

# **World Phosphate Rock Reserves and Resources**

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**S. Van Kauwenbergh  
Geologist and Principal Scientist  
Research and Development Division  
IFDC**



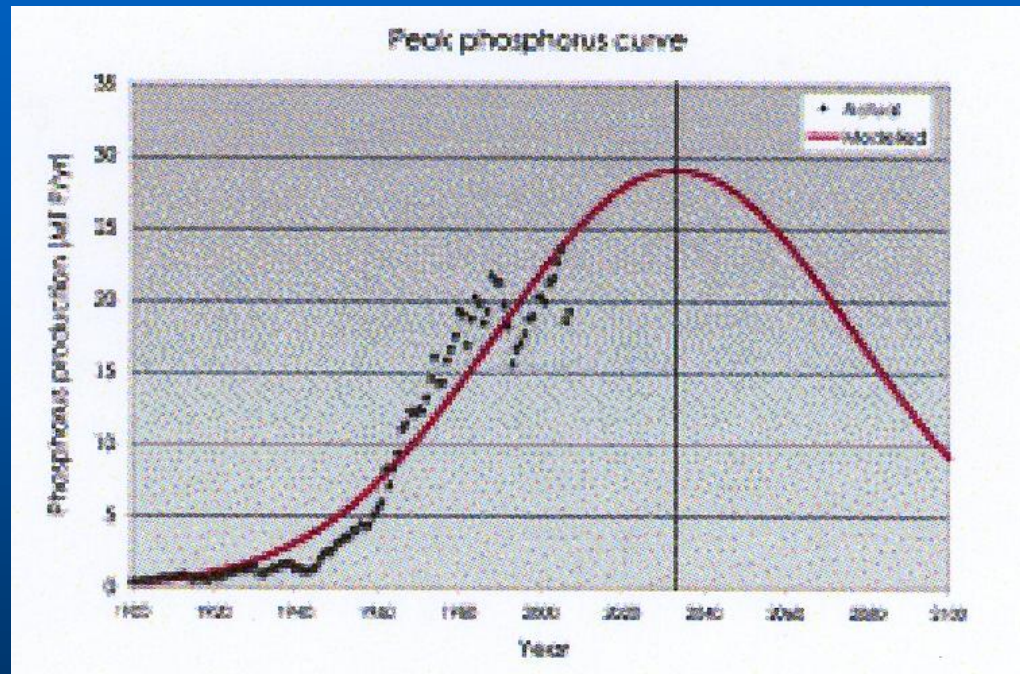
**Numerous articles suggest phosphorus (phosphate rock) reserves — resources will be depleted in the 21<sup>st</sup> century.**

- 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 – “Apate,” Greek Goddess of deceit, guile, fraud and deception released from Pandora’s Box





# Economic and Potentially Economic Phosphate Deposits of the World

IFDC





# 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  $P_2O_5$

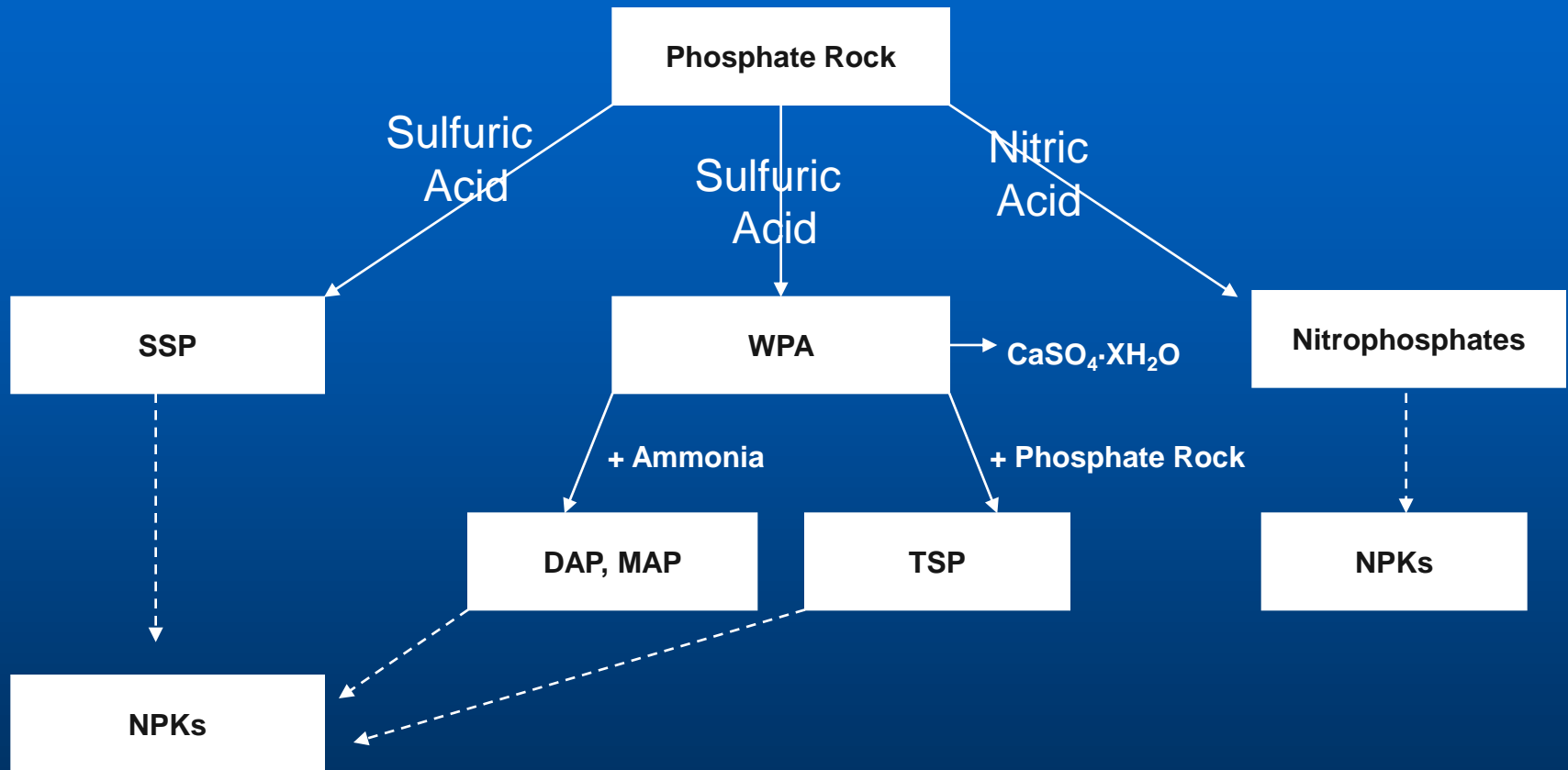
82% – Fertilizer

18% – Industrial Uses

Losses range from 2% to 15% with the weighted average of 5%

(Prud'homme, 2010)

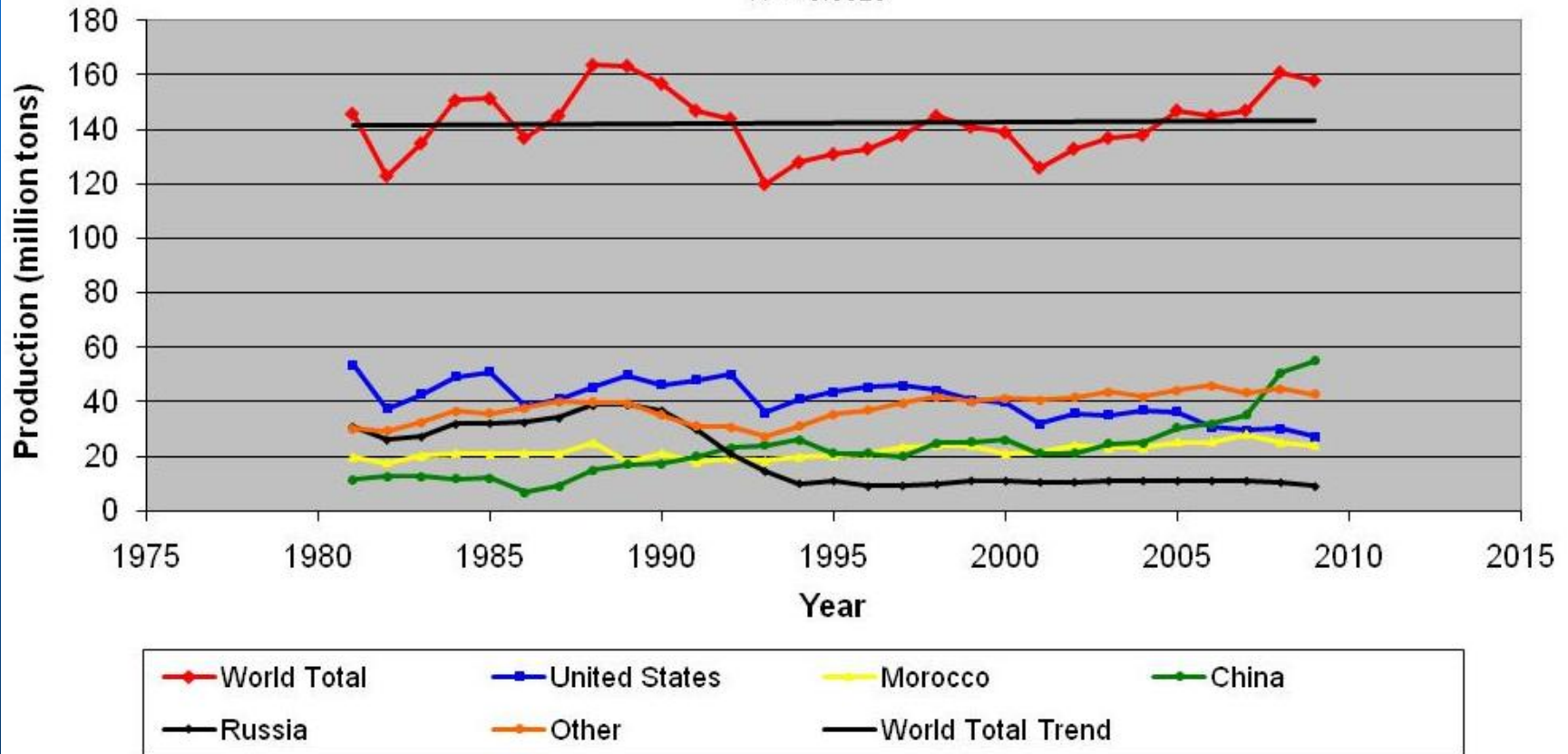
# Relationship of Phosphate Rock<sup>IFDC</sup> and Phosphate Fertilizers



# World Phosphate Rock Production <sup>IFDC</sup>

(USBM/USGS Mineral Commodity Summaries, 1982–2010)

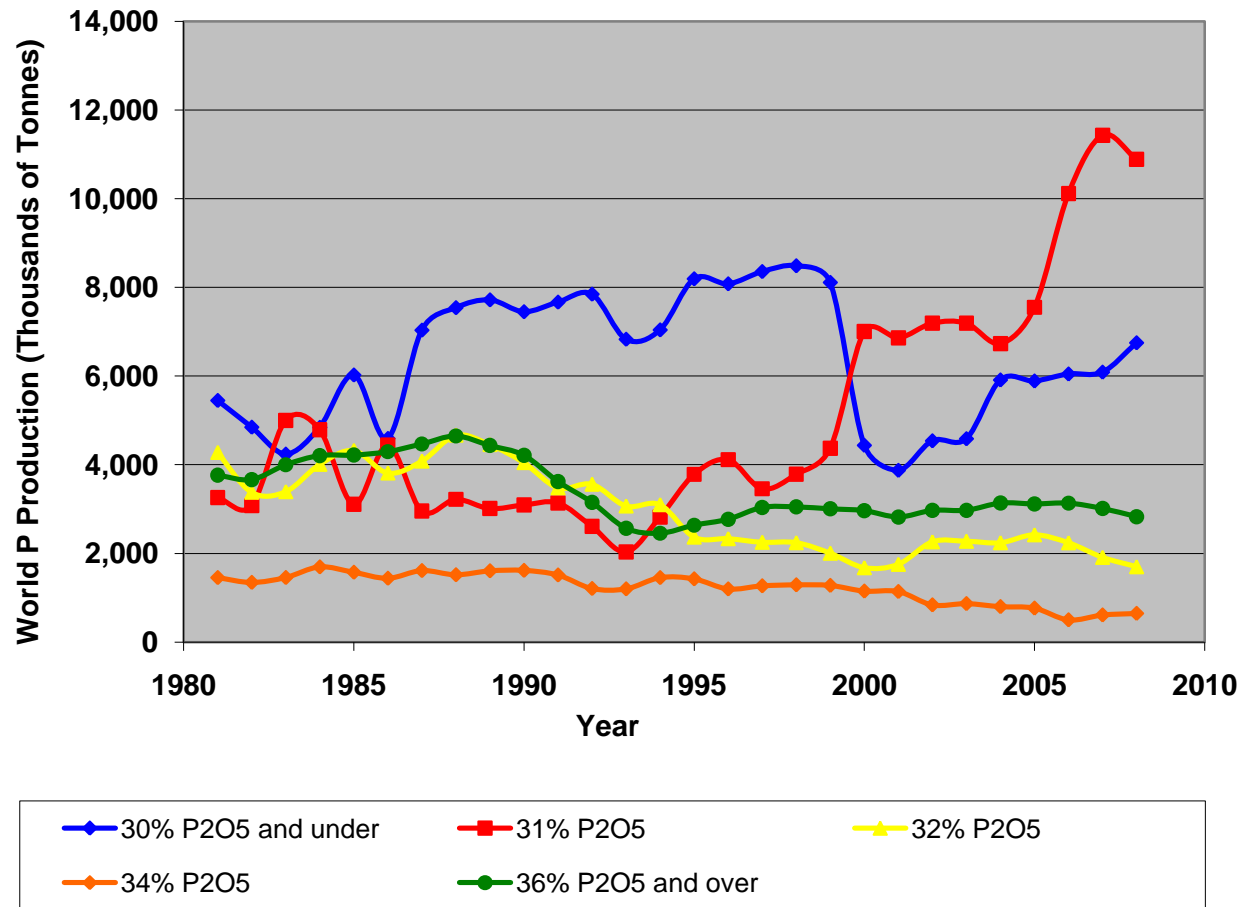
$$y = 0.0677x + 7.2845$$
$$R^2 = 0.0025$$



**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?**

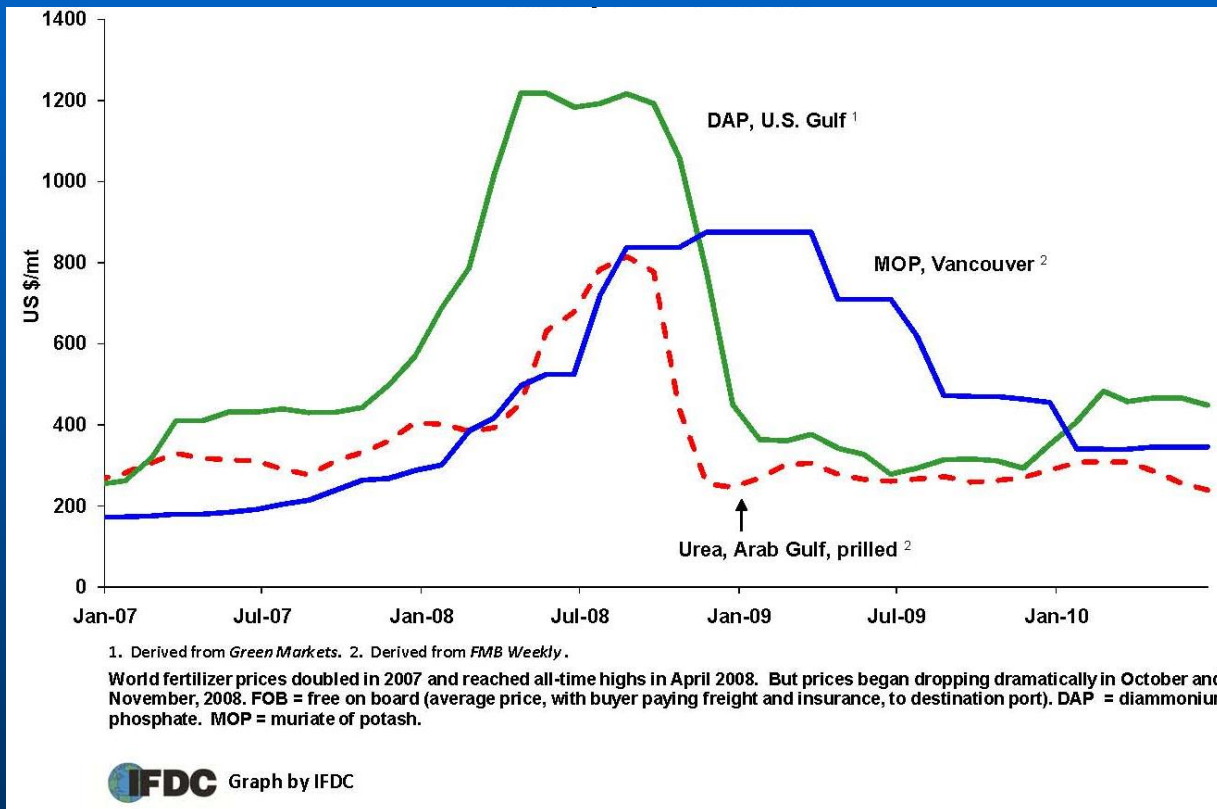
## World Phosphorus Production by Grade



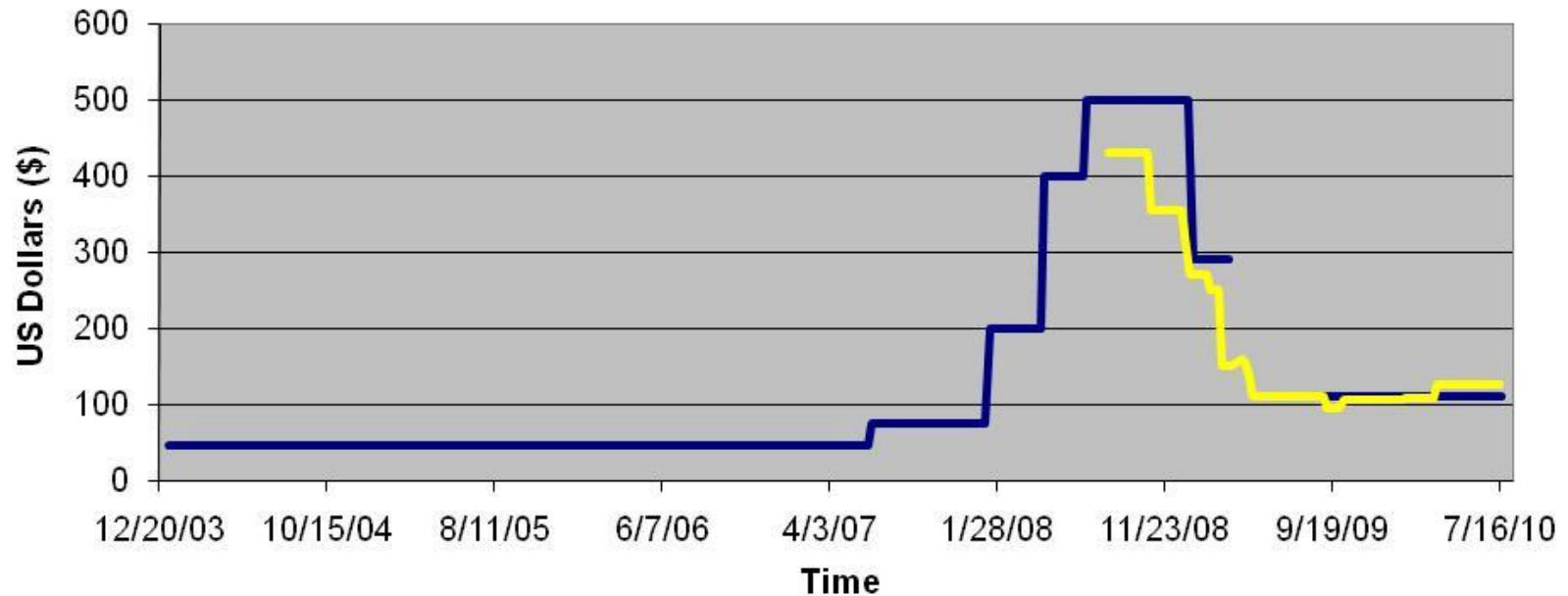


# **Phosphate Rock Has Been a Relatively Low-Value Bulk Commodity**

# Fertilizer Prices (FOB, bulk) Monthly Averages January 2007–June 2010



## North African Phosphate Rock Prices (fob)



# 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

# Past World Phosphate Rock Reserve and Resource <sup>IFDC</sup> Estimates Based on Author's Terminology

	Phosphate Rock Resources	Estimated Recoverable Product	Reserves	Reserve Base
	[metric tons x 10 <sup>9</sup> (U.S. Billion)]			
Emigh (1972)			1,200	
Wells (1975)			530 (30% P <sub>2</sub> O <sub>5</sub> )	
DeVoto and Stevens (1979)	1,200	265 (~30% P <sub>2</sub> O <sub>5</sub> )		
Cathcart (1980)	91		20 (≥30% P <sub>2</sub> O <sub>5</sub> )	
Fantel et al. (1988)		37		
Notholt, Sheldon and Davidson (1989)	163 (~22.5% P <sub>2</sub> O <sub>5</sub> )			
USGS (2009)			15 <sup>a</sup>	47 <sup>b</sup>

a. Originally described as phosphate rock that could be produced at less than US \$40/ton.

b. 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, $P_2O_5$ Recovery

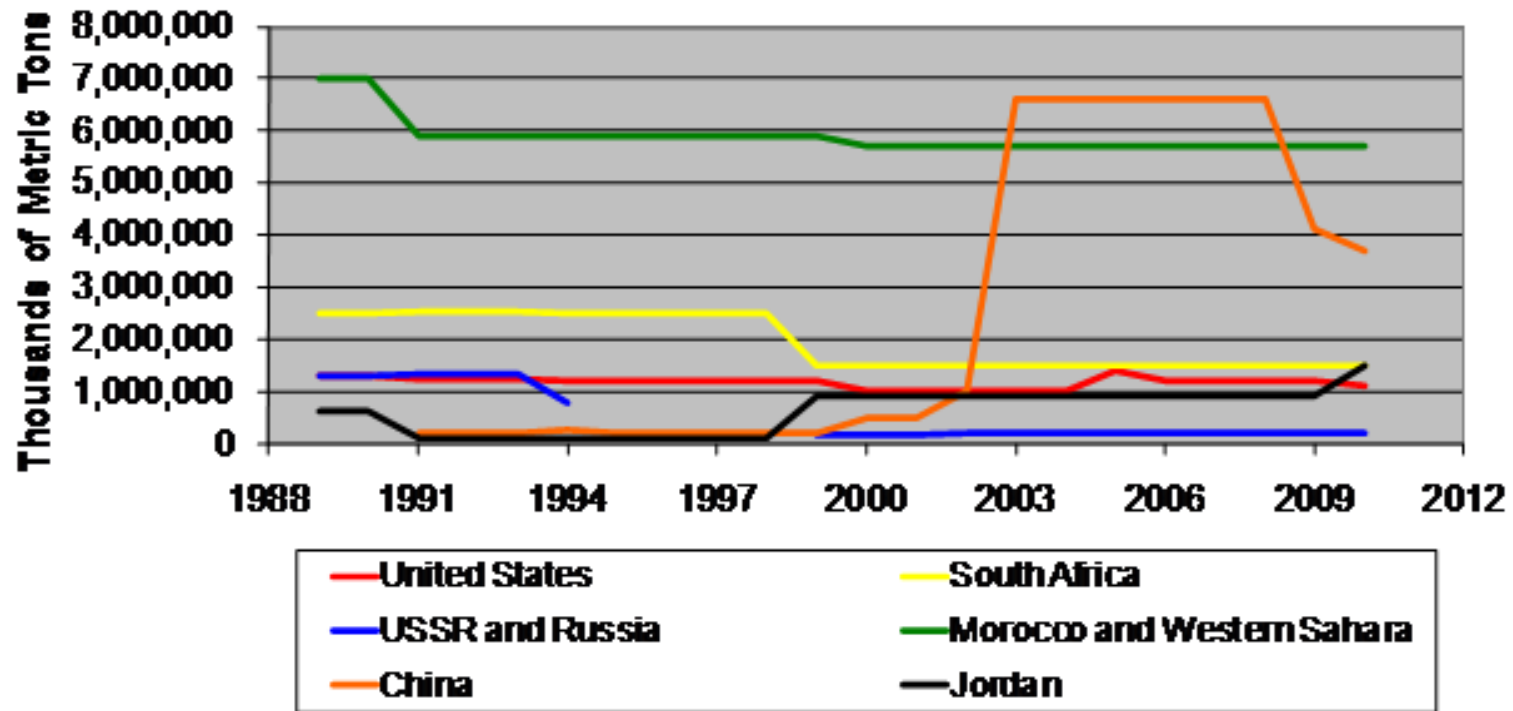
Mining – Economic = Large-Scale

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

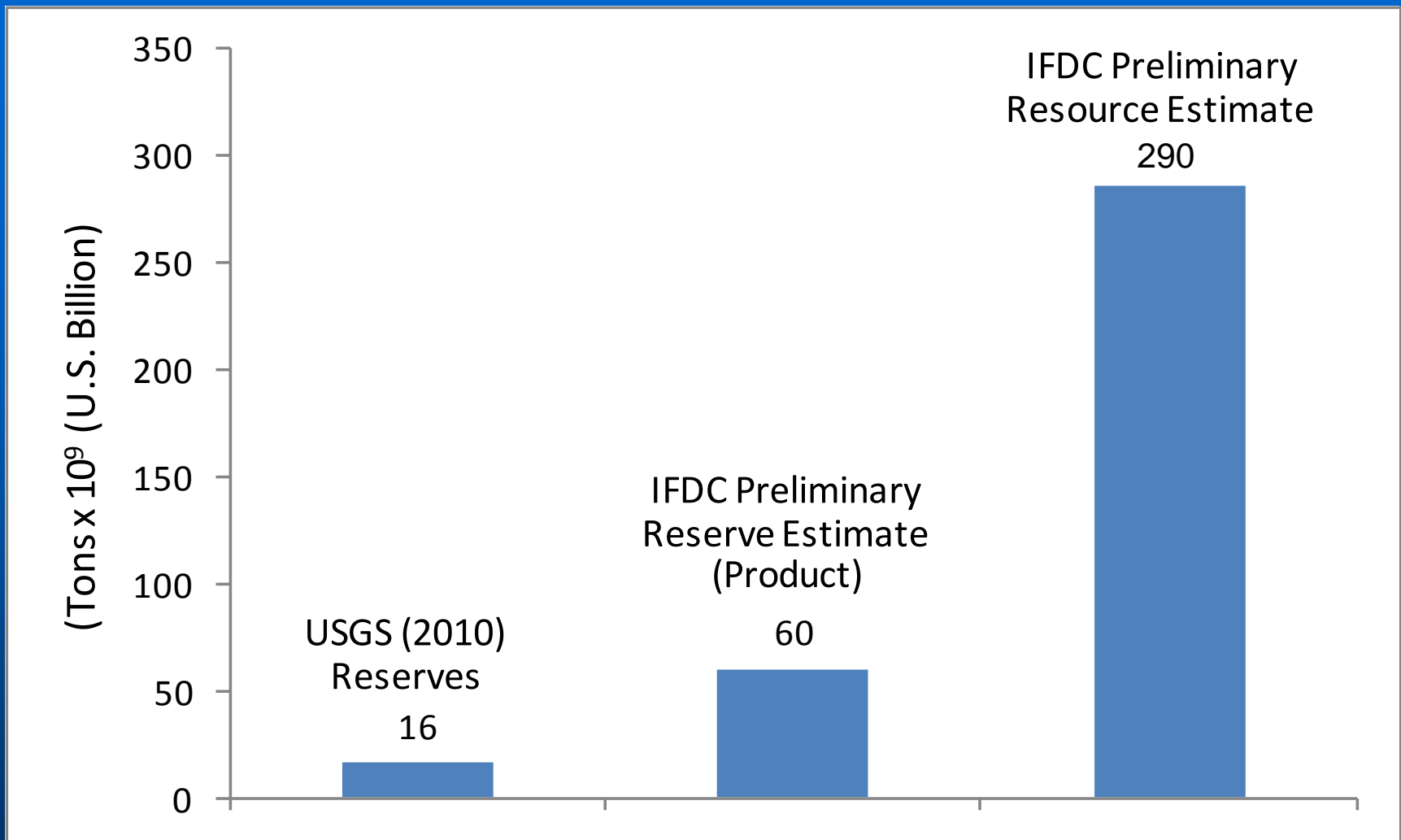
- **Reserves** – Phosphate rock that can be economically produced at the time of the determination to make suitable products, reported as tons of concentrate
- **Resources** – Phosphate rock of any grade that may be produced at some time in the future, including reserves

# Phosphate Rock Reserves as Published<sup>IFDC</sup> 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