CHAPTER FOUR

Geology

of Colorado National Monument

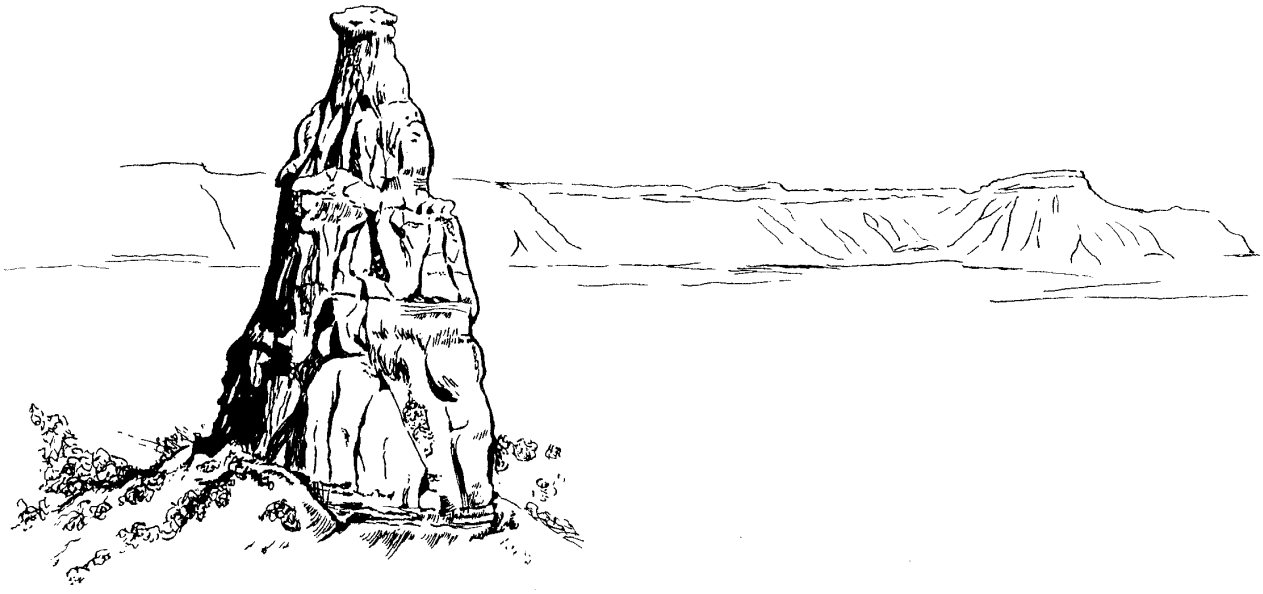
Photo from *Through the Eyes of the Children*
by Diane Hirschinger Gallegos and Tope Elementary Students

The Rocks Before You

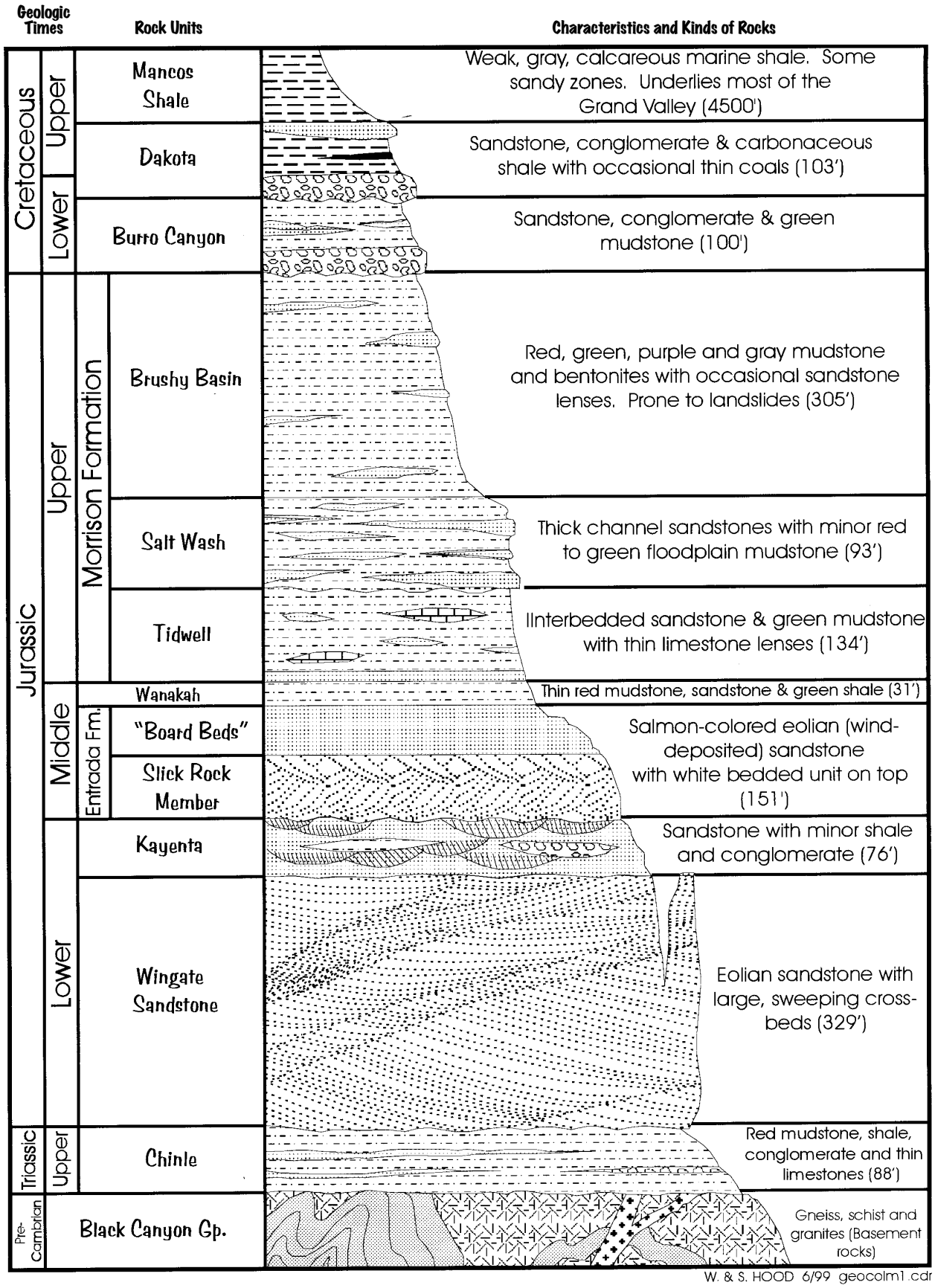
The concept of geologic time is a remarkable one. Like little else, it forces one to see how small and insignificant humans are in the span of life on our planet. Looking at the canyons of Colorado National Monument sparks musings such as, "How did things come to be as they are, and what might happen in the future?" In the exposed rock are tales of changing environments and climates, of creatures and plants living and dying. The folds of the land speak silently but powerfully of forces so great and so enduring that we can scarcely fathom them. Every vista point, cliff, and boulder-strewn slope offers up clues to the past. The canyon bottoms, drainages, and waterfalls demonstrate processes that are vital to the creation and the cycling of the Earth's crust. The rocks before us have many stories to tell if we take the time to look.

Introduction: Taking Geology Into the Field

Schoolchildren, who have a difficult time conceptualizing the age of a parent, or how long until lunch, have a very hard time grasping the meaning of millions, much less billions, of years. They are more interested in the concrete: finding out what something is. "What is this rock?" is their way of getting a handle on larger, less answerable questions posed by their surroundings. Because they can imagine a desert or an ocean, the information about the rock formations that follows concentrates on what the area would have looked like when the rock was created. Descriptions of how the rocks look today; where they can be found; and how they got their names are given more attention than the age of the rocks. This information is to give teachers and trip leaders a working knowledge of the rock formations so that they will be successful and comfortable with taking geologic studies out of the classroom and *into* the field.



Stratigraphic Column of Colorado National Monument



The Rocks Before You

Part 1: Geologic Review

When geologists study the Earth, they make and refer to **geologic maps**, which portray the different kinds of rock *exposed on the surface*, as if all the soil were stripped off of a given area. In contrast, **geologic columns** or **stratigraphic columns** summarize an area's geology *below the surface*. The columns show views of an area as if it were cut open for you to look at the layers piled up on top of each other from the side. These one-dimensional stacks depict thickness and relative age of rock units in a given area. The rock layers are shown in sequence from the oldest layer, at the bottom, to the youngest layer, at the top. Sometimes the sequence varies or is altered due to uplifting, faulting, or erosion. Occasionally the sequence has a gap, where rocks of a certain time period are missing. Known as an **unconformity**, what is missing from the stratigraphic column can be as telling about an area, and as interesting to geologists, as what is captured in the rocks.

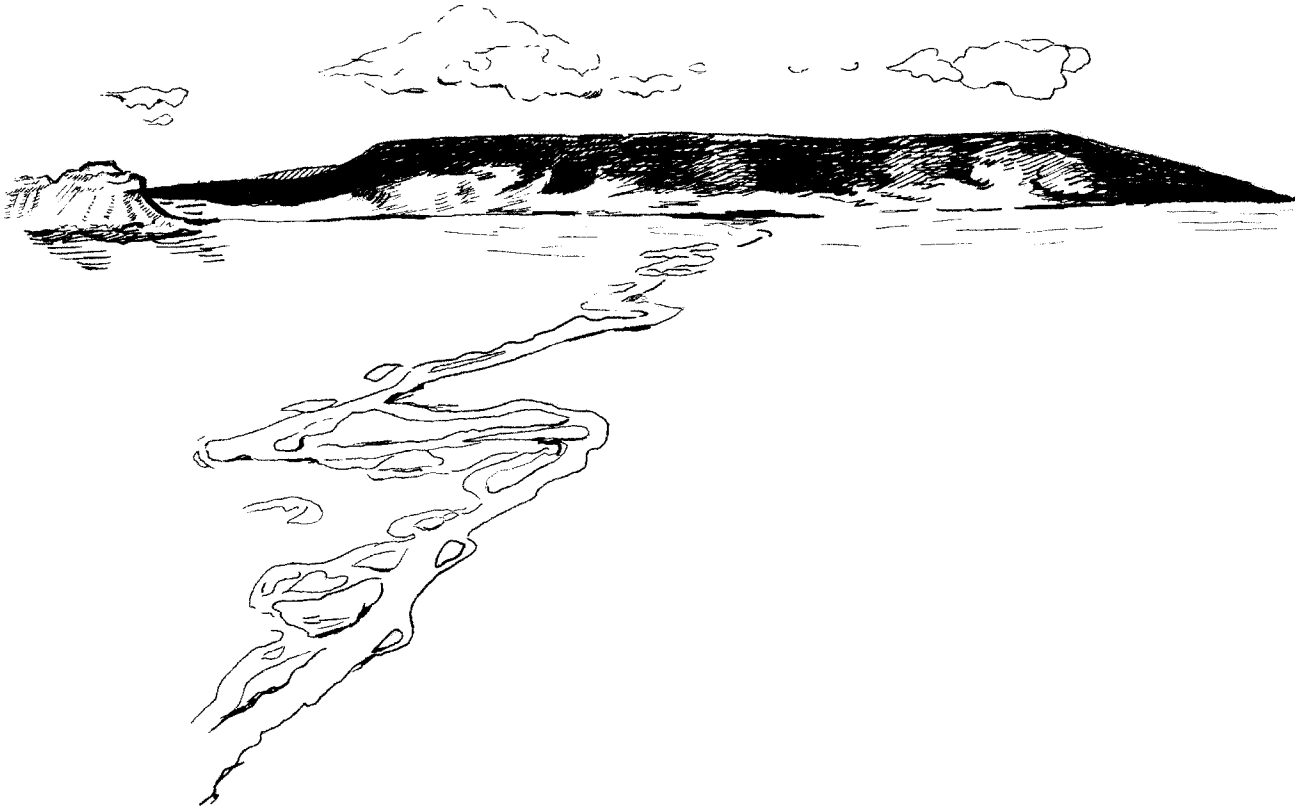
Geologists study the rocks before them using such terms as formations, members, layers, strata, beds, and lamina(e). These words are helpful for distinguishing large sections of rock from the tiniest tier. **Formations** are mappable units of rock that are similar throughout, with a distinguishable bottom and top. Created under the same conditions, such as an ocean or a desert, and during a single period of time, they are different from rocks that are above and below them. Some formations are made up of only one kind of rock, such as sandstone. In this case, the term "formation" is sometimes dropped and the kind of rock is substituted. Wingate Sandstone, for instance, is an impressive cliff-forming rock of a single kind of rock: sandstone. The Burro Canyon Formation, on the other hand, includes mudstones, siltstones, shales, cherts, and sandstones.

The Rocks Before You

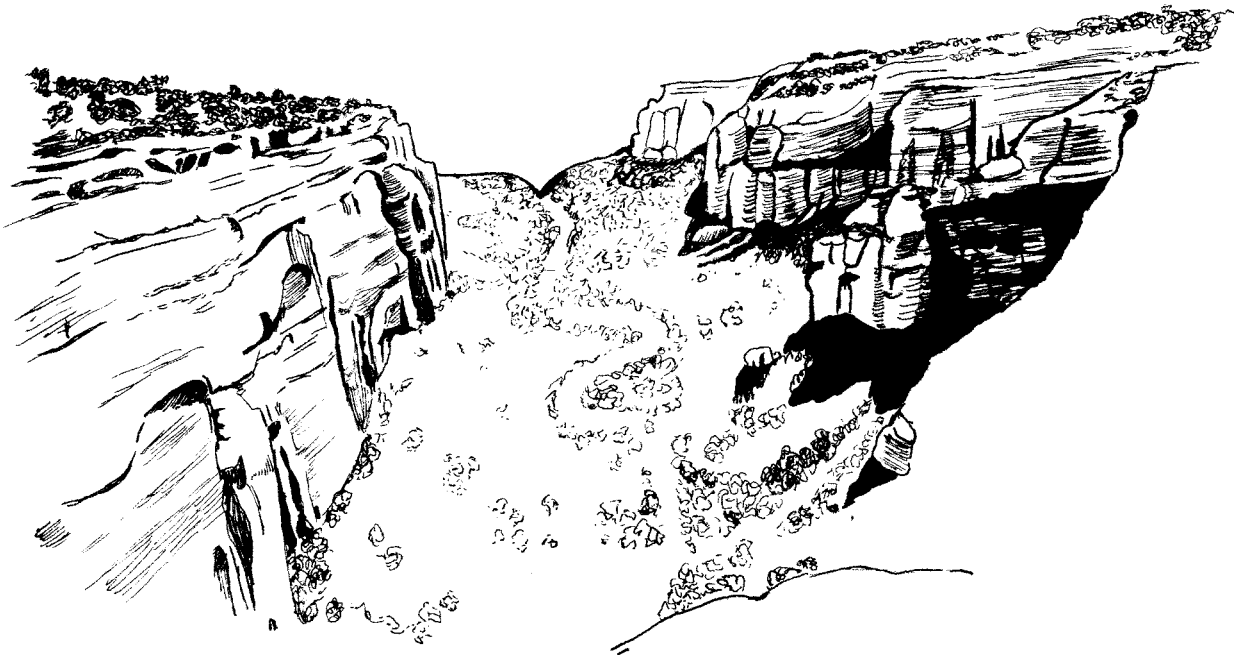
Another term used to describe formations that exhibit a variety of rocks, or sub-units within a larger grouping, is **members**. For example, in the Morrison Formation, different conditions existed on the land over an extended period of time. In some places there are rock lenses of ancient sand bars from long ago rivers. Fine-grained muds from the quieter water of lakes are also found. Even beds of volcanic ash are seen. Consequently, the Morrison is divided into the Brushy Basin, Salt Wash, and Tidwell members. Entrada Sandstone also has different members, some deposited during a marine environment, and others developed in sand dunes alongside the marine habitat. When discussing an area as large as the one that many of these formations covered, it is not surprising that underlying surface conditions, or micro-climates on the ground, would affect the nature of the rocks being created.

The terms **layers** and **strata** and **beds** are used interchangeably, all describing smaller, often horizontal, units of rock that exhibit similar characteristics. Within a formation, strata may vary in color, grain size, thickness, yet still have enough in common to be linked together. **Laminae** (singular) and lamina (plural) are the individual, thin layers of rock that are one centimeter or less in thickness and make up a larger strata.

Many classes will not venture deeply enough into the basics of geology to need these words and definitions. Still, these terms are useful underpinnings for any exploration of the rocks before you at Colorado National Monument.



The Rocks Before You



Part 2: Geologic Formations of Colorado National Monument

When describing rocks in a stratigraphic column, geologists begin with the oldest rock at the bottom. They move upwards through the formations to the uppermost, and youngest, rock. Thus, in the "Rocks Before You", the Precambrian rock at the bottom of the canyons is the starting point, and the Dakota Sandstone, at the highest point in Colorado National Monument, is the finish.

The Rocks Before You

Precambrian Rocks

Precambrian rocks make up a significant part of Colorado National Monument. They underlie all the other rocks, forming the floor, or "basement rock", of all the canyons. Their dark gray to black color stands in somber but striking contrast with the reds, oranges, browns, tans, and grays of the rocks above. One common Precambrian rock, called **gneiss** (pronounced "*nice*"), has distinctive layers of minerals. Quartz creates the white or translucent color, feldspar creates the pink color, and biotite, a form of mica, creates the black color. Some rocks are beautifully laced with large-sized crystals of feldspar and quartz. Other rocks are intruded by mixtures of smaller crystals of white, pink, and black color. Dark-colored granite also occurs in the Precambrian of the monument. (For more information on colors in rocks, see "White to Black and In Between".)

Precambrian rocks represent the oldest known rocks, having been dated in some parts of the Earth as over four billion years old. Here at Colorado National Monument, preliminary radiometric age dates indicate that they are about 1.7 billion years old. Because they go back to the beginnings of the Earth's history, they are of great interest to geologists. Yet studying these rocks is not easy, since many clues to the past have been obliterated by the enormous changes through which they have gone. For instance, most Precambrian rocks lack fossils, a tool widely used in geologic dating. Mineral composition and content must be utilized instead.

The Great Unconformity

One fascinating feature of the rocks at Colorado National Monument is the rocks that are missing. There is a huge gap in geologic time represented by the contact between the Precambrian rocks and the overlying Chinle Formation. About one and one-half billion years of geologic history are represented by that gap. That's about one-third of earth's history! Geologists call gaps like this "unconformities" and local geologists call this one "The Great Unconformity" because it represents so much lost time. But the fact that there is a huge gap in the rock record tells us a lot in itself. Nearby, there are many rocks formed between the Precambrian and the Chinle. From the character of these rocks geologists have determined that this area rose up as part of a large mountain range that extended from New Mexico into Utah. This happened in late Pennsylvanian time, roughly 300 million years ago. The mountains were eroded for a hundred million years until they were finally worn low enough that the Chinle was deposited on them. So the "gap" tells the story of an incredible amount of erosion, the debris of which was deposited far across the southwest and makes up some of the rocks that we see in other national parks.

The Rocks Before You

BACKGROUND FOR **TEACHERS**

Chinle Formation

The Chinle Formation rests atop the Precambrian rock. This sedimentary shale and sandstone unit stands in sharp contrast to the dark basement rock below, and forms broad brick-red to brown colored slopes. On close inspection, beds of purple and gray can occasionally be found. Highlighting these colors are green shrubs seemingly sprinkled across the slanted Chinle outcrops. Many boulders have also fallen onto it from the steep cliffs above. If you stand at the canyon rim and look down, the Chinle rocks seem to be pressed out of the sequence of formations by the weight of the towering canyon walls above. In some places, the strata seem to fan out symmetrically, like a skirt with a petticoat underneath.

The Chinle Formation is a significant indicator of changes in environmental conditions of the region. The base of the Chinle marks an unconformity in the rock, a gap in the time sequence of rock layers. Whereas the Precambrian rock dates back to 1.7 billion years ago, the Chinle dates to the Triassic times, approximately 210 to 230 million years ago. The missing rocks are a mystery, but geologists think that for millions of years, rocks were deposited in the area only later to be eroded away. This left a smooth, beveled surface on the Precambrian rock, on which the Chinle Formation currently rests.

Chinle rocks formed during a time when seas were far away to the south and the west of the area, and the Ancestral Rockies were eroding to the east. Streams flowing from east to west brought in great loads of sediment, depositing them across flood plains and lowlands that existed in the region. Some areas were covered by ponds and lakes. Much of the sediment was thus fine-grained, and eventually compacted and solidified to create shale. Other rock was more coarse-grained, forming sandstone lenses and sections of conglomerate rock. The area must have been heavily vegetated with cycads, conifers, and ferns given the number of plant fossils and specimens of petrified wood that have been found. Dinosaur and reptile tracks are also known to occur.

While not a thick formation at Colorado National Monument, near Holbrook in northern Arizona, the Chinle is exposed in high and colorful slopes in an area known as the Painted Desert. Nearby is Petrified Forest National Park, which was set aside to preserve a remarkable concentration of fossil logs that weathered out of the rock. Not far away is the Chinle Valley from which these shales get their name.

The Rocks Before You

BACKGROUND FOR **TEACHERS**

Wingate Sandstone

Wingate Sandstone rises steeply above the softer Chinle Formation. This sandstone is possibly the most striking rock formation in Colorado National Monument, as well as in many parts of the southwest. It is characterized by huge red, orange, and brown cliffs that rise over 300 feet high. Dark patinas of desert varnish are common on the rock face. Up close the Wingate Sandstone is very striking because you can see how it is composed of tiny grains of sand tightly compacted and cemented together. Over 200 million years in age, the cliffs tell stories of a long-ago desert that stretched across this region, replacing the fresh-water environments of the Chinle times. Geologists speculate that the Wingate climate was similar to the present day Saharan Desert in Africa, with miles of sand dunes blown by the wind, shifted first in one direction, then in another. With your finger, you can trace the movements of the sand by that ancient wind in the cross-bedding found throughout the strata. Called an eolian (carried by the wind) deposit, the wind is now a factor in the Wingate's erosion.

Striking exposures of Wingate Sandstone are found throughout southeastern Utah, northern Arizona, northern New Mexico, and southwestern Colorado. The name was given during western surveys of the 1880's for a sandstone cliff outside of Fort Wingate, New Mexico. Later, the set of cliffs east of Gallup was found to be Entrada Sandstone, not Wingate, but the name was retained.

A striking feature of Wingate Sandstone cliffs is how they fracture in long vertical lines, called joints. Freezing and thawing, heating and cooling, winds, water, and other forms of erosion and weathering seem to cause the Wingate to break down quite easily. The effects of the elements on the desert sandstone are dramatically exhibited in the decaying mounds of Wingate Sandstone known as the Coke Ovens. Standing at the Coke Ovens Overlook, or at the end of the Coke Ovens Trail, you can see how a once massive rock wall has worn away to leave behind beehive shaped mounds resembling the dunes of their origin.

Among the beauties of the canyons of Colorado National Monument is the Wingate Sandstone. From one end of the park to the other, the sheer, massive cliffs highlight spectacular vistas and breathtaking drops. Many overlooks and trails offer dramatic views of it. Independence Monument View, Artists Point, Red Canyon Overlook, and Cold Shivers Point are especially notable. Near to the Visitor Center, short hikes, such as Otto's Trail, Window Rock Trail, and Canyon Rim Trail, bring you right to the canyon rim for excellent sightings of the cliffs. On the east side of the monument, Serpents Trail, Devils Kitchen, and No Thoroughfare Canyon Trails are other locations from which to enjoy the Wingate. Trips along Rim Rock Drive give close-up perspectives, especially near the three tunnels that have been constructed through Wingate Sandstone.

The Rocks Before You

Kayenta Formation

Next in the stratigraphic column is the Kayenta Formation. It contrasts strongly with the tall, fractured cliffs of Wingate Sandstone that lie below it, and the smooth, rounded cliffs of Entrada Sandstone that rise above it. Sandwiched between these two periods of sand dunes and desert, the red beds of Kayenta look like layers of cheese or peanut butter between two thick pieces of bread. Not only does it form a much narrower band of rock, one that is about 75 feet thick, but it is also more brightly colored, and more hospitable to vegetation than its neighbors. Its red, gray, and beige-colored sand and siltstones are highlighted by the dark greens of pinyon and juniper trees. Created when streams crisscrossed this area, the Kayenta is considered to be a fluvial formation. Dissolved silica, likely carried in the water that permeated the sediments washing into the area, filled in spaces between the sediments and solidified into a strong cement between particles. Geologists estimate Kayenta rocks to be about 190-195 million years old.

Of note is that the Kayenta Formation is the surface on which much of Rim Rock Drive atop the mesa is situated. The flat area with the wide views where the Visitor Center is located is also on Kayenta rock. Other places where it can be seen are the Alcove Nature Trail, Coke Ovens Trail, Independence Monument View, Cold Shivers Point, Devils Kitchen Trail, Serpents Trail, and No Thoroughfare Canyon Trail. Otto's Trail and Overlook give one of the best views of Kayenta in its role as a caprock for many monoliths.

Hard Kayenta sandstone is resistant to erosion. It acts as a barrier to the elements, slowing down the effects of weathering on the Wingate Sandstone below it. If you look closely at such features as the Kissing Couple, the Pipe Organ, and Independence Monument, you can see a mushroom-like cap of Kayenta Sandstone that sits atop each one. This shelters the cliffs below, much like an umbrella shelters us from rain or sun. In areas where the Kayenta has eroded, the Wingate Sandstone seems to quickly follow. The fins of rock of which Independence Monument was once a part are examples of this more rapid erosion without the protection of the Kayenta.

The Kayenta Formation was named for Kayenta, Arizona, where thick deposits of it have been studied. While it is up to 250 feet thick in parts of Arizona, at Colorado National Monument it is 80 feet thick at most. Geologists have discovered many interesting plants, fresh water mollusks, fish, and invertebrates within this unit of rock. Also, dinosaur footprints have been located, indicating the beginning of the age of dinosaurs during this time. Thus, the Kayenta serves as a reminder of how much climates can and do change in a given area. From fresh water to desert to fresh water habitat again is encapsulated in the rocks before you. What comes next?

The Rocks Before You

Entrada Sandstone

Entrada Sandstone creates a distinctive band of rounded cliffs that sit atop the Kayenta Formation. Although not as high or as darkly colored as the Wingate Sandstone, the Entrada is easily distinguished by its two tiers of cliffs. The lower (and older) section is characterized by dark pink, salmon, orange, and brown-colored sandstone cliffs up to perhaps 80 feet high. The upper (younger) section is white to pale salmon-colored sandstone that erodes into tall ledges and rock staircases.

Created over 165 million years ago, the Entrada tells stories of wind-blown sand dunes inland from an ancient sea. A close look at the rocks reveals how, even today, they still resemble sand dunes. When you touch the rock, you can imagine a primeval wind, like a paintbrush, sweeping patterns ahead of it across the sand. Whenever the wind changed direction, the sands whirled with it, forming lines going first one direction, then the other. Geologists call them cross-bedding.

The shapes, colors, and textures of Entrada Sandstone may be seen in many parts of western Colorado, Utah, New Mexico, and Arizona. Possibly the most famous outcroppings contain the arches and balanced rocks sculpted by the elements found in Arches National Park, near Moab, Utah. Enjoyment of this topography has led to an expansion of the tourist industry into the southwest deserts. Mountain biking the Entrada "slickrock" has become a passion for some. Since the formation is composed of quartz sand grains held together by cement of calcium carbonate and silica, smooth, wide slopes of hardened dunes offer challenging and unusual conditions for traveling on two wheels. Elsewhere, oddly enchanting "hoodoo" and mushroom shapes have eroded out of the Entrada Sandstone at Goblin Valley, Utah.

Slick Rock Member

Type rocks for the Entrada come from areas 850 feet thick in the San Rafael Swell in west-central Utah. Formed under marine conditions, these rocks are red, orange, and brown. The white to pale salmon-colored rock at Colorado National Monument is thought to have formed farther from the ocean, in dunes and swirling sands that bordered the ancient sea. Because of the diversity of environments, the Entrada has been divided into sub-units called members. The Slick Rock Member, named for the town of Slick Rock, Colorado, forms the rounded cliffs in the monument. The upper, thinner-bedded part is informally called the "board beds". Both parts have a similar composition consisting of quartz sand grains cemented together with calcium carbonate. Because this cement is more easily dissolved than the quartz, what is often left behind when the Entrada Sandstone weathers are the individual grains of sand, which are born away by the wind or water, and reincorporated into future rocks.

Rim Rock Drive is bordered by these distinctive white, pale yellow, salmon, and orange colored sandstone cliffs from the Visitor Center to near the Coke Ovens Overlook. The Saddlehorn Picnic Area and Campground, Alcove Nature Trail, Coke Ovens Trail, Upper Monument Trail, and Otto's Trail all either travel through the Entrada or offer excellent views of its round, smooth outcroppings and cliffs that seem almost polished.

The Rocks Before You

Wanakah Formation

As you move farther up in the stratigraphic column into the younger rocks of Colorado National Monument, the Wanakah Formation is next. Pronounced "Wuh-NAW-kuh", with the emphasis on the second syllable, this is one of the smaller, more difficult strata to identify. Until recently, this section of rock was labeled as the Summerville Formation, and it is described as such in several National Park Service maps and publications. However, new geologic investigations show that the Summerville Formation does not actually reach this part of Colorado. Instead, this layer of rock has been relabeled as the Wanakah. This is a classic example of how geology is always changing and evolving. With careful new mapping comes more and better information on the details of the rocks. The Wanakah Formation at Colorado National Monument is a good example of the progress being made in this science.

Compared to other nearby formations, the Wanakah is very thin, only about thirty feet thick, where it can be seen at all. Much of it is covered over by rock debris and vegetation. When it does crop out, it is composed of fifteen feet of thin, horizontal beds of reddish siltstone topped by approximately fifteen feet of green siltstone. Geologists think that this formation developed approximately 160 million years ago, when a large lake or playa dried up with a return to desert conditions. Located between the more thick, colorful, and dramatic exposures of the Morrison Formation and the Entrada Sandstone, it easy to miss. Yet, to the touch, the Wanakah is soft and crumbly, and much easier to scratch than either of its neighbors. A good place to see it exposed is along Rim Rock Drive at Artists Point.

Morrison Formation

Resting atop the Wanakah Formation is the Morrison Formation. With its bands of pink, red, gray, white, green and purple, this sedimentary rock is very distinctive. The colorful array of siltstones, mudstones, clays, and shales is broken up periodically by thick, tan sandstone ledges. The Morrison developed about 150 to 155 million years ago, during a time when mountains rose to the south and west of what is now Colorado National Monument. Because our area was lower, streams and rivers carrying sediments from the highlands deposited them here. The floodplain included other fresh-water habitats such as lakes and swamps. Fossil remains of cycads, palms, and conifers attest to the variety of plants that thrived in this environment. An even more impressive number of dinosaurs, fresh-water mollusks, turtles, and small reptilians also flourished.

Of all the geologic formations, the Morrison is among the best known because so many remarkable dinosaur fossils have been found within its multicolored rocks.

First described near Morrison, Colorado, similar rocks have since been recognized throughout the Western United States and Canada. Three sub-units, named the Brushy Basin, Salt Wash, and Tidwell Members, are recognized in Colorado National Monument. The Morrison Formation also interests geologists because it contains deposits of uranium.

The Rocks Before You

You can see the Morrison Formation at several locations at Colorado National Monument, including along Rim Rock Drive near Artists Point, and along the Black Ridge Trail. Perhaps the best examples of it are just outside of the Colorado National Monument boundaries. The land on either side of Monument Road as you approach the East (Grand Junction) Entrance is colorfully banded with grays, purples, pinks and whites. A ridge of Morrison stands out just east of Echo Canyon. The Old Gordon Trail offers spectacular views of the layered rocks. Riggs Hill, the Elmer Riggs Quarry just off Redlands Parkway between Highway 340 and South Broadway, is an outcrop of the Morrison Formation where some of the largest bones of the plant-eating dinosaur, *Brachiosaurus*, have been uncovered.

Dinosaur Hill, near Fruita, along Highway 340 and across from King's View Estates has an interpretive trail through Morrison rocks; one huge rock has the mold of an enormous dinosaur leg bone.

Burro Canyon Formation

The Burro Canyon Formation is next in the stratigraphic sequence. It can be recognized in three ways. Sandwiched between the yellow brown marine sandstone cliffs of the Dakota Sandstone, and the variegated fresh-water mud, silt, and sandstones of the Morrison Formation, its bands of green claystones and beds of sandstone and conglomerate are not as visually dramatic as its neighbors. The Burro Canyon Formation creates gentle slopes broken by periodic sandstone ledges but in the monument it is often disrupted by landslides.

The Burro Canyon Formation marks another change of environmental conditions in the region. It also heralds the earliest times of the Cretaceous Period, from 98 to 140 million years ago. Then, sediments from highlands to the west (central and western Utah, and eastern Nevada) were deposited in the lower elevations of eastern Utah and western Colorado, and distributed by streams and rivers. Layers of chunky conglomerate and fine-grained rock alternately formed. Hence, the Burro Canyon Formation contains areas of rounded slopes mixed with ledges and cliffs. Named for Burro Canyon in San Miguel County, Colorado, where it was first detailed, it is also called the Cedar Mountain Formation to the south and west of the Colorado River.

In Colorado National Monument, it can be seen below the towers at the top of Black Ridge, forming a gentle slope below the microwave and radio towers. Outside of the Colorado National Monument, the lower sections of No Thoroughfare Canyon display the mixed gray and green siltstones, mudstones, and shales characteristic of this formation in a band of rock about 100 feet thick. Look for it, too, as you drive northeast along Monument Drive, about two and one-half miles before the East (Grand Junction) Entrance Station. Along South Camp Road, and near the Fruita Bridge that spans the Colorado River, outcrops of it are also visible. The Burro Canyon Formation is perhaps most significant where its sandstone lenses cap Riggs and Dinosaur Hills, slowing down erosion of significant deposits of dinosaur bones buried in the softer Morrison sediments below.

The Rocks Before You

Dakota Sandstone

Dakota Sandstone is the youngest, and therefore the uppermost, formation of rock discussed here. It is found atop Black Ridge, just outside of the highest part of Colorado National Monument, where it stands out as medium-grained, yellow and brownish sandstone cliffs. The radio and microwave towers, as well as the airport beacons, rest on this outcrop of Dakota Sandstone. The Dakota is also found at much lower elevations north of the monument. As you travel southwest along Monument Road toward the East (Grand Junction) Entrance to the monument, a narrow band of cliffs of Dakota Sandstone top the west-facing slope of No Thoroughfare Canyon (on your left). Many boulders have broken off from above and litter the gentler slope below. Another band of Dakota Sandstone occurs in the Redlands area, flanking the Colorado River.

This peculiar arrangement of Dakota Sandstone exposed at the top and the bottom of the monument is the result of displacement and shifting of lands along the Redlands Fault. The fault runs in a northeasterly direction along the edge of the mesa of which Colorado National Monument is a part. Movement along the fault strongly bent and broke the rocks. To the northeast of the fault, the rocks dip beneath the Grand Valley. Where the rocks are unbroken, this landform is called a monocline.

Among the most widespread Cretaceous rocks in Colorado, Dakota Sandstone is familiar to, and used by, many people in the state. It was first identified and described in Dakota, Nebraska, which gives it its name. On the Front Range between Boulder and Colorado Springs, it is one of the more scenic rocks, forming parts of the dramatic rock outcrops and ridges. For example, the “hogback” on Interstate 70, just west of Denver, is a place where the road was blasted through the Dakota, revealing colorful rock layers underneath. In the eastern portion of the state, it holds significant deposits of oil and gas. In the San Luis Valley, the Dakota Sandstone contains ground water important to the agricultural production of that area. Clays have also been mined from the Dakota for use in the porcelain-making operations of Coors Brewing Company. Pockets of coal, oil, and gas have also been found within it.

Dakota Sandstone was formed during the Cretaceous Period. During that time, an ocean, called the Western Interior Seaway, extended southeast from the Arctic Ocean to the Gulf of Mexico, and westward to the Gulf of California. As the waters of this sea moved in and out, coastal plains, beaches and marshy areas were alternately formed, eroded and formed again. This resulted in some places where sandstone is 100 -150 feet thick and others where it is non-existent. Near Colorado National Monument, the yellowish sandstone ledges of the Dakota Formation remind us of a long ago ocean moving over this now near-desert, on the edge of the mountains…quite a curious leap for the mind to make.

The rock and soils upon which we walk today are the beginnings of another new layer of rock, one whose story is still being composed. It will contain bits and pieces of all the rocks described here, fragments of the rocks before you. If you wonder what this region will look like in the future, stick around for a million more years and find out!

The Rocks Before You

White to Black and In Between: Colors in the Rock

Red rock country: it has been written about many times. Its beauties have been the backdrop to, the inspiration for — and in some cases, the best part of — innumerable movies, television shows, paintings, photographs, weavings, ceramics, even calendars. Tourists from all over the world travel to see the colorful southwestern landscape. What makes the colors in the rocks that make this landscape so striking?

Quartz

First, rocks are made up of aggregates of minerals that are strongly bonded together. Minerals are naturally-occurring substances that have distinct physical and chemical properties. Quartz, for instance, is a compound of silicon and oxygen, or silica. Because quartz forms under many different conditions, not only does it have a range of crystal forms, but traces of other elements, or impurities, can also occur in it. As a result, numerous variations of it may be found. Pure quartz is clear and colorless (rock crystal). With manganese or iron added, quartz may turn purple (amethyst) or pink (rose quartz). With a higher percentage of water in it, or if fractured, quartz takes on a milky, opaque color. Igneous, sedimentary, and metamorphic rocks may all contain quartz. At Colorado National Monument, it forms both clear or whitish sand grains in sandstone, granite, and gneiss.

Feldspar

Not only does the mineral feldspar make up much of the Earth's crust, but it gives color to many rocks at Colorado National Monument as well. It is an aluminum silicate mineral that contains potassium, calcium or sodium. White and pink grains in Precambrian granites, and white to pink bands found in Precambrian gneiss come from feldspars. Thus, only a small amount of a mineral may make a major difference in the texture and color of a rock.

Iron Oxide

Several other minerals influence the colors in the rocks at Colorado National Monument. When the element, iron, bonds with oxygen, it forms the compound iron oxide, or hematite. Better known as rust, iron oxide can saturate the cement between the sand grains, creating varied reds, oranges, and browns in the Wingate and Entrada Sandstones. The deep red of the Chinle and the Kayenta Formations results from concentrations of one-half to one percent of this mineral. Iron oxide, in the form of limonite, gives a yellowish color to clays and Dakota Sandstone. Concentrations of iron also distinguish mica minerals found in granite and gneiss of Precambrian rock. While those with no iron content are white mica (muscovite), black mica (biotite) with its high iron content gives the dark color to the basement rock of the Colorado National Monument's canyons.

Morrison Formation

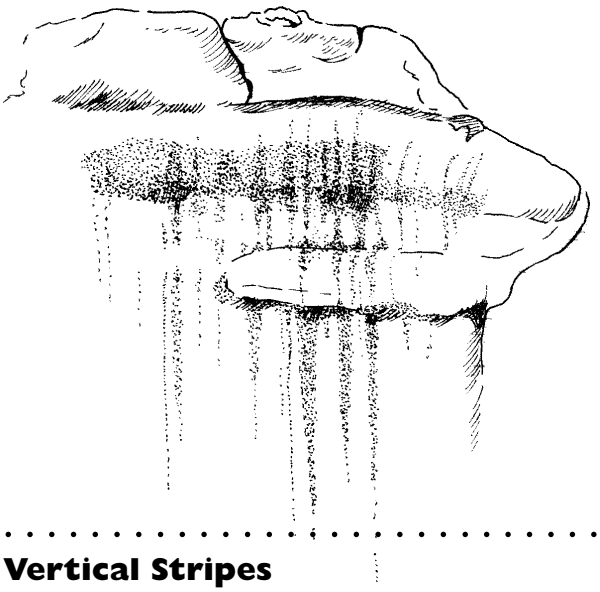
The Morrison Formation is recognized by its colorful rock layers. Its mud and siltstones are made up of tiny clay minerals. Compounds of silica, oxygen, and aluminum clays color the rocks with gray to brown to green to white. Across the Grand Valley, the deeply furrowed slopes of Mancos Shale get their gray color from clay minerals. Volcanic ash also contributes white to gray color in Morrison deposits.

The Rocks Before You

Calcite

Calcite is another mineral that brings color to rocks. A combination of calcium, carbon, and oxygen, calcite forms patches of white that can make a powdery crust on some rocks. Often found on the surface of sandstone, this soft coating can be broken apart with a fingernail.

As you look down from the rim of Fruita, Red, Ute, Monument, or No Thoroughfare Canyons, many of the sandstone cliffs have stripes or a sheen of black or brown. What causes them? How are they made?



Vertical Stripes

Geologists distinguish between the vertical stripes, reminiscent of zebra markings on the canyon walls, and the broad surfaces tinted brown or black, seemingly "varnished" by time. The stripes begin at the top of a cliff face and seem to fade out near the bottom. They look as if an elf poured paint over the edges of the canyon. In fact, they are mixes of algae, fungi, lichen, and bacteria growing on the rock. Rainwater flowing over the cliffs in storms appears to play a part in creating the stripes, both by carrying the organisms onto the rock and by bringing them moisture. Just as cryptobiotic soil crust swells and brightens after rains, so do the stripes. As they age, the stripes also become darker. Look carefully and see if you can locate one of these vertical stripes on a canyon wall. Is it new and light-colored, or is it older and blacker? Can you spot the place where the stripe begins?

Desert Varnish

Stains of brown, purple, and black that stretch across large rock surfaces are what geologists call desert varnish. They create a sheen that resembles shellac that has been painted across a cliff face. Desert varnish is comprised of 70% clay and its color is influenced by manganese and iron oxides. Varnishes high in manganese are black; varnishes low in manganese and high in iron are red or orange; varnishes having equal amounts of manganese and iron are brown. In general, the older the varnish the darker the color. Hard sandstone surfaces have more varnish on them than softer and easily eroded ones, and areas with high exposure to the sun appear to have darker stains.

There are several theories explaining how desert varnish is created. Both propose that the manganese and iron come from outside sources such as windblown dust or rain water containing trace amounts of these elements. Where the theories differ is in the way the materials are cemented to the rock surface. One theory postulates that rainwater mixes with the clay on the rock surface. The water combines with the manganese and iron in a chemical reaction to create oxides which bond to the rock surface. In the second theory, bacteria is necessary for the creation of the desert varnish. The bacteria grow on the rock surfaces and are able to take manganese out of the environment and oxidize it, creating the varnish. These bacteria seem to thrive in the desert ecosystem.

Desert varnish is probably formed by a combination of the above factors. Regardless of the origin, desert varnish highlights and enhances the colors of many cliffs throughout Colorado National Monument.

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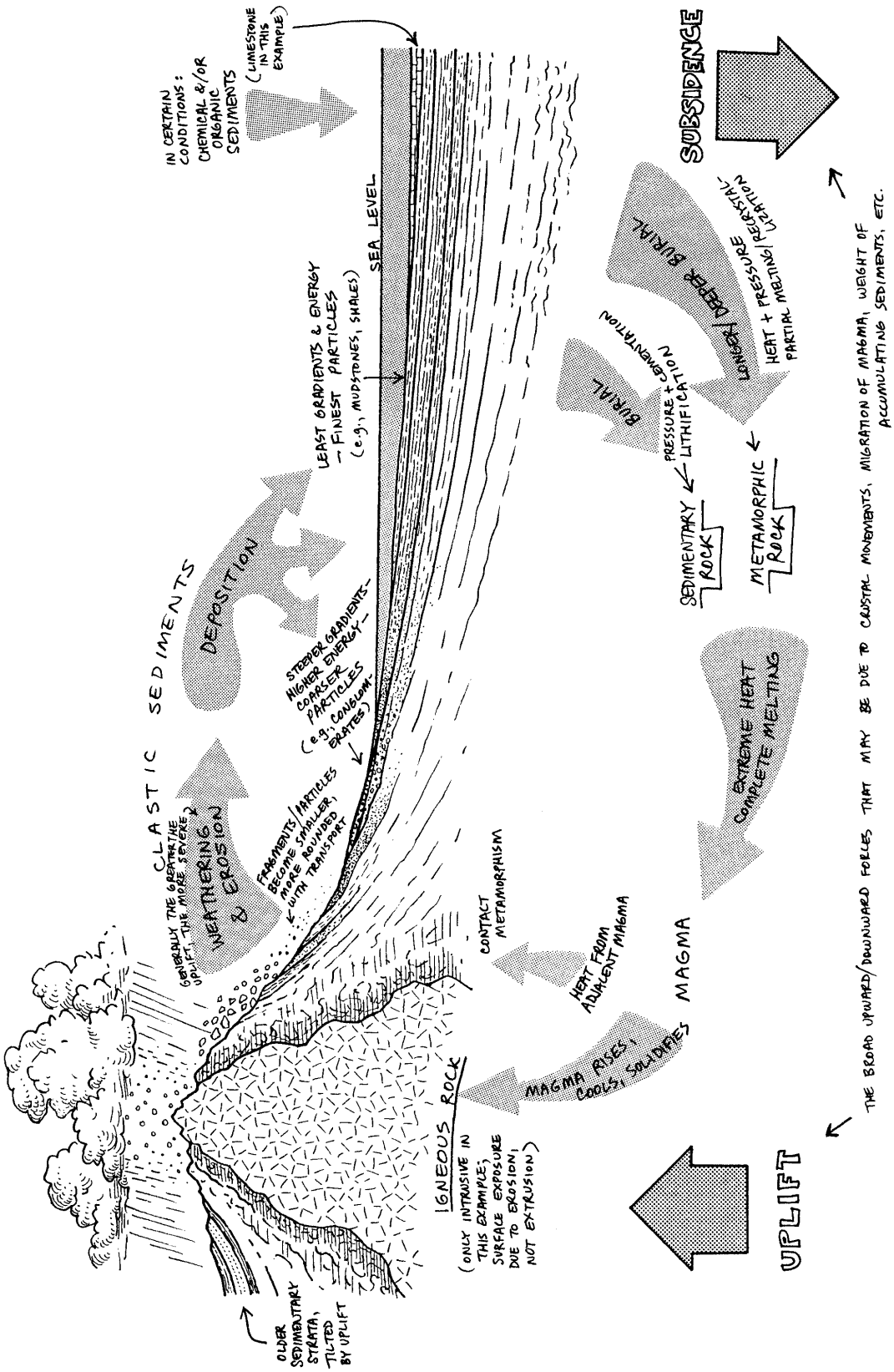
A Rock Cycle Sampler



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Age Level

4th through 8th grades. The lower grades will need more time and guidance to get through the activity.

Purpose of the Activity

"Three Types of Rocks" is a useful introduction to, or review of, igneous, sedimentary, and metamorphic rocks. By using clay to represent rocks, students explore the processes of eruption, intrusion, erosion, sedimentation, compaction, cementation, metamorphism, and subduction. This three-part activity gives students a hands-on, close-up experience with a basic geologic premise: the "rock cycle".

Amount of Time Required

45 - 60 minutes. The activity goes fast; the discussion of what happens will vary in length with age and curriculum.

Best Location

This activity may be done in the field or in the classroom. Suggested sites at Colorado National Monument are Saddlehorn or Devils Kitchen Picnic Areas, Devils Kitchen Trail, or the Old Gordon Trail. Choose an area with plenty of small rocks nearby for students to pick up and observe. In the school setting, desks, lawn, playground, even pavement may be used for this activity. Wherever it is done, be sure to remind students to keep track of little bits of their clay. Plan a clean-up brigade before leaving the area or the room.

Materials Needed

- ☐ Play-Doh™ or another soft clay. Each student will need two handfuls of **two** different colors of clay. The Play-Doh™ Party Pak works well in this situation, because it contains numerous small jars of colored clay. If you prefer to make your own clay, or have access to other brands, they will work just as well, so long as a variety of different colors is available.
- ☐ 8 1/2" x 11" pieces of tin foil, plastic wrap, or waxed paper for each student to use as a working surface.
- ☐ Tables or other flat areas on which to work with clay.
- ☐ Trash bag for cleaning up of tiny bits of clay that escape.
- ☐ **Optional**: Specimens of sedimentary, metamorphic, and igneous rocks to share with the class. If you are doing this activity along the trail, take advantage of textures, shapes, and colors of the surrounding rocks.

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Background Information

This activity helps students to learn about three basic rock types that are studied by geologists, and seen at Colorado National Monument. In "Three Types of Rock", the origins of "*rock*" are explored as students "*roll*" handfuls of clay into representations of igneous, sedimentary, and metamorphic rock. With the clay, they enact ways that rocks are formed. The teacher describes the processes in detail. A final option is for children to look at real rocks around them, to classify into one of the three categories. Accompanying this activity with the song, "Rock Around the Clock", helps to set a rollicking mood. Educational content standards in science are met by this activity.

What is the Rock Cycle?

Just as there is a water cycle on the Earth, so there is a **rock cycle**. It begins with the creation of *igneous rocks* by volcanic activity, and the rising and cooling of magma from the mantle. Next, *weathering and erosion* act on these rocks, breaking them down into smaller and smaller pieces. Over time, the fragments are transported to new locations where *deposition* occurs. As layers of these particles build up atop one another, they *compact and cement (lithify) into sedimentary rocks*. The next phase of the rock cycle happens as the blankets of new sedimentary beds cover the older layers, causing them to slowly heat up. Eventually, the *pressure* and temperature may become great enough to cause the sedimentary rocks to *recrystallize* into *metamorphic rocks*. Finally, movements among the Earth's crustal plates can cause rocks to melt partially, or to be forced down through *subduction back into the mantle*. Once more within the deep, hot region of the Earth, the rocks return to where they came from, and the rock cycle begins again. Thus, continual upwelling from the mantle; eruption and formation into igneous rock; break down and erosion; sedimentation and deposition; lithification; build up of heat and pressure leading to recrystallization; and finally movement of the Earth's plates causing subduction are all parts of the never ending rock cycle. The construction of new rock thus begins in the roots of the old.

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What Are Weathering and Erosion?

Erosion and weathering are two important parts of the rock cycle. Both are part of the breakdown of rocks, the leveling of the land, the smoothing of high places matched with the filling of low places. As soon as rocks are exposed to the atmosphere, rain, cold, heat, and humidity begin to act on rocks, slowly wearing them away. Scientists call this **weathering**: physical and chemical processes that break down rocks in place, as they come in contact with the environment. After they have fractured and broken into smaller pieces, the forces of wind, running water, gravity, and glaciers can then move the fragments to new locations in the process known as **erosion**. Both weathering and erosion are vital parts of the creation of the Earth's landforms, and essential in revealing the stories found in the rocks. They may be dramatic and happen quickly, or they may occur very slowly. The composition of the rocks affects the pace at which they occur, with soft rock breaking down more quickly than hard rock. Fins, monoliths, and monuments are some of the dramatic features of Colorado National Monument that result from differing rates of weathering and erosion in adjacent layers of hard and soft rock.

"Three Types of Rock" gives students hands-on experience with processes of the rock cycle. We live upon the results of eruption, erosion, sedimentation, compaction, cementation, transformation, and subduction. Although the rock cycle is part of life in the world everyday, observing it first-hand is difficult. Volcanoes only erupt occasionally, and often at far distant locations. Watching mountains grow or the slow lithification of sediments is beyond the scope of most of our abilities. Luckily, at Colorado National Monument, not only is an enormous span of time revealed in the rock, but igneous, sedimentary, and metamorphic rocks may be also found. Along with them come uplifting, folding, faulting, and the remarkable sculpting by the forces of erosion. Because few other places in the United States have such unique exposures of rock, Colorado National Monument was set aside for preservation and protection in the National Park Service. No wonder that it offers such a marvelous place for a geology field trip!

Thus, even though "Three Types of Rocks" is a good classroom project, it can be a very successful component of a hike. Working with clay is an excellent tool for refocusing the group after lunch, or for quieting the group down under the shade of tree. In addition, it complements both the "Erosion Hike" and the "Stratigraphy Hike", and provides a good introduction to the "Make a Stratigraphic Column" activity.

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How to Do the Activity

Preparations

Before you begin, review information about the layers of the Earth, about igneous, sedimentary, and metamorphic rocks, and the rock cycle.

1 Practice doing this activity beforehand to be comfortable with the clay, and familiar with what happens.

2 Any type of dough or clay that is easy to work with may be used to make the different kinds of rock. The key is that the clay needs to be brightly colored for the students to see clearly the processes described. For this reason, the "Play-Doh™" product works well. You can divide the small tubs of Play-Doh™ in half to distribute among the group. If you send a letter home ahead of time, you may find that many families have this product at home and will donate it to the class.

If you make your own dough, figure that each student will need two large handfuls or a total of 1/3 to 1/2 cup of dough per person. Remember also that each student needs to have two different colors of dough for this activity. A parent, student aide, or the class itself can be enlisted to do this part of the project.

3 Gather interesting specimens of rock to share with the class. Whether you collect rocks outside, or borrow rocks from someone's collection, be sure that you can identify if they are igneous, sedimentary, or metamorphic in origin.

The Day of the Activity

1 Prepare two handfuls of clay for each student. These may be set out on the desk or table just before the activity, or stored in plastic wrap until the appropriate time on the hike has been found.

2 Pass out one letter-size piece of foil or wax paper to each student. This will be used to help to enact compression and metamorphism. It will also aid in clean-up.

3 The class may benefit by seeing a picture of the Earth on the chalkboard or a piece of paper. Draw a large circle to represent Planet Earth. Just inside that circle, make a second slightly smaller circle. In between the two is the crust. In the center of the planet, make a small circle for the core. The large area in between is the mantle.

4 In addition, a sketch of the rock cycle is a useful reference. Be sure to show its different stages, beginning with igneous rock (both extrusive and intrusive), and continuing on through erosion; deposition; compaction; cementation; lithification into sedimentary rock; heat and pressure leading to metamorphism; and subduction returning rocks to the mantle. This, too, may be recorded on the chalkboard or on a hand-out.

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Set Some Rules

Two Warnings If You Are on a Hike

Warning #1): If you plan to use this activity at Colorado National Monument, remind students that all rocks, even the tiniest, are protected by law, and must remain at Colorado National Monument. Collecting plants, animals, reptiles, insects – and even rocks – is strictly forbidden in national parks and monuments. Everything in these special places is to be protected and preserved into the future, so that others will be able to discover and enjoy them as well. However, students are welcome to look at and to share any especially interesting rocks with the group. Afterwards, the rocks *must* be returned to where they were found, so that they may continue on their journey as part of the rock cycle of the Earth.

Warning #2): If students are going to be picking up rocks, it is important that the teacher explain that rocks are shelters for a wide range of desert dwellers. Ants, beetles, spiders, scorpions, centipedes, lizards, and snakes all make their homes in and under rocks. Removing a rock can not only destroy the shelter of a creature, but it can result in the very real dangers of desiccation and predation. In addition, some of those creatures protect their territory with quite a dangerous bite or sting. **Look carefully around a rock before lifting it up. Tip it *towards you* slowly to examine who or what is underneath before picking it up. If something is under it, replace the rock *very gently* in *exactly the same position* as you found it.**

Step-by-Step Instructions

Step One: Pass Out the Clay and Paper.

Two balls of clay and one wax paper or foil sheet should go to each person. The clay should be two different colors.

Step Two: Set Some Rules for the Group.

These include:

1 Listen carefully to directions to have the right outcome in this activity.

2 Handle the clay carefully. Avoid getting the dough on the floor, carpet, or ground. Not only it is no fun to have lots of little bits of it to clean up later, but also it can be hard to get out of carpets. You do not want to leave any of it out in nature as it is littering, and no animals will get near it.

3 To show that you have completed each step of the activity, you should hold up what you have done in the air.

Step Three: Set the Scene.

Set the scene by asking students to observe the different sizes, shapes, and colors of rocks around them. Reflect on the ways rocks are used in our daily lives. Buildings, streets, roads, gardens, sculptures, metals, coal, granite or marble in fireplaces and counter tops, even pigments in paint, all derive from rocks. Soil, in which we grow food for people and animals, can also be added to that list. When you think about it, a great deal of our lives is connected to rocks. Indoors, ask students to identify things in the school setting that are made from rock, including: cement, bricks, stone walls, nails, chalk, glass, copper wire for electricity, as well as other classroom materials.

Step Four: Getting Started.

Ask students to pick up one of the balls of clay and roll it around in their hands. Introduce the activity by explaining that the class will be investigating three types of rocks found on the Earth. They will explore the diverse origins of these *rocks* by *rolling* and working with clay to create them.

Definition of Rock

Next, the teacher should ask if students know what rocks are, and where they come from. The variety of answers may be interesting to record on the chalkboard. One of the simplest definitions of rocks is: **Rocks are *consolidated* mixtures of minerals that occur naturally.** The different mineral grains are held together very strongly through chemical and physical bonds. Over time, and exposure to the elements, rocks may decay and break down into soil, or the fragments may be carried away by wind and water, eventually to become lithified into new rock.

Rocks form in three ways. The first is from hot, molten material from the Earth's mantle rising up to create **igneous** rock. The second way is from loose sediments compacting and cementing together into **sedimentary** rock. The third way that rocks form occurs when heat, pressure, or both act on igneous or sedimentary rock to change or recrystallize them into **metamorphic** rock.

Step Five: Introduce Igneous Rocks.

Use the drawing of Planet Earth for reference here. Go over the parts of the Earth, and explain that igneous rock is formed when molten material from within the mantle rises up into the crust. When this magma pours out onto the Earth's surface from a volcano, it is known as lava. Geologists call this process **extrusion**. You may want to draw a picture of a volcano on the chalkboard to help illustrate this process.

If the molten material remains underground, it is known as **intrusion**. Under the Earth's crust, this molten material may force its way into the older rocks. If a large enough mass rises up, it may cause a bulge in the crust (an uplift) or a mountain range to form.

Again, a sketch on the chalkboard may help students to grasp this idea.

Both extrusive and intrusive igneous rock may be seen all over the world. Hawaii and Iceland are both examples of places where volcanoes are active. Mount St. Helens in Washington State and Mount Pinatubo in the Philippine Islands are recently active volcanoes that have had huge impacts on their surrounding communities, and even the world's atmosphere. Closer to home, ancient lava flows cap Grand Mesa. The Uncompahgre Uplift, of which Colorado National Monument is a part, and the Yosemite Valley in Yosemite National Park in California, contain ancient intrusive rocks. Granite and pegmatite are the two forms of igneous rock found at Colorado National Monument.

Step Six: Rock and Roll.

In this section, it is helpful for the teacher to demonstrate what to do with the clay each step of the way. Having students hold up their clay each time they have completed the required action will give the instructor an idea of how everyone is progressing. It will also aid in showing who may need help. Because each person will have a unique result, students also enjoy seeing how others' clay looks.

- Instruct students to choose one of their balls of clay. They should roll it in their hands until it is soft. This should take no more than 30 seconds.
- Next, they should break the ball in half, and exchange one-half with a neighbor *who has a different color of clay*. The outcome should be that everyone now has two small balls of clay, and one larger ball of clay, each of which is a different color.
- When the exchange is complete, the class should flatten one of the two small balls by pressing down on it with the palm of their hands. The clay should be thin, but not so thin as to see through it, or have holes in it. This flat piece will be the Earth's crust in the simulation of the formation of igneous rock.
- Set aside the "crust" briefly, and pick up the second small ball of clay. Roll it around in the hands until it is a soft round ball. Carefully lay the flattened "crust" on top of it. The edges can drape over it without any problem.
- Ask students to hold up the ball of clay with one hand and lightly stabilize the flat piece on top with the other. Then, they should push the ball of clay up *strongly* into the flat piece. Ask them to watch carefully to see what happens to the "Earth's crust" when pressure comes from below. This action represents what happens as magma rises from the mantle into the Earth's crust. Where it finds an opening, or a thin, weak place in the crust, it can come out onto the land.
- When everyone is done, ask how many students had the ball of clay break through or into the flat top layer. This exemplifies the process of extrusion. The ball of clay acted like magma, and pushed through the crust out onto the Earth's surface. Pick out one or two examples of clay to show to the whole class.
- The balls of clay that did not break through the top layer demonstrate the process of intrusion. The crust may have risen or domed up, but the magma ball did not come through. This happens in places where the crust is very thick, or the magma cools and hardens before it reaches the surface.
- Depending on what the students observed, and depending on your time, you may want to repeat this experiment.

Step Seven: Introduce Sedimentary Rocks.

This segment of the activity focuses on a second type of rock known as **sedimentary rock**. Its origin is in igneous rock that slowly breaks down from the action of wind, water, freezing, thawing, and heat. Over time, what was once a large dome of granite, or a slope of basalt, fractures into smaller and smaller pieces. Eventually, these fragments, most no bigger than a grain of sand, are carried away in a river, blown away by the wind, or "roll" to a new location. Places where accumulations of sediment occur include the ocean floor, shore and coast lines, reefs, rivers, deltas, lakes, ponds, etc. In these sites, particles may be buried under yet more sediment. The weight of new layers atop the old squeezes out water, and compresses the grains. Compacted, and under increasing pressure and temperature, some minerals solidify together, while others dissolve to flow between the grains. Still others, like quartz, remain unchanged. Slowly, fragments of old rock cement together as minerals solidify into new rocks from old sediments. This, then, is a simple definition of sedimentary rock: a new generation of rocks formed from the decay, erosion, and re-deposition of older rocks.

Step Eight: The Break Down.

In this step, the children are simulating the actions of weathering, erosion, deposition, compaction, and lithification. In the center of the foil or wax sheet, students should break up their "igneous rock" into small pieces. This should include both small balls of clay. (The one that has not yet been used still should not be touched.) When the clay is broken into fragments, pile up the pieces in the center of the sheet. Next, fold the sheet over the top of the pile of clay. This should create a "foil sandwich," with the foil as the "bread" on the outside, and the clay as the "filling" on the inside. Remind the class to do the break down carefully to minimize clean-up later.

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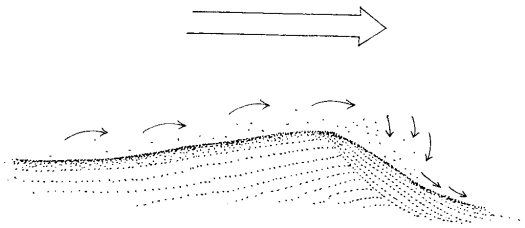
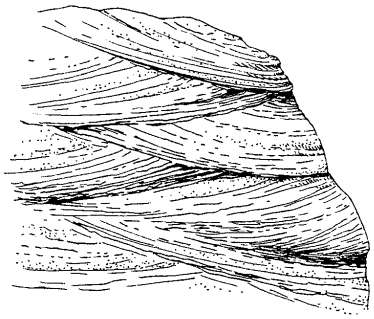
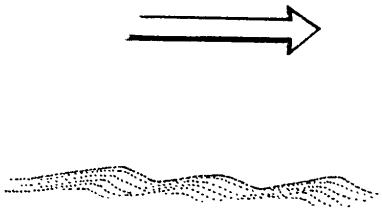
2 KINDS OF COMMONLY-SEEN SEDIMENTARY STRUCTURES

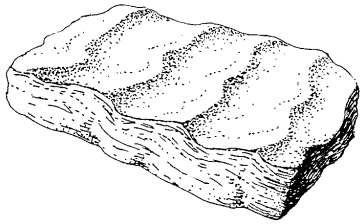




EOLIAN CROSSBEDS

at top, "active" sand dune showing wind direction (large arrow) and sloping sand layers formed as grains roll & bounce (small arrows) up upwind slope, drop to form steeper downwind slope / below, crossbedded sandstone, showing multiple sets of beds at varying angles from shifting winds





RIPPLE MARKS

water current (arrow, top) may form ripples similar in shape to sand dunes but on a smaller scale; symmetrical ripples can also form (such as on a shoreline with ebbing/flowing wavelets)

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Compaction and Lithification

When this is complete, ask students to place the palm of **one** hand on the foil, and press down **lightly** to flatten the pile of clay. They should not press hard, or for a long time. Merely flattening the clay is all that is needed.

Erosion and Weathering Simulation

Step Nine: The Uncovering.

The group should carefully open up their foil packets and inspect what is inside. What happened to the clay? Their observations should include that the tiny pieces of clay are all squished together (compacted), thereby forming a new rock from the pieces of old rock (lithification).

Ask everyone to hold up their new rocks so the group can see the unique mix of "rock" material, color, shape, thickness and texture that each person has. In nature, the variety of particle shapes; the minerals composing them; the way that they were compacted; and the amount of pressure applied, act together to create different types of sedimentary rocks. For example, sandstone (grainy) is distinct from clay (fine particles), breccia (large, angular fragments), or conglomerate (round pebbles).

Checking the Results

Step Ten: Testing the Sedimentary Rock.

1 Can the students break their new rock apart into some of the original pieces of clay? The students' answer should be yes, but with some effort. It is important to note that nothing has actually changed within the rock, merely individual pieces have been compressed and stuck together.

2 A second test is to break the new rocks in half and look inside. The students should see loosely consolidated particles of colored clay, along with some areas of open space. This is typical of sedimentary rocks, such as sandstones, where particles may touch one another but still have some space in between. As layers and layers of rock build up on top of the first sediments, they compress them, but do not change the original pieces. Silica, calcite and other minerals can flow into the spaces and act as cement that ultimately holds the individual pieces together, forming a new type of rock.

Put aside these "sedimentary" rocks to save for the next part of the activity.

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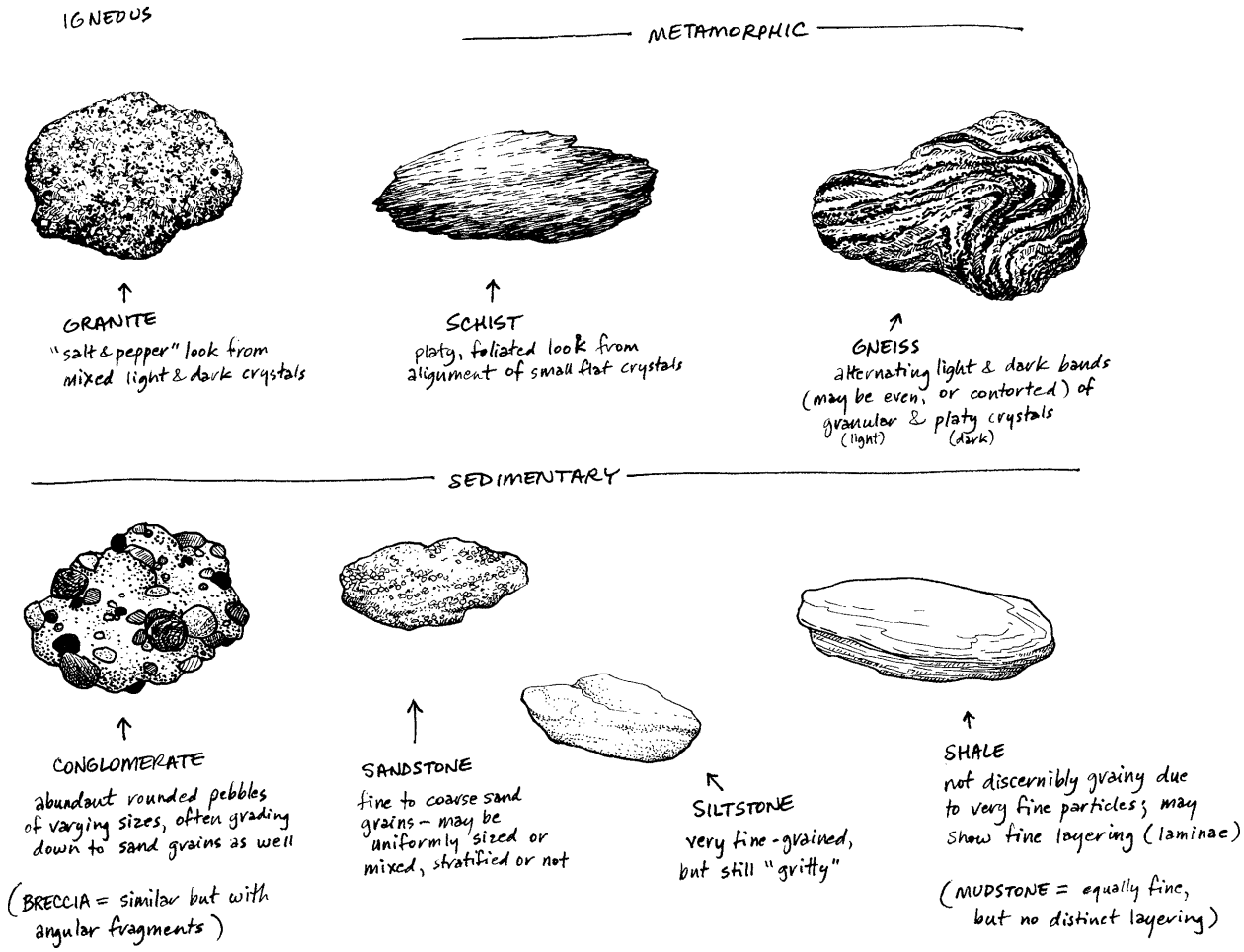

Metamorphic Rocks

Step Eleven: Introduce Metamorphic Rocks.

Metamorphic rock is formed when pre-existing igneous, sedimentary, or metamorphic rock is exposed to great pressure or high temperature. Under these conditions, the rock may be changed or "transformed" into an entirely new type of rock. Metamorphism occurs in several ways. First, when lava from volcanoes, or from intrusions of the mantle, rises up into the crust, rocks in the vicinity are heated to such high temperatures that minerals re-form into new types of rock. Secondly, during times of mountain-building, folding, or movement of the Earth's crust, rocks may be squeezed and subjected to such high pressure that they recrystallize into new rocks. Examples of metamorphic rock are quartzite deriving from sandstone, and marble coming from limestone and slate forming from shale. Metamorphic rock itself can become hot enough that it can turn to molten rock, or magma. This type of partial melting of metamorphic rock has been found at Colorado National Monument.

Step Twelve: Rock and Roll, Part Two.

For this final segment, students use the handful of clay that has not yet been used. They should "roll" this piece in their hands to soften it. Then they should lightly flatten it into a small pancake, and place it on one side of the foil or wax paper. Next, they should place the "sedimentary rock" made in Steps Eight and Nine on top of it. This action simulates the deposition of layers one upon the other that build up in depth, weight, and pressure on the layers below. Cover both the old and the new clay with the remaining portion of the foil or wax paper.

Step Thirteen: Heavy Pressure.

In this segment, it is important that students listen carefully to the directions to obtain the best outcome. First, ask students to take off one shoe, and put it out of the way nearby. Secondly, students should place the foil packet on the floor, or a flat piece of ground where no rocks will protrude into the clay. Thirdly, students should stand up, and step down hard, with full weight, onto the clay packet. *NOTE: Do not grind or twist feet on the clay, as foil rips easily, ruining the effect. For this reason, stocking feet are also recommended: the soles of shoes can rip through the clay.*

This action represents how the weight of layers of rock atop one another can build up enough pressure and heat to effect change in rocks. In our case, the weight of the student symbolizes the weight of sediments upon each other. Stepping down heavily denotes the pressure those sediments create, thereby compacting and compressing the rock, and causing it to transform and recrystallize into a new rock. This process is known as metamorphism.

Ask the students to open up their packets very gently and carefully. The clay, this time, should be a swirl of all three colors. They should be so closely blended that they cannot be separated from one another. How does the new, "changed rock" look? How is it different from the earlier sedimentary rock?

A test for metamorphic rock: Can you separate the two layers of clay from one another with your hands? What does this new rock look like on the inside when broken open? Which rock appears to have more air spaces within it? What causes metamorphic "rock" to be so different from sedimentary rock? The response that you want is that with greater pressure comes greater change to the rock.

Step Fourteen: Clean up.

Clean up the classroom or the area where the students did the activity. Especially if you are outside, you want to make sure that no traces of the clay are left on the ground. Plan a cleanup brigade to leave the area spotless.

A final (optional) observation segment is very effective. Look at several examples of rocks from a rock collection, to see if the class can decide if they are igneous, sedimentary, or metamorphic. If you are at Colorado National Monument, pick up a rock that is on the ground near you (see earlier warning about picking up rocks), or get up close to a large boulder. Feel the texture of the rock. Can the class figure out what it is composed of? Review the definitions of the three rock types if students seem unsure.

Depending on where you are at Colorado National Monument, the majority of rocks should be sedimentary or metamorphic. However, you may want to note that many of the grains of sand composing the sedimentary rock could have had their origins with magma, or igneous rock, from long ago volcanoes, sea-floor spreading, or mountain building. Quartz, or silica, is a primary element in sand, and often derives from mantle rock.

Conclusion

Using simple materials like clay, students are able to simulate key elements in the formation of rock and in the rock cycle: extrusion, intrusion, erosion, weathering, sedimentation, and metamorphism. After this activity, the class should have a much better awareness of and appreciation for the rocks around them.

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Extensions

For younger students, this activity can be divided into several sections and spread over several days. Another option is to do only one part of the activity, highlighting how one kind of rock is formed. Numerous children's books are available about rocks, minerals, and rock hunting. You may want to include exploration of those books, either as a group or as individuals. Your local library should be a good resource.

For older students, a drawing or writing component can be added to this activity. Students can make a record of what happens in each segment either by drawing or writing. To encourage the use of the scientific method of observing and recording, students can be given a homework assignment to write up their "laboratory" experience with making rocks, and put it in the structure that scientists use when they conduct experiments. The structure includes the following:

~ Summary of what took place.

~ Hypothesis of what student expects to happen with the experiment.

~ List of materials used.

~ Step-by-step description of what was done with the materials.

~ Observations of what took place when actions were taken.

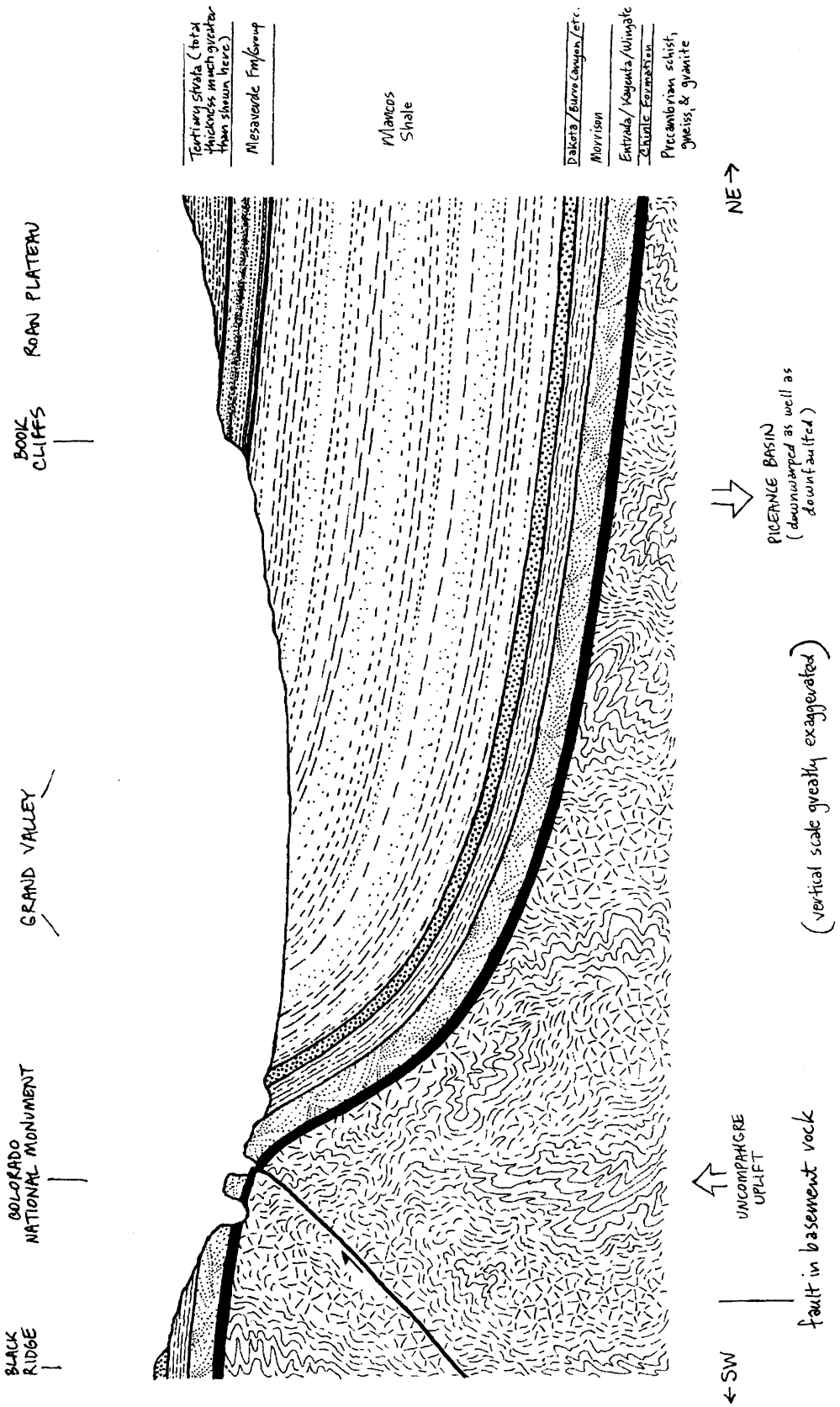
Other options for students are:

1 Visit the Museum of Western Colorado for a tour of their rock collection.

2 Take a field trip to a site where rocks can actually be collected. Ask a local geologist for suggestions of interesting geologic sites in the region. Remember, however, that rock collecting must be done only where it is permitted. Do not attempt it at Colorado National Monument, which is federally protected land. Be sure you have permission of the owner to collect on private property.

Make a Stratigraphic Column
of Colorado National Monument

ACTIVITY PAGE



Make a Stratigraphic Column
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Age Level

4th through 8th grades.

Purpose of the Activity

Through this activity, children experience a hands-on, close-up look into the workings of geology. First, they learn about a stratigraphic column, a diagram of the sequence of rock layers of a given area. Secondly, when they create their own stratigraphic column of the rocks found at Colorado National Monument, students gain knowledge about the features of individual rock layers, including composition, depth, color, fossil life, age, texture, and hardness. Thirdly, basic tenants of geology, such as the "Law of Original Horizontality" and the "Law of Superposition" are incorporated into the activity. While these are complex sounding terms, the concepts, that rocks are laid down in horizontal layers, with the oldest at the bottom, and youngest at the top, are easy for children to grasp with the column.

Making a stratigraphic column is also good preparation for a field trip to Colorado National Monument. Students are better able to find, identify, and appreciate actual rock formations after they have made the column. Alternatively, this activity makes a useful follow-up to a geologic exploration of Colorado National Monument. Because it is against the law to collect rocks (or anything else, for that matter) in a national park, the column is a good way for students to make and keep a tangible record of their experience.

Amount of Time Required

Three hours are needed for this activity: one hour for preparation and two hours for the column itself. Some extra time may be required for clean-up and labeling of formations. The column project can be completed either in one class session or in several.

Preparation time, estimated to be one hour, is for locating and gathering materials. The results are well worth the effort. The teacher's time can be reduced by sending a note home requesting parental assistance with "unearthing" materials. In addition, the more organized you are in setting up, the more quickly and smoothly the activity goes.

Activity time should be about two hours for 4th through 6th graders. Times will vary depending on how artistic or meticulous a given class is. 7th and 8th graders may need less time. The activity is easily done in stages. It may also be finished at home.

Make a Stratigraphic Column
of Colorado National Monument

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Materials Needed

The list of ingredients for the stratigraphic column is long because nine different rock formations are created by the class. Since students really enjoy making the columns, and learn a lot in the process, it is more than worthwhile to spend the time gathering materials. Enlist parental help by sending home a note about the project several weeks in advance. Ask for donations and assistance from families, and getting the materials will be much easier.

Amounts given for this project are estimated for a class of 25. If your class is different in size, change the amounts proportionally. If you cannot come up with one or more of these elements, *feel free to improvise* with what you have on hand.

Ingredient List for Stratigraphic Columns

- ☐ 25 pieces of 8 1/2 x 11 inch scratchboard, mat board, or thick cardboard. (Due to the weight of the sands and glue, a sturdy base, such as mat board, is needed. The size and color may vary: you just want the sands to show up against the background. Picture framing stores and art suppliers often have scraps of mat board that they will donate for this project.)
- ☐ 3 packages of 3 ounce paper cups. (For holding sand.)
- ☐ 2 packages of toothpicks. (For flattening and smoothing glue, and for dinosaur bones.)
- ☐ 25 plastic spoons. (For sprinkling sand and other materials.)
- ☐ School glue—one bottle per student. (Easy access to glue speeds up the activity.)
- ☐ 1/4 lb. wood shavings. (The shavings should be natural colored. They can be purchased in the pet department of stores, or gathered from a wood worker.)
- ☐ 1/2 lb. of tiny shells. (These can be the kind for craft use, or leftover from other projects.)
- ☐ 1/4 lb. of pea gravel. (The kind from fish tanks or foot paths.)
- ☐ 1 container of sparkles.
- ☐ 1/4 lb. of peat moss.
- ☐ 4 - 6 briquettes of coal crushed into small, gravel-sized pieces.
- ☐ Plenty of newspaper. (For covering work areas and the floor.)
- ☐ Copies of the "Stratigraphic Column of Colorado National Monument" for each student.
- ☐ Pencils, markers, and rulers. (For marking off and labeling different rock strata.)
- ☐ Sand. (10 - 12 cups *each* of beige, pink, gray, white, red-orange, purple, and black sand are needed to simulate colors of the different rock formations. Some sand can be dug up locally. Another option is purchasing Art Sands™, pre-colored sands, which are found at art supply stores.) *See note.*
- ☐ Ziplock™ plastic bags and a trowel or old spoon. (For digging up sand.)

Access to a sink is helpful.

Make a Stratigraphic Column
of Colorado National Monument

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A Note About Sand

You will need a number of different colors of sand to simulate the rock layers in the "Stratigraphic Column". To save the expense of buying sand, and to make the project more authentic, beige, pink, gray, purple, and white colored sands can be collected locally for this project. Approximately 10 - 12 cups of each color are recommended. The source of the sand is not as important as the range of colors. Use a trowel or old spoon to dig up sand from any of the sites listed below. Ziplock™ plastic bags work well to hold the sand. Do not take sand from Colorado National Monument itself, and get permission if you plan to dig on private property. When digging sand, be sure to park off-road, and watch out for car and bicycle traffic.

Best Location

Where to Find Sand Locally

- **Along Monument Road** out of Grand Junction, you will enter into an area where the gray, green, purple, pink and white rocks of the Morrison Formation come right down to the road. You can dig up sands in this area.
- **Along the Broadway/Redlands Road**, in the vicinity of the Lower Monument Canyon Parking Lot turn-off, and approximately three miles east of the West (Fruita) Entrance Station, is another area where the colorful bands of the Morrison Formation may be found. Again, gray, green, purple, pink and white sands can be found here.
- **By the Fruita Bridge** over the Colorado River, or at other bridges or boat launches along the river, yellow-brown beach type sand can be found.
- **Sandboxes** can also be raided for beige or tan-colored sand.

Art Sands™

Art Sands™, like those used in sand painting, are available in many discount and artist's supply stores. These can be utilized to make the colorful layers such as the Entrada (white and yellow), Wingate (orange), Kayenta (dark red), and Precambrian rock (black). If you explain that you need the sands for a school geology project, many suppliers will donate or give discounts on your purchase. Parents may have them also.

Make a Stratigraphic Column
of Colorado National Monument

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Background Information

The Classroom

This activity is intended to increase students' awareness of and appreciation for the diversity of rocks contained within Colorado National Monument and the region. One of the reasons that the monument was created was because of the remarkable span of time and rock that is exposed there. In few places other than the Grand Canyon and Dinosaur National Monument can such a time span be observed in the rocks. Making a map of the rock layers of the monument gives students a hands-on opportunity to learn about the different layers of rocks and how they were formed. In addition, a stratigraphic column is fun to make and serves as a concrete reminder of a place visited. As a result, this activity makes an excellent follow-up to a field trip. Since no rocks can be collected on any National Park Service property, the Colorado National Monument stratigraphic column is a personal, artistic, and scientific way to make a record of a visit.

How Geologists Use Stratigraphic Columns

Geologists use stratigraphic columns as visual maps from which to learn more about a place. Just as road maps to help guide us from point A to point B on the surface of the Earth, these columns help geologists to keep track of the sequence of time spanned through the rocks. If a particular fossil is sought, or if a mineral is desired, these views of the arrangement of rock layers are useful to pinpoint the right area to look. Columns are also invaluable for comparing rocks found in different parts of the country and the world. When a road or shopping mall is projected to be built, geologists and engineers consult stratigraphic columns to determine that the rocks below will support development. Answers to such questions as: "Is an area prone to landslides in heavy rain?" or "Is water accessible at a certain depth?" may be found in stratigraphic columns. Last, but not least, these useful devices function as teaching tools in the study of geology. Basic concepts of geology, such as the "Law of Original Horizontality", the "Law of Superposition", and the concept of "Uniformitarianism", are exemplified in them.

Constructing stratigraphic columns of the rock formations in a given area is one aspect of the work of a geologist. The experience of constructing their own column of the stratigraphy of Colorado National Monument offers students the chance to learn what is involved in real-life geology. Content standards in geography and science are also met through this activity.

Make a Stratigraphic Column
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Definition of Stratigraphy

What is stratigraphy? Geology is the study of the Earth, and stratigraphy is a branch of that science. It focuses on rock formations, how they are related to one another, and how they are distinct. The characteristics of each formation, such as the fossils and minerals, and their arrangement within the rock, are of special interest. By investigating the composition and arrangement of rock layers, stratigraphers can begin to ascertain the dates when different environments existed on our planet.

Stratigraphic Column Defined

What is a stratigraphic column? It is a representation of the layers of rock as they rest one upon the other, from the deepest layers known up to the surface of the Earth. The Grand Canyon is an example of a stratigraphic column that has been exposed by nature. It is an ideal place to view the many layers of rock that compose our world. The canyons of Colorado National Monument are another place where layers of rock have become visible due to uplifting, faulting, and erosional forces. Because so many formations are exposed, geologists come here to observe and draw the rock layers into maps they call stratigraphic columns. Other terms for these maps are rock columns, rock sequences, and geologic columns.

How the Column Works

How does a stratigraphic column work? Geologists use stratigraphic columns to study the different rock layers for their unique character, including mineral composition, fossil life, texture, color, thickness, and hardness. Geologists learn to distinguish the layers, just the way a detective uses fingerprints to identify a person. Because the layers occur in a sequence that holds true across vast areas, geologists use stratigraphic columns to predict that if they are standing in white to yellow to salmon-colored rocks of the Entrada Formation, then the Navajo Formation should be below. Places such as at Colorado National Monument, where the Navajo Formation is actually missing in the rock sequence, are just as interesting – if not more so!

Because sedimentary rocks are created in flat, horizontal layers, and only later being folded, faulted, and eroded, stratigraphic columns help to keep track of the original order and organization for comparison with what actually exists. Finally, stratigraphic columns help geologists to estimate the age of rocks. The oldest rocks are always shown at the bottom of the column, with each rock layer above being younger than the previous layer. Stratigraphic columns are, thus, highly informative and useful geologic tools.

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How to Do the Activity

Preparations

1 Recruit some parental assistance in gathering the materials. Much of what is needed is available in garages, art boxes, and storage bins at people's homes. A note home requesting supplies should bring you many of the supplies that you need. Use the services of a volunteer to dig up, or purchase, the remaining sand and fixings.

2 A sturdy base for the stratigraphic column is essential to its success. Regular paper will soak up the glue and become very flimsy under the weight of the sand. Use mat board, or another thick type paper for this activity.

3 Review the information about geology and rock formations in "The Rocks Before You" section of this chapter. Copy off the "Stratigraphic Column of Colorado National Monument" for each student to use for reference in this activity.

4 Enlist several parents or a teacher's aide to come assist you on the day of the activity. This will help speed preparations, assist students through the process, and ease clean up pressures.

5 On the day of the activity, allow 30 minutes for two people to set out the materials in advance of class. Each student will need the following supplies:

~ Newspaper (to cover the desk and floor below).

~ One piece of mat board.

~ Bottle of glue.

~ Pencil and ruler.

~ Plastic spoon and toothpick.

~ Copy of the "Stratigraphic Column of Colorado National Monument".

The rest of the materials can be shared by the group.

Setting Up the Classroom

6 If space allows, set the classroom up like a cafeteria, with groupings of sands, shells, gravel, shavings for each rock formation in different locations. This structure allows students to work more easily on their own: as they complete one layer, they can return excess materials to that station, clean up, and move on to the next formation. Setting out supplies in the same order as the "Stratigraphic Column of Colorado National Monument", beginning with the oldest rock and moving to the youngest rock, makes it easy for students to keep track of where they should be.

7 If time permits, pour sand into paper cups and arrange other supplies in advance. Remember that some materials will be used in more than one formation, so pay attention to amounts listed in the "recipe" below. If time runs short, set out cups and bags of sand for students to fill themselves.

Make a Stratigraphic Column
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Recipes for Rock Formations in the Stratigraphy Column

■ **Precambrian Rock** (Bottom layer of rock, and the thickest.)

~ One-quarter cup of black sand. (Art Sands™.)

~ One-quarter cup of pink sand. (Art Sands™ or Morrison sediments.)

~ Paper with large pinch of sparkles.

■ **Chinle Formation** (Slope-forming layer, atop the Precambrian.)

~ One-quarter cup of dark red sand, or red and gray mixed. (Art Sands™.)

~ Paper with a pinch of peat moss and a pinch of wood shavings.

■ **Wingate Sandstone** (Thick, cliff-forming layer, over the Chinle.)

~ One-third cup (total) of orange, red, beige sand mixed. (Art Sands™.)

~ Pinch of black sand.

■ **Kayenta Formation** (Thin, slope-forming rock, found above the Wingate.)

~ One-quarter cup of red or dark red sand. (Art Sands™, or use rest of Chinle sand.)

~ One-quarter cup of purple or gray sand. (Taken from Morrison sediments.)

~ Paper with pinch of wood shavings. (Or use up Chinle shavings.)

■ **Entrada Sandstone** (Cliff-forming formation, over the Kayenta.)

~ One-quarter cup of white sand. (Art Sands™ or river sand.)

~ One-quarter cup of orange sand—or orange and red mixed. (Art Sands™, or use rest of Wingate.)

■ **Wanakah Formation** (Thin, banded rock between the Entrada and Morrison.)

~ One-quarter cup of pink Morrison sediments, or red Art Sands™.

- **Morrison Formation** (Thick, colorful, banded rock formation, above the Wanakah.)

~ One-quarter cup of gray sand. (Morrison sediments.)

~ One-quarter cup of pink sand. (Morrison sediments.)

~ One-quarter cup of white or beige sand. (Art Sands™, river sand, or use up Entrada.)

~ Paper with large pinch of peat moss. (Use up Chinle, if some is left over.)

~ Paper with large pinch of wood shavings. (Use up Chinle, if some is left over.)

~ Several toothpicks broken into small pieces to represent dinosaur bones.

- **Burro Canyon Formation** (Found above the Morrison.)

~ One-quarter cup of grayish, or gray-greenish sand. (Morrison sediments.)

- **Dakota Sandstone** (Cliff-forming layer above the Burro Canyon.)

~ One-quarter cup of beige sand. (Sandbox or river sand.)

~ Paper with 5-8 shells.

~ Paper with several small chunks of charcoal.

Suggestion for Younger Students

A Suggestion for Younger Students: The teacher should plan to be the guide for this exercise, making a demonstration column alongside the students. Visual as well as oral explanations may be helpful for some classes. One option is to draw the stratigraphy column step-by-step on the chalkboard. Another is to set the class up like a cooking or home improvement show, where the instructor makes his or her own sample in front of the students. Extra parents can be put to use circulating in the room to assist with any problems that come up.

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Step-by-Step Instructions

1 Introduce the activity to the class by explaining what a stratigraphic column is and how it works. Ask students to think of situations where horizontal layers pile up from old to new. Common examples in the home are laundry baskets, stacks of pancakes, and garbage in trash cans. Examples from nature are: snow drifts (oldest snow on the bottom, freshest on top), and tree rings (oldest layers in center, youngest on outside). That the layers on top are younger than those underneath (or down below) is a fundamental tenant of geology: the Law of Superposition.

Perhaps the most dramatic and extensive example of layers piling up is found in the Earth's crust. The rock we live on originates from eroded particles of ancient rocks that have been compacted and cemented together. Geologists go to places with a lot of exposed rock to be able to look "inside" the Earth and learn about what happened in the past. The deeper we look in the crust, the older the rocks are. Colorado National Monument's deep canyons, steep cliffs, and unique erosional features make it an ideal place to study the span of geologic time. In preparation for a visit there, or as a follow-up afterwards, students will be creating their own stratigraphic column of area rock formations.

Review the Rock Column of Colorado National Monument

2 Review the "Stratigraphic Column of Colorado National Monument" hand-out with the class. Discuss the how each formation has its own unique features and composition. Explain how each layer of rock was created as a horizontal "bed" under a set of distinct environmental conditions. (Law of Original Horizontality.) This same process is going on today. Layers of soil and rock are breaking down into smaller and smaller pieces. These sediments are being washed down streams and rivers, and swept off the continents to pile up atop one another in oceans. Little by little they are solidifying into rock. Entirely new rock is also extruding onto the Earth's surface through volcanoes, and rifts in the crust. These processes are the very same ones that created the very oldest rocks on Planet Earth. (Uniformitarianism.) Thus, fundamental lessons of geology are revealed within the stratigraphic column.

Students Simulate Work a Geologist Does

3 Begin the activity by explaining that each class member will learn about the work that geologists do by creating their own stratigraphic column of Colorado National Monument. To simulate what geologists do in the field, students will glue different materials to a piece of mat board to create a map of the layers of rock seen at the monument. The supplies that they will need are set out on their desks and at stations within the classroom. The teacher should show the different stations from which to get supplies, and explain that there is enough sand and rock for each person and each formation.

Individual Artistry

4 Commence the artistry and the individuality. Each student can interpret the rock column in his or her own way. Remind them, however, that nine layers, some quite sizable, must fit on the mat board. Since students need room to label the formations, they should plan to leave space at one side or the other of the column for them. Refer them to their "Stratigraphic Column" hand-out to get an idea of how their final product might look. Students may find it beneficial to sketch an outline of their column onto the mat board before applying the glue and sand. The "Stratigraphic Column" hand-out is a useful guide if they need one. A ruler may be helpful in drawing boundary lines between the rock formations. When this is complete, students should proceed to collect materials for making Precambrian Rock, the oldest rock found in the monument.

Precambrian Rock

5 Precambrian rock makes up a significant part of Colorado National Monument. It is found underlying all the other rocks here, forming the floor, or "basement rock". Much of the Precambrian rock here is metamorphic in origin, meaning that it is composed of rocks that have been exposed to such pressure and heat that, over time, the original rocks have been transformed into different ones. The new rocks have been bent, folded, melted, and recrystallized, and curiously, eroded off to form a flat, smooth surface on which other rock layers have been deposited. The Precambrian rocks in the monument formed about 1.7 billion years ago. Because Precambrian rock represents the some of the oldest rock known, geologists study it for clues as to how the Earth might once have looked, and to understand about the geologic processes that created it. What happened to this rock, and what are the stories contained within it? These are questions to which answers are still being sought.

At Colorado National Monument, most of the Precambrian rock is metamorphic. It is composed of dark gray to black gneiss (pronounced "nice") intermingled with areas of white, pink, and black granite. Gneiss is a distinctively layered rock made up of the minerals quartz, biotite, and feldspar.

To make this rock: Spread a wide band of glue across the bottom two-thirds of the mat board. Use a toothpick or spoon to smooth it into a solid layer. Sprinkle black Art Sands™ evenly across the top of the glue, covering it entirely. When this is complete, use a toothpick to draw a series of wavy lines across the sand and glue. Make some of the lines thin and close together, and others wider and far apart. Imagine that you are trying to write while on a bumpy road to get the unpredictable, contorted waviness. Sprinkle a pinch of sparkles into the lines. This is to represent the mica and quartz crystals that are often found within the Precambrian rock. Fill in any patches without sand with sparkles.

A Cautionary Note About Glue: From this point on, be very careful about glue. If you put on too much, it will run into the surrounding formations. Also, avoid shaking off excess sand by tipping the mat board up at a high angle. The wet glue can drip causing a mess on the column. Use a spoon to apply sand carefully and evenly. Use a piece of paper or a paper towel to wipe any off any extra below the formation that is being worked on.

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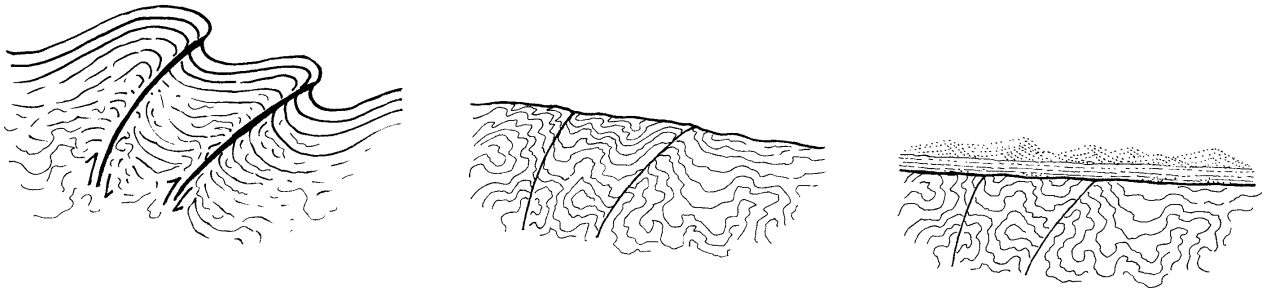
ACTIVITY PAGE

MAKING A GREAT UNCONFORMITY



ANCIENT ROCKS ARE SEVERELY COMPRESSED, FOLDED, & FAULTED; INTENSE PRESSURE & HEAT MAY PRODUCE DYNAMIC METAMORPHISM, CONTORTING &/OR RECRYSTALLIZING ORIGINAL ROCKS.

(FOLD & FAULT SHAPES HYPOTHETICAL; USED SIMPLY TO SHOW DISTORTION OF ORIGINAL ROCKS)

EROSION (ACTUALLY OCCURRING SIMULTANEOUSLY WITH COMPRESSION & UPLIFT) WEARS AWAY UPPERMOST ROCKS, GRADUALLY BEVELS OFF OLD, DEEPLY-BURIED ROCKS TO NEARLY FLAT SURFACE LYING NEAR SEA LEVEL.

(MEANWHILE, SO MUCH FOR THE ENTIRE PALEOZOIC ERA....)

SEDIMENTS FINALLY BEGIN TO BE DEPOSITED ON BEVELED SURFACE OF ANCIENT ROCKS – IN THIS EXAMPLE, CHINLE FM. HAS BEEN DEPOSITED, AND SAND DUNES OF FUTURE WINGATE SANDSTONE ARE PILING UP ON TOP OF IT. BRING ON THE DINOSAURS!

The Great Unconformity

6 Between the Precambrian rock and the Chinle Formation that lies above it is a mystery, a gap in time that local geologists call "The Great Unconformity". While the Precambrian rock is estimated to be 1.7 billion years old at Colorado National Monument, the Chinle Formation is approximated to be between 210 and 230 million years old. What happened to the rocks in between? No one knows the answer for sure, but geologists theorize that sediments that accumulated in this area during the mystery years eroded, and were then washed or blown away. This left the smooth, flat surface of the Precambrian rock that is found today.

To make the unconformity: Leave a small space atop the Precambrian rock and below the Chinle. Do not fill it in with anything.

The Chinle Formation

7 The Chinle Formation is a narrow layer of brick-red rock, intermingled with purples and greens. Composed of fine sand and silt, it was formed during an arid to semi-arid time when rivers meandered and flowed westward across the land, when volcanoes spewed, and when sediment accumulated. The Chinle is best known for its bright colors and petrified wood that seem to be at their finest in the Painted Desert and Petrified Forest National Park in Arizona. At Colorado National Monument, few fossils are found, for the soft slopes of the Chinle are often littered with rock fall and debris from the cliff-forming Wingate Formation that sits above it.

To make this formation: Spread a narrow band of glue above the Precambrian rock and the "unconformity." Smooth out the glue, then take a spoonful of Chinle sand and sprinkle them gently across the glue. Press pieces of the moss and shavings into sand and glue. Finish by attaching several pieces of gravel onto the Chinle to replicate fallen Wingate boulders.

Wingate Sandstone

8 Wingate Sandstone is the third formation that you will make. It is a thick rock layer, as much as 300 feet thick in places, and famous for its scenic quality. The unique rock monoliths and tall, orange to red cliffs that so distinguish Colorado National Monument are part of the Wingate Sandstone. In some parts of the Four Corners region, Wingate cliffs pose impenetrable barriers for travelers and explorers. Everywhere, they make for awe-inspiring scenery. This formation tells of a time, approximately 200 million years ago, when much of Colorado was buried under the blowing and drifting sand of a desert, not unlike today's Sahara Desert. When you look closely at Wingate cliffs, you can imagine how long-ago winds swirled sand first in one direction, then in the next. The shape of a monolith, such as the Coke Ovens, is reminiscent of the ancient dunes that once dominated this landscape.

To make this formation: Spread a wide band of glue across the mat board. Make swirls in different directions in it with the spoon or your finger. Cover glue with orange Art Sands™. As the glue dries, drag a toothpick from the top to the bottom of the formation to create long, vertical lines. Sprinkle a tiny bit of black Art Sands™ along these lines to represent streaks of desert varnish down the face of the Wingate cliffs.

Kayenta Formation

8 The Kayenta Formation is the next formation that you will make. It is dark red, sloped rock that is sandwiched between the cliffs of Wingate and Entrada Sandstones. In some places, the Kayenta is made up of soft, easily eroded shales. In others, it is hard, resistant sandstone with a high silica content. In this form, it functions as an important cover or "caprock" slowing down erosion of the Wingate underneath. Portions of Rim Rock Drive traverse the Kayenta Formation. Independence Monument has a small "cap" of Kayenta, which protects it from erosion. Created more than 190 million years ago when the region had many rivers and streams crossing it once more, Kayenta sand ranges from medium to fine-grained. During those times, dinosaurs and crocodile-like reptiles roamed the land, and in some areas of the southwestern United States, their tracks have been preserved, seemingly frozen in time.

To make this formation: Above the Wingate, make a narrow strip of glue, and cover it with a mix of dark red Art Sands™, and purple and gray Morrison sediments. Stick on a few wood shavings to represent thicker areas of sandstone. Draw in a dinosaur track with a toothpick.

Entrada Sandstone

9 Entrada Sandstone lies atop the Kayenta Formation. Although not as high or as orange in color as the lower-lying Wingate Sandstone, Entrada is still easily distinguished by its two-tier tendency. The lower (older) section is characterized by darker pink, salmon, orange, and brown colored sandstone cliffs. In the upper (younger) section, the Entrada forms white to pale salmon-colored sandstone that erodes into ledges and rock staircases. Over 165 million years old, the shapes, colors, and textures of Entrada Sandstone were created by wind-blown sand and dunes inland from the edge of an ancient sea. Not surprisingly, it is composed of rounded quartz sand grains held together by cements of calcium carbonate and silica.

To make this formation: Spread a smooth layer of glue above the Kayenta Formation. Use the back of the spoon, or your fingertip, to make swirl shapes in the glue. If you have sand left from the Wingate Sandstone, use it to fill in the lower layer of the Entrada cliffs. If not, mix together a small amount of orange and pink sand, and sprinkle them on the lower section of the glue. For the upper half, use white or tan river sand (or Art Sands™) to complete the sandstone cliffs.

Wanakah Formation

10 Next is the Wanakah Formation. Pronounced wuh-NAW-kuh, with emphasis on the second syllable, this narrow, ten foot band of reddish siltstone, with some green mudstones and clays, is not visible consistently through the monument or in the stratigraphy of the region. Where it crops out, it forms a distinct rock layer, approximately thirty feet thick, that is red in the bottom half and green in the upper. It is frequently covered with debris and rock fall from the Morrison Formation, making it difficult to identify in some areas. Yet, in other parts of Colorado, the Wanakah Formation is much thicker and more dramatic. Geologists think that this formation developed approximately 160 million years ago, when either a shallow sea ebbed in the area, or a large lake or playa dried up with a return to desert conditions. (Note to teachers: Due to the narrowness of this formation, and its similarity to the Morrison rocks above, you may want to skip this layer. Because it is included on several area maps, the Wanakah is listed here.)

To make this formation: Spread a thin line of glue above the Entrada Sandstone. Use a pinch of pink Morrison sediment, or red Art Sands™, to cover it.

Morrison Formation

11 The Morrison Formation follows the Wanakah Formation. Composed of fine white, pink, gray, and occasionally purple and green sediments, this is the thickest section of rock fully exposed in and around the monument. Formed approximately 150 million years ago, when fresh water was once more plentiful in the area, the Morrison Formation is a mixture of muds, silts, sands, and volcanic ash. Geologists theorize that swamps, lagoons, and river channels were part of a vast flood plain that extended from higher lands in west-central Utah eastward into Colorado. Volcanoes to the west spewed ash, which eventually drifted over the area. Fossils of vegetation, trees, mammals, turtles, lizards, amphibians, fish, fresh-water clams, crayfish, and snails, and a wide variety of plant and meat-eating dinosaurs have all been preserved in the Morrison rocks. They indicate what a rich and diverse environment it must have been in those long ago Jurassic times.

Geologists divide The Morrison Formation into three sub-units, which are called "members". The Tidwell Member is the oldest of the three, and occurs after the Wanakah Formation in the stratigraphic column. It is composed of bands of green, gray, and yellow mudstones and siltstones with a few thin gray limestone lenses. Next is the Salt Wash Member whose small cliffs and ledges of white to tan and rusty-colored sandstones alternate with bands of gray, green, and occasionally red mudstones. This alternating cliff-slope pattern is a useful characteristic in distinguishing the Salt Wash from the other members. Topping the Morrison Formation is the Brushy Basin Member. The youngest of the sub-units, it contains lenses of beige sandstone that emerge amongst bands of pink, tan, gray, green, and purple mudstones.

Note to the teacher: With younger students, and depending on the amount of time that you have, you may want to skip dividing the Morrison Formation into its members. Instead, the students can create numerous bands of colored sand and mudstone representing the Morrison Formation as a whole.

To make this formation: If you are making the three members of the Morrison Formation, make them one at a time so that you get the proper arrangement of sand-, mud-, and siltstones. This also keeps the glue from drying out. The Tidwell is first in the column, lying above the Wanakah Formation. The Salt Wash is next, followed by the Brushy Basin, the thickest of the members, on top. If you are not going to differentiate the members, simply cover a large area with glue, and smooth it with a toothpick or spoon.

To make the bands of colored rock, take one spoonful of colored sand at a time, and sprinkle a line of it from one side of the column to the other. Imagine that you are writing one line at a time on some homework, or drawing a rainbow. The lines do not have to be perfectly drawn, but you do want to create distinctive horizontal bands of color that vary in thickness and arrangement in the Morrison Formation. Alternate colors, making a line of white followed by one of gray, followed by one of pink, etc. Add in bits of peat moss to represent plant fossils. Periodically, place bits of gravel to symbolize the larger rocks that are occasionally found amongst the silt and mudstones. Lastly, tuck in broken bits of toothpicks to symbolize dinosaur bones.

Burro Canyon Formation

12 The Burro Canyon Formation is the second youngest rock in the monument area, and correspondingly, it is second from the top of the stratigraphic column. It marks the beginning of the Cretaceous Period. Its tan to brown sandstone cliffs stand out against the surrounding slopes of softer gray, white, and green mudstones. Conglomerate rock made of pieces of compacted gravel size rocks is also present throughout the formation. Together, they suggest an environment some 110 to 120 million years ago, when streams continued to flow from west to east, as in the earlier Morrison. Because the thickness of the Burro Canyon Formation varies throughout the region, disappearing altogether in some locales, some geologists theorize that it was also a time of substantial erosion.

To make this formation: Apply a layer of glue above the Morrison Formation. Sprinkle gray or gray-green sand onto the glue. Press in wood shavings, representing sandstone cliffs. Place pea gravel randomly into the sand as well.

Dakota Sandstone

13 Dakota Sandstone is the youngest rock found near the monument and tops the stratigraphic column for Colorado National Monument. Look for its tan to grayish sandstone cliffs that act as a hard “caprock” above the softer Burro Canyon and Morrison mudstones and siltstones. Because it formed during a time when a sea advanced westward from what is now the central part of the United States, Dakota Sandstone is considered to originate from shoreline and beach deposits. In some areas, coal beds are found interspersed with the sandstone, suggesting that marshy or lagoon conditions also existed in this region over 95 million years ago.

To make this formation: Spread a layer of glue at the top of the mat board. Sprinkle yellowish-beige river sand across the glue. Mid-way through the layer, place new dots of glue and affix a thin, broken line of charcoal bits, representing coal beds that are found within the Dakota in some parts of the western United States. Make more dots of glue and apply shells, to indicate that the Dakota was in part a marine formation.

14 The Stratigraphic Column is now complete. Set the completed columns aside to dry while the students put away supplies, and clean off the desks and floor. Refrain from pouring excess sand off the columns until they are dry. This will keep the glue from running all over the mat board, and ruining the effect of the two-dimensional column.

Labeling the Formations

15 The last step in the columns is to label the formations. It is best to wait until the next day so that everything is dry before labeling the rock formations. Go back over the "Stratigraphic Column of Colorado National Monument" handout with students, and make sure they are clear which formation is which. This makes for an excellent review of what students have learned in this exercise.

Conclusion

Making a stratigraphic column of Colorado National Monument gives each student a personal connection to the different rock formations, and a greater appreciation for the forces at work in creating and eroding rocks. From it, they get a clear sense of how rocks are formed in layers that build up in a sequence, one atop the other, from the oldest to the youngest. Perhaps the most enjoyable aspect of this activity is the opportunity for individual artistic expression in a scientific investigation. For most students, such an experience is truly memorable.

Extension

This exercise coordinates well with other activities in this chapter, including the "Stratigraphy Hike", the "Erosion Hike", and "Three Types of Rocks: The True Origins of Rock and Roll". Completed columns can be brought along on a field trip to Colorado National Monument to aid in rock identification. Study of the geologic time scale coordinates well with this activity. Lastly, this exercise is an excellent method of meeting Earth Science curriculum standards for fourth grade and up.

Stratigraphy Up and Down Hike

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Age Group

4th through 8th grades.

Purpose of the Activity

The purpose of the "Stratigraphy Up and Down Hike" is threefold. First, in the course of this 2-1/2 mile hike (round trip) in Colorado National Monument, students investigate rock formations as a real-life geologist might. Secondly, students travel through nine different rock layers on this hike, and use scientific and artistic methods to document them. Thirdly, they learn how to recognize different rocks by their color, hardness, texture, and relationships to other nearby strata.

Amount of Time Required

Two and one-half hours (for older groups) and three hours (for younger students) are needed to complete this activity.

Materials Needed

Supplies that each student will need are:

- ☐ Clipboard.
- ☐ Stratigraphy Field Notes: Worksheet #1 (one copy).
- ☐ Stratigraphy Field Notes: Worksheet #2 (three copies).
- ☐ Copy of the "Stratigraphic Column of Colorado National Monument."
- ☐ Pencil.
- ☐ Magnifying glass.
- ☐ Small nail.
- ☐ Watercolors and brush.
- ☐ Blank art paper to paint on.
- ☐ Small size cup to hold water.
- ☐ Water for mixing paint.

The watercolors, art paper, and cups can be kept by the teacher or chaperones for distribution at the Coke Ovens Overlook. For the safety of the children, and the safety of the monument's resources, the nails should also be kept by an adult, and distributed only when required.

Stratigraphy Up and Down Hike

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Background Information

Students should be properly prepared for this outing. This is a backcountry hike into an area of the park that has no services, and is distant from other people. Therefore, everyone in the class, including chaperones, needs good hiking shoes, clothing appropriate for the weather, snacks, lunch, water bottle, and a backpack to hold everything. While students will carry most of their own materials for this activity, the teacher and chaperones may want to distribute supplies among their packs to lighten the loads of younger students.

Colorado National Monument Stratigraphy

First and foremost, this hike is a marvelous way to explore Colorado National Monument. Spectacular views into Monument Canyon inspire geologic inquiry. Area stratigraphy is presented close-up, as students traverse through time in a real-life stratigraphic column, that includes the Morrison and Wanakah Formations, Entrada Sandstone, and Kayenta Formation. At the highest and lowest points of the hike, Dakota Sandstone, Burro Canyon Formation, Wingate Sandstone, Chinle Formation, and Precambrian rocks are also visible, to complete students' experience of the column. Scientific investigation and artistic expression are the methods that the class uses to explore and record the textures, colors, hardness, and beauties of the different rock formations. Because the hike takes place on trails lightly used by visitors, the group can spread out and immerse themselves in investigations of the rock strata. Together, the impressive vistas and the hands-on inspection of rocks keep student involvement and energy at high levels.

The "Stratigraphy Hike" takes place in the center of Colorado National Monument, along the C.C.C./ Upper Monument Canyon/ Coke Ovens Trails. These adjoining trails can be accessed from Rim Rock Drive, just past Artists Point (if you come from the East (Grand Junction) Entrance or just beyond the Coke Ovens Overlook if you come from the West (Fruita) Entrance. En route to the trailhead through the monument, take note of the fascinating views of rock layers and rock sculptures that you pass.

Stratigraphy Defined

The study of layered rocks and their origins is called **stratigraphy**. It is a branch of geology that developed after people observed that rocks found in one area matched those found in other locales. As geologists studied more about rock layers, they learned that sedimentary rocks form in horizontal beds, only later to be bent, folded, cracked, transformed — and eroded. Over time, investigations showed that the younger rock layers rested on top of older rock strata. These fundamentals of geology became essential to the study of stratigraphy, and are very helpful for young geology students today. The activity, "Make a Stratigraphic Column," will also give students useful background on this subject. It can be helpful to bring the columns along on this hike.

Stratigraphy Up and Down Hike

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Colorado National Monument was established, in part, because of its stratigraphy. Nine rock formations are exposed within the canyons and mesas, each encapsulating an environment that previously existed in the region. The forces of uplift, faulting, and erosion have brought rock layers that were deep within the earth back to the surface once more. That so many conditions, from deserts to rivers, to oceans and beaches, and back again, can be found in order in one area is remarkable and curious for geologists and visitors of all ages. The dramatic relief and exposure of the strata is what inspired John Otto and other local residents to strive to set aside the canyons for protection by the National Park Service. In 1911, this area was designated a National Monument by presidential decree, thereby preserving "the extraordinary examples of erosion" and "natural formations" of this dramatic landscape.

What is a Stratigraphic Column?

A tool that geologists use when studying about rock formations is the **stratigraphic column**. It is a type of diagram that looks at the Earth from within it, instead of down onto it from above, as a road map does. A stratigraphic column views layers of rock from the side, as they rest one upon the other, from the deepest layers known up to the surface of the Earth. To understand how the column works, imagine nine pancakes piled up on each other in a stack. A knife cuts through the stack to remove a huge bite. Afterward, the inside layering of the stack is revealed. The different pancakes, as well as the places where the pancakes touch, become visible. This point of view is similar to that of a stratigraphic column, which looks at layers of rocks laid atop one another. Just as the knife reveals the inside of the pancake stack, so, too, the stratigraphic column shows an portion of the Earth's crust sliced open with the rocks inside exposed.

Geologists utilize stratigraphic columns to identify, compare, and study about the different layers of rock that are part of the Earth's crust. Because rocks are unique mixtures of minerals, each having a specific composition, fossil life, texture, color, thickness, and hardness, geologists can distinguish them, just the way a detective uses fingerprints to identify a person. Since rocks occur in a sequence of layers that holds true across vast areas, stratigraphic columns help geologists to predict that if they are standing against the deep orange and brown cliffs of the Wingate Sandstone, then below them should be the Chinle Formation. When the sequence of rocks is broken because some of the layers are missing, geologists gain just as much information by these "unconformities".

What is a Rock Formation?

Key elements of the stratigraphic column are the rock formations themselves. Geologists define formations as mappable units of rock that were deposited under a particular set of conditions. Within a formation, all the fossils represented are similar, as are the materials composing the rocks.

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At different times throughout the Earth's history, the environment has changed. Sometimes the seas have been high; at other times low. Sand dunes and deserts have predominated in certain periods, while swamps and freshwater inhabitants have taken over in others. Each one of these environments has left a record of its plant and animal inhabitants, soil, climate, and conditions on the Earth's surface. New life built on the roots of the old, leaving a fresh story of what occurred atop that of the past. It is the rocks layered upon each other, yet distinct from those around them, that geologists use to interpret Earth's history.

Type Rocks

Each rock formation is identified with a name. The name is usually based on the area where the features were first studied and identified. For example, the Morrison Formation, known for its bands of multi-colored rocks, siltstones, mudstones, and extensive deposits of dinosaur bones, gets its name from the town of Morrison, Colorado, where it was extensively studied. The **type** rocks for this section were established there, and form the basis for comparison throughout the world. When similarly banded rocks are discovered in other places, they are compared with the type rocks to be sure of their identification.

Definitions such as those above will be helpful in the "Stratigraphy Hike" both for aiding in the identification of rocks and in the completion of the worksheet. While there are technical parts of the activity, there is also a creative, artistic element that gives balance to the experience. Children seem to enjoy as well as benefit by the mix.

How the Colorado National Monument Stratigraphy Column Will Work

The stratigraphic column designed in this exercise is more conceptual and artistic than one a working geologist would use. It involves answering questions about characteristics of different rock formations that are encountered on a hike on the C.C.C. Trail and adjoining Upper Monument and Coke Oven Trails. At the end of the trail is an overlook of the Coke Ovens monoliths where students have excellent views of the rock strata as they are in sequence from the youngest at the top of the column to the oldest in the depths of the canyon. Before this dramatic vista, they will use watercolors to paint their impressions of the stratigraphic column of Colorado National Monument.

A Word of Caution About the Trail

This trail is spectacular from a geologic perspective, but also rocky and narrow for hiking. Teachers should be sure to keep students together, and under control. Travel should be at a slow pace, with chaperones scattered amongst the group. A ratio of one chaperone per five students is advised for this outing. No more than one to two classes should do this activity at one time. In addition, because the class will be in an area that is distant from services and the Visitor Center, children and adults should be well prepared for a backcountry hike.

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How to Do the Activity

Getting Ready - Preparations

1 To assure that all goes safely, a large number of chaperones — a ratio of 5 students per adult — is recommended. While the hike can be done with fewer adults, this ratio is especially important with energetic groups, and will ease the mind of the teacher throughout. Since many parents need advance notice to take time off from work, or to arrange a babysitter, send out a notice about the hike several weeks ahead of time.

2 As part of planning the outing, the teacher should review "Preparing for Your Field Trip" (Chapter 1), and the "Rocks Before You" section on geology. Information in both these areas will give a base of knowledge and material that will assure that the exploration goes smoothly and successfully. If desired, copies of information can be given to chaperones as well.

3 Gather materials that are needed for the hike. Parents may be able to assist you in locating some supplies. Copy off worksheets and information on the different rock layers for students to use. The sheets can be stapled together to make a small geology field notebook if desired.

4 This hike will take two and one-half to three hours depending on the ages and abilities of the students. As a result, the teacher may want to plan a full day outing, including a stop at the Visitor Center, picnic at Saddlehorn or Devils Kitchen Picnic Areas, short hike along the Alcove Nature Trail or Otto's Trail. A tour of the Colorado National Monument along Rim Rock Drive, with stops at the many scenic overlooks, would be another excellent accompaniment to this activity.

Parking for Cars and Buses

5 Parking at the trailhead for this activity is limited to two bus lengths in size, or approximately six cars. Since park visitors also use the trail, make careful arrangements if using a carpool. Additional car and bus parking is available at Artists Point and the Coke Ovens Overlook, both of which are located nearby, to the east and west of the trailhead. Because walking along Rim Rock Drive is not recommended, drivers should drop students at the trailhead, park their cars, and then walk back to meet the group. Urge caution along the road, and be sure to watch out for cars.

Appropriate Clothing for a Field Trip

6 **The day before the hike**, ask students what is appropriate clothing for the weather. Make a list on the board of their answers. Have them make a list of what they should bring in their backpacks for the hike. Lastly, take time to define and discuss what stratigraphy is, how it helps scientists, and how to make a stratigraphic column. You may want to coordinate this hike with the "Make A Stratigraphic Column" activity shown elsewhere in this chapter. It is a good introduction or follow-up to this hike.

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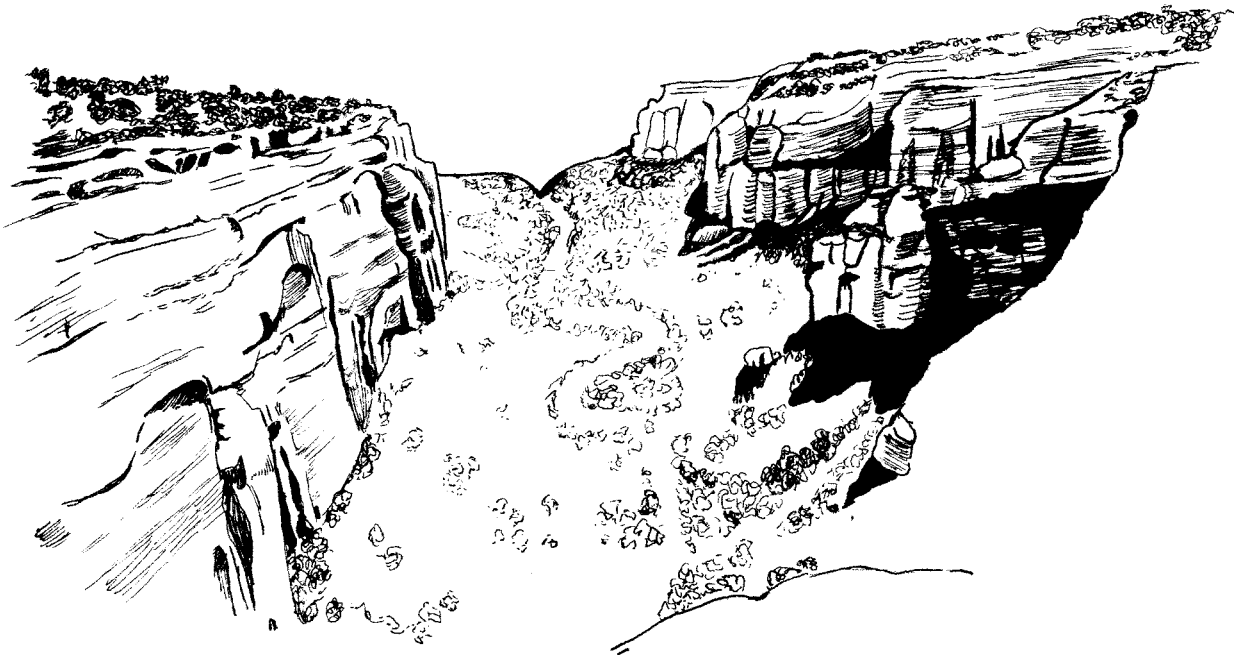

Step-by-Step Instructions for the Stratigraphy Hike

The day of the field trip, and before you leave the classroom, double check the gear of the students to be sure that they have all the supplies that they need. *Remind students to use restrooms at school beforehand*. There is neither a restroom, nor an easy place to go to the bathroom trailside on this hike. The narrowness and the lack of cover on the trail create difficulty in finding appropriate places to defecate or urinate. The trail itself should not be used!

What to Look for on the Way to the Monument

En route to the monument, ask students and drivers to pay attention to the rocks that they pass. Notice the different colors, shapes, textures, and hardness of the rocks. If you enter from the East (Grand Junction) Entrance, have students compare the rocks they see outside of the Entrance with those that they see as the road climbs up to the top of the mesa. If you come from the West (Fruita) Entrance, observe how the road must wind around the face of the mesa. Why is that? Get everyone to notice where changes in the rock take place: cliffs become talus slopes; black rock shifts to red or orange rock; shrub-covered slopes turn back to cliffs. Observations like these will help to set the scene for more in-depth study on the "Stratigraphy Up and Down Hike."

Stratigraphy Up and Down Hike

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The Trail – C.C.C./ Upper Monument Trail

The "Stratigraphy Up and Down Hike" takes place along the C.C.C./ Upper Monument Canyon/Coke Ovens Trails. They are located in the center of the monument, about halfway along Rim Rock Drive from either entrance. Artists Point and Coke Ovens Overlook are nearby. Because parking is limited, drivers should pull as far forward in the lot as they can to make room for other vehicles. If there is not room for all the cars, then drop students off at the trailhead, and send drivers to park at the Artists Point or the Coke Ovens Overlook lots. They can walk back to the group. Keep students off Rim Rock Drive if possible. Everyone should bring their backpacks, clothing, food, water, and project materials when they gather at the park map and sign at the top of Upper Monument Canyon/Coke Ovens Trails. A set of wooden steps and trash can are nearby, but there is no restroom.

Stops Along the Trail

The following is a description of the stopping places on the trail, what is found at each one, useful information for the students, and explanations of what to do.

Introduction at the Trailhead

While everyone gathers at the sign for the Upper Monument Canyon/Coke Ovens Trails, ask the students to describe some of the rocks and rock formations that they saw on their way from school. No doubt they will mention the large orange-red cliffs that they passed, but try to get them to describe some of the other colors, textures, and types of rocks that they observed. This makes a useful warm-up to the identification of rock formations on the "Stratigraphy Hike".

Because students have been cooped up in a bus or in cars during the drive, the best way to begin this activity is to hike up the C.C.C. Trail non-stop, one-quarter mile, to a wide meadow. The views from that point are an excellent place to begin in-depth observation and discussion. Thus, use the time at the sign for people to gather, and to handout materials that you will use on the hike. Reviewing trail safety rules, and reminding everyone about the no collecting regulation in national parks and monuments is paramount. Ask chaperones to spread out amongst the group, and designate one adult to be at the end of the group for safety. The teacher should be the leader.

Begin the hike on the C.C.C. Trail which is located across Rim Rock Drive on the *opposite* (southwest) side from the trail sign where the group just gathered. Look for the C.C.C. trail sign across the road from the north end of the parking area, the one that is closest to the Coke Ovens Overlook. Soft, reddish-maroon rock of the Wanakah Formation follows along the road there.

Stratigraphy Up and Down Hike

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The C.C.C. Trail

The C.C.C. Trail was named after the Civilian Conservation Corps (C.C.C.), which came to Colorado National Monument in the mid-1930's to help with the construction of Rim Rock Drive. This trail connects an old cattle and logging road atop Black Ridge with the sites of the C.C.C. work camps along the canyon rim. After the hardships of the Depression, the C.C.C. was part of the Roosevelt Administration's effort put people back to work, to teach job skills, and to improve conditions in people's lives. Besides Colorado National Monument, there were several other sites chosen for C.C.C. projects in Colorado, including Mesa Verde National Park, Rocky Mountain National Park, Garden of the Gods, and Grand Mesa.

From the road, you will go steadily upward. The trail makes three switchbacks before straightening out. Next, follow a wide curve to the left as you go up the ridge. Approximately one-quarter of a mile along the trail, the trees open out onto a grassy meadow. While your group may find many interesting rocks in and along the path, save exploring them until you begin the trip back down the hill. Use this part of the hike to stretch legs, use up excess energy, and just enjoy the day.

Stop #1: The Meadow

When the group reaches the open, grassy meadow, they can put their backpacks on the ground, take a short break, and relax. This is a good place to have a snack and drink of water.

Caution students to step carefully here, because the meadow contains cryptobiotic soil crust, a black, lumpy covering on the ground. It is easily damaged when people walk on it. By looking carefully where they step, and where they put their backpacks, students can avoid harming it. For more information about cryptobiotic soil crust, see the activity, "The Magic of a Drop of Water", in the "Plants of Colorado National Monument" chapter.

The main reason to stop in the meadow is the view, which encompasses almost all the different rock formations found in the Colorado National Monument, as well as those in the Grand Valley and the Book Cliffs. Such an expanse of rock offers an excellent introduction to the activity and to the concepts underlying it.

When the break is over, ask students to be seated along the trail, and get out their clipboards, worksheets, and pencils. The teacher should explain that from this point on, students will be learning an important element of geology known as "stratigraphy". An explanation of how geologists use stratigraphic columns to learn about the rock formations in places such as Colorado National Monument should also be given. While this information is fresh in students' minds, they should write down their definitions of stratigraphy and stratigraphic columns on the "Stratigraphy Field Notes Worksheet #1."

Stratigraphy Up and Down Hike

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Next, ask students to look out at the view of the mesas and canyons before them. Have them guess how many different rock formations are out there. Can they actually count the rock layers? How many do they find? (The correct answer is eleven, with nine in the monument and two visible on the Book Cliffs on the opposite, or north, side of the Grand Valley.)

Students should then look at the gray, fluted rock of the Mancos Shale that composes much of the cliffs and mesas that line the far (northeast) side of the Grand Valley. What characteristics of it make it distinct? Some of the features that the class might notice are: single, solid color; seeming single texture; fluting of sides of the rock from erosion that is unlike any other rock nearby. Such observations will parallel the definition of a rock formation given previously: rocks that are layered upon each other, yet distinct from those around them, are likely created under a similar set of conditions. Within a formation, all the fossils represented are the same, as are the materials composing the rocks.

Ask the class to look above the Mancos Shale to what is above it. Is this the same or different rock? What distinguishes the two? (Observations should include that the brown color is different, and the cliffs that form make this layer appear to be a harder rock.) A final question is to ask students to point out other "formations" that they observe around them. Such observations lead very easily to a definition of rock formation, which is the third question to be answered on Stratigraphy Field Notes Worksheet #1.

Stratigraphy Up and Down Hike

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Area Stratigraphy

Rock formations to note from this vantage point are:

1 **Mesa Verde Formation**: Brown and tan sandstones create a thick block of cliffs atop the Mancos Shale. This formation is among the youngest rocks to be found in the area, dating back to the Cretaceous Period.

2 **Mancos Shale**: These gray to black thinly-bedded shales were formed during a time when this region was covered by an ocean. Although this formation is very thick, it is also very soft, and easily erodes into valleys and ridges, creating a scalloped effect.

3 **Dakota Sandstone**: The microwave towers on Black Ridge are located on an outcrop of this marine sandstone. Look for its beige, yellow-brown cliffs that form a distinctive ledge at the top of the mesa.

4 **Burro Canyon Formation**: This white, gray, beige sandstone and siltstone forms tree and shrub filled slopes that are broken up by numerous small sandstone outcroppings. You can see it above the meadow, and below the top ridge of Dakota Sandstone.

5 **Morrison Formation**: A colorful array of soft gray, white, pink, purple, and green siltstones, mudstones, clays, sandstone and shale are broken up by periodic, thick, tan sandstone ledges. Found beneath the Burro Canyon, and throughout the area of the meadow where students are currently. Many blocks of Morrison sandstone are in and along the trail as you go back down the ridge.

6 **Entrada Sandstone**: A distinctive band of salmon to white-colored cliffs rise off to the east and north. They form a smooth, rounded ledge that rims the steeper canyon walls below.

7 **Kayenta Formation**: Heavily vegetated slopes below the Entrada are composed of thin layers of red, tan, gray, and purple silt and mudstones. Across much of the top of the mesa, Rim Rock Drive is built on this formation.

8 **Wingate Sandstone**: Many of the sculptured and named features of the Monument are made of eroded Wingate Sandstone. It also creates the dramatic reddish-brown to orange cliffs that so distinguish the canyons here.

Spend about fifteen minutes discussing stratigraphy and looking at the different rock formations from this vantage point. Then, proceed back down the ridge. You should have been out for approximately thirty minutes by this time. **Be sure that no food, litter, or other belongings of the group are left behind.**

Stop #2: The Morrison Formation and Worksheet #2

After the wide curve on the C.C.C. Trail, the path narrows, and you enter some trees. In this portion of the trail, look for rocks such as pink and white striped or beige sandstones, or gray mudstones and siltstones scattered along the path. These rocks are characteristic of the Morrison Formation. This is a good stopping spot for completion of "Stratigraphy Field Notes Worksheet #2", which involves a close-up inspection of one rock.

Each student should have three copies of "Worksheet #2", one copy for use here. The questions on it direct the student to investigate a rock of their choosing for color, texture, grain size, and hardness. The techniques used on this exploration are similar to those used by geologists in the field, when they identify and record information about rocks. As students answer the questions on "Worksheet #2", and use their fingernails, small nails, and magnifiers to examine their rocks, the teacher and chaperones should float among the group to assist with any questions or problems. The worksheet should take no more than 10 to 15 minutes to complete. Those students who finish quickly can go further down the trail to the road with an adult. Several rocks of note along the way are large boulders of sandstone that show distinctive signs of weathering, including impacts of lichens, tree roots, heat and cold. All rocks should remain in place, and only notes and impressions from the rock be taken away.

It is recommended that a time frame for completing the worksheets be established at the start of this segment, so that the group will have plenty of time to do the other activities on the hike. Ten to fifteen minutes should be adequate to fill in the worksheet.

Hardness Test

A Note About the Use of Nails: Hardness is one of methods by which geologists investigate rocks. Nails are often used to evaluate where a rock fits on the Mohs scale of hardness. The softest mineral, talc, has a hardness of 1. Gypsum has a hardness of 2. A fingernail will make a scratch mark on any rock with hardness of 2 or under. A rock with a hardness of 3 to 5 will show a mark when scratched by a nail, but not a fingernail. If a nail does not leave a mark, then the rock must have a hardness of 6 to 10. Quartz is rated at 7, topaz at 8, corundum at 9, and hardest of all, diamonds, are rated at 10. In our area, there is a lot of quartz mixed in with other minerals. Therefore, if your rock does not show a scratch from a nail, it is likely that quartz is making it so hard.

Hazards

Nails, however, can be a safety risk with children. Not only do they have sharp points that could injure a student, but they can also do damage to the environment. In the hands of some individuals, nails can lead to scratches and marks that do permanent harm to rocks, trees, or plants. Such "graffiti" is actually forbidden under federal law, and can result in fines or ticketing. Therefore, the teacher must think carefully about whether the benefits of using a hardness test are worth the potential risks.

Should nails be used, instructions about making only a TINY scratch are essential. This should be done only on a part of the rock that will not show it or be damaged by it in any significant way. Teachers and chaperones should keep a close eye on all students using nails, and request the nails be returned upon completion of the test.

Should no nails be used, then students should attempt the fingernail scratch test, and questions regarding hardness over level 2 on the worksheet should be skipped.

Stop #3: The Wanakah Formation (optional stop for those who finish their worksheets more quickly)

The C.C.C. Trail ends at Rim Rock Drive, where the surrounding rock is from the Wanakah (pronounced wuh-NAW-kuh, with the emphasis on the second syllable) Formation. This stop can be for those students who finish up their worksheet quickly. It can be skipped if time is "eroding" rapidly. Those who have time should explore this layer of rock to determine how it is different from the Morrison. As the group comes down the trail to the road, can it spot the place where the Morrison Formation ends and the Wanakah Formation begins? The bottom of the Morrison is sandstone about two feet thick.

Features that distinguish the Wanakah Formation are:

- It is only about thirty feet thick, as compared to the Morrison, which is over 450 feet thick.
- It is composed of 15 feet of thin, horizontal beds of reddish siltstone overlain by another 15 feet of gray, green, and light brown mudstones and shales. In spite of its banding, its location between the more thick, colorful, and dramatic exposures of the Morrison Formation and the Entrada Sandstone makes it easy to miss.
- The thin, uniform strata create long, even lines reminiscent of wet hair that has just been combed, or of a newly raked sand trap on a golf course.
- To the touch, the Wanakah is soft and crumbly, and it is much easier to scratch with a nail than either the Morrison Formation or the Entrada Sandstone.

No record of this formation needs to be made unless there is plenty of time for the group to complete the rest of the hike, which will take from one to one and one-half more hours. Once students are familiar with the way that the worksheets go, they should be able to complete them more quickly.

Stop #4: The Wanakah / Entrada Interface

Cross the road back to the parking lot and the Upper Monument Canyon/Coke Ovens Trail sign. **Reconvene the entire group before heading downwards into the canyon.** Once everyone is together, ask the students to be geologic detectives in the next section of the trail. They should look for the spot where the Wanakah Formation stops and the next formation, Entrada Sandstone, begins. Tell them to keep in mind that the lower Wanakah is red to brick-red in color, whereas the Entrada is harder, white to salmon-pink to tan-gray in color. While the Wanakah is soft and crumbles easily, the Entrada is a harder, more ledge-forming, sandstone.

Challenge them to spy the change without any clues. If not, direct them to look approximately 25 to 40 steps down the path from the stairs. There, on the right-hand (uphill) side, is the place you are looking for, where reddish sloping rocks give way to a ledge of fine-grained, white to tan-gray sands that bulges out beside the trail. The Entrada begins at about knee height and with each step down the trail gets higher and more distinct. Just before the first switchback, the transition to this new formation is complete.

There is plenty of room along the trail in this area for everyone to observe the change in texture, color, hardness, and grain size that has taken place. Whereas the Morrison is a mixture of different types of rock, from sandstone to mudstone, siltstone, and clay, the Entrada Sandstone is remarkably similar throughout. While its color may change from white to pinkish orange, it has a uniformity of grain size and texture. Formed when desert-like conditions and wind-blown sand covered this region, those ancestral dunes were eventually compacted and compressed to create the rounded cliffs now exposed in the stratigraphic column.

Drainage Tunnel

A Note of Caution in This Area: Students will undoubtedly discover a large "cave" or cavern off the trail and across the drainage. While it beckons to them, *do not attempt to go there*, even if you see other visitors by it. Getting to the "cave" is not safe due to loose rocks, and awkward climbs. What may appear as a path is really a pile of jumbled boulders that are not firmly in place in the soil. It is not recommended that anyone go there. Instead, explain that while Rim Rock Drive was being built, efforts were made to prevent the road from washing out or being damaged in storms and flash floods. Because several small canyons bisect the road right here, the road builders did extensive drainage work. What appears as a cave is really a drainage tunnel directing run-off from the Morrison and Wanakah Formations above the road under the roadbed and down into the canyon. This tunnel is not a place to be during a rainstorm!

Stop #5: Entrada Sandstone

Just past the Entrada and the view of the drainage tunnel is the first switchback. Keep students under control and walking carefully in this section of the trail. Seasonal and flash floods have washed boulders and debris down the drainage on the right. While it may be hard to imagine the force of a raging torrent of water down this stream bed now, remember that water is a powerful agent of erosion, and capable of transporting large rocks as if they were small. (For more information on erosion, see the "Erosion and Weathering Hike" in this chapter.)

The second switchback is the site of the next extended stratigraphy exploration. Just off the path, on the uphill side, is a long expanse of Entrada Sandstone that students will investigate using another of the "Stratigraphy Field Notes Worksheets #2". Several logistics are important along the trail at this point.

Ask students to find a place along the trail around the switchback to put down their backpacks and be seated. Ask them to leave room enough for people to move up or down the path without hindrance. This is a public trail, where other park visitors may be hiking. Station adults at either end of the group so that no students stray along the path, and so that the group can be alerted to hikers coming through. The teacher should stand in the center of the group by the sandstone cliff.

In small groups of eight to ten, students should approach the cliff to make measurements and observations. They may step off the trail to get close-up views of the texture and color of the Entrada Sandstone cliff with their magnifiers. While one group works, the rest of the students can answer questions about other features of the formation that do not require such inspection.

All measurements may be made on the Entrada Sandstone *with the exception of the nail scratch*. Scratches on rock, such as sandstone, can leave a permanent mark. The teacher should ask students to observe where other people have scraped their initials into the rock. Can the children tell who made them? Why do they think that people did this? What effect do these markings have on how the students feel about the rock? Is carving your initials in a rock the proper thing to do? Answers to these questions are subjective, but in the eyes of the National Park Service, markings on rocks by modern people are the equivalent of graffiti. Damaging rocks breaks federal laws prohibiting harm to trees, plants, wildlife, insects, and rocks that are part of Colorado National Monument. While ancient peoples used rock art as a means of communication and expression, initials or designs scratched in the rock by modern people are not considered to be art or of value. Thus, the class will not use the nail to do a hardness test in this area. Instead the group will estimate hardness based on the existing carvings on the cliff. Hardness estimates should be approximately 5.

To conclude with the Entrada Sandstone, ask the young geologists which formation they think is the oldest: the Morrison Formation or the Entrada Sandstone. If they have understood the concept of the stratigraphic column, they should say the Entrada. For more details on age and environments that once existed here, please refer to the "Stratigraphic Column of Colorado National Monument" or "Make Your Own Stratigraphic Column" activity in this chapter.

Take the Coke Ovens Trail at the Intersection

In about twenty minutes, when the worksheets are complete, hike on to the next trail marker. It is located where the Upper Monument Canyon and Coke Ovens Trails divide. **Your group will take the Coke Ovens Trail**, to the right, and head along the canyon wall to the east.

Stop #6: Entrada Sandstone - Kayenta Formation Contact

After the trail marker, and the right-hand turn, the group will go down some steps to an area of flat smooth rock. Stop here for a moment. Another portion of Entrada Sandstone is exposed on the uphill side. Where it ends, seemingly abruptly, is the Kayenta Formation. The Kayenta Formation is the fourth rock formation that will be investigated in depth on this "Stratigraphy Up and Down Hike". Whereas the Entrada forms a distinct band of cliffs, the Kayenta forms ledges and slopes that are more easily overlooked. Nevertheless it is significant in the stratigraphic column because its bottom layers, those contacting the Wingate Sandstone, are very strong, and resistant to erosion. In fact, they protect the Wingate Sandstone from erosion in such places as Independence Monument. Where Kayenta has eroded, such as off the tops of the Coke Ovens, the Wingate, too, has worn down into rounded domes. (See *Colorado National Monument Official Map and Guide* for a good photo of the effects of erosion here.) The Kayenta's durability made it the choice for construction of much of Rim Rock Drive on it across the mesa top.

At this point, ask the students to be geologic detectives again, only this time, they should find where the Entrada Sandstone ends and the Kayenta Formation begins. As the trail follows the interface of these two formations, many students should be able to identify the exact places where the two meet. Color, texture, layering, and shape of the rock should make the distinction easy. If there is time, have students make a record of this interface using their third copy of "Stratigraphy Field Notes Worksheet #2". What differences do they observe between the colors, layering, and textures of the Entrada and Kayenta? Avoid using the nail for a hardness test, except if an adult, or the teacher, would demonstrate it for the entire group.

The last stop is down the trail at the Coke Ovens Overlook.

Stop #7: Coke Ovens Overlook

The trail follows the Kayenta Formation for approximately one-third mile until it ends at the Coke Ovens Overlook. This fenced vista point affords dramatic and expansive views of the stratigraphy of Monument Canyon. Have the group stand at the fence and look down at the canyon below. Can they see some of the other rock formations in the stratigraphic column of Colorado National Monument? As geologic detectives, they should be able to recognize three more formations below them.

The group is standing on the dark red-brown layer of the Kayenta Formation. Its horizontal layers of rock top huge, smooth cliffs of orange, brown, and black called the Wingate Sandstone. Can everyone locate an expanse of the Wingate Sandstone? Which would be older in the stratigraphic column: the Entrada Sandstone or the Wingate Sandstone? Hopefully the students will respond with the Wingate Sandstone, which lies lower in the column and deeper in the canyon.

Still lower in the column, below the Wingate, are the maroon-colored slopes of the Chinle Formation. They are littered with rocks fallen from the cliffs above, and sprinkled with shrubs, pinyon pines, junipers and grasses. Next, look still deeper into the canyon, to the very bottom, for the slate gray, pink, and black Precambrian rock, the oldest rock found in Colorado National Monument. It is called the "basement rock" of these canyons, because all other strata rise above it. Recognizing these different formations should be relatively easy for the class now that they have seen so many different colors, textures, and hardness in the rocks. While they may not remember individual formation names, relationships of rocks to one another — harder caprock protecting softer rock below, slopes littered with debris from cliffs above, the stair step effect of Entrada cliffs above Kayenta slopes above Wingate cliffs above Chinle slopes — should be more clear in their minds. What they have learned and observed should be reflected in the final activity of the "Stratigraphy Up and Down Hike", painting a stratigraphy column of the canyon around them.

Ask students to find a place to sit at the overlook where they have a view of the canyon that they like. Pass out art paper, cups, watercolors, and brushes. Instruct students to design and paint their own stratigraphic column of the formations of rock that compose the mesa and canyon that they have just explored. Remind them that the youngest age rock, Dakota Sandstone, is found at the highest point in the area, whereas the oldest rock, Precambrian, is found in the depths of the canyons. Encourage the artists to strive to match the colors of the rock with the paints before them. To give them an idea of what their column should look like, show them the "Stratigraphic Column of Colorado National Monument" that is a part of this activity. If students seem to have difficulties, let them copy the structure of the column but have them make their own colors.

Plan 15 to 20 minutes for this activity. For those that finish quickly, have them label the individual formations, or paint a vista that they especially like. Gather up the paper cups, pouring the colored water back into a water bottle. Before heading back up the trail, do a careful check of the area for litter or items left behind. The return trip should take 15 -20 minutes.

Conclusion

The "Stratigraphy Up and Down Hike" combines both scientific inquiry and artistic expression in the exploration of the rock formations of Colorado National Monument. The hands-on investigation makes the rock layers come alive for the students in a way that cannot be replicated in a classroom setting. The "Stratigraphy Field Notes Worksheets #1 and #2" not only help to focus students' attention on the differences between the individual formations, but they increase awareness of and appreciation for the overall stratigraphy and geologic processes of the region.

Stratigraphy Up and Down Hike

ACTIVITY PAGE

Ways to Adapt This Activity for Other Ages

The "Stratigraphy Up and Down Hike" is not recommended for children below 4th grade. This is due both to the narrowness of the trail, and to the more complex subject matter, which is difficult even for some adults to grasp! Older age groups, including junior high school, high school, college students, and adults will enjoy the hike immensely. The hike can be shortened by eliminating the worksheets. The watercolor stratigraphy column should be kept in the hike if at all possible. Capturing the diverse colors and textures of the rocks with paint is remarkably effective for integrating useful geologic information with artistic expression.

Extensions

The "Stratigraphy Up and Down Hike" is an excellent complement to "Make a Stratigraphic Column," "Three Types of Rock" as well as the "Erosion Hike". It can relate to work in the classroom including researching details on individual rock formations or geologic principles.

Stratigraphy Field Notes:
Worksheet #1

ACTIVITIES FOR STUDENTS

1) Fill in the blanks to complete the sentence.

Stratigraphy is the study of _____

_____

_____

A stratigraphic column is a _____

_____

_____

A rock formation is _____

_____

_____

2) Answer True or False.

The rock at the bottom of a stratigraphic column is younger than the rock at the top.

☐ True ☐ False

All rock formations have the same hardness and texture.

☐ True ☐ False

Rock formations help geologists to learn about the kinds of environments that used to exist on the Earth.

☐ True ☐ False

3) Make a list of words that describe the environment around you today. (Hints to get you going: Is it an ocean? Is it a desert? Is there fresh water? Are there lakes, rivers, streams, swamps, bogs? What is the temperature like? Is it humid or dry? Is it windy or not?) _____

_____

_____

4) What kinds of things do you think will be preserved from our time on Earth for future geologists to discover? What will "fossils" from our civilization look like? _____

_____

_____

Stratigraphy Field Notes:
Worksheet #2

ACTIVITIES FOR STUDENTS

Find a rock that interests you, big or small. Look at it closely, and answer the following questions.

Caution!! Rocks may be the home or hiding place for insects, spiders, birds, or reptiles, like rattlesnakes and lizards. Choose your rock with care, so as to avoid disturbing creatures that may be using it. Always look your rock over, checking the areas on top, beside, and below it before touching or investigating it. Remember, you are merely a visitor here. That rock may be some animal's shelter, nest, protection from predators, or place for avoiding heat or drying out.

Size — My rock is about the same size as:

- ☐ my fingernail
- ☐ my foot
- ☐ my backpack
- ☐ my bed at home
- ☐ a school bus
- ☐ it's HUGE!

Texture — Touch your rock with your fingertips, then describe how it feels.

- ☐ soft
- ☐ bumpy
- ☐ hard
- ☐ crumbly
- ☐ smooth
- ☐ rough
- ☐ other: _____

■ Look at your fingertips after touching your rock. Did any material come off on your fingers?

☐ Yes ☐ No

■ If your fingers feel powdery, you may be touching siltstone, shale, or mudstone. If they feel sandy, you may be touching sandstone. Can you guess what your rock is? _____

Hardness

Geologists determine hardness using the Mohs scale. The softest mineral, talc, has a hardness of 1. Gypsum has a hardness of 2. A fingernail will make a scratch mark on any rock with a hardness of 2 or under. A nail will leave a scratch mark on a rock with a hardness of 4 or 5. If a nail does not leave a scratch mark, then the rock has a hardness of 6 to 10. Quartz is rated at 7, topaz at 8, corundum at 9, and hardest of all, diamonds, are rated at 10. In our area, there is a lot of quartz mixed in with other minerals. Therefore, if your rock does not show a scratch from a nail, it is likely that quartz is making it so hard.

■ Scratch your rock with your fingernail. Do you see a mark on the rock?

☐ Yes ☐ No

Stratigraphy Field Notes:
Worksheet #2

ACTIVITIES FOR STUDENTS

- Check if hardness is under 2. ☐
- Use a nail to make a tiny scratch of your rock. Can you see a mark on the rock?
  ☐ Yes ☐ No
- Check if hardness is 5 or greater. ☐
- If you cannot scratch the rock, what other ways can you tell its hardness? _____
  _____
  _____

Color

- Use a magnifier to look at your rock. Describe the color(s) that you see. _____
  _____
  _____

Grain Size

- Look closely at the rock with the magnifier.
  Can you see the tiny particles that make it up? ☐ Yes ☐ No
- Are all the pieces that make up your rock the same size? ☐ Yes ☐ No

  Geologists call same size grains "uniform", and different sized grains "mixed".

Other Interesting Features

- Do you see any fossils on your rock? ☐ Yes ☐ No
- In the Entrada Sandstone, can you find any cross-bedding, or signs of wind blowing sand first in one direction. Then the other? Cross-bedding will look like all the layers slope up in one direction, then slope off in another direction.
  ☐ Yes ☐ No
- How is this rock different from other rocks that you have looked at? _____
  _____
  _____
- Are there any other observations about your rock that you would like to make? _____
  _____
  _____
  _____

Erosion Hike

ACTIVITY PAGE

Age Level

4th through 8th grades

Purpose of the Activity

The purpose of this activity is to give students an opportunity to discover the many forms of erosion taking place on and in the canyons. Colorado National Monument was set aside for protection and preservation in part because of the remarkable erosional features of the canyons and mesas. On a three-mile hike round-trip, students will use methods of scientific inquiry, individual observation and creative recording to document types of erosion that they find.

Amount of Time Needed

Four hours for younger students and three hours for older groups. It is best to plan this to be a part of a day-long experience in the park.

Best Location

This activity has been developed specifically for the Old Gordon Trail at Colorado National Monument. The trail is easy to moderate for hiking and travels across sand, rocks, a wash, and up onto slickrock. Striking views of area canyons, rock formations, erosion, and geology are found throughout the hike. Remember, however, no water or restrooms are available.

Materials

As this hike goes into a distant part of the park, it is important that students be suitably prepared. In addition to good walking shoes and seasonally appropriate clothing, they will need a day pack to carry water bottle, lunch and snacks. Each student will also need the following items:

- ☐ Erosion Worksheet #1: Looking at Rocks.
- ☐ Erosion Worksheet #2: Discovering Erosion and Weathering.
- ☐ Pencil.
- ☐ Clipboard.

Erosion Hike

ACTIVITY PAGE

Background Information

This activity is intended to give students an opportunity to observe, record, and reflect on the different layers of rocks found in the park. They will also see first-hand the way that rocks erode or decay, to become the building blocks for new rocks.

The "Looking at Rocks and Discovering Erosion and Weathering" worksheets are the focus for this activity. They are a place for students to document their observations. Students must record some notes about a rock that they discover along the trail. Their observations and notes will be similar to those that a geologist might make in the field. Worksheet #2 will be used to make notes of places where they see the types of erosion. Using these worksheets, students not only learn terms and concepts of geology, but they get to experience them first hand.

For the teacher/leader, a trail map and list of suggested stops accompanies this activity. The trail is marked with cairns, or small rock piles, to show the route. In places boulders line the trail as well. The information at each stop is intended to spotlight certain places, views, ideas and geologic concepts to the group.

How to Do the Activity

Preparations

Before going on this hike, it is important for the teacher to review some areas of information in this guide. First, look at the "Preparing for a Field Trip" section to get familiar with the park and the things to do to get ready. Second, it is helpful to contact monument headquarters to find out if other schools or groups are planning to be using the same trail on the same day. (This affects parking availability as well as the quality of the experience for all.) Third, arrange for some parents to accompany the group. A ratio of one parent for every five students works well. Fourth, plan your visit to be during the best weather for hiking, usually the months of September, October, March, April, and early May. Other times may also work, but wind, temperature and moisture may make those months less agreeable.

Preview the Trail

As with any field trip, the teacher should preview the trail. It is ideal to do this several days in advance of the trip, at the same time of day that the class will be traveling. While not a requirement, taking this extra time before the trip will give the teacher a familiarity and confidence with the area and material that enhances the experience and safety of the group. If, for example, you discover a great vista from which the rock formations are especially visible, then you will be able to tailor your time on the trail to give an adequate amount at that spot. If the water is running high in the wash, then you will know to have students be prepared to get wet. These details can make the difference between an average and a great trip.

Erosion Hike

ACTIVITY PAGE

Know the Rock Formations

Take time to get familiar with the different rock layers by reviewing the information given in this activity and elsewhere in "The Rocks Before You" part of this guide so that you can correctly identify the Precambrian, Chinle, Wingate, and other units present in the monument. Look over information about erosion so that you can help guide students to see signs of it.

Worksheets and Supplies

Copy off the worksheets in this activity so that each student will have them. An option is to collate and staple them together to form a notebook for the hike. Hope for good weather and enjoy the beautiful geology and erosion taking place around you.

Step-by-Step Instructions

Before You Leave the School

Before you leave the school, remind everyone to use the restroom. There are no flush toilets during much of the year at the Devils Kitchen area, and no restrooms on the trail. Remind students also of methods of handling urination and defecation in the desert. Discuss other "trail etiquette" such as staying together, hiking on the trails and the "No Collecting" policies in national parks and monuments. Make sure everyone has a lunch, full water bottle, snacks, appropriate clothing for the weather, and good walking shoes.

Rules to Remember on the Trail

When you arrive at the Devils Kitchen parking lot or before, a discussion of trail safety is important.

1 Many creatures, from snakes to lizards to scorpions and spiders, take refuge from the hot sun by hiding in crevices and under rocks. Use caution when climbing or picking up rocks. Be able to see the area where you place your hands, toes, and seat.

2 Desert soils are delicate and yet sustain a remarkable variety of life. Please stay on existing trails rather than making your own.

3 Watch your footing. Rocks may appear to be sturdy and strong, yet can be surprisingly weak, loose and dangerous. If one begins to roll down on hikers below you, call out "ROCK!" to alert them to its path.

4 Do not carve on the rocks or scratch your initials into them. This is a violation of NPS regulations as much as being poor trail manners.

5 Remind students of the importance of watching out for one another in the desert. If someone seems to be having a difficult time, offer to carry his or her pack. If someone mentions getting a headache, remind him or her to drink more water. Take care of one another.

Erosion Hike

6 Make sure everyone has their water bottle, lunch, snacks, jackets, hats, and sunscreen, as well as their supplies for the activity, in their pack prior to departure.

7 Due to the confusing nature of the trail, with many small footpaths going off of it, it is imperative that the teacher be the leader. A parent or student teacher should be the last person in line and make sure that everyone has come along.

Stay Oriented

As you head down the trail, be aware of your surroundings. Where is the road? Serpents Trail? No Thoroughfare Canyon? The wash? Observe how the trail begins as a wide path going downhill to a split. You want to stay on the major marked trails, not the little wandering footpaths that go off the trail at many places. Pay attention to this. The trail that you want to follow is described in detail here and is marked with cairns, or small piles of rocks, and is lined with rocks throughout. When in doubt, look for a cairn.

Introduction

Gather at the trail map/sign. Begin by saying that today you will be going on a three-mile round trip hike into a remote part of the park on Old Gordon Trail. The purpose of the hike is to learn about the many forms of erosion taking place in the area, and to learn more about its role in creating rocks too. Each student has a set of worksheets that need to be filled out as the hike goes along. As you walk, try to notice the different colors and textures of the rocks that you pass. Can you match any with the formations listed in your worksheet? The teacher should pick up a rock and use it as an example. Note its color, texture, grain size, and location in relation to other rocks. Can you guess what type of rock it might be? Then try to find signs of how it has eroded or broken down from a larger rock.

Hike down the trail until it splits in two.

Stop #1: The First Trail Split

Going right takes you up No Thoroughfare Canyon. You will take the left fork, which is Old Gordon Trail. Stop at the split.

At this stop, and down toward the wash, you have good views up No Thoroughfare Canyon. Point out the dark, slate gray color of the rock up in the canyon. This Precambrian formation underlies Colorado National Monument and is one of its unique features.

The combination of erosion, seasonal flooding, and floods due to storms has washed boulders of many sizes down the drainage. These black to gray rocks, some beautifully laced with pink and white crystals, may be seen along the trail. They show evidence of two powerful but silent forces at work, metamorphism and erosion. Encourage students to record some of these rocks on “Erosion Worksheet #1.” You will see many of them between here and the wash.

Notice, also, the outcrop of whitish-red rock to your left. It is a useful landmark. You can use it to underscore how layer upon layer of sand, silt, mud, decaying vegetation, and other materials build up. The pressure of these layers, one on top of the other, is instrumental in the creation of sedimentary rocks from sediments.

Erosion Hike

ACTIVITY PAGE

Stop #2: The Wash

Whether the wash has water or not, stop here for a few moments to notice the change of temperature and humidity you experience. Observe how the vegetation is different. (Leaves are larger, cottonwood and willow trees grow along the water's edge, and plants are closer together.) Look for signs of animals coming down to the water. Coyote, fox, deer, mouse, rabbit, and even domestic dog tracks may be found (although dogs are not supposed to be here.)

If water is flowing, look for places where it moves quickly or slowly. Talk about how water affects the local topography, aiding in the breakdown of rocks into tiny pebbles, washing grains of sand downstream to new locations, where someday they may reform into new rocks. Notice where the current moves and how it goes faster in some places and slower in others. How would this affect the surrounding rocks? What would the effect be from the standpoint of erosion?

If the wash is dry, spread out along its banks and notice places where there are large rocks and places where there are only sand grains. Observe the cliffs where the force of water undercut the banks and caused them to wash away. Look for places where the water was quiet, such as the downstream side of large rocks or on the edges of the creek. These are places where sand grains were deposited and built up. See if you can find signs of the high water line on the opposite bank. Ask students to find more evidence of erosion breaking down the Precambrian rocks and carrying them away.

Get out "Erosion Worksheet #2" for the next part of the hike.

Cross the wash and head up onto the hill on the other side. Be careful to stay on the boulder-lined path, and not to stray onto the side paths that take you over to the park service boundary line and fence. Remind students of the no collecting rule. It is very tempting here.

Stop #3: Among the Junipers

Climbing up the ridge, you pass through Utah junipers and pinyon pines. Junipers have scales that clasp around the branches and blue berries. Pinyons have short thick needles and cones. Look for signs of tree roots causing physical weathering as they've grown into cracks in the rocks. Humans cause another type of erosion. As they hike, their footsteps make the trail deeper and wider. Soil in this area is fragile and dry, easily damaged by human wanderings. Thus it is important to stay on the trail to minimize our impact. Can students see the "rut" that is developing as the trail?

Look to the north, toward Grand Junction and the Book Cliffs, for a third type of erosion: where water in the wash has undercut banks and carved cliffs as it helps to carry sediments downstream.

Have you seen any of the Precambrian boulders lately? No. That is because you have moved onto a different kind of rock formation, one that is above, and younger than, the Precambrian. Look at a rock. Feel its granular texture. Can you imagine what kind of an environment existed long ago to create a rock with such a coarse, sandy quality? You can make another rock identification on your worksheet here.

Erosion Hike

ACTIVITY PAGE

Stop #4: Slickrock

As you leave the trees and cross the slickrock, watch carefully for the boulders lining the trail and follow the cairns up the ridge. This area is a good place to rest if it is not too hot. The class can spread out on the rock and enjoy the view. Do not let students wander too far to the west, as there are steep cliffs dropping off. Remind them also to drink plenty of water as they travel across this dry ridge.

Examine the lichens that make colorful, crust-like patterns on the rock. Lichens are a combination of a fungus (which gives the lichen its structure and means of reproduction) and an algae (which makes it possible for it to create sugars and photosynthesize). As they slowly grow, lichens secrete a mild acid, which helps to break down the surrounding rock. Their rooting structures, known as rhizomes, penetrate the surface of the rocks, further contributing to its weathering. For these reasons, scientists consider lichens to be valuable pioneers in the creation of soil. Can you find a large lichen and see any of the effects that it has had on its rock host?

Follow the cairns and boulders along the trail upward along the ridge. As there is little shade in this next one-half mile, use caution on hot days. Watch how the sandstone has different features and colors in this section. Some places it is white, others yellow; in some spots it is smooth, others flaky or knobby. Can you tell what might make for such differences?

When you come to a large dead tree, the trail turns east.

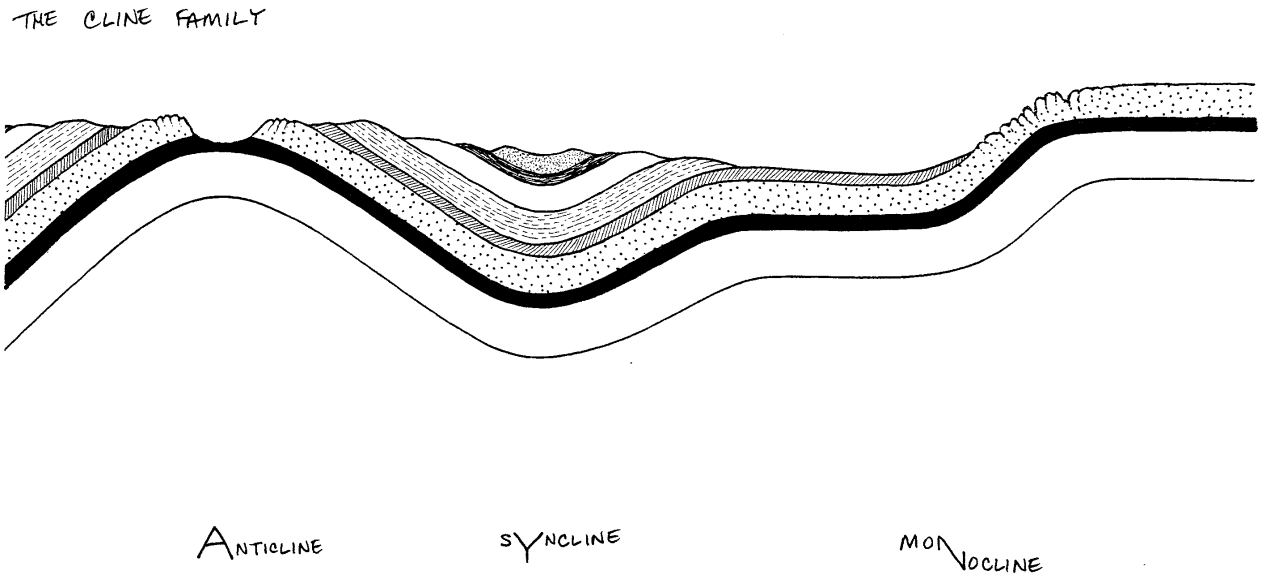
Stop #5: The Old Road

As the trail gets higher on the ridge, it turns south. You will become aware of how the path widens and takes on the quality of a road. This is the Old Gordon Trail, the remains of a private toll-road built by pioneer John Gordon in the early 1880's. According to the National Park Service, this road gave people access to logging camps in the high country. As the class walks along it, think of all the people who have preceded you here, stepping where you are, perhaps leading a mule loaded with supplies, or hauling down timbers from up on Black Ridge. Can they find any other signs of other people passing here?

Farther up the road, find a place where the group can sit down with good views to the east. This is a good place to have lunch or a snack.

Erosion Hike

ACTIVITY PAGE



Stop #6: Erosion at Work

After a rest, get out the worksheets on erosion and review the findings thus far. As the class is sitting on the mesa, many erosional features are visible. 1) The drainages to the west and east, though full of water only seasonally, carry enough water to be deepening and widening these two canyons. 2) In the little drainage to the east, Echo Canyon, look for joints in the rocks where freezing and thawing can loosen boulders and cause rock falls. 3) Notice the difference in caprock and the softer rocks below it on the colorfully banded hillside across the canyon. Which will erode more quickly, the brown cliffs at the top of the hill or the gray rocks below?

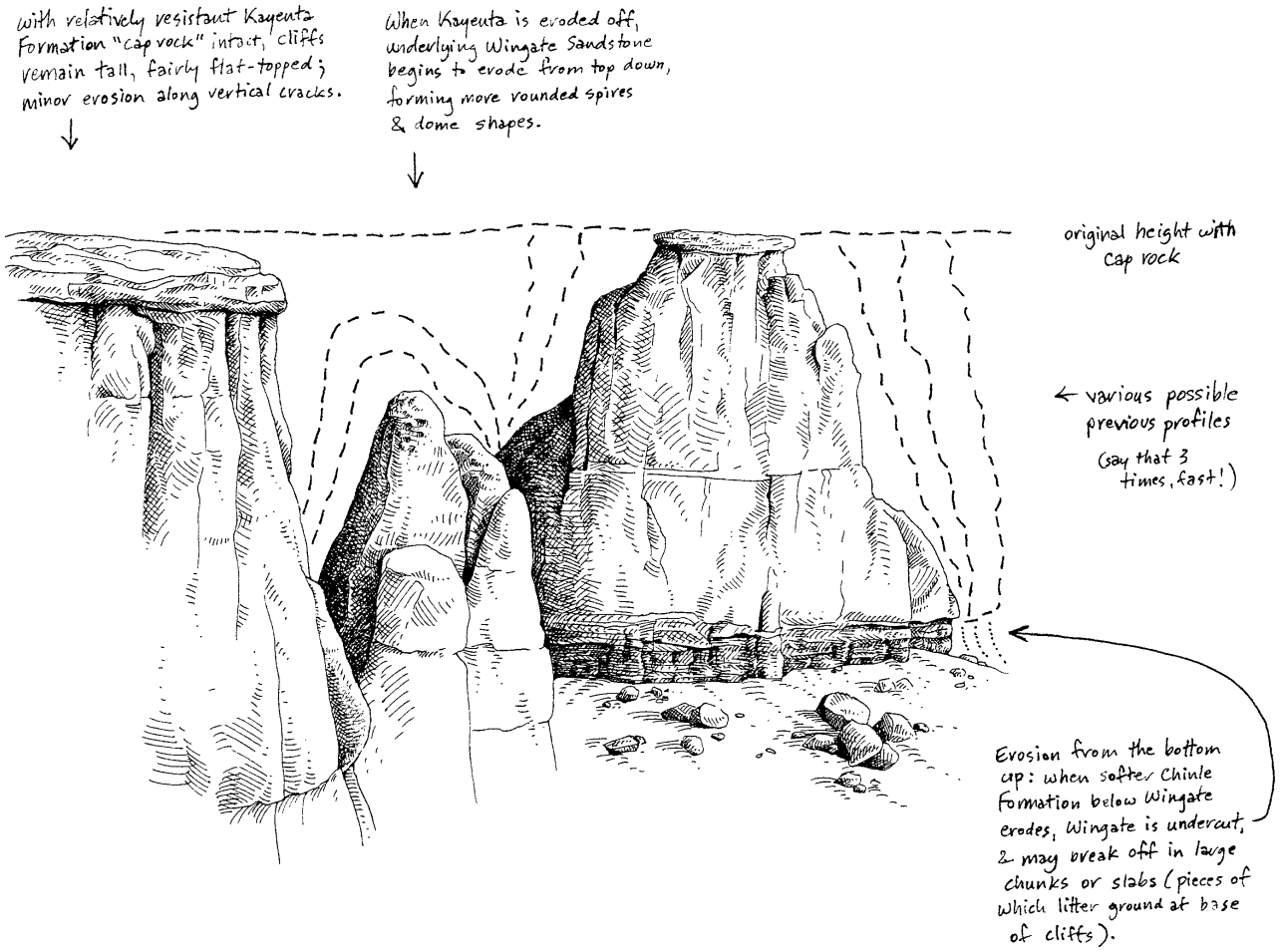
Ask if anyone can identify which formation the gray rocks are a part of. If the students answer the Morrison, they are right. What kinds of fossils are famous for being found in the Morrison Formation? How could you go about finding one, based on information about erosion that you have learned today?

From this point, the trail continues on approximately one-half mile further, heading up the pinyon and juniper-dotted mesa. If you have time, continue on up the trail. If not, return the same way that you came. Again, pay close attention to the locations of cairns. Going downhill can be more difficult than many people think, so give a few words of advice to the class before taking off.

1) The knees act like brakes for the body on the downhill and thus must work very hard. Speed is not appreciated by them.

Erosion Hike

ACTIVITY PAGE



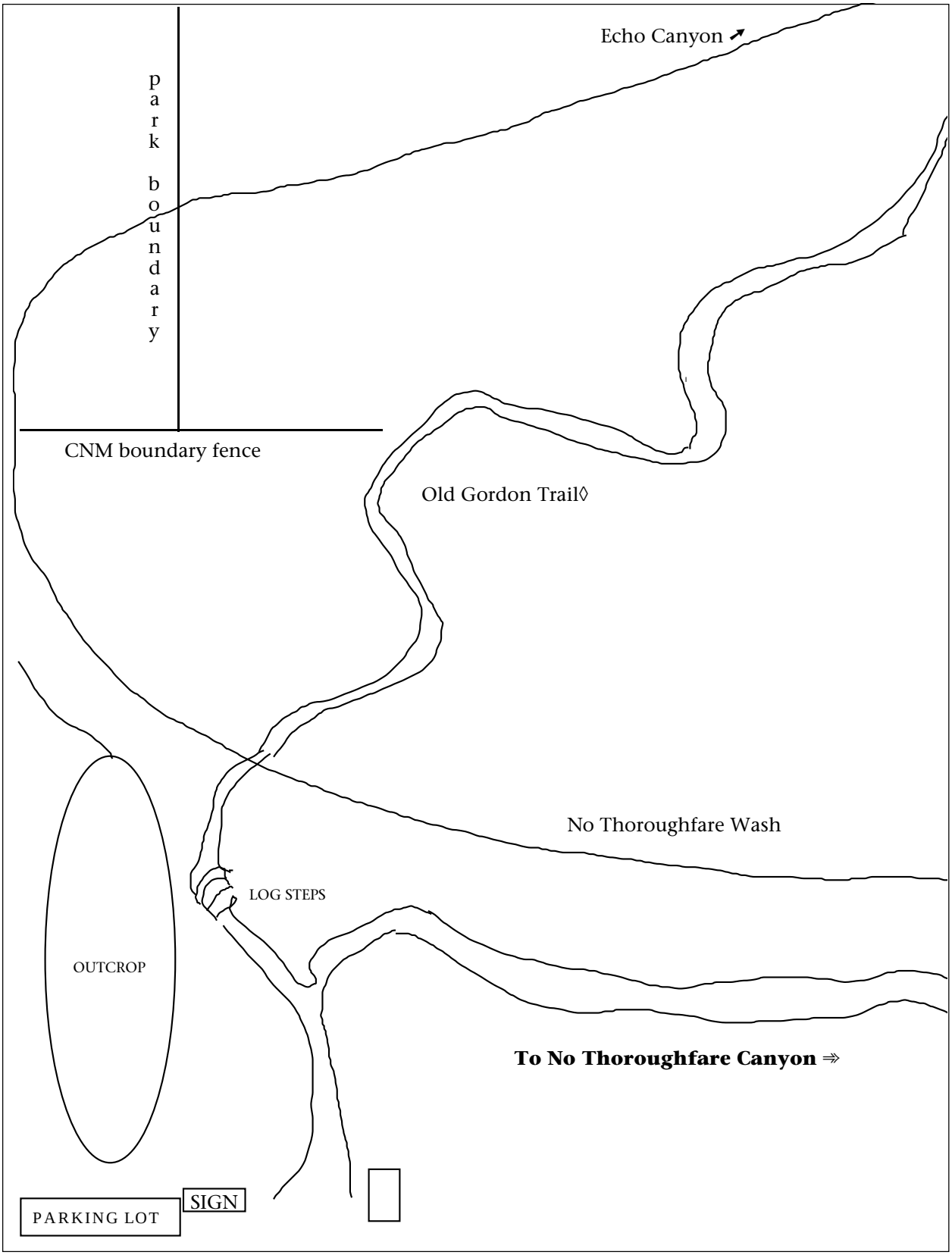
2) Slickrock is exactly what it says it is, slick. Walk carefully on it and pay attention to your foot placement. Little rocks and gravel can mean that you slip very easily.

3) Due to the importance of finding the trail on the way back, the teacher will be the leader.

Conclusion

Through observation, inquiry and recording, students have learned about the different forms of erosion. Since erosion has such an important role in both the removal of weathered rocks and the creation of the landscape, it is a force of nature to be appreciated. Through awareness of its role, students may be able to better understand why Colorado National Monument has been set aside for protection as a national monument.

Erosion Hike



Erosion Worksheet #1
Looking at Rocks

ACTIVITIES FOR STUDENTS

Find a rock that interests you along the trail. Look at it closely, feel its texture, note its colors and other interesting features. Make a record of your rock on this paper by answering the following questions. **Remember, no matter how special or unique your rock discovery, you cannot take it home. The national parks were established to *"PRESERVE AND PROTECT"* natural and scenic resources in perpetuity. That means forever...so your children's children's children— and so on — will be able to come to places like this and share your experiences. So LEAVE THAT ROCK, but make a record of it on this paper! Come back to visit your rock any time.**

1) **How big is your rock?** Bigger than your hand? your backpack? a car? Smaller than your fingernail? Think of something to compare it to in size.

_____

_____

2) **What color(s) is your rock?**

_____

3) **What does your rock feel like?** Describe its texture. Sandy, sharp, knobby, smooth, or ?

_____

_____

4) **Does your rock have any interesting things on it**, such as fossils, crystals, ripple marks, lines, colors or patterns? If yes, please describe.

_____

_____

5) **How hard is your rock?** Scratch it with your fingernail. Can you see a mark? If so, your rock is soft. Try scratching it with another rock. Can you see a mark now? If so, it is medium hard. If you still don't see a scratch, it is a very hard rock. Check the answer that best describes your rock.

My rock is: ☐ soft ☐ medium hard ☐ very hard

6) **Do you know the kind of rock that you have found?**

_____

7) **Can you see another rock, or rock formation, nearby that matches the color, hardness, and texture of your rock?**

_____

8) **How do you think that your rock came to be where it is?** Can you imagine the chain of events leading to your rock's arrival at this place? What type(s) of erosion or weathering might have brought it to this point? Which would cause it to move to where you found it? Wind, water, heating, cooling, freezing, drying, flooding, gravity, animals, plants, or humans?

_____

_____

_____

9) **For your record, sketch your rock, or describe it with words, on the back of this page.**

Erosion Worksheet #2
Discovering Erosion and Weathering

ACTIVITIES FOR STUDENTS

All around you the land is wearing away, going from high to low, peaked to smooth. This never-ending cycle is known as **erosion**. In erosion, material is **moved** from one point to another by the action of water, wind, or gravity. **Weathering** is one part of the erosion process. It is the wearing away of rocks exactly where they sit. No movement is involved. Thus, a rock that is washed down a stream is eroded, but a rock that cracks open but does not move anywhere is weathered.

Listed below are ten different ways that erosion and weathering work. On your hike, look around you. Can you find a place where the rocks have been carried away because of flooding? Can you locate a rock that is weathering in place due to the heat of the sun? Each time that you discover an example, use a few words to record your findings in the spaces on the sheet. Feel free to use the back of the sheet too. You do not have to see water at work, or frost in action. Just describe the places where you see **signs** or **effects** of these types of erosion occurring. Good Luck!

1) Running water in streams or drainages moves small rocks and pebbles to new areas.

_____

_____

_____

2) Running water undercuts banks, breaking off softer rock or soil, and carrying away the loosened material.

_____

_____

_____

3) Flash floods and summer downpours deposit large boulders in unexpected places, some even long distances from streambeds.

_____

_____

_____

4) Wind blows loose sand around and around in a crevice, eventually creating a hole in a rock.

_____

_____

_____

5) Rocks fall off a cliff, pulled downward by gravity, and create piles of rubble and boulders (called talus) on the slopes below. Sometimes you can see the place from which the rock fell as a patch of clean, pale, or white rock on the cliff above.

_____

_____

_____

Erosion Worksheet #2
Discovering Erosion and Weathering

ACTIVITIES FOR STUDENTS

6) Sun heats up the surface of a rock causing the outer layers to expand and crack. The inner rock stays cool and does not heat up. The result is exfoliation: thin layers of rock peel off on the outside or top of the rock.

_____

_____

_____

7) Moisture gets into cracks in rocks. When it freezes, the moisture expands; when it thaws, it contracts. This alternating cycle loosens grains of sand, widens cracks to grooves, and eventually breaks off whole slabs of rock.

_____

_____

_____

8) Lichens, a combination of algae and fungi, grow in colorful crust-like patterns on rocks. They secrete a mild acid that causes the surface of rocks to soften, and break up into tiny pieces. They also cause cracks in some rocks.

_____

_____

_____

9) The roots of trees or plants act as wedges, widening and deepening spaces in the rocks as they grow.

_____

_____

_____

10) Humans cause erosion by wandering off trails, breaking down soils and soil crust, and making new paths across the desert. As our footsteps scrape across the surface of rocks, each passage deepens trails. Among the most damaging forms of erosion caused by humans are initials or symbols carved on rock. Called graffiti, these diggings and scraping on rocks can have ugly, as well as harmful, effects on the rocks. List one or more forms of erosion caused by humans that you find along the trail.

_____

_____

_____

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Age Level

4th grade and up.

Purpose of the Activity

Maps are useful, if not essential, tools in the city as well as in nature. One of the best ways to learn about using maps is to make one. In this activity, the class makes two different kinds of maps: a classroom map and a topographic map. Then, they explore the features of maps and the techniques of map-making by creating a third map, this one of the Grand Valley as seen from Colorado National Monument. Reading, geography, mathematics, and art skills are all utilized.

Amount of Time Required

The classroom map and the topographic maps each take forty-five minutes to complete. Because the mapmaking activities are self-contained, it is easy to do one map at a time, even different maps on different days.

Best Location

The classroom map and topographic map activities are most easily done at school. Both may be incorporated into a longer map-making session held on a field trip to Colorado National Monument.

See *Extensions* for information about this alternative.

Materials Needed

For the Classroom Map:

- ☐ Paper and pencil for each student.
- ☐ Rulers for each student, and a tape measure (optional).
- ☐ Variety of maps for reference.

For the Topographic Map:

- ☐ Washable markers with fine tips — 3 per team of students.
- ☐ Ruler — one for each team of students.
- ☐ Topographic maps for reference. A topographic map of Colorado National Monument, entitled *Colorado National Monument: Topographic Map and Hiking Guide*, is available at the monument Visitor Center. It will be a helpful resource for this activity, even though it includes different information from a United States Geological Survey (USGS) topographic map. As a result, you may also want to have a 7.5-minute USGS Colorado National Monument Quadrangle topographic map for reference in this activity. If that one is not available, any other USGS maps will still be usable. Topographic maps are available for purchase at local outdoor gear and sporting goods stores.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Background Information

Maps are a useful part of everyday life. They take many forms, including mental maps, city, land, world, as well as constellation maps. Pollsters, census takers, economists, entrepreneurs, pilots, planners, architects, astronomers, weather reporters, recreationists, as well as geologists utilize maps. With the help of maps, political as well as personal boundaries are drawn. Decisions about everything from military actions to fence lines between neighbors, to right-of-ways along roads, to the fastest route between two places, are made with maps.

Your mind, too, is full of maps. When you walk through your room in the dark, your mind holds an image of where the bed, the bureau, the chair, the wastebasket are situated. That way, you do not stub your toe on the way to the light switch. As you hunt for your keys, homework, or backpack, your mind re-runs a map of where you were earlier, in order to help you locate what is lost. Packing a suitcase for vacation at the beach, you bring different clothes than you do to go camping or sledding. This is because your brain projects a map of the conditions that you will experience in this new location. Maps, big and small, make life a lot better for us all.

Definition of a Map

What is a map? Dictionaries define maps as representations of places on flat surfaces. In other words, maps attempt to show a three-dimensional site, such as a canyon, within the limits of a two-dimensional piece of paper, rock, skin, or patch of dirt.

Earliest Maps

No one knows when or how the first pathfinder used a stick in the dirt to draw a route for his or her people to follow. Still, for thousands of years, maps have conveyed important information about navigation, taxation, and location of natural resources. Directions to water holes, hunting grounds, trade routes, ocean currents, sacred grounds, as well as the homes of friends and loved ones, have been given with maps. One of the oldest maps known is from 4000 years ago. It was made on a slab of clay by the Babylonians. Early Egyptians designed maps as way of determining property lines for the purpose of taxation. The remarkable array of maps for exploration of the oceans and continents reflects the importance of maps throughout the Middle Ages and Renaissance. In our modern era, satellites help us pinpoint our own or another's location to within a few feet. This accuracy in mapping opens up entire new dimensions and opportunities in the way that people can use maps.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Viewpoint

Maps come in many shapes and sizes. The purpose of a map will often dictate its form and **viewpoint**. A map of the floor of the ocean might look at features from above, looking down and in. If one is following a path through the mountains, the orientation may be at ground level, with the landforms on either side. A chart of the night sky is designed for the reader to be below, looking up. Most maps use a **bird's eye or aerial view** for their reference. When referring to any map, the reader should note the viewpoint to be able to follow the map successfully.

Scale

Scale is another facet of maps. It is impossible to make a map as large or deep as an ocean, or as tall as a mountain. Therefore, everything must be made smaller proportionally to fit on a piece of paper. For instance, one inch on the Colorado National Monument 7.5-minute map equals 24,000 inches of space on the **ground**. Another way to look at this is that two and one-half inches on the map represent 60,000 inches (about one mile) of land. Scale is usually expressed as a ratio, such as 1:24,000. The ratio states a relationship between the two parts, with one unit on the map representing 24,000 of the same units on the ground. Every map has a notation of its individual scale for reference. The scale may be in a variety of sizes from miles to centimeters. Thus, it is important to pay attention to the amount shown in the scale since it varies from map to map. On topographic maps, the interval of the contour lines is given with or near the scale, another valuable detail to remember when reading or making maps.

Legend

Another feature of maps is the **legend**. It lists all the different symbols, lines, and colors on the map, and explains what each one means. If you look at a state map of Colorado, for example, the legend shows that the wide lines are interstate highways. The narrow lines represent state highways and the fine double lines are unpaved roads. In contrast, lines on a topographic map have an entirely different meaning: they indicate elevation changes, and show the contours of the land. Careful reading of the legend on the Colorado National Monument map may make the difference between traveling on a constructed trail (dashes), or an undeveloped route where you must pick your way along a drainage (dots). Therefore, it is important to check the legend on each map to be sure that you are accurately interpreting what is depicted.

Grids

Grids are often seen on maps, dividing them into equal segments. Time zones, longitude, and latitude are familiar grids on maps. Tourist maps often use a grid system of numbers and letters to help locate attractions quickly and easily. On many topographic maps the latitude and longitude are given in the corners of the map.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Township and Range Grids

Because so many people use public lands in the United States, a grid system called **township and range** is projected onto many land maps. This method of viewing the land was first developed in the 1800's as lands west of Ohio were explored for the first time. In order to incorporate new lands into the United States, a standardized method of surveying the new territories had to be developed. As a result, longitude and latitude lines became the basis for dividing the land up into smaller, more manageable segments. These segments measured six miles long by six miles wide. Those that were north or south of specific latitude were called **townships**. Those that were east or west of a given longitude were labeled **ranges**. Once the components are understood, the uniformity of this grid system makes it easy to read any land map of the United States. For the purposes of classroom map reading, knowing that the north and south lines determine the township, and that east and west lines determine the range, is adequate. Township is stated first, followed by the range. Thus, Colorado National Monument is part of Townships 1 N (North), 11 S (South), 12 S (South), and Ranges 102 W (West), and 101 W (West).

Section

The six-by-six mile townships are further divided into thirty-six smaller **sections** usually one mile square. The sections are organized one atop the other for ease of identification. They are numbered consecutively in a continuous line from number one to number thirty-six, beginning in the upper right-hand (northeast) corner, and ending in the lower right-hand (southeast) corner. Thus, anyone buying, selling, working, or recreating on western lands can easily determine where they are, down to a one mile section. Often sections are divided into quarter sections for more specific details. While it takes practice to get comfortable with, the grid system of township, range, and section is so widely used that it is very worthwhile to learn.

Since each map has a structure and features that make it unique, learning how to use them can be a challenge. However, because map reading can get you safely to the place you want to visit, or save you from getting lost, it is a valuable skill to develop. In the following activities, students will investigate how maps are made, while developing their map-reading abilities. Educational content standards are also met with these activities.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

How to Do the Activity

Preparation

Before you begin the first map-making activity, gather the materials that you will need. Take a good look around the classroom. Where are the desks? The bookcases? The chalkboards? The pencil sharpener? Note the locations of the doors and windows in the room. All these details are included in the maps that your students will make. You may want to sketch a map of the room for your reference and for comparison with the student maps.

Next, review the information about topographic maps in the "Let's Get Oriented" activity. Practice making the topographic map on your hand or someone else's, so that you will be able to draw and demonstrate the contour lines with confidence. Make sure that you are familiar with the elements of topographic maps, and that you can comfortably read and explain one.

Lastly, if you are going to make the map of the Grand Valley, plan an advance visit to the site from which the map will be made so that you can be familiar with the vista. Find different landmarks to give to students to pick out. Such preparations will make these challenging activities successful.

Not All Students Are Mapmakers

A word of advice: Not all students are mapmakers or comfortable in the role of artist. These individuals will need assistance and encouragement to "see" as a mapmaker does. Often, just the change of perspective from human scale to aerial is difficult to accomplish. Be patient with these children, and give everyone lots of positive feedback. Extra parental or chaperone support is very helpful in this activity. If you know of a student who may need extra assistance with this activity in advance, you may want to assign him or her to work in a team with another student, or link the student with the adult.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Introduction to Mapmaking: The Classroom Map

Map #1: Introduction to Mapmaking: The Fly on the Ceiling

Step One: The teacher may want to have several different types of maps hanging up in the classroom and available for students to look at as part of this activity. Begin by asking the class who has used a map before. On the chalkboard, list different kinds of maps that the students know. Atlases, globes, road maps, state maps, constellation maps, and treasure maps are just a few of the maps with which they should be familiar. Others to mention are property maps (for taxation and real estate), architectural maps (for building designs), and mental maps (knowing by memory where to go to find milk at the supermarket). Of course, you want to mention geologic maps that are used to study rock formations, and to search for such valuable commodities as oil, gas, coal, and precious metals.

Next, find out what the students think are the important parts of a map. If they do not mention viewpoint or scale, explain these terms to them. Discuss how a map is a two-dimensional representation of three-dimensional place. To illustrate that concept, ask them to draw a picture of their neighbor's face (three dimensions) on a piece of paper (two dimensions). As they attempt to do that, describe how the mapmaker's challenge is to represent a mountain or canyon on a mere piece of paper.

Step Two: Draw a map of the classroom. The purpose of this activity is to acquaint students with the concept of "viewpoint". Students are to make a map for a fly that is stuck on the ceiling of the classroom. The fly is very hungry, and needs something to eat. It is looking around the room from high above, hoping to find an apple, a sandwich, a cookie, or some crumbs that a student left behind. Therefore, the students' maps should be made to assist the fly in finding food. The viewpoint should be as if the student mapmaker were the fly looking down from the ceiling. Features of the classroom should be drawn in, including the doors, windows, bookcases, desks, wastepaper basket, and so on. Of course, somewhere on each map, the mapmakers should hide a piece of food for the fly.

Begin the map by drawing an outline of the room, and marking the directions north, south, east and west on it. Next, add windows and doors. If desired, different colors or symbols can be used to label desks, bookcases, and other features of the room. Only when the map is complete, should the food be hidden somewhere. If students have trouble thinking of places, give them suggestions such as gum on the trash can, an open lunch box under a desk, the teacher's cup of coffee or tea on a desk. Encourage the class to think of this project as making a treasure map - for a fly. As the class works, the teacher should assist with any questions that come up. If a student has difficulty with viewpoint, adapt this assignment for the student's abilities.

Step Three: After 15 minutes, ask students to give their maps to a friend. This person will be the fly, and must use the map to find where the food is hidden. Exchanging papers gives the mapmakers a chance to see how other people drew maps, and to learn tips for future efforts. After the "flies" have found their food, discuss what the students learned about making maps. If there is time, ask students to make a **legend** for their maps to show the different elements of their map.

A fun addition to this activity is for the teacher to hide a snack in the classroom for the students. The only way that the treat can be located is by using the aerial viewpoint that a fly would.

Optional Activity

Determining the Scale of a Map

Step Four: *This is optional*, and focuses on **scale**. Depending on how well students understood the element of viewpoint, and on their math skills, this is a useful step to incorporate. Get out rulers and use the back side of Map #1 for this exercise. First, students measure the length and the width of the room that they drew in Map #1. On the back side of the map, they should record their findings. Next, the class should use a tape measure to determine the length and width of their classroom. The students should also record these numbers on their worksheets. Together, these notations will be used to calculate the scale of Map #1. Alternatively, the class can find the scale together.

The class will benefit by using one student's notes as a sample for calculating what the scale of Map #1. Remember that scale is presented as a ratio: one unit on the map equals so many of the same sized units on the ground. Thus, if the student's map size is in inches, and the real room size is in feet, the room size must be converted to inches for the ratio to work.

A sample worksheet might look like this:

Pat's Map

Length of room in Map #1 = 8 inches
Length of Classroom = 10 feet 6 inches (Conversion) = 126 inches

Ratio of Room to Classroom
8-inch room map: 126-inch classroom
1-inch room map: 15.75-inch classroom

Therefore, ***scale*** *of map is 1:15.75.*

(Note: No one answer will be correct for this activity. Because each classroom map will be a different size, the ratio will differ slightly for each student.)

Through Map #1, "The Fly on the Ceiling", students will learn about key elements in making and reading maps: viewpoint, legend, and scale. They will appreciate the complexity of the job of mapmaker, as well as to understand about the mapmaker's tools. In the next exercise, they will learn about another kind of map: the topographic land map.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Map #2: Making Topographic Maps Using Your Fist

Map #2: Making topographic maps[1]

Step One: Introduce this activity by asking if anyone has ever gone hiking or camping and used a topographic map. Show a topographic map to the students. In what ways does the topographic map seem different from the state map? Encourage students to notice the colors and the squiggly lines, called **contour lines**, on the topographic map. Explain how contour lines work with information from the "Let's Get Oriented" activity, later in this chapter.

Step Two: In this activity, students draw on their partner's hands to illustrate the concept of making topographic maps. Remember to use washable markers. Divide the group into teams of two. One person draws while the other is "the map". Later, roles will be reversed. The person to be mapped, hereafter referred to as Mapmaker A, makes a fist. Keeping his/her arm straight, he/she places the fist palm down near the edge of the desk. The fingernails and palm should be as flat as possible against the desk. (Note: Different hands make different fists. Some will prefer the thumb inside the fingers, others will not. What matters is not the placement of the fingers, but the ability of A to hold the fist position steadily flat against the desk for the time it takes the map-maker to draw the map.) For ease of reference, the fingers should be labeled #1 (thumb) to #5 (little finger).

Step Three: The person making the map, hereafter referred to as Mapmaker B, needs to look closely, preferably at eye level, at the fist. The different lumps and bumps, lines and ridges covering A's hand should be noted. Then, B should find the 1/4-inch mark on the ruler. Placing the ruler next to the #1 finger (thumb), B should make a series of dots *all exactly 1/4 inch up from the desk* around to the next finger. **It is important to keep the marker straight out from the 1/4 inch notation on the ruler to assure that the dots are the same distance from the surface of the desk all the way around.** This is a very important feature to stress, as mapmakers draw contour lines with precision. Each one represents an exact elevation above sea level. In this exercise, contour lines should be measured with a ruler to be exact distances from the desk. After all measurements of the fingers are completed, the dots/lines should be extended around the hand to the wrist.

Step Four: When the first series of dots is complete, Mapmaker B should carefully draw a line to connect them. With the first contour line now finished, a new color of marker should be chosen for the second contour. Repeat the procedure, using the 1/2 inch notation on the ruler this time. Make dots around the fingers and hand to the wrist. If it is easier to make the line directly, go ahead and do so. Continue around the fist, making sure the dots are *exactly* 1/2 inch above the surface of the desk. When these are connected, repeat the dots a third time with a third color of marker. With each new line, move up 1/4 inch on the ruler. Make more contour dots and lines around the fist until the knuckles are reached.

Pay attention to the indentations between fingers. Make the lines go continuously all the way into and through those spaces rather than jumping from finger to finger.

[1] The concept for this activity comes from *Earthsearch, A Kid's Geography Museum in a Book*, by John Cassidy. Klutz Press. Palo Alto, CA. 1994, p. 46.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Remind students to make the lines with the marker as straight as possible from the ruler. The result will be that some lines are closer to one another than others. This is all right, because mapmakers know that each contour line is a specific distance from the base measurement of sea level, and not specific distances from each other. Topographic maps show just this feature when contour lines are wide apart on flat areas and close together on cliffs and steep places. In the context of the topographic map on the fist, the flatter places will be on the hand and wrist, therefore the lines farther apart. On the steep "cliffs" of the fingers, lines will be closer together.

Step Five: When you reach the knuckles, notice how one or two of them are taller than the others. Complete the lines around all but the tallest knuckle. Finish the "map" by making a **benchmark symbol** on the topmost knuckle. Surveyors routinely place benchmarks at sites where they have made a permanent calculation of the elevation. These can be found atop mountains, deep in canyons, even on buildings in the heart of the city. The mapmakers may create a benchmark of their own choosing to place on the highest point of their topographic map of the fist.

Step Six: Change roles so that Mapmaker A may now draw contour lines around Mapmaker B's fist. When the class has completed all the topographic maps, ask students to lay their hands flat on their desks. Notice how the lines are closer together in some places, and farther apart in others. Then make a fist again. Where the hand is flattest, the lines are widest. Where the fist was steepest, over the fingers, the lines are closest. These contour lines mirror those made on the topographic map! That's how a topographic map is made.

Step Seven: Bring out topographic maps from Colorado National Monument and other areas. Lay them out, and let the class gather around them. Ask the students to point to steep areas (where contours lines are close together) and flat areas (where contour lines are wide apart) on the maps. Where contour lines change from close to wide, what does that mean happens to the land? Review any other questions that the students have.

Some advice for making the contour lines on hands legible:

~ Be sure hands are completely dry before beginning the lines.

~ Go slowly when connecting the dots or making the lines. Follow the shape of the fingers, going in and out of the spaces between.

~ Alternating colors helps the mapmaker to keep track of where she or he is.

~ Hold the ruler very still and straight, but feel free to move it from finger to finger and around the hand. Carefully keep the marker level with the 1/4, 1/2, or 1 inch notation on the ruler.

~ It is helpful for students to see a demonstration of what they will be doing. The instructor may want to make a sample topographic map on the fist of an obliging student.

Contour lines represent intervals of 10 or 20 feet on most maps. They must be precisely measured to give accurate data about elevations. Try to be as exact about your measurements as you can.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Conclusion

By making a map of the classroom, and by drawing a map on their hands, students will learn the elements of mapmaking. These skills will enable them to better read and appreciate maps that they may use in and out of the classroom.

Extensions

Map #3: Mapping the Grand Valley

This map can be done alone or in conjunction with the previous two maps, the classroom map and the topographic map. The purpose of this activity is to allow the students to integrate the elements of mapmaking that they have learned about previously into a map of their own. Vistas from Colorado National Monument are ideally suited for this activity. Not only are they dramatic and beautiful, but the clarity of the air and the width of the view make them striking places for mapping the lands below. Above all, being high on the mesa looking out and down gives young mapmakers an already established viewpoint from which to work. They are much like golden eagles soaring high above the canyon rims and looking down to the valley below. (Or, they are like that proverbial fly on the ceiling!)

The best location for this activity is the Historic Trails turnout, off Rim Rock Drive, above the West (Fruita) Entrance Station. This turnout has room for a bus or group of cars, and has excellent vistas of the Grand Valley, the Book Cliffs, Colorado River, and beyond. Alternative sites include Saddlehorn Campground, Canyon Rim Trail, Window Rock Trail, Book Cliff Shelter, or Grand View turnout on Rim Rock Drive. Even the porch area at the Visitor Center could be used for this mapmaking activity.

For the map of the Grand Valley, the following materials are needed.

~ Paper, pencils, and colored pencils for each student.

~ Clipboard for each student.

~ Binoculars will be helpful and inspirational for these maps.

~ Parent chaperones are highly recommended for this activity, both to aid with the mapmaking and group management in the turnout area.

Plan for approximately thirty to forty-five minutes to complete the map.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Step One: Before you begin, make sure that students each have a clipboard, a piece of paper, pencil, and colored pencils. Upon arriving at the Historic Trails Overlook or another site that you chose for this activity, stress safety to your students. Ask them to watch out for one another, since they are in a parking area, just off a road where people are sight-seeing, and near the edge of the canyon. Danger, however, is minimized since the activity takes place at a fenced overlook that is a short distance from the road. If there are students for whom travel on unpaved or uneven surfaces is not possible, there is plenty of space for the class to do the activity from the sidewalk.

Step Two: The purpose of this activity is to make a map of the Grand Valley. Review what the class has learned so far about maps, namely the importance of viewpoint and scale. Here, along the cliffs of Colorado National Monument, they are able to have a bird's eye view of the valley below. This is the way their maps should read—from above looking down.

Step Three: Take five or ten minutes to look around. Let people call out the areas and places that they can identify. Ask students to find: Interstate 70, railroad tracks, the Colorado River, the Book Cliffs, the Fruita Bridge, McDonalds in Fruita, Broadway or Highway 340, Dinosaur Hill, the West (Fruita) Entrance Station, Rim Rock Drive, etc. Afterwards, let students spread out around the overlook to find a place where they would like to work. Explain that they have 20 minutes to design a map of the Grand Valley. Encourage students to do the outlines and placement of sites with pencil, and do the coloring later. The teacher and chaperones can rove among the class giving ideas and advice.

Be aware that mapmaking is not for everyone. No matter how hard they try, some people have difficulty translating what they see in real life onto the smaller scale of paper. For these people, suggest that they draw or write about something that interests them that is located nearby. They may not wander around.

Progress on the maps will vary. For those who finish quickly, get them to color in their maps. Remind them to make a legend of all the different colors or symbols that they have used. This can go on the back of the paper or in a lower corner. Also have them make a scale for the size of their map, and design a directional symbol or compass showing the direction from which to read the map.

Mapmaker, Mapmaker, Make Me A Map

ACTIVITY PAGE

Extensions

Ways to Adapt Mapmaking Activities

1 All activities can be done by those physically challenged. The area at Colorado National Monument is accessible for wheelchairs. Restroom facilities are available at the monument Visitor Center and Saddlehorn Campground.

2 Turn the "Fly on the Ceiling Map" into a maze, by having a specific destination for the fly to reach, a peanut butter sandwich on someone's desk, or the door to the principal's office.

3 Younger students will enjoy making maps as much as older students. For them, the details of viewpoint, scale and legend can be omitted.

4 "Let's Get Oriented", the following activity, complements this one, and will make a good follow-up or extension.

5 Many maps and books on maps are available through local libraries and sporting goods stores. If students show an interest, you can also explore map reading with a compass.

6 Plan a map day, when everyone can share a map from home. People have amazing secret supplies of maps left from previous explorations and vacations. These will give useful comparisons of viewpoint, scale, design, and legends. Students could vote which they find the most useful, beautiful, etc. Mapmakers of the past were highly skilled artists and technicians.

7 Plan a field trip to see how people actually use maps in their work. There are a number of fascinating options for this in the Grand Valley area.

8 Modern maps are increasingly being made with computers. A local engineering or surveying company, land development company, architectural firm or environmental assessment company might be willing to share some of the design technology that they now use.

a. The Colorado Department of Transportation would have an interesting selection of maps that they use in road management and planning.

b. Many federal government offices, such as the Bureau of Land Management or United States Forest Service, now use the GPS (Global Positioning System) for mapping. Maps of the future will use these advances in satellite and computer technology.

c. The Colorado Division of Wildlife may also have interesting maps that they use to track and protect wildlife.

Let's Get Oriented

ACTIVITY **PAGE**

Age Level

5th grade and up.

Purpose of the Activity

This activity is designed to introduce students to the way that maps are structured, and to help them begin to locate places on one. Using a scavenger hunt format, students attempt to locate items on the attached worksheet within a given amount of time.

Amount of Time Required

One class period or approximately 45 minutes.

Best Location

As maps must be spread out, a classroom, or site sheltered from the wind is recommended.

Materials Needed

- ☐ Map of Colorado — one for every two students.
- ☐ Map of Colorado National Monument — one for every two students.
- ☐ Topographic Map (optional).
- ☐ "Let's Get Oriented in Colorado" worksheets #1 and #2 — one for every student.
- ☐ Pencils — one for every student.

Background Information

Maps get us to new places. They help us find our way. They also offer a record of an amazing world beyond our familiar neighborhoods. Mount Everest, The Bay of Fundy, Corsica, Yemen, Baffin Island, Mongolia, Sri Lanka, Nigeria, Uzbekistan, the Amazon River, Antarctica, the Pyrenees…exotic and far away places come alive through maps.

Every map has a structure and features that make it unique. Learning how to read and use maps can be challenging. This activity uses a scavenger hunt format to make it fun. Students investigate a Colorado map and a Colorado National Monument map trying to locate important sites on both. They must first find information about the map itself, when it was made, and what the symbols mean. Then, they must identify specific places, roads, rivers, and landforms. The teacher may use the worksheet as a starting point or develop his or her own.

"Let's Get Oriented" works well as a supplement or addition to the "Mapmaker, Mapmaker, Make Me a Map" activity.

Let's Get Oriented

ACTIVITY PAGE

How to Do the Activity

Preparation for the activity involves locating enough Colorado maps for your class. Figure that you need one for every two students. Many families have them at home, and could lend them to the class for a day. Often the Chamber of Commerce has them available for purchase for a nominal fee, or for free. A local business or filling station might be willing to donate maps to your class. If this route is used, be sure to have students write or draw a map as a thank you note.

If you borrow the maps, make sure names are on them so they don't get lost or mixed up with others. If you are to have some permanently, consider laminating them to protect them for future use.

Colorado National Monument Official Map and Guides are available at no cost from the Visitor Center. One map is included in the back of this book. The Colorado Welcome Center just off Interstate 70 in Fruita is another source for them. Be sure to call ahead to let them know that you will be coming with a request for a large number of maps. Again, you will need one for every two students.

Topographic maps are available from local sporting goods and outdoor equipment stores. Again, you might be able to get them donated. You can also order them from the U. S. Geological Survey in Denver, Colorado 80225 or Reston, Virginia 22092. You can also check the U.S.G.S. website for further map options. A topographic map of Colorado National Monument specifically is sold at the CNM Visitor Center. It is more detailed and informative than the standard topographic map, and makes an excellent resource for the class.

Copy the worksheets, making any changes that you want.

Look at your maps and become familiar with the symbols and places shown on them. This will help you to direct the students without having to search around with them.

Let's Get Oriented

ACTIVITY PAGE

Step-by-Step Instructions

1 Chose a sheltered site if outdoors or move the desks out of the way and let the children lie on the floor of the classroom for this activity. Divide the class into teams of two. Each team will need a Colorado map. Let students look at the maps for a short while before passing out the scavenger hunt worksheets. Walk around the room to assist any team having difficulty. Setting a time limit for completion is optional.

2 When the Colorado map hunts are complete, give students the Colorado National Monument maps for comparison. What differences do they notice right away? Why are the maps so distinct? (The teacher may want to refer to the title of the Colorado National Monument map. It is both a map and a "guide." This is in keeping with the role of the monument, as part of the National Park Service, to educate people about what they are seeing. Parks are established to preserve and protect unique scenic, cultural, historic, and natural areas, and leave them "unimpaired for the enjoyment of future generations.") How does this compare to a road map, which is intended to help you find the road you need to get places? Which type of map does the class prefer? Is there a place for both?

If you have time, use the Colorado National Monument map worksheet. Students should complete it using the same process as with the Colorado map.

To continue your investigation of maps, share the topographic maps of the monument and worksheets next. Depending on the skill and interest level of the students, you may let them answer the questions on their own, or you may choose to do the worksheet together. Highlighting the different contour lines and other symbols on the chalkboard may be useful.

Conclusion

In Conclusion, take students on a "dream tour". This can be done in writing or verbally. Each child is an explorer preparing for a trip to a far away land. What country or place in the world would they go if they could go anywhere they want with no restrictions, and no parents? What things would they take with them that are ABSOLUTELY essential? Money, clothes, food, water, medicines, first aid, pack or luggage, tickets, toys are some of the things they might mention. Hopefully, now, too, they will remember a map!

Ways to Adapt This Activity for Other Ages

This activity is difficult to adapt for younger students as it is complex, detailed, and requires a facility with reading and vocabulary. However, children are never too young to look at globes, maps, atlases, or compasses to gain an appreciation for the world.

Let's Get Oriented

ACTIVITY PAGE

Extensions

- With a globe and an atlas, do a tour of the world. Spin the globe, close your eyes, and set your finger down at a random spot. Where did you land? Look up that place in the atlas for more close-up inspection. What is the capital of that place? Where are the mountains, rivers, deserts, ports, and highways — if any? Where is it in relation to the equator? How hot or cold do you think it would be there? An endless number of questions and curiosities are explored this way. For follow up, look your place up in the encyclopedia, or check out a book about it from your local library.
- See "Mapmaker, Mapmaker, Make Me A Map" in this manual.
- Teach students how to use a compass to assist in map reading.
- Practice the art of triangulation.
- Take the topographic map of Colorado National Monument to a trail and overlook, such as Otto's Trail or the Coke Ovens Trail and Overlook. Challenge students to find their location on the map. Afterwards, get them to identify mesas, buttes, monoliths, drainages, trails, roads, canyons, and even elevations on their maps.
- Hike Monument Canyon or No Thoroughfare Canyon using a topographic map to stay oriented.

Resources

Be Your Own Map Expert. Barbara Taylor. Sterling Publishing Company. New York, New York. 1994.

Earthsearch: A Kid's Geography Museum in a Book. John Cassidy. Klutz Press. Palo Alto, CA. 1994.

Everything You Need to Know About Geography Homework: A Desk Reference for Students and Parents. Anne Zeman and Kate Kelly. Irving Place Press. Scholastic Books. New York, New York. 1997.

Finding Your Way On Land And Sea: Reading Nature's Maps. Harold Gatty. Stephen Green Press. Brattleboro, VT. 1983.

How To Teach With Topographic Maps. Dana Van Burgh, Elizabeth Lyons, and Marcy Boyington. National Science and Teachers Association. Arlington, VA. 1994.

United States Geological Survey. Denver, Colorado 80225 or Reston, Virginia 22092. Look also for their website.

Let's Get Oriented in Colorado
Worksheet #1

ACTIVITIES FOR STUDENTS

Directions

With your Colorado map spread out in front of you, look it over from top to bottom. Then, get more specific, and see if you can find the following 25 items. Some are cities and towns; others are rivers and significant lands or parks. You will also need to locate features of the map itself, such as the title of the map, date of publication, explanation of symbols, etc. Fill in the blanks or put a check mark on your sheet when you find an answer. If you cannot locate an item, move on, and return after you have the other answers completed. GOOD LUCK!

Find the following items on your Colorado map:

1. What is the title of your map? _____

2. Who produced or published it? _____ Year? _____

3. Does your map have legend or explanation of symbols? ☐ yes ☐ no

4. What is the scale of your map? _____

5. Can you find a grid system of numbers or letters or both to help locate places on the map?
☐ yes ☐ no

Locate these places:

☐ Grand Junction
☐ Montrose
☐ Colorado Springs
☐ Pueblo
☐ Bent's Old Fort
☐ Black Canyon of the Gunnison National Park
☐ Colorado National Monument
☐ Dinosaur National Monument
☐ Rocky Mountain National Park
☐ Mesa Verde National Park
☐ Pawnee National Grasslands
☐ Colorado River
☐ Gunnison River
☐ Fruita
☐ Denver
☐ Boulder
☐ Sterling
☐ Cortez
☐ Arkansas River
☐ South Platte River

Optional:

☐ Find a national forest
☐ Southern Ute Indian Reservation
☐ Find a county line
☐ Ute Mountain Indian Reservation

Let's Get Oriented in Colorado
Worksheet #2

ACTIVITIES FOR STUDENTS

Directions

Spread out the Colorado National Monument (CNM) Official Map and Guide. Look on both sides. Then, answer the following questions about your observations of the map.

1. Name three differences that you notice between this map and the Colorado map.

   _____

   _____

2. Locate the scale of the CNM map. Compare it with the Colorado map.
   One inch at CNM equals how many miles? _____
   One inch on the Colorado map equals how many miles? _____
   Which map shows more detail? _____

   If the Colorado map and the CNM map had the same scale, what would happen?
   (Hint: Imagine what the CNM map would look like if the scale were 20 miles equals one inch. Would it be bigger or smaller? If you are not sure, look at the Colorado map and see how tiny CNM is.)

   _____

   _____

3. Find the legend or explanation of symbols on the CNM Offical Map and Guide.
   What does – – – – – mean? _____
   What does —•— mean? _____

4. Find the East (Grand Junction) Entrance to the monument.
   Find the West (Fruita) Entrance to the monument.

5. Locate Rim Rock Drive. How many whole tunnels are there on it? _____

6. How many canyons, large and small, are in the monument? _____

7. What is the elevation of the highest point on Rim Rock Drive? _____

8. What community has two roads coming into Rim Rock Drive? _____

9. What is the name of the campground in Colorado National Monument? _____

10. The Visitor Center is closer to which entrance of the monument? ☐ East ☐ West

11. How many picnic areas are there in the monument? _____

12. How high is Independence Monument? _____

13. Who said these canyons "felt like the heart of the world to me"? _____

14. In what year was the monument created? _____

15. How many square miles are in the monument? _____

Answer Sheet for Let's Get Oriented in Colorado Worksheet #2

1. Three differences are: size, shape, scale. Other possible answers are:
   - The amount of information given for CNM is greater than for places on the Colorado map.
   - Colorado National Monument is only a small part of the state.

2. One inch on the CNM map equals one mile; on the Colorado map one inch is 20 miles.

3. – – – – – means trail. —•— means overlook.

5. There are three whole tunnels and one "half" tunnel.

6. There are eleven canyons.

7. The highest point is just past Ute Canyon View at 6640 ft. or 2024 m.

8. Glade Park.

9. The campground is called Saddlehorn.

10. The Visitor Center is closer to the West (Fruita) Entrance.

11. There are two official picnic areas: Devils Kitchen and Saddlehorn.

12. Independence Monument is 450 feet high.

13. John Otto said those words. He was instrumental in founding the monument.

14. Colorado National Monument was founded in 1911.

15. Colorado National Monument is 32 square miles in size.

Geologic Pursuits

ACTIVITY PAGE

Age Level

4th through 8th grades.

Purpose of the Activity

The purpose of this activity is to give students an opportunity to test what they know about geology in general, and Colorado National Monument in particular. The format, similar to a game of musical chairs, is sure to keep pupils on their toes!

Amount of Time Required

Fifteen to twenty minutes of preparation.

The game itself moves quickly. How long it lasts is determined by how many questions there are to answer. Twenty-five questions last approximately fifteen minutes.

Materials Needed

- ☐ Paper plates: one for each student.
- ☐ Wide-tipped marker.
- ☐ A list of questions about geology (or any other subject) to which only the teacher has the answers. The questions provided with this activity are just a starting point; many more questions can be added.
- ☐ *(Optional)* Rocks to hold down paper plates in the wind may be needed if the game is played outside on a windy day. One fist-sized rock per plate should work.

Best Location

Location is flexible. It can be indoors or outdoors, but a space for students to run is needed. Options include a gymnasium, playing field, parking lot, even a classroom where the chairs have been pushed back. Noise can be a factor in determining the location of this game, as students tend to yell out the answers.

Geologic Pursuits

ACTIVITY PAGE

Background Information

"Geologic Pursuits" is a fun game to use as a filler at the end of a class; to wake students up on a sleepy morning; to introduce a new topic, or to review an old one; even to use while waiting for a bus at the end of a field trip. Students will enjoy the combination of moving and thinking while in "pursuit." Teachers will appreciate getting an idea how much pupils have retained out of a lecture or study session, while chuckling over the "hunt" for answers.

At the heart of this activity is a list of twenty-five true or false questions about geology. The questions are based on general geology as well as topics specific to Colorado National Monument. They are meant to act as a resource for the teacher, who may choose to develop a question list that is specific to both his or her curriculum and the needs and interests of the students. Teachers should feel free to make up questions on other subjects as well. "Geological Pursuits" is a very adaptable game.

This activity does not stress competition so much as it encourages individual achievement. After the teacher asks a question about geology, students must show their answer by running to a plate that is marked with "T" for "True", or "F" for "False". Those who do not have the right answer are not penalized, nor are those who are accurate rewarded. It is merely a game of wits — with plenty of running around! In the Extensions section of this activity, however, other ways to play "Geologic Pursuits" more competitively are suggested.

Geologic Pursuits

ACTIVITY PAGE

How to Do the Activity

Step-by-Step Instructions

Preparations

1 Review the questions about geology that follow. Use them, or others that reflect topics from your curriculum, to create a list of twenty-five (or more) questions to ask the students. All answers must be "true" or "false". The resulting questions will be the centerpiece of the game of "Geologic Pursuits". You may want to develop a few easy questions to use at the start, while the students get familiar with how the game works. Several bonus questions to challenge what they know might be fun for the end of the game.

2 Gather one paper plate per student, plus a few extras. On half of the plates, mark a large, bright-colored "T" for True. Make an "F" for false on the other half. Keep two or three blank. Students will answer the questions by running to either a "T for True" plate or an "F for False" plate.

3 Make sure that you have a large enough space to accommodate the game. An area at least forty to fifty feet long and twenty-five feet wide, should be used. This allows the class to spread out and really run to the answer plates. As movement is key to the enjoyment of the game, a larger space is preferred, but running distances can be consolidated to accommodate smaller spaces. Also, keep in mind that "Geologic Pursuits" can become very noisy, which also affects the choice of site. If possible, avoid asphalt and cement surfaces. They can be hazardous to the skin on knees of the runners. If no other alternative is available but asphalt, allow only walking to get to the answers.

4 Preparing the game field ahead of time is helpful, but not necessary. Students can easily be incorporated into the process, by setting out plates, and pacing off distances.

a) Choose a starting line for the game. Mark it at either end with a *blank* paper plate. It should be in the middle of the space to be used. Optimally, twenty to twenty-five feet of open space should be available on either side of this line. Plan for students to be single file along this line. This is the place where everyone must be when the questions are read.

b) From the starting line, pace off twenty-five feet in one direction. Make a line of "T for true" plates that parallels the starting line. Leave some space between each plate.

c) Return to the starting line. Pace off twenty-five feet in the opposite direction for a row of "F for false" plates. The result should be three parallel lines, two of which have 10 to 15 plates, and one of which marks the center starting line.

A Reminder: The plates should be placed in a line on the ground with all the "T's" or all the "F's" facing skywards. Plates should not touch. This gives students space to stand on the plates with their feet. Remember, in total, there should be one plate per student. Half of those should be marked with "T", and the other half with "F".

Geologic Pursuits

ACTIVITY PAGE

The Game of "Geologic Pursuits"

1 Begin by explaining what the class will be doing: testing their knowledge of geology (or other subjects) by answering a series of true-or-false questions. To do this, students will listen to a question read by the teacher, and then state their answer by running to either a "true" plate, marked with the letter "T", or a "false" plate, marked with the letter "F".

2 Ask students to form a single-file line between the two blank plates in the middle of the game field. This becomes the starting line for the rest of the game. Ask students to look in one direction, to the plates marked "T" for "True." If they think the answer to a question is "true", then they should run as fast as they can to the "T" for "True" plates. Ask students to look in the other direction to the "F" for "false" plates. If they think the answer to a question is false, then that is the direction that they should run.

3 Try a practice question. Ask the students to point to the correct answer: "The sky is blue."

4 Now, go over the rules of the game.

RULES for "Geologic Pursuits"

1. This is a test of how much you have learned about geology.
2. When you think you know the answer to a question, run to the plate marked T (for true) or F (for false). Stand on it.
3. *Only two people are allowed to stand on any plate.* If there are more than two, and a dispute occurs, then everyone must get off and return to the starting line.
4. If you cannot get on a plate, go back to the starting line, and see if you can answer the next question more quickly.
5. Stay on your answer plate until the correct answer is given. Then return to the starting line for the next question.
6. No pushing or shoving is permitted. You are automatically out if this occurs.
7. The teacher is the final arbitrator, and whatever he or she says is not to be disputed.

5 The teacher should stand at the head of the starting line facing the students, and read questions and give answers from there. Remind them that those who do not find a plate return to the middle. Those who answered incorrectly are next to return to the middle line. Finally, everyone who correctly answered returns to the middle in preparation for the next question. Stress safety and respect for one another.

6 Play the game until all the questions have been answered. Afterwards, the class may want to discuss any questions that were difficult to answer, or ones to which they thought there would be more than one answer.

Geologic Pursuits

ACTIVITY PAGE

Conclusion

"Geologic Pursuits" is an active and fun way for the teacher and students to find out how much they know about a subject such as geology. With a few props and a little preparation, this activity may be used as a filler between other topics or projects, or it may be extended to cover an entire class period.

Ways to Adapt the Activity for Other Ages

This game can be played with any subject, from math to oceanography to spelling. It can also be used by a variety of age groups, with the subject matter appropriate to their classroom studies. Everyone enjoys the movement, and the similarity to the familiar parlor game of musical chairs. What is unique about "Geologic Pursuits" is it does not stress competition, but places the focus on each individual's achievement.

Extensions

A) A fun variation of "Geologic Pursuits" is to conduct it like the long-time favorite parlor game, "Musical Chairs". To do this, arrange students as before, on the starting line. The "T for True" and "F for False" plates should be in the same lines. The rules of "Geologic Pursuits" remain the same, with several changes.

First, while the game begins with enough plates for everyone to land on an answer, *with each question, one "T for True" plate and one "F for False" plate are removed*. As a result, students must choose an answer to a question as quickly as possible to assure that they reach a spot on a plate. If a student cannot find a vacant spot on a plate, he or she is out of the game, and must step to the sidelines.

Second, those with the wrong answer are also out of the game.

Third, the last two people remaining in the game have a run-off. Whoever reaches the plate with the correct answer first is the winner.

B) For older students, the accuracy of their answers can be tracked. Enlist one or two students to make a list of students in the class. As each question is answered, the "trackers" record those who answered incorrectly, or did not find an empty plate. Later, the class can make a bar graph, or other type of graph, to show how many answers each student knew.

Geologic Pursuits

ACTIVITY PAGE

Geologic Pursuits Question Sheet

Questions	Answers
1. Geology is the study of the solar system.	False
2. The Earth is made up of the atmosphere, the crust, the mantle, and the core.	True
3. As soon as a rock is exposed to the air it begins to grow.	False
4. Someone who makes maps of the Earth is known as a paleontologist.	False
5. Lava is a type of igneous rock.	True
6. Dinosaur bones are found in the Morrison Formation.	True
7. The outermost layer of the Earth is the mantle.	False
8. Mica is a shiny mineral that creates sparkles in some rocks.	True
9. Mudstones, siltstones, and sandstones are types of sedimentary rock.	True
10. Topographic maps are useful to help you get around in urban areas.	False
11. Stratigraphy is the study of rock layers.	True
12. The Laramide Orogeny took place in Laramie, Wyoming on 9/11/1875.	False
13. Colorado National Monument became part of the National Park Service in order to protect the large number of dinosaur bones discovered there.	False
14. Quartz is a mineral composed of tiny grains of salt.	False
15. Chinle, Wingate, and Kayenta are three rock formations found locally.	True
16. Metamorphic rocks contain many interesting fossils.	False
17. Freezing and thawing, tree roots, heating and cooling all contribute to the breakdown of rocks into smaller and smaller pieces.	True
18. A map legend is a story told by geologists about where to find gold.	False
19. Precambrian rock is the oldest rock known at Colorado National Monument.	True
20. Desert varnish is a white powdery crust occurring on some rocks.	False
21. Anticlines look like arches and synclines look like troughs.	True
22. The core of the Earth is estimated to be between 200 and 300 degrees F.	False
23. Uniformitarianism is a premise that things happening today on the Earth are different from things that happened in the past.	False
24. Igneous rock is formed by layers of rock building up on one another.	False
25. When you look down into a canyon, the oldest rocks are at the bottom.	True

Three Types of Rocks:
The True Origins of Rock and Roll

BACKGROUND FOR **TEACHERS**

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts	**Standard 4** Listening 4.01 4.05 4.06 4.08 Thinking 4.01 4.03 4.07 4.08 4.15 **Standard 5** Thinking 4.04 4.06 4.18	**Standard 4** Listening 5.02 5.03 5.05 5.06 5.08 Thinking 3-5.01 3-5.04 3-5.15 3-5.17	**Standard 4** 6.25 6.26	**Standard 4** 7.24 7.26 7.28	**Standard 4** 8.23 8.20
Math	**Standard 2** 4.2.1 4.2.3 **Standard 3** 4.3.1 4.3.2	**Standard 2** 5.2.1 5.2.2 5.2.3 **Standard 3** 5.3.1 5.3.3 5.3.4 5.3.5 5.3.6	**Standard 2** 2.1 2.3 **Standard** 3.3 3.4 3.5 3.6	**Standard 2** 2.1 2.3 **Standard 3** 3.3 3.4 3.5 3.6	**Standard 2** 2.1 2.3 **Standard 3** 3.3 3.4 3.5 3.6
Science	**Standard 1** 1.01 1.02 1.03 1.04 **Standard 2** 2.11 2.12 2.21 **Standard 4** 4.14 **Standard 6** 6.01 6.02 6.03 **Standard 7** 7.03	**Standard 1** 1.03 1.05 1.06 1.08 **Standard 2** 2.11 2.33 **Standard 6** 6.01 6.02 **Standard 7** 7.03 7.04	**Standard 1** 6.1.01 6.1.03 6.1.05 6.1.06 6.1.07 6.1.08 **Standard 2** 6.2.01 6.2.02 **Standard 4** 6.4.01 6.4.02 **Standard 7** 6.7.03 6.7.04	**Standard 1** 7.1.01 7.1.03 7.1.05 7.1.06 7.1.07 7.1.08 **Standard 2** 7.2.01 7.2.04 7.2.05 **Standard 7** 7.7.03 7.7.04	**Standard 1** 8.1.01 8.1.03 8.1.05 8.1.06 8.1.07 8.1.08 **Standard 2** 8.2.01 8.2.05 8.2.06 **Standard 7** 8.7.03 8.7.04

Make a Stratigraphic Column
of Colorado National Monument

BACKGROUND FOR **TEACHERS**

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts	**Standard 4** Reading Obj. 4.09 Listening Obj. 4.01 4.02 4.05 4.08 Thinking Obj. 4.01 4.03 4.07 4.08 4.21 **Standard 5** 4.06	**Standard 4** 5.02 5.05 5.08 5.06 **Standard 5** 5.23	**Standard 4** 6.3.04 6.2.05	**Standard 4** 7.2.04 7.2.06	**Standard 4** 8.17 8.23 8.35
Math	**Standard 2** 4.2.1 4.2.3 **Standard 3** 4.3.1 **Standard 4** 4.4.1a 4.4.2 4.4.3 4.4.5	**Standard 2** 5.2.1 5.2.3 **Standard 3** 5.3.1 5.3.5 **Standard 4** 5.4.1 5.4.2 **Standard 5** 5.5.2 5.5.3	**Standard 2** 6.2.1 6.2.3 **Standard 3** 6.3.1 6.3.5 **Standard 4** 6.4.1 6.4.2 **Standard 5** 6.5.2 6.5.3	**Standard 2** 7.2.1 7.2.3 **Standard 3** 7.3.1 7.3.5 **Standard 4** 7.4.1 **Standard 5** 7.5.2 7.5.3	**Standard 2** 8.2.3 **Standard 3** 8.3.1 8.3.5 **Standard 4** 8.4.1 8.4.2 **Standard 5** 8.5.2 8.5.3
Science	**Standard 1** 1.04 **Standard 2** 2.1 2.11 2.12 2.3 2.31 **Standard 3** 3.2 3.22 3.23 3.4 3.44 **Standard 4** 4.1 4.12 4.14 **Standard 7** 7.01 7.02 7.04 7.05	**Standard 1** 1.02 1.05 1.06 1.07 1.08 **Standard 2** 2.1 2.11 **Standard 4** 4.25 **Standard 7** 7.01 7.02 7.03 7.04 7.05	**Standard 1** 6.1.01 6.1.02 6.1.05 6.1.06 6.1.07 6.1.08 6.1.10 **Standard 2** 6.2.01 6.2.02 **Standard 4** 6.4.01 6.4.02 **Standard 7** 6.7.01 6.7.02 6.7.03 6.7.04 6.7.05	**Standard 1** 7.1.01 7.1.02 7.1.05 7.1.06 7.1.07 7.1.08 7.1.10 **Standard 2** 7.2.01 7.2.03 7.2.05 **Standard 4** 7.4.01 **Standard 7** 7.7.01 7.7.02 7.7.03 7.7.04 7.7.05	**Standard 1** 8.1.01 8.1.02 8.1.05 8.1.06 8.1.07 8.1.08 8.1.10 **Standard 2** 8.2.01 8.2.05 8.2.06 **Standard 3** 8.3.09 **Standard 4** 8.4.01 8.4.02 **Standard 7** 8.7.01 8.7.02 8.7.03 8.7.04 8.7.05

Make a Stratigraphic Column
of Colorado National Monument

BACKGROUND FOR **TEACHERS**

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Social Studies	**Geography** **Standard 1** 4.40 **Standard 2** 4.45 4.50 4.51	**Geography** **Standard 4** 5.18 5.38	**Geography** **Standard 1** 6.19 **Standard 4** 6.35 6.36	**Geography** **Standard 1** 7.23 7.24 7.27 7.28 **Standard 2** 7.35 **Standard 4** 7.59 7.60 7.62 7.63	**Geography** **Standard 1** 8.11 8.12 8.15 **Standard 2** 8.18 8.19 **Standard 4** 8.40 8.41
Art	**Standard 1** **Standard 2**	**Standard 1** **Standard 2**	**Standard 1** Art .01 Art .02 **Standard 2** Art .04 Art .09 Art .11	**Standard 1** Art .01 Art .02 **Standard 2** Art .04 Art .09 Art .11	**Standard 1** Art .01 Art .02 **Standard 2** Art .04 Art .09 Art .11

Stratigraphy Up and Down Hike

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts	**Standard 1** Writing Obj. 4.01 4.05 4.08 4.12 4.07 Thinking Obj. 4.02 4.06 4.07 **Standard 3** Reading Obj. 4.03 4.04 4.05 4.06 4.09 4.10 4.11 4.21 **Standard 4** Writing Obj. 4.09 4.10 4.11 Listening Obj. 4.01 4.02 4.05 4.08 Thinking Obj. 4.01 4.03 4.15 4.16 4.21 4.07 4.08	**Standard 1** Writing Obj. 5.01 5.05 5.07 **Standard 3** 5.05 5.06 5.12 **Standard 4** Listening Obj. 5.02 5.05 5.08 5.10 Thinking Obj. 3-5.01 3-5.04 3-5.05 **Standard 5** 5.23	**Standard 4** 6.01 6.06 6.20 6.22 6.25 6.27 6.34	**Standard 4** 7.01 7.08 7.19 7.22 7.24 7.26 7.27 7.28 7.35	**Standard 4** 8.01 8.02 8.14 8.17 8.23
Math	**Standard 1** 4.1.3 **Standard 2** 4.2.1 4.2.2 4.23 **Standard 3** 4.3.1 4.3.2 4.4.5	**Standard 2** 5.2.1 5.2.3 **Standard 3** 5..3.1 5.3.4 5.3.5 5.3.6 5.3.7 **Standard 5** 5.2	**Standard 2** 2.1 2.3 **Standard 3** 3.1 3.4 3.5 3.6 3.7 **Standard 5** 5.2 5.3	**Standard 2** 2.1 2.3 **Standard 3** 3.1 3.4 3.5 3.6 3.7 **Standard 5** 5.2 5.3	**Standard 3** 3.1 3.3 3.4 3.5 3.6 3.7 **Standard 5** 5.2 5.3

Stratigraphy Up and Down Hike

BACKGROUND FOR **TEACHERS**

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Science	**Standard 1** 1.01 1.02 1.03 1.04 **Standard 2** 2.1 2.11 2.12 **Standard 4** 4.1 4.12 4.14 4.15 **Standard 5** 5.01 5.05 **Standard 6** 6.03 **Standard 7** 7.02 7.03 7.04 7.05	**Standard 1** 1.02 1.03 1.05 1.06 1.07 1.08 **Standard 2** 2.1 2.11 **Standard 3** 3.24 3.43 **Standard 6** 6.02 **Standard 7** 7.02 7.03 7.05 7.06	**Standard 1** 6.1.02 6.1.03 6.1.04 6.1.05 6.1.06 6.1.07 6.1.08 **Standard 2** 2.1 6.2.01 6.2.02 2.3 6.2.04 **Standard 3** 3.2 6.3.01 6.3.02 **Standard 4** 4.1 6.4.01 6.4.02 **Standard 6** 6.6.01 **Standard 7** 6.7.03 6.7.05 6.7.06	**Standard 1** 7.1.02 7.1.03 7.1.05 7.1.06 7.1.07 7.1.08 **Standard 2** 2.1 7.2.01 7.2.02 7.2.03 7.2.05 **Standard 4** 4.2 7.4.02 **Standard 6** 7.6.02 **Standard 7** 7.7.02 7.7.03 7.7.05 7.7.06	**Standard 1** 8.1.02 8.1.03 8.1.05 8.1.06 8.1.07 8.1.08 **Standard 2** 2.1 8.2.01 8.2.02 2.3 8.2.05 8.2.06 **Standard 3** 3.4 8.3.09 8.3.10 **Standard 4** 4.1 8.4.01 8.4.02 4.2 8.4.03 **Standard 7** 8.7.02 8.7.03 8.7.05 8.7.06
Social Studies	**Geography** **Standard 1** **Standard 2** 4.45 4.49	**Geography** **Standard 1** 5.18 **Standard 4** 5.18 5.38	**Geography** **Standard 2** 6.21 6.22 6.23 6.24 **Standard 4** 6.35 6.36 6.37 6.38 6.39	**Geography** **Standard 1** 7.24 7.25 7.26 7.28 **Standard 2** 7.35 7.36 7.37 7.38 **Standard 4** 7.59 7.60 7.62 7.63	**Geography** **Standard 1** 8.11 8.12 8.13 8.14 8.15 **Standard 2** 8.18 8.19 **Standard 4** 8.40 8.43
Art	**Standard 1**	**Standard 1**	**Standard 1** Art .01 **Standard 2** Art .04 Art .09 Art .11 **Standard 3** Art .12 Art .14	**Standard 1** Art .01 **Standard 2** Art .04 Art .09 Art .11 **Standard 3** Art .12 Art .14 Art .17	**Standard 1** Art .01 **Standard 2** Art .04 Art .09 Art .11 **Standard 3** Art .12 Art .14 Art .17

Erosion Hike

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts	**Standard 1** Writing Obj. 4.05 4.07 4.08 4.12 Thinking Obj. 4.06 4.07 **Standard 3** 4.21 **Standard 4** Listening Obj. 4.01 4.02 4.05 4.08 Thinking Obj. Obj. 4.01 4.03 4.14 4.15 4.20	**Standard 1** Writing Obj. 5.07 **Standard 3** 5.05 5.06 **Standard 4** 5.11 Listening Obj. 5.02 5.05 5.08 Thinking Obj. 3-5.01 3-5.04 3-5.15 **Standard 5** 5.01 5.23	**Standard 1** 6.32 6.37 **Standard 2** 6.18 **Standard 4** 6.01 6.06 6.20 6.22 6.25 6.27 6.34 6.37	**Standard 4** 7.01 7.08 7.19 7.21 7.22 7.24 7.26	**Standard 4** 8.01 8.02 8.14 8.17 8.20 8.23 **Standard 5** 8.33
Math	**Standard 1** 4.13 **Standard 2** 4.2.1 4.2.3 **Standard 3** 4.3.1 4.3.2 **Standard 4** 4.4.5 **Standard 5** 4.5.2 4.5.3a 4.5.3.b	**Standard 2** 5.2.1 5.2.3 **Standard 3** 5.3.1 5.3.3 5.3.4 5.3.5 5.3.6 5.3.7 **Standard 5** 5.5.1 5.5.2 5.5.3	**Standard 2** 6.2.1 6.2.2 **Standard 3** 6.3.1 6.3.3 6.3.4 6.3.5 6.3.6 6.3.7 **Standard 5** 6.5.1 6.5.2 6.5.3	**Standard 2** 7.2.1 **Standard 3** 7.3.1 7.3.3 7.3.4 7.3.5 7.3.6 7.3.7 **Standard 5** 7.5.2 **Standard 6** 7.6.3	**Standard 2** 8.2.1 **Standard 3** 8.3.1 8.3.3 8.3.4 8.3.5 8.3.6 8.3.7 **Standard 5** 8.5.2 **Standard 6** 8.6.3
Science	**Standard 1** 1.01 1.02 1.03 1.04 **Standard 2** 2.11 2.12 **Standard 3** 3.14	**Standard 1** 1.02 1.03 1.05 1.06 1.07 1.08 **Standard 2** 2.11 2.33	**Standard 1** 6.1.02 6.1.03 6.1.05 6.1.06 6.1.07 6.1.08 **Standard 2** 6.2.01 6.2.04	**Standard 1** 7.1.02 7.1.03 7.1.05 7.1.06 7.1.07 7.1.08 **Standard 2** 7.2.01 7.2.02	**Standard 1** 8.1.02 8.1.03 8.1.05 8.1.06 8.1.07 8.1.08 **Standard 2** 8.2.01 8.2.02

Erosion Hike

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Science (cont.)	**Standard 4** 4.12 4.14 4.15 4.22 4.31 **Standard 7** 7.01 7.02 7.04	**Standard 4** 4.25 **Standard 7** 7.01 7.02 7.03 7.05	**Standard 3** 6.3.01 6.3.02 **Standard 4** 6.4.01 6.4.02 6.4.07 **Standard 7** 6.7.01 6.7.02 6.7.03 6.7.05	**Standard 2** (cont.) 7.2.05 **Standard 4** 7.4.01 **Standard 7** 7.7.01 7.7.02 7.703 7.7.05	**Standard 2** (cont.) 8.2.03 8.2.05 8.2.06 8.2.07 8.2.08 **Standard 4** 8.4.01 8.4.02 8.4.03 **Standard 7** 8.7.01 8.7.02 8.7.03 8.7.05
Social Studies	**Geography** **Standard 2** 4.45 **Standard 4** 4.63 4.64 4.65 4.67	**Geography** **Standard 1** 5.18 **Standard 3** 5.05 **Standard 4** 5.18 5.38	**Geography** **Standard 4** 6.35 6.36 6.38	**Geography** **Standard 1** 7.33 **Standard 2** 7.35 7.36 **Standard 4** 7.59 7.60 7.62 7.63 7.66	**Geography** **Standard 1** 8.16 **Standard 2** 8.18 8.19 **Standard 4** 8.40 8.41 8.43

Mapmaker, Mapmaker, Make Me a Map

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts	**Standard 1** Reference Obj. 4.26 Thinking Obj. 4.06 4.07 **Standard 3** 4.01 4.04 4.05 4.06 4.21 **Standard 4** Listening Obj. 4.01 4.02 4.05 4.08 Thinking Obj. 4.01 4.08 4.16 4.21 **Standard 5** 4.11	**Standard 3** 5.05 5.06 **Standard 4** Listening Obj. 5.02 5.08 Thinking Obj. 3-5.01 3-5.04 **Standard 5** Reading Obj. 5.01 5.23 5.06 5.07 Reference Obj. 5.23	**Standard 4** 6.01 6.06 6.20 6.25 6.34	**Standard 1** 7.43 **Standard 4** 7.01 7.08 7.19 7.22 7.24	**Standard 4** 8.01 8.02 8.14 8.23
Math	**Standard 1** 4.1.3 **Standard 4** 4.4.1a 4.4.2 4.4.5 **Standard 5** 4.5.1 4.5.2 4.5.3a 4.5.3b	**Standard 2** 5.2.1 5.2.3 **Standard 4** 5.4.1 5.4.2 **Standard 5** 5.5.1 5.5.2 5.5.3 5.5.6	**Standard 2** 6.2.1 6.2.3 **Standard 4** 6.4.1 6.4.2 **Standard 5** 6.5.1 6.5.2 6.5.3 6.5.6	**Standard 2** 7.2.1 7.2.3 **Standard 4** 7.4.1 7.4.2 **Standard 5** 7.5.1 7.5.2 7.5.3 7.5.6	**Standard 2** 8.2.3 **Standard 4** 8.4.1 8.4.2 8.4.4 **Standard 5** 8.5.1 8.5.2 8.5.3 8.5.6
Science	**Standard 1** 1.02 1.03 1.04 **Standard 2** 2.11 2.12 **Standard 6** 6.01 6.02 6.03 **Standard 7** 7.03 7.04	**Standard 1** 1.03 1.05 1.06 1.07 **Standard 2** 2.11 **Standard 7** 7.04 7.05	**Standard 1** 6.1.03 6.1.05 6.1.06 6.1.07 **Standard 2** 6.2.11 **Standard 7** 6.7.04 6.7.05	**Standard 1** 7.1.03 7.1.05 7.1.06 7.1.07 **Standard 2** 7.2.11 **Standard 7** 7.7.03 7.7.04	**Standard 1** 8.1.03 8.1.05 8.1.06 8.1.07 **Standard 2** 8.2.11 **Standard 7** 8.7.03 8.7.04

Mapmaker, Mapmaker, Make Me a Map

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Social Studies	**Geography** **Standard 1** 4.39 4.40 **Standard 2** 4.49 4.50 **Standard 4** 4.65 4.67	**Geography** **Standard 1** 5.18 **Standard 4** 5.18 5.38	**Geography** **Standard 1** 6.16 6.19 **Standard 2** 6.21 **Standard 4** 6.35 6.36 6.38	**Geography** **Standard 1** 7.23 7.24 7.25 7.26 7.27 7.28 7.30 **Standard 2** 7.35 7.36 **Standard 4** 7.59 7.60 7.62 7.63	**Geography** **Standard 1** 8.11 8.12 8.14 8.15 8.16 **Standard 2** 8.18 8.19 **Standard 4** 8.40 8.41 8.43
Art	**Standard 1**	**Standard 1**	**Standard 1** Art .01 **Standard 2** Art .04 Art .09 Art .10 Art .11 **Standard 3** Art .12 Art .13 Art .14 **Standard 4** Art .23	**Standard 1** Art .01 **Standard 2** Art .04 Art .09 Art .10 Art .11 **Standard 3** Art .12 Art .13 Art .14 **Standard 4** Art .23	**Standard 1** Art .01 **Standard 2** Art .04 Art .09 Art .10 Art .11 **Standard 3** Art .12 Art .13 Art .14 **Standard 4** Art .23

Let's Get Oriented

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts		**Standard 1** Reading Obj. 5.13 Thinking Obj. 3-5-18 **Standard 3** 5.05 5.06 5.09 5.11 5.12 **Standard 4** Reading Obj. 5.11 Listening Obj. 5.02 5.08 Thinking Obj. 3-5.01 3-5.04 3-5.17 **Standard 5** 5.06 5.23	**Standard 1** 6.20 6.22 6.25 **Standard 3** 6.01 6.05 **Standard 4** 6.06 6.20 6.22 6.25 6.34	**Standard 2** 7.19 7.23 **Standard 4** 7.01 7.08 7.22 7.24 7.26 7.38 **Standard 5** 7.39	**Standard 4** 8.01 8.02 8.14 8.17 8.20 8.23 8.35 **Standard 5** 8.33
Math		**Standard 2** 5.2.1 **Standard 3** 5.3.1 5.3.3 5.3.4 5.3.7 **Standard 5** 5.5.1 5.5.2 5.5.3 5.5.4	**Standard 2** 6.2.1 **Standard 3** 6.3.1 6.3.3 6.3.6 6.3.7 **Standard 5** 6.5.1 6.5.2 6.5.3 6.5.4	**Standard 2** 7.2.1 **Standard 3** 7.3.1 7.3.3 7.3.6 7.3.7 **Standard 5** 6.5.1 6.5.2 6.5.3 6.5.4	**Standard 2** 8.2.1 **Standard 3** 8.3.1 8.3.3 8.3.6 8.3.7 **Standard 5** 8.5.1 8.5.2 8.5.3 8.5.4
Science		**Standard 1** 1.03 1.05 1.06 1.07 1.08 1.12 **Standard 2** 2.11 **Standard 5** 5.04 **Standard 7** 7.05	**Standard 1** 6.1.03 6.10.5 6.1.06 6.1.07 6.1.08 6.1.12 **Standard 2** 6.2.11 **Standard 5** 6.5.03 **Standard 7** 6.7.05	**Standard 1** 7.1.03 7.1.05 7.1.06 7.1.07 7.1.08 7.1.12 **Standard 2** 7.2.11 **Standard 5** 7.5.03 **Standard 7** 7.7.05	**Standard 1** 8.1.03 8.1.05 8.1.06 8.1.07 8.1.08 8.1.12 **Standard 2** 8.2.11 **Standard 5** 8.5.03 **Standard 7** 8.7.05

Let's Get Oriented

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Social Studies			**Geography** **Standard 1** 6.16 6.19 **Standard 2** 6.21	**Geography** **Standard 1** 7.23 7.24 7.25 7.27 7.28 7.30 7.33 **Standard 2** 7.35 **Standard 4** 7.59 7.60 7.62	**Geography** **Standard 1** 8.11 8.12 8.15 8.16 **Standard 2** 8.18 8.19 **Standard 4** 8.40 8.41 8.43

Geologic Pursuits

CONTENT STANDARDS	4th Grade	5th Grade	6th Grade	7th Grade	8th Grade
Language Arts	**Standard 4** Listening Obj. 4.01 4.02 4.05 4.08 Thinking Obj. 4.07 4.13 4.14 4.15	**Standard 4** Listening Obj. 5.02 5.06 5.08 5.09	**Standard 4** 6.25 6.35	**Standard 4** 7.22 7.24	**Standard 4** 8.23
Math					
Science	**Standard 2** 2.1 2.11 2.12 2.2 2.21 **Standard 4** 4.1 4.12 4.14	**Standard 1** 1.06 1.08 **Standard 2** 2.1 2.11	**Standard 1** 6.1.06 6.1.08 **Standard 2** 2.11 **Standard 4** 6.4.01 6.4.02	**Standard 1** 7.1.06 7.1.08 **Standard 2** 7.2.01	**Standard 1** 8.1.06 8.1.08 **Standard 2** 8.2.01 **Standard 3** 8.3.09 **Standard 4** 8.4.01 8.4.02

Depending on the questions that the teacher chooses, this activity can be adapted to meet many other content standards. "Geologic Pursuits" works well for subjects like a quiz on spelling or vocabulary, a review of historical figures or events, an investigation of food chains, or test of math facts.

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Geology

Key References

The written and verbal comments of Dr. Bill Hood, Professor of Geology at Mesa State College have been of immeasurable assistance in the development of this chapter. Dr. Hood was generous with his time and his vast knowledge, for which the author is grateful.

Contact or visit the Colorado National Monument Association bookstore for availability of these titles.

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