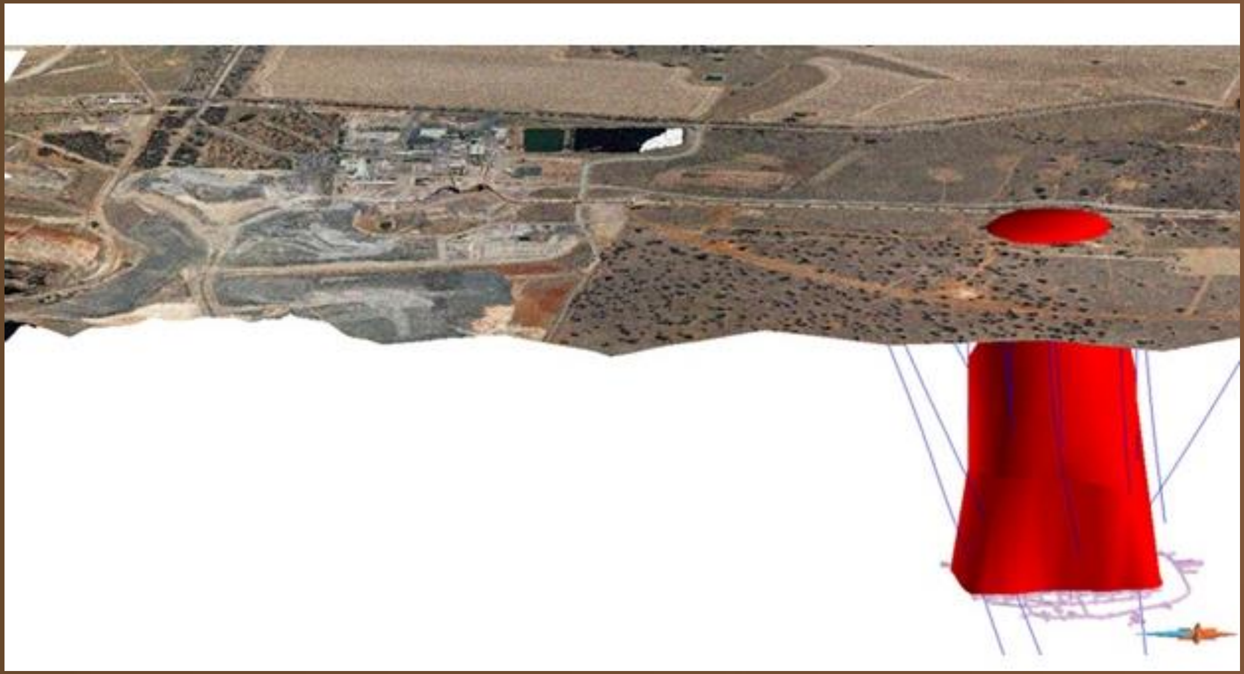
Deep Mining Queensland (1)

SMI BRC
WH Bryan Mining & Geology Research Centre

New Initiatives in Exploration (18th February, 2015)

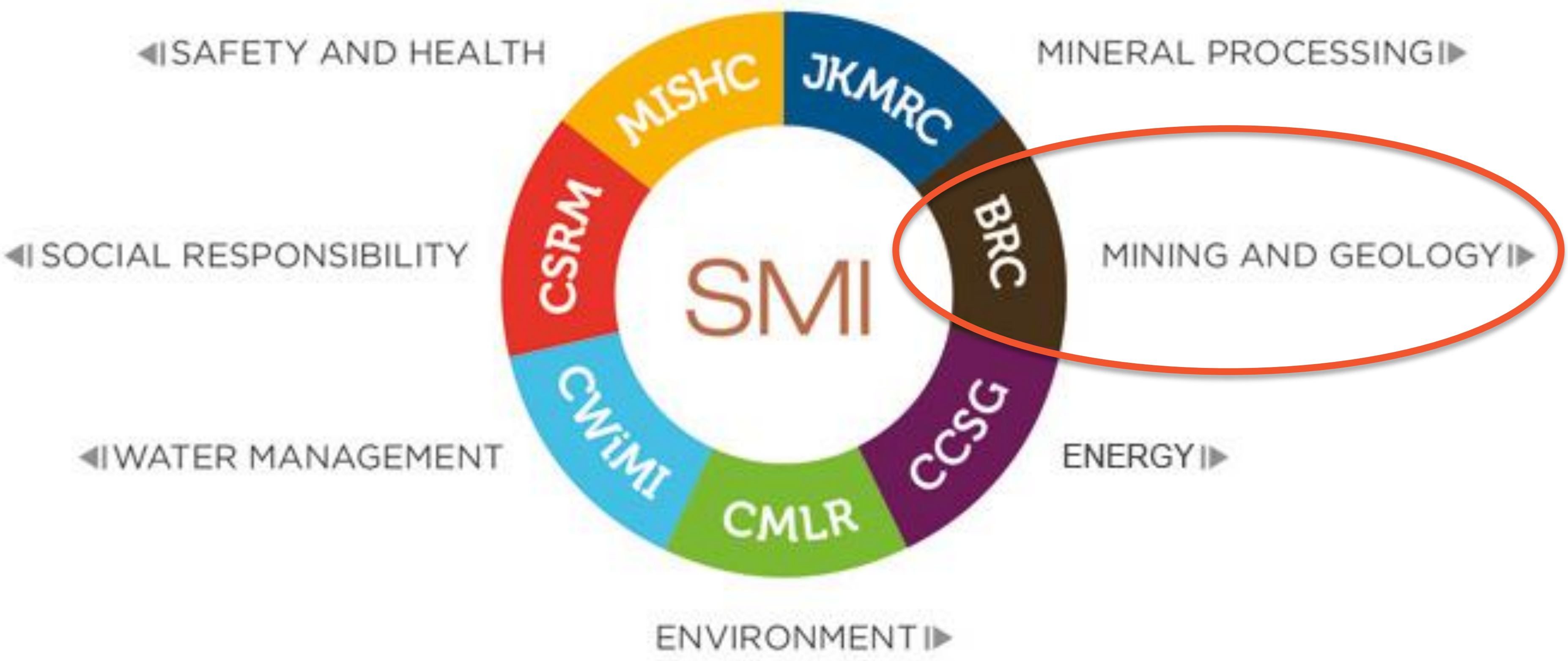
Dr Travis Murphy

(M. Scott, D. Wood, & T. Webster)



THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

UQ - Sustainable Minerals Institute



WH Bryan Mining and Geology Research Centre

BRC

Transforming Mining.

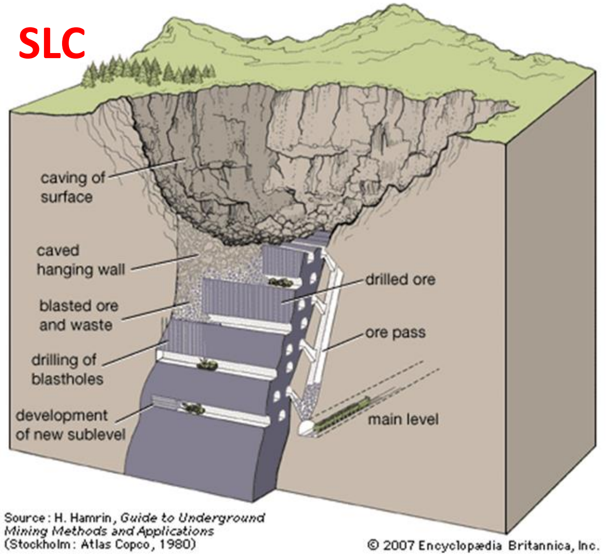
Program 1	Program 2	Program 3
Applied Geology	**Deep Mass Mining**	**Orebody Decision Science**
Resource Stewardship	Higher Capacity Mining	Variability & Uncertainty
'Using Deposit Knowledge'	*'Step change mine practices'*	*'Capturing & Communicating Value and Risk'*

QEC – Queensland Exploration Scorecard (2014)

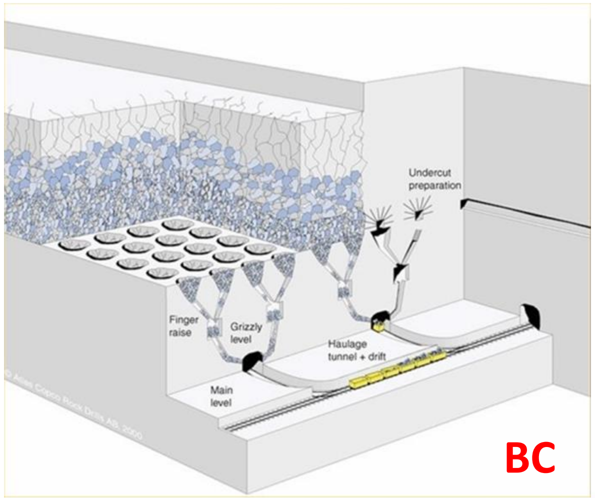
LAG INDICATORS – EXPLORATION SUCCESS	2011	2012	2013	2014
	Year to June...			
Minerals exploration (Section 6) • In 2014, Queensland recorded a 35% decrease in minerals exploration ($732 million to $475 million). Western Australia also recorded a 35% decrease ($1,774 million to $1,152 million) • Queensland's Greenfields performance as a percentage of total minerals exploration expenditure improved to 36%. • Queensland spent 1.6% of its minerals revenues (sales) on exploration, a decrease from 2.3% in 2012-13. The Northern Territory spent the most in 2014 with 4% of its sales revenues reinvested in exploration.				
Petroleum exploration (Section 6) • Petroleum exploration expenditure in Queensland in 20114 was $655 million, the second highest year on record. While it declined 6.4% to $613 million, it compares with a 7.7% decrease recorded in Western Australia (down from $3,294 million to $3,038 million)				
Levels of reserves (Section 7) • Reserve/production levels for **copper, gold, lead, silver, and zinc** remain low.				
• Based on known resources and current depletion rates, Queensland's **coking coal** reserves will last 96 years.				
• Queensland reserves of **coal seam gas** continued to increase to 41,598 PJ in 2013 providing a current reserve/ production level for Queensland of 140 years. This figure is likely to decrease when LNG operations commence.				

Good	
No significant impediment	
Cause for concern	
Significant problems	

Future of metalliferous extraction in QLD

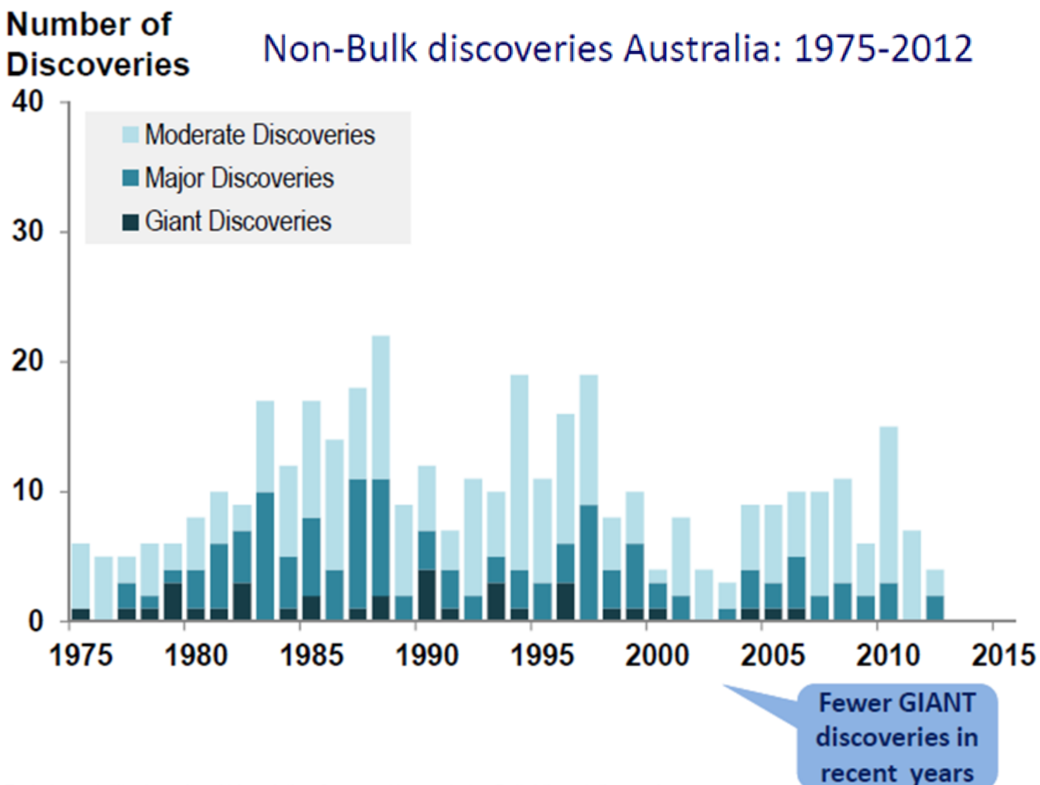


1. Need to look deep
2. Deep needs to be big
3. Big needs to be mass-mined (i.e. Sub-level Cave or Block Cave) if low grade.



Why Deep?

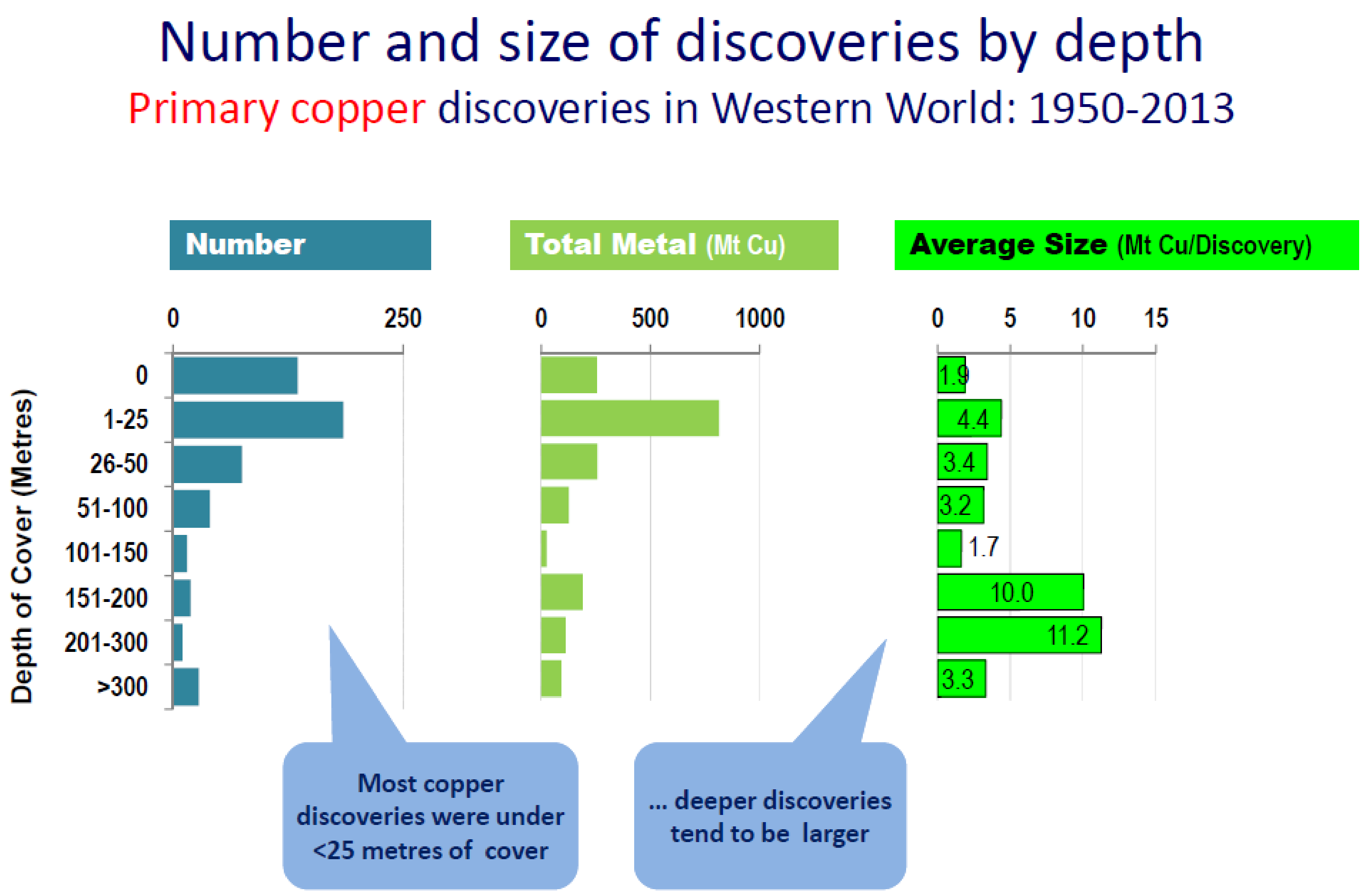
- Declining discovery rate, largely recognised that the potential for shallower discoveries has diminished and deeper exploration (and under-cover) is required.



Note: Excludes satellite deposits within existing Camps. Also excludes Bulk Mineral discoveries..
Analysis based on Moderate-, Major- and Giant-sized deposits

Source: MinEx Consulting © November 2013

Copper discoveries: deeper = larger



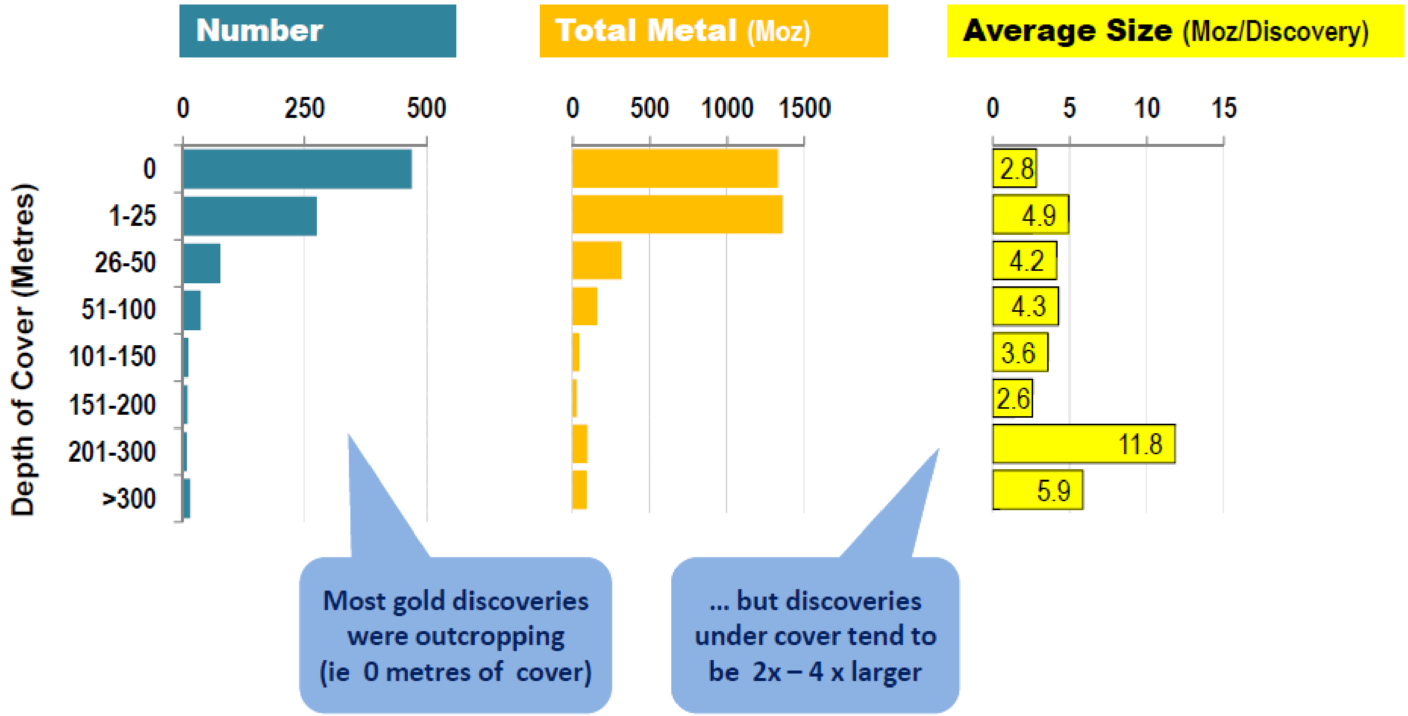
Note: Analysis based on detailed analysis of 507 primary copper discoveries > 0.1 Mt Cu
Excludes satellite discoveries in existing camps. Excludes undersea deposits

Source: MinEx Consulting © March 2014

Gold discoveries: deeper = larger

Number and size of discoveries by depth

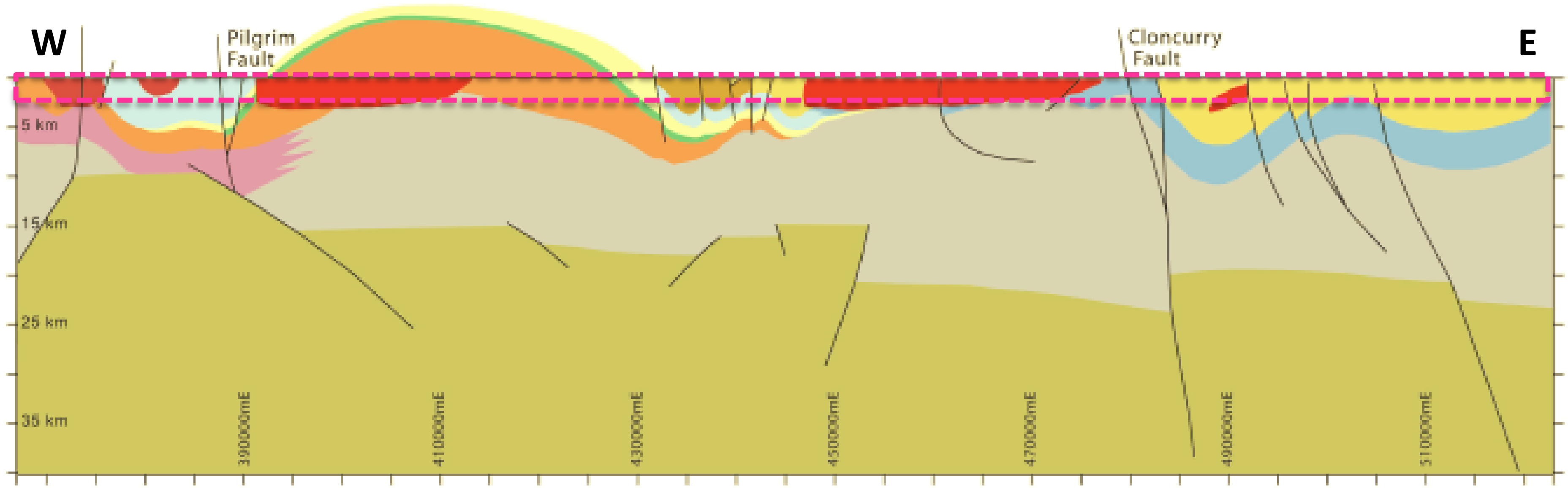
Primary gold discoveries in Western World: 1950-2013



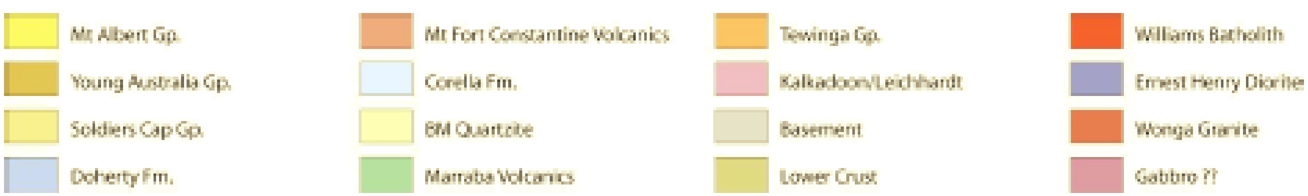
Note: Analysis based on detailed analysis of 902 primary gold discoveries > 0.1 Moz
Excludes satellite discoveries in existing camps. Excludes South Africa

Source: MinEx Consulting © March 2014

Not too deep though!



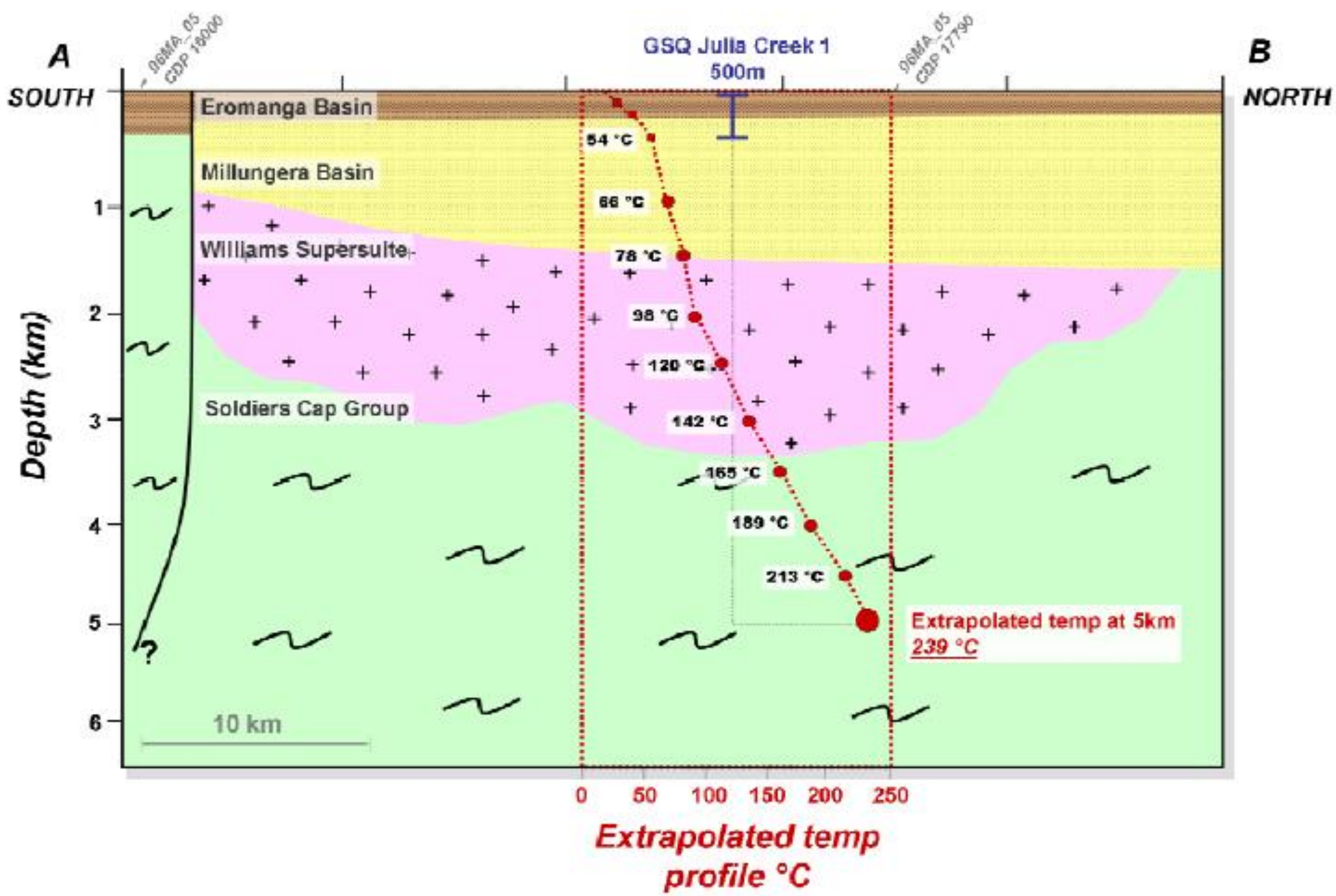
[*pmd**CRC* – 2005]



Interpretative cross-section of the Eastern Mt Isa Inlier

- Underground mass-mining is limited to approximately 2km depth. Until future technical advances unlock the potential of the >2km depth crust, exploration below this is misdirected.

Geothermal gradient – potential depth constraint

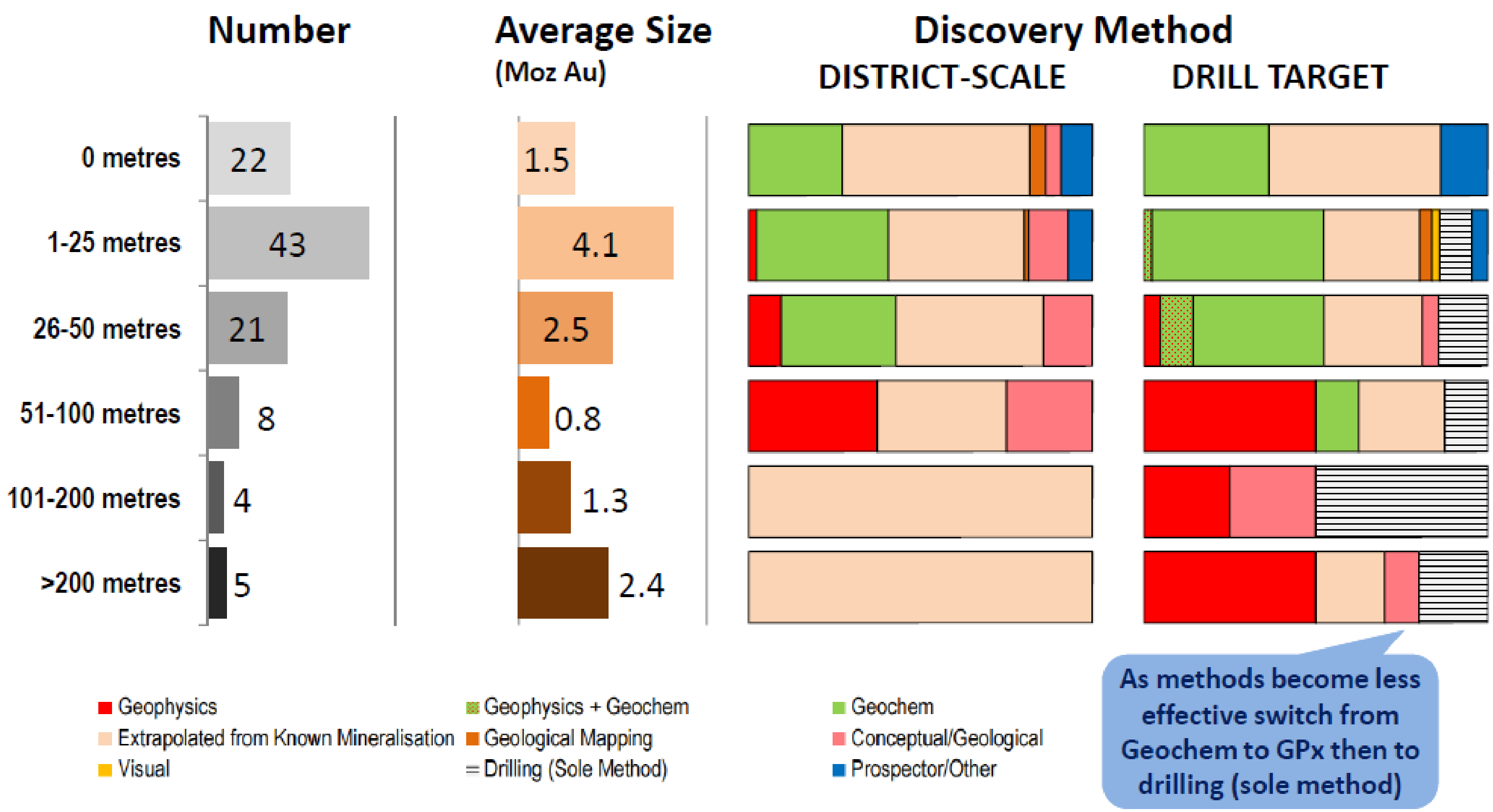


http://mines.industry.qld.gov.au/geoscience/coastal-geothermal.htm

Challenges of targeting deeper deposits

Discovery method changes with depth

Primary gold discoveries >0.1 Moz in Australia: 1980-2013



Source: MinEx Consulting © March 2014

Why big?

- Deep deposits need to be large (very HG deposits will be the exception). Conversely, large deposits are more likely to be discovered than smaller deep deposits…..bigger target with larger alteration footprint.

- Exploring/drilling deeper has inherent additional risk, both technical and financial. Offset by the prize of discovery with a large deposit (?).

- Desirable to replace large long-lived mines coming to the end of their mine lives. Impact on government revenue, remote towns, momentum of mining development, loss of capability.

Deep + Big = Challenging

- Few exploration geologists are knowledgeable in deep exploration, and discovery tools become more costly / less effective

- It is a new frontier in mining with massive increases in cost and technical risks (geological & engineering) to be overcome

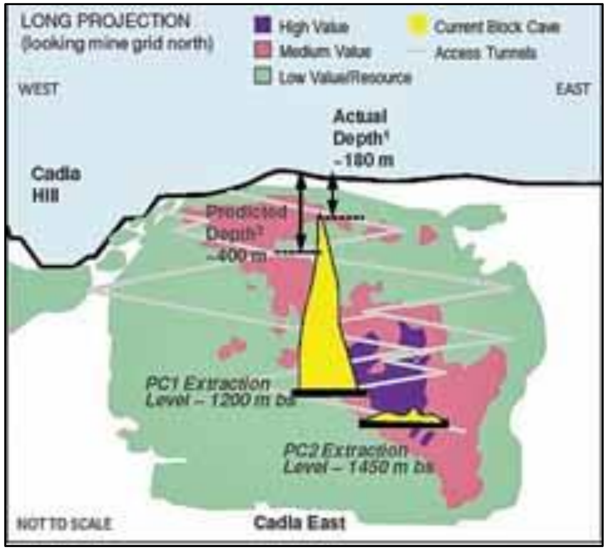
New approach to ‘prospectivity’ - mining objective at the forefront.

Why mass-mining?

- Large, low grade orebodies at depth are currently only able to be economically extracted using lower-cost mass-mining methods. Deep high grade orebodies can support open-stope (higher-cost) mining.

- Block Cave vs Sub-level Cave : dependent on orebody geometry/orientation and geotechnical characterisation.

- Underground mass-mining feasibility depends on:
  - Stress field
  - Geothermal gradient
  - Caveability of rock mass
  - Geometry/orientation of orebody
  - Local topographic influences
  - Community acceptance



http://www.womp-int.com/

DMQ1

Project

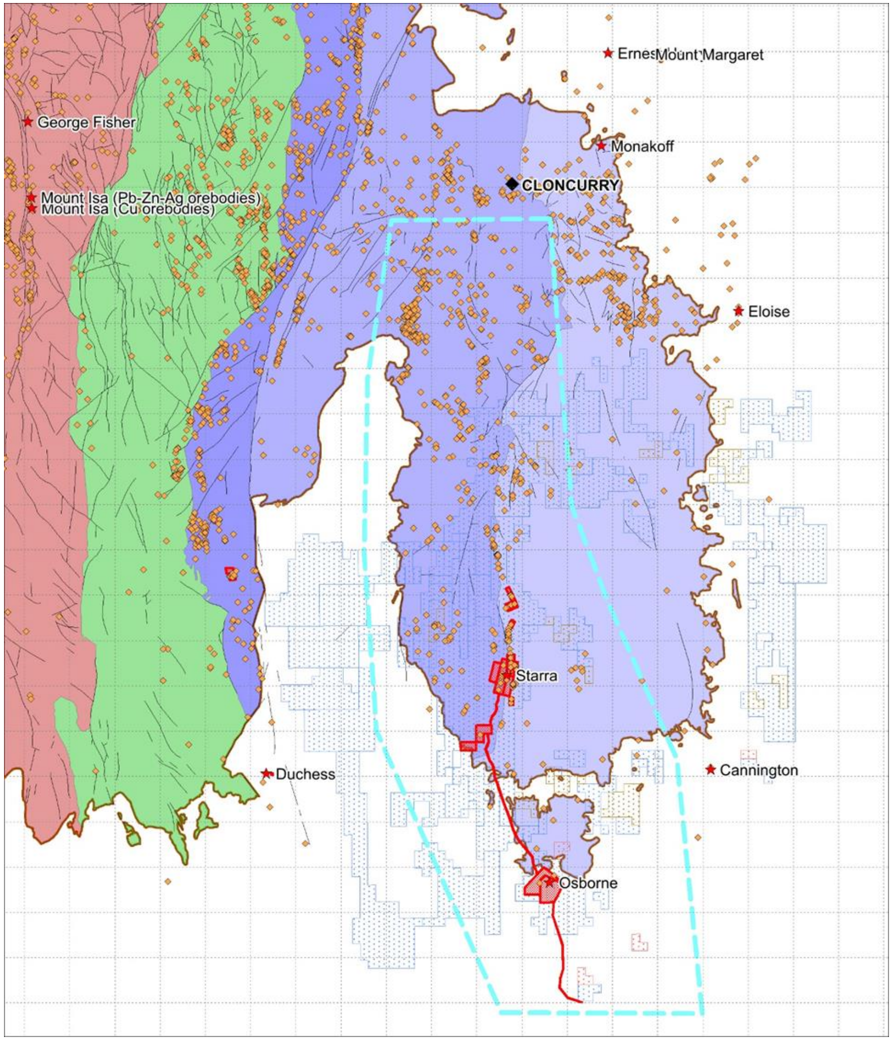
Partnership: Industry – Researchers – Geological Survey Queensland
NW Queensland: world class assets
IOCG and related deposit styles – mass mining targets.

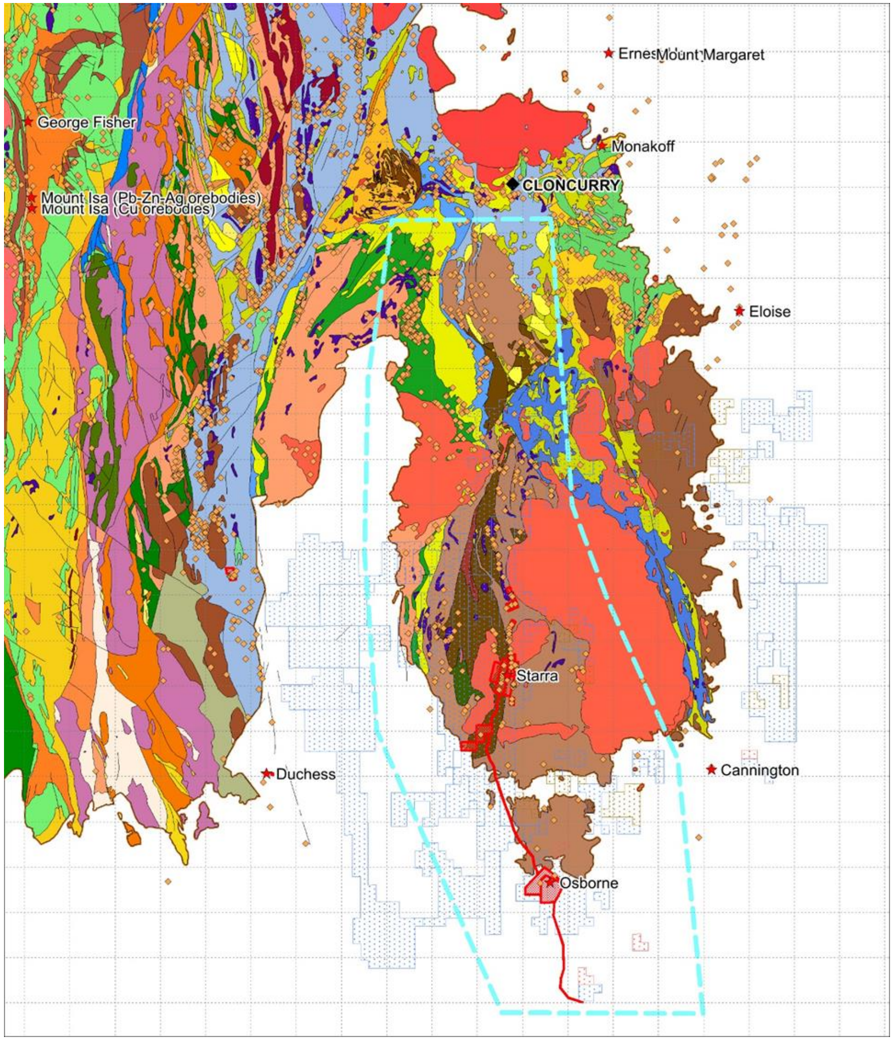
Data rich - leveraging GSQ held data/information & company geoscientific data (geological/geotechnical).

Building on The University of Queensland's W.H.Bryan Mining and Geology Research Centre's (SMI-BRC) track record of:

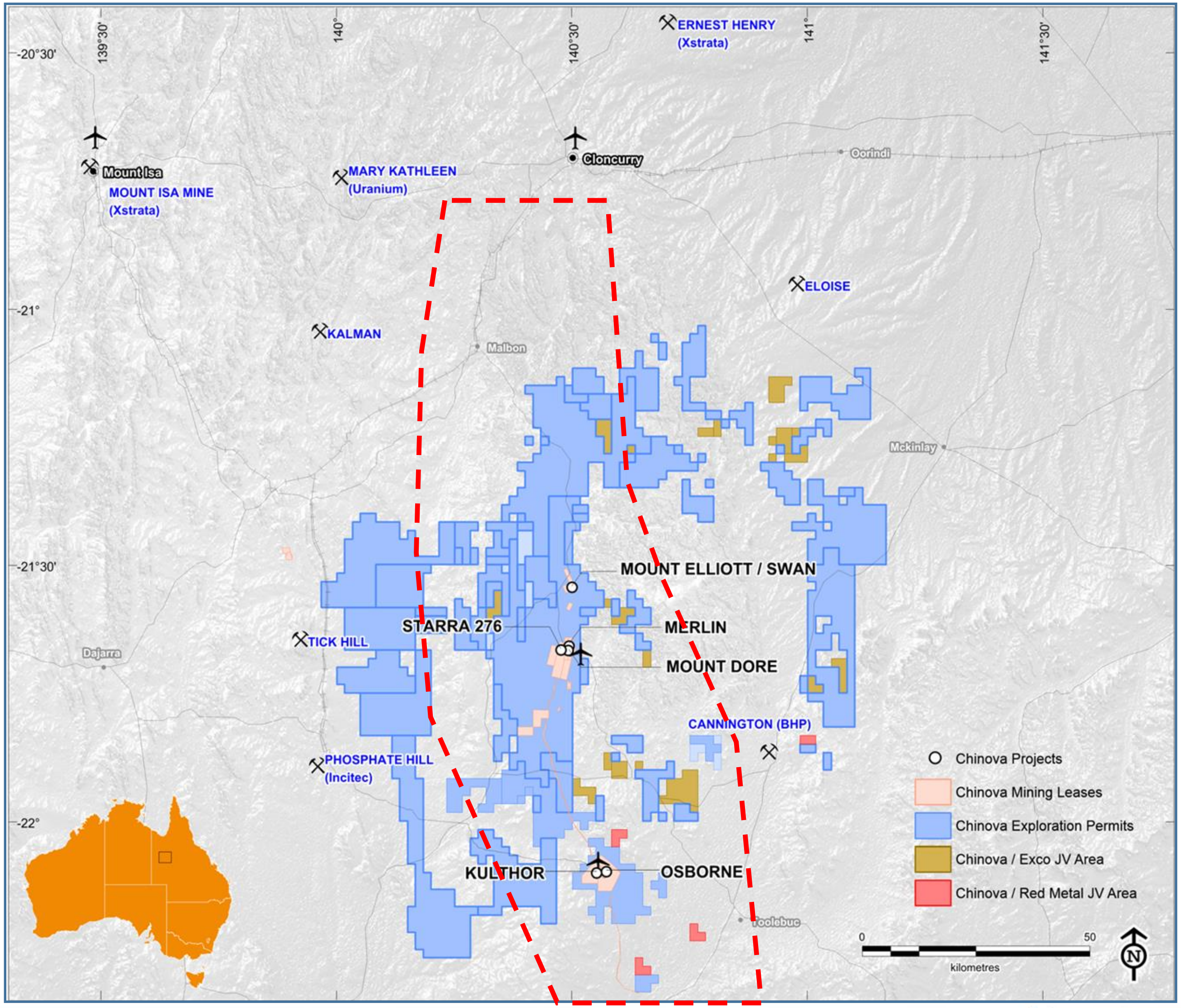
- assembling international multi-disciplinary research teams,
- conducting high quality research which has delivered outcomes to industry, and
- gaining support of the largest international companies for research targeting mining in deeper frontier settings

DMQ1: Cloncurry-focussed project





DMQ1: Strategic collaboration with Chinova Resources



DMQ1: Cloncurry-focussed project

- **What potential is there at depth (500m – 2000m)?**
    - *Mass-mining opportunities in the data (data(mass)mining!), deposit associations, other commodities?*

- **What techniques are optimal for exploration of these deeper targets?**
    - *Geophysical scenarios, update 3D modelling, data analytics*

- **(How) Can we mine them?**
    - *Compile criteria required for mass-mining analysis, keep a mining-mindset.*

Phased project

1. Compilation of openfile and pre-competitive data – unique opportunity.
2. Review IOCG Cu-Au deposits globally in terms of:
    - Grade
    - Tonnage
    - Orebody geometry
    - Depth
    - Rock mass characteristics
    - Deposit associations, potential for mineable plumbing systems, low-grade haloes
    - Discovery history (successful exploration technologies and strategies in analogous terranes)
    - Mineral processing characteristics
3. Review Cloncurry field IOCG Cu-Au deposits in context of the above. Evaluate the near-mine potential and depth potential given learnings of deposit associations, and mass-mining expertise of the BRC.
4. Update 3D modelling of the geo-architecture and include supplementary detail on the local controls on ore deposits.

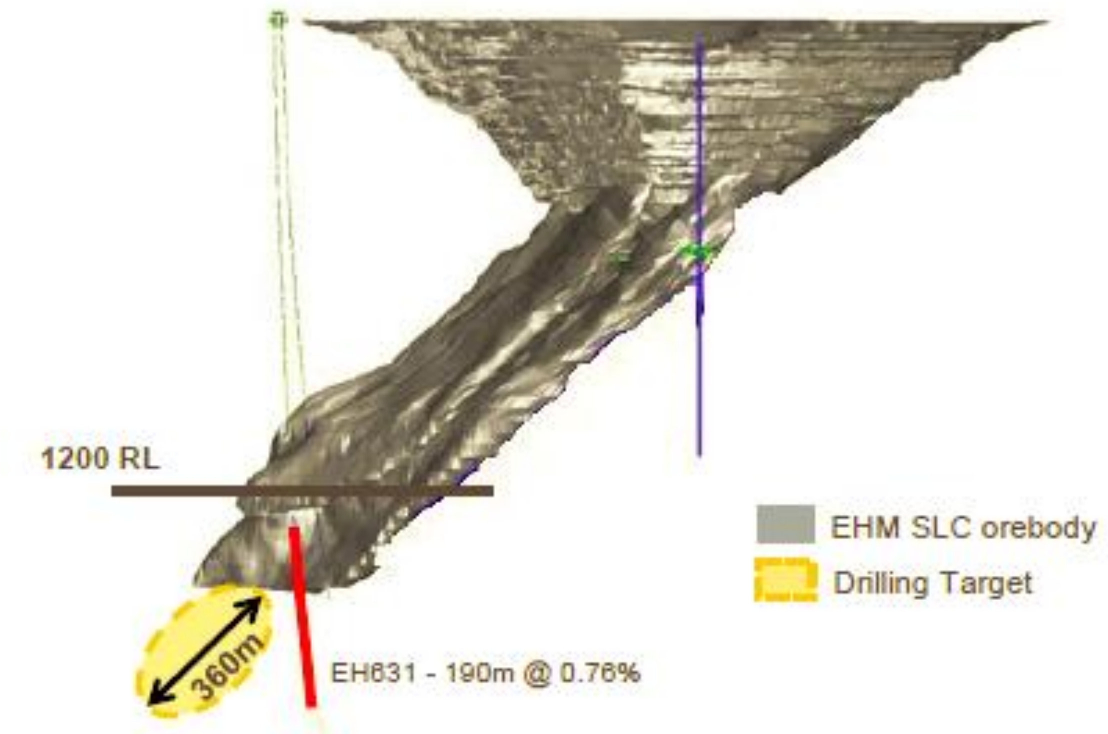
Phased Project

5. Geochemical and geophysical characterisation of the Cloncurry belt IOCG Cu-Au deposits. Model scenarios of re-orientation and/or re-positioning of ore deposits to evaluate geophysical response as a guide for explorers.

Reduce the risk profile of exploring at depth in the Cloncurry field by identifying tracts of ground which are:

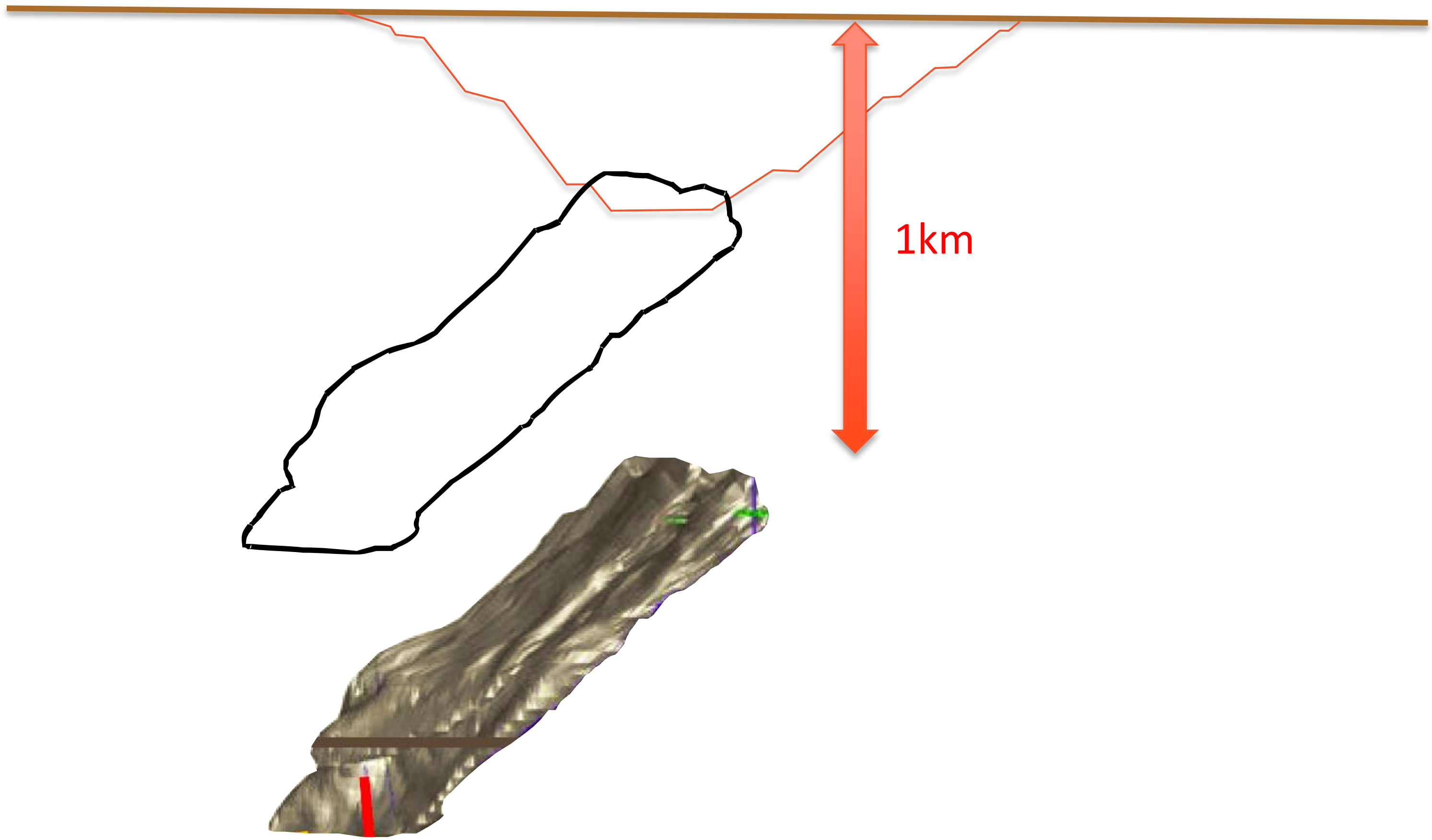
- **prospective for large, mass-mineable deposits, and**
- **comprise geotechnical, geothermal, geographical conditions which are amenable to mass-mining methods.**

Ernest Henry IOCG deposit & mine



http://www.glencore.com/assets/media/doc/speeches_and_presentations/glencore/2014/20140930-Glencore-Sell-Side-Analyst-Visit-Copper.pdf

EH – model geophysical response



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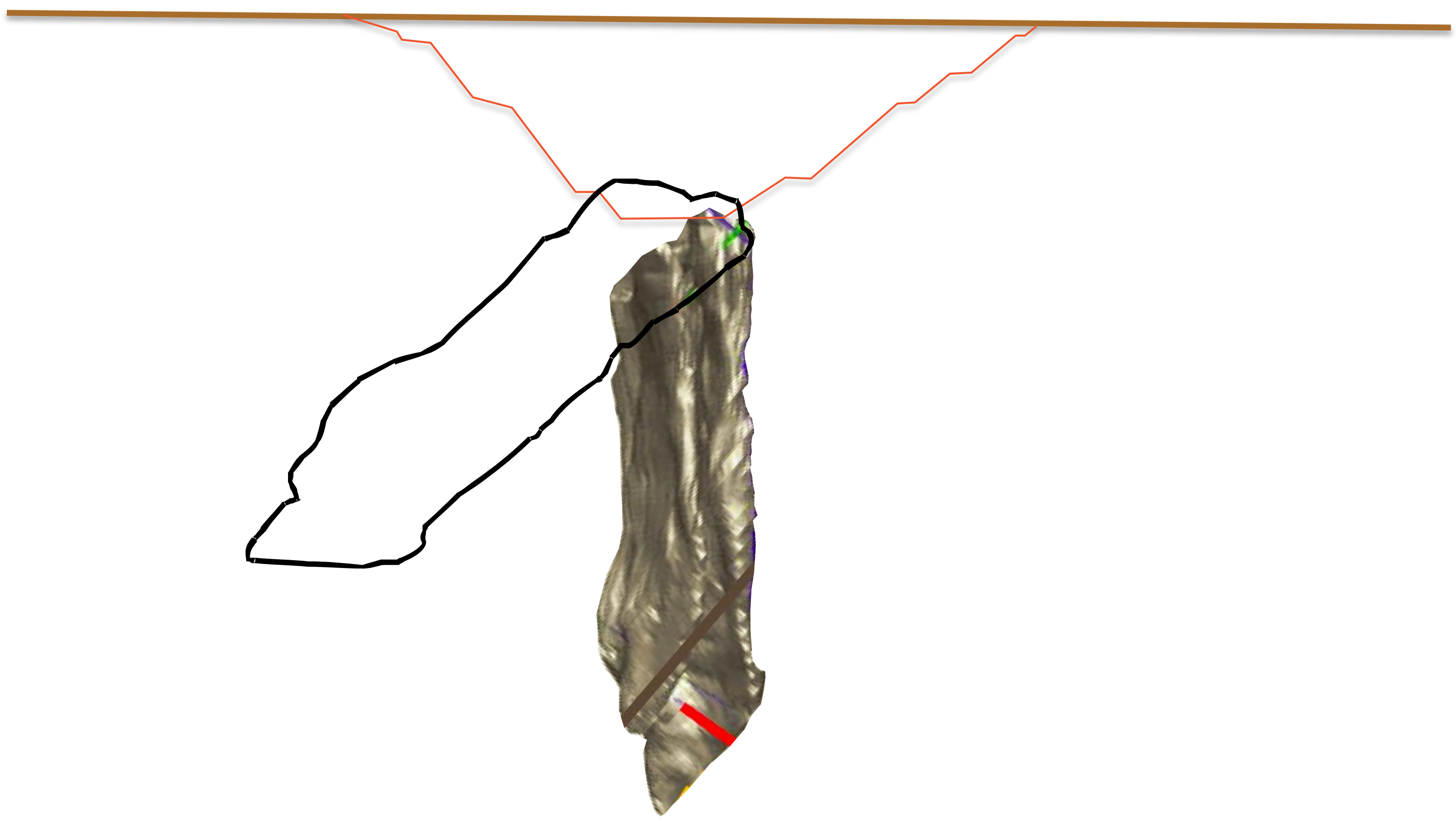

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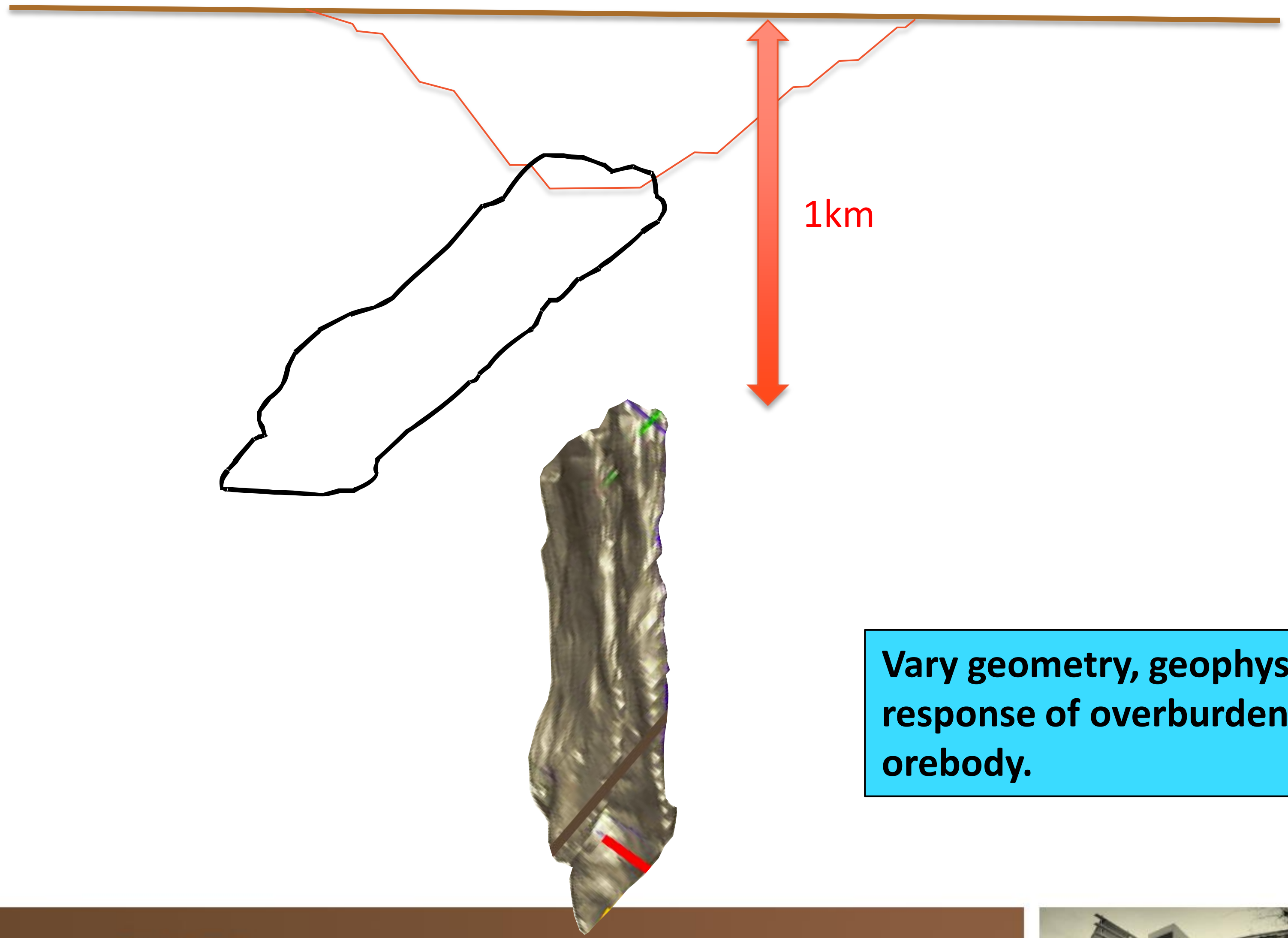
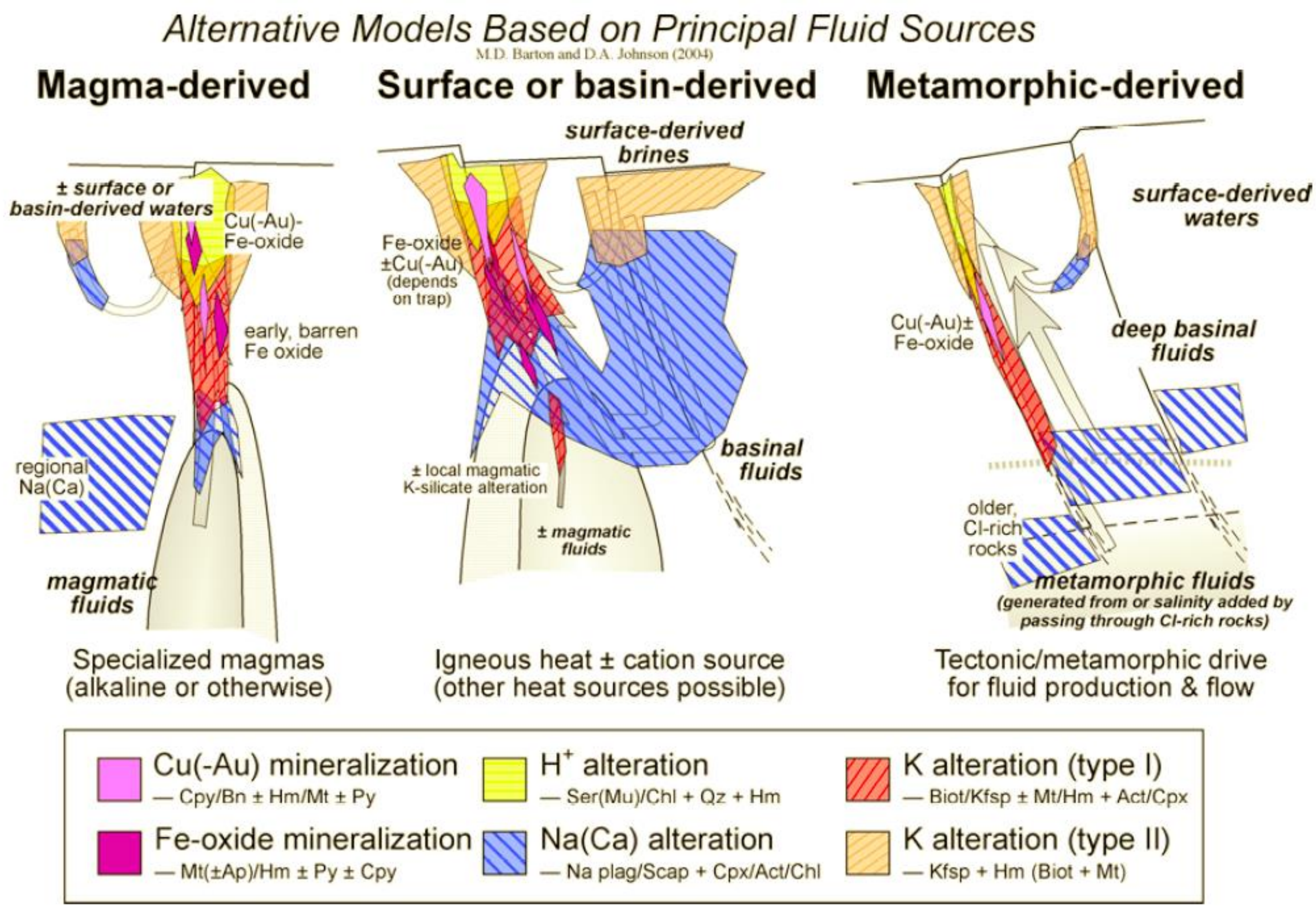


Vary geometry, geophysical response of overburden and orebody.

Data-driven analysis – avoid genetic ambiguity



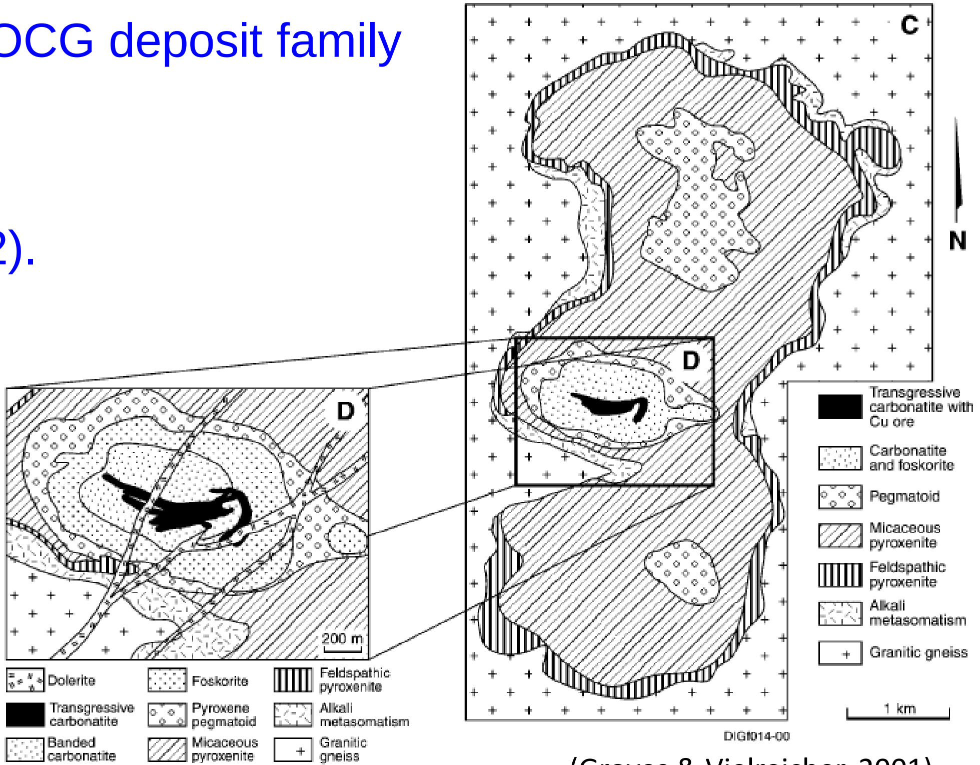
(Barton & Johnson, 2004)

Mineral deposit associations

- Collerson (Session 1) – Devonian plume track. Carbonatites/Phoscorites recognized, enhanced prospectivity at depth for differing mineralization styles.

- The Phalaborwa example.
  - A possible end-member to the IOCG deposit family (Groves & Vielreicher, 2001).
  - Carbonatite-Phoscorite hosted.
  - ~850Mt @ 0.5%Cu (Leroy, 1992).
  - PGEs
  - Current Block-Cave mine.

- What can we learn from a review of global IOCG deposits/fields which may indicate a new/-different mineralisation style at depth in the Cloncurry district?



(Groves & Vielreicher, 2001)

Impact/benefit to companies - Improved Data Access

Information Package:

- **Reviews:**

  - **exploration technologies and strategies** applied in similar terranes

  - **mass-mining IOCG Cu-Au operations world-wide**: spatial relationships, deposit size, rock character, geophysical signature and spatial genetic relationships to other deposit types

  - **local mines and projects/resources** including revisiting the litho-structural controls on orebody location/size/character, geophysical and geochemical response, geotechnical characteristics, mineral assemblages and processing characteristics.

- **Database** comprising new geological/geotechnical and other relevant data/information for the Cloncurry region (e.g. litho-structural data from open-file data sources, geological data such as vein abundance, mineralogy and where possible paragenesis, geotechnical variables and proxies) to assess broader 'favourable zones' suggested by distal geochemical indicators and to improve the understanding of the key constraints to deep mining operations. Litho-geochemical classification of key stratigraphic horizons.

Impact/benefit to companies - Improved Data Access

- **District-scale 3D scenarios** of select well known deposits/resources projected to greater depths, at different geometries (recognising the impact of regional structural architecture) and including geothermal gradient, stress regime to demonstrate the impact of key geological/rock character features on resource distribution and ‘mineability’. Geophysical response of differing deposit configurations.

Guide for deep exploration in the Cloncurry field

Impact/benefit to companies

- Reducing Risk - minimising costs (resources, time) on non-viable deposits, optimal usage of exploration drill hole information
- Revitalise Prospectivity – ensure potentially viable projects are not overlooked
- Combining technical data & expertise from multiple disciplines (geology – exploration & mining, engineering, geophysics, geochemistry) to develop and present a business understanding / mining-informed exploration strategy.
- Recognised by industry – e.g. Chinova, Glencore.
- To effectively evaluate mining potential at greater depth requires new interpretation/information re: the key drivers of project viability. This project will provide interpretations and data to assist explorers in assessing mining related issues associated with target/prospect areas.

DMQ2 - Concept

Phase 2: Filtering for Deep Mass Mining

Expand area of analysis through alliance with Glencore.

1 - **Review key engineering constraints/opportunities** using select deep mining operations (Australian and international - highlighting current knowledge of Cloncurry)including successful conceptual development of mass mining projects in deeper terranes; characteristics of deposits in a mining context and impact of current/near future technological advances in terms of extraction opportunities.

2 - **Develop cost model to prioritise areas** using estimates of operating and capital expenditure by deposit form, grade, depth. Modelling to accommodate variation in commodity price

3 - **Re-evaluating Cloncurry region potential from a mass mining perspective:** commence data interpolation and quantitative analysis

5 - Identifying and prioritising areas - **'prospective tracts favourable for deep mass mining'**, potentially large scale deposits.