# TECHNOLOGY FOR PROCESSING OF REFRACTORY GOLD-CONTAINING CONCENTRATES BASED ON ULTRAFINE GRINDING AND ATMOSPHERIC OXIDATION

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## ABSTRACT

Autoclave oxidation, bacterial and chemical liberation, roasting, acid oxygen processes, atmospheric oxidation prior to cyanidation are applied to process refractory sulphide concentrates. It is obvious that the processes with the maximum effect regarding gold recovery are those in which complete destruction of sulphides takes place and gold becomes accessible for further cyanidation through liberation from sulphide “capsula”. But the significant recovery increase is often accompanied by a process complexity, high expenses for equipment purchase and maintenance. It makes material processing cost-inefficient. Process optimization has led to progress in ultrafine grinding, bacterial and autoclave oxidation processes. In our opinion sulphide atmospheric oxidation processes are the most interesting as oxidation there runs without high temperature (up to 100 $^{o}$C) and excess pressure (open units), and with acid environment close to neutral. The process of sulphide concentrates treatment named “Albion” (Albion Process™) represents a combination of ultrafine grinding and oxygen oxidation without pressure and external heating. The process has a number of advantages: sodium cyanide consumption decrease during gold leaching and high ecological compatibility. TOMS institute in collaboration with Glencore Technology Pty ltd (Australia) tested Albion technology aiming at liberation of finely disseminated gold from flotation concentrate produced from refractory ore of one Russian deposit. The testing has shown that Albion technology makes it possible to process refractory products with quite small capital investments. It enables involving medium and small refractory gold deposits into processing.

## KEYWORDS

Gold, atmospheric oxidation, refractory concentrate, leaching

## INTRODUCTION

The considerable part of the world Au-bearing reserves is present by refractory ores with finely disseminated gold. Gold in such ores is often associated with sulphide minerals and locked in so called "sulphide capsula" since it is closed inside dense sulphide grains and inaccessible to recovery by cyanidation. To treat refractory sulphide concentrates containing gold a number of processes were developed and they can be divided into three groups (Figure 1):

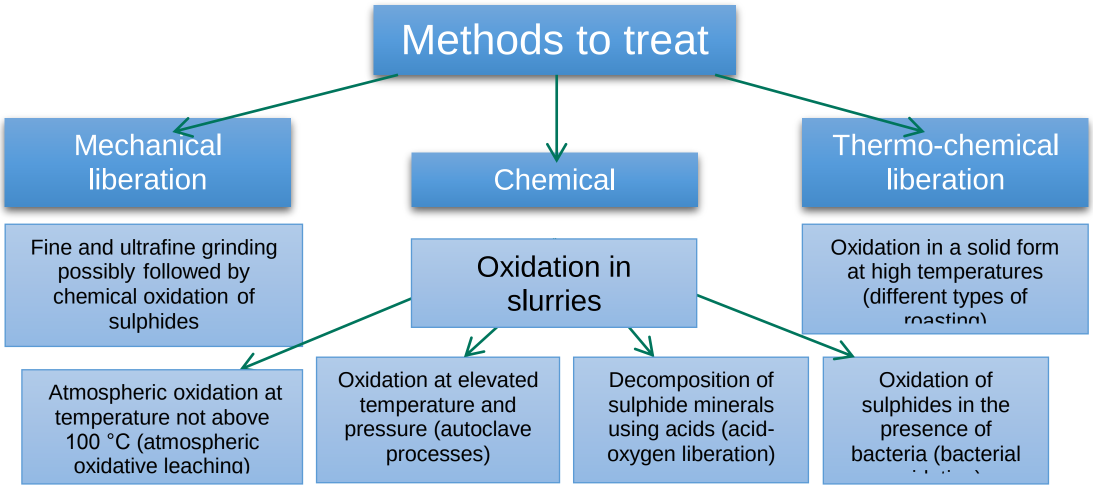



Figure 1 – Methods to liberate finely disseminated gold

Chemical liberation methods to recover finely disseminated gold mean either complete destruction of gold-bearing sulphides (autoclave leaching, bacterial-chemical leaching, acidic-oxygen processes etc.) or partial alteration of the specified minerals (mild atmospheric oxidation prior to cyanidation).

The technologies aimed at complete destruction of sulphide minerals provide for the best Au recovery since they allow one to almost completely liberate finely disseminated gold, which makes it accessible to the subsequent cyanidation. However, these processes are usually characterized by arrangement complexity, high equipment investments and operating costs. It is quite often that the resulted oxidation products contain compounds which will react with NaCN in the course of cyanidation causing its high consumption. This along with the other complicating factors makes the material processing less attractive in terms of cost efficiency.

Continuous search for technologies devoid of the disadvantages takes place resulting in improvements of ultrafine grinding and advance of bacterial and autoclave oxidation methods. The authors consider atmospheric oxidation of sulphides as the technology of the most interest. This process assumes that oxidation proceeds at temperatures not exceeding 100°C, without excessive pressure and under acid conditions close to neutral.

## ALBION PROCESS™ DESCRIPTION

One of such atmospheric oxidation technologies is Albion Process™, developed by Xstrata Pty Ltd (Glencore Technology Pty Limited), Australia. This technology is a combination of ultrafine grinding and oxidative leaching without pressure and external heating. The process sequence is schematically shown in Figure 2.

Grinding of a concentrate is conducted in stirred mills to about 80% -10 um size. Due to ultrafine grinding of the concentrate minerals surface area increases significantly. Mechanical and chemical activation of sulphides results in the enhanced rate of the subsequent oxidation.

Oxidation of the finely ground concentrate is conducted in a series of agitated vessels at atmospheric pressure. Oxygen of technical grade is introduced to the leach slurry to oxidize the sulphide minerals. Intensive chemical reaction leads to self-heating of the slurry higher than 80°C but lower than the boiling point. The Albion Process™ is an autothermal technology.

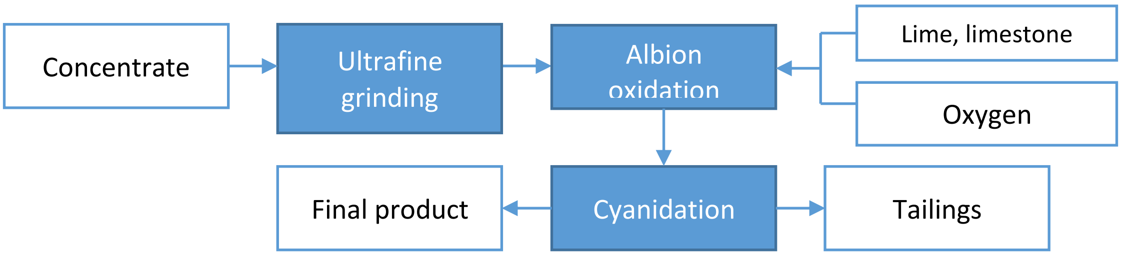



Figure 2 – Schematic flowsheet to treat refractory Au-bearing sulphide concentrates using Albion Process™

The creators of the process indicate that sulphide minerals will leach according to the reactions below.

$$2FeS_2 + 7.5O_2 + H_2O = Fe_2(SO_4)_3 + H_2SO_4 \quad (1)$$

$$2FeAsS + 5.5O_2 + H_2O = 2HAsO_2 + 2FeSO_4 \quad (2)$$

$$2FeSO_4 + 0.5O_2 + H_2SO_4 = Fe_2(SO_4)_3 + H_2O \quad (3)$$

$$HAsO_2 + Fe_2(SO_4)_3 + 2H_2O = H_3AsO_4 + 2FeSO_4 + H_2SO_4 \quad (4)$$

As was earlier mentioned the Albion Process™ is carried out under relatively neutral conditions: pH of the slurry is higher than 4.0. Limestone, the cheapest reagent, is used to neutralize sulphuric acid generating according to equations (1) and (4). In this way the sulphides leaching in the course of the Albion Process™ can be essentially described by the following reactions.

$$2FeS_2 + 7.5O_2 + 9H_2O + 4CaCO_3 = 2FeOOH + 4CaSO_4{\cdot}2H_2O + 4CO_2 \quad (5)$$

$$FeAsS + 3.5O_2 + 2H_2O + CaCO_3 = FeAsO_4 + CaSO_4{\cdot}2H_2O + CO_2 \quad (6)$$

The Albion Process™ has several advantages over conventional oxidative processing of sulphide minerals. One of the benefits is a relative inertness of the oxidation products towards cyanide and their environmental compatibility. Since the Albion Process™ runs on under relatively neutral conditions almost all sulphur passing into solution precipitates as gypsum. Therefore no suplphur accumulation occurs in the solution (S concentration in the solution is maintained less than 2 g/L). So the oxidative leaching of sulphides results in generation of sulphates instead of elemental sulphur as it happens in the processes with lower pH level (bacterial oxidation, acidic-oxygen oxidation etc.). Elemental sulphur (if any in the oxidation product) will actively react with $CN^-$ in the course of the following cyanidation that leads to thiocyanates formation and consequent high consumption of NacN. In this context the Albion Process™ application allows one not only to liberate finely disseminated gold but as well to ensure relatively low reagent consumption during the following cyanidation of the oxidized material.

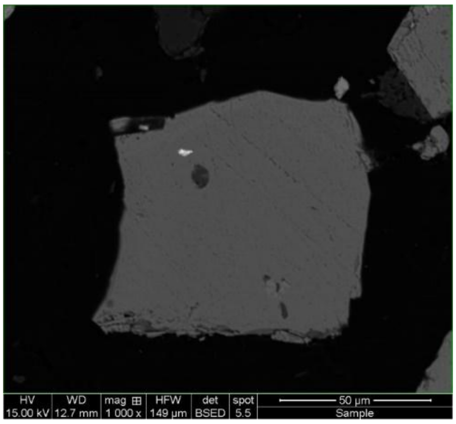
The elevated temperature (higher than 80°C) of the Albion Process™ provides precipitation of iron and arsenic from the solutions with formation of goethite and scorodite which have crystalline structure. These minerals are very inert towards NaCN. Moreover crystalline scorodite is the most stable and environmentally safest form to store As-containing wastes. The processes running at lower temperatures than the Albion Process™ may result in precipitation of iron and arsenic in the form of iron hydroxides and amorphous scorodite as well as jarosite and complex sulphates. The presence of these compounds in the oxidized material leads to the increased consumption of NaCN during gold leaching. Amorphous scorodite contributes to partial arsenic dissolution during storage of leaching tailings, which has adverse environmental effects.

## RESULTS AND DISCUSSION

TOMS institute conducted testing of the Albion Process™ aimed at liberation of finely disseminated gold from the flotation concentrate resulted from processing of a refractory ore of one of Russian gold deposits.

### Concentrate description

Gold grade of the head flotation concentrate was 29.6 g/t. The concentrate size was 80% -80 um. Mineral composition of the concentrate comprises 17% of rock-forming minerals, 59% of pyrite and 24% of arsenopyrite. Gold size (Figure 3) in the concentrate of interest was less than 10-15 um, some gold particles were detected with size of less than 1.0 um.



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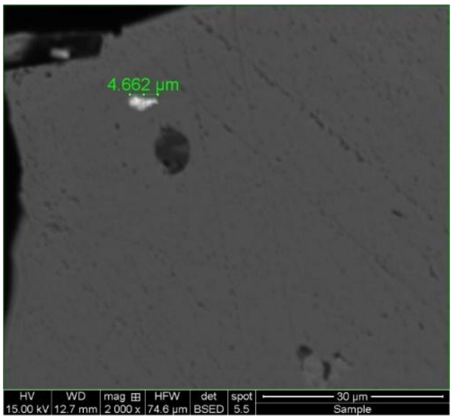


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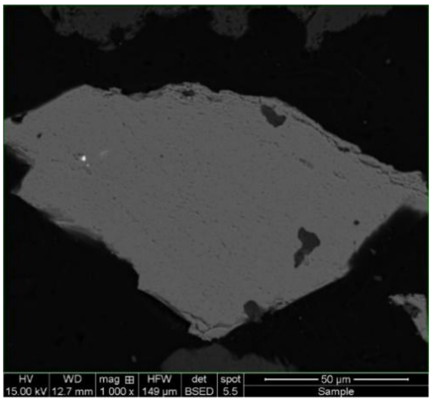

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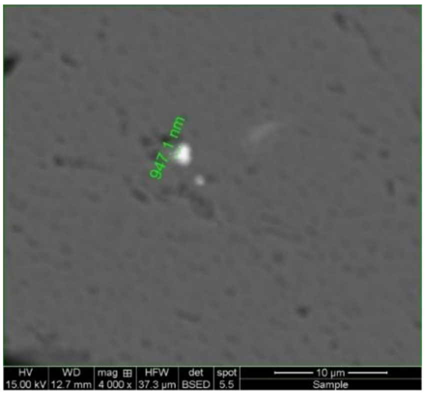


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Figure 3 – Au particles in sulphide minerals:
a – general view of a grain, b – zoomed

**Cyanidation of the head concentrate**

Based on the material composition study for the concentrate and on sorption cyanidation tests (Table 1) it was determined that amount of cyanide-leachable gold in the concentrate was about 20-25%, basic part of gold (more than 70%) in the concentrate is finely disseminated into sulphide minerals and inaccessible to leaching solutions.

Table 1 – Data from sorption cyanidation tests for flotation concentrate prior to oxidation (cyanidation conditions: NaCN rate – 2 g/L; cyanidation time – 24 h; slurry pH – 10.5; solids in slurry – 40%; sorbent load (active carbon Norit RO 3515) – 8% of slurry volume)

| Concentrate size, um | Au grade, g/t | | Au recovery, % | Reagent rate, kg/t of concentrate | | |
|---|---|---|---|---|---|---|
| | | | | NaCN | | |
| | Head material | cake | | Total added | Total consumed | CaO |
| 80% -80 (head) | 29.6 | 23.7 | 19.9 | 3.0 | 1.8 | 3.7 |
| | | 23.5 | 20.6 | 3.0 | 1.8 | 3.7 |
| 80% -20 | | 23.5 | 20.6 | 4.0 | 2.8 | 4.7 |
| | | 23.2 | 21.6 | 4.0 | 2.8 | 4.7 |
| 80% -10 | | 22.1 | 25.3 | 6.5 | 5.2 | 6.5 |
| | | 22.0 | 25.7 | 6.5 | 5.3 | 6.5 |

**Concentrate grinding**

A grindability test in Netzsch-IsaMill M4 was carried out to estimate power consumption to grind the concentrate. The testing was performed according to the method of Glencore Technology – the stirred mill manufacturer. The testing data indicated that 87 kW-h/t specific power was required to grind the concentrate to 80% -10 um. Media specific consumption in the course of the ultrafine grinding equaled 0.9 kg/t (based on stirred mills operational practice).

**Concentrate oxidative leaching**

The ground concentrate was leached in a special unit manufactured under the guidance of the Albion's creators. The oxidation time was 48 hours. Figure 4 shows the main results from the testing.

**Cyanidation of the oxidized concentrate**

The oxidized concentrate was cyanided under the same conditions as the concentrate prior to oxidation. Consumption rate of NaCN for cyanidation of the concentrate previously leached in Albion unit was 19.8 kg/t.

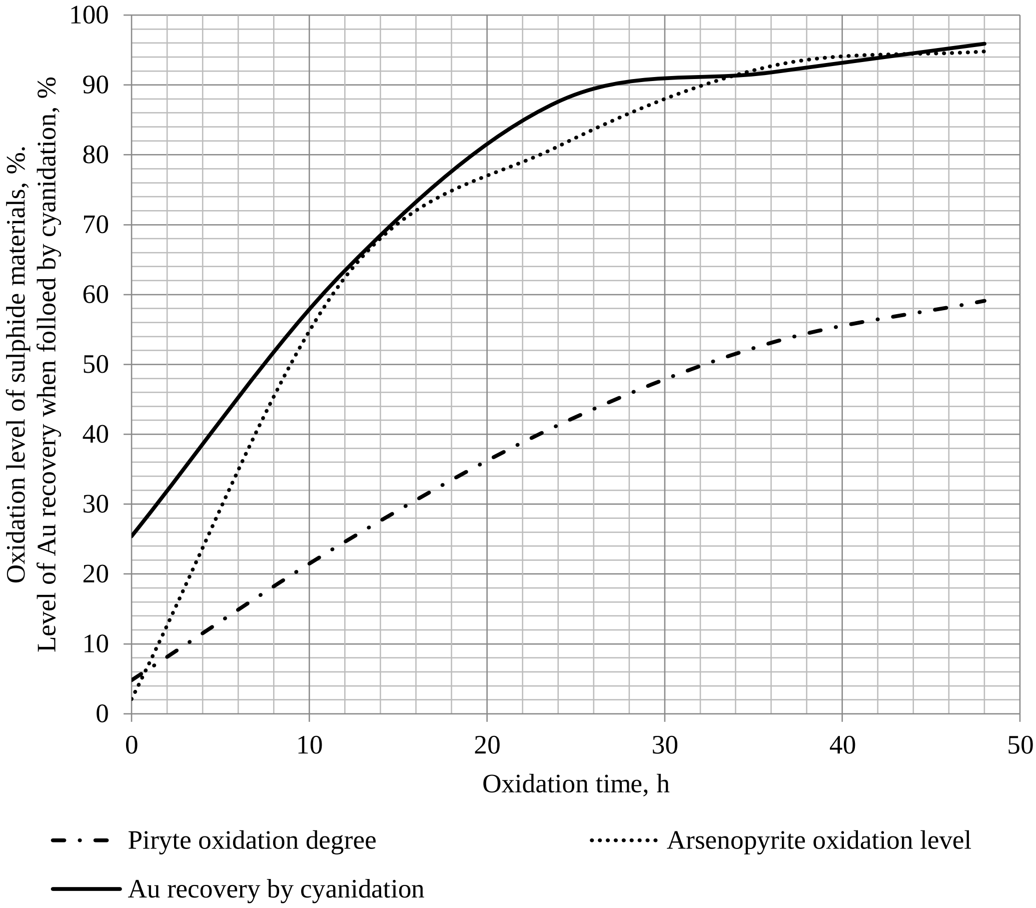


Figure 4 – Basic data from the concentrate processing according to Albion technology

Table 2 represents comparison of data from the concentrate processing by the Albion Process™ and by autoclave oxidation.

Table 2 – Comparison of the data from Albion Process™ and from autoclave oxidation

| Process | Oxidation cake mass pull, % | Sulphide oxidation level (based on S), % | Specific consumption of reagent, kg/t of head concentrate | | | Au recovery at the following cyanidation, % |
|---|---|---|---|---|---|---|
| | | | $O_2$ | Limestone | Lime | |
| Autoclave oxidation* | 81 | более 98 | 520 | 670 | 94 | 97.2 |
| Albion | 190 | 64 | 360 | 660 | 11 | 95.9 |

* autoclave oxidation conditions: 210°C, $O_2$ addition at 10 bar, oxidation for 1 h

## CONCLUSIONS

The test data confirm that the Albion Process™ allows efficient processing of concentrates containing finely disseminated gold at lower operational costs (consumption of $O_2$, limestone, and lime) and at level of Au recovery comparable to autoclave oxidation technology.

The Albion Process™ makes it possible to arrange processing of refractory products at significantly lower capital costs. In contrast to the competitive processes (autoclave and bacterial oxidation) Albion technology does not require constant presence of high-quality specialists as well as there is no need to build processing plants with high concentrate throughput or a separate plant to oxidize and cyanide concentrates from several sites. The Albion Process™ enables arrangement of a small-scale on-site plant, which allows involving of small and medium refractory gold deposits in processing.

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