History and Future of Phosphate Mining and Beneficiation in South Africa

Marius Porteus
Foskor, South Africa, mariusp@foskor.co.za

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Key Note Address

History and Future of Phosphate Mining and Beneficiation in South Africa

Marius Porteus (Pr.Eng)
South Africa
SOUTH AFRICA AT A GLANCE
“Note worthy statistics”

• Arable land (Ha)/person: 0.23 (2015), (World: 0.19, Asia: 0.11, North America: 0.55)

• Fertilizer consumption (% of Fertilizer production): 58.5% (2015), (Australia: 53.6%)

• 2nd Largest Economy in Africa (GDP $ 295.4 billion)
  (Source: World Bank Open Data)

• World’s largest producer of chrome, manganese, platinum, vanadium.

• One of the World’s 15 largest producer of Phosphates

• 6th Largest Phosphate deposits in the world

• Surface Area: 1 213 090 km²

• Population: 55.7 million (2016)

• GDP per capita: $ 5 274 (2016),
  World: $10 189, North America: $ 56 835
HISTORY OF THE SOUTH AFRICAN FERTILIZER INDUSTRY

1652  Dutch settlers used manure in the governors gardens in the Cape

1840  Guano was mined from a small bird island on the West Coast of Namibia

1890  Chemical fertilizer imported in small quantities

1903  South African Fertilizer Company commissioned first phosphate plant using animal bones in Durban

1904  Phalaborwa Igneous Complex discovered. (Rapid Growth in the South African Mining Industry)

1919-1921  Development in mining resulted in $\text{H}_2\text{SO}_4$ production, Kynoch (Durban) & CAPEX (Somerset West) started fertilizer production from imported rock. Today's AECI was formed 1924

1943  Mining of the marine sedimentary onshore deposits in Western Cape started

1951  Phosphate Development Corporation established (Foskor) by the state to develop and mine Phalaborwa Complex

1953-2017  Large scale commercial mining of phosphates in Phalaborwa was a catalyst for the establishment and growth of many industries and companies i.e. OMNIA, AECI, SASOL, KYNCH,

Source: Mineral Economics – An overview of South Africa’s Mineral Based Fertilizers, 2003, Department of Mineral s and Energy
## SHORT INTRODUCTION OF PHOSPHATE DEPOSITS

<table>
<thead>
<tr>
<th>Ref</th>
<th>Deposit</th>
<th>Mineralogy</th>
<th>In-sito % $P_2O_5$</th>
<th>Deposit Size (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phalaborwa</td>
<td>Foskorite &amp; Pyroxenite</td>
<td>5% -10%</td>
<td>9 698 million</td>
</tr>
<tr>
<td>2</td>
<td>Schiel</td>
<td>Foskorite</td>
<td>5.1%</td>
<td>36 million</td>
</tr>
<tr>
<td>3</td>
<td>Glendover</td>
<td>Pyroxenite</td>
<td>20%-25%</td>
<td>+/-10 million</td>
</tr>
<tr>
<td>4</td>
<td>Spitzkop</td>
<td>Pyroxenite</td>
<td>7.5%</td>
<td>Unknown</td>
</tr>
<tr>
<td>5</td>
<td>Onshore Sedimentary Deposits of the West Coast Sandveld</td>
<td>Phosphatic sand</td>
<td>4% -13%</td>
<td>+/- 250 million</td>
</tr>
<tr>
<td>6</td>
<td>Offshore Sedimentary Deposits South Coast</td>
<td>Phosphetized Limestone</td>
<td>10%-25%</td>
<td>5 000 million</td>
</tr>
<tr>
<td>7</td>
<td>Offshore Sedimentary Deposits West Coast</td>
<td>Authigenic pellet phosphorite</td>
<td>16 %</td>
<td>3 500 million</td>
</tr>
</tbody>
</table>


At current mining rates of 34 million tons per year, reserves of 70 years and resource of 100 years plus. Mine ore is upgraded from circa 6.8% $P_2O_5$ to a final rock phosphate product of 37 % $P_2O_5$
MINERALOGY OF THE PHALABORWA COMPLEX

Pyroxenite mineral make-up.

The percentage distribution for the three main minerals in the North Pit and South Pit areas are as follows (Percentage by volume according to the Measured Resource Model);

<table>
<thead>
<tr>
<th></th>
<th>North Pit Mine</th>
<th>South Pit Mine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%Apatite</td>
<td>%Diopside</td>
</tr>
<tr>
<td>Apatite</td>
<td>14,9</td>
<td>63,3</td>
</tr>
<tr>
<td>Diopside</td>
<td>68,0</td>
<td>17,9</td>
</tr>
<tr>
<td>Phlogopite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MINERALOGY OF THE PHALABORWA COMPLEX

**Apatite**  \( Ca_5(PO_4)_3(OH,F,Cl) \)

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>39,36%</th>
<th>18,25%</th>
<th>0,07%</th>
<th>2,32%</th>
<th>38,76%</th>
<th>1,24%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>Ca</td>
<td>P</td>
<td>H</td>
<td>Cl</td>
<td>O</td>
<td>F</td>
</tr>
<tr>
<td>55,07%</td>
<td>41,82%</td>
<td>0,59%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>P2O5</td>
<td>H2O</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18,25%</td>
<td>0,07%</td>
<td>2,32%</td>
<td>38,76%</td>
<td>1,24%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Apatite crystals are liberated at circa 300 um and upgraded to 37% \( P_2O_5 \)
**MINERALOGY OF THE PHALABORWA COMPLEX**

**Diopside**  \((Ca,Mg)Si_2O_6\)

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>(Ca)</th>
<th>(Mg)</th>
<th>(Si)</th>
<th>(O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.51%</td>
<td>25.90%</td>
<td>18.61%</td>
<td>55.49%</td>
<td>-</td>
</tr>
<tr>
<td>11.22%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.94%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.33%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diopside exceeding 70% in mass of ROM causes pumping and mixing challenges and leads to settling in sumps, pipelines and flotation cells. This is due to its sharp edged structure of particles after grinding.
MINERALOGY OF THE PHALABORWA COMPLEX

**Phlogopite**  \( \text{K} \text{Mg}_3(\text{Si}_3\text{Al})\text{O}_{10}(\text{F,OH})_2 \)

<table>
<thead>
<tr>
<th>Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>9,33% K</td>
</tr>
<tr>
<td>17,39% Mg</td>
</tr>
<tr>
<td>6,44% Al</td>
</tr>
<tr>
<td>20,10% Si</td>
</tr>
<tr>
<td>0,24% H</td>
</tr>
<tr>
<td>41,98% O</td>
</tr>
<tr>
<td>4,53% F</td>
</tr>
</tbody>
</table>

As part of a research project between 1994 and 2000 to produce Alumina, phlogopite was extracted from the milled product using spirals, pressure leached with sulphuric acid, aluminium extracted through solvent extraction, crystallized and calcined to produce Alumina. By-product was MgO and potassium-bi-sulfate. (Process named the “Croyden Process”)

BENEFICIATION PROCESS OF PHALABORWA IGNEOUS ROCK

**FOSKOR** is currently mining and beneficiating igneous phosphate rock at Phalaborwa

**Mining:** Conventional drill, blast, load and haul

**Crushing:** Primary, secondary and tertiary crushing

**Milling:** Wet milling, primary and secondary (rod-mill, rod-mill), Dry milling (Loesche roller mill) and rod-mill, ball mill configuration

**Flotation:** Self aerated conventional and tank cell (Wemco and Ultimate flotation cells) four stage flotation. Fatty acid & sulphonic acid float.

**Filtration:** Horizontal vacuum belt filters

Mine ore is upgraded from circa 6.8% $P_2O_5$ to a final product of 37% $P_2O_5$
SIMPLIFIED FLOW DIAGRAM OF BENEFICIATION PROCESS OF THE PHALABORWA PHOSPHATE DEPOSIT

Southern Pyroxenite Pit
- 70%
  
  Drill & blast
  Load & Haul

Northern Pyroxenite Pit
- 30%
  
  Drill & blast
  Load & Haul

Crushing (P,S&T) Stockpiling Mills (P,S&T) #13–24

Crushing (P,S&T) Stockpiling Mills (P&S) #A–12

Milling
Loesche (Dry)/Rod&Ball (Wet P&S)

Filtration & Stock

Flotation DSF
- 20%

Flotation E Bank
- 22%

Flotation E Bank
- 20%

Flotation F Bank
- 38%

82-83BPL

Drying and Dispatch

Exports
Domestic Sales

Slurry Pumps
Bosveld Plant
BASIC PROCESSING AND PRODUCT PARAMETERS

ROM P2O5

- Mine
- P2O5: 6.80%

Primary Crusher

- P80 Size: 200 mm

Secondary & tertiary Crushers

- P80 Size: 10 mm

Filtration (Belt filter) – final product

- F80 Size: 183 um
- Moisture: 8%

Flotation (4 stages)

- F80 Size: 300 um
- Fatty Acid (450 g/ton), Sulphonic Acid (90 g/ton)

Grinding (Primary & Secondary)

- F80 Size: 10 mm

Rod mills

Product Stockpile

- 37 % P2O5
- Moisture: 4%-6%

Rotary Driers

- Temp: 900 °C
- Moisture: 1%

Dispatch (800 km to acid plant)

- 37 % P2O5
- 183 um
- 1% Moisture
**BENEFICIATION CHALLENGES OF THE PHALABORWA PHOSPHATE DEPOSITS**

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Mitigation/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original design did not provide for sufficient blending of ROM material to processing plants.</td>
<td>In pit blending and intermediate product stockpiles provide some level of blending before processing.</td>
</tr>
<tr>
<td>Scale up of pilot plant test results to full scale design of new grinding equipment (new technology) problematic.</td>
<td>Introduce another testing phase as close as possible to the commercial size equipment and circuit.</td>
</tr>
<tr>
<td>“One Size does not Fit all”. Correct design and configuration of tank cells for use in coarse phosphate flotation.</td>
<td>Different resident times for particles in the flotation cells were used for the different flotation stages resulting in different tank sizes for each flotation step.</td>
</tr>
<tr>
<td>“Bigger and Less” is not always “better”. Use of higher capacity and less equipment in high throughput processes can results in lower utilisation and higher equipment and shutdown costs.</td>
<td>Higher equipment redundancy in milling and flotation reduces the risks of unnecessary total plant stoppage. (Balance between CAPEX, OPEX and plant run time need to be considered).</td>
</tr>
</tbody>
</table>

Learn from your previous mistakes and stick to what work! Have sufficient scale up steps! Document test work properly and ensure institutional memory.
ACTIVELY MINED PHOSPHATE DEPOSITS
“West Coast Sand Veld Sedimentary Phosphate Deposits”

Google Image of Saldanha Bay and Langebaan Lagoon
Western Cape

Mine ore is upgraded from circa 8% $P_2O_5$ to a final product of circa 30% $P_2O_5$
Typical types of phosphates found in the Langebaan area are unconsolidated pelletal deposits, consolidated crust type deposits (phoscrete). According to (Birch 1990), phosphorites in this area were formed in an estuary next to a region of upwelling and high biological activity.
BENEFICIATION PROCESS OF THE ELANDSFONTEIN DEPOSIT (Varswater Formation)

*KROPZ* is currently mining and beneficiating the sedimentary phosphate at Elandsfontein

**Typical West Coast beneficiation processes:**

**Mining:** Strip Mining

**Crushing, Washing & Screening:** Grizzly, jaw crusher for oversized material, vibrating screens

**Milling:** Wet milling (ball mill)

**Flotation:** Reverse Flotation, Amine float. (Elandsfontein process)

*Mine ore is upgraded from circa 8% P$_2$O$_5$ to a final product of 30% P$_2$O$_5$* (Optimisation is continuing after commissioning. Kropz indicated in a media statement that the plant will be operational December 2018)
### Major Players in the South African Phosphate Industry

<table>
<thead>
<tr>
<th>Company</th>
<th>Phosphate products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foskor(Pty)Ltd</td>
<td>Phosphate rock (37% P$_2$O$_5$), Phosphoric acid (54% P$_2$O$_5$), Granular Fertilisers (MAP)</td>
</tr>
<tr>
<td>Phalaborwa &amp; Richards Bay</td>
<td></td>
</tr>
<tr>
<td>OMNIA</td>
<td>Granular fertilisers, Liquid fertilisers, Nitro-Phosphates, animal feeds (MCP &amp; DCP), MAP, DAP</td>
</tr>
<tr>
<td>Sasolburg</td>
<td></td>
</tr>
<tr>
<td>YARA (South Africa)</td>
<td>Animal feeds, Liquid Fertilizers</td>
</tr>
<tr>
<td>Western Cape, Durban</td>
<td></td>
</tr>
<tr>
<td>BioMinerale</td>
<td>Animal Feeds (MDCP, DCP)</td>
</tr>
<tr>
<td>Numerous smaller companies</td>
<td>Numerous smaller companies exist producing speciality phosphate related products. (Refer to the Fertilizer Association of South Africa website)</td>
</tr>
</tbody>
</table>

Source: Fertilizer Association of South Africa website [www.fertasa.co.za](http://www.fertasa.co.za)
## FUTURE OF THE PHOSPHATE INDUSTRY IN SOUTH AFRICA

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vast phosphate Reserves circa &gt;2 000 million tons</td>
<td>Water scares country. Extended droughts. Possible climate change impacting negative on agriculture</td>
</tr>
<tr>
<td>Well established mining, processing and fertilizer manufacturing industry</td>
<td>Expansion of coal mining. (Coal mining expanding into arable land area, major corn growing area. 40 % of fertiliser used for corn growing)</td>
</tr>
<tr>
<td>Limited arable land. High crop yields required. Fertilizers essential.</td>
<td>Phosphate deposits occur in environmental sensitive areas: Phalaborwa next to Kruger National Park, Onshore sedimentary deposits in well known palaeontological and water scares areas, offshore deposits in key commercial fishing waters.</td>
</tr>
<tr>
<td>Low fertilizer usage in subsistence farming</td>
<td>Cost of deep level opencast phosphate mining</td>
</tr>
<tr>
<td>Recovery of Zimbabwe economy. (Was the “bread basket” of Southern Africa).</td>
<td>Government land expropriation and land distribution Policies &amp; Programs. Sustainable commercial agriculture?</td>
</tr>
<tr>
<td>Sub-Saharan Africa a growing market.</td>
<td></td>
</tr>
<tr>
<td>High quality phosphate rock. Low cadmium.</td>
<td></td>
</tr>
<tr>
<td>Logistically well positioned for exports to Southern Africa, Australasia, Brazil and India</td>
<td></td>
</tr>
<tr>
<td>South Africa currently the only main source of phosphate in Southern Africa</td>
<td></td>
</tr>
<tr>
<td>Bio-fuels as an alternative to fossil fuels.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Fertilizer Society of South Africa (May 2006)
OBSERVATION AND KEY MESSAGE

WHETHER SOUTH AFRICA, CHINA, USA OR GERMANY, THE MESSAGE WORLDWIDE IS THE SAME:

In a message to the United States Congress in 1938, President Franklin D Roosevelt stressed the importance of phosphate to agriculture and people.

‘The phosphorus content of our land, following generations of cultivation, has greatly diminished,’ President Roosevelt said. ‘It needs replenishing. I cannot over-emphasize the importance of phosphorus not only to agriculture and soil conservation but also the physical health and economic security of the people of the nation. Many of our soil deposits are deficient in phosphorus, thus causing low yield and poor quality of crops and pastures…’

Source: Florida Industrial and Research and Phosphate Institute: Phosphate Primer

80 years later this message is as valid as it was in 1938...

The only difference, there is less phosphate to be mined today, the world population has increased by 5.4 billion to 7.6 billion (2017) and expected to reach 9.8 billion by 2050 (United Nations) and arable land world wide are declining (Food and Agriculture Organization of the United Nations )

IS INDUSTRY DOING ENOUGH TO AVERT A FUTURE WORLD SHORTAGE OF PHOSPHATE ???

What can we learn from the Cape Town (Western Cape) “Water Crisis”?
“DO NOT WAIT UNTIL A KNOWN RISK BECOMES A CRISIS!”

PHOSPHATE – A LIMITED/NON RENEWABLE RESOURCE

Understand the risk (Probability & Impact): When do we reach an irreversible situation or crisis? Can we afford to leave this to the next generation to solve?

Improved efficiencies/recoveries (The Source): Every gram of phosphate counts. Low recoveries or conversion should not be acceptable!

Innovation: We need to become smarter to do it better. Research and Development is critical.

Recycle: 37% of available recyclable phosphorus in the USA could satisfy the need of the total corn production in the USA. (Andrew Urevig, ENSIA. (2016))

Environmental responsibility: Phosphorus, a “life giving” element should not become the cause of an “environmental destructive” process.

Let’s continue to MINE, BENEFICIATE and USE phosphate responsibly!
References

1. Mineral Economics – An overview of South Africa’s Mineral Based Fertilizers, 2003, Department of Minerals and Energy


References


10. Fertilizer Association of South Africa. www.fertasa.co.za
