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Spring 3-29-2015

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Leonid Lisiansky, Mike Baker, Keren Larmour-Ship, and Olga Elyash, "A Tailor Made Approach for the Beneficiation of Phosphate Rock" in "Beneficiation of Phosphates VII", P. Zhang, FIPR; J. Miller, Univ. of Utah; L. Leal, Univ. of Sao Paolo; A. Kossir, OCP Group; E. Wingate, Worley-Parsons Services Pty Ltd. Eds, ECI Symposium Series, (2015). http://dc.engconfintl.org/phosphates_vii/24

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A Tailor Made Approach for the Beneficiation of Phosphate Rock

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Abstract

Tenova Bateman Technologies (TBT), part of Tenova Mining & Minerals is known as a provider of advanced process technologies in solvent extraction, phosphate beneficiation and fertilizer production.
TBT has participated in a number of phosphate projects and offers a comprehensive range of phosphate treatment technologies: from beneficiation to the production of purified phosphoric acid and downstream salts.
The beneficiation of phosphate rock can often be simplified and made more economic by taking into account the distribution of P_2O_5 and impurities as a function of their deportment between the size fractions resulting from mined and comminuted sedimentary phosphates.
A number of case studies developed by TBT are presented in the current paper. For each project, the particular properties of the feedstock were taken into account as the beneficiation process was being developed.

Keywords: tailor made approach, phosphate beneficiation, sedimentary phosphate, size fractions, P_2O_5 distribution, distribution of impurities, comminution, dense media separation (DMS), flotation.

Introduction

Phosphate rocks from different deposits possess a wide range of properties related primarily to the geological origin of the phosphate. In parallel, beneficiation methods for phosphate rock are finite and include: comminution and size separation (crushing, grinding, attrition, screening and classification), mineral separation (flotation, gravity and magnetic separation) and ocassionally, chemical and thermal methods (acidulation, calcination etc.).

Despite the fact that flotation is a universal beneficiation operation, applied to the majority of phosphates, the preparation (comminution) of the phosphate differs significantly from plant to plant, from deposit to deposit and reflects the particular technological properties of the source rock.

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The initial characterization of a specific phosphate usually involves complex mineralogical, chemical and sink-float analyses applied to mined and comminuted material. This is followed by a series of detailed laboratory and pilot plant tests that allow an in-depth understanding of the phosphate's technological properties. Consideration of the results of the research together with the requirements of the market, the economic climate and the particular constraints of the client leads to the selection of an optimal tailor made combination of processing methods for the treatment of the phosphate.

As is well known, phosphates are classified into sedimentary, igneous and guano according to their origin. About 75% of the today's phosphate production is based on sedimentary deposits and 23% from igneous deposits.

The composition of igneous rock is the result of the crystallization of cooling magma. The distribution of P_2O_5 and other minerals is often random across the size fractions of the rock. Therefore, igneous phosphate beneficiation is usually similar to the processing of base metal ores and involves grinding following by flotation.

The structure of sedimentary phosphate often reflects the size and form of the prehistoric marine life, the source of the phosphate. Sedimentary phosphates from different deposits show a surprisingly common distribution of P_2O_5 in the size fractions of the mined and crushed rock. The P_2O_5 concentration is significantly higher in the central "sweet" size fractions, while the coarse and fine fractions are poorer in grade (Figure 1).

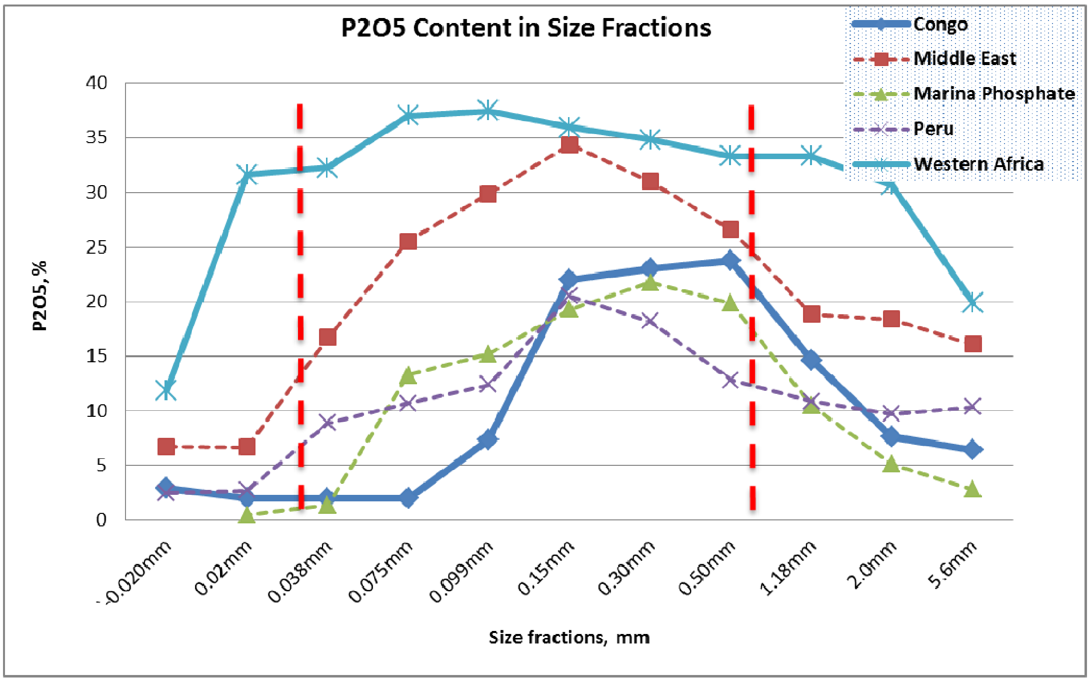

FIGURE 1. Sedimentary phosphate rock. P_2O_5 Deportment

The distribution of the impurities (MgO, Al_2O_3, Fe_2O_3 etc.) is the inverse: the central size fractions are significantly cleaner than the coarse and the fines (Figure 2).

This phenomenon frequently permits the rejection of a significant proportion of the gangue minerals and impurities for relatively low P_2O_5 losses by simple inexpensive operations at the front end of the process.

In some cases, it is possible to direct the rich fraction to the final concentrate right at the beginning of the process.

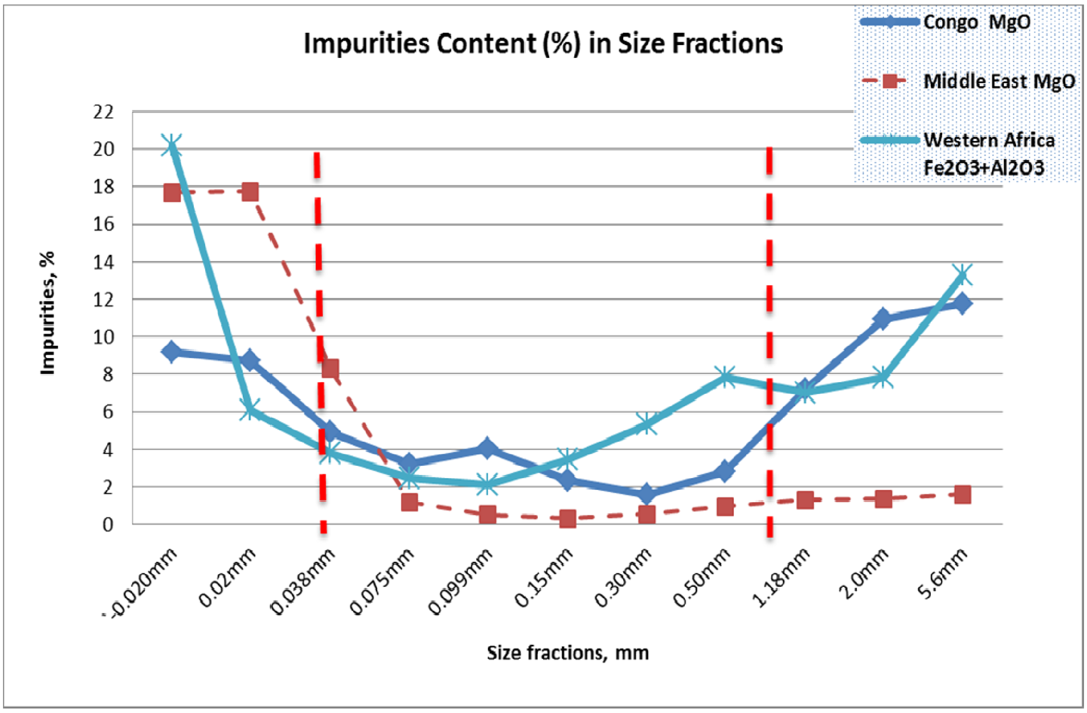

FIGURE 2. Sedimentary phosphate rock. Deportment of contaminants

This "pre-beneficiation" allows the processors to concentrate their beneficiation efforts towards the treatment of the relatively small remaining stream, thereby significantly reducing the extent of the expensive grinding, flotation and tails handling operations.

The characteristics of P_2O_5 deportment as a function of the size fraction is not a "law" but repeats itself often and can be exploited for the development of a reasonable beneficiation flowsheet configuration.

A number of examples of TBT case studies demonstrating a tailor made approach to sedimentary phosphate beneficiation is presented in this paper.

It should be noted that the results describe the beneficiation as developed by TBT and do not necessarily represent the actual process adopted.

Case Study 1: Middle East Phosphate

- The deposit is a sedimentary calcareous phosphate with no significant contaminants.
- Liberation size is 480 microns.
- ROM grade averages 21.9% P_2O_5.
- A concentration of P_2O_5 to the 1000/100 micron size fraction is observed (Figure 3). This high grade sweet size fraction represents 40% of the total ore.

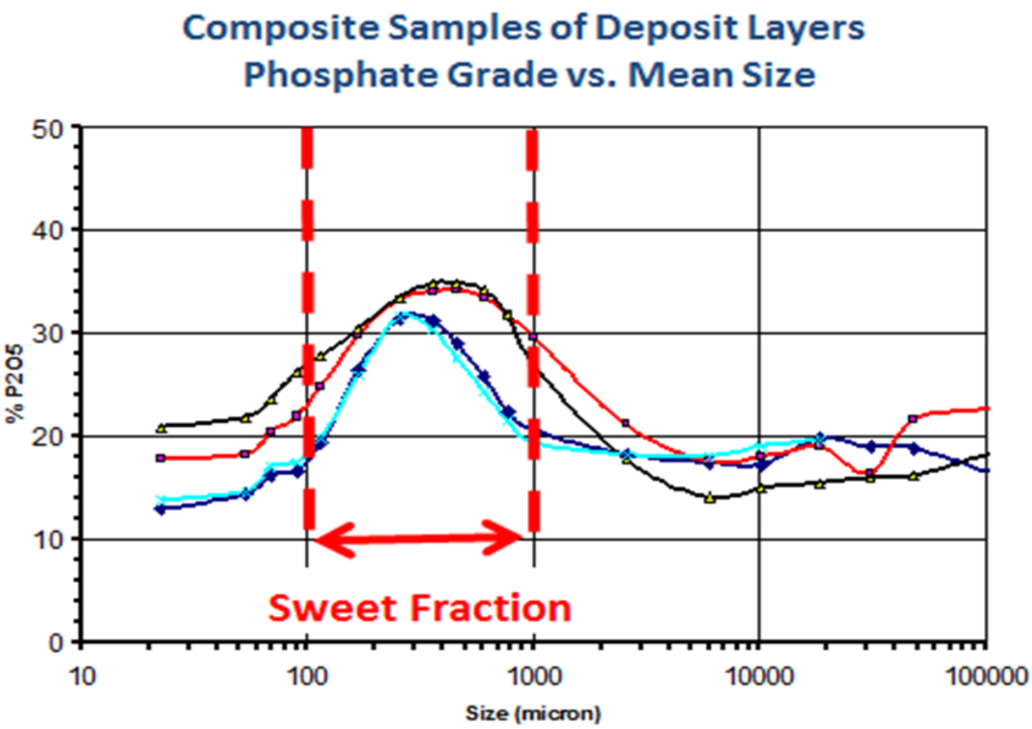

FIGURE 3. Middle East phosphate project. Composite samples of deposit layers. Phosphate Grade vs. Mean Size

The phosphate deportment to particular size fractions leds to the development of the beneficiation scheme presented in Figure 4:

- Three stage crushing with the creation of a sweet concentrate fraction (710/212 micron) by screening and classification.
- As a result, ~70% of the final concentrate was produced at the front of the process, prior to the more expensive grinding and flotation .
- The remainder of the material following grinding and desliming was fed to flotation (feed to flotation amounted to ~ 33% of the ROM).

The resulting beneficiation flowsheet is significantly simpler and cheaper than the traditional full grinding-flotation technology.

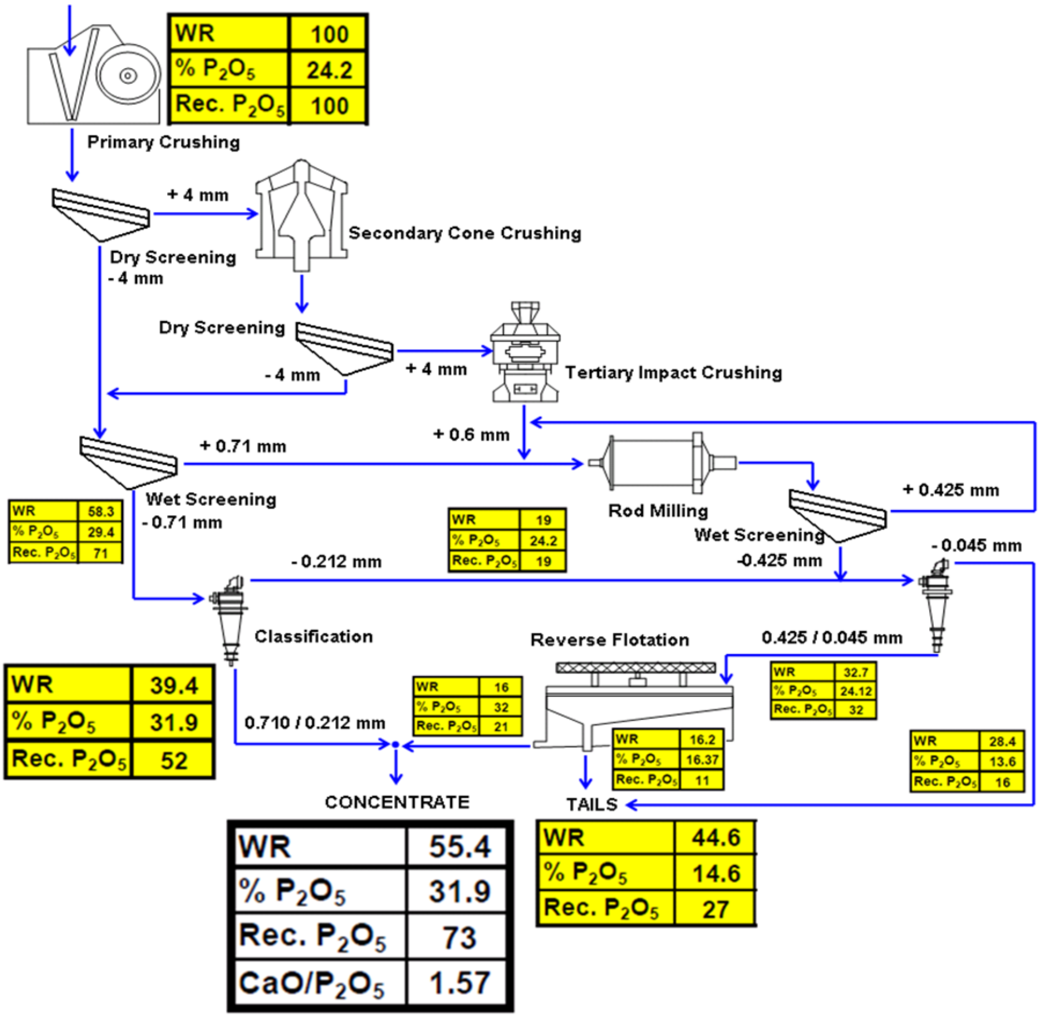

FIGURE 4. Middle East Phosphate Project. Beneficiation Flowsheet

Case Study 2: Hinda Phosphate (Cominco Project, Republic of Congo)

- Hinda contains sedimentary siliceous-calcareous phosphate with dolomite.
- The primary impurities are MgO, Al_2O_3, Fe_2O_3.
- Liberation size ~ 250-300 microns.
- ROM grade 9-16% P_2O_5; 2.1-6.9% MgO.
- The deportment of P_2O_5 and MgO to the size fractions of the crushed rock was assessed and is presented in Figure 5.
- Unlike the previous Middle Eastern phosphate case, the grade of the Hinda sweet fraction was not sufficiently rich (~20% P_2O_5) for separation as direct concentrate. However, the fine and coarse size fractions were poor and a significant proportion of the impurities reported to these fractions. This allowed the rejection of these size fractions at the start of the beneficiation by screening and classification.

The beneficiation flowsheet for Hinda phosphate is shown in Figure 6.

- Discard of coarse and fine rejects allowed:
  - a reduction of the feed to grinding-flotation circuit to ~50% of the original ore,

- increased grade of flotation feed from 12% P_2O_5 (ROM) to ~ 20% P_2O_5,
- removal of ~ 72% MgO,
- removal of ~ 60% Fe_2O_3,
- removal of ~ 80% Al_2O_3.

- A modified two-stage flotation resulted in the production of marketable grade concentrate.

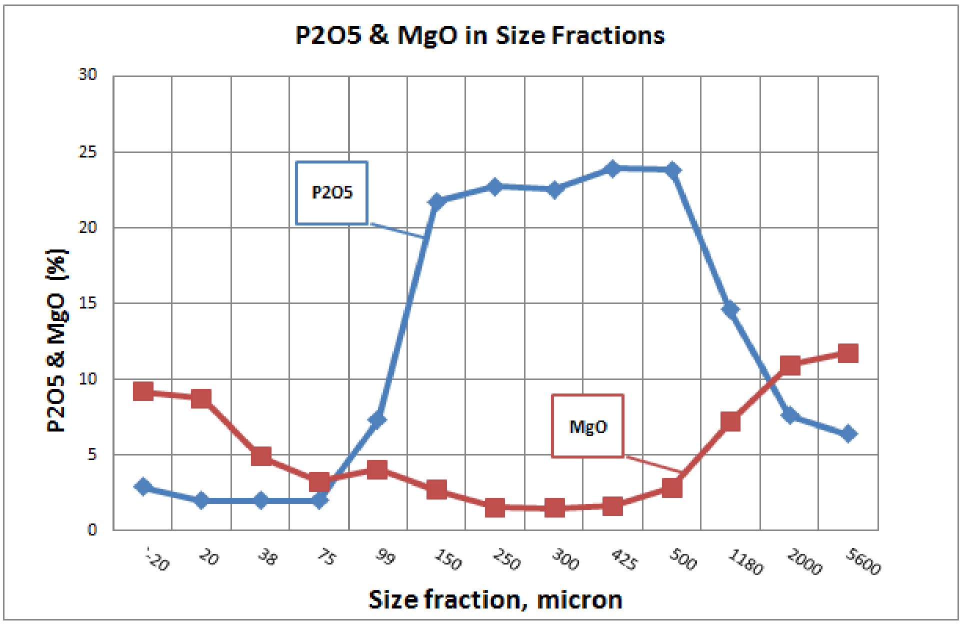

FIGURE 5. Hinda Phosphate (Cominco Project, Congo). P_2O_5 and MgO Deportment

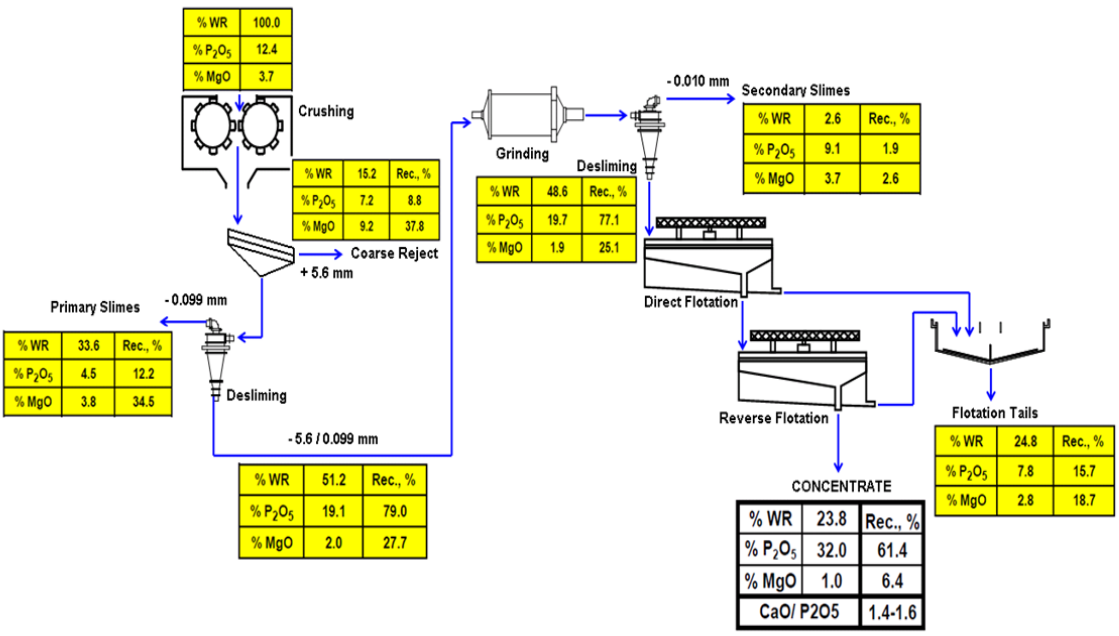

FIGURE 6. Beneficiation Flowsheet (Hinda phosphate)

Case Study 3: Western Africa Phosphate

The deposit is a sedimentary siliceous phosphate with high levels of Al_2O_3 and Fe_2O_3 contaminants.

- Liberation size ~ 500 microns.
- ROM grade: ~19.0-22.0% P_2O_5.
- Sieving the ore did not reveal any interesting clues, but crushing to -5mm resulted in the formation of a rich coarse size fraction with a reduced content of impurities (Figure 7).
- Unlike previous cases, no low grade coarse size fraction was observed.

The recommended beneficiation flowsheet is shown in Figure 8:

- The rich coarse size fraction of the crushed ore was scalped, attrited and deslimed to remove the Al_2O_3 and Fe_2O_3 contaminents. As a result, a coarse high grade (36% P_2O_5) concentrate representing ~56% of the overall final concentrate was produced prior to flotation.
- The remaining 45% of the ROM was fed to flotation after attrition and desliming. Fine high grade concentrate was produced.
- It should be noted, that as a result of the approach described above, grinding was not neccessary in the flowsheet proposed to achieve merchant grade concentrate.

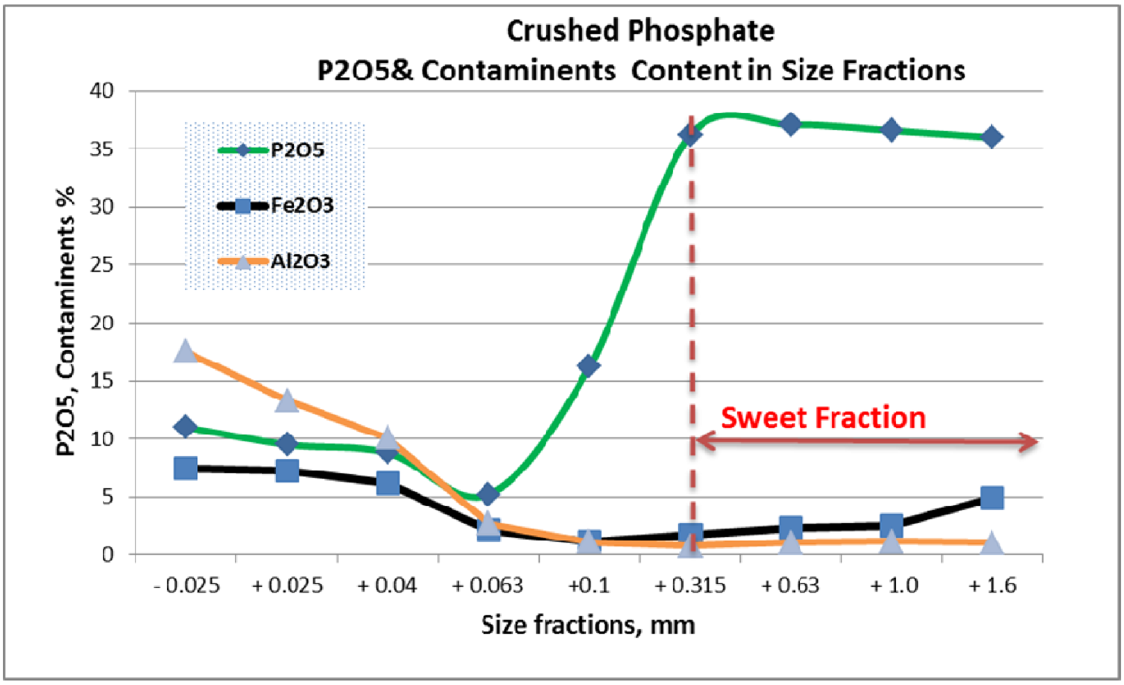

FIGURE 7. Western Africa I. Rich coarse size "sweet" fraction with reduced impurities in the crushed phosphate

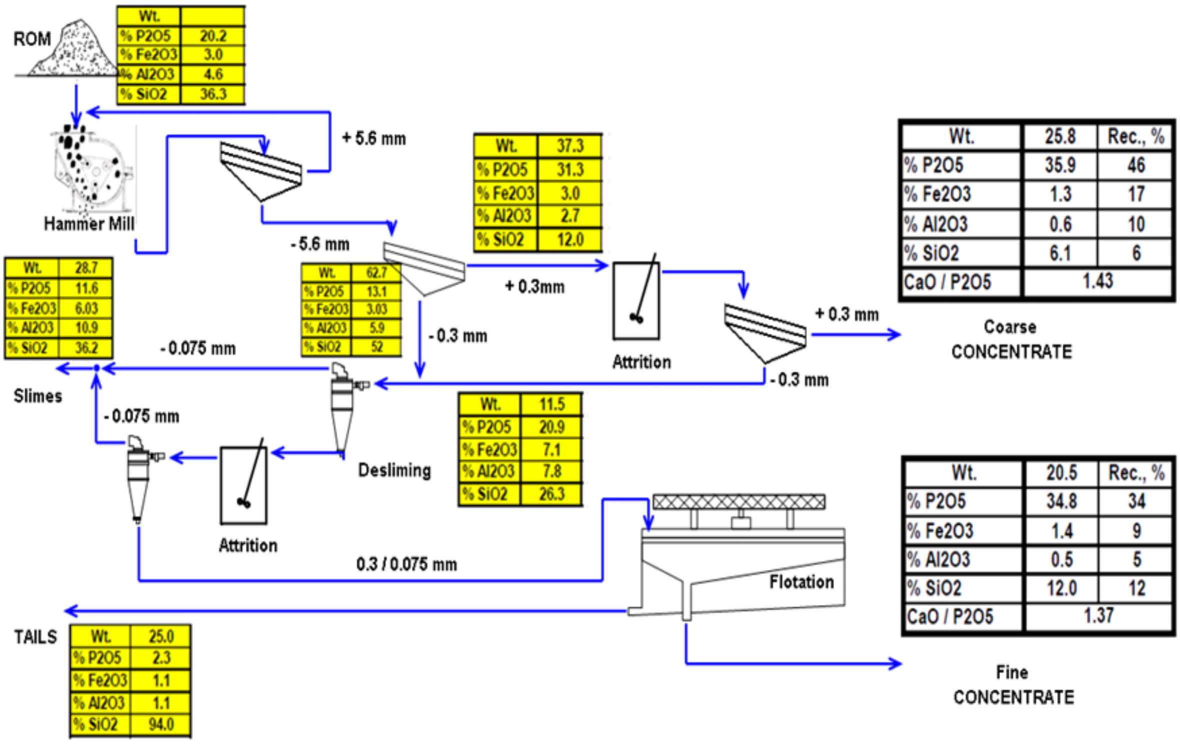

FIGURE 8. Western Africa. Beneficiation Flowsheet

Case Study 4: Australia, Nolans Project

Nolans ore is fundamentally different. This is a sedimentary siliceous-calcareous phosphate that contains economic grades of rare earth elements (REE).

- Liberation size 300 micron.
- ROM grade: 18.7 % P_2O_5 and 4.9% REE.
- No particular rich or rejectable size fractions were observed in the crushed ore (Figure 9).

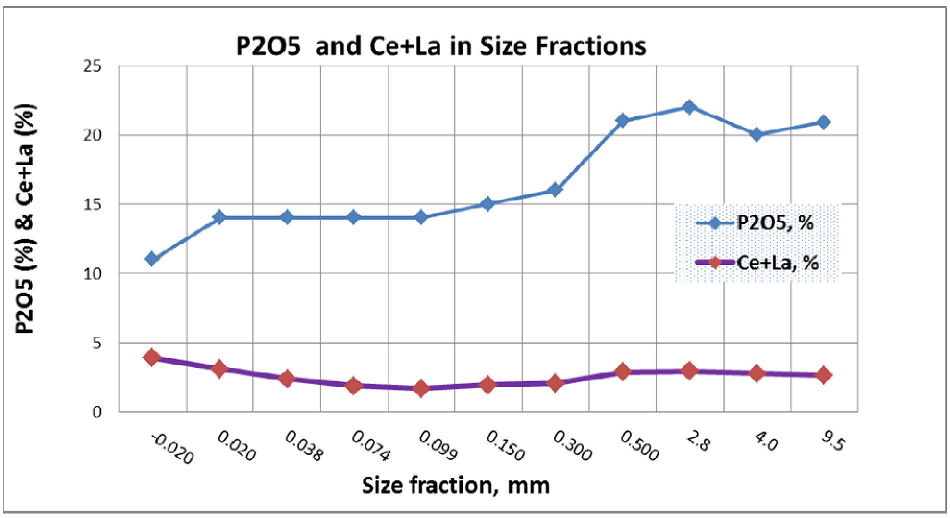

FIGURE 9. Nolans P_2O_5 and REE grade in Size Fractions

- Project specifics:
    - No infrastructure at the deposit site, desert area.
    - Remote location, extremely long transportation distance to downstream processing plant; high haulage costs.
    - Radioactive ore that necessitates return of wastes from rare earth recovery plant to the mine for disposal (double haulage).

The main goal of the process development was maximum rejection of silica by low energy operations.

In regard to the DMS feed size, the common feed size of >1mm was replaced by the project's >0.3mm. This is a rare application for DMS and proved effective in series of specially designed tests. The success of the application of DMS to this >0.3mm size fraction permitted the omission of grinding from the process flowsheet (see Figure 10).

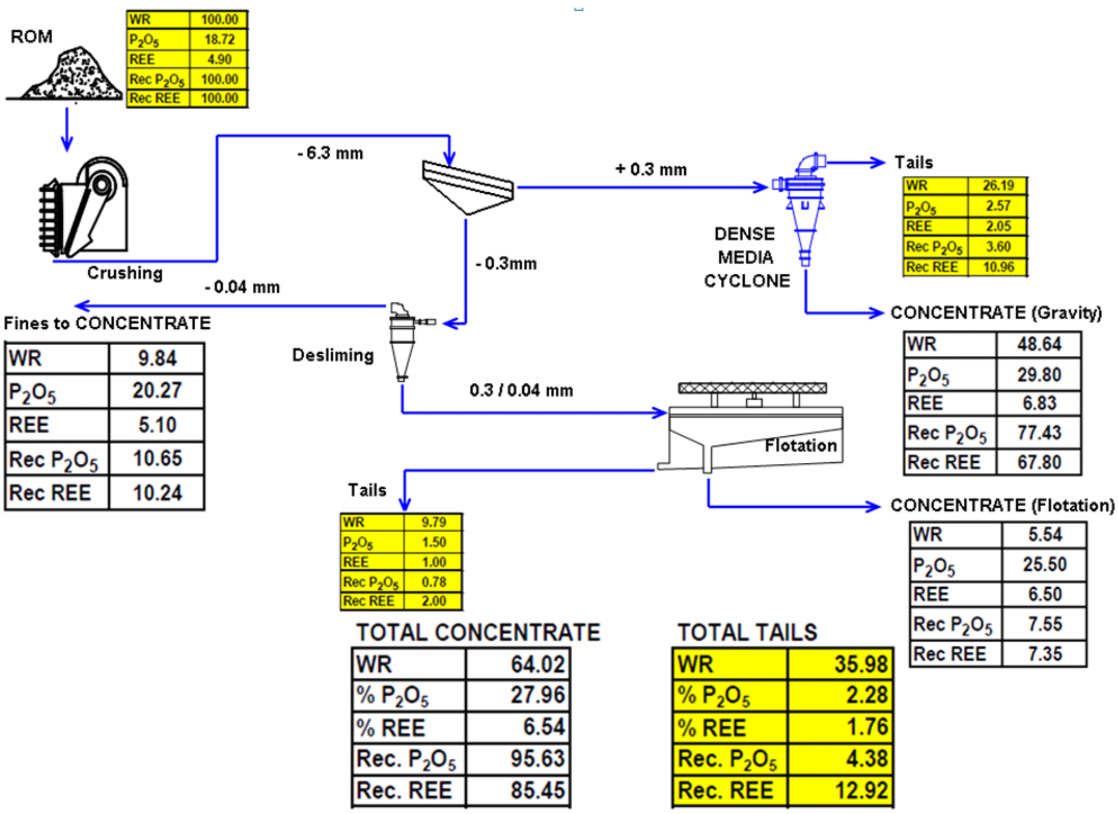

FIGURE 10. Nolans Beneficiation Flowsheet

The flowsheet includes the following operations:

- Three stage crushing.
- Screening at 300 microns.
- DMS for the screen oversize (75% of ore), rejection of 26% as coarse tails and production of coarse concentrate.

- Desliming the screen undersize with high REE content slimes, included in the final concentrate in spite of the lowish P_2O_5 grade.
- Flotation was applied to only 15% of the ROM with discard of additional fine tails.
- The final concentrate was composed of DMS concentrate, flotation concentrate and slimes (low P_2O_5 but rich in REE).

As a result of the process development, about 36% high silica tails could be discarded directly at the deposit, obviating transportation to the processing plant.

<u>Case Study 5: Namibia Marine Phosphate</u>

This "juvenile" phosphate originates from the coastal shelf of Namibia and contains as major gangue, carbonate and insolubles.

- Liberation size is very fine at <106 microns.
- ROM grade: ~ 20.0% P_2O_5.
- Typical P_2O_5 deportment across the size fractions is presented in Figure 11.
- The deportment presented in Figure 11 indicates that the coarse and fine fractions being poor grade are discardable.
- The central sweet fraction is not rich, however the high solubility of the phosphate encourages its attractiveness as a direct application fertilizer.

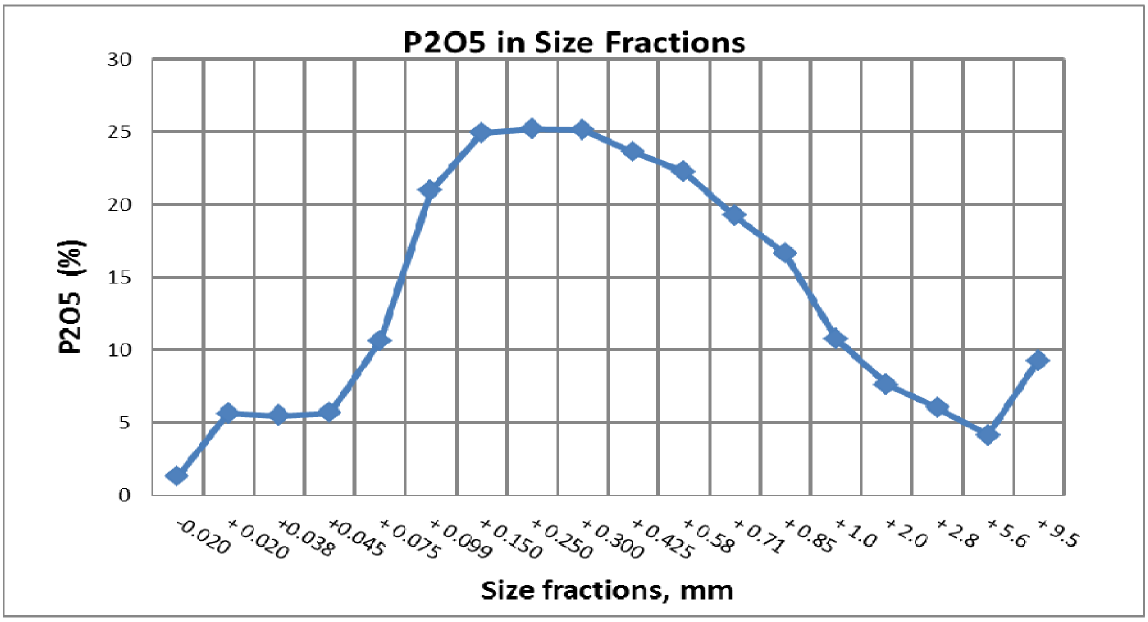

FIGURE 11. Namibian Marine Phosphate. Typical form of P_2O_5 deportment

The recommended flowsheet (Figure 12) includes:

- Scalping of the low grade coarse size fraction (+1mm).
- Desliming (100 microns) with rejection of the low grade slimes.
- Gravity separation for the "sweet fraction" based on a combination of particle gravity and shape to achieve concentrate grade.

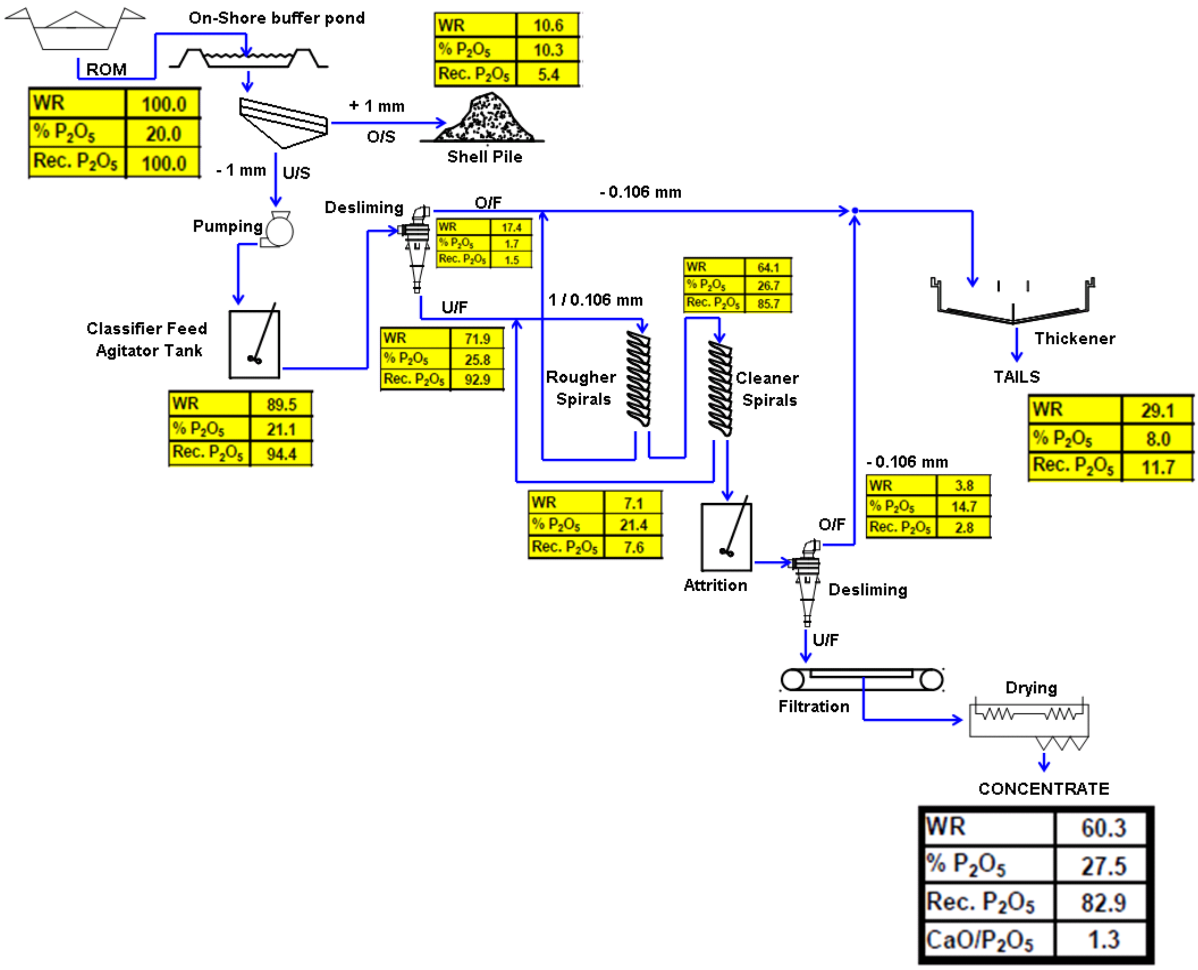

FIGURE 12. Beneficiation Process Flowsheet for Marine Phosphate

Note, sink-float tests did not predict an efficient gravity separation for this phosphate, however tha actual tests resulted in a low grade tailing. Observation of the concentrate and tails under the microscope indicated separation based on shape rather than specific gravity.

FIGURE 13. Marine Phosphate. Gravity Concentrate

FIGURE 14. Marine Phosphate. Gravity Tails

Conclusions

The wide variation of technological properties of phosphate ores necessitate a flexible approach to beneficiation.

Five different sedimentary phosphate rocks are presented, resulting in five different process solutions. In each case, an appropriate tailor made combination of processing methods was developed to produce merchant grade concentrate.

In every case, the particular properties of the phosphate were taken into account to achieve a robust and effective beneficiation process.