Minerals

Designed to meet South Carolina Department of Education 2005 Science Academic Standards

Department of Natural Resources

South Carolina Geological Survey

SOUTH CAROLINA GEOLOGICAL SURVEY 1825

Table of Contents

- What is a Mineral? (slide 3) (Standards: 3-1.1 ; 3-3.2)
- Chemical Composition and Internal Structure of Minerals (slide 4)
- How do Minerals Grow? (slide 5)
- Mineral Properties (slide 6-20) (Standards: 3-1.1 ; 3-3.2)
  - Crystal Form (slide 7 , slide 8, and slide 9)
  - Hardness (slide 10-13) (Slide 12 -13: Standards: 3-1.4 ; 3-1.7 ; 4-1.3 ; 4-1.4 ; 4-1.6 ; 5-1.1; 5-1.2; 5-1.3; 5-1.6; 5-1.8)
    - MOHS Scale of Mineral Hardness (slide 11)
    - How to Measure a Minerals Hardness (slide 12)
    - Determining Approximate Hardness (slide 13)
  - Color (slide 15)
  - Streak (slide 16)
  - Cleavage (slide 17 and slide 18)
  - Fracture (slide 19)
  - Specific Gravity (slide 20)
- Mineral Classification (slide 21)
  - Silicates (slide 22)
  - Native Elements (slide 23)
  - Halides (slide 24)
  - Carbonates (slide 25)
  - Oxides (slide 26)
  - Sulfates (slide 27)
  - Sulfides (slide 28)
- South Carolina Mineral Resources (slide 29)
- Household Uses of Common Minerals (slide 30)
- South Carolina Science Academic Standards (slide 31, slide 32, slide 33, and slide 34)
- Resources and References (slide 35)

What is a Mineral?

A mineral:

- is a naturally occurring inorganic crystalline solid
- has an ordered internal arrangement of atoms
- has specific physical properties that are either fixed or that vary within some defined range.
- has a definite chemical composition that may vary within specific limits

Quartz Amethyst

Amethyst is South Carolina's state mineral.

Chemical Composition and Internal Structure of Minerals

- Elements are the building blocks of minerals.
- Some minerals exist as single elements; however, most minerals consist of a combination of several elements joined by a chemical bond to form a stable mineral compound.
- Elements chemically bond to one another when their atoms gain, lose, or share electrons with other elements.
- Ionic bonds occur when valence electrons are transferred from one atom to another, constituting a respective gain or lose between one or the other atom.
- Covalent bonds occur when atoms from different elements share their valence electrons with one another to form a chemically stable bond.
- In addition to ionic and covalent bonds, other bonds can also occur through various combinations of transferred and shared electrons.
- Of the 112 elements, only 92 are naturally occurring.
- Nearly 4,000 minerals are identified on the planet Earth, and new minerals continue to be discovered all the time.

How Do Minerals Grow?

- New minerals are forming everyday on the Earth's surface, in the Earth's crust, and deep within the Earth's interior.
- Minerals form from molten rock and volcanic magma within the Earth's interior and crust. In these environments, changes in temperature and pressure and chemical composition influence the type of minerals which form, the size of their individual crystals, and their growth rate.
- Minerals grow from saturated solutions in rock cavities. Differences in temperature, chemical composition, and the saturation content of the solution influence the type of minerals which form, the size of their individual crystals, and their growth rate.
- The arrangement of atoms during crystal formation determines what the mineral will be and what crystal shape it will have.
- The crystal form is one of several characteristics that Geologists use to identify different minerals.

Mineral Properties

Minerals have distinctive physical properties that geologists use to identify and describe them.

There are 7 major physical properties of minerals:

- 1. Crystal Form
- 2. Hardness
- 3. Luster
- 4. Color
- 5. Streak
- 6. Cleavage
- 7. Specific Gravity

A variety of different minerals.

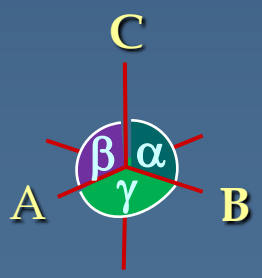
Crystal Form

- Crystal form is the external expression of the internally ordered arrangement of atoms.
- During mineral formation, individual crystals develop well-formed crystal faces that are specific to that mineral.
- The crystal faces for a particular mineral are characterized by a symmetrical relationship to one another that is manifest in the physical shape of the mineral's crystalline form.
- Crystal forms are commonly classified using six different crystal systems, under which all minerals are grouped.

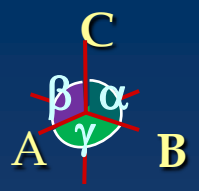
The six major crystal forms:

1. **Isometric (Cubic)**
2. **Tetragonal**
3. **Orthorhombic**
4. **Hexagonal**
5. **Monoclinic**
6. **Triclinic**

Axes and Angles



Standard 3-3.1
Standard 3-3.2

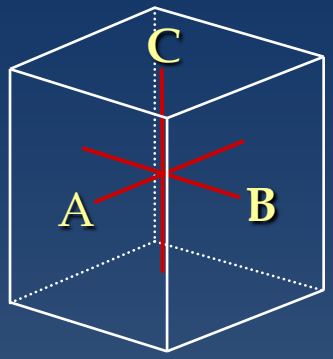


Crystal Form, cont.

❖ Isometric:

Isometric crystals are block shaped with relatively similar and symmetrical faces. The crystal form has three axes all at 90° angles and all the same length.
Mineral Example: Pyrite

Axes Length Relationships: A = B = C
Angles: $\alpha = \beta = \gamma = 90°$



Isometric: Pyrite

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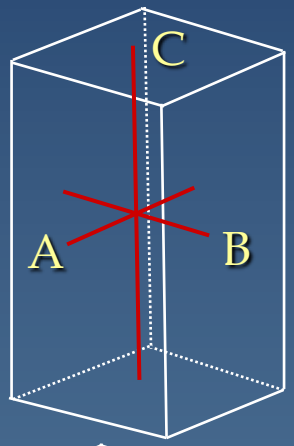
❖ Tetragonal:

Tetragonal crystals are shaped like four-sided pyramids or prisms. The crystal form has three axes that are all perpendicular to one another. Two axis have the same length, and one is different. The axes that are the same length lie on a horizontal plane, with the third axis at a right angle to the other two.
Mineral Example: Zircon

Axes Length Relationships: A = B ≠ C
Angles: $\alpha = \beta = \gamma = 90°$



Tetragonal: Zircon

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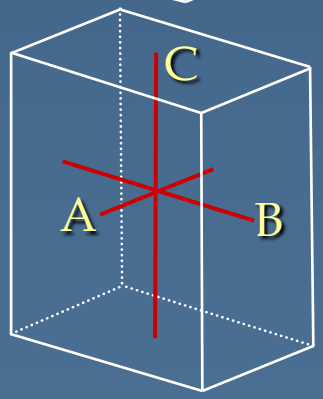
❖ Orthorhombic:

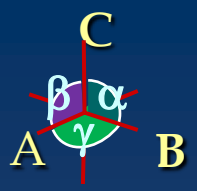
Orthorhombic crystals are shaped like a rectangular prism with a rectangular base. The crystal has three axes of different lengths and intersect at 90° angles.
Mineral Example: Topaz

Axes Length Relationships: A ≠ B ≠ C
Angles: $\alpha = \beta = \gamma = 90°$



Orthorhombic: Topaz

Photo Courtesy USGS



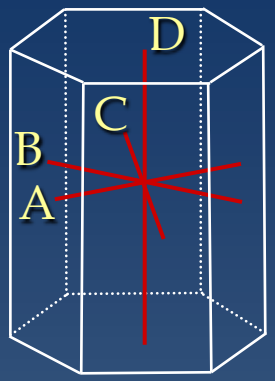
Crystal Form, cont.

❖Hexagonal:

Hexagonal crystals have three symmetrical axes that occur in the same plane and are all the same length. The fourth axis may be either longer or shorter, and it intersects the other three axis at 90° angles. The sides intersect at 120 ° angles. Mineral Example: Amethyst

Axes length Relationships: A = B = C ≠ D

Angles: $\alpha = \beta = 90°$ and $\gamma = 120°$



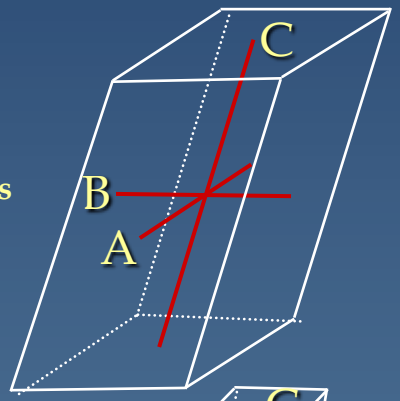
Hexagonal: Amethyst

❖Monoclinic:

Monoclinic crystals are short and stubby with tilted faces. Each crystal has three axes that are unequal. Two of the axes lie in the same plane at right angles to each other, the third axis is inclined. Mineral Example: Gypsum

Axes Length Relationships: A ≠ B ≠ C

Angles: $\alpha \neq \gamma = \beta = 90°$



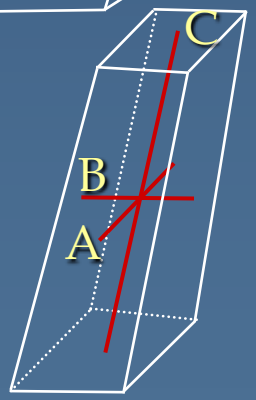
Monoclinic: Gypsum

❖Triclinic:

Triclinic crystals have three axis which are all different lengths and all three axis intersect at angles other than 90°. Mineral Example: Kyanite

Axes Length Relationships: A ≠ B ≠ C

Angles: $\alpha \neq \beta \neq \gamma$



Triclinic: Kyanite

Standard 3-3.1
Standard 3-3.2
Standard 3-3.14
Standard 3-3.17

Hardness

- Hardness is the ability of a mineral to resist abrasion or scratching on its surface.
- One way geologists measure hardness is using a relative scale referred to as Moh's scale of mineral hardness which ranks 10 common minerals along a scale from 1-10 (1 refers to the softest minerals while 10 refers to the hardest mineral).
- Geologists measure a mineral's hardness by scratching the surface of a mineral using minerals of known hardness, or by scratching the surface using a variety of other hardness indicators such as fingernails, pennies, or glass.

Talc

Talc is a soft mineral that you can scratch with your fingernail, and has a hardness of "1" measured by Moh's relative scale of mineral hardness.

Moh's Scale of Mineral Hardness

Hardness of Common Minerals:

Softest
- 1-Talc
- 2-Gypsum
- 3-Calcite
- 4-Fluorite
- 5-Apatite
- 6-Orthoclase
- 7-Quartz
- 8-Topaz
- 9-Corundum

Hardest
- 10-Diamond

Common Scratching Tools:

....your fingernail has a hardness of 2.5

....a penny has a hardness of about 3.5

....glass and a steel nail have nearly equal hardness of 5.5

....a streak plate has a hardness of 6.5

Standard 3-3.1
Standard 3-3.2
Standard 4-1.3
Standard 4-1.4
Standard 4-1.6

Measuring a Mineral's Hardness

Standard 5-1.1
Standard 5-1.2
Standard 5-1.3
Standard 5-1.6
Standard 5-1.8

Students can conduct the following experiment to measure a mineral's hardness:

- Hold the specimen firmly and attempt to scratch it with the point of an object of known hardness. In this example, we use a nail (H=5.5).
- Select a fresh, clean surface on the specimen to be tested.
- Press the point of the nail firmly against the surface of the unidentified specimen.
- If the "tool" (in this case the nail) is harder, you should feel it scratching into the surface of the specimen.
- Look for an etched line. It is a good idea to rub the observed line with your finger to ensure that it is actually etched into the surface of the specimen.
- Because the specimen was scratched by the nail, we know its hardness is less than that of the nail-less than (H<5.5).
- If there is any question about the result of the test, repeat it, being sure to use a sharp point and a fresh surface.

In this exercise students will make observations to infer a minerals hardness, but before they measure the hardness, the students can predict what hardness they think it might be.

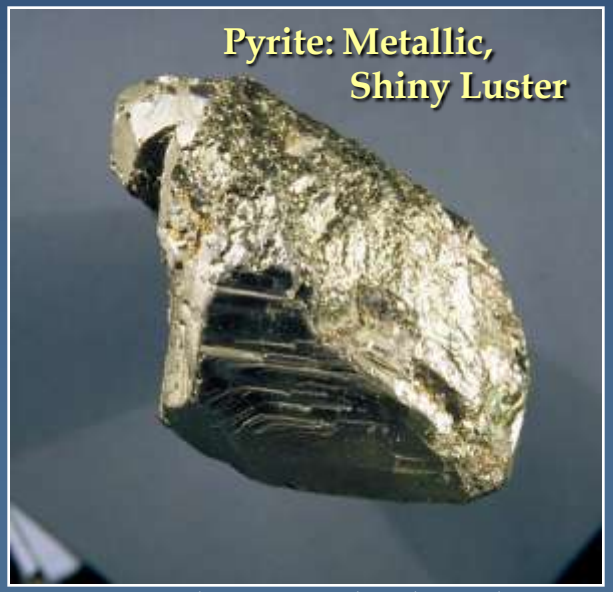
- **Observations:** the assimilation of knowledge through senses or collection of data using an instrument
- **Predictions:** a statement that a particular outcome will occur on the basis of evidence or reasoning
- **Inferences:** the process of making a conclusion based on observations

Approximating Hardness

- Take the unknown mineral and attempt to scratch with your fingernail (H=2.5), copper penny (H=3.5), a glass plate (H=5.5), and a streak plate (H=6.5).
- If the mineral scratches any of the materials, then it is harder than that material.
- If it scratches your fingernail and not the penny, than the hardness is between 2.5 and 3.5, probably 3.0.
- By this process, we can determine the approximate hardness of the unknown mineral.
- We do not need to know the exact hardness of the mineral because we will use other physical properties to refine the identification.

Luster

- Luster refers to how light is reflected from the surface of a mineral.
- There are two main types of luster: metallic and non-metallic:
  - Minerals with a metallic luster are described as shiny, silvery, or having a metal-like reflectance.
  - Non-metallic minerals may be described as resinous, translucent, pearly, waxy, greasy, silky, vitreous/glassy, dull, or earthy
- Luster may be subjective, and thus is not always a reliable identifier

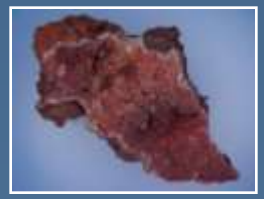


Color

- Mineral color is determined by how the crystals absorb and reflect light. Although color is easy to recognize, it is often misleading.
- Minerals, such as quartz, fluorite, halite, and calcite occur in a wide variety of colors, and other minerals, such as olivine, malachite, and amphibole have fairly distinctive colors.
- Variations in a mineral's color may be the result of impurities in the atomic structure of the crystal or the presence of a particular chemical when the crystal formed.
- Because some minerals can occur in several colors, color is generally not a good characteristic for describing and identifying minerals.

Different Colors of Calcite

Image courtesy of the USGS



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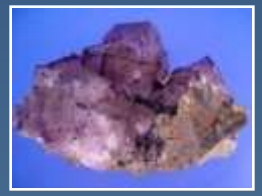
Different Colors of Fluorite



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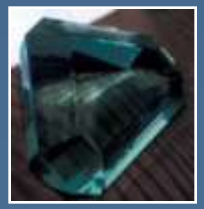

Image courtesy of the Albert Copley Oklahoma University Archives

Different Colors of Quartz

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Streak

- Streak refers to the color of a mineral's powdered form left behind after it is scraped or rubbed across a porcelain streak plate.
- A mineral may appear one color and then produce a streak with a different color.
- A mineral's streak color is a more reliable identification characteristic than the minerals perceived surface color.

Photo: SCGS

Even though the mineral pyrite is gold in color, it leaves a grey "pencil lead" streak on the porcelain streak plate.

Cleavage

- Cleavage refers to the tendency of a mineral to break along planes of weakness in the chemical bonds, or along planes where bond strength is the least.
- Some minerals break along one dominant plane of cleavage producing parallel sheets, where as others may break along two or more planes of cleavage, producing blocks or prism shapes.
- Not all minerals have distinct planes of weakness that produce cleavage, but those minerals that do, will consistently produce predictable cleavage planes.

Cleavage, cont.

- One direction of cleavage (one plane)
  - Mineral Example: Micas (muscovite)
- Two directions of cleavage (two planes)
  - Mineral Example: Feldspar
- Three directions of cleavage (three planes)
  - Cubic : Mineral Example: Galena
  - Rhombohedral: Mineral Example: Calcite
- Four directions of cleavage (four planes)
  - Mineral Example: Flourite

Feldspar: Two Cleavage Planes

plane one:

plane two:

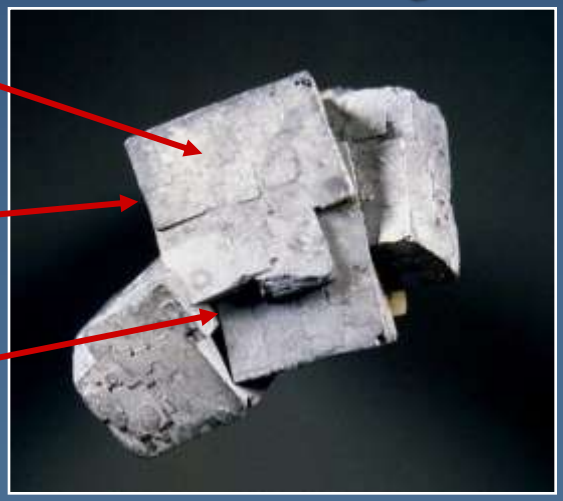
Courtesy United States Geological Survey

Galena: Three Cleavage Planes

Plane one:

Plane two:

Plane three:



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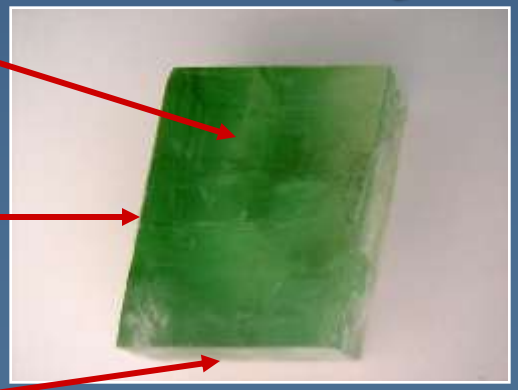
Calcite: Three Cleavage Planes

Plane one:

Plane two:

Plane three:



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Fracture

- Fracture refers to the non-planar breakage of minerals.
- Minerals that break along fractures (as oppose to cleavage planes) do not exhibit predictable weakness along specified bonds.
- Fractures may be described as splintery, uneven, or conchoidal.

Conchoidal Fractures on a Quartz Mineral

Specific Gravity

- Specific gravity refers to the weight or heaviness of a mineral, and it is expressed as the ratio of the mineral's weight to an equal volume of water.
- Water has a specific gravity of 1. Therefore, a mineral with a specific gravity of 1.5, is one and a half times heavier than water.
- Minerals with a specific gravity ≤ 2 are considered light, 2-4 are average, and >4.5 are heavy
- Specific gravity can be measured using complex lab tools such as the hydrostatic balance or more simple procedures involving beakers and water displacement measurements.

Mineral Classification

Minerals are classified by their chemical composition and internal crystal structure.

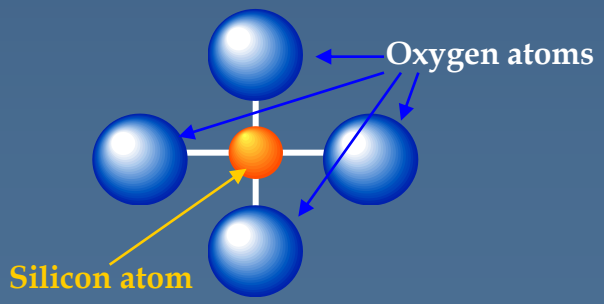
There are 7 Major Mineral Groups:

- Silicates
- Native Elements
- Halides
- Carbonates
- Oxides
- Sulfates
- Sulfides

Silicates

- Silicates are composed of silicon-oxygen tetrahedrons, an arrangement which contains four oxygen atoms surrounding a silicon atom (SiO_4^{-4}).
- Silicates are often divided into two major groups: ferromagnesian silicates and non-ferromagnesian silicates
  - Ferromagnesian silicates contain iron or magnesium ions joined to the silicate structure. They are darker and have a heavier specific gravity than non-ferromagnesian silicate minerals.
  - Ferromagnesians include minerals such as olivine, pyroxene, hornblende, and biotite
  - Non-ferromagnesians include muscovite, feldspar, and quartz
- Silicates comprise the majority of minerals in the Earth's crust and upper mantle. Over 25% of all minerals are included in this group, with over 40% of those accounting for the most common and abundant minerals.
- Feldspar, Quartz, Biotite, and Amphibole are the most common silicates

Silicon-oxygen tetrahedron (SiO4-4)



Native Elements

- Native elements are minerals that are composed of a single element.
- Some examples are: Gold (Au), Silver (Ag), Copper (Cu), Iron (Fe), Diamonds (C), Graphite (C), and Platinum (Pt)

Image Courtesy of the USGS

Image Courtesy of the USGS

Halides

- Halides consist of halogen elements, chlorine (Cl), bromine (Br), fluorine (F), and iodine (I) forming strong ionic bonds with alkali and alkali earth elements sodium (Na), calcium (Ca) and potassium (K)
- Some examples include Halite (NaCl) and Flourite (CaF_2).

Halite

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Fluorite

Image courtesy of USGS

Carbonates

- Carbonates are anionic groups of carbon and oxygen. Carbonate minerals result from bonds between these complexes and alkali earth and some transitional metals
- Common carbonate minerals include calcite $CaCO_3$, calcium carbonate, and dolomite $CaMg(CO_3)_2$, calcium/magnesium carbonate
- Carbonate minerals react when exposed to hydrochloric acid. Geologist will often carry dilute hydrochloric acid in the field to test if a mineral contains calcium carbonate. If the mineral fizzes when it comes in contact with the hydrochloric acid it contains calcium carbonate. Some cola soft drinks can also be used for this test because it contains enough hydrochloric acid to react with calcium carbonate.

Dolomite

Calcite

Oxides

- Oxides are minerals that include one or more metal cations bonded to oxygen or hydroxyl anions.
- Examples of oxide minerals include: Hematite (Fe_2O_3), Magnetite (Fe_3O_4), Corundum (Al_2O_3), and Ice (H_2O)

Hematite

Courtesy National Oceanic and Atmospheric Administration

Sulfates

- Sulfates are minerals that include SO_4 anionic groups combined with alkali earth and metal cations.
- Anhydrous (no water) and hydrous (water) are the two major groups of Sulfates.
- Barite ($BaSO_4$) is an example of a anhydrous sulfate and Gypsum ($CaSO_4 \cdot 2H_2O$) is an example of a sulfate.

Image Courtesy of the USGS

Image Courtesy of the USGS

Sulfides

- Sulfides are minerals composed of one or more metal cations combined with sulfur. Many sulfides are economically important ores.
- Pyrite (FeS_2) or "fool's gold", Galena (PbS), Cinnabar (HgS) an Molybdenite (MoS_2) are a few commonly occurring sulfide minerals

Pyrite "Fool's Gold"

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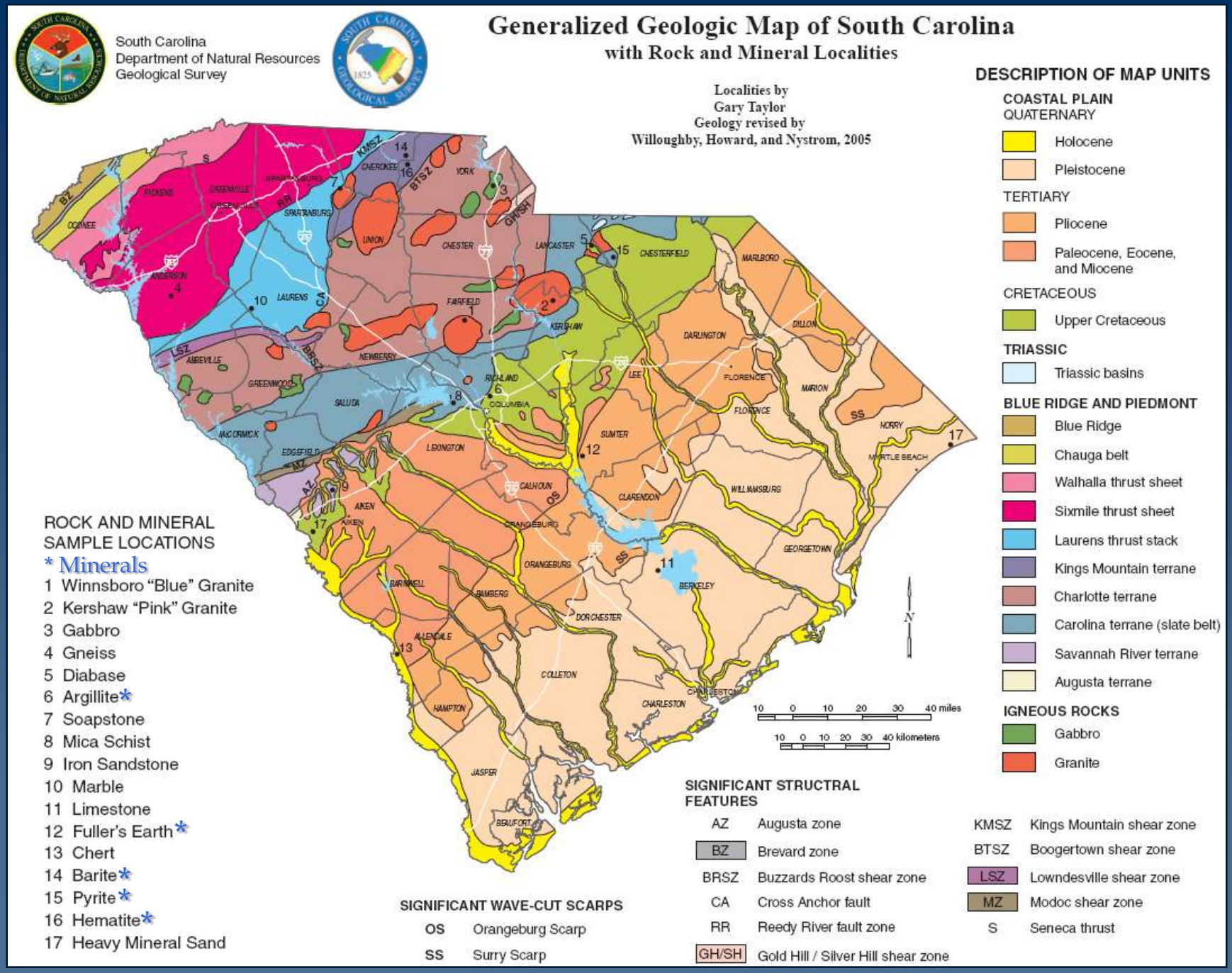
Cinnabar

Image Courtesy of USGS



This map is available in a poster size graphic from the SCGS .

Uses of Common Minerals

Minerals are a non-renewable natural resources, meaning that once we mine or extract them they will not replenish in enough time to be used again by humans. Industrial minerals are non-renewable minerals that are mined for commercial value and are not used as fuel or as a source of metals. These minerals are either used in their raw form or as additives with other materials. Industrial minerals are used for construction, ceramics, cement, paints, electronics, glass, detergent, paper, plastics, filtration, and variety of other common household applications.

- Copper is a native element used for electrical wiring.
- Gold, Diamonds, Silver, and Platinum are native elements used for jewelry.
- Talc is a silicate mineral used for cosmetics and cat litter.
- Quartz is a silicate mineral used to make glass.
- Graphite is a native element used for pencil lead.
- Halite is a halide mineral used for common table salt.
- Kaolin is a silicate mineral used in ceramics, coated paper, and as a medicine.
- Barite is a sulfate mineral used in cement or as an additive to petroleum.

South Carolina Science Academic Standards: Grade 3

1) Scientific Inquiry:

Standard 3-1:

The student will demonstrate an understanding of scientific inquiry, including the processes, skills, and mathematical thinking necessary to conduct a simple scientific investigation.

Indicators:

3-1.1: Classify objects by two of their properties. (slides: 3 and 6-20)

3-1.4: Predict the outcome of a simple investigation and compare the result with the prediction. (slides: 10-13)

3-1.7: Explain why similar investigations might produce different results. (slides: 10-13)

2) Earth's Materials and Changes:

Standard 3-3:

The student will demonstrate an understanding of Earth's composition and the changes that occur to the features of Earth's surface.

Indicators:

3-3.2: Identify common minerals on the basis of their properties by using a minerals identification key (slides: 3 and 6-20)

South Carolina Science Academic Standards: Grade 4

1) Scientific Inquiry:

Standard 4-1: The student will demonstrate an understanding of scientific inquiry, including the processes, skills, and mathematical thinking necessary to conduct a simple scientific investigation.

Indicators:

4-1.3: Summarize the characteristics of a simple scientific investigation that represent a fair test (including a question that identifies the problem, a prediction that indicates a possible outcome, a process that tests one manipulated variable at a time, and results that are communicated and explained) (Slides: 10 - 13) .

4-1.4: Distinguish among observations, predictions, and inferences (Slides: 10 - 13) .

4-1.6: Use appropriate procedures when conducting investigations (Slides: 10 - 13) .

South Carolina Science Academic Standards: Grade 5

1) Scientific Inquiry:

Standard 5-1:

The student will demonstrate an understanding of scientific inquiry, including the processes, skills, and mathematical thinking necessary to conduct a simple scientific investigation.

Indicators:

5-1.1: Identify questions suitable for generating a hypothesis ((Slides 10 - 13).

5-1.2: Identify independent (manipulated), dependent (responding), and controlled variables in an experiment (Slides 10 - 13) .

5-1.3: Plan and conduct controlled scientific investigations, manipulating one variable at a time (Slides 10 - 13).

5-1.6: Evaluate results of an investigation to formulate a valid conclusion based on evidence and communicate the findings of the evaluation in oral or written form (Slides 10 - 13).

5-1.8: Use appropriate safety procedures when conducting investigations (Slides 10 - 13).

South Carolina Science Academic Standards: Grade 8

1) Earth's Structure and Processes:

Standard 8-3: The student will demonstrate an understanding of materials that determine the structure of the Earth and the processes that have altered this structure.

Indicators:

8-3.5: Summarize the importance of minerals, ores, and fossil fuels as Earth resources on the basis of their physical and chemical properties. (Slide: 30)

Resources and References

Blackburn, W.H. and Dennen, W.H., 1988, Principles of Mineralogy: Iowa, WCB Publishers . 413 p.

Klein, C. and Hurlbut, C.S.Jr., 1985, Manual of Mineralogy (20th Ed.): John Wiley and Sons, 596 p.