Application of GlyLeach™ to Heaps - Early Commercialisation Opportunities

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Overview

- Background and history of GlyLeach & MPS
- Advantages of GlyLeach – General
- Commercialisation strategy
- Why heap leach suits GlyLeach
- Target projects
  - Carbonate hosted copper
  - Oxide cap
  - Gold ore with nuisance copper
  - L/G primary sulphides
  - Slag retreatment
- Research status / Development program
GlyLeach™ development history

- Curtin University Gold Technology Group, 2014
- Professor Jacques Eksteen, Dr Elsayad Oraby
- Methodically investigating alternatives to cyanide for gold leaching
- Arrived at glycine as ticking all the boxes
- Soon realised broader potential of alkaline glycine as a leaching reagent for:
  - Copper
  - Nickel
  - Cobalt
  - Zinc
  - Lead
- MPS – global, exclusive license to commercialise GlyLeach

- Leach performance
- Non-toxic
- Water-soluble
- Stable
- Non-volatile
- Re-usable
- Low cost
- Available in bulk
- Control/complexity
Why GlyLeach?

- **Selectivity:**
  - Leach: Cu, Ni, Co, Zn, Pb, Au...
  - Ignore: Fe, Mn, CO$_3$...

- **Alkaline environment:**
  - Co-leach base + precious metals
  - Cheap materials of construction
  - Heaps: Enables cement agglomeration

- **Conventional downstream**
  - SXEW, sulphide ppt, carbon adsorption
  - No detox

- **Re-usable reagent**
  - Return barren solution directly to leach
Commercialisation Strategy

- We are NOT competing with gold cyanidation
- We are NOT competing with copper smelting / POX, etc
- We ARE offering a way to treat deposits where no conventional economic process route exists:

Copper ores
- High acid consumption

Gold ores
- High cyanide consumption
Why GlyLeach + Heap Leach?

- **Recovery:**
  - Time is on our side
  - High pH enables cement agglomeration

- **Operating cost:**
  - Lower reagent concentration & consumption

- **Capital cost**
  - Lower barrier to commercialisation

- **Simplicity**
  - Combination of conventional Cu & Au heap leach
  - Reagent re-cycle inherent in process
  - Operate well within solubility limits

- **Testing & piloting**
  - Extended closed cycle columns – Effectively test the chemistry
Heap Leach Process Concept

- Lime / cement
- Feed ore
- Glycine makeup
- Cyanide
- Lime
- Agglom
- Heap leach Stage 2
- Heap leach Stage 1
- Solvent Extraction
- Carbon adsorption
- Electrowinning
- Cu cathode
- Bleed
Target #1: Carbonate hosted copper

- Malachite and other Cu oxides leach ready in GlyLeach
- Carbonate gangue (calcite, magnesite etc) are completely inert

<table>
<thead>
<tr>
<th>Acid leach</th>
<th>GlyLeach</th>
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| • >400kg/t acid consumption  
  • Severe heap instability  
  • Several long neglected projects | • Glycine regenerated  
  • Cement agglomeration + no gangue dissolution = stable heaps  
  • Very robust economics |
Target #2: Oxide cap

- Strip to access sulphides – Mining cost sunk
- Typical target:
  - Cu: Good grades, mostly oxides / secondary sulphides
  - Au: low grade, but significant
- Poor physical properties - High clay

<table>
<thead>
<tr>
<th>Acid leach</th>
<th>GlyLeach</th>
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<tbody>
<tr>
<td>• Agglomeration ineffective</td>
<td>• Cement agglomeration</td>
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<tr>
<td>• Gold value squandered</td>
<td>• Add CN for gold</td>
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<tr>
<td>• Acid consumption high</td>
<td>• Glycine/lime cost low</td>
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ALTA 2017
Target #3: Gold with nuisance copper

- **Au**: 0.7 g/t
- **Cu**: 0.15%
- GlyLeach + cyanide Vs. conventional cyanide
- 4 – 5 fold reduction in cyanide consumption
- Catalytic effect
- Eliminate detox

![Graph](image)

- GlyLeach: CN: 0.32 kg/t
- Straight cyanide: CN: 1.52 kg/t
Target #4: Primary copper sulphides

- Below mill feed grade
- Limited, but promising data
- Chalcopyrite dissolves “slowly” in GlyLeach, but:
  - Much faster than acid/ferric bio-leach
  - Steady rate – less flattening out due to surface layers
  - Opportunities to optimise
Target #5: Copper slag

- Chilean smelter slag – decades old stockpile
- 8.9Mt @ 1.15% Cu, 0.12 g/t Au (dissolved + entrained)
- GlyLeach works after fine grinding…but costly
- Preliminary economics support heap leaching
Status of R&D

- **Ongoing Research:**
  - Curtin University: Fundamental chemistry, specific details
  - MPS: Project focussed, amenability testing
  - Small scale
  - Short duration (mostly)
  - Idealised conditions

- **Pathway to commercialisation:**
  - Address unknowns / risks
  - Larger scale/longer duration
  - Mimic commercial conditions
  - Support with process engineering / economics
Heap Leach R&D Program

- 2 year program
- Consortium including industry partners, Curtin University, MPS
- Project mission:
  - Fundamental rate limitations
  - Extensive closed-cycle column leach tests
  - Process engineering / flowsheet models / economic evaluations

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<th>Develop</th>
<th>Detail</th>
<th>De-risk</th>
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| Leach extraction – crushed, cement agglomerated | Realistic reagent consumption  
Optimum crush size, reagent conc, irrigation rate, temperature etc…  
Circuit configuration / downstream options | Process robustness - multiple ore types  
Reagent durability  
Solution chemistry / impurity levels  
Saturation / precipitation  
Water balance / Solution management |