

ACCELERATING IMPACT

Session 1



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THE UNIVERSITY OF
MELBOURNE



Australian Government
Department of Industry,
Innovation and Science

Business
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Centres Program

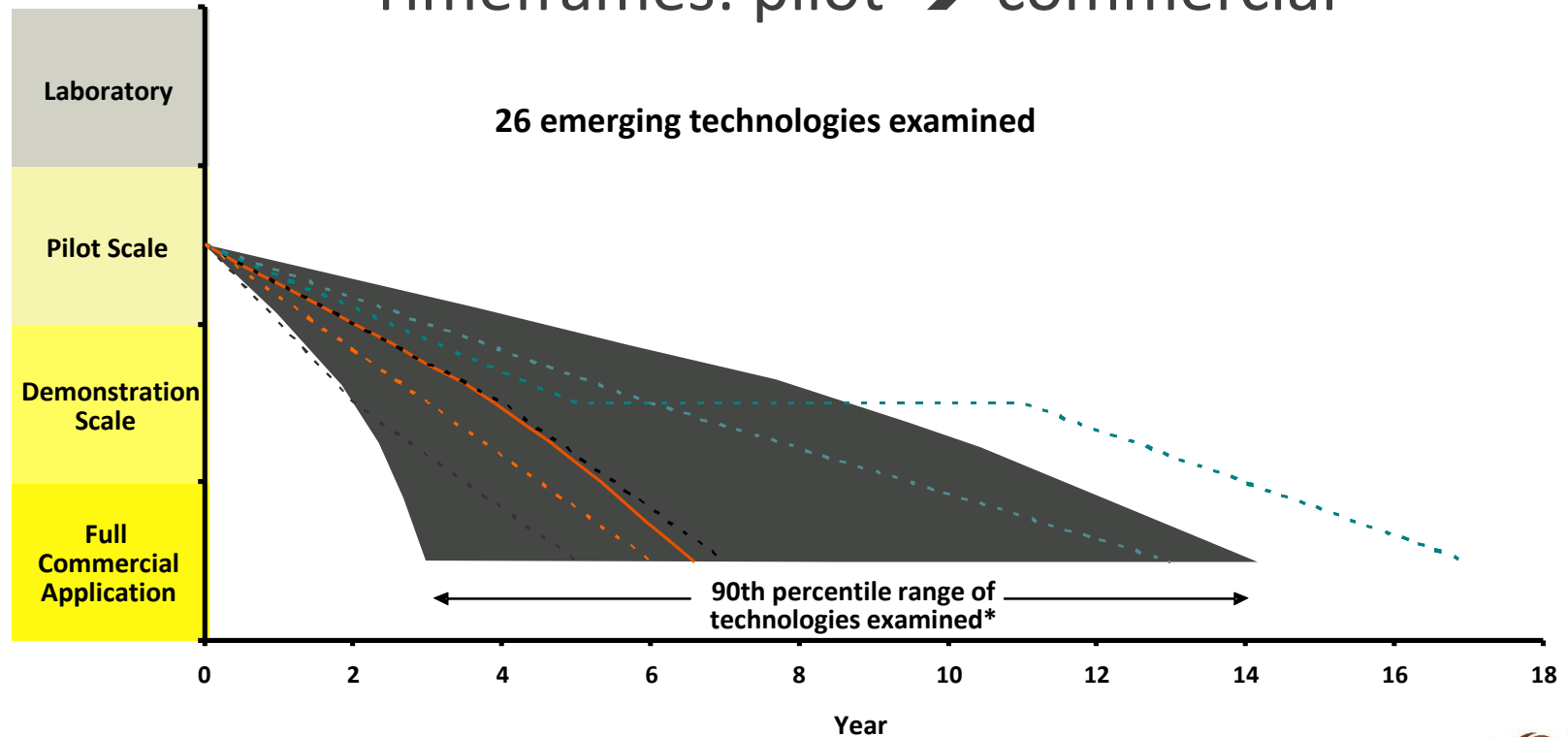
CRCORE
Optimising Resource Extraction

CROSSING THE GREAT DIVIDE: BALANCING IMAGINATION & APPLICATION IN RESEARCH

- The nature of mining research, has it changed?
- Mining in the future

BHP DATA FROM 15 YEARS AGO: A LINEAR PROCESS

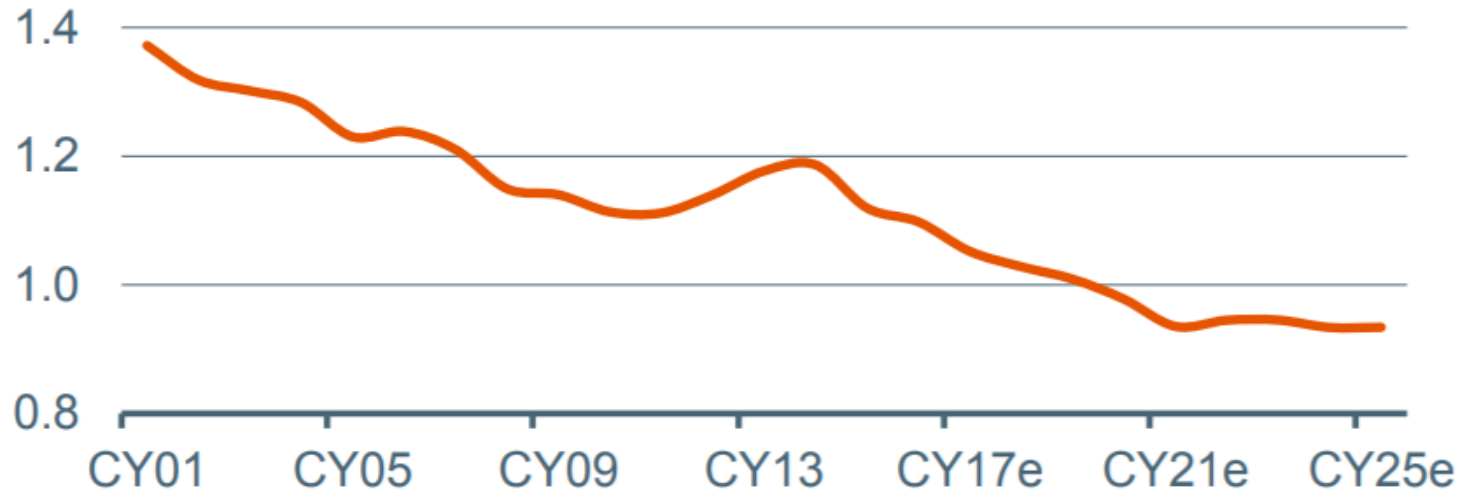
Timeframes: pilot → commercial



MINERAL PROCESSING FACES SOME EXTREME CHALLENGES. WILL INCREMENTAL IMPROVEMENT BE ENOUGH?

Let's look at copper

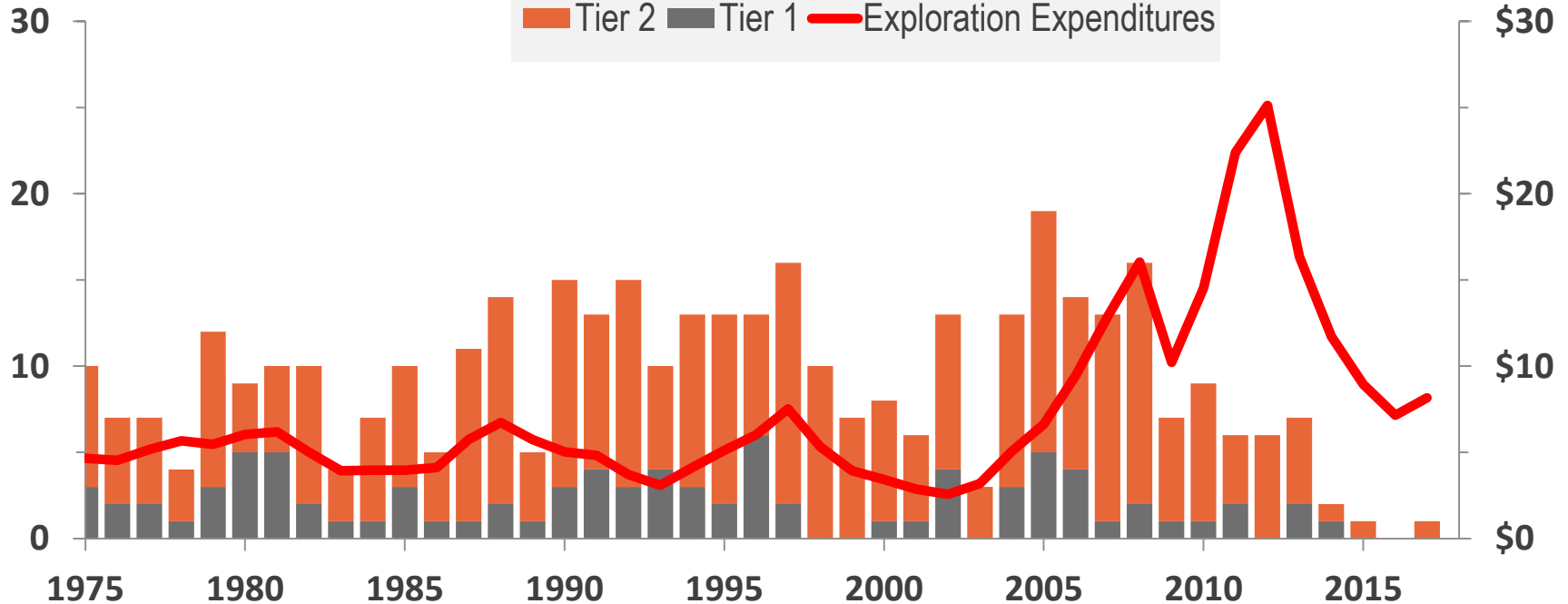
Industry grades continue to decline
Weighted average copper grade¹, %



Source: http://www.bhp.com/-/media/bhp/documents/investors/news/2015/151201_coppersitetourday1.pdf?la=en

EXPLORATION SEEMS UNLIKELY TO REVERSE THE TREND

Number of Tier 1&2 Discoveries



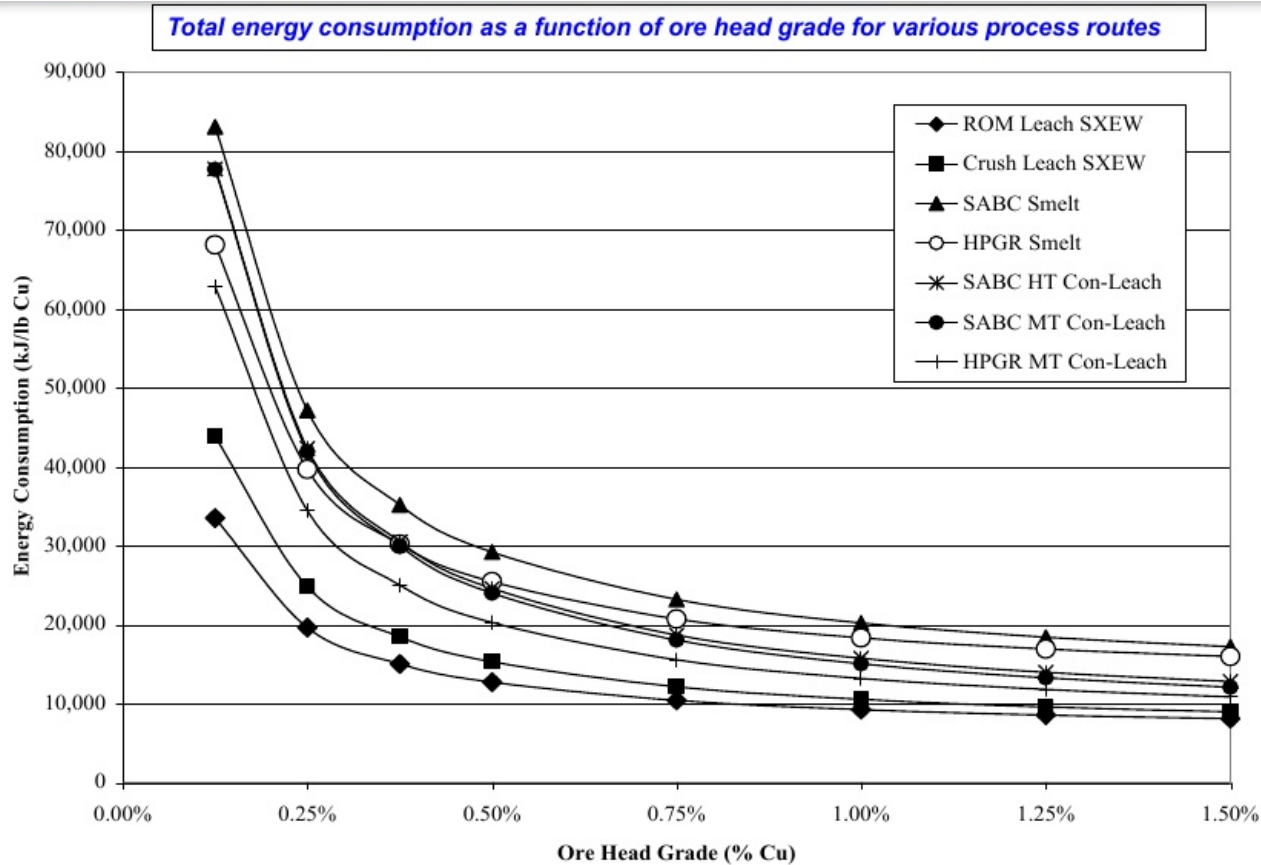
Note: No adjustment has been made for unreported discoveries or potential upgrades in known deposits

Tier 1 deposits are World Class Mines

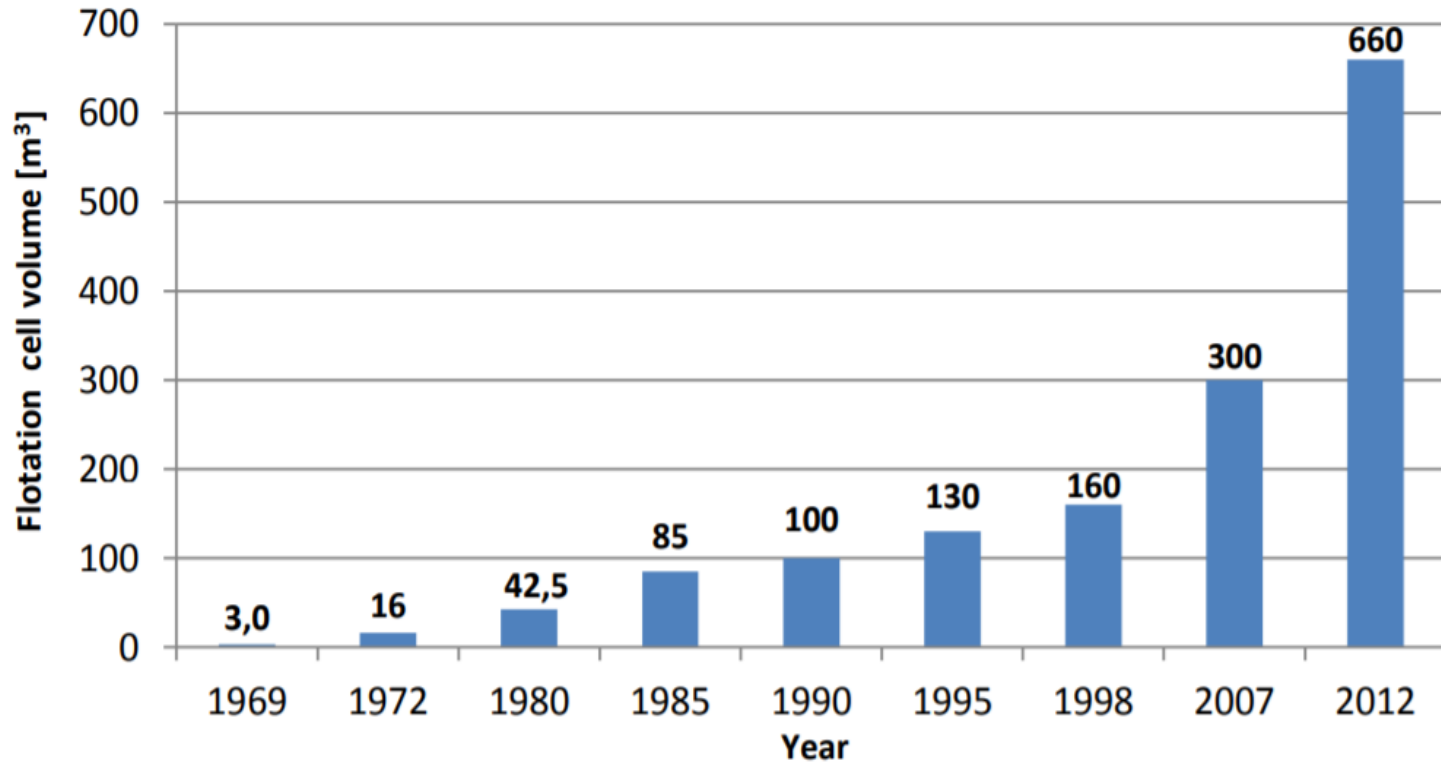
Tier 2 deposit have some but not all the characteristics of a T1

Source: Schodde, R.C., 2018. MinEx Consulting. Private communication.

DECREASING GRADE ENTAILS MORE ENERGY



DECLINING GRADE HAS BEEN THE MAIN DRIVER OF INCREASING SIZE OF FLOTATION PLANT

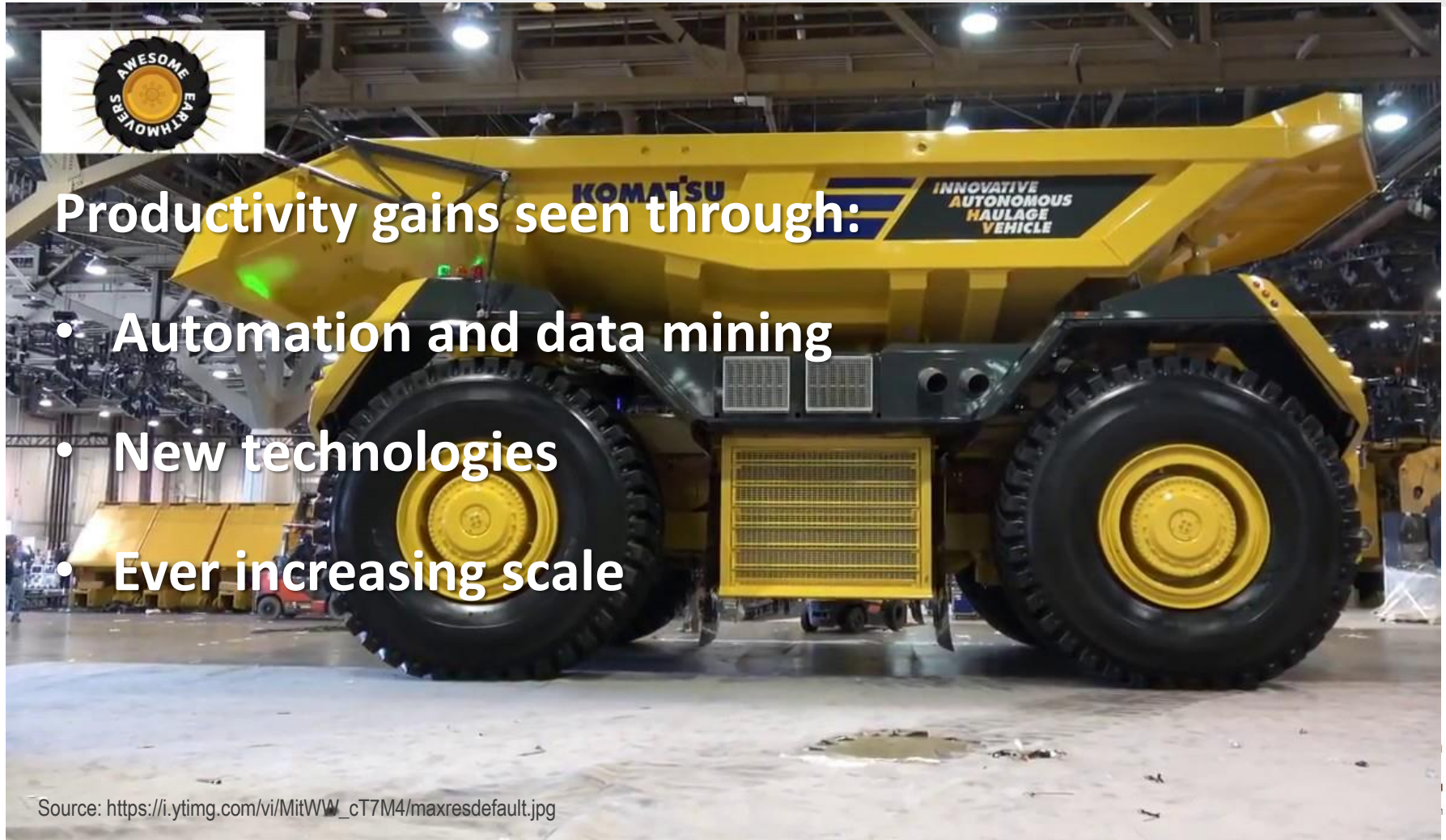


IS AUTOMATION, DEEP DATA, DATA ANALYTICS ENOUGH?



Productivity gains seen through:

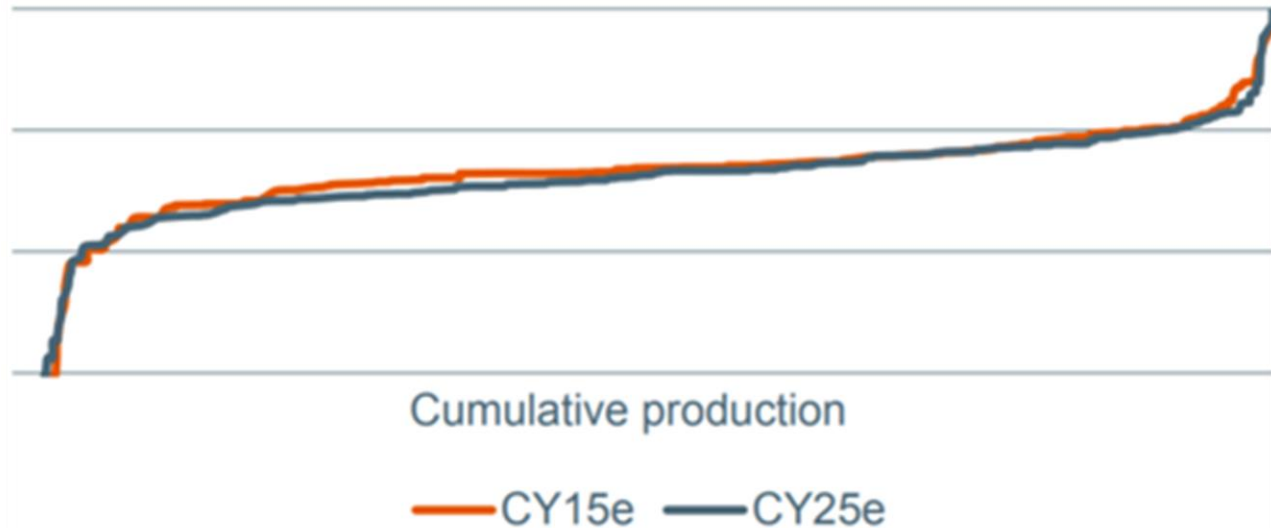
- Automation and data mining
- New technologies
- Ever increasing scale



Source: https://i.ytimg.com/vi/MitWW_cT7M4/maxresdefault.jpg

DESPITE THE 100 YEAR MARCH OF DECREASING COSTS, SOME SEE LITTLE IMPROVEMENT IN THE FUTURE

C1 cash cost, copper US\$/lb



SO, DO FAST FOLLOWERS BEAT FIRST LEADERS?



XXIX
IMPC 2018
SEPTEMBER, 15-21, 2018
MOSCOW, RUSSIA



John Marsden. Plenary lecture:

“Technological Innovation and Sustainable Competitive Advantage in the Copper Industry – Real or Imaginary?”

- 100 years of analysis of 20+ innovations in the copper industry
- Most took 30+ years before half the industry followed
- First movers had NPV positive results > industry returns
- Fast followers also superior but not as great as first movers

MORE GENERALLY, HAS MINING RESEARCH CHANGED?

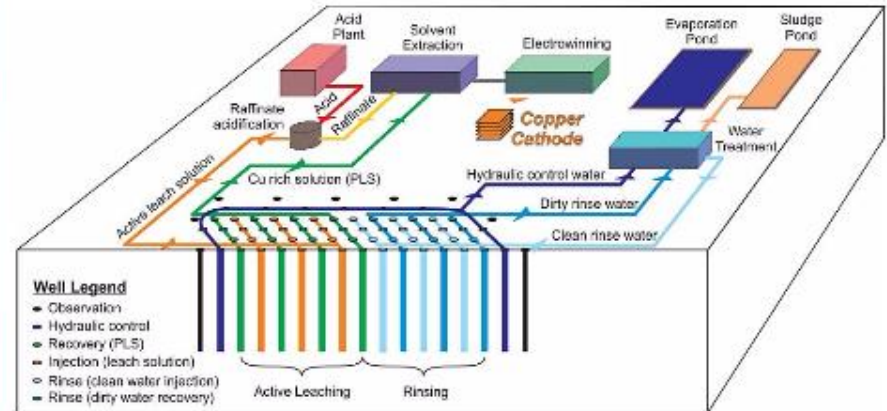
- Addressing the challenges, note the efforts in “open innovation”
 - A string of CRC’s
 - The Rio Tinto \$55m, Alcoa \$55m, Apple \$13m, Canada \$60m, Quebec \$60m investment in carbon free aluminium production
- And investment in “rapid innovation”
 - CRCORE – a prime example
 - Many others, particularly in China

And now, mining in the future

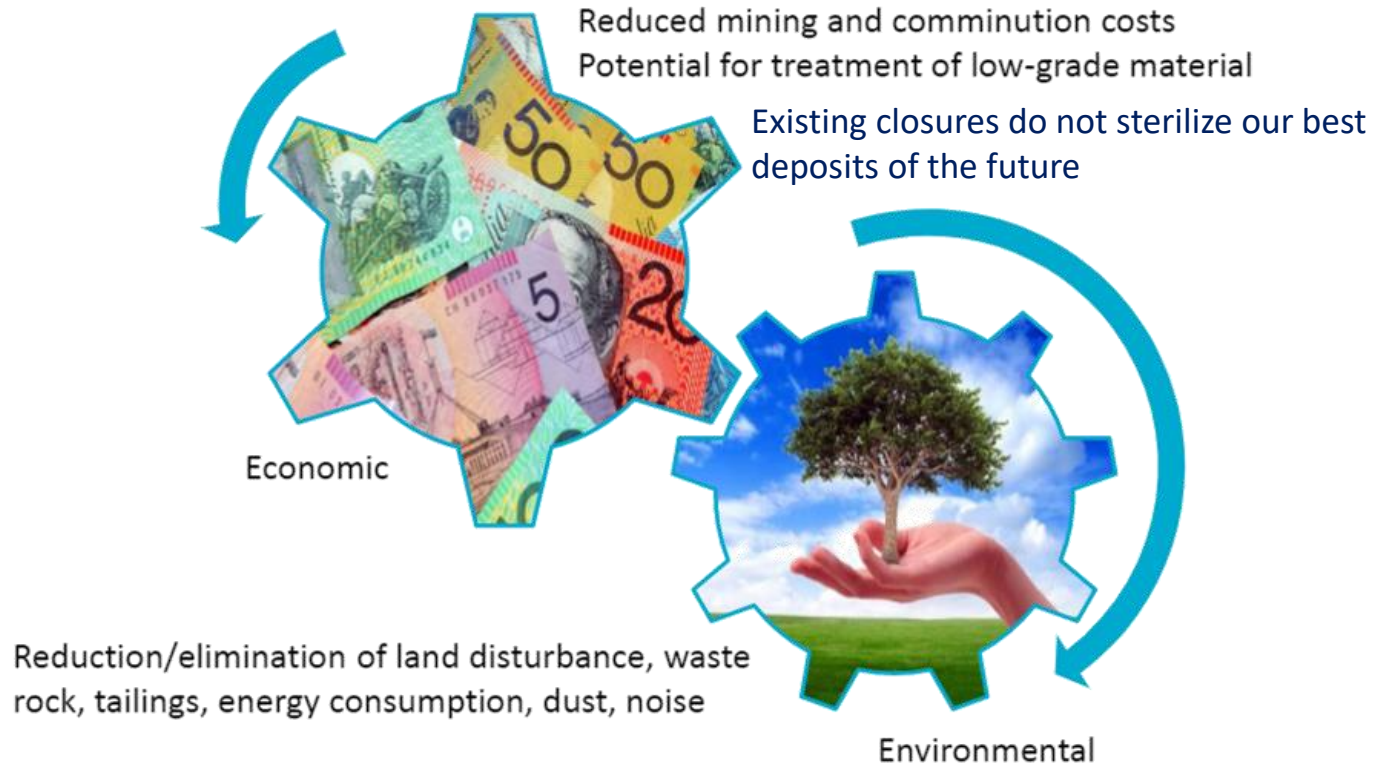
How brave do we need to be?

Can we balance imagination and application?

In-situ recovery (ISR): a mining process used to recover minerals through boreholes drilled into a deposit, in situ

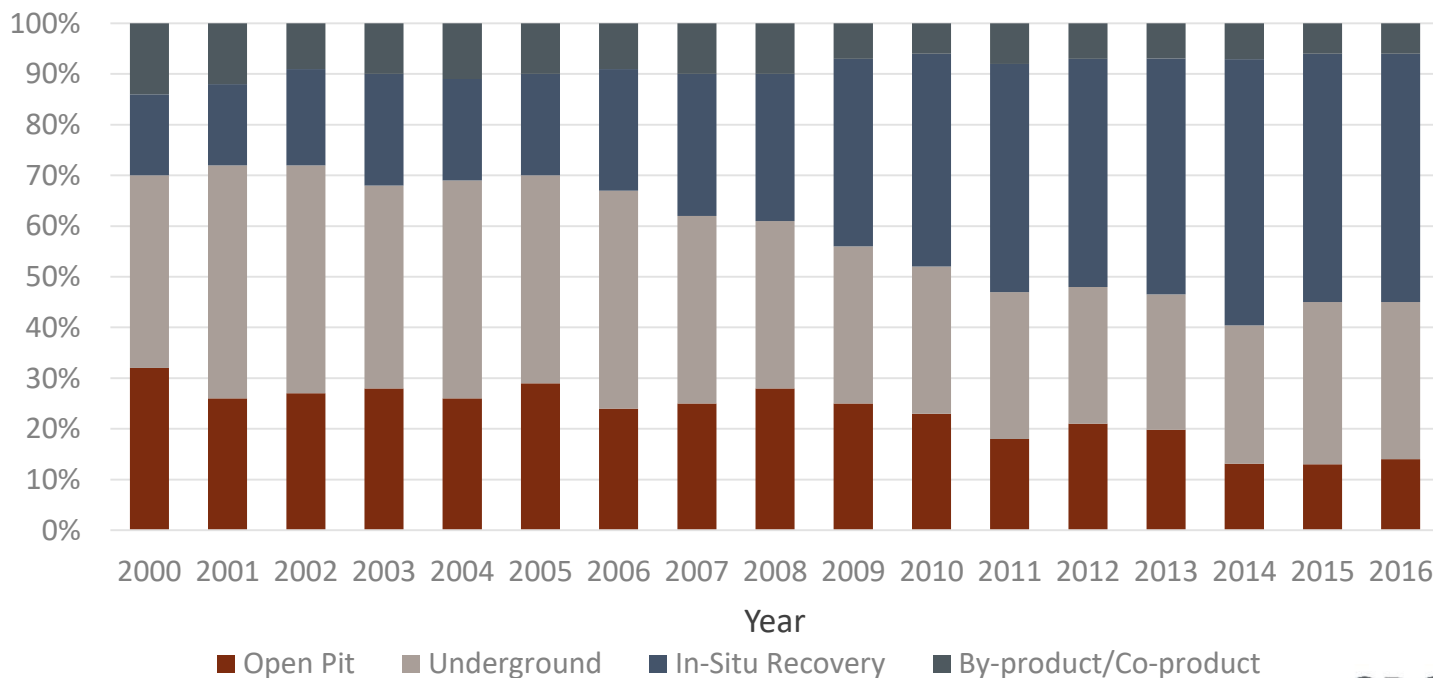


WHY IS ISR ATTRACTIVE?



ISR NOW A KEY PRODUCTION METHOD FOR URANIUM

World Uranium Production by Mining Method 2000-2016



Source: UX Consulting '2017 Uranium Production Cost Study'

STEPS TO ISR: BALANCING IMAGINATION AND APPLICATION

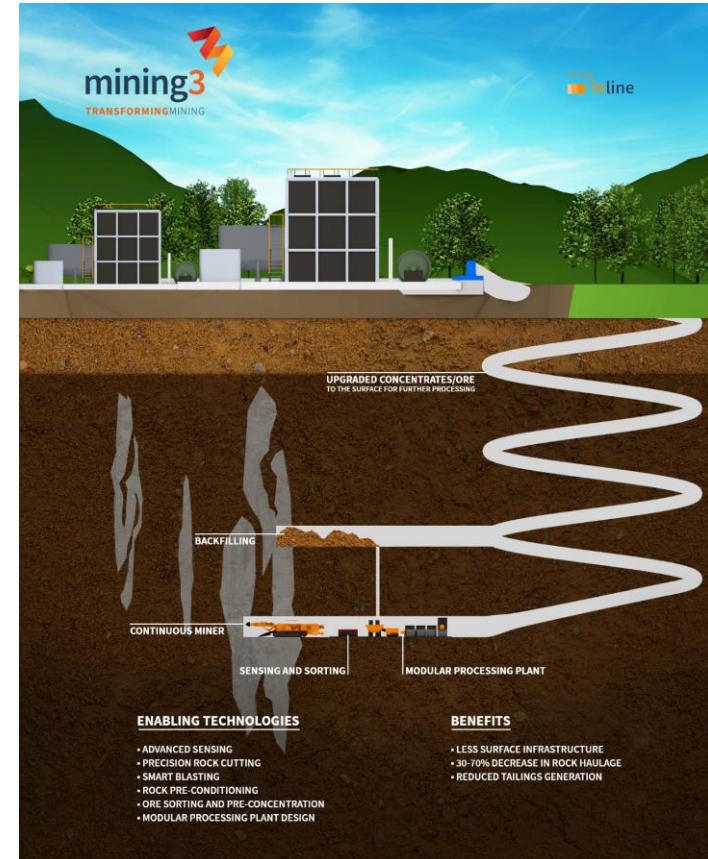
- **Significantly reduced surface footprint**
- Reduced mine transportation infrastructure - waste material remains in mine
- Smaller processing plant size due to higher grade feed and processing underground
- Reduction in tailings dam
- Modular production units with the ability to scale or contract as required
- Reduced energy



REDUCED ROCK MOVEMENT AND FOOTPRINT

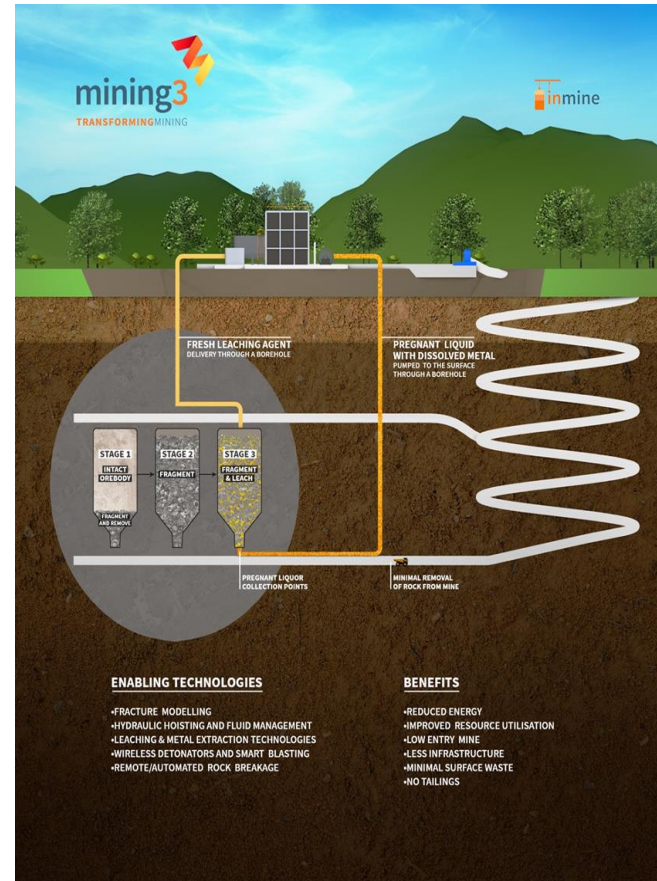
inline recovery

- Reduced material movement
- Underground extraction
- Selective (precision) mining
- Pre-concentration at the face
- Ore sorting technologies
- Underground modular plant



inmine recovery

- Low to no material movement
- Underground extraction
- Fracturing ore in place underground
- Leaching to extract ore



INDIVIDUAL PROGRESS ON TECHNOLOGY DEVELOPMENTS:

- Barrier technology (routine in oil and gas) both as barriers and to minimize short circuiting
- Designer bugs
- Eh-pH manipulation for primary sulphides
- Geophysics for real time tracking of lixivate
- Chemical tracers and nanoparticles
- Automated small bore drilling for permeability control
- Flood irrigate (saturated or not...) to minimize pumping costs

- Mining in the future is now imaginable with almost no environmental footprint and much improved economics
- The individual steps necessary to prove up in place mining are being trialled commercially and supported by extensive R&D.
- Rapid and open innovation are key to unlocking the future
- As John Marsden indicates, first movers are generally winners

Additional slides

crcore.org.au

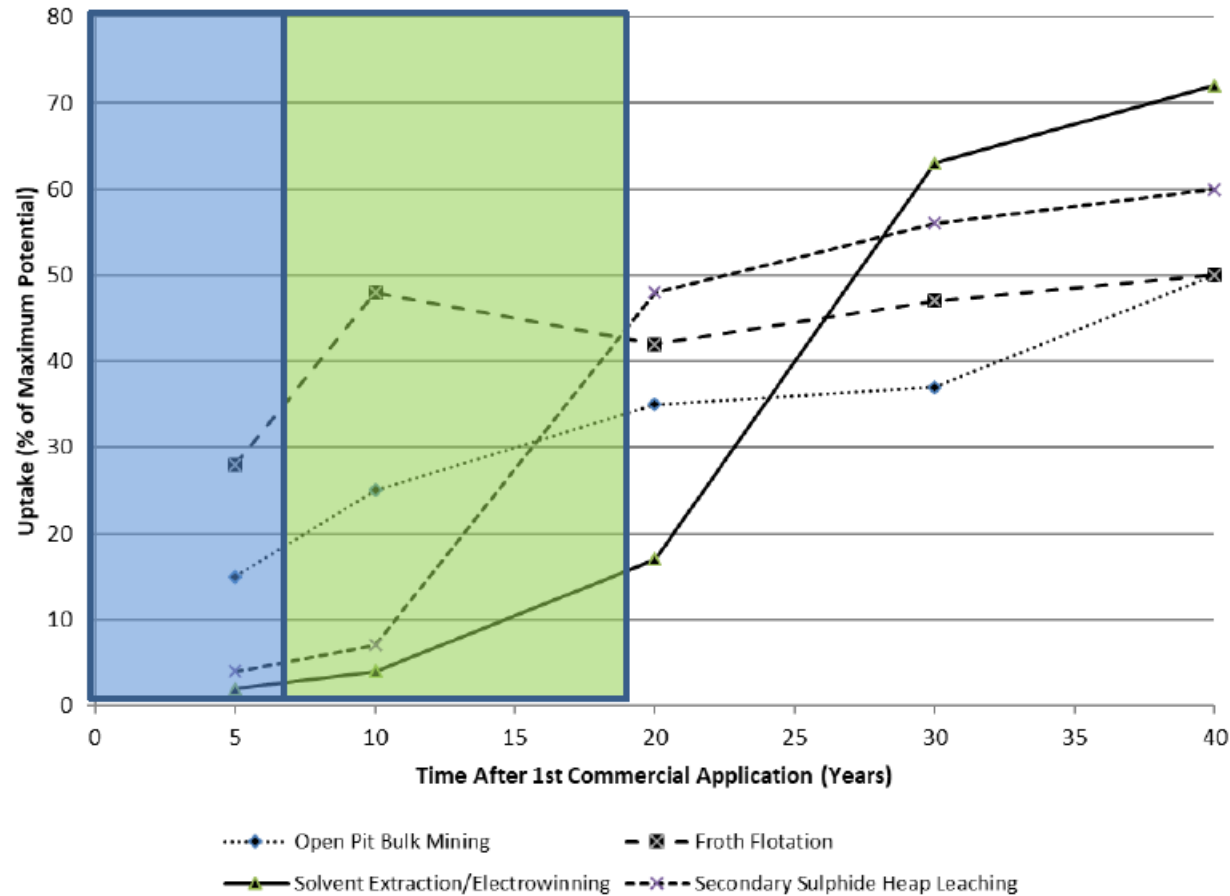


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CRC**ORE**
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TECHNOLOGY UPTAKE – FAST FOLLOWERS



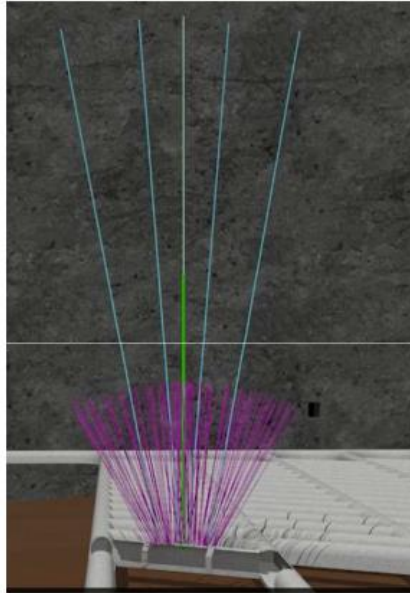
Source: John Marsden "Technological Innovation and Sustainable Competitive Advantage in the Copper Industry – Real or Imaginary?". XXIX IMPC 2018, Moscow Russia. 19 September 2018

Precise geology, chemistry, rock properties, hydrogeology and other local factors combine so that ISR is not the “silver bullet” for all future opportunities.

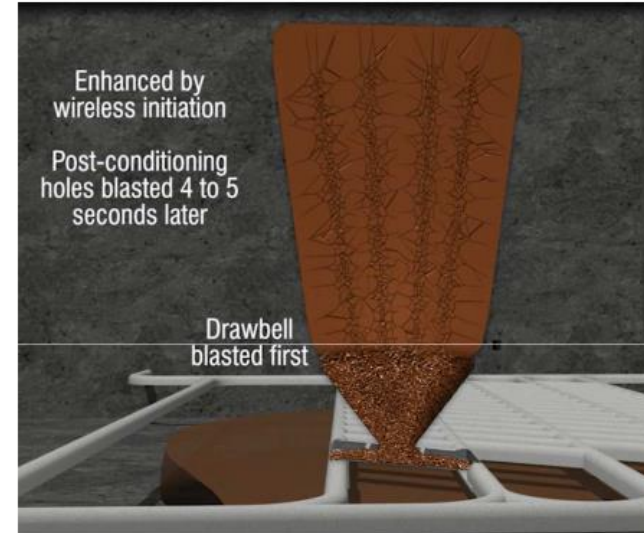
Advances in blasting:

- Explosives now available from half to three times the relative bulk strength of ANFO
- Electronic ignition soon to be wireless (regulatory hurdles noted)
- High fidelity blast models

HIGH LIFT DRAWBELL PLUS POST CONDITIONING CONCEPT



- Box hole to create free face
- Large diameter preconditioning blastholes
- All blastholes loaded from the draw point

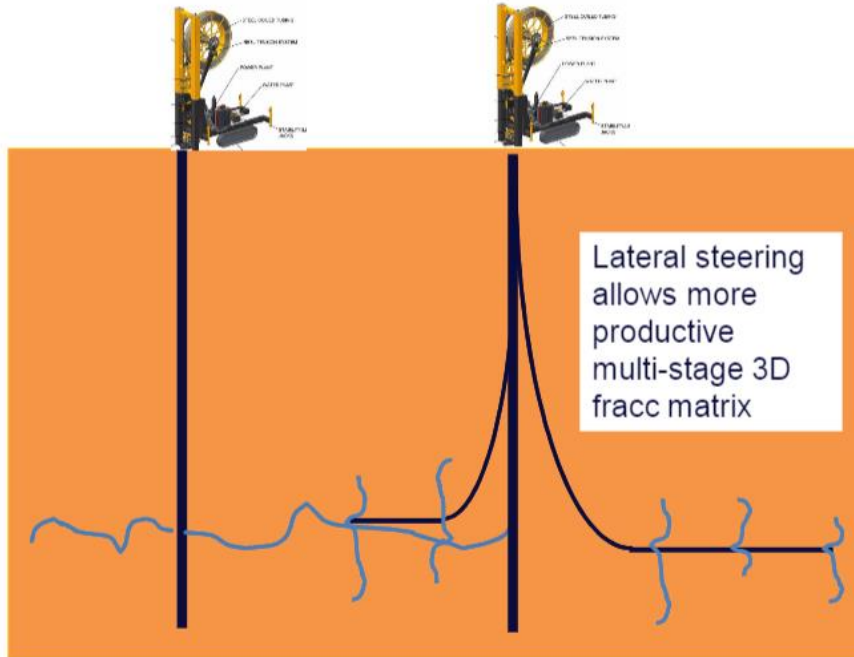


- Could the concept be adopted for an insitu reactor ??

LOW COST DRILLING, STEERING AND FRACCCING

DEPARTMENT OF PETROLEUM ENGINEERING

INNOVATION IN SCIENCE
AND TECHNOLOGY

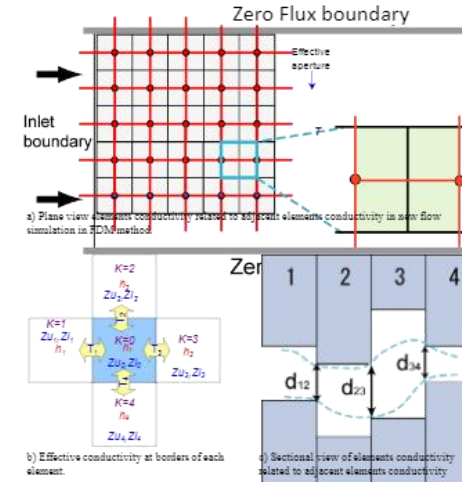
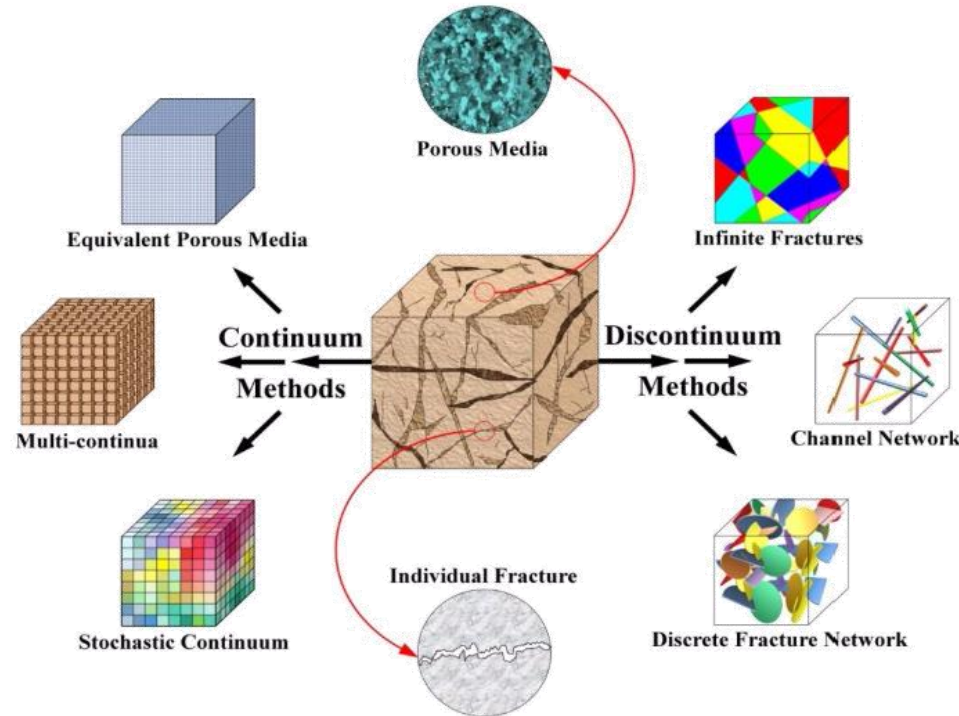


**Low cost drilling
and geosteering
means improved
fracture matrix
development**



Curtin University

MODELLING RAPIDLY IMPROVING



NEW STIMULATION TECHNOLOGIES EMERGING

- Under development/study is the use of microwaves, sonic waves, temperature gradients, high voltages, injectable explosives, percussion techniques, pulsed combustion et al.
- One example:

NaturaFrac Pulsed Combustion Formation Stimulation Technology Highlights

NaturaFrac™
Advanced Dynamic Formation Stimulation

Game Changing

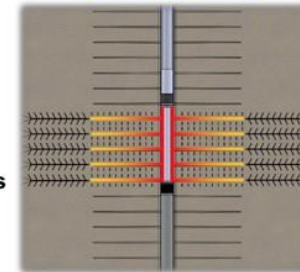
- Water-Free Stimulation For Subterranean Rock Structures
- Advanced Rocket Science + Advanced Rock Mechanics
- A More Complex And Optimal Fracture Matrix

Safe & Environmental

- Horsepower Put Down-Hole Via Pulsed Combustion Physics
- LNG/Air or Diesel/Air Propellants
- Reduced Surface Footprint & Complexity

Economic

- Flexible Tool To Match The Formation Response Requirements
- More Resource Production Potential Per Well
- Lower Projected CapEx & OpEx Over Current Technologies
- Flexible Tool Architecture For Multiple Markets/Applications



Numerous examples of leaching in place after blasting

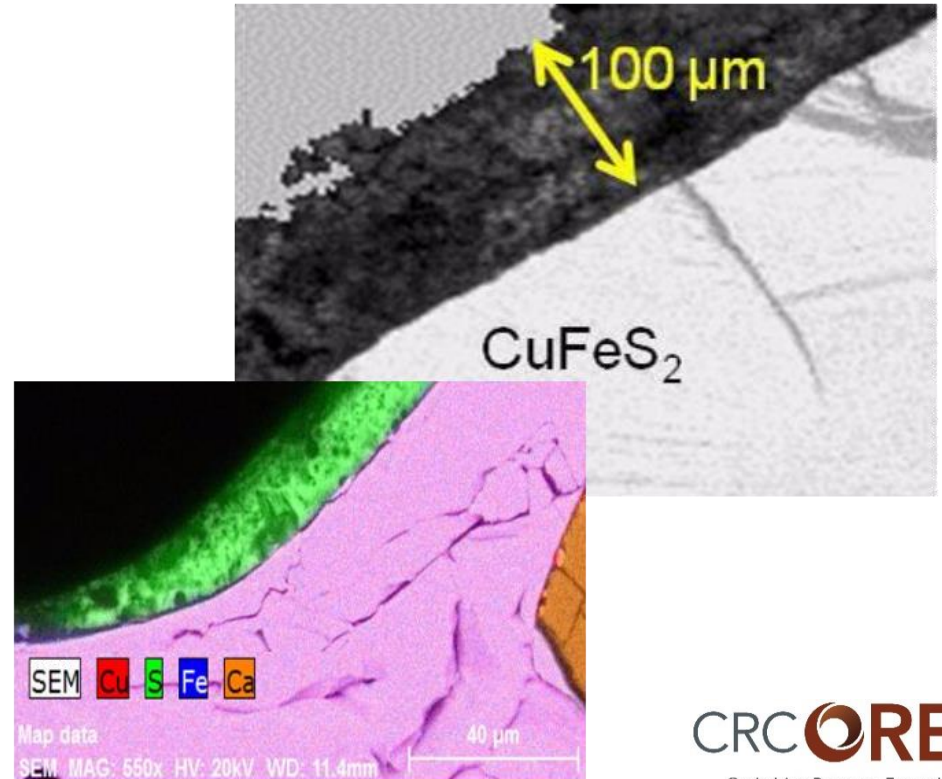
- Both primary and secondary sulphides
- Often after other mining completed

ISR commercial operations emerging

- Florence, Gunnison, Uralgidromed / Gumeshevskove

UNDERSTANDING OF SECONDARY PRODUCT FORMATION

- Secondary product formation influenced by (gangue) mineral dissolution, temperature, solution pH
 - Sulfur
 - Iron, metal hydroxide precipitates
 - Calcium sulfate (gypsum)
 - Silica gel
 - Iron-deficient copper sulfide surface layers



CASE STUDY: FLORENCE COPPER

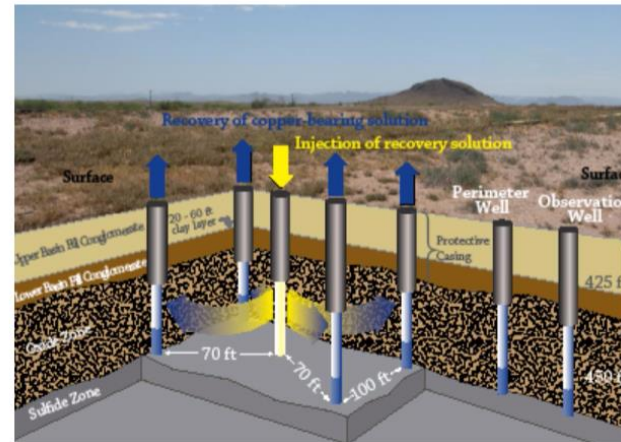
- Expected full commercial life of project: 25 years
- 55 million pounds annually for first six years, 85 million pounds annually for 14 years



Source: CSIRO In-situ recovery symposium (May/June 2017)

CASE STUDY: FLORENCE COPPER

- 2-year production test facility: pilot-scale demonstration
- 24 wells over 2 acres, 4 injection wells, 9 recovery wells, 4 geochemical sampling wells, 7 observation wells
- '99.5% water and 0.5% sulfuric acid, and similar in pH to household vinegar'
- SX/EW to manufacture 1–2 million pounds of 99.999% pure copper cathode



Source: CSIRO In-situ recovery symposium (May/June 2017)

Excelsior Mining Corp



TSX: **MIN** / OTCQX: **EXMGF**

- Canadian junior listed company with head office in Phoenix, AZ
- Core facility in Casa Grande & mine office at Johnson Camp (Gunnison)
- Sole focus: **Gunnison Copper Project**, Cochise County, AZ

Highlights:

- In-situ recovery of Cu oxide resource
- US\$52M spent since 2010
- Ex-Magma Copper Co. project
- Feasibility complete: low Opex & Capex
- Permitting underway (State and Federal)
- Production in Q2/Q3 2018



Gunnison Operations



Source: CSIRO In-situ recovery symposium (May/June 2017)

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