TEACHER BACKGROUND KNOWEDGE

Minerals, Rocks and the Rock Cycle

Core Concepts

- Rocks in the Earth's crust vary in their form and structure based on process that made them. The constant changing of the form and structure of rocks is called the **rock cycle**. The energy powering the rock cycle comes from the sun and the earth's core.

  - Minerals
  - Igneous Rock
  - Metamorphic Rock
  - Sedimentary Rock
  - The Rock Cycle

Minerals

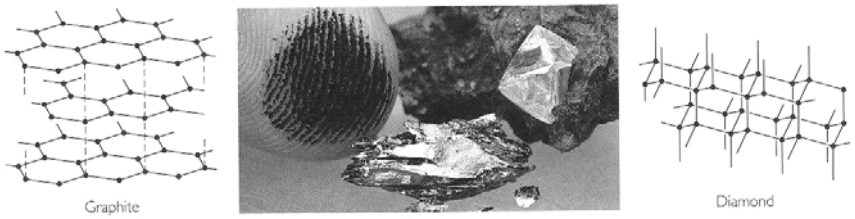
The study of minerals is important because *all rocks are made of minerals.* A mineral is a solid substance that occurs in nature, is inorganic, and has a specific chemical composition. Examples of minerals are diamonds, quartz, and table salt. Minerals are

crystalline, meaning that they are made up of atoms in specific, orderly, repeating structure. Rocks can be broken down mechanically into their individual minerals. Minerals themselves cannot be mechanically divided down into any of their constituent parts.

The two main factors that differentiate one type of mineral from another are the **chemical composition** and the **crystalline arrangement** of the atoms. Chemical composition refers to the type and proportion of atoms that make up the mineral. For example, table salt is made up of two kinds of atoms (sodium and chlorine) in equal proportion (one sodium atom for each chlorine atom as shown by the formula NaCl). Quartz is made up of a combination of one silicon atom for every two oxygen atoms and is shown by the formula SiO_2. A different ratio of materials would result in a different kind of mineral.

Crystalline arrangement refers to the 3-dimentional form that the constituent atoms take when bonding to each other. Some crystals form as cubes (such as table salt), while some form in hexagons, diamond shapes, or even in flat sheets. Minerals made with the same chemical compositions but in different crystalline arrangements become very different minerals. Graphite (what pencil

lead is made out of) is made of carbon atoms which crystallized quickly into sheets. Diamonds are also made of carbon atoms, but are built into a very strong 3-D structure called a tetrahedron where each atom is bonded to 4 other atoms. The multiple bonds surrounding each carbon atom results in the diamond being the strongest of all crystals.



Graphite and Diamonds are both made of the same element, Carbon. Different crystal structures give them different properties. Source: Understanding Earth, Press & Siever.

Rocks

Rocks are made up of minerals. Some rocks may be made up of only one mineral, while others are made up of complex combinations of many minerals. The appearance and other properties of a rock are determined by two main factors, its **mineralogy** and its **texture**.

Mineralogy refers to the type and proportion of minerals that exist within a rock. A chunk of solid quartz would be made up of only the mineral quartz, while a piece of granite has grains of quartz, feldspar, mica, and other minerals mixed together inside of it.

Texture refers to the sizes and shapes of minerals within the rock, and the way that they are put together. The texture is generally called **coarse** if the grains are large enough to see with your eye (such as in granite) or **fine** if you need a magnifying glass or microscope to see the grains (as in shale).

Types of Rocks

All rocks fall into one of three main categories: igneous, sedimentary, and metamorphic. The three types differ in the processes that resulted in their formation, as well as their basic physical properties – their mineralogy and their texture. Geologists study and classify rocks so that they can determine what geologic processes occurred in the different parts of the Earth.

Igneous Rocks

Igneous rocks begin deep beneath the Earth's surface as magma. Magma is rock in the liquid phase. This means that it has reached a temperature of 700˚C or more, allowing it to melt. Igneous rocks crystallize as the magma cools, much like ice crystals form when water is cooled to below 0˚C. In general, small crystals appear when

magma cools quickly and large crystals appear when magma cools slowly.

Magma that seeps from the mantle into the crust and becomes trapped there when it cools is called **intrusive igneous rock**. The rock surrounding intrusive magma as it cools is not much cooler than the magma itself causing the igneous rock to cool very slowly. These igneous rocks have large crystals in them that are easily visible without magnification. Examples of intrusive igneous rocks are granite, gabbro, and anorthosite.

Magma that erupts onto the Earth's surface or out of an underwater volcano into the ocean cools very quickly. Quickly cooling rocks are called **extrusive igneous rocks**. The resulting igneous rock will have very small crystal grains, probably microscopic. Grains may be so small that the rock appears glassy. Examples of extrusive igneous rocks are basalt, obsidian, and felsite. Rock that is formed from volcanic debris thrown out during an eruption is also classified as an extrusive, and is called **pyroclastic**. Examples of pyroclastic rock include pumice and volcanic ash.

Sedimentary Rocks

Rocks that are exposed to the wind, rain, running water, and ice exist at the Earth's surface are broken up in a process called **weathering**. The pieces of rock broken loose can vary in size from grains of sand to boulders. The broken material can exist small enough to dissolve in water. All of these materials are called **sediments**. The same forces that weather rock, especially wind and running water, also **transport** these sediments into stream valleys, lakes, and eventually into oceans.

Over long periods of time, sediments collect on the bottoms of lakes and oceans. Sediment dissolved in water can seep between the larger particles of sediment and act as cement. This natural cement, along with the pressure of water and new sediment that continues to settle on top of existing sediment, binds the sediments together into a new kind of rock – a **clastic sedimentary rock**. Sedimentary rock is classified by the kinds, proportions, and sizes of rocks and minerals that make it up, as well as by the kind of material that acted as cement.

A second kind of sedimentary rock is a **chemical** sedimentary rock. It is formed by sediments dissolved in water coming out of

solution (precipitating) and gathering on the ocean floor. One example of this is rock salt, or halite. A third type of sedimentary rock is **organic sedimentary rock** which is formed from the remains of once living things. As sea creatures die and their shells collect at the bottom of the ocean, limestone is created. Close observation of limestone will reveal these shells. Coal and chalk are other examples of organic sedimentary rock.

Metamorphic Rocks

Rocks buried deep in the Earth's crust experience pressure and temperatures higher than at the surface, but not quite high enough to reach their melting point. The pressure and the temperature are high enough to change the rocks without completely melting them. In addition, chemicals buried in the crust with the rock can cause changes as well. An igneous or sedimentary rock that has been buried and undergone any or all of these changes is classified as a **metamorphic** rock. With a few exceptions, this is a very slow process.

White marble is an example of a metamorphic rock. It begins as the sedimentary rock limestone, often with fossil shells of the living

organisms that piled up on the ocean floor to create the rock visible in it. If limestone is buried and undergoes enough pressure and thermal energy, the calcite which makes up much of the shells will compact and re-crystallize, all without melting. The result will be a much harder, denser rock with none of the original fossils showing – we know this as marble.

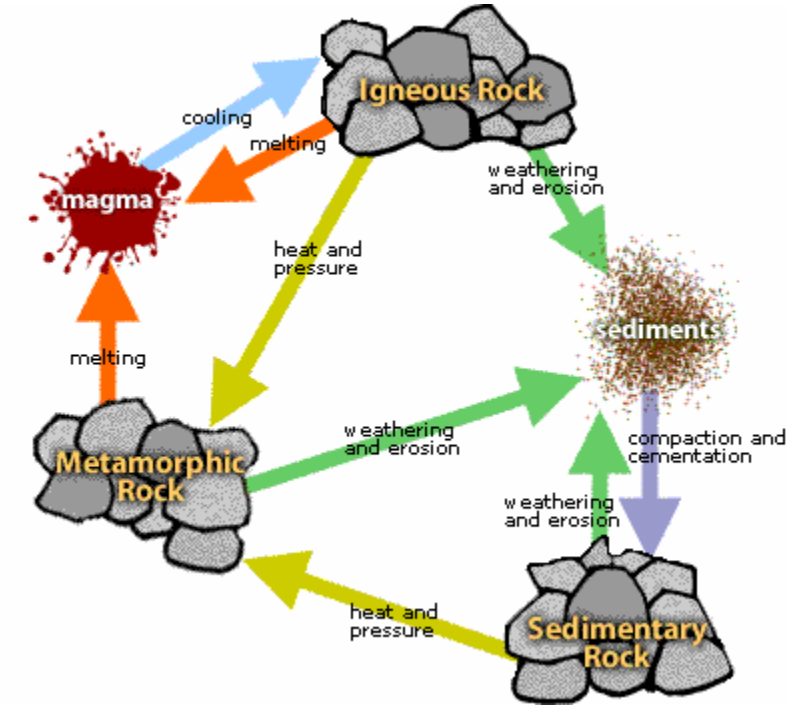
There are several main types of metamorphism. **Regional metamorphism** occurs when large-scale changes, such as the motion of the Earth's plates, create large areas of pressure or temperature changes. This type of metamorphism usually happens near subduction zones where plates are colliding and large amounts of pressure occur. Regional metamorphism should be distinguished from other types because it occurs over large areas like entire mountain ranges.

Most other examples of metamorphism are categorized as local. **Contact metamorphism** happens to a rock that is in direct contact with molten lava but doesn't melt itself. The heat conducted from the lava changes the rock. **Hydrothermal metamorphism** works much the same way, but the heat comes from steam rising through vents. **Cataclastic metamorphism** occurs along fault lines where

plates are rubbing against each other. The temperature and pressure caused by the friction between the plates cause changes in the rock. Finally, **burial metamorphism** occurs to rock that has been slowly buried under sediment, adding heat and pressure. The pressure and temperature changes are not as great as regional metamorphism, and the rocks regain much of their composition and texture with only partial alteration.

The Rock Cycle

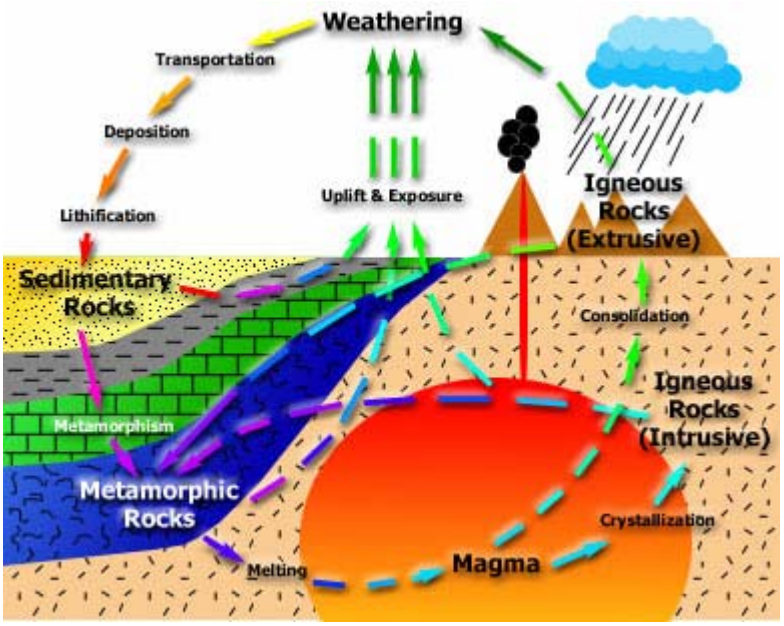
The three major types of rock are related to each other by their composition and the processes that form and change them. Throughout Earth's history, rocks of each type have been changed into the other types of rocks by natural forces. This constant changing is called the **rock cycle.** The first version of the rock cycle was proposed by James Hutton more than 200 years ago, but it is only with the acceptance of the idea of plate tectonics that it has been fully understood and integrated into our understanding of the Earth and its processes.



The Rock Cycle, Source: NASA Classroom of the Future

Metamorphic, igneous, and sedimentary rocks can undergo weathering (breaking rock apart by water, wind, and other agents) and erosion (moving rock particles from a higher to a lower elevation by water, ice, wind, or gravity). These processes break apart the existing rock, forming sediments. These sediments become new sedimentary rocks when they are compacted by pressure or cemented together when water between the particles evaporates. Sedimentary, igneous, and metamorphic rocks can undergo tremendous heat and pressure inside the Earth. This changes the minerals themselves in the rocks or their grain size, forming new metamorphic rocks. Sedimentary, metamorphic, and igneous rocks can be transported to

the mantle of the earth at subduction zones where they are melted into magma. In this way, rocks of each type are changed into the other types. They are broken, heated, pressed, and pushed around over and over again.



The Rock Cycle, Source: Mineralogy for Kids