Deep mining

Mikael Svartsjaern, ITASCA

SOFTWARE

CONSULTING

RESEARCH

itasca.se

What is deep mining?

The concept of 'Deep' is ever changing

- The large-scale timeline indicates deeper and deeper mining with time

- This is true both for open pit and underground mining (though at different scales)

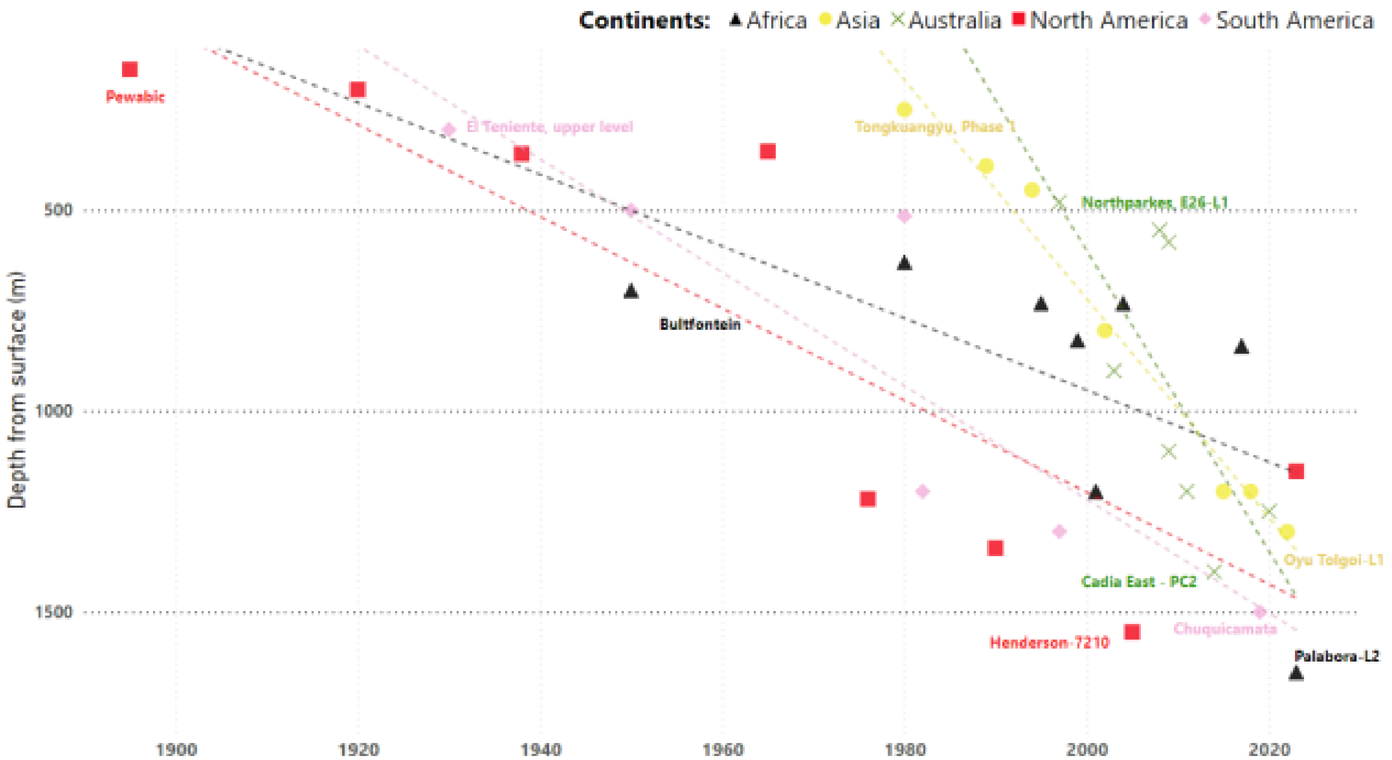


Figure 1 Timeline of operational depths of Block and Panel cave mines by continents, as of 2023, based on various sources, including SME mining engineering handbook series.

*B. Batkhuu , A. van As and J. Lett. *Evolution of undercutting in panel and block caves: from shallow to deep/high-stress environments*. 9th International Conference and Exhibition on Mass Mining (MassMin 2024), September 17-19, 2024, Kiruna, Sweden

The concept of 'Deep' is ever changing

- There is no single definition for what deep means, some common definitions include:
  - Overburden depth 1000–1500 m, or
  - Initial stress 30–40 % of intact rock strength

The concept of 'Deep' is ever changing

- There is no single definition for what deep means, some common definitions include:
  - Overburden depth 1000–1500 m, or
  - Initial stress 30–40 % of intact rock strength

- 30–40 % of UCS represents 'fracturing initiation' but is less straight forward than direct overburden depth
  - Primary or secondary stress field?
  - Primary field is a more generalized metric but has less physical correlation to spalling
  - Secondary field is directly related to spalling but is related to geometry and orientation

The concept of 'Deep' is ever changing

- There is no single definition for what deep means, some common definitions include:
  - Overburden depth 1000–1500 m, or
  - Initial stress 30–40 % of intact rock strength

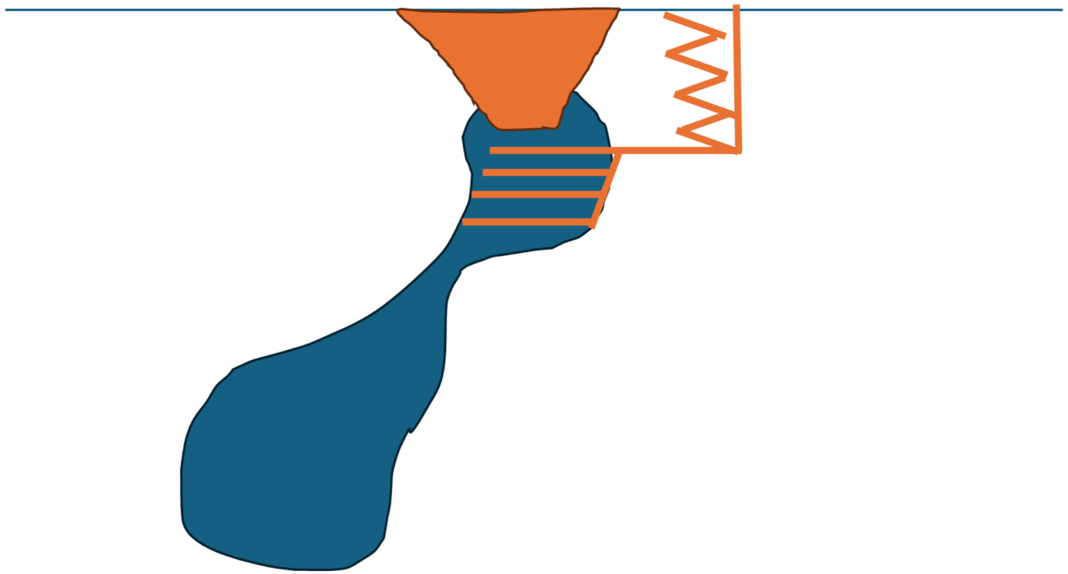
- 30–40 % of UCS represents 'fracturing initiation' but is less straight forward than direct overburden depth
  - Primary or secondary stress field?
  - Primary field is a more generalized metric but has less physical correlation to spalling
  - Secondary field is directly related to spalling but is related to geometry and orientation

- Over time, deep mining represents the depths at which we are currently experiencing challenges, or depths to which we have yet to reach

Why Deep Mining?

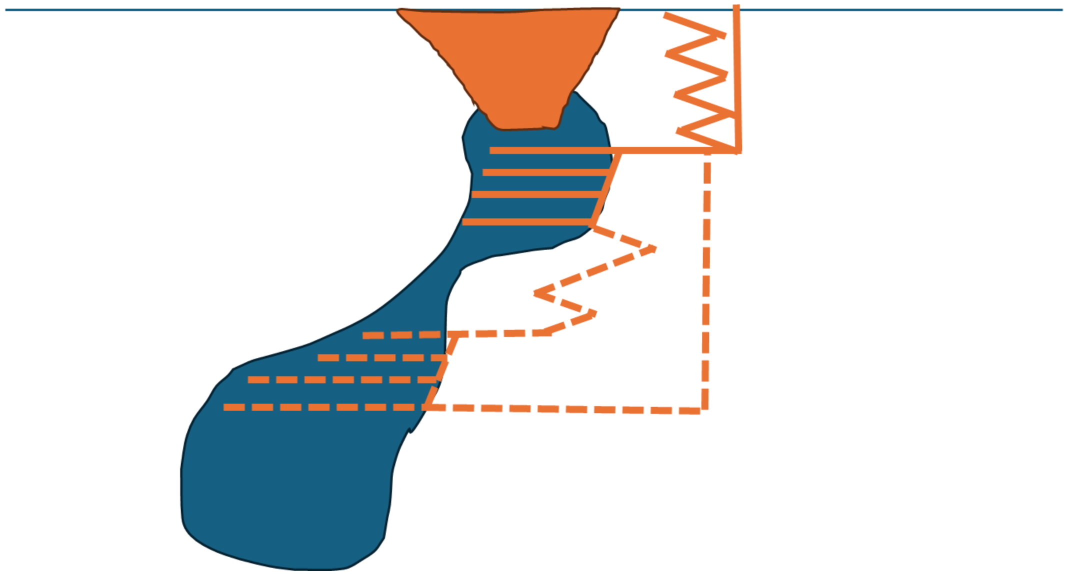
Why Deep Mining?

- Shallow deposits are limited, and most are already mined
  - Easy access and high grades were the first to go



Why Deep Mining?

- Shallow deposits are limited, and most are already mined
  - Easy access and high grades were the first to go
- More cost effective to expand existing operations than to start new
  - Lower grades below current mining are often more economic than higher grades at a different location
  - ‘Preparing to mine’ is very capital intensive
  - Easier to expand permits than to get new permits



Challenges in Deep Mining

Technology and Cost drivers

- **Technical challenges**
  - Geothermal gradient
  - Hoisting
  - Stress-rock strength ratio
    - Seismicity
    - Squeezing

- **Cost drivers**
  - Ventilation
    - Cooling
    - Dust
  - Haulage
  - Transportation / distance
  - Rock support
    - Rehabilitation and production disruption

Seismicity

- Violent, sudden failure
- Little to no warning prior to event
- Cannot be prevented – only mitigated

Controlled Failure or Stable Designs?

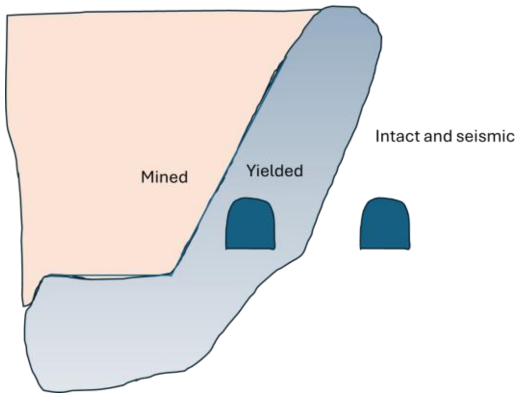
- Yielding pillars
- Stress shielding
- Drifting in yielded rock
- Size scaling with stress

Controlled Failure or Stable Designs?

- Yielding pillars
  - Controlling the failure
  - Slow energy release
- Drifting in yielded rock
- Stress shielding
- Size scaling with stress

Controlled Failure or Stable Designs?

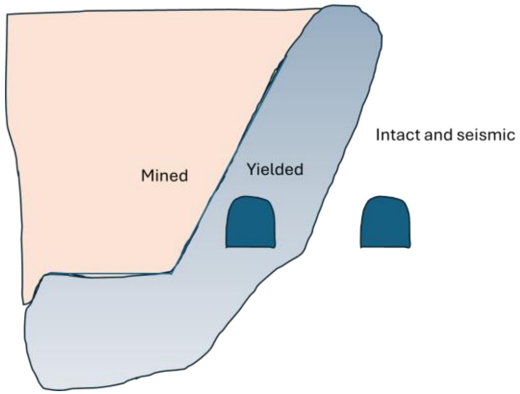
- Yielding pillars
  - Controlling the failure
  - Slow energy release
- Drifting in yielded rock



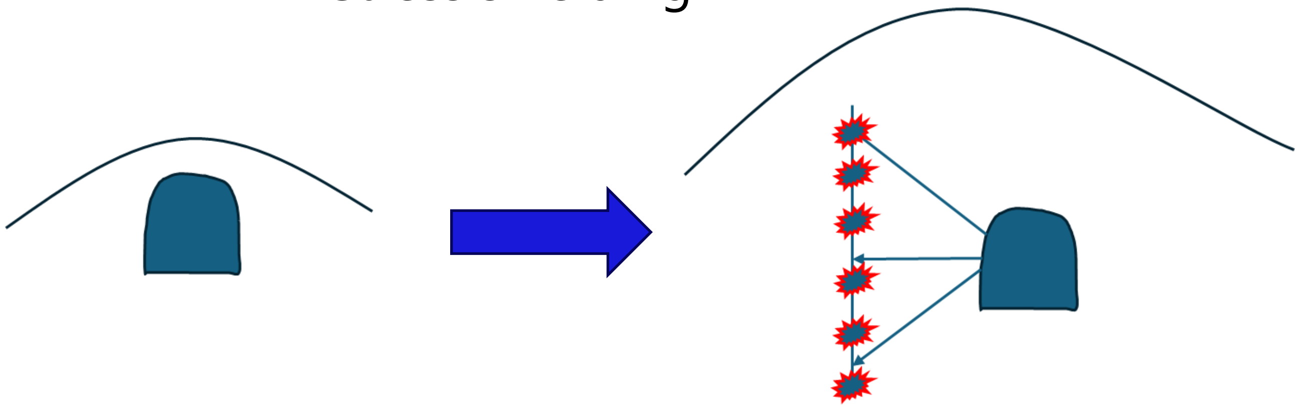
- Stress shielding
- Size scaling with stress

Controlled Failure or Stable Designs?

- Yielding pillars
  - Controlling the failure
  - Slow energy release
- Drifting in yielded rock



- Stress shielding

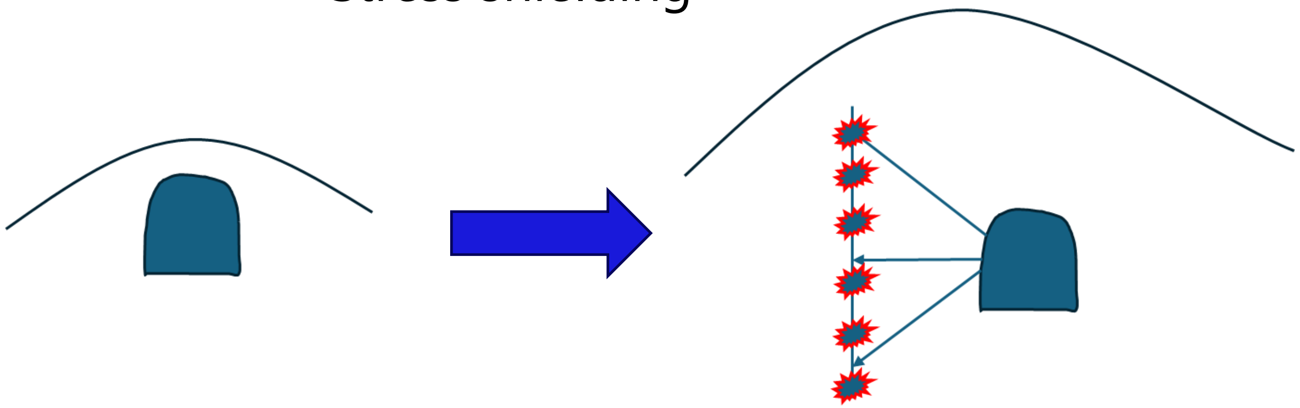


- Size scaling with stress

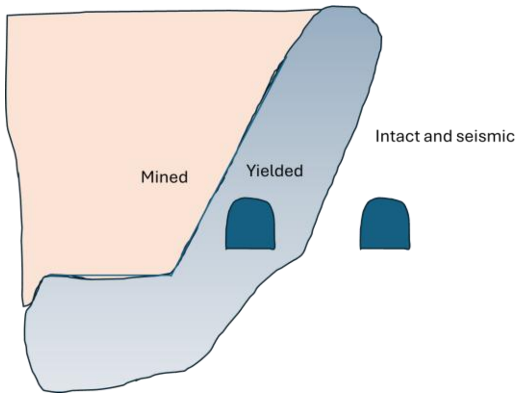
Controlled Failure or Stable Designs?

- Yielding pillars
  - Controlling the failure
  - Slow energy release

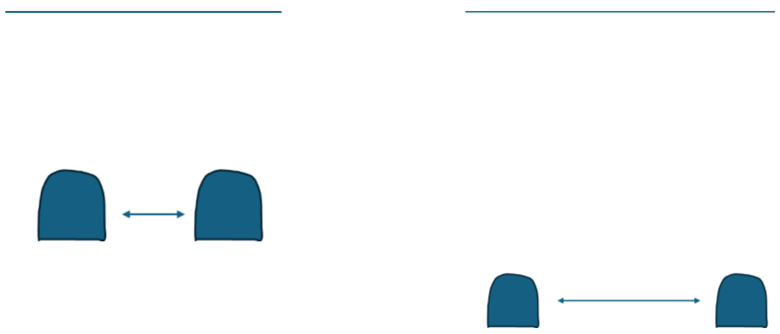
- Stress shielding



- Drifting in yielded rock



- Size scaling with stress

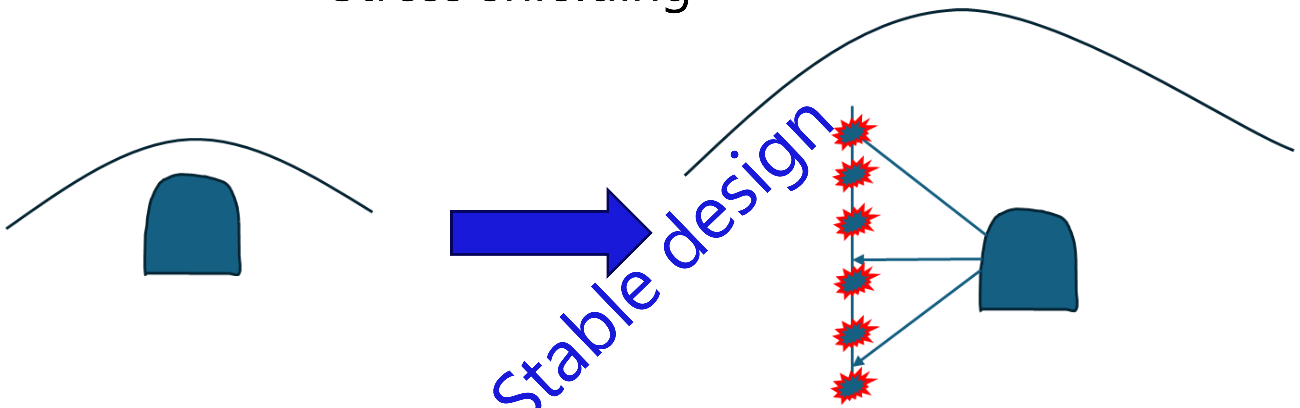


Controlled Failure or Stable Designs?

Controlling failure

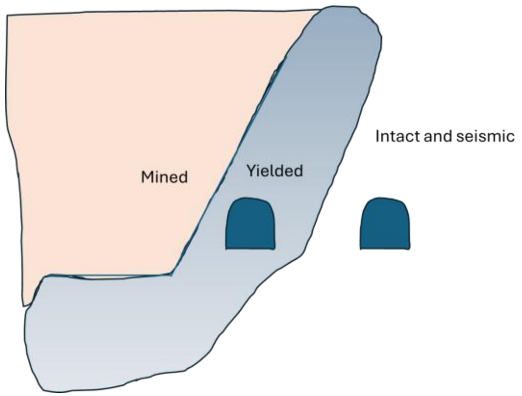
- Yielding pillars
  - Controlling the failure
  - Slow energy release

- Stress shielding



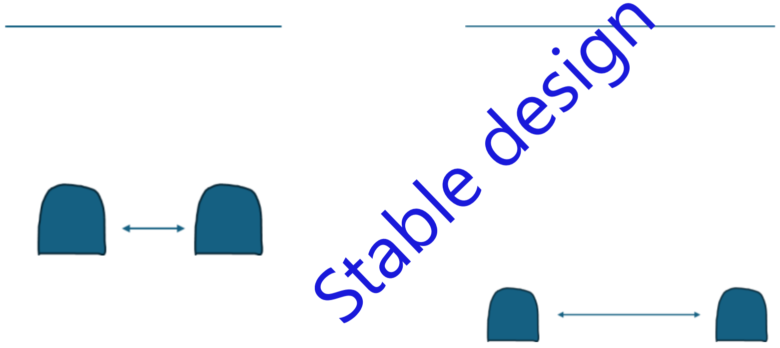
Stable design

- Drifting in yielded rock



Controlling failure

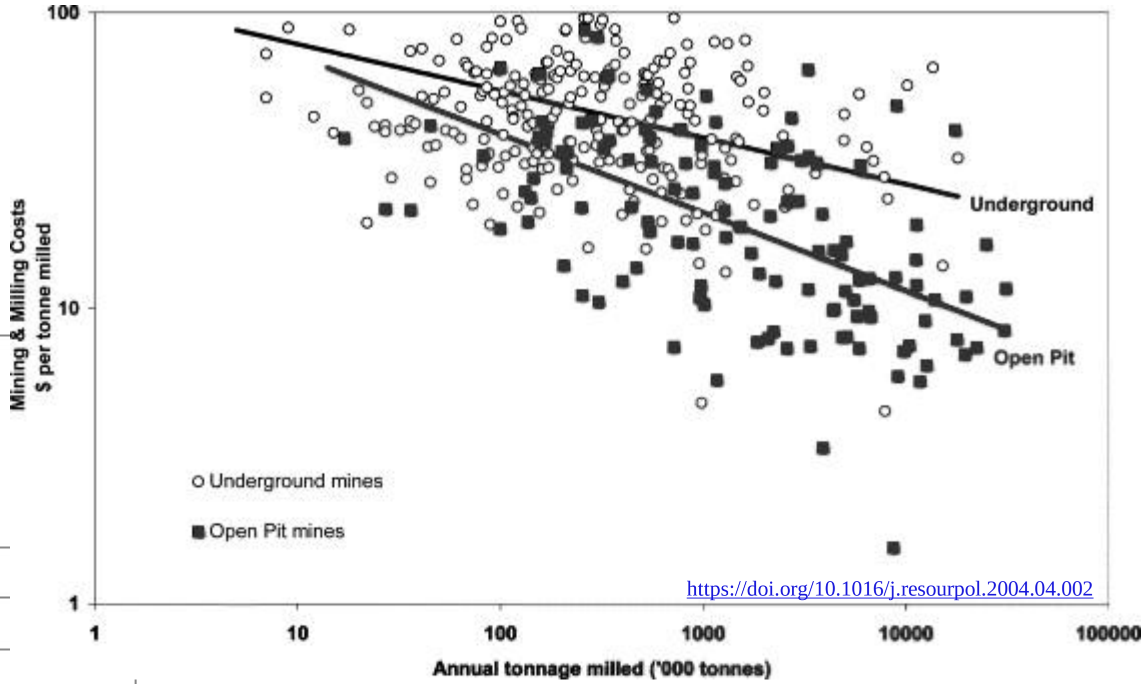
- Size scaling with stress



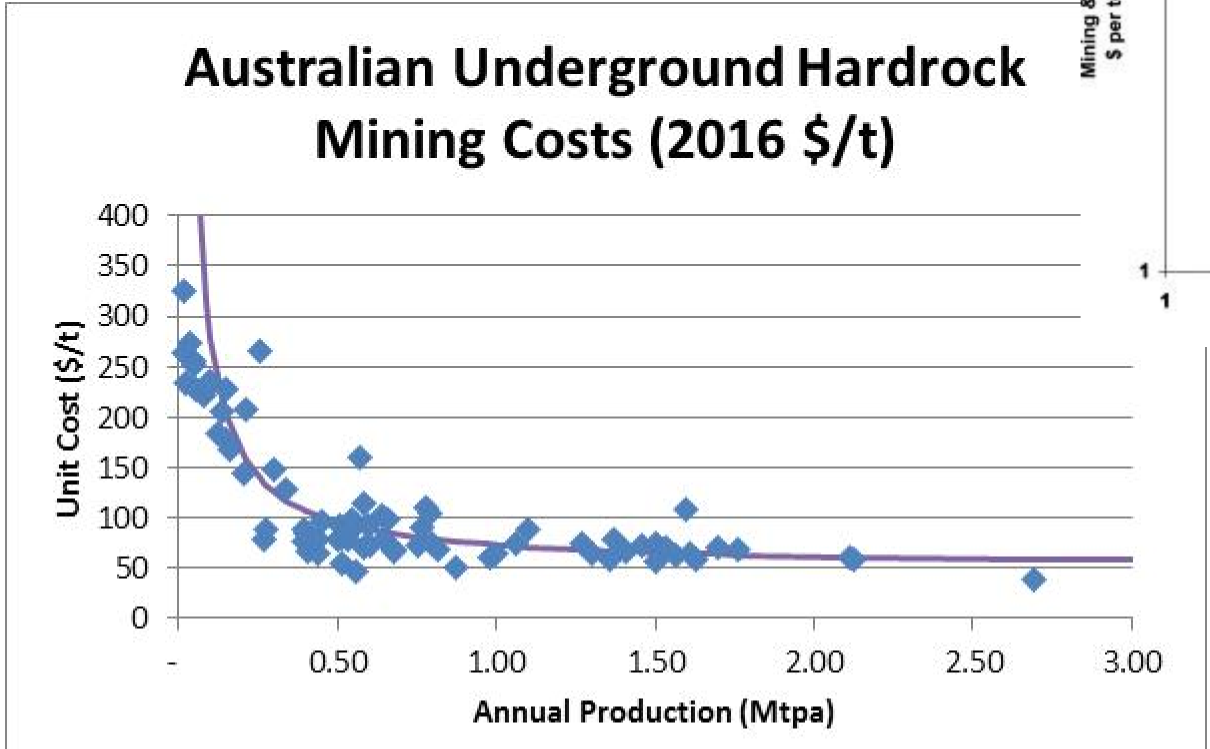
Stable design

Going Deep is Going Big

Mining Cost / Ton



https://doi.org/10.1016/j.resourpol.2004.04.002



*https://im-mining.com/2016/06/16/trends-in-australian-underground-mining-costs/

Automation

- Issues with **working environment** and **safety** are major sources of production delays

- By removing the operator from the active production area a higher probability of failure can be accepted

Unacceptable

On site personell	Event	Consequence	Probality	Risk rating
Yes	Rock burst	4	3	12
No	Rock burst	2	3	6

Acceptable

Automation

- Issues with **working environment** and **safety** are major sources of production delays

- By removing the operator from the active production area a higher probability of failure can be accepted

On site personell	Event	Consequence	Probality	Risk rating
Yes	Rock burst	4	2	8
No	Rock burst	2	3	6

Faster re-entry with automated loader

Recap – Deep mining

- Shallow deposits are limited, and most are already mined
- Deep mining represents the depths at which we are currently experiencing challenges, or depths to which we have yet to reach
- Mining costs goes up with increasing depth and down with increased production
- Going deep is going big (historically not always the case)
  - Caving methods
  - Automation
- Delays and production interference are significant cost sinks
  - Adequate rock support is an investment

ITASCA

" We drive the evolution of geological engineering and geosciences to improve the world, collaboratively developing innovative solutions to challenging problems."

Aurorum 2
SE-977 75 Luleå
Sweden

info@itasca.se

itasca.se