

How phosphate is mined and processed

Learning outcomes:

By completing the reading, you should be able to meet outcomes #1 and #4 below. By also completing the in-class activity, you should be able to do all of the following:

1. Describe the mining and beneficiation techniques used to recover phosphate.
2. Identify the primary wastes created during the different stages of phosphate fertilizer production and use.
3. Discuss how waste products are managed.
4. Describe the phosphate cycle, and how the use of chemical phosphate fertilizer alters this cycle.
5. Identify how air, water, and land can potentially be polluted by phosphate mining, fertilizer production and fertilizer use.
6. Summarize the effects of phosphate mining on land use in Florida.
7. Identify stakeholders, appreciate their viewpoints, and weigh their diverse views in determining if, how and where to mine.
8. Predict future demand of the phosphate based on (a) population change, (b) technology change, (c) people's choices and (d) changes in national and international phosphorus supply.
9. Communicate how individual choices impact phosphate demand and the phosphate cycle.

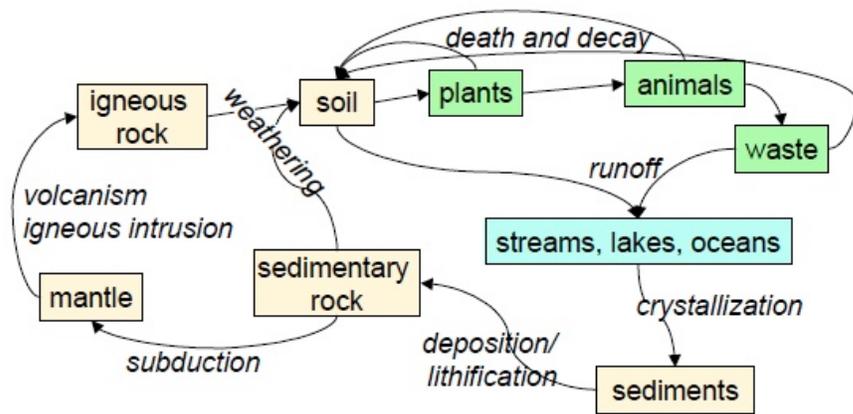
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Introduction

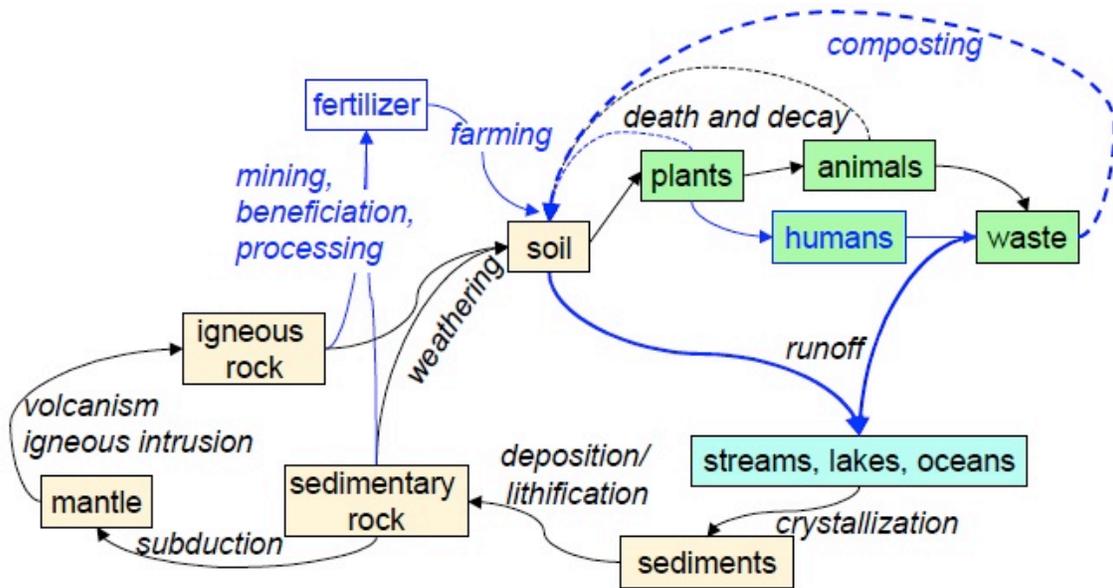
Phosphorus is not one of the most common elements in Earth's crust and mantle, yet it is essential for all life, plant and animal. Phosphorus makes up our bones and teeth, and importantly, phosphorus comprises DNA.

Even though plants require more nitrogen and oxygen than they do phosphorus, phosphorus is often the limiting nutrient; the amount of available phosphorus determines the amount of plant growth and development. Where phosphorus is plentiful, plants thrive, and vice versa. However, plants cannot absorb limitless amounts of phosphorus. Phosphorus not used by plants remains in the soil or runs off in streams and groundwater.

The diagram below shows the reservoirs of the phosphorus cycle (in boxes). The processes that move phosphorus from one place to another are in italics, and arrows show the direction in which phosphorus flows.



In a given area of land, plants grow and remove phosphorus from the soil. But then those plants die, and the phosphorus in their tissues is recycled back into the soil. When land is farmed, plants absorb the phosphorus, but then the plants are removed to be eaten. Because this reduces the amount of soil phosphorus available, humans started adding phosphorus fertilizer to soils in the 1800s. Some of the fertilizer was organic, from ground up bones or mined guano (bat dung). But humans then started mining phosphorus from both igneous and sedimentary (but mostly sedimentary) rock. The use of inorganic phosphate fertilizer (aka chemical fertilizer) greatly altered the phosphorus cycle, as shown in this second diagram.



Phosphorus in rock is pretty insoluble and thus not directly available to plants. In nature, rock phosphate can become soluble (and available to plants) either by chemical weathering or through the actions of certain types of plants. The solubility also depends on rock type and the pH of the soil; phosphorus is most soluble when contained in sedimentary rocks as opposed to igneous rock, and when soil pH is between 5.5 and 7.2.

Therefore, spreading phosphate rock on fields had little effect on plant growth. However, in the mid-1800s, chemists discovered that mixing sulfuric acid with phosphate rock would make a soluble fine powder called superphosphate; this discovery turned phosphate rock into the valuable fertilizer it is today. A caveat, however, is that once fertilizer is applied to the soil, the phosphorus not absorbed by plants can adhere to soil or clay particles, and become an insoluble solid once again.

The origin of phosphate deposits

About 15% of phosphate reserves are found in volcanic (extrusive) igneous rocks. These reserves are found in Russia, Finland, South Africa and Brazil.

Most phosphate reserves are from sedimentary rocks. The phosphate forms in the shallow oceans mainly due to bacterial activity, but only when several conditions are met. Their formation is pretty rare! For example, phosphates form only in warm, tropical oceans where there is a cold upwelling next to shore. There needs to be a source of phosphorus. Usually this is an abundance of dead organic matter. (There's a reason that Florida's phosphate region is also called the Bone Beds.) Bacteria feed off nutrients from the organic matter and the cold upwelling water and release the phosphorus element from the organic matter. Other bacteria help crystallize that phosphate as a mud. Finally, the right set of processes is needed to concentrate the phosphate into one layer. This can be a combination of physical processes (wave erosion) and biological processes (benthic organisms eating and then excreting phosphate pellets). It should be noted that the previous paragraph overly simplifies a complicated process that is not yet fully understood, in spite of being studied for more than one hundred years!

How phosphate is mined and processes

Mining

Sedimentary phosphate tends to be found in loose sediment, so it can be mined with dredge lines (or picks and shovels). In Florida, the phosphate is found mainly in one layer of clay and sand that's about 10-20 feet thick, and 15-50 feet below the surface. After the heavy equipment digs out the overburden (the sediment above the desired layer), they remove and dump the phosphate-rich sediment into a pit. That sediment is mixed with pressurized water to make a slurry, and that slurry sent through miles of pipeline. Making and pressurizing the slurry requires a lot of electricity (15 kwh per ton of phosphoric acid) as well as water. Many phosphate mines recycle their water, and in Florida, 95% of water is reused.

Beneficiation

The fast movement of the slurry causes it to bang against the pipes, and this breaks apart any clay balls. What arrives at the beneficiation plant are fine-grained sand, clay and phosphate sediments suspended in water. At the beneficiation plant, the slurry is first run through a screen, which filters out the coarser sand. To separate the phosphate from the

clay, different equipment cause the finer-grained particles to separate from the coarser grains. Finally, a process called flotation is used to separate the phosphate from smaller-grained sand. In this process, the phosphate is coated with a hydrocarbon. When bubbles move through the liquid, the coated particles attach to the bubbles and rise to the surface. This can be done a second time, but using a different hydrocarbon to attach to the sand.

At this point, the sand, clay and phosphate have been separated. The sand and overburden are used to help reclaim land (fill mine pits). Because it remains soggy for a long time, the clay is more of a problem. The clay is spread out over the land. After 3-5 years a solid crust will exist on the clay, but underneath the clay will be soft and pudding-like (not ideal to build upon).

Processing

The phosphate is sent to a chemical processing plant, or fertilizer manufacturing plant. Here, molten sulfur, shipped to Florida ports and trucked to the plant, is used to create sulfuric acid. The sulfuric acid is then mixed with the phosphate to make phosphoric acid. The phosphoric acid is the main ingredient in fertilizer, but can also be used in animal feed supplements, soda, or soap.

Sulfuric acid production creates a lot of heat. This heat is used by a power plant to generate electricity, which helps to power both sulfuric acid production and phosphoric acid production.

The mixing of sulfuric acid and phosphate creates gypsum (called phosphogypsum) as a byproduct. Although gypsum can be used for a variety of purposes, the EPA prevents usage of Florida's phosphogypsum because it retains low levels of radioactivity found in the host sediments. At present, phosphogypsum is piled up around the processing plant. Wastewater is also produced. Much is reused, but some fills ponds at the tops of gypsum stacks where water evaporates.