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THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

FUTORES II - 2017

# Augmenting Prospectivity Analysis with Mining Criteria: A Test for Viability

**T. Murphy, A. Pratt, M. Hinman, J. Donohue, M. Pirlo, & R. Valenta**

Townsville, Queensland
5th June, 2017

# Context & Support

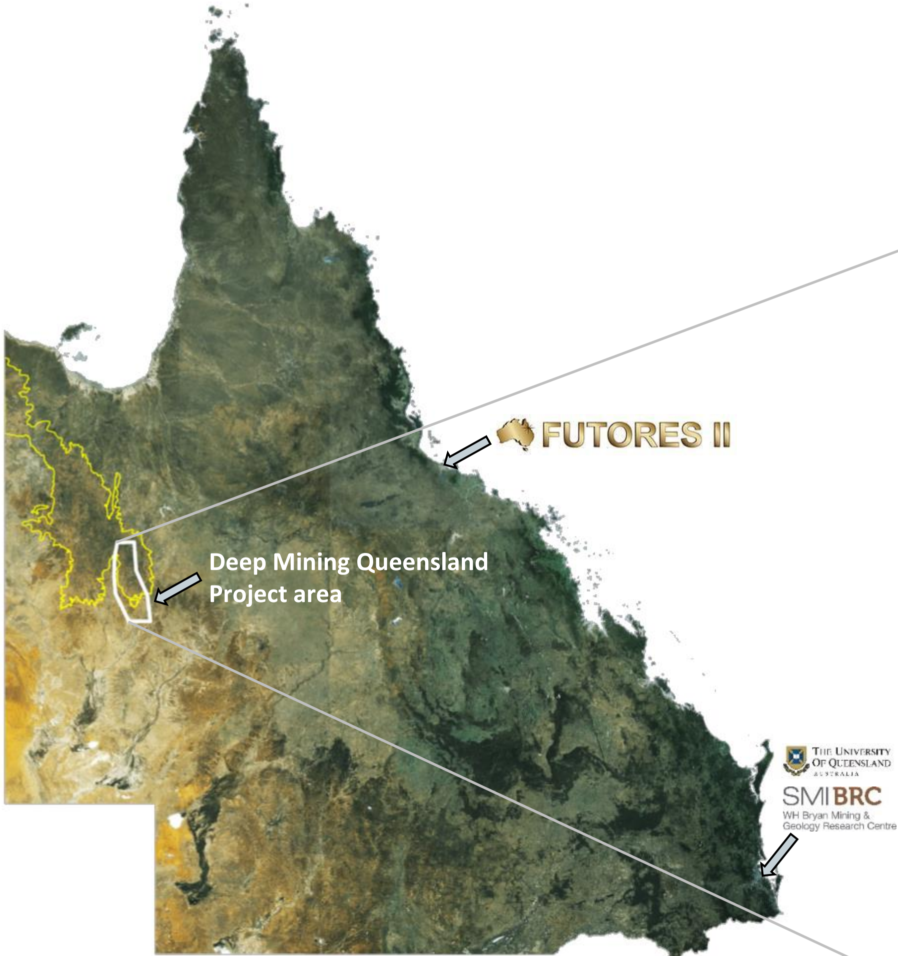
The Deep Mining Queensland (DMQ) project, a 2 year project (2015-17), is part of the Queensland State Government's investment in priority geoscience projects identified by the mining and petroleum industries. This initiative is part of the Geological Survey of Queensland's (GSQ) Future Resources Program.

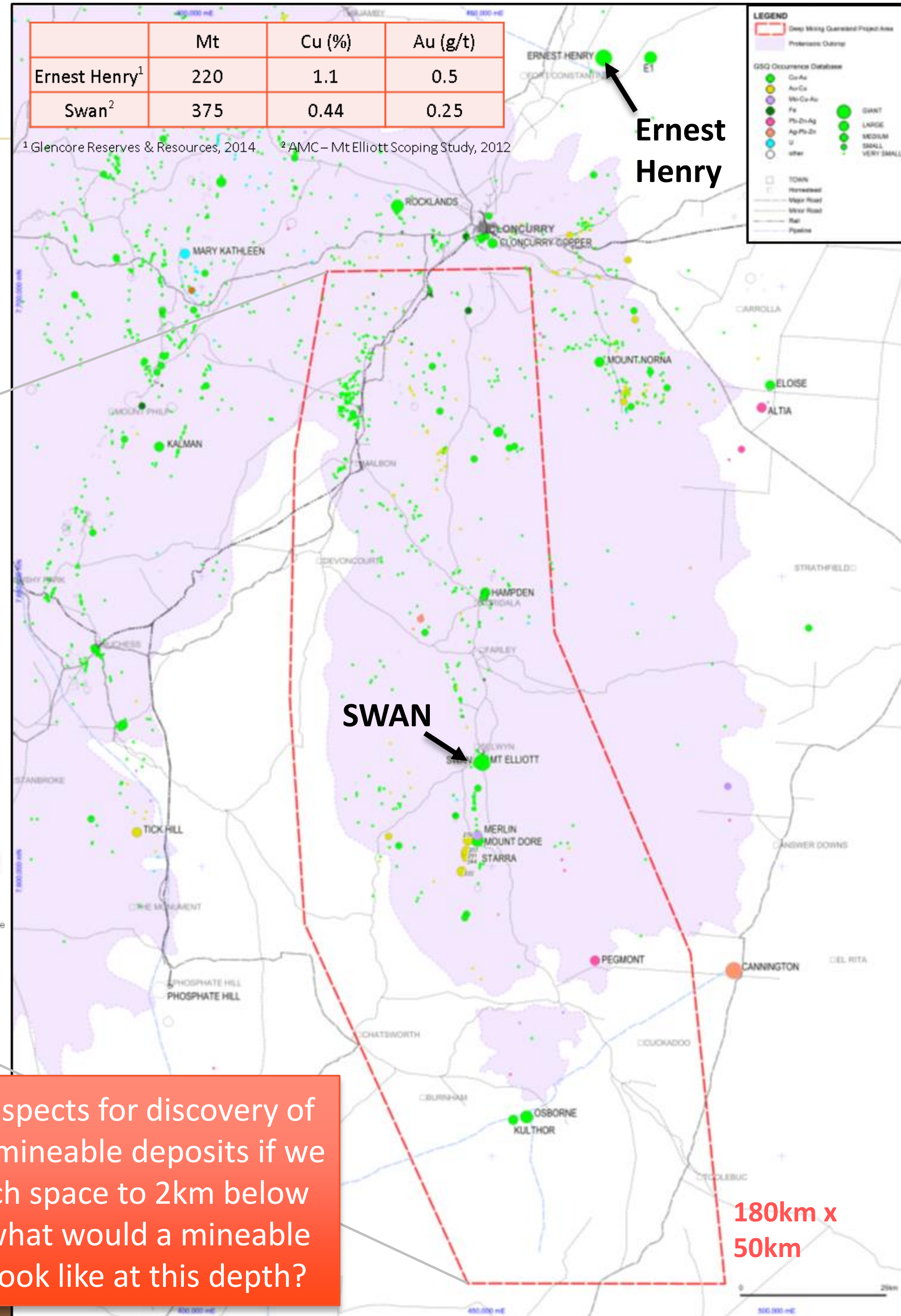
The DMQ project represents a holistic approach to resource prospectivity, from discovery through to an assessment of 'mineability', and focusses on the highly endowed Cloncurry Cu-Au district from Cloncurry township to south of the Osborne mine (totalling 8,743km2).

Sponsored by: Queensland Government; Geological Survey of Queensland

In-kind support: chinova resources

Software & data processing: DATAMINE; leapfrog; Fullagar Geophysics; HiSeis




| | Mt | Cu (%) | Au (g/t) |
|---|---|---|---|
| Ernest Henry[1] | 220 | 1.1 | 0.5 |
| Swan[2] | 375 | 0.44 | 0.25 |

[1] Glencore Reserves & Resources, 2014 [2] AMC – Mt Elliott Scoping Study, 2012

What are the prospects for discovery of additional mass-mineable deposits if we deepen the search space to 2km below surface?.....and what would a mineable deposit need to look like at this depth?

# Holistic approach to Prospectivity Analysis

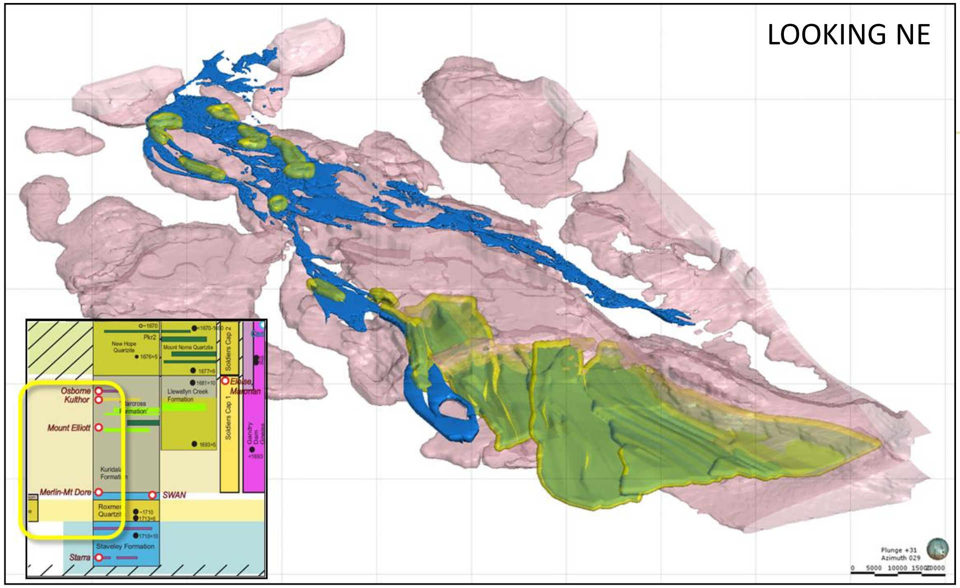
- Review of characteristics of Iron-Oxide Copper Gold (IOCG) provinces and deposits, globally
- Evaluation and updating of the 2D and 3D geology of the Cloncurry Project area
- Analysis of the geological controls on deposit location and formation in the context of the new geological model
- Development of a 3D prospectivity analysis utilising the interpreted controls on deposit-formation
- Development of an evaluation tool for explorers to assess the potential relative value (future viability) of prospects and targets.

M. Hinman in concurrent session

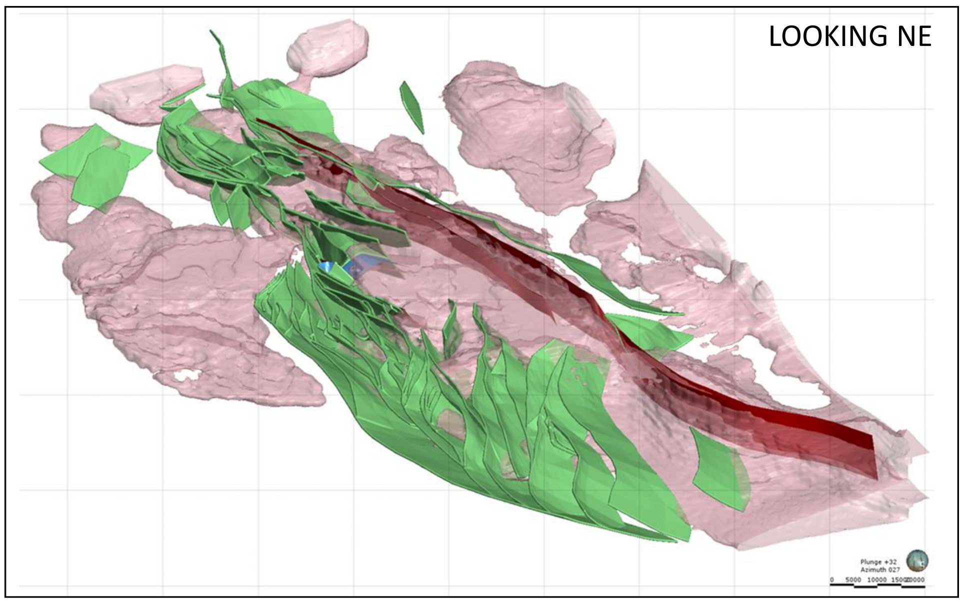
This presentation



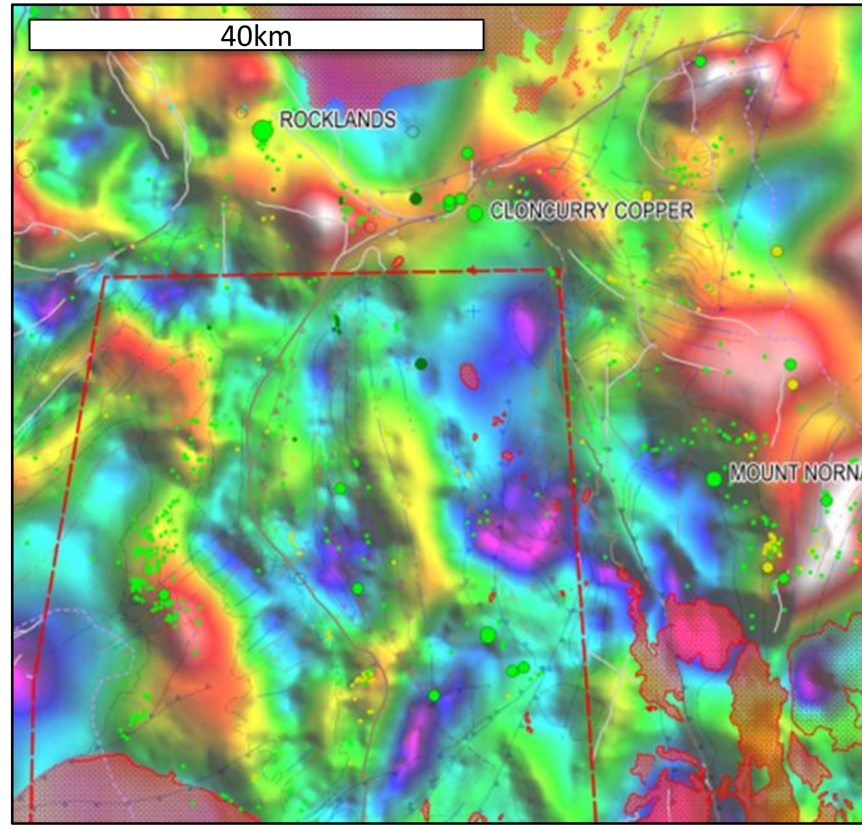
# Prospectivity Analysis - Inputs




Asymmetric buffering (yellow) of the Top of Staveley Formation stratigraphic surface (-300m/+1500m).



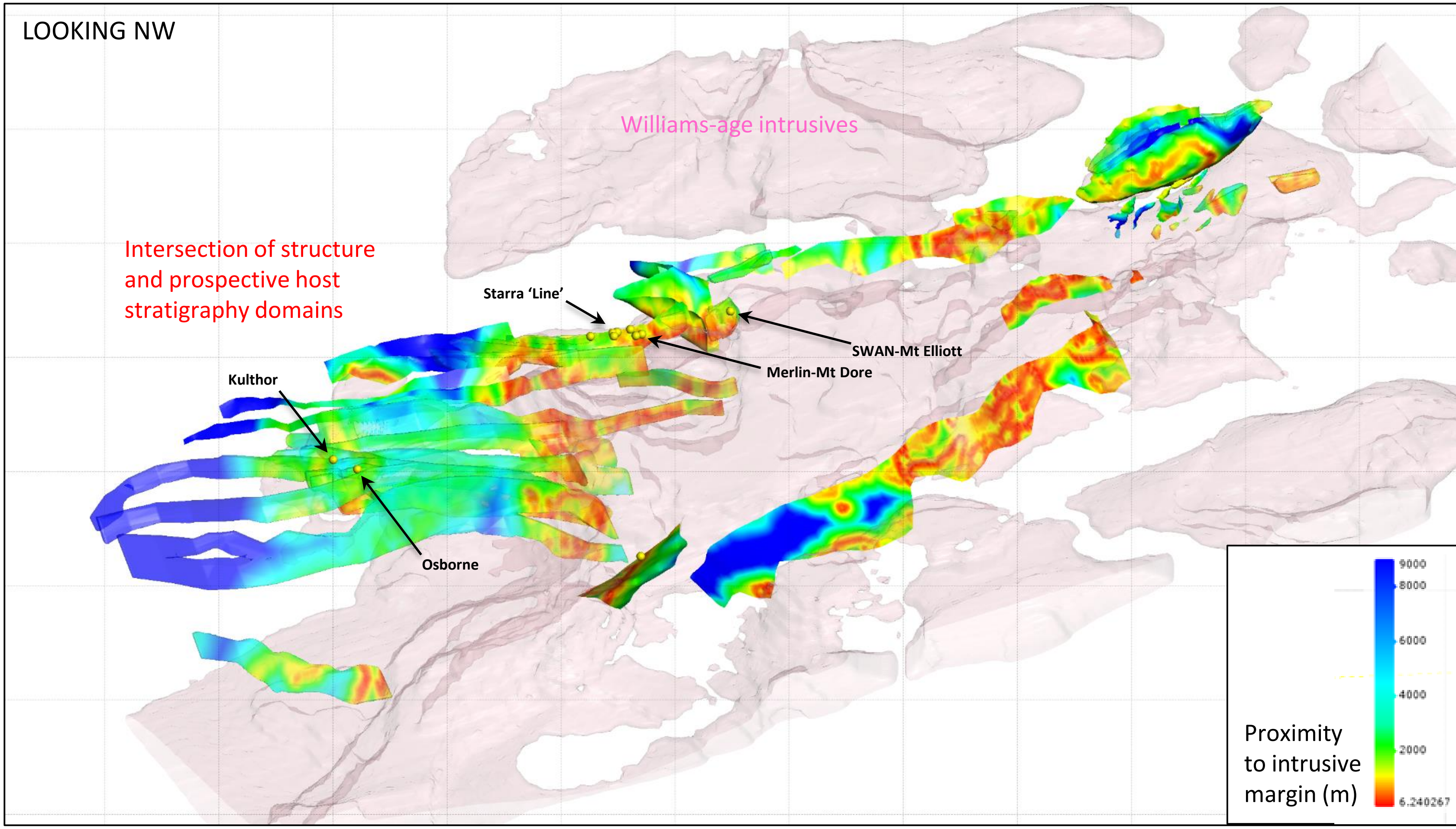

Buffered faults (green) where interpreted to predate the latter stages of D4. The green buffer is ±250m each side of the modelled faults.




Apparent Density

Subsurface geometry of the granites has an empirical relationship with clusters of mineral occurrences at surface

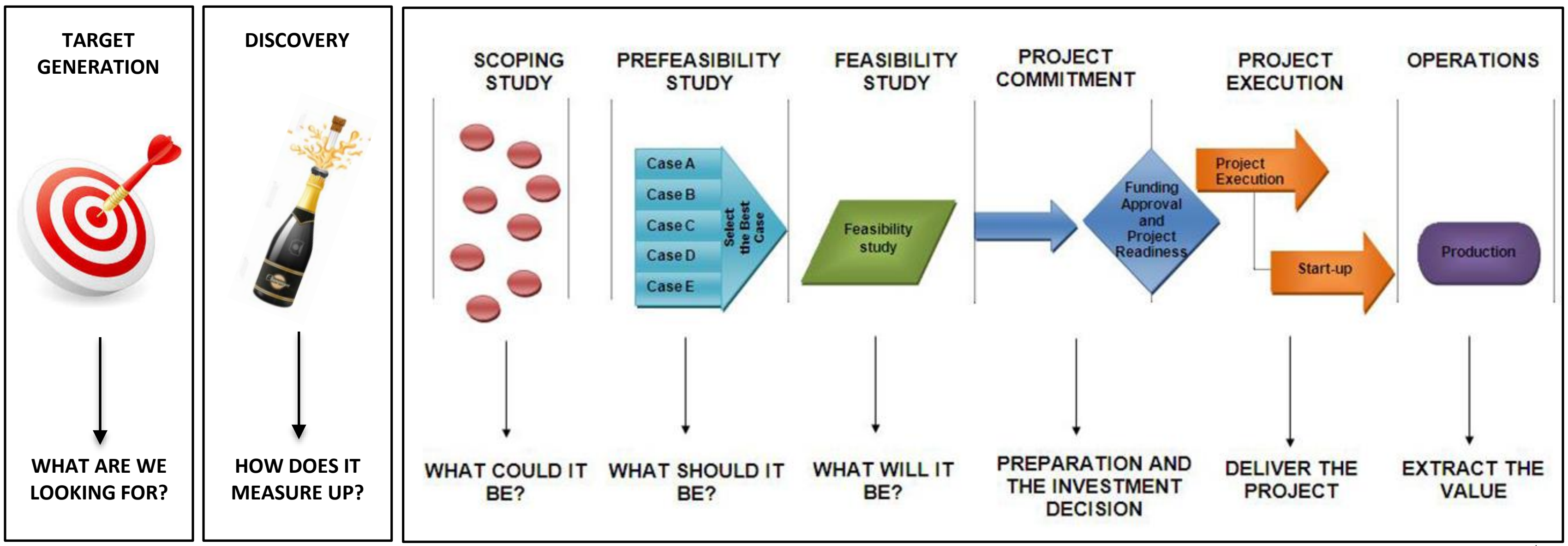
# Prospective domains identified….now what?



# Evaluation by Project Stage

Pre- Concept/Scoping-Study Evaluation

Multidisciplinary Project Evaluation




**The progress of studies for mineral projects** (Source: AusIMM Cost Estimation Handbook, 2nd ed.)

Company-specific practices

Established Processes and Guidelines

# Introduction to PEET-UG

**PROSPECT ECONOMIC EVALUATION TOOL - UNDERGROUND**

Interactive, spread-sheet based tool, for prospect/target evaluation (Pre-'Concept level' analysis) in relative terms.

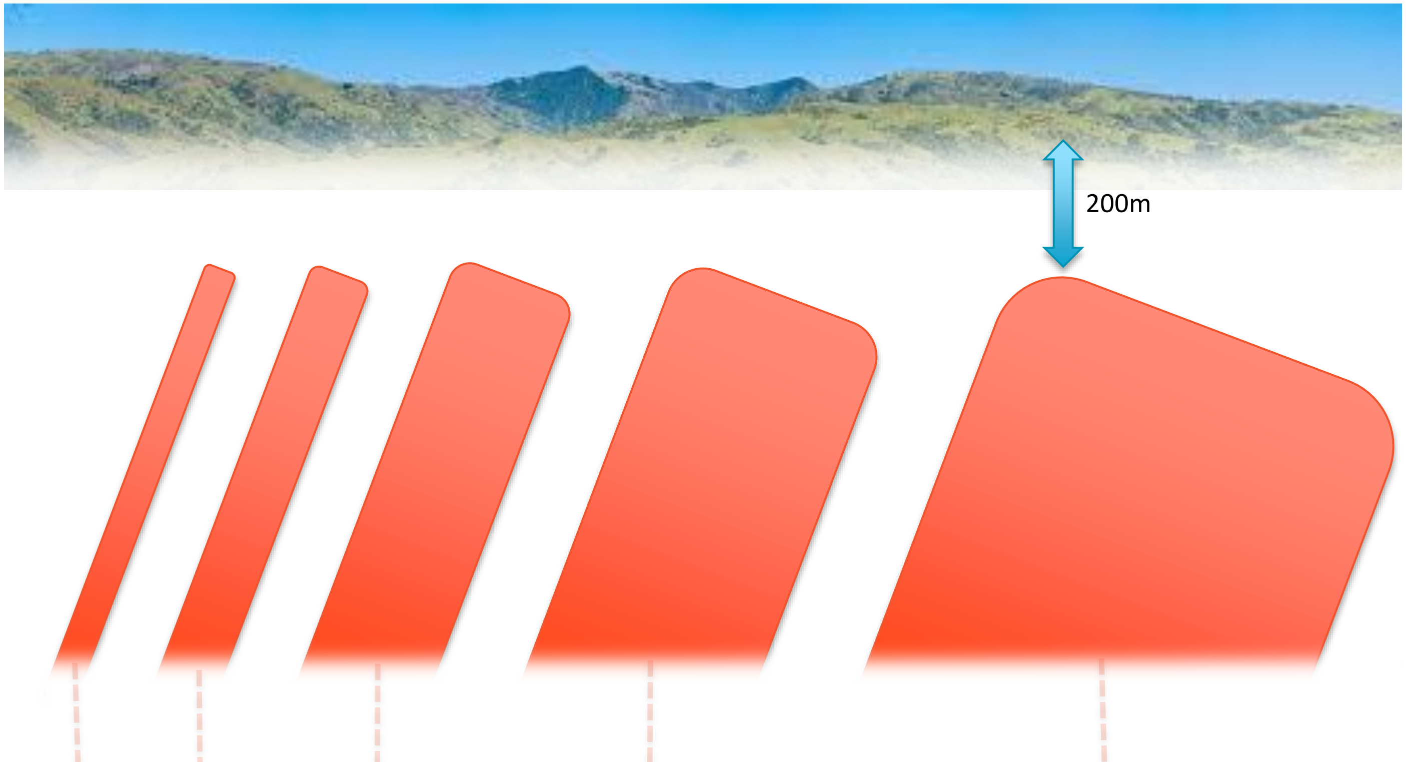
20170418_PEET-UG

3 key purposes:

1. Where should I be exploring? …..mining constraints on prospectivity utilized in exploration strategy development.
2. Amongst my portfolio of targets/prospects, which of these has the potential to sustain a mining operation? Tool for ranking geological targets in terms of potential viability.
3. Tool for stage-gating the exploration process: is the prospect worth continued effort/expenditure?

**The evaluative tool has been constructed to determine relative value of deposits amenable to underground mining, and as a standalone operation.**

# Where is the money?.....same endowment




*Parameters:*
- *500m mining block height only*
- *80 degree dip*
- *CuEq calculation assumed a 20k:1 ratio of Cu:Au, as broadly observed in IOCG systems.*

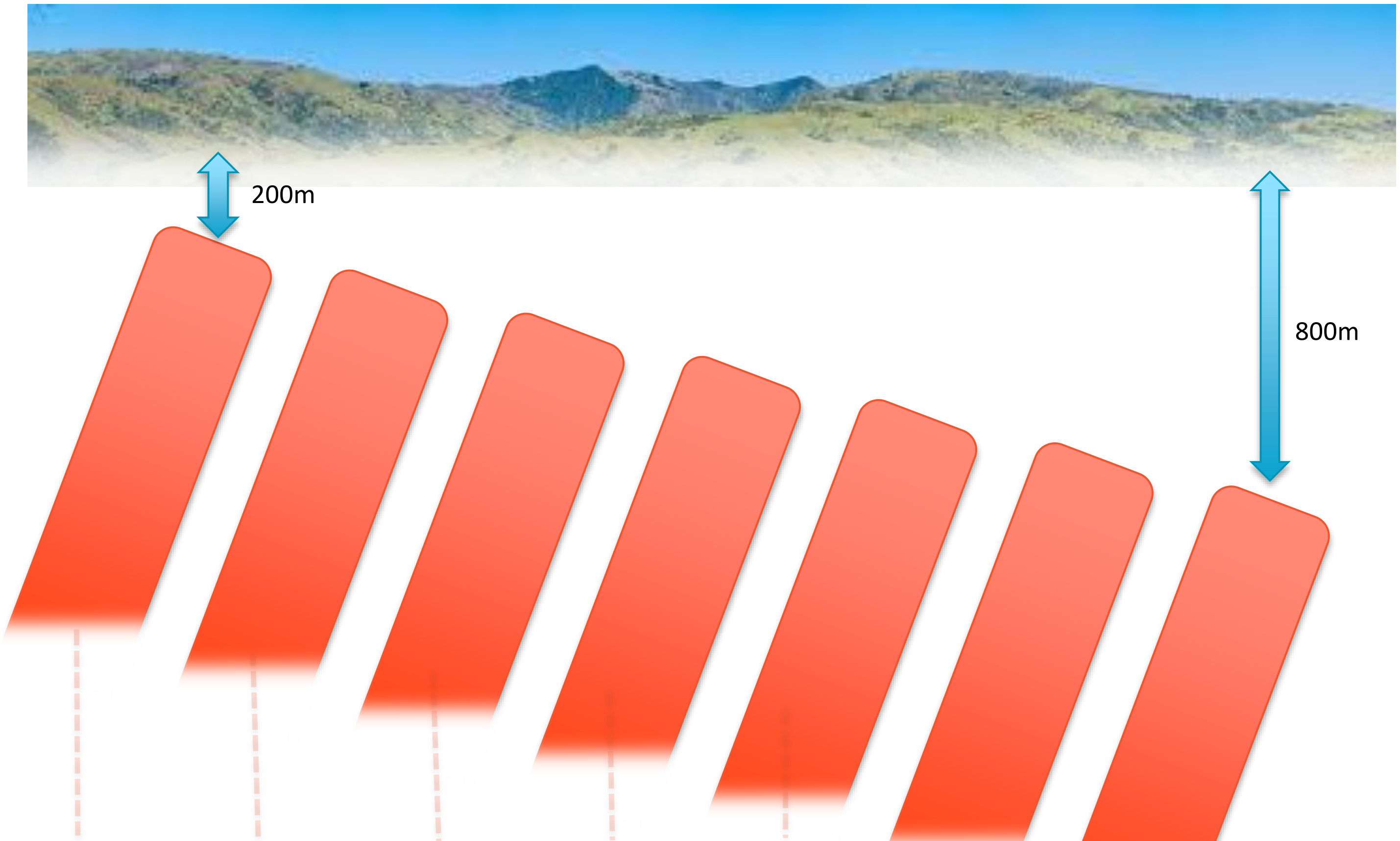
| | | | | | |
|---|---|---|---|---|---|
| ***Depth b.s.*** | **200m** | **200m** | **200m** | **200m** | **200m** |
| ***Width (m)*** | **12.5m** | **25m** | **50m** | **100m** | **200m** |
| ***Grade (%Cu)*** | **9.6** | **4.8** | **2.4** | **1.2** | **0.6** |
| ***Tonnes (Mt)*** | **5.3** | **10.5** | **20.8** | **41.5** | **86.5** |
| ***Value/t ($)*** | **$528** | **$264** | **$132** | **$66** | **$33** |
| ***Profit/t ($)*** | **$202** | **$68** | **$22** | **$0.1** | **-$4.6** |
| ***NPV ($m)*** | **$408m** | **$219m** | **$53m** | **$0m** | **$0** |

# Where is the money?..... same depth & width but differing grade


*Parameters:*
- *500m mining block height only*
- *80 degree dip*
- *CuEq calculation assumed a 20k:1 ratio of Cu:Au, as broadly observed in IOCG systems.*

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Depth b.s.*** | **300m** | **300m** | **300m** | **300m** | **300m** | **300m** |
| ***Width (m)*** | **50m** | **50m** | **50m** | **50m** | **50m** | **50m** |
| ***Grade (%Cu)*** | **4.0** | **3.5** | **3.0** | **2.5** | **2.0** | **1.5** |
| ***Tonnes*** | **20.8** | **20.8** | **20.8** | **20.8** | **20.8** | **20.8** |
| ***Value/t ($)*** | **$220** | **$193** | **$165** | **$138** | **$110** | **$83** |
| ***Profit/t ($)*** | **$77** | **$59** | **$41** | **$23** | **$6** | **-$12** |
| ***NPV ($m)*** | **$608** | **$426** | **$244** | **$61** | **$0** | **$0** |

# Where is the money?..... same width & grade but differing depth



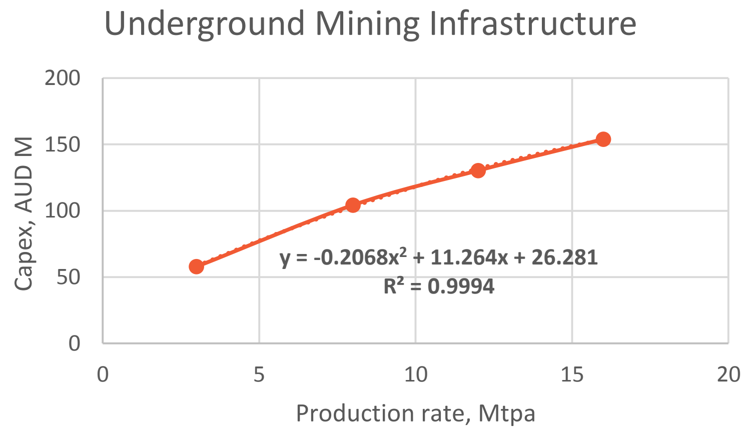

*Parameters:*
- *500m mining block height only*
- *80 degree dip*
- *CuEq calculation assumed a 20k:1 ratio of Cu:Au, as broadly observed in IOCG systems.*

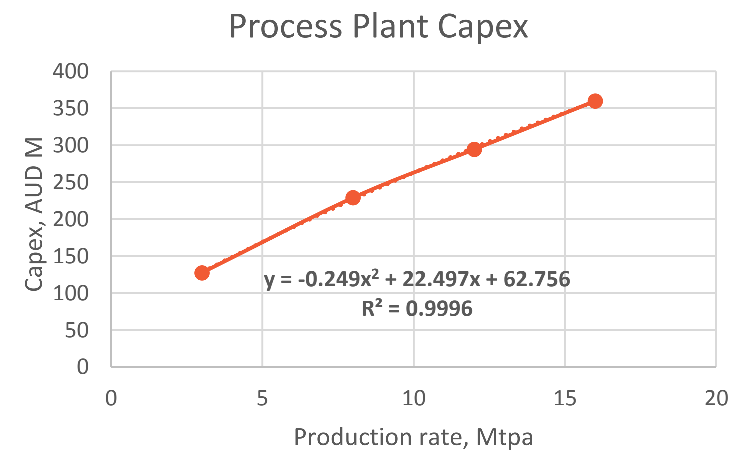
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Depth b.s.*** | **200m** | **300m** | **400m** | **500m** | **600m** | **700m** | **800m** |
| ***Width (m)*** | **50m** | **50m** | **50m** | **50m** | **50m** | **50m** | **50m** |
| ***Grade (%Cu)*** | **2.4** | **2.4** | **2.4** | **2.4** | **2.4** | **2.4** | **2.4** |
| ***Tonnes (Mt)*** | **20.8** | **20.8** | **20.8** | **20.8** | **20.8** | **20.8** | **20.8** |
| ***Value/t ($)*** | **$132** | **$132** | **$132** | **$132** | **$132** | **$132** | **$132** |
| ***Profit/t ($)*** | **$22** | **$20** | **$17** | **$27** | **$27** | **$26** | **$25** |
| ***NPV ($m)*** | **$53** | **$25** | **$0** | **$80** | **$66** | **$53** | **$39** |

# Beyond back-of-envelope calculations

Unlimited permutations of varying any or all of:

- Grade
- Width
- Depth & extent
- Dip
- Metal prices
- Criteria for mining method selection
- Mining development and advance rates
- Mining Recovery & Dilution
- Metallurgical Recovery
- Discount rate
- Mining and processing OpEx and CapEX costs
- Refining charges
- Royalties
- …and more.






# Key workings of PEET-UG

## 1. Inputs & Assumptions

Grade Distribution

Depth of Cover

Down-dip Extent

Length of new road required

Grade

Dip

Width

Strike-length

Discount rate

Metal prices

Distance to transport hubs

S.G.

Mining & Met. recovery

Exchange rate

## 2. Derived Quantities

Tonnage

In-ground value

Tonnes/vertical metre

Mine capex estimates

Contained metal

Mining rate potential

Mining advance rate

Haulage distances

Opex estimates (Mining + Geology + Processing + Admin)

## 3. Mining Method Selection

Potential mining block height

SLOS vs SLC vs BC determined by deposit geometry, dip , min. block height, in-ground 'ore' value

Truck vs Conveyor test (determined by depth below surface and production rate)

## 4. Project & Prodtn. Schedule

Mine development by year

Schedule of ore processed and recovered metal

Production by year

Schedule of concentrate produced (tonnes and grade)

# Key workings of PEET-UG (cont'd)

**5. Revenue Schedule**

- Payable metal by year
- Realisation costs by year
- Refining charges per year
- Total Gross Revenue by year

**6. Capex Estimate Models**

- Declines
- Vertical development
- Fixed plant and Infrastructure
- Processing Plant
- Lateral development
- Mobile equipment
- Infrastructure and services
- Sustaining capex
- Total capex
- Tax deduction for capex

**7. Opex Estimate Models**

- Mining costs assuming steady state production
- Processing costs " "
- General & Admin costs by year

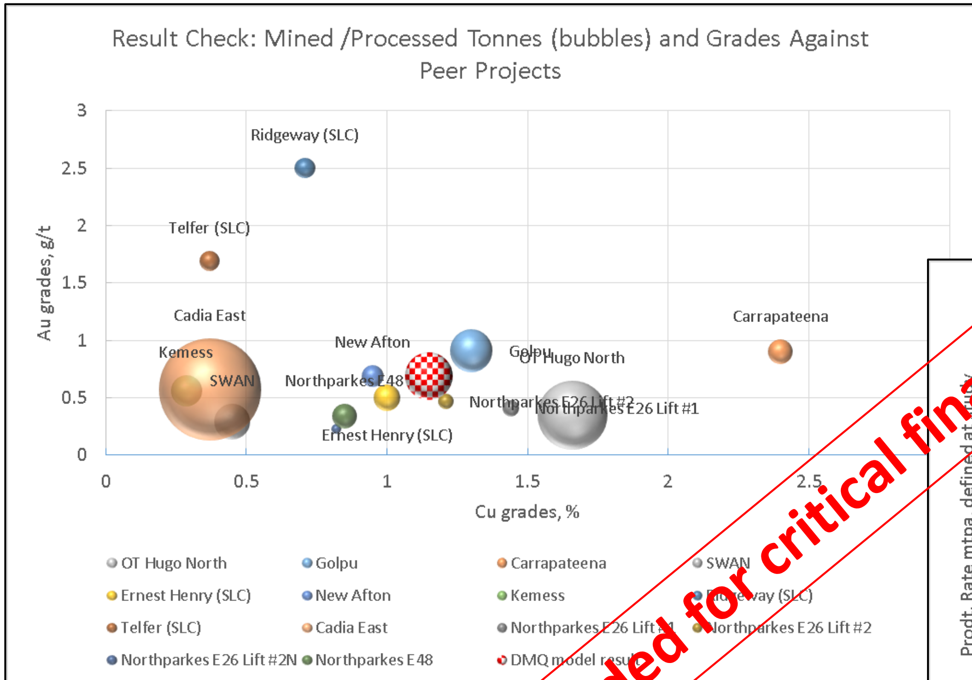
**8. Evaluation Model**

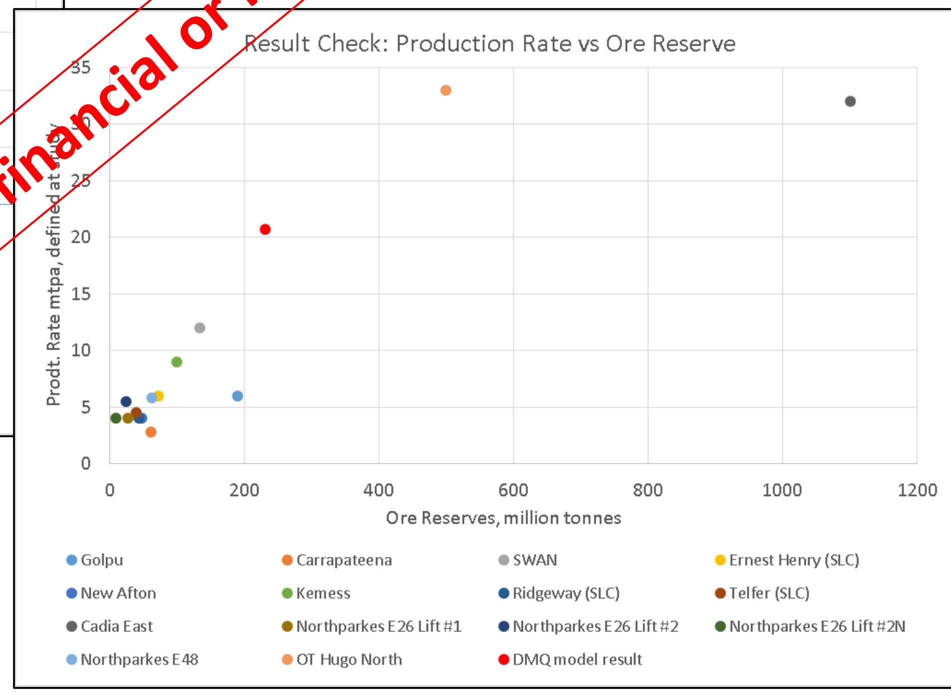
- Collated revenue, capex, opex
- IRR calculation
- Maximum negative cash position
- NPV calculation
- EBITDA
- Time to payback
- Net Cashflow



# Results: comparison with peer projects


Collated key inputs and outputs on single sheet



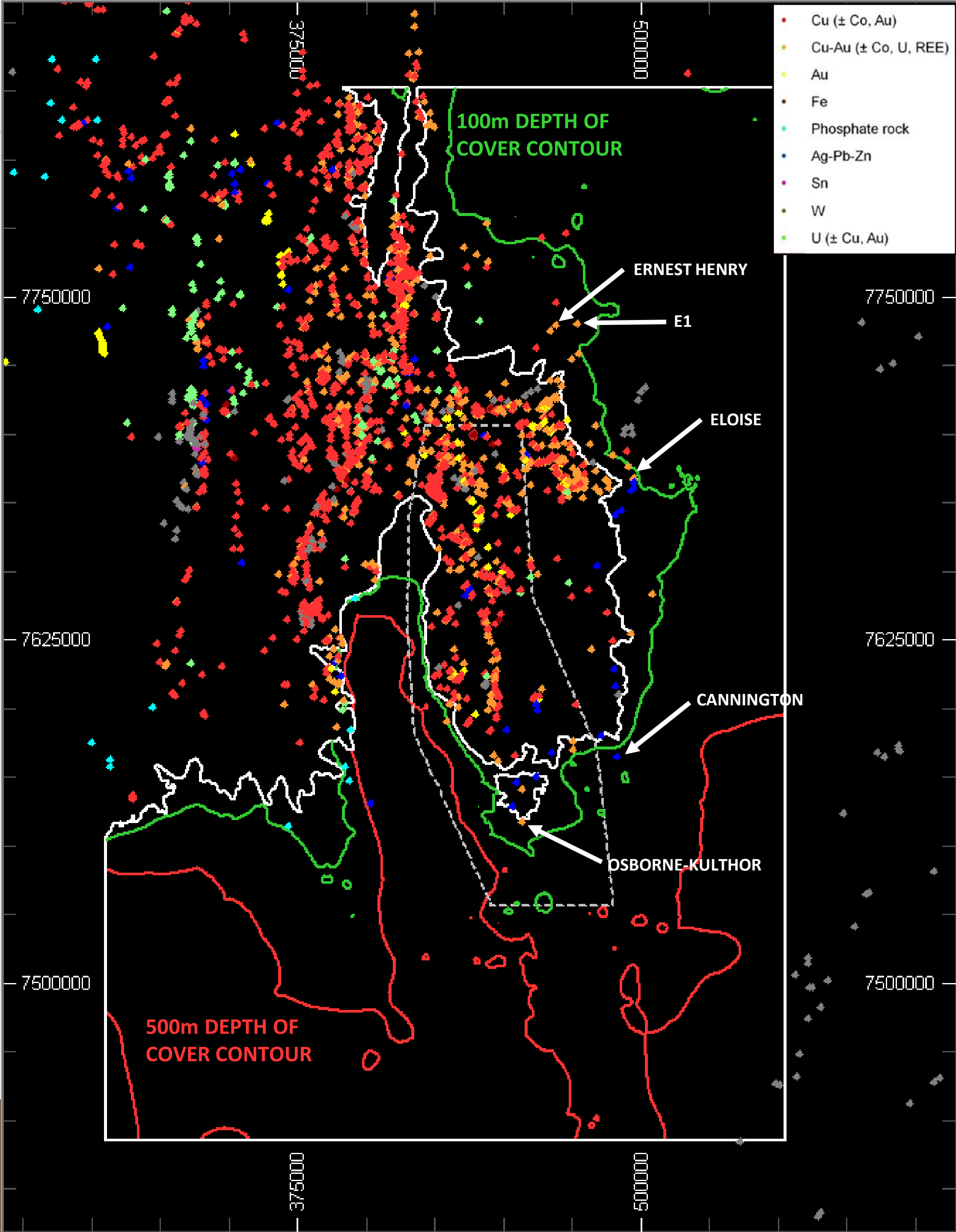



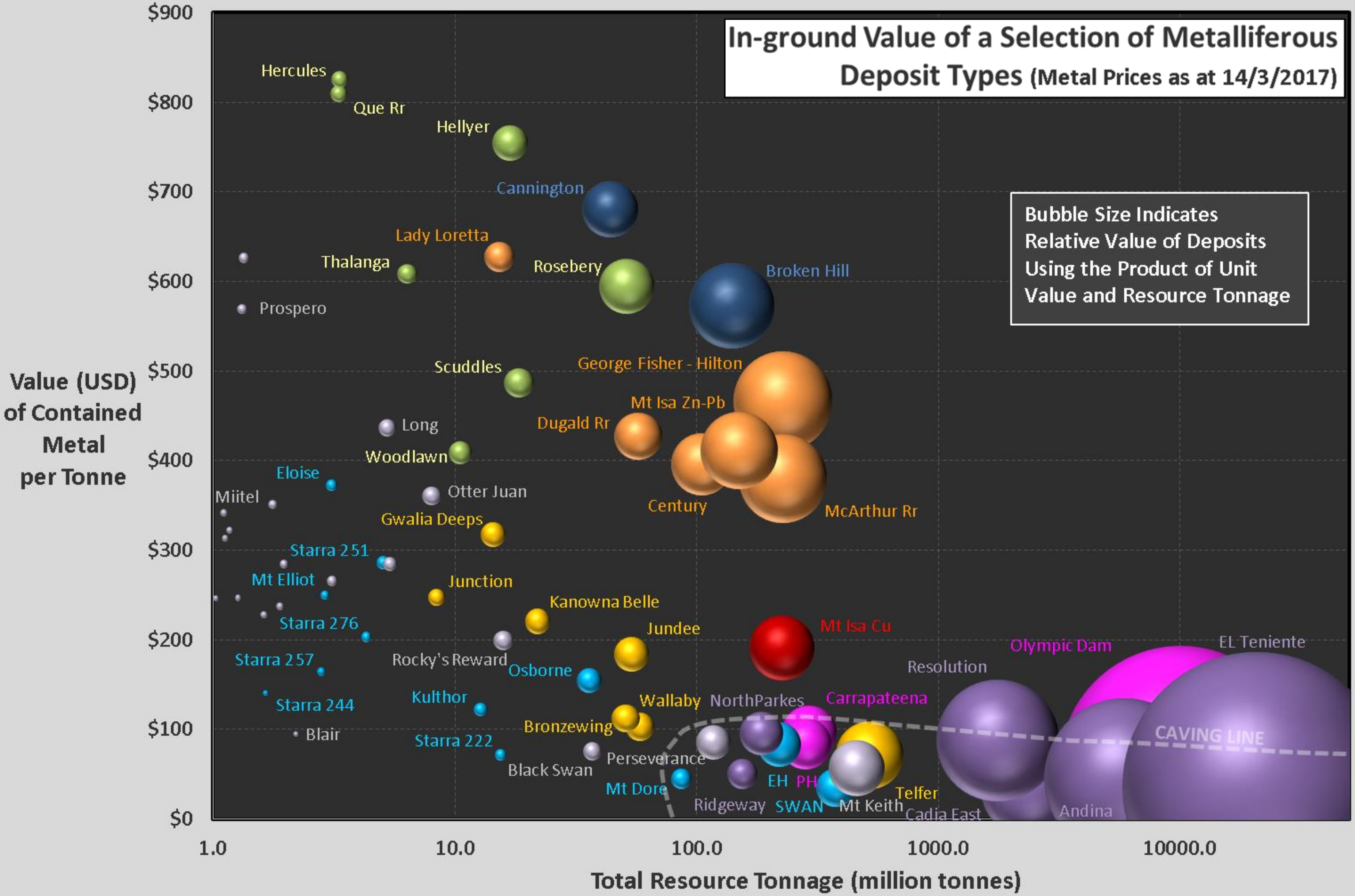

Not intended for critical financial or feasibility analysis

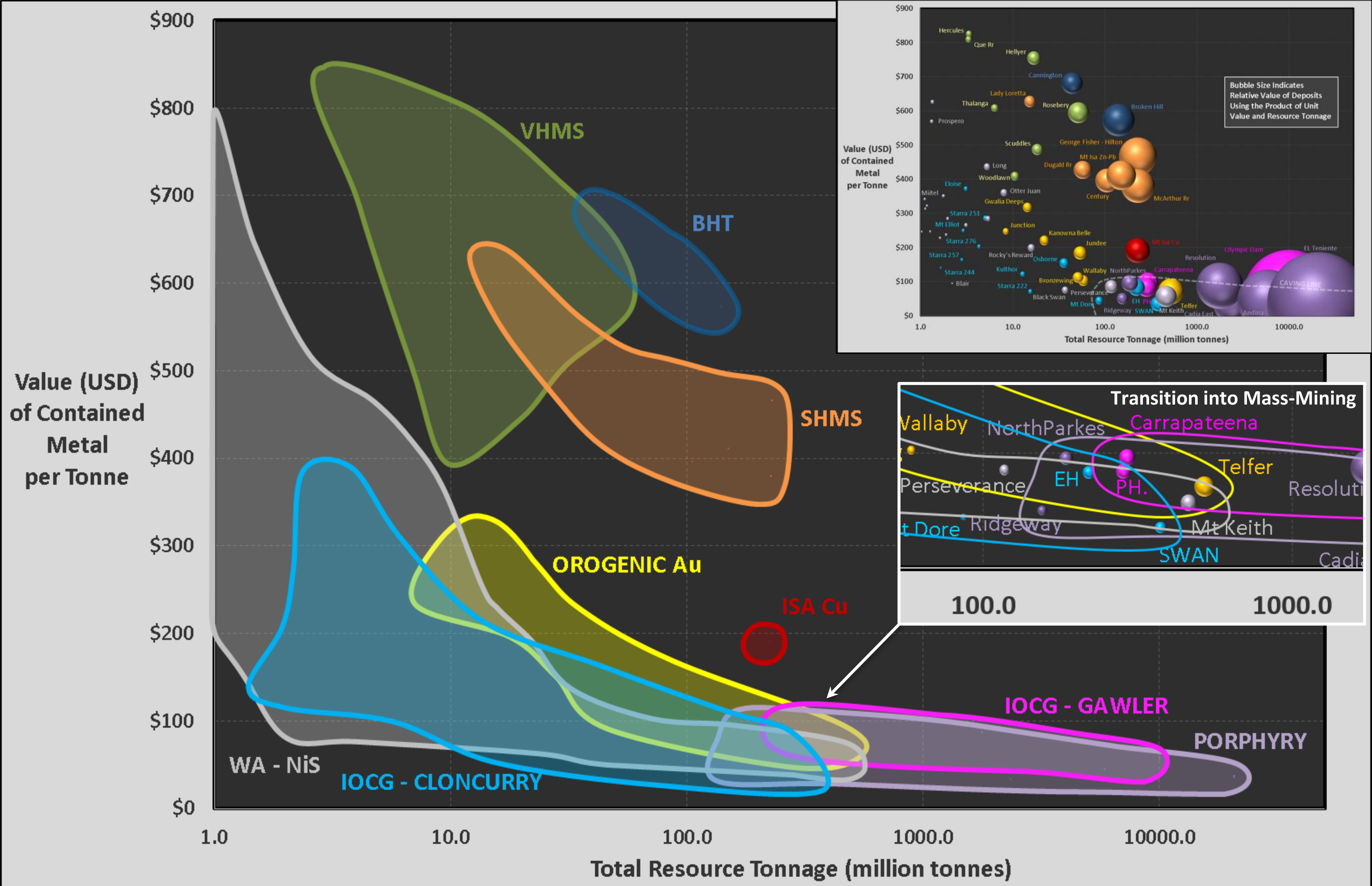
# Focussing back on Cloncurry….

What do we need to find at 500m depth in order to establish a viable mining operation?

Is this reasonable in the context of known deposits in the area we are exploring?

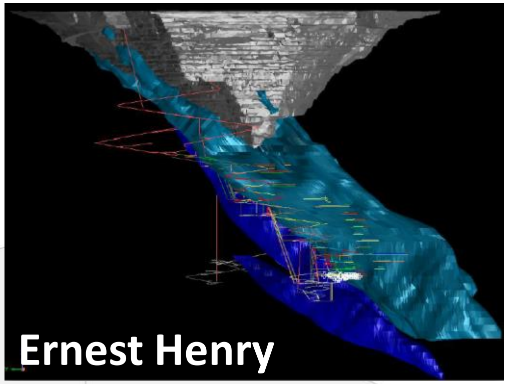


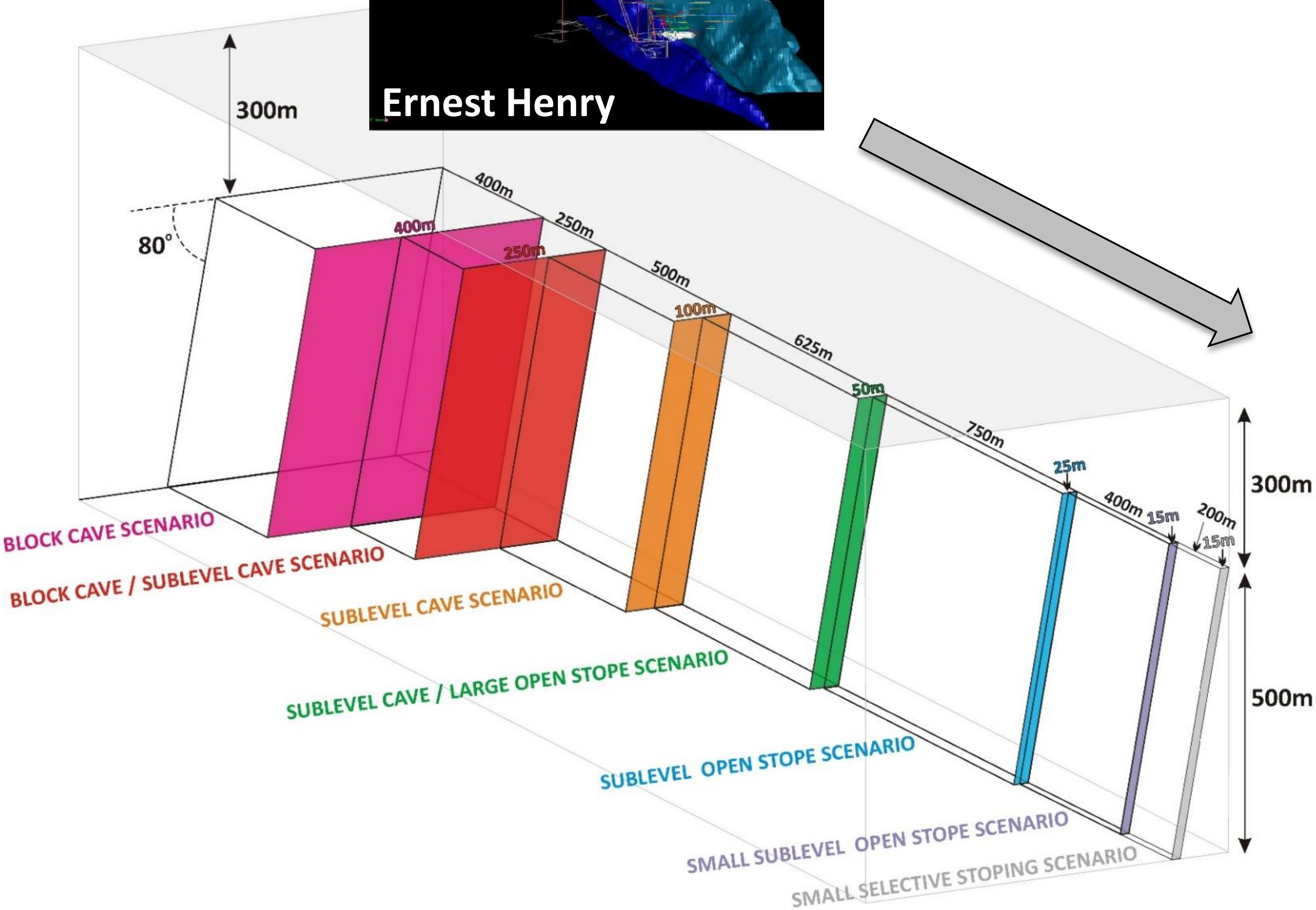

In-ground Value of a Selection of Metalliferous Deposit Types (Metal Prices as at 14/3/2017)
Bubble Size Indicates Relative Value of Deposits Using the Product of Unit Value and Resource Tonnage
Value (USD) of Contained Metal per Tonne
Total Resource Tonnage (million tonnes)
$900
$800
$700
$600
$500
$400
$300
$200
$100
$0
1.0
10.0
100.0
1000.0
10000.0
Hercules
Que Rr
Hellyer
Cannington
Lady Loretta
Thalanga
Rosebery
Broken Hill
Prospero
Scuddles
George Fisher - Hilton
Mt Isa Zn-Pb
Dugald Rr
Long
Woodlawn
Eloise
Miitel
Otter Juan
Gwalia Deeps
Century
McArthur Rr
Starra 251
Mt Elliot
Junction
Kanowna Belle
Starra 276
Jundee
Mt Isa Cu
Olympic Dam
EL Teniente
Starra 257
Rocky's Reward
Osborne
Resolution
Kulthor
Starra 244
Wallaby
NorthParkes
Carrapateena
Bronzewing
Blair
Starra 222
Perseverance
Black Swan
CAVING LINE
Mt Dore
EH
PH
Telfer
Ridgeway
SWAN
Mt Keith
Cadia East
Andina

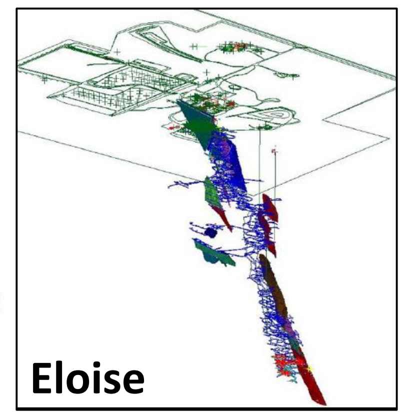

$900
$800
$700
$600
$500
$400
$300
$200
$100
$0
Value (USD) of Contained Metal per Tonne
1.0
10.0
100.0
1000.0
10000.0
Total Resource Tonnage (million tonnes)
VHMS
BHT
SHMS
OROGENIC Au
ISA Cu
IOCG - GAWLER
PORPHYRY
WA - NiS
IOCG - CLONCURRY
Bubble Size Indicates Relative Value of Deposits Using the Product of Unit Value and Resource Tonnage
Transition into Mass-Mining
Wallaby
NorthParkes
Carrapateena
Telfer
Perseverance
EH
PH.
Resoluti
t Dore
Ridgeway
Mt Keith
SWAN
Cadi
100.0
1000.0



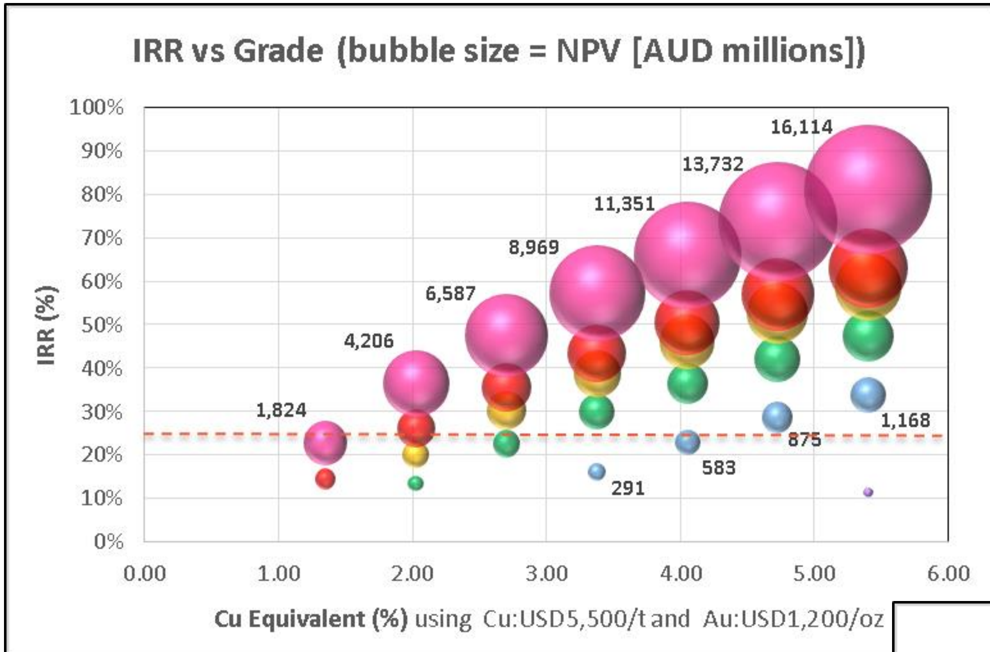
# PEET-UG used in anger…..on simulated data



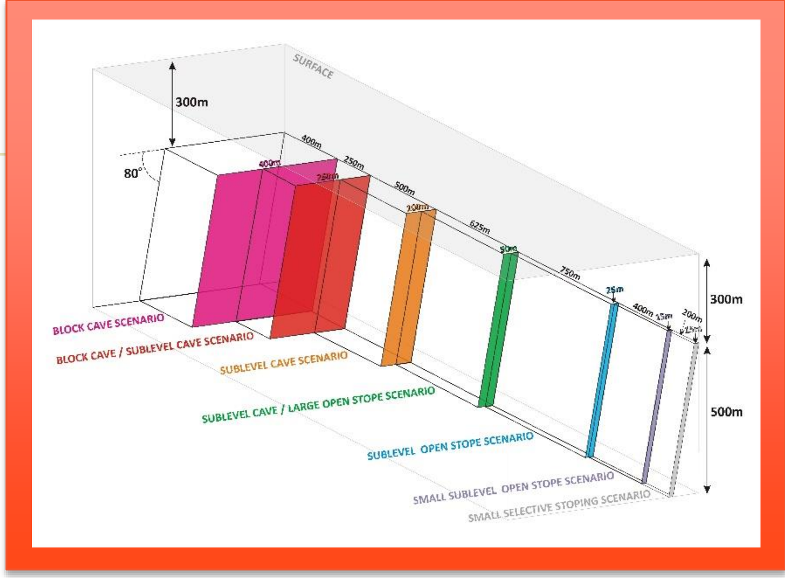

# Financial measures vs grade/-tonnage/geometry (mining method)



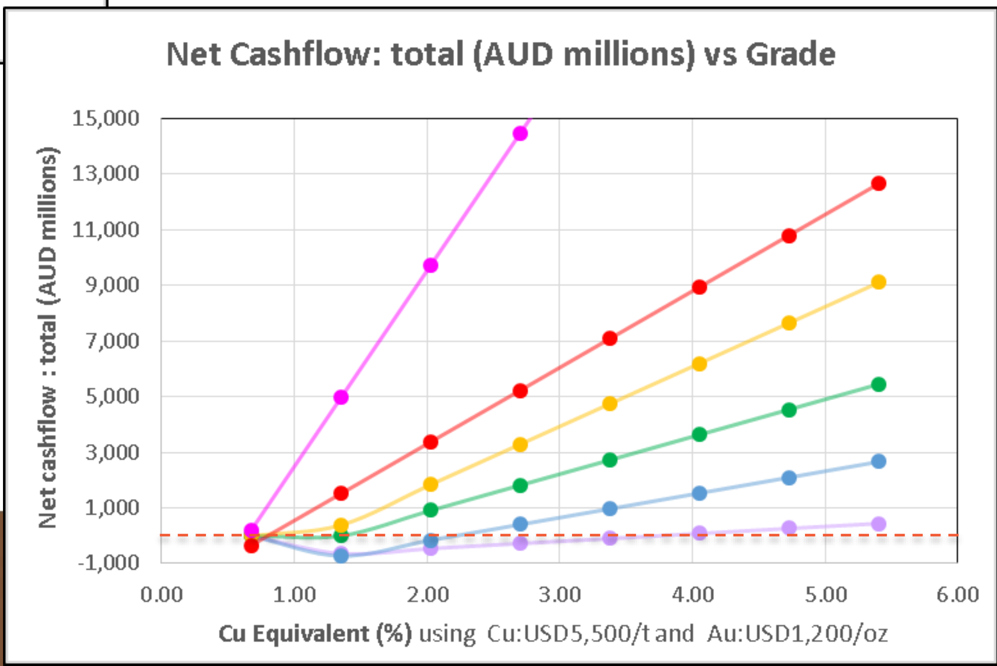

Above, Internal rate of return (IRR) vs grade. Bubble colour corresponds with geometry/mining-block (see image in top RH corner of slide). Bubble size is proportional to NPV, some annotated. Bigger target = more tonnes = higher value. Dashed line represents the 25% IRR 'target' outcome (AP pers. comms, 2016).

*Parameters:*

- *300m depth to top of deposit*
- *80 degree dip*
- *CuEq calculation assumed Cu at USD$5500/t, and Au at USD$1200/oz, and a 20k:1 ratio of Cu:Au, as broadly observed in IOCG systems.*




Below, net-cashflow (total) vs grade. Dashed line = 0 cashflow. SLOS methods achieve negative cashflows at grades where caving methods are profitable.

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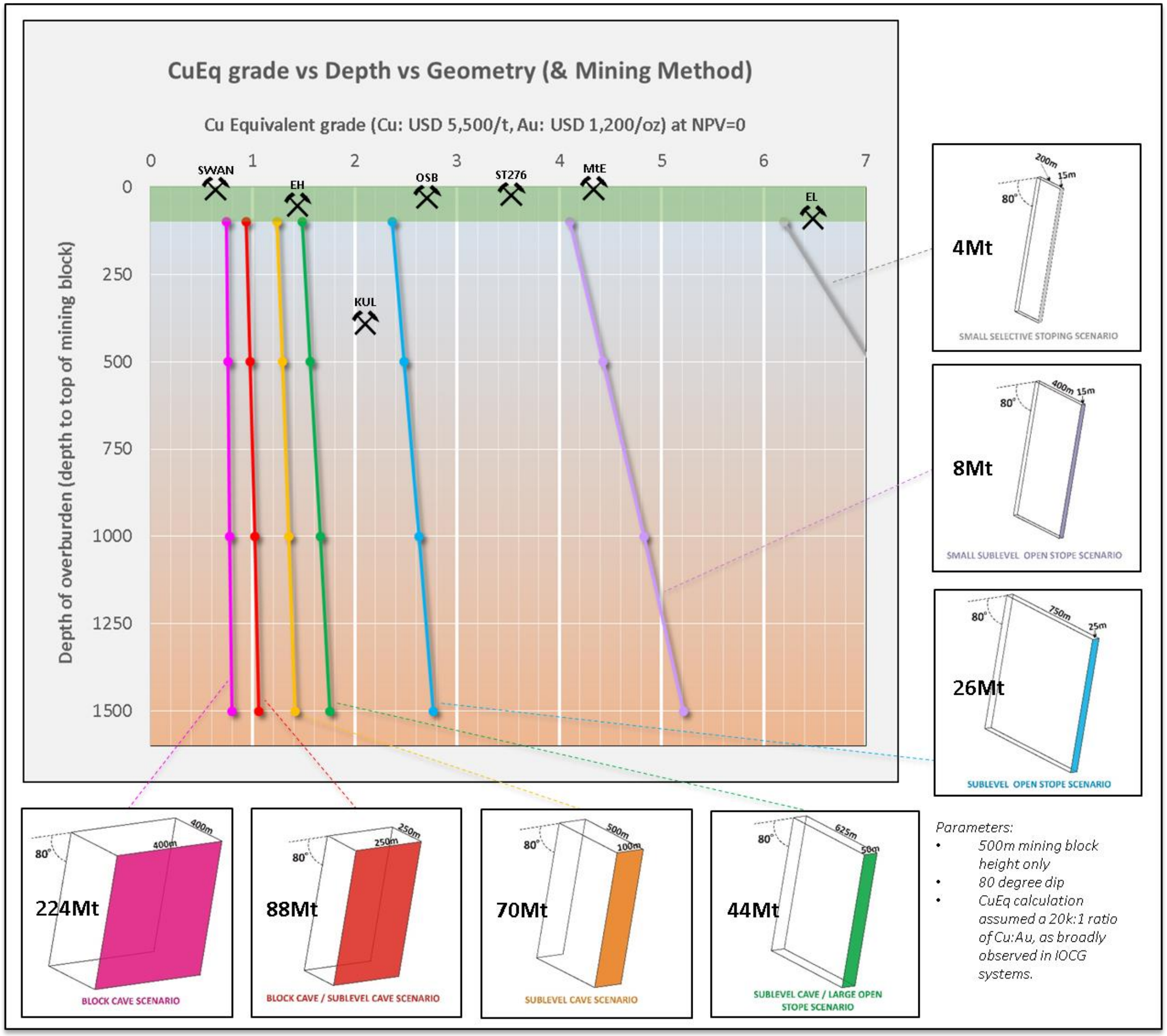
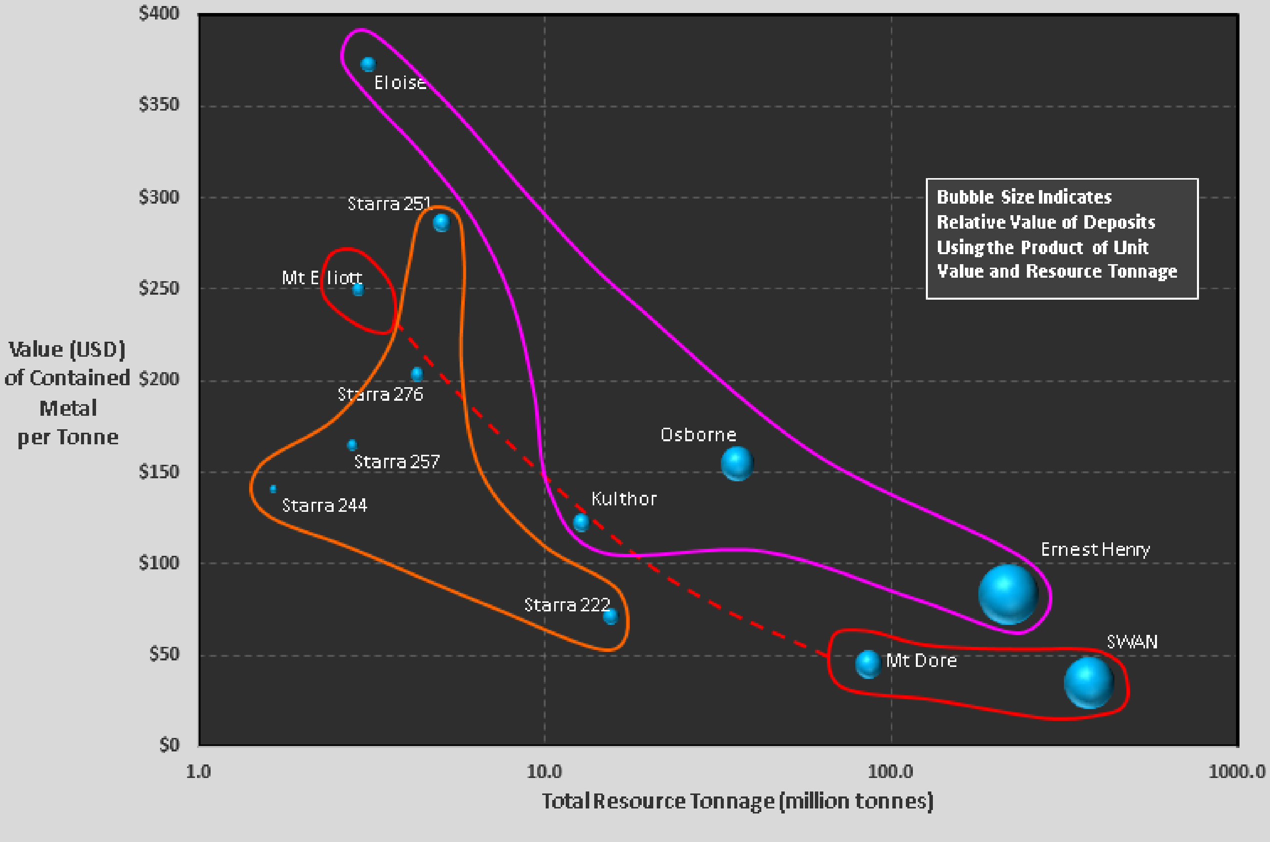
# Indicative ‘cut-off’ grades by mining method/orebody geometry




## Key observations:

- Depth insensitivity of Block and Sub-level Caving scenarios.
- SWAN occurs left of its corresponding geometry curve (orange) and is uneconomic in the assumed price environment
- Eloise, despite being significantly higher grade, would likely be sub-economic if the top of the ore-reserve was 250m below surface.
- The more selective and development intensive (per tonne of mined ore) stoping methods have a shallower gradient to their CuEq vs Depth curve. Extensions to these mines with depth, carries additional costs; and these costs are amortised across fewer tonnes mined and metal produced.
- Kulthor is well to the left of its corresponding geometry curve (purple) and was economically extracted as it was an incremental expansion of an existing mine and utilized existing processing facility. Discovery of a Kulthor-analogue away from this infrastructure would likely be sub-economic.

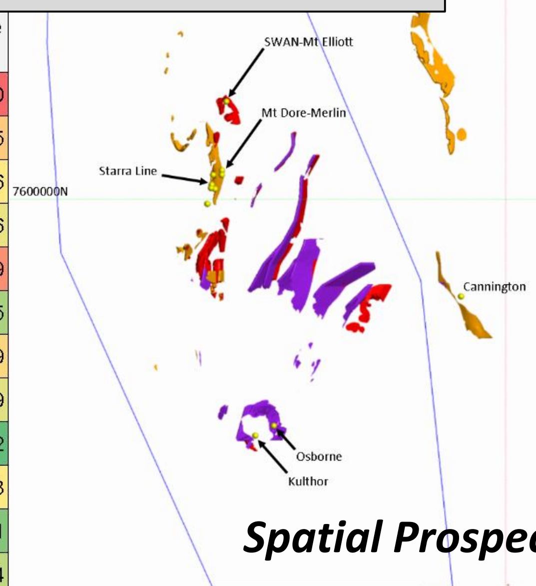


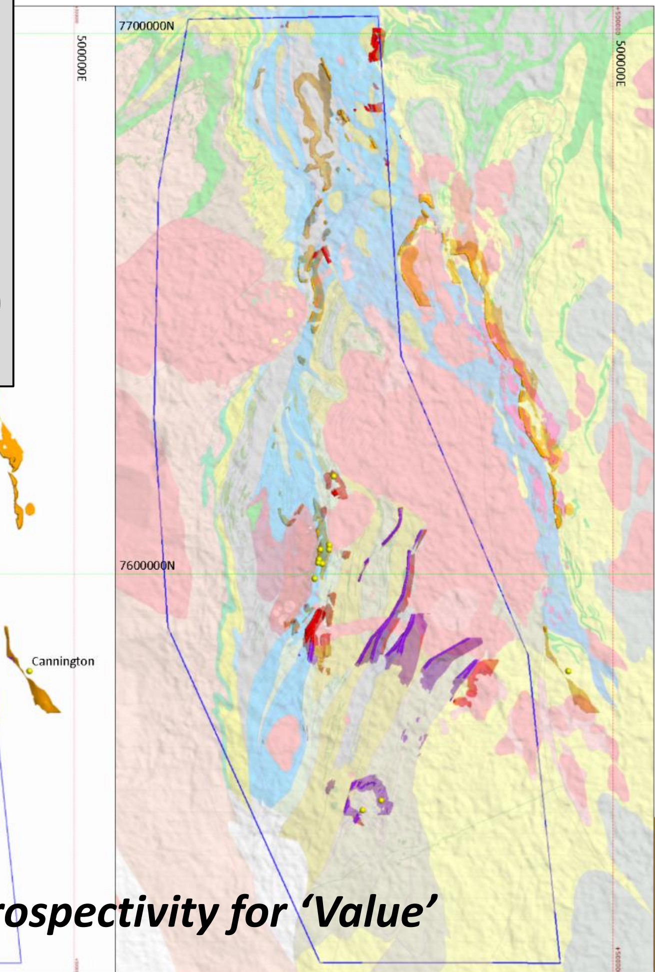

# Are some Cloncurry Cu-Au deposits more prospective than others?

Polygons represent grouping of Cloncurry Cu-Au deposits based on the following deposit-styles:

- Orange polygon: Structural juxtaposition with Staveley Fmn;
- Red polygon: Staveley/Kuridala contact domain,
- Magenta polygon: deposits well into the hangingwall of the Staveley Fmn.

| Deposit | Tonnes | Cu (%) | Au (ppm) | Cu_Eq (%) | Value/t ($AUD) | Total Value ($m) |
|---|---|---|---|---|---|---|
| Ernest Henry | 220,000,000 | 1.1 | 0.5 | 1.4 | $83 | $18,280 |
| Osborne | 36,000,000 | 2.0 | 1.0 | 2.7 | $155 | $5,565 |
| Kulthor | 12,800,000 | 1.5 | 1.0 | 2.1 | $122 | $1,566 |
| Eloise | 3,100,000 | 5.5 | 1.4 | 6.4 | $373 | $1,156 |
| SWAN (resource) | 375,000,000 | 0.4 | 0.3 | 0.6 | $35 | $13,189 |
| Mt Elliott | 2,900,000 | 3.3 | 1.5 | 4.3 | $250 | $725 |
| Mt Dore (resource) | 86,500,000 | 0.6 | 0.1 | 0.8 | $45 | $3,879 |
| Starra 222 | 15,500,000 | 0.6 | 1.0 | 1.2 | $72 | $1,109 |
| Starra 244 | 1,650,000 | 0.7 | 2.6 | 2.4 | $141 | $232 |
| Starra 251 | 5,040,000 | 2.3 | 3.9 | 4.9 | $286 | $1,443 |
| Starra 257 | 2,800,000 | 0.7 | 3.3 | 2.8 | $165 | $461 |
| Starra 276 | 4,300,000 | 2.7 | 1.2 | 3.5 | $203 | $874 |

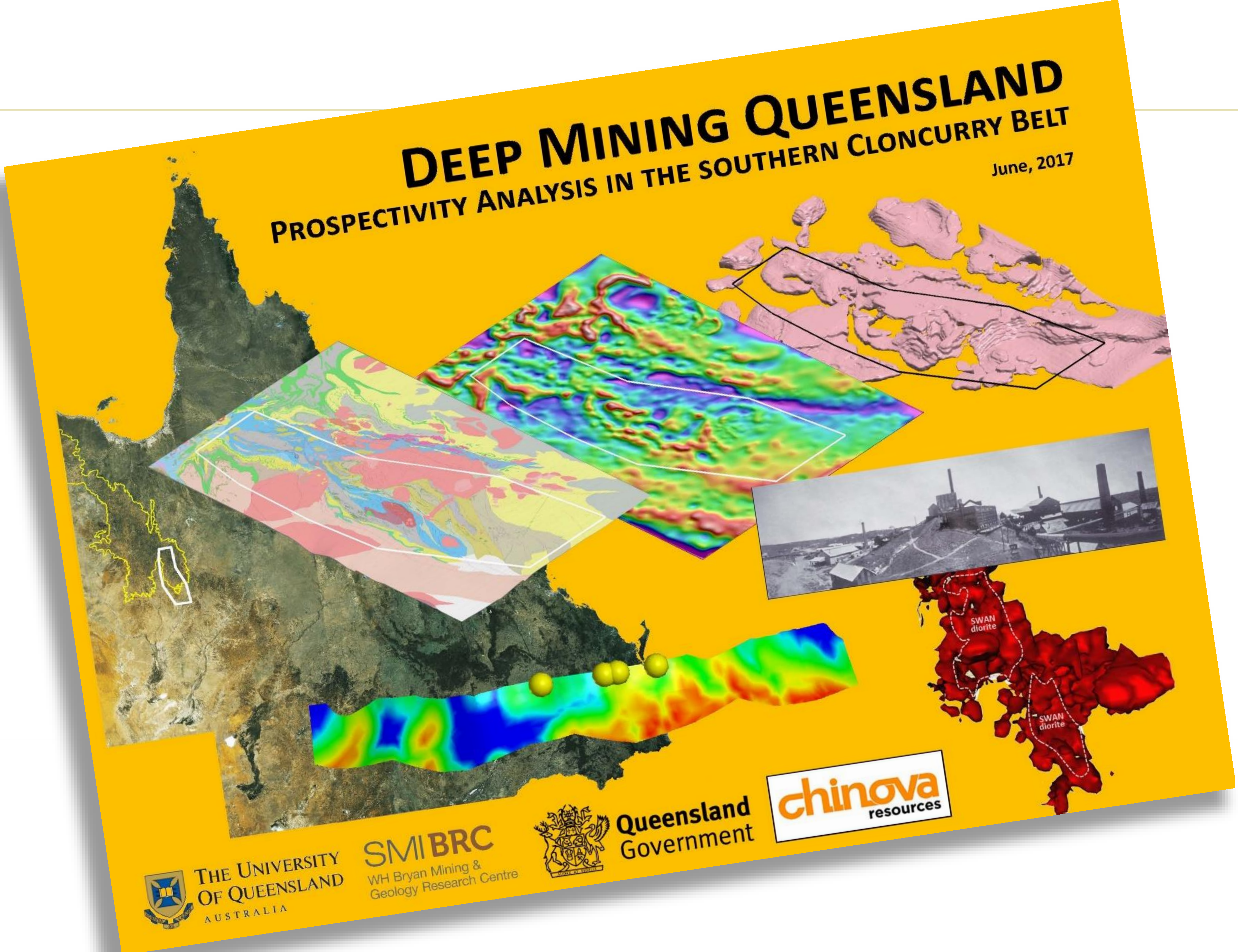



***Spatial Prospectivity for 'Value'***

# CONCLUSIONS

- Deeper/covered exploration is a reality
- Traditional pre-competitive data not always sufficient in covered areas
- Geological understanding derived from geophysics and known nearby analogous geology will be the key driver for exploration targeting
- The DMQ project  has comprised a holistic approach to prospectivity for deeper deposits within the Cloncurry district through enhanced understanding of IOCG systems, improvement to the geological knowledge, provision of tangible geoscience products, and complemented with a prospect assessment tool.
- Potential for DMQ results to have a material impact on future exploration of the Cloncurry district, particularly in the deeper search space.

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