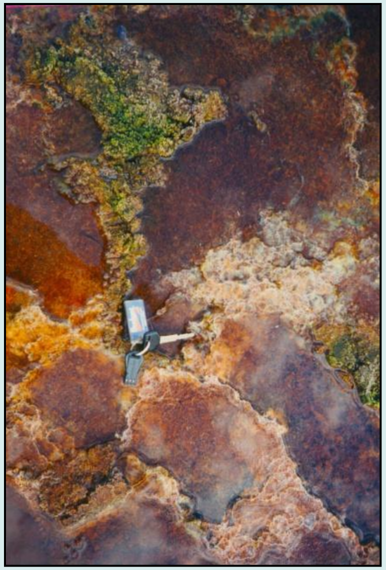
- Metal Leaching & Acid Rock Drainage are *naturally* occurring processes.
- ML & ARD are caused when metal sulphides come into contact with both air and water.
- Rocks at most metal and some coal mines contain sulphide minerals.
- Excavating and crushing of ores greatly increases amount of rock surfaces which can be exposed to oxygen and water.
- So, mining activities can have high potential for leaching acid and metals.

What is ML & ARD ?



- ML/ARD can occur from mining wastes (tailings & waste rock), in an open pit or along underground mine surfaces.
- Potential for environmental impacts depends on:
  - Amount of metals in the mine drainage;
  - Amount of acid-neutralizing ability in nearby rocks & water;
  - Amount of dilution available in streams; and
  - Sensitivity of the receiving environment.

Why are ML and ARD important ?



- They can have significant negative impacts on the environment if not adequately managed:
  - High levels of metals and/or acid can be harmful or toxic to living organisms;
  - Metals that are absorbed by plants & animals can be passed through food chain.
- Once initiated, it can persist for hundreds of years until sulphides are completely oxidized, and acid and metals are leached from rocks.
- It can be VERY expensive to manage once it has developed

  e.g. BC water treatment plants to treat ML/ARD have cost >$10million (capital), with further $1.5million/yr operating cost.

Mitigation Options 1

- Proper planning of new mining developments can reduce risks, liabilities & costs associated with ML/ARD.
- Geochemical testing of rocks prior to mining can predict the likelihood of ML/ARD being an issue.
- Many strategies are available for prevention and management of ML/ARD.
- Every strategy has strengths and weaknesses, and not all strategies are applicable to all mine sites and their environments.
- For best results, a combination of strategies may be required.

Mitigation Options 2

- Basic principle behind management strategies:
  - Preventing oxygen contact with sulphide minerals
  - Reduce amount of water that comes into contact with acid generating wastes to minimize the amount of leaching.
- Most commonly used strategies include:
  - Avoidance
    i.e. Don't mine the sulphide-bearing stuff !
  - Flooding of mine waste materials
    Timing is crucial …
  - Covers
    Susceptible to breakdown over time
  - Blending of materials
    Only successful on a small scale
  - Drainage treatment
    The last resort !

Mitigation Options 3

- Mitigation strategies must be designed to last forever !!
- Mine sites and their environments are dynamic and continue to change long after mining has ceased ….. changes can influence the effectiveness of mitigation strategies over time.
- Regular monitoring, maintenance and responsive management are key to long-term success in preventing impacts from ML/ARD.

Case Studies

Implications of producing large volumes of contaminated water … can mine water be a commodity ?

e.g. Coal mines in South Africa

Background to SA Coal Mining

- Collieries exploiting the Witbank coalfields in South Africa have to continuously pump water out to reach the coal seams.
- Pyrite occurs naturally in coal formations, and when water enters the workings it becomes contaminated.
- SA environmental law requires water to be *suitable* for release back into the environment (which may involve management and treatment).
- Mines are located in the Upper Olifants catchment, which suffers from a chronic water shortage.
- Future mining developments are situated downstream, as is the scenic “Lowveld” and Kruger National Park.
- Water is characterized by high Ca, Mg and SO_4.

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Case Study: Irrigation (South Africa)

- Decided to investigate ways in which contaminated effluent could become a useful resource.
- Partnership between ACSA, WRC, Univ Pretoria & Coaltech 2020.
- Natural irrigation water varies greatly in quality.
- Some common soil problems that may develop:
  - Salinity
  - Water infiltration rate (↑Na & ↓Ca are problematic)
  - Specific ion toxicity (Na, Cl, B)
- SACE commissioned three centre-pivot irrigation systems, covering 82ha. Aim was to test viability of irrigating crops with saline effluent, that is high in SO_4 and K.

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Case Study: Irrigation (South Africa)

- These salts are taken up by certain crops and are highly beneficial if managed correctly.
- Irrigation of prime agricultural soils nearby, using this water, has improved productivity by 300%.
- Further research required:
  - Significance of crop selection
  - Impact of irrigated salts on soil conditions
  - Effects on groundwater
- Significant benefits for small-scale farmers in neighboring communities.

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Case Study: Treatment (South Africa)

- The Emalahleni Water Reclamation Project sees the abstraction and treatment of acidic mine water from existing and old mines to a level fit for use by the local municipality.
- Sale of the water allows the mining companies involved to offset the costs of water treatment.
- In 2005, the local municipality was drawing 80-90MLD from Witbank Dam, but this was ~20MLD short of that required.
- A 0.120MLD demonstration plant was built and run for 3 months.

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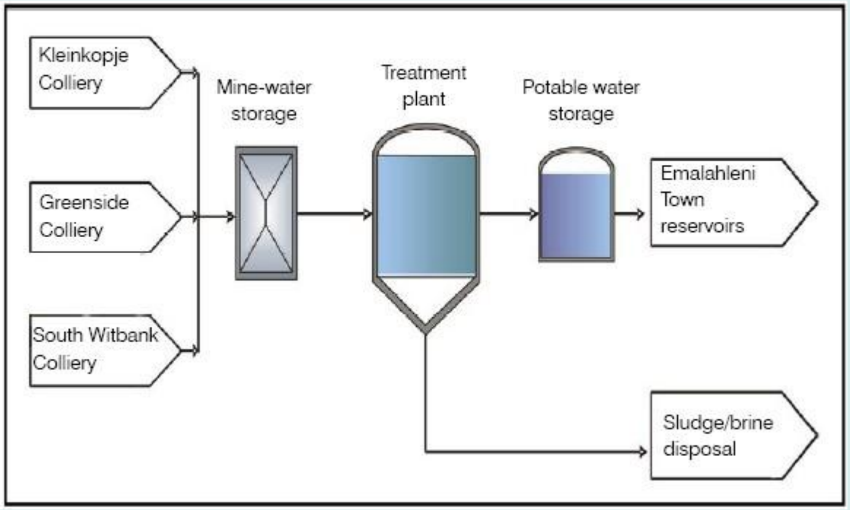
Case Study: Treatment (South Africa)

- Results from the demonstration plant indicated that:
  - pH increased from 2.9 to ~7.
  - Total dissolved solids concentration reduced from 4500mg/L to 135mg/L.
  - SO_4 concentrations reduced from 3500mg/L to 80mg/L.
  - A yield of 98% was achieved.
- Treated water meets SABS 241 Class 0 Drinking Water Quality Limit.
- A full scale plant (20MLD) was commissioned in 2007, and is now fully operational.
- The full scale plant draws water from 3 mines, conveys it to a storage facility at treatment site.
- Storage facility has capacity for 46MLD, so caters for seasonal fluctuations.

Case Study: Treatment (South Africa)



- Acid water first undergoes neutralization using lime/ limestone.
- This increases pH and allows metals to precipitate out.
- Following clarification water is treated using ultrafiltration to remove remaining metals & bacteria.
- Reverse osmosis using spiral membranes then removes remaining salinity.
- 500 UF membranes and 1200 RO membranes are being used.

Case Study: Treatment (South Africa)

- Treated water is stored in 10MLD dome-shaped concrete reservoirs before being pumped 9km to the municipal reservoir for distribution to consumers.
- Approx 100m^3/day of brine and 100t/day gypsiferous waste is produced.
- Brine is disposed of in 330,000m^3 evaporation ponds.
- An on-site laboratory monitors water quality.

Case Studies

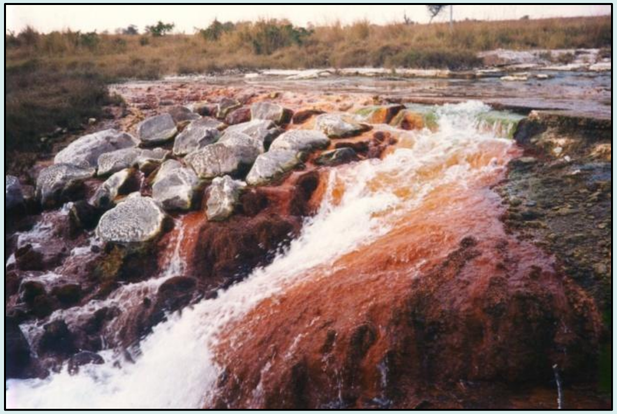
Geochemistry to show impact of abandonment and rehabilitation

e.g. Coal mine in South Africa & Pb-Zn mine in Ireland

Case Study: TNDBC (South Africa)

Surface subsidence

Burning u/g workings



AMD

Polluted river

Closure Objectives

Main closure objectives include:

- Physical stability
- Chemical stability
- Biological stability
- Hydrological & hydrogeological environment
- Geographical and climatic influences
- Local sensitivities and opportunities
- Successive land use
- Funds for closure
- Socio-economic considerations

Criteria for Mine Closure

Closure plans:

- Costs included in the assessment of alternatives
- Adopt a risk assessment approach
- Are developed in Mine Planning phase
- Should be maintained during active life of a facility, and routinely updated when modifications are made
- Facilities to be designed to facilitate premature closure
- After-care design should minimize the need for active management

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Case Study: New Largo (South Africa)

Does this qualify for a closure certificate ?

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