World Reserves of Phosphate Rock... a Dynamic and Unfolding Story

By Steven J. Van Kauwenbergh, Mike Stewart and Robert Mikkelsen

Phosphorus is essential for life, and the input of P fertilizer is critical to the production of sufficient food, feed, fiber, and fuel to support a growing world population. Most modern P fertilizer is made from phosphate rock (PR), a nonrenewable natural resource. Over the past decade or so there has been concern that the world would soon deplete its PR resources, and face a catastrophic P shortage; however, recent and thorough estimates of world PR supply indicate that a P crisis is not imminent, and that the we will not soon run out of PR.

Practically all of today's inorganic P fertilizers are produced from PR. Phosphate rock is an imprecise term that describes naturally occurring geologic materials (minerals) that contain a relatively high concentration of P. The term PR is used to describe raw (unbeneficiated) phosphate ores, but may also be applied to beneficiated or concentrated products.

Phosphate rock occurs in both sedimentary and igneous deposits across the world (**Figure 1**). Most (80 to 90%) of PR used to produce fertilizer is sedimentary in origin, and was deposited in ancient marine continental shelf environments. Sedimentary deposits, sometimes called phosphorites, occur throughout geologic time. Most PR is mined by open pit techniques, but a significant amount of deposits in China, Russia and other countries are extracted by underground mining. Apatite, a calcium phosphate mineral, is the principle P bearing component of PR.

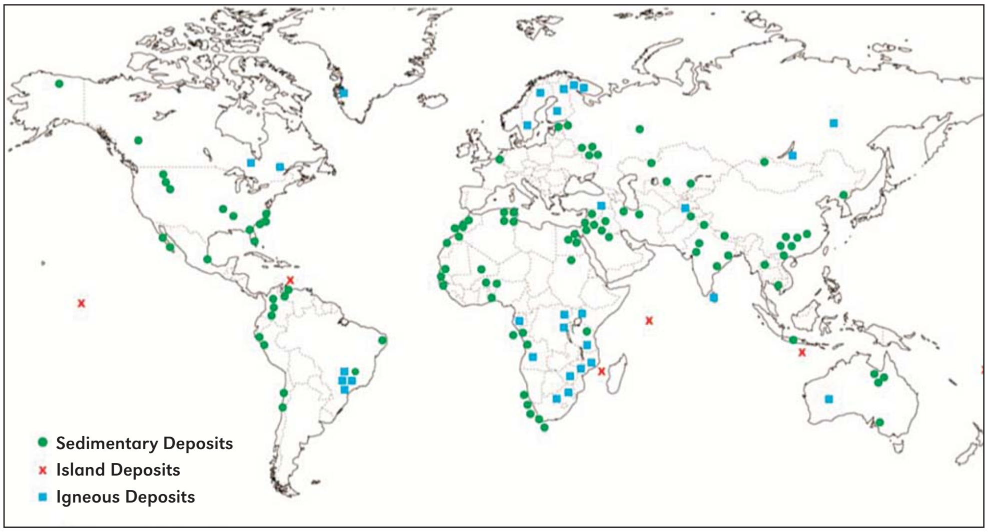

Figure 1. World phosphate rock resources (Source: IFDC).

The origin of the modern P fertilizer industry can be traced back to the mid-1800s when the first patents were granted for treating "phosphoritic substances" such as apatite and bones with sulfuric acid to produce "superphosphate". In 1842 patents were granted in England to both John Bennet Lawes and James Murray for the manufacture of P fertilizer by the process of acidulation. Although others, including Justus von Liebig, had been studying the process, Lawes and Murray have been credited as "the laymen who put the idea into permanent commercial practice" (Jacob, 1964). Practically all P fertilizers today are made by this "wet process" of treating PR with acid (e.g., sulfuric, nitric, or phosphoric) to produce phosphoric acid or triple superphosphate (TSP). Phosphoric acid is then used to produce both granular and fluid P fertilizers.

Phosphorus is essential for life, and the input of P fertilizer is critical to the production of sufficient food, feed, fiber, and fuel to support a growing world population. Considering these facts, and that PR is a finite and non-renewable natural resource, it is reasonable to question just how much PR there is in the world, and how long we can continue to extract it. This is a question that has generated considerable interest, discussion, and even some controversy. Following is a compressed narrative of some relevant history and current status of world PR supply.

Abbreviations and Notes: P = phosphorus.

Reserves and Resources

There are two terms that must be defined prior to discussion of world PR supplies. Van Kauwenbergh (2010) simply defined reserves and resources as:

Reserves: PR that can be economically produced at the time of the determination using existing technology

Resources: PR of any grade, including reserves, that may be produced at some time in the future

Relevant History

Commercial production of PR increased by a factor of about 1,000 from the mid 1860s to the mid 1970s (**Table 1**). With increased exploitation came more attention to PR as a finite natural resource. In the early 1970s the Institute of Ecology (1971) published results of a workshop where it was suggested that the known world reserves of PR might be exhausted within 90 to 130 years. Some believe this published projection is what fueled a period of expanded interest in estimating PR reserves and resources. Through the 1970s and 1980s there was a vast amount of

Table 1.. Early progression of world PR production (Source: IFDC).

Year	PR production tons
1847	500
1850	5,000
1853	10,000
1865	100,000
1885	1,000,000
1928	10,000,000
1974	100,000,000

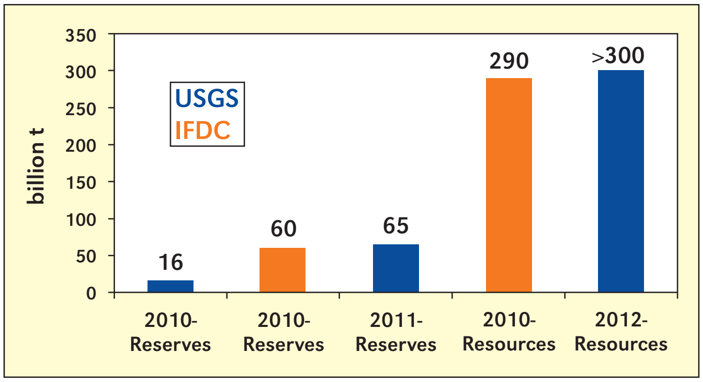

Figure 2. Phosphate rock reserve estimates reported by the USGS and IFDC (Sources: USGS and Van Kauwenbergh, 2010).

research done in this area. Chief among the groups involved in these efforts was the U.S. Bureau of Mines (USBM) and the United States Geologic Survey (USGS). However, in the mid 1990s significant funding and human resources that were once directed at PR research were diverted in other directions. The U.S. Congress voted to defund the USBM in 1995, and by the end of 1996 it was closed. Since the USBM closure, the USGS has had sole responsibility for reporting PR statistics in the U.S. through the Mineral Commodity Summaries. Since the early to mid 1990s there has generally been a limited amount of detailed publicly available information on PR reserves and resources both from the USGS and other worldwide sources.

Beginning in about the mid to late 2000s several articles and postings appeared suggesting that the world was facing a looming shortage of PR. Most of these were based on USGS reserve estimates of the time. Among the most notable of these articles was one by Cordell et al. (2009) that stated "current global reserves may be depleted in 50-100 years." Various other articles propagated mainly through the internet and news articles featured anxious headlines such as "phosphorus famine", "the disappearing nutrient", and "no phosphorus-no food". Many of these articles came on the heels of the world food crisis of 2007-08 when, as commodity prices escalated, images of food riots appeared in news releases across the world. These factors combined to set an alarmist tone and apocalyptic outlook regarding the world PR supply situation for the future.

Current Status

In response to this keen interest, the International Fertilizer Development Center (IFDC) launched an effort to update the estimates of world PR reserves and resources. The effort included a review of publically available information, such as government and industry reports and statistics, scientific literature, proceedings publications, conference presentations, etc. The review was published by IFDC as World Phosphate Rock Reserves and Resources (Van Kauwenbergh, 2010).

This IFDC report revealed significantly more PR reserves than had previously been estimated by the USGS. The USGS figure for PR reserves reported in the 2010 Mineral Commodity Summary was 16 billion t, but the IFDC report released later the same year estimated 60 billion t of reserves. By 2011 the USGS had revised its estimate upward by a factor of about four, from 16 to 65 billion t (**Figure 2**). The official USGS estimates have stayed in about the 60 to 70 billion t range since 2010.

Table 2. Reserve estimates for the world's top 10 PR reserve holders and their percent of world reserves held (Source: USGS Mineral Commodity Summary, 2013).

Country	Reserves, 2012 million t	World total %
Morocco and Western Sahara	50,000	75
China	3,700	6
Algeria	2,200	3
Syria	1,800	3
Jordan	1,500	2
South Africa	1,500	2
United States	1,400	2
Russia	1,300	2
Peru	820	1
Saudi Arabia	750	1
Others	2,268	3
World total (rounded)	67,000	100

Most of the PR reserves that were added in the 2011 USGS report came from Morocco. **Figure 3** shows USGS/USBM PR reserve estimates from 1989 through 2011 for several key countries. Morocco hovered at about 6 billion t until 2011 when estimated PR reserves were revised to over 50 billion t.

Notice also in **Figure 3** that prior to 2003 China was thought to be a relatively small PR reserve holder, but in 2003 it suddenly had more PR reserves than any other country. This happened because 2003 was the first year that the Chinese government released official PR data. Since that time, their reserve estimates have been revised downward by the USGS. Both the Morocco and China revisions show how reserve estimates are fluid and subject to dramatic change based on discovery and best available information.

Table 2 shows the latest USGS estimates for world PR

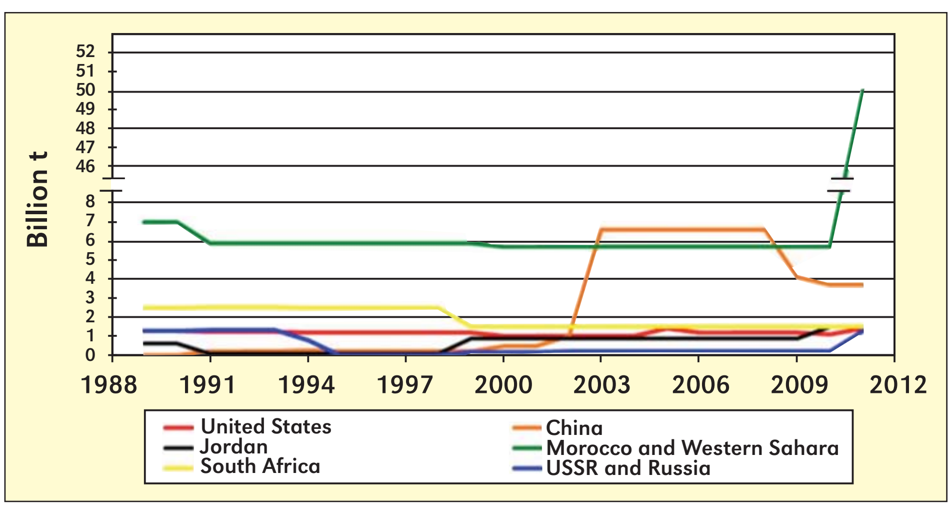

Figure 3. Phosphate rock reserve estimates for select countries from 1989 to 2011 (Source: USGS).

according to the latest USGS report is at 210 million t. This same report suggests that within the next year, world PR production capacity could go from 220 to 256 million t, with the largest expansion project occurring in Morocco.

A simple calculation of PR reserve longevity using current reserve and production figures indicates that the world has over 300 years of reserves and over 1,400 years of resources. Thus the world will not soon face a PR crisis. It should again be emphasized that estimates for PR reserves are subject to change with updated information and discovery, and with changes in economics and technology. In the last 5 years, several new deposits have been discovered and the resources of previously located deposits are being studied to quantify more reserves. As mining and processing technology develops and improves, today's resources can become tomorrow's reserves. Nonetheless, PR is a non-renewable natural resource and, from production to end use, should be stewarded as efficiently as possible. BC

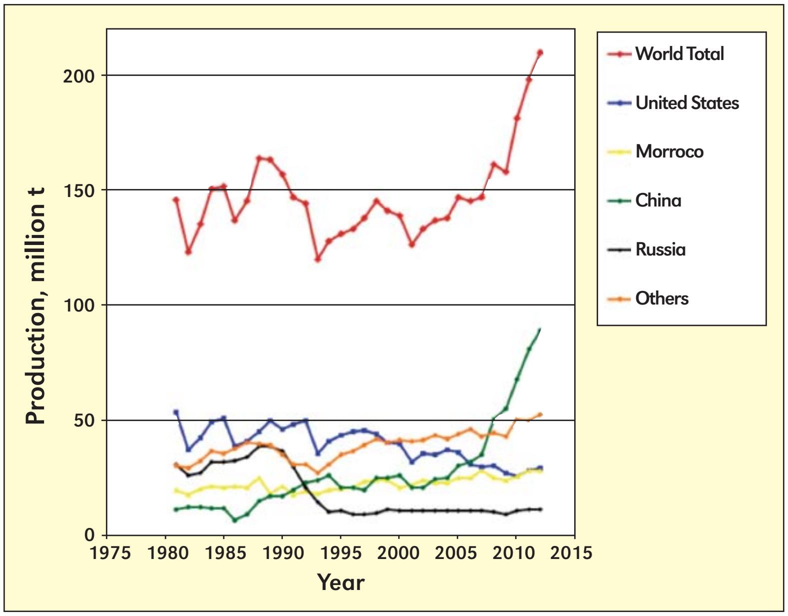

Figure 4. Phosphate rock production (1981 to 2012) for the world and selected countries (Source: USBM and USGS).

reserves for the top 10 holders. Morocco is estimated to have about 75% of the worlds PR reserves, while China is a distant second with 6%. The United States is estimated to hold about 2% of world PR reserves. Based on data found in the IFDC report, the Unites States was thought to hold about 76% of the world's recoverable phosphate product (~30% P_2O_5) in the late 1970s. As the 2010 IFDC report indicated, world phosphate rock reserves and resources are dynamic due to a wide variety of factors.

Figure 4 shows PR production for the world and selected countries from 1981 to 2012. World PR production varies considerably over this time frame, but is trending upward in recent years. Production has increased sharply since 2009 and

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