World Phosphate Rock Reserves and Resources

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Numerous articles suggest phosphorus (phosphate rock) reserves — resources will be depleted in the 21st century.
- Rosemarin, 2004
- Rosemarin et al., 2009
- Cordell, Dragert and White, 2009
- de Haes et al., 2009
- Vaccari, 2009

Institute of Ecology, 1971
Phosphate rock reserves exhausted, 90-130 years
Indicative peak phosphorus curve, illustrating that, in a similar way to oil, global phosphorus reserves are also likely to peak after which production will be significantly reduced (Jasinski, 2006; European Fertilizer Manufacturers Association, 2000).

Source: Cordell, Drangert and White, 2009
Recent articles on phosphorus depletion rely on USGS data for phosphate rock reserve and resource estimates.
Phosphorus From Phosphate Rock

Two major types
- Sedimentary
- Igneous

Composed of apatite
- Sedimentary, carbonate apatite
- Igneous, fire formed (fluor-chlor-hydroxyl-apatite)

Apatite – “Apte,” Greek Goddess of deceit, guile, fraud and deception released from Pandora’s Box
Economic and Potentially Economic Phosphate Deposits of the World

Igneous Deposits
Sedimentary Deposits
Island Deposits

Figure 5. Economic and Potentially Economic Phosphate Deposits of the World.
Global Phosphate Rock Production

- >160 mmt (2008)
Phosphate Rock

72% – Phosphoric Acid
12% – SSP
2% – TSP (excludes $P_2O_5$ from PA)
14% – Other Uses
(Nyri, 2010)

Total $P_2O_5$

82% – Fertilizer
18% – Industrial Uses
Losses range from 2% to 15% with the weighted average of 5%
(Prud’homme, 2010)
Relationship of Phosphate Rock and Phosphate Fertilizers

- **Phosphate Rock**
  - Sulfuric Acid
  - Nitric Acid

  - **SSP**
  - **WPA**
    - CaSO₄·XH₂O
    - + Ammonia
    - + Phosphate Rock
  - **DAP, MAP**
  - **TSP**
  - **NPKs**

  - **Nitrophosphates**

- **NPKs**
World Phosphate Rock Production
(USBM/USGS Mineral Commodity Summaries, 1982–2010)

The graph shows the production of phosphate rock from 1975 to 2015. The production is measured in millions of tons. The line graph indicates a positive trend with a linear equation given by $y = 0.0677x + 7.2845$ and a coefficient of determination $R^2 = 0.0025$. The production shows some fluctuations over the years, with a general increase from 1975 to 2015.
There has been a continuous decrease in world phosphate rock quality as reserves of high-grade and high-quality phosphate rock are being depleted.

—Is this true?
World Phosphorus Production by Grade

- 30% P2O5 and under
- 31% P2O5
- 32% P2O5
- 34% P2O5
- 36% P2O5 and over
Phosphate Rock Has Been a Relatively Low-Value Bulk Commodity
Fertilizer Prices (FOB, bulk) Monthly Averages January 2007–June 2010

IFDC Reserve-Resource Study

- Literature review
- Past reserve-resource estimates
- Evaluate current phosphate rock mining, beneficiation methods and $P_2O_5$ recovery
- Make a preliminary estimate of world reserves and resources
Phosphate Rock Literature Review

- Limited since early 1990s
- Some information on websites, trade magazines, conference papers, papers with limited distribution
- Reserve-resource terminology is not standardized
<table>
<thead>
<tr>
<th>Phosphate Rock Resources</th>
<th>Estimated Recoverable Product</th>
<th>Reserves</th>
<th>Reserve Base</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[metric tons x 10⁸ (U.S. Billion)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emigh (1972)</td>
<td></td>
<td>1,200</td>
<td></td>
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<tr>
<td>Wells (1975)</td>
<td></td>
<td>530 (30% $P_2O_5$)</td>
<td></td>
</tr>
<tr>
<td>DeVoto and Stevens (1979)</td>
<td>1,200</td>
<td>265 (~30% $P_2O_5$)</td>
<td></td>
</tr>
<tr>
<td>Cathcart (1980)</td>
<td>91</td>
<td>20 (≥30% $P_2O_5$)</td>
<td></td>
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<tr>
<td>Fantel et al. (1988)</td>
<td></td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Notholt, Sheldon and Davidson (1989)</td>
<td>163 (~22.5% $P_2O_5$)</td>
<td></td>
<td></td>
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<tr>
<td>USGS (2009)</td>
<td></td>
<td>15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Originally described as phosphate rock that could be produced at less than US $40/ton.
<sup>b</sup> Originally described as phosphate rock that could be produced at less than US $100/ton.

Emigh (1972) – No data for Middle East, North Africa.
DeVoto and Stevens (1979) – Only for free world.
Fantel et al. (1988) – Little or no data for much of Middle East. No data for China.
Mining, Beneficiation, \( \text{P}_2\text{O}_5 \) Recovery

Mining – Economic = Large-Scale

Beneficiation – Generally as simple as possible
– Froth flotation employed in U.S. in 1920s–1930s, employed in North Africa and Middle East in last 15 years
Reserves and Resources – This Study

- Reserves – Phosphate rock that can be economically produced at the time of the determination to make suitable products, reported as tons of concentrate
- Resources – Phosphate rock of any grade that may be produced at some time in the future, including reserves
Phosphate Rock Reserves as Published in USBM/USGS Mineral Commodity Summaries
Reserves and Resources – This Study

- Original or most current literature or other sources
- Evaluated if reserves were given as ore or concentrate
- Assumed 95% mining recovery
- Applied ore to concentrate ratio applicable to the deposit or processing of similar ore
- Calculated reserves as product
- Resources are in terms of raw materials at a range of grades
Reserves

- Established on technology, potential market, prices and costs of production
- Established with study and considerable manpower
- Established on a planning horizon (15-20 years, longer for some producers)

Reserves Are Dynamic
Summary

- Phosphate rock is a finite non-renewable resource

- Reserves and resources
  - Reserves are a dynamic quantity
  - There are more reserves than some studies indicate
    - Need further study
  - There is no indication of “peak” phosphorus

- Recovery and utilization
  - Recovery should be maximized as much as feasible
  - Alternative products
    - Utilize low-grade phosphate rock
    - Make fertilizer available at the lowest cost