Application of the Albion Process for the treatment of refractory ores

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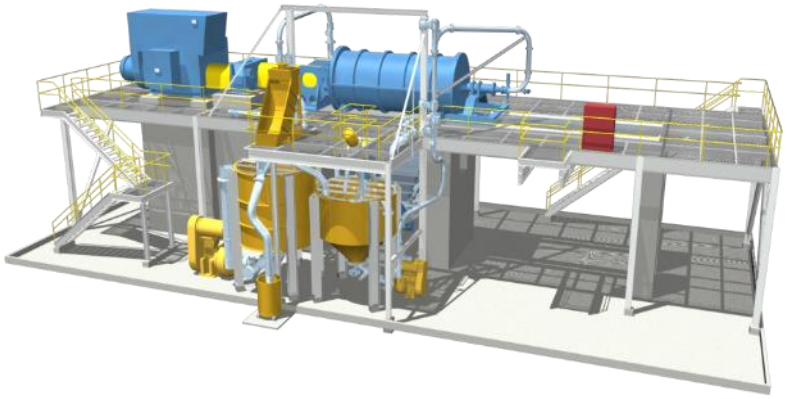
Outline

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

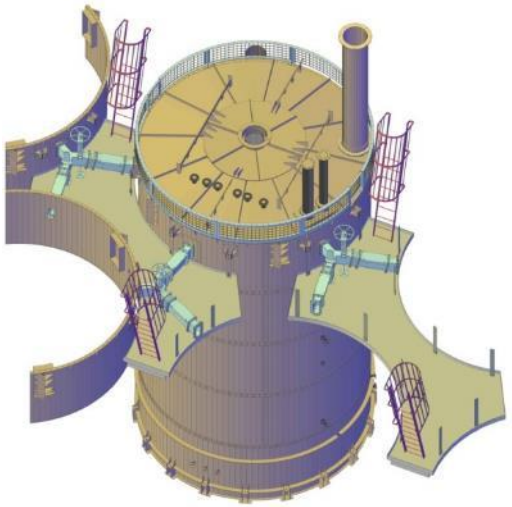
1. Albion Process™ Technology

Albion Process™

The Albion Process is a combination of mechanical and chemical liberation

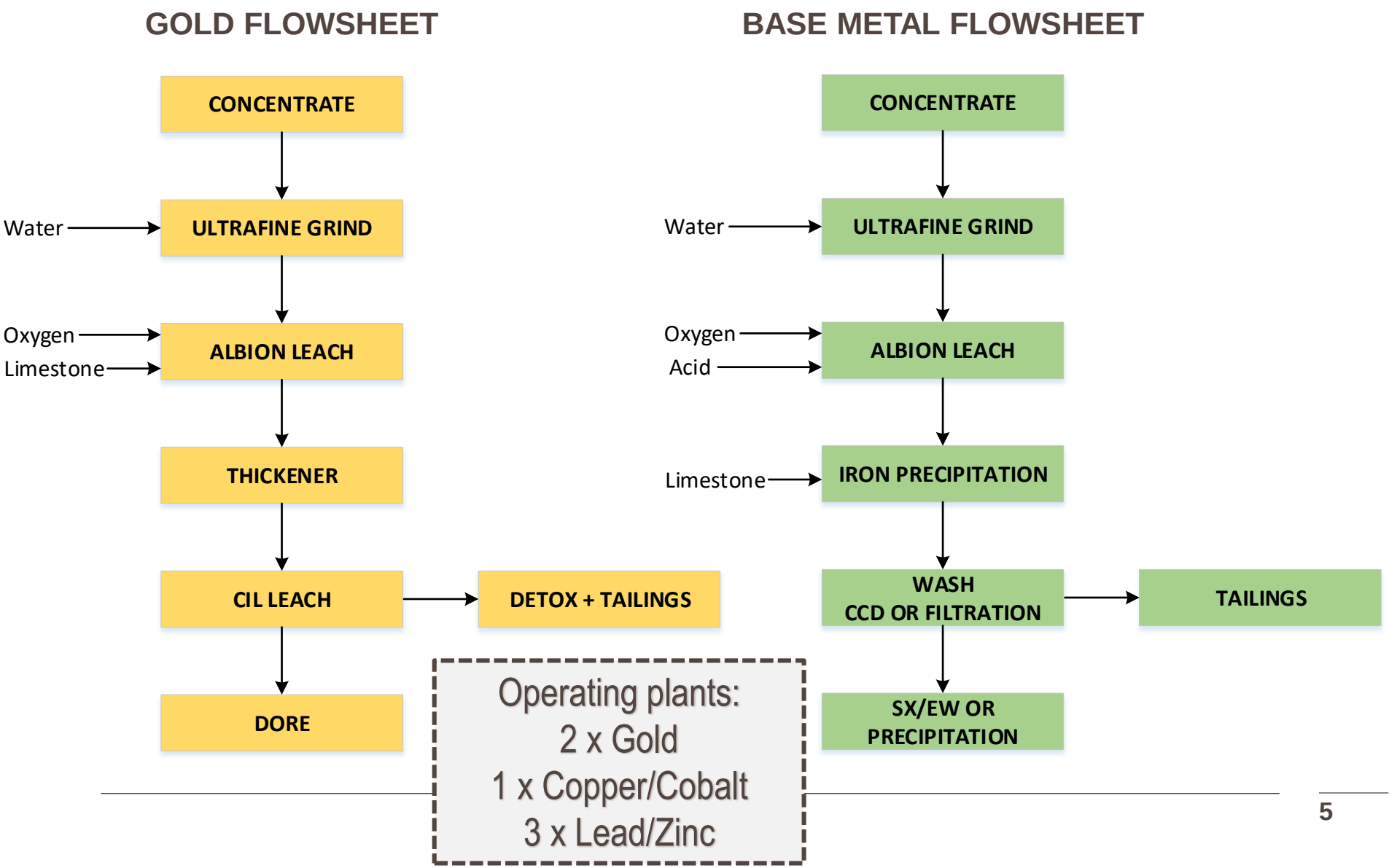


- **Ultrafine grinding:**
  - *IsaMill™ stirred mill:*
  - *FeS_2 = 80 % passing 10 – 14 microns*
  - *$CuFeS_2$ = 80 % passing 12 – 18 microns*
  - *$Ni_9Fe_9S_{32}$= 80 % passing 10 – 14 microns*
  - *ZnS = 80 % passing 16 – 20 microns*



- **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™



Albion Process™ - Wide Applications

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: precipitati
- » 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…..

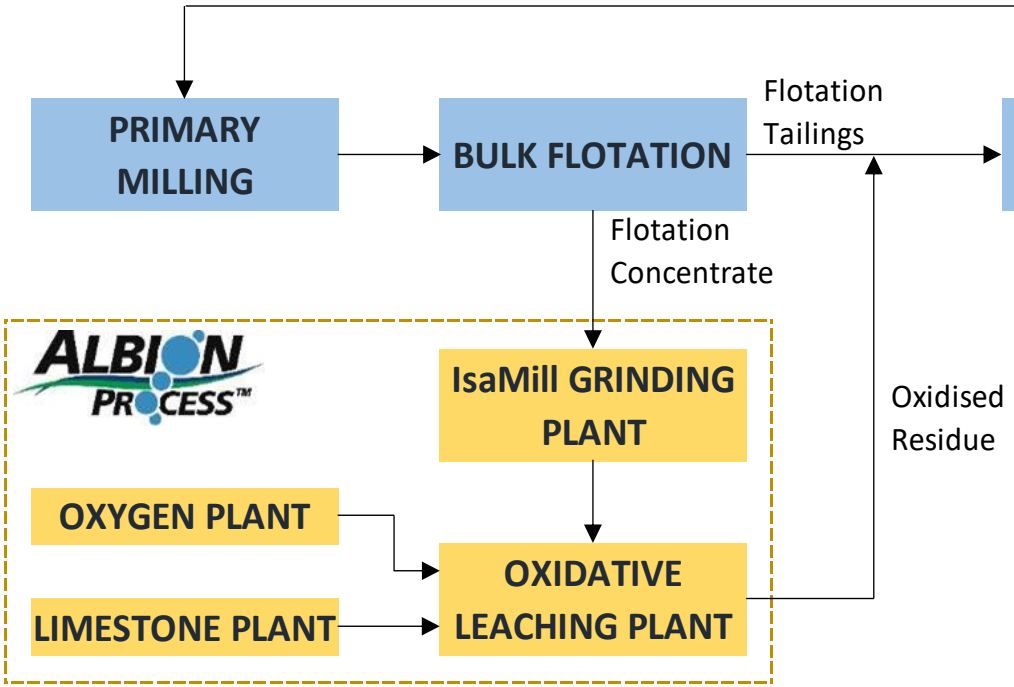
Study phase at Core Resources:

- 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

Process Plant Overview



Au recovery without Albion = 20%

Au recovery with Albion = 95-98%

GPM Gold – The success of a technology

Challenges faced…..

- Lack of skilled workforce in local area
- -30^{o}C to +40^{o}C weather
- Russian/Armenian/English language complication
- Armenian design institute interface
- Magnitude 9 earthquake
- Brownfields location

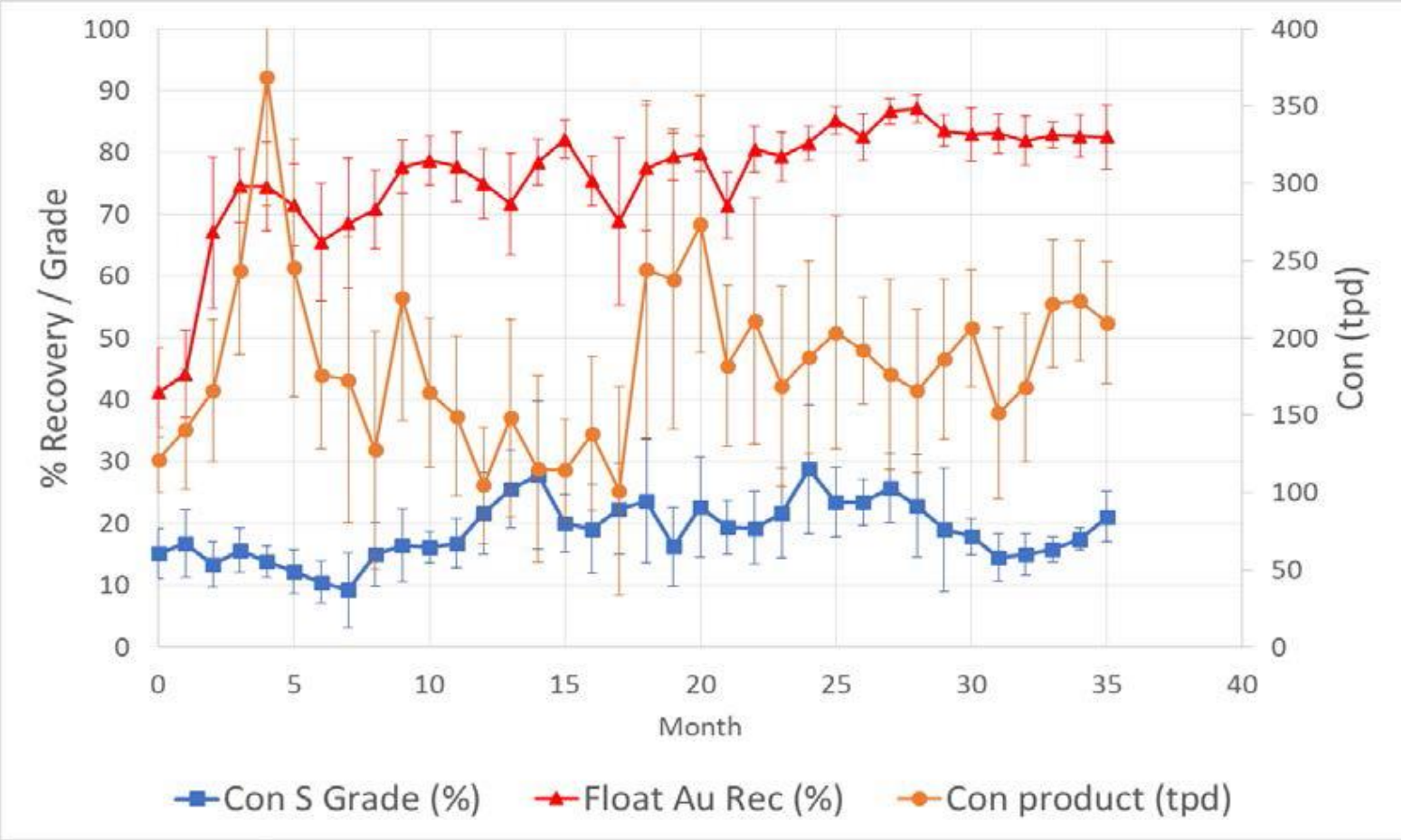
GPM Gold – The success of a technology

What was the result….

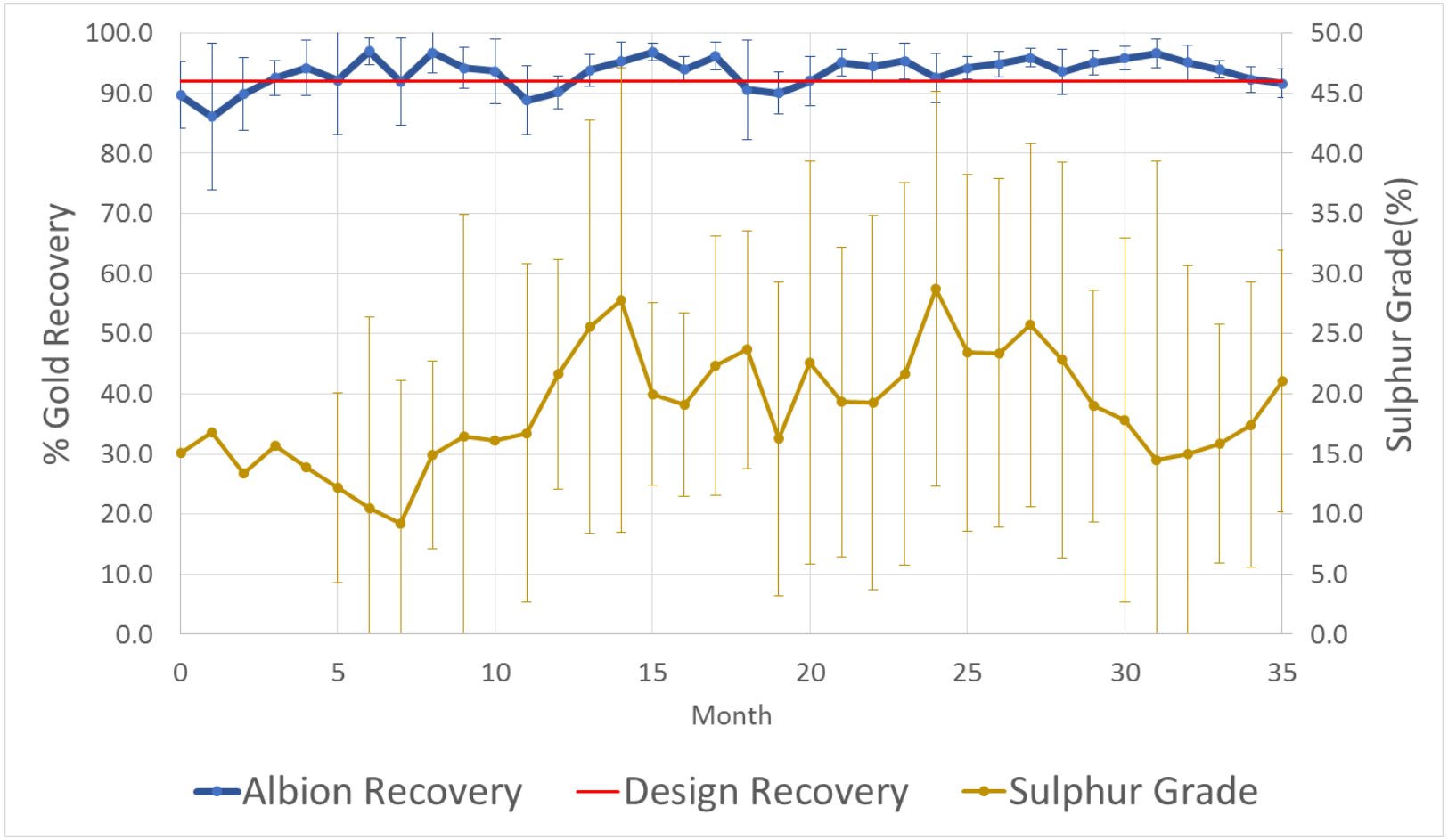
- Commissioned in 2014
- McNulty Series 1 / 2 ramp up
- Plant producing 16% above design in 2017
- Achieving 97% recovery on Albion Process™ residue in CIL

3. GPM Project - Albion Process™ Plant Performance

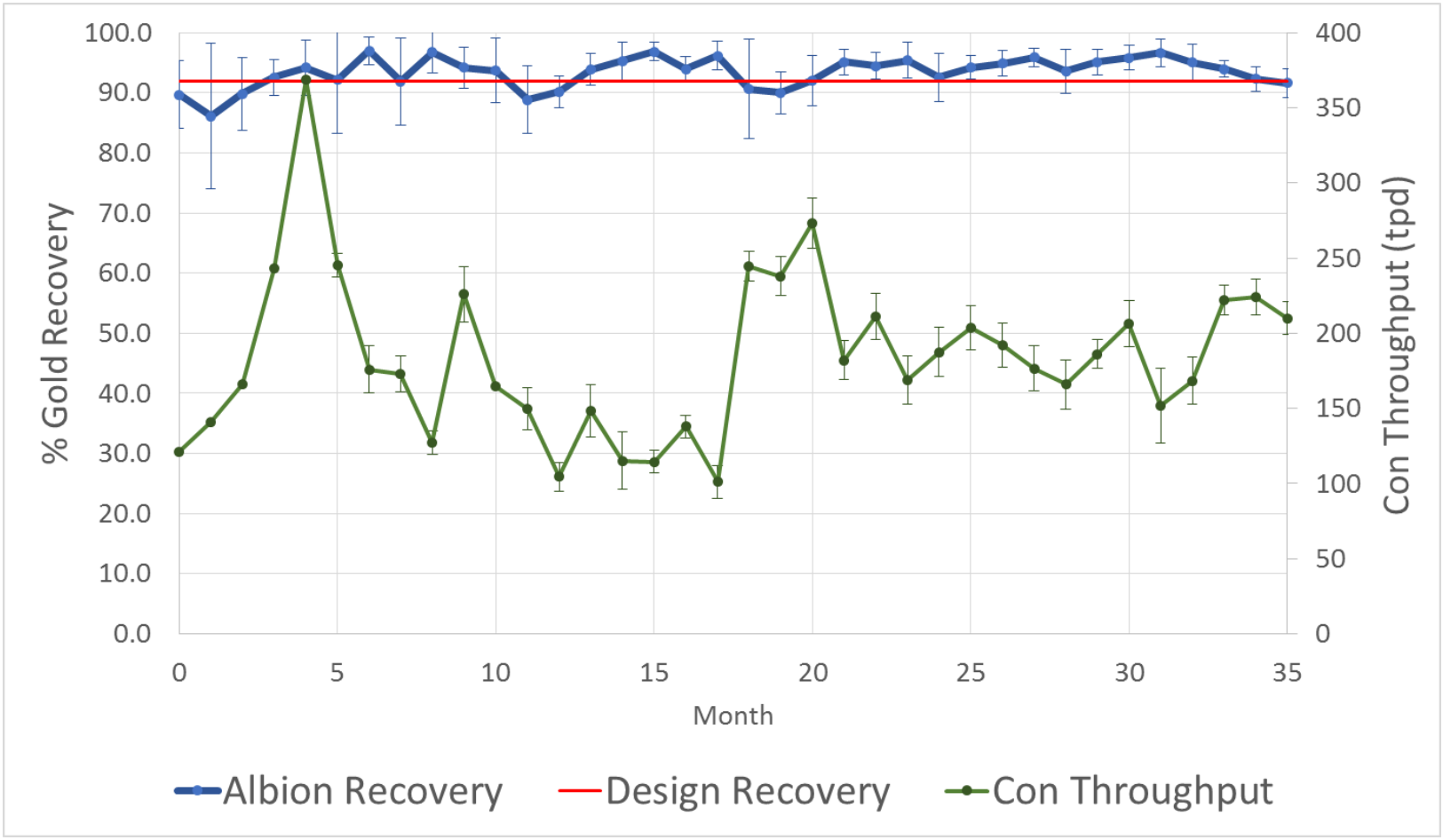
Concentrator Performance (3 years)



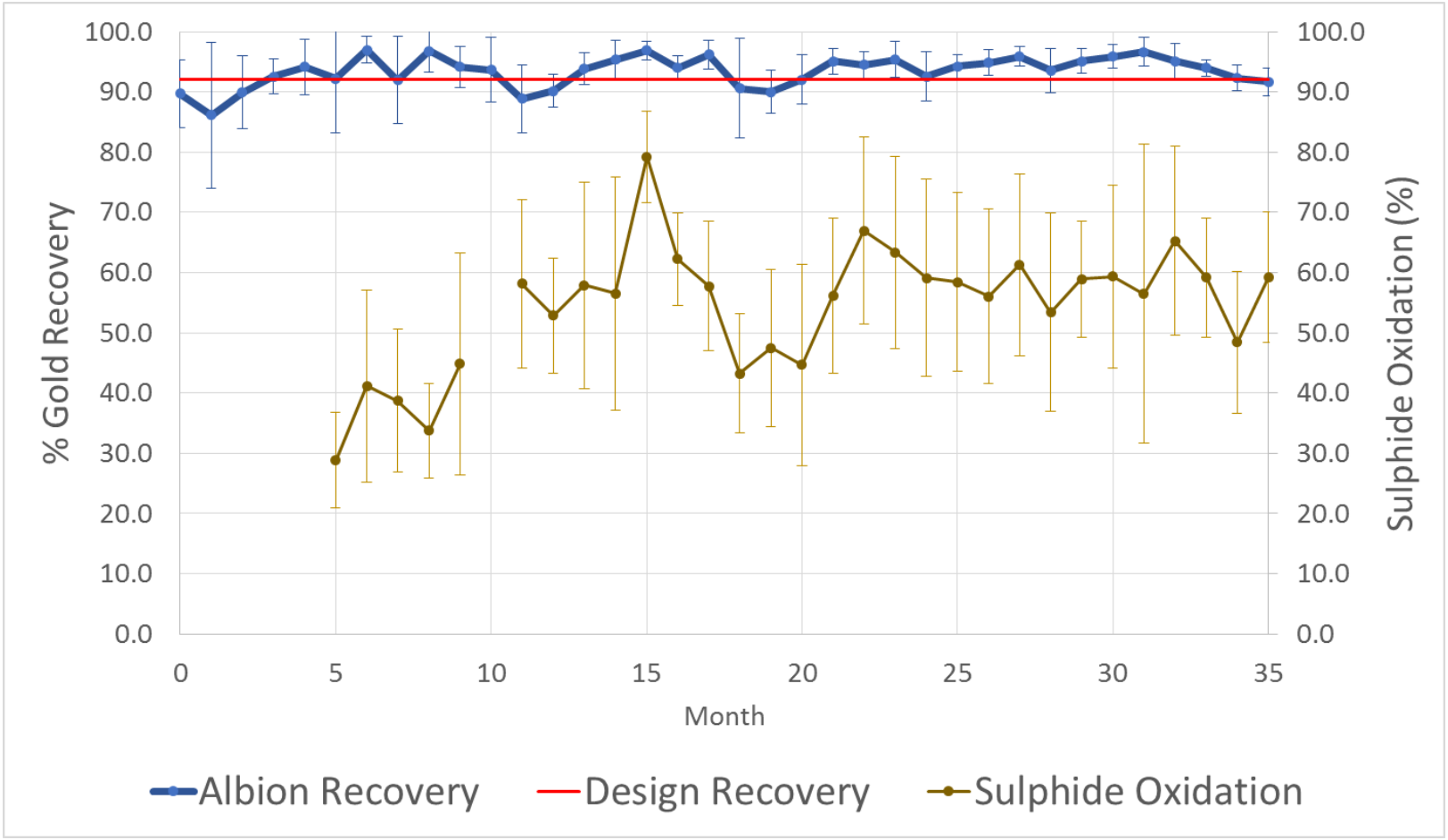
Albion Gold Recovery vs S Grade (3 years)



Albion Gold Recovery vs Throughput (3 yrs)

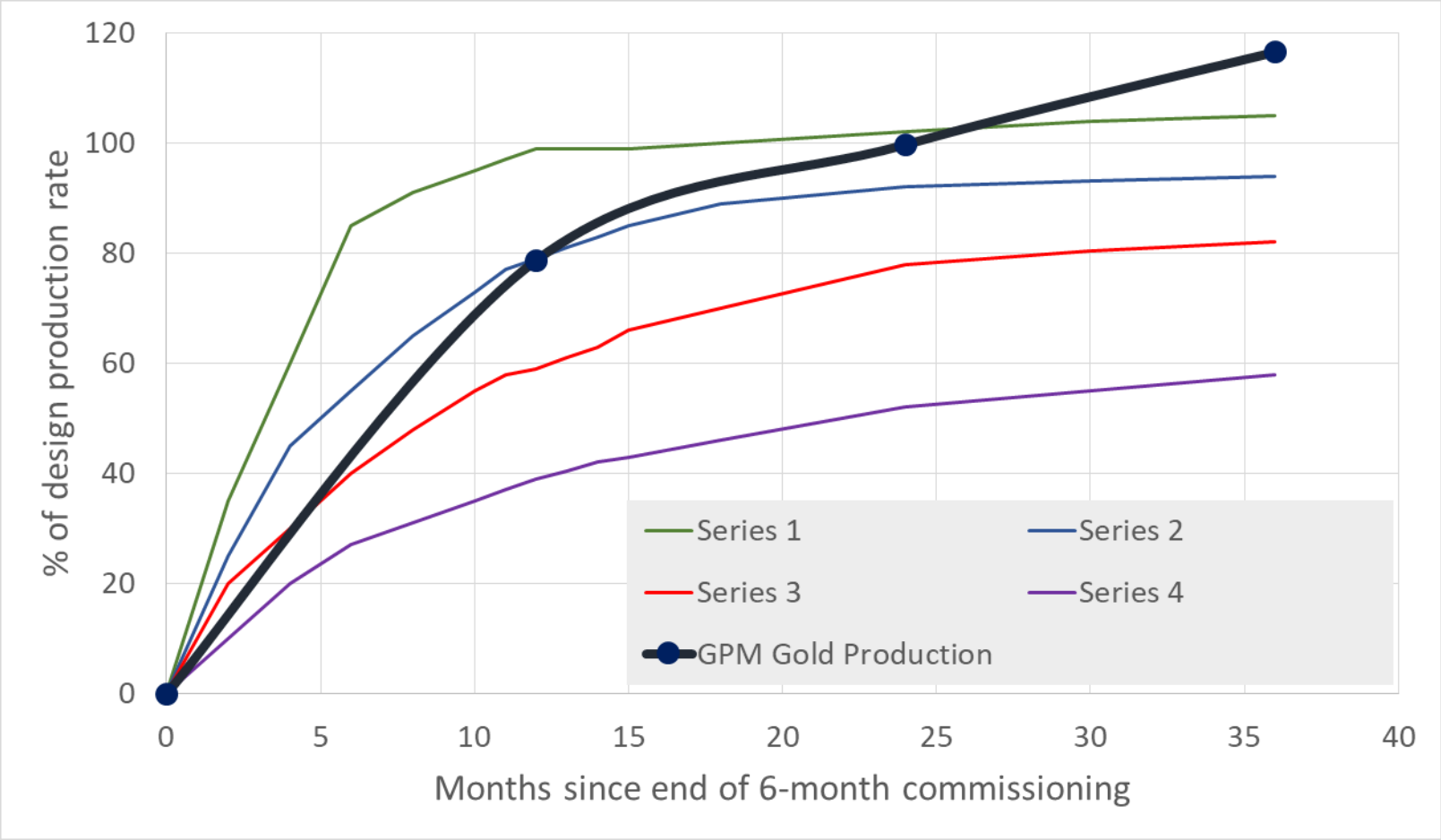


Albion Gold Recovery vs SOx (3 years)



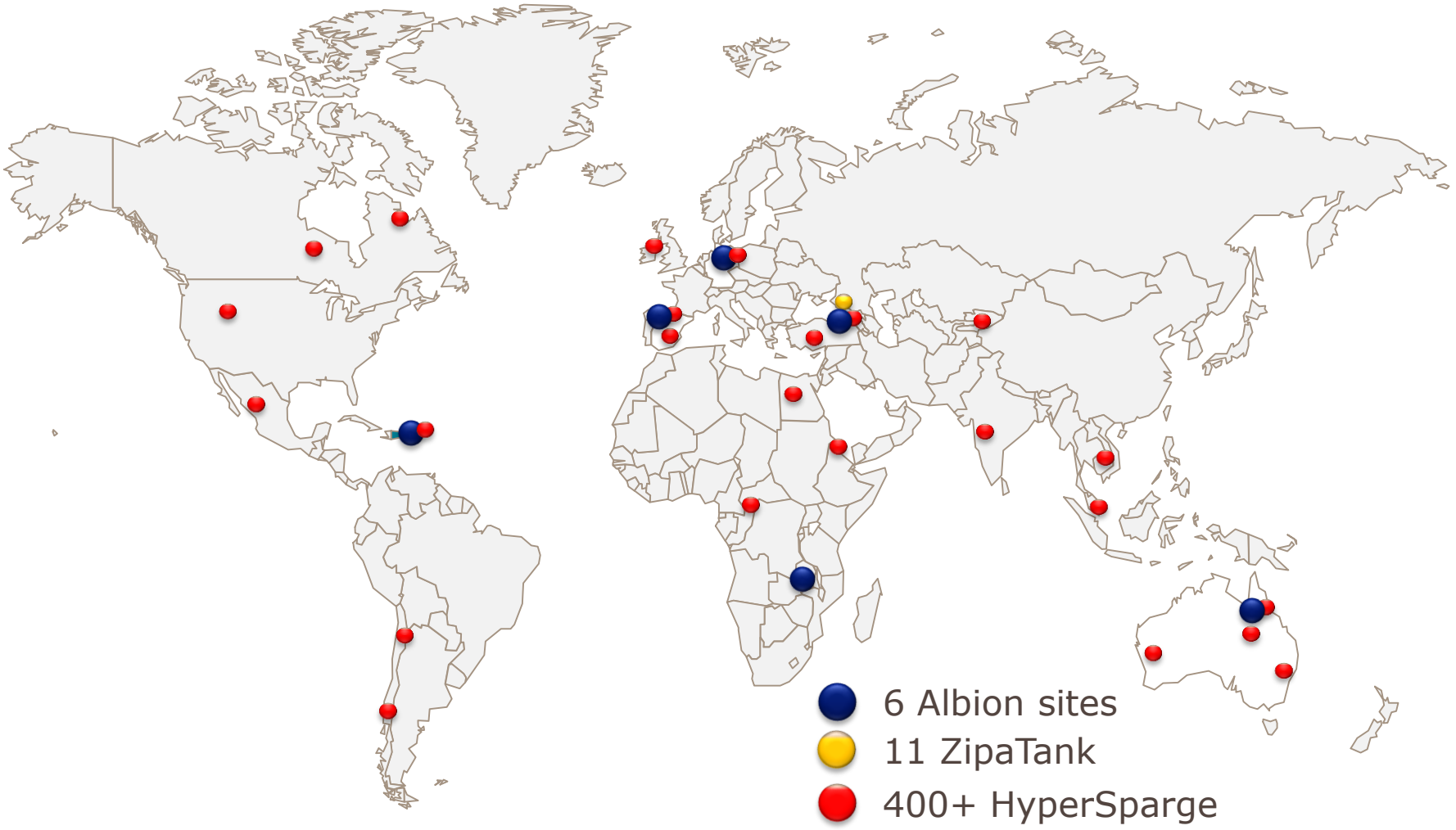
GPM Ramp Up – Relative McNulty Curve

Series 1-2 Performance



3. Albion Process™ - Global Installations

Albion Process™ Installations



GPM Gold Project – Albion Process™ Plant

Oxidative Leach Circuit

M5000 IsaMill™

Limestone Grinding Plant

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

M5000 IsaMill™ being installed

HyperSpargers™ oxygen addition

First gold pour from Albion

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

Oxidative Leach Circuit

First Copper Cathode Production

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

Oxidative Leach Circuit

Sparging systems

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

Oxidative Leach Circuit

Sparging system

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

MRM – Albion Process™ Plant

Oxidative Leach circuit

Off Gas Scrubber

HyperSparge 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

	Albion Process™	POx
Demonstrated high recoveries	✓	✓
Demonstrated in current operations	✓	✓
Guaranteed by technology provider	✓	✓/X
Lower capital costs	✓	X
Simple equipment + low skills requirement	✓	X
Short commissioning and ramp up period	✓	X
Can treat high carbonate material	✓	X
Tolerates variable feed rate and quality	✓	X
High availability and low maintenance	✓	X

Detailed advantages of Albion Process™ (Gold)

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

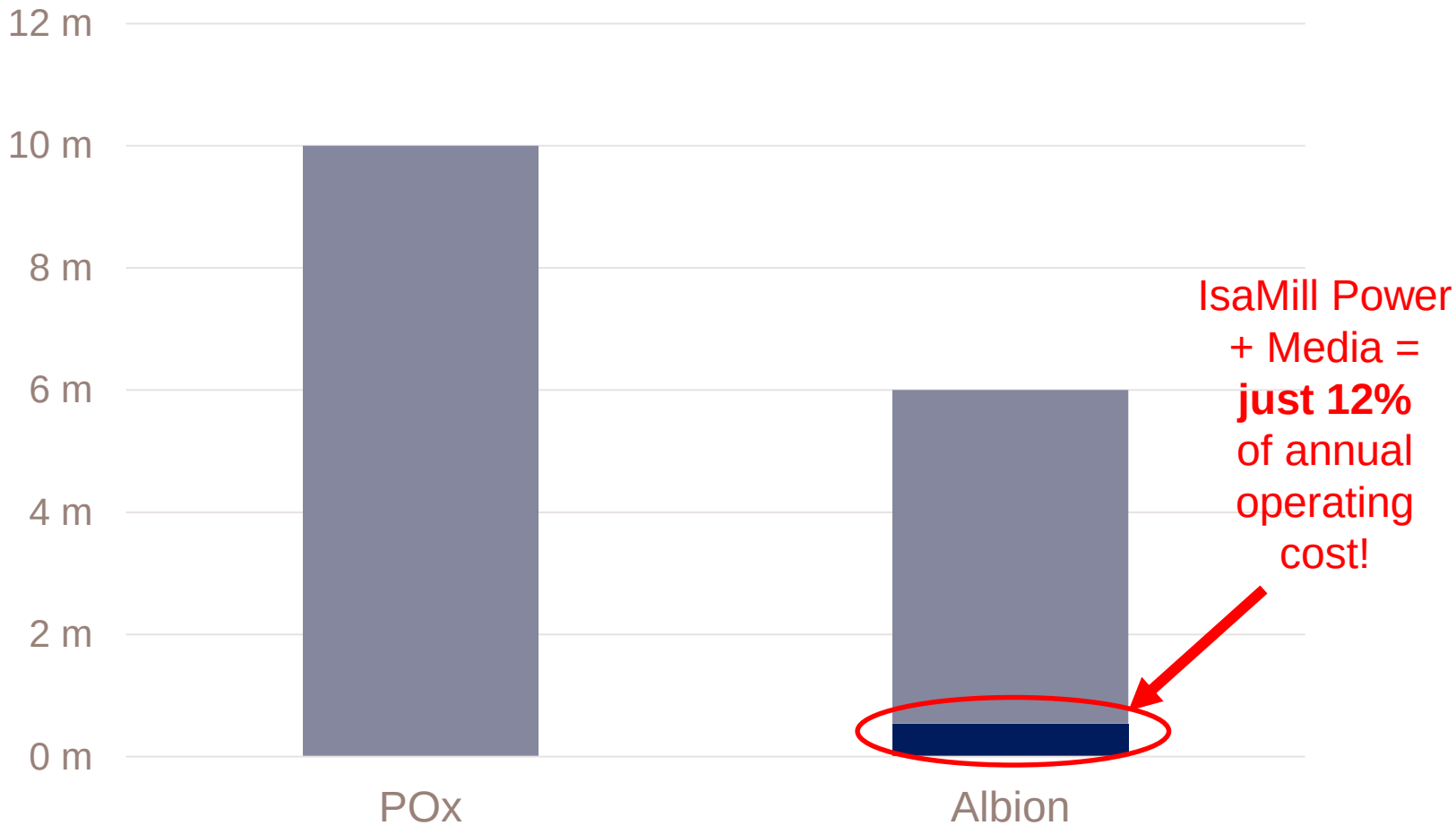
- CAPEX for Albion Process:
  - Less oxidation required (= less tanks) – just oxidise as much as required
  - Lower oxygen generation pressure – a cheaper VPSA can be used with turndown; no cryogenic oxygen plant required.
  - Less equipment – no CCD, no dedicated neutralization, no expensive autoclave

- 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)

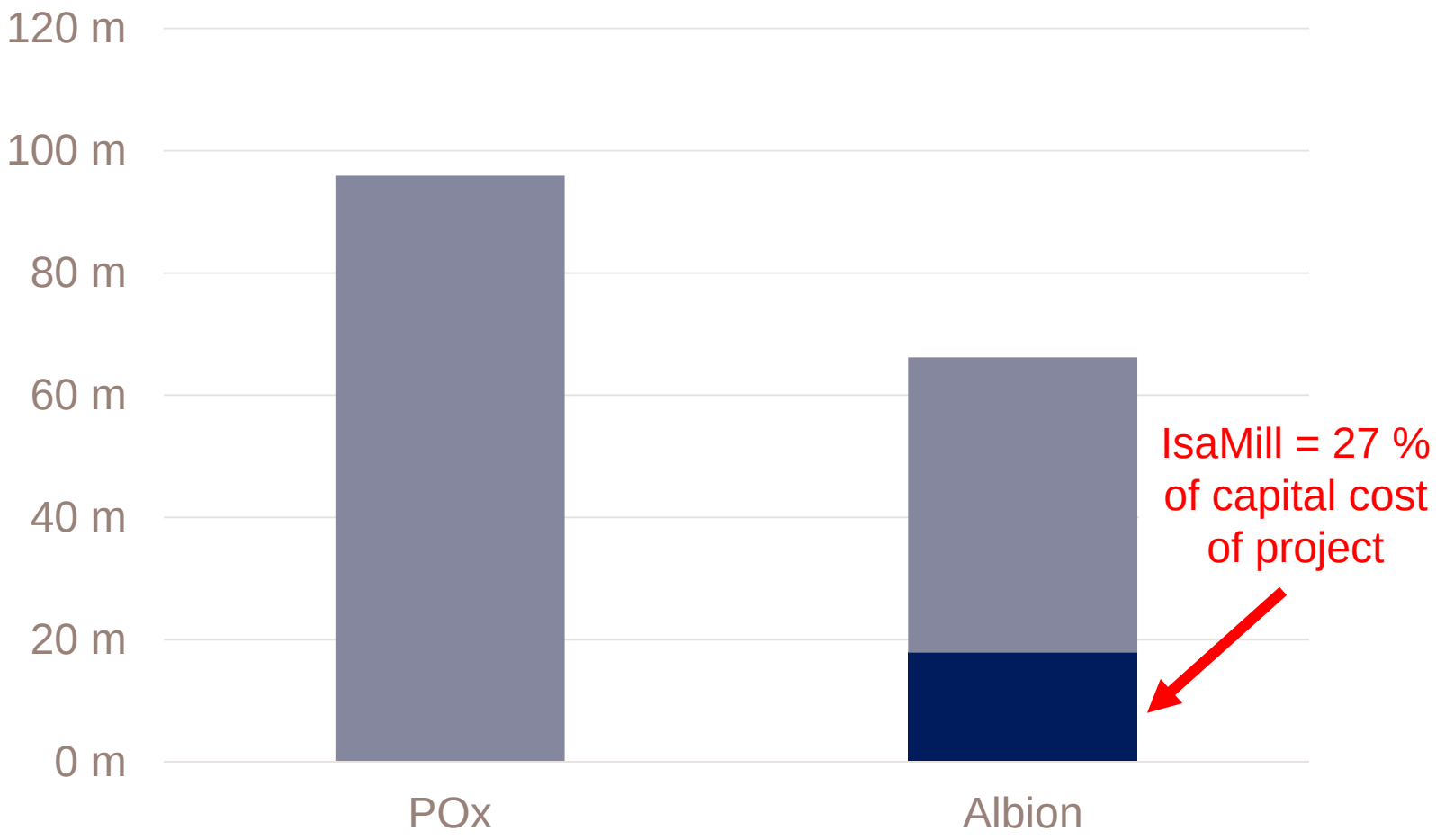
- Critically: **safety, operability & availability** are qualitatively better in Albion Process.

Detailed advantages of Albion Process™ - OPEX (US$/a)

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



Detailed advantages of Albion Process™ - CAPEX (US$)



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

GLENCORE TECHNOLOGY

Albion Process – Technology Access

Information and contacts:

www.albionprocess.com

GLENCORE TECHNOLOGY

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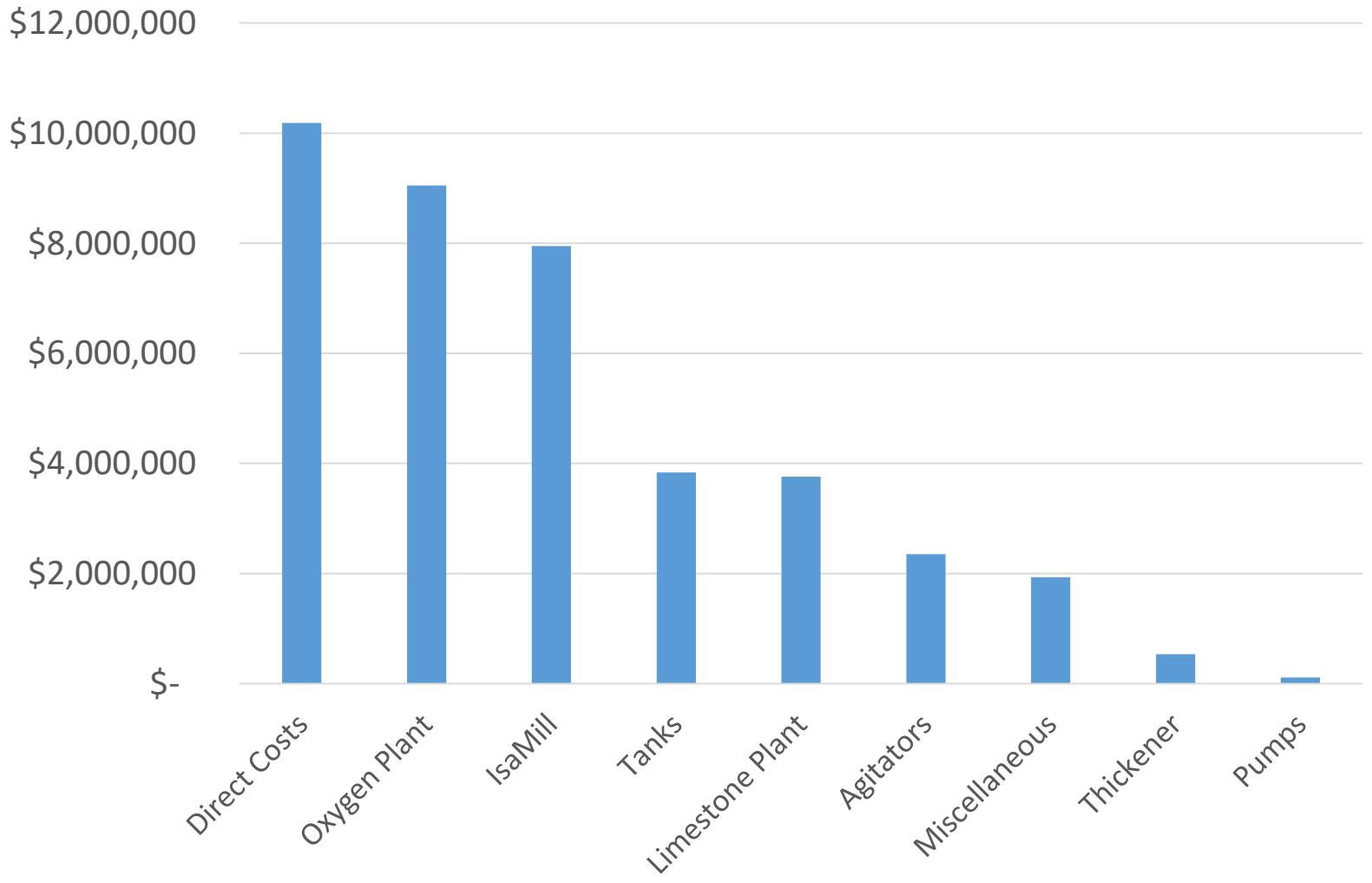
Thank You.

Albion Process Plant – CAPEX breakdown (US$)



Albion Process Plant – OPEX breakdown (US$/a)