



Chapter 5: Mineral Resources of the Southeastern US

What is a mineral?

A **mineral** is a naturally occurring inorganic solid with a specific chemical composition and a well-developed crystalline structure. Minerals provide the foundation of our everyday world. Not only do they make up the rocks we see around us in the Southeast, they are also used in nearly every aspect of our lives. The minerals found in the rocks of the Southeast are used in industry, construction, machinery, technology, food, makeup, jewelry, and even the paper on which these words are printed.

Minerals provide the building blocks for rocks. For example, **granite**, an **igneous rock**, is typically made up of crystals of the minerals feldspar, quartz, **mica**, and **amphibole**. In contrast, **sandstone** may be made of **cemented** grains of feldspar, quartz, and mica. The minerals and the bonds between the crystals define a rock's color and resistance to **weathering**.

Several thousand minerals have been discovered and classified according to their chemical composition. Most of them are **silicates** (representing approximately a thousand different minerals, of which quartz and feldspar are two of the most common and familiar), which are made of silicon and oxygen combined with other elements (with the exception of quartz, SiO_2). Carbonate rocks are made of carbon and oxygen combined with a metallic element; **calcium carbonate** (CaCO_3) is the most common example, and most of it today originates as skeletal material precipitated by organisms. Other mineral categories include native elements (such as gold), oxides and **sulfur-bearing** minerals, and **salts**.

Metallic minerals are vital to the machinery and technology of modern civilization. However, many metals occur in the **crust** in amounts that can only be measured in parts per million (ppm) or parts per billion (ppb). A mineral is called an **ore** when one or more of its elements can be profitably removed, and it is almost always necessary to process ore minerals in order to isolate the useful element. For example, **chalcopyrite** (CuFeS_2), which contains copper, **iron**, and sulfur, is referred to as a copper ore when the copper can be profitably extracted from the iron and sulfur. Ores are not uniformly distributed in the crust of the Earth, but instead occur in localized areas where they are concentrated in amounts sufficient for being economically extracted by mining.

Non-metallic minerals do not have the flash of a metal, though they may have the brilliance of a **diamond** or the silky appearance of **gypsum** ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Generally much lighter in color than metals, non-metallic minerals can transmit light, at least along their edges or through small fragments.

granite • a common and widely occurring type of igneous rock.

igneous rocks • rocks derived from the cooling of magma underground or molten lava on the Earth's surface.

mica • a large group of sheetlike silicate minerals.

amphibole • a group of dark colored silicate minerals, or either igneous or metamorphic origin.

sandstone • sedimentary rock formed by cementing together grains of sand.

weathering • the breakdown of rocks by physical or chemical means.

CHAPTER AUTHORS

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quartz • the second most abundant mineral in the Earth's continental crust (after the feldspars), made up of silicon and oxygen (SiO_2).

copper • a ductile, malleable, reddish-brown metallic element (Cu).

gold • a soft, yellow, corrosion-resistant element (Au), which is the most malleable and ductile metal on Earth.

feldspar • an extremely common group of rock-forming minerals found in igneous, metamorphic and sedimentary rocks.

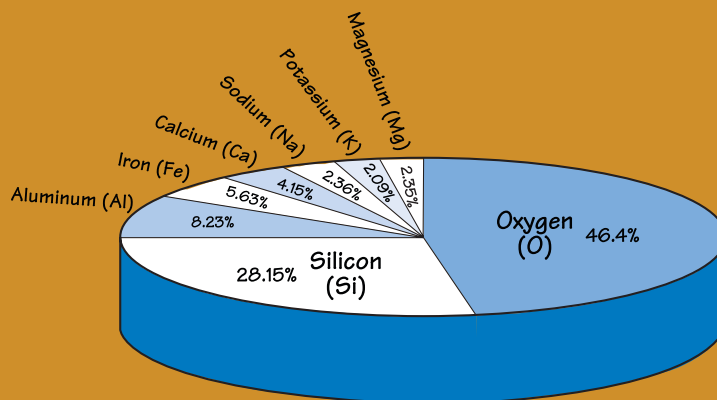
hardness • a physical property of minerals, specifying how hard the mineral is, and its resistance to scratching.

erosion • the transport of weathered materials.

calcite • a carbonate mineral, consisting of calcium carbonate (CaCO_3).

Elements: The Building Blocks of Minerals

Elements are the building blocks of minerals. The mineral **quartz**, for example, is made of the elements silicon and oxygen, and, in turn, is also a major component of many rocks. Most minerals present in nature are not composed of a single element, though there are exceptions such as gold. Elements such as **copper** (Cu), **lead** (Pb), **zinc** (Zn), and even **silver** (Ag), **gold** (Au), and **diamond** (C) are not rare, but they are usually widely dispersed throughout rocks and occur at very low average concentrations. Eight elements make up (by weight) 99% of the Earth's crust, with oxygen being the most abundant (46.4%). The remaining elements in the Earth's crust occur in very small amounts, some in concentrations of only a fraction of one percent. Since silicon (Si) and oxygen (O) are the most abundant elements in the crust by mass, it makes sense for silicates (e.g., **feldspar**, **quartz**, and **garnet**) to be some of the most common minerals in the Earth's crust and to therefore be found throughout the Southeast.



Mineral percentage by mass in the Earth's crust.

Mineral Identification

Although defined by their chemical composition and crystal structure, minerals are identified based on their physical properties. A variety of properties must usually be determined when identifying a mineral, with each such property eliminating possible alternatives.



Hardness is a very useful property for identification, as a given mineral can only exhibit a narrow range of hardnesses, and since it is easily testable, this property can be used to quickly and simply minimize the number of possibilities. Hardness is important because it helps us understand why some rocks are more or less resistant to weathering and **erosion**. Quartz, with a rating of 7 on the **Mohs scale**, is a relatively hard mineral, but the mineral **calcite** (CaCO_3), rating 3 on the Mohs scale, is significantly softer. Therefore, it should be no surprise that quartz sandstone is much more resistant to erosion and weathering than is **limestone**, which is primarily made of calcite. Quartz is a very common mineral in the Earth's crust, and it is quite resistant due to its hardness and relative insolubility. Thus, quartz grains are the dominant mineral type in nearly all types of **sand**.

Mohs Scale of Hardness

In 1824, the Austrian mineralogist Friedrich Mohs selected ten minerals to which all other minerals could be compared to determine their relative hardness. The scale became known as the Mohs scale of hardness, and it remains very useful as a means for identifying minerals or for quickly determining their hardness. Everyday items can be used to determine hardness if the minerals in the scale are not available. These include a streak plate or piece of unglazed porcelain (hardness 7), a piece of glass (hardness 5), a penny (hardness 3), and a fingernail (hardness 2).

1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Color is helpful in identifying some minerals such as sulfur, but it is uninformative or even misleading in others such as garnet. **Luster** describes how light is reflected from a mineral's surface, and it can range from adamantine, seen in diamonds, to dull or earthy (effectively no luster), such as in **kaolinite**. **Crystal form**, if visible, can also be diagnostic. For example, **fluorite** and calcite may appear superficially similar, but fluorite forms cubic crystals while calcite forms trigonal-rhombohedral crystals.

Relatedly, crystals may have planes of weakness that cause them to break in characteristic ways, called **cleavage**. Or they may not, but instead display **fracture** when broken. For example, mica and **graphite** have very strong cleavage, allowing them to easily be broken into thin sheets, while quartz and

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limestone • a sedimentary rock composed of calcium carbonate (CaCO_3).

sand • rock material in the form of loose, rounded, or angular grains, and formed as a result of the weathering and decomposition of rocks.

color (mineral) • a physical property determined by the presence and intensity of certain elements within the mineral.

luster • a physical property of minerals, describing the appearance of the mineral's surface in reflected light, and how brilliant or dull it is.

kaolinite • a silicate clay mineral, also known as china clay.

crystal form • a physical property of minerals, describing the shape of the mineral's crystal structure.

fluorite • the mineral form of calcium fluoride (CaF_2).

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density • a physical property of minerals, describing the mineral's mass per volume.

streak • a physical property of minerals, obtained by dragging the mineral across a porcelain plate and effectively powdering it.

luminescence • the emission of light.

radioactivity • the emission of radiation by an unstable atom.

marble • a metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite.

jade • a word applied to two green minerals that look similar and have similar properties: jadeite (a kind of pyroxene) and nephrite (a kind of amphibole).

soapstone • a metamorphic schistose rock composed mostly of talc.

glass (the latter not being a mineral) have no cleavage, instead displaying a distinctive curved fracture form known as conchoidal. The **density** of a mineral may also aid in identifying it (e.g., metals tend to be very dense). Finding the exact density is straightforward, but it does require measuring the volume of the sample. Placing an unknown mineral in water (or other liquid) to find its volume by displacement can be a risky undertaking since several minerals react violently with water, and many more break down with exposure. A mineral's **streak** is obtained by dragging it across a porcelain plate, effectively powdering it. The color of the powder eliminates conflating variables of external weathering, crystal habit, impurities, etc. Some minerals are **magnetic** (affected by magnetic fields), while a few are natural magnets (capable of producing a magnetic field).

Most minerals can be identified through the process of elimination after examining a few of these properties and consulting a mineral identification guide. Mineral testing kits often include several common objects used to test hardness: a porcelain streak plate, a magnet, and a magnifying glass. Some minerals have rare properties, which may be more difficult to test. For example, there are minerals that exhibit **luminescence** of all types, giving off light due to a particular stimulus. Some minerals are **radioactive**, usually due to the inclusion of significant amounts of uranium, **thorium**, or potassium in their structure. Carbonate minerals will **effervesce** when exposed to hydrochloric acid. **Double refraction** describes the result of light passing through a material that splits it into two polarized sets of rays, doubling images viewed through that material. For example, a single line on a sheet of paper will appear as two parallel lines when viewed through a clear calcite crystal.

There are many more interesting and distinguishing properties that minerals may possess, and there are many more elaborate and precise means for identifying them. The branch of geology that studies the chemical and physical properties and formation of minerals is called **mineralogy**.

What Are Minerals Used For?

Mineral resources fall into many different categories, including industrial minerals, construction materials, **gemstones**, and metallic and non-metallic ores. Some minerals and rocks are abundant and are used in the construction industry or in the manufacturing of many of the products we commonly find in stores. Construction materials include **dimension stone** (e.g., sandstone, limestone, and granite), which is used for the exterior or interior of structures.

Minerals used in manufacturing include kaolinite for ceramics, gypsum for wallboard, fluorite for the fluoride in toothpaste, and halite for common table and rock salt. We also seek out specific rock types and sediment to use in the construction of buildings, highways, and bridges. Decorative statues are commonly constructed of **marble**, **jade**, or **soapstone**. Granite, travertine, and other decorative stones are increasingly used to beautify our home interiors and



to make art, in addition to being used in public buildings. Some minerals are considered to be precious or semi-precious and are used in jewelry, including diamond and some crystalline forms of quartz.

What distinguishes a regular mineral from a gem?

Minerals are assigned to the category of gemstones based primarily on our interpretation of what has value. Typically, the beauty, durability, and rarity of a mineral qualify it as a gemstone. Beauty refers to the luster, color, transparency, and brilliance of the mineral, though to some degree it is dependent on the skillfulness of the cut. Not all gems are prized for these reasons; for example, scarcity may be artificially inflated, or a mineral may be valued for its unusual color.

Gemstones can be further categorized as precious or semiprecious stones. Precious stones, including diamond, topaz, and sapphire, are rare and translucent to light. They are more durable because they are hard, making them scratch resistant. On the Mohs scale of hardness, the majority of precious gemstones have values greater than 7. Semi-precious stones are generally softer, with hardness scale values between 5 and 7. The minerals peridot, jade, garnet, amethyst, citrine, rose quartz, tourmaline, and turquoise are examples of semi-precious stones that can be cut and used in jewelry.

Gems may have common names that differ from their geological ones, and these names may be dependent on mineral color. For example, the mineral beryl is also referred to as emerald, aquamarine, or morganite depending on its color. Corundum can also be called sapphire or ruby, and peridot is another name for olivine.

Metallic minerals have many applications and are used to manufacture many of the items we see and use every day. For example, iron comes from **hematite** and **magnetite**, and from it we make steel. **Lead**, from the mineral **galena**, is used in the manufacture of batteries and in the solder found in electronic devices. **Titanium**, from the mineral **ilmenite**, is used in airplanes, spacecraft, and even white nail polish. **Aluminum** comes from **bauxite** and is known for being both lightweight and strong—many of the parts that make up today's

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hematite • a mineral form of iron oxide (Fe_2O_3), with vivid red pigments that make it valuable as a commercial pigment.

magnetite • a mineral form of iron oxide (Fe_3O_4) with naturally occurring magnetic properties.

lead • a metallic chemical element (Pb).

galena • an abundant sulfide mineral with cubic crystals.

titanium • a metallic chemical element (Ti) that is important because of its lightweight nature, strength and resistance to corrosion.

ilmenite • an ore of titanium, produced for use as a white pigment in paint.

aluminum • a metallic chemical element (Al), and the most abundant metal in the Earth's crust.

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magma • molten rock located below the surface of the Earth.

intrusive rock • a plutonic igneous rock formed when magma from within the Earth's crust escapes into overlying strata.

rift • a break or crack in the crust that can be caused by tensional stress as a landmass breaks apart into separate plates.

volcanism • the eruption of molten rock onto the surface of the crust.

felsic • igneous rocks with high silica content and low iron and magnesium content.

gabbro • a coarse-grained, mafic and intrusive igneous rock.

mafic • igneous rocks that contain a group of dark-colored minerals, with relatively high concentrations of magnesium and iron.

automobiles are made of this metal. Copper comes from a variety of copper-bearing minerals, including chalcopyrite, and is used to make electrical wire, tubing, and pipe.

Mineral Formation

Economically recoverable mineral deposits are formed by geologic processes that can selectively concentrate desirable elements in a relatively small area. These processes may be physical or chemical, and they fall into four categories:

Magmatic processes separate minor elements of **magma** from the major elements and concentrate them in a small volume of rock. This may involve either the early crystallization of ore minerals from the magma while most other components remain molten or late crystallization after most other components have crystallized. Magmatic processes responsible for the formation of mineral deposits are usually associated with igneous **intrusions** (formed during mountain building events, **rifting**, and **volcanic** activity), which can range in composition from granite (**felsic**) to **gabbro (mafic)**. **Metamorphism** may also cause **recrystallization** of minerals and concentration of rare elements. Under conditions of extreme high-temperature metamorphism, minerals with the lowest melting temperatures in the crust may melt to form small quantities of **pegmatite** magmas.

Hydrothermal processes involve **hydrothermal solutions** that dissolve minor elements dispersed through large volumes of rock, transport them to a new location, and precipitate them in a small area at a much higher concentration. Hydrothermal solutions are commonly salty, acidic, and range in temperature from over 600°C (~1100°F) to less than 60°C (140°F). Some of these fluids may travel very long distances through **permeable sedimentary rock**. Eventually, the hydrothermal fluids precipitate their highly dissolved load of elements, creating concentrated deposits.

Sedimentary processes gather elements dispersed through large volumes of water and precipitate them in a sedimentary environment, such as in sedimentary layers on the ocean floor or on lakebeds. Sedimentary mineral deposits form by direct precipitation from the water.

Weathering and erosion break down large volumes of rock by physical and chemical means and gather previously dispersed elements or minerals into highly concentrated deposits. **Residual weathering deposits** are mineral deposits formed through the concentration of a weathering-resistant mineral, as a result of surrounding minerals being eroded and dissolved. In contrast, mineral deposits formed by the concentration of minerals in moving waters are called **placer deposits**.

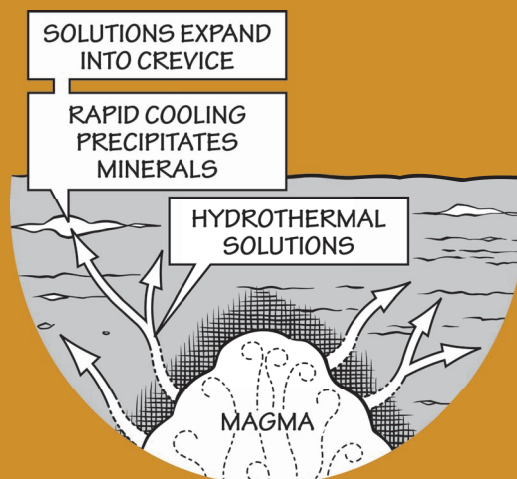


What are hydrothermal solutions?

Hot water enriched in salts such as sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride (CaCl₂) is called a hydrothermal solution, or simply "brine." The brine is as salty or even saltier than seawater, and may contain minute bits of dissolved minerals such as gold, lead, copper, and zinc. The presence of salt in the water stops the metallic minerals from precipitating out of the brine because the chlorides in the salt preferentially bond with the metals. Additionally, because the brine is hot, the minerals are more easily dissolved, just as hot tea dissolves sugar more easily than cold tea does.

Hot water brines can have varying origins. Most bodies of magma contain mineral-enriched, superheated water, which is released into the surrounding rock as the magma cools. Rainwater can become a hydrothermal solution as it filters through rocks and picks up soluble materials along its path. Seawater, which is already enriched in salt, often becomes a hydrothermal solution in the vicinity of volcanic activity on the ocean floor where tectonic *plates* are pulling apart.

Hydrothermal solutions move away from their source of heating through cracks, faults, and solution channels into the adjacent cooler rocks. As the water moves quickly through fractures and openings in the rock (where it experiences changes in pressure or composition and dilution with groundwater), it can cool rapidly. This rapid cooling over short distances allows concentrations of minerals to be deposited. When a hydrothermal solution cools sufficiently, the dissolved salts form a precipitate, leaving behind minerals in a vein or strata-bound deposit.



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metamorphic rocks • rocks formed by the recrystallization and realignment of minerals in pre-existing sedimentary, igneous, and metamorphic rocks when exposed to high enough temperature and/or pressure.

recrystallization • the change in structure of mineral crystals that make up rocks, or the formation of new mineral crystals within the rock.

pegmatite • a very coarse-grained igneous rock that formed below the surface.

hydrothermal solution • hot, mineral-rich water moving through rocks.

permeability • a capacity for fluids and gas to move through fractures within a rock, or the spaces between its grains.

sedimentary rock • rock formed through the accumulation and consolidation of grains of broken rock, crystals, skeletal fragments, and organic matter.

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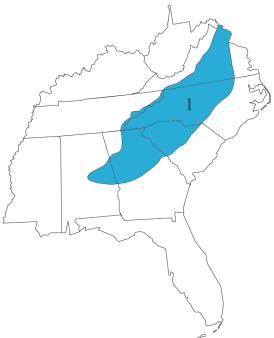
zinc • a metallic chemical element (Zn, atomic number 30).

lithium • a metallic chemical element (Li) used in the manufacture of ceramics, glass, greases, and batteries.

olivine • an iron-magnesium silicate mineral ($(\text{Mg,Fe})_2\text{SiO}_4$) that is a common constituent of magnesium-rich, silica-poor igneous rocks.

oxidation • a chemical reaction involving the loss of at least one electron when two substances interact.

Grenville Orogeny • a mountain-building event, about 1.3 to 1 billion years ago, that played a role in the formation of the supercontinent Rodinia.



A mineral is not necessarily restricted to one method of concentration or environment of formation. For example, economically important deposits of gypsum may form as a precipitate from evaporating water. However, gypsum formation may also be associated with volcanic regions where limestone and sulfur gases from the volcano have interacted, or from other areas as a product of the chemical weathering of pyrite.

Minerals in the Southeast

The Southeast's mineral resources contributed significantly to Colonial economies, the struggle for independence, and the rise of the United States as a world power. The first metals mined by Europeans in the United States were extracted in 1621 from a lead deposit in Virginia. This same deposit supplied shot for the Continental Army during the American Revolution, and was a point of contention during the Civil War. In the early 19th century, the first gold rush in North America spread across the southern Appalachian Piedmont from a small farm in central North Carolina.

During the 17th, 18th, and early 19th centuries, mines in the Southeast were generally numerous and small, often producing minerals for local use. Mines were fewer in number but larger in scale during the late 19th and early 20th centuries, serving mostly regional and national markets. Today, there are relatively few mines in the Southeast, but the area's existing mines are commonly large or highly specialized operations that produce minerals for the global marketplace. The Southeast is currently a major supplier of **zinc**, cadmium, germanium, **lithium**, pyrophyllite, **olivine**, mica, and feldspar.

Mineral Resources of the Blue Ridge and Piedmont

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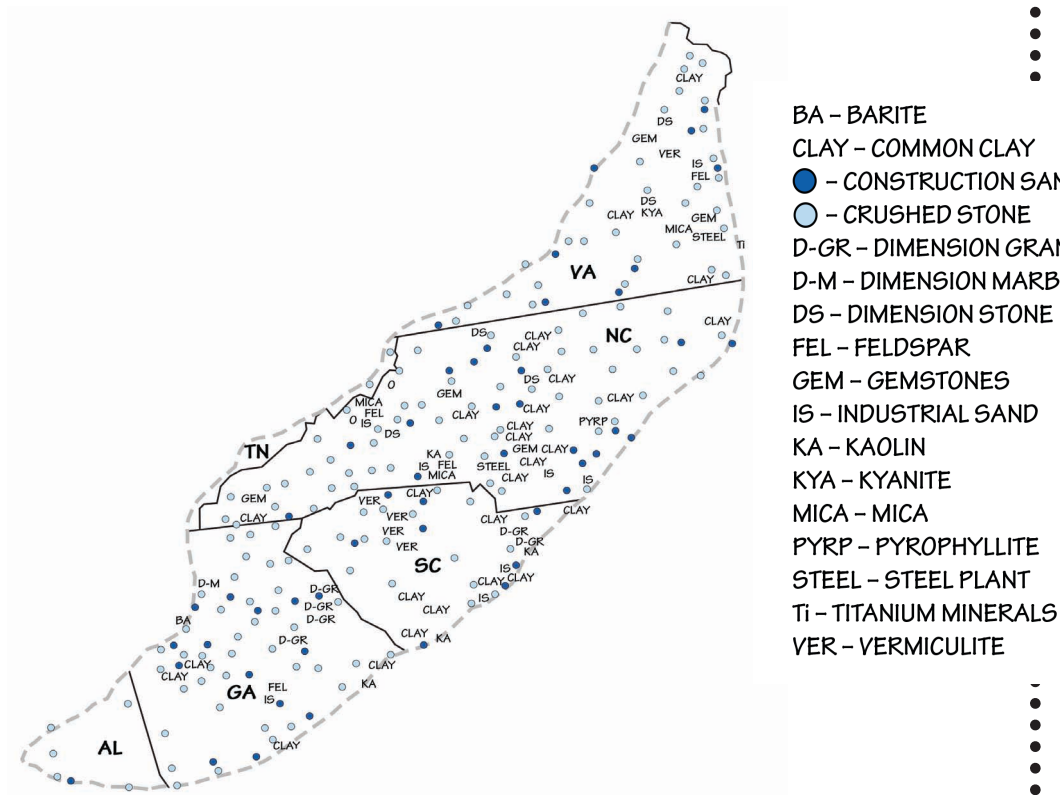
The Blue Ridge and Piedmont contains many distinct types of mineral deposits, which formed by different geologic processes throughout the Southeast's geologic history. Over the last billion years, these processes and their associated geologic environments have operated to produce the abundance and diversity of mineral deposits found in the region today (*Figure 5.1*).

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Iron and titanium **oxide** deposits, associated with igneous intrusions that occurred during the **Grenville Orogeny**, can be found scattered throughout the Grenville rocks that stretch from Virginia to Georgia. These rocks formed one billion years ago as the supercontinent **Rodinia** formed and ocean floor



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- BA – BARITE
- CLAY – COMMON CLAY
- – CONSTRUCTION SAND AND GRAVEL
- – CRUSHED STONE
- D-GR – DIMENSION GRANITE
- D-M – DIMENSION MARBLE
- DS – DIMENSION STONE
- FEL – FELDSPAR
- GEM – GEMSTONES
- IS – INDUSTRIAL SAND
- KA – KAOLIN
- KYA – KYANITE
- MICA – MICA
- PYRP – PYROPHYLLITE
- STEEL – STEEL PLANT
- Ti – TITANIUM MINERALS
- VER – VERMICULITE

Figure 5.1: Principal mineral resources of the Blue Ridge and Piedmont.

Rodinia • a supercontinent that contained most or all of Earth's landmass, between 1.1 billion and 750 million years ago, during the Precambrian.

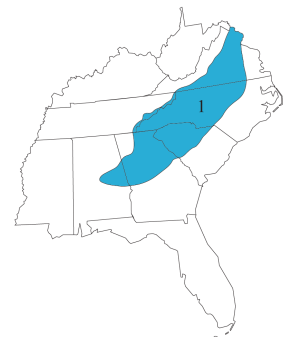
rutile • a typically reddish brown mineral formed of TiO_2 .

phosphate • an inorganic salt of phosphoric acid, and a nutrient vital to biological life.

sediment was pushed onto ancient North America. The tectonic processes that formed the Grenville rock and mineral deposits are often obscured by strong metamorphism and deformation.

See Chapter 1: Geologic History to learn more about ancient supercontinents and building events.

The titanium oxide minerals **rutile** and ilmenite were mined in the Roseland District of central Virginia (western Amherst and Nelson counties) between 1900 and 1971. This area once supplied a large percentage of the rutile consumed in the United States, used largely as a white pigment and an ingredient in refractory ceramics (Figure 5.2). During the milling process, significant tonnages of the **phosphate** mineral apatite were also recovered, from which phosphorous chemicals were produced. From 1931 to 1971, the American Cyanamid Company operated a plant at Piney River, which refined the titanium ore and produced titanium dioxide for paint pigment. After the plant closed, its waste disposal sites remained behind. Today, the 20-hectare (50-acre) area is classified as a Superfund site due to the leaching of highly acidic iron sulfate, which has degraded the Piney River's water quality, destroyed vegetation, and contaminated local groundwater. More than



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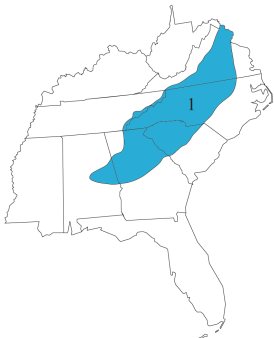
sphalerite • zinc sulfide (ZnS), the chief ore mineral of zinc.

pyrite • the iron sulfide mineral (FeS_2) with a superficial resemblance to gold, known commonly as "fool's gold."

Precambrian • a geologic time interval that spans from the formation of Earth (4.6 billion years ago) to the beginning of the Cambrian (541 million years ago).

rift basin • a topographic depression caused by subsidence within a rift.

heat • a form of energy transferred from one body to another as a result of a difference in temperature or a change in phase.



200,000 fish died between 1977 and 1981 as a result of runoff from the plant's waste piles; today, about 200 people live within one mile of the site.

A Superfund site is a heavily polluted location, designated by the government to receive a long-term clean-up response in order to remove environmental hazards and contamination.



Figure 5.2: A crystal of rutile, composed primarily of titanium dioxide (TiO_2). Although it appears dark in color, when powdered it becomes a brilliant white. Specimen is 4.4 centimeters (1.7 inches) in width.

Small but rich magnetite (iron oxide) deposits at Cranberry, North Carolina occur in a 40-kilometer-long (24-mile-long) area associated with a large intrusion of gabbro, a dark-colored igneous rock. Around 1.5 million tons of high-purity magnetite was produced in this area of North Carolina from 1882 to 1930.

Sulfides, including iron, zinc, lead, and copper sulfides (galena, **sphalerite**, chalcopyrite, and **pyrite**), make up the majority of ore minerals in the Southeast's **Precambrian rift basins**, which formed during the breakup of Rodinia. These minerals were largely deposited by hydrothermal processes. Seawater circulating through thick sequences of sediments, some of which were volcanic in origin, was **heated** by geothermal **energy** from subsurface magma. These hydrothermal fluids dissolved base metals, sulfur, and other elements from the sediments through which they migrated. Because the mineral-laden solutions were hot, they rose upward to the surface of the rift basins. As the hydrothermal fluids cooled at the surface, minerals precipitated from the solutions to form blankets of sulfides (including iron, copper, and zinc sulfides) within the rift basin sediments. During the **Taconic** and **Acadian orogenies**, these deposits were folded to form thick lenses, and recrystallized into coarse crystals that are

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easily extracted. Numerous small sulfide deposits are present from southwest Virginia to northeast Georgia. The region's largest deposits are those found in the Gossan Lead District in the Ashe Formation of Virginia, with 28 kilometers (17 miles) of iron sulfide deposits, and the Ducktown District in Tennessee's Ocoee Basin, which contains nine separate sulfide bodies totaling almost 200 million tons of ore (Figure 5.3).

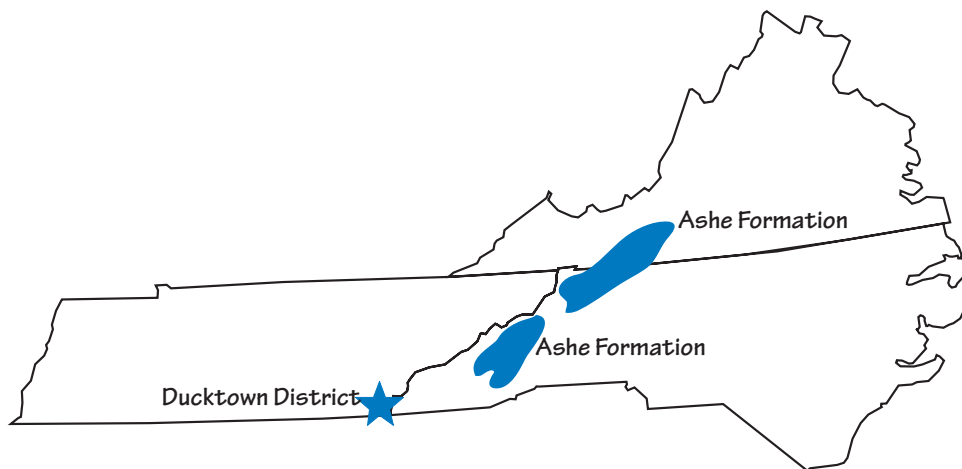


Figure 5.3: The Gossan Lead District is in the Ashe Formation of Virginia; the Ducktown District is in southeastern Tennessee.

The Ducktown District was first worked in the early 1840s, initially for iron and later for gold formed by surface weathering of the sulfide ore bodies. The district also produced zinc and **silver**. Rich secondary copper ores were discovered below the **gossans** and mined from 1847 to 1879. Initially, the rich ore was piled on huge stacks of cordwood and set to burn for several weeks to oxidize the sulfur. The roasted ore was then placed in smelters fired by charcoal to recover the copper metal. The entire valley was stripped of **trees** to fuel the roasters and smelters, consuming over 600 hectares (1500 acres) of mature timber each year by 1876. By 1878, 122 square kilometers (47 square miles) of forest had been consumed in and around the valley. Sulfur gases released by roasting and smelting fell with rain as sulfuric acid, killing virtually all remaining vegetation in the valley. High rainfall resulted in extensive erosion and gulying, producing terrain similar to a desert (Figure 5.4). Mining of the primary sulfide ore bodies underground began in 1890, and continued until the end of the district's mining in 1987. Cleaner smelting technologies and extensive reclamation and planting efforts from the 1970s through the 1990s restored vegetation in much of the valley, an effort that continues to the present.

Manganese oxide deposits are locally present in the Blue Ridge and Piedmont's Precambrian rift basin sediment, especially in the Ashe Formation near the North Carolina-Virginia border. These include the deposits at Bald Knob, North Carolina, which are composed of manganese oxides, **carbonates**, and silicates. The formation of these manganese deposits is similar to that of the sulfide deposits described previously, but here they took place at lower temperatures.

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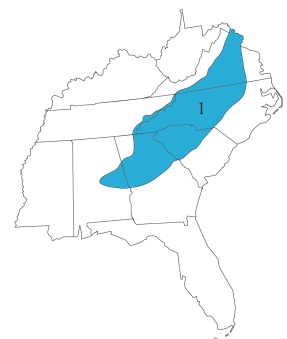
Taconic Orogeny • a late Ordovician mountain-building event involving the collision and accretion of a volcanic island arc along the eastern coast of North America.

Acadian Orogeny • a Devonian mountain-building event involving the collision of the eastern coast of North America and the accreted terrane of Avalon.

orogeny • a mountain-building event generally caused by colliding plates and compression of the edge of the continents.

silver • a metallic chemical element (Ag).

gossan • the near-surface, oxidized portion of a sulfide-rich ore body.



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Cambrian • a geologic time period lasting from 541 to 485 million years ago.

Ordovician • a geologic time period spanning from 485 to 443 million years ago.

fault • a fracture in the Earth's crust in which the rock on one side of the fracture moves measurably in relation to the rock on the other side.

barite • a usually white, clear, or yellow mineral (BaSO_4) found in limestone, clay-rich rocks, and sandstones.

Avalon • an early Paleozoic microcontinent offshore of what is now the eastern coast of North America.

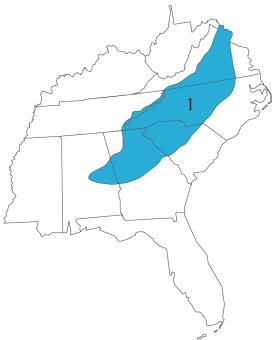


Figure 5.4: A train brings copper ore out of the Tennessee Ducktown mines in 1939. Fumes from the burning of sulfide ores caused severe erosion and loss of the area's vegetation.

During mountain building in the **Cambrian** and **Ordovician**, hydrothermal fluids migrated along fractures and thrust **faults**, following units of permeable rock. Minor occurrences of zinc and lead sulfides from this time period are present in the Blue Ridge, and there are several large **barite** deposits formed along thrust faults—for example, the barite deposits found in the Hot Springs District of Madison County, North Carolina. Because it is heavy, soft, and chemically inert, barite is widely used as an additive and filler, largely to increase the density of lubricating muds used in oil and gas drilling.

The rocks of the Inner and Outer Piedmont host numerous hydrothermal sulfide and gold deposits, although most were relatively small and largely mined out in the 19th century. Many of the region's high-grade gold deposits are concentrated within quartz veins. In the Outer Piedmont, numerous deposits of sulfides (copper, lead, and zinc), gold, iron, manganese, barite, and tungsten are associated with Precambrian to Cambrian volcanic activity and igneous intrusions that occurred before the **Avalon terrane** was attached to North America. The Carolina Slate Belt, a weak to moderately metamorphosed section of Avalon rocks that stretches over 970 kilometers (600 miles) from Georgia to Virginia, is thought to contain significant quantities of undiscovered gold and silver (Figure 5.5).

See Chapter 2: Rocks for more on Avalon and other exotic terranes that accreted to North America during the Paleozoic.

Mineral Resources



5

Over 300 different minerals have been found in North Carolina—a greater variety than in any other state.



Figure 5.5: A lead-rich ore with patches of silver, from the Silver Hill Mine in the Carolina Slate Belt, Davidson County, North Carolina. Specimen is 8.8 centimeters (3.5 inches) wide.

Many of these deposits also contain abundant pyrite, sometimes in crystals up to 20 centimeters (8 inches) across. The deposits were modified, and in some cases further concentrated, by hydrothermal processes accompanying the Acadian and **Alleghanian** orogenies. Subsequent weathering and erosion formed rich placer and residual gold deposits that were the initial target of mining in the Piedmont. **Alluvial** mining gave way to **lode** mining as placer deposits were exhausted and the gold was traced to its source in the bedrock. Although much of the Blue Ridge and Piedmont's gold has already been commercially extracted, gold panning and sluicing (Figure 5.6) is a popular recreational activity in many parts of the region.

Gold was first reported in North Carolina in 1774, but the Carolina Gold Rush began after 12-year-old Conrad Reed found an 8-kilogram (17-pound) gold nugget on the family farm in 1799. Mining had begun at deposits in five North Carolina counties by 1820, and 14 kilograms (500 ounces) of North Carolina gold arrived at the US Mint in Philadelphia in 1824. Mining experts and engineers were recruited from Britain, Germany, Italy, and South Africa, and miners came to the Southeast from more than a dozen countries. The Carolina Gold Rush spread through the southeastern Piedmont from Virginia to Alabama and westward across the Blue Ridge by 1830, and included the deposits of the Inner Piedmont.

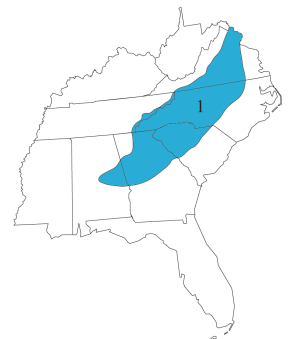
Region 1

terrane • a piece of crustal material that has broken off from its parent continent and become attached to another plate.

Alleghanian Orogeny • a Carboniferous to Permian mountain-building event involving the collision of the eastern coast of North America and the northwestern coast of Africa.

alluvial • a layer of river-deposited sediment.

lode • an ore deposit that fills a fissure or crack in a rock formation.





Region 1

How is gold mined?

Gold can be extracted using a wide variety of methods. Placer mining searches stream bed deposits for minerals moved from their original source by water. Placer deposits can be mined in several different ways: panning, which uses a small, hand-held pan to manually sort the gold from sand and rock fragments; sluicing, in which water is sent through a man-made stepped channel that traps particles of gold; or dredging, where a large machine uses mechanical conveyors or suction to pull loads of material from the river bottom and then dump smaller fragments into a sluice box. Gold that is trapped in layers of rock may be excavated through underground mining, where tunnels or shafts are used to locate the ore, or by open pit mining, which is used when deposits are relatively close to the surface.

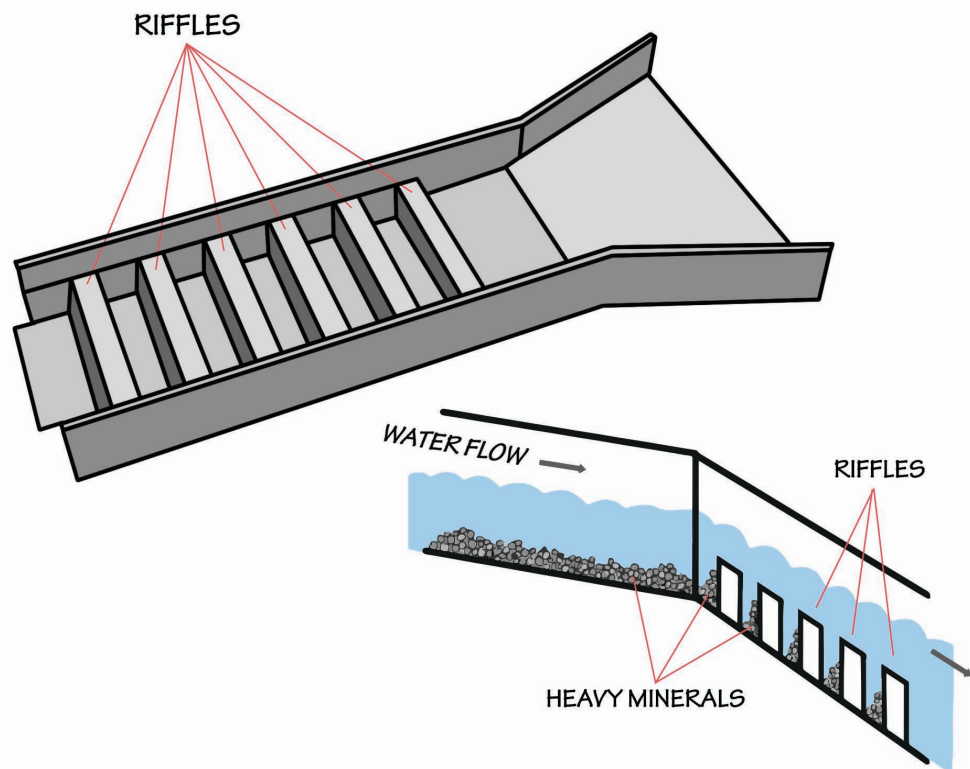
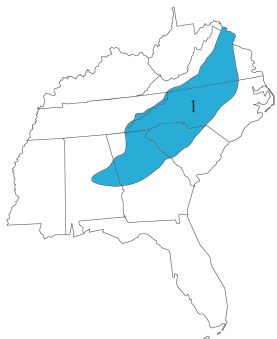


Figure 5.6: A sluice is a long tray through which water that contains gold is directed. The sluice box contains riffles, or raised segments, which create eddies in the water flow. Larger and heavier particles, such as gold, are trapped by the eddies and sink behind the riffles where they can later be collected.

Mineral Resources



5

Region 1

There are over 300 known gold, silver, and base metal mines and prospects in Virginia, but the most important are clustered in a narrow zone of volcanic rocks called the Virginia Gold-Pyrite Belt, which extends for about 160 kilometers (100 miles) (*Figure 5.7*). At least 100 old gold mines are present along this trend, opened along veins and sulfide deposits of hydrothermal origin. Total gold production from Virginia from 1804 through 1947 was 9300 kilograms (330,000 ounces). Copper, zinc, and lead from sulfide deposits also were mined in this area.

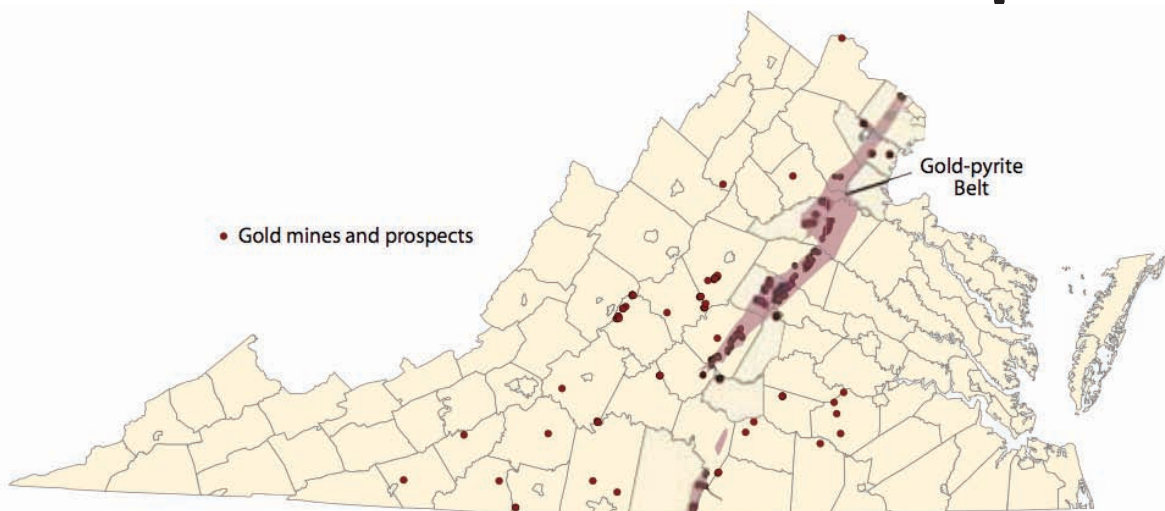


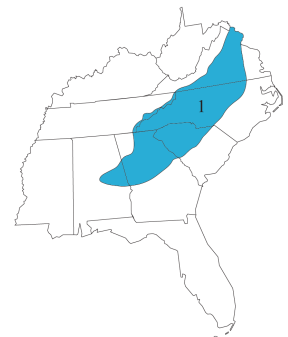
Figure 5.7: The Virginia Gold-Pyrite Belt, and associated gold mines and prospects.

Northern Georgia's Dahlonega Belt—volcanic rocks containing rich hydrothermal gold-bearing quartz veins and sulfide deposits—produced over 14,000 kilograms (500,000 ounces) of gold between 1838 and 1941 (*Figure 5.8*). Gold was first discovered in the Dahlonega area in 1828, leading to a period of feverish prospecting known as the Georgia Gold Rush. A branch of the US Mint operated in Dahlonega between 1838 and 1861, striking United States coins from Dahlonega gold.

South Carolina was the scene of a modern-day gold rush between 1985 and 1999, with four major open-pit mines—the Ridgeway Mine (Fairfield County), Barite Hill Mine (McCormick County), Brewer Mine (Chesterfield County), and Haile Mine (Lancaster County)—in operation. Total gold production from the entire Southeastern Piedmont through 1969 is estimated at 77,000 kilograms (2.7 million ounces). South Carolina's production from 1985 to 1999 increases this figure to about 123,000 kilograms (4.35 million ounces) of gold.

A **banded iron formation** extends for almost 137 kilometers (85 miles) through the Avalon rocks in North and South Carolina. Hydrothermal in origin, the iron was originally deposited in sediments on the ancient seafloor. These deposits were first mined just before 1760, and supplied iron for the weapons of the Continental Army during the American Revolution. The same banded iron formations were also a major source of iron for the weapons of the Confederate

banded iron formation • rocks with regular, alternating thin layers of iron oxides and either shale or silicate minerals.



5



Mineral Resources

Region 1

Triassic • a geologic time period that spans from 252 to 201 million years ago.

Jurassic • the geologic time period lasting from 201 to 145 million years ago.

Pangaea • supercontinent, meaning "all Earth," which formed over 300 million years ago and lasted for almost 150 million years.

gneiss • a metamorphic rock that may form from granite or layered sedimentary rock such as sandstone or siltstone.

beryl • a white, blue, yellow, green, or pink mineral, found in coarse granites and igneous rocks.

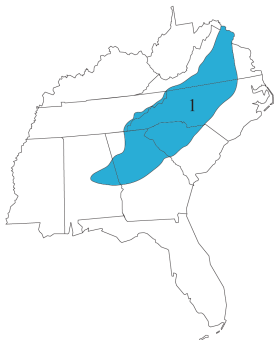


Figure 5.8: A view into the tunnels of the Consolidated Gold Mine, Dahlonega, Georgia. This mine was the site of one of the world's largest gold-bearing quartz veins, and it is the largest hard rock gold mine east of the Mississippi.

Dahlonega and the Trail of Tears

The "official" discovery of gold in Georgia was made in 1828 by Frank Logan in present-day White County, well within the territory of the Cherokee Nation. The Cherokee were aware of the presence of gold on their lands, and gold mines were operated illegally in Cherokee Territory as early as 1819. As word of the discovery spread, a systematic campaign to remove the Cherokee and open the area to gold mining was crafted in Georgia and Washington, DC. In 1830, Congress quickly passed the Indian Removal Act. In December 1835, the US government signed a treaty with a small group of disaffected Cherokee, none of whom were elected officials of the Cherokee Nation. Twenty signed the treaty, ceding all Cherokee territory east of the Mississippi to the US, in exchange for \$5 million and new homelands in the Indian Territory (Oklahoma). More than 15,000 Cherokees protested the illegal treaty, but the US Senate ratified it by one vote. Most of the Cherokee people were forced to leave their ancestral home in northern Georgia and adjacent states, and relocate to the Indian Territory in the winter of 1838–1839. Over 4000 Cherokee died as a result of the removal, nearly a fifth of the Cherokee population. Their journey is called "The Trail of Tears."

Mineral Resources



5

armies during the Civil War, including shot, cannonballs, and armor plates for naval ironclads. Production declined after the war and ended around 1900.

Uranium ore is found in **Triassic-Jurassic** rift basin sediments that were deposited as **Pangaea** began to split apart. The uranium was transported in dissolved form by groundwater, then concentrated in the sediments and deposited. In 1982, the Marline Uranium Corporation announced the discovery of a 30-million ton deposit of uranium ore in Pittsylvania County, Virginia. The ore body is developed in an intrusion of **gneiss** in the Danville rift basin. This uranium deposit was never commercially developed, due to a drop in uranium ore prices and local opposition to the project.

Non-Metallic Resources

During the Taconic and Acadian orogenies, numerous pegmatites intruded Precambrian rift rocks throughout the Blue Ridge. Many of these pegmatites have been mined for feldspar, kaolinite, quartz, and mica (*Figure 5.9*). Among the most important districts for pegmatite mining are the Franklin-Sylva and Spruce Pine districts in North Carolina, where hundreds of pegmatites intrude into the Ashe Formation (*see Figure 5.3*). These two districts have produced over half of all US sheet and scrap mica and feldspar since mining began there in 1868, and North Carolina remains the nation's top producer. Ancient mine pits and shafts in the Blue Ridge Mountains of North Carolina were long thought to be pre-colonial silver and gold prospects attributed to early Spanish explorers, but these old prospects are now thought to be the work of Native Americans who mined the pegmatites for sheets of muscovite mica. **Beryl** is a common mineral in some pegmatites, and mines in the Spruce Pine District have produced gem quality aquamarine and emerald (varieties of beryl). Pegmatites are also widespread in the Inner Piedmont, although they are generally no longer mined there. An unusual group of lithium-bearing pegmatites in Alexander County, North Carolina produces gem-quality emeralds and hiddenite, a gem form of **spodumene** (*Figure 5.10*). Lithium-rich pegmatite deposits between Lincolnton, North Carolina and Gaffney, South Carolina represent one of the largest concentrations of silicate lithium in the world.

The mineral olivine, concentrated in the **ultramafic** igneous rocks dunite and **peridotite**, is present throughout the Blue Ridge from Virginia to Alabama. It occurs in highly deformed Precambrian rift rocks that were thrust westward onto the margin of North America during the Taconic Orogeny.

Two of the most common mica minerals are muscovite (light-colored) and biotite (black). Mica minerals are used in heating and insulating.

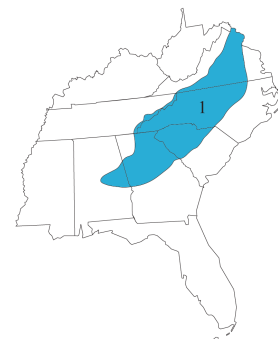
The fibrous mineral asbestos is a very slow conductor of heat, and was commonly used as a fireproofing material and as electrical insulation. Concerns over health effects on the lungs have led to its removal from common use.

Region 1

spodumene • a translucent pyroxene mineral (lithium aluminum inosilicate) occurring in prismatic crystals, and a primary source of lithium.

ultramafic rocks • igneous rocks with very low silica content (< 45%), which are composed of usually greater than 90% mafic minerals.

peridotite • a coarse-grained plutonic rock containing minerals, such as olivine, which make up the Earth's mantle.



5



Mineral Resources

Region 1

asbestos • a fibrous silicate mineral that is resistant to heat, flames, and chemical action.

Paleozoic • a geologic time interval that extends from 541 to 252 million years ago.

corundum • an aluminum oxide mineral (Al_2O_3) that is, after diamond, the hardest known natural substance.

aggregate • crushed stone or naturally occurring un lithified sand and gravel.

talc • hydrated magnesium silicate, formed during hydrothermal alteration accompanying metamorphism.

silt • fine granular sediment most commonly composed of quartz and feldspar crystals.

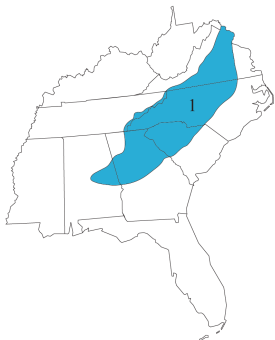


Figure 5.9: A portion of a feldspar-rich pegmatite from Pine Mountain Mine in Mitchell County, North Carolina, with inclusions of muscovite mica and garnet. Specimen is 13 centimeters (5 inches) wide.



Figure 5.10: A crystal of hiddenite, a variety of spodumene, from the Adams Hiddenite and Emerald Mine in North Carolina. Hiddenite was first discovered in Alexander County, North Carolina in 1879. A nearby community was also named after the mineral.

Mineral Resources



5

Western North Carolina leads the nation in olivine production; the Webster-Balsam District in Jackson County and the Spruce Pine District in Yancey and Mitchell counties have produced commercial quantities of this mineral for use in industry and as the gemstone peridot. Ultramafic deposits in the Blue Ridge have also produced minor quantities of **asbestos** and chromite.

Paleozoic mountain building altered the Blue Ridge and Piedmont's ultramafic rocks, resulting in the formation of distinctive localized deposits. In the Blue Ridge, deposits of **corundum** are common. Corundum is used as an abrasive, and in gem form is known as ruby (red) or sapphire (blue). The Macon County area continues to produce gem-quality forms of corundum, especially rubies and sapphires—in 1985, two rubies totaling almost 1000 carats with an uncut value of around \$40,000 were found there. In the Inner Piedmont, Paleozoic metamorphism formed deposits of vermiculite, used in lightweight concrete **aggregates**, insulation, agriculture, and other products. The United States is one of the two largest producers of vermiculite in the world; all US production comes from deposits in the Inner Piedmont of Virginia and South Carolina.

Talc deposits are associated with the Murphy Marble in a belt extending through Cherokee and Swain counties, North Carolina. The talc formed through tectonic-metamorphic alteration of **silty dolomite** or associated sediments during one of the Paleozoic orogenic events. While talc can form from a variety of **parent materials**, including ultramafic rocks rich in olivine, talc formed from dolomitic marbles tends to be cleaner and more pure, making the Murphy deposits economically viable.

These deposits were mined as early as 1859 and well into the 1980s, but are currently inactive. The district has produced over 200,000 tons of high-grade talc.

See Chapter 2: Rocks to learn more about the Murphy Marble and other metamorphosed rocks of the Southeast.

The Blue Ridge and Piedmont also produces numerous industrial minerals in the form of crushed stone, sand and **gravel**, and common **clays**. **Holocene** sand and gravel deposits found along streams and **terraces** are locally quarried for use as construction aggregate, which is used to strengthen concrete, make blacktop, produce building materials, and as road and dam foundations. Limestone, and to a lesser extent dolomite (**dolostone**), is also mined and crushed for use as aggregate, and Georgia is the national leader in the production of granite used as crushed stone. Some types of sand are quartz-rich, which makes them useful for other industrial purposes. This "industrial sand" is used in sandblasting, filtering, and the manufacturing of glass, and is mined from quartz-rich Paleozoic sandstones and **quartzites**.

Dimension stone is the commercial term applied to quarried blocks of rock that are cut to specific dimensions and used for buildings, monuments, curbing and facing. Granite, limestone, and sandstone are often quarried as dimension stone. The largest open-face granite quarry in the world is located at Mt. Airy, North Carolina (*Figure 5.11*). Polished granites from Georgia (in particular the Elberton area) and North Carolina have been used in many government

Region 1

dolomite • a carbonate mineral, consisting of calcium magnesium carbonate ($\text{CaMg}(\text{CO}_3)_2$).

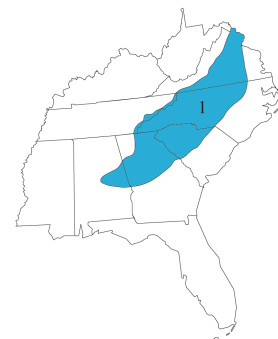
parent material • the original geologic material from which soil formed.

gravel • unconsolidated, semi-rounded rock fragments larger than 2 millimeters (0.08 inches) and smaller than 75 millimeters (3 inches).

clay • the common name for a number of very fine-grained, earthy materials that become plastic (flow or change shape) when wet.

dolostone • a rock primarily composed of dolomite, a carbonate mineral.

quartzite • a hard metamorphic rock that was originally sandstone.



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Mineral Resources

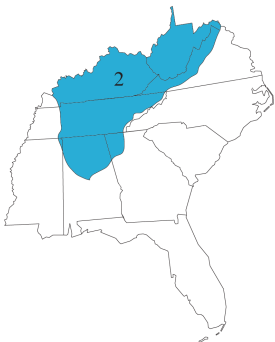
Regions 1–2

Appalachian Basin • an inland basin, formed by the Taconic and Acadian mountain-building events.

inland sea • a shallow sea covering the central area of a continent during periods of high sea level.

evaporite • a sedimentary rock created by the precipitation of minerals directly from seawater, including gypsum, calcite, dolomite, and halite.

Silurian • a geologic time period spanning from 443 to 419 million years ago.



buildings and monuments, including the US Capitol building and the Jefferson Memorial in Washington, DC.



Figure 5.11: The open-faced granite quarry at Mt. Airy, North Carolina, produces over 610,000 meters (2 million feet) of white granite each year for use in construction and facing. The quarry was opened in 1743, and covers an area of roughly 372,000 square meters (4 million square feet).

Mineral Resources of the Inland Basin Region 2

The major mineral deposits of the Inland Basin include sulfide and non-sulfide minerals associated with hydrothermal processes (Figure 5.12). Occurrences of lead and zinc are widespread throughout much of the **Appalachian Basin** and Valley and Ridge, where thrust faults and fractures provided pathways for fluid migration and sites for ore deposit formation during the Acadian and Alleghanian orogenies to the east. In addition, a vast reservoir of sedimentary rocks was deposited in the Paleozoic **inland sea** that covered the western half of the Inland Basin. Extensive precipitation of **evaporite** salts in this shallow sea occurred during the **Silurian**, and locally at other time periods. Weathering and erosion have also been

See Chapter 4: Topography for more information on the Appalachian Basin, Valley and Ridge, and other physiographic subregions of the Inland Basin.

Mineral Resources



5

important processes in the formation of mineral deposits in the Appalachian Basin. Chemical weathering of limestone and dolostone have formed numerous small deposits of iron, manganese, and bauxite at the surface, and concentrated lower-grade hydrothermal deposits of barite.

Region 2

karst topography • a kind of landscape defined by bedrock that has been weathered by dissolution in water, forming features like sinkholes, caves, and cliffs.

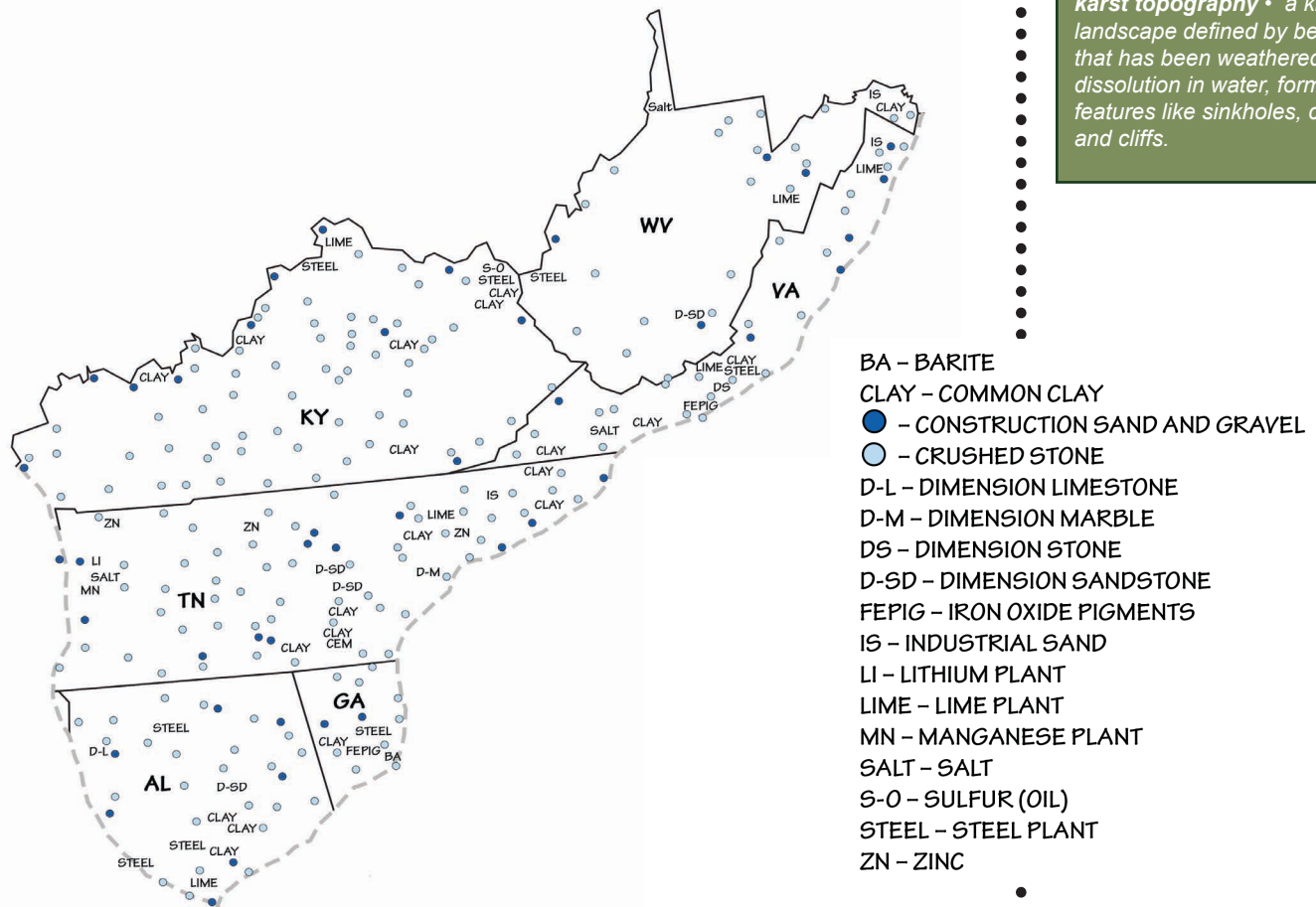
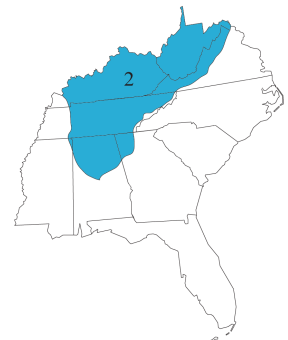


Figure 5.12: Principal mineral resources of the Inland Basin region.

Metallic Resources

Extensive deposits of lead, zinc, fluorite, and barite minerals occur in Cambrian and Ordovician dolostones along the eastern margin of the Valley and Ridge from south of Bethlehem, Pennsylvania, through western Virginia and eastern Tennessee, and into northern Georgia. These deposits generally developed as a result of hydrothermal fluids migrating through zones of higher permeability, **karst**, fractures, and faults. Important mining districts include the Mascot-Jefferson District in Tennessee and the Austinville-Ivanhoe District in Virginia (Figure 5.13). The lead and zinc works in southern Wythe County, Virginia, played a vital role in two early chapters in United States history. The Wythe County lead mines were opened in 1756 by Colonel John Chiswell, a British officer who discovered the lead deposits while hiding in a cave near the New



5



Mineral Resources

Region 2

Pennsylvanian • a subperiod of the Carboniferous, spanning from 323 to 299 million years ago.

River to escape pursuing Indians. The mines were an important source of lead shot ammunition for the Colonial Army during the American Revolution, and the workings were expanded from 1775 to 1781 to meet the growing demand of the Continental Army. The Wythe County mines were also a critical resource for the Confederacy during the Civil War—reports suggest that about 1.6 million kilograms (3.5 million pounds) of lead for bullet-making were produced at the mines during the Civil War, accounting for one-third of the estimated 4.5 million kilograms (10 million pounds) of lead consumed by the entire Confederacy in the manufacture of 150 million cartridges. Production ended on December 31, 1981, when the New Jersey Zinc Company permanently closed the mine, ending its 225-year run.

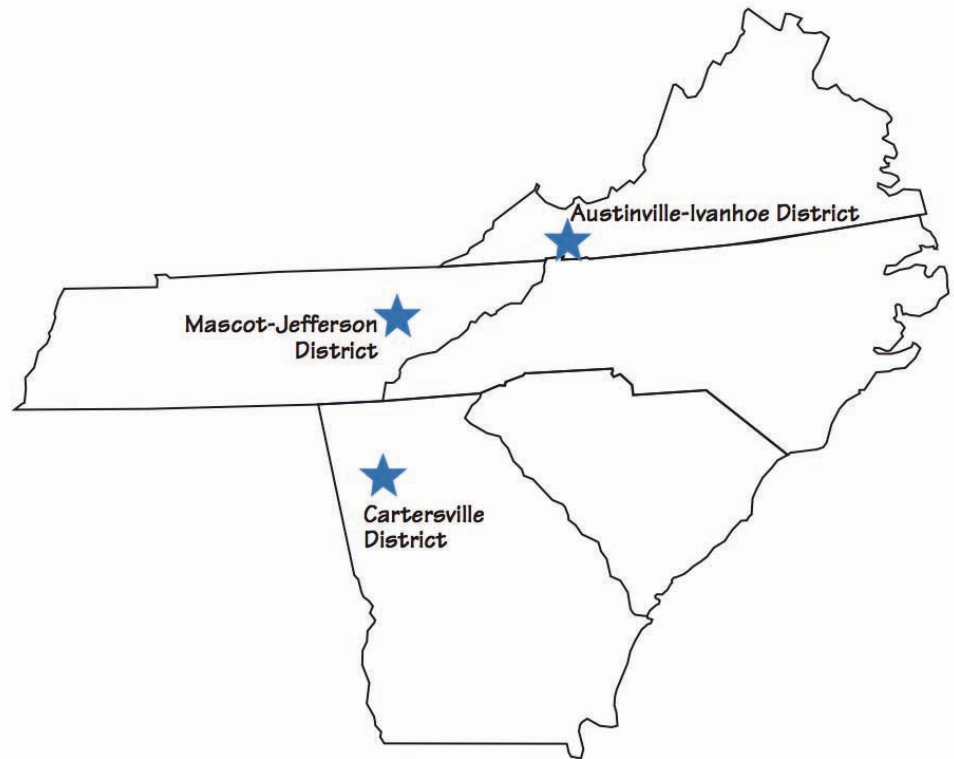
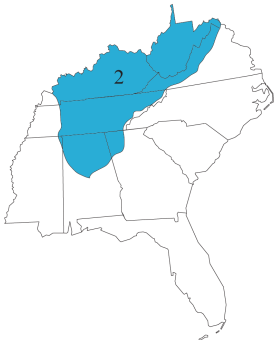


Figure 5.13: Significant lead, zinc, fluorite, and barite deposits are found in Virginia, Tennessee, and Georgia.



The last of Virginia's lead and zinc mines closed in 1984, but mining continues in eastern Tennessee, and barite is still extracted from lower grade lead-zinc deposits of the Cartersville District in northern Georgia (see Figure 5.13). These deposits vary widely in their relative proportions of lead and zinc sulfides, pyrite and chalcopyrite, and fluorite and barite.

Widespread deposits of sedimentary iron in the Inland Basin range in age from Cambrian to **Pennsylvanian**. The most extensive iron ore deposits in the Southeast are the middle Silurian Clinton Formation deposits (and their



Region 2

Mining

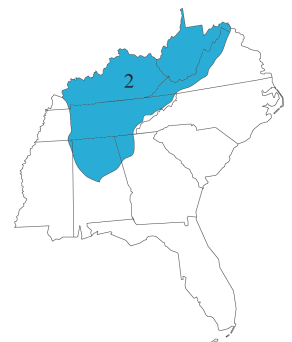
Mining is a profit-focused undertaking. The profitability of mining minerals or rocks depends on a number of factors, including the concentrations of recoverable elements or material contained in the deposit, the anticipated amount of the deposit that can be mined, its accessibility using current mining methods and technologies, its marketability, and lastly the cost of returning the site to its original state once the extraction phase of mining has ended (reclamation). All these factors determine the choice of mining method. Types of mining include underground (tunnel or shaft), surface (open pit or quarry), hydraulic operations (placer), solution using hot water, and seawater evaporation ponds. Once a mineral resource has been removed from the ground, the next step is to process it in order to recover its useful elements or to transform it so that it can be used in manufacturing or other industrial processes.

Modern mining is accomplished in three phases: exploration, extraction, and reclamation. Exploration is performed to determine the extent of the mineral resource and usually involves extensive use of drilling and geophysical techniques to determine the shape, size, and quality of the resource. Extraction involves removing the mineral resource from the ground. Reclamation is undertaken when mining ceases and is designed to restore the land to a condition where it can be used for other purposes. This last phase usually involves removing sources of contamination, which can be considerable depending on the scope of the mining activity.

equivalents) that extend along the eastern side of the Appalachian Basin from New York to Alabama (*Figure 5.14*). Iron weathered from the eroding Taconic Mountains was deposited in various forms along the edge of the ancient seaway to the west, and occurs as oxides, carbonates, and silicates in sandstones, **shales**, and limestones. Weathering increases the grade of the ores and makes them more easily mined. The Clinton iron ores are especially rich and

See Chapter 6: Energy to learn where coal is found in the Inland Basin, and how it formed.

shale • a dark, fine-grained, laminated sedimentary rock formed by the compression of successive layers of silt- and clay-rich sediment.



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Mineral Resources

Region 2

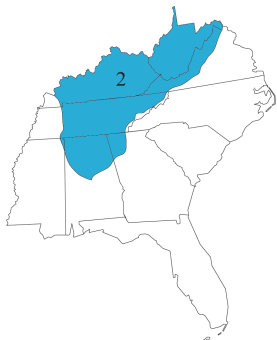
coal • a combustible, compact black or dark-brown carbonaceous rock formed by the compaction of layers of partially decomposed vegetation.

flux • a mineral added to the metals in a furnace to promote fusing or to prevent the formation of oxides.

commodity • a good for which there is demand, but which is treated as equivalent across all markets, no matter who produces it.

lime • an inorganic white or grayish-white compound made by roasting limestone (calcium carbonate, CaCO_3) until all the carbon dioxide (CO_2) is driven off.

soil • the collection of natural materials that collect on Earth's surface, above the bedrock.



thick near Birmingham, Alabama, where the dominant iron mineral is hematite. These iron deposits made Birmingham a major center of steel production (Figure 5.15), and about 375 million tons of hematite ore were mined there between 1840 and 1975. The success of the iron and steel industry around Birmingham was due to the thick, high-grade nature of the Clinton iron ore deposits, the close proximity of deposits of Pennsylvanian **coal** to fuel the blast furnaces, and the use of Cambrian and Ordovician limestone and dolostone as **flux** for smelting.

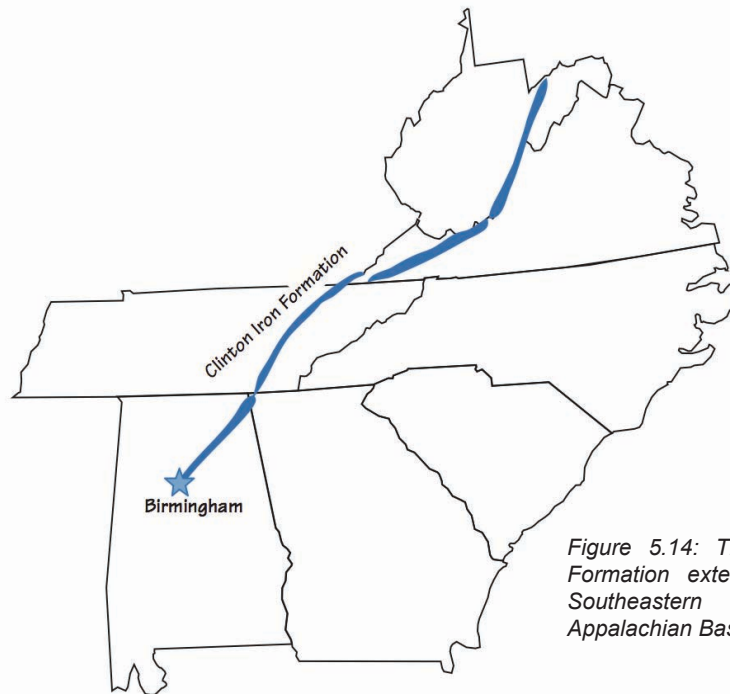


Figure 5.14: The Clinton Iron Ore Formation extends through several Southeastern states along the Appalachian Basin.



Figure 5.15: The furnace track at Sloss Furnaces National Historic Site in Birmingham, Alabama. The site was constructed in 1881, and by the end of its first year of operation it had sold 24,000 tons of iron. Most of the buildings and structures remaining on the site today date from 1900–1914. Sloss is the only 20th-century blast furnace preserved in the US as a historic industrial site.

Mineral Resources



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Numerous small secondary iron deposits occur throughout the Inland Basin. Most are the products of weathering, formed when iron oxide was concentrated as residuum from carbonate rocks that were chemically weathered and eroded away. Some iron deposits are gossans, residual iron oxide deposits formed by the weathering of sulfide deposits at the surface. Small deposits of both types were mined in every state in the Southeast during the 1700s and 1800s to supply local forges that turned out small quantities of iron and steel for local markets. The first iron furnaces in the Southeast were built around 1765 in Virginia. Small furnaces appear in North Carolina in 1780, Tennessee, and West Virginia in 1790, Kentucky in 1791, and Alabama in 1815.

Non-Metallic Resources

The Inland Basin's industrial minerals are some of its most valuable non-metallic resources (see Figure 5.12). Sand and gravel is used for aggregate, and common clay is collected for use in brick making. Paleozoic limestone and dolomite (dolostone), which form the bedrock across much of the Inland Basin, are quarried for crushed stone throughout the region. The Reed Quarry in Kentucky is one of the largest producers of crushed stone in the United States, and crushed stone has been Tennessee's leading mineral **commodity** (by value) for over 25 years. Most of this crushed stone is used for construction aggregate and for the production of **lime** and cement. Once considered a waste byproduct of crushed stone, lime has important uses in agriculture, where it is regularly applied to make the **soil** "sweeter" (less acidic). Lime is also used in steel making, water purification, sulfur removal from smoke stacks, sewage treatment, and paper manufacturing. Alabama and Kentucky are two of the top lime-producing states in the nation.

Local dimension sandstone and industrial sandstones are quarried in the eastern part of the region, within the Valley and Ridge. The quartz-rich Tuscarora and Oriskany sandstones are commonly mined and crushed for use as industrial sand because they are 98% silica, and therefore useful for glass manufacturing. These stones, abundant in West Virginia, have made the state one of the nation's leading glass manufacturers. Some **Mississippian** and Pennsylvanian sandstones also contain natural **bitumen**, or tar. These tar sands historically have been quarried for the natural **asphalt** they contain.

Extensive evaporite deposits formed during the late Silurian in a shallow tropical sea at the northern end of the Appalachian Basin, and are present below the surface in northern West Virginia. Natural brines present as ancient seawater trapped in **porous** sedimentary rocks (**aquifers**) are found throughout the Inland Basin and contain in excess of 15% dissolved salts within 610 meters (2000 feet) of the surface throughout eastern Ohio, western West Virginia, and northeastern Kentucky. Mississippian-aged halite deposits occur below the surface around Saltville, Virginia, where salt was first discovered in 1840 in a mineshaft at a depth of 66 meters (215 feet).

Halite is mined in two ways. When deposited in thick beds, this salt can be excavated by mechanically carving and blasting it out. This method, called "room and pillar" mining, usually requires that pillars of salt be left at regular intervals to prevent the mine from collapsing (Figure 5.16). Another method,

Region 2

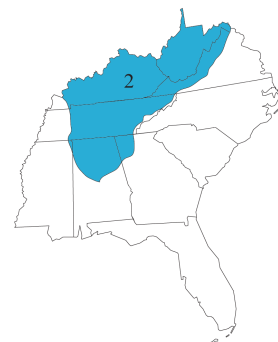
Mississippian • a subperiod of the Carboniferous, spanning from 359 to 323 million years ago.

bitumen • any of the various flammable mixtures of hydrocarbons and other substances.

asphalt • a black, sticky, semi-solid and viscous form of petroleum.

porosity • the percentage of openings in a body of rock such as pores, joints, channels, and other cavities, in which gases or liquids may be trapped or migrate through.

aquifer • a water-bearing formation of gravel, permeable rock, or sand that is capable of providing water, in usable quantities, to springs or wells.





Mineral Resources

Region 2

solution mining • the extraction of soluble minerals from subsurface strata by the injection of fluids.

salt lick • a naturally occurring salt deposit that animals regularly lick.

petroleum • a naturally occurring, flammable liquid found in geologic formations beneath the Earth's surface.

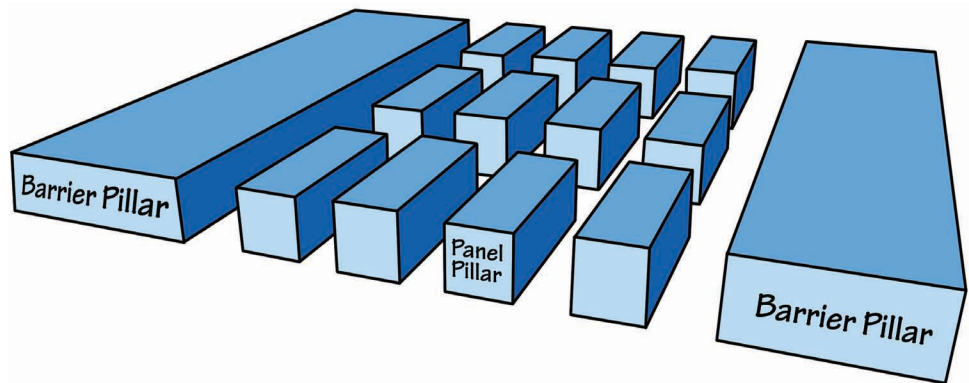
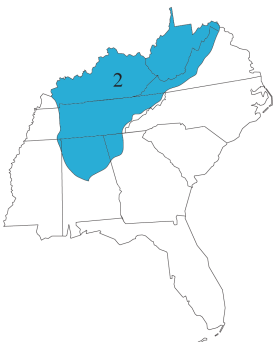


Figure 5.16: In pillar and room mining, the mine is divided up into smaller areas called "panels." Groups of panels are separated from one another by extra-large (barrier) pillars that are designed to prevent total mine collapse in the event of the failure of one or more regular-sized (panel) pillars.

Natural brine springs in the Kanawha Valley, near Charleston, West Virginia, formed **salt licks** that were extensively utilized by animals and later exploited by Native Americans, who boiled the brine to obtain salt. The Kanawha Licks near the town of Malden, West Virginia, became the center of a major colonial salt industry in the early 19th century (Figure 5.18). Salt, a powerful antibacterial, was a critical commodity for curing butter and meats in the absence of refrigeration.

Although it represents only a small fraction of total US salt production, the proximity of salt, coal, and **petroleum** resources with good railroad and river access has resulted in the growth of an extensive chemical industry in West Virginia along the Ohio River and in the Kanawha Valley, between Wheeling and Huntington. The Kanawha Valley salt industry reached a peak production of 113,638 cubic meters (3,224,786 bushels) in 1846, and was one of the largest salt manufacturing centers in the US. This brine industry declined in importance after 1861, but it was revitalized thanks to demand for chemical products during World War I, with the 1914 opening of the Warner-Klipstein Chemical Company plant in South Charleston to produce chlorine and caustic acid. West Virginia hosts three principal salt-producing companies: two in Marshall County and one in Tyler County. Most of the area's salt is now used by a

See Chapter 6: Energy for more about petroleum resources in the Inland Basin.



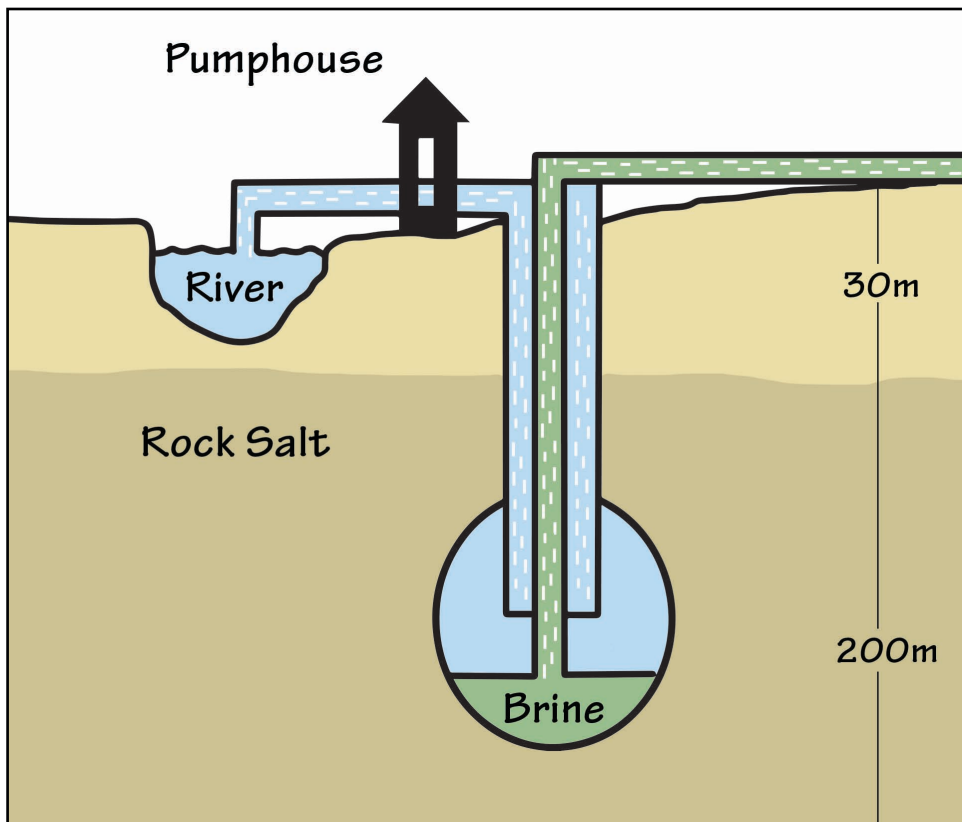


Figure 5.17: An example of solution mining that involves the pumping of fresh water through a borehole drilled into a subterranean salt deposit.

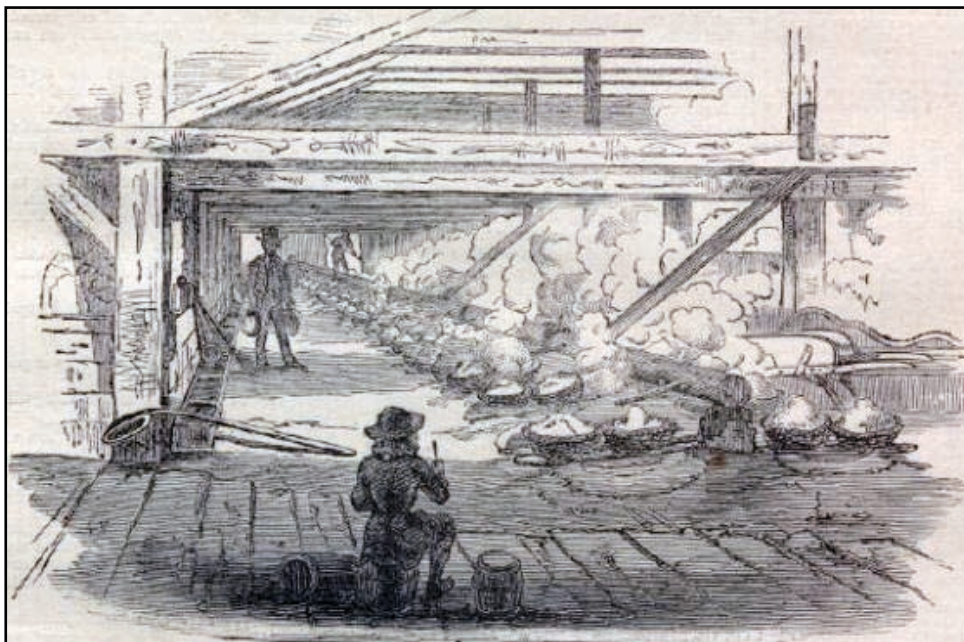
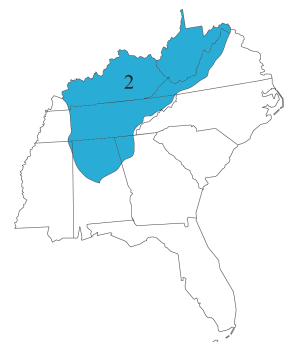


Figure 5.18: This 19th-century illustration depicts the boiling of brine-filled kettles to make salt during the Civil War.



5



Mineral Resources

Regions 2–3

Cretaceous • a geologic time period spanning from 144 to 66 million years ago.

Paleogene • the geologic time period extending from 66 to 23 million years ago.

Neogene • the geologic time period extending from 23 to 2.6 million years ago.

Quaternary • a geologic time period that extends from 2.6 million years ago to the present.

variety of chemical companies that have developed along the Kanawha River since that time. Today, the Westvaco Chlorine Products Corporation is the largest chlorine producer in the world.

Douglas Lake in Jefferson County, Tennessee, is known for distinctive quartz crystals called "Douglas Diamonds." During periods of water fluctuation, when expanses of the lake bottom are exposed, these crystals can be found scattered across the dry surface. The quartz precipitated from silica-rich hydrothermal solutions that flowed through fractures in the region's limestone and calcite bedrock; later weathering eroded the surrounding rock to expose these more resistant crystals (*Figure 5.19*).



Figure 5.19: Quartz crystals from Douglas Lake, Tennessee, also known as "Douglas Diamonds," on a 22-centimeter (8.5-inch) paper plate.



Mineral Resources of the Coastal Plain Region 3

The Southeast has been largely tectonically inactive for about 150 million years; weathering and erosion are the dominant geologic processes that have operated during this time. Most of the Coastal Plain has eroded to a gently tilted plain,

Mineral Resources



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where erosion and deposition around rivers and coastlines has formed numerous placer concentrations of heavy minerals. Fluctuating sea levels during the **Cretaceous, Paleogene, Neogene, and Quaternary** left thick, extensive sedimentary deposits throughout the region (Figure 5.20).

See Chapter 4: Topography to find out how erosion has influenced the Southeastern landscape.

Region 3

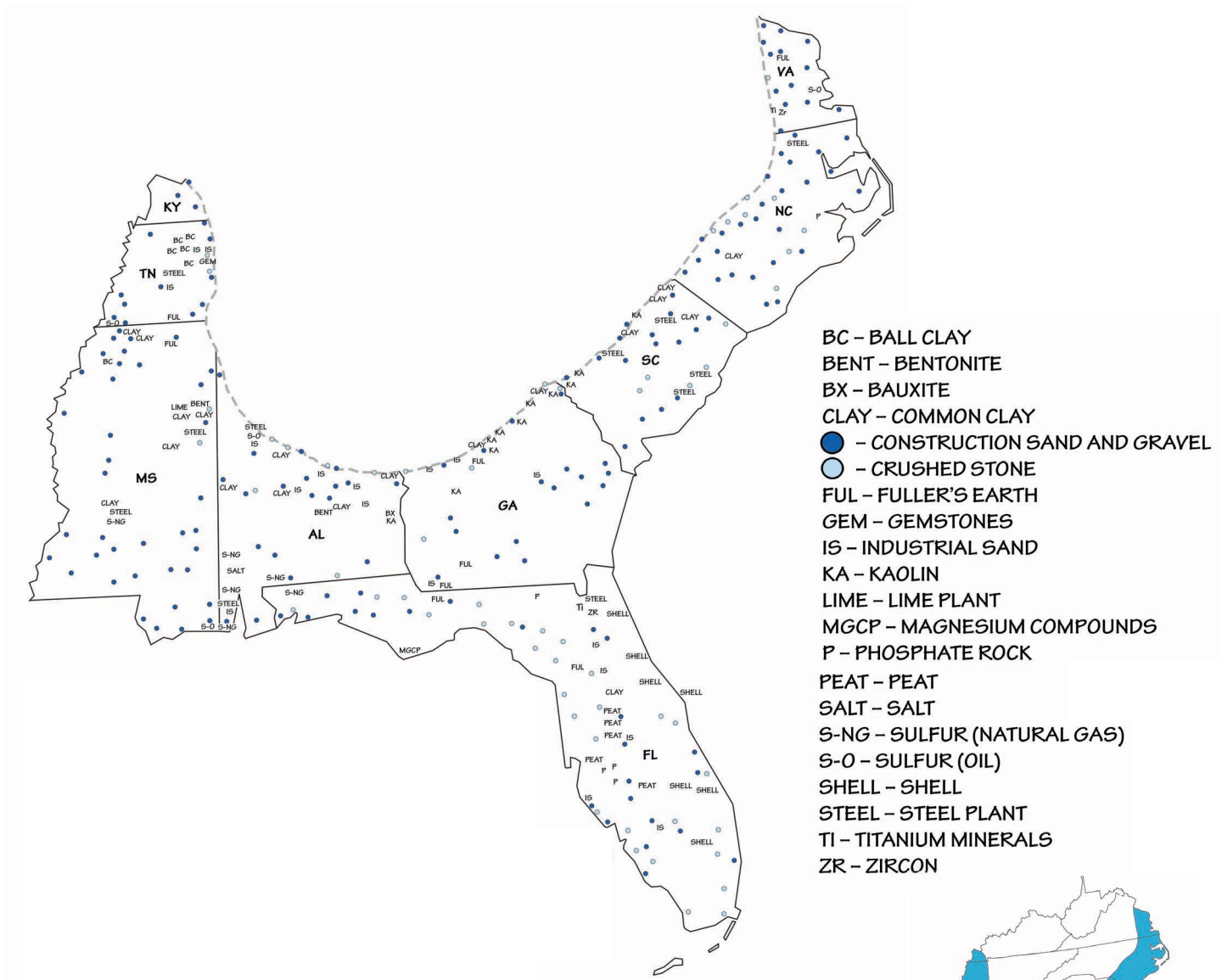


Figure 5.20: Principal mineral resources of the Coastal Plain region.



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Mineral Resources

Region 3

Metallic Resources

Although not mined commercially, numerous concentrations of heavy mineral sands have been identified in ancient river and beach deposits along the western margin of the Coastal Plain and offshore on the continental shelf. Deposits of rutile, ilmenite, monazite, zircon, and gold have been investigated in North and South Carolina. Although minor production has occurred in the past, these deposits are currently not economically viable to mine; some of them occur in environmentally sensitive or urban areas.

Bauxite is a residual product of weathering in the Coastal Plain's Cretaceous carbonate rocks, and bauxite deposits can be found in Georgia, Alabama, Tennessee, and Virginia. This clay-like mixture of several minerals is mined primarily as an ore of aluminum; most bauxite ore contains 45–55% aluminum oxide (*Figure 5.21*). The Southeast's bauxite deposits are generally small and of limited potential. Small-scale production has continued in Alabama to the present.



Figure 5.21: Bauxite is a rich aluminum ore, and the world's main source of aluminum. Specimen is 4.1 centimeters (1.6 inches) wide.



From the 17th to 19th centuries, iron foundries and steel mills in the Coastal Plain were fueled by "bog" iron ore mined from coastal swamps and Triassic basin coal. Steel mills of the late 19th and 20th centuries were more dependent on imported iron and coal, and tended to be near the ocean on navigable rivers, as their operation was heavily reliant on a considerable supply of fresh water.

Mineral Resources



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Non-Metallic Resources

The Coastal Plain is blanketed by sand and gravel that were eroded from the Appalachian Mountains and redistributed by rivers and the ocean. These materials (along with clay) are the dominant natural resource mined on the Southeast Coastal Plain because they are abundant along the coast, in rivers, and along river terraces. Sand and gravel are primarily used in construction, concrete, and road fill; the region also produces industrial sand. Sedimentary rock is not commonly exposed at the surface, but sedimentary bedrock is mined in many quarries where sediment and soil cover are thin. Limestone is quarried as a building stone, to make crushed stone used as construction aggregate, and in the manufacture of cement and lime. In some areas, Cretaceous and **Cenozoic** sediments at the surface have been sufficiently hardened for use as a dimension stone. For example, Alabama's Marianna Limestone, though soft enough to be cut with a saw, hardens upon exposure and was commonly used as a dimension stone. Because much of Florida was deposited as a carbonate platform, there are extensive carbonate (limestone and dolomite) resources near the surface. Florida is one of the top producers of crushed stone in the US, and annually leads the nation in the manufacture of masonry cement. Shell limestone (**coquina**) can also be easily cut into dimension stone, and was used as a building material in many of the historic buildings in St. Augustine, Florida, including the Castillo de San Marcos—the first permanent European settlement in the United States.

See Chapter 2: Rocks to learn more about coquina and its historic use in construction.

Six of the top ten clay producers in the US occur in the Southeast's Coastal Plain, with Georgia and South Carolina in the lead. Several types of clay are found in the region, each used for different purposes. Common clay is used in the manufacture of bricks, lightweight aggregate, cement, and other structural clay products—North Carolina is annually the US leader in brick production because of its common clay resources. Ball clay is a plastic clay, so named because it was rolled into balls during the days of hand mining. Ball clay is used as a bonding agent in the manufacture of ceramics and is common in the upper Mississippi River Embayment.

At one time, sheep's wool was cleaned through a process called "fulling" before it was spun. The wool was cleaned using an absorbent type of clay that became known as "fuller's earth." Dusting this clay through the sheep's wool absorbed dirt and grease, making the wool easier to spin.

Kaolinite is an earthy white clay, also known as "china clay," which is used in the manufacture of ceramics (including fine porcelain), as a paper coating, in refractories, and as an additive in rubber products, fertilizers, cosmetics, and detergents. Before the Revolutionary War, kaolinite from South Carolina was exported to England for the production of Wedgwood pottery and china. Deposits of kaolin clay occur along the western margin of the Coastal Plain

Region 3

Cenozoic • the geologic time period spanning from 66 million years ago to the present.

coquina • a porous, sometimes crumbly limestone, composed of fragments of shells and coral, and used as a building material.



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Mineral Resources

Region 3

bentonite • a clay, formed from decomposed volcanic ash, with a high content of the mineral montmorillonite.

volcanic ash • fine, unconsolidated pyroclastic grains under 2 millimeters (0.08 inches) in diameter.

wind • the movement of air from areas of high pressure to areas of low pressure.

Miocene • a geological time unit extending from 23 to 5 million years ago.

potash • a name used for a variety of salts containing potassium.

along a 480-kilometer-long (300-mile-long) trend from Aiken, South Carolina, through Macon, Georgia, to Eufaula, Alabama (*Figure 5.22*). These clays are formed from the weathering of the Piedmont's crystalline rocks, and occur as lenses in late Cretaceous- to Neogene-aged sediments. Mining of these deposits accounts for around 90% of total United States kaolinite production and 40% of global production. Fuller's earth is another type of earthy clay with a higher moisture content than other clays. Because it naturally absorbs water, it is used in the manufacture of kitty litter, as an adsorbent in refining oils, and as an additive to various types of pastes and putties.



Figure 5.22: Tailings from an old open-pit kaolin mine in Hitchcock Woods near Aiken, South Carolina.

Bentonite is currently mined in Mississippi and Alabama; it is altered **volcanic ash** that originated from Cretaceous volcanoes in the central and western US and was subsequently blown into the Southeastern US by prevailing **winds**. Bentonite is used in drilling muds and can be used as a sealant in instances where it is important to provide a barrier for water flow through rock or sediment.

Phosphate is present in Coastal Plain sediment along the Atlantic coast from the Chesapeake Bay to Florida. These deposits developed in deep ocean waters during the Neogene, where current and wave action concentrated phosphate-rich sediment that eventually hardened to become phosphate rock. Phosphates are used primarily to make fertilizers, but are also used in the manufacture of phosphoric acid, detergents, food additives, pesticides, soft drinks, and other products. The highest grade and most extensive deposits occur in the **Miocene** formations of North Carolina and Florida, which together account for about 95% of domestic production of phosphate and about half of global production. The



Mineral Resources



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Aurora phosphate operation at Lee Creek in Beaufort County, North Carolina is the largest integrated phosphate mining and chemical plant in the world. In fact, it is the world's largest **potash** producer and is capable of producing over six million tons of phosphate ore per year. Florida, however, contains the largest known deposits of phosphates in the US; the state provides two-thirds of the country's phosphate needs and nearly one quarter of the world's phosphates. Fertilizer is one of Florida's leading exports, with an annual value of over \$2 billion (Figure 5.23).



Figure 5.23: A phosphate fertilizer processing plant in Nichols, Florida.

Some of the largest swamps in the US are found in the Coastal Plain, including the Everglades of Florida, the Okefenokee Swamp of Georgia, and the Great Dismal Swamp of Virginia and North Carolina. Swamps, bogs, and marshes support abundant vegetation, thick piles of which accumulate as the plants naturally die and are buried by successive layers of dead plants. This creates a low-oxygen environment in which the plant material is not being decomposed. As the layers are buried deeper, they are **compressed** into **peat** (with further compression and much longer spans of time, the organic material becomes **lignite** and then coal). Peats produced in these swampy environments are a valuable resource, and Florida is the top peat producer in the country. Peats are used in potting soil, as a soil conditioner, as insulation for packing fruits and vegetables, and as a protein additive in cattle food.

Thick salt sequences, related to the early rifting of Pangaea and the formation of the Gulf of Mexico during the Triassic and Jurassic periods, underlie much of the Gulf Coast. However, salt is currently only mined in Alabama. Sulfur is produced from sources associated with **salt domes** along the Gulf Coastal Plain, and as a byproduct from the processing of oil and gas.

Region 3

compression • flattening or squeezing as a result of forces acting on an object from all or most directions.

peat • an accumulation of partially decayed plant matter.

lignite • a soft, brownish-black coal in which the alteration of plant matter has proceeded farther than in peat but not as far as in bituminous coal.

salt dome • a largely subsurface geologic structure, consisting of a vertical cylinder of salt embedded in horizontal or inclined sedimentary strata.





Resources

Resources

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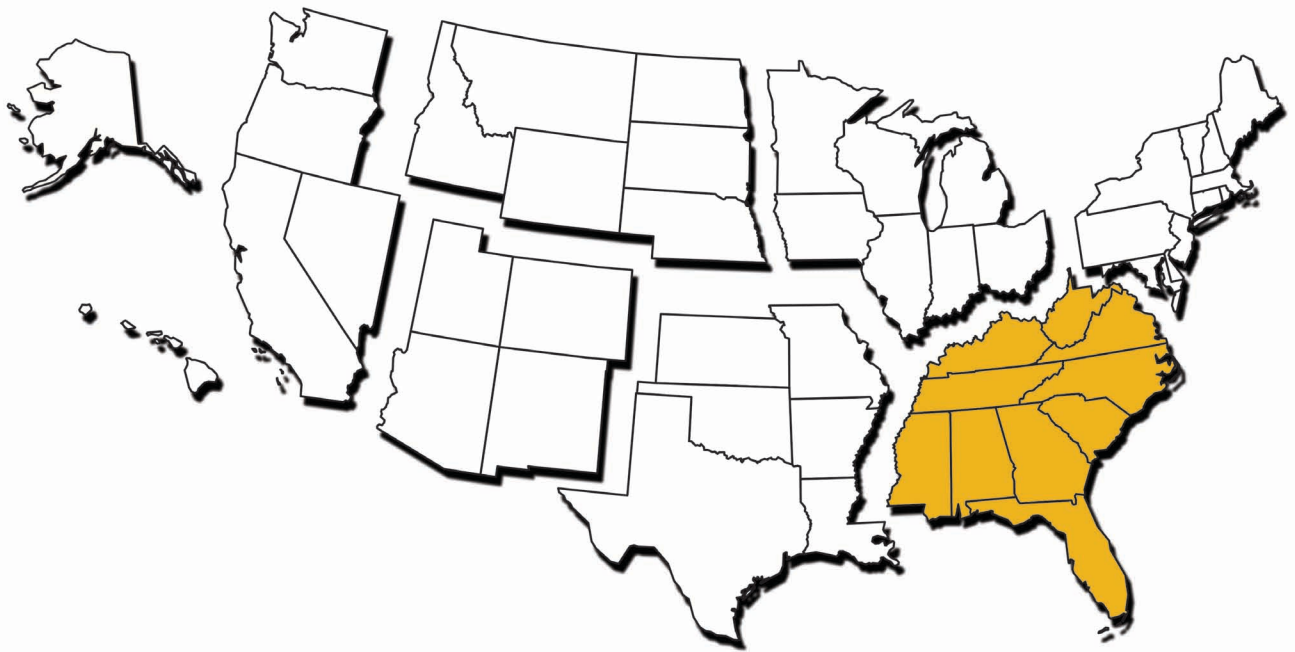
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Resources

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