Workshop on CO_2 Mineralization for ENERGY RELEVANT MINERAL EXTRACTION

Pre Breakout Pep Talk

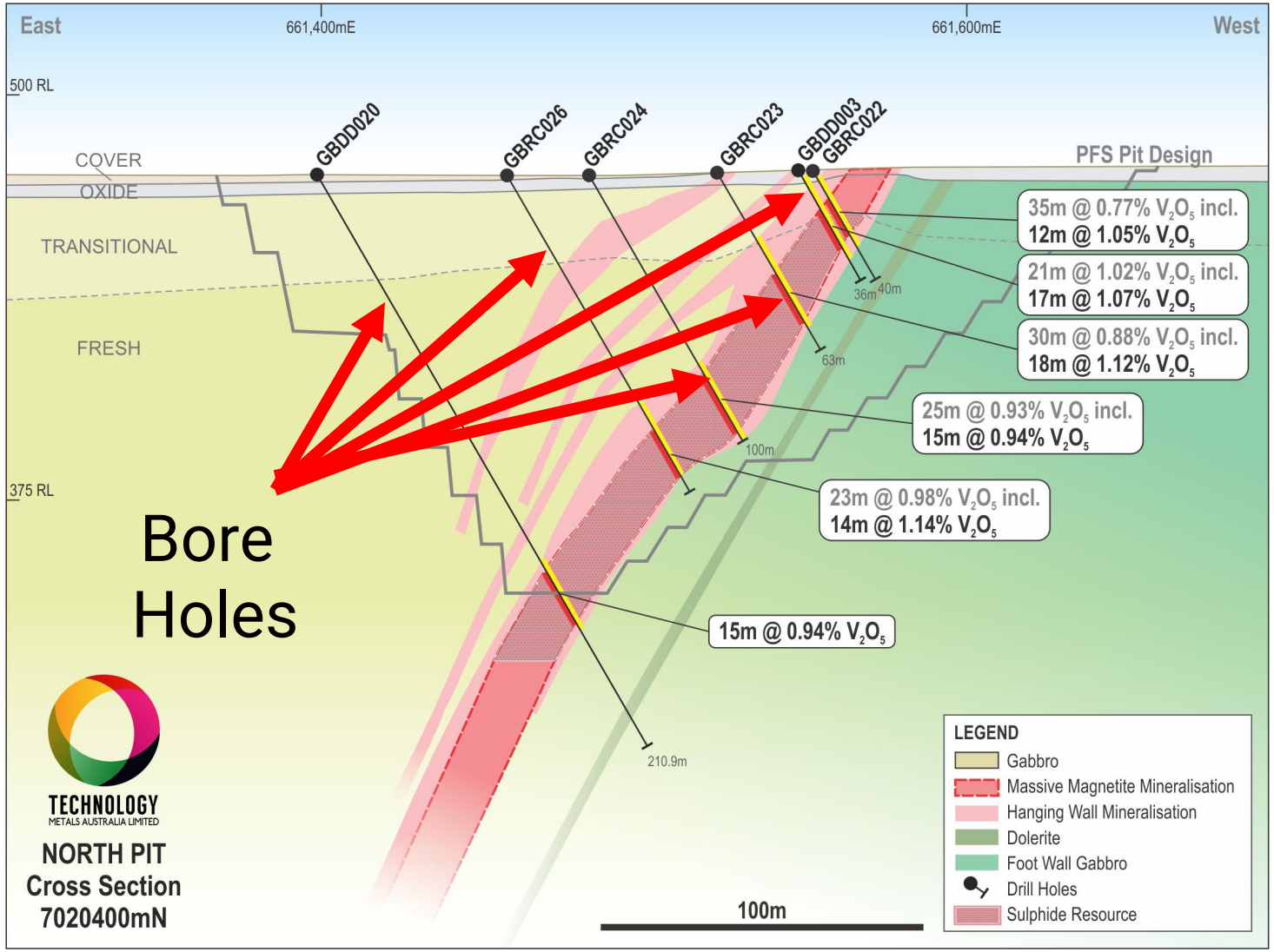
July 15, 2021

General Thoughts on Approaches

- **Approaches will not use a single step**
  - Could be pretreatment feeding an existing process
  - Imagine biological followed by electro chemistry
  - Electrically powered bugs
- **Use the strengths of any given tech to drive the process**
  - Increase rate of rock dissolution to leave behind the good stuff (think of laterite formation)
  - Adjusting pH, ionic strength, oxidation state…
  - Preferentially precipitating targets

In-situ CO_2 Pretreatment (Incorporating in Mine Planning?)

- **Basically**
  - Drill holes to the ore body
  - Flood the hole with CO_2 cocktail
  - Cap then allow overburden and target ore to react
  - Excavate and measure
- **Incorporation into planning**
  - Cores are taken at specified intervals to map a deposit before extraction



GREAT MODEL FOR DOWNHOLE

https://www.tmtlimited.com.au/geology

Base assumptions

- **CO_2 price**
  - Equation of costs:

[CO_2 Mineralization expenses] + [Metal Extraction]-[CO_2 credits] ≤ [Existing Process Cost/ton]

  - We've estimated reasonable mineralization expenses to be $15-20 with no improvement in yield. THIS does not include the cost of capture.

- **CO_2 availability**
  - Point
  - On-site DAC/DOC
  - Pipelines where warranted
  - Enhanced CO2 concentration – mining doesn't need 100% purity
  - Ambient if one is clever

Known Unknowns beyond the Engineering

- **Ore Bodies**
  - Subterranean mapping
  - Compositional analysis for trace metals
  - Predicting ore reactivity and CO_2 capacity
- **Chemistry**
  - Solubility and kinetics of complex mixtures
- **Deployment**
  - Measurements and protocols for extrapolation to scale
  - LCA
  - TEA
  - Fate of impurities

What do we envision at end of project?

- ***In Situ* pretreatment for mining**
  - Modeling advances that allow for prediction of efficiency and placement of bores
  - Downhole demonstration (multiple holes?, depth of 100 M ?)
- **Energy Mineral Extraction**
  - Demonstration at 10's of kg scale
  - Demonstration of CO_2 capture
- **Process Waste Before Tailings Pile**
  - Demonstration using actual overburden and process materials
  - Demonstration of continuous process
- **Phytomining**
  - Demonstrated growth on target tailings or soil from site
  - Can be done in a laboratory setting to avoid seasonal requirements

Potential Metrics - Mining

- Pretreatment of ore *in situ* or *ex situ*
  - >80% of deployed CO_2 should result in mineralization
  - Maximum extent of reaction should take place within 90 days for in-situ and 1 day for ex-situ
  - Energy of comminution should be reduced by 50%
- Incorporation of CO_2 mineralization into metal extraction or concentration steps.
  - Feed for this process could be extracted ore or existing mine tailings that contain recoverable energy relevant minerals
  - >90% of deployed CO_2 should result in mineralization
  - CO_2 reaction can take place during comminution, flotation, sorting and separation
  - IF CO_2 is generated during the process (for example – reduction of siderite into Fe) it has to be either captured or offset within the overall process.
- Reaction of process tailings before land disposal
  - Feed for this process would be residuals from the active metal extraction steps.
  - >90% of deployed CO_2 should result in mineralization
  - Maximum extent of reaction should be achieved PRIOR to moving to tailings storage and not take more than 24 hours

Potential metrics – *In situ* disposal and phytomining

- PHYTOMINING
  - Carbon negative LCA
  - Annual or more frequent harvests of plants or sap
  - Energy of comminution should be reduced by >90%
  - Feed for this process could vary from unprocessed rock to existing mine tailings that contain recoverable energy relevant minerals
  - Processed metal costs are lower than conventional mining, including value-added products that result (e.g. biochar, carbon credits)