Educational Series 12

The Nonfuel Mineral Resources of Pennsylvania

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF GEOLOGICAL SURVEY

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FRONT COVER: The top photograph shows a sand and gravel operation known as Mt. Cydonia No. 2, operated in the eastern part of Franklin County in the early 1980s. The bottom photograph shows the same operation about 10 years later, following reclamation of the land to form a pond and golf course. Photographs courtesy of Randy Van Scyoc, Valley Quarries, Inc.

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The Nonfuel Mineral Resources of Pennsylvania

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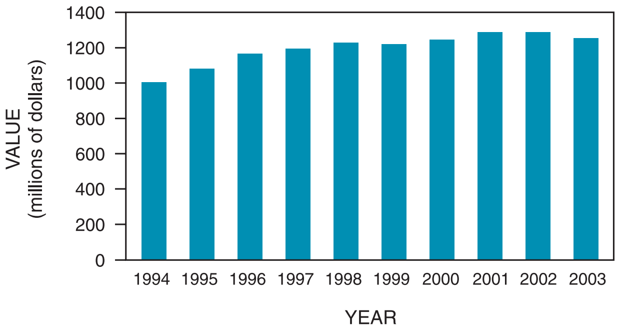
The Nonfuel Mineral Resources of Pennsylvania

One day, several million years ago, a very early ancestor of ours whose identity is lost forever picked up a rock and used it to do something. Whether the rock was used to crack open a nut, frighten away a predator, or was simply a toy to play with, this was the start of our dependence on mineral products. With time, our ancestors were shaping rocks into better tools. By 2.3 million years ago, prehuman toolmakers in east Africa realized that some rocks were better for making sharp-edged tools than other rocks. After many millennia of evolution and learning, the knowledge of how to separate the chemicals that make up rocks was unlocked. This allowed the use of rock products to manufacture other products. Centuries later, this knowledge helped to give rise to the industrial revolution and our modern way of life.

At the dawn of the twenty-first century, we live in an information age dominated by the excitement of powerful new technologies. We refer to the long-ago era of stone tools and spear points as the Stone Age. But our need for "stone" is as great now as ever. New uses are constantly found for the raw materials that come *only* from the earth. *Everything* that we need to build the most advanced computer comes from the earth and has been available since prehistoric times! Today we use knowledge accumulated over centuries to combine raw materials in new and exciting ways. Tomorrow, raw materials from the earth will be combined in ways that we cannot even imagine. Despite all of our advances, we are at least as dependent on nature's raw materials as any cave dweller ever was.

According to the U.S. Geological Survey, $1.26 billion worth of nonfuel minerals was mined in Pennsylvania in 2003. We will explore the past, present, and future impact of that production. At the end of the booklet is a list of books that have additional information. We also recommend reading Educational Series booklets 3, 7, and 8 to learn about Pennsylvania's groundwater, coal, and oil and gas resources. For an introduction to geological concepts discussed in this booklet and an overview of the events that, over billions of years, formed Pennsylvania's mineral resources, we recommend Educational Series booklet 4, *The Geological Story of Pennsylvania*.



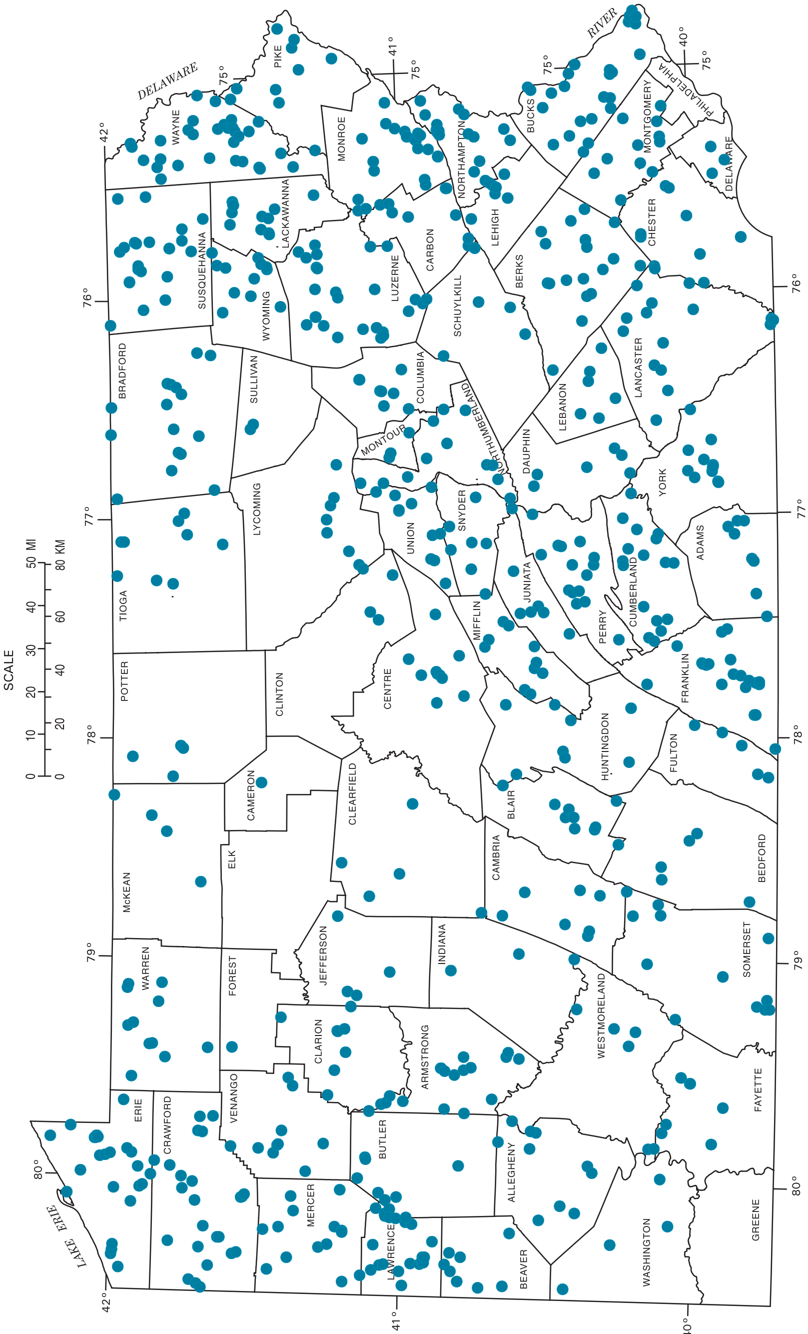
WHAT ARE MINERAL RESOURCES?

Mineral resources are naturally occurring materials that are found in the ground and are used in our daily lives. When the resources are extracted from the ground they are referred to as mineral products. Most of the items that we deal with in life are made from mineral products. These include nearly everything you might think of, including television sets, refrigerators, stoves, computers, autos, planes, and trains. Even our homes contain mineral materials in the bricks, tiles, window panes, roofing, cement, wiring, pipes, linoleum, and insulation. Although plant and animal products, such as wood, wool, and cotton, are not minerals, they are processed and manufactured by machinery made of metals and are fastened by nails, buttons, or zippers.

All rocks are made up of minerals, but only mineral occurrences for which there is a market and commercial use qualify as mineral resources. To be extracted (or mined), a mineral resource has to have a high enough quality and quantity to cover the cost of mining and processing. Pennsylvania is fortunate to have a considerable number of minable resources whose annual total value makes this state a leading mineral producer.

The word "mineral," like many words, has more than one meaning. To a person who works with mineral products and resources, "mineral" includes rocks, sand, gravel, and even coal and petroleum. This is different than the definition used by scientists who study a branch of geology called mineralogy.

To a mineralogist, a mineral is a naturally occurring, inorganic substance that has a specific composition and crystal form. Minerals are the building blocks that make up rocks. Some minerals that are commonly found in Pennsylvania include the silicon-based minerals quartz, feldspar, mica, and pyroxene; and the carbonate minerals calcite (calcium carbonate) and dolomite (calcium magnesium carbonate). Rocks that are considered to be mineral resources include two carbonate rocks, limestone, which consists mostly of calcite, and dolomite, which consists mostly of the mineral dolomite; diabase, which consists mainly of interlocking laths of feldspar and pyroxene (a microscopic view is shown to the right); and sandstone, which commonly contains quartz and feldspar.



At the end of the twentieth century, approximately 700 active quarries and mines dotted the landscape of 64 of Pennsylvania's 67 counties. They produced nonfuel minerals useful for construction, agriculture, preventing pollution, and manufacturing many products, including bricks, roofing materials, glass, china, pottery, refractories, and fluxes.

WHAT MINERAL RESOURCES ARE PRESENTLY BEING MINED IN PENNSYLVANIA?

Mineral Products Used in Building

The most obvious way in which we see mineral products in use in our daily lives, and the one that consumes the greatest amount of material in Pennsylvania, is construction. Many buildings, roads, and monuments contain stone that is used with little modification, as it has been for centuries. The production of these raw materials is a large industry. Just in Pennsylvania, mined construction products had a total value of more than a billion dollars in 2002.

Dimension stone. A good place to see stone used in its purest form is a cemetery. The monuments are examples of dimension stone. Dimension stone is cut and commonly polished, and it may be artistically carved, but it is otherwise unprocessed after it is extracted from the earth. If a cemetery in your town contains graves that date from before the twentieth century, you may see monuments that are made of locally quarried rock such as sandstone, slate, or marble. Marble was a favorite because of its beauty and because it is easily cut and polished. The people who requested it probably did not anticipate that the writing on these stones would become hard to read with time. The principal mineral in marble is calcite, which gradually dissolves because it is attacked by weak acids that are naturally present in rainwater.

A walk through the cemetery demonstrates how some types of stone are more suited to certain uses than others. Some monuments, such as this one, stand the test of time better. They are made of granite or diabase. Diabase is inaccurately called "black granite" by some people. These igneous rocks were formed by the crystallization of red-hot, molten material underground. They are composed of interlocking crystals of silicon-based minerals such as quartz, feldspar, and pyroxene, and are not readily attacked by rainwater. Writing carved on granite or diabase is easy to read for centuries. Diabase for dimension stone is found in many places in southeastern Pennsylvania and is currently quar-

ried in Chester County. Granite, which has a lighter color, is quarried in North Carolina, Vermont, and other states.

Dimension stone is also used in constructing buildings and bridges. In Gettysburg, diabase is plentiful and was used in many buildings. The wall in this photograph is made of diabase. West Chester is noted for its green buildings constructed of serpentinite, an unusual type of rock that was quarried nearby.

Pennsylvania is also known for its slate quarries. Slate is a metamorphic rock. The word "metamorphic" means "changed form." Metamorphic rocks were changed from their original form by heat and/or pressure in the earth. Marble is another metamorphic rock. Before their forms were changed, marble was originally limestone or dolomite and slate was originally shale. Several quarries northeast of Allentown obtain slate from a bedrock unit called the Martinsburg Formation. The slate that is mined is used as the hard, flat surface underneath the felt of many billiard tables. It is also split and cut into shingles and used for roofs, such as the roof in the photograph above. A slate roof is heavy and expensive, but it can last for more than a century and requires little maintenance.

"Bluestone" is a type of fine-grained sandstone that is obtained from many small quarries in the Catskill Formation in northeastern Pennsylvania and the adjacent part of New York. It is more gray than blue to most people's eyes, and is used as flagstone for floors and sidewalks.

There are other quarries around the state from which dimension stone is obtained. Some mine sandstone. Two in southeastern Pennsylvania mine the metamorphic rock schist, which makes an interesting decorative stone.

Altogether, in 2003, Pennsylvania was the nation's tenth largest producer of dimension stone, producing a total of 51 thousand tons worth nearly $10 million.

Aggregate. Of all of Pennsylvania's nonfuel mineral resources, the biggest in terms of both dollars earned and tons mined is aggregate. Aggregate is the name given to materials such as crushed stone, sand, and gravel. Modern, inexpensive, high-speed transportation would be impossible without it. Highways, airport runways, railroad-track beds, and wharves for large ships could not

be built without aggregate. In 2003, Pennsylvania was the nation's third-largest producer of crushed stone, producing approximately 106 million tons having a value of $547 million. If it all met the standards for highway construction, this would be enough to pave about 700 miles of four-lane highways. The state also produced nearly 20 million tons of sand and gravel worth $115 million. Most of the operations on the map on page 3 produce either construction aggregate or other materials required for building, such as shale or other "fill" that is used to level the ground at construction sites.

Aggregate cannot be made from just any type of rock. As we have seen in looking at dimension stone, some types of rock are better than others, depending on the use. The Pennsylvania Department of Transportation tests aggregate for durability and resistance to polish, which can contribute to skidding. In Pennsylvania, most aggregate is made by quarrying limestone, dolomite, or sandstone and crushing it. In the areas of northeastern and northwestern Pennsylvania that were covered by glaciers during the Pleistocene Epoch, sand and gravel deposited by the glaciers can sometimes be used for aggregate. Sediments from former river channels are also mined. Most sand and gravel is mined from open pits on land, but it is also dredged from the Allegheny and Ohio Rivers and even from Lake Erie.

Aggregate is commonly mixed with portland cement or a black, tarry material, asphalt, to make concrete. It is sometimes spread and compacted or applied without a binder to make gravel roads.

Riprap is a type of aggregate made up of chunks of rock up to several feet across, depending on the application. It is commonly used along shorelines and riverbanks to protect property from wave erosion.

Railroad-track beds contain fist-sized aggregate that is used as ballast to keep the rails from shifting as trains pass over them. Diabase is very tough and dense and is especially suited to this purpose.

Portland cement. The portland cement that is mixed with aggregate to make concrete is another product of Pennsylvania. It is ideally made from shaly limestone that is low in magnesium and contains the correct amounts of silica, iron, and alumina. This kind of limestone is found in eastern Pennsylvania, especially north of the Allentown-Bethlehem area. Pulverized limestone is burned at approximately 2,000°F with a clayey material such as shale and a source of iron to form calcium silicates or aluminates. Pulverization of this substance and the addition of gypsum to slow the rate of curing completes the process of making portland cement.

Portland cement is a step beyond the other construction materials that we have looked at, which we said represent the most obvious and pure use of stone. It is the first product that we have mentioned that is manufactured from stone that has been altered chemically to create different substances.

The use of cement dates back thousands of years. The ancient Egyptians made a relatively soft cement from gypsum, which was used as mortar between the stones of the pyramids. This type of cement, known today as plaster of paris, is still used for some purposes. The Romans later developed a stronger cement that was made from limestone and fine silicon-based minerals that are present in volcanic ash. That type of cement was used in the construction of such enduring landmarks as the Colosseum, the Appian Way, and the aqueducts.

Following the fall of the Roman Empire, the knowledge of how to make such durable cement was lost during the Middle Ages. Research on cement in the seventeenth, eighteenth, and nineteenth centuries led to the first manufacture of portland cement by Joseph Aspdin in England in 1824. Portland cement is stronger than the cement made by the Romans, and was said to resemble stone obtained from the Isle of Portland off the coast of England.

Pennsylvania was the site of the first facility to manufacture portland cement in the United States. In 1871, David O. Saylor set up the first plant in Coplay, Lehigh County. His early plants used vertical kilns, pictured here, to heat the ingredients required to make cement. This procedure was soon replaced by rotary kilns, which are more nearly horizontal. Rotary kilns have the advantage that they can be operated continuously. Ingredients are fed in at one end, and the product, called clinker, comes out at the other end. The clinker is pulverized and gypsum is added to make cement.

In 2003, Pennsylvania ranked third among the states in the production of portland cement, producing 6.8 million tons valued at $457 million.

Mineral Products Used in Manufacturing

We mentioned that slate is used to make billiard-tabletops and roofing shingles. These are just a few of the many uses of Pennsylvania's mineral products in manufacturing. They are also among the most direct uses. Many manufactured products contain the state's minerals, processed and combined with other ingredients so that the original mineral is no longer recognizable. Very few people think of minerals when they use paper, tile, plastic, pottery, or paint, but these are among the products that contain minerals extracted from Pennsylvania's quarries.

When the Quaker colonists arrived in Philadelphia in the late 1600s, one of their first tasks was to build **brick** houses. William Penn wisely recommended this to reduce the danger of fire, which had devastated so many other cities of that time when most buildings were constructed of wood. Bricks are still an important building material in Pennsylvania. At the close of the twentieth century, the clays and shales that are the principal raw materials for making bricks were being mined in Adams, Allegheny, Armstrong, Beaver, Berks, Montgomery, Northumberland, and York Counties. Clays and shales mined in Armstrong and Clinton Counties are also used in the manufacture of various kinds of **tiles and sewer pipe.**

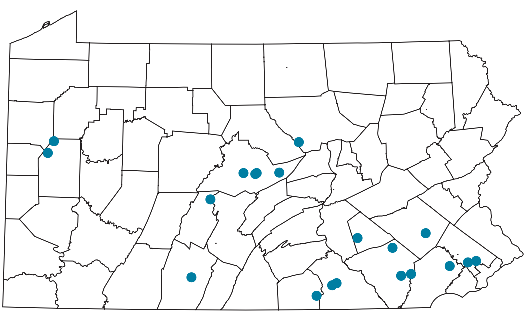
Another important use of clays is as **filler.** Fillers add bulk, strength, or other desired properties to a product. Depending on how they are to be used, fillers can also consist of limestone or other materials. They are used in products as varied as plastics, rubber, paint, shingles, and even food and medicine. York County is an important source of white limestone and dolomite fillers in Pennsylvania. Limestone filler is also quarried in Northumberland, Lancaster, and Snyder Counties. Clay fillers are found in Bucks and Northumberland Counties. A sandstone deposit in Huntingdon County is a source of silica filler.

Some of the limestone quarried in York County, from the Kinzers Formation, has a high calcium carbonate content and a special quality known as **whiting** and is used to improve the properties of paper. The limestone is pulverized and added during the papermaking process. The limestone fills in irregularities between cellulose fibers so that the paper will be smooth and the ink will be absorbed properly. It also protects paper from aging by neutralizing acids, and it may also improve the whiteness of the paper.

Some of the deposits that are sources of fillers also provide the raw materials for **glass and ceramics.** Limestone from the quarries in York County is used as an ingredient in the manufacture of ceramics and glass. A quarry in Huntingdon County produces sand that is of the quality needed for making glass, enamel, and pottery, and also for making molds that are used for casting metal objects such as automobile engine parts.

High-purity limestones and dolomites are used for their chemical properties in industrial applications. Pennsylvania is one of the nation's leading states in the production of **lime.** Lime is made by heating limestone or dolomite to a high temperature, at which it breaks down into carbon dioxide gas and calcium and magnesium oxides. Lime is a highly reactive chemical. It is used in the paper industry to bleach pulp, a step toward producing white paper. It is also used as a **flux** in steelmaking to remove impurities such as phosphorus, silicon, and sulfur and lower the processing temperature. Chemical compounds formed by the reaction of the lime and the impurities float to the top of the furnace and are removed as **slag.** Slag is of value as lightweight construction aggregate for building skyscrapers and for use as antiskid material on icy roads. Companies in Allegheny, Beaver, Berks, Cambria, Chester, Dauphin, Lawrence, Northampton, and Westmoreland Counties sell slag for these purposes.

Dolomite is also used in the manufacture of **refractory** materials. Refractories have the opposite effect of fluxes in that they can withstand extremely high temperatures without melting or reacting chemically. York County is the United States' only source of dolomite that is used in the manufacture of refractory bricks for steel furnaces and cement kilns.



Carbonate rocks that are mined for their chemical properties include Annville limestone in Berks, Lancaster, and Lebanon Counties; Snyder and Linden Hall limestones in Bedford, Blair, Huntingdon, and Lycoming Counties; Kinzers limestone in Adams and York Counties; Ledger dolomite in Adams, Chester, Montgomery, and York Counties; Valentine limestone in Centre County; and Vanport limestone in Butler County.

Mineral Products Used in Farming

It has been said that any large deposit of a single mineral is an economic resource. Pennsylvania has extensive deposits of relatively pure **limestone,** a rock that is composed principally of a single mineral, calcite. Pennsylvania has many limestone quarries, such as the one pictured here as seen from above, as well as underground limestone mines, because the chemical and physical properties of limestone give it so many uses.

From U.S. Department of Agriculture aerial photograph AQA–9HH–78, 1967, Ashcom quarry, Bedford County.

The strength and durability of limestone make it useful for construction aggregate. The appearance of some kinds of limestone make it desirable as dimension stone. Its chemical properties allow the manufacture of cement, provide stability to glass, and make limestone useful as a fluxing agent to remove impurities from molten steel. Because of its nontoxic properties and ease of grinding, limestone is used as filler in foods and medicines and as an abrasive in household cleaning products. The color of some limestone makes it useful as filler in paper and other materials. Limestone is also an important resource in preventing air and water pollution.

In addition to all those other uses, limestone is important to farmers. When **agricultural limestone or dolomite** is pulverized and applied to a field, its chemical properties reduce the acidity of soil, making the soil better suited for growing most crops. (This product is commonly referred to as "ag lime," which is not the same as the "lime" described on page 9.) Farmers also use limestone as **poultry grit,** which is given to chickens to aid their digestion and produce stronger eggshells.

Agricultural limestone and dolomite are produced in Pennsylvania by quarries and mines across the state in Adams, Armstrong, Berks, Blair, Butler, Centre, Chester, Cumberland, Franklin, Lancaster, Lawrence, Mifflin, Montour, Montgomery, Northumberland, Snyder, Somerset, Union, and York Counties.

Mineral Products That Help Keep the Environment Clean

The importance of protecting Earth's environment became especially apparent during the final decades of the twentieth century. The old attitude inherited from our nation's pioneer days, that air, water, and land can be thought of as inexhaustible and able to absorb unlimited dumping of waste products, is no longer acceptable.

This change of attitude has affected the mineral-resources industry in two ways. First, the operators of quarries and mines try to be better neighbors through efforts such as using water to keep dust under control, providing buffers, such as this Christmas tree farm, around quarries, and using better blasting techniques. They now accept the responsibility of restoring the land after they have finished mining it. Second, the requirement that other industries also do a better job in protecting the environment has created new uses for some mineral products.

Carbonate rock. One of those products is carbonate rock such as limestone and dolomitic limestone. For many years, pollutants were released from coal mines and facilities that burn coal. Some of these pollutants can now be captured before they reach the environment by taking advantage of the chemical properties of these rocks.

Water that drains from coal mines is typically acidic because coal deposits contain sulfur-bearing minerals such as pyrite. The sulfur reacts with water to form a weak solution of sulfuric acid. Just as farmers have long used limestone to neutralize the acidity of soils, the operators of coal mines can now use limestone to neutralize acid mine drainage before the water reaches and pollutes streams.

When coal is burned, the sulfur-bearing minerals in the coal burn with it. This releases sulfur dioxide into the atmosphere. The sulfur dioxide mixes with rain, sometimes hundreds of miles from the place where it was released, and makes the rain more acidic than normal. This acid rain can cause damage to plant and aquatic life as well as to buildings and monuments containing copper, aluminum, limestone, and marble.

The use of limestone has helped facilities that burn coal to become better neighbors than in the past. The sulfur dioxide in flue gases from burning

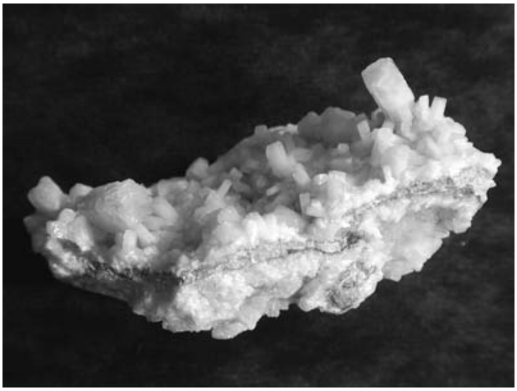
coal can now react with limestone (or with lime, which is more reactive) *before* it is released into the atmosphere, reducing damage to wildlife and structures caused by acid rainfall. The use of limestone also makes the burning of coal waste for power generation (shown in the photograph above) environmentally acceptable. The by-products of this reaction are gypsum, which can be disposed of safely or utilized in the manufacture of wallboard, and carbon dioxide. Limestone for sulfate absorption is mined in Bedford, Blair, Huntingdon, Lancaster, Mifflin, Northumberland, and Union Counties. This solution is not perfect, though. There is concern that the release of too much carbon dioxide into the atmosphere may have long-term effects on Earth's climate. Also, the use of limestone does not reduce the amount of particulate matter, known as fly ash, that is given off.

Limestone is also used in underground coal mines to reduce the risk of explosion and fire. Powdered limestone is sprayed on the walls to create a light-colored, fire-resistant layer. It is also used to dilute the coal dust in the air, reducing the possibility of an explosion. "Coal-mine rock dust" is mined in Bedford, Blair, Butler, Centre, and Huntingdon Counties.

Clays. Clays are also important in keeping the environment clean. Most clay minerals consist of extremely tiny, flat plates that can only be seen by using an electron microscope. Just like a deck of playing cards that is tossed onto the floor, the clay particles tend to lie flat against each other in an overlapping arrangement, creating a barrier that liquids cannot easily penetrate. Because of this property, clays are used to line landfills to prevent pollutants from leaking into the groundwater and streams. Clays used for that purpose are mined in Berks, Dauphin, Fayette, and York Counties.

Sand. Unlike landfills, septic systems are not effective unless water can flow away from them quickly and efficiently. But the water must be filtered as it moves away, to protect the groundwater. Certain types of sand make an efficient filter for septic systems. As of the late 1990s, mining operations in Bradford, Bucks, Dauphin, Erie, Jefferson, Lackawanna, Lawrence, Lehigh, Mifflin, Monroe, Northampton, Northumberland, Tioga, Union, and Wyoming Counties reported the production of sand that is appropriate for this use.

Mineral Products Used in Recreation



Mineral products play as important a role in recreational activities as in other aspects of life. The most obvious recreational activity that involves rocks and minerals is **rock, mineral, and fossil collecting.** Clubs organize trips for their members to quarries and other sites that are not open to individuals. Hundreds of fossil and mineral species, such as celestine, pictured here, have been identified in Pennsylvania. At least eight minerals were unknown to the world before they were discovered in Pennsylvania. The discovery of **celestine,** strontium sulfate, in Blair County was announced to the world in a German publication in 1797. Nearly 80 years later, in 1875, the discovery of a zinc-bearing clay mineral, **sauconite,** in Lehigh County was revealed. In 1888 and 1890, two hydrated magnesium carbonates, **lansfordite** and **nesquehonite,** were discovered in stalactites in coal mines in Carbon County. Another long gap, this time of 87 years, passed before the publication in 1977 of the discovery of **downeyite,** selenium dioxide, an elusive mineral associated with burning coal mines in Schuylkill County. This was followed quickly by **matulaite,** hydrated calcium aluminum phosphate, from the Bachman iron mine in Northampton County in 1980; **laphamite,** arsenic selenide-sulfide, from a burning anthracite waste pile in Northumberland County in 1986; and **eastonite,** a magnesium-bearing mica, from a serpentine quarry in Northampton County in 1998.

Amateur **artists,** as well as their professional counterparts, are also dependent upon mineral products. Sculptors cannot work without a medium and commonly use natural materials such as clay or dimension stone. Skilled craftsmen in Pennsylvania carve small items from slate and anthracite. Various minerals are used as pigments in paint, as well.

Weekend **gardeners** need the same mineral products as farmers, but on a much smaller scale. Besides spreading pulverized limestone in their gardens, gardeners who wish to modify their soil might also purchase topsoil that can be blended with their existing soil. A number of companies in Pennsylvania mine and sell topsoil, usually from the floodplains of rivers.

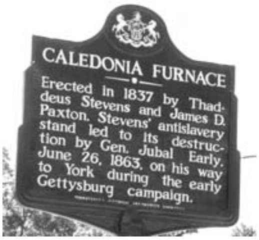
For those whose activities center on **sports,** mineral products play a significant role. The suitability of Pennsylvania's slate for making smooth, flat, and stable billiard-tabletops has already been mentioned. But what about outdoor sports? Have you ever wondered where the sandy material for the infield of a baseball diamond comes from? As of the late 1990s, there were several mining companies in Pennsylvania that reported the production of "baseball infield mix." The lines on a football field are made of pulverized carbonate rock. A golfer whose ball lands in a sand trap can take heart that this may not be ordinary, everyday sand. Mining companies report the production of sand specifically for use in sand traps. The operators of horse tracks, too, are very particular about the type of sand the horses tread on.

It would be hard to think of any recreational activity that does not, in some way, depend upon mineral resources. Even **reading a book** involves the use of paper that may contain limestone to provide a clearer printed image on the page and to make the page whiter and last longer, and clay to provide a glossy coating. Inks may contain mineral pigments. Of course the press on which the book was printed contains metals and other products of mining. So do the chair and lamp in the reader's home. Even the golfer who always manages to stay out of sand traps and the gardener who has perfect soil use metal clubs and garden tools.

Can you think of any products or activities in which mineral resources play no role at all?

PENNSYLVANIA'S OTHER MINERAL RESOURCES

So far, we have talked about only mineral resources that are presently being mined in Pennsylvania. They make up only a small fraction of the variety of mineral resources that can be found in the state. Many others, especially metal ores, have been mined in the past, and a few may be mined in the future.



The story of past mining in Pennsylvania is a colorful and interesting one. You may be surprised at what resources Pennsylvania holds, the stories that surround them, and how far back into history we must go to find the earliest evidence of mining in Pennsylvania.

What is being mined at any given time depends a great deal on the basic economic law of supply and demand. Any mineral commodity will usually be mined from occurrences from which it can be delivered to the consumer at a competitive cost. Some commodities, such as precious metals and gems, are in such limited supply and have such high demand that they have a high unit value and can be shipped economically halfway around the world. High-unit-value commodities are obtained where the deposits are easiest to mine and in greatest supply, or in nations where labor costs are low and concern for the environment might be weak. In contrast, commodities such as sand and gravel have a low unit value and must be mined in volume close to the place where they will be used. Most of the commodities presently being mined in Pennsylvania have a relatively low unit value and are used in high volumes.

Many of the mineral resources that are no longer mined in Pennsylvania have a moderate to high unit value and are now obtained elsewhere at less expense. But that does not mean that the presence of these commodities should be forgotten. Changes in demand, politics, and economic developments can lead to the closing of some mines and the opening of others. Commodities that had been mined in Pennsylvania in the 1800s were considered for mining again in the 1900s during both World Wars when access to foreign sources became uncertain. A resource remains a resource, even if it is not presently being mined, as long as there is the potential that it may be used.

Knapping Materials

The use of materials in Pennsylvania that can be **knapped** began at least 15,000 years ago when continental glaciers were still present. Mining in Pennsylvania may have begun approximately 11,000 years ago in the South Mountain area of Adams and Franklin Counties. This was about 2,000 years after the glaciers last left Pennsylvania. We know almost nothing about the miners or where they came from. The metamorphosed volcanic rock **metarhyolite** was mined, possibly by more than one method, and knapped using hammers made of an extremely tough, dense igneous rock known as Rossville Diabase. The Rossville Diabase forms Seminary Ridge in Gettysburg, the Confederate position on the final day of the Battle of Gettysburg, July 3, 1863.

Based on the duration of mining and the fact that metarhyolite from South Mountain was transported hundreds of miles, it is apparent that this was a very important resource and an important trade good. Because South Mountain metarhyolite is not an easy material to knap into useful tools, it may resemble a material with which the original miners had previous experience or that they held in esteem before they reached South Mountain.

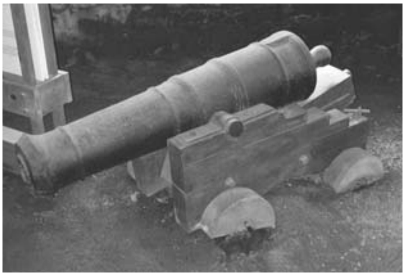
Higher quality knapping material was mined, perhaps for 11,000 years, from several quarries in the Reading Prong of Lehigh and Berks Counties. Here, distinctive tan jasper, which becomes reddish when fired, was mined from pits up to about 12 feet deep and utilized in an area extending hundreds of miles from the quarries. Jasper was also quarried in Centre County.

Quartz, especially as the closely related varieties chert, jasper, and flint, was recovered from dozens of sites and used to produce tens of thousands of tools. These varieties were commonly found within belts of limestones and dolomites and along the streams draining them. **Quartzite,** a metamorphic rock, was a popular knapping material in southeastern Pennsylvania.

Native Americans also carved bowls from a soft rock containing talc and serpentine, called **steatite,** in and near Lancaster and Chester Counties.

Iron

Pennsylvania's abundant and diverse iron ores and the abundant limestone for the flux required to process them enabled the American colonies to support Great Britain's dominance over France in North America in the 1700s. A few decades later, they enabled the colonies to become independent of Great Britain. The Revolutionary-era cannon at right was made at the Cornwall Furnace in Lebanon County. Still later, Pennsylvania's iron ores and industry provided a substantial proportion of the iron needed by the Union army to support President Abraham Lincoln's goals of preserving the Union and ridding the nation of slavery. By 1859, there were 160 charcoal-fired and 97 anthracite-fired iron furnaces operating in nearly all regions of Pennsylvania except the northern tier of counties.



In addition to instruments of war, Pennsylvania's iron industry produced household items such as stoves, cooking utensils, and nails that helped Americans meet their needs independently of British industry. This stove was cast at the Hopewell Furnace in Berks County in 1772.

Rich **hematite** and **magnetite** ores, typically containing 68 percent ferric oxide (Fe_2O_3), were known in the Reading Prong in the Durham area of northern Bucks County by 1698, and limited mining may have begun then. The first iron furnace at Durham was in operation by 1727 and, using local ores, it supplied cannon shot for both the French and Indian War and the War for Independence. A "new" 2,000-foot-long mine adit was completed two years prior to the Civil War.

The Rittenhouse Gap district in the Reading Prong was worked prior to 1785, resulting in open cuts up to 60 feet deep and 200 feet long from which shafts were sunk at least another 160 feet. Typically, magnetite veins were 10 to 20 feet thick, and remarkable ground magnetic anomalies remain today. In 1899, Thomas A. Edison had a magnetic survey done of the Vera Cruz district of the Reading Prong in Berks County. From this, he estimated that 20 million tons of magnetite could be recovered magnetically. However, the actual magnetite veins were no more than 15 feet thick and the "reserves" included 260-foot-thick sections containing only approximately 20 percent iron. Efforts at magnetically beneficiating similar ores in New Jersey failed, and all of the 300,000 tons of ore produced from the veins at the Vera Cruz district was recovered using traditional methods.

Mining in Berks County likely goes back to the start of Colebrookdale Furnace on Ironstone Creek in approximately 1720. This is the oldest known iron furnace in Pennsylvania, and it may have used both local Cornwall-type ores and ores from the Reading Prong.

The expression "Cornwall-type ore" refers to the type of ore deposit found at Cornwall, Lebanon County, and elsewhere in southeastern Pennsylvania. Such deposits are found where the dark igneous rock called diabase came in contact with limestone.

From U.S. Department of Agriculture aerial photograph AHN–2LL–166, 1970, Cornwall open pit.

Iron mining began at Cornwall in 1742 and ceased on June 30, 1973. During that period, 106 million tons of magnetite ore, probably averaging approximately 54 percent Fe_2O_3, was mined. The mining removed three hills and left a deep pit (shown above in an aerial view), which is now a lake filled with high-quality water. Another Cornwall-type iron-copper deposit was discovered in southern Berks County in 1948 via an aeromagnetic survey. This deposit was developed as the Grace mine and produced an estimated 45 million tons of ore between 1958 and 1977. Drilling to the northeast just before closure confirmed thicker, rich ore. Very large unmined Cornwall-type deposits are reported to occur near Gettysburg, Adams County, and Pine Swamp, Chester County. Much smaller Cornwall-type deposits yielding more than 1 million tons of ore were located at Boyertown, Berks County; Dillsburg, York County; and French Creek, Chester County.

In many valleys in southeastern Pennsylvania, limestones and especially dolomites dissolved over time, leaving behind their impurities as orange-brown **limonite** iron ores and clays. As iron furnaces multiplied, farmers at first picked wagonloads of limonite from fields during seasons when crops could not be grown and the fields were accessible. Eventually, the fields that were richer in limonite evolved into open pits as some farmers evolved into iron miners. At the best of these, it was not uncommon for shafts to be sunk in pursuit of still more ore. From approximately 1850 to 1890 there were likely more than a thousand of the small "valley ore" pits and mines supplying several dozen local iron furnaces, such as the one at Pine Grove Furnace, Cumberland County, pictured here, and the historic Caledonia Furnace in Franklin County, pictured on page 15. Lehigh County alone had at least 261 such pits and mines. Statewide, these pits may have supplied 100,000 to 1 million tons of ore per year for this period. Their significance far exceeded their actual production because they enabled dozens of small, scattered furnaces to support local economies in large portions of Penn's Woods.

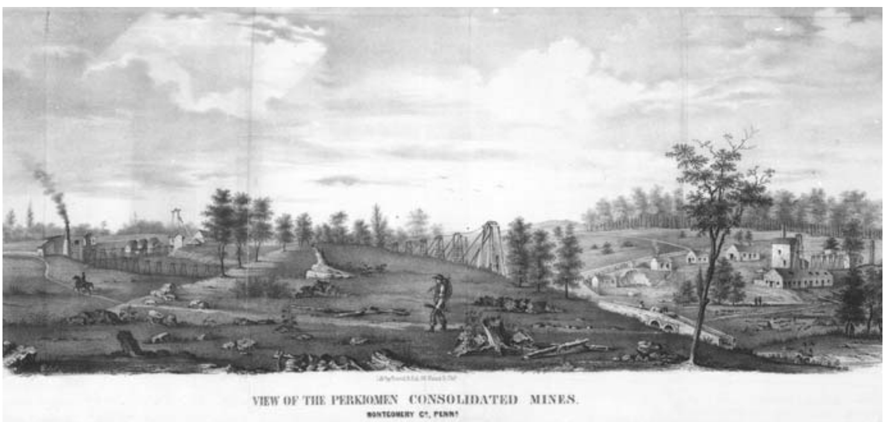
Siderite, or iron carbonate, was one of the least important types of iron ore by volume, but its use permitted the operation of small iron furnaces in areas lacking other ores, such as in western Pennsylvania. Siderite had the advantage of being nearly self-fluxing, meaning that it was unnecessary to have access to a separate source of limestone to mix with the ore to remove impurities from the molten iron. The best-known siderite ore, the "buhrstone ore," occurred on top of the Vanport Limestone in Venango County and was typically only 6 inches thick.

Iron ores occurring within layers in metamorphosed sedimentary rock were once mined at Strickhousers in York County. "Clinton ores," so named after the geologic formation in which they occur, were mined throughout the Ridge and Valley province of south-central Pennsylvania, spreading out the iron industry even more.

Lead and Zinc

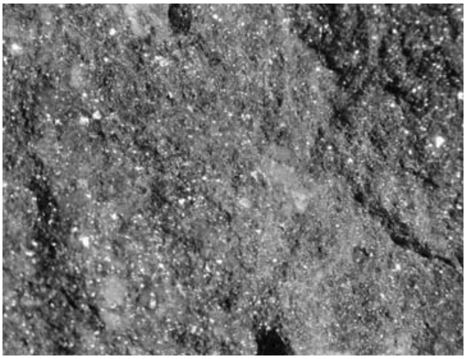
Although nobody was looking for **lead** at the time, silver-bearing lead sulfide was being mined at Pequea, Lancaster County, prior to 1709 when William Penn inquired about possible royalties due him. Less than 70 years later, shipments of lead from southern Sinking Valley, Blair County, helped supply the Continental Army during the American Revolution. The cost of obtaining lead from that frontier outpost rose to $6.00 per pound to cover

View of Perkiomen-Whim-Ecton mines, Audubon, Montgomery County, from Smith (1977), p. 254, courtesy of A. V. Heyl.



the expense of protecting the miners from attack by the Native American residents, who did not appreciate the presence of a lead mine in their area. Lead mines in the Audubon area of Montgomery County, as shown above, may have supplied the same army. Jean Audubon, father of the naturalist J. J. Audubon, bought the property, which was operated by the famous naturalist and the son of a business partner. Under different ownership in 1835, zinc ores from these same mines were used to help make the standard brass weights and measures that were requested by Congress.

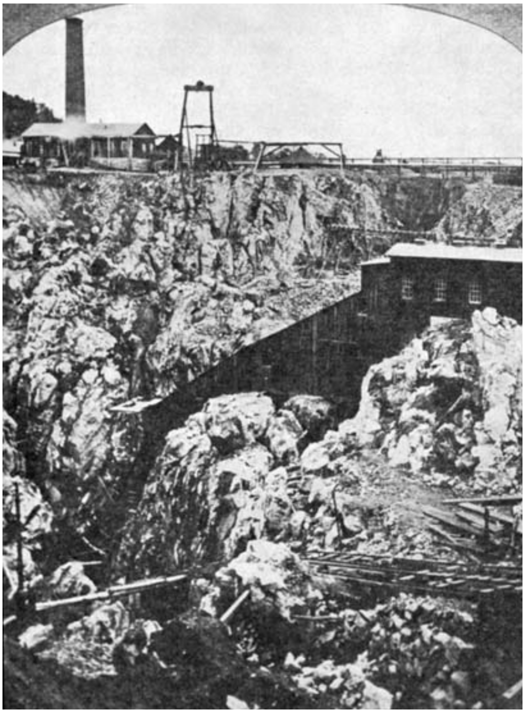
Nearly all lead ores have a bright, metallic appearance, as shown in the photograph of millimeter-sized crystals of galena at the top of the next page. This appearance helped attract attention to them. They were generally easy



to smelt, and lead was useful locally. Thus, there were many small lead mines and prospects in central Pennsylvania. A genre of folklore evolved about lead mines, wherein an early white settler befriended a Native American who returned the favor by taking the settler blindfolded to an outcrop rich in pure lead—so pure that it only needed to be cut out with a knife and carved to make bullets!

Zinc ores lack the silverlike appearance of most lead ores, are difficult to smelt, and zinc itself was frequently regarded only as an adulterant to copper until the mid-1800s, even when used to make brass. An attempt to smelt iron from high-grade zinc ore from Friedensville, Lehigh County, circa 1830, failed miserably. Likewise, attempts to smelt zinc- and lead-bearing iron ores from the Old Clippinger mine, Cumberland County, resulted in the interior of the iron-furnace stack being coated with 92 percent zinc and 6 percent lead!

From Miller, B. L., 1924, Lead and zinc ores of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 5, p. 70.

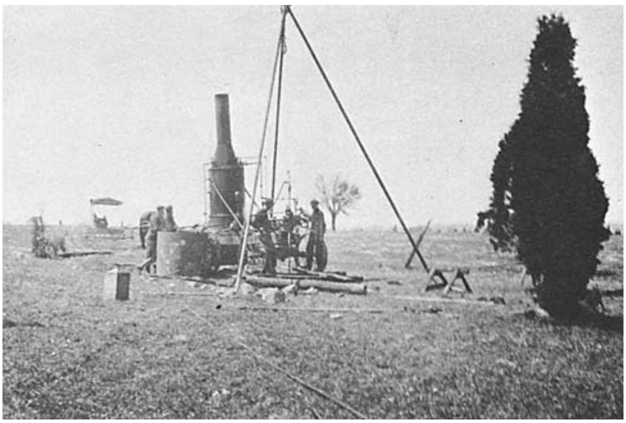


By approximately 1850, the combination of abundant, rich zinc ore, efficient smelting technology, and markets came together for the Friedensville zinc deposits in Lehigh County. These deposits lacked arsenic, which was deleterious in brass shell casings, and lead, both of which are present in many zinc ores. The Ueberroth mine at Friedensville is pictured here as it appeared in 1877. By the time the mining ended in 1983, at least 885,306 *tons of zinc* had been produced. Ore still remains at Friedensville at the start of the twenty-first century. Interesting zinc and lead prospects also remain in several other areas of Pennsylvania, especially in the central part of the state.

Chromite

A Baltimore industrialist, Isaac Tyson, controlled nearly the entire world's supply of **chromite** between 1828 and 1850. A major use of chromite at that time was for paint pigment, and most of it was obtained from the State Line District of southeastern Pennsylvania and northeastern Maryland. Most of it was mined in Lancaster County, where the Wood mine alone produced more than 96,000 tons and the Red Pit more than 25,000 tons.

Part of Tyson's success was that he looked for chromite deposits in the appropriate geological environment. He recognized that chromite deposits occur only in a relatively rare type of rock called serpentinite. He also correctly associated the occurrence of serpentinite with areas of unusual, sparse vegetation known as barrens, such as the area near the Wood mine pictured here in the 1920s. Another reason for Tyson's success was that he controlled not only the sources of chromite, but also its processing and recovery. Today, some serpentinite bedrock and even some chromite grains concentrated in stream sediments (known as placer deposits) can be seen nearby in Nottingham County Park, Chester County.

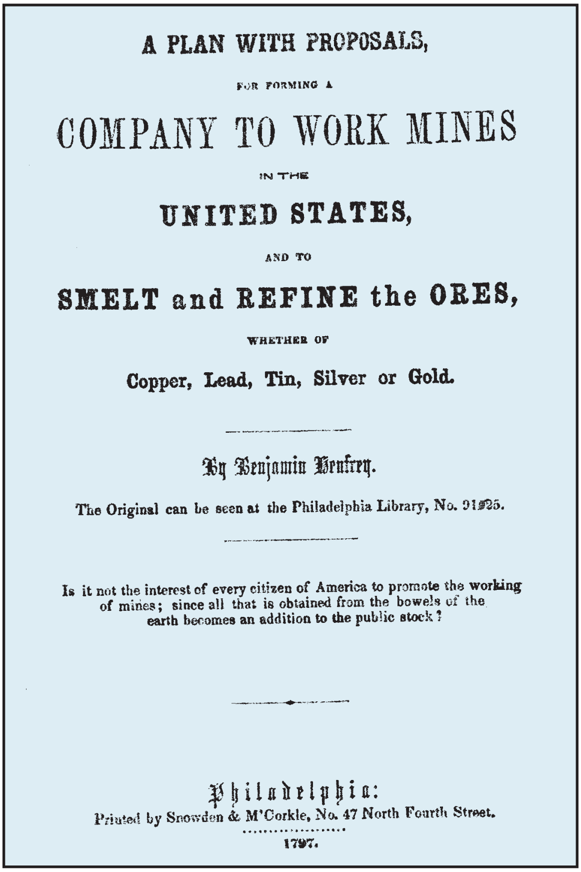


From Smith (1978), p. 172. Used with permission of Friends of Mineralogy, Pennsylvania Chapter.

At present, global monopolies such as Tyson's are not usually possible for ores that, because of their high unit value, can be shipped great distances. The successful producers are the ones who are in the lowest third in terms of cost per unit of ore delivered to the consumer. Unfortunately, this tends to shift metal mining to Third World countries, which are frequently unable to apply the least disruptive mining and recovery techniques. Sometimes, attempts to prevent mining in prosperous countries only shift the mining to places where the damage to the environment is much greater.

Nickel and Cobalt

The element **nickel** was discovered by A. F. Cronstedt in 1751. Word apparently was slow to spread to Lancaster County, where prospectors seemed to know that they had found something that might be of value, but they did not know exactly what. One Benjamin Henfrey offered a vaguely worded 1797 stock proposal ". . . to Smelt and Refine the [Gap] Ores, whether of Copper, Lead, Tin, Silver or Gold." What he and his investors did not know was that the real value of the deposit at Gap was in the newly discovered element nickel. It was not until 1852 that the Mine Captain, Charles Doble, turned to Dr. Friedrich August Ludwig Karl Wilhelm Genth, later to become the Chief Mineralogist of the Pennsylvania Geological Survey, who set progress at the Gap mine on its proper course by identifying the ore as nickel rich.



A PLAN WITH PROPOSALS,

FOR FORMING A

COMPANY TO WORK MINES

IN THE

UNITED STATES,

AND TO

SMELT and REFINE the ORES,

WHETHER OF

Copper, Lead, Tin, Silver or Gold.

By Benjamin Henfrey.

The Original can be seen at the Philadelphia Library, No. 91925.

Is it not the interest of every citizen of America to promote the working of mines; since all that is obtained from the bowels of the earth becomes an addition to the public stock?

Philadelphia:

Printed by Snowden & M'Corkle, No. 47 North Fourth Street.

1797.

With this new information and his political influence, the new owner, Joseph Wharton, perhaps following the example of Isaac Tyson, arranged for the Gap nickel mines to supply nickel for the 75 percent copper, 25 percent nickel U.S. 5-cent and 3-cent coins. From 1863 through 1893, Whar-

ton's mines produced 8 million pounds of nickel and 135,000 pounds of **cobalt.**

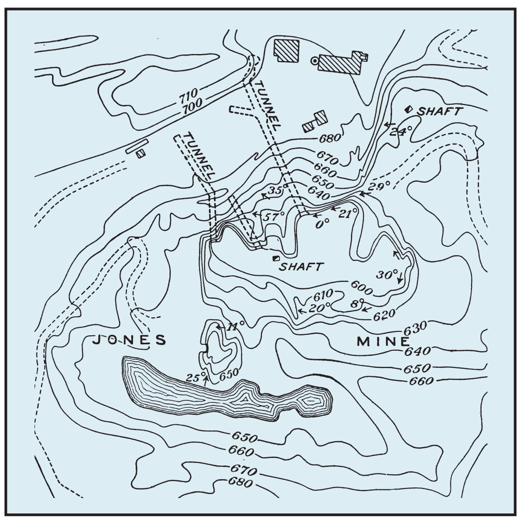
Cobalt was also obtained from the Cornwall mines in Lebanon County as one of several by-products of iron and copper mining. **Pyrite** (iron sulfide) separated from the ore typically contained 1.1 to 1.4 percent cobalt. Sulfide concentrates from the similar Grace mine in Berks County contained from 0.5 to at least 0.7 percent cobalt.

Copper

Reddish metallic **copper** and the colorful copper carbonates deep-blue **azurite** and green **malachite** generally excite primal instincts far more than their economic value warrants. In Michigan, Native Americans reportedly recovered up to *one billion* pounds of copper, some of which was released from enclosing rock by glacial erosion during the Pleistocene Epoch. In south-central Pennsylvania, the glaciers stopped approximately 35 miles short of the smaller 1- by 5-mile belt containing trace- to minor amounts of native copper in Adams and Franklin Counties, so copper nuggets there were never released from their enclosing metabasalt. Eight named mines are known in the native-copper belt in Pennsylvania, but production was minimal.

The 106 million tons of iron-copper ore mined at Cornwall, Lebanon County, contained 0.3 to 0.7 percent copper, and probably averaged 0.4 percent. The primary interest of the mine operators was in obtaining iron, so magnets were used to separate ore from waste. Because of that, much high-grade copper ore from the upper side of the orebody was lost in milling. The similar Grace mine in Berks County had the potential to produce slightly smaller amounts of copper, but closed before the ore to the east, richer in copper and up to 480 feet thick, was reached. Still farther east, the Jones mine, also in Berks County, produced 500,000 tons of ore, at least several thousand tons of which contained 6 to

From Spencer, A. C., 1908, Magnetite deposits of the Cornwall type in Pennsylvania: U.S. Geological Survey Bulletin 359, pl. 18.



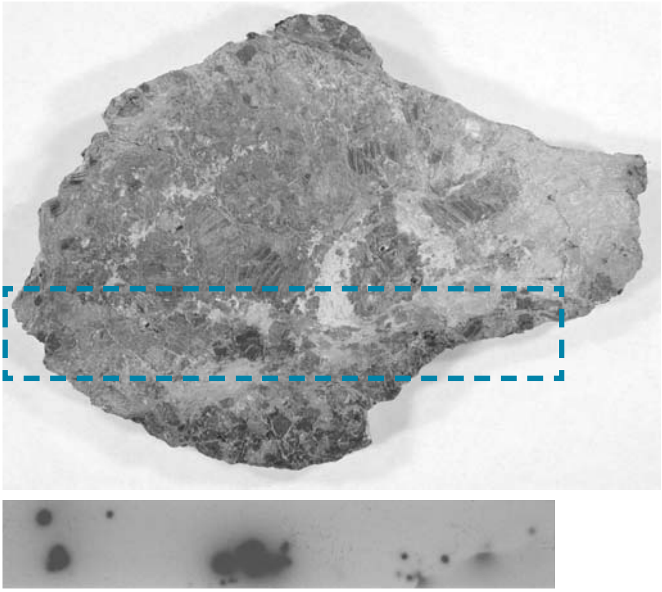
Contour map showing the locations of the buildings and tunnels of the Jones mine, about 1908.

7 percent copper. There are numerous other copper prospects in the reddish Mesozoic-age rocks of southeastern Pennsylvania. The Perkiomen mine, Montgomery County, was in a deposit of this type and is recorded to have produced 617 tons of concentrates containing 18 percent copper in 1852.

Attracted by thin films of bright-green malachite, prospectors dug dozens of prospects in the Devonian red beds of the Catskill Formation of northeastern Pennsylvania. Only mines in the New Albany area, Bradford County, are known to have shipped even a few tons of ore. The amount of copper produced at the Gap nickel mine in Lancaster County is unknown, but 270,000 tons of ore containing 0.68 percent copper and 1.12 percent nickel remains.

Uranium and Thorium

At the start of the nuclear age in the early 1950s, the U.S. Atomic Energy Commission offered to pay a bonus to anyone mining **uranium** ore. Thus, 300 tons of uranium ore was mined at Mt. Pisgah in Carbon County. The only value of the ore was in the bonus, however. It was never shipped to any of the available mills, all in western states, and so was never used for anything. The deposit that produced this ore has since been proven to contain 2 million pounds of uranium oxide and probably twice that amount of vanadium oxide, but that is not enough to support a mill. Mills to handle radioactive ores are typically not welcomed in populated areas, anyway. Furthermore, demand for uranium declined late in the twentieth century following incidents in 1979 at Three Mile Island and in 1986 at Chernobyl, Ukraine.



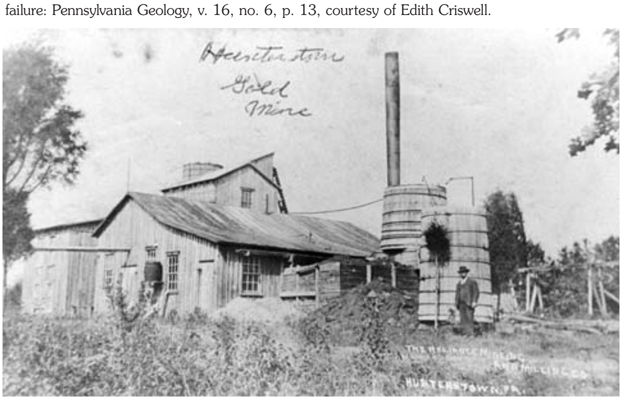
Other moderate-sized deposits are known elsewhere in Pennsylvania. Uranium and **thorium** occur together on the south side of the Reading Prong, a belt of metamorphic rocks extending from near Reading to Easton and into New Jersey. A shipment from the Pennsylvania Uranium mine in Berks County turned out to be mainly thorium. Uranium and thorium also occur in an outlier of the Reading Prong called Chestnut Hill. Smaller uranium prospects and occurrences associated with copper are known in Bradford, Bucks, Columbia, Huntingdon, Lycoming, and Sullivan Counties. There are also other deposits in Carbon County.

The rock pictured on the previous page, from eastern Pennsylvania, contains dark patches of thorium-bearing **uraninite.** The radioactive nature of this mineral is revealed by the strip of photographic film, shown below the photograph, which was placed on the flat, sawn rock slab in the area outlined by the dashed line for several hours. The radioactive elements formed the dark spots on the film.

Gold and Silver

It is true that there is **gold** in "them thar hills," but most of them thar hills on the east coast are in Georgia, South Carolina, North Carolina, Virginia, Maryland, Vermont, New Hampshire, and Maine. The "hills" that contained gold in Pennsylvania were Big Hill, Middle Hill, and Grassy Hill, all at Cornwall in Lebanon County, but those hills are no more. They were mined to create a large open pit at the Cornwall mine, which operated from 1742 to 1973. An estimated 67,000 ounces of gold and 443,000 ounces of **silver** were recovered as a by-product of iron mining at Cornwall. The similar Grace mine at Morgantown, Berks County, produced lesser amounts from 1958 to 1977.

From Hoff, D. T., and Smith, R. C., II, 1985, An Adams County copper-gold mine—Doomed to failure: Pennsylvania Geology, v. 16, no. 6, p. 13, courtesy of Edith Criswell.



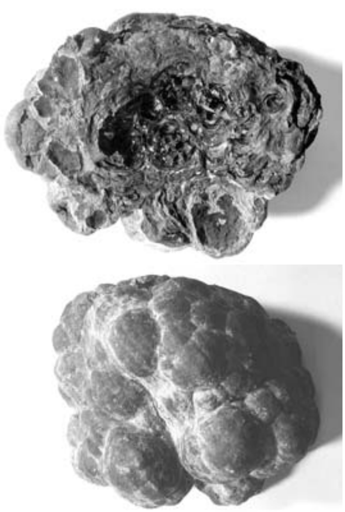
One of the more interesting attempts to mine gold in Pennsylvania took place at the Reliance Mining and Milling Company's Hunterstown mine in Adams County around 1905, shown in the photograph above. No production resulted.

Placer gold (loose grains found in sediment) was discovered in southeastern Pennsylvania in 1978, and has been the target of recreational gold panning. Perhaps as much as 2 ounces of placer gold has been recovered since then, and recreational opportunities are likely to continue unless mechanized equipment is allowed. **Flour gold** (gold grains the size of flour) has been verified in the glaciated areas of Pennsylvania. Outside the glaciated areas, colors (grains smaller than 1/50 of an inch) are found in the region of Pennsylvania east of Interstate Route 81 and south of U.S. Route 30.

As much as 10 tons of **galena** (lead sulfide), perhaps containing 275 ounces of silver per ton, may have been mined from at least three underground mines known as the Pequea silver mine area, Lancaster County. Mining there began in colonial times. One of the mines has been open at times as a tourist attraction. Also in colonial times, five 50-foot-deep shafts were being dug for silver in 1754 in Bucks County, but only a very small quantity of silver was recovered.

Manganese

Deposits containing impurities that cannot be economically removed are not ore. **Manganese** is an essential metal used in making steel hard and tough. However, manganese deposits such as we have in Pennsylvania, which typically contain minor amounts of phosphorus, do not constitute ore in normal times. Thus, of the 3,512 tons of manganese ores produced in Pennsylvania, 2,240 tons was produced during an abnormal time, in support of the World War II effort in 1940.



Manganese nodule from Huntingdon County; top, interior; bottom, exterior.

Deposits of manganese having known grades and tonnages occur on the north slope of South Mountain, Cumberland County, and in Sherman Valley, Bedford County. Such deposits formed as insoluble residues from the weathering of dolomite during the Miocene Epoch, from 6 to 24 million years ago, and near the beginning of the Eocene Epoch, about 58 million years ago.

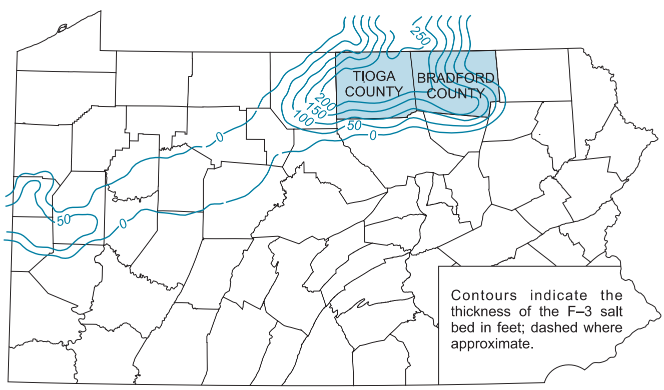
Most of the manganese deposits in Pennsylvania were found accidentally while attempting to locate limonite iron ores for charcoal-fueled iron furnaces. Iron ores containing too much manganese and phosphorus were unsatisfactory for making good pig iron.

Although not directly related to Pennsylvania, nodules containing more than 20 percent manganese, as well as some cobalt, occur on vast areas of the ocean floor. They cannot presently be mined economically and therefore are not ore, but they are a potential resource.

Salt

Prior to the arrival of Native Americans in Pennsylvania, wild animals gathered around **salt licks** that were found near oil seeps. In the area around Oil Creek in northwestern Pennsylvania, Native Americans and, later, settlers from Europe utilized the seeps as hunting sites and recovered petroleum for medicinal purposes. Perhaps because of a disagreeable petroleum aftertaste and the dilute nature of the brines, recovery of salt from the petroleum seeps did not develop into a thriving industry in that area.

Brines pumped from wells drilled to depths of as much as several hundred feet were evaporated to make salt in western Pennsylvania from at least 1815 to 1860. Some of the best-known areas included Conneautville in Crawford County, Natrona Heights and Tarentum in Allegheny County, and, certainly not least, Saltsburg in Indiana County. Many of these wells also produced gas, petroleum, or both in what was at first a nuisance amount. By 1841, however, coal was being partly replaced by the gas from the wells as a fuel for evaporating brines. Drilling technology advanced to keep up with the demand for salt brine. Petroleum by-products for perceived medicinal purposes, lamp fuel, and lubricants grew in importance, and refineries were built at Tarentum. As a result, those who wanted to take advantage of Colonel Edwin Drake's earthshaking oil discovery were able to utilize the existing brine-drilling technology and operational petroleum refineries *that predated* his discovery in western Pennsylvania.



From Fergusson, W. B., and Prather, B. A., 1968, Salt deposits in the Salina Group in Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 58, p. 27.

There is the potential for deep solution mining of salt in several counties to create underground cavities that would be useful for the storage of natural gas. If various problems can be overcome, the synthetic brines that are removed to create the cavities might be sold and used for road deicing.

The map on the previous page shows the thickness of the F–3 salt bed, one of several salt units in Pennsylvania. Much of Tioga County is underlain by at least 600 feet of Silurian-age salt at depths ranging from 3,000 to 6,000 feet. Areas in Bradford County are underlain by up to 776 feet of salt.

Feldspar

Feldspar is the most abundant mineral in the crust of the earth, but deposits that are pure enough for use in manufacturing ceramics or glass are uncommon. However, such deposits were found and mined in Chester and Delaware Counties and worked mainly in the early twentieth century. During the period from 1900 to 1920, Pennsylvania produced 265,000 tons of feldspar. In 1907, Pennsylvania was the second-largest producer of feldspar in the country. Pits from feldspar mining are up to 200 by 80 feet across and up to 115 feet deep. Millstones used to grind feldspar near a mine in Chester County are pictured below.

Many of the deposits in Chester County occurred in coarse, light-colored igneous rocks called **pegmatite dikes** that cut serpentinite. The feldspar was present as the sodium-bearing species albite. This type of feldspar occurrence can be seen at Nottingham County Park in Chester County. Pegmatite dikes outside the serpentinite in Chester County and in Delaware County tend to contain more of the potassium-bearing feldspar microcline. Many of these are weathered to a white clay, composed of the mineral **kaolinite,** near the surface. The kaolinite was also mined for the ceramics industry, but not for the glass industry.

From Stone, R. W., and Hughes, H. H., 1931, Feldspar in Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 13, p. 23.

Other Mineral Resources in Pennsylvania

COMMODITY	HISTORY	GEOLOGY AND LOCATION
Abrasives	Corundum masses up to 200 tons and corundum crystals were mined in the 1800s. Garnet was mined in the early 1900s, presumably to make abrasive papers having sharp-edged grains.	Corundum in low-silica pegmatites, usually in or near serpentinite, Chester, Delaware, and Lehigh Counties. Garnet in unusual gneiss, Delaware County.
Asbestos	Chrysotile and amphibole asbestos such as tremolite have been observed at many localities, but no records of the small quantities produced are known.	Chrysotile in Chester, Delaware, and Lancaster Counties. Amphibole in Delaware and Northampton Counties.
Barite	Barite from hydrothermal veins and breccia fillings, as well as loose lumps weathered free from these, was mined, mainly in the period 1880 to 1900. Barite appears to have been mined in an unsuccessful search for silver in Bucks County in 1754. Undeveloped occurrences of nodular barite are also known.	Veins in faults in rocks ranging in age from Cambrian, Ordovician, and Silurian to Triassic. Small-scale mining of these in Blair, Bucks, Franklin, and Fulton Counties. Nodular barite occurs in Purcell limestone in Bedford, Huntingdon, Montour, and Northumberland Counties. In the latter county, it occurs with sphalerite. Nodular barite also occurs in the Hamburg Sequence of western Berks County.
Beryl	A few shipments of hand-sorted beryl were mined and sold. One shipment in 1962 contained 10,138 pounds of beryl.	Commercial beryl occurs in complex pegmatites of igneous origin, Chester County.
"Flint" (vein quartz)	A vein of white quartz was mined for sandpaper and flux in iron furnaces. Several moderately pure deposits in metarhyolite were prospected and/or mined.	Most veins cut Chickies quartzite, Chester County. The other deposits were associated with metarhyolite, Adams County.
Ganister (quartzite)	Mining for silica refractories is documented for approximately 100 years beginning in 1887. Originally, much of the material was trimmed from raw blocks. More recently, the quartzite was crushed and various binders were added to make a variety of sizes and shapes.	From Tuscarora quartzite, Blair, Bedford, Centre, Huntingdon, Juniata, and Mifflin Counties. Lesser amounts were produced from Chickies quartzite, Chester and Montgomery Counties, and from Hardyston quartzite, Berks and Lebanon Counties.
Graphite	Production began in 1750. The major graphite-producing district operated intermittently from the late 1870s to 1948. Graphite was mined for crucibles, lubricants, and stove polish.	Mostly from black shales metamorphosed to graphitic gneiss in an 8-mile-long belt, Chester County, but deposits were also worked in Bucks and Lehigh Counties.

Kaolinitic white clay	(A) In 1967, the Philadelphia Clay Company was producing 40,000 tons per year for white-cement manufacture. Production began in 1890 for paper filler. (B) From approximately 1870 to the mid-1960s, 100,000 tons was produced, mainly for refractory mortar in steel making. The Stormstown deposit was at least 2,000 feet long. Most of these deposits were first prospected for iron. (C) Production beginning in 1891 was for a variety of products, but since 1932 has apparently been mainly for white cement. For at least 30 years, production has been 200 or more tons per day.	(A) Alteration of limestone by weathering and hydrothermal processes yielded a deposit at least 1,600 feet long, Cumberland County. (B) Weathering of carbonate rocks associated with sandstone. At Stormstown, Centre County, leached to the stage of gibbsite (a bauxite mineral) formation. Other deposits worked in Bedford, Blair, and Huntingdon Counties. (C) Weathering of impure carbonate rocks has progressed only to kaolinite and a fine mica called illite, Monroe County.
Lapidary materials	(A) "Williamsite" occurred as a sheath about the Line Pit chromite ore body. (B) Moss agate. (C) Various native copper- or piemontite-bearing metavolcanic rocks. (D) Tan jasper. (E) Blue quartz. (F) Oolitic chert.	(A, B) Serpentinite, Lancaster County. (C) Catoctin Formation, Adams and Franklin Counties. (D) Cobbles weathered from Hardyston Formation, Lehigh and Berks Counties. (E) Mafic gneiss, Chester County. (F) Nittany Dolomite, Centre County.
Magnesite	Intermittent underground and surface mining from before 1828 to 1871 yielded well over 10,000 tons of magnesite, mainly used to manufacture Epsom salts.	Veins up to 3 feet wide in serpentinite, southwestern Chester County and southern Lancaster County.
Mica	Small shipments of split and trimmed muscovite from Walters mine in 1951. Muscovite sheets were stockpiled from near Coatesville; however, no sales of these have been confirmed.	Pegmatites in the Womelsdorf outlier of the Reading Prong, Berks County, and Honeybrook Upland, Chester County, respectively.
Mica-bearing fillers	Ground for filler by Gross Minerals and used in many applications for a few decades until approximately 1995. Mine area now part of a nature preserve. Several earlier operations in this area, one of which also contained pyrophyllite.	Sheared metarhyolite (a light pastel volcanic rock) from southwestern Adams County. Summit Mining produced sericite schist from southwestern York County.
Mineral pigments	From 1856 to 1947, at least 200,000 tons of red pigment was produced from the "Paint Ore Bed." The ore was blue-gray as mined but turned red, especially when roasted. Ochre, umber, and sienna were	The primary paint ore was a sedimentary layer of an iron carbonate called siderite mined along a length of at least 16 miles in Carbon County. Many of the other operations were

Other Mineral Resources in Pennsylvania *(Continued)*

COMMODITY	HISTORY	GEOLOGY AND LOCATION
Mineral pigments *(continued)*	mined from numerous other operations, which recovered mainly limonitic ore, but some slimes from washing limonitic iron ores were also recovered.	in residual limonitic deposits in limestone in Berks, Lehigh, and Northampton Counties.
Molybdenum	Molybdenite was exposed in several iron and filler mines as well as road cuts and dam excavations.	Granites, gneisses, and skarns of the Reading Prong in Berks, Lehigh, and Northampton Counties.
Phosphate	"Mineral manure" phosphate nodules were produced from Newman mine from 1899 to 1904. Wavellite from Moore's Mill was mined from 1900 to 1906. It was reduced to elemental phosphorus locally first and then at York Haven using hydroelectric power.	The phosphorus was concentrated by organisms and preserved in sedimentary rocks. Some is further concentrated by weathering. W. L. Newman phosphate mine, Juniata County, and Moore's Mill, Cumberland County.
Rare earth elements	Minerals bearing rare earth elements have been mined as an unrecovered by-product in rock associated with iron, dimension stone, thorium, and other commodities and are exposed in roadcuts.	In the mineral allanite in pegmatite rocks and in the mineral titanite in contact metamorphic rocks in the Reading Prong in Berks, Lehigh, and Northampton Counties and the Honeybrook Upland in Chester County.
"Soapstone" (steatite)	(A) First worked by Native Americans for bowls some three millennia before Columbus discovered that America was not lost. (B) From along the Schuylkill River from the late eighteenth century into the early twentieth century. Most notable for heat-retaining fireplace and stove linings.	(A) Talc-bearing rock called steatite, Lancaster and Chester Counties. (B) The Schuylkill deposits were from Philadelphia and Montgomery Counties.
Talc	In one deposit, 1.1 million tons of ore was proven in 1979, but some tremolite bands were also present.	Serpentinite, Lancaster County.
Titanium	Small crystals of pure rutile were handpicked from fields and sold for 35 to 50 cents per ounce to dentists to create white false teeth.	The rutile crystals weathered out of rocks in Chester and York Counties and possibly Lancaster County.
Vanadium	Observed as bright-yellow coatings that also contain uranium. Assays of drill core yield 0.1 to 1.6 percent vanadium oxide (V_2O_5) from ores that are 3- to 20-feet thick, and channel samples at the surface contain up to 5 percent.	Carbon-bearing beds of sedimentary conglomerate, Carbon County.

MINERAL RESOURCES ARE FINE, BUT NOT IN *MY* BACKYARD!

In the past, Pennsylvania's mineral resources helped to win our nation's independence, preserve the Union, and build a great and prosperous nation and state. Today, products derived from mineral resources in Pennsylvania and elsewhere are important to almost everything we do. They make our way of life possible. They are important to the state's economy. And people say, "Great! Keep up the good work. But don't, under any circumstances, put a quarry or a mine anywhere near me!"

NIMBY! "Not in *my* backyard!" That is an understandable sentiment. Quarries and mines can be noisy. They can intrude upon a beautiful landscape. "Put the quarry somewhere else, preferably on the other side of the state," is a cry heard from residents and politicians alike. But there are problems with this solution:

(1) "The other side of the state" for one person is "my backyard" for someone else.

(2) The resource that is needed may not exist on the other side of the state. To quote noted exploration geologist Charles Hunt's First Law of Mining, "Mines that are not close to deposits are not very satisfactory." Resources are where you find them.

(3) If a resource that has a low cost per ton, such as gravel, does exist on the other side of the state, the expense of trucking it across the state could turn an inexpensive resource into a very expensive one. Few people would be happy about the large increase in their tax bills that would be necessary to pay for road repairs completed using aggregate that was trucked from a quarry 300 miles away.

(4) For high-cost resources such as chromite or copper, transportation costs are not a problem, and the product can be shipped around the world. Unfortunately, by encouraging mining companies to focus on the Third World, we encourage mining in countries where the absence of environmental regulations and poor working conditions can make everyone except the mining companies losers in the long run.

It is not surprising that the word "mining" has such bad undertones to so many people. In the olden days in this country, mining companies would simply find the commodity that they were interested in and obtain the mining rights. They would dig out what they needed with relatively little regard to workers' safety and environmental effects, then abandon the mine when the commodity was depleted or they had no further need to mine it. The legacy left to the local community was a hole in the ground, piles of waste, and an unemployed workforce.

Much has changed in the last century. Today, before any mining can be done, the land must be studied extensively to determine the impact that mining would have on the environment. If a problem is found, it must be solved or no mining will be allowed. Environmental controls are installed to prevent sediment and other forms of pollution from entering streams and groundwater, and to minimize problems from dust leaving the site. Even blasting is controlled to reduce the vibration in nearby buildings.

The Baker Refractories dolomite quarry, York County, in 2000.

Many important factors are considered before mining can begin:

Availability of mineral resources. Most resources are found only in very limited areas. In such cases there may be few alternatives as to where to locate a quarry or mine. On the other hand, if several local operators who are able to meet the demand already mine a common resource, there is little incentive to open another operation.

From U.S. Department of Agriculture aerial photograph 478–165.

Aerial photograph of the J. T. Dyer diabase aggregate quarry, Berks County, in 1979.

Interference with water resources. Water is our most precious resource, essential for life itself. Before any new mining activity is started, studies are conducted to determine the effect the mining would have on both surface water and groundwater. If it appears that contamination would be likely, mining is not allowed. If water supplies are likely to be affected, alternate sources of water must be found before mining can take place.

Interference with wild resources. Today we have a much greater appreciation of the importance of maintaining a diverse ecosystem. A mining venture is unlikely to go forward if it is determined that doing so would result in loss of habitat for a rare or endangered species. Loss of habitat for more common species is also a consideration.

Availability of the land and land use. Land in the middle of a residential district is undesirable for mining because acquiring such land is usually too expensive, and because mining could conflict with the local land use plans and zoning. Other considerations in land acquisition are whether an area includes prime farmland, and whether it is of special historical, archaeological, recreational, or scenic interest.

Reclamation of the land. Mining has always been a temporary use of the land. After a mine or quarry is opened and the resource is extracted for a number of years, the deposit may become depleted, the need for the resource may disappear, or economic changes may make the cost of continuing to mine the resource at that site too expensive. When this happens, a company is no longer allowed to simply move on, leaving an abandoned mine as a permanent reminder that they had been there. Before mining can begin, the company must submit a plan as to how the land will be restored after the mining has been completed. Attempts must be made to restore the land to contours that are reasonable and safe. Vegetation must be established and the land must be made suitable for new uses. Former mining sites are used today for farming, recreation, storage, and other activities. The Hopewell Furnace National Historic Site in Berks County, pictured here, is an eighteenth-century iron furnace that now serves as a living-history museum. Iron Mountain National Underground Storage in Butler County is a former limestone mine that provides secure storage for government records, including millions of trademark and patent records and every Social Security application filed since 1937. It also contains historic original sound recordings and film classics that are being preserved for the enjoyment of future generations.

In the evaluation of mining applications, agencies that regulate mining must weigh many factors in making a decision as to whether a mining company should be granted a permit. Consider the following situations and decide what *you* would do:

(1) A quarry has **operated for many years,** producing a **high-quality** commodity that is **not easily found elsewhere.** The company has provided steady employment to the community for all those years. The supply of the commodity in the quarry is still good, so the quarry could operate for many more years. But a **new** housing subdivision has been built nearby, and the quarry's new neighbors do not like the view, the heavy trucks, and the noise. The residents want to have the quarry shut down for those reasons and to rapidly increase the value of their property. What would you do?

(2) A quarry has **operated for many years,** producing a **low-quality** commodity that is **found in many other locations** nearby. The company has provided steady employment to the community for all those years. The supply of the commodity in the quarry is still good, so the quarry could operate for many more years. But a **new** housing subdivision has been built nearby, and the quarry's new neighbors do not like the view, the heavy trucks, and the noise. The residents want to have the quarry shut down for those reasons and to rapidly increase the value of their property. What would you do?

(3) A mining company locates a **new** source of a **high-quality** commodity that is **not easily found elsewhere,** and officials decide that they want to open a new quarry that they hope will operate for many years. The site is near a **long-established,** quiet residential neighborhood. The residents do not like the idea of a quarry as a new neighbor, and try to prevent the opening of the quarry. What would you do?

(4) A mining company locates a **new** source of a **low-quality** commodity that is **found in many other locations** nearby, and officials decide that they want to open a quarry that they hope will operate for many years. The site is near a **long-established,** quiet residential neighborhood. The residents do not like the idea of a quarry as a new neighbor, and try to prevent the opening of the quarry. What would you do?

What would your answers to questions 3 or 4 be if the site were in an industrial area? Farmland? A historic district? A forest? A wetland? Habitat for a rare plant or animal? Adjacent to a shopping center? Upstream from a public water supply? Would your answer be different if the new pit was only to supply construction material for a short-term project, then be closed and the land reclaimed? Would it be different if the pit was to be operated for a few months each year? What would you do?

These are the kind of questions that regulatory officials face in considering applications for mining permits. They are also the kind of questions that industry officials must consider before they apply for a permit, and that they must be prepared to address in a manner that satisfies not only the regulatory officials but also the community in which they plan to operate.

WHAT DOES THE FUTURE HOLD?

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There is no alternative to mineral products. Recycling helps us use our resources more efficiently, but it does not completely replace the need for newly extracted resources from the earth to replace the materials that cannot be recycled and that are used to meet new needs of society. No matter how anybody may feel about mining, it is here to stay. But mining is not the same as it was in the past. In the United States today, operators of mines and quarries are held accountable for their actions. They must maintain certain standards to reduce pollution and prevent adverse impacts on their neighbors. They are required to clean up after themselves when they have completed their mining operation and to return the land to a usable condition.

In addition to the evolution of the mining industry to cleaner, more environmentally responsible operations, other forms of evolution are taking place in the world. Mining activity constantly shifts to keep pace with technological and economic changes. For example, Pennsylvania was a world leader in the mining of chromium in the 1800s. The chromium was used as a pigment in yellow paint. In the middle of the twentieth century, most people associated chromium with shiny bumpers on cars, reflecting a change in technology that created a new use for chromium. However, Pennsylvania was no longer a source of chromium in the middle of the twentieth century. The discovery of deposits that could be mined more economically, first in the western United States, then in Turkey, shifted chromium production away from Pennsylvania. Meanwhile, have you seen many chrome bumpers on new cars in the early twenty-first century? Change continues.

What does the future hold? Probably both continuity and change. Continuity in our need for mineral resources, but change in how those resources are used and in the economics of mining. Although Pennsylvania's chromium resources were considered uneconomical early in the twentieth century, the U.S. Government considered reopening Pennsylvania's chromium mines during World War II when access to foreign sources became imperiled. The war ended and the more economical foreign sources became available once again before any mining took place. No mining of Pennsylvania's chromium is anticipated in the foreseeable future, but the resource remains available should conditions change drastically once again.

We cannot be certain what the future holds, but we can be sure that mineral resources will play an important part in it.

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[1]Web addresses are subject to change.

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