Mobile processing plant to reinvigorate small capital gold mining

Paul Breuer | Gold Processing Team Leader
MetFest 2017
Outline

1. CSIRO overview
2. Thiosulfate as an alternative to cyanide
3. Mobile low capex gold processing demonstration project
Who we are

People ~5000

Sites 55

Business Units 9

Budget $1B+

We develop ~750 postgraduate research students with our university partners
CSIRO: Australia’s innovation catalyst

5000+ staff across 54 sites

Australia’s largest patent holder (1862 patents)

Top 1% of global research institutions in 14 of 22 research fields

Working with 1200+ SMEs every year

Inventors of wifi and soft contact lenses (and so much more)

64% of our people hold uni degrees.

2000+ hold PhDs

500+ hold Masters

2800+ industry partners totaling $220M+ per year

159 Aussie companies started from CSIRO technology

130 active licences
World-class facilities and connections

GLOBAL PRECINCTS

- NATURAL & ENVIRONMENTAL SCIENCES
  CANBERRA | ACT
- NATIONAL RESOURCE SCIENCES PRECINCT
  PERTH | WA
- ECOSCIENCES
  BRISBANE | QLD
- HUMAN LIFE SCIENCES
  PARKVILLE | VIC
- MANUFACTURING & MATERIALS INNOVATION PRECINCT
  CLAYTON | VIC

MAJOR INFRASTRUCTURE

- MARINE RESEARCH VESSEL
  HOBART | TAS
- ASKAP RADIO TELESCOPE
  MURCHISON | WA
- THE PAWSEY SUPERCOMPUTING CENTRE
  PERTH | WA
Mineral Resources

CSIRO’s R&D in the minerals domain:

- Budget ~$70m pa (~$30m pa external sources)
- Involves about 250 scientists and engineers
- 12 sites located in 5 states;
- Collaboration with >50 universities and other institutions, nationally and internationally;
- Engagement with >300 companies across the value chain; and
- Based on a technology vision for where the sector is going.
Mineral Resources - Our purpose...

Growing Australia's Resource base
- How do we find it?
- How do we process it?

Improving productivity
- Improve unit operations (brownfield)
- Design of new process options

Driving environmental performance
- Low energy processing
- Reduce C footprint in metal production
- AMD, tailings & rehabilitation

Resources supporting society
- Community attitudes and buy-in
Gold Processing Technologies

Cyanidation
- Cyanide speciation analysis and management
- Complex ores – characterisation and leaching
- Carbon management
- Cyanide destruction evaluations (Caro’s acid, Inco & H₂O₂)
- Cyanide recovery & recycle (SART and IX resin/carbon based processes)
- Trace element deportment (eg. mercury)

Thiosulfate based process development
- Alternative to cyanide
- New market opportunities
Thiosulfate processes for gold recovery
Many different thiosulfate based systems

Often classified by oxidant:
- Copper-ammonia
- Oxygen (+ copper)
- Other metal complexes
  - Metals such as copper, iron and nickel
  - Ligands such as organic amines, oxalate

Catalysts/additives
- Thallium and lead
- Thiourea
- sulfite

Thiosulfate consumption typically proportional to gold leach rate
Application developments

Barrick Goldstrike
- Calcium thiosulfate + copper
- Process development and on-site demonstration
- Commercial implementation in 2014

Gravity concentrates
- Copper-ammonia system able to achieve acceptable leach rates
- Developed to the pilot plant stage

In-situ (the future)
- Laboratory column evaluations conducted for specific deposits / companies
- Field trials under consideration
Additional gold recovery (small gold miners)

Combined process benefits
- High and predictable overall gold recovery
- Gold recovery risk lower – robust leach process captures gold not recovered by gravity
- Gravity recovery doesn’t have to chase the fine gold – optimise for recovery of the coarse gold
## Performance of CSIRO product (thiosulfate system)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Size (µm)</th>
<th>Head grade (g t⁻¹)</th>
<th>NaCN leach recovery</th>
<th>CSIRO product leach recovery</th>
<th>Thiosulfate consumption (kg t⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Low sulfide ore</td>
<td>$P_{90} - 74$</td>
<td>0.9</td>
<td>90% @ 24 hrs</td>
<td>90% @ 24 hrs</td>
<td>2.2</td>
</tr>
<tr>
<td>B</td>
<td>Carbonaceous ore; gold partially encapsulated</td>
<td>$P_{80} - 75$</td>
<td>1.9</td>
<td>51% @ 24 hrs</td>
<td>70% @ 24 hrs</td>
<td>1.6</td>
</tr>
<tr>
<td>C</td>
<td>Aged sulfide ore gravity tails</td>
<td>&lt; 2000</td>
<td>1.2</td>
<td>73% @ 24 hrs</td>
<td>67% @ 24 hrs</td>
<td>1.1</td>
</tr>
<tr>
<td>D</td>
<td>Oxide ore</td>
<td>&lt; 10000</td>
<td>1.4</td>
<td>59% @ 24 hrs</td>
<td>56% @ 2 days</td>
<td>1.5</td>
</tr>
<tr>
<td>E</td>
<td>Oxide ore gravity tails</td>
<td>&lt; 1000</td>
<td>2.1</td>
<td>80% (intensive cyanidation with LeachWell)</td>
<td>76% @ 7 days</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>F</td>
<td>Oxide ore; potential ISR candidate</td>
<td>&lt; 4000</td>
<td>~5</td>
<td>38% @ 24 hrs; 81% @ 7 days</td>
<td>79% @ 2 days</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Cyclic testing

- Batch leaching of gold RDE
- Tetrathionate added to mimic ore leaching

![Graph showing Au concentration over time](image)

Resin columns cycled after every 2 batch leaches
Cyclic testing

Gold breakthrough
- Required resin columns to be cycled faster
Cyclic testing

Resin elution

- Sharp gold elution profile
- > 99% Au recovery
- Tetrathionate converted to trithionate

<table>
<thead>
<tr>
<th>Sample</th>
<th>Au (g t⁻¹)</th>
<th>Efficiency (%)</th>
<th>Thiosulfate (mM)</th>
<th>Trithionate (mM)</th>
<th>Tetrathionate (mM)</th>
<th>Pentathionate (mM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preg. resin</td>
<td>3186</td>
<td>99.81</td>
<td>62</td>
<td>142</td>
<td>229</td>
<td>111</td>
</tr>
<tr>
<td>Barren resin</td>
<td>6</td>
<td>2</td>
<td>101</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Hurdles in adoption of new lixiviants for gold recovery

Proof at scale a process can economically recover gold

- Leaching and gold recovery R&D conducted but limited process development
- Reagents require recovery and recycle due to the concentrations used
  - More complex / undeveloped circuits
- Risks with scaling laboratory / pilot plant data

Process is practical and robust

- Low impact (economic and physical), including operability of the process and resources
- Able to cope with typical ore variability
- Applicable to a range of ores
Addressing the challenges

Research facility in the field
• End user / operator involvement to ensure the technology is practical and robust
• Pilot / demonstration information attained in conjunction with development at scale

Process development
• Vat leach with cyclone to remove fines
• Tank leach with thickener / filter as parallel circuit to treat fines
• Nano-filtration to aid reagent recovery and minimise water use
  – Evaporation will be adopted initially to maintain the water balance
• Plug and play modules allowing testing and development of alternative flowsheets
Mobile low capex gold processing demonstration at Menzies
Key Project Collaborator – Nu-Fortune Gold

Menzies stamp battery site
- Existing mill and gravity plant operating at 200 t/d
- Existing infrastructure
- Central location at Menzies
- Site leased from the Perth Mint
- No hurdles with approvals

Nu-Fortune Gold
- Shared vision and Entrepreneurs
- Experience in mineral processing
Demonstration Plant

Process
- Thiosulfate system developed with high reagent stability and moderate gold leach rate
- Low capex vat leach application
- 100 t/d demonstration plant
  - Construction underway and commissioning to commence soon
  - Operational January 2018 (seeking process technicians/metallurgists)
  - Multiple ore feeds, including gravity tails and battery sands

Evaluation of ores to be demonstrated
- Cyclic column leach testing and resin adsorption
- Benchmarking data for comparison with plant performance
Initial facility set-up

Key aspect is recovery and recycle of reagents from the leach tail.
Improved facility set-up

Ore

Water

SAG Mill

Screen

Oversize (+10 mm)

Gravity tails

Gravity concentrate

Water

Tank/Dam

Leach Feed

Cyclone

Vat Leach

Dewatering screen

Dry Tailings

Fines Dam

Leach Solution Processing Plant

Existing plant

New plant

Ore

Oversize (+10 mm)

Screen

Rinse Water Dam

Evaporation

PLS

BLS

Water Tank/Dam

Oversize (+0.8 mm)

Rinse Water
Leach Solution Processing Plant

Filtered Gravity tails

Vat Leach Process

Leach tails

PLS Tank or Dam

Loaded IX Resin

CSIRO Product

BLS Tank or Dam

Water

CSIRO Product

Loaded IX Resin

Barren IX Resin

Reagents

Filter

Smelt
R&D activities

Lixiviant recovery/recycle
- Optimisation of tails washing
- Process modelling to optimise washing to minimise gold and lixiviant losses within constraint of maintaining the water balance
- Monitor build-up of any potential deleterious species in the leach solution with recycle/reuse and impact on gold recovery

Gold recovery rate
- Lixiviant concentration (impacts also lixiviant recovery/recycle)
- Vat leach solution circulation rate
Bigger Vision

Research facility that allows in the field

- Development of alternative lixiviant systems
  - Various thiosulfate based
  - Glycine
  - Iodine/Iodide

- Testing and development of
  - Process flowsheets for a greater range of ores
  - Unit operations

- Application to
  - Tank leaching to treat fines
  - Vat, heap, dump, in-place and in-situ leaching
  - Combinations
Enabling / improving uptake of new technologies

- Mets sector able to test/develop innovations to improve productivity
- Researchers able to test/develop alternative lixiviants and process flowsheets
- Gold miners able to test and evaluate processes to treat their ore
Questions?

Paul Breuer
Gold Processing Team Leader

+61 8 9334 8074
paul.breuer@csiro.au