Considerations for Hard Rock In-Situ Mining in Australia

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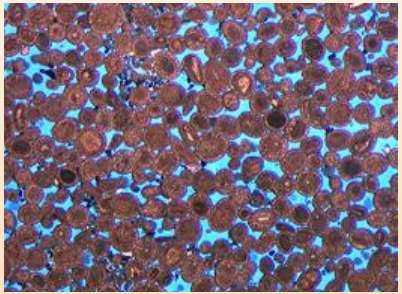
CSIRO

ALTA 2023 27
1 - 5 May | Perth, Australia

Accessing ore in hard rock?

https://www.excelsiormining.com/project

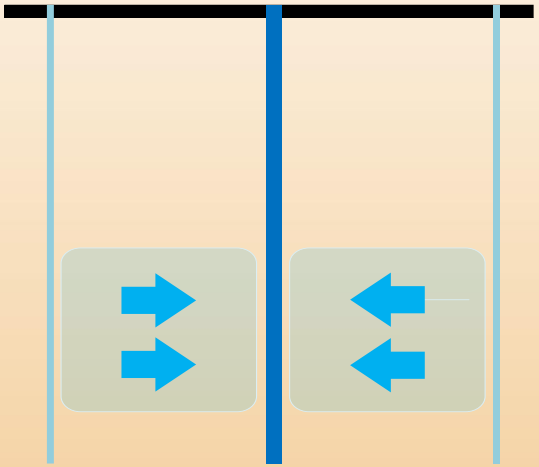
Naturally fractured with copper oxide minerals mostly on the fracture surfaces.



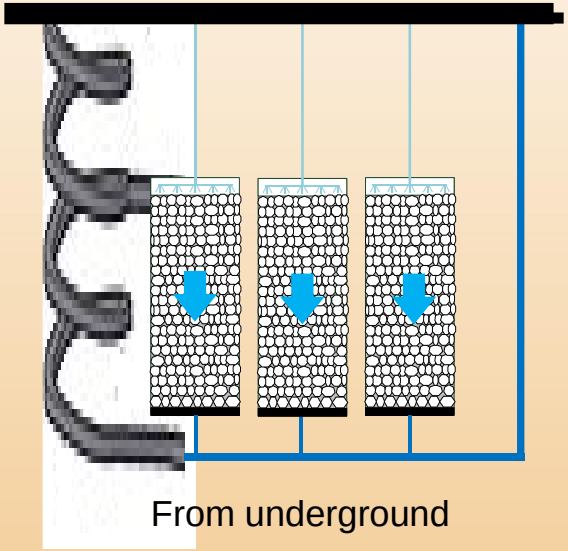
- Hard rock is jointed, stronger, not porous and less permeable. Needs to be fractured
- Can we use modify conventional methods?
- To access the ore we need to reimagine what a mine looks like and use traditional mining methods in new ways

A new approach to underground mining

- In situ mining considers drill holes from surface and flow fluids through permeable strata
- **Hard Rock In Situ Mining (HRISRM)** needs to create it's own permeability at depth



From surface



From underground

http://encyclopedia.che.engin.umich.edu/Pages/SeparationsChemical/DistillationColumns/DistillationColumns.html

How to gain access?

Access Creation

- Automated Mining – ROES 2011

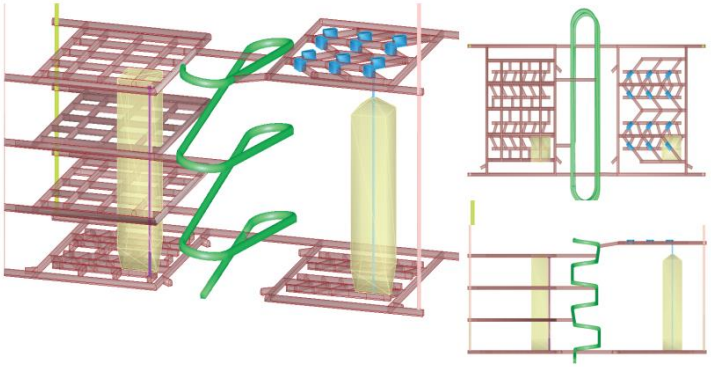


FIG 1 - ROES® overview.

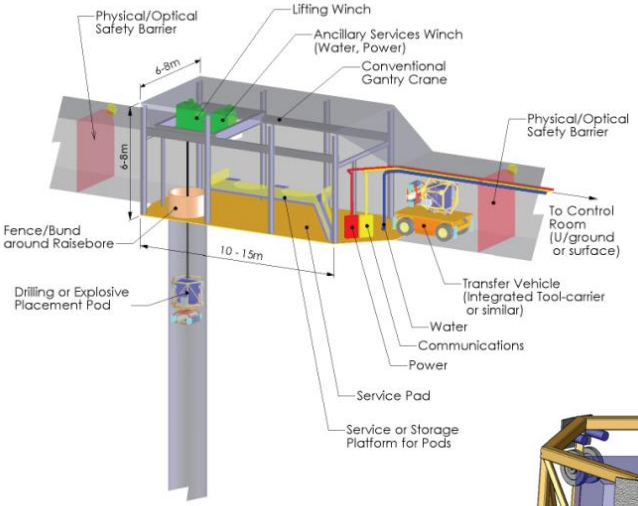


FIG 2 - ROES® chamber.

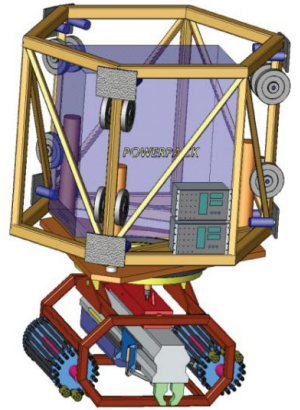


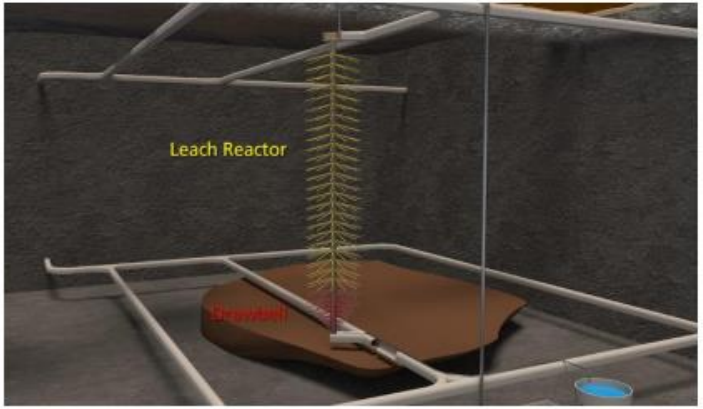
FIG 3 - Drill platform.

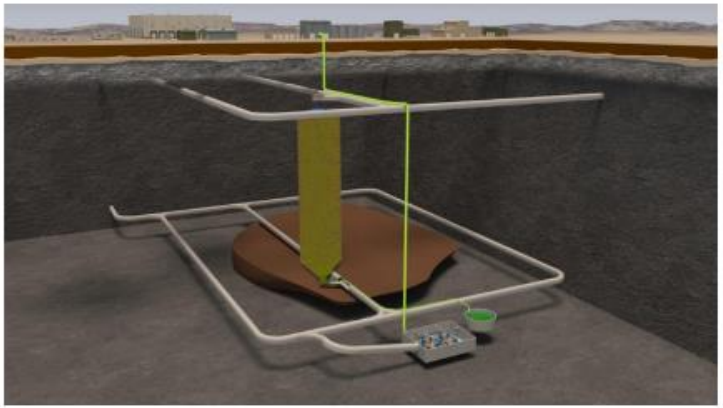
I Gipps and J Cunningham

SECOND INTERNATIONAL FUTURE MINING CONFERENCE / SYDNEY, NSW, 22 - 23 NOVEMBER 2011

Access Creation

- Taking ROES to HRISM
- Supported by wireless detonators
- Challenged by geotechnical conditions

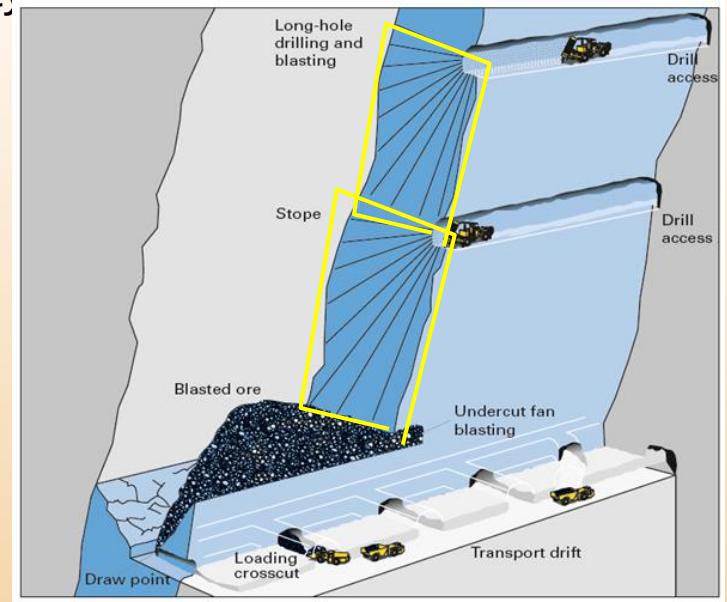




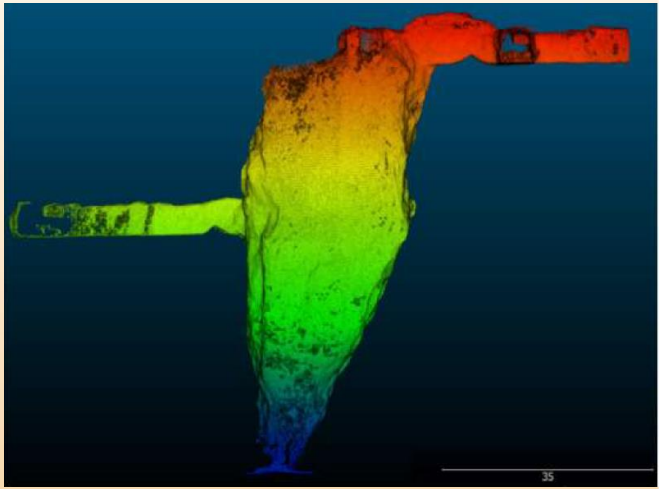
ALTA 2017: Fragmentation & Fracture From Blasting For Insitu Recovery,
Stephen Boyce, Alan Minchinton

Access creation

Creating permeability underground using standard stoping methods?



Sublevel open stoping (SLOS) (Atlas Copco, 2007)

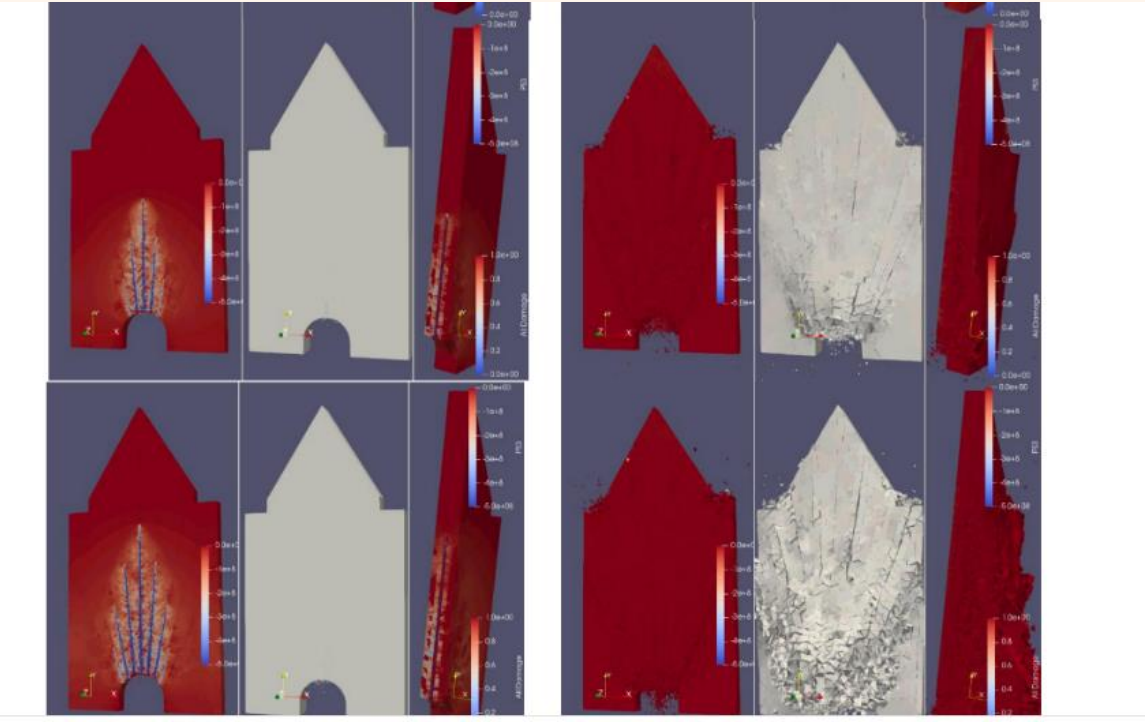


Canales and Sellers, Massmin, 2020

Access creation

Creating permeability underground using standard stoping methods?

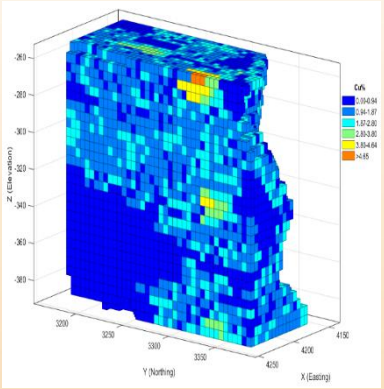
Numerical modelling: At what stage is permeability and fragmentation sufficient?



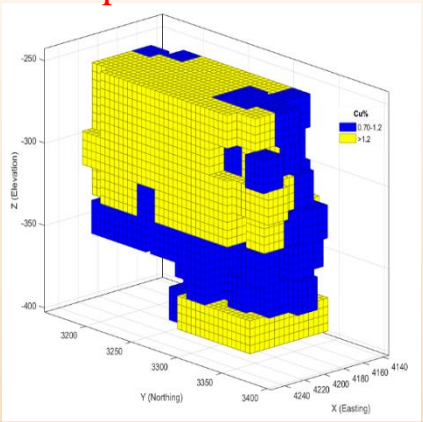
Sellers and Salmi, UMT2020; Liu et al, IOP 2021

Hybrid Open Stope / IMR for Marginal ore recovery

Block Model



Stope Model



NPV Improvement: 40%

- Positive NPV
- Many assumptions

	# Stopes	NPV(m$)	# Mined Stopes	Ave Cu(%)
Hybrid OS/IMR	196	5.47	157	1.57 1.12
OS	196	3.91	98	1.12

Mousavi & Sellers, Resources Policy, 2019

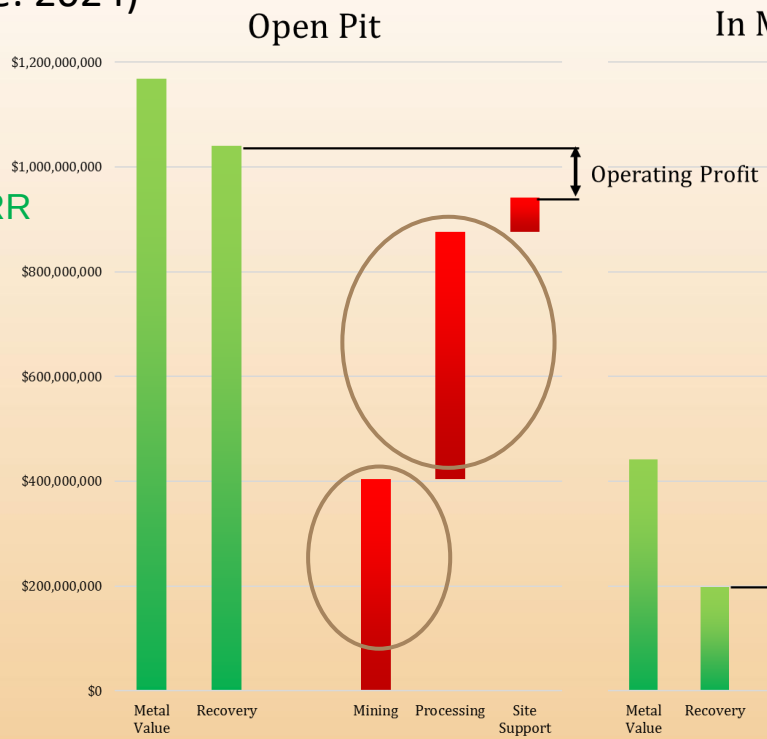
Value of Recovery of stranded ore – Actual gold mine

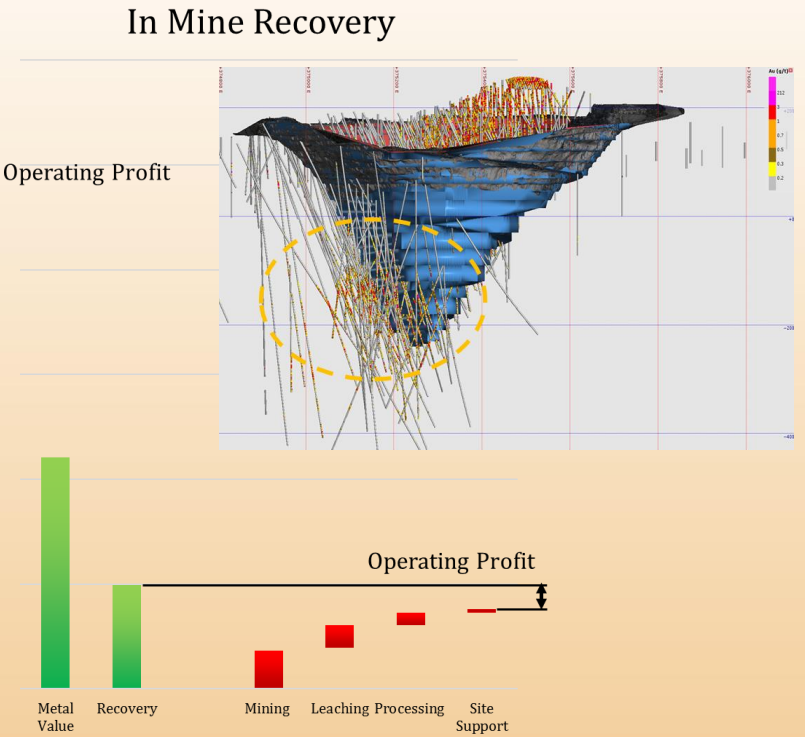
- 6 years (Mine closure: 2024)

NPV
u/g = -560M$
Pit cutback = -140M$
IMR = +27M$ @ 44% IRR

Similar profit
Triple ROCE

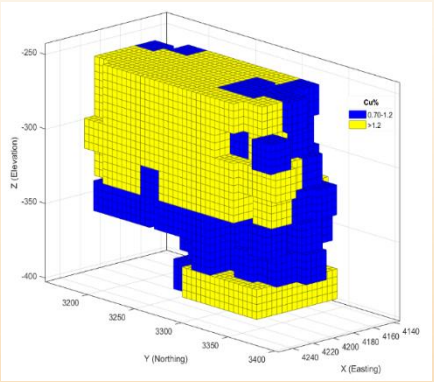
Benefits in removing diesel and comminution energy





Case study energy and diesel benefits

- Save 2.8 Billion kWh on Milling @ 20KWh/t
  - **~ 1 Adelaide / yr**
- Save 12 megalitres of diesel (equivalent electricity)
  - Australia consumed a total of 34,170 megalitres of fuel in 2018.



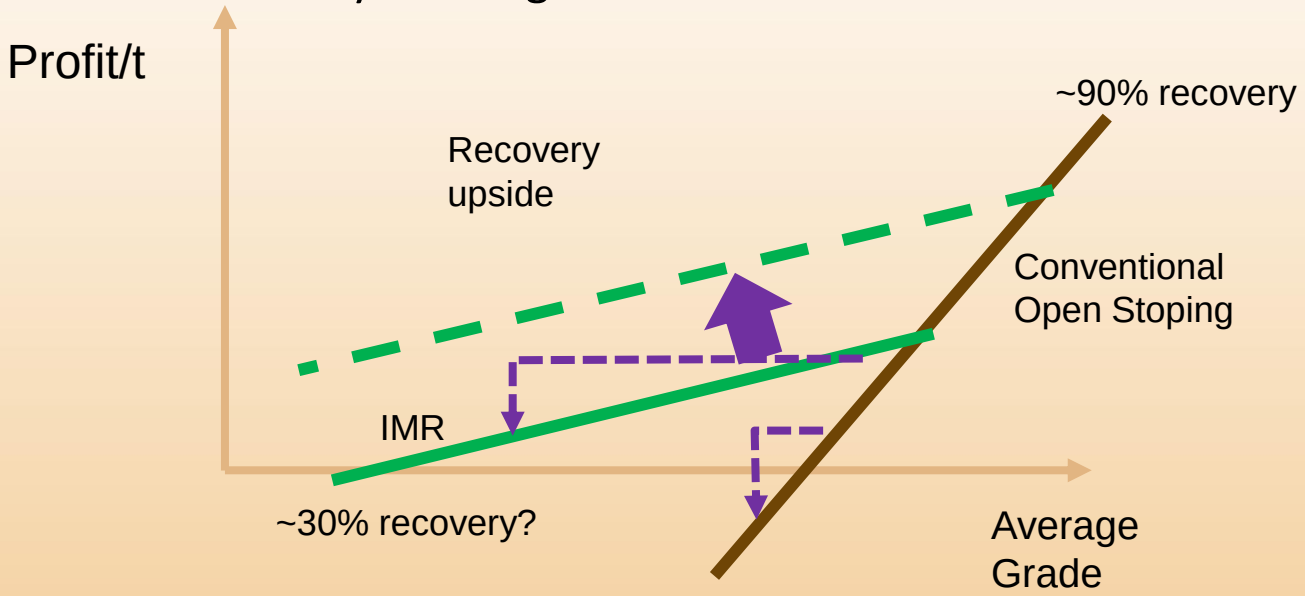
600KW @ 20km/h @ .1 L/KWh

https://www.cat.com/en_AU/products/new/equipment/underground-hard-rock/underground-mining-trucks/18349061.html

Sellers and Lever, ALTA, 2020

Value of IMR

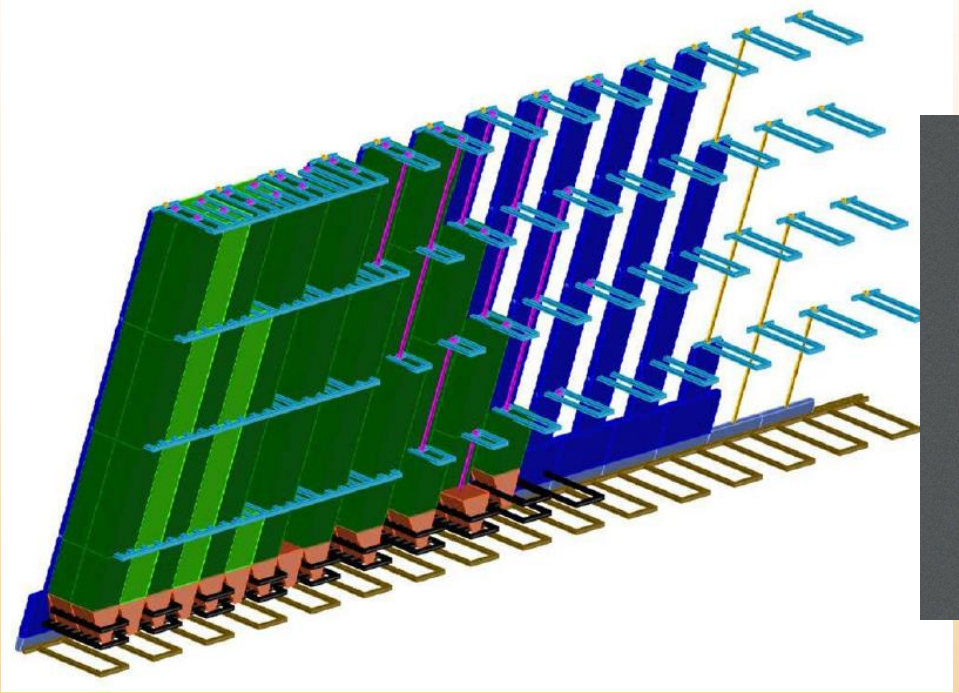
- In a conventional u/g operation, high energy costs mean that unexpectedly lower grade or reduced recovery have significant effect

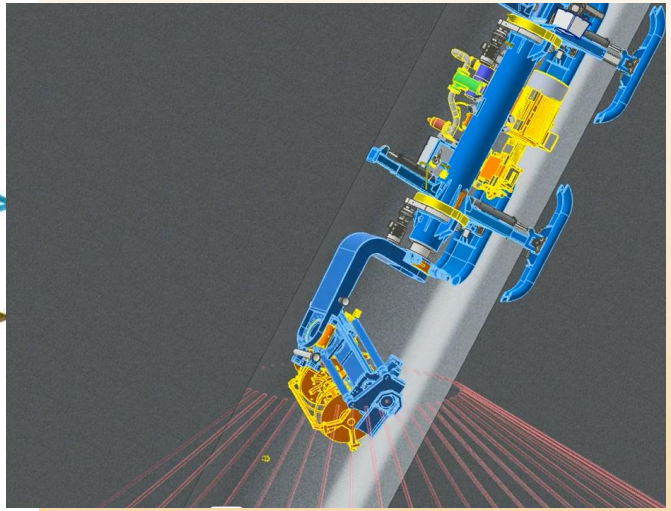


- IMR is more resilient to grade and recovery is expected to increase in future

Sellers and Lever, ALTA, 2020

Access Creation





Ladinig, T., Wagner, H., Karlsson, M. *et al.* Raise Caving—A Hybrid Mining Method Addressing Current Deep Cave Mining Challenges. *Berg Huettenmaenn Monatsh* **167**, 177–186 (2022). https://doi.org/10.1007/s00501-022-01217-3

Access Creation

- **New drilling technology**

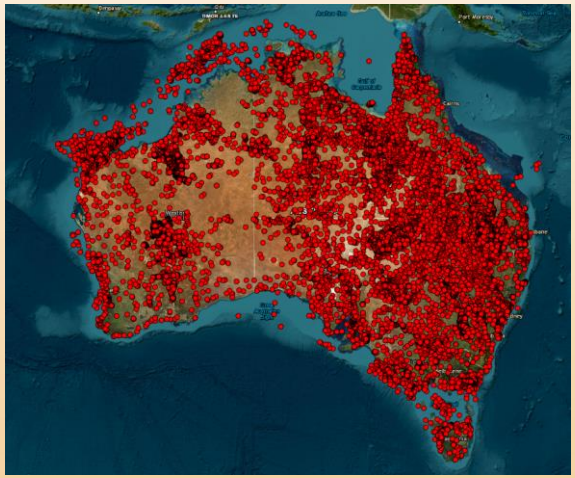
Coiled tube drill rig (MinexCRC, 2023)

- Potential for coiled tube drill rigs to access ore at much faster rates. MinexCRC (2023)
- Anglo American project - 12 holes into basement rock with 400 -450m of regolith cover.
- penetration rates > 100 m – 232m/12h
- Working on 1000m and steering to target straight holes and designed deviation at depth.

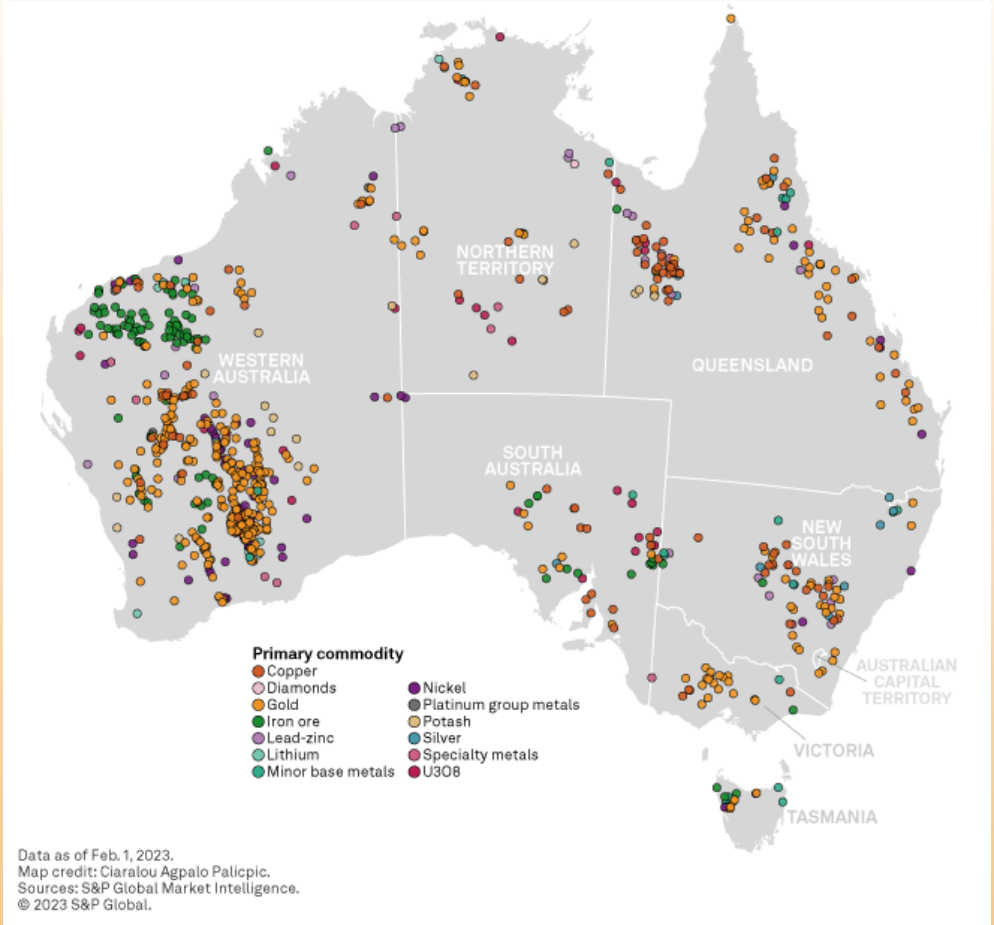
Where to mine?

Minerals in Australia

- Significant exploration
- Wide range of minerals
- More opportunity



Drill holes - https://portal.ga.gov.au/persona/eftf



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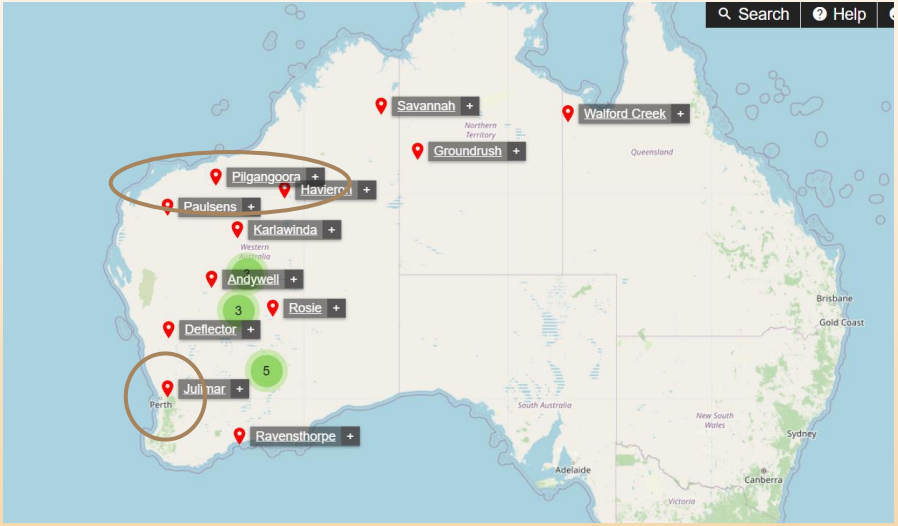
Australian Geology

- Consider some new projects
- Gold
- Critical Minerals



- Disclaimer: Projects discussed here for illustrative purposes only. This does not imply in situ mining will occur, or is being considered, or provide any investment advice

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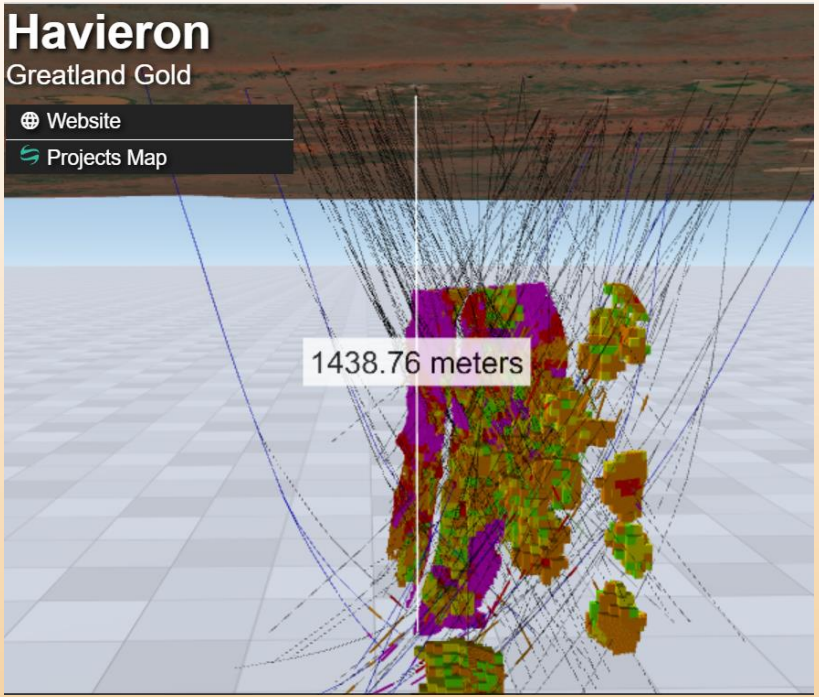
Gold mining



https://inventum3d.com/c/greatlandgold/havieron

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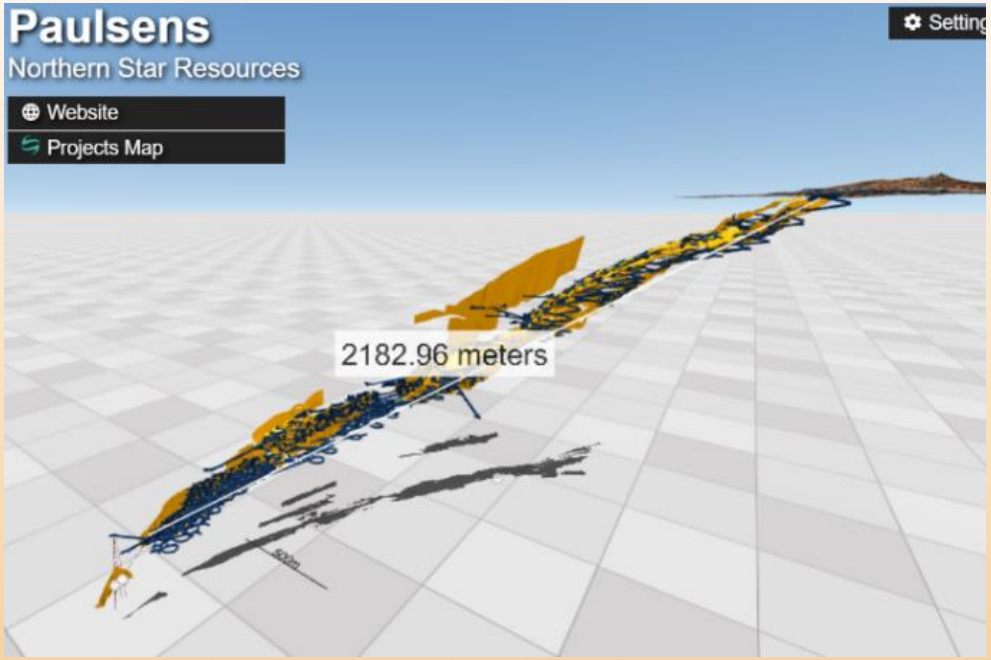
Gold mining



https://inventum3d.com/c/nsrltd/paulsens

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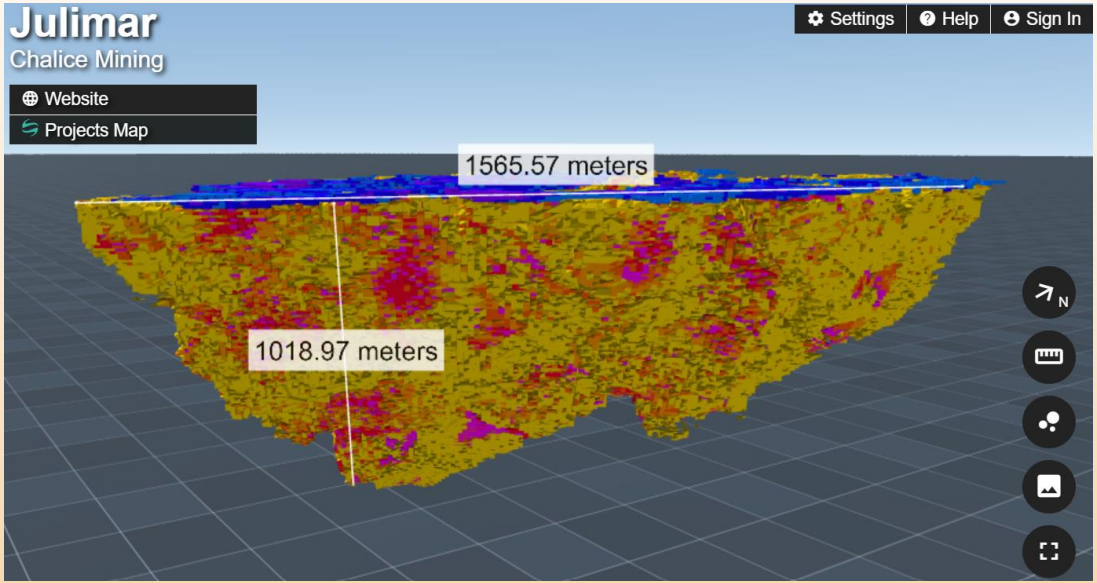
Cu, Ni, PGE



Julimar Ni, Cu, PGE https://inventum3d.com/c/chalicemining/julimar

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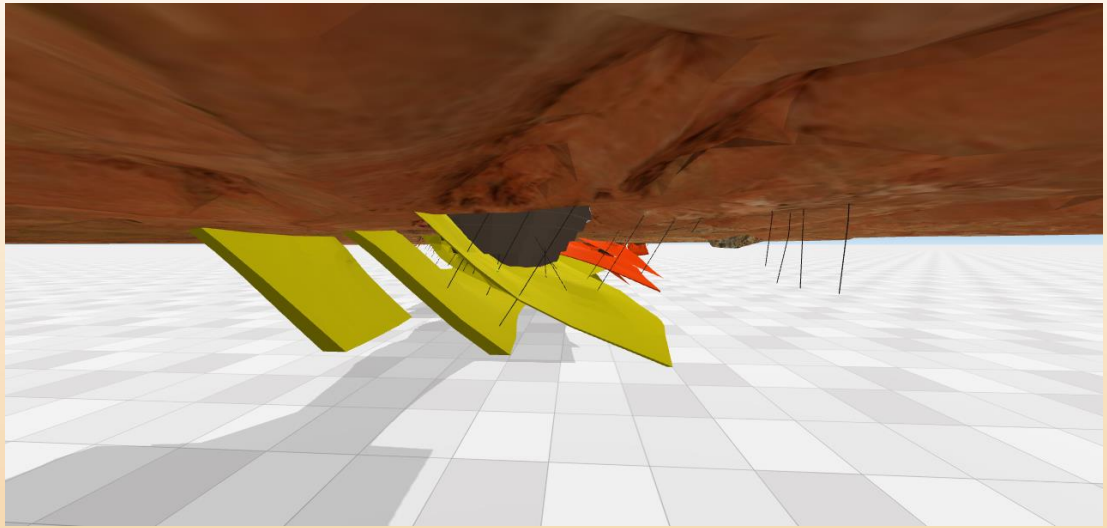
Li



https://inventum3d.com/c/pilbaraminerals/pilgangoora

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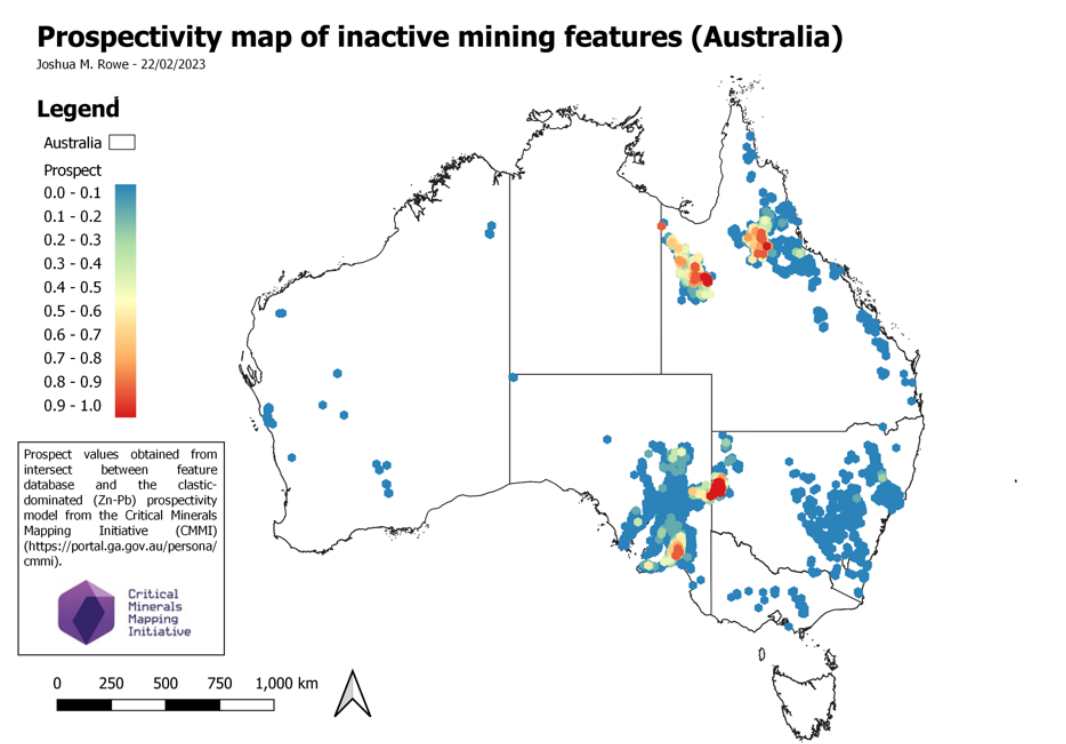
Where else? Abandoned mines?



Notes:

- 10,759 sites were identified to have some sort of prospect via the clastic-dominated model.
- 586 fall exclusively in significant urban areas.
- 574 fall exclusively in CAPAD areas.
- 32 fall in both CAPAD and SUAs.

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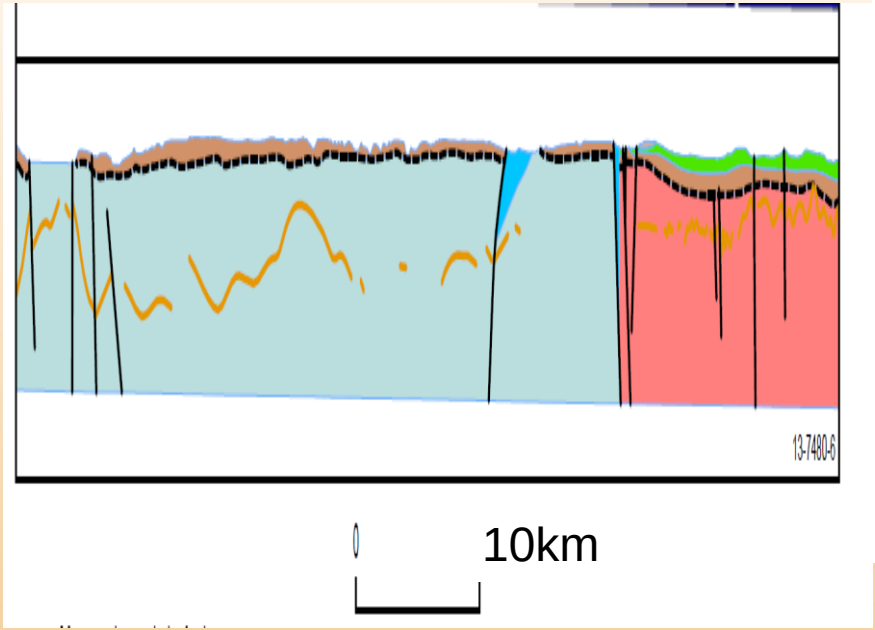
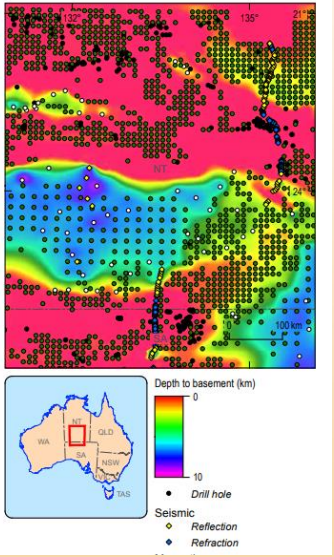
The challenge of Regolith

- Large regions of Australia are covered by Regolith
- Sandstones and mudstones with limited mineralisation
- Hard to explore through
- Varies over short distances

Near surface basement / deep basement





(GA, 2013)

stretched vertically for visibility

Cu Ore under Cover

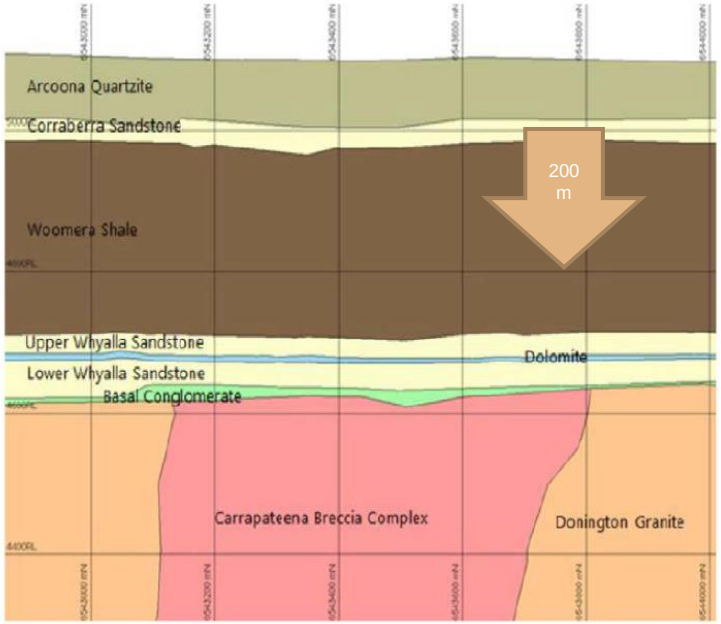
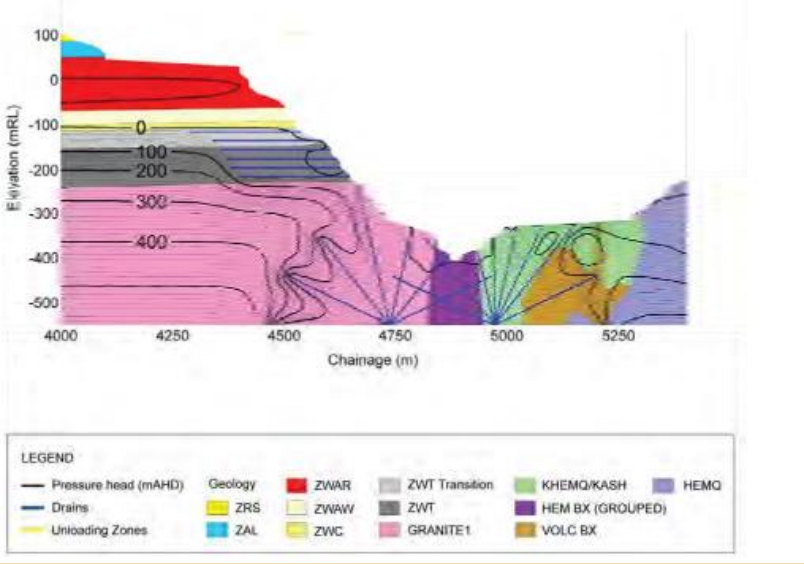


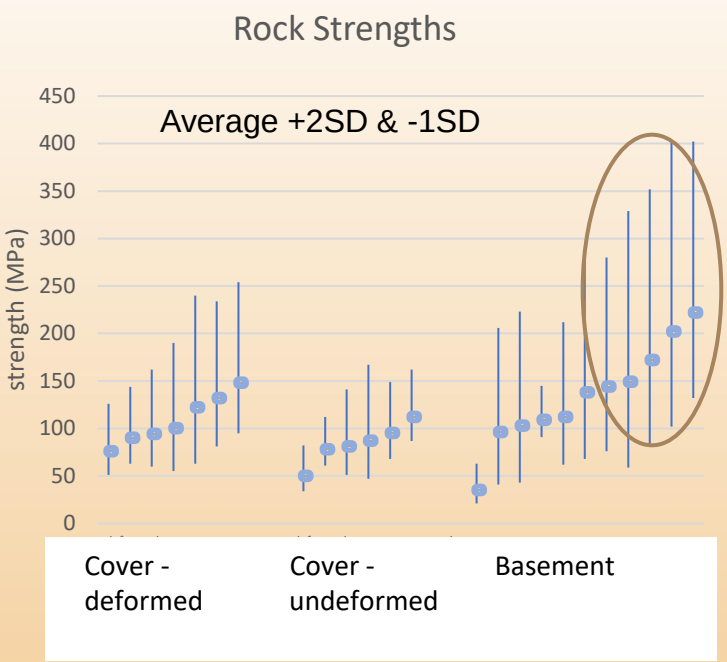
Figure 21: Stratigraphy and cover sequence at Carrapateena mine (Chauvier, 2022; Hocking et al., 2020).



https://www.bhp.com/-/media/bhp/regulatory-information-media/copper/olympic-dam/0000/supplementary-eis-appendices/appendix-c_description-of-the-proposed-expansion.pdf
(PKM2011)

Strength

- Basement rocks are:
- Stronger

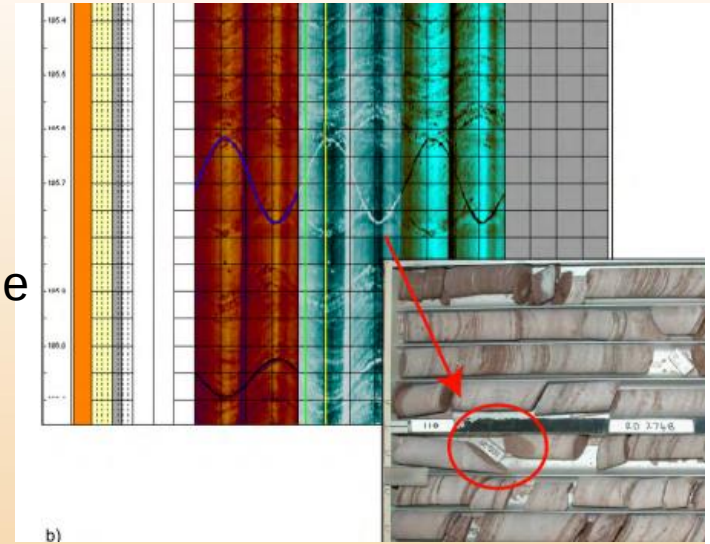


Data from PKM, 2011

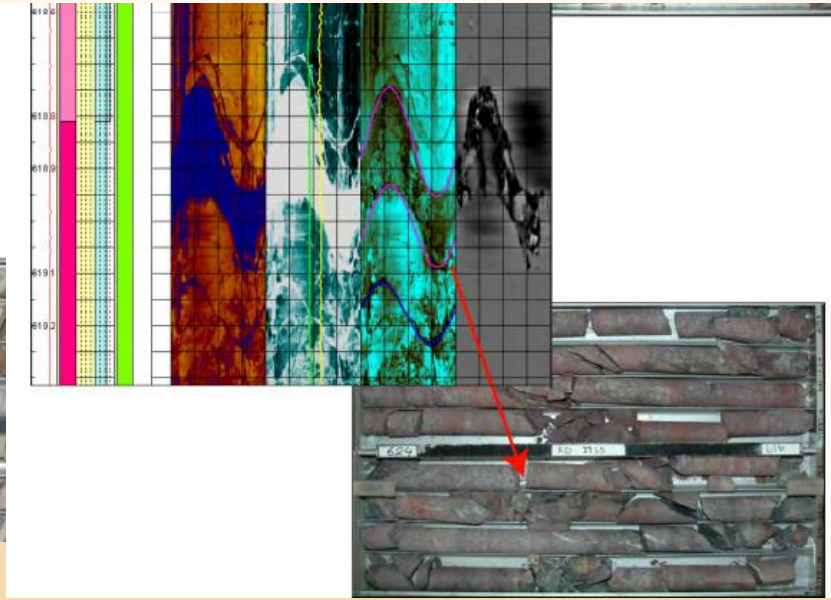
https://www.bhp.com/-/media/bhp/regulatory-information-media/copper/olympic-dam/0000/supplementary-eis-appendices/appendix-c_description-of-the-proposed-expansion.pdf

Permeability

- Basement rocks are:
- Stronger
- Less permeable



Controlled by horizontal layers



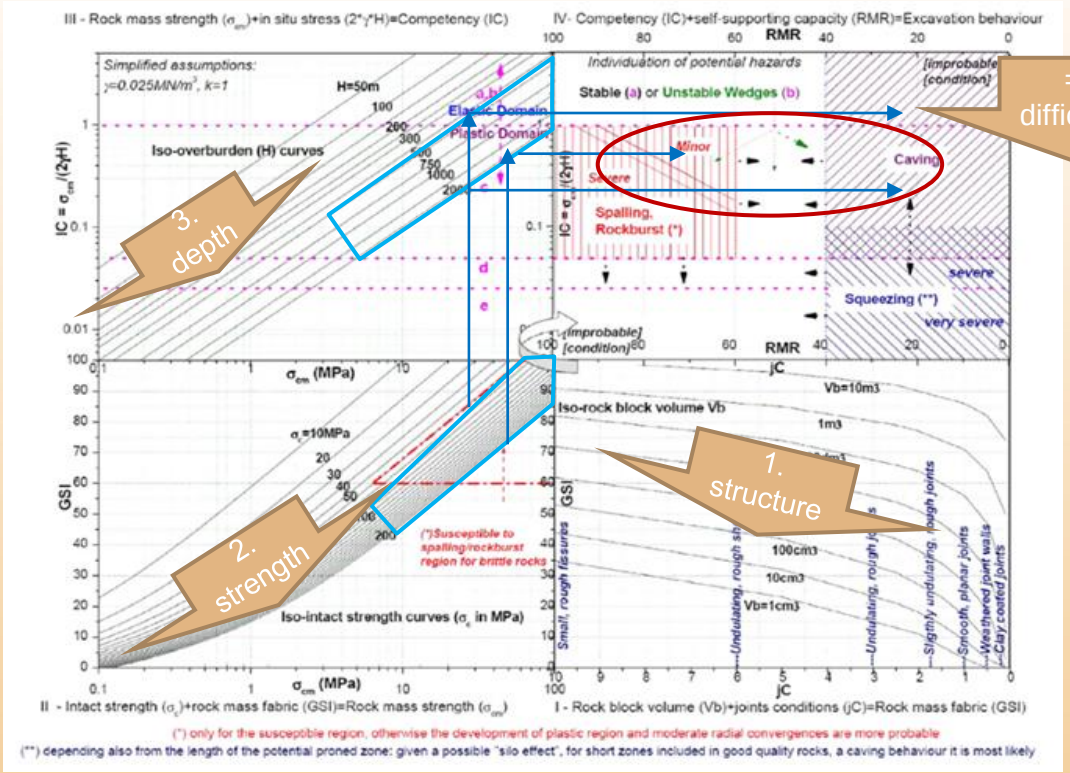
Controlled by joints and faults

Data from PKM, 2011

https://www.bhp.com/-/media/bhp/regulatory-information-media/copper/olympic-dam/0000/supplementary-eis-appendices/appendix-c_description-of-the-proposed-expansion.pdf

The challenge of stress

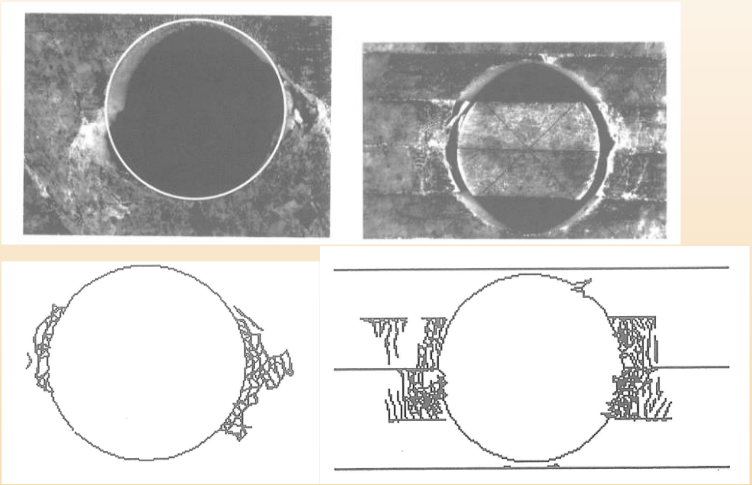
- > 500m deep
- How to keep holes open?



Adapated from Russo (2014)

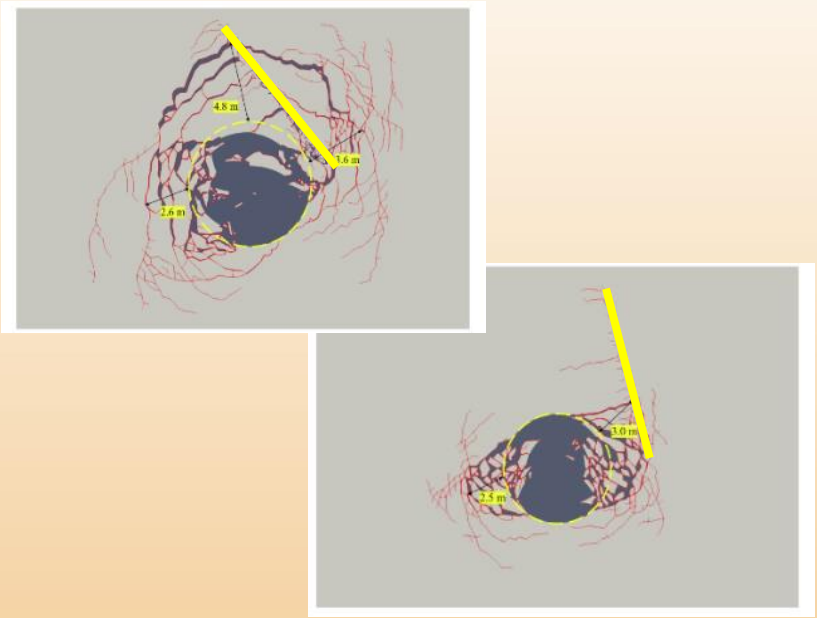
The challenge of stress

- Influence of jointing



(Sellers, Klerck, TUST, 2003)

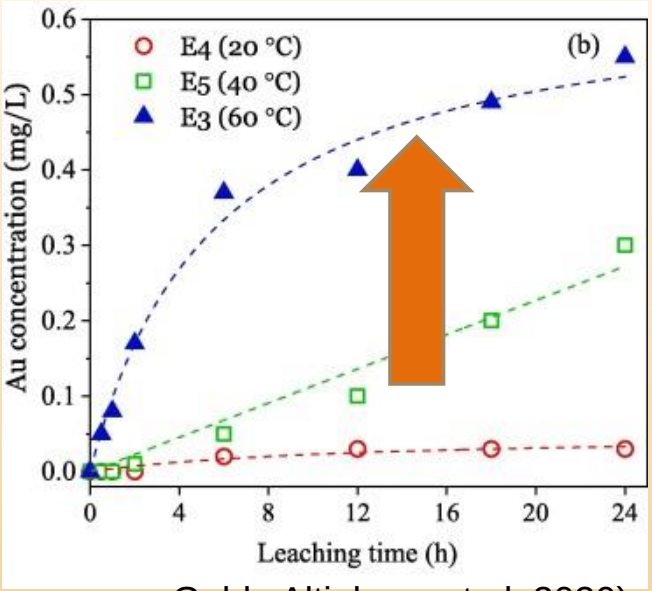
- Influence of Faults



(Han et al, Computers and Geotechnics, 2021)

Is temperature an opportunity?

Increased, and/or faster leach recovery with temperature



Gold : Altinkaya et al, 2020)

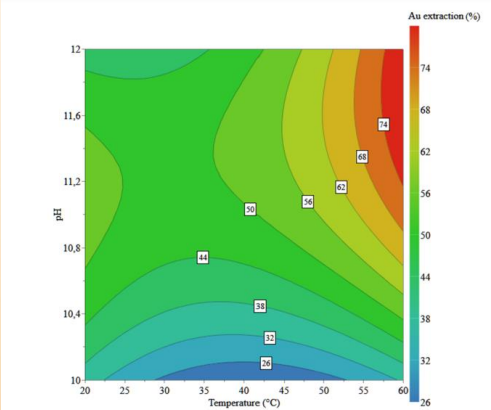
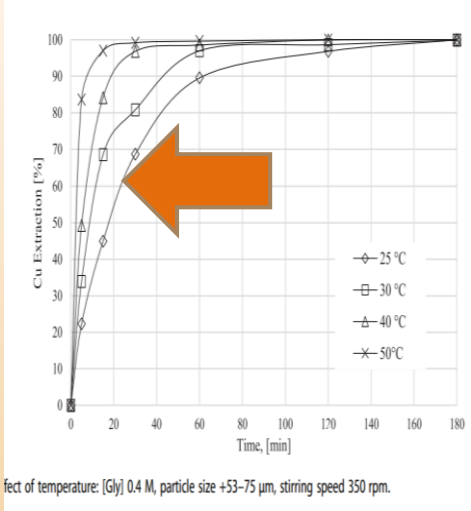


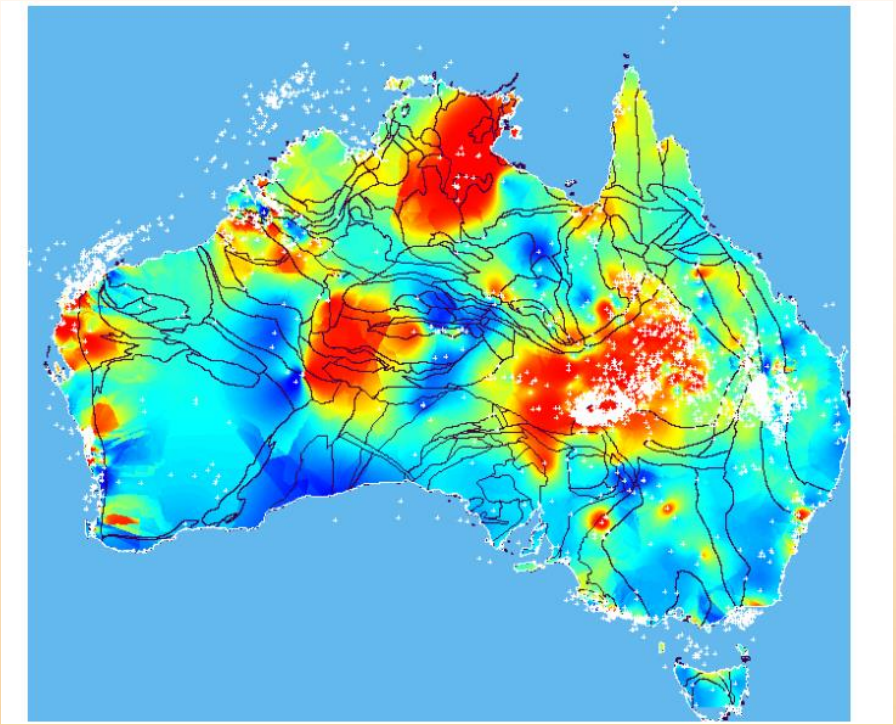
Fig. 3. Predicted effect of temperature and pH on gold extraction (%).



fect of temperature: [Gly] 0.4 M, particle size +53–75 µm, stirring speed 350 rpm.

Copper: (Tanda et al, 2018)

Australian Rock temperature



- Temperature at 5km depth in Australia (Chopra and Holgate, 2005)
- Blue is ~100^{o}C and red >~200^{o}C
- Lower temperatures where the basement (mineralised) rocks have surface exposure (Yilgarn Block, Gawler Craton and Lachlan Fold Belt).
- Higher temperature at depth associated with regolith cover (Basins).
- Implies temperature improvement for deeper ore bodies that are harder to find and access

Where Next?

Research

- MRIWA M0519
- Mining3, CSIRO, Curtin, Murdoch
  - Hydraulic and gas fracturing is possible
  - Leaching is possible from fractures
  - Leach recovery depends on:
    - Mineralogy
    - Liberation
    - Lixiviant
    - Deleterious gangue minerals

Kuhar (ALTA, 2019),
Karami et al (2021/2022),
Sun (ALTA, 2022)

- MRIWA M0545
- Curtin — Mawire et al, (ALTA 2021)
  - Evaluation of in-situ barrier technology
  - Cementitious
    - Biotechnology
- MRIWA M0529
- Murdoch
  - Lixiviant access creation

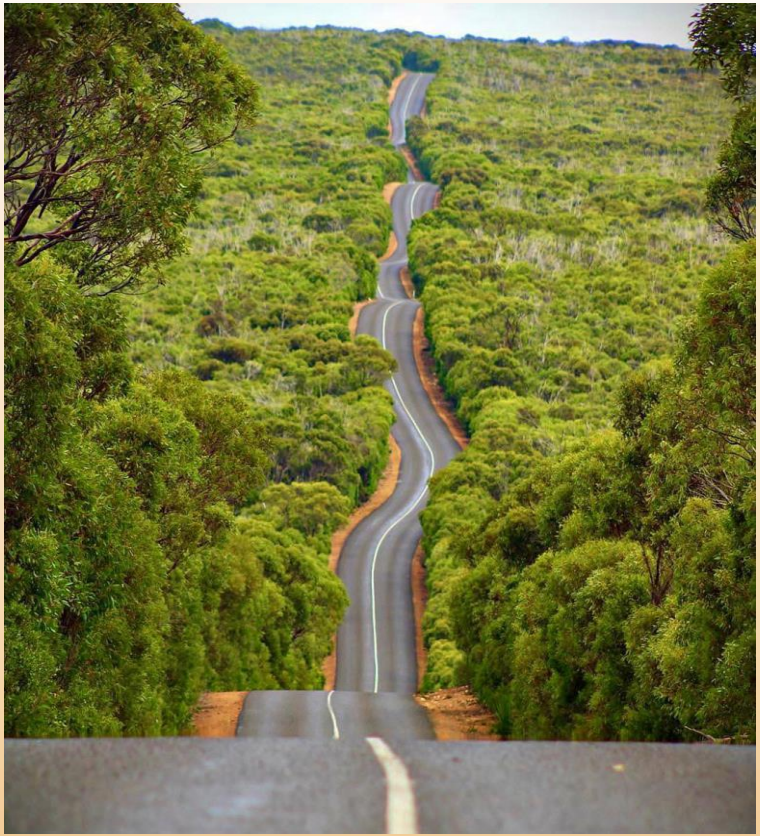
Research Challenges

Key questions remain to be answered:

Breakage: how to create the correct size distribution
Ore characteristics: Deeper and different mineralization
Recovery: less recovery, but higher return?
Temperature: more recovery with higher?
Geometry: Can we have higher stopes/silos?
Aeration: Alternative oxidant transport mechanism?
Particle size: Size distribution of blast-fragmented ?
Leach Time: Months or years?

Conclusions

- A long road ahead for Hard Rock In Situ Mining in Australia
- Opportunities exist in Australia though near-surface, conventional ISR opportunities and tailings dams likely to be first.
- Identify and prevent future environmental issues
- Change management for miners, regulators and society
- Need to pilot test at scale for confidence



https://southaustralia.com/travel-blog/south-australias-top-6-instagrammable-roads

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Questions?

https://southaustralia.com/travel-blog/flinders-ranges-and-outback-natural-wonders-bucket-list