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
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).
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.
Subsurface geometry of the granites has an empirical relationship with clusters of mineral occurrences at surface.
Prospective domains identified....now what?

Looking NW

Intersection of structure and prospective host stratigraphy domains

Williams-age intrusives

Kulthor

Starra ‘Line’

SWAN-Mt Elliott

Merlin-Mt Dore

Osborne
Evaluation by Project Stage

Pre-Concept/Scoping-Study Evaluation

WHAT ARE WE LOOKING FOR?

HOW DOES IT MEASURE UP?

TARGET GENERATION

DISCOVERY

Multidisciplinary Project Evaluation

SCOPING STUDY

WHAT COULD IT BE?

PREFEASIBILITY STUDY

WHAT SHOULD IT BE?

FEASIBILITY STUDY

WHAT WILL IT BE?

PROJECT COMMITMENT

PREPARATION AND THE INVESTMENT DECISION

DELIVER THE PROJECT

EXTRACT THE VALUE

Company-specific practices

Established Processes and Guidelines

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

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

<table>
<thead>
<tr>
<th>Depth b.s.</th>
<th>Width (m)</th>
<th>Grade (%Cu)</th>
<th>Tonnes (Mt)</th>
<th>Value/t ($)</th>
<th>Profit/t ($)</th>
<th>NPV ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200m</td>
<td>200m</td>
<td>200m</td>
<td>200m</td>
<td>200m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12.5m</td>
<td>25m</td>
<td>50m</td>
<td>100m</td>
<td>100m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.6</td>
<td>4.8</td>
<td>2.4</td>
<td>1.2</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5</td>
<td>10.5</td>
<td>20.8</td>
<td>41.5</td>
<td>86.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$528</td>
<td>$264</td>
<td>$132</td>
<td>$66</td>
<td>$33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$202</td>
<td>$68</td>
<td>$22</td>
<td>$0.1</td>
<td>-$4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$408m</td>
<td>$219m</td>
<td>$53m</td>
<td>$0m</td>
<td>$0</td>
<td></td>
</tr>
</tbody>
</table>

Parameters:
- 500m mining block
- Flank only
- 60 degree dip
- Cu/Au calculation assumed a 20:1 ratio of Cu:Au as broadly observed in IOCG systems.
Where is the money?..... same depth & width but differing grade

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

Parameters:
- 500m mining block
- 80 degree dip
- Cu/Au calculation assumed a 20:1 ratio of Cu/Au, as broadly observed in IOCG systems.
Where is the money?..... same width & grade but differing depth

<table>
<thead>
<tr>
<th>Depth b.s.</th>
<th>Width (m)</th>
<th>Grade (%Cu)</th>
<th>Tonnes (Mt)</th>
<th>Value/t ($)</th>
<th>Profit/t ($)</th>
<th>NPV ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$22</td>
<td>$53</td>
</tr>
<tr>
<td>300m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$20</td>
<td>$25</td>
</tr>
<tr>
<td>400m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$17</td>
<td>$0</td>
</tr>
<tr>
<td>500m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$27</td>
<td>$80</td>
</tr>
<tr>
<td>600m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$27</td>
<td>$66</td>
</tr>
<tr>
<td>700m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$26</td>
<td>$53</td>
</tr>
<tr>
<td>800m</td>
<td>50m</td>
<td>2.4</td>
<td>20.8</td>
<td>$132</td>
<td>$25</td>
<td>$39</td>
</tr>
</tbody>
</table>

Parameters:
- 500m mining block
- Freight only
- 60° degree dip
- Cu:Au calculation assumed a 20:1 ratio of Cu:Au, as broadly observed in IOCG systems.
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.

Underground Mining Infrastructure

\[ y = -0.2068x^2 + 11.264x + 26.281 \]
\[ R^2 = 0.9994 \]

Process Plant Capex

\[ y = -0.249x^2 + 22.497x + 62.756 \]
\[ R^2 = 0.9996 \]
Key workings of PEET-UG

1. Inputs & Assumptions
   - Grade Distribution
     - Grade
     - Dip
     - Width
     - S.G.
     - Distance to transport hubs
     - Strike-length
     - Down-dip Extent
     - Depth of Cover
     - Length of new road required
     - Mining & Met. recovery
     - Metal prices
     - Discount rate
     - Exchange rate

2. Derived Quantities
   - Tonnage
   - In-ground value
   - Contained metal
   - Mine capex estimates
   - Mining rate potential
   - Mining advance rate
   - Haulage distances
   - Tonnes/vertical metre
   - Opex estimates (Mining + Geology + Processing + Admin)

3. Mining Method Selection
   - SLOS vs SLC vs BC determined by deposit geometry, dip, min. block height, in-ground ‘ore’ value
   - Potential mining block height
   - Truck vs Conveyor test (determined by depth below surface and production rate)

4. Project & Prodtn. Schedule
   - Mine development by year
   - Production by year
   - Schedule of ore processed and recovered metal
   - 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
- Lateral development
- Mobile equipment
- Infrastructure and services
- Processing Plant
- 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
- NPV calculation
- IRR calculation
- Maximum negative cash position
- Time to payback
- EBITDA
- Net Cashflow
Results: comparison with peer projects

Collated key inputs and outputs on single sheet

Summary of Results | Charts

Result Check: Mined/Processed Tonnes (bubbles) and Grades Against Peer Projects

Result Check: Production Rate vs Ore Reserve

Not intended for critical financial or feasibility analysis
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)
Transition into Mass-Mining
PEET-UG used in anger.....on simulated data
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.
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.

### Table: Deposit Characteristics

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Tonne</th>
<th>Cu (%)</th>
<th>Au (ppm)</th>
<th>Cu_Eq (%)</th>
<th>Value/ (SAUD)</th>
<th>Total Value (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernest Henry</td>
<td>220,000</td>
<td>1.1</td>
<td>0.5</td>
<td>1.4</td>
<td>$83</td>
<td>$18,280</td>
</tr>
<tr>
<td>Osborne</td>
<td>36,000</td>
<td>2.0</td>
<td>1.0</td>
<td>2.7</td>
<td>$155</td>
<td>$5,665</td>
</tr>
<tr>
<td>Kulthor</td>
<td>12,800</td>
<td>1.5</td>
<td>1.0</td>
<td>2.1</td>
<td>$122</td>
<td>$1,566</td>
</tr>
<tr>
<td>Eloise</td>
<td>3,100</td>
<td>5.5</td>
<td>1.4</td>
<td>6.4</td>
<td>$373</td>
<td>$1,156</td>
</tr>
<tr>
<td>SWAN (resource)</td>
<td>375,000</td>
<td>0.4</td>
<td>0.3</td>
<td>0.6</td>
<td>$35</td>
<td>$13,189</td>
</tr>
<tr>
<td>Mt Elliott</td>
<td>2,900</td>
<td>3.3</td>
<td>1.5</td>
<td>4.3</td>
<td>$250</td>
<td>$725</td>
</tr>
<tr>
<td>Mt Dore (resource)</td>
<td>86,500</td>
<td>0.6</td>
<td>0.1</td>
<td>0.8</td>
<td>$45</td>
<td>$3,879</td>
</tr>
<tr>
<td>Starra 222</td>
<td>15,500</td>
<td>0.6</td>
<td>1.0</td>
<td>1.2</td>
<td>$72</td>
<td>$1,109</td>
</tr>
<tr>
<td>Starra 244</td>
<td>1,650</td>
<td>0.7</td>
<td>2.6</td>
<td>2.4</td>
<td>$141</td>
<td>$232</td>
</tr>
<tr>
<td>Starra 251</td>
<td>5,040</td>
<td>2.3</td>
<td>3.9</td>
<td>4.9</td>
<td>$286</td>
<td>$1,443</td>
</tr>
<tr>
<td>Starra 257</td>
<td>2,800</td>
<td>0.7</td>
<td>3.3</td>
<td>2.8</td>
<td>$165</td>
<td>$461</td>
</tr>
<tr>
<td>Starra 276</td>
<td>4,300</td>
<td>2.7</td>
<td>1.2</td>
<td>3.5</td>
<td>$203</td>
<td>$874</td>
</tr>
</tbody>
</table>

**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.
Deep Mining Queensland
Prospectivity Analysis in the Southern Cloncurry Belt

June, 2017

Coming to a QDEX near you in June 2017!