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XI BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

Critical minerals and rare earths: lessons from Australia to support the global energy transition

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The University of Queensland, Australia

Resourcing the Energy Transition

‘*The need*’ for transition – is globally recognised as a ‘*burning platform*’ - one we must all solve urgently!

but

‘*The solutions*' are still being tackled in silos – fragmented - with different agendas – competing - rather than working collectively and effectively

Including discovery, development and extraction

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Clean Energy requires far great amounts of metals – ~**2 to 10 times more** –
and a wider variety of metals than '**traditional**' energy supply

The challenges with Resourcing Decarbonisation (supplying resources for the energy transition)

The challenges with Resourcing Decarbonisation

Our #1 priority – The **timely** sourcing of the supply of critical minerals and metals

1. Understanding - research
2. Discovery – exploration (permitting)
3. Assessment - studies
4. Development – approval (permitting) & construction
5. Processing – extraction
6. Downstream – refining
7. Skills – future workforce

Our ‘second, equally #1’ priority - Achieving the above #1’s **responsibly** (ESG)

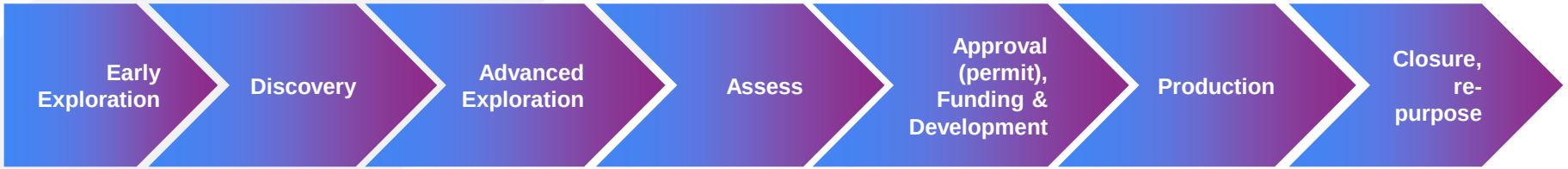
Solving how we:
1. **Discover** and
2. **Develop, and extract**

the quantum of critical metals projects in the **timeframe** needed?

Reducing the time for discovery to mine development

Reduce the timeline from say **15 years to 7 years and less**

- How do we do this responsibly across the range of new projects and mines needed?
- Requires we all work together (government=permitting, communities=access, industry, research & academia=skills, funding, etc)



How do we successfully develop new supply in the timeframe we need?

Copper Example

Copper demand predictions

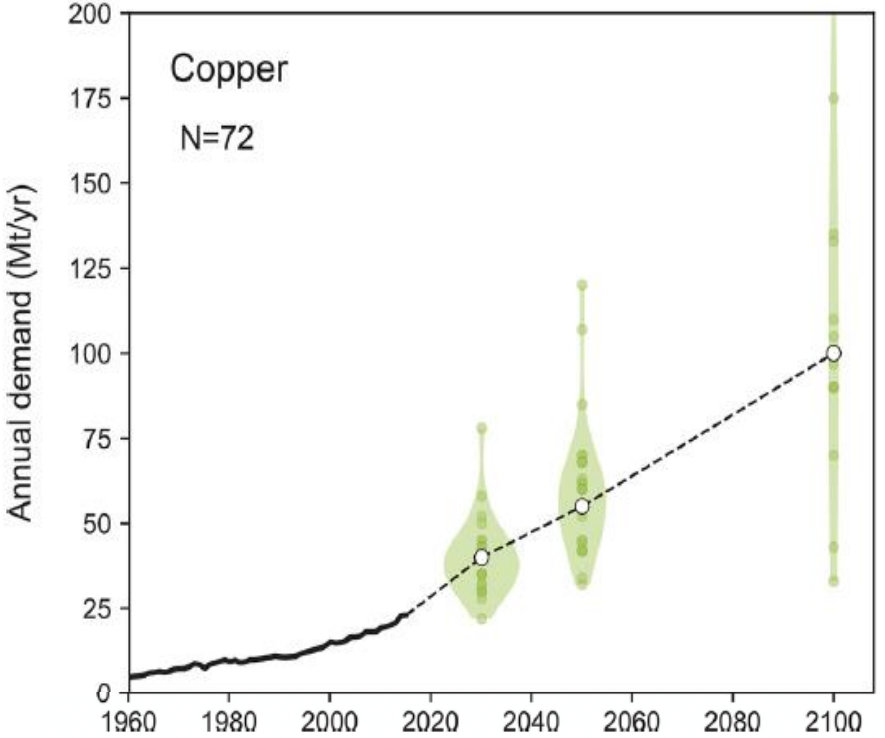
- Copper demand predicted to rise from 25Mt/yr to 50Mt/yr by 2035
- This amounts to ~500Mt of copper to be produced in the next 12 years, 1,000Mt in next 25 years

Some historical context…

It is estimated that in the entirety of human history, ~700Mt of copper have been mined.

https://www.usgs.gov/faqs/how-much-copper-has-been-found-world

Where are we going to get it?



Watari et al, 2021

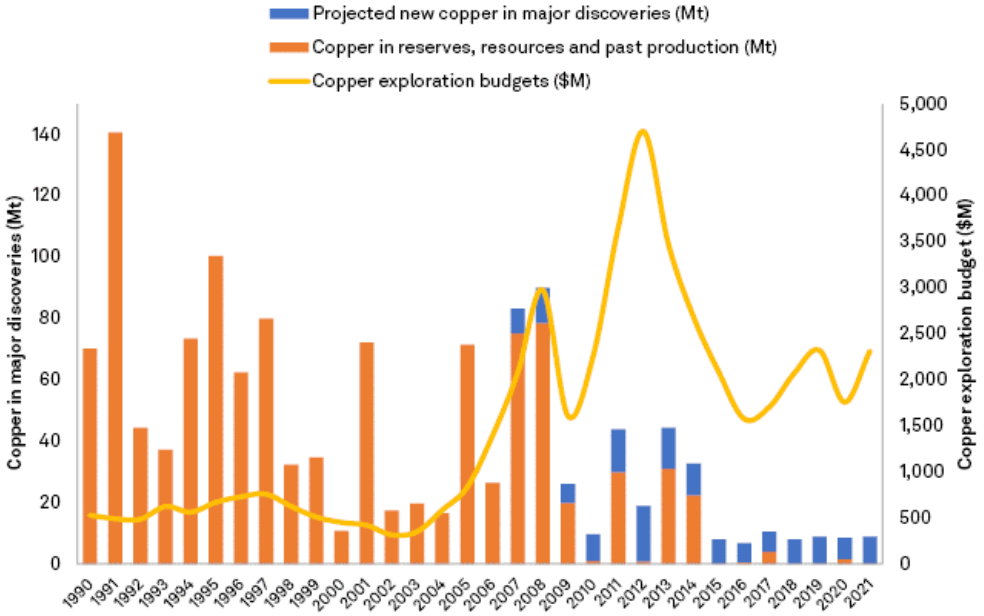
Discovering and developing new deposits

Finding new mineral deposits is getting more difficult and more expensive

- The obvious ones have been found
- Grades of existing reserves reducing
- New additions to global metals inventory are from:
  - ✔ New discoveries under deep cover
  - ✔ Known sub-economic deposits becoming viable

It generally takes a 7-15+ years from discovery to first production

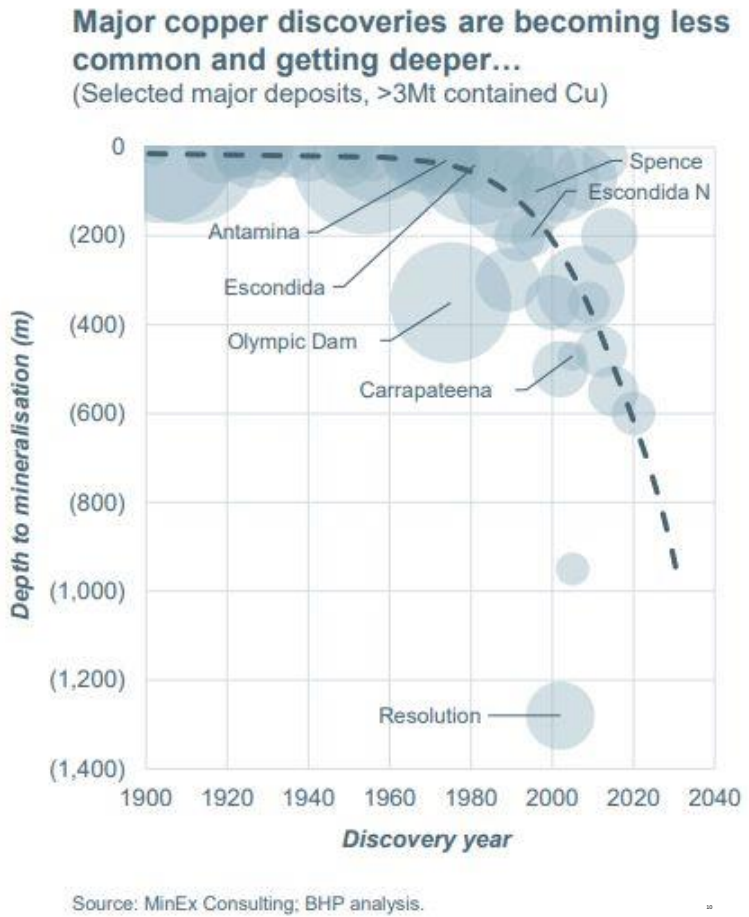
- Timeframes are becoming longer, not shorter



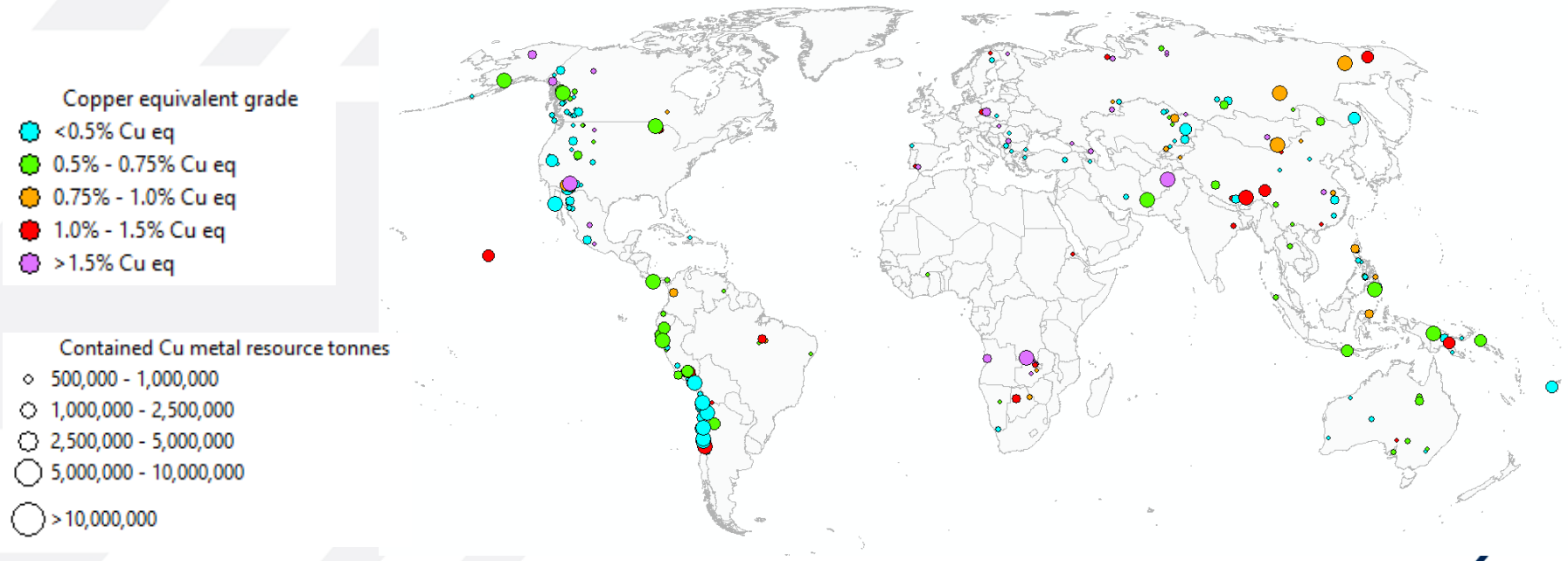
Data as of May 10, 2022.
* Annual average London Metal Exchange Copper Grade A cash price.
Source: S&P Global Market Intelligence

Discovering and developing new deposits

- Major discoveries have been **declining**
- Major discoveries have become **deeper**
- Both large open pits and future underground massive mines have **increasing complexity**
  - ✔ Technical, infrastructure, environmental, social, and governmental complexity



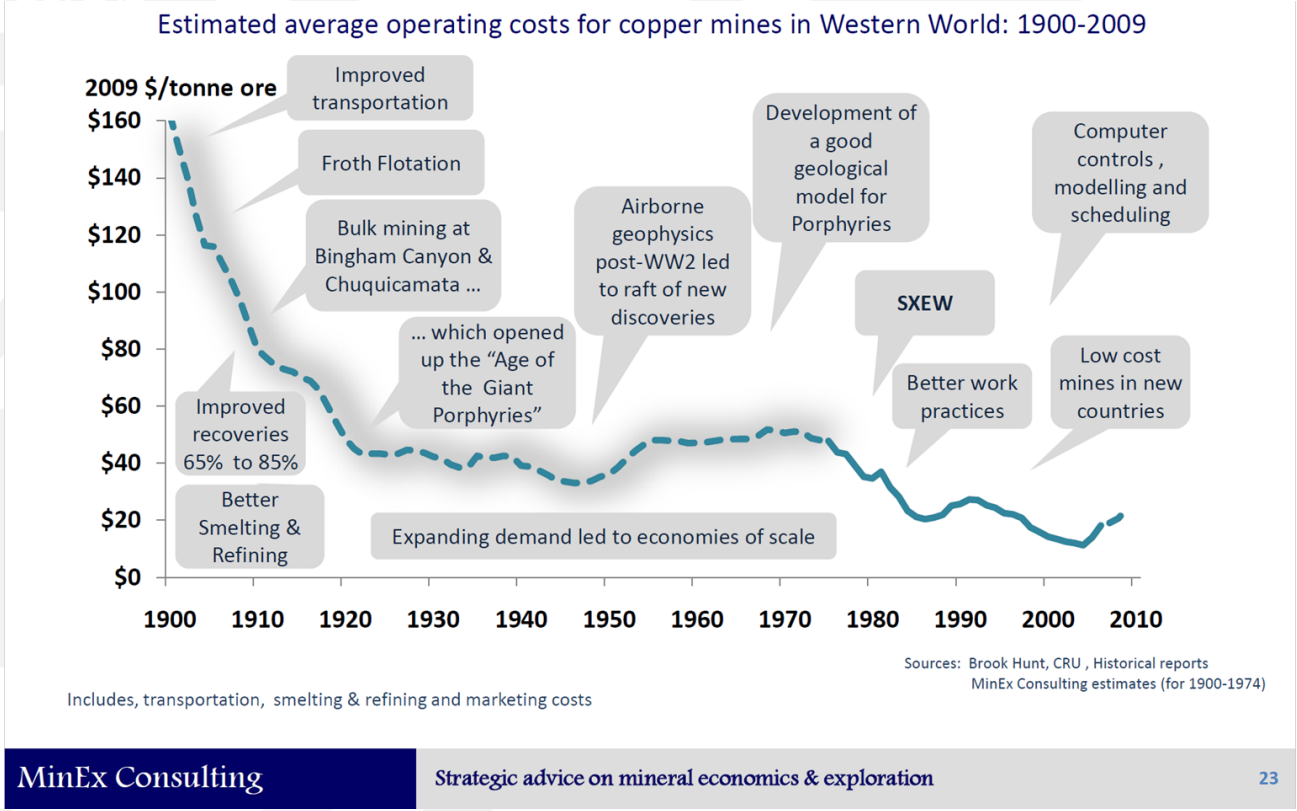
For example, about 35% of known Copper resources are inaccessible



Distribution of undeveloped copper deposits

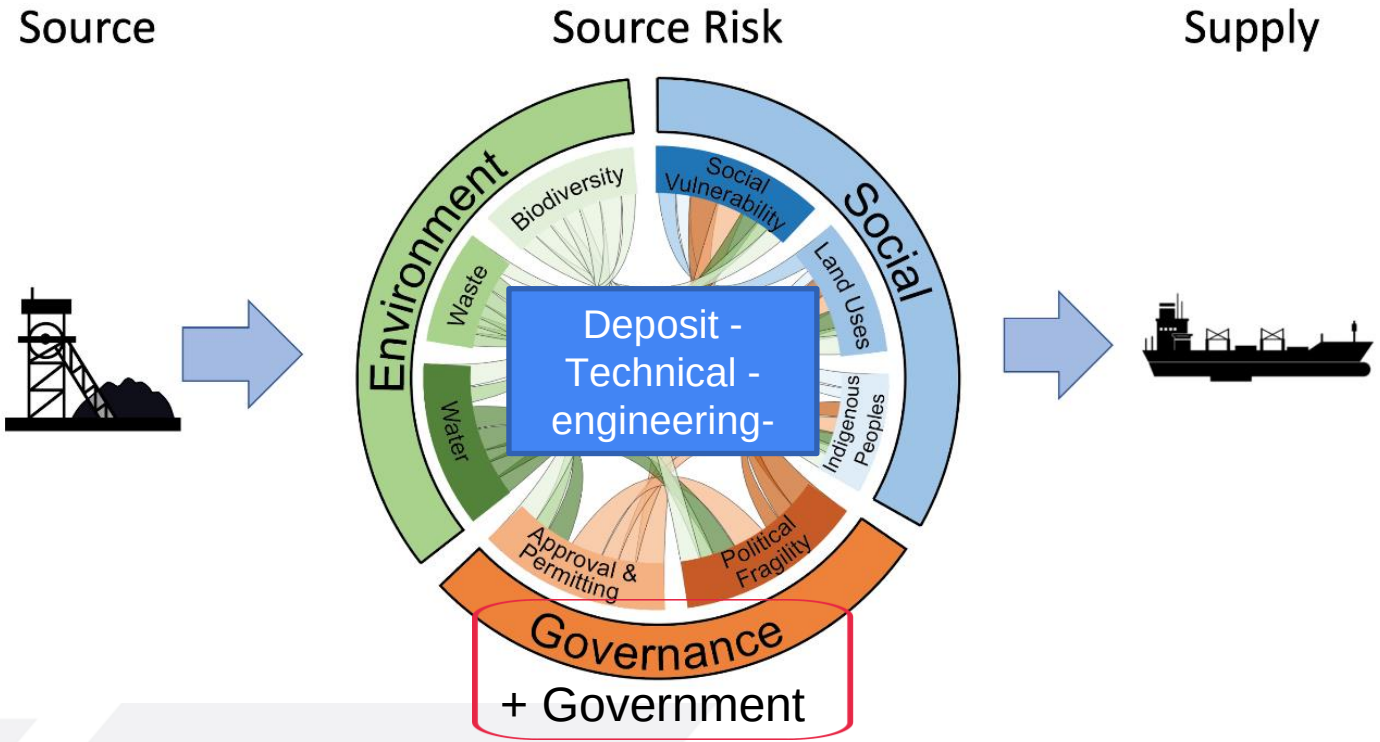
Source: S&P Market Intelligence

What we are good at – Scale, Efficiency=Cost Reduction



Can continued cost reduction unlock Complex Copper Orebodies?

What we are not so good at - unlocking undeveloped “Complex Orebodies”



What we doing in Australia to resource the critical minerals and REE needed for the Energy Transition

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Australia’s global footprint in critical minerals

- Based on 2022 data and US$

- Prepared by: Ian Satchwell, Adjunct Professor

- December 2023

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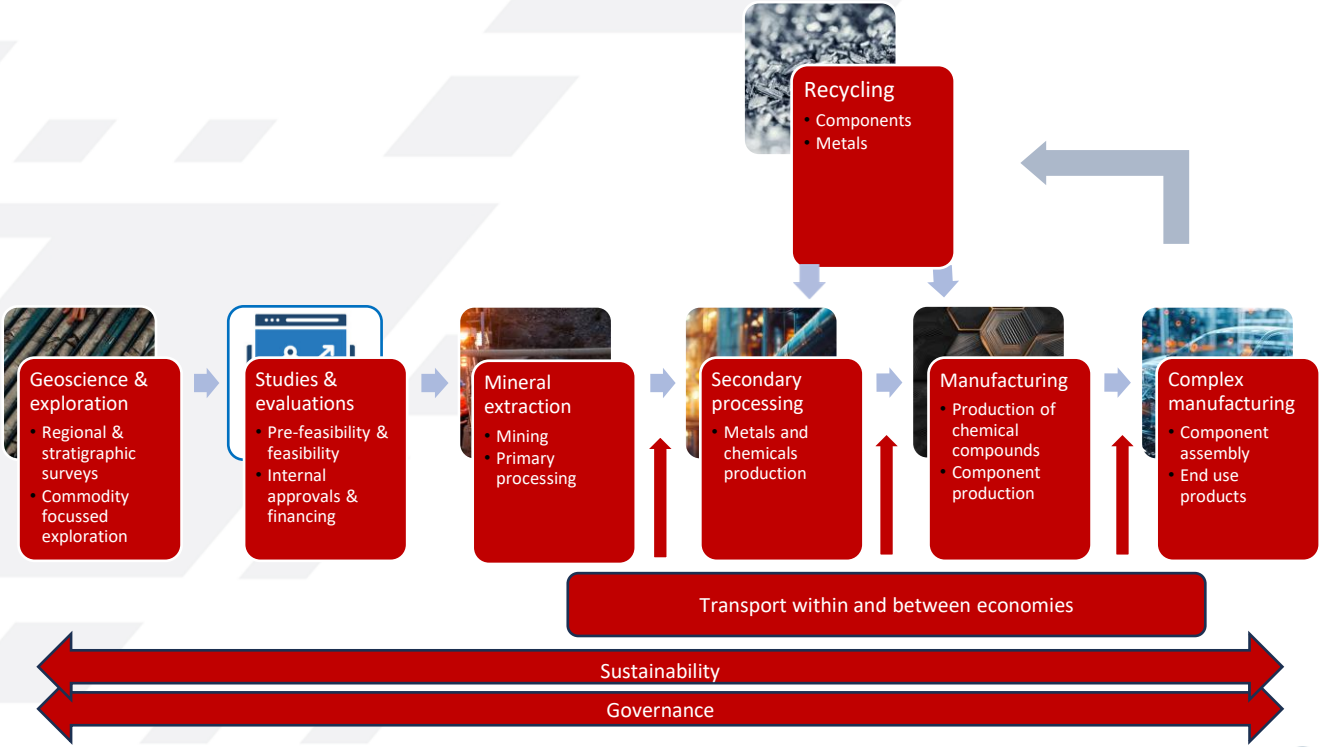
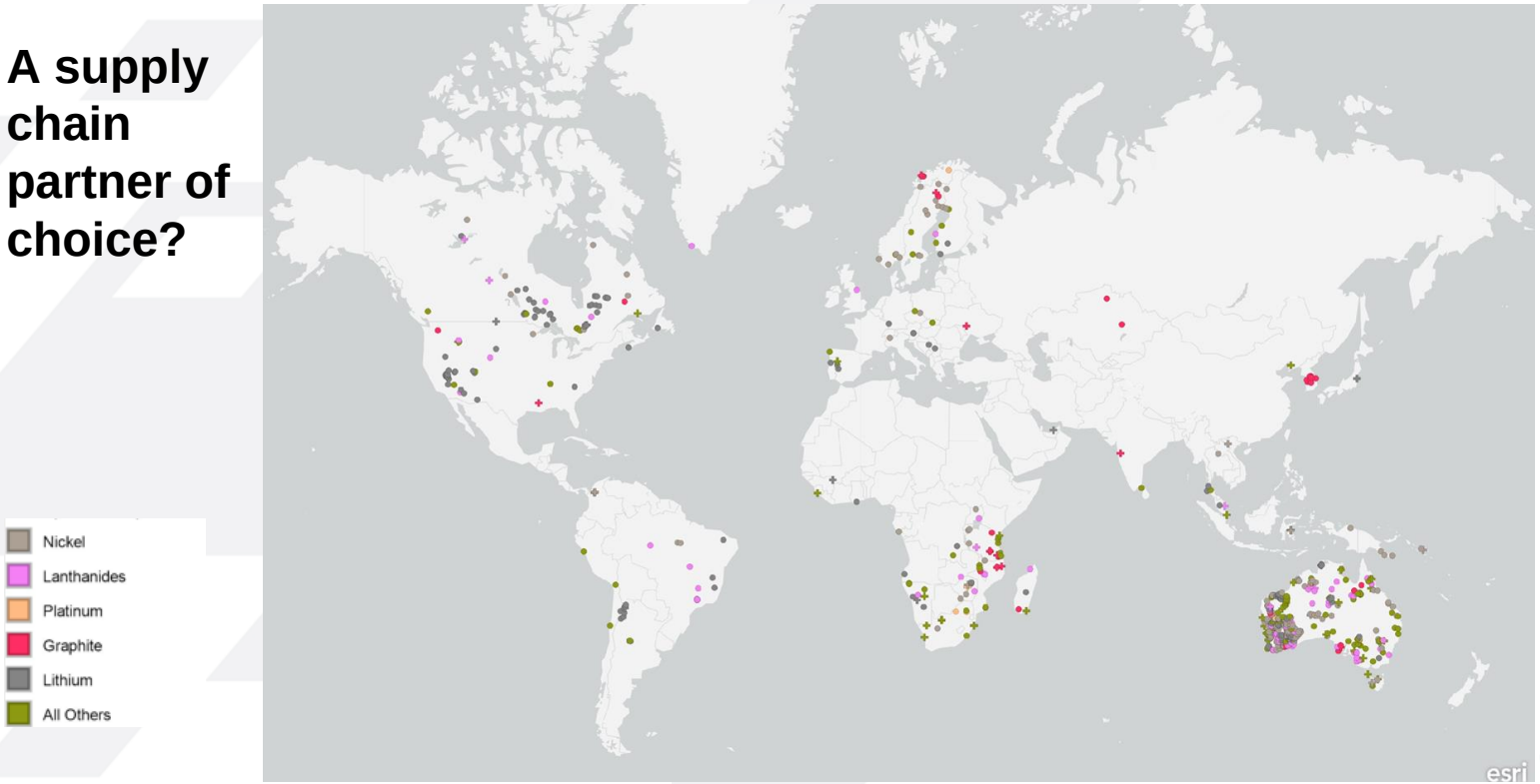
Australia – a supply chain of choice?



Australia's global footprint in critical minerals

A supply chain partner of choice?



Locations of critical minerals exploration and mining properties owned by ASX-listed and Australian HQ companies:

- 597 exploration properties
- 109 mining & processing projects
- US$1,081m exploration 2023
- Reserves US$895b

Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

Critical minerals properties of global companies

Exploration, mining, processing

1151 companies

2137 properties

Exploration budgets $1351m (2022) – 10% of total budgets, but rising fast (battery mineral budgets up 42% in 2023)

Capex $214b

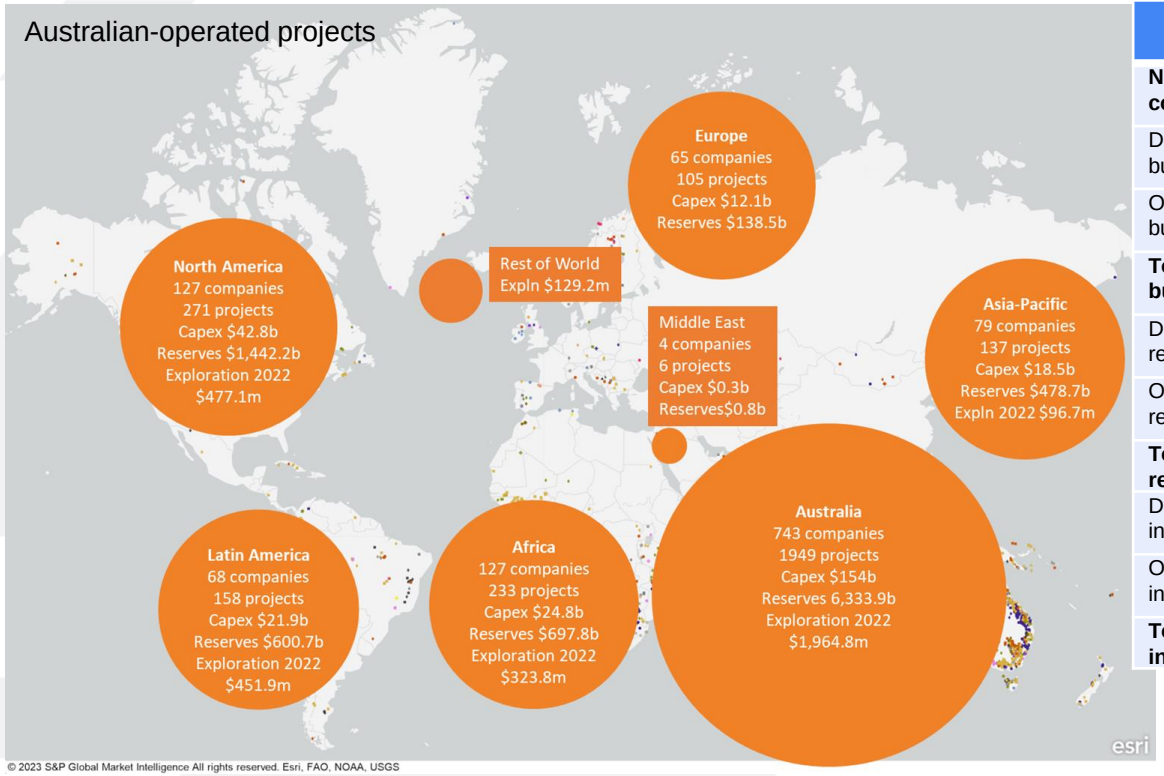
Hotspots

Regional concentrations

Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

Australia is #2 in all minerals globally; Canada #1

Australia's gone global: outbound mining FDI is 53% of total of inbound mining FDI* (ABS)



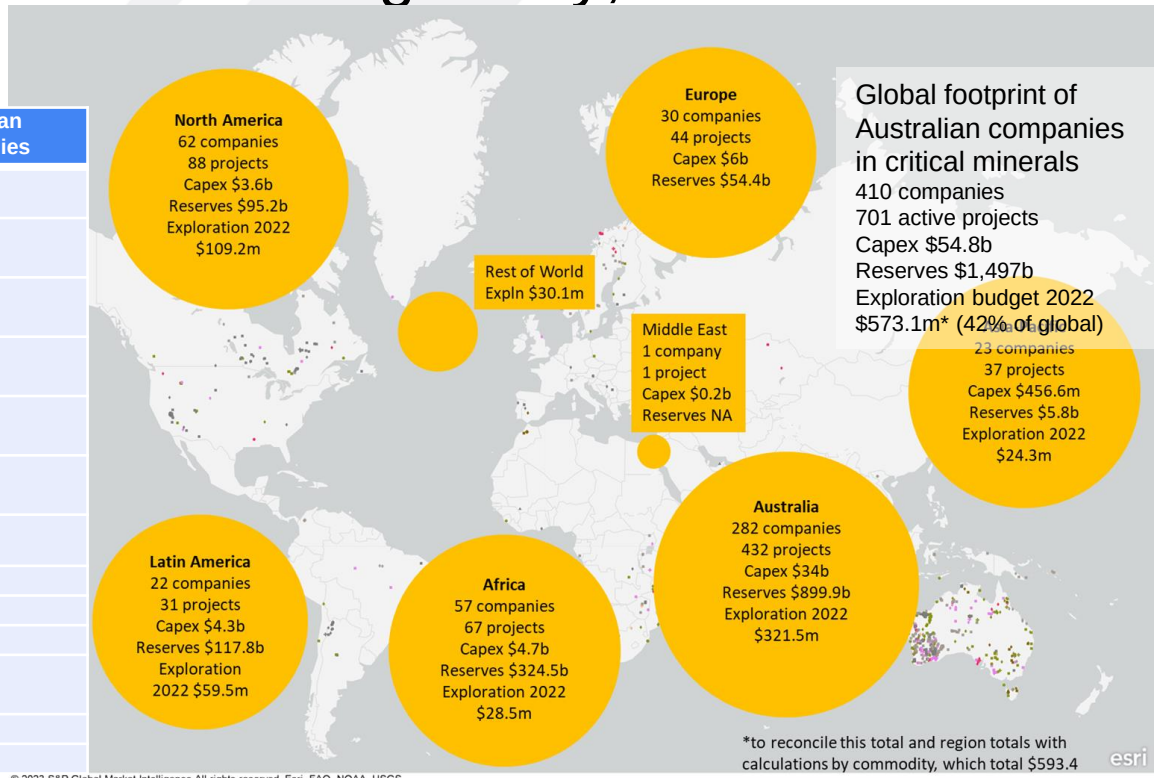
	Canadian companies	Australian companies
Number of minerals companies	**1527**	**1071**
Domestic exploration budgets 2022	$2,196.6m (43% of total)	$1,964.9m (62% of total)
Overseas exploration budgets 2022	$2,913.6m (57% of total)	$1,184.5m (38% of total)
Total exploration budgets 2022	**$5,110.2m**	**$3,443.5m**
Domestic mineral reserves	$3,473b (49%)	$6,713b (67%)
Overseas mineral reserves	$3,620b (51%)	$3,311b (33%)
Total mineral reserves	**$7,093b**	**$10,024b**
Domestic capital investment	$124.6bm (37%)	$156.9b (56%)
Overseas capital investment	$209.7b (63%)	$123.2b (44%)
Total capital investment	**$334.3b**	**$280.1b**

*includes petroleum

Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

Australia is #1 in critical minerals globally; Canada #2

	Canadian companies	Australian companies
Number of companies in critical minerals	**257**	**410**
Domestic critical minerals exploration projects	263	379
Overseas critical minerals exploration projects	101	211
Total critical minerals exploration projects	**364**	**590**
Domestic critical minerals production projects	9	55
Overseas critical minerals production projects	25	56
Total critical minerals production projects	**34**	**111**
Domestic critical mineral reserves	$428b	$884b
Overseas critical mineral reserves	$177b	$598b
Total critical mineral reserves	**$605b**	**$1,497b**
Domestic critical minerals capital investment	$24.1b	$34.2b
Overseas capital investment	$18.3b	$20.6b
Total capital investment	**$42.4b**	**$54.8b**



Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

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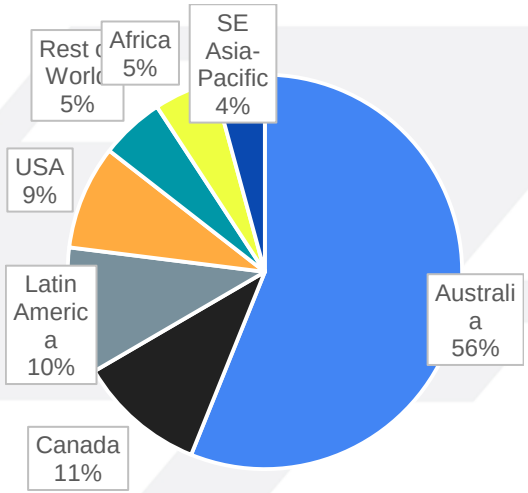
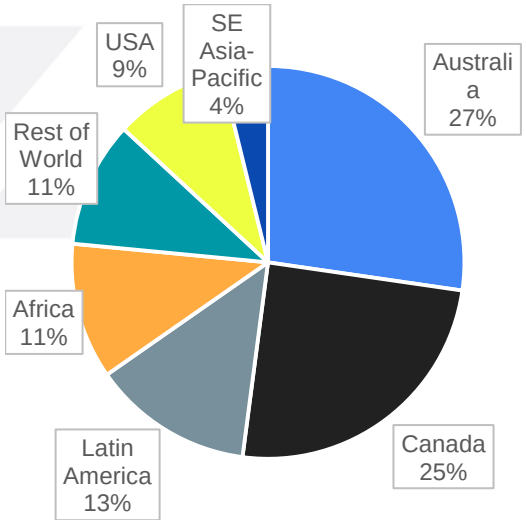
Australia in critical minerals exploration context

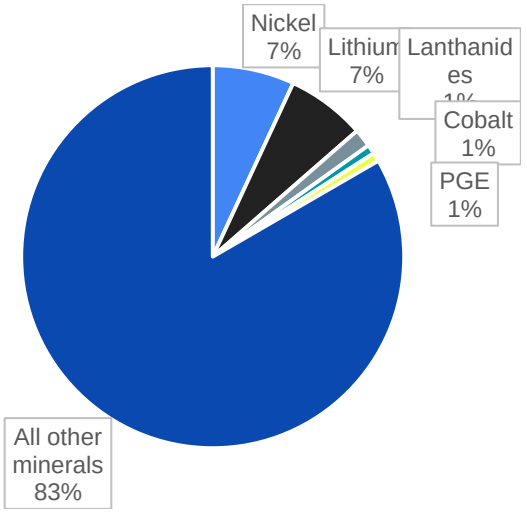
Both the leading global exploration investor *and* destination for investment, but critical minerals still a small proportion of exploration budgets



Critical minerals exploration budgets of Australian companies, by location, 2022



Critical minerals exploration budgets of global companies, by location, 2022

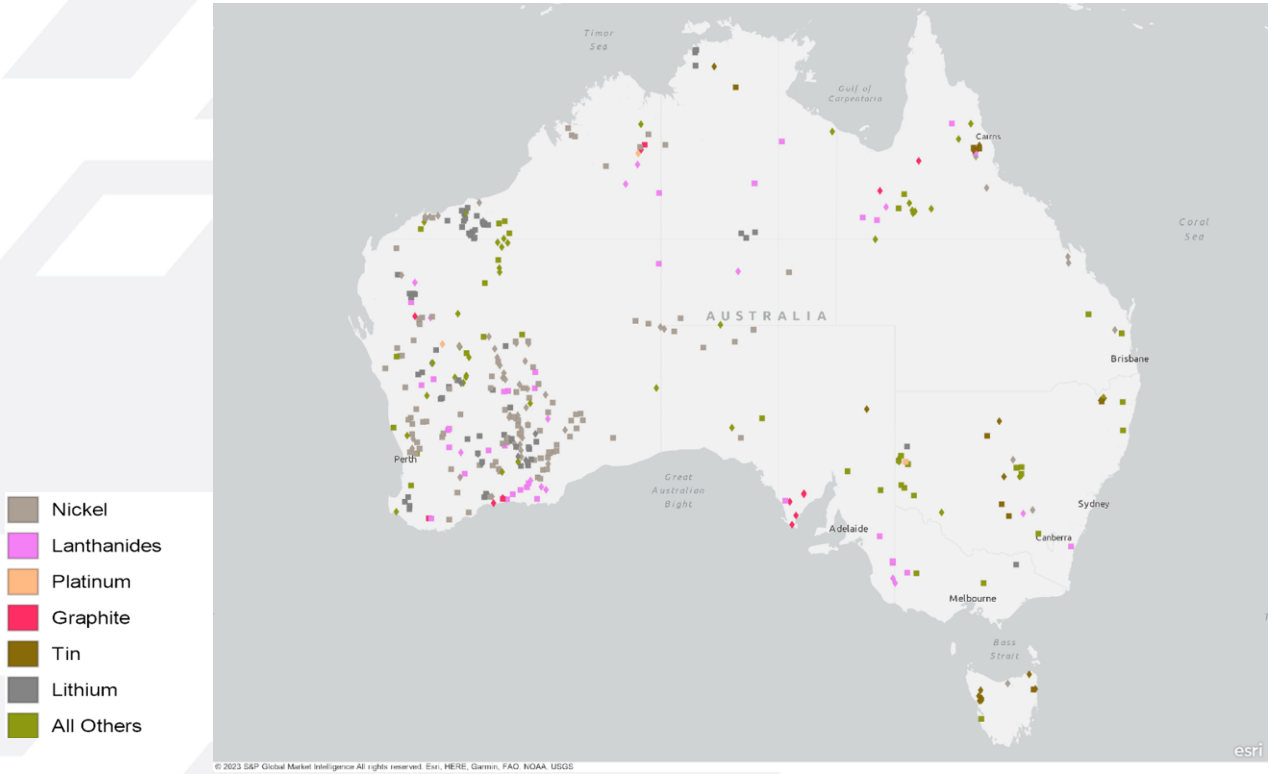


Australian exploration budgets, selected critical minerals vs. other minerals, 2022

Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

Exploration and reserves

Critical minerals exploration properties in Australia, all companies



379 Australian-operated properties

270 Australian companies

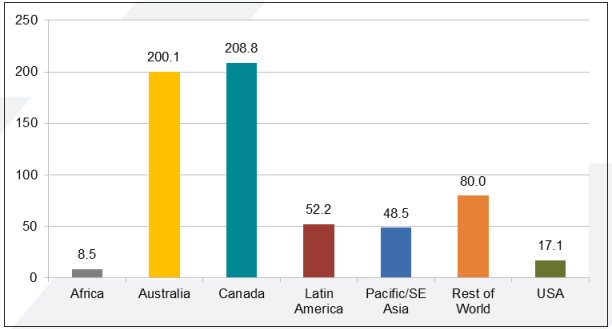
31 foreign-operated properties

8 non-Australian companies

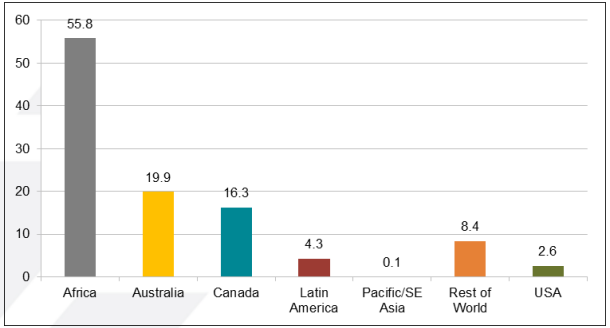
Reserves on exploration properties $1,095 billion

Australia a leading destination for exploration

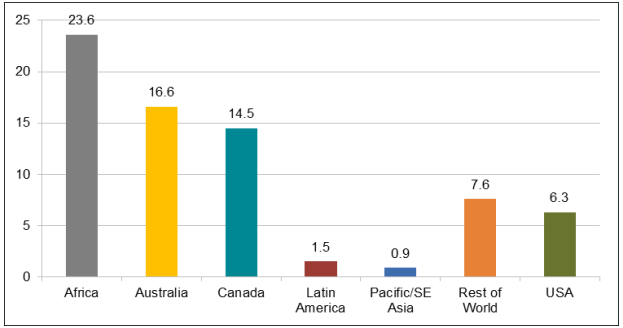
Global exploration budgets, selected critical minerals by region, 2022



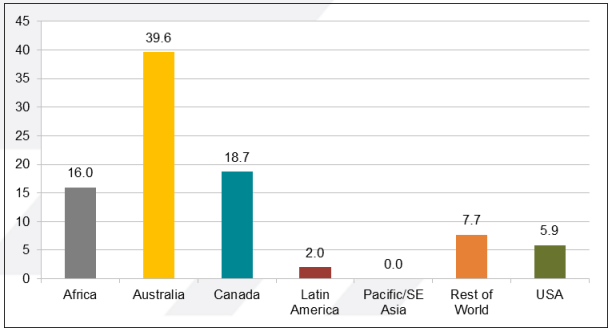
Nickel



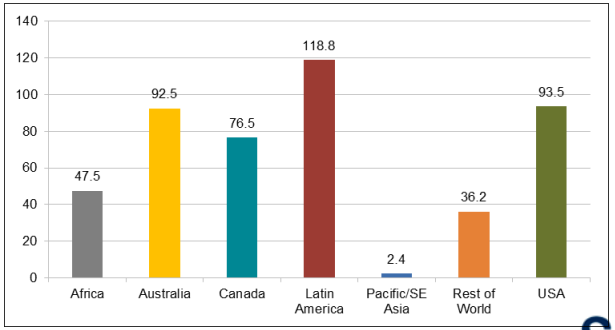
PGE



Cobalt



Lanthanides (REE)



Lithium

Mining equipment, technology and services (METS)

METS firms have a vital critical minerals role in Australia and overseas

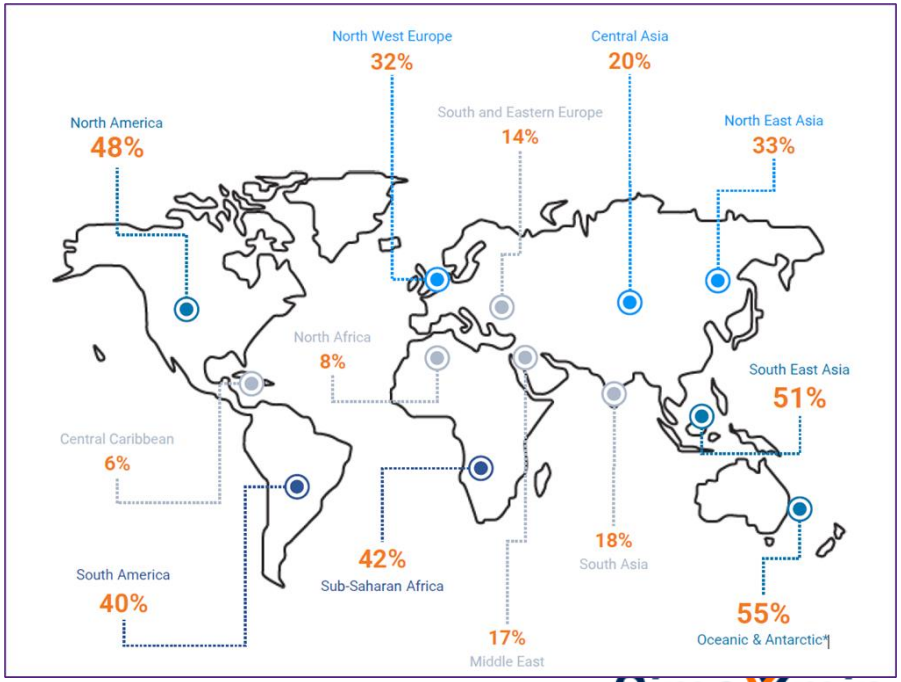
METS typology

- Service providers, including engineering, project management, mining, professional services and logistics
- Manufacturers of goods and equipment
- Information and communications technology, software
- Distributors and service providers for goods made by others
- Universities, training providers, research organisations

Proportion of METS firms operating in critical minerals: 34 per cent in 2015; 47 per cent in 2020

Annual revenues from mining ~ AU$65b incl $17b exports

65 per cent of METS companies export



Percentages of METS firms from Australia that export, by region

Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

Success factors in critical minerals

Why Australian minerals and METS firms are successful globally

- World-leading knowledge and technology from 60+ years of modern mining in Australia
- Sophisticated exploration approaches developed in rich geological and policy environment
- Able to operate worldwide in frontier environments and complex orebodies
- Leveraging mineral industry clusters (technical, ESG, financial, legal) and company ecosystem (juniors to majors)
- METS follow, support and leverage explorers and miners

Investment in Australia

Global success of Australian companies underlines domestic competitiveness imperative

BHP's "key pillars" (November 2023):

1. Stable and globally competitive policy, regulatory and fiscal settings
2. Robust, transparent and streamlined permitting
3. Best-in-class enabling infrastructure
4. A world-class METS sector and workforce of the future

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Australian government strategies

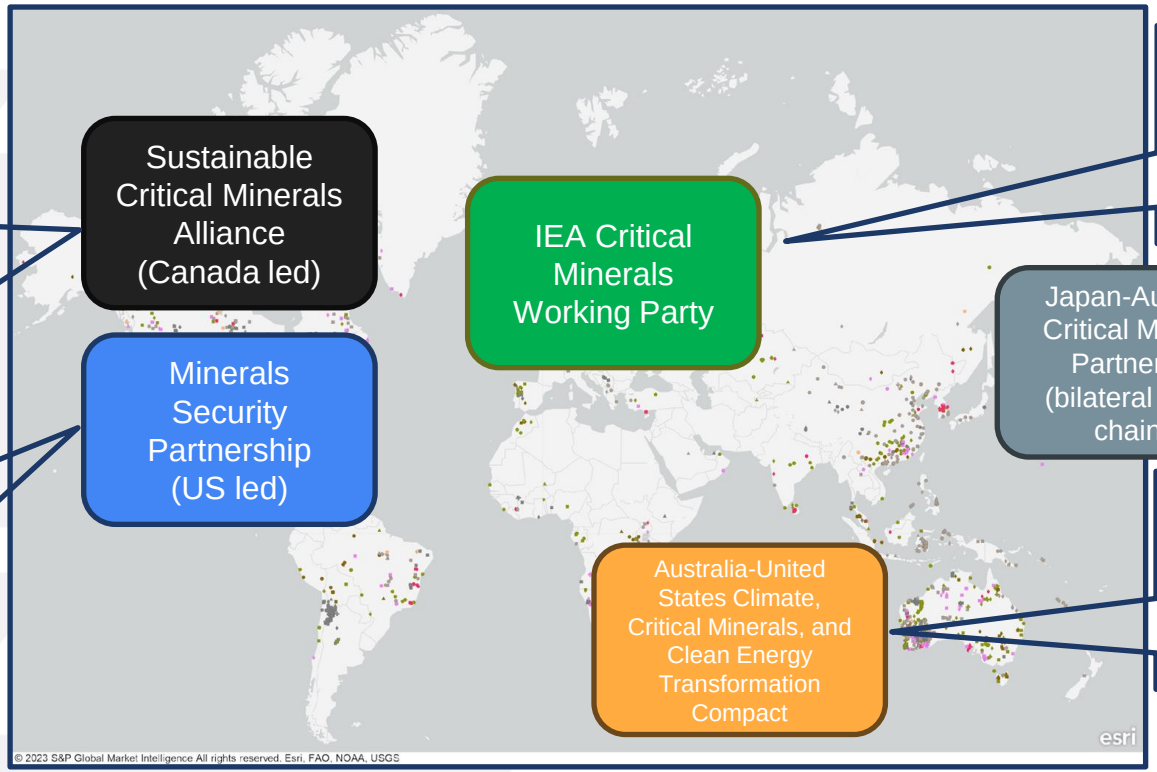
- Critical minerals and metals

Key critical mineral agreements

How Australia has agreed to work with others to build secure and sustainable supply chains across all continents

"…to drive the global uptake of environmentally sustainable and socially inclusive and responsible mining, processing and recycling practices and responsible critical minerals supply chains."

"…strive to elevate ESG standards across the global minerals sector both within and beyond MSP partners' borders."



"…accelerate progress towards diversified and sustainable supplies of critical minerals." (Australia's dominance in some minerals a supply risk)

"…promote investment in strategic critical minerals projects across four continents involving Australian and U.S. companies."

Australia's global footprint in critical minerals, Ian Satchwell, Dec 2023

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Federal Government

The Government wants Australia to grow the geostrategic and economic benefits of its critical minerals sector, become a globally significant producer of raw and processed critical minerals, and support diverse, resilient and sustainable supply chains.

The 'Critical Minerals Strategy: 2023 – 2030' outlines how it will achieve this. Its objectives are to:

- create diverse, resilient and sustainable supply chains through strong and secure international partnerships
- build sovereign capability in critical minerals processing
- use our critical minerals to help Australia become a renewable energy superpower
- extract more value from our resources onshore, which creates jobs and economic opportunities, including for regional and First Nations communities.

The Strategy sets out priorities across 6 focus areas:

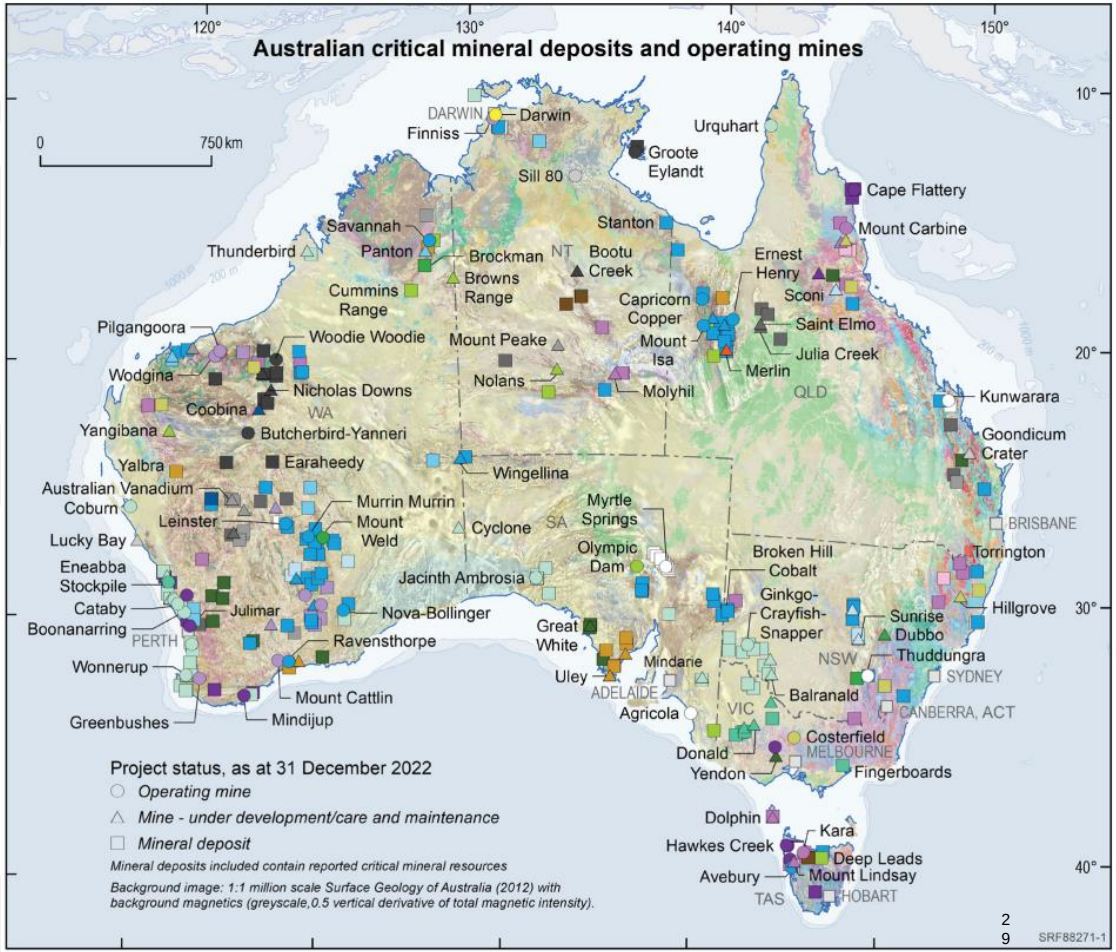
1. Developing strategically important projects
2. Attracting investment and building international partnerships
3. First Nations engagement and benefit sharing
4. Promoting Australia as a world leader in ESG performance
5. Unlocking investment in enabling infrastructure and services
6. Growing a skilled workforce

Focus Areas	What does success look like?
Developing strategically important projects	Targeted, proportionate support from the Australian Government to de-risk strategically important critical minerals projects, attract private finance and ensure Australian processing and manufacturing projects can access Australian minerals. Alignment between States, Territories and Australian Government on developing strategically important projects.
Attracting investment and building international partnerships	Increased investment from, and collaboration with, likeminded partners to grow Australia's downstream processing capability and build diverse, resilient and sustainable global supply chains.
First Nations engagement and benefit sharing	Genuine engagement and collaboration with First Nations communities that promotes benefit sharing and respects the land and water rights and interests of First Nations people and communities.
Promoting Australia as a world leader in ESG performance	Regulatory and policy frameworks that: • enable fast, efficient and durable environmental approvals while upholding robust environmental protections • embed strong ESG practices that enable access to global markets • support the sector's enduring social license to operate • fairly share the benefits of critical minerals development with communities, including First Nations Australians.
Unlocking investment in enabling infrastructure and services	Working with states and territories, strategically planned enabling infrastructure and services help develop industrial hubs and link the critical minerals sector to global markets. This reduces costs, lowers project risk and attracts large-scale investment.
Growing a skilled workforce	A skilled, diverse and growing workforce that enables the desired development of Australia's critical minerals sector, particularly as we move into downstream processing.

Federal Government Strategy – Critical Minerals

"Australia is well-endowed with critical mineral deposits"

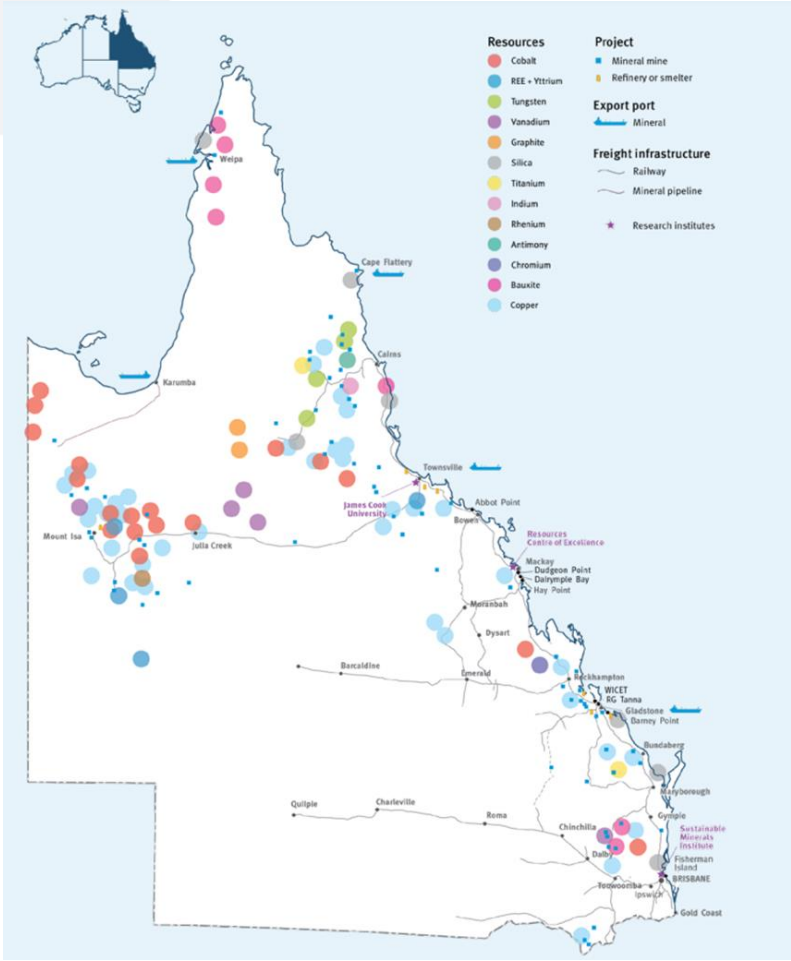
However, we do still need to discover, develop and extract these deposits!



State example - Queensland State Government

“I want Queensland to be a global leader, supplier and manufacturer of critical minerals and this strategy will help us achieve that.”

- **Queensland Premier Annastacia Palaszczuk – June 2023**



Queensland Critical Minerals Strategy

Move faster, smarter

Accelerate the pace of development

- ✔ Critical Mineral zones Funding: **$75 million**
- ✔ Explore remaining mineralisation in mine waste Funding: **$5 million**
- ✔ Facilitate secondary prospectivity for critical minerals

Maximise investment

Enhance investor confidence

- ✔ Rent reduction for exploration **$55 million**
- ✔ Profile and promote Queensland Funding: **$1 million**

Build value chains

Diversify the economy and enhance export potential

- ✔ Deliver the Critical Minerals and Battery Technology Fund Funding: **$100 million**

Foster research and ESG excellence

Support industry to meet the expectations of global markets and governments

- ✔ Partner with industry to build ESG excellence Funding: **$1 million**
- ✔ Research and development in circular economy and mining Funding: **$8 million**

All actions underpinned by the establishment of **Critical Minerals Queensland**, a centralised point for industry, investors and community to bring dedicated focus to grow the sector.

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Federal and State level strategic minerals policies

- Typically aimed at down-stream processing value add opportunities
- Don’t necessarily address the front-end requirements of:
  - Understanding - research
  - Discovery - exploration
  - Assessment - studies
  - Development – approval & construction
  - Processing – extraction
  - Permitting (timelines)
  - Skill – future workforce

While not fully addressed in the Critical Mineral Strategies, these topics are addressed
at the level of Geological Surveys, Geoscience Australia, Universities, Research Institutes and Industry

Example of what Universities/ Research Institutes are doing to support Critical Minerals and Metals supply challenges

- Examples from The Sustainable Minerals Institute (SMI), The University of Queensland

Unlocking “Complex Orebodies” projects

- Queensland New Economy Minerals Compilation (Atlas)
- Supergene enrichment of REE in phosphorite
- Massive geodata visualisation for New Economy Minerals
- Assessing recommercialisation potential at abandoned mines
- Exploration of new economy metals in Queensland’s mine waste
- The Social and Environmental Complexities of Extracting Energy Transition Metals

Projects covering discovery, upstream processing, downstream processing, recovery from mine waste, and social and environmental aspects

Funding - $4.1 million seed (2020-2024), +$15 million from collaboration

Collaborative arrangements with 15 external organisations

Resourcing Decarbonisation

A new SMI Strategic Program that will address the crucial supply, policy and business readiness risks arising from the unprecedented quantities of mineral resources required for renewable energy technologies.

The Program aims to:

- unlock responsible energy transition mineral supply in a manner that respects ecosystems
- reduces energy intensity
- deliver against the non-financial values implicit in rising expectations of performance in environmental, social and government (ESG) issues.

Issues at a glance

1. Energy minerals: complexities of supply and risk

2. Mitigating the carbon intensity of resource production

3. Market incentives and business readiness

4. Policy protections and social safeguards

5. Risk interactions and complex system behaviour

Secured stakeholders & Collaborators

Geoscience Australia

Department of Resources, Queensland

Geological Survey Queensland

QUEX, Camborne School of Mines, UQ School of Business & Economics

Volkswagon

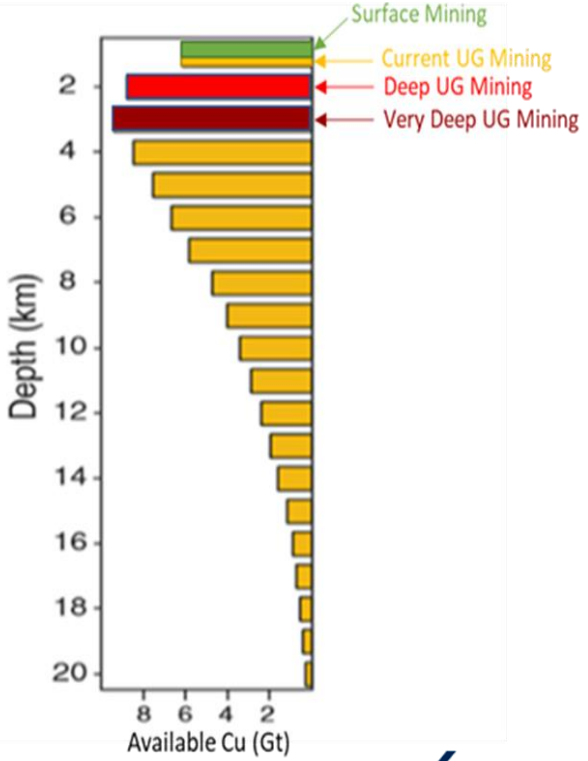
Short Term (2023)	Medium Term (2024 – 2026)	Long term (2026 – 2033)
• Commence co funded research projects • Consult on business models for scale up	• Grow scale of initiatives • Establish consortium model for global resource security hub	• Enable responsible and efficient secure access to the resources needed for the energy transition • Establish $>5 million/a partnership

The opportunity for Underground Mining

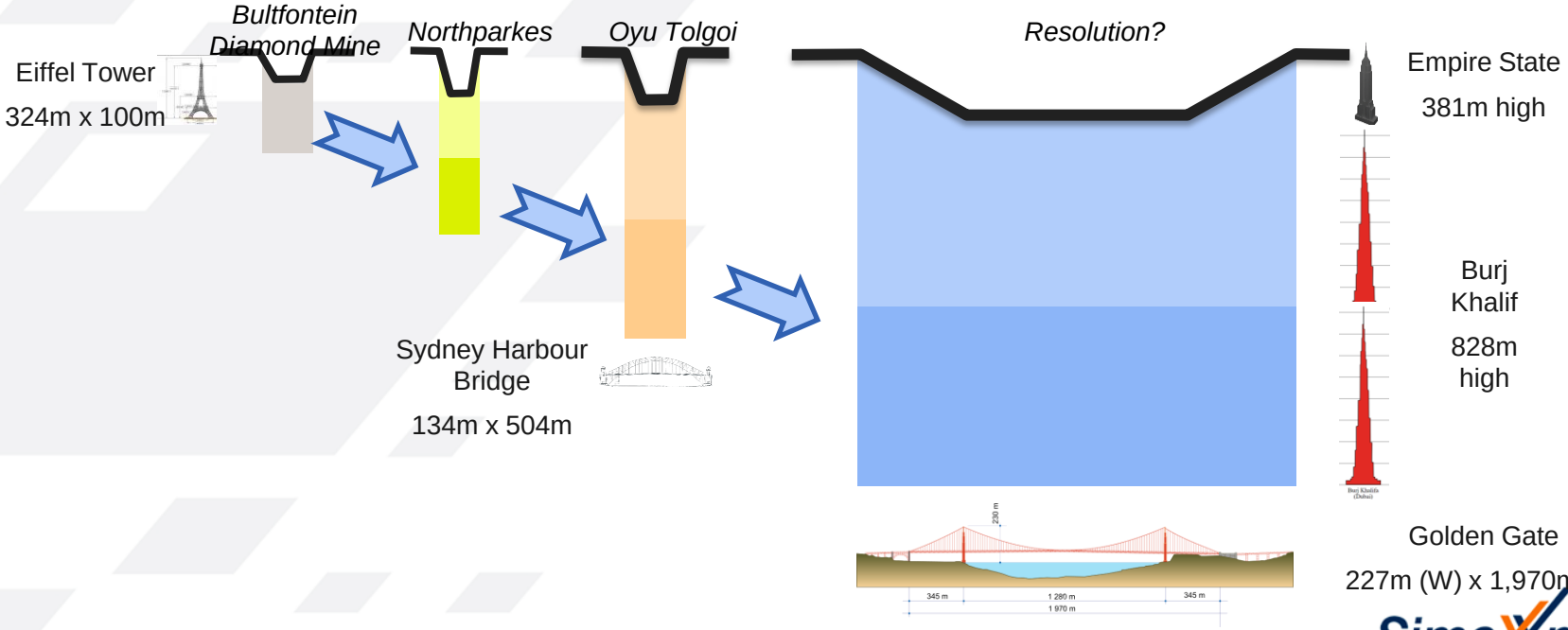
Replace / supplement Copper from Open Pit with massive Underground Mining

- Near surface deposits are becoming exhausted and new discoveries are deeper
- Deep and very deep underground deposits have potential to provide significant copper supply,
- And with lower mining footprints and waste

However, these mines require a scale and depth not achieved before and require substantial research to resolve their challenges to meet their potential



These new underground mines require a scale and depth not achieved before and require substantial research to resolve their challenges to meet their potential



Here we show the evolution of Cave-Scale Underground Mining

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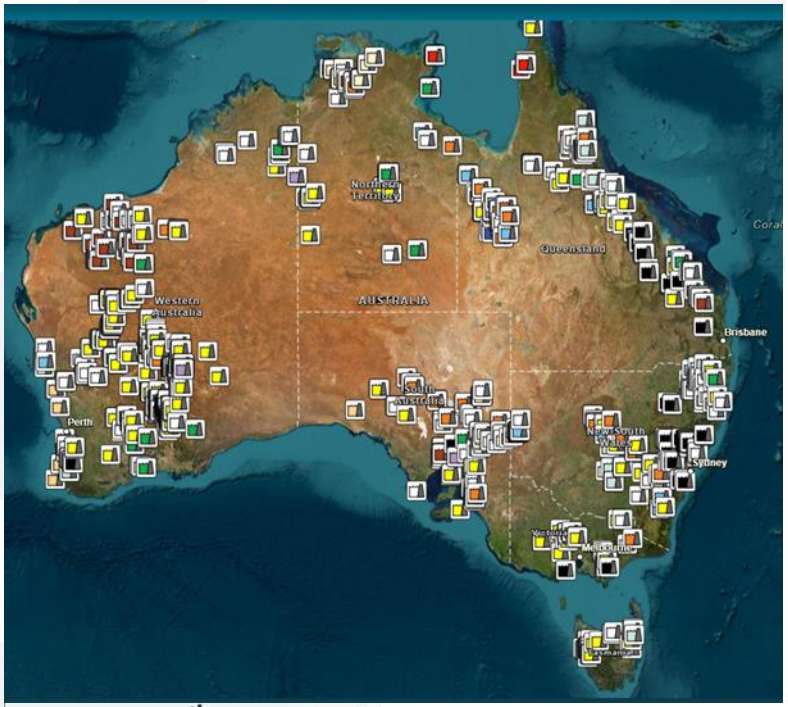
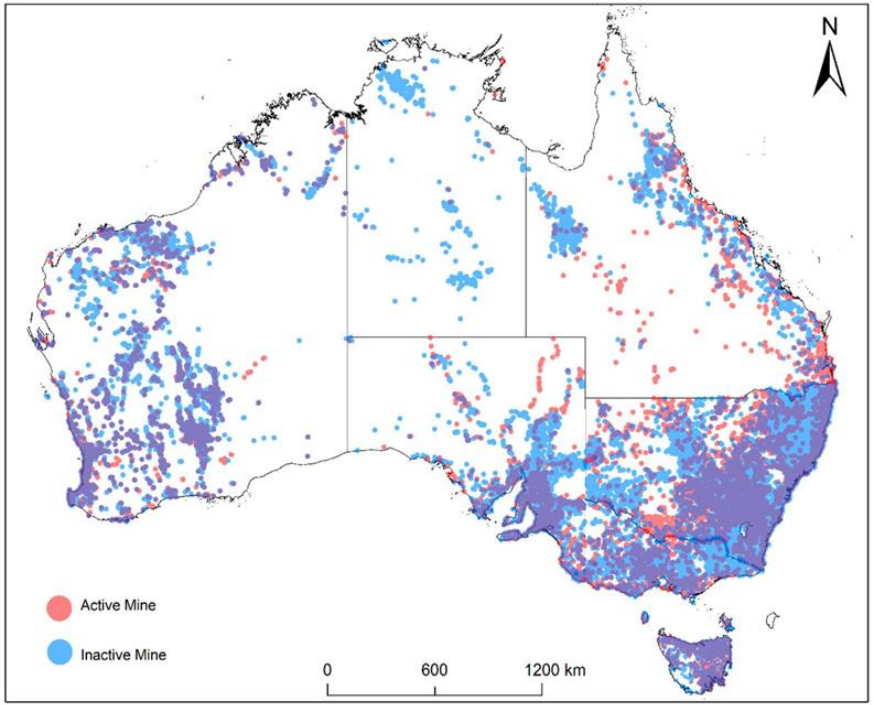
Circular economy and mine waste: ~ *50,000 sites*

Atlas of Australian Mine Waste



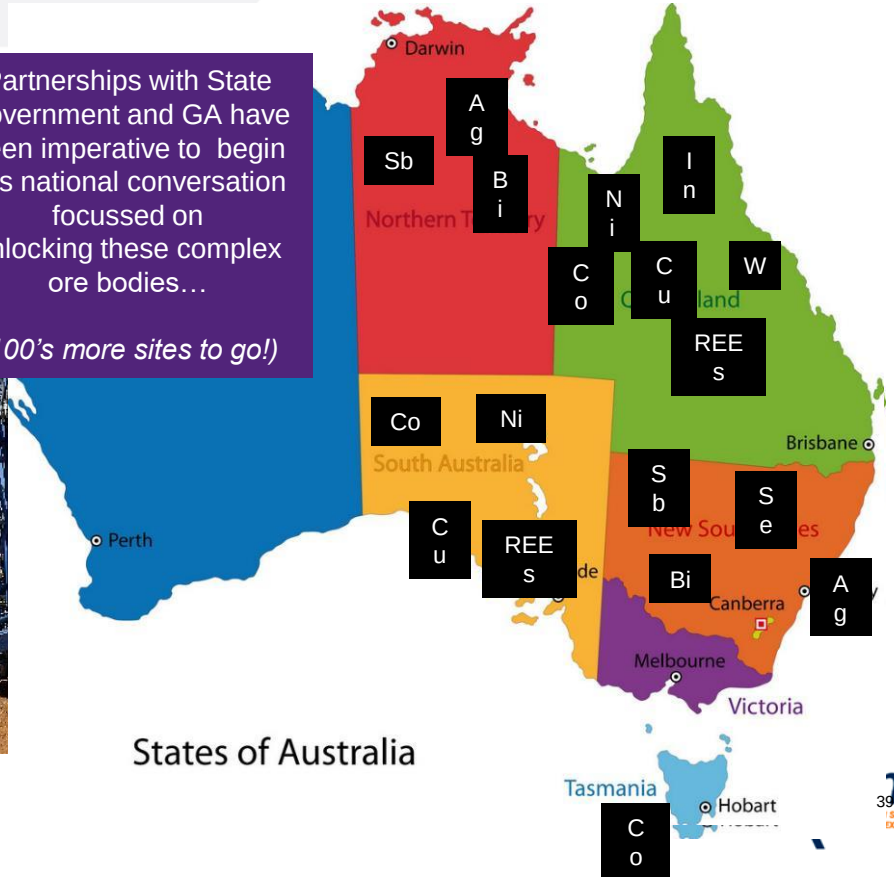


National sampling program - Mine waste atlas

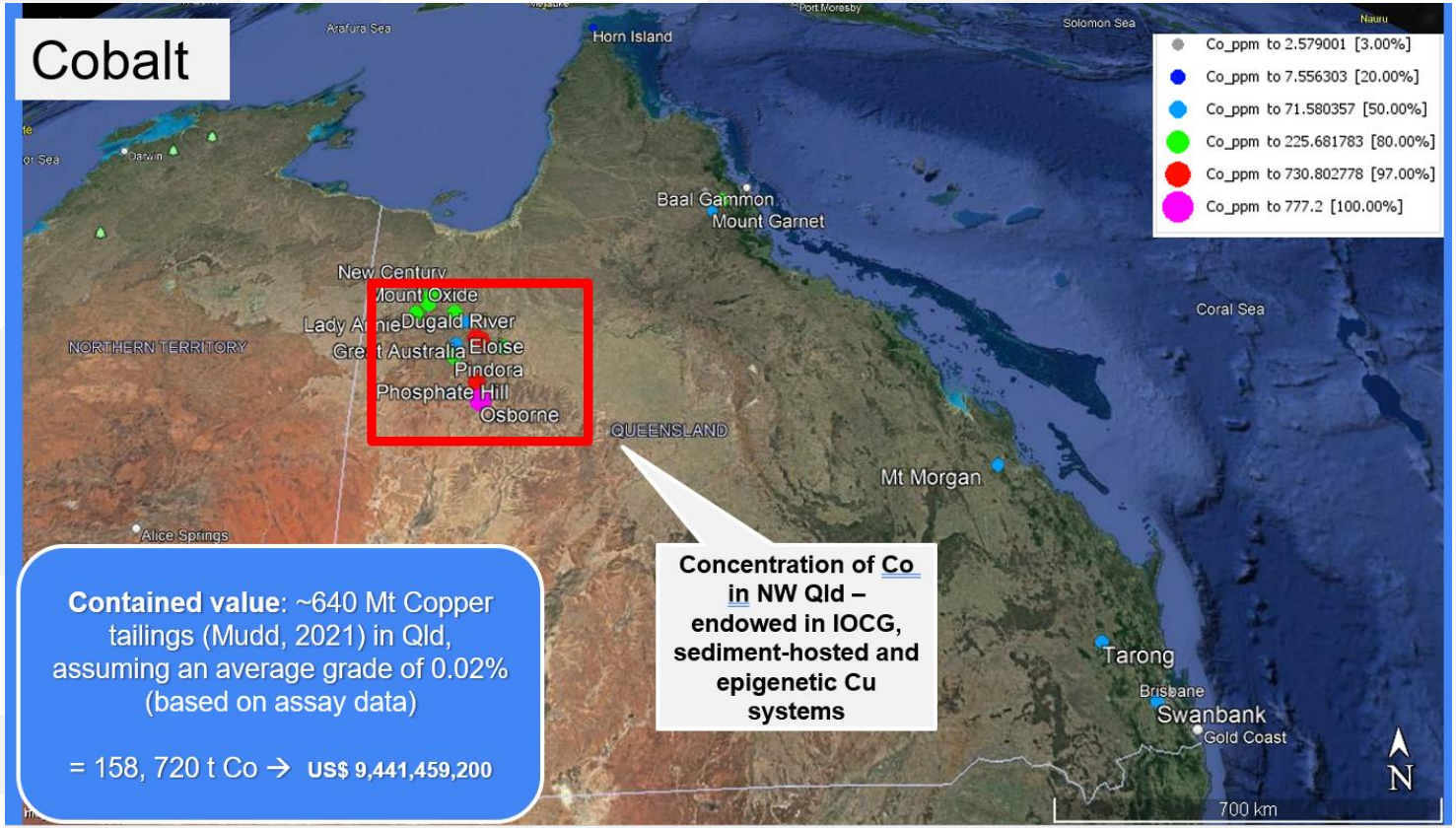
MIWATCH, SMI-BRC, University of Queensland

Partnerships with State Government and GA have been imperative to begin this national conversation focussed on unlocking these complex ore bodies…

(100's more sites to go!)



Example - Cobalt potential in secondary (mine waste)



Next steps - technologies for critical metal recovery

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Mineral Processing

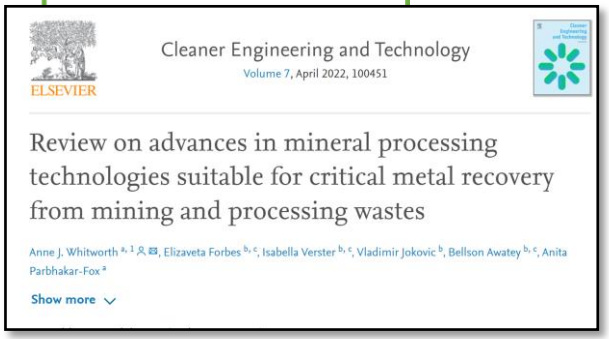
- Early gangue rejection ★
- Stirred milling
- Semi-inverted cyclones ★
- Hybrid classification
- Fluidized bed flotation
- Reactor-separator induced air flotation
- Flotation flocculants ★
- Counter flow fluidized bed separators

Metal Extraction

- Bioleaching ★
- Phytoextraction ★
- Atmospheric leaching ★
- High pressure acid leaching
- Pyrometallurgy ★
- Solvometallurgy

Metal Recovery

- Biometallurgy
- Supported (ionic) liquid membranes
- Thin-film composite anisotropic membranes
- Supported ionic liquid phases
- Synergistic solvent extraction



ELSEVIER

Cleaner Engineering and Technology

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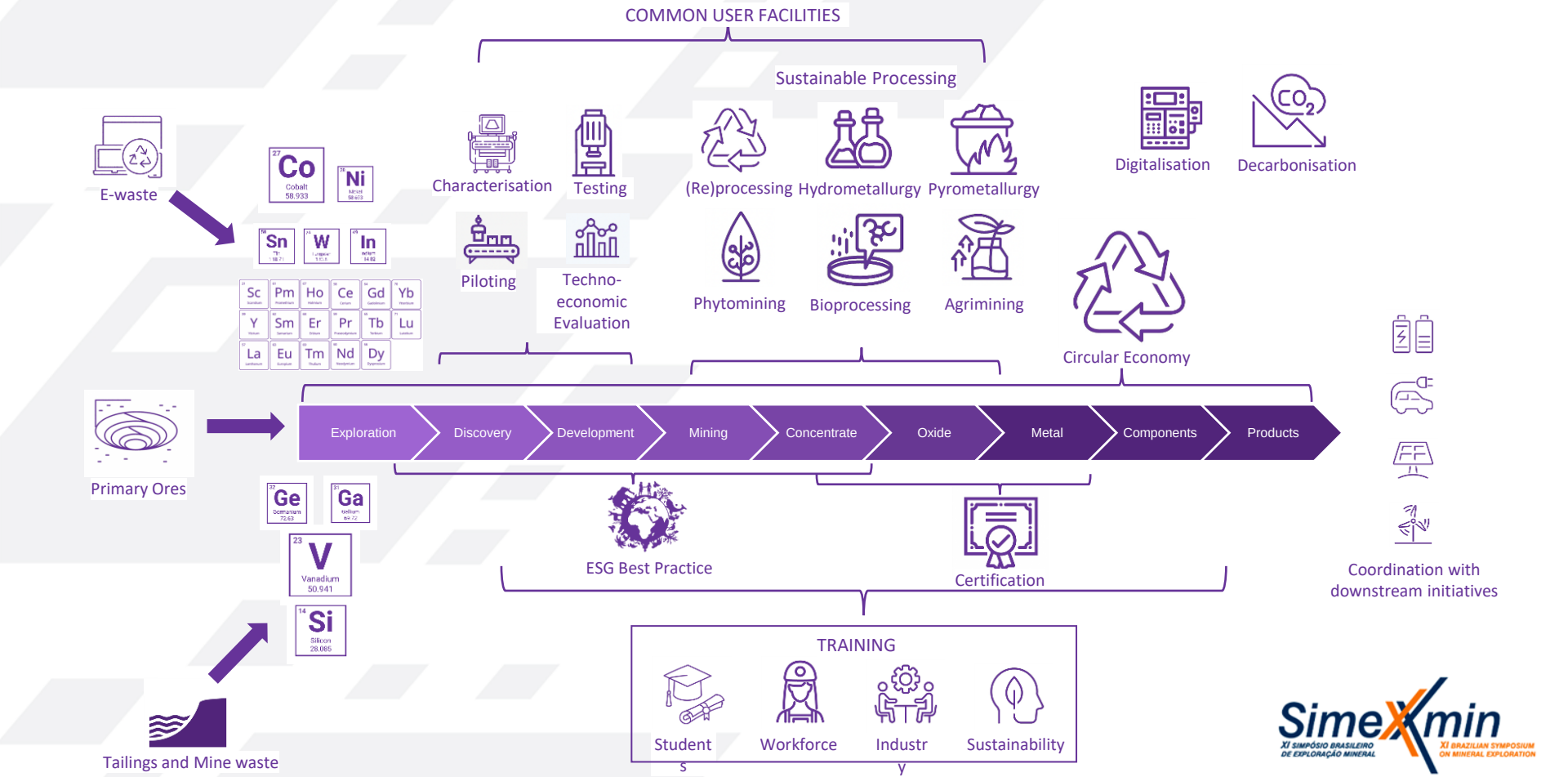
Review on advances in mineral processing technologies suitable for critical metal recovery from mining and processing wastes

Anne J. Whitworth [a, 1], Elizaveta Forbes [b, c], Isabella Verster [b, c], Vladimir Jokovic [b], Bellson Awatey [b, c], Anita Parbhakar-Fox [a]

Show more

A model for an integrated solution…



Conclusion – Meeting the demand for Critical Metals and REE to feed the Energy Transition

- Are we ready?
- Are we capable?
- Can we do it?
- What do we need?

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XI SIMPÓSIO BRASILEIRO DE EXPLORAÇÃO MINERAL
XI BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

The challenges with Resourcing Decarbonisation

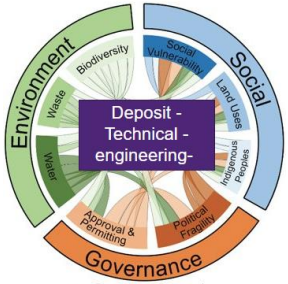
Our #1 priority – The timely sourcing of the supply of critical minerals and metals

1. Understanding - research
2. Discovery – exploration (permitting)
3. Assessment - studies
4. Development – approval (permitting) & construction
5. Processing – extraction
6. Downstream – refining
7. Skills – future workforce

Our ‘second #1’ priority - Achieving the above #1’s responsibly (ESG)

How do we:
1. Discover and
2. Develop
3. Permit (approval for)
4. Skill

For the quantum of critical metals projects in the timeframe needed?



+ Government

Resourcing the Energy Transition

Requires that ‘the solutions' are tackled **collaboratively** and

the new **'burning platform**’ is for countries, companies, research and finance to work together on discovery and development!

Learn lessons from each country and share
– the time to collaborate is NOW!

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Obrigado!

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