Application of the Albion Process for the treatment of refractory ores

Paul Voigt, Glencore Technology  (paul.voigt@glencore.com.au)
David Walker, Core Resources  (dwalker@coreresources.com.au)

www.albionprocess.com
Outline

1. Albion Process™ technology
2. The GPM Project
3. Performance of the Albion Process™ at GPM
4. Review of global installations
5. Albion Process™: A proven alternative
1. Albion Process™ Technology
The Albion Process is a combination of mechanical and chemical liberation.

**Ulrafine grinding:**
- IsaMill™ stirred mill:
- FeS$_2$ = 80 % passing 10 – 14 microns
- CuFeS$_2$ = 80 % passing 12 – 18 microns
- Ni$_9$Fe$_9$S$_{32}$ = 80 % passing 10 – 14 microns
- ZnS = 80 % passing 16 – 20 microns

**Oxidative Leaching:**
- Atmospheric pressure leach
- Gold Applications – pH = 5.5 (“Neutral Albion Leach”)
- Base Metal Applications – pH = 1.0 (“Acid Albion Leach”)
- Conventional baffled tank (Modular)
- Sulphate solutions - no chlorides
- Supersonic oxygen injection
Albion Process™

GOLD FLOWSHEET

1. CONCENTRATE
2. ULTRAFINE GRIND
3. ALBION LEACH
4. THICKENER
5. CIL LEACH
6. DETOX + TAILINGS
7. DORE

BASE METAL FLOWSHEET

1. CONCENTRATE
2. ULTRAFINE GRIND
3. ALBION LEACH
4. IRON PRECIPITATION
5. WASH CCD OR FILTRATION
6. TAILINGS
7. SX/EW OR PRECIPITATION

Operating plants:
- 2 x Gold
- 1 x Copper/Cobalt
- 3 x Lead/Zinc

Water, Oxygen, Limestone, Acid
1. **Neutral oxidation of pyrite and arsenopyrite before cyanidation**
   - Low grade concentrates can be used
   - As low as 6% sulphur grade sufficient to drive autothermal conditions
   - Only oxidizing as much as required to maximize recovery benefit

2. **Acid leaching of base metal concentrates**
   - Treatment of high grade cons or very low grade cons (even ore!)
   - Polymetallic feeds – PMs recovered from base metal feeds
   - Tailings projects
   - Downstream recovery of metals from solution: precipitation
   - IsaMill™ can run with raffinate to manage water balance

3. **Albion Process™ in general**
   - Existing plants can be retrofitted
   - Fixation of arsenic
   - Simple equipment that is economic at small scale / tonnes
   - Allows modularity and staged deployment
2. GPM Project - Albion Process™ Plant Project
GPM Gold – The success of a technology

Where GPM started……

• Armenian gold project, owned by GeoProMining LLC
• Open cut mine - 1 Mtpa ROM, 14.5 Mt reserves
• Historical grinding & flotation plant (1976) + CIL plant (1997)
• Oxide ores exhausted 2012
• Remaining gold units hosted with pyrite
• Incumbent flowsheet gold recovery from pyrite 20 – 30%
• Oxidation process required
GPM Gold – The success of a technology

What GPM did…..

**Study phase at Core Resources:**

- Core Resources worked with GPM to frame the resource geology/mine plan and process options.
- Detailed testwork & pilot plant.
- Managed BFS, interfacing with Glencore on detailed plant design.
- Core involved with GT in plant commissioning

**Plant designed and constructed for:**

- Gold recoveries of 95%+
- Plant tolerates highly variable throughput, sulphur grades and climate
- Treat 100ktpa concentrate
- Aggressive schedule
- Fixed price, full Glencore supply, construction supervision and commissioning
GPM Gold – The success of a technology

Process Plant Overview

Au recovery without Albion = 20%
Au recovery with Albion = 95-98%
Challenges faced.....

- Lack of skilled workforce in local area
- \(-30^\circ\text{C} \text{ to } +40^\circ\text{C}\) weather
- Russian/Armenian/English language complication
- Armenian design institute interface
- Magnitude 9 earthquake
- Brownfields location
GPM Gold – The success of a technology

What was the result....

- Commissioned in 2014
- McNulty Series 1 / 2 ramp up
- Plant producing 16% above design in 2017
- Achieving 97% recovery on Albion Process™ residue in CIL
3. GPM Project - Albion Process™ Plant Performance
GPM Albion Process™ Plant Performance

Concentrator Performance (3 years)
Albion Gold Recovery vs S Grade (3 years)
GPM Albion Process™ Plant Performance

Albion Gold Recovery vs Throughput (3 yrs)
Albion Gold Recovery vs SOx (3 years)
GPM Ramp Up – Relative McNulty Curve

Series 1-2 Performance

% of design production rate

Months since end of 6-month commissioning
3. Albion Process™ - Global Installations
Albion Process™ Installations

- 6 Albion sites
- 11 ZipaTank
- 400+ HyperSparge
Commodity – Gold
Location – Armenia
Client – GeoProMining

Refractory pyrite concentrate
116,000 ozpa gold
Commissioned June 2014

Application: Recovery of precious metals from a refractory arsenic bearing deposit within the setting of a soviet era mining complex
Las Lagunas Tailings – Albion Process™ Plant

Commodity – Gold
Location – Las Lagunas, Dominican Republic
Client – Panterra

Complex arsenopyrite/gold tailings
80,000 ozpa gold
Commissioned in 2012

Application: Albion Process required to recover gold from complex matrix in tails dam (80% recovery, up from 35%), and leave arsenic minerals inert
Copper Project – Albion Process™ Plant

Commodity – Copper
Location – Africa
Client – Glencore

Copper Concentrate
10,000 tpa copper cathode
>99 % copper recovery
Commissioning late 2017

Application: Recovery of copper and cobalt from low and medium grade concentrates in the African region containing chalcopyrite
Asturiana de Zinc – Albion Process™ Plant

Commodity - Zinc
Location – Spain
Client – Glencore

Bulk lead/zinc concentrate
4,000 tpa zinc cathode
>99 % zinc recovery
Commissioned 2010

Application: Recovery of zinc from a bulk concentrate as electrowon cathode with lead and silver in residue for smelting
Nordenham – Albion Process™ Plant

Commodity - Zinc
Location – Germany
Client – Glencore

Bulk lead/zinc concentrate
35,000 tpa zinc cathode
>99 % zinc recovery
Commissioned 2011

Application: Recovery of zinc from a bulk concentrate as electrowon cathode with lead and silver in residue for smelting

Oxidative Leach Circuit

Sparging system
Commodity - Zinc
Location – Australia
Client – Glencore

Bulk lead/zinc concentrate
150,000 tpa of cleaned zinc concentrate
Commissioned 2014

Application: Selective oxidation of galena in a bulk concentrate to chemically liberate lead from zinc
4. Albion Process™: a proven alternative
## Demonstrated Alternative

<table>
<thead>
<tr>
<th>Feature</th>
<th>Albion Process™</th>
<th>POx</th>
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</thead>
<tbody>
<tr>
<td>Demonstrated high recoveries</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Demonstrated in current operations</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Guaranteed by technology provider</td>
<td>✔</td>
<td>✔/×</td>
</tr>
<tr>
<td>Lower capital costs</td>
<td>✔</td>
<td>×</td>
</tr>
<tr>
<td>Simple equipment + low skills requirement</td>
<td>✔</td>
<td>×</td>
</tr>
<tr>
<td>Short commissioning and ramp up period</td>
<td>✔</td>
<td>×</td>
</tr>
<tr>
<td>Can treat high carbonate material</td>
<td>✔</td>
<td>×</td>
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<tr>
<td>Tolerates variable feed rate and quality</td>
<td>✔</td>
<td>×</td>
</tr>
<tr>
<td>High availability and low maintenance</td>
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Detailed advantages of Albion Process™ (Gold)

• Jacobs engineering comparison (2018):
  • POx has 45% higher CAPEX than Albion
  • POx has 65% higher OPEX than Albion

• CAPEX for Albion Process:
  • Less oxidation required (= less tanks) – just oxidise as much as required
  • Lower oxygen generation pressure – a cheaper VPSA can be used with turndown; no cryogenic oxygen plant required.
  • Less equipment – no CCD, no dedicated neutralization, no expensive autoclave

• OPEX for Albion Process:
  • Lower pressure oxygen and less of it = less power.
  • Less neutralizing agent as less oxidation
  • Downstream lower cyanide consumption (no elemental sulphur formation)

• Critically: safety, operability & availability are qualitatively better in Albion Process.
Detailed advantages of Albion Process™ - OPEX (US$/a)

- Question: What contribution to Albion Process™ opex is fine grinding?

IsaMill Power + Media = just 12% of annual operating cost!
Detailed advantages of Albion Process™ - CAPEX (US$)

- IsaMill = 27% of capital cost of project
The Future – **Currently** Active Studies
Albion Process – Project Development

Study phase well defined and understood

- Scale up now well understood, less sample and testwork required to define process.
  - Phase 1 – Amenability testwork and Class 5 Engineering Study (+/- 40%)
  - Phase 2 – Further batch testwork and Class 4 Engineering Study
  - Phase 3 – Feasibility study
- Piloting can be conducted if client requires, but not required for process guarantees.
- Study management can be provided by Core Resources (GT’s laboratory and marketing partner).
- Basic engineering conducted by Glencore Technology.

Flexible project delivery model

- Can work direct to client or through engineering companies
Information and contacts:

www.albionprocess.com

GLENCORE TECHNOLOGY

Paul Voigt
Manager – Hydrometallurgy, Glencore Technology
paul.voigt@glencore.com.au
+61 7 3833 8500

CORE

David Walker
General Manager – Integrated Solutions, Core Resources
dwalker@coreresources.com.au
+61 7 3637 8100
Thank You.
Albion Process Plant – CAPEX breakdown (US$)

- Direct Costs
- Oxygen Plant
- IsaMill
- Tanks
- Limestone Plant
- Agitators
- Miscellaneous
- Thickener
- Pumps
Albion Process Plant – OPEX breakdown (US$/a)