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MEM

The science behind success

The effect of ore processing on tailings properties

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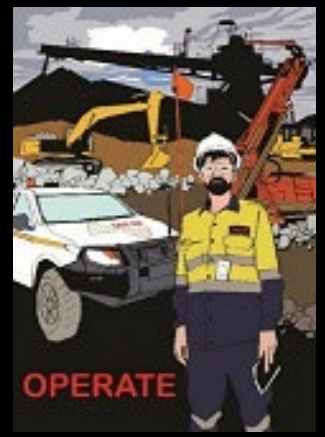
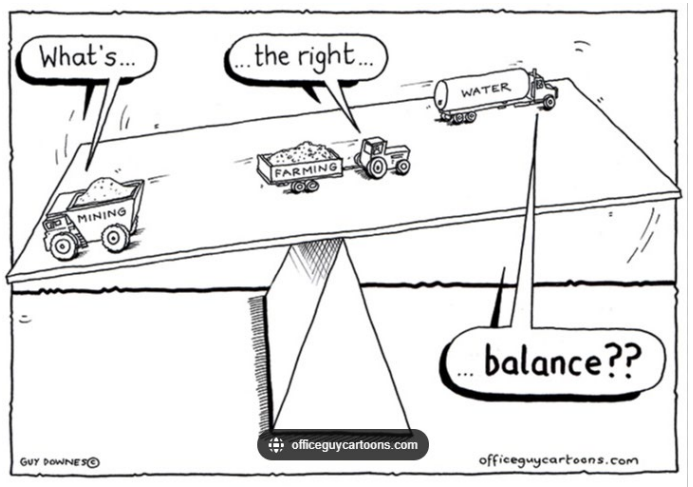


Overview

Outline:

- Tailings are the product of processing
- **Recovery ($)** drives ore processing flow sheet development
- But processing will fundamentally control geotechnical and geochemical properties of the tailings produced
  - Physical properties
  - Geochemical properties
  - Leaching properties of tailings
- Geotechnical and geochemical properties have direct impact on costs/risk/liability **($)** for tailings management
- Opportunities for creating a lower risk tailings product via consideration of processing



Overview of processing steps

PHYSICAL:

Primary crush/grinding (size decrease)

Impacts size, but also moisture-retaining properties, reactivity, leaching properties through availability and solubility of existing minerals and oxidation

CHEMICAL:

Flotation/oxidation
Leaching e.g. CIL process

Addition of chemicals, pH changes, re-distribution of metals from primary to secondary mineral phases.

Recovered product

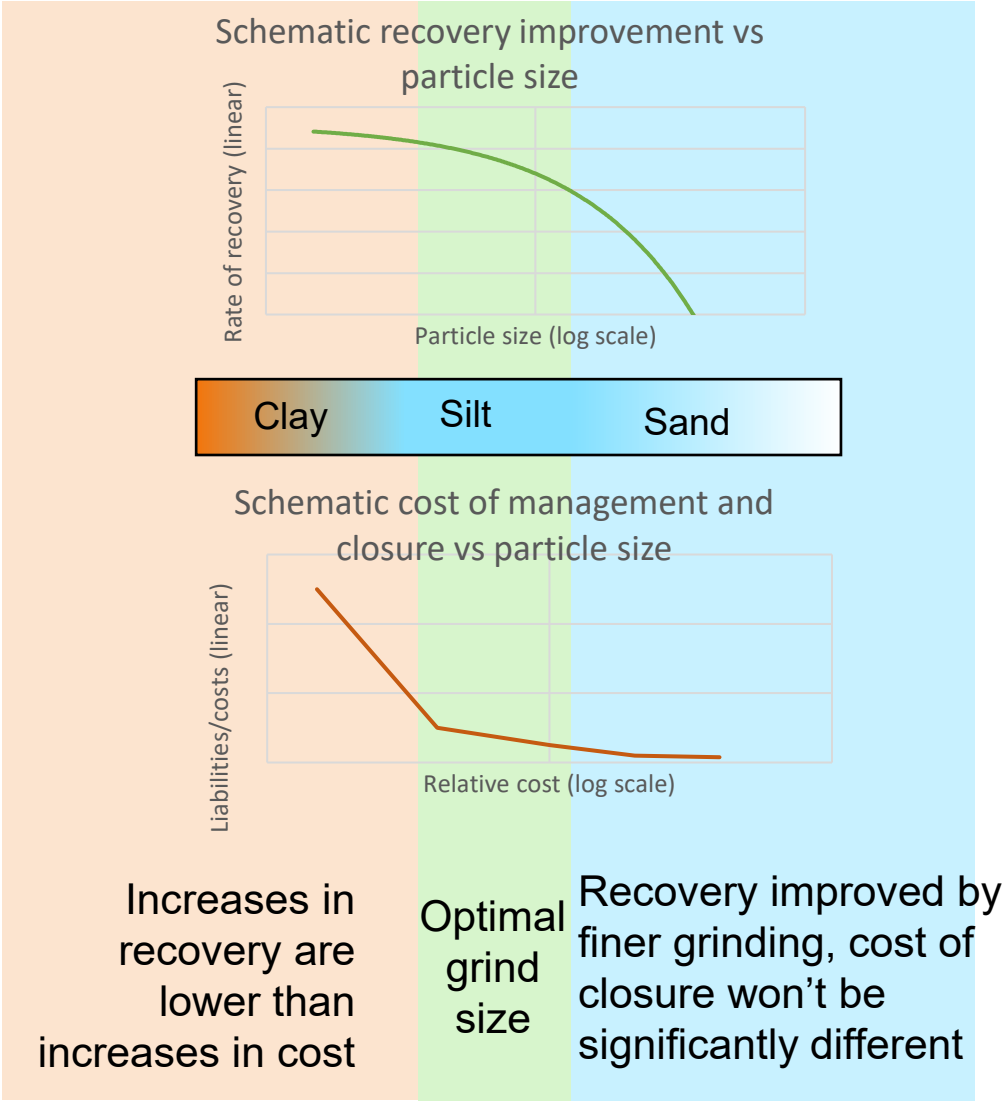
TAILINGS

Solids with properties resulting from processing.
Entrained process water (including in filtered and de-watered tailings)

This process is optimised on the basis of recovery value

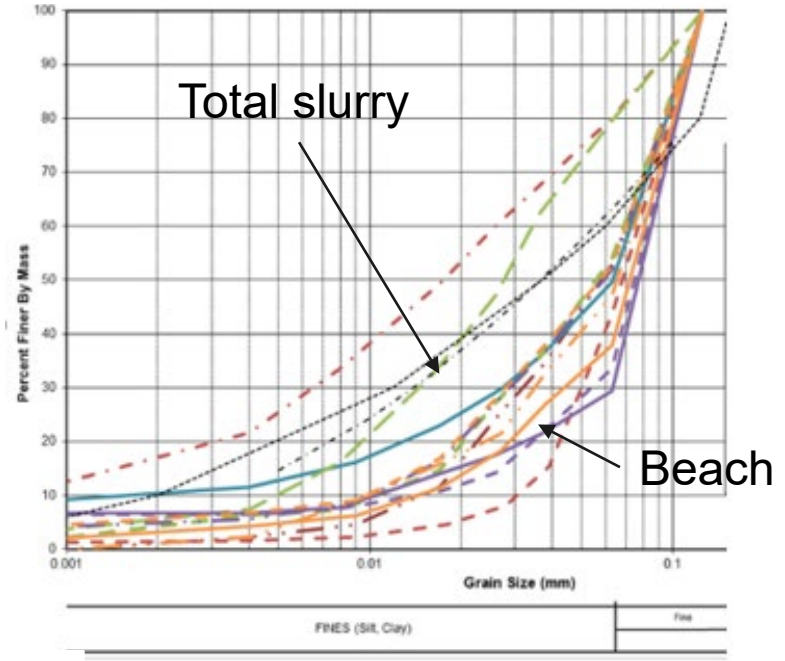
Grinding size and “integrated” cost curve

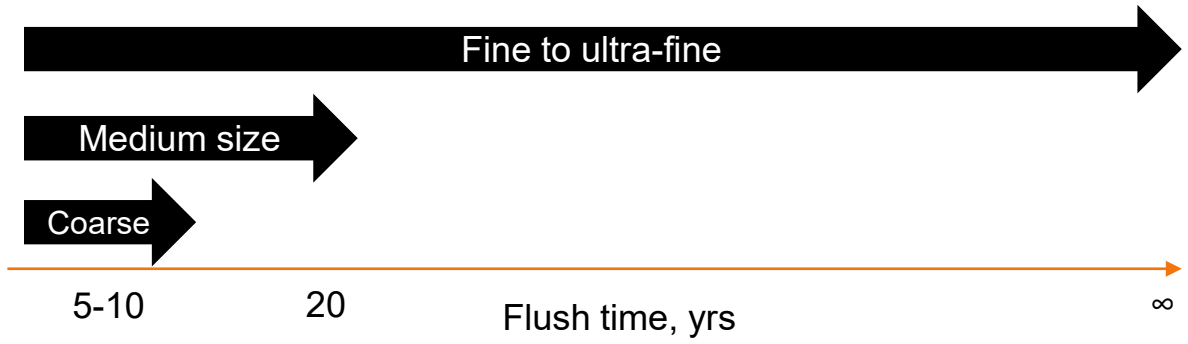
- Particle size affects geotechnical properties including plasticity and strength
- Operational management and closure engineering can be very challenging if the tailings are “soft”
- Size is a physical property, but has impact on geochemistry
- Finer grainsize in many cases increases risk/liability/cost of management and therefore requires considering alongside recovery as a key metric as part of optimising process flow sheets

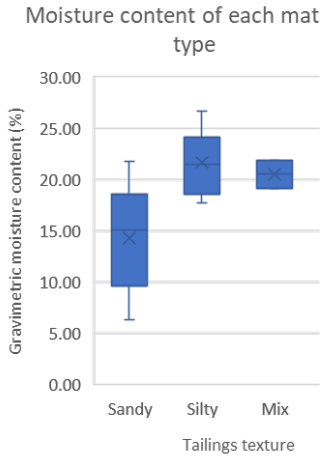


Particle size and moisture content

- We can observe the effects of particle size in slurry tailings because hydrodynamic separation from spigoting causes particle segregation – different properties in beach vs pond
  - Beach areas = coarser particles (higher k, lower porosity)
  - Pond area = finer particles (lower k, higher porosity)
- Beach areas are prone to quicker draindown = improved geotechnical condition and faster flush times for pore water but dry conditions and possibility for oxidation and weathering
- Pond areas may have slower draindown = challenging geotechnical condition and greater flush times for entrained process water
- A very long time may be required to exchange the pore water entrained in finer tailings due to lower k and higher water content



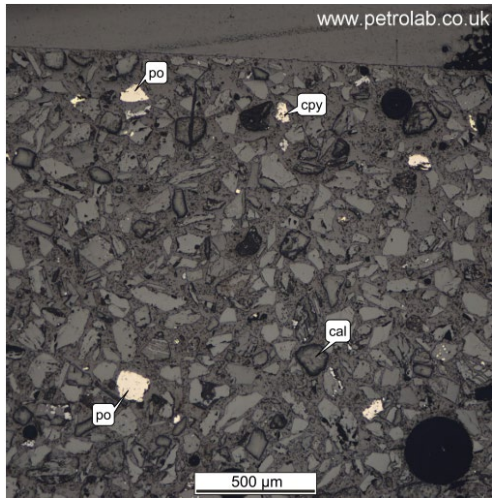




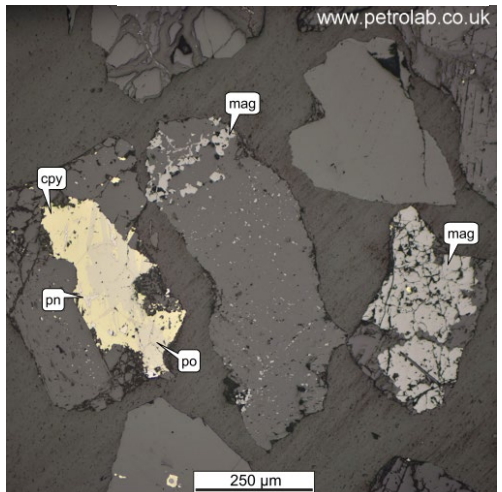
Particle size effect on leach quality

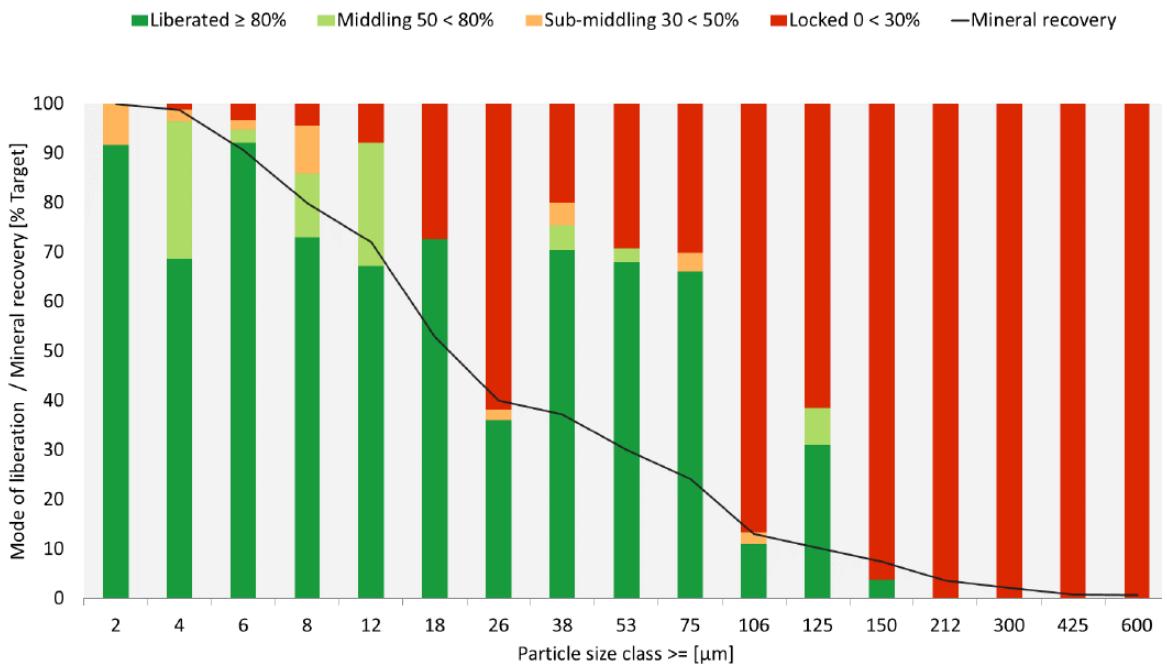
- Finer size = greater liberation of reactive mineral surfaces but **highly site specific** based on mineral species and rock type.
- The plot shows liberation profile of pyrite in different size fractions of a tailings sample
- Coarser than 0.1 mm = mostly locked pyrite. Finer than 0.1 mm = mostly liberated pyrite
- Liberated grains react, weather and dissolve

Liberated



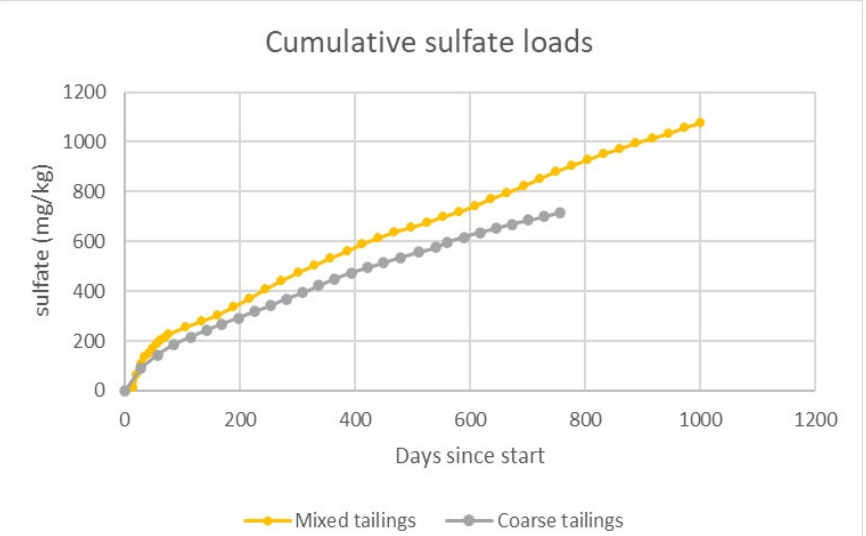
Locked

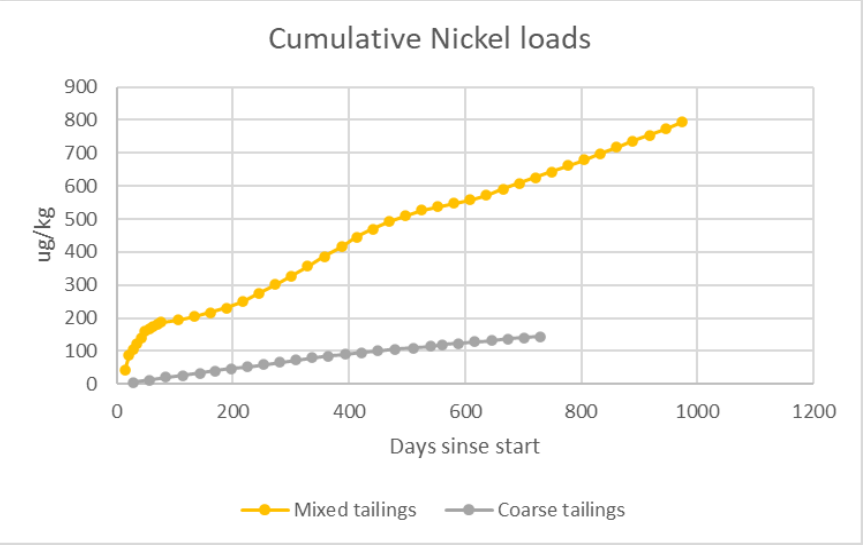




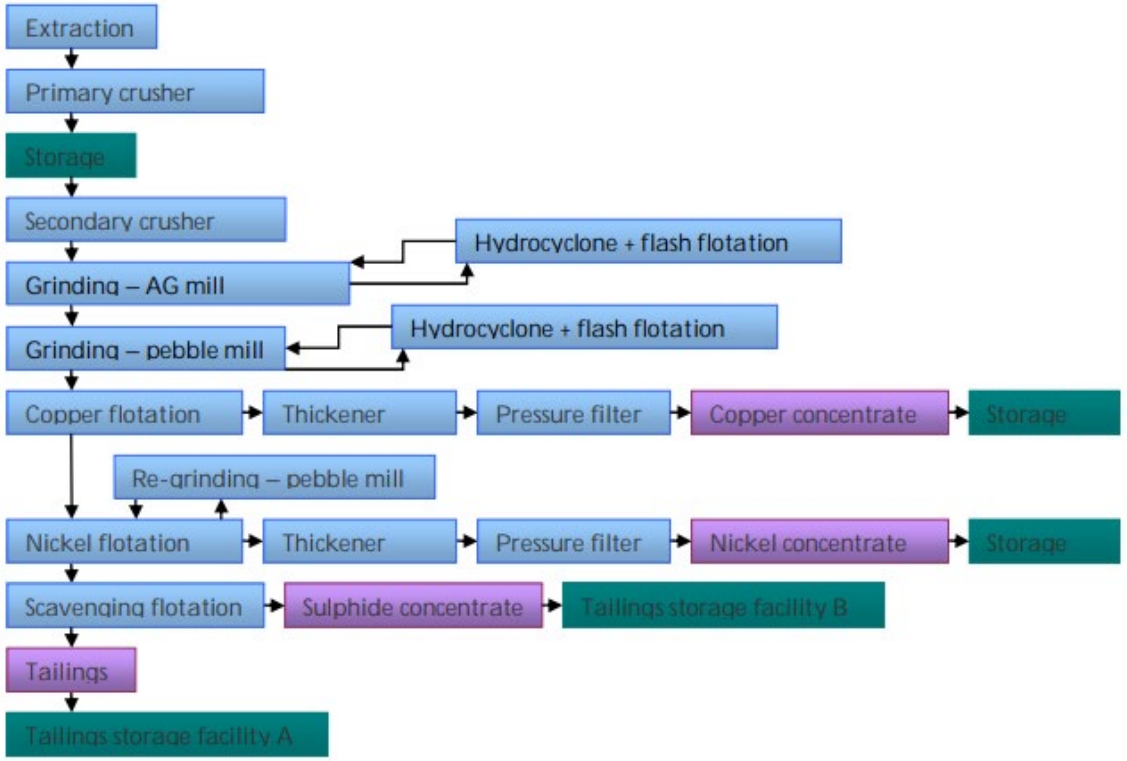
Particle size effect on leach quality

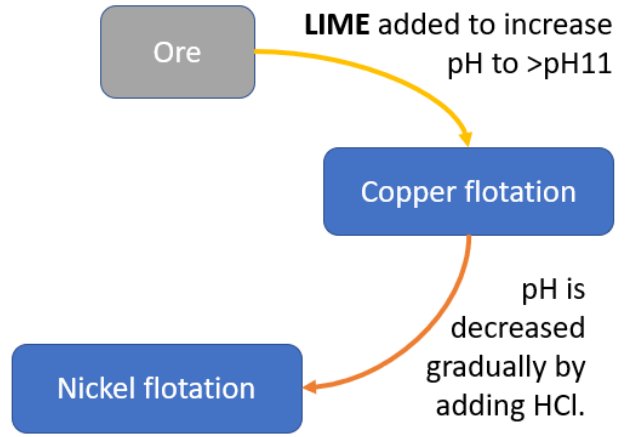
- Results from free draining tailings leaching columns
- Tailings direct from the spigot (mixed) and coarse tailings (from beach) have similar total sulfur content and thus sulfide oxidation rates (similar sulfate loads)
- However key difference is that nickel release from coarse tailings is significantly lower than mixed tailings
- Results suggest that
  - Iron sulfides are equally distributed and liberated by the two particle sizes
  - On the other hand, nickel sulfides are significantly more liberated in the finer particles
- Suggests that metal leaching potential is very sensitive and directly related to grind size implying that:
  - AMD risks may be reduced by slightly coarser grind size
  - Ultra fine fraction may contain additional “recoverable” metal resource





Secondary minerals created through processing



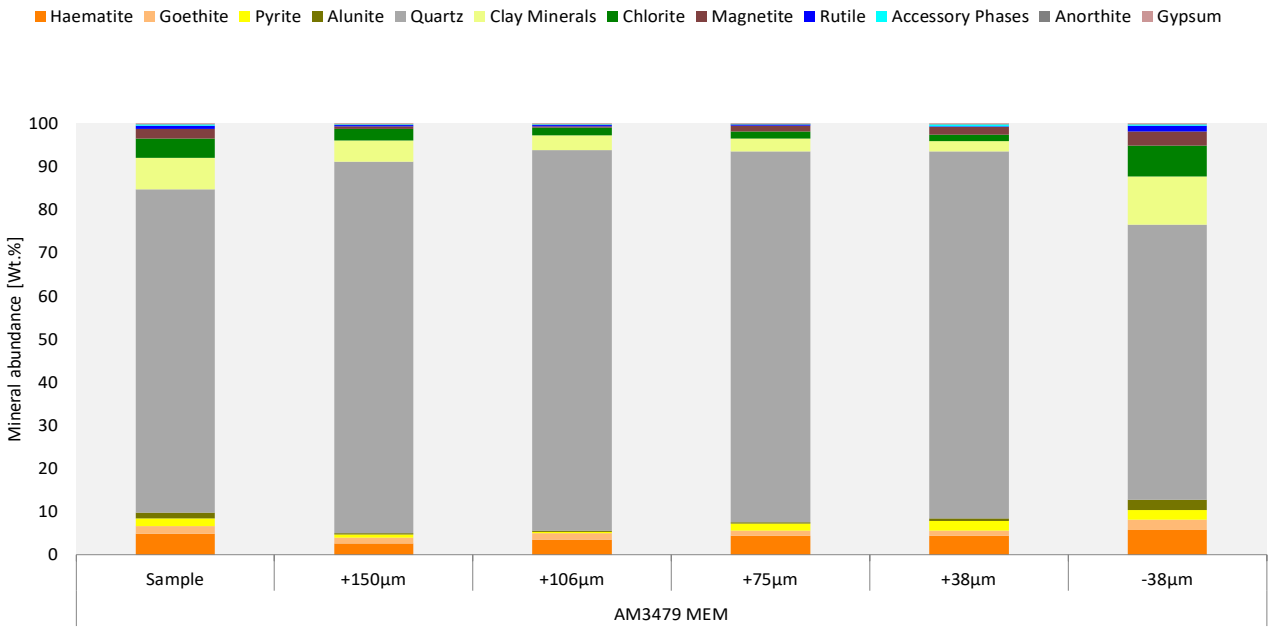


Lime adds Ca to the tailings and can facilitate gypsum precipitation in the presence of sulfate and at high pH

Lime is added to the cleaner cells to maintain selectivity

Secondary minerals

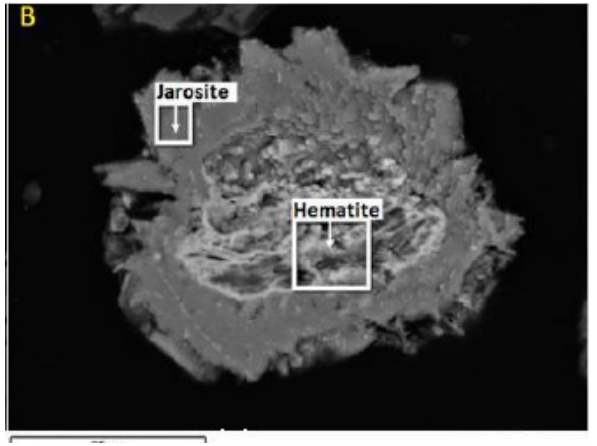
- Recalcitrant silicate minerals remain in the tailings (quartz, feldspars)
- XRD or SEM can be used to pick up a number of secondary phases (gypsum, oxides, jarosite etc)
- XRD does not include the amorphous or poorly-crystalline phases, which can contribute a significant weight % and be the most reactive fraction



Note the <38um fraction contains most of the clay, sulfate and iron oxide phases which has implications for geotechnical, geophysical and geochemical properties

Secondary minerals

- Secondary phases nucleate on existing grains, forming rims around them.
- They can also form amorphous clumps or mixtures, which cannot be readily identified as a specific mineral phase, making characterisation and prediction difficult.
- Metals which are in solution are sorbed to these phases and trapped within the structure but are *meta-stable* and can be released if pH/REDOX conditions change during storage
- It follows that they can be released when those minerals dissolve in the environment



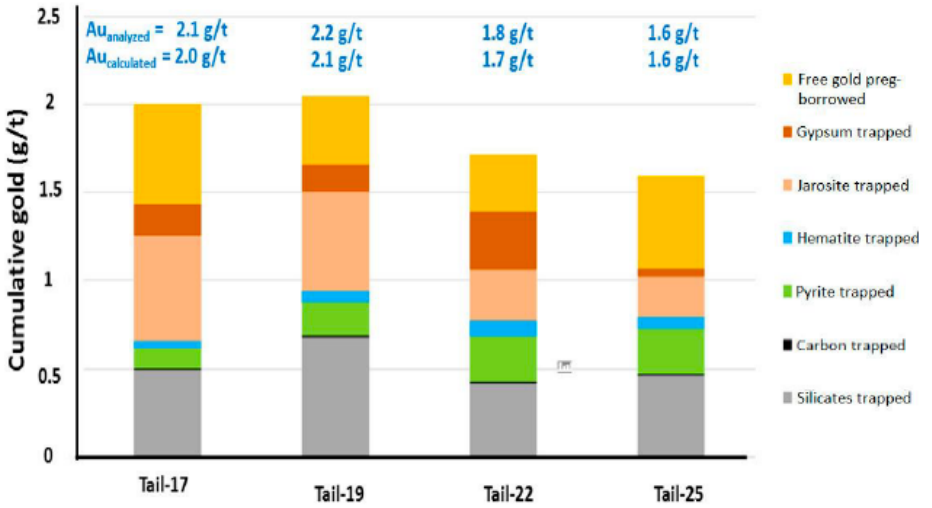
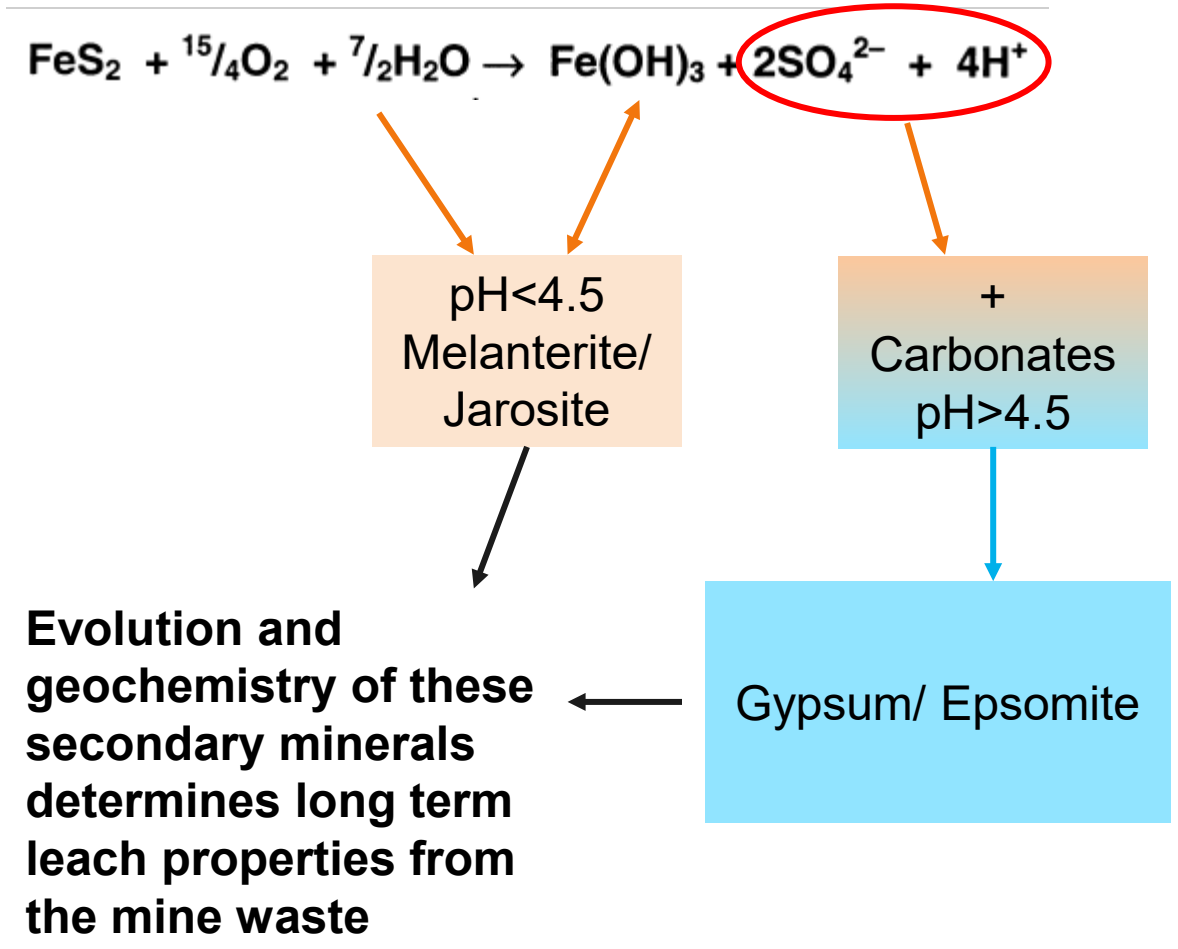


Figure 11. Diagnostic leach test results.

Edahbi et al 2019. CIL gold loss characterisation with oxidised leach tails (Minerals, 9)

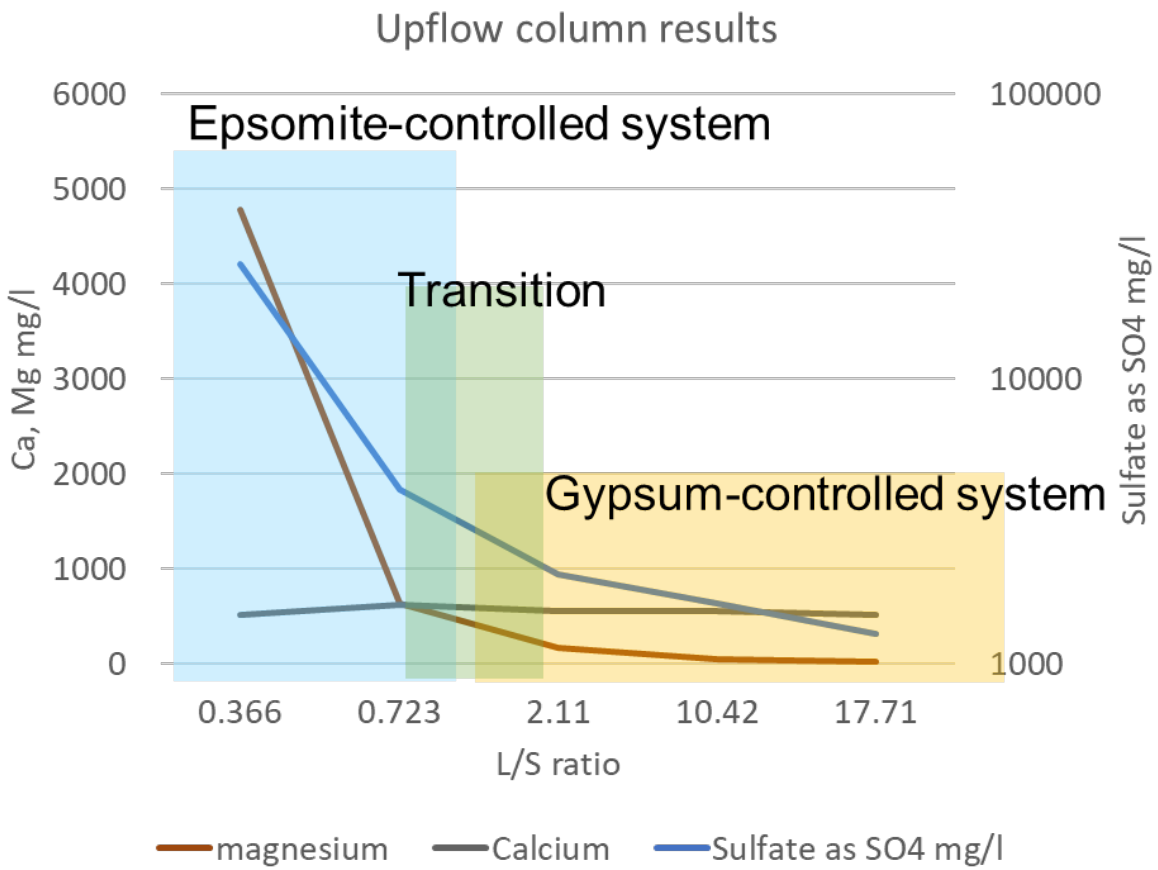
Secondary mineral generation

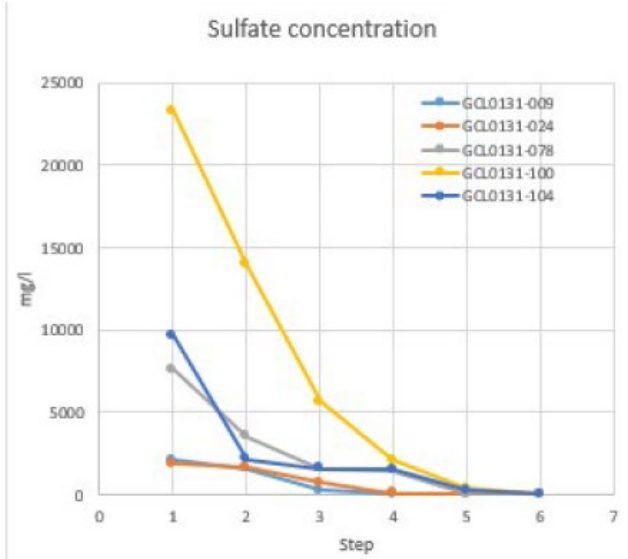
- Oxidation of some sulfides (e.g. pyrite) present in ore can occur intentionally or unintentionally as a result of mining and processing
- Formation of secondary minerals is dependent on the pore water pH conditions at the time of precipitation:
  - Low pH conditions as a result of pH adjustment can lead to precipitation of acid sulfate minerals (e.g. melanterite and jarosite), which themselves can release stored acidity upon dissolution
  - Circum neutral conditions created by dissolution of carbonates or neutralant as part of pH adjustment releases Ca and Mg, leading to formation of gypsum and epsomite as S-hosts, and Fe oxy-hydroxides. Secondary Fe minerals sorb potentially toxic metals that are released as part of the sulfide oxidation (for example As).

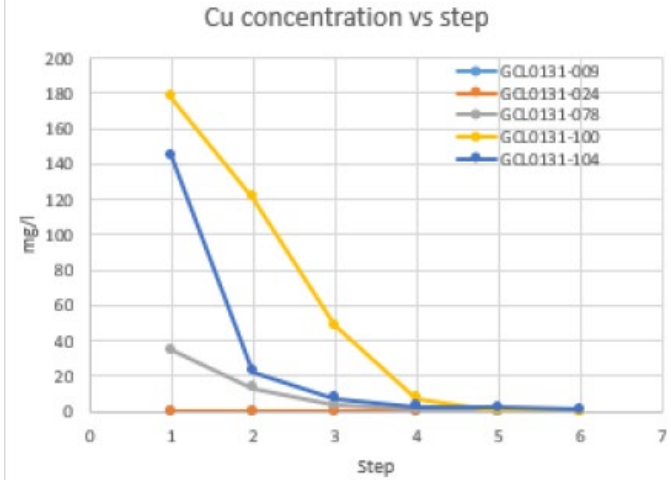


After McElnea et al, (2002)
•DOI: 10.1071/SR01100

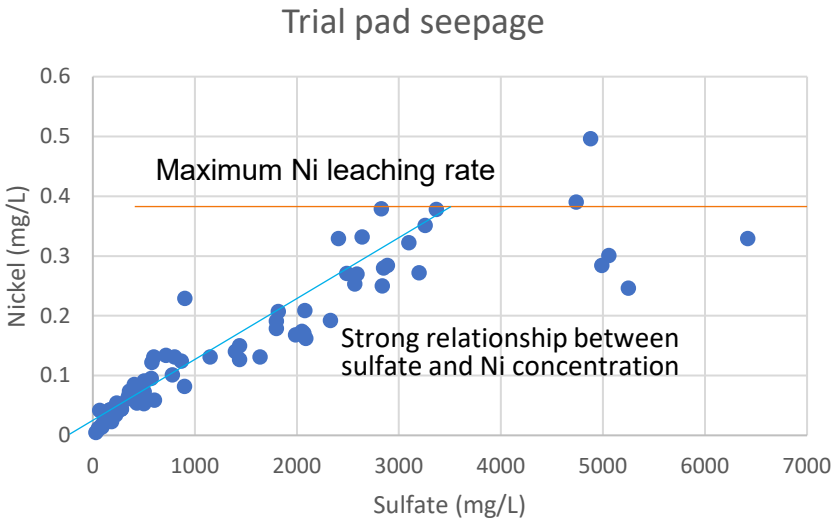
Metal leaching linked to sulfate





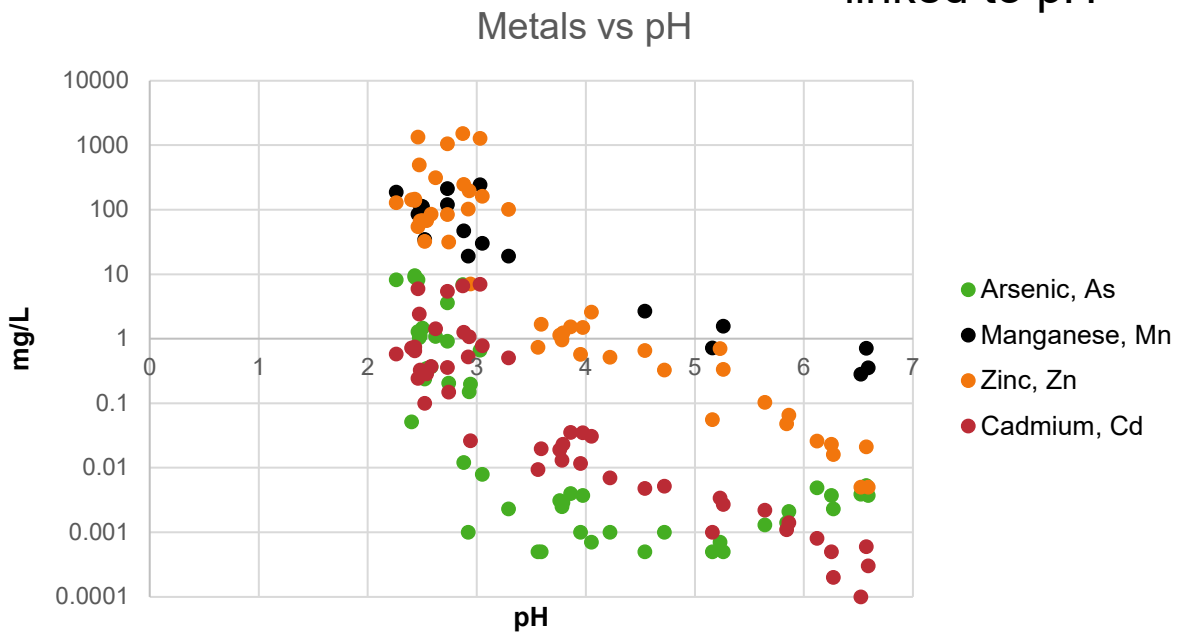


Metal leaching linked to pH



Leaching linked to sulfate

Leaching linked to pH



Note arsenic mobility increases with pH from 5-8 so higher pH does not always mean lower metal leaching

Process flow optimisation opportunities

- **Particle size decisions** require balance between optimisation of recovery and minimisation of geotechnical risks for disposal and closure, and impacts on geochemistry such as reactivity (leading to requirements for less permeable cover or water treatment)
- **Process flow steps and reagents** have the potential to cause formation of a variety of secondary minerals with differing crystallinity and metal content, which will have a long-term impact on water quality
- Minimising down-stream impacts of processing on tailings while optimising ore recovery is a key area where mining sustainability can be increased

Thank you