Mine Arnaud Project: Flotation Circuit Adjustment and Collector Reduction

Christine Croteau
COREM, Canada, christine.croteau@corem.qc.ca

Patrick Laflamme
COREM, Canada

Michel Lafontaine
Mine Arnaud

Follow this and additional works at: http://dc.engconfintl.org/phosphates_viii

Part of the Engineering Commons

Recommended Citation
Christine Croteau, Patrick Laflamme, and Michel Lafontaine, "Mine Arnaud Project: Flotation Circuit Adjustment and Collector Reduction" in "Beneficiation of Phosphates VIII", Dr. Patrick Zhang, Florida Industrial and Phosphate Research Institute, USA Professor Jan Miller, University of Utah, USA Professor Laurindo Leal Filho, Vale Institute of Technology (ITV), Brazil Marius Porteus, Foskor-Mining Division, South Africa Professor Neil Snyders, Stellenbosch University, South Africa Mr. Ewan Wingate, WorleyParsons Services Pty Ltd., Australia Prof. Guven Akdogan, Stellenbosch University, South Africa Eds, ECI Symposium Series, (2018). http://dc.engconfintl.org/phosphates_viii/29
Mine Arnaud project:
Flotation circuit adjustment and collector reduction
Beneficiation of Phosphates VIII
Cape Town, April 29 - May 4 2018
Presented by Christine Croteau
Contents

- What is COREM
- Mine Arnaud project
- Test work timeline
- Recent test work
- Conclusions / highlights
What is COREM
Consortium of applied research on mineral processing

Technical services :
• Characterization;
• General test work / Laboratory services;
• Flowsheet development and optimization;
• Pilot testing.

Pre-competitive research program funded by members :
What is COREM Expertise

- Iron and titaniferrous ores
- Iron ore pelletizing
- Base and precious metals
- Industrial minerals
- Rare earths
Mine Arnaud project

- Open deposit located in Sept-Îles, Qc, Canada
- Igneous apatite grading around 5% P$_2$O$_5$
- Project currently under development

Beneficiation:
- Grinding to liberation size
- Magnetic separation to remove titaniferous magnetite
- Phosphate flotation

Targeted metallurgical performance
Concentrate > 39% P$_2$O$_5$
Overall P$_2$O$_5$ recovery > 90%
Previous testwork
Original flowsheet

- Feed ground to P80 of 430 µm
- Rghr and scav stages at pH~9.5-10
  - Reagents:
    • Na$_2$CO$_3$ (at grinding)
    • NaOH (pH regulator)
    • Starch WW82 (iron depressant)
    • Sylfat FA-2 (collector)
    • Texanol (frother)

- Regrind rghr conc to P80 of 110 µm
- 3 clnr stages + 1 clnr/scav stage
- LIMS/HIMS on clnr 3 conc

\(\Rightarrow\) Concentrate at 40.9% P$_2$O$_5$ and 82.5% P$_2$O$_5$ recovery

Can the flowsheet be simplified?
Can the recovery be improved?
# Testwork timeline

## Laboratory testwork at COREM (2011)

<table>
<thead>
<tr>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1)</strong> Optimal flotation feed grind at P80 of 125 µm</td>
</tr>
<tr>
<td>‣ Apatite liberation around 150 µm</td>
</tr>
<tr>
<td>‣ Finer grind lead to fine losses and decrease of P$_2$O$_5$ recovery</td>
</tr>
<tr>
<td><strong>2)</strong> Magnetic separation prior to flotation</td>
</tr>
<tr>
<td>‣ Volume to flotation</td>
</tr>
<tr>
<td>‣ Amount of Fe to depress and depressant dosage</td>
</tr>
<tr>
<td>‣ Number of cleaner stages</td>
</tr>
<tr>
<td>‣ Size dimension of flotation equipment</td>
</tr>
<tr>
<td><strong>3)</strong> New collectors tested</td>
</tr>
<tr>
<td>‣ Rice oil and Liacid 1800 (Fatty acid extract from soybeans)</td>
</tr>
<tr>
<td><strong>4)</strong> Conditioning at high percent solids (50-60%)</td>
</tr>
<tr>
<td>‣ Favorable</td>
</tr>
<tr>
<td><strong>5)</strong> Higher pulp temperature (20-22 vs 10-12°C)</td>
</tr>
<tr>
<td>‣ Promotes fatty acid collector solubility/collecting power</td>
</tr>
<tr>
<td><strong>7)</strong> Column flotation vs mechanical cell</td>
</tr>
<tr>
<td>‣ Columns seem to improve performance (P$_2$O$_5$ grade), possibly due to froth washing</td>
</tr>
</tbody>
</table>

⇒ Concentrate at >39% P$_2$O$_5$ with 81 - 83% P$_2$O$_5$ recovery
Testwork timeline
Continuous pilot testwork at COREM (2012)

96-h continuous operation

Feed rate: 200 kg/h

Reagents

- Causticized starch (WW82)
- Liacid 1800 (collector)
- \( \text{Na}_2\text{SiO}_3 \) (silicate depressant) to lower mica content
- pH at 10.8
- One clnr stage is sufficient to meet concentrate specs
- Addition of clnr/scav stage allows improvement of \( \text{P}_2\text{O}_5 \) recovery

Can the \( \text{P}_2\text{O}_5 \) recovery be further improved?
Is the reagent suite optimal? Can the operating costs be lowered?
Hypotheses:

• With magnetic separation ahead of flotation, the need for iron depressant is lower;

• Lower pH should yield a lower collector efficiency on the apatite. However, iron gangue and other gangue minerals flotation should be more impacted by a lower pH than apatite flotation.

Conclusion of laboratory testing:

Flotation at natural pH was achieved using Liacid 1800, a frother and Na$_2$SiO$_3$

⇒ Concentrate at 38% P$_2$O$_5$ and 86% P$_2$O$_5$ recovery
Testwork timeline
Mini-pilot testwork at COREM (2014)

Objectives:
– testing of a new reagent suite at natural pH including Flotigam 5806, a fatty acid derivative formulated by Clariant for phosphate flotation;
– producing high grade apatite concentrate from 2 tons of LIMS non-mag.

Conditions
- 50 kg/h;
- Combination of cells and columns;
- Collector dosage: 450-550 g/t (at rghr and scav);
- Na$_2$SiO$_3$ at 150 g/t (at clnr/scav and clnr 2);

⇒ Concentrate at 40.3% P$_2$O$_5$ and 79.7% P$_2$O$_5$ recovery
Laboratory testing preceding two pilot campaigns:

Objective:
- Comparison of 2 collectors at 450 g/t
  - Flotigam 5806 – Clariant (Fatty acid and derivatives) or Flotigam
  - Soltiflot TP-C5 – Soltimum (Fatty acid mixture) or C5

Results:
- Flotigam and C5 collector showed similar metallurgical performance, >39% P₂O₅ grade and >90% P₂O₅ recovery;
- C5 showed better selectivity and faster flotation kinetics;
- Fe (pyrrhotite) was found in apatite concentrate, meaning that starch could be required.
Objectives:

– Validation of a new reagent suite at natural pH;

– Production of high grade apatite concentrate from a 50 tons blend sample;

– Selection between 2 collectors formulated for apatite flotation, Flotigam and C5;
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (1st pilot - Jan 2017) (cont’d)

Final flowsheet selected and operated @ 100 kg/h

Flotation feed

6” Rougher

4” Scavenger

4” Cleaner 1

4” Cleaner 2

Apatite concentrate

Tailings
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (1\textsuperscript{st} pilot - Jan 2017) (cont’d)

Results: Final concentrate $\text{P}_2\text{O}_5$ grade/recovery

C5 collector provides higher $\text{P}_2\text{O}_5$ grade but lower $\text{P}_2\text{O}_5$ recovery at same dosage

**Best results:**
- 41.3% $\text{P}_2\text{O}_5$ and 88.3% $\text{P}_2\text{O}_5$ recovery
- Flotigam at 850 g/t
- MIBC at 20 g/t
- $\text{Na}_2\text{SiO}_3$ at 70 g/t

~80% of the lost apatite units in the $\text{-20 \mu m}$ of the final tails (unrecovered free fine particles).

Presence of Fe (pyrrhotite) not associated to apatite in concentrate, lowered by starch addition
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (1st pilot - Jan 2017) (cont’d)

Conclusions & recommendations

• Flotigam 5806 outperformed C5 collector;

• Dosage of both Flotigam 5806 and C5 was higher (up to double) than the collector dosage required in the laboratory testing to obtain the same metallurgical performance. Investigation of the following is recommended to decrease collector consumption:
  • % solids at rghr conditioning: difference between lab and pilot;
  • type of impeller used for conditioning;
  • pulp temperature.

• P₂O₅ losses in tailings mainly from fines (-20 µm). Investigation of the following:
  • better control of the grinding stage;
  • improvement of the hydrodynamic parameters around fine particles flotation.

• Addition of starch reduced the Fe content in concentrate possibly related to the presence of pyrrhotite. Its addition should be considered to meet the specs when this mineral is present.
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (2nd pilot - March 2017)

Objectives:

– Testing of a new reagent suite at natural pH using:
  • Flotigam in combination to a frother (MIBC) at rghr and scav
  • Na$_2$SiO$_3$ at clnr and clnr/scav;

– Production of high grade apatite concentrate from 2 tons of LIMS non-mag;

– Reduction of collector dosage;
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (2\textsuperscript{nd} pilot - March 2017) (cont’d)

Final flowsheet selected and operated @ 85 kg/h

Additional modifications

- Dilution and wash water heated up to 20°C and pulp temperature maintained above 20°C;

- 10-inch square shape propeller instead of marine propeller in conditioning tank to provide high shearing effect.
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (2nd pilot - March 2017) (cont’d)

Results: Final concentrate P$_2$O$_5$ grade/recovery

- P$_2$O$_5$ grade of the final concentrate was constant regardless of collector dosage
- Open or closed circuit yield similar results

**Best results:**
- 40.7% P$_2$O$_5$ and 88.9% P$_2$O$_5$ recovery
  - Flotigam at 530 g/t
  - MIBC at 41 g/t
  - Na$_2$SiO$_3$ at 147 g/t
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (2nd pilot - March 2017) (cont’d)

Laboratory flotation tests after 2nd pilot campaign to evaluate the potential of collector reduction

**Conditions:**
- Conditioning at 65% solids;
- Pulp T° above 20°C;
- Flotigam dosage reduced from 350 g/t to 175 g/t;
- Addition of frother MIBC (10-20 g/t) at lower collector dosage;
- Addition of Na₂SiO₃ (125-150 g/t).

**Results – P₂O₅ grade vs recovery**
Final validation of Mine Arnaud flowsheet
Pilot testwork at COREM (2\textsuperscript{nd} pilot - March 2017) (cont’d)

Conclusions

- Similar metallurgical performance (>40% $\text{P}_2\text{O}_5$ and >88% $\text{P}_2\text{O}_5$ recovery) achieved at pilot scale with lower a collector dosage (530 g/t in March 2017 vs 850 g/t in Jan 2017);

- The potential of collector reduction was demonstrated at laboratory scale when frother is added in proper dosage.

Recommendations on optimization of the following:

- Sodium silicate addition to the cleaner and the cleaner/scavenger stage;

- Flotation hydrodynamic parameters of the cleaner and the cleaner/scavenger stage in order to improve the apatite recovery, including the frother selection/dosage;

- Percent solids at the conditioning as a function of temperature and agitation.
Grinding to apatite liberation size from start allows for a high recovery with a simplified flowsheet;

Magnetic separation before flotation helps simplifying the flowsheet and reagent suite (less cleaner stages, no iron depressant);

Flotation at natural pH favors selectivity of apatite vs gangue minerals. A slightly higher collector dosage seems to compensate for the lower phosphate collecting power of the fatty acid at natural pH without increasing impurities to the final apatite concentrate;

Among the different collectors tested (Liacid 1800, Soltiflot TP-C5 and Flotigam 5806), the ones especially formulated for phosphate rock flotation performed better compared to general fatty acid extract;
Highlights
Mine Arnaud flowsheet development from 2011 to 2017

Optimisation of frother addition is key to minimize the collector (fatty acids derivative) consumption;

\[ \text{Na}_2\text{SiO}_3 \] was shown to be an efficient depressant for mica minerals in phosphate flotation;

In presence of Fe (pyrrhotite) that is not removed by magnetic separation, depression with starch (WW82) is an option;

Proper conditioning (\% solids, agitation/shearing rate, pulp temperature) is key to flotation performance improvement.

The optimisation of these factors led to the simplification of the flowsheet (from 2 grinding steps to 1 and 6 flotation stages to 3) that both increased recovery and decreased operating cost.
Mine Arnaud flowsheet development

Questions / Comments