CASE STUDY REVIEW OF THE ALBION PROCESS™ AS AN EFFECTIVE ALTERNATIVE TO PRESSURE OXIDATION

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ABSTRACT

As free-milling oxide ores become depleted operations are progressively looking to mine and treat sulphide deposits. Whilst pressure oxidation (POX) is typically the default processing option for many operations, it is accompanied by a higher technical safety risk, requires more expensive and technically complex ancillary equipment (thus high capital expenditure), and requires more skilled operators with greater technical expertise compared to some alternative solutions. Simple, less complex alternatives that are proven commercially exist for the treatment of sulphidic ores, however are often overlooked under the assumption that they are not as effective. The Albion Process™ is one such solution offered by Glencore Technology, which combines IsaMill™ ultrafine grinding with oxidative leaching in the OxiLeach™ reactor. The tank design of the OxiLeach™ reactor, combined with supersonic oxygen injection by the HyperSparge™ system, allows for high oxygen mass transfer and oxygen utilisation of 80% or higher, yielding very high metal extractions that can match those achieved via POX. This paper details the Albion Process™ and compares through case studies the results between POX and Albion Process™ testwork for several base and precious metal projects to support the Albion Process™ as a viable alternative for oxidative leaching.

KEYWORDS

Oxidative leaching, Pressure Oxidation, POX, Albion Process, Atmospheric leaching, Refractory Gold, Sulphide minerals

INTRODUCTION

As simple, ‘free milling’ ore bodies are progressively depleted, extracting commodities from complex ores is becoming a more frequent challenge. From a processing perspective, ores are often broadly classified into ‘oxides’ and ‘sulphides’. Oxides typically result from the weathering of sulphide ores, as those minerals closest to the surface are exposed to oxygen and water. The subsequent weathering results in enhanced metal content which is soluble and amenable to direct leach extraction (typically cyanide for precious metals and sulphuric acid for base metals), thus oxide ores are often referred to as ‘free milling’ ores.

Conversely, sulphide minerals, which are formed through geological processes, are considered refractory, meaning they do not yield high recoveries via traditional leaching techniques. Target metals are associated with, or finely disseminated within, the sulphide matrix. During the leaching process, elemental sulphur that forms a by-product of the leach reaction creates a passivating surface layer, significantly retarding leaching kinetics and extent. As such, sulphide ores typically require pre-treatment to liberate metals from the sulphide matrix and make them amenable to further processing for economical extraction of the target metal/s.

There are several commercialised processing routes for the treatment of sulphide ores and concentrates, and the underpinnings of these processes and their suitability to specific commodities and mineralogies has been extensively covered in existing literature. In brief, key processing options for the treatment of sulphides include:

Roasting, has been applied to refractory gold ores and particular base metal concentrates. Roasting is an established method that involves a gas-solid reaction as a sulphide concentrate is heated to high temperatures (450 to 820 °C) in the presence of air, converting the sulphide to an oxide and generating sulphur dioxide gas (Lunt & Weeks, 2016). Roasting flowsheets are ideally suited to low arsenic containing predominately pyrite material. Arsenic is both volatile, fuming and condensing in the off-gas stream, and oxidised and hence would need to be hydrometallurgically treated to allow for stabilisation. Roasters produce a sulphur dioxide rich gas stream amenable to acid production through a metallurgical acid plant. This type of flowsheet thus requires permitting and necessary environmental capture and scrubbing of tail gases as appropriate to the jurisdiction.

Pressure Oxidation (POX), involves the leaching of both base and precious metal sulphide ores or concentrates with oxygen at high temperature and pressure. Pressure oxidation can be performed under both acidic and alkaline chemistries for base and precious metals, with the latter typically applied for whole of ore leaching for precious metal recovery. The process utilises high pressure vessels (autoclaves) which typically operate with oxygen overpressures of 350 to 700 kPA(g), allowing for operating temperature of 180 to 230 °C (Thomas & Pearson, 2016). As a result of these conditions, residence times in POX are notably lower (60 – 90 minutes) compared to atmospheric alternatives. By controlling the density of the feed to the autoclaves, temperature can in turn be regulated through control of the exothermic oxidation reactions. The oxidation of sulphides in high temperature POX typically exceeds 98%; whilst this offers high recoveries, it also contributes to higher costs associated with oxygen requirements and acid neutralisation. Additionally, the specialised equipment required for POX, including the autoclaves themselves and ancillary equipment such as high-pressure pumps, flash vessels etc. contribute to higher capital expenditure (CAPEX) and operating expenditure (OPEX) for this processing route. Low and medium temperature pressure leaching have been developed, which run at 80 – 140 °C and 140 – 180 °C respectively. Pressure oxidation performed at these lower temperatures requires fine grinding to enhance leach kinetics and/or the addition of specific reagents to minimise surface wetting by molten sulphur (which would retard the leach kinetics) (McDonald & Muir, 2007).

Biological Oxidation (BIOX®), designed predominantly for the treatment of refractory gold ores, biological oxidation utilises bacteria as a catalyst to oxidise sulphide minerals prior to conventional treatment. The process involves feeding a flotation concentrate to a dedicated oxidation circuit in which sulphides are oxidised via the action of biological organisms. Oxidation occurs through direct contact of the bacteria with the sulphide minerals, as well as indirectly via the oxidation reduction cycle of ferrous and ferric ions at the mineral-solution interface. The process temperature is controlled to ~ 45 °C during a primary oxidation stage, and 65 °C during secondary oxidation. The oxidation reaction results in exothermic heat, negating the need for external heating. The process runs at a pH below two and ambient pressure, with typical residence times ranging from two to five days (Metso Outotec, 2023). The process is simple and well established, however is less robust to variations in feed compared to other processing solutions. Stable feeds or very slow changes over time are required for optimal operation.

The **Albion Process™**, involves the leaching of both base and precious metal sulphide ores or concentrates with oxygen at elevated temperatures and atmospheric pressures. The innovation combines two simple unit operations; ultrafine grinding of a flotation concentrate followed by oxidative leaching in Glencore

Technology's patented OxiLeach reactor units. Ultrafine grinding is undertaken in the IsaMill™ to achieve an ultrafine target P80 and a tight size distribution, with low fine grinding energy input. The ultrafine grinding allows for the mineral to be completely leached before the passivation layer is thick enough to inhibit further leaching. The finely ground product is leached in agitated tanks with the addition of oxygen. The combination of the tank aspect ratio, agitator design and use of the Hypersparge™ oxygen sparging system maximises oxygen mass transfer, conservatively allowing for 80% oxygen utilisation. The extent of sulphide oxidation is managed by controlling leach resident time, as such the minimum oxidation required for high extractions can be targeted, resulting in lower oxygen and acid neutralisation requirements, which translates to lower operating costs compared to other alternatives. Additionally, the simplicity of the process and ancillary equipment result in ~30% lower CAPEX compared to pressure oxidation. The Albion Process™ is well established, with eight plants commissioned around the world for the treatment of copper, lead-zinc and gold concentrates (Bartsch, Hourn, & Rohner, 2005; Hourn & Turner, 2004; Voigt, Littleford, Stieper, & Hourn, 2019; Roche, Bishop, & McKechnie, 2022; Voigt, Walker, Kloiber-Deane, & Tsvetkov, 2018).

In treating base metal or polymetallic concentrates containing both base and precious metals, Acid Albion Process™ Leaching (AAL) is adopted. The process is controlled via the monitoring of free acid levels, which are maintained via a combination of fresh acid addition, spent raffinate return (where downstream processing involves solvent extraction and electrowinning SX-EW), and via the generation of acid through the oxidation reduction cycle of ferrous and ferric ions. On completion of the oxidative leach, the oxidised slurry is discharged to a 'neutralisation' circuit in which a neutralising agent, such as limestone or acid consuming gangue in the ore, is added to neutralise acid and remove iron and other impurities, forming gypsum and goethite. If arsenic is present, it will also leach during the oxidative leaching stage and will coprecipitate with iron during neutralisation to form a stable ferroarsenate species suitable for disposal, this is typically in the form of scorodite. The slurry then undergoes solid-liquid separation, with the PLS containing the target base metals progressing to downstream processing such as SX-EW or precipitation. Precious metals do not leach and remain in the solid residue, creating a separate stream to progress on to downstream processing such as Carbon-in-Leach (CIL). A generic AAL flowsheet is provided in Figure 1.

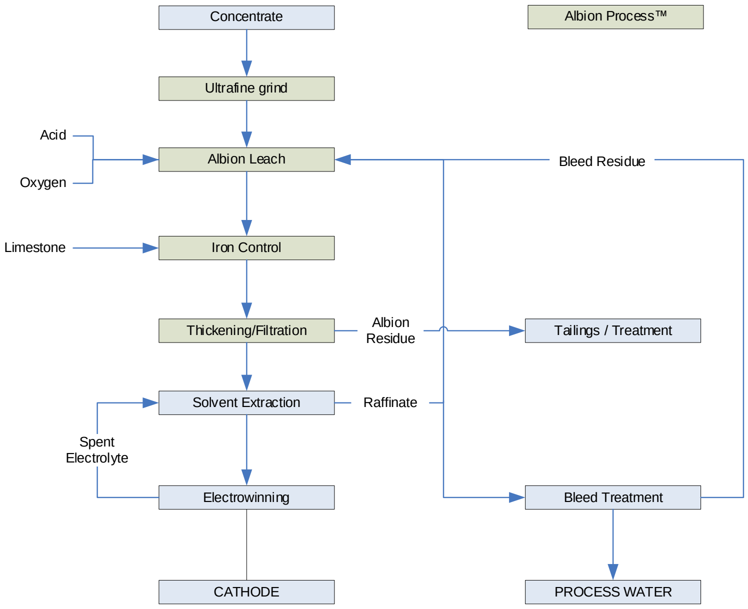

Figure 1 – Generic Acid Albion Process™ Flowsheet

When treating precious metal concentrate in which metals are predominantly hosted in pyrite and/or arsenopyrite, 'neutral' leaching conditions conducive to the oxidation of pyrite are adopted. In the Neutral Albion Process™ Leach (NAL) the pH is maintained at 5 – 5.5 via the dosing of a neutralising agent, such as limestone or acid consuming gangue, down the leach train to neutralise the acid generated by the oxidation reactions. This results in the generation of gypsum and goethite as iron leached into solution precipitates. Arsenic present in concentrates containing arsenopyrite will also leach and immediately co-precipitate with iron, forming a stable ferroarsenate species (typically scorodite), suitable for disposal. Precious metals remain in the solid residue, liberated from the sulphide matrix. Upon discharge from the leach circuit the slurry undergoes solid-liquid separation, with the thickener overflow reporting to process water and the underflow progressing to downstream treatment such as CIL. A generic NAL flowsheet is provided in Figure 2.

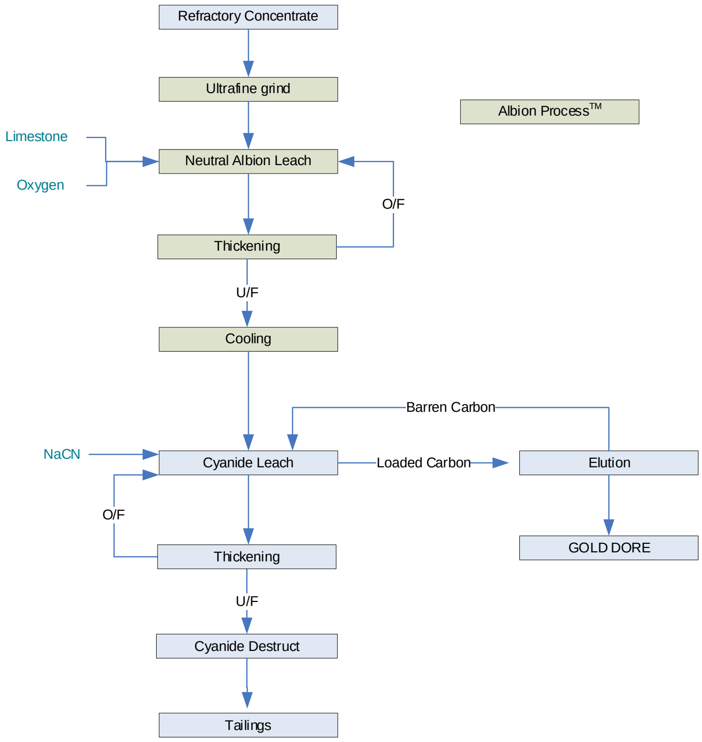

Figure 2 – Generic Neutral Albion Process™ Flowsheet

The objective of this paper is to share the results of several recent projects which compared POX and the Albion Process™ directly via testwork. Whilst this information is publicly available, it is not easily accessible without already knowing which projects have had both POX and Albion Process™ testwork performed as a part of their respective studies/investigations. The following case studies present the results of Albion Process™ and POX testwork performed on the same project/ concentrates, allowing for direct comparisons between each technology.

Whilst we acknowledge the well-established nature and effectiveness of BIOX, there was no information available regarding BIOX testing for the projects presented in this paper, thus the paper is constrained to only comparisons of recoveries achieved using the Albion Process™ and POX. The authors recommend that the reader consult established reviews of technology completed by others for further information (Bartsch, Hourn, & Rohner, 2005; Aylmore & Jaffer, 2012; McNeice, 2021).

METHODS

A review of publicly available information was undertaken, based on Glencore Technology's database where clients had undertaken both POX and Albion Process™ testwork for their respective projects. Relevant documentation was retrieved and data relating to concentrate specifications, mineralogy, testwork conditions and results were extracted and summarised as case studies for this review.

For one case study, a high-level order of magnitude estimate was derived for the cost of an Albion Process™ plant to treat the concentrate at the throughputs specified in the respective press releases. The cost estimates for the Albion Process™ were based on the sulphur grade, anticipated residence time and target sulphur oxidation and high-level mechanical equipment list (process equipment). Parametric estimates were used to calculate equipment costs, based on industry standards (AACE International, 2020).

A factor was then applied to the Albion Process™ CAPEX and OPEX estimates to generate estimates for a POX plant to treat the same feed. These factors were derived using previous AACE package generated pricing by Jacobs (Bartsch, Hourn, & Rohner, 2005) and Bateman (Aylmore & Jaffer, 2012), as well as cost data obtained from other projects and supporting engineering documents.

In deriving these costs, comparisons have been limited to just the oxidative leaching plants, assuming upstream and downstream processing areas would remain the same for the Albion Process™ and POX.

CASE STUDIES & RESULTS

Base Metals

Case study 1 – Coda Minerals, Elizabeth Creek - Emmie Bluff (Cu, Co, Zn concentrate)

Coda Mineral's Elizabeth Creek project is located in South Australia, 30 km South-East of Woomera and 135 km North-West of Port Augusta. The polymetallic Co-Cu-Zn-Ag deposit includes the Emmie Bluff Resource which has both Indicated and Inferred components, providing a combined total of 560,000 tonnes of copper and 20,000 tonnes of cobalt (Coda Minerals, Coda Minerals: Elizabeth Creek, 2023). A concentrate from the Emmie Bluff deposit was subjected to both POX and Albion Process Testwork, a high-level overview of concentrate grades for the key elements of interest are summarised in Table 1.

Table 1 – Emmie Bluff Testwork Concentrate

	Units	Value
Cu	%	18.0
Co	%	1.05
Ag	g/t	312.6
S	%	14.4

The concentrate exhibits a moderate copper grade of 18% and cobalt grade of 1%, thus not falling within typical grades for saleable concentrate. The copper is predominantly hosted as bornite/chalcocite or chalcopyrite, whilst the cobalt is typically contained in Carrollite. The sulphur grade of 14% would allow for autothermal operation in full scale leaching operation (minimum sulphur grade for autothermal operation is 10% sulphide sulphur in atmospheric conditions).

The conditions for each Albion Process™ and POX testwork are summarised in Table 2. These conditions reflect standard amenability testwork conditions and have not undergone process optimisation.

Table 2 – Oxidative Leaching Testwork Conditions

	Units	Albion	POX
Residence Time	Hours	72	2
Pulp Density	%	10	9.5
Target Sulphur Oxidation	%	75	~98
Grind Size (P80)	Micron	10	15[1]
Target pH		1.5	NS
Pressure	kPa(g)	0	3018
Process temperature	°C	90 - 95	220

[1] *P80 of flotation regrind*

The results of the oxidative leach tests are summarised in Table 3.

Table 3 - Oxidative Leach Test Results

	Cu Recovery (%)	Co Recovery (%)	Zn Recovery (%)
Albion Process™	99.6	99.4	99.8
POX	96.2	96.7	96.2

The Albion Process™ yielded slightly higher recoveries for copper, cobalt and zinc compared to POX, with greater than 99% extraction of all metals (Albion Process™) compared to 96 – 97% via POX, evidencing amenability of the process to the Emmie Bluff concentrate and establishing the Albion Process™ as a viable alternative to POX for this particular project (Coda Minerals, ASX Release: >99% Recoveries of Cu, Co from

Emmie Bluff Concentrate Using Albion Process, 2022; Coda Minerals, ASX Release: Positive Scoping Study – Elizabeth Creek Copper-Cobalt Project, 2023).

Precious Metals

The following projects were identified as having publicly available results for Albion Process™ and POX testwork. For conciseness a brief summary and discussion relating to the results for each project have been provided alongside the high-level overview of the operation. A summary of the key concentrate grades, mineralogy (where available), Albion Process™ test conditions and oxidative leach test results is provided in Table 4. POX test conditions were available only for the Boumadine project (Case Study 4).

Case study 2 - Rox Resources – Youanmi: Located 480km North-East of Perth and 400km East of Geraldton in Western Australia, the Youanmi Resource Estimate is 27.9 million tonnes with an average gold grade of 3.57 g/t, providing 3.2 million ounces of gold. Gold is associated with both sulphides (pyrite and arsenopyrite) and silicates (Rox Resources, Youanmi Gold Project, n.d.).

Albion Process™ testwork on concentrates generated from two different zones (Upper Hanging Wall and Upper Main) and 'as mined' surface stockpiles (ROM Stockpile), yielded comparable results to POX. Gold recoveries after Albion Process™ leaching ranged from 92% to 99%, whilst gold recoveries after POX ranged from 98% to 99% (Rox Resources, ASX Announcement: Impressive Albion Process Results Received for Youanmi Ore, 2021; Rox Resources, ASX Announcement: Youanmi Gold Project Scoping Study, 2022).

Case study 3 - De Grey – Hemi: Located 1,300 km North of Perth and 85 km South of Port Hedland in the Pilbara (Western Australia), the Mallina deposits are estimated at 251 million tonnes with a grade of 1.3 g/t gold, with 6.9 million ounces classified. Gold hosting is predominantly across pyrite, and arsenopyrite to a lesser degree (De Grey Mining, n.d.).

Albion Process™ and POX testwork was performed on concentrates generated from three different deposits (Brolga, Withnell and Mallina). Again, after oxidative leaching the Albion Process™ yielded results that were comparable to POX (94 – 98% gold recovery after Albion Process™ leaching compared to 91% - 97% gold recovery after POX), indicating amenability of the Albion Process™ for the Hemi concentrates, and supporting its effectiveness as an alternative processing solution to POX (De Grey Mining Ltd, ASX Announcement: Further Metallurgical Testwork Confirms High Gold Recoveries at the Mallina Gold Project, 2021).

Case study 4 - Aya Gold & Silver – Boumadine: Located in Western Morocco, exploration is ongoing, and the resource estimate is expected in 2024. Gold is hosted predominantly in pyrite, and to a lesser degree arsenopyrite.

Conditions for Albion Process™ testwork are summarised in Table 4. POX testwork was performed 225°C for 60 minutes, with 690 kPa (~100 psi) of oxygen over pressure applied and pulp density of 5.5%. The pulp had been pre-acidulated with sulphuric acid for 30 minutes at pH 1.5.

Gold recoveries following the Albion Process™ correlated strongly with sulphur conditions. Under more standard amenability conditions (P80 10 µm and 78 hours residence time), sulphur oxidation of 75% was achieved, which corresponded to a gold recovery of 85%. A finer grind size (6 µm) and longer residence time (96 hours) achieved a higher sulphur oxidation of 96% corresponding to 94% gold recovery (Aya Gold & Silver, 2023). The sulphur oxidation and subsequent gold recoveries achieved using the more aggressive Albion Process™ conditions were comparable to those achieved via POX (99.8% sulphur oxidation achieved, corresponding to gold recoveries of 97 – 98%). These results highlight the highly refractory nature of the gold and the extensive oxidation required for gold liberation. The application of more aggressive Albion Process™ leach conditions resulted in comparable gold recoveries to POX, and further investigation as to the economics of a full-scale plant adopting these conditions must be compared against the economics of a POX plant.

Table 4 – Precious Metal Project Concentrate Grades, Mineralogy, Albion Process™ Test Conditions and Oxidative Leach Test Results

	Units	**Case Study 2** **Rox Resources, Youanmi[1] (Western Australia)**	**Case Study 3** **De Grey, Hemi (Western Australia)**	**Case Study 4** **Aya Gold & Silver, Boumadine (Morocco)**	**Case Study 5** **Undisclosed client (North America)**
References		(Rox Resources, ASX Announcement: Impressive Albion Process Results Received for Youanmi Ore, 2021) (Rox Resources, ASX Announcement: Youanmi Gold Project Scoping Study, 2022)	(De Grey Mining Ltd, ASX Announcement: Further Metallurgical Testwork Confirms High Gold Recoveries at the Mallina Gold Project, 2021)	(Aya Gold & Silver, 2023)	
Concentrate Grades					
Au	g/t	32 - 61	11.9	3.8	13
Ag	g/t	NA	NS	76.2	70
As	%	3.1	NS	1.7	0.3
S	%	28.0	10.6	41.4	9
Test conditions (Albion)					
Residence Time	Hours	49 hours (ROM Stockpile) 30 hours (Upper Hanging Wall) 21 hours (Upper Main)	72	78, 96*	72
Grind Size (P80)	Micron	10	8	10, 6*	8
Target pH		5.5	5.5	5.5	5.5
Process temperature	°C	93	95	95	95
Pulp Density	%	10	10	10	10
Oxidative Leaching Test Results					
Sulphur Oxidation **(Albion Process™)**	%	75 – 78		75, 96*	90
Gold Recovery **(Albion Process™)**	%	99.3 (ROM Stockpile) 97.3 (Upper Hanging Wall) 92.0 (Upper Main)	98.0 (Brolga), 94.6 (Withnell) 94.4 (Mallina)	84.9 (91.3% Ag Rec'y), 94.4 (94.8% Ag Rec'y)*	85.0
Gold Recovery **(POX)**	%	98.8 (ROM Stockpile) 98.4 (Upper Hanging Wall) 99.0 (Upper Main)	96.9 (Brolga), 91.5 (Withnell) 97.0 (Mallina)	98.2 (96.6% Ag Rec'y)	94.0

[1] *Hanging Wall and Main combined domains represent > 30% of Youanmi Mineral Resource*

** Second Albion Process™ test for Boumadine project, applying more aggressive conditions, including longer residence time and finer grind size*

Case study 5 – Undisclosed project: Located in North America with a combined indicated and inferred resource of nearly 40 million tonnes at an average gold grade of ~1.5 g/t. Gold is hosted predominantly in pyrite. This project has had identifying details removed as results are not yet publicly available, and for the purpose of performing a high-level financial overview.

The Albion Process™ achieved a final gold recovery of 85% after oxidative leaching, compared to 94% via POX. Of note, this particular concentrate contains very high amounts of quartz (40%), which may also host a substantial percentage of gold. Whilst POX is able to recover some amount of silicate hosted gold, when adopting the Albion Process™ the only means of recovering silicate hosted gold is to grind progressively finer. The results of this test reinforced the highly refractory nature of the ore, with high oxidation extent (90%) required to achieve high recoveries.

High Level Financial Analysis (Case Study 5)

Where recoveries achieved by one process do not match those of another, such as the lower gold recovery achieved using the Albion Process™ in Case Study 5, consideration must be given to the economic viability of each processing option. Previous work performed by Jacobs and Bateman have indicated that the CAPEX and OPEX associated with POX may be up to 30 to 40% higher compared to those of an Albion Process™ plant. The lower recoveries exhibited in Case Study 5 equate to a difference of 1.17 g/t of gold recovered, which should be contextualised within the different economics of each processing solution. A high-level estimate for the CAPEX and OPEX associated with an Albion Process™ plant for Case Study 5 were generated using the concentrate grades and Albion Process™ leach conditions specified in Table 4. Using the independent work by Jacobs (Bartsch, Hourn, & Rohner, 2005) and Bateman (Aylmore & Jaffer, 2012), factors of 1.35 and 1.3 were applied to the cost of an Albion Process™ plant to estimate the CAPEX and OPEX for a POX plant respectively. It is assumed that both plants would treat the same throughput. The assumed grind energy of 150 kWh/t was based on Glencore Technology's database, and in calculating the cost of the POX plant adjustments were made account for the lower implication of ore hardness on POX CAPEX and OPEX.

The results of the high-level economic analysis are presented in Table 5. Despite the lower gold recovery, the economics of an Albion Process™ plant were in fact comparable to POX. The lower capital and operating expenditures associated with an Albion Process™ plant resulted in a slightly lower payback period, however final NPV for the Albion Process™ plant was lower compared to POX. These considerations may be particularly important to junior operations for which immediate capital expenditure may be a particular constraint.

Table 5 - High level financial overview (Case Study 5)

	Gold Recovered	Total Revenue	CAPEX	OPEX	Payback Period	NPV
	(g)	(USD M)	(USD M)	(USD M/ annum)	(Months)	(USD M)
Albion Process™	3,558,100	226.8	112.0	21.5	7	727.2
POX	3,934,840	250.8	135.5	24.7	8	818.3

Revenue calculated using current gold price of USD63.75 per gram and leaching plant throughput of 40 tph (322,000 tpa). Estimated grind energy of 150 kWh/t, power cost of $0.12 /kWh and limestone cost of $35/t tonne used in calculation of OPEX.

CONCLUSIONS

The objective of this paper was to provide a direct comparison of testwork results for the Albion Process™ compared to pressure oxidation. Using publicly available data, the case studies above evidence that the combination of ultrafine grinding and atmospheric oxidative leaching that characterise the Albion Process™ are capable of achieving comparable results to those achieved using POX.

High base metal extractions (> 99%) and high gold recoveries post Albion Process™ oxidative leaching (~ 95%) were achieved across each case study presented above, with the exception of Case study 5. For the latter, a higher than usual percentage of quartz present in the concentrate likely explain this lower recovery, especially given the high level of oxidation achieved during the Albion Process™ testwork. In such instances, only further fine grinding would serve to liberate the remaining encapsulated gold. Despite the lower recoveries, a high-level economic analysis comparing the Albion Process™ to POX suggest that the economic viability of installing an Albion Process™ plant is comparable to a POX circuit.

The selection of the preferred processing route should be unique to each project. Where possible all current options for processing should initially be considered, and selection criteria must extend beyond just the recoveries achieved to also include CAPEX, OPEX, recovery attributable to each unique processing solution, the subsequent payback period and NPV. The Albion Process™ allows for short project implementation time, is a technically simple process and offers reliable metallurgical performance. For many projects this solution may offer metal recoveries comparable to those achieved via pressure oxidation. Where it does not, the difference in recovery should be contextualised within a thorough investigation of project economics. The quantifiable cost benefits and technical simplicity associated with the Albion Process™ make it an effective and viable alternative for processing refractory sulphide concentrates, warranting its consideration in flowsheet development for operations looking to process sulphide ores.

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REFERENCES

AACE International. (2020, 08 7). Cost Estimate Classification System - As Applied in Engineering, Procurement, and Construction for the Process Industries. TCM Framework. *AACE International Recommended Practice No. 18R-97.* AACE International.

Aya Gold & Silver. (2023, 11 9). *Aya Gold & Silver Reports Recoveries of 89% Silver and 85% Gold from Metallurgy Test Work on Boumadine*. Retrieved 12 1, 2023

Aylmore, M., & Jaffer, A. (2012). Evaluating Process Options for Treating Some Refractory Ores. *ALTA International Gold Conference: Annual Gathering of the Global Gold Ore Processing Industry.* Perth.

Bartsch, P., Hourn, M., & Rohner, P. (2005). Benefits of Using the Albion Process for a North Queensland project, and a Case Study of Capital and Operations Cost Benefits Versus Bacterial Oxidation and Pressure Oxidation. *Randol Gold Conference.* Perth.

Coda Minerals. (2022). ASX Release: >99% Recoveries of Cu, Co from Emmie Bluff Concentrate Using Albion Process.

Coda Minerals. (2023). ASX Release: Positive Scoping Study – Elizabeth Creek Copper-Cobalt Project.

Coda Minerals. (2023). *Coda Minerals: Elizabeth Creek*. Retrieved 12 1, 2023, from https://www.codaminerals.com/projects/

De Grey Mining. (n.d.). *Hemi Gold Deposit*. Retrieved 12 1, 2023, from https://degreymining.com.au/hemi-gold-deposit/

De Grey Mining Ltd. (2021, 02 16). ASX Announcement: Further Metallurgical Testwork Confirms High Gold Recoveries at the Mallina Gold Project.

De Grey Mining Ltd. (2022, 05 12). ASX Announcement: Hemi Pilot Testwork Confirms High Recoveries at Brolga.

Hourn, M., & Turner, D. (2004). *Commercialisation of the Albion Project.* Brisbane: Glencore Technology.

Lunt, D., & Weeks, T. (2016). Process Flowsheet Selection. In M. Adams, *Gold ore processing, project development and operations* (pp. 113 - 129). Great Britain: Elsevier Science & Technology.

McDonald, R. G., & Muir, D. M. (2007). Pressure oxidation leaching of chalcopyrite. Part I. Comparison of high and low temperature reaction kinetics and products. *Hydrometallurgy, 86*(3-4), 191 - 205.

McNeice, J. M. (2021). Gold Extraction from Refractory Sulfide Gold Concentrates: A Comparison of Bio-oxidation and Neutral Atmospheric Pre-treatment and Economic Implications . *Journal of Sustainable Metallurgy*, 1354 - 1367.

Metso Outotec. (2023). BIOX Process.

Roche, K., Bishop, F., & McKechnie, R. (2022). The Use of the Albion Process to Produce Copper Sulfate Reagent for Use in Zinc Flotation (Case Study). *Perumin.* Peru.

Rox Resources. (2021, December 23). ASX Announcement: Impressive Albion Process Results Received for Youanmi Ore. Australia.

Rox Resources. (2022). ASX Announcement: Youanmi Gold Project Scoping Study.

Rox Resources. (n.d.). *Youanmi Gold Project.* (Rox Resources) Retrieved 12 1, 2023, from https://www.roxresources.com.au/projects/youanmi-project/

Thomas, K. G., & Pearson, M. S. (2016). Pressure Oxidation Overview. In M. Adams, *Gold ore processing, project development and operations* (pp. 341 - 358). Great Britain: Elsevier Science & Technology.

Voigt, P., Littleford, D., Stieper, G., & Hourn, M. (2019). First Commercialisation of the Albion Process for Copper. *ALTA.* Perth: Glencore Technology.

Voigt, P., Walker, D., Kloiber-Deane, O., & Tsvetkov, A. (2018). Ramp-up and Long-term Performance of the Albion Process™ Plant at GeoProMining Gold Armenia. *14th AusIMM Mill Operators' Conference,* (pp. 339 - 350).