

# PHOSPHATES

Fig. 2. The land-based phosphorus

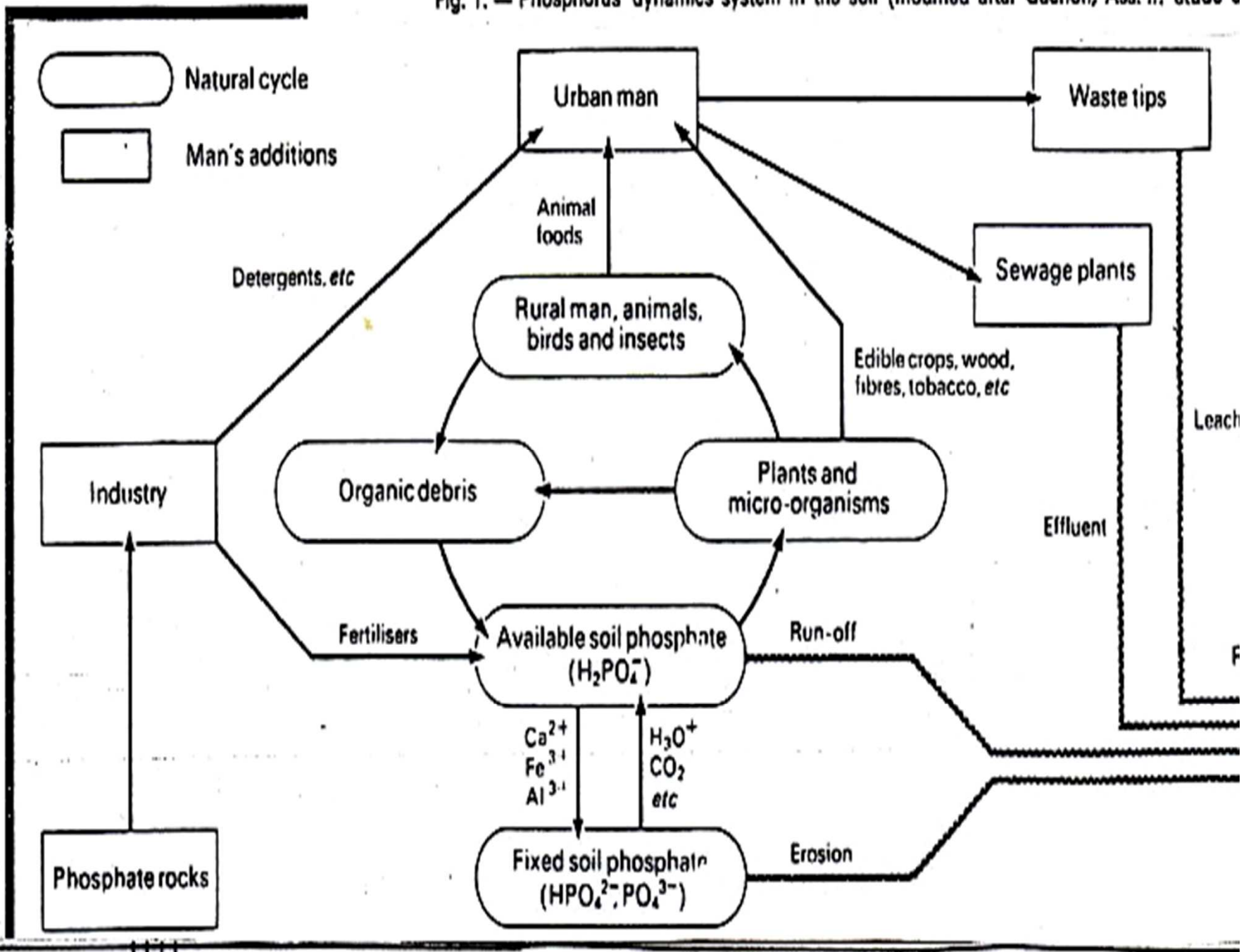


Fig. 1. — Phosphorus dynamics system in the soil (modified after Gachon, Ass. fr. étude d

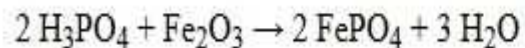
The dominant use of phosphoric acid is for [fertilizers](#), consuming approximately 90% of production.<sup>[7]</sup>

Application	Demand (2006) in thousands of tons	Main phosphate derivatives
Soaps and detergents	1836	<a href="#">STPP</a>
Food industry	309	<a href="#">STPP</a> (Na <sub>5</sub> P <sub>3</sub> O <sub>10</sub> ), <a href="#">SHMP</a> , <a href="#">TSP</a> , <a href="#">SAPP</a> , <a href="#">SAIP</a> (NaA), <a href="#">MCP</a> , <a href="#">DSP</a> (Na <sub>2</sub> HPO <sub>4</sub> ), H <sub>3</sub> PO <sub>4</sub>
<a href="#">Water treatment</a>	164	<a href="#">SHMP</a> , <a href="#">STPP</a> , <a href="#">TSPP</a> , <a href="#">MSP</a> (NaH <sub>2</sub> PO <sub>4</sub> ), <a href="#">DSP</a>
<a href="#">Toothpastes</a>	68	<a href="#">DCP</a> (CaHPO <sub>4</sub> ), <a href="#">IMP</a> , <a href="#">SMFP</a>
Other applications	287	<a href="#">STPP</a> (Na <sub>3</sub> P <sub>3</sub> O <sub>9</sub> ), <a href="#">TCP</a> , <a href="#">APP</a> , <a href="#">DAP</a> , <a href="#">zinc phosphate</a> (Zn <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> ), <a href="#">aluminium phosphate</a> (AlPO <sub>4</sub> , H <sub>3</sub> PO <sub>4</sub> )

## Food additive[\[edit\]](#)

Food-grade phosphoric acid (additive [E338](#)<sup>[8]</sup>) is used to acidify foods and beverages such as various [colas](#).

## Rust removal[\[edit\]](#)



Diammonium phosphate (DAP) and monoammonium phosphate (MAP) are the world's leading concentrated phosphate products. These products are manufactured by combining phosphoric acid with ammonia. Typical grades, respectively, are 18-46-0 and 11-52-0.

Merchant grade phosphoric acid (MGA) contains less than 2% suspended solids, making it suitable for export or shipment to domestic customers. Its analysis is 0-54-0.

Triple superphosphate (TSP or GTSP), a concentrated phosphate fertilizer with an analysis of 0-46-0, is made by acidulating phosphate rock with wet-process phosphoric acid.

**Table 1. Percentages of water-soluble and available phosphate in several common fertilizer sources.**

P <sub>2</sub> O <sub>5</sub> Source	N	P <sub>2</sub> O <sub>5</sub>		
		Total	Available	Water Soluble*
		----- % -----		
Superphosphate (OSP)	0	21	20	85
Concentrated Superphosphate (CSP)	0	45	45	85
Monoammonium Phosphate (MAP)	11	49	48	82
Diammonium Phosphate (DAP)	18	47	46	90
Ammonium Polyphosphate (APP)	10	34	34	100
Rock Phosphate	0	34	3-8	0

\*Water-soluble data are a percent of the total P<sub>2</sub>O<sub>5</sub>

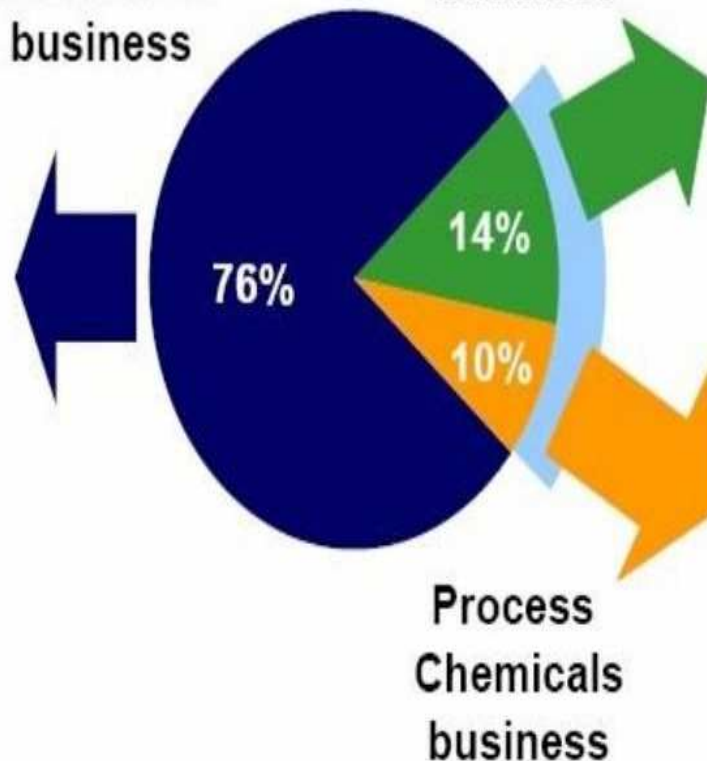
Source: *Ohio Agronomy Guide*. Ohio Cooperative Extension Service Bull.472.

# Overview of main markets

## Mineral fertilizer market

- USD 70 billion global annual market (some EUR 15 bn in Europe)
- Almost 144 Mt p.a. of nutrients sold globally (22 Mt in Europe)
- 2.0% annual growth (flat growth in Europe)

Crop Cultivation business



## Feed phosphates

- USD 1.8 billion annual global market
- 6 Mt market - 2Mt in Europe
- 2.0 - 3.0% annual growth

## Phosphoric acid

- Large global market, but regional in nature
- Captive use dominating

## Industrial chemicals

- Nitrogen based chemicals for industrial applications
- Growth in line with economic growth

**TABLE 23.3 World Production of Phosphate Rock  
(Million Metric Tons)**

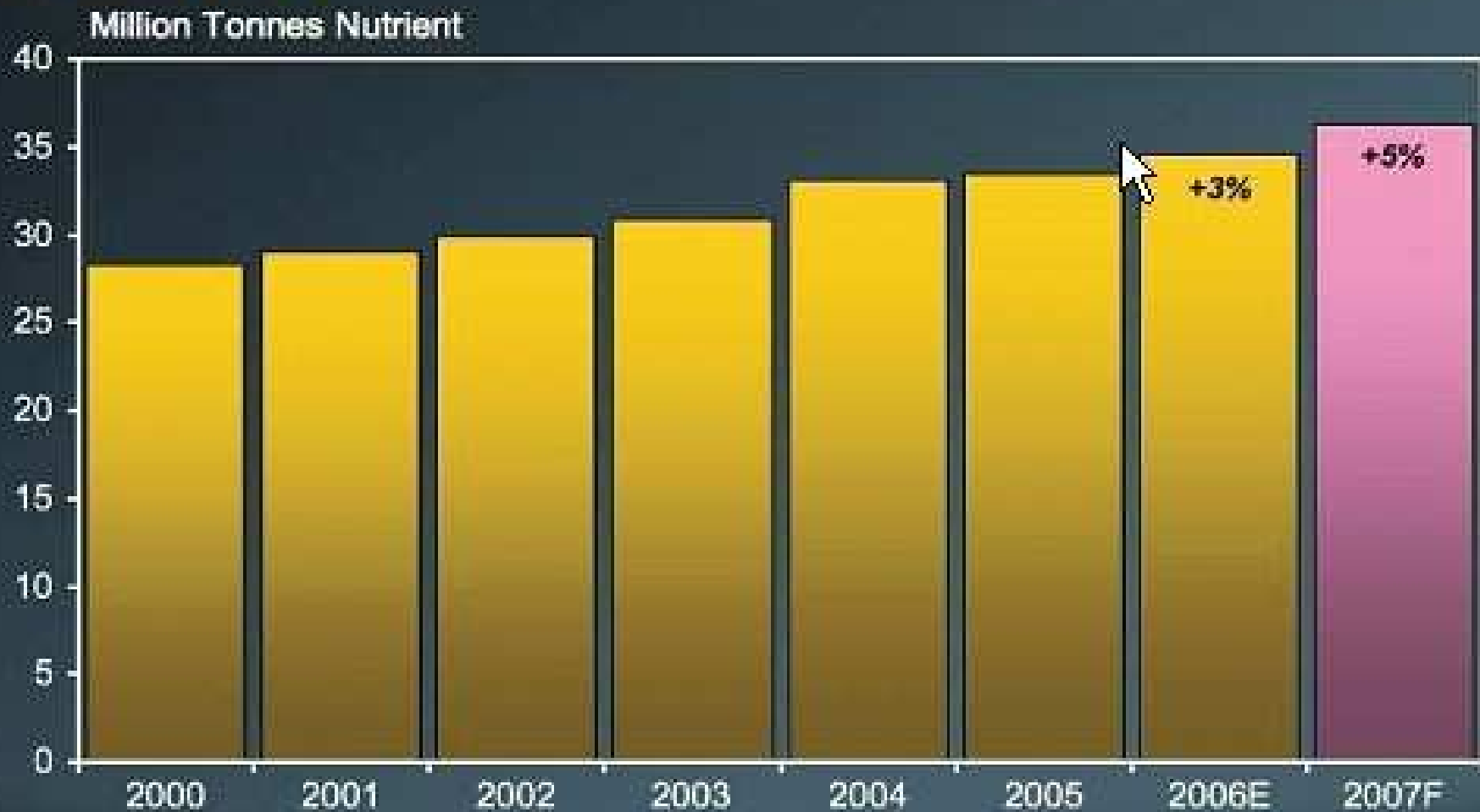
	<i>1980</i>	<i>1990</i>	<i>2000</i>	<i>2001</i>	<i>2002</i>	<i>2003</i>
United States	53.4	45.8	39.2	31.7	36.2	34.1
Morocco	18.8	21.2	21.6	21.8	23.0	23.3
China	10.7	17.3	19.4	21.0	23.0	24.5
USSR/Russia	24.7	36.9	11.1	10.5	10.6	11.1
Tunisia	4.6	6.6	8.3	8.1	7.6	7.9
Jordan	4.2	5.9	5.5	5.8	7.2	6.8
Other	22.2	22.8	26.6	26.5	28.2	29.0
Total world	138.6	156.5	131.6	125.4	135.8	136.6

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*Source:* The International Fertilizer Industry Association (1990/2000).

# Global Phosphate Fertilizer Consumption

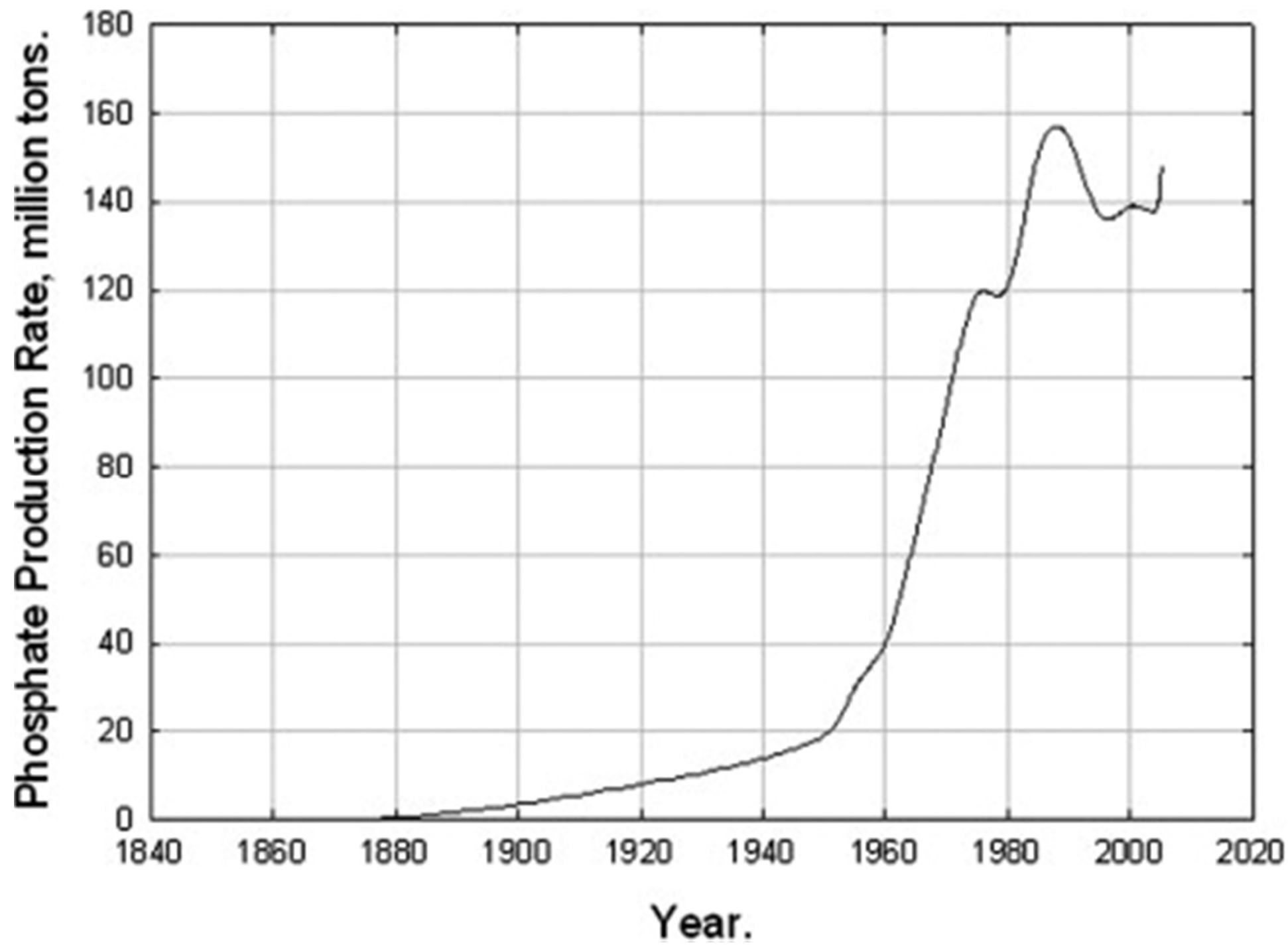
*Excludes US*



Source: Fertecon







# DAP and MGA

# Merchant grade Phos acid

\$US/MT

— MGA FOB US Gulf

— DAP FOB CFL \$/ST

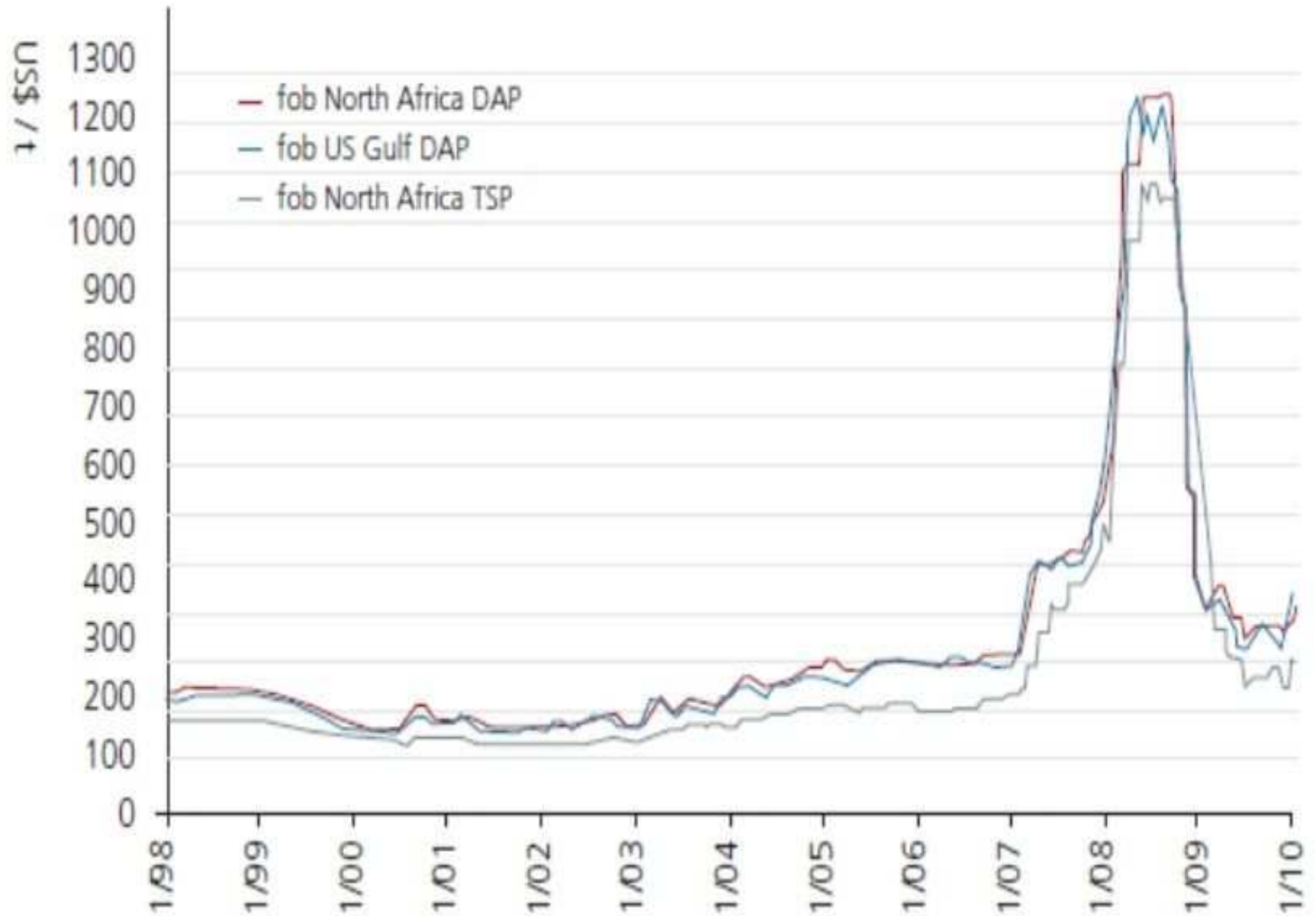
— DAP FOB Tampa



Source: Fertecon

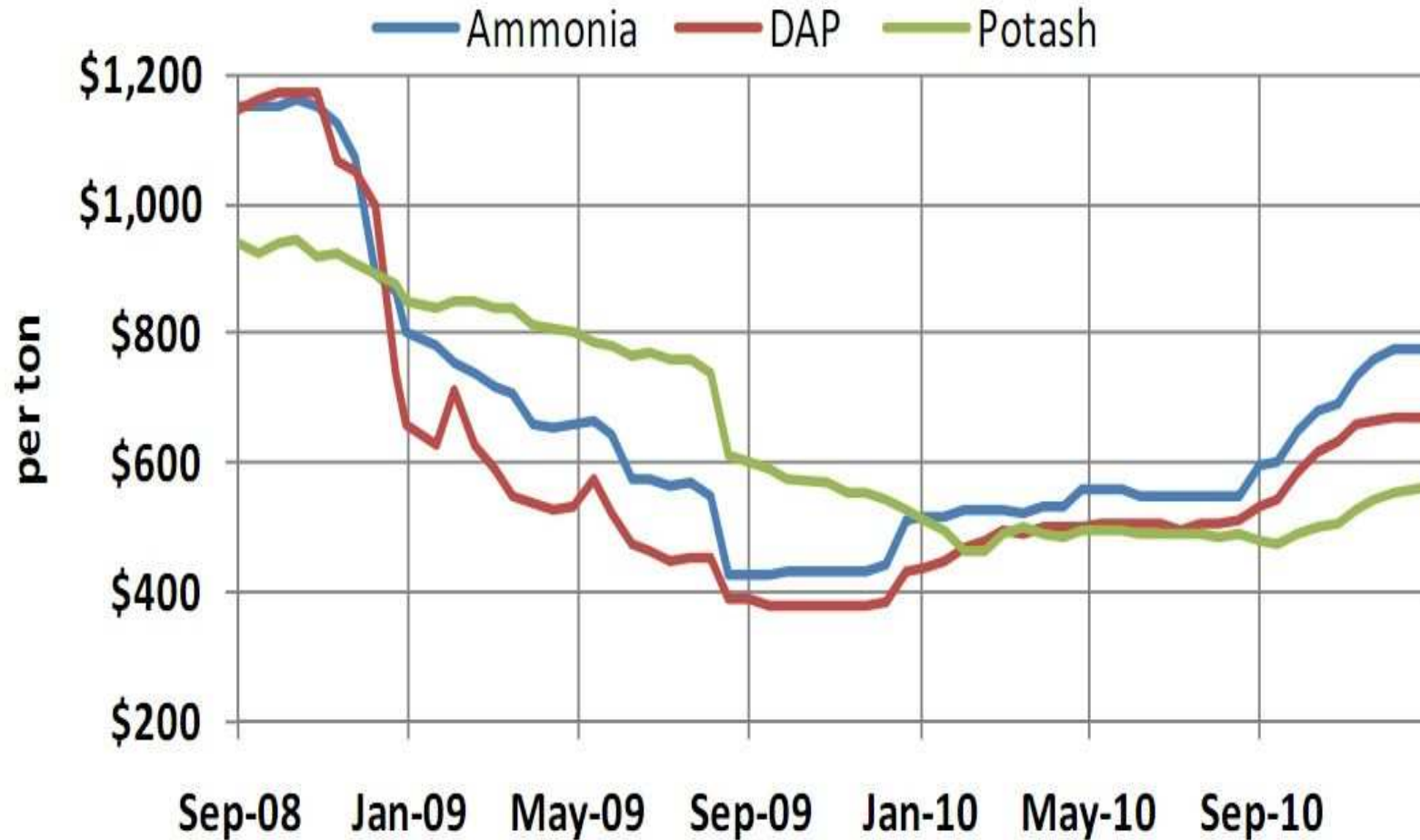


## Phosphate fertilizer prices over time



Source: FertEcon December 2009

# Illinois Fertilizer Prices

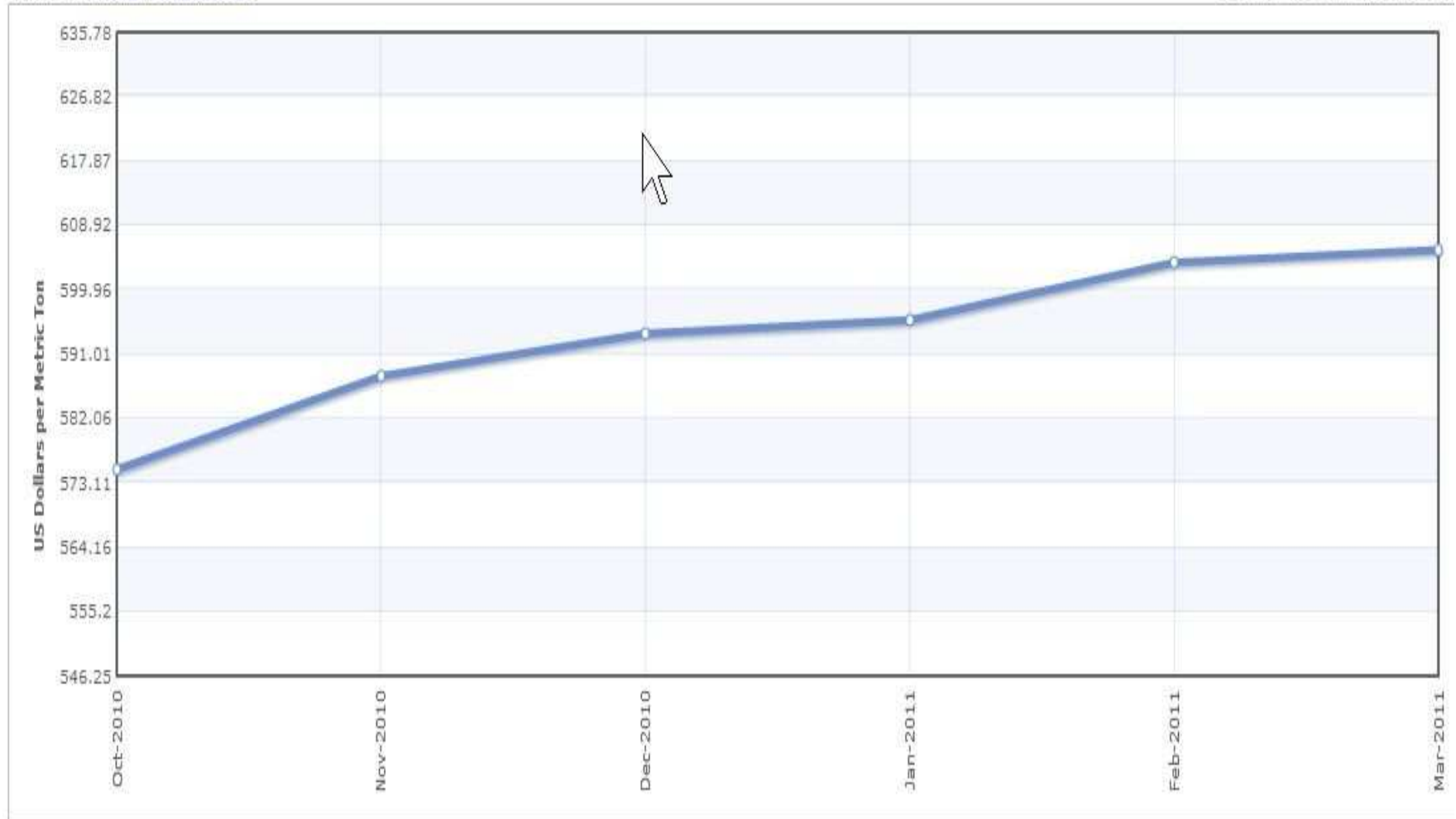


Source: USDA

## DAP fertilizer Monthly Price

Range 6m [1y](#) [5y](#) [10y](#) [15y](#) [20y](#) [25y](#) [30y](#)

Oct 2010 - Mar 2011: 30.500 (5.30 %)



# Phosphorous production

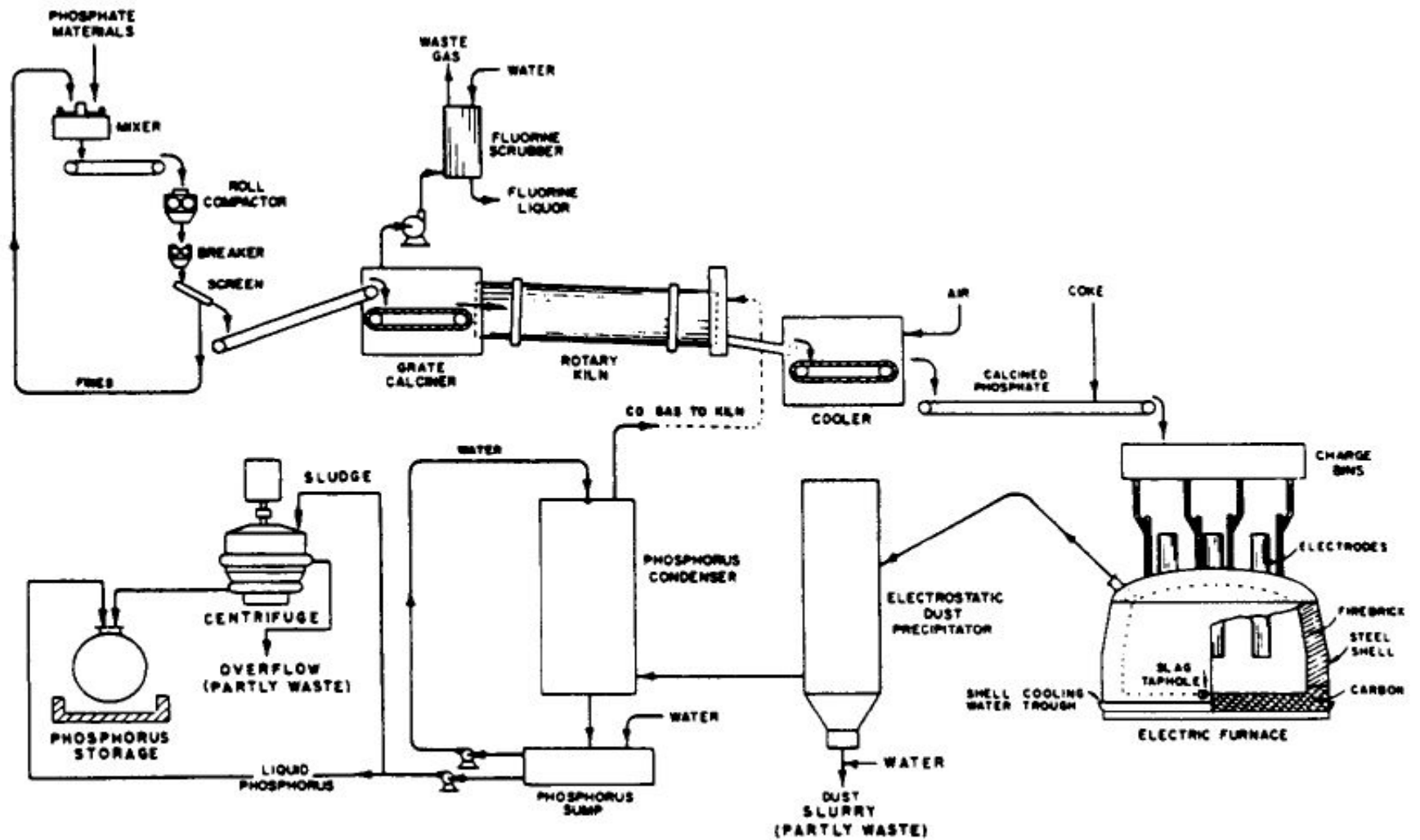


Fig. 23.8. Electric furnace process for production of elemental phosphorus.

# PHOSPHATE ROCK

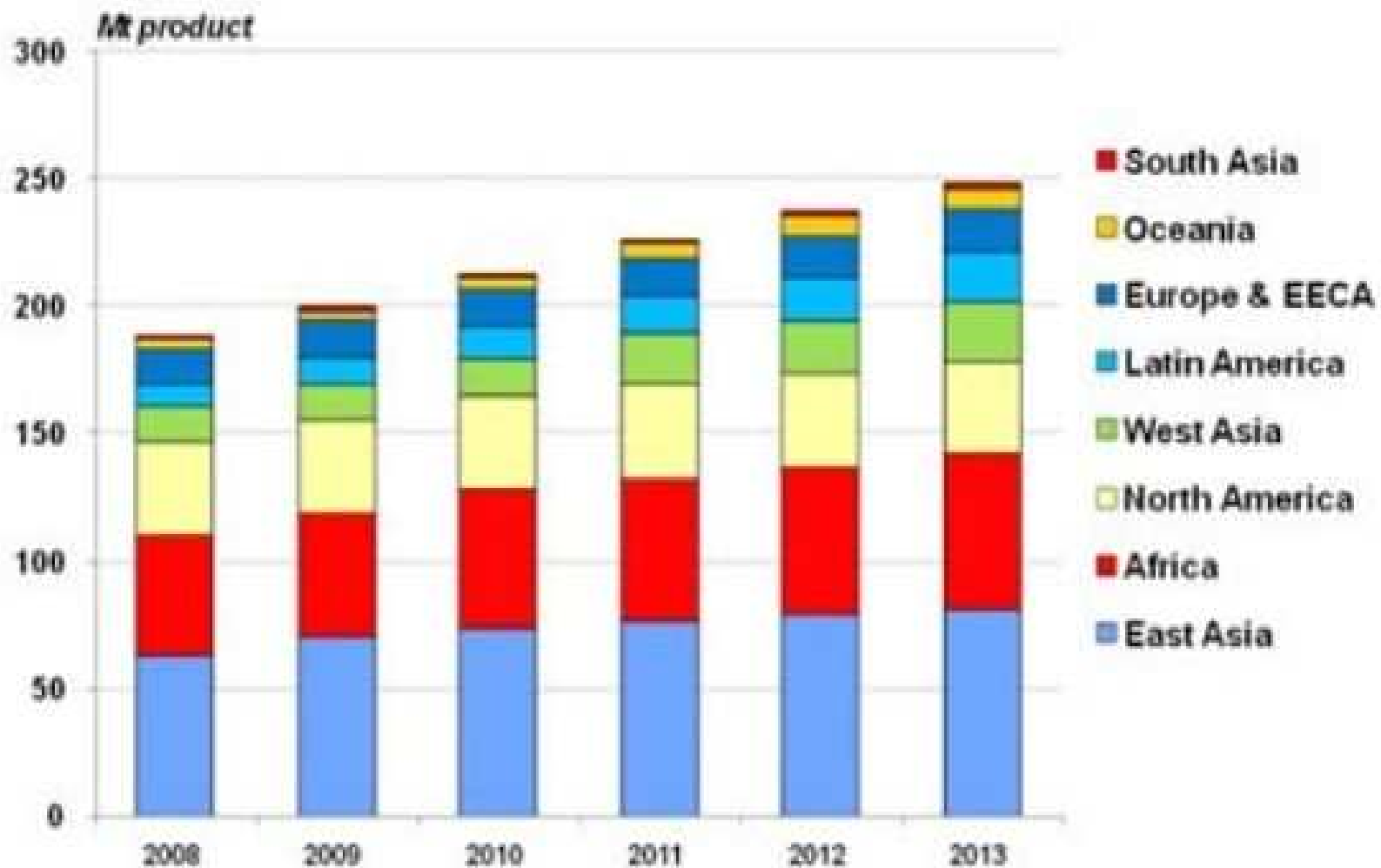


**ECONOMIC AND POTENTIALLY  
ECONOMIC PHOSPHATE  
DEPOSITS OF THE WORLD**

- Sedimentary Deposits
- Igneous Deposits
- Island Deposits



# World Phosphate Rock Capability



Source: IFA/PIT Committee

(Thousand metric tons)

Commodity and country <sup>3</sup>	Gross weight					P <sub>2</sub> O <sub>5</sub> content				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Phosphate rock:										
Algeria	784	878	1,510 <sup>r</sup>	1,800 <sup>r</sup>	1,800 <sup>e</sup>	300	260	450	536 <sup>e</sup>	536
Australia	2,600 <sup>r</sup>	2,700 <sup>r</sup>	2,750 <sup>r</sup>	2,850 <sup>r</sup>	2,800	730 <sup>r</sup>	760 <sup>r</sup>	770 <sup>r</sup>	800 <sup>r</sup>	780
Brazil, concentrate	5,690	5,631 <sup>r</sup>	5,932 <sup>r</sup>	6,185 <sup>r</sup>	6,200 <sup>p</sup>	2,181	2,050 <sup>r</sup>	2,111 <sup>r</sup>	2,185 <sup>r</sup>	2,200 <sup>p</sup>
Burkina Faso <sup>e</sup>	2	2	2	2	2	1	1	1	1	1
Canada <sup>e</sup>	1,000	900	550	700	950	370 <sup>r</sup>	335 <sup>r</sup>	200 <sup>r</sup>	260 <sup>r</sup>	350
Chile, including phosphorite <sup>4</sup>	21	20	14	25 <sup>r</sup>	38	5	5	4 <sup>e</sup>	6 <sup>r</sup>	10 <sup>e</sup>
China	25,500	30,400	38,600	45,400 <sup>r</sup>	50,700	7,650	9,130	11,600	15,100	15,200
Christmas Island	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	--	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	--
Colombia <sup>e</sup>	43	43	43	43	24	8	8	8	8	7 <sup>s</sup>
Egypt, beneficiated	3,269 <sup>r</sup>	2,144	2,200	2,200 <sup>e</sup>	3,000 <sup>e</sup>	948 <sup>r,e</sup>	622	625 <sup>r,e</sup>	625 <sup>r,e</sup>	1,000 <sup>e</sup>
Finland <sup>e</sup>	840	825	825	825	825	306	301	300	300	300
India <sup>e</sup>	1,180	1,200	1,200	1,210	1,220	349	355	355	358	631
Indonesia <sup>e</sup>	1	1	1	1	1	(6)	(6)	(6)	(6)	(6)
Iran <sup>e</sup>	230 <sup>s</sup>	324 <sup>s</sup>	325	330	330	28	40	40	41	41
Iraq, beneficiated <sup>e</sup>	30	1 <sup>r</sup>	1 <sup>r</sup>	1 <sup>r</sup>	10	10	(6) <sup>r</sup>	(6) <sup>r</sup>	(6) <sup>r</sup>	3
Israel	3,290	3,236	2,949	3,069	3,088	900 <sup>e</sup>	890 <sup>e</sup>	810 <sup>e</sup>	840 <sup>e</sup>	850 <sup>e</sup>
Jordan	6,188	6,375	5,805	5,552 <sup>r</sup>	6,265	1,980	2,040	1,860	1,780 <sup>e</sup>	2,005

Commodity and country <sup>3</sup>	Gross weight					P <sub>2</sub> O <sub>5</sub> content				
	2006	2007	2008	2009	2010 <sup>e</sup>	2006	2007	2008	2009	2010 <sup>e</sup>
Phosphate rock:										
Algeria <sup>e</sup>	1,510 <sup>4</sup>	1,800 <sup>4</sup>	1,805 <sup>4</sup>	1,070 <sup>r</sup>	1,800	450	536	542	305 <sup>r</sup>	540
Australia <sup>c</sup>	2,750 <sup>4</sup>	2,850 <sup>4</sup>	2,950	2,500 <sup>r</sup>	2,600	770	655	678	575 <sup>r</sup>	600
Brazil, concentrate	5,932	6,185	6,343	6,000 <sup>r</sup>	5,700	2,111	2,185	2,242	2,100 <sup>r</sup>	2,000
Burkina Faso <sup>c</sup>	2	2	2	2	2	1	1	1	1	1
Canada <sup>c</sup>	500	700	700	670 <sup>r</sup>	700	165	210	210	200	200
Chile:										
Apatite	12	13	21	11	15	4 <sup>e</sup>	4 <sup>e</sup>	7 <sup>e</sup>	3 <sup>e</sup>	5
Guano	--	--	3	2	2	NA	NA	NA	NA	NA
Phosphorite	2	12	17	1	1	NA	NA	NA	NA	NA
China	38,600	45,400	50,700	60,200	68,000 <sup>4</sup>	11,600	15,100	15,200	18,000	20,400 <sup>4</sup>
Colombia <sup>c</sup>	43	43	27	27 <sup>r</sup>	30	8	8	8	8	8
Egypt, beneficiated	2,177	3,890	5,523	6,627 <sup>r</sup>	6,000	653	1,167	1,657	2,000 <sup>r</sup>	1,920
Finland <sup>c</sup>	825	825	825	650 <sup>r</sup>	825	300	300	300	225 <sup>r</sup>	300
India <sup>c</sup>	1,200	1,210	1,220	1,230	1,240	355	358	631	640	645
Indonesia <sup>c</sup>	1	1	1	1	1	(5)	(5)	(5)	(5)	(5)
Iran <sup>c</sup>	325	330	325	330	330	40	41	36	40	40
Iraq, beneficiated <sup>c</sup>	1	1	10	30	10	(5)	(5)	3	10	3
Israel	2,949	3,069	3,088	2,697	3,135 <sup>4</sup>	810 <sup>e</sup>	840 <sup>e</sup>	850 <sup>e</sup>	740 <sup>e</sup>	860
Jordan	5,805	5,552	6,265	5,281	6,000	1,860	1,780	2,005	1,620	2,000

MIDDLE EAST: HISTORIC AND PROJECTED PHOSPHATE ROCK PRODUCTION, 1995-2015

(P<sub>2</sub>O<sub>5</sub> content of ore in thousand metric tons)

Country	1995	2000	2005	2007	2009 <sup>e</sup>	2011 <sup>e</sup>	2013 <sup>e</sup>	2015 <sup>e</sup>
Iran	NA	20	40	41	41	42	42	43
Iraq	300	200	1	1	100	100	100	100
Israel	1,264	1,305	890	840	980	1,140	1,140	1,140
Jordan	1,655	1,824	2,040	1,780	1,800	1,800	1,800	1,800
Saudi Arabia	--	--	--	--	1,000	1,000	2,500	2,500
Syria	477	646	1,080	1,135	1,190	1,190	1,190	1,190
Total	4,000	4,000	4,000	4,000	5,000	5,000	7,000	7,000

<sup>e</sup>Estimated; estimated data and totals are rounded to no more than three significant digits; estimated data may not add to totals shown. NA Not available.

-- Negligible or no production.

	Mine production		Reserves <sup>4</sup>
	<u>2008</u>	<u>2009<sup>e</sup></u>	
United States	30,200	27,200	1,100,000
Australia	2,800	2,500	82,000
Brazil	6,200	6,000	260,000
Canada	950	900	15,000
China <sup>5</sup>	50,700	55,000	3,700,000
Egypt	3,000	3,300	100,000
Israel	3,090	3,000	180,000
Jordan	6,270	6,000	1,500,000
Morocco and Western Sahara	25,000	24,000	5,700,000
Russia	10,400	9,000	200,000
Senegal	700	700	80,000
South Africa	2,290	2,300	1,500,000
Syria	3,220	3,000	100,000
Togo	800	800	60,000
Tunisia	8,000	7,000	100,000
Other countries	<u>7,440</u>	<u>7,000</u>	<u>950,000</u>
World total (rounded)	161,000	158,000	16,000,000

	Mine production		Reserves <sup>4</sup>
	<u>2009</u>	<u>2010<sup>9</sup></u>	
United States	26,400	26,100	1,400,000
Algeria	1,800	2,000	2,200,000
Australia	2,800	2,800	82,000
Brazil	6,350	5,500	340,000
Canada	700	700	5,000
China <sup>5</sup>	60,200	65,000	3,700,000
Egypt	5,000	5,000	100,000
Israel	2,700	3,000	180,000
Jordan	5,280	6,000	1,500,000
Morocco and Western Sahara	23,000	26,000	50,000,000
Russia	10,000	10,000	1,300,000
Senegal	650	650	180,000
South Africa	2,240	2,300	1,500,000
Syria	2,470	2,800	1,800,000
Togo	850	800	60,000
Tunisia	7,400	7,600	100,000
Other countries	<u>8,620</u>	<u>9,500</u>	<u>620,000</u>
World total (rounded)	166,000	176,000	65,000,000

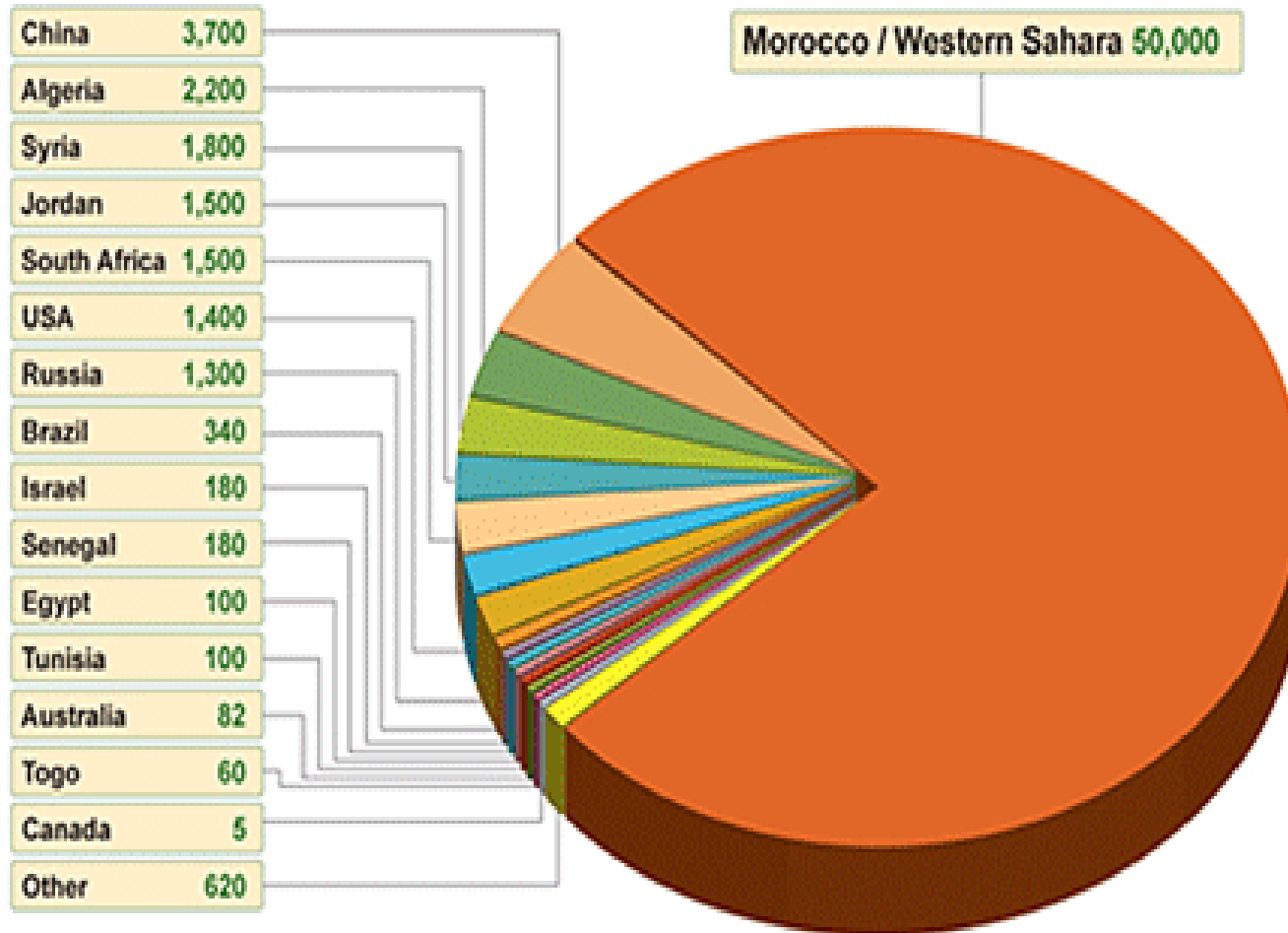
	Mine production		Reserves <sup>4</sup>
	<u>2012</u>	<u>2013<sup>e</sup></u>	
United States	30,100	32,300	1,100,000
Algeria	1,250	1,500	2,200,000
Australia	2,600	2,600	870,000
Brazil	6,750	6,740	270,000
Canada	900	300	2,000
China <sup>5</sup>	95,300	97,000	3,700,000
Egypt	6,240	6,000	100,000
India	1,260	1,270	35,000
Iraq	200	350	430,000
Israel	3,510	3,600	130,000
Jordan	6,380	7,000	1,300,000
Kazakhstan	1,600	1,600	260,000
Mexico	1,700	1,700	30,000
Morocco and Western Sahara	28,000	28,000	50,000,000
Peru	3,210	3,900	820,000
Russia	11,200	12,500	1,300,000
Saudi Arabia	3,000	3,000	211,000
Senegal	1,380	920	50,000
South Africa	2,240	2,300	1,500,000
Syria	1,000	500	1,800,000
Togo	870	900	30,000
Tunisia	2,600	4,000	100,000
Other countries	<u>5,500</u>	<u>5,630</u>	<u>520,000</u>
World total (rounded)	217,000	224,000	67,000,000

	Production (million tonnes)	Commercial Resource * (years)	Total Reserves (years)
Europe	0.2	64	345
Soviet Union (former)	6.7	223	477
North America	14.3	94	566
South America	1.2	315	863
Africa	11.1	1165	1590
Middle East	3.3	358	1239
Asia	6.1	359	553
Oceania	0.4	170	1775
World	43.4	452	670

*\* Given present exploitation rates. All figures have been rounded.*



# World Phosphate Rock Reserves 65,000 million tonnes\*



**Fig. 5: Lifetime of reserves**

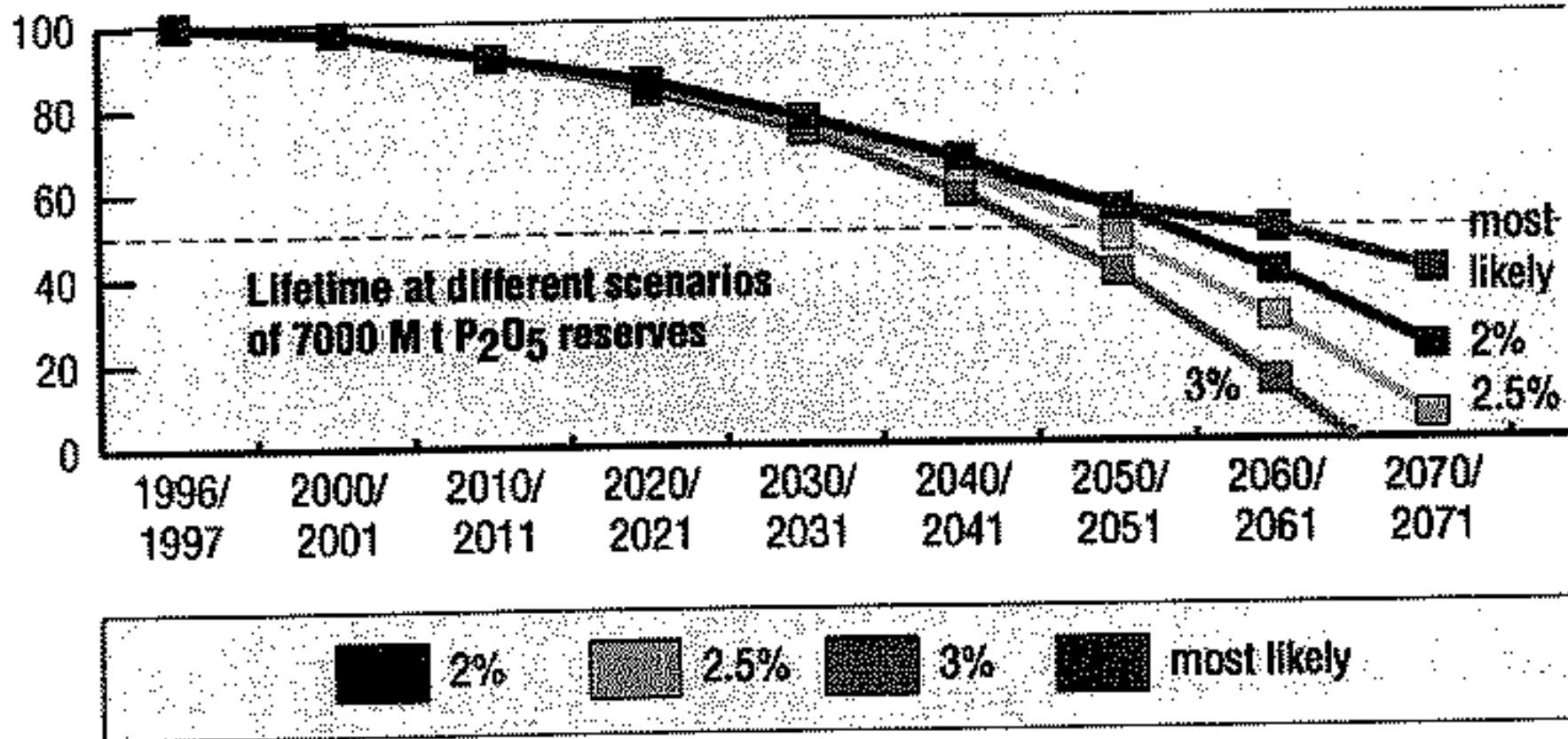
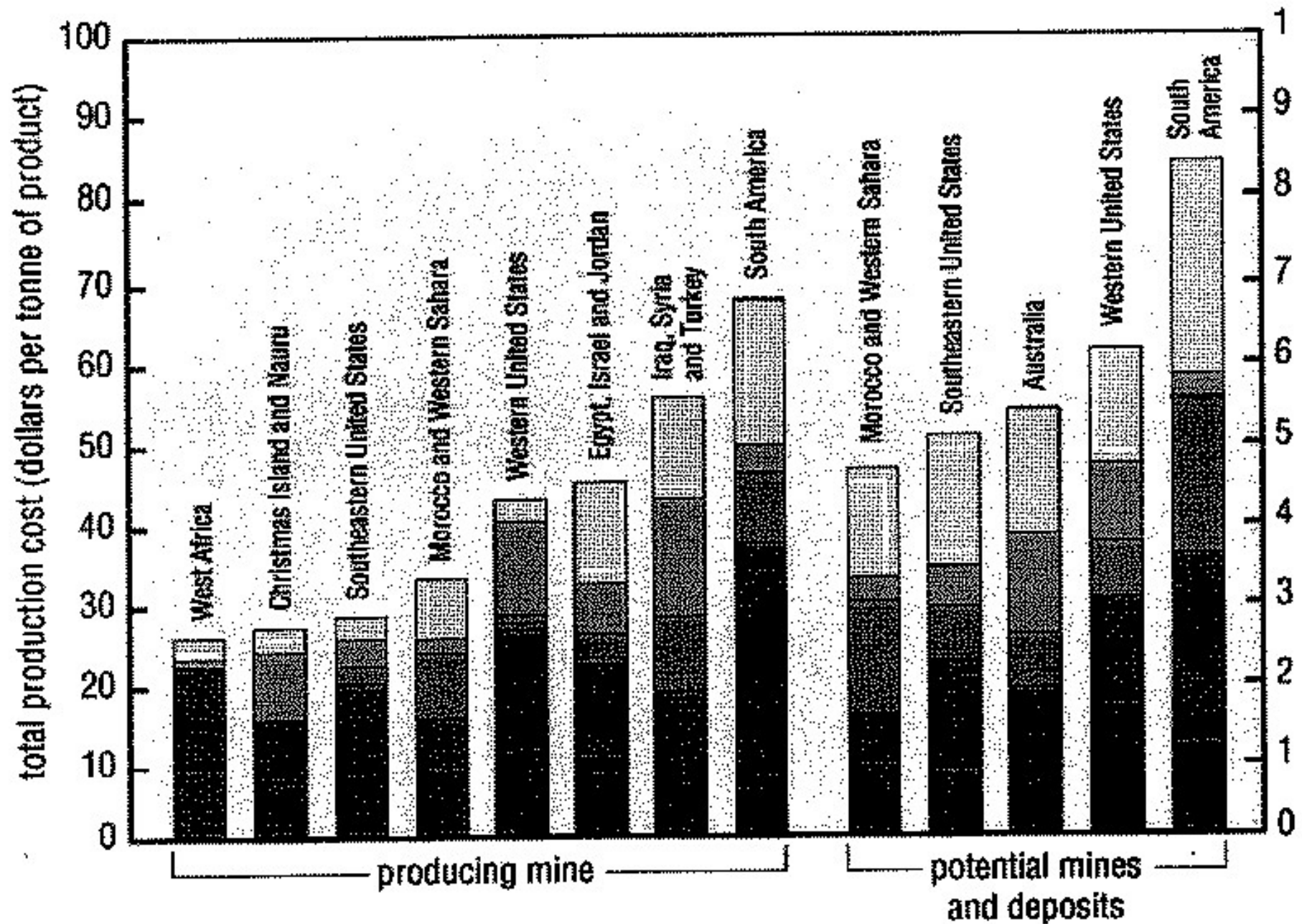


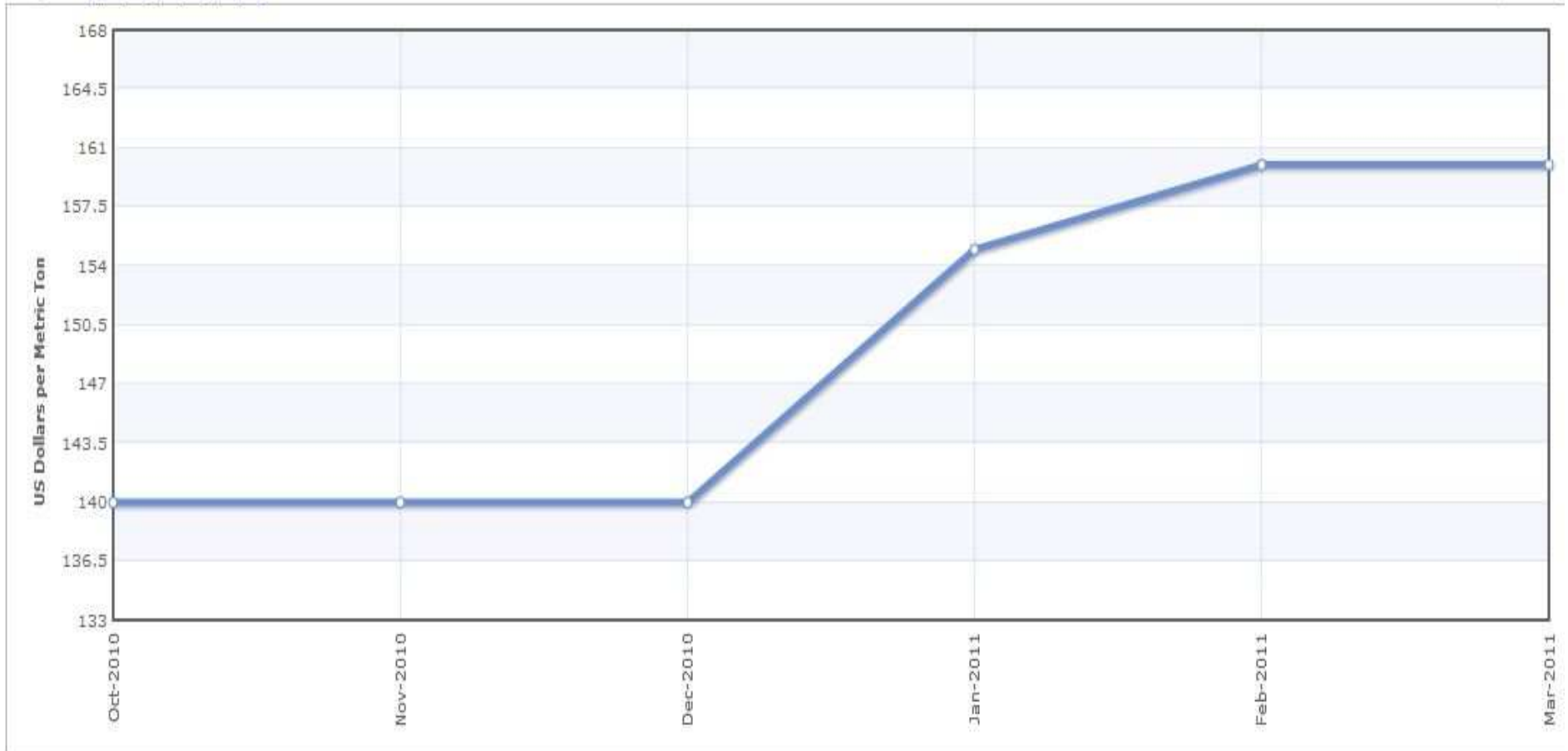
Fig. 1: Phosphate rock production costs



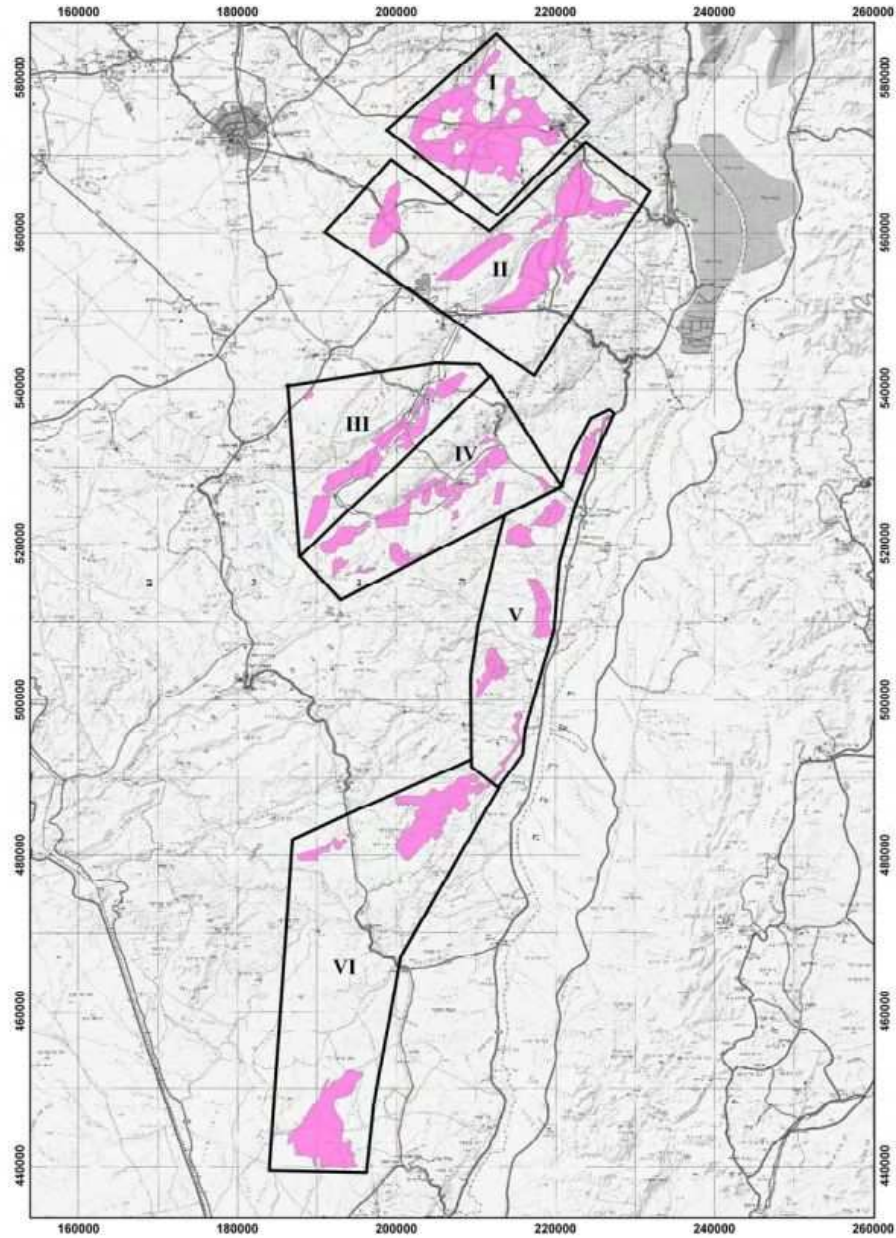
## Rock Phosphate Monthly Price

Range 6m [1y](#) [5y](#) [10y](#) [15y](#) [20y](#) [25y](#) [30y](#)

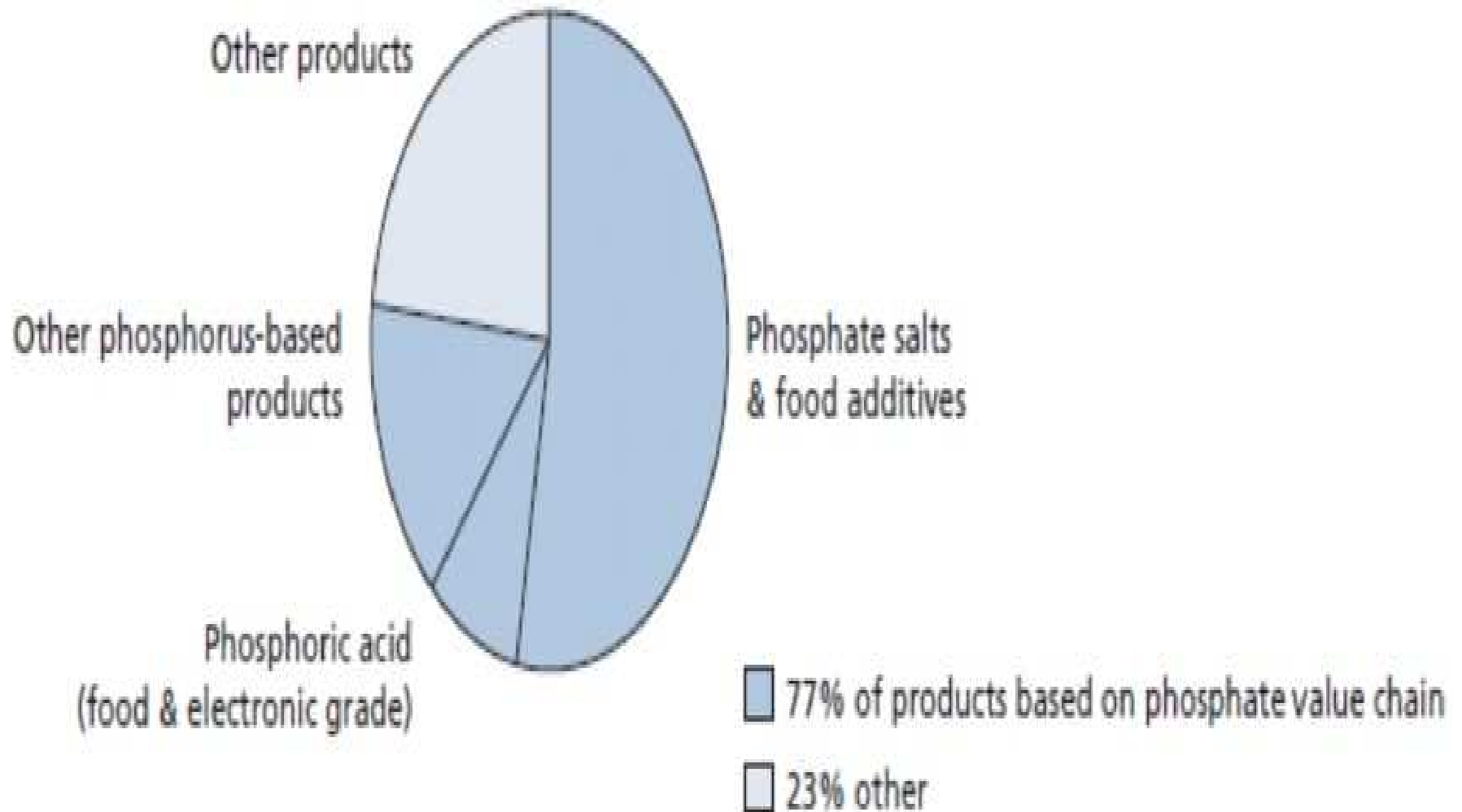
Oct 2010 - Mar 2011: 20.000 (14.29 %)



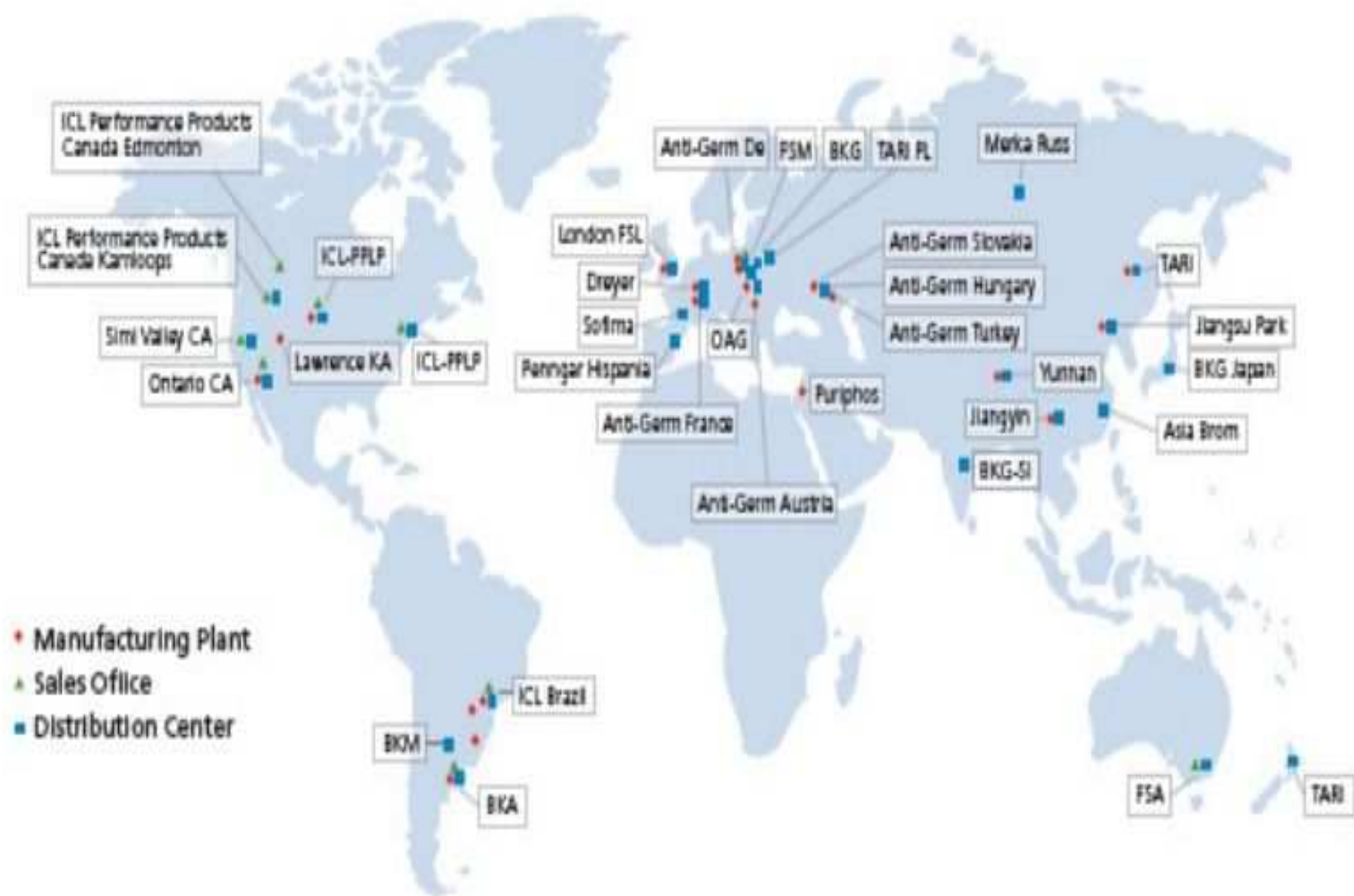
# Israel



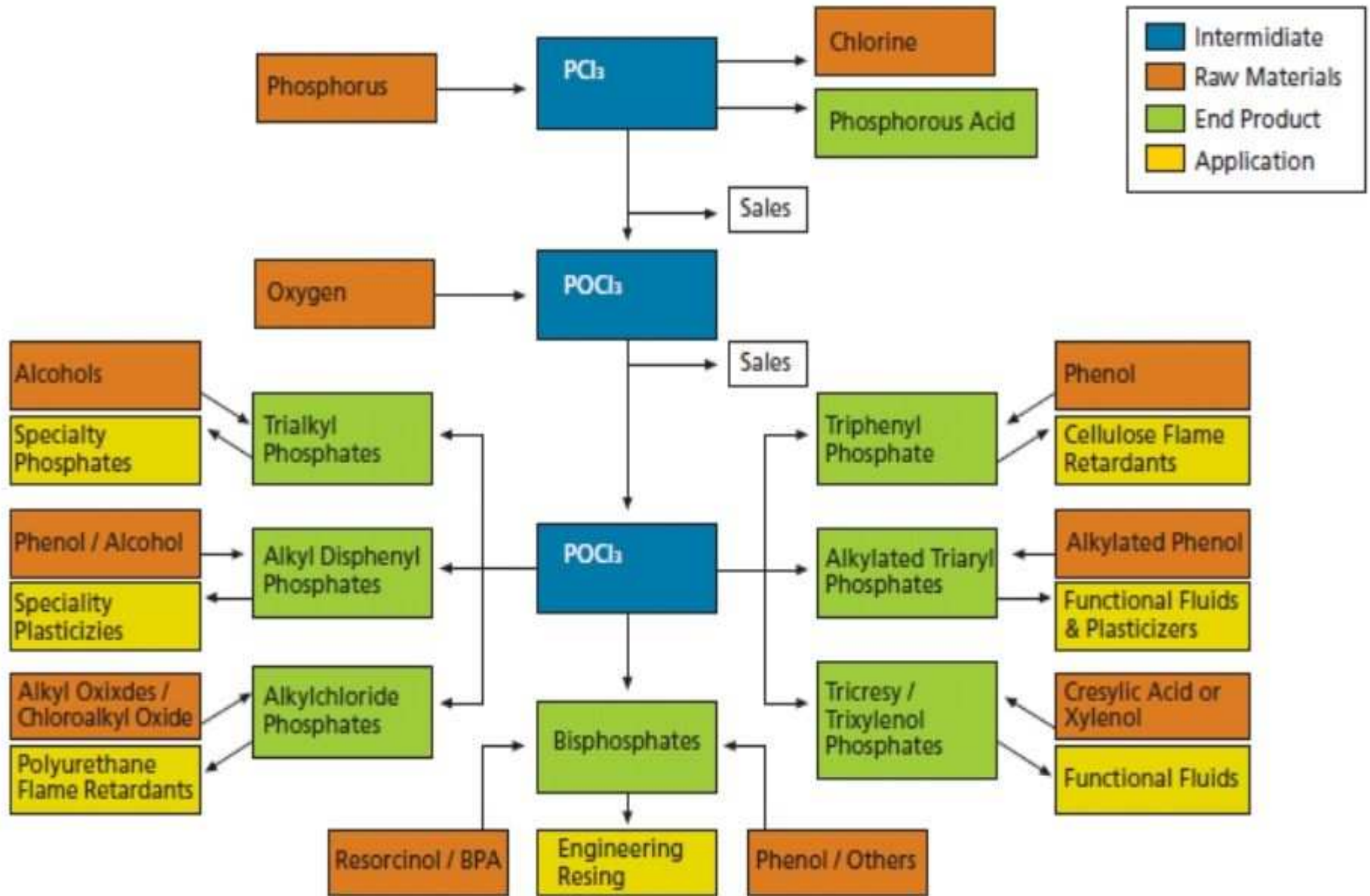
Total external sales for 2009: \$1,294 million



## Geographic distribution of the production plants of ICL Performance Products



The following is a graphic representation of the production process:





## Mining Characteristics of Some Major Phosphate Deposits<sup>a</sup>

Phosphate deposit	Av. thickness, m.		P <sub>2</sub> O <sub>5</sub> grade, %		Concn. ratio	Recovery effic., %
	Overburden	Ore bed	Ore	Product		
Florida (pebble)	4.6	9.1	10-15	33	2.2-3.3	60-70
North Carolina	27.4	12.2	15	30-32	2.0	85
Western U.S. <sup>b</sup>	(variable)	3-9	26-36	32-36	1.0-1.2	90
Angola	2-3	10-40	34-37	34-37	1	100 <sup>d</sup>
Morocco <sup>c</sup>	9-10	2	33-34	35-37	1	100 <sup>d</sup>
Spanish Sahara <sup>e</sup>	10-30	4	31-33	34-37	1.0-1.2	(?)

<u>Deposit Source</u>	BPL grade	Constituent, % <sup>a</sup>							
		CaO	P <sub>2</sub> O <sub>5</sub>	F	CO <sub>2</sub>	R <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	MgO	SiO <sub>2</sub>
Central Florida	73	48.9	33.4	3.9	3.0	2.12	0.53	0.29	4.5
North Carolina	66	48.5	30.2	3.7	5.5	1.14	0.83	0.54	2.1
Morocco	70	51.6	32.1	4.1	5.3	0.55	0.79	0.43	1.4
Gafsa, Tunisia	63	43.3	28.8	3.4	6.3	1.22	1.30	0.59	1.8
Taiba, Senegal	82	51.2	37.4	4.0	1.7	2.06	0.20	0.06	2.9
Togo	80	52.3	36.6	4.0	1.8	1.78	0.27	0.11	1.8
Kola, Russia	83	52.0	38.2	3.1	0.2	3.14	0.50	0.06	2.0
Spanish Sahara	78	51.9	35.8	3.8	2.3	1.17	0.40	0.14	3.4
Angola	81	51.3	37.2	4.0	2.1	1.47	0.62	0.10	1.5
Jhamar Kotra, India	88,	54.2	40.1	3.6	0.7	0.70	0.11	0.04	1.2
Jordan	74	53.0	33.8	4.0	4.9	3.36	0.51	0.18	5.6
Israel (Oron)	68	52.7	31.3	3.6	7.5	0.45	0.75	0.24	0.2
Sechura, Peru	66	46.5	30.2	2.9	4.4	1.65	1.85	0.50	3.2
Algeria	63	49.3	29.0	3.6	7.4	0.70	2.00	0.81	1.0

Acidulation requirements<sup>a</sup>

Product Source	Properties of concentrate			Tons rock per ton 54% WPA	Tons H <sub>2</sub> SO <sub>4</sub> per ton of:			Tons sulfur per ton of:		
	%	%	Wt. ratios		Rock	54% WPA	P <sub>2</sub> O <sub>5</sub>	Rock	54% WPA	P <sub>2</sub> O <sub>5</sub>
	CaO	P <sub>2</sub> O <sub>5</sub>	CaO/P <sub>2</sub> O <sub>5</sub>							
Central Florida	48.9	33.4	1.464	1.617	0.856	1.384	2.563	0.279	0.451	0.83
North Carolina	48.5	30.2	1.606	1.788	0.849	1.518	2.811	0.277	0.495	0.91
Morocco	51.6	32.1	1.607	1.682	0.903	1.519	2.811	0.294	0.495	0.91
Gafsa, Tunisia	48.3	28.8	1.677	1.875	0.845	1.584	2.933	0.276	0.516	0.95
Taiba, Senegal	51.2	37.4	1.369	1.444	0.896	1.294	2.400	0.292	0.421	0.78
Togo	52.3	36.6	1.429	1.475	0.915	1.350	2.500	0.298	0.440	0.81
Kola, Russia	52.0	38.2	1.361	1.414	0.910	1.287	2.383	0.297	0.419	0.77
Spanish Sahara	51.9	35.8	1.458	1.508	0.908	1.369	2.535	0.296	0.446	0.82
Angola	51.3	37.2	1.379	1.452	0.898	1.304	2.415	0.293	0.425	0.78
Jhamar-Kotra, Ind	51.2	40.1	1.352	1.347	0.949	1.278	2.367 <sup>w</sup>	0.309	0.417	0.77
Jordan	53.0	33.8	1.568	1.598	0.928	1.483	2.746	0.302	0.483	0.85
Israel (Oron)	52.7	31.3	1.684	1.725	0.922	1.590	2.944	0.300	0.518	0.95
Sechura, Peru	46.5	30.2	1.540	1.788	0.814	1.455	2.694	0.265	0.474	0.87
Algeria	49.3	29.0	1.700	1.862	0.863	1.607	2.976	0.281	0.524	0.97

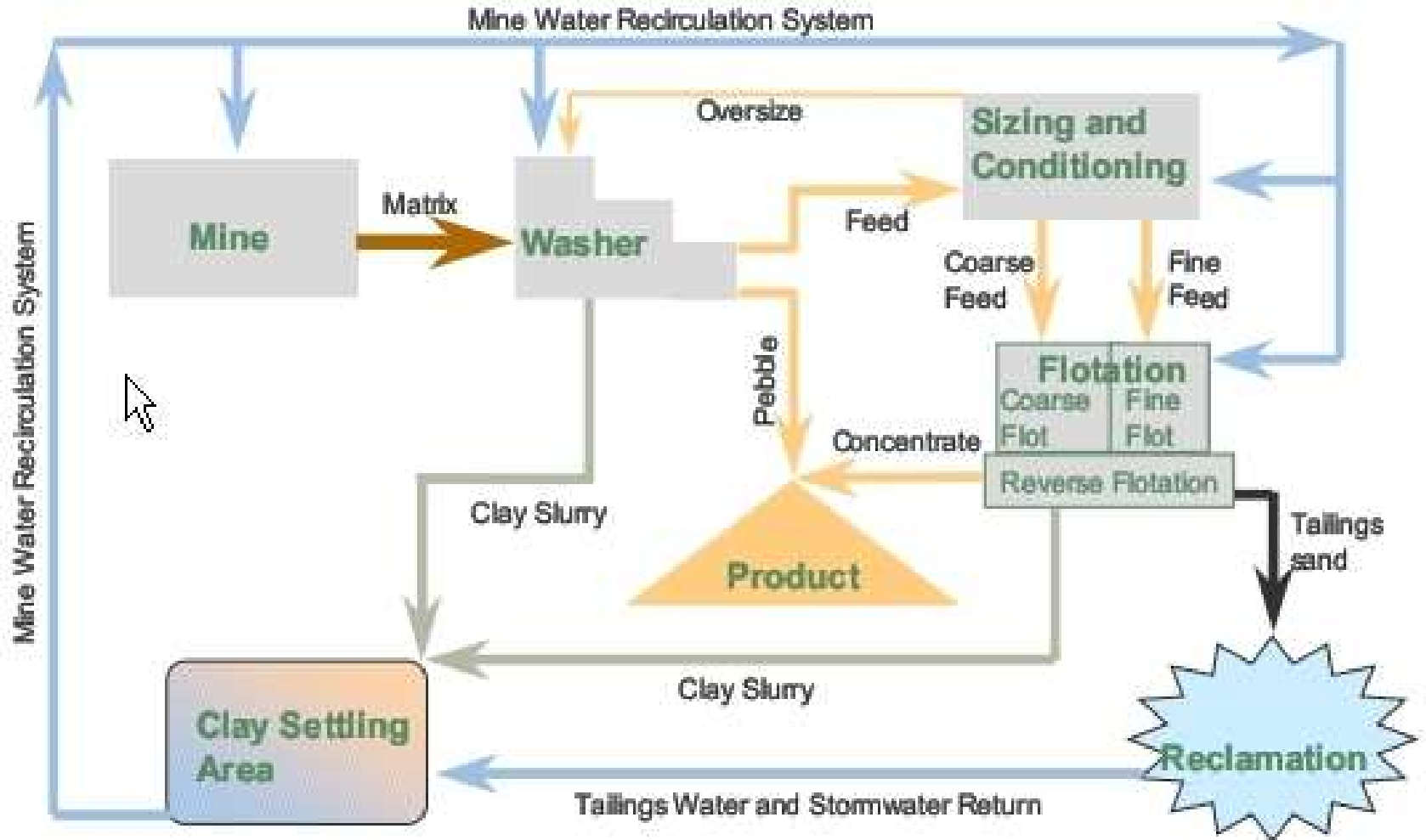
# Processes

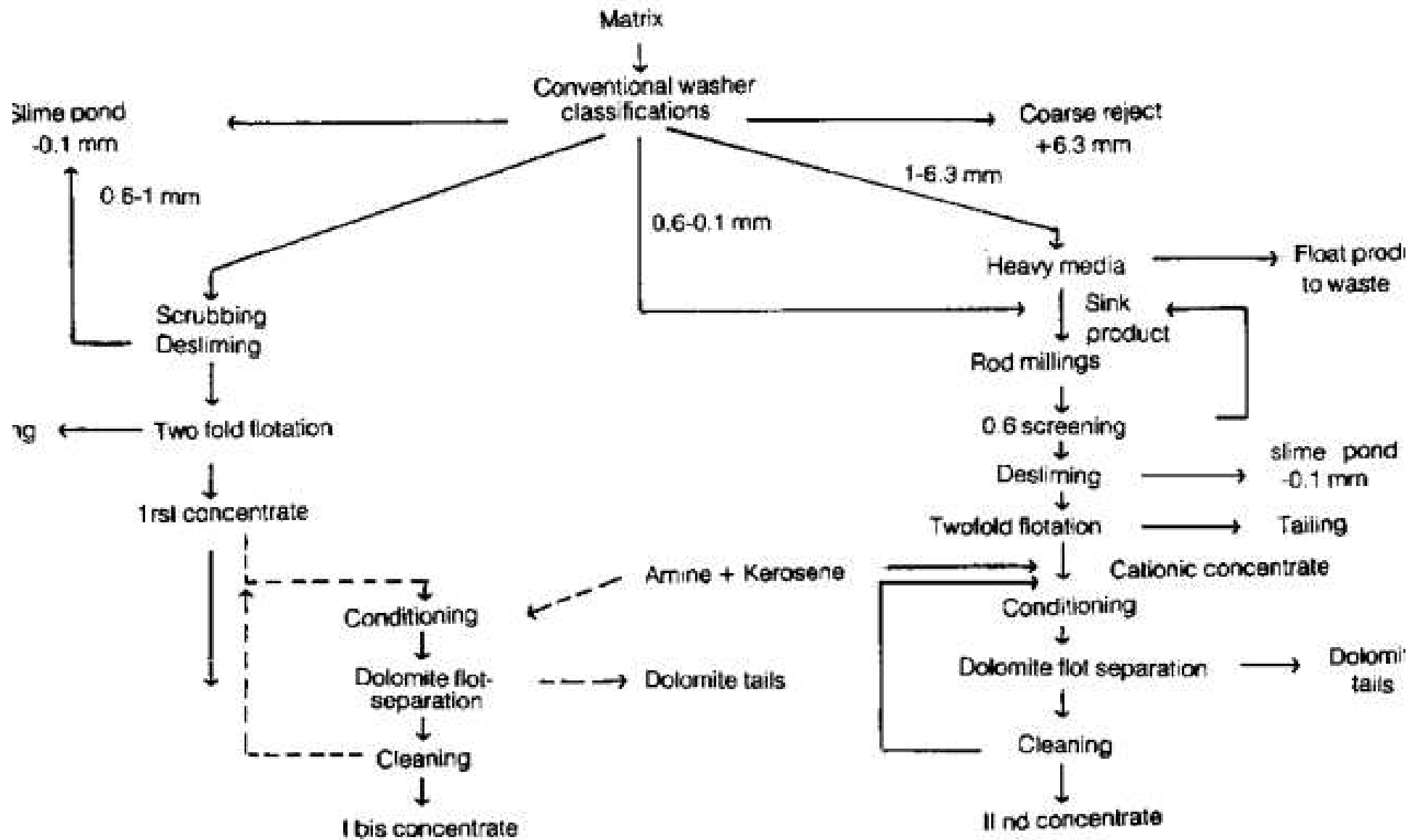


# Beneficiation processes

- Flotation
- Grinding and separation by size
- Part acidulation
- Calcination and separation by size
- Calcination and washing

# Phosphate Rock Processing





1. Basic process diagram for IMC process



# Phosphate Rock Beneficiation



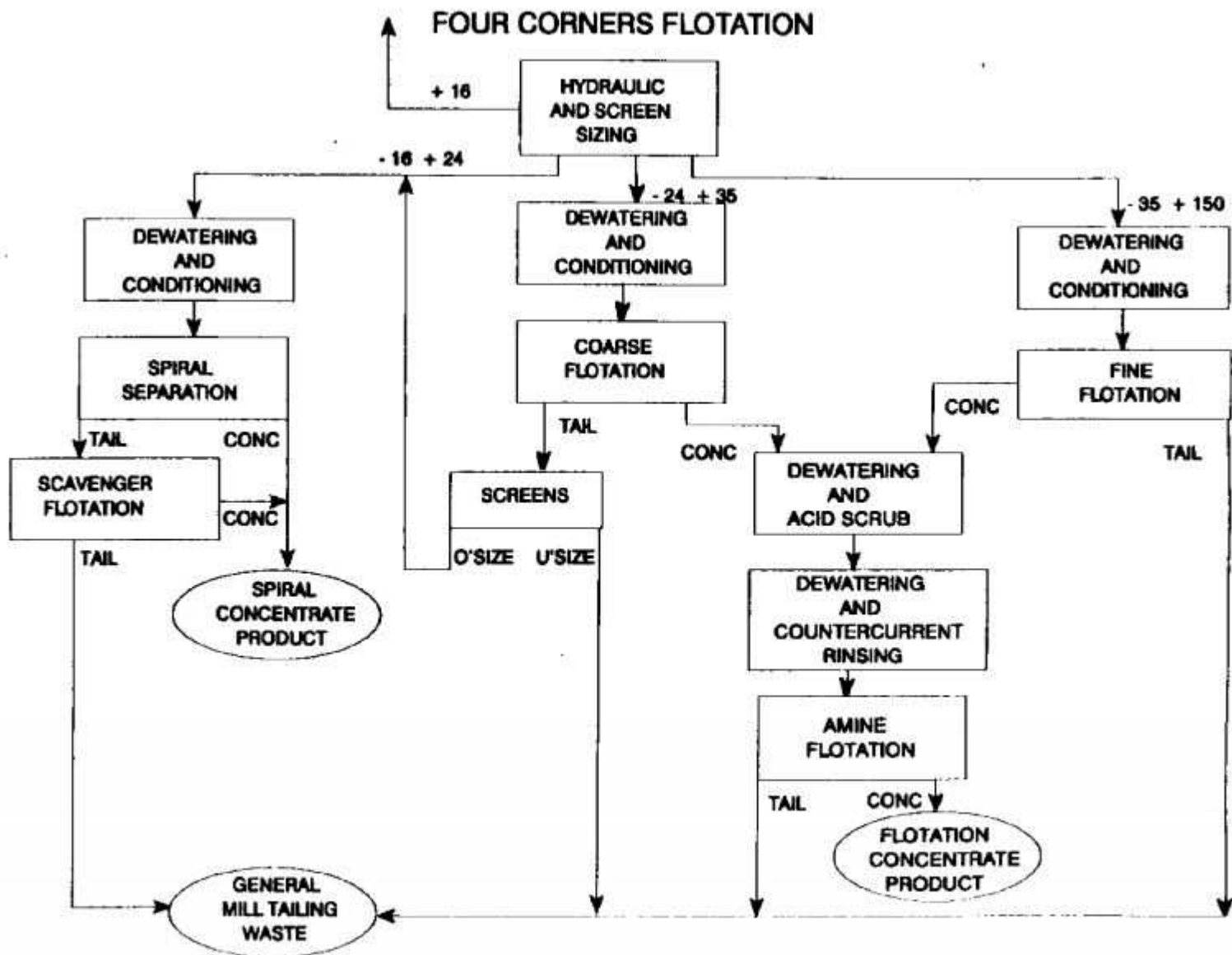
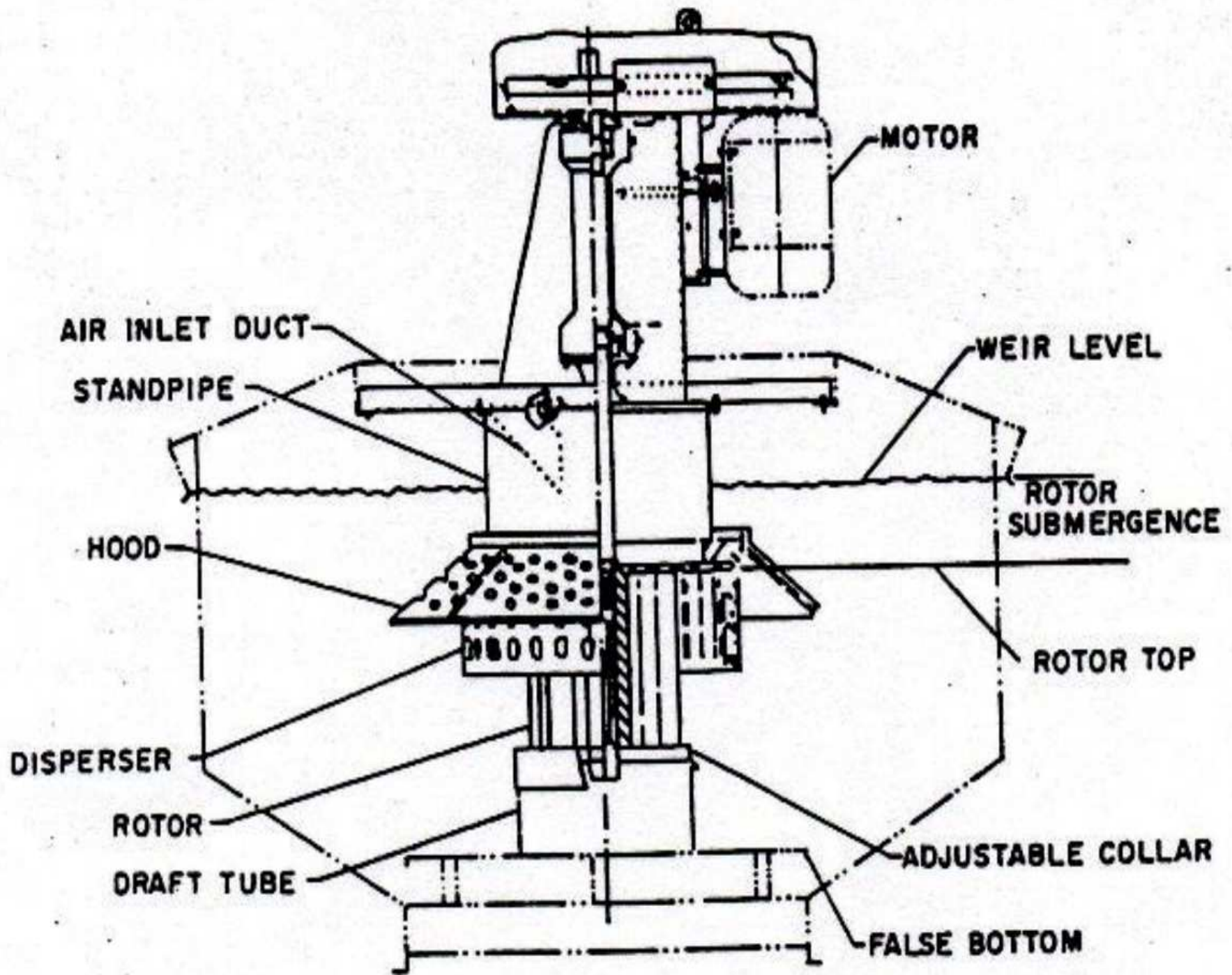


Figure 6. Flotation Plant Flow Diagram  
(Source: IMC Fertilizer, Inc.)



The reagents used in beneficiation of Florida phosphates are listed below with typical consumption rates:

<b>Circuit</b>	<b>Reagent</b>	<b>Rate, kg/ton of Feed</b>		
<b>Rougher</b>	Fatty acid island	0.4	-	0.8
	Fuel oil	0.75	-	1.5
	Base (ammonia)	0.2	-	0.4
<b>Deoiling</b>	H <sub>2</sub> SO <sub>4</sub>	1.0	-	2.0
<b>Cleaner</b>	Amine (tallow)	0.125	-	0.25
	Kerosene	0.25	-	0.50
	Caustic soda	0.25	-	0.50

These usage rates are relatively low compared with those used in flotation of the siliceous ore from Senegal as listed below:

Tall oil	1.8 kg/ton feed
Diesel oil	4/1 kg/ton
Sodium hydroxide	0.6 kg/ton
Sodium carbonate	0.1 kg/ton