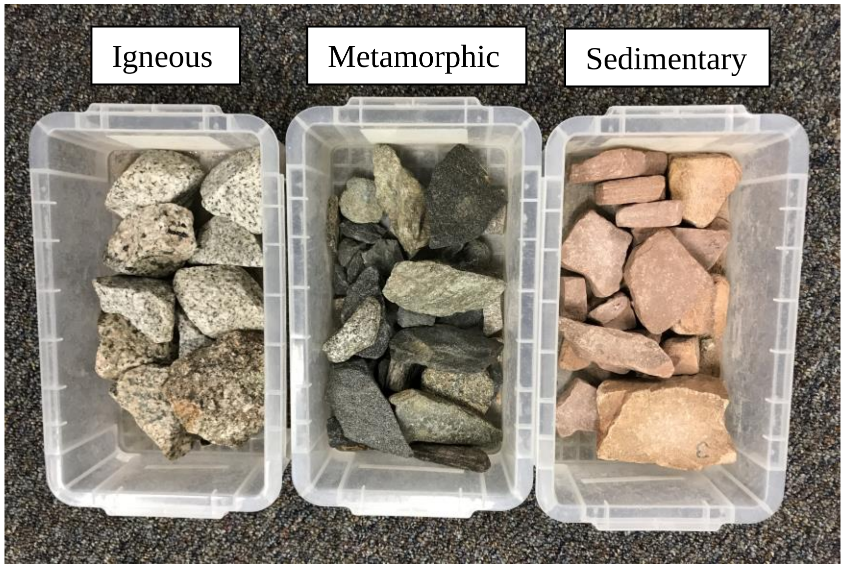
ROCKS HAVE A STORY TO TELL

Sue Hirschfeld, Geologist and Boulder County Volunteer Naturalist

Note: There are three boxes of rocks that can be used with this activity. They can be checked out from the VN Center at Walden Ponds, and look like this:



INFORMATION FOR THE PROGRAM INSTRUCTOR:

The purpose of this exercise is to look for the clues that indicate how and where the rock specimen formed. Names (igneous, granite, etc.) can be provided later, but the primary objective is to have the participants carefully observe and describe what they see. Too often when we name something, we don't really see it and we are ready to move on, thus missing the information that can be obtained from observing the details.

Participants work together in pairs. Three rock samples (igneous, metamorphic, and sedimentary) are to be observed closely and in detail. Participants are to draw what they see. Have them look for differences in size, shape, color, arrangement, and surfaces within the rock sample, and then describe these to their partner. Have the participants describe what they have observed to the group.

Background Information: A **mineral** is defined as a naturally occurring inorganic solid with a definite chemical composition in which atoms are arranged in an orderly fashion, and with physical properties that are defined or vary within a definite range. A **crystal** can be defined as a multi-sided form of a mineral bounded by planar growth surfaces that is the outward expression of the ordered arrangement of the atoms within it. Crystals grow from an aqueous (water) solution (such as salt or sugar crystals) or from a melt (igneous minerals in rocks such as granite). In the process of crystallization, atoms/ions bond together to begin the process of forming a crystal. Atoms are then added to the outer margin of the growing crystal and it grows larger and larger as long as there is available solution/melt. Most often, other crystals are also growing in the solution/melt and when the growing crystals contact one another growth stops where they meet. They can continue growing only where they are still in contact with the solution/melt. When crystallization is complete, there is a mass of intergrown, interlocking "crystals". In order to have a single crystal with crystal faces, the crystal must have grown without contacting other crystals. This is a rare circumstance in nature and thus perfectly formed crystals are not common. The mass of intergrown crystals making up rock sample #1 is described as **crystalline**.

Sample #1 (igneous):
Participants observe how rocks are usually composed of more than one mineral (the different colors and surfaces). Also, this rock sample is composed of "crystals" of the different minerals. What is viewed in the sample is not what most people think of when they think of crystals. Depending on the age/maturity of the group and their background, the instructor may want to hold up a single crystal or show a picture of a crystal with crystal faces. **Note:** here, "crystal" is in quotation marks to signify that there are no apparent crystal faces observed in the sample. The shiny surfaces that you see in the sample represent "crystals" that were broken when the rock was broken. These flat, shiny surfaces are not original crystal faces of the mineral. These "crystals" have formed (crystallized) from molten rock (magma). Show where the rocks form on the **rock cycle diagram** below.

Other important characteristics of sample #1 are that the "crystals" are large (visible even without a magnifying glass) and randomly arranged. They are large because they grew slowly giving the atoms time to bond to the outer margins of the "crystals". Slow cooling happens deep underground (10-15 miles) because there are miles of overlying rock and the heat escapes very slowly. If the "crystals" in a rock are very, very small (or very small "crystals" surround a scattering of somewhat larger "crystals"), it indicates that the minerals crystallized rapidly. This happens when the molten rock is at or near the earth's surface and loses heat quickly such as in a lava flow. (No sample provided). Another very important distinguishing characteristic is that the crystals of the different minerals are randomly arranged – all mixed up without any particular order. This results from the minerals crystallizing from a melt.

Summary of the observations: rock sample #1 is made of relatively large intergrown crystals of different minerals that are randomly arranged. These characteristics tell us that the rock was once molten, deep underground in an environment hot enough to melt rock. The rock then cooled and crystallized slowly at depth. This rock type is igneous and the sample rock is granite made of light-colored minerals with a scattering of darker minerals.

Sample #2 (metamorphic):
Now contrast sample #2 with sample #1. Have the participants draw what they see and describe the differences in size, shape, color, arrangement, and surfaces within the rock. Have them describe these observations to their partner. Then have them describe what they observed to the group.

Sample #2 is also made of "crystals". However, in this sample the crystals appear to be oriented and layered. This is a metamorphic rock. Show metamorphic rocks on the rock cycle diagram below.

Background Information: This layering of "crystals" is what happens when the "crystals" are subjected to high temperatures (but cooler than the melting point of the minerals in the rock) and high pressures over long periods of time at depth. A rock that is composed of "crystals" that are layered indicates deforming conditions of heat and pressure while the rock was in a solid state (it can bend and flow, new minerals can form, but it was not molten). Any rock can be metamorphosed at depth in a high temperature, high pressure environment. This includes igneous rock that has cooled and crystallized but remained at high temperatures under deforming pressures, lower grade metamorphic rocks, and sedimentary rocks formed on the earth's surface that were deeply buried later.

Sample #3 (sedimentary):
Participants repeat the observations as with the earlier samples. Note differences in size, shape, color, arrangement, surfaces within the rock, and have them describe these to their partner. Have the participants describe what they have observed to the group. They should see that the rock is made of particles of pre-existing rocks and the particles are often rounded. Something is holding the particles together to make the rock solid, but the rock is not made of intergrown "crystals". Sample #3 is sedimentary rock. The participants learned that rock samples #1 and #2 formed at depth. How do we get these rocks to the earth's surface to form

sedimentary rock? Discuss **uplift** and **erosion** that removes the 10-15 miles of overlying rock to expose igneous and metamorphic rocks at the surface. Sedimentary rocks form on the earth's surface by the surface processes of **weathering** (producing the particles of sediment), **erosion** (transportation) by running water, wind and ice, and **deposition** (settling of the sediment) in some low place such as a river channel, lake, or ocean basin. Illustrate these processes on the rock cycle diagram.

Background Information: Particles of sediment are held together by minerals precipitated between the grains literally cementing them together. The **cement** is usually quartz or calcite (calcium carbonate).

Detailed observations of the shape and composition of the particles in sedimentary rock provide specific information about the environment in which the rock formed, and what processes and events were occurring on the earth's surface at the time of their formation. They also provide evidence of the existence of mountain ranges long since eroded away, and seas that long ago disappeared. For example, the closer the mountain source is to where the sediment is deposited, the larger and more angular the particles will be. The farther the larger particles travel away from the source rock, the smaller and more rounded the sediment becomes. When igneous and metamorphic source rocks weather, clay is produced. Clay is easily picked up and quickly carried away. Sediment transported far from the source is sorted by water and wind. The resulting sedimentary rock will be free of clay and will be composed of pure quartz sand that is uniform in size and very rounded.   The clay is carried far away and is deposited in quiet water to form mudstones and shale.

Some of the concepts that the participants can be encouraged to think about and to discuss concerning sample #3 are: What is the material holding the particles together and where could that material come from? Introduce the concept of cement. The particles in sample #3 are similar in composition to the minerals in the samples #1 and #2 observed earlier. What does this compositional similarity indicate about the source of the particles? Introduce the concepts of transportation of sediment particles by running water, ocean currents, wind and glaciers. Have the participants think about some environments on the surface of the earth where sample #3 might form. The size and shape of the particles helps us to infer how far away from the source area the particles were transported before they were deposited.

Summary of Observations and Interpretations: Rocks that form from a melt are made of randomly arranged inter-grown crystals. Large crystals indicate that the rock cooled and crystallized at depth, whereas small crystals indicate cooling at the surface.   Rocks that are crystalline and the crystals are arranged in layers formed at depth in an environment of high pressure and high temperature that was below the melting point of the rock. A rock made of fragments or particles of other rocks forms on the earth's surface by surface processes of weathering, erosion, and deposition. Each of these rocks contain clues to their origin and process of formation. These are the stories in the rocks.

Additional Processes That Add to the Story Rocks Tell: If time permits, rock formation can be tied into the plate tectonic model (see discussion below). Igneous rock sample #1 and metamorphic rock sample #2 form at depth along the boundary where two tectonic plates collide. Mountains are also raised in plate collisions. These mountains weather and erode. After tens of millions of years of uplift and erosion, the igneous and metamorphic rocks are exposed at the surface. These are then weathered to produce the sediment that makes up the sedimentary rock sample #3.

THE STORIES IN THE ROCK

DESCRIPTION OF ROCKS AND ROCK FORMING PROCESSES

There are three types of rocks: **igneous**, **sedimentary**, and **metamorphic**. These rock types are defined based upon their origin, that is, how and where they formed. **Igneous rocks** were molten at some time in their history. The melt is called **magma** when it's found beneath the earth's surface or **lava** when it is erupted onto the surface. When the melt cools, it forms a rock made of inter-grown, interlocking crystals composed of several different minerals. When the melt cools slowly, the crystals have time to grow large (easily visible without a magnifying lens) producing an igneous rock such as granite. If the crystals are very large, it is called pegmatite. If the melt cools quickly as lava at or near the earth's surface, the crystals are very small, often too small to be seen with the unaided eye. Andesite and basalt are examples of lava that cooled quickly. In Boulder County, these types of igneous rocks can be seen at Heil Valley Ranch Open Space and the Valmont Dike. The major source of heat for the generation of magma is the collision of tectonic plates. We can see evidence of this collision today in volcanoes, such as Mt. St. Helens, Mt. Pinatubo, around the margin of the Pacific Ocean, and hot spot volcanism such as the Hawaiian volcanoes and Yellowstone. At depth, beneath these volcanoes, large bodies of magma cool slowly to produce granite and granodiorite (has more dark minerals than granite).

Sedimentary rocks are formed on the earth's surface by surface processes, such as weathering, erosion, deposition, and cementation. When any type of rock (igneous, metamorphic, or sedimentary) is exposed at the earth's surface, it comes in contact with the atmosphere which is very corrosive. The rocks are mechanically broken apart and react chemically with oxygen in the atmosphere and weak acids in rainwater. These weathering processes breaks the rock into smaller particles that are then eroded or transported by wind, running water, ocean currents, or glaciers. Eventually the rock particles are deposited in some low place, such as on the bottom of a lake or on the floor of the ocean, and they accumulate layer by layer. The weight of the overlying sediment and the precipitation of minerals in between the rock particles turns the loose sediment into solid sedimentary rock.

Most sedimentary rocks are made of particles of pre-existing rocks. These sedimentary rocks are classified based on the size of the particles making up the rock. Large rounded pebbles cemented together form a **conglomerate**. Sand-sized particles form **sandstone**, while mud and clay-sized particles form **mudstone and shale**. Sandstones and conglomerates make up the Boulder Flatirons (Fountain and Lyons Formations) and Dakota Ridge (Dakota Formation). Shales make up formations in between. Because they contain clay, shales are more easily eroded and form vegetation-covered valleys between the ridge-forming rock formations. **Limestone** is also a sedimentary rock, but it forms from the remains of shelled organisms or the precipitation of calcium carbonate. Limestone is mined for cement from the Fort Hays Limestone in the Niobrara Formation near Lyons.

If sedimentary rock or crystallized igneous rock is deeply buried or remains at depth and is subjected to high temperatures (below the melting temperature of the rock) and high pressures, it will be altered to **metamorphic rock**. Metamorphic rocks are usually composed of crystals that are visible (but often small), as in igneous rock, but the crystals are arranged in layers (called **foliation**), reflecting the modifying heat and pressure. Examples of metamorphic rocks are slate, schist and gneiss. In gneiss, the minerals may be similar to those in granite and they alternate light and minerals in distinct bands. Schist is foliated and is composed of one dominant mineral, often mica, with a scattering of a second mineral through the rock. Gneiss and schist can be found associated with the granite in the high country and canyons in Boulder County. Quartzite and marble are also metamorphic but they are not foliated. Quartzite is quartz sandstone that has been metamorphosed so the sand grains have been recrystallized and have grown together. It still appears to be composed of grains of sand but it is much harder and the grains cannot be scratched off with a knife blade. Some quartz sandstones have been cemented with quartz and are also very hard. These may be difficult to distinguish from quartzites. The Lyons Sandstone is an example of very hard, well-cemented quartz sandstone and is an excellent building stone for this reason.

ROCK CYCLE – THE MOVEMENT OF PLATES AND BUILDING OF MOUNTAINS

The story of the formation of the different types of rocks involves the formation and movement of large blocks of the earth-- tectonic plates. The outer portion of the earth is divided into about a dozen rigid plates that are "floating" on a plastic-like portion of the upper mantle (the layer of the earth beneath the crust). These plates are in motion; some move apart and some move toward each other. Where plates move apart, molten magma comes to the surface in the rift and cools to form new **oceanic crust**. When this process occurs under the ocean, the process is called **seafloor spreading**. As spreading occurs and new crust is formed, the plates move away from each other. As the plates separate, they move toward other plates. Where plates collide, one plate moves down under the other, a process called **subduction**. Deep within subduction zones, magma forms and metamorphism occurs at depth within the overriding plate. Mountains are formed where two plates collide. These uplifted mountains are exposed to the elements of the atmosphere. Weathering occurs breaking down the exposed rock into smaller particles or sediment. Erosion by water, wind, or glacial ice carries the sediment down slope to a basin of deposition (low place such as an ocean basin). Where plates collide, sedimentary rock can be carried to depth (+10-15 miles) where it can be metamorphosed or melted again, and the rock cycle is complete.