Mineral Resources of the Southeastern US:
a brief review

A mineral is a naturally occurring solid with a definite chemical composition and crystalline structure that is formed through inorganic processes. Minerals are literally the foundations of our everyday world. Not only do minerals make up the rocks we see around us in the Southeast, they are used in nearly every aspect of our lives. The wide variety of 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.

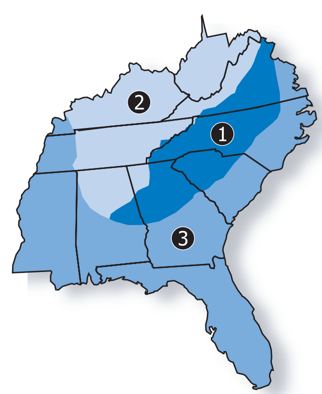
Southeast mineral resources contributed significantly to Colonial economies, the struggle for independence, and the rise of the United States as a world power. The first metal mining by Europeans in the United States was in 1621 at a lead deposit in Virginia. The same deposits supplied shot for the Continental Army during the American Revolution, and were a point of contention during the Civil War. The first gold rush in North America spread across the southern Appalachian Piedmont from a small farm in central North Carolina in the early 19^{th} ***Century.***

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

Processes Forming Mineral Deposits

All of the 92 naturally occurring elements are present in the Earth's crust, but many of them at very low average concentrations. Elements such as copper (Cu), lead (Pb), zinc (Zn), and even silver (Ag) and gold (Au) are not rare, but they are usually widely dispersed through the rocks. Elements are the building blocks of minerals, and ***minerals are the building blocks of rocks***. The mineral quartz, for example, is made of the elements silicon and oxygen; quartz 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 (Au).

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. Sandstone may be made of cemented grains of feldspar, quartz and mica. The minerals and the connections among the crystals define the color and resistance to weathering of a rock.*



Mineral Resources

Quartz

Quartz may be one of the most common minerals in the crust, but it does not always appear in the same form. There are a wide variety of different types of quartz, including coarsely crystalline and microcrystalline quartz. Onyx, agate, jasper, flint, chert, and petrified wood are microcrystalline varieties of quartz. Though agate is naturally banded with layers of different colors and porosity, commercial varieties of agate are often artificially colored. The most common, coarsely crystalline varieties include massive quartz veins, the distinct, well-formed crystals of 'rock crystal', and an array of colored quartz, including amethyst (purple), rose quartz (pink), smoky quartz (gray), citrine (orange), and milky quartz (white).

Eight elements make up (by weight) 99% of the Earth's crust, with oxygen being the most abundant (46.4%) *(Figure 6.1).* Since silicon (Si) and oxygen (O) are by far the most abundant elements in the crust by mass, it makes sense that ***quartz*** (SiO_2, silicon dioxide or silica) is one of the most common minerals in the Earth's crust and is found all over the Southeast.

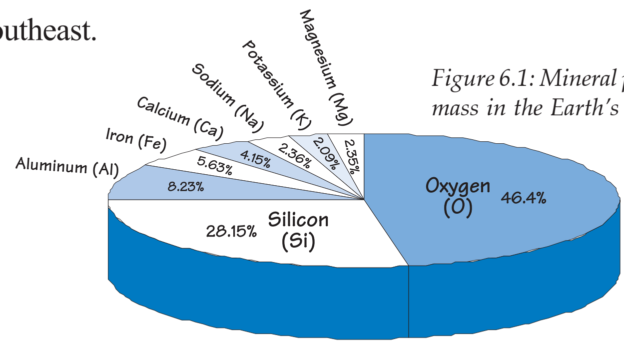


Figure 6.1: Mineral percentage by mass in the Earth's crust.

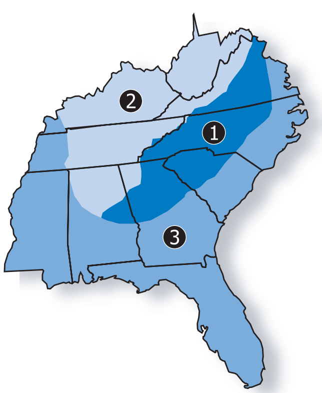
The average amount of aluminum (Al) in the crust is around 8%. **Ore** *grade deposits are about 25% to 30% aluminium, a concentration of 3-4 times the average aluminium abundance in the crust. The amount of copper (Cu) in the crust is 0.006%. Copper ore deposits have grades of 0.6% to 1.2% at 100-200 times the average abundance of copper in the crust. Minable gold deposits have grades as low as 0.1 ounce gold per ton of ore, or about 0.003%. Ore grade gold deposits have a concentration of1500 times the average crustal abundance of 0.0000002%.*

The remaining elements in the Earth's crust occur in very small amounts, some in concentrations of only a fraction of one percent. Many metallic minerals occur in extremely small amounts in the crust. A mineral is called an ***ore*** when one or more of its elements can be profitably removed. It is almost always necessary to process ore minerals in order to get the useful element.

Metallic vs. Non-Metallic minerals

Luster refers to the appearance of the mineral surface in reflected light. **Metallic minerals** *have a luster like an aluminum pan or a dull metal like a rusty nail. Metallic minerals are vital to the machinery and technology of modern civilization.* **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. Generally much lighter in color than metallic minerals, non-metallic minerals can transmit light, at least through pieces or edges.*

What distinguishes a regular mineral from a gem? Beauty, durability and rarity of the 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. Most gems, including tourmaline, topaz, and corundum, are durable because they are hard (scratch-resistant.) On the ***Mohs Scale of Hardness***, the majority of gemstones are greater than 7. A gem's value is also dependent on the rarity of the mineral. With limited supply (commercially or in nature), the value of a gem increases significantly, such as with rubies or diamonds. Quartz may have a brilliant luster and be quite durable, but it is extremely common. Therefore, quartz has significantly less value as a gemstone, though some microcrystalline and colored varieties of quartz have moderate value.



Mohs Scale of Hardness

In 1824, the Austrian mineralogist, F. Mohs, selected ten minerals to which all other minerals could be compared to determine relative hardness. The scale became known as Mohs scale of hardness, and is very useful as a means for identifying minerals or quickly determining hardness. A piece of glass has a hardness of approximately 5 on the scale; your fingernail is just over 2. Hardness is important because it helps us understand why some rocks are more or less resistant to weathering and erosion. Quartz (7) is a relatively hard mineral, but calcite (3) is significantly softer. Therefore, it should be no surprise that quartz sandstone is more resistant to erosion and weathering than a limestone, the primary constituent of which is the mineral calcite.

The mineral deposits of the Southeast range in age from over 1 billion years old to just a few thousands or tens of thousands of years. The various mineral deposits are related to different types of geologic processes operating in different geologic environments. First, let's consider the processes by which mineral deposits form. Forming economically recoverable mineral deposits requires processes that can selectively remove desirable elements from up to several cubic miles of rock and concentrate them in an area of a few thousand cubic yards. These processes may be physical or chemical, and fall into four categories:

1. Magmatic Processes:

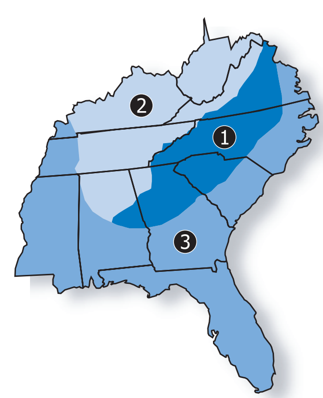
Processes that **segregate** *minor components of magma and* **concentrate** *them in a small volume of rock. This may involve early crystallization of ore minerals from the magma while most other components remain molten, or late crystallization after most other components have crystallized (Figure 6.2).*

Figure 6.2: Magmatic processes segregate minor components of magma and concentrate them in a small volume of rock.

Magmatic processes responsible for the formation of mineral deposits in the Southeast are associated with a wide variety of igneous intrusions (formed during mountain building events, rifting and volcanic activity), ranging in composition from granite to gabbro. Metamorphism may also cause recrystallization of minerals. Under conditions of very high temperature metamorphism, minerals with the lowest melting temperatures in the crust may melt to form small quantities of **pegmatite** *magmas. Pegmatites throughout the Blue Ridge and Piedmont are mined for silica, mica, feldspar, and locally for gemstones.*

Pegmatites

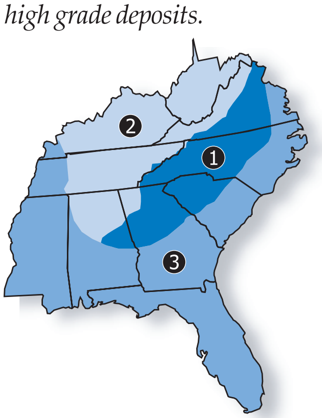
Pegmatites are very coarse-grained igneous rocks that formed below the surface usually rich in quartz, potassium feldspar, and muscovite mica. Pegmatite magmas are very rich in water, carbon dioxide, silicon, aluminum, and potassium, and form as the last fluids to crystallize from magma or the first minerals to melt at high temperatures during metamorphism. Individual crystals may be less than an inch to as much as 10-feet across, and rarely up to 30 or 40 feet. Pegmatites are commonly rich in a wide range of rare "incompatible elements" that do not fit readily into the crystal structure of most rock-forming minerals. These elements include boron (B), beryllium (Be), lithium (Li), tin (Sn), tungsten (W), phosphorus (P), and uranium (U), as well as base metals (Cu, Pb, Zn) and precious metals (Au, Ag). These elements commonly form unusual silicate, oxide, carbonate, phosphate, and sulfide minerals. Pegmatite deposits of both types are abundant throughout the Southeast Blue Ridge and Piedmont.



Mineral Resources

Hydrothermal fluids *migrate through the Earth's crust along fractures and faults or through porous and permeable rocks. These fluids react chemically with the rocks they come into contact with, changing the composition of the rock and that of the hydrothermal fluid. As hydrothermal solutions cool, their dissolved minerals crystallize in rocks or in veins. Dissolved minerals may also precipitate due to chemical reactions with adjacent rocks, especially highly reactive rocks like limestone and dolostone.*

*"***Grade***" refers to mineral concentration in a rock or sediment. Low grade mineral deposits have relatively lower concentrations of valuable minerals in a rock, vein, or sediment. Low grade deposits are often concentrated further by hydrothermal fluids to become high grade deposits.*



2. Hydrothermal Processes:

Processes involving **hydrothermal solutions** *(hot water) that* **extract** *(dissolve) minor elements dispersed through large volumes of rock,* **transport** *them to a new location, and* **precipitate** *them in a small area at much higher concentration. Hydrothermal solutions are commonly saline, acidic, and range in temperature from over 600°C to less than 60°C.*

They are formed through a variety of processes, in a variety of environments, and have a wide variety of compositions, but many are composed in large part of groundwater or seawater. The hydrothermal fluids are released from rock or magma during volcanism, metamorphism, igneous intrusions and mountain building events, and migrate through cracks and pores in surrounding rocks. (Figure 6.3). In addition, these hot water solutions commonly carry a high dissolved load of elements that vary with their temperature and chemistry. Some of these fluids may travel very long distances through porous sedimentary rocks.

Figure 6.3: Formation of hydrothermal solutions and subsequent mineral deposits.

3. Sedimentary Processes:

Processes that **extract** *elements dispersed through large volumes of* **water** *and* **precipitate** *them in a small area at much higher concentration (such as in layers of sediment on the ocean floor.) (Figure 6.4)*

Sedimentary mineral deposits form by direct precipitation from seawater, and in the Southeast include evaporite salt deposits of West Virginia and the Clinton iron deposits of Alabama.

4. Weathering and Erosion:

Processes that **remove** *large volumes of rock by physical and chemical breakdown, and* **concentrate** *previously dispersed elements or minerals as a* **residuum** *(Figure 6.5).*

· **Placer deposits**– *Mineral deposits formed by concentration of sediments in streams or in coastal areas. Examples include gold, rutile, and monazite placer deposits that occur throughout the Southeast such as a river that carries sediment downstream but leaves behind in concentration heavy minerals such as gold.)*

· **Residual weathering deposits** – *Mineral deposits formed by concentration of a mineral resistant to weathering while other minerals are eroded and dissolved. The erosion of areas of small, low grade gold veins and the concentration of the gold as stream sediment or residual weathering deposits produced hundreds of placer deposits that were mined throughout the Southeastern Piedmont during the 19th Century. Weathering and erosion have also been important in producing ore* **grade** *barite deposits in the Georgia Cartersville District, titanium placer sands in the North Carolina piedmont, and phosphate deposits of the North Carolina and Florida Coastal Plain.*

Many Southeastern mineral deposits are the products of several different concentration processes, sometimes operating tens or hundreds of millions of years apart. Many of the gold deposits of the Southeastern Piedmont initially formed by hydrothermal processes, but at very low grades. Subsequent metamorphism and deformation in the region concentrated these low grade deposits together to produce high grade vein deposits, as in the Dahlonega District of Georgia. Weathering and erosion then further concentrated the gold in surface deposits that were even higher grade and more easily mined.

Common rock-forming minerals

There are over 3,500 different minerals identified in the world, and a wide variety occur in the Southeast. However, the number of common rock-forming minerals is much smaller. The most common minerals that form igneous, metamorphic and sedimentary rocks (and the ones that you will most commonly see) include quartz, feldspar, micas, pyroxenes and amphiboles. Though quartz occurs in several colors, it is most commonly white, gray or clear. Feldspar may be a variety of colors, including pink, white, and black or gray. Mica, a thinly sheeted, flaky mineral, is most commonly either light in color (muscovite) or black (biotite). Pyroxene and amphibole are dark green to black, generally needle-like crystals.

Environments Where Mineral Deposits Form

There are a variety of geologic environments in which these mineral- depositing processes have operated over the past billion years to produce the abundance and diversity of mineral deposits found in the Southeast today, including:

see Geologic History and Rocks chapter for more on these **environments.**

- Rift basins ***(Late Proterozoic and Mesozoic)***
- Passive continental margins ***(Precambrian-Cambrian and Jurassic-Present)***
- Volcanic island arcs ***(such as the Taconic volcanic islands and Avalon Terrane in the Ordovician and Devonian respectively.)***
- Mountain building events ***(Grenville, Taconic, Acadian, Alleghanian)***
- Basins **formed by mountain building events *(ex. Paleozoic Appalachian Basin)***

Distribution of Mineral Deposits in the Southeast

Now let us put it all together, the various types of processes that form mineral deposits and the different geologic environments that have characterized the Southeast over the past 1 billion years. We'll take it step by step, looking at each geologic region; it's geologic history, the processes that have formed mineral deposits, and some examples of those deposits.