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Figure 17. Trail map at Stop 2 showing places of geologic interest and are keyed to the descriptions and pictures shown on the accompanying table.

and

The Many Faces of Delaware Water Gap

The Many Faces of Delaware Water Gap
A Curriculum Guide for Grades 3-6

An integrated guide to the geology of
Delaware Water Gap National Recreation Area developed by:

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Thank you, all of you, for your help!
Dear Teacher

We hope that you and your students enjoy exploring the geology of Delaware Water Gap National Recreation Area as much as we did. Before you begin your adventure, we’d like to share some important information with you - information that can make the journey more enjoyable and rewarding for you and for those who come after you.

First, when we created these materials, we also created trunks that contain equipment, materials, and sample projects for many of the activities. If you are teaching in one of the following places, you can borrow a trunk by contacting your school district’s science coordinator: Bangor School District, Blairstown Elementary, Delaware Valley School District, East Stroudsburg School District, Knowlton Township Elementary, Montague Elementary, Pocono Mountain School District, Sandyston-Walpack Consolidated Elementary, Stillwater Elementary and Stroudsburg School District. If you are not associated with one of these school districts, trunks can also be borrowed directly from the park. To borrow a trunk from the park, call 570-588-2451.

If you are interested in having a ranger lead the activities, you may be able to arrange for one to come to your classroom or meet your class at the field site that you have chosen. To do so, call the park at 570-588-2451. If a ranger is not available or if you would prefer to teach the activities yourself, you can certainly do so. In writing these materials, we have made every effort to include enough background information to answer your questions about geology in general and about the park sites in particular.

When preparing for your fieldtrip and while visiting the park, please keep safety in mind. Anytime you take a class out in the field, there is a certain element of risk involved. You should familiarize your students with poison ivy so they can avoid it while exploring the park. Also, you should read up on Ticks and Mosquitos and the diseases that they could potentially carry and should take precautions to minimize the risk to you and your class. Additionally, please visit the sites yourself before you visit the park with your students. Some sites are rocky, have ledges or are near water. It is your responsibility, as the teacher to scout out the sites ahead of time and consider site safety with
your class' behavior in mind. Some sites that are appropriate for a responsive, well-behaved class may not be appropriate if your class includes a few difficult students. Make sure you have visited each site ahead of time and have a plan for how you will manage your class to provide a safe and educational visit. If you are unable to visit the park ahead of time, you may want to choose an easier site like Dingmans Falls or Point of Gap overlook.

Finally, after visiting the park, please let us know how your visit went and how many participants you had. Although this may seem like a hassle, it is a very important step. Parks competing for funding to develop materials such as these must justify the expense based in part on the number of people using the materials. If you would like to see similar materials developed for different topics, or if you have suggestions that would improve the program prior to being reprinted, please provide us with this information as well. You can provide usage statistics or suggestions by calling the park (570-588-2451) or send them to: Education Coordinator; Delaware Water Gap National Recreation Area; Bushkill, PA 18324.

Thanks! We hope you enjoy your adventure.
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Preface

Geology is a topic that many students, both children and adults, find confusing. And because they do not see how geology relates to their own personal situation, they also find it dull. Yet beneath their feet are stories hidden in the rocks. If these rocks could speak, they would tell of dramas that have unfolded. Of colliding continents, of oceans come and gone, of inhabitants that are no more, of mountains of ice that scraped away the evidence of time gone by. These rocks have seen much. They have controlled the fate of the Delaware Valley and have passively influenced everything from the local environment to human history and economics.

To engage students in the study of geology, we must teach them the basics, but we must also help them to understand how the rocks that they see relate to more intangible ideas. We must help them to discover clues to the ancient past. We must encourage them to explore how local geology controls the distribution of plants and animals, through its influence on soil types, precipitation, and temperature. We must engage them in inquiry about how the landscape has controlled human settlement, keeping folks out of hard to reach places or luring them in for valuable natural resources. We must facilitate an understanding of how geology is tied to our freedom, having changed the pathways and outcomes of wars.

Delaware Water Gap National Recreation Area is an outdoor classroom waiting to be discovered. Hidden in the ridges and valleys of the park, the patient explorer can find a seemingly endless array of animals and plants, each living in a microhabitat controlled by the rocks. The plant and animal communities range from aquatic river communities to cactus barrens, providing myriad opportunities for students to study biological and geological concepts and the inter-relationships between the two.

Along the riverbank, fields of crops remind visitors of the tradition of agriculture in the valley and preserve the historic landscape. Stonewalls, foundations and historic buildings hint at the story of early European settlers. These settlers traveled into the area along the river's flat floodplain, following trails that had been used by Native Americans for hundreds or even thousands of years. Both the settlers, and the Lenape who preceded them,
settled where fertile floodplain soil made agriculture productive and used local materials to build their homes and outbuildings. Indeed, the region's geologic past directly controlled their patterns of settlement.

Drill core holes hidden in the rocks and hundreds of vacated buildings hint at the park's contentious beginning. In 1955, a flood in the valley catalyzed the federal government to plan a dam on the Delaware River. The project was controversial for many reasons, not the least of which was the taking of 70,000 acres of privately owned land through the right of eminent domain. While a variety of factors were involved, the instability of the glacial till beneath the proposed dam site and the possibility of a landslide were major factors in the demise of the dam and the eventual formation of a National Recreation Area.

Today, the Poconos is a major destination (as it has been since the early 1800s), attracting visitors with hundreds of waterfalls, heart-shaped lakes, and the famous Delaware Water Gap. Though transportation has changed from carriage, to train, to automobile, the scenic river valley continues to inspire its guests. It is a landscape shaped by glaciers, a mountain shaped by time, an economy shaped by geology.

Through hand-on exploration of local rocks, ecosystems, and remnants of local history, we offer students the opportunity to connect to the resource in a meaningful way, providing access for them to better understand their heritage and helping them to answer the question "Why should I care?" These experiences can help to illuminate the interactive relationship between the landscape and its inhabitants and can excite students about the study of geology, provoking a life-long love of learning.

Teachers, geologists, and National Park Service staff worked in partnership to develop these materials. It is our hope that this curriculum will make it easier for students to understand geology and recognize the significance of the geologic story preserved in our National Parks. It is our belief that a visit to the park, for a personal encounter with the local geology, will help students to internalize the materials studied in class and will inspire curiosity about the role of geology in their lives and those of their ancestors. We hope these materials make it easier for you to use park resources to teach geology.
Rocks and Minerals

How soil forms, how the landscape is shaped and where the river flows... all are determined by rocks, or rather by the minerals of which they are made. There are thousands of different minerals that can combine to form rocks; however, the vast majority of the Earth's rocks are made up of just a handful of common minerals. The type and proportion of each mineral determines the kind of rock, just like the type and proportion of ingredients in a recipe determine whether the outcome is a cheese pizza or a chocolate chip cookie. Yet defining precisely what a mineral is can be tricky. Let's take a look at a few characteristics that all minerals have in common.

What is a mineral?
Minerals are inorganic. Organisms use, and may even concentrate minerals. For example, clams use Calcium Carbonate to build the shells that protect them from rough waves and hungry predators. However, animals and plants do not make minerals. The clam does not make Calcium Carbonate; it filters it out of the water and uses it to build a shell.

Minerals are homogenous; they are the same throughout. Think about what happens when you make a cake. When you start, you have eggs, flour, sugar, butter and of course cocoa powder. You mix them all together, but there are still lumps of butter with sugar stuck on them and pockets of flour that aren't mixed into the batter. This is not homogenous. However, after you bake the cake, you have a homogenous solid (unless you added walnuts or raisins); it is cake throughout. Now think about rocks in the same way. Some rocks are homogenous, for example, silver. When you look at a lump of silver, no matter how closely, all you will see is silver atoms. Even if you could shrink yourself down and crawl around between the atoms, all you would find is silver. Silver is a mineral. Sandstone, in contrast, is not a mineral. It is composed of tiny particles cemented together by silica, calcite, iron ore or quartz. If you were to look closely at a piece of sandstone, you would find tiny grains of "sand" - largely quartz particles, but also small amounts of magnetite, feldspar, garnet or other minerals. You might even find a fossil or a pebble of a different kind of rock cemented into the rock. Sandstone is not homogenous; and, it is not a mineral. Minerals may be elements, having only one ingredient, or they
may be **compounds**. If the mineral is an element, it is made up only of one kind of atoms. For example, gold atoms bound to other gold atoms. If the mineral is a compound (for example, calcium carbonate, also known as chalk), then it is made up of atoms of different elements (calcium, carbon and oxygen). Either way, the atoms are bound together into molecules, not floating around independently. And, the mineral contains only one type of molecule, making it homogenous.

In most minerals, the atoms are arranged in a pattern that fits the most molecules into the smallest space. This pattern is called a **crystalline** structure. Different kinds of molecules have different shapes and different forces pushing them apart and pulling them together. As a result, the most efficient packing structure is different for different molecules. To illustrate this more clearly, think about what happens when you put marbles in a box; they pack most tightly if each marble sits down in the crevice between four other marbles. If, however, you were packing sugar cubes instead of marbles, a different packing structure, one that packs the cubes tightly side-by-side, would be more efficient.

While crystalline structure is something that happens at the level of an atom and cannot be seen without high-tech equipment, it expresses itself in the growth of **crystals**. Under ideal circumstances, with plenty of room in which to grow, a mineral will grow a crystal that has a characteristic shape. For example, opal crystals are said to be amorphous, they are shaped like knobby drops of dried glue, while diamond crystals are cubic in shape. (But be careful, with crystals, cubic doesn’t necessarily mean that it is shaped like a sugar cube). Unfortunately for us, ideal crystal growing conditions are rare. Often, crystals grow squeezed into a tight spot or several crystals start in the same location. Crystals that grow in confined spaces often have an imperfect shape that is constrained by the space in which they grew. Generally, a crystal’s growth is determined by a combination of time, temperature and pressure. Changing any of these factors can change the crystal that forms or even whether a crystal forms. For example, compressed carbon may form into rock (coal), but carbon can also form crystals. When carbon crystals grow under moderate pressure they form graphite, a soft black mineral that is used instead of lead in modern day pencils. In contrast, when carbon crystals grow under high pressure they are known as diamonds, which of course are valuable gemstones as well as important industrial abrasives and drill tips.
Properties of Minerals

Now that we know what a mineral is and that there are over two thousand different minerals, how do we tell them apart? Minerals have several characteristics that are useful in determining their identity. Characteristics of minerals include:

Color is the color that you see when you look at a hunk of mineral. Pigments in the rock may cause the color or it may be caused by impurities that disrupt the crystalline structure. Because structural colors are dependent on the reflection of light, they are variable. Consequently, color is not always a useful way to identify a mineral.

Streak is the color of the mineral powder and it is more consistent than “color.” You can see the streak of a mineral, by rubbing it on unglazed porcelain, by scratching the mineral with a knife or by crushing it.

Luster is the appearance of the mineral in ordinary (i.e. not black) light. Generally, luster is described as being either metallic or non-metallic. Some non-metallic lusters include brilliant (like a jewel), vitreous (shiny, like water or glass), pearly (like an opal), greasy, silky, resinous (waxy) or dull (like chalk).

Cleavage is a characteristic way that the mineral breaks. Some minerals have only a single cleavage plane; others have two or more. If a mineral has multiple planes, it may be important to know the angles of the different planes relative to one another. How many planes and whether they are smooth is directly dependent on the crystalline structure.

Hardness is a measure of how resistant the mineral is to being scratched. Generally, if a mineral can scratch another mineral, it is considered to be harder than that second mineral. Scales, such as Moh’s scale, rank the hardness of minerals. On Moh’s scale, hardness ratings of 5 or below indicate that the mineral could be scratched with a knife. Minerals rating 2.5 or below could be scratched with a fingernail. Hardness of minerals, and of the rocks they form, is a very important factor influencing the shape of the landscape. Hard rocks are more resistant to erosion, while softer rocks are more easily worn away. Often, mountains are made up of “harder” rocks, while river valleys are carved out of softer rocks.
Specific Gravity is a measure of the density of a mineral. It is determined using a ratio of the weight of the mineral to the weight of an equal volume of water.

Tenacity describes whether the mineral is brittle, malleable (can be shaped by pounding), sectile (can be cut like cheese), flexible (bends and stays bent), or elastic (bends and springs back into its original shape).

What is a rock?
We've all seen rocks - big rocks along the highway, small rocks in parking lots, smooth rocks on the bottoms of rivers, but what exactly is a rock? A rock is a mixture of different minerals. Different rocks have different amounts of different minerals. The minerals that are present and their abundance relative to one another determines the rock’s properties and identity. Some rocks contain just one mineral; most are made of several minerals, but usually a single rock does not contain more than a few.

How do rocks form?
There are three types of rocks - Igneous, Sedimentary and Metamorphic; which are distinguished by how they are formed.

Igneous rocks are formed from hot melted rock (magma) that cools and solidifies. Magma usually contains several minerals, which may form into crystals when the magma cools or may escape as gases. The type of igneous rock that forms when the magma cools depends on the minerals present and the rate at which the molten rock cools. Igneous rocks that form underground (intrusive) generally cool slowly and, because of the extended time, large crystals are formed. In contrast, lava that erupts or oozes out above ground (extrusive) tends to cool quickly and forms very small crystals. An extreme example is obsidian, which cools so fast that it looks like dark tinted glass. Igneous rocks are not found in the park, except in tombstones and building materials that people brought in from elsewhere.

Sedimentary rocks are formed as a result of the weathering and erosion of previously existing rocks. As older rocks break down, the rock particles are carried by wind or water and eventually deposited in a calm, wind-sheltered depression or at the bottom of a body of water. Along with the rock particles, organic
material may be deposited as sediment. Sediments tend to settle in layers one on top of the other, often sorting out according to particle size. As a result, sedimentary rocks often have distinct layers (bedding planes) that are caused by differences in the material deposited or the rate of deposition. Over time, these layers of sediment may develop into rocks.

Lithification is the process through which a heap of fragments is changed into a rock. First, the fragments must be buried until the weight of the layers on top compress it, squeezing the fragments into one another and squeezing out the air. Then, water seeping through the pores deposits minerals into the spaces, forming a natural cement. Or, the ground water may cause mineral crystals to be formed using the minerals in the fragments themselves. Eventually, the cement fills in the spaces between the particles or the growing crystals interlock holding the rock together. If you have well water, you may be familiar with the residues that form in your pipes or on your dishes. These are the types of mineral deposits that eventually build up and hold a rock together.

The third type of rock is metamorphic rock. A metamorphic rock is a previously existing rock (sedimentary, igneous, or even metamorphic) that has been heated or squeezed until its minerals have rearranged to form a different kind of rock. The new rock is typically denser and more compact than the original rock. Most metamorphic rocks are formed during times of mountain building because at these times the movement of plates causes tremendous heat and pressure, which squashes the sorted layers and squeezes out the water. The heat source could be pressure in the rock or could be magma beneath the rock. However, it is important to remember that metamorphic rocks are at no point heated hot enough to melt; if they did they would be igneous rocks.

**What kinds of rocks are found locally?**

In Delaware Water Gap National Recreation Area, most of the rocks are sedimentary rocks. Sedimentary rocks often form in an aquatic environment such as a river, lake or ocean. Often these rocks have features that teach us about the environment in which they formed. For example, they may show ripple marks - in essence these are fossil ripples, though they aren't considered to be fossils because they are not caused by a living organism. Likewise, the type of rock tells us about the environment. Shales
have very fine particles and are indicative of a muddy environment, whereas sandstone has larger particles and suggests a more dynamic environment where fine particles either do not exist or are not deposited.

Rocks are classified based on their mineral content, the relative proportions of the different minerals and the grain size. The classification of a metamorphic rock depends on what type of rock it was before it was metamorphosed.

Fossils (Secrets in the Rocks)

Fossils are clues to the past hidden within the rocks. They tell us of creatures that once lived on Earth, record the history of evolution and teach us about the past environment. They allow us to track dinosaurs that walked 70 million years ago and learn about their habits. They help us to use our imaginations to transport us to a different time. And yet, they do not tell the whole story.

A fossil is...

A fossil is evidence of a prehistoric organism that is preserved in the rock. The fossil may take the shape of the organism, or of a piece of the organism, or it may preserve some evidence of an organism’s movement - a track in the mud, a burrow in the ground, the crescent path of a blade of grass blown by the wind.

A fossil may preserve an entire organism unchanged, as when an insect becomes trapped in sap that later hardens into amber. Or it may preserve a trace of an organism’s original tissue, as when the carbon in a leaf leaves a black imprint on a rock.

A fossil may preserve a replica of an organism (partial or entire) that was buried in sediments that later became rock. Sometimes the replica is so exact that even the cellular structure of the original organism is preserved (petrification). In other cases, the fossil may be less exact.

A fossil may record the shape of the preserved piece as a mold or a cast. A mold is a rock cavity that records where an organism once was. When a mold forms, the water moving through the rock eventually removes the original material, but does not replace it with minerals as it is dissolved away (or it replaces it
with minerals that are themselves later eroded away). You can imagine how you might model a mold, by sticking an acorn into wet cement. After the cement dried, you could remove the acorn and see only a mold of the nut. A cast is a mold that later fills with dissolved minerals or other sediments, which then harden into a rock of their own. You can imagine how you might fill the acorn mold with play-doh® and then pull it out to reveal a cast of your “fossil” acorn.

Or, a fossil may preserve evidence of an organism’s activity. Studying past life using trace fossils is like studying current wildlife by the tracks, scat and markings that they leave behind. Trace fossils include fossilized footprints, scat, burrows and feeding trails (for example, today’s deer path could be a fossil in the future). What kinds of clues do you and your students leave behind that could be a trace fossil in the future?

**How fossils form**

Fossils are formed under very special circumstances. Generally, when a plant or an animal dies, it falls to the ground or, if it is in water, it settles to the bottom. Once there, it may be pulled apart by scavengers or broken down by bacteria. If it is buried (or covered) before it is eaten or decays, it has the potential to become a fossil; even then, a fossil is not guaranteed. Once an organism is buried, it must be undisturbed throughout the long process of becoming a fossil. It cannot be uncovered and exposed to decay or crushed by pressures within the rock.

Very few organisms that die are preserved as fossils. It is estimated that only one in a million organisms is buried before natural processes destroy it (Haskins, 1999). And of these, only a tiny portion end up becoming fossils. It is important to remember that not all sediments end up forming into rocks. Often, sediment is deposited, then is later picked up and transported elsewhere and re-deposited. And when sediments do form into rocks, they are not preserved indefinitely. Processes such as erosion and weathering break down rocks into new particles and in the process the information stored in the rock is destroyed. When natural (or unnatural) processes break down a rock that contains fossils, the fossils may be lost or broken down into sediments too.
Where fossils are formed

Fossils are most often found in sedimentary rocks, and if you think for a moment about the three types of rocks, it will be obvious why this is the case. Igneous rocks are formed from magma that either erupts at the surface as lava or stays trapped underground, cooling and hardening into rock. It is rare to find fossils in igneous rocks because the high temperatures associated with molten rock destroy most evidence of life. Animals or plants that are covered in lava are in most cases burnt into ash and thus are not preserved as fossils.

Metamorphic rocks are those that were subject to extreme temperatures and/or pressures. A plant or animal that has been squeezed under pressures capable of metamorphosing a rock is in all likelihood flatter than a pancake and totally unrecognizable.

Sedimentary rocks are formed by the breakdown of previously existing rocks, which produces small and mid-sized particles. These particles may be deposited as sediment and ultimately restuck together into a new rock. An animal or plant that dies and is stuck between layers in this sediment is thus poised to be a future fossil.

Generally, fossils form in sediments that were deposited at the bottom of a body of water. To become a fossil, an organism (or a track) must be buried before it is destroyed (scavenged, rotted or washed away). Burial is more likely in an aquatic environment where streams and currents continuously move and deposit sediments. An organism exposed on land is much more likely to be scavenged or to decay because it will likely take much longer before it is buried. The exception to this is when an animal or plant or even a whole community is buried suddenly, as when a mudslide pours down on top of them killing and burying them instantly. The fossil record created by such an event can often provide an illuminating glimpse into the past, providing a snapshot of what was happening at that exact moment in time.

What is fossilized?

Some materials are more likely to be preserved as fossils. For example, it is common in some places to find fossilized bones, but rare to find fossilized skin or hair. In many cases, the hard parts (shells, bones and teeth) of an organism may be preserved, while soft tissues are lost for all time. Soft tissue is much
more likely to decay or be eaten by scavengers before it can be buried in the sediment. Hard parts are less desirable as foods, are more resistant to decay and are often more persistent in the environment, allowing them a longer time in which to be buried. However, even bones and shells may be broken or dissolved and never form into fossils.

Because hard parts are more likely to be preserved, the fossil record tells a biased story. It displays a disproportionately large number of organisms that have hard parts (i.e. there are more fossilized clams than fossilized worms) making it seem like previous time periods were dominated by corals, clams, vertebrates and trees. In reality, the relative abundance of different species in the fossil record does not accurately portray their abundance in the prehistoric ecosystem. While organisms with hard or bony parts may be most abundant in the fossil record, an equal or greater number of soft-bodied organisms may have lived in the environment. In addition, the fossil record teaches us more about the hard parts within an organism (i.e. we are more likely to find fossilized dinosaur bones, than dinosaur lips) giving us only partial information about creatures from the past.

Depending on the circumstances, a whole fossil organism may be found, but more often only a part of the organism is preserved. Some organisms easily break into pieces. A fossil may preserve just one piece or several pieces may be preserved as separate fossils. For example, a geologist might find a fossilized disk from the stem of a crinoid (i.e. this would be like finding a single vertebrae from a spine) and find the calyx elsewhere or (s)he may only find the stem. Even if several pieces are found, it may be years before scientists realize that they are from the same organism (or they may never know). Think for example of a tree. Trees have seeds that fall off and may be separated from the tree, even transported long distances by wind, water or wildlife. Trees also have leaves that fall off and blow in the wind and branches that break off and are raked into piles. Imagine that you are a paleontologist several million years in the future. You could find a fossil acorn, a fossil oak leaf, a fossil oak branch and a trunk, all in different places. How would you know that the acorn and the oak leaf were from the same organism?

**Why do we study fossils?**
So why do we study fossils anyhow? For quite a few reasons
actually. Fossils provide us with information about the past, including information about organisms that once roamed the earth, about past environments and previous locations of continents. Fossils can even help us to determine the ages of rocks.

Of course the obvious value of fossils, is that they tell us about plants and animals (and other things) that have lived on the earth in the past. They show us the shapes and structures of these organisms, or of parts of these organisms, and let us appreciate the diversity of life that has preceded us. In some cases, they record behaviors (burrows, trails), actions (how an animal walks) and life cycles (plant seeds, nests with eggs) that we couldn’t learn from just the fossilized animal itself. Life assemblages, those in which animals are preserved as they lived, can show us which organisms lived in proximity to one another and can show their relation to one another enabling us to study past communities.

Fossils can also give us clues about past environments. Sometimes knowing which fossils are in a given type of rock can tell us what the environment was like. For example, knowing that a filter-feeding coral fossil is found in the rock can tell us that the rock formed in a clear water environment; a muddy environment would have clogged its filaments. Facies fossils are those that are good indicators of past environments. (For a good summary of what you can learn about past environments, see Ansley, 2000.) Death assemblages, which consist of broken apart and scattered skeletons and/or shells, can tell us how strong the currents were and what direction they were moving. Death assemblages do not tell us about past communities because organisms or even other fossils may be washed to the final resting spot from other environments.

Fossils also give us evidence supporting the theory of evolution and illuminate the process of species diversification. The fossil record lets us view the progression of evolution by preserving the steps through which species evolved to their present form and introducing us to evolutionary dead ends. In addition, it lets us look at the changes occurring over a time scale of millions of years, rather than being confined only to the tiny changes that occur during our lifetimes.

Fossils can help us to determine past climates and environments and help us to figure out how continents were positioned relative
to one another. Fossils found in the eastern US and western Africa suggest that these two plates once collided and that a small island from off the coast of Africa was left behind attached to the eastern United States.

Fossils also help us to determine the relationship between rocks found in different places (a process called correlation.) Imagine if you will a series of ponds scattered around the earth and one particular clam species that lives in many of those ponds. Perhaps that clam species survived for a period of one million years before it went extinct or evolved into a different clam species. Looking at a rock and finding that particular clam would suggest when (during those 1 million years) and where (in a pond bottom) the rock was formed. Certain fossils, known as Index Fossils, are particularly useful in dating and relating rocks. Index fossils are those that have a short, well-known time of existence. This means that they must either have gone extinct in a relatively short amount of time (i.e. a few million years) or have evolved into a recognizably different species within that time. And further, index fossils must be widespread, so they are useful in relating rocks that are located in places that are far apart.

Finally, we study fossils because we use fossil fuels. By knowing what kinds of organisms to expect in what environments, we can better predict where we will find the fossil fuels that we are so dependent upon.

**Fossils in Delaware Water Gap National Recreation Area**

Delaware Water Gap's rocks formed primarily in the Silurian (408-438 million years ago) and Devonian (350-408 million years ago.) This does not mean that the local area did not experience all of the other periods, nor that it was not once home to organisms characteristic of those periods (i.e. Dinosaurs in the late Triassic, Jurassic and Cretaceous - 80-275 million years ago.) Rather it means that the rock that we see tells us only about the time when what is now Delaware Water Gap National Recreation Area was an ocean during the Silurian and the Devonian. Fossils from other time periods either are not exposed, were not formed, or have since eroded away.

**A note on illegal collecting**

It is not legal to collect fossils within the park. Fossils provide the most information when they are found and examined by a trained
professional in their original location. This is because the location can provide clues to the identity of the fossil or conversely, the fossil could help to identify the environment. Fossils that are removed from their original site lose much of the information that they could potentially have shared. Further, fossils that are removed from the park are no longer available for future visitors to discover. To preserve the scientific value of fossils in the park and to protect the resource for future visitors to experience, fossil collecting has been made illegal.

While fossils are commonly found in the park, specific locations for finding these fossils have been intentionally excluded. We realize that this makes it more difficult to share examples with students, however, we believe that it is a necessary precaution to protect the resource.

**Fossils of the Future**
Think about the world today. What will geologists of the future think about how we look? How we act? What will the fossils of the future be? Will our trace fossils be Nike™ treads and coke bottles? Will we be preserved as fossils? Will our pets? Our bones? Our homes? Will geologists in the future look at concrete rectangles in the rock and wonder what kind of animal made such a burrow for itself?

**Erosion and Weathering**
From the human perspective, rocks seem constant. Walking the same path day after day, you see plants that grow and bloom and die, you see trees that sprout and stretch toward the sky, but the rocks seem stagnant. Years later, the same rock sits in the same place and looks the same as it always has... or does it?

The unchanging nature of rocks is an illusion caused by our biased perspective. A human lifetime is miniscule compared to the colossal lifecycle of a rock. Changes occur so slowly that we humans do not notice them at all. Yet, even as we carry out the activities of our daily life, the rocks beneath our feet are slowly wearing away. Daily, they are assaulted by the environment and slowly splintered apart. Their broken pieces float away in rivulets and streams and rivers; the tiny fragments deposited unnoticed where someday they might build a new rock. Only when the
change is dramatic, when an earthquake shakes our very foundations or when a volcano spews molten rock high into the air, do we awaken to the dynamic earth around us. And then, a short time later, habit takes over and we once again take rocks for granted. We view a lifetime as very long, but geologically speaking it is only an instant.

What are erosion and weathering?
Erosion and weathering are the processes that are responsible for the laborious task of breaking rocks apart and carrying the material away. Different types of rocks weather at different rates; however, regardless of the speed, it is weathering that loosens rock particles, preparing them to be removed by erosion. Weathering may be accomplished through either chemical or physical processes.

During physical weathering, rock is broken down into smaller particles, but the composition of those particles is unchanged. They are just smaller pieces of the original rock. Physical weathering can occur in a variety of ways.

The repeated freezing and thawing of water can split rocks apart. Known as ice wedging, the process begins when water seeps into cracks and pores in the rock, then freezes within these confined spaces. Water expands when it freezes, so a wrestling match between rock and water ensues. If the crack is shallow and wide, the rock may be the victor, squeezing the excess water out of the crack; but often cracks are long, deep or narrow, and the water is trapped within. Unable to escape, the water freezes in place and the crack is widened by the wedge-like action of the water expanding within its walls. Round two begins when the ice has thawed and water once again begins to seep into the rock. The crack is bigger now, so more water fits into the space. Again and again the battle is fought. Each sequential thaw allows additional water to enter the rock, and each freeze expands the crack a little bit more, until finally the rock breaks apart.

Heating and cooling can also weather rocks. Rocks, like most substances, expand when warm and contract when cold (water is an exception). Repeated heating and cooling stresses the rock and eventually breaks it apart. Because the outside surface warms and cools more quickly than the center, this hot/cold
cycle may cause the surface layers to break free, a process known as **exfoliation** or **onion-skin weathering**. The developing cracks also provide an entry point for water to seep into the rock and accelerate ice wedging.

When pieces of rock break free, gravity assists the process of weathering by carrying the rock down slope. As pieces of rock fall from above, they chip the rocks below them doing some mechanical weathering of their own. In some areas (for example, Mount Tammany at the Gap) large rock faces break apart and the pieces build up in one large pile. This is called a **talus slope**.

While physical weathering processes leave the rock chemically unchanged, during **chemical weathering**, chemical reactions change the composition of the rock in a way that weakens it. For example, when a rock is exposed to oxygen, oxidation may occur. If the rock contains iron, this is basically the process of rusting; however, other elements can also be oxidized. Oxidation is what gives the Statue of Liberty its characteristic green patina.

Chemical weathering also occurs when acids contact rocks and dissolve away minerals, causing solution pits. Carbon dioxide (or industrial pollutants) in the atmosphere can dissolve in rainwater forming acids that can dissolve some types of rock. This is visible if you visit an old cemetery. Notice how the words in the headstones have been worn down through time, sometime to the point of being completely illegible.

Plants and animals also play a role in weathering. Lichens growing on rock surfaces chemically weather rocks by using acid to leach minerals off the surface. Plant roots that grow into cracks and crevices can push the rock apart (physical weathering). In rocky areas with little soil, rock crevices may be the only place where roots can grow; they certainly can’t push through a solid, unblemished surface of rock. Additionally, crevices in the rock may accumulate soil, concentrating nutrients that may be unavailable on sheer rock surfaces. As the root grows, it extends deeper into the crack and thickens outward until it cracks the rock.

Animals, including humans, also contribute to weathering. When animals habitually burrow or walk along the same part of a rock, their activity can wear away the surface of the rock. And humans
can disintegrate rock by quarrying, mining, cutting roads and tunnels and by plowing the land.

The end result of weathering, regardless of the mechanism, is the formation of soil. Soils differ greatly from place to place - in depth, in texture, in composition, and in their ability to support plant life. These characteristics have to do with the rock from which the soil originated, but also have to do with the process of erosion. Certainly, we would expect that the composition and nutrient content of the soil is related to the composition of the original rock. The original rock type can also influence soil depth, because some rocks break down more easily into soil. However, as we will soon see, erosion is also a very important factor in determining soil depth because the rate of erosion determines how much soil remains in an area.

**Agents of erosion**

Erosion is the process of moving soil and rock particles from one location to another. Erosion may carve gullies on the side of a steep hill, carry topsoil away in a flooding stream, or clear away materials loosened by weathering. There are two basic agents of erosion - wind and water, including ice. In recent years, an additional agent has in many instances accelerated the rate of erosion; this latest agent is of course, the human. While erosion by wind, water and ice are natural processes; the activities of humans can change the rate at which they alter the earth. For example, while raindrops naturally splash onto the earth, vegetation can help to hold the soil together and protect it from pummeling by a storm. However, agricultural fields often have little vegetation in the spring, when they are first plowed and planted, and in the fall after the crops have been harvested. During these times, the soil in the field is very vulnerable to erosion. A rainstorm on an unvegetated field can loosen an amazing amount of soil and carry it away causing problems both to the farmer who has lost valuable soil and to streams below, which may end up with a sudden addition of nutrients, as well as gill-clogging sediments.

**What’s soil got to do with it?**

So why do we care about weathering and erosion anyhow? Weathering and erosion control the type and availability of soil, and soil is very important to all forms of life - either directly, as plants use nutrients out of the soil, or indirectly, as animals eat
plants. Particle size can influence how well the soil holds water and control how much surface area is available to provide minerals to plants. In Delaware Water Gap, cactus barrens are found in areas with sandy soil that do not hold water and thus provide a dry, desertlike, microclimate within the temperate northeastern forest.

**Glaciers (shaping the landscape)**

So what forces shaped the landscape that we see before us? Wind? Water? Ice? Actually, all three played a role in wearing away the mountains and carving the river valley. But glaciers produced the most dramatic effect. Today, it's way too warm for glaciers, but the climate wasn't always so mild. Over the last three million years, the climate has warmed and cooled several times and during the coldest periods, glaciers from Canada expanded south into Pennsylvania and New Jersey.

These glaciers played a huge role in shaping this section of the Delaware Valley. They followed the river valley into the area, scraping the riverbanks into cliff faces and leaving behind hundreds of waterfalls and lakes. It is the landscape features created by the glaciers that attract so many people to the Poconos today. And since glaciers played such a big role in shaping the landscape that we live in, it's only fair to devote some time to figuring out what exactly a glacier is and how it does its work.

**What is a glacier?**
The logical place to start is with "what is a glacier?" The easy answer is that a glacier is a very large block of ice that scrapes and changes the shape of the landscape as it creeps forward and then melts away. But that begs the question of how a glacier comes to be, why it moves, and how it shapes the earth.

Before you have a glacier, you have snow. Here in the Delaware Valley we get snow almost every year, but certainly not enough to grow a glacier. Each spring, as things start to warm up, the snow melts away. In order to have a glacier, the snow must stay on the ground year round, for many years, perhaps hundreds, thousands, or even tens of thousands of years. So, in order to have a glacier, you need to have a climate that is colder than the current climate in the Poconos. That doesn't mean that it doesn't warm up in the summer, just that it doesn't warm up enough (or
long enough) to melt away all the snow that fell during the previous winter. So each winter, the pile of snow grows, and each spring it only melts part way back to the size from the year before.

The snow piles up until the weight of the snow on the top squeezes the air out of the snow at the bottom. As the snow pile grows, the pressure of the snow on top changes the snow below from flakes to compact ice granules and eventually into one giant block of ice. With all the air squeezed out, the glacial ice appears blue instead of white.

However, just turning to ice doesn’t make our snow pile a glacier, it makes it a snowfield. In order to be considered a glacier, the ice must move. The force that moves the glacier is gravity. When the glacier gets big enough, the pressure of the snow weighing down on the top squeezes the ice below. We usually think about ice as being a solid; we certainly don’t think of it as flowing like water, or even like glue. But in reality, the pressure from above melts the ice below and causes it to flow outward. Where and how fast it flows depends on how much resistance the glacier encounters in each direction.

If the glacier were sitting in a flat, open field, the ice would probably squeeze evenly out on all sides. But in an area like the Delaware Valley, there are rock walls on two sides, so when the glacial ice is squeezed the path of least resistance is to follow the valley. Think for a moment about a glass of milk. If you accidentally drop the glass and the milk falls to the floor, it will spread out into a somewhat roundish puddle. But imagine what would happen if you were instead to pour the milk into a section of rain gutter. Instead of spreading out into a round puddle, the milk would spread until it hit the sides, then it would stop spreading to the sides and would instead spread towards the ends of the gutter. Take it one step further, and put the gutter on an angle, after all, your standard river valley is always on an angle (remember, water flows downhill). Now, if you pour your glass of milk into the gutter it will spread as far as the sides and downhill, but not up towards the top of the gutter. The milk in the tilted rain gutter models the action of a glacier that is confined by a valley. Glaciers that follow valleys are usually smaller glaciers, often only a few hundred feet thick and are known as Valley Glaciers or Mountain Glaciers. The valley controls their path,
just as a track controls a train. In contrast, larger glaciers, which may be thousands of feet thick, are not constrained by the topography. These Continental Glaciers, or Ice Sheets, are so massive that features such as river valleys and hills are inconsequential in comparison. Continental glaciers flow right over the mountains and valleys rather than being controlled by them. Generally continental glaciers flow outward in all directions from a high point near the center of the glacier. The glacier that crept into the Delaware Valley was a continental glacier; however, as it first moved into the valley, the relatively shallow edges acted more like a valley glacier.

Ice is, of course, more sluggish than the milk in our model. There is gravity pulling the glacier downhill, but friction keeps the glacier from sliding freely. When the weight of the ice pushing down is more than the friction between the ice and the ground (or between two layers within the ice), the glacier will begin to move. As the glacier flows downhill, it moves into lower elevations where the temperature is warmer and there it begins to melt. When enough snow melts, the weight drops to the point where friction again exceeds gravity and the glacier stops. When additional snow falls, the weight pushing down increases and the glacier once again advances. If temperatures warm and more snow melts than accumulates, the glacier retreats.

How glaciers change the landscape
As it moves, grows, and melts, a glacier shapes its surroundings. Valleys that have been glaciated have steeper valley walls and flatter floor bottoms than valleys shaped only by streams. The U-shaped topography of these glaciated valleys attests to the power of the ice, and yet, ice is softer than rock. How then, is it possible for the ice to so drastically change the ravine.

It is possible, because it is not the ice itself that scratches and scours the bedrock, but rather pieces of rock carried along by the glacier. The ice at the base of the glacier is constantly melting and refreezing. A review of basic physics reminds us that ice melts when either heat or pressure is applied. The climate around (and beneath) a glacier is cold, so in this instance it is pressure that melts the ice - pressure from the weight of the immense pile of ice and snow pushing down from above. When this bottom ice melts, the water flows into cracks and crevices in the underlying rock. When the ice refreezes, the material is torn
loose changing the shape of the land. This process is called **plucking** or **glacial quarrying**. As the quarried material is carried along beneath the glacier, this rocky sandpaper scours down into the bedrock leaving behind telltale scratch marks known as **glacial striae**.

Later, when the glacier melts, the debris carried by the glacier is deposited and this material, known as **glacial till**, again changes the lay of the land. At the front edge of the glacier, an **end moraine** is formed. Studying the location and size of the end moraine can tell a geologist about the extent of the glacier and the rate at which it melted. Generally, the material carried by the glacier is dropped over a wide area as the melting ice weakens its hold and the captured rocks break free. If, however, the glacier cycles through several expansions and retreats without significantly changing its location, a large end moraine will accumulate. This end moraine indicates how far the glacier extended when it was at its largest.

Sometimes, a piece of the glacier breaks off and is covered in till. When the block of ice melts, the rock above it is left unsupported and it collapses into the cavern where the ice once was. The resulting hole may fill with water forming a **kettle** pond. Sunfish Pond, along the Appalachian trail just north of the gap is an example of a kettle pond.

**What do we know about glaciers in the Delaware Valley**

Looking at the evidence left behind, geologist have learned a lot about the glaciers that came through this area. The presence of three separate end moraines suggests that there was not one ice age, but rather several. Each one wipes out much of the evidence of previous ice ages, so it’s hard to know just how many there have been. But we do know that at least three occurred in this area. The most recent glaciation, the Wisconsinan, occurred 12,000-25,000 years ago. At it’s peak, the Wisconsinan glacier may have towered up to a mile high over the Delaware Valley. It is the effects of this latest glaciation that are visible in the park today.

**Their Place in History**

We humans like to think that we make decisions independently; however, the local geology influenced many of the decisions that
Native Americans and settlers made and continues to influence our decisions today. The Native Americans who were living in the valley when the settlers arrived were the Lenape, or Delaware. Early transportation, both by the Lenape and by European settlers, was along the river’s floodplain or on the river itself rather than across the rocky ridge. The Lenape chose paths that crossed dry, level ground, choosing direct routes from site to site. Later, when the settlers built roads, they followed the trails that the Lenape had used. The three main roads in the park today, route 209, River Road, and Old Mine Road, all follow roughly the same routes.

On the river, transportation was by canoe, ferry, raft or Durham boat. The geology of the river bed played a role. Shallow, rocky sections made transportation dangerous when the water was low, so most shipping occurred in the spring when melting snow and rain kept the water deeper.

Choosing homesites and fields, the people living in the valley took advantage of the geology. First, Lenape and later settlers located their fields on the fertile, floodplain soil. As the settlers built their farms, they even arranged the farm buildings along the hillsides off the floodplain, so that fertile land was used for fields and not for building sites. Early farms were fenced with wooden fences; however, as the population in the valley increased and the fertile floodplain was filled, those starting new farms were forced to use the rockier, mountain slopes. Before they could till the land, these farmers needed to remove the rocks. They used these rocks to form rock fences, which can still be seen snaking through the woods in the park. When you see such a stone row, you can assume that the area was once cleared and the forest that you are seeing has grown up in more recent years.

During the first half of the nineteenth century, artist came to the area to paint the Delaware Water Gap and other landscape features. Their work helped to stimulate an interest in the local scenery and after the civil war, Delaware Water Gap and the surrounding areas became a popular summer vacation destination. Tourism became a major part of the economy of the area. While historians now talk about the decline of the resort industry in this area, tourism is clearly still an important aspect of the economy of the Poconos.
**Tocks Island Dam**

Today the Delaware Water Gap and the 70,000 acres of land along the river are preserved as a unit of the National Park Service. However, this land was not always a National Recreation Area. In fact, most of it was privately owned land, much of it owned by families for generations.

For many years, the states of New York, New Jersey and Pennsylvania discussed the possibility of damming the Delaware River and using the resulting reservoir to supply water to New York City and Philadelphia. However, nothing ever came of the discussions until the river flooded in 1955. Then the US Corps of Engineers got involved and the dam looked like it would be built. Local landowners lost their land to the federal government as the Corp collected land that would be flooded when the dam was built. But politics, citizen action and geology conspired to stop the dam after all. Certainly politics and protest by citizens played a huge role in stopping the dam, however, for the purposes of these materials, our interest is in the geology. Just what was it about the geology of the area that made it unsuitable for a dam? And why couldn’t modern (in the 60s) engineering overcome the challenges that mother nature presented. The answer is complicated, and yet it is simple. The problem is glaciers.

Not glaciers in the valley of course, but the remnants of those that were here in the Pleistocene. When the mainstem of the glacier retreated out of the Delaware Valley it left behind hundreds of feet of mud and gravel. Unable to attach the dam to bedrock, there was a very real fear that the substrate would shift when rainwaters filled the reservoir and the dam would give way, not preventing a flood, but actually exacerbating it.

In addition, there was concern that the tilted layers on the mountains would landslide if the toe of the mountain was blasted out. Much like a tower of cards collapses if one of the bottom cards is pulled.
Site 1: Point of Gap Overlook
### PA Environment and Ecology Standards:

4.8.7D Explain the importance of maintaining the natural resources at the local, state and national levels.

### PA Science and Technology Standards:

<table>
<thead>
<tr>
<th>Standard</th>
<th>A Sedimentary Sandwich</th>
<th>Towel Technics</th>
<th>Recording Rock Layers</th>
<th>Mapping Mountains</th>
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<tbody>
<tr>
<td>3.1.4B Know models as useful simplifications of objects or processes.</td>
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<tr>
<td>3.1.7B Describe the use of models as an application of scientific or technological concepts.</td>
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<td>3.1.4E Recognize change in natural and physical systems.</td>
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<tr>
<td>3.1.7E Identify change as a variable in describing natural and physical systems.</td>
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<td>3.2.4A Identify and use the nature of scientific and technological knowledge.</td>
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<td>3.2.7A Explain and apply scientific and technological knowledge.</td>
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<td>3.2.7B Apply process knowledge to make and interpret observations.</td>
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<td>3.2.4C Recognize and use the elements of scientific inquiry to solve problems.</td>
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<tr>
<td>3.5.4A Know basic landforms and earth history.</td>
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<td>3.5.7A Describe earth features and processes.</td>
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### NJ Core Curriculum Content Standards:

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</thead>
<tbody>
<tr>
<td>5.2.1 State a problem about the natural world in the form of a question.</td>
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<td>5.2.2 Develop strategies and skills for information-gathering and problem-solving, using appropriate tools and technologies.</td>
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<td>5.10.1 Recognize and demonstrate the use of different kinds of maps.</td>
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<td>5.10.2 Identify materials that make up the earth, including rocks, minerals, soils, and fossils, and how they are formed.</td>
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<td>5.10.5 Compare different map projections, and explain how physical features are represented on each.</td>
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<td>5.10.6 Identify the major features of the earth’s crust, the processes and events that change them, and the impacts of those changes on people.</td>
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<td>5.10.8 Describe and explain the causes of natural processes and events that shaped the earth’s surface and interior.</td>
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Site 1: Point of Gap Overlook

From a vantage point across the river, students will observe and record the folded rock layers of Mount Tammany and will develop a theory about how the famous Delaware Water Gap formed. Before visiting the park, students will practice diagramming sedimentary rocks and will investigate the changes that occur when tectonic plates collide. While visiting the park, students will look for clues about how the Delaware Water Gap was formed and will use this information to propose an explanation. Back in the classroom, students will synthesize the information and use creative expression, through poetry, art or drama, to share their theory with the class.

A Park System to be Proud Of

Many National Parks owe their uniqueness to their geologic framework. Yellowstone's thermal features, Yosemite's stunning waterfalls, and the Grand Canyon itself are among the most famous geologic features in the world, and certainly in the National Park System. But even in scenic and cultural history parks, geology may play a hidden but important role. Have you ever considered, for example, how even subtle landscape features affect the outcomes of battles? Or pondered what the Battle of Bunker Hill would have been like without the hill? Have you thought about how different the swampy Everglades would be if the terrain was steep? How about Canyon de Chelly without the cliffs? Shenandoah's Skyline Drive without the Appalachian Mountains? or Homestead National Monument of America without the rich prairie soil? Obvious or not, geology plays a huge role in shaping each and every park in the system, and Delaware Water Gap National Recreation Area is no different.

The most famous feature in the park is of course the feature it is named for ... the Delaware Water Gap. A gap is a notch in a mountain range; a place where a river carved through from one side of the ridge to the other. Gaps are classified as either water gaps or wind gaps, depending on whether the river continues to flow through or has shifted its location or dried up. The Delaware River flows through our gap, so it is known as the Delaware Water Gap. It is often cited as a classic example of a water gap in the Appalachian Mountains, so considering just how this quintessential gap formed can be quite instructive.
Building Rocks
The gap is bounded by Mount Minsi in Pennsylvania and Mount Tammany in New Jersey. Before the gap formed, the two were connected into one continuous ridge. This ridge, the Kittatinny Ridge, is composed of two rock formations - the Bloomsburg Redbeds and the Shawangunk formation. Both are sedimentary rock formations.

The Shawangunk formation is the older of the two and forms the bulk of the mountain. Laid down approximately 430 million years ago by rapidly flowing streams originating on a now gone mountain, their fast water origin is evident in the rocks themselves. The turbulent environment swept small particles downstream and deposited only larger pebbles and sand grains. These layers of sand and pebbles later changed to rock, forming the grey sandstones and conglomerates of the Shawangunk formation. As the mountain from which the stream flowed eroded, the landscape flattened and the stream became slower.

The Bloomsburg Redbeds are more recent and cover the top of the mountains. There is some debate about the origin of the Redbeds; however, it is widely believed that they were laid down either by meandering streams and rivers (possibly the same one that laid down the Shawangunk, slower on the flattened terrain) or on a tidal flat. Either way, the ever-changing flow left layer upon layer of sand and mud that later became the reddish sandstones and shales of the formation.

Building Mountains
Although they now tilt upwards at a precarious angle, the layers of the Shawangunk and Bloomsburg Redbeds were laid down horizontally. When the African plate collided with the North American plate, 250 million years ago, the force of the collision kinked and bent the rock into folds forming the Appalachian Mountains (note: this is also when Pangea came together). If you compare the rock layers of Mount Minsi and Mount Tammany and imagine how the layers once connected across the chasm that is now the gap, you can see that the layers must have been folded. Erosion has removed all of the rock from what is now the gap, so we will never know the exact shape of the folded layers. But clearly, the only way to line up the corresponding layers on the two mountains is with a bent or broken line.
There are several theories about how the gap may have formed; the two most popular explanations are superposition and headwater erosion. The theory of headwater erosion proposes that folding of the rock was a critical factor determining the location of the gap. Under the headwater erosion theory, the PA side folded more than the NJ side, resulting in a weakened spot where the two sides pulled apart. Creeks flowing down the mountain and into New Jersey slowly eroded their way back through the ridge until they cut the whole way through and captured a river flowing parallel to the ridge along its western side.

Under the theory of superposition, no structural weakness need ever have existed; the folding of the rocks is only coincidental. According to this explanation, creeks that flowed across the land slowly eroded an ever deepening channel. When they hit the folded hard rock layer, they continued eroding the rock, following their old channel much as a train follows its tracks.

A Word about Glaciers
Although it might be convenient to assume that a glacier carved through the mountain and created the gap, this is almost certainly incorrect. Glaciers came and melted away several times over the course of millions of years, most recently melting away from the area 20,000 years ago. While glaciers certainly came to this area, and likely carried away talus from the crumbling rock, the gap was here first.

During the last glaciation (the Wisconsinan), the ice was thick enough to cover the entire valley and mountain, possibly more than 2,000 feet thick. We know this because there are glacial striae on the walls of the gap itself, all the way to the very top of the mountain. There are also glacial erratics and till deposits in the valley and boulders left by the glacier far up the peaks on either side.

What You Can See
As you look across the valley at Mount Tammany, you can see layers of rock. The rock is considered to be part of two formations, but each formation has several layers. The Shawangunk is considered to have three members. The top and bottom members are composed largely of sandstone, with little shale. The middle layer has a mix of sandstone and shale. It is this area where weaker shales and sandstones are mixed that trees grow.
Prior Knowledge

♦ sedimentary rocks

Standards

PA Environment and Ecology
1.4d, 1.7b, 1.4e, 1.7e, 3.4a, 3.7a

PA Science and Technology
3.1.4b, 3.1.7a

NJ Core Content Standards
5.2.1, 5.10.2, 5.10.6, 5.10.8

Vocabulary

Diagram, fossil, layer, model, sandstone, sedimentary, siltstone

A Sedimentary Sandwich

Overview

Using a peanut butter and jelly sandwich as a model, students will study the formation of sedimentary rock.

Objectives

♦ Students will identify the visual characteristics of sedimentary rocks.
♦ Students will diagram layers of “rock.”

Materials

White bread, wheat bread, creamy and crunchy peanut butters, jelly, raisins, plastic picnic knives, paper plates, drawing paper (or graph paper) and pencils.

Procedure

1. Explain to students that they will be modeling the formation of sedimentary rocks by making a sandwich. Each ingredient in the sandwich represents a different kind of sediment that is deposited and turned to rock. For example, white bread might represent siltstone, while wheat bread could represent sandstone. Raisins could represent rocks or even dead organisms that will become fossils in their sedimentary sandwich.

2. Have each student create their own sandwich. If students will be eating their sandwiches after the activity, make sure they wash their hands before they make their sandwich. Students can include whichever ingredients they would like, but tell them that their sedimentary sandwich needs to have at least three layers of “rock.”

3. Explain to students that it is bad manners to play with their food, but for this exercise, the sandwich is a model, so they will be studying it before they eat it. Cut the sandwich in half to expose the layers.

4. Explain to students that geologists make diagrams to record the rock layers beneath their study areas. Have students diagram their sandwiches, labelling each layer on the diagram.

Extension: If you also want to discuss metamorphic rock, wrap half of the sandwich in wax paper and place several heavy books on top. To dry and harden the metamorphosed sandwich, microwave it for 30-60 seconds before unwrapping the wax paper.
Towel Tectonics

Overview
Students will study the folding and distortion of layers by modelling the collision of tectonic plates using hand towels.

Objectives
♦ Students will model the folding of rock.
♦ Students will identify synclines and anticlines resulting from tectonic activity.

Materials
3-4 hand towels of different colors for each group, drawing paper and pencils.

Procedure
1. Give each group 3-4 hand towels in a variety of colors. Have them fold the towels lengthwise and stack them one on top of another.
2. Explain to the students that each towel represents a layer of rock laid down before the mountains formed.
3. Tell students that scientists use models to help them understand forces that are too big or too slow to study in the field. Explain to students that in this activity, they will be modelling the distortion of rock layers when the rock is folded and squeezed by colliding tectonic plates. Have one student place a hand on each side of the layered towels and push the towels together. This pressure represents the force of the African Plate colliding with the North American Plate. Some students may try to slam their hands together quickly. Don't worry, this model works at any speed.
4. Once students have modelled the collision, ask them to draw a picture of the result. You may want to have them diagram where the folds are from the top (i.e. a topo map of their towel landscape), as well as observing and recording the folds in the layered towels as viewed from the edge.
5. Explain to students what anticlines and synclines are. Have students find the anticlines and synclines on their towels and label them on their diagram of the towel edges.
6. Repeat the exercise until each student has had a chance to "create" mountains.

Prior Knowledge
♦ sedimentary rocks
♦ plate tectonics
♦ anticlines, synclines, folding

Standards
PA Environment and Ecology
3.1.4b, 3.1.7b, 3.1.4e, 3.1.7e, 3.5.4a, 3.5.7a

NJ Core Content Standards
5.2.1, 5.10.2, 5.10.6, 5.10.8

Vocabulary
Anticline, collision, diagram, fold, model, plate, plate tectonics, syncline.
Prior Knowledge
♦ sedimentary rock
♦ joints and bedding
♦ weathering and erosion
♦ maps and map keys

Standards
PA Environment and Ecology
4.8.7d

PA Science and Technology
3.1.4e, 3.1.7e, 3.2.4a, 3.2.7a, 3.2.7b, 3.2.4c, 3.2.7c, 3.5.4a, 3.5.7a

NJ
5.2.1, 5.2.2, 5.10.1, 5.10.2, 5.10.5, 5.10.6, 5.10.8

Vocabulary
Anticline, bedding, conglomerate, diagram, fold, layer, sandstone, shale, syncline, talus.

Recording Rock Layers

Overview
Using a blank diagram of Mount Tammany, students will record their observations about layering in the sedimentary rock composing the mountain.

Objectives
♦ Students will observe and record the different rock layers of Mount Tammany.
♦ Students will order the layers from oldest to youngest on their map.

Materials
Recording Rock Layers Activity Sheets, clipboards, crayons, Mount Tammany photo (from trunk).

Procedure
1. Have students follow the walkway to the viewing platform at Point of Gap Overlook. Remind them to watch carefully for cars as they cross the parking area to the path.
2. Pass out the Recording Rock Layers activity sheets and instruct students to carefully observe the mountain recording their observations on the Mount Tammany Diagram.
Have students color the layers that have plants growing on them one color, the bare rock layers another color, and the talus slope (smaller rock pieces piled on top of one another) a third color. Remind them to color the key as well.
3. Have students label which layer is the oldest and which is the most recent on their diagram.
4. After students have finished their diagrams, ask them why they think there are plants growing in some layers and not in others? Don’t tell them the answer yet, but do encourage them to suggest possibilities.
5. Ask students where they think the talus comes from? (it is pieces of the Shawangunk that are breaking off the cliff and piling up below).
6. Show students the picture of Mount Tammany with the layers labelled. Ask them to compare their diagrams with the photo. Now, ask them why they think vegetation grows in some places and not in others? (the trees are growing in the middle member of the Shawangunk, which has more shale mixed with the sandstone. Shale weathers more quickly than sandstone.)
Mapping Mountains

Overview
Comparing their Recording Rock Layers diagrams to an extended geologic map, students will consider the shape of the missing layers.

Objectives
♦ Students will observe and record the different rock layers of Mount Tammany.
♦ Students will compare their observations to geological maps and pictures.
♦ Students will match their map with an extended geologic map.
♦ Students will order the layers from oldest to youngest on their map.

Materials
Extended Gap Map, completed Recording Rock Layers activity sheet from the previous exercise, clipboards, crayons or pencils.

Procedure
1. Pass out Extended Gap Maps. Have students compare their diagram to this extended diagram and draw a box around the section of the extended map that is represented by their diagram.
2. Tell students to look at the rock layers on Mount Tammany (the part of the map they colored before) and on Mount Minsi (the corresponding mountain on the Pennsylvania side). Ask them to draw where they think the layers might have gone before the gap formed on their Extended Gap Map. (Their imaginary rock layers should connect each layer on Mount Tammany to the corresponding layer on Mount Minsi).
3. Explain to students that no one knows exactly what the layers looked like. They might have gone across the gap in one smooth fold, they may have folded or twisted in several places, or they could have gone up and down in lots of little folds the whole way across the gap.
4. Ask students what they think the missing layers could tell us about how the gap formed. (They could tell us how folded or broken up the rock was.)
5. Challenge students to think about what they learned even though they can't see the missing layers (This area was folded; there's no way the rock could have been flat).

Prior Knowledge
♦ sedimentary rock
♦ joints and bedding
♦ weathering and erosion
♦ plate tectonics and folding

Standards
PA Environment and Ecology
4.8.7d

PA Science and Technology
3.1.4e, 3.1.7e, 3.2.4a, 3.2.7a, 3.2.7b, 3.2.4c, 3.2.7c, 3.5.4a, 3.5.7a

NJ
5.2.1, 5.2.2, 5.10.1, 5.10.2, 5.10.5, 5.10.6, 5.10.8

Vocabulary
Anticline, bedding, conglomerate, diagram, fold, gap, layer, syncline, water gap.

Point of Gap
5. Ask them why that is important. (That's why the rock is weaker, and why we believe the gap is here.)
The Gap

Overview
Students will use their knowledge of plate tectonics and weathering and erosion, as well as their observations of the structure of the rock layers of Mount Tammany to develop an explanation for how the gap may have been formed.

Objectives
♦ Students will explain how they think the gap may have formed.
♦ Students will describe the difference between a theory and a law.

Materials
Art supplies, paper, costumes... depending on student projects.

Procedure
1. Write the following questions on the board to guide students through the process of developing a theory. Instruct students to write down the answer to each question before beginning their project.
♦ What do you think it looked like here before the gap formed?
♦ Why do you think the gap formed at this spot and not somewhere else along the Kittatinny Ridge?
♦ Why do you think the rock layers are tilted on an angle and not in horizontal layers?
♦ Do you think the answers to questions 2 and 3 are related?
♦ What happened to the rock that was where the gap is today?
♦ Describe step-by-step how you think the gap formed.
♦ What name would you give your theory?
2. Tell students that they will be using art, music, poetry or drama to share their theory about the gap with the class. Explain that they will be allowed to choose any kind of creative media for their project. They could write a poem, construct a panorama, make a series of paintings or a paper mache sculpture, write a song or a rap, present a skit. It is up to them what their project will be, but they should be prepared to share their work with the class - presenting their skit, song or poem, or explaining their artwork.
3. Celebrate students work with a special “Gap Day” or invite their parents to an openhouse so students can share their projects.

Vocabulary
Anticline, bedding, conglomerate, diagram, fold, gap, layer, syncline, water gap.
Recording Rock Layers

Look carefully at Mount Tammany. Notice the rock layers. Some layers have trees growing on them, while other places are bare rock. Elsewhere the mountain is made up of large pieces of rock all piled on top of one another. This rocky pile-up is known as a talus slope. Color the layers that have plants growing on them one color, the bare rock layers another color, and the talus slope a third color. Don’t forget to color the key so you remember what’s what when you look at your diagram later.

Color Key

- Covered with Plants
- Bare Rock
- Talus Slope
Getting There:
From I-80: Take exit 310 (Delaware Water Gap). Pick up route 611S. (Note: If you are coming from the east, this will be a left off the exit ramp. If you are coming from the west, you will go straight off the exit ramp.) At the stoplight in the town of Delaware Water Gap, make a left to continue on 611S. The Point of Gap overlook will be on the right 2.2 miles south of the light.

Take Along Tips for Teachers:
Mount Tammany is composed of two rock formations, the Shawangunk Formation and the Bloomsburg Redbeds. Within the Shawangunk, you can see several distinct layers of rock.

The Shawangunk Formation is considered two have three members. The top and bottom members are composed of sandstone, with little shale. The middle layer (where trees are growing) is composed of a mixture of sandstone and shale. The Shawangunk is believed to have been laid down by a quickly flowing river or stream.

The Bloomsburg Redbeds are the top layer of the mountain and are composed of reddish colored sandstones and shales. They are believed to have been laid down by either a meandering stream or a tidal flat.
Site 2: Lake Lenape

GEOLOGIC MAP OF THE LAKE LENAPE AREA

12 Strike and dip of bedding

12 Axis of syncline
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<th>PA Environment and Ecology Standards:</th>
<th>How Do Lakes Form?</th>
<th>Making a Grain Size Scale</th>
<th>Making a Clinometer</th>
<th>Using a Compass</th>
<th>How Did Lake Lensage Form?</th>
<th>On the Bank and in the Water</th>
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<tbody>
<tr>
<td>4.1.4B Explain the difference between moving and still water.</td>
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<td>4.1.7B Understand the role of the watershed.</td>
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<td>4.1.4C Identify living things found in water environments.</td>
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<td>4.1.7C Explain the effect of water on the live of organisms in a watershed.</td>
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<td>4.3.4C Understand that the elements of natural systems are interdependent.</td>
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<td>4.3.7C Explain biological diversity.</td>
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<td>4.6.4A Understand that living things are dependent on non-living things in the environment for survival.</td>
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<td>4.6.7A Explain flows of energy and matter from organism to organism within an ecosystem.</td>
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<td>4.7.4A Identify differences in living things.</td>
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<td>4.7.7A Describe diversity of plants and animals in ecosystems.</td>
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<td>4.7.4B Know that adaptations are important for survival.</td>
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<td>4.7.7B Explain how species of living organisms adapt to their environment.</td>
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<td>4.8.7D Explain the importance of maintaining the natural resources at the local, state and national levels.</td>
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<td>3.1.4B Know models as useful simplifications of objects or processes.</td>
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<td>3.1.7B Describe the use of models as an application of scientific or technological concepts.</td>
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<td>3.2.4C Recognize and use the elements of scientific inquiry to solve problems.</td>
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<td>3.5.4A Know basic landforms and earth history.</td>
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<td>3.5.7A Describe earth features and processes.</td>
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<td>3.7.4B Select appropriate instruments to study materials.</td>
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<tr>
<td>3.7.7B Use appropriate instruments and apparatus to study materials.</td>
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<tr>
<td>5.2.1 State a problem about the natural world in the form of a question.</td>
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<td>5.5.2 Use a variety of measuring instruments, emphasizing appropriate units.</td>
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<td>5.5.3 Use mathematical skills and concepts in ordering, counting, identifying, measuring and describing.</td>
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<td>5.6.11 Explain how organisms are affected by different components of an ecosystem and the flow of energy through it.</td>
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<td>5.7.4 Identify and describe external features of plants and animals that help them survive in varied habitats.</td>
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<td>5.10.1 Recognize and demonstrate the use of different kinds of map.</td>
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<td>5.10.2 Identify materials that make up the earth, including rocks, minerals, soils, and fossils, and how they are formed.</td>
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<td>5.10.6 Identify the major features of the earth's crust, the processes and events that change them, and the impacts of those changes on people.</td>
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<td>5.12.1 Identify the interdependence of living things and their environment.</td>
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Site 2: Lake Lenape

An inquiry lesson at Lake Lenape will involve students in the process of science as they explore the origin and importance of the lily covered pond. Before visiting the park, students will learn about the different ways that lakes can form and will create their own models to understand these processes. Arriving at the site armed with the knowledge learned from the in-class modeling activity, students will investigate the Lake Lenape area in an attempt to answer the question “How did Lake Lenape form?” After students have proposed their own hypotheses for the origin of Lake Lenape, they will investigate it’s impact on the local ecosystem.

Laying Down Rock
Lake Lenape is located at the base of Mount Minsi, a 1463 foot mountain that forms the Pennsylvania side of “the gap” and which was once connected to the rest of the Kittatinny Ridge. A rocky trail leads to the top of the mountain, taking the ambitious hiker on a walk across time. The mountain is composed of two rock formations - the Bloomsburg Redbeds and the Shawangunk. Both are sedimentary rock formations and although they now tilt upwards at a precarious angle, they, like most sedimentary rocks, were laid down on a flat, horizontal surface.

The Shawangunk formation is the older of the two, laid down 430 million years ago by a streams flowing down the side of a steep mountain. The turbulent environment swept small particles downstream and deposited only larger pebbles and sand grains. These layers of sand and pebbles later changed to rock, forming the grey sandstones and conglomerates of the Shawangunk formation. As the mountain from which the stream flowed eroded, the landscape flattened and the stream became slower.

The Bloomsburg Redbeds were laid down later, about 400 million years ago. Its maroon colored layers are believed to be deposits from either a tidal flat or a meandering stream or river (possibly the same one that laid down the Shawangunk, after erosion had leveled the terrain and slowed its pace.) Either way, the ever-changing flow left layer upon layer of sand and mud that later became the reddish sandstones and shales of the formation.

Lake Lenape
Building Mountains
So how did all these layers of flat rock get turned on end? A series of tectonic plate collisions pushed the Appalachian Mountains high into the air as the rock beneath bent and twisted into a folded mountain chain. The collisions date back 440 million years; however, considering the age of the rock (400-430 million years old), it is the collision of the North American and African plates 250 million years ago that is believed to have folded the rock at this site. The intense pressure of the collision squeezed the rock, wrinkling the layers like a rug folding up when someone trips on the edge. The folds are visible on exposed rock faces along the trail as anticlines (bumped up areas) and synclines (dipped down areas). Since that time, weathering and erosion has softened the topography, wearing away the ridge tops and breaking apart the rock. The shape of the landscape is controlled both by the folded structure of the rock layers and by the relative ability of each rock type to withstand weathering. By recognizing the different types of rocks, recognizing structures such as joints and cleavage, and looking at the direction that the rocks tilt (known as dip), geologists have been able to piece together an explanation for the mountain, gap, and lake that we see today.

The Lake
Lake Lenape is located in a basin formed by a syncline. As you walk down the Mount Minsi fire road from the parking area towards the lake, you are in fact walking down the side of the syncline in which the lake rests. A look at the rock outcrop on the left side of the trail will show that the rock dips down in the direction that you are walking. As you come to the lake, you will find yourself standing on a human made dike that dams the end of the syncline, preventing the water from escaping out the end of the trough. As you pass the lake and start up the hill, you will be walking up the opposite side of the syncline. An exposed rock
face to the left of the trail has visible layers that indicate the tilt of the fold and the point at which you reach the peak of the adjacent anticline and the rock starts bending down into the next fold.

**A Very Little Lake Biology**
This little water-filled fold in the rock is a very important component of the local ecosystem. It is home to fish, insects, frogs and salamanders that depend on its aquatic habitat for life. For some species, the lake is only a temporary home, a nursery in which they grow from an egg until they venture out to lay eggs of their own. To other species, it is a full time residence. And to still others, it is something of a snack bar. Here, deer and fox come to drink, herons come to fish, and raccoons come to search for anything from which to make a meal. Young dragonflies, mayflies and other “aquatic insects” grow and mature (sometimes for years) until they finally reach adulthood, living only a few days in order to mate, lay eggs, and die. Water lilies flourish in the shallow lake, producing teacup sized flowers and a sea of lily pads. We strongly encourage you to explore not just the geology, but also the local biology with your students. To do so, you could help the students to key out some of the common trees or have them sit quietly to watch as the creatures that call the area home return to the business of living.
### How do Lakes Form?

**Overview**
Students will model ways that lakes can form and will make a hypothesis about what types of lakes they might see on their field trip to Delaware Water Gap National Recreation Area.

**Objectives**
- Students will explore the different ways that lakes can form.

**Materials**
For each group: a plastic sheet or plastic garbage bag, bendable foam, sand, water, gravel, a block of ice, a golf ball, a balloon, a turkey baster with a rubber tube on the end, small pieces of wood, play-do or clay, *How Lakes Form* activity sheets.

**Procedure**
1. Brainstorm with students all the ways that they can imagine a lake forming.
2. Discuss the processes that form lakes, using examples of actual lakes formed by these processes.
3. Break students into groups and assign each group with the task of modelling three ways that lakes can form. You may want to assign each group two possible ways and let them pick their third so that all the possibilities are modelled.
4. Have students prepare a list of materials that they think they will need to build their models.
5. Take students outside to the playground and give each workgroup a set of modelling materials and three copies of the *How Lakes Form* activity sheet.
6. After students have modelled their three processes, ask each group to present one of their models to the class. Continue until a model of each of the methods has been shared.
7. Have students predict which type of lake they might see at Delaware Water Gap National Recreation Area.
Making a Grain Size Scale

Overview
Students will make a grain size scale that they can use to judge grain size on their fieldtrip to the park.

Objectives
♦ Students will use a grain size scale to determine sedimentary rock type.

Materials
Brown crayon, brown pebbles such as those used at the bottom of an aquarium, 4" X 5" cardboard or oak tag rectangles, glue, magnifying glass, sandpaper (three grain sizes - 1" square of each grainsize per student), Grain Size Scale Activity Sheet.

Procedure
1. Cut sandpaper into one inch squares, enough for each student to have one square of each grain size. Also, cut out the activity sheet pieces and the 4" X 5" cardboard rectangles. Do these steps ahead of time.
2. Have each child glue his or her activity sheet onto his/her piece of cardboard.
3. Have students match each square of sandpaper to the correct box on their worksheet.
4. After checking to see if all children have the correct placement, have students glue on their sandpaper.
5. Have students color the conglomerate box with a brown crayon, then glue the small pebbles in the box.
6. Let the glue dry.
7. Have students practice classifying sedimentary rocks using any rock samples that you have in your classroom.

Remember, it is illegal to collect rocks in the park. You should be able to find sedimentary rock samples in your own yard or have students bring in samples from home to test with their Grain Size Scale.

Prior Knowledge
♦ sedimentary rocks
♦ classification of sedimentary rocks based on grain size

Standards
PA Environment and Ecology
3.2.4c, 3.2.7c, 3.7.4b, 3.7.7b

NJ Core Content Standards
5.5.2, 5.5.3

Vocabulary
Conglomerate, grain, sandstone, sedimentary, shale, siltstone.
Making a Clinometer

Overview
Students will make a clinometer to use on their fieldtrip and will practice measuring "dip."

Objectives
- Students will measure and cut parts to make a clinometer to be used on their fieldtrip.
- Students will practice using their clinometer to measure dip.

Materials
Cardboard, string, magic markers, protractor, fishing weight (not lead) or a nut.

Procedure
1. Give each student a piece of cardboard or posterboard, scissors, magic-markers, a ruler, a protractor, string, and a fishing weight (not lead).
2. Have students measure and cut their cardboard into an 8" by 8" square.
3. Have students find the center of their cardboard square and mark it with a dot.
4. Have students mark a line from the middle of one edge of the square to the middle of the other edge of the square going through the dot in the middle.
5. Students should label the line as 90 degrees on both ends.
6. Have students mark a line from the dot to the middle of the bottom of the square and label this line as 0 degrees.
7. As students are ready, have them bring their square to you and help them to poke a hole through the center dot and put the string through the hole.
8. Have students tie a knot on one end of the string to keep it from falling back through the hole.
9. Have students tie the fishing weight to the other end of the line. Their clinometer is now complete.
10. Have students practice using their clinometers by setting up an obstacle course of angled items in the classroom and having students measure the dip of each item (for example, you could prop a book on a chalkboard eraser.)
Using a Compass

Overview
Students will practice using a compass to measure direction so that they are prepared to collect directional data on their field trip.

Objectives
♦ Students will practice using a compass to measure direction.

Materials
Compasses, treasure hunt cards, prizes.

Procedure
1. Set up a treasure hunt in the classroom, playground, or other area in the school. To do this, you will need to make a series of treasure hunt cards with five or more cards in the set. For best results you may want to set up 4 or 5 different sets of cards and randomly assigning students to different sets. This will force students to actually use the compass instead of following other students from site to site.
2. Each card in a set should give students a direction and a distance to move in that direction. When the student follows the directions on a given card it should take them to the spot where they will find the next card in the set.
3. Students should follow the cards in their set until they reach the final destination, perhaps receiving a prize when they get there.

Extension: Have students use their compasses to measure the direction of dip of the items on the Making a Clinometer obstacle course.

Prior Knowledge
♦ None

Standards
PA Environment and Ecology
PA Science and Technology
3.2.4c, 3.2.7c, 3.7.4b, 3.7.7b
NJ Core Content Standards
5.5.2

Vocabulary
Compass, direction.
Prior Knowledge
- classification of sedimentary rocks using grainsize
- bedding, joints and cleavage
- dip
- ways that lakes can form
- map and compass skills
- plate tectonics and folding

Standards
PA Environment and Ecology
4.1.4b, 4.1.7b, 4.8.7d

PA Science and Technology
3.2.4c, 3.2.7c, 3.5.4a, 3.5.7a

NJ Core Content Standards
5.2.1, 5.6.11, 5.10.1, 5.10.2, 5.10.6, 5.12.1

Vocabulary
Anticline, bedding, cleavage, dip, direction, joints, plate tectonics, syncline, fold.

How did Lake Lenape Form?

Overview
Students will use their knowledge of how lakes form to investigate the geologic clues in the Lake Lenape area and develop a theory about how Lake Lenape formed.

Objectives
- Students will determine rock type using a grainsize scale.
- Students will determine the slope of bedding using a clinometer.
- Students will use a compass to determine direction of dip.
- Students will use prior knowledge to predict how Lake Lenape was formed.

Materials
Clinometer, compasses, grainsize scales, Lake Lenape Area Map, pencils.

Procedure
1. Ask students to look for places where rock is exposed as they are walking up the trail towards Lake Lenape.
2. If they do not notice it on their own, point out the layered rock exposed on the left side of the trail. Ask students to make observations about the size, shape and any cracks in the rock.
3. Have students use their grainsize scales to determine the kind of rock (sandstone.)
4. Have students use their clinometers to measure the angle of dip and their compasses to measure the direction of dip. Ask them to record this information on their Lake Lenape area map with an arrow indicating the direction of dip. Remember: a rock dips downhill. If in doubt, which way would water flow?
5. Have students determine and record rock type, slope of bedding and direction of dip at the second location (indicated on the map.)
6. As a group, discuss what students learned from their measurements (that the rock is folded and that the lake is at the bottom of a folded layer.
7. Have students discuss how they think Lake Lenape formed. (It is a syncline, on an angle, with the bottom of the trough dammed by humans - the trail is on the dam.)
On the Bank and In the Water

Overview
Students will observe and compare plants and animals from aquatic and terrestrial habitats.

Objectives
- Students will explore the environment in and around Lake Lenape.
- Students will observe adaptations of animals to aquatic and terrestrial habitats.
- Students will compare animals found in living in Lake Lenape to those living in nearby terrestrial habitats.
- Students will consider the role geology plays in determining what lives in the Lake Lenape area.

Materials
Clipboards; field guides, if available; Lake Lenape Observation Sheets; Venn Diagram.

Procedure
1. Explain to students that they will be studying organisms living in and around Lake Lenape. Remind them that these are living organisms and they should be handled gently.
2. Divide students and chaperones into two groups. One will investigate Lake Lenape first; the other will investigate the nearby terrestrial habitat.
3. Have students observe three plants and three animals living in their habitat. Students should list and/or sketch these organisms on their Lake Lenape Observation Sheet and should record the organism’s size and behavior.
4. Switch and have students collect the same information for the other habitat.
5. Instruct students to find 3-4 other students to work with.
6. Using the information recorded on their group members’ observation sheets, have students fill in the Venn Diagram.
7. Ask students to consider the differences between organisms living in the Lake and in the forest. Challenge them to form a hypothesis about why different organisms are found in different habitats.
8. Gather students together to discuss what role geology plays in making these two environments different. (Geology influences slope, rate of flow, dissolved oxygen and temperature, as well as substrate type and turbidity - how murky the water is.)

Prior Knowledge
- Familiarity with local plants and animals, including insects
- skill using a dicotomous key
- habitat parameters
- adaptations and habitats
- understand that water creatures must be kept in water in order to survive.

Standards
PA Environment and Ecology
4.1.4b, 4.1.7b, 4.1.4c, 4.1.7c, 4.3.4c, 4.3.7c, 4.6.4a, 4.6.7a, 4.7.4a, 4.7.7a, 4.7.4b, 4.7.7b, 4.8.7d

PA Science and Technology
NJ Core Content Standards
5.6.11, 5.7.4, 5.10.6, 5.12.1

Vocabulary
Habitat, lake, stream, Venn Diagram.

Lake Lenape
Prior Knowledge

♦ measuring skills
♦ mathematics skills
♦ erosion and weathering
♦ understand that non-living things in the environment affect living things

What's the Difference?

Overview
Students will study the characteristics of aquatic environments to which organisms must adapt.

Objectives
♦ Students will explore the environment in and around Lake Lenape.
♦ Students will compare the plants and animals found in Lake Lenape to those found in the nearby terrestrial habitat.
♦ Students will observe behavioral adaptations of animals to aquatic life.

Materials
Cabbage water, orange, stop watch, tape measure, thermometer, What’s the Difference? activity sheet.

Procedure
If you are coming early in spring when the creek along the Appalachian Trail is flowing, or if you will be visiting Dingmans Falls or Haney Mills, consider having students study the organisms found in and around a creek and compare them to those found in and around a lake.

If not, there is still value in having students consider the characteristics of the lake environment to which organisms must adapt.

1. Ask students why they think different organisms are found in different aquatic habitats. You may have to help students come up with a list of habitat characteristics that may differ between habitats. (depth, rate of flow, pH, temperature, dissolved oxygen, etc.)
2. Tell students that they will be measuring several parameters that might influence what lives in the water. Break students into groups of 4 and have them pick one person to measure each characteristic and one to record their data.
3. Give each group a set of “What’s the Difference?” Activity Sheets.
4. After students have collected all of their data, discuss whether their results are conclusive or whether more than one factor could be responsible for the differences between lake and stream life.

Standards
PA Environment and Ecology
4.1.4b, 4.1.7b, 4.1.4c, 4.1.7c, 4.3.4c, 4.3.7c, 4.6.4a, 4.6.7a, 4.7.4a, 4.7.7a, 4.7.4b, 4.7.7b, 4.8.7d

PA Science and Technology

NJ Core Content Standards
5.2.1, 5.5.3, 5.6.11, 5.7.4, 5.10.6, 5.12.1

Vocabulary
Flow rate, temperature, parameter, pH.
Use the clinometer that you made in class to measure the angle of dip. Use a compass to measure the direction of dip. Record your results on the map below.
How Lakes Form Activity Sheet

Fill out one activity sheet for each lake formation model that you create. Begin by answering questions 1 and 2.

1. What method of lake formation are you modeling?  __Kettle hole__________________________

2. Explain how this method results in the formation of a lake.  a piece of ice from a retreating glacier is left behind and it is buried in rocks and soil that the glacier dropped. When the ice melts, a hollow spot is left under the rocks and dirt and it collapses. When the depression fills with water, it is called a kettle pond.

Now, build a model that show how this kind of lake forms. Answer the questions below about your model.

3. How did you model this process of lake formation?  __We put an ice block under a pile of gravel and sand and let it melt in the sun__________________________

4. What keeps the water from running out of your lake?  __the play doh™ liner__________________________

5. What keeps water from running out of a real lake formed in this way?  __________little tiny particles that are so close together that the water doesn't go through__________________________

6. What keeps water from filtering out the bottom of your lake?  __the plastic under it__________________________

7. What keeps water from filtering out of a real lake formed in this way?  __________the layer of bedrock that is under the lake__________________________

8. If you were looking at a lake that you thought had been formed by this method, what clues would you look for to confirm your prediction?  __rounded boulders dropped by a glacier nearby and in the bottom of the lake__________________________
How Lakes Form Activity Sheet

Fill out one activity sheet for each lake formation model that you create. Begin by answering questions 1 and 2.

1. What method of lake formation are you modeling? __________________________

2. Explain how this method results in the formation of a lake. __________________________
   __________________________
   __________________________
   __________________________

Now, build a model that show how this kind of lake forms. Answer the questions below about your model.

3. How did you model this process of lake formation? __________________________
   __________________________

4. What keeps the water from running out of your lake? __________________________

5. What keeps water from running out of a real lake formed in this way? __________
   __________________________

6. What keeps water from filtering out the bottom of your lake? __________________________

7. What keeps water from filtering out of a real lake formed in this way? __________
   __________________________

8. If you were looking at a lake that you thought had been formed by this method, what clues would you look for to confirm your prediction? __________________________
Find three different plants and three different animals around Lake Lenape and list or draw them in the spaces under “On the Bank.” Then, find three different plants and three different animals in the lake and list or draw them in the spaces under “In the Water.”

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<thead>
<tr>
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<th>On the Bank</th>
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<td>Animal #1</td>
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<td>Plant #1</td>
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<td>Plant #3</td>
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</table>
Use the information that you and the other members of your group collected to fill in the Venn Diagram. Then answer the question below.

Do the same organisms live in the lake as in the forest? Why do you think that is?
What's the Difference? Activity Sheet

In this activity you will be collecting data about the pH, temperature and rate of flow of water. Follow the directions carefully and record your data below.

Are you at Lake Lenape or at Caledonia Creek? ____________________________

**Water Temperature:**
Use the thermometer in your kit to measure the temperature of the water.

Water Temperature = ______________ degrees Celsius

**pH:**
Use the cabbage water and jars to test the acidity of the water.

What color is the water? ____________________________

Is the water more acidic or more basic? ____________________________

**Rate of Flow:**
To calculate the rate of flow, you will be timing how long it takes a stick (or an orange) to float downstream. Pick one group member to put the orange in the creek and have him or her stand on the bank upstream. Pick a second person to retrieve the orange at the bottom and have them stand somewhere downstream. Measure the distance between the person putting the orange in and the person retrieving the orange.

What is the distance? ____________ ft.

Have the upstream person place the orange in the water. As soon as the orange is in the water, start the stopwatch. Stop the stopwatch when the orange reaches the retrieving person. Remember, the retriever should wait for the orange to come all the way down to his or her location. Try to collect the orange. A net could come in handy.

How long did it take to float downstream? ____________ sec.

Divide distance by time to figure out the rate of the water.

\[
\frac{\text{distance}}{\text{time}} = \text{rate of flow (ft. per sec)}
\]
Getting There:
Take I-80 to exit 310 in Pennsylvania (the Delaware Water Gap exit.) Get onto route 611S. If you are coming from the west, you will go straight off the exit ramp to get onto 611S. If you are coming from the east, you will make a right turn off the exit ramp to get on 611S. Turn left at the light. Proceed 300 yards to the Deerhead Inn and make a right onto Mountain Road. Take the first left off Mountain Road into the Lake Lenape parking area.

Take Along Tips for Teachers:
- Notice the large rock across the trail from the lake. It is made of sandstone with thin layers of shale. Feel the grittiness and observe the slant. The rock is aligned North/South. This slant is the result of the folding of continental plates.
- Beyond the lake, next to the stream, is another rock tilting the opposite direction, toward the stream and lake.
- Lake Lenape sits within this trough formed by the folding of the sandstone.
- Continue uphill past the lake. Watch for the long rock ledge on your right. This sandstone ledge contains some prehistoric rock shelters/caves. Further up the path one of these rock shelters is easily observed.
- As you walk along the road you'll notice gray rocks containing white veins. These veins are quartz. They were formed when this area was under a great deal of heat and pressure during the folding. Water dissolved the quartz which was redistributed into cracks. If the cooling was gradual enough, quartz crystals grew.
Site 3: Cemetery in Bushkill
### PA Environment and Ecology Standards:

- **4.6.4B** Understand the concept of cycles.
- **4.6.7B** Explain the concept of cycles.
- **4.8.7D** Explain the importance of maintaining the natural resources at the local, state and national levels.

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### PA Science and Technology Standards:

- **3.1.4B** Know models as useful simplifications of objects or processes.
- **3.1.7B** Describe the use of models as an application of scientific or technological concepts.
- **3.4.7A** Describe concepts about the structure and property of matter.
- **3.5.4A** Know basic landforms and earth history.
- **3.5.7A** Describe earth features and processes.

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### N.J. Core Curriculum Content Standards:

- **5.5.2** Use a variety of measuring instruments, emphasizing appropriate units.
- **5.5.3** Use mathematical skills and concepts in ordering, counting, identifying, measuring and describing.
- **5.10.2** Identify materials that make up the earth, including rocks, minerals, soils, and fossils, and how they are formed.
- **5.10.6** Identify the major features of the earth’s crust, the processes and events that change them, and the impacts of those changes on people.
- **6.4.1** Compare and contrast similarities and differences in daily life over time.

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### PA Proposed Civics and Government Standards:

- **5.2.3C** Identify sources of conflict and disagreement and different ways conflict can be resolved.
- **5.2.3E** Describe ways citizens can influence the decisions and actions of government.
- **5.2.7E** Identify examples of rights and responsibilities of citizenship.

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Site 3: Cemetery in Bushkill

The cemetery near the Bushkill Reformed Church is an ideal location for students to study the relationship between local geology and human history. In the cemetery, students can see how geologic resources are used, discuss how cemetery sites are chosen and observe the effects of weathering. As they continue on their trip, students can view the Delaware Valley and relate the shape of the landscape to the weathering processes they studied in the cemetery. A discussion about the controversial Tocks Island Dam project that once threatened to flood the valley illustrates the complexity of environmental issues, challenges students to consider the role of geology in the debate, and empowering them to make their own decision about whether the dam should have been built.

Using the Earth
In ways big and small, humans rely upon the earth. We build our homes and towns on sites that offer advantages for trade, transportation, or defense or that offer a beautiful view. From the ground, we extract materials (oil, gas, coal, petroleum, gold, sand and gravel) that we use to build roads, manufacture a plethora of products, and design beautiful artwork or jewelry. And at the end of our lives, we return to the earth once again for a place to bury our loved ones. Cemeteries, in fact, can teach us a great deal about geology.

When choosing a cemetery location, geology is an important consideration. A site where bedrock lies just inches below the surface is not practical, as the underlying rock would make digging graves nearly impossible. Likewise, one wouldn’t want to build a cemetery in a wetland, or in any area where drainage is poor. In this region, well-drained, easy to dig sites are often found where glaciers deposited loose material, such as sand.

To remember our loved ones, we erect headstones that we hope will withstand the erosive forces of nature. But a close look at the headstones in an old cemetery will reveal that some headstones endure the test of time better than others. Just what is it that enables one old marker to stand straight and proud with an epitaph as clear as the day it was carved, while nearby, on a
more recent stone, time has rubbed away all but the faintest trace of a name and date? The secret is found in the rock itself.

Rock can be categorized into three categories - sedimentary, igneous and metamorphic. Sedimentary rocks are soft compared to metamorphic and igneous rocks and, as a result, weather more quickly. In addition, polished sedimentary rocks don't form the attractive, shiny surface that most feel that a memorial to a beloved ancestor should have. Sedimentary rocks may be found in and around the cemetery, but only a few are used as headstones. Igneous and metamorphic rocks, on the other hand, can be cut and polished into striking markers. And because these types of rock are more resistant to weathering, the sentiments engraved on the stones stay clear for many years. The igneous rocks found at this site are all from magma that cooled slowly, probably underground. Because the crystals had plenty of time to grow, they are relatively large, though size varies between stones. Geologists classify rocks based on the minerals that they contain. We will be referring to the igneous rocks in the cemetery as granite; however, a geologist would consider them to be several different kinds of rocks.

Metamorphic rocks are those that have been changed as a result of extreme pressure and temperature. Two different metamorphic rocks are found in the cemetery - marble and gneiss. Marble is formed from limestone that is heated and squeezed until the grains take on a sugary texture. Gneiss is formed from shale or sandstone. When the shale or sandstone metamorphoses, the grains become larger and the original layering becomes irregular and forms swirls.

As students explore the cemetery, they will discover that although local people lived in a landscape composed mainly of sedimentary rocks, the headstones that they used to memorialize
their loved ones are mostly igneous and metamorphic. Encourage them to compare the markers, looking at the condition of the words engraved in the headstones. Which rocks are hardest? Which resist weathering the best? What is the date on the oldest marker that can still be read? What kind of rock is it?

Weathering the Test of Time
As they continue their fieldtrip or return to school, students can view the Delaware Valley and relate the small scale weathering of headstones to the larger effects of weathering on the landscape.

The cemetery is located in the valley only a couple hundred feet above the Delaware River, which flows across a bed of weak shales and sandstones (cemented with clay). Unable to resist the river’s constant erosive force, the valley has been cut down until it is now well below the tops of the ridges to either side. The river, with help from intruding glaciers, has carved this valley.

The ridge south of the cemetery, the Walpack Ridge, is composed primarily of limestone, with small amounts of shale, dolomite, sandstone and conglomerate rocks. The ridge has withstood the erosive forces of nature moderately well and stands 600 feet above the valley floor.

Across the valley, the Kittatinny Mountain dominates the landscape. Composed only of tougher sandstone (cemented with quartz instead of clay) and conglomerates, the Kittatinny Mountain has resisted erosion even better, towering 1300 feet above the river.

The Ghost of Tocks
Just a short bus ride north of the cemetery, students can view the Delaware River. It’s cycle of flooding makes agriculture productive and once enabled loggers to transport rafts of timber as long as football fields to market in the lower reaches of the watershed. Spilling over its banks during floods, the Delaware enriches the soil and brings life to the valley.

But the flood of '55 threatened to change the river’s fate. In 1955, two heavy storms following months of drought awakened the river, causing surges of floodwater to course through the
valley. Hundreds of people were killed and in the aftermath of the flood, it seemed the furious beastly Delaware would be shackled once and for all. A dam was not a new idea, but with the inertia of the flood and the sudden involvement of the federal government, it seemed that this time the dam might actually be built. Yet today, more than 50 years later, we find ourselves not on the shore of a man-made lake, but in a shady cemetery along a highway in a valley, where a placid river flows peacefully southward. So what happened in the intervening years? Why is there no lake? No dam? Should we be exuberant or frustrated?

The answer is complex and a few pages of explanation cannot do it justice. To better understand the story, we recommend selecting some pertinent books from the bibliography. Or having students research the history of the park by interviewing friends or family members who lived in the area at the time. Briefly though, the dam was never built. Many citizens protested against the project, and ultimately won, showing the power of citizens working together. A few of their concerns were:

- Environmental concerns, particularly the flooding of Sunfish Pond to create a reservoir for hydroelectric generation.
- Concern that fish populations could be harmed by fluctuating water levels due to the demands of hydroelectric generation.
- Concern that eutrophication would make the reservoir unusable as a water supply or a recreation site.
- Engineering challenges caused by a deep layer of glacial till beneath the proposed dam site making it impossible to anchor the dam to bedrock.
- Concern that removing the base of the mountain would cause the steeply tilting layers to slide and cause massive landslides.

In addition, much of the land that is now park was at that time privately owned. Local landowners were understandably upset by the loss of homes and communities that their families had lived in for generations as land was purchased against their will to provide for the reservoir and the surrounding recreation area.
Putting it to the Acid Test

Overview
Students will experiment with whether marble, granite or limestone tiles react with acid. After testing the different tiles, students will discuss how the reactivity of metamorphic rock is related to the composition of the original, pre-metamorphic rock.

Objectives
♦ Students will identify properties of metamorphic, sedimentary and igneous rocks.

Materials
Marble, granite, and limestone tile; vinegar.

Procedure
1. Set up stations for each of the three stone tiles and assign a group of students to each station.
2. Have students observe their sample and write down observations such as the color, crystal size, and identity of each rock.
3. Have students use their knowledge of how metamorphic rocks form to make predictions about which metamorphic rocks will fizz in the presence of acid. (Marble is metamorphosed limestone and will fizz; granite is a metamorphosed igneous rock and will not react with acid).
4. Have students use vinegar to test the rock kit samples. Note that in order to test for reactivity, students will need to first scratch the surface of the tile (perhaps with sandpaper) to expose unoxidized rock and then apply the vinegar to the scratch.
5. After students have recorded their observations, ask students to rotate to the next station. Repeat until each student has had the opportunity to test each of the tiles.
6. Tell students that on their fieldtrip they will be examining marble, granite and gneiss headstones and ask them to predict which headstones will show more effects of weathering.

Note: NO Acid will be permitted in the cemetery. This activity should be completed in the classroom prior to visiting the site.

Prior Knowledge
♦ three types of rock
♦ understand that the properties of metamorphic rocks are related to the properties of the rocks from which they were formed
♦ understand that acids and bases react with one another

Standards
PA Environment and Ecology
PA Science and Technology
3.4.7a
PA Civics and Government
NJ Core Content Standards
5.5.3

Vocabulary
Acid, crystal, gneiss, granite, hardness, igneous, marble, metamorphic.
Igneous Edibles

Overview
Students will conduct an experiment to determine the effect of cooling time on crystal size.

Objectives
♦ The students will explain how cooling time affects crystal size.

Materials
Fudge ingredients, hot plate, saucepan, mixing spoon, 3 pie plates.

Procedure
1. Explain that crystal size is related to the speed at which magma cools. Tell the students that they will be conducting an experiment to see just what effect cooling time has on crystal size.
2. Ask students how they can control cooling time. Some possibilities include cooling the fudge in the freezer, refrigerator, or on ice; insulating the pan; warming an oven or stove burner, then turning it off and letting the fudge cool in the oven or on the burner (an electric burner works better than a gas burner.) When practical, use the students’ suggestions in your experimental design.
3. Help students prepare the igneous fudge recipe. To avoid burns, an adult should do the cooking.
4. Grease three pie pans, pour equal amounts of the molten fudge magma into each. Cool one quickly (i.e. in refrigerator or on ice), one at room temperature, and one slowly (i.e. in a cooling oven).
5. Once the fudge has cooled, have students compare the crystal size of the fudge - by tasting it of course. The fudge with the biggest crystals will feel the grittiest.

Recipe for: Igneous Fudge

1/3c. water
1c. sugar
pinch of salt
3 tbsp. cocoa
1 tsp. vanilla extract
In a saucepan, mix water, sugar, salt, cocoa, and vanilla extract together. Pour into pans and cool.
Modelling Metamorphosis

Overview
Students will use clay to model the changes that crystals undergo during metamorphosis.

Objectives
- Students will model the process of metamorphosing igneous rock.
- Students will observe and compare the crystal structure of igneous and metamorphic rock using a clay model.
- Students will identify properties of igneous and metamorphic rocks.

Materials
Three or more different colors of modelling clay or dough.

Procedure
1. Have students use different colors of clay to form several thin snakes or coils of clay. Students should make at least three different colored "snakes."
2. Have students lay the "snakes" together to form a block. The "snakes" represent the minerals in an igneous rock.
3. Help students to slice the model in half.
4. Have students twist and compress one half of the model to make a "metamorphic" rock.
5. After you have both an igneous model and a metamorphic model, slice it into a cookie (a disk approximately 1/4 inch thick.) If you used a homemade play dough, bake it according to the recipe.

Igneous

Metamorphic

6. Take these models along on your trip to the cemetery so that students can compare the "crystal structure" of their models to the crystal structure visible in the granite and gneiss headstones.

Prior Knowledge
- three types of rock

Standards
PA Environment and Ecology
4.6.4b, 4.6.7b

PA Science and Technology

PA Civics and Government
5.2.3c, 5.2.3e, 5.2.7e

NJ Core Content Standards

Vocabulary
Crystal, gneiss, granite, igneous, metamorphic.
Researching the Past

Overview
Students will learn about the Tocks Island controversy by interviewing people who lived in the area during the 1950's and 1960's.

Objectives
- Students will identify the geological and political factors influencing the creation of the Delaware Water Gap National Recreation Area.

Materials
Video camera (optional), interview activity sheet.

Procedure
1. Tell students that they will be learning about the creation of Delaware Water Gap National Recreation Area and that the way that the park was made is very controversial. Explain that when issues are controversial, people have different opinions and it is important not to depend on any single person's opinions, but rather to research many different points of view.
2. Ask students to think about how they could find out what people thought about the dam and why. Students will probably suggest talking to the people themselves.
3. Explain to students that they will be conducting interviews to learn about the Tocks Island Dam project and ask them to brainstorm ideas about how to find people who lived in the area at the time. (Some possibilities are students' relatives and friends if they grew up in the area, teachers or school staff members who may have lived in the area at the time, contacting historical societies, inviting a speaker to the school, contacting the National Park Service...)
4. Have students schedule the interviews (or assign it as homework if they will be talking to relatives or family friends). Try to find people with a variety of opinions, both supporting and opposing the project.
5. Review the interview questions with the class, clarifying any terms that the students are unfamiliar with (i.e. squatter). You may also want to have students add questions of their own.
6. Instruct students to conduct the interviews, recording their answers on the activity sheet or if possible videotaping the interview.
Weathering the Test of Time

Overview
Students will examine marble headstones of different ages to discover how weathering alters the stones.

Objectives
♦ Students will discuss the hardness of the headstones by observing clarity of epitaphs on the stones.
♦ Students will observe the effects of weathering by examining headstones that have been exposed to the environment for different amounts of time.

Materials
Test of Time activity sheets.

Procedure
1. Give each student a copy of the Test of Time activity sheet.
2. Show students examples of marble headstones and instruct them to find and record data for four marble headstones - one with a deathdate in the 1820s, one with a deathdate in the 1870s, one from the 1920s, and one from the 1970s.
3. Remind students that they are in an active cemetery and that they should be on their very best behavior as they explore the area.
4. Have students compare the readability of the different stones and consider what other factors might influence the rate of weathering (i.e. whether the stone is flat or upright, which direction the inscription faces, etc.)
5. Also have students hypothesize about the agents of weathering that are at work in the cemetery. Possible answers include acid rain, lichens on the stones, plant roots pushing up on the stones, freeze-thaw...
6. Discuss what the students observed as a group.

Prior Knowledge
♦ three types of rock
♦ physical and chemical agents of weathering
♦ understand that acid rain speeds the rate of weathering

Standards
PA Environment and Ecology
4.6.4b, 4.6.7b

PA Science and Technology

PA Civics and Government

NJ Core Content Standards
5.10.2

Vocabulary
Crystal, erosion, hardness, marble, metamorphic, weathering,
That Sure is a Gneiss Rock!

Overview
By investigating the differences between headstones, students will discover the distinctions between igneous and metamorphic rocks.

Objectives
♦ The students will identify properties of metamorphic and igneous rocks.
♦ The students will observe and compare the crystal structure of igneous (granite) and metamorphic (gneiss) rock.

Materials
A Gneiss Rock activity sheets.

Procedure
1. Explain to students that they will be conducting an investigation to identify differences between igneous and metamorphic rocks.
2. Remind students that they are in a cemetery where many peoples friends or family members are buried and they should be on their best behavior.
3. Take students to the two gneiss headstones located in the northwest corner of the cemetery. Pass out student activity sheets. Give the students 5-10 minutes to draw and describe the crystal patterns in the gneiss stones.
4. Show students what granite looks like. Instruct them to find a pink, granite headstone and collect the same information about it.
5. Show students the clay models of igneous and metamorphic rocks that they made in the “Modeling Metamorphosis” activity. Remind students that their models were subjected to change by pressure.
6. Ask students to compare the clay models to their drawings of the headstone to determine which headstone is igneous rock and which is metamorphic.
7. Extension: Have students “vote” on the nicest rock for a headstone: marble, granite or gneiss.
A Headstone as Hard as Rock?

Overview
Students will study the effects of weathering by exploring an old cemetery. By evaluating readability of marble and granite markers, students will discover that different kinds of rocks weather at different rates.

Objectives
- Students will discuss the hardness of the headstones by observing clarity of epitaphs on the stones.
- Students will observe the effects of weathering by comparing headstones made of different rocks from the same time period.

Materials
Large (poster-size) sheets of paper, crayons, copies of student worksheets, cemetery guide, tiles.

Procedure
1. Have students locate two headstones - one marble and one granite - with the same death dates.
2. Have students record data collected from these markers on the Hard as Rock student worksheet.
3. Have students answer the questions on the sheet, reminding them to think about what they learned from the Acid Test experiment that they did in class before visiting the park. Remember, NO acid is permitted in the cemetery. Students should recognize that although the headstones were carved in the same year, the rocks have weathered at different rates because of their composition. Marble weathers faster than granite.
4. Discuss why the marble stone is more weathered. Remind students to think about the results of their Acid Test experiment. Which rock reacts with acid? (Marble fizzed, granite did not) Could acid rain be an agent of weathering? If so, does that explain why the marble tombstone has weathered more than the granite tombstone?

Extension - if students have time, give them crayons and a sheet of paper and have them do rubbings of hard to read stones. Can they read information on the rubbing that they couldn’t read on the stone? Have students compare the clarity of upright and flat stones. Why are the flat stones more weathered?

Prior Knowledge
- three types of rock
- properties of minerals, including hardness and weathering strength
- agents of physical and chemical weathering
- understand that acid rain speeds the rate of weathering.

Standards
PA Environment and Ecology
4.6.4b, 4.6.7b
PA Science and Technology
PA Civics and Government
NJ Core Content Standards
5.10.2

Vocabulary
Acid, crystal, erosion, gneiss, granite, hardness, igneous, marble, metamorphic, sedimentary, weathering,
Prior Knowledge

- three types of rock
- factors that affect crystal growth
- familiarity with common minerals

Standards

PA Environment and Ecology
4.5.4b, 4.6.7b

PA Science and Technology

PA Civics and Government

NJ Core Content Standards
5.5.2, 5.5.3, 5.10.2

Vocabulary

Crystal, granite, igneous, magma, mineral.

An Igneous Investigation

Overview

Students will study crystals and crystal growth by identifying and measuring crystals found in headstones. Using data that they have collected, students will make predictions about the conditions under which the stones formed.

Objectives

- The students will use mineral samples to identify the crystals composing the different types of rock used as headstones.
- The students will measure and compare crystal sizes between igneous rocks and use this information to predict which rocks cooled faster.

2. Instruct students to find two headstones with crystals of different sizes.
3. Have students identify three different colors in each stone and record the colors on the Igneous Investigation activity sheet.
4. Have students measure and record the size of one crystal of each color to the nearest millimeter.
5. Ask students to compare the data from the two headstones and use it to answer the questions on the activity sheet.
6. Gather students together to discuss their investigation results.

Materials

Magnifying lenses, Igneous Investigation activity sheet, mineral samples, metric rulers.

Procedure

1. Before beginning the investigation, point out the crystals in the “granite” headstones and ask students to look for differences between markers. Students should observe markers with different colors and different crystal sizes.
Weak Rocks and Strong Water

Overview
Students will discuss the importance of rock hardness in determining the shape of the weathered landscape they see before them.

Objectives
♦ Students will identify properties of metamorphic, sedimentary and igneous rocks.
♦ Students will observe the landscape and discuss how erosion and the hardness of rocks have played an important part in the creation of ridges and valleys.

Materials
none

Procedure
1. As you travel to other sites in the park or return to the school, have students observe the shape of the landscape.
2. Ask students why they think there are high mountain areas and low valleys. Why has the landscape weathered and eroded unevenly?
3. Have students predict which areas are composed of soft rocks, which of moderately resistant rocks, and which of hard rocks.

4. Explain to students that just as rocks in headstones weather at different rates, rocks in nature weather at different rates.

Extension: (for when you return to the classroom) If you have rock samples, have students test limestone, shale, sandstone, dolomite, and conglomerates by scratching them against one another and recording which is harder. After testing the rocks, have students arrange them into three groups - soft, moderate, hard. Ask students to think about the landscape that they saw on their fieldtrip and predict which types of rocks form mountains and which are found in the valley floors.

For your information: Kittatinny Mountain, which runs parallel to the river down the New Jersey side, then crosses the river at the gap is composed of sandstone and conglomerates. The Walpack Ridge, which crosses the river at the bend (near Bushkill) is composed of limestone, with some amount of shale, dolomite, sandstone and conglomerate. The valley floor is made of weak shales and sandstones.
Who's Who in the Cemetery

Overview
Students will examine epitaphs to collect data about how long people could expect to live in the past and in the present.

Objectives
Students will recognize that life expectancies were shorter in the past and will suggest reasons why this was so.

Materials

Procedure
1. Pass out activity sheets.
2. Tell students that they will be trying to find out how long people lived in the past. Instruct students to find one headstone for each of the time periods indicated on the activity sheet (1800-1833, 1834-1866, 1835-1899, 1900-1933, 1934-1966, 1967-1999) and to record information about the person memorialized on their activity sheet. Explain to students that they will be combining data later, so to get the most accurate information they should try to use different headstones than their peers.
3. Remind students that they are in an active cemetery and must be on their best behavior.
4. After students have collected information for all six time periods, have them begin graphing their results while others finish data collection.
5. Students can make preliminary observations about life expectancies in the past and present; however, explain that they will be making a bigger graph in class and their conclusions may change.
6. After the trip, hang a large sheet of graph paper in the classroom and have all of the students put their data on the chart. You may want students to mark data from women and girls in one color and data from men and boys in another color. Discuss why the class graph is more accurate than the graphs with only one data point for each time period.
7. Ask students to make some observations about life expectancies and brainstorm reasons why people live longer today (nutrition, medical care, safer transportation, etc.)

Extension: Have students find markers for veterans from as many different wars as possible. Hint: G.A.R. stands for Grand Army of the Republic, the northern army in the Civil War.
Talk about Tocks

Overview
Through a role-playing activity, students will put themselves in the place of people with various opinions about the proposed Tocks Island Dam. Group discussions will help students appreciate how complex environmental issues can be and promote tolerance towards people whose opinions differ from their own. After debating whether or not to build the dam, students will recognize that for some questions there is more than one right or wrong answer.

Objectives
♦ Students will identify the geological and political factors influencing the creation of the Delaware Water Gap National Recreation Area.

Materials
Photo of proposed Tocks Island Dam, map of proposed reservoir outline.

Procedure
1. Give each student an identity card indicating who they are role-playing and giving a short summary of that person’s history and interests.

Possible identities include: homeowner, politician, Corps of Engineers employee, biologist, geologist, business person, emergency worker ...
2. Read students the story of the Tocks Island Dam, stopping at the point where local citizens are discussing the controversy.
3. Tell students that they are to imagine how they would feel if they were the person on the identity card and ask them to decide whether or not they support the dam. Have them write down their decision and three reasons why.
5. Put students in groups (5-7 students) and have them share their decision with the group. Then, still in their roles, have group members discuss the dam and decide whether or not to build it. Give students about 15 minutes to complete their discussions.
6. Have each group pick a representative to share their decision with the class and explain how group members’ concerns were addressed.
7. After all the groups have shared their decisions, finish telling the story and offer students the opportunity to discuss the decision that was actually made.

Prior Knowledge
♦ Tocks Island Dam project
♦ recognize that there are many opinions about the project
♦ glaciation
♦ sedimentary rocks
♦ landslides
♦ basic map skills

Standards
PA Environment and Ecology
4.8.7d
PA Science and Technology
PA Civics and Government
5.2.3c, 5.2.3e, 5.2.7e

NJ Core Content Standards

Vocabulary
Glacial, landslide, layers, till, Tocks Island Dam.
Interview someone who was a resident of this area at the time of the intended construction of the Tocks Island Dam in the 1960s and 1970s. Ask them the following questions. You may also want to ask them some questions of your own.

1. Where were you living at the time when the Dam was proposed?

<table>
<thead>
<tr>
<th>Stroudsburg</th>
<th>East Stroudsburg</th>
<th>Delaware Water Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shawnee</td>
<td>Bushkill</td>
<td>Where the park is now</td>
</tr>
<tr>
<td>Bevans</td>
<td>Walpack</td>
<td>Other: ____________</td>
</tr>
</tbody>
</table>

2. Were you a student or an adult?

3. Was your home in the area close to the river?

4. Was your home bought by the U.S. Government?

5. Did your family have to move from this home? If not, skip to question #7.

6. If your answer is yes, please describe the effect this move had on your family.

7. If you did not have to move from your home, how else were you affected by other people having to do so?
8. Were you and your family for or against the building of the dam? Why?

9. Do you remember the controversy between residents and the government?

10. Do you know the reason the dam was not ever built?

11. What do you remember about the events concerning the "squatters" who came and lived in the abandoned homes along the Delaware River?

12. What do you remember about how people felt about the removal of the squatters from the river homes?

13. How do you feel now about the National Recreation Area as opposed to the lake that the dam would have created?

14. In what way would this area be different if the dam had been built?
A Gneiss Rock Activity Sheet

Locate John Dewitt Gunn and Elizabeth Gunn’s headstones in the back left corner of the cemetery and copy the colored pattern of mineral crystals in the block below. Then, find a pink granite headstone (perhaps that of Norman Nyce Guillot and Anna Wolf Guillot.) Write down the name on the stone and sketch the crystal pattern in the block below.

Name: John or Elizabeth Gunn

Name: Norman and Anna Guillot

Describe the difference between the two stones in one or two sentences.
In the Guillot’s headstone you can see all the different crystals, but in John and Elizabeth Gunn’s headstones the crystals are all swirled together.

Consider the clay models that you made in class. Which of these headstones do you think is an igneous rock or are they both? Norman and Anna Guillot’s headstone
Which is metamorphic? John and Elizabeth Gunn’s headstones

Can you find any other igneous rocks in the cemetery? There are lots of red and grey granite headstones.

Are there any other metamorphic rocks? These are the only Gneiss markers, but marble is also metamorphic.
Locate John Dewitt Gunn and Elizabeth Stoddart Gunn's headstones in the back left corner of the cemetery and copy the colored pattern of mineral crystals in the block below. Then, find a pink granite tombstone (perhaps that of Norman Nyce Guillot and Anna Wolf Guillot.) Write down the name on the stone and sketch the crystal pattern in the block below.

Name: __________________________

Name: __________________________

Describe the difference between the two stones in one or two sentences.

_____________________________________________________________________

_____________________________________________________________________

Consider the clay models that you made in class. Which of these headstones do you think is an igneous rock or are they both? __________________________

Which is metamorphic? __________________________

Can you find any other igneous rocks in the cemetery? __________________________

Are there any other metamorphic rocks? __________________________
Hard as Rock Activity Sheet

Find two tombstones that are made of different kinds of rock, but have the same death date. Or at least have death dates within five years of one another. Find out everything you can from the two stones and record the information below.

Tombstone # 1
Name: Charles and Clarissa Heller
Date of birth: 1833 & 1843
Date of death: 1889 & 1923
Age at time of death: 56 & 80
Male or female: Male & Female
Readability: good
Crystal color(s): Black, white, gray
Predicted type of rock: granite
Other observations: 

Tombstone # 2
Name: John and Julia Heller
Date of birth: (must subtract) 1809 & 1812
Date of death: 1880 & 1889
Age at time of death: 71y 8m & 77y 9m
Male or female: Male & Female
Readability: good
Crystal color(s): White, sparkley, gray
Predicted type of rock: marble
Other observations: 

Which tombstone rock appears older? marble (John and Julia Heller)
Which rock actually is older or are they the same? they are the same

Find the tile or rock sample that looks most like the two tombstones. What type of rock is each tombstone?

Tombstone # 1 is made of granite
Tombstone # 2 is made of marble

Explain why one appears older than the other. Use what you know about rock types and erosion and what you learned from the acid test that you did in class.
The marble weathers faster. At least one reason is that it reacts with acid rain and granite does not.
Find two tombstones that are made of different kinds of rock, but have the same death date. Or at least have death dates within five years of one another. Find out everything you can from the two stones and record the information below.

<table>
<thead>
<tr>
<th>Tombstone #</th>
<th>Name</th>
<th>Date of birth</th>
<th>Date of death</th>
<th>Age at time of death</th>
<th>Male or female</th>
<th>Readability: good fair poor</th>
<th>Crystal color(s)</th>
<th>Predicted type of rock</th>
<th>Other observations</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Tombstone #</th>
<th>Name</th>
<th>Date of birth</th>
<th>Date of death</th>
<th>Age at time of death</th>
<th>Male or female</th>
<th>Readability: good fair poor</th>
<th>Crystal color(s)</th>
<th>Predicted type of rock</th>
<th>Other observations</th>
</tr>
</thead>
</table>

Which tombstone rock appears older? __________________________________________
Which rock actually is older or are they the same? __________________________________________

Find the rocks in the rock kit samples that looks most like the two tombstones. What type of rock is each tombstone?

Tombstone # ____ is made of ______________________
Tombstone # ____ is made of ______________________

Explain why one appears older than the other. Use what you know about rock types and erosion and what you learned from the acid test that you did in class.

__________________________________________________________________________
Igneous Investigation Activity Sheet

Find two tombstones that have visible mineral crystals. Your teacher will help you choose a good pair. Record the name that is carved on the tombstone. Find three different minerals in each stone and record the color and size (to the nearest millimeter) for each.

<table>
<thead>
<tr>
<th>Name</th>
<th>Color</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jennie Smith Guillot</td>
<td>pink</td>
<td>1 mm</td>
</tr>
<tr>
<td></td>
<td>black</td>
<td>1 mm</td>
</tr>
<tr>
<td></td>
<td>white</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Color</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>James and Mary Alleger</td>
<td>pink</td>
<td>up to 10 mm</td>
</tr>
<tr>
<td></td>
<td>black</td>
<td>1-4 mm</td>
</tr>
<tr>
<td></td>
<td>white</td>
<td>1-5 mm</td>
</tr>
</tbody>
</table>

Compare the data that you collected from each marker by answering the following questions:

1. Which tombstone had larger crystals? _______ James and Mary Alleger’s _______

2. Which rock cooled slower during its formation. Use your knowledge of the effects of cooling time on crystal size. Explain your answer. _______ James and Mary Alleger’s _______
   Crystal size is influenced by cooling time. The slower the magma cools (and the longer the crystals have to grow), the bigger they are.

3. Are the two headstones composed of the same minerals or are the minerals different in the two stones? _______ They appear to be made of the same minerals _______

4. Do you think that the type of mineral has any effect on crystal size? _______ yes, but they’re the same _______

5. Using the mineral samples, can you identify any of the crystals in the tombstones? What are they? _______ quartz, feldspar and mica _______
Igneous Investigation Activity Sheet

Find two tombstones that have visible mineral crystals. Your teacher will help you choose a good pair. Record the name that is carved on the tombstone. Find three different minerals in each stone and record the color and size (to the nearest millimeter) for each.

Name ____________________________

Color: __________________________
Size: __________________________

Name ____________________________

Color: __________________________
Size: __________________________

Compare the data that you collected from each marker by answering the following questions:

1. Which tombstone had larger crystals? __________________________

2. Which rock cooled slower during its formation. Use your knowledge of the effects of cooling time on crystal size. Explain your answer. __________________________

3. Are the two headstones composed of the same minerals or are the minerals different in the two stones? __________________________

4. Do you think that the type of mineral has any effect on crystal size? ________________

5. Using the mineral samples, can you identify any of the crystals in the tombstones? What are they? __________________________
Find tombstones with deathdates that fall into each of the following time periods: 1800-1833, 1834-1866, 1867-1899, 1900-1933, 1934-1966, and 1967-1999. Try to pick different headstones than your classmates. Record the information for each tombstone in one of the boxes below. After you have collected your data, graph it in the space provided.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Name</th>
<th>Date of birth</th>
<th>Date of death</th>
<th>Age at time of death</th>
<th>Male or female</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800-1833</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1834-1866</td>
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<tr>
<td>1867-1899</td>
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<tr>
<td>1900-1933</td>
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<td></td>
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<tr>
<td>1934-1966</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1999</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Test of Time Activity Sheet

Find four marble headstones, one with a deathdate in the 1820’s, one from the 1870’s, one from the 1920’s and one from the 1970’s. Record the information from each headstone in the appropriate block below.

1820’s Headstone
Name __________________________
Date of birth __________________
Date of death __________________
Observations __________________

Readability: good fair poor

1870’s Headstone
Name __________________________
Date of birth __________________
Date of death __________________
Observations __________________

Readability: good fair poor

1920’s Headstone
Name __________________________
Date of birth __________________
Date of death __________________
Observations __________________

Readability: good fair poor

1970’s Headstone
Name __________________________
Date of birth __________________
Date of death __________________
Observations __________________

Readability: good fair poor

Which tombstone looked oldest? Is it the oldest? ____________________________
If not, what factors could have made it seem older? ____________________________

What agents or weathering are at work in the cemetery? ______________________
________________________________________________________________________

Were any of your stones laid flat on the ground? If so, find a tombstone of the same age that is upright. Which one is more weathered? ____________________________
Getting There:
The cemetery is located next to the Bushkill Reformed Church. To get there from I-80, take exit 309 (route 209N). Several miles north, you will come to a light where route 209 and business 209 intersect. Make a right to continue on route 209N. Counting the light where you turned as the first light, go through 4 stop lights and one blinker light. The church is on the right immediately after the blinker light.

To get there from the north, take route 209S. The church is on the left side approximately 21 miles south of Milford, PA. It is about 1 mile south of the Bushkill Access.

Important: This is an active church and parking a bus in their parking lot may interfere with church activities. Please call the park to schedule your fieldtrip. Have the bus drop the students, then go 100 yards south to the Bushkill Visitor Center to park.

Take Along Tips for Teachers:
There are four distinct kinds of rock used in these headstones.
- Granite, an igneous rock, possibly from quarries in Vermont
- Marble, a metamorphic limestone
- Gneiss, a metamorphic shale or sandstone
- Siltstone, a sedimentary rock, probably collected locally.

Marble and Gneiss are found in a band of rock throughout the Appalachian Mountains. These headstones probably came from quarries in Easton or northern New Jersey.

Cemeteries are often located on glacial sand deposits for ease of digging.

Tip: Instruct students that courteous, respectful behavior is expected in the cemetery.
Site 4: Dingmans Falls
<table>
<thead>
<tr>
<th>PA Environment and Ecology Standards:</th>
<th>The Field Journal</th>
<th>Making a Grain Size Scale</th>
<th>The Cabbage Juice Test</th>
<th>Waterfall Wise</th>
<th>The Dirt on Dingmans</th>
<th>Like Water in a Bowl</th>
<th>Circles on the Soil</th>
<th>The pH at Dingmans Runnel</th>
<th>Aliens at the Falls</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.4C Understand that the elements of natural systems are interdependent.</td>
<td></td>
<td></td>
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<tr>
<td>4.3.7C Explain biological diversity.</td>
<td></td>
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<td></td>
<td>x x x</td>
</tr>
<tr>
<td>4.6.4A Understand that living things are dependent on non-living things in the environment for survival.</td>
<td></td>
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<td></td>
<td>x x x</td>
</tr>
<tr>
<td>4.6.7A Explain flows of energy and matter from organism to organism within an ecosystem.</td>
<td></td>
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<tr>
<td>4.6.4B Understand the concept of cycles.</td>
<td></td>
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<td>4.6.7B Explain the concept of cycles.</td>
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<td>4.7.4B Know that adaptations are important for survival.</td>
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<td>4.7.7B Explain how species of living organisms adapt to their environment.</td>
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<td>4.8.7D Explain the importance of maintaining the natural resources at the local, state and national levels.</td>
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<td>3.1.4B Know models as useful simplifications of objects or processes.</td>
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<td>3.1.7B Describe the use of models as an application of scientific or technological concepts.</td>
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<td>3.2.4B Describe objects in the world using the five senses.</td>
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<td>3.2.7B Apply process knowledge to make and interpret observations.</td>
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<td>3.4.7A Describe concepts about the structure and properties of matter.</td>
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<td>3.5.4A Know basic landforms and earth history.</td>
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<td>3.5.7A Describe earth features and processes.</td>
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<td>3.7.4B Select appropriate instruments to study materials.</td>
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<td>3.7.7B Use appropriate instruments and apparatus to study materials.</td>
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<td>5.1.9 Identify and diagram feedback loops that occur in biological and ecological systems.</td>
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<td>5.2.4 Keep a journal record of observations, recognizing patterns of observations and summarizing findings.</td>
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<td>5.5.2 Use a variety of measuring instruments, emphasizing appropriate units.</td>
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<td>5.6.11 Explain how organisms are affected by different components of an ecosystem and the flow of energy through it.</td>
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<td>5.7.4 Identify and describe external features of plants and animals that help them survive in varied habitats.</td>
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<td>5.10.2 Identify materials that make up the earth, including rocks, minerals, soils, and fossils, and how they are formed.</td>
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<td>5.10.6 Identify the major features of the earth's crust, the processes and events that change them, and the impacts of those changes on people.</td>
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<td>5.12.1 Identify the interdependence of living things and their environment.</td>
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<td>5.12.7 Analyze the components of various ecosystems and the effects of those components on organisms.</td>
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Site 4: Dingmans Falls

Exploring the beautiful Dingmans Ravine with journals in hand, students will discover the intricate relationship between rocks, soil and life. Using field journals to focus their attention, students will study the structures of the waterfalls and record their observations. After carefully collecting information about soil composition and testing soil pH, students will discover that both the underlying rock and the organisms living in the ravine contribute to the soil covering the ravine floor and will learn how the crumbling rocks and decaying vegetation support a truly unique array of plants and animals. Faced with a potential threat to the ravine, students will consider their responsibility to the earth and suggest strategies to resist this and future invasions.

A Trip to the Beach
Today Dingmans is a beautiful ravine with two waterfalls and a creek flowing beneath the shade of 200 year old Hemlock trees. In the creek, there are frogs and salamanders, a plethora of insects and native Brook Trout. Along its bank there are chipmunks, voles and warblers. However once, long ago, an ocean covered the area and rather than hemlocks and warblers, the ocean floor was home to brachiopods, crinoids and other long forgotten creatures. The ravine’s story starts then, 380 million years ago, in the mud on that ancient ocean floor.

A careful look at the rocks scattered in the creek provides a clue to the ravine’s past. The alert observer will notice that the rocks in the creek have two basic shapes - round & pillowy and flat & angular. The rounded rocks are sandstone, while the flat rocks are siltstone. Both are sedimentary rocks, but they differ in composition. Sandstone is made of sand particles, much like those one might find on an East Coast beach. Siltstone, on the other hand, is composed of silt, that oozey, soft mud that squeezes between your toes when you wade in an old farm pond. The difference is important for what it tells us about the environment. Moving water, of course, has the ability to transport soil and rock particles. Small, fine-grained particles are the lightest and easiest to transport, while sand grains or pebbles are heavier and are transported only by more quickly flowing water. As water slows, it deposits larger, heavier particles and then increasingly small, lightweight particles. You can see this happening in the present day creek. In the rocky riffle areas, the
bottom is swept clean and only pebbles sit on the creek bed amongst the rocks. However, in pools, where the creek water slows, the bottom is muddy from fine particles deposited by incoming water as the stagnant pool water slows its pace.

Because the rocks that we are looking at were formed in water, we can assume that the siltstone formed in a still area and the sandstone where the water was moving more quickly. The area that is now Dingmans Ravine was covered by an ocean when the sediments were deposited, so we can hypothesize that the slow water was well offshore where the water was too deep for waves and the incoming rivers had slowed enough to drop even the smallest particles. The sandstone was likely formed in a near shore environment where wave activity kept the smaller particles in suspension. But our investigation is not as simple as imagining a single ocean at a single point in time. To figure out what happened here, we must figure out where the rocks in the creek came from.

The majority of the rock that is visible along the trail is siltstone. Layers of particles that differ slightly in mineral composition, possibly because of natural variations in stream flow, can be seen in both falls, as well as in the rock faces along much of the trail. Except for the rounded rocks and boulders scattered along the creek, no sandstone can be found. What we cannot see from our vantage point at creek level is that the tops of the ridges on either side of the ravine are sandstone. The location of the sandstone on top of the siltstone tells us that it was formed, not at another spot in our ocean, but at a later, more recent time. Clearly this ocean was changing. Most likely the shift from deep water to shallow water at this particular site was a result of a drop in sea level as the Acadian orogeny raised the level of land by folding the sea bottom up into the air. Sediments deposited by the river entering the ocean also contributed to the change as the delta slowly filled in and the water became shallower, eventually turning to beach.

But if there was beach where the ridgetops are today, presumably there was once beach all the way across. Something must have happened here; something dramatic. Something that left a ravine where once solid rock stood.
A Cold Day at Dingmans

100,000 years ago, a glacier began to "move" south into the area. The accumulating sediment had long since filled the ocean basin and changed to rock. Now, the former ocean bottom was a plain dissected by creeks and rivers slowly making their way to the Atlantic Ocean. Following the shape of the river valley, the glacier crept into the area and spread up the creeks feeding the river. As the glacier grew, the valleys beneath became insignificant compared to its size. No longer at the mercy of the landscape, the glacier began to cross over whole mountains without changing direction.

A smaller glacier, or perhaps an arm of the main glacier, formed on a tributary somewhere in the vicinity of what is now Dingmans Creek. This smaller glacier carved the V-shaped creekbed into a characteristic U-shaped valley, even as the main glacier shaped the Delaware Valley into a wide U-shape. The volume of ice made the main glacier much heavier and gouged a much deeper ravine in the main Delaware Valley than the relatively smaller glacier carved along Dingmans Creek.

When the glaciers retreated, the small creeks feeding tributaries like Dingmans Creek were left stranded on the cliffs above the newly carved valleys. These creeks tumbled over the ledges forming waterfalls that have since been sculpted by the cycle of freeze-thaw and by rock particles carried in the water.

Ice Sculptures

In the colder climate just after the glacier retreated, ice wedging broke apart the rock and gravity forced the loosened pieces to the ground. The process continues today; but in the milder present-day climate, it occurs more slowly. It is through cracks at joints and between beds that water enters the rock to do its work.

Bedding layers are formed as materials of similar size and com-
position are deposited. While we tend to think of these bedding layers as discrete periods of time, this is not necessarily true. The layers are visibly distinct only because the particles in one layer are in some way different from the particles in an adjacent layer. While this could represent a permanent change in the environment, it may also represent something as simple as a storm flood, depositing larger particles for a short time.

Bedding layers are generally deposited in horizontal or nearly horizontal layers, even when the surface below them is uneven. You can prove this to yourself by putting gravel, sand and soil in a jar of water and waiting for them to settle. The particles make horizontal layers, even if the jar is tilted on an angle. After the bedding layers have formed; however, movement within the earth's crust can fold and twist them in many different ways. At Dingmans, the bedding surfaces are slightly tilted indicating that at some time the rocks were folded.

Joints are rock fractures that result from stress when the rock is pushed, pulled or bent. A series of cracks form (usually perpendicular to the surface) and may separate slightly, but the rock pieces move very little. Weathering along joints can result in a straight-sided cliff. This is particularly evident in the straight sides of Silverthread Falls. Other joints can be seen on the hillside to the right of Silverthread, and in the pool beneath Dingmans Falls.

The joints in Dingmans ravine are all oriented in the same direction, indicating that they probably all formed in response to the same stress. Glaciers do not create joints and there have been no regional stresses since the glacier retreated, so we must conclude that these joints have been here since before the glacier carved the ravine. Most likely this rock was cracked by stresses related to the opening of the Atlantic Ocean.

Whatever the cause, the joints and beds provide access for water to crack the rock, explaining how the falls are changing. But, why is the top, the top? The lips of falls are usually composed of rock that is more resistant to weathering than the rock below it. This could be caused by differences in mineral composition or grain size. When the rock on top is much harder than the
underlying rock, a steep falls, like Silverthread is formed. In contrast, when the difference between the rock on top and the layers below is less extreme, a more gradual waterfall, like Dingmans Falls, is formed.

A Few Words About Soil
Soil is composed of rock particles and decaying organic matter and as a result both the type of underlying rock and the kinds of plants and animals influence soil characteristics. During this fieldtrip, your students will be testing the pH of the soil in Dingmans ravine. To answer their questions, there are a few thing you should know.

The organism with the greatest biomass in the ravine is of course the Hemlock Tree, and while everything that decays influences the soil, the dominant Hemlock is likely to have the greatest effect on the soil. Hemlocks produce chemicals called tannins that help to protect them from insect pests. It is these tannins that dye the creek water the color of tea. And incidently, it is tannins that give tea its characteristic color. These tannins are acidic and they greatly influence the pH of the soil. If the tannins were contributing to soil in which the rock particles were limestone, we might expect a neutral soil because the limestone would neutralize the acidic tannins. However, here at Dingmans, the rock particles are neutral, or possibly acid, and have little ability to buffer the acids from the Hemlocks. Consequently, the soil in the ravine is acidic - just the type of soil that rhododendrons prefer.
**The Field Journal**

**Overview**
Students will be engaged in a variety of creative journaling and data collection activities during their field trip. In this activity, students will prepare the field journals that they will take with them to Dingmans Falls.

**Objectives**
- Students will use a journal to record field observations and data.

**Materials**
For each student - two 8.5"x11" pieces of cardboard or posterboard, 1 copy of each Activity Sheet, 3 or more sheets of blank drawing paper, 1 or more sheet(s) of lined writing paper, and 18" of yarn.

In addition, students will need art materials such as construction paper, fabric, glue, old magazines, magic markers or crayons, 2 hole punch and scissors.

**Procedure**
1. Give each student a full set of materials, including cardboard, activity sheets, drawing and writing paper, yarn, and any additional pages you want them to include.
2. Have students arrange the pages in the following order:
   - 1 piece of cardboard
   - 1 sheet blank paper
   - 1 pH Page
   - 1 Waterfall Wise
   - 3 sheets blank paper
   - 2 sheets lined paper
   - 2 sheets blank paper
   - 1 sheet lined paper
   - 1 piece of cardboard
3. Have students punch two holes in their journal, approximately 1/3 and 2/3 of the way down the left margin.
4. Have students thread their yarn in one hole, through the stack and out the other hole, tying a double knot and then a bow to bind their book together.
5. Give students time to use the art materials to personalize and decorate their journal's cover and make a title page.
Making a Grain Size Scale

Overview
Students will make a grain size scale that they can use to judge grainsize on their fieldtrip to the park.

Objectives
♦ Students will use a grain size scale to determine sedimentary rock type.

Materials
Brown crayon, brown pebbles such as those used at the bottom of an aquarium, 4" X 5" cardboard or oak tag rectangles (1 per student), glue, magnifying glasses, sandpaper (three grain sizes - 1" square of each per student), Grain Size Scale Activity Sheets.

Procedure
1. Cut sandpaper into one inch squares, enough for each student to have one square of each grain size. Also, cut out the activity sheet pieces and the 4" X 5" cardboard rectangles.
2. Have each child glue his or her activity sheet onto his/her piece of cardboard.
3. Have students match each square of sandpaper to the correct box on their worksheet.
4. After checking to see if all children have the correct placement, have students glue on their sandpaper.
5. Have students color the conglomerate box with a brown crayon, then glue the small pebbles in the box.
6. Let the glue dry.
7. Have students practice classifying sedimentary rocks using any rock samples that you have in your classroom.

Remember, it is illegal to collect rocks in the park.
You should be able to find sedimentary rock samples in your own yard or have students bring in samples from home to test with their Grain Size Scale.

Prior Knowledge
♦ sedimentary rocks
♦ classification of rocks

Standards
PA Environment and Ecology
PA Science and Technology
3.1.4b, 3.1.7b, 3.2.4b, 3.2.7b, 3.4.7a, 3.7.4b, 3.7.7b
NJ Core Content Standards
5.5.2

Vocabulary
Conglomerate, grain, sandstone, sedimentary, shale, siltstone.
Prior Knowledge

Overview
Students will prepare cabbage water to use to test the pH of soil and water samples while on their fieldtrip.

Objectives
♦ The students will prepare cabbage water to use to test pH.

Materials
Red cabbage, distilled water, knife, chopping board, sauce pan, pitcher, jars (baby food size is fine), sieve, soil samples from the teacher's house, school, and each student's yard, The pH Page

Procedure
1. Take students outside the school and show them how to collect a small (3-4 Tbsp.) soil sample. Assign students to bring in a similarly sized soil sample from their own homes. You may want to bring in a sample from your own yard, as well.

After students have brought in their samples, prepare the cabbage juice:
2. Cut the cabbage in half. Because this will require a sharp knife, the teacher should complete this step.
3. Soak 1/2 of the cabbage in distilled water for 30min.
4. Drain the water from the cabbage into a pitcher.
5. Pour the cabbage water into the jars until each is 1/4 full. Make sure that you prepare 1 jar for each sample that you intend to test.
6. To test a sample, add soil or water (whichever you are testing) to the jar until it is half full.
7. Prepare a control jar for comparisons by adding distilled water instead of a sample of water or soil.
8. Have students compare the color of each sample to the control jar (containing cabbage water only). If the water stays pinkish, the sample is acidic. If the water becomes bluish, the sample is basic. Students should record their results on The pH Page in their journal.

Since the cabbage water is natural, you can dump everything at the site or you can safely dump it down the drain. However, make sure that you remove all cabbage pieces and soil before putting it down the drain so the drain doesn't clog.
Waterfall Wise

Overview
Students will observe geologic features and evidence of past geologic events as they walk along the Dingmans Falls trail.

Objectives
- Students will describe how glaciers formed Dingmans Falls.
- Students will describe how weathering and erosion have affected and continue to affect Dingmans Falls.
- Students will identify visual characteristics of sedimentary rocks, including bedding layers and joints.
- Students will identify an erratic deposited by a glacier.

Materials
Student worksheets, drawing paper or field journals, pencils, clipboards.

Procedure
1. Point out the erratic to the right of the trailhead and discuss its presence.
2. Have students use a grain size scale to determine what kind of rock it is (sandstone).
3. Instruct students to watch for other erratics as they walk.
4. Point out the rocks in the stream under the bridge and discuss the reasons for the different shapes.
5. Find a flat rock and have students use their grain size scales to identify it (siltstone).
6. Have students observe Silverthread Falls and sketch it in their field journals, completing questions 1 and 2 on the Waterfall Wise Page.
7. Proceed to Dingmans Falls. Have students illustrate the falls in their journal and answer the Dingmans Falls questions on the Waterfall Wise page.
8. Ask students to compare the two falls and discuss the differences between them. Challenge them to speculate on the reasons for these differences.
9. Discuss the formation of the falls pointing out the bedding layers and joints, the slope of Dingman’s and the possible causes.
10. Have students label the diagrams on the Waterfall Wise worksheet indicating which falls each represents.

Extension: Have students try to determine the reason for the turn the stream takes at the bottom of the falls.

Prior Knowledge
- sedimentary rock
- joints and bedding
- weathering and erosion
- rock hardness
- glaciers

Standards
PA Environment and Ecology
4.6.4b, 4.6.7b

PA Science and Technology
3.1.4b, 3.1.7b, 3.4.7a, 3.5.4a, 3.5.7a

NJ
5.1.9, 5.2.4, 5.10.2, 5.10.6

Vocabulary
Bedding, erratic, erosion, glacier, hardness, joint, pothole, sedimentary, striae, weathering.

Extension: Have students (and chaperones!) climb the trail to the top of Dingman’s Falls and observe the pothole formed there by the swirling water.
The Dirt on Dingmans

Overview
Through close observation of the components of topsoil, students will be introduced to the concept of soil composition and will be challenged to consider factors that affect soil characteristics and therefore vegetation communities.

Objectives
♦ Students will identify the composition of soil as weathered rock and decomposed organic materials.
♦ Students will describe how weathering and erosion have affected and continue to affect Dingmans Falls.
♦ Students will describe how plants and animals adapt to rocks and soil in their environment.

Materials
Magnifying glasses, journals or writing paper, pencils.

Procedure
1. Explain to students that they will be conducting an investigation to identify the different things that make up soil.
2. Place students into groups of twos or threes.
3. Space the groups out along the walkway reminding students that they should stay on the walkway.
4. Have students lay on their stomachs and peer over the edge of the walkway. This will help them get a better view of the soil.
5. Have students observe the soil below them and record the different materials that they see either by identifying it or drawing a picture.
6. Bring the class back together to discuss what each group observed. If groups found very different items, you may want to have each group lead the class to their spot on the walkway to see the different types of materials.
Like Water in a Bowl

Overview
Students will explore the bowl shaped rock faces at Dingmans Falls through a creative writing activity.

Objectives
♦ Students will describe how weathering and erosion have affected and continue to affect Dingmans Falls
♦ Students will role play as a geologist proposing a theory to explain an observation.

Materials
Pencil and paper.

Procedure
1. One of the exciting things about science is discovering the answers to questions that no one has answered before. Explain to students that for this activity, they should imagine that they are geologists trying to figure out why the walls of the ravine at the base of Dingmans Falls are rounded out into a bowl shape. Explain that their theories are neither right nor wrong, because geologists haven't answered this question yet.
2. Ask students to write a hypothesis about how the ravine got to be this shape.
3. Give students 5-10 minutes to write their theory down, then have students share what they wrote with the class.

Prior Knowledge
♦ sedimentary rock
♦ joints and bedding
♦ erosion and weathering
♦ rock hardness

Standards
PA Environment and Ecology
PA Science and Technology 3.4.7a
NJ Core Content Standards 5.1.9, 5.10.2, 5.12.1, 5.12.7

Vocabulary
Bedding, erosion, geologist, hypothesis, joints, sedimentary, theory, weathering.
Circles in the Soil

Overview
By systematically observing their surroundings, students will become aware of the many species of plants, animals and fungi that inhabit the Dingmans Ravine.

Objectives
- Students will observe and record organisms living in Dingmans Ravine.
- The students will describe how plants and animals adapt to rocks and soil in their environment.

Materials
Journals, pencils

Procedure
1. Explain to students and chaperones that this activity will be a silent activity. By sitting quietly (not talking and not moving around), they may get to see animals that live in the ravine but that most people don't see because they are hiding.
2. Explain to students that while they are sitting quietly, they should use their journal to record everything that they see. Ask them to first look around and write down all the things that they see or hear that are within an arm's length of where they are sitting.
3. Next, they should look all around and observe and record everything that they see or hear that is within a body length of where they are sitting.
4. Finally, they should look around and record the things that they observe that are within 20 feet of them. You will probably need to show students how far 20 feet is.
5. Remind students that their journals are their own and they should record their observations in the way that will best remind them of what they saw later. They could write a description, draw a picture, make a map showing where things are, or compose a poem or song.
6. Place students along the trail, far enough apart to discourage whispering and talking and give them 15 minutes to journal.
7. Bring the class back together and encourage students to share their observations.
The pH at Dingmans Ravine

Overview
Students will use cabbage water prepared in the classroom to test the pH of the soil and water at Dingmans Ravine.

Objectives
- Students will evaluate the pH of the soil and water at Dingmans Ravine.
- Students will describe how plants and animals adapt to rocks and soil in their environment.
- Students will describe how weathering and erosion have affected and continue to affect the soil in the Dingmans Ravine.

Materials
Cabbage water prepared in The Cabbage Juice Test, the pH Page.

Procedure
1. Have students predict whether the soil and water will be acidic or basic.
2. Have students use an empty jar to collect a water sample from Dingmans Creek. Students can access the creek at the end of the parking lot closest to the entrance.
3. Explain to students that Dingmans is a fragile ravine and that walking on the exposed soil can compact it or cause erosion. To help protect the ravine, ask students to stay on the boardwalk and to collect only enough soil to test the pH.
4. Ask one student to step off of the boardwalk and collect a small soil sample.
5. Have students test the pH of the sample using the procedure described in The Cabbage Juice Test.
6. Discuss their results. Why are the soil and water acidic?

Other Possibilities:
You can also use litmus paper or pool testing kits to measure pH. However, remember that anything that is not completely natural (including soil that was tested with chemicals) should be disposed of properly and not dumped in the park.

Samples tested with cabbage juice can be dumped onsite.

Prior Knowledge
- acids, bases and pH

Standards
PA Environment and Ecology
4.3.4c, 4.3.7c, 4.6.4a, 4.6.7a, 4.7.4b, 4.7.7b, 4.8.7d

PA Science and Technology
3.2.4b, 3.2.7b, 3.4.7a, 3.7.4b, 3.7.7b

NJ Core Content Standards
5.5.2, 5.6.11, 5.12.1, 5.12.7

Vocabulary
Acid, base, pH.
Aliens at the Falls

Overview
Dingmans Falls is under siege by the Hemlock Wooly Adelgid. Students will look for these exotic insect pests under the boughs of the Hemlock trees and will discuss the effect that losing the Hemlock trees would have on the ravine.

Objectives
♦ Students will identify the composition of soil as weathered rock and decomposed organic materials.
♦ Students will explain why non-native species are a problem.
♦ Students will describe how plants and animals adapt to their environment.

Materials
Journals

Procedure
1. Explain that the Hemlock trees at Dingmans may be up to 200 years old and have never been cut. Now they are in grave danger because of a tiny insect that sucks sap from the tree. Hemlock trees protect themselves from native insects by producing tannins to repel them, but the tiny adelgids are aliens. Hemlock Wooly Adelgids normally live in Asia, but were accidentally introduced to North America with a shipload of timber. Now, they are all over the northeastern United States, and in many Hemlock stands in the park.
2. Have students list ways that losing the Hemlocks would change Dingmans Ravine. Some possibilities include: won’t look as nice, hotter, more sun, change soil pH, change humidity, change rate of erosion; loss of habitat.
3. Ask students to think of ways to solve the problem. Explain that the park has an experimental program to release an adelgid predator. The predator should eat the adelgids, but it is also exotic. Ask students whether they think this is a good or bad way to solve the problem.
4. When you are back at school, have students write a letter to an imaginary Park Ranger explaining their opinion about the problem. (What do they think of the park’s program? How would they solve the problem?) You may want to put the letters on a bulletin board so that students can read each other’s ideas.
Grain Size Scale Activity Sheet

- Shale - very fine
- Siltstone - fine
- Sandstone - coarse
- Conglomerate - very coarse

- Shale - very fine
- Siltstone - fine
- Sandstone - coarse
- Conglomerate - very coarse
Eastern Hemlock trees are found in Northeasten Pennsylvania. They usually grow in acidic soil because they have tannins in their bark and needles, which help protect them from insects. It is the tannins that make the soil acidic.

1. Look at the plants that are growing near your school, near your house, at your teacher's house, and at Dingmans Falls. Predict whether the soil will be acidic or basic at each location:
   - At school
   - At your teacher's house
   - At your house
   - At Dingmans Ravine

2. Test a soil sample collected at each location. In the corresponding jars below, write what color the cabbage juice turned when the soil was added. Circle A if the soil is more acidic (pinkish) or B if it is more basic (bluish).

   ![Cylinders labeled Home, Teacher's, School, Dingmans with A and B options]

3. Were your predictions correct? Why or why not?

4. Now do the same acidity test on the water at Dingmans. What color is the water?

5. Compare the pH of the soil at Dingmans to the pH of the water. What did you find out?
Waterfall Wise

Silverthread Falls
1. Illustrate Silverthread Falls on a blank page in your journal.

2. Explain why you think Silverthread Falls has such steep sides.

Dingmans Falls
3. Illustrate Dingmans Falls in your field journal.

4. Compare and contrast Dingmans and Silverthread falls. Write a description of the similarities and differences.

Diagramming Waterfalls
5. Sometimes geologists use diagrams to create a simplified image of a feature that they observe. Look at the three diagrams and decide which one represents Dingmans Falls, which represents Silverthread Falls and which is neither. Label each diagram with the name of the waterfall that it represents and label the bedding layers and the joints on the diagrams.
Getting There:

From I-80: Take exit 309 (route 209N). Several miles north, you will come to a stoplight where route 209 and business 209 intersect. Make a right turn at the light to continue on route 209N through 3 additional stoplights and one blinking light. Once you enter the park, there will be mile markers. At mile marker 13, make a left turn onto Johnny Bee Road (the last left before the stoplight.) Follow the signs to Dingmans Falls.

From route 739:
Take route 209S and make the first right onto Johnny Bee Rd. Follow the signs to Dingmans Falls.

From Milford: Take route 209S going straight through the light at the intersection of routes 209 and 739. Make the first right after the light onto Johnny Bee Rd. Follow the signs to Dingmans Falls
Take Along Tips for Teachers:
Before the arrival of glaciers, this was a fairly level offshore area.

♦ Notice the large boulder to the right of the trail as you leave the parking lot. This is an erratic dropped by a glacier. Careful observation will reveal glacial striae (scratches) as well as a characteristic shape (rounded at the front, rougher in back).
♦ Look down at the creekbed and note two shapes of rocks - round sandstone and angular siltstone.
♦ Look for cracks at Silverthread Falls. The horizontal (or slightly slanting) cracks throughout the rock on either side of the falls are bedding layers. The vertical cracks seen to the right of the falls (and as straight walls within the falls) are joints.
♦ As you walk through the ravine, notice the U shape of the valley. A creek generally carves a V-shaped ravine. The U-shape indicates that the ravine has been shaped by glaciers.
♦ Look directly into the pool of water at the base of Dingmans Falls. Notice the joints in the rocks.
♦ From the viewing area at the top of the falls, notice the smooth, round curve polished into the rock. This is a pothole, formed when pebbles and sand settled in a small depression. Quickly moving, spiraling water swirled the pebbles and sand carving out the pothole.
Site 5: Haneys Mill
**PA Environment and Ecology Standards:**

4.1.4B Explain the difference between moving and still water.
4.1.7B Understand the role of the watershed.
4.8.7D Explain the importance of maintaining the natural resources at the local, state and national levels.

**PA Science and Technology Standards:**

3.1.4B Know models as useful simplifications of objects or processes.
3.1.7B Describe the use of models as an application of scientific or technological concepts.
3.2.4A Describe objects in the world using the five senses.
3.2.7A Apply process knowledge to make and interpret observations.
3.5.4A Know basic landforms and earth history.
3.5.7A Describe earth features and processes.
3.7.4B Select appropriate instruments to study materials.
3.7.7B Use appropriate instruments and apparatus to study materials.

**NJ Core Curriculum Content Standards:**

5.2.1 State a problem about the natural world in the form of a question.
5.5.2 Use a variety of measuring instruments, emphasizing appropriate units.
5.5.3 Use mathematical skills and concepts in ordering, counting, identifying, measuring and describing.
5.10.2 Identify materials that make up the earth, including rocks, minerals, soils, and fossils, and how they are formed.
5.10.6 Identify the major features of the earth's crust, the processes and events that change them, and the impacts of those changes on people.
Site 5: Haneys Mill

The unique rock formations at Haneys Mill provides a clue, challenging students to solve the mystery of how it formed. Before visiting the site, students will model mud cracks and will learn about which types of rock react with acids. Arriving at the site, students will examine the structure and composition of the ancient mud cracks, relating what they see to what they learned during the pre-visit activities. Returning to the classroom, students will consider how the climate has changed and will pack their suitcases for an imaginary trip to the past.

What are those things?
At Haneys Mill, an unusual rock outcrop dips into the edge of the Flatbrook Creek. The surface of this rock is angled, victim of tectonic collisions. What is striking, however, is the visible honeycomb pattern. This rock, more eloquently than most, whispers of a past in the muddy waters of a tropical sea.

The rock is limestone, formed as the tides advanced and retreated, depositing layer after layer of sediment on a shallow mudflat. Fine bedding layers, visible in the rock, tell the sea's story, just as rings in a tree trunk tell the history of the tree. Slight differences in the layers are probably due to changes in the sea as stormy weather made the waves more violent and clear weather returned them to gently lapping at the shore.

The sediments that were deposited were composed of broken seashells and tiny calcareous organisms. Because the rock is composed of calcite, it will react when tested with acid. When visiting the site, we ask that you not put acid, even vinegar, on the rock formation itself; however, as you walk from the parking area towards the formation, you will see several pieces of limestone on your right. An acid test could be conducted on one of these limestone pieces.

The surface of the rock seems to be sectioned into polygons. What you are seeing are ancient mud cracks that were preserved when the sediments turned to rock. The polygonal structures are known as desiccation columns. Because they were caused by cracking of the sediment and not by the action of organisms, they are not considered to be fossils.

Haney's Mills
Cracked Up

Overview
Students will make "mud cracks," learning that sediments sometimes crack as they dry.

Objectives
- Students will compare the shape of the polygons to the shape of the mudcracks made in the classroom.
- Students will observe and record the structure of mudcracks.

Materials
Brownie recipe, baking pan.

Procedure
1. Explain to students that scientists sometimes model processes in order to understand them better. In this activity, students will be modelling the formation of mudcracks.
2. Pick a favorite brownie recipe, one that cracks on the top when it bakes. Have students bake the brownies, then, before eating them, ask students to draw a diagram of the cracks on the top of the brownies.
3. Ask students why they think the brownies cracked (they cracked as they dried out.)
4. Ask students to think of examples of other things that crack as they dry. Some possibilities include paint, playdoh,™ pound cake, vinyl car seats, old glue, cement, walnut hulls...
5. Show students the photo of mud cracks. Ask them to compare the shape of the cracks in the mud to the shape of the cracks on the brownies. How many sides do the polygons formed by the cracks have?

Extension: Have students cut out polygons with different numbers of sides - pentagons, hexagons, heptagons, octagons... Ask them to figure out which shapes nest together the best. They can do this either by manipulating several pieces that are the same shape or by tracing the shape.

Prior Knowledge
- sedimentary rocks
- water sorting

Standards
PA Environment and Ecology
PA Science and Technology
3.1.4b, 3.1.7b
NJ Core Content Standards

Vocabulary
Dessication column, layering, polygon, sedimentary.
Cabbage Water Prep

Overview
Students will prepare cabbage water for pH tests while on their fieldtrip.

Objectives
♦ The students will prepare cabbage water to use to test pH.

Materials
Red cabbage, distilled water, knife, chopping board, sauce pan, pitcher, jars (baby food size is fine), sieve.

Procedure
1. Assign students to find out whether their drinking water at home is well water or municipal water and ask each student to bring in a small water sample from home.

   After students have brought in their samples, prepare the cabbage juice:
2. Cut the cabbage in half. Because this will require a sharp knife, the teacher should complete this step.
3. Soak 1/2 of the cabbage in distilled water for 30min.
4. Drain the water from the cabbage into a pitcher.
5. Pour the cabbage water into the jars until each is 1/4 full. Make sure that you prepare 1 jar for each sample that you intend to test.
6. Have students practice using the cabbage water test by testing the samples that they brought in from home. To test a sample, add the sample water to the jar until it is half full.
7. Prepare a control jar for comparisons by using distilled water instead of a sample.
8. Have students compare the color of each sample to the control. If the water stays pinkish, the sample is acidic. If the water becomes bluish, the sample is basic.
9. Have students record their results and graph the class' results on the blackboard or on a large sheet of graph paper.
10. Don’t forget to pack several jars of cabbage water to take with you on your fieldtrip.

Since the cabbage water is natural, you can dump everything at the site or you can safely dump it down the drain. However, make sure that you remove all cabbage pieces before putting it down the drain so the drain doesn’t clog.

Prior Knowledge
♦ properties of rocks
♦ pH
♦ sedimentary rocks

Standards
PA Environment and Ecology
PA Science and Technology
3.2.4a, 3.2.7a, 3.7.4b, 3.7.7b
NJ Core Content Standards
5.5.2

Vocabulary
Acid, base, pH, properties.
Prior Knowledge

- properties of rocks
- sedimentary rocks
- acids and bases

What Kind of Rock is That?

Overview
Students will use a weak acid to test the reactivity of the rock found at the Haneys Mill site to identify the rock as limestone.

Objectives
- Students will identify limestone using an acid test.

Materials
Vinegar, limestone tile or seashell, sandpaper, eye dropper.

Procedure
1. Have students lightly sand a portion of the limestone tile or seashell and wipe off the dust.
2. Using an eye dropper, have them put several drops of vinegar on the sanded surface.
3. Tell students to observe what happens. Bubbles forming on the tile indicate a chemical reaction.
4. Have them record their results on a piece of paper.
5. Discuss the results of the experiment with the class. If a weak acid reacts with lime and this tile reacts when exposed to vinegar (an acid), what kind of rock is this? (limestone)
6. You may also want to have students experiment with the other tiles or with other rock samples that you have in your classroom.
7. When you get to Haneys Mill, remind students that they know one way to identify rock. Find the limestone on the right of the path to the mud cracks. Have students test this rock to determine its composition (limestone.)
8. Don’t forget to remind students that they are in a National Park and should behave accordingly. While they may test the rock along the trail, they should not put acid on the mud crack formation itself.

Standards
PA Environment and Ecology
4.8.7d

PA Science and Technology
3.5.4a, 3.5.7a, 3.7.4b, 3.7.7b

NJ Core Content Standards
5.2.1, 5.5.2, 5.10.2, 5.10.6

Vocabulary
Acid, base, pH, properites.
Mud Column Measurements

Overview
A data collection activity will guide students to carefully observe the dessication columns found at Haneyes Mill.

Objectives
- Students will observe and record the structure of desiccated columns or polygons of limestone.
- Students will measure the height and width of the polygons and calculate an average polygon size.
- Students will compare the shape of the polygons to the shape of the “mudcracks” made in the classroom and the picture of cracked mud.
- Students will use data collected onsite to predict how dessication columns form.

Materials
*Measuring Mud Columns* activity sheets, rulers, pencils, crayons.

Procedure
1. Have students use a ruler to measure the short width of 8 different mud columns (see figure at right) and record their measurements on the activity sheet.
2. Repeat steps 1-3, measuring the long width of the columns.
3. Have students calculate the average size of the measured mud columns.
4. Have students use crayons to make rubbings of the mud columns on the back of the *Measuring Mud Columns* activity sheet. Also, have them make a rubbing of the layers. You may have to help students find a good spot for the rubbings. In some areas the edges stand out in good relief, while in others the rock is worn relatively smooth.
5. Discuss the results with the students. Are the cracks all the same size or are they different? Why?

Prior Knowledge
- sedimentary rocks
- mud cracks

Standards
PA Environment and Ecology
4.8.7d

PA Science and Technology
3.2.4a, 3.2.7a, 3.5.4a, 3.5.7a, 3.7.4b, 3.7.7b

NJ Core Content Standards
5.2.1, 5.5.2, 5.5.3, 5.10.2, 5.10.6

Vocabulary
Column, dessication column, layering, properties, polygon, sedimentary.
What are these Things?

Overview
The class will discuss how the dessication columns formed and will consider whether similar rocks could form at this site today.

Objectives
♦ Students will use data collected at the site to predict the environment in which the dessication columns were formed.
♦ Students will recognize that the local environment has changed since the time when the dessication columns formed.

Materials
none

Procedure
1. After students have tested the rock and determined that it is limestone and have carefully examined the cracks, ask them to think about how they got here.
2. Ask students where they think the mud came from. In this case, the mud is very small particles of shells, and not the same as the mud in their backyards.
3. Discuss with the group how

Prior Knowledge
♦ sedimentary rocks
♦ properties of rocks
♦ water sorting
♦ stream characteristics
♦ climate change

Standards
PA Environment and Ecology
4.8.7d

PA Science and Technology
3.2.4a, 3.2.7a, 3.5.4a, 3.5.7a, 3.7.4b, 3.7.7b

NJ Core Content Standards
5.2.1, 5.5.2, 5.10.2, 5.10.6

Vocabulary
Column, dessication column, layering, pH, polygon, sedimentary, wave.
What's Happening Now?

Overview
Students will collect data about the pH, temperature and rate of flow of Flatbrook Creek and will consider whether desiccation columns might be forming at Haneys Mills right now.

Objectives
* Students will measure rate of flow, temperature and pH of Flatbrook creek.
* Students will use data collected at the site to predict the environment in which the desiccation columns formed.

Materials
Cabbage water, orange, tape measure, stopwatch, thermometer, calculator, net.

Procedure
1. Tell students that they will be collecting data about the creek that they can use to figure out whether the creek laid the sediments in these formations or not. Explain that since the formation is found on the edge of the water, the water might have something to do with how it formed.
2. Ask students what water characteristics might affect the rock. Students will probably suggest characteristics such as how fast the water moves, and might also suggest the water temperature and pH.
3. Break students into groups of 4 and have them pick one person to measure each characteristic - flow, temperature, & pH, and one to record their data.
4. Give each group a set of "What's Happening?" Activity Sheets.

Extension: If you are also visiting Lake Lenape, consider having students compare the pH, temperature and flow of Flatbrook Creek to that of Lake Lenape.

Prior Knowledge
* stream characteristics

Standards
PA Environment and Ecology
4.1.4b, 4.1.7b

PA Science and Technology
3.5.4a, 3.5.7a, 3.7.4b, 3.7.7b

NJ Core Content Standards
5.2.1, 5.5.2, 5.10.2, 5.10.6

Vocabulary
Layering, sedimentary, wave.
A Trip to the Past

Overview
Students will synthesize the information that they learned on their field trip and use it to pack for a vacation to the past.

Objectives
♦ Students will recognize that the local environment has changed since the time when the dessication columns formed.

Materials
Paper and pencils.

Procedure
1. Explain to students that rocks sometimes preserve information about what the environment was once like. Challenge students to think about what the rocks at Haney's Mill teach us about what the environment was like when the rocks were forming. Students should come up with suggestions such as: there was water, it was muddy, it was on the edge of the ocean.
2. Ask students to think of places that they could go today to find a similar environment.
3. Challenge students to imagine that they are packing for a time-travelling trip to the ocean at Haney's Mill. Have them think of what kinds of things they would pack for their trip. There are several ways to do this:
   ♦ You could have students do a creative writing or drawing exercise about what they will pack.
   ♦ You could ask each student to bring one item from home to add to a class suitcase. Display the class suitcase in the classroom or in a display case explaining that it was packed for a trip to the past.
   ♦ Play a game of “I'm going on a trip...” with the students. Have each student think of one item that they would pack to travel to the past and challenge them to remember what items their classmates are planning to bring.
**Mud Column Measurements Activity Sheet**

Pick eight different dessication columns. For each one, record the number of sides, the distance across it in the longest direction (to the nearest mm) and the distance across in the short direction (to the nearest mm.)

<table>
<thead>
<tr>
<th>Number of Sides</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>2</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>3</td>
<td>______</td>
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<td>4</td>
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<td>5</td>
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</tr>
<tr>
<td>6</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>7</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>8</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>

Add up the lengths of all eight columns and divide the total by 8. This is the average length.

Add up the widths of all eight columns and divide the total by 8. This is the average width of a column.

Pick a dessication column and make a rubbing of it on the back of this paper.

Find a place where the layers of the rock are visible and make a rubbing of it on the back of the page.
What's Happening Now? Activity Sheet

In this activity you will be collecting data about the pH, temperature and rate of flow of water. Follow the directions carefully and record your data below.

What is the name of your study site? ________________________________

**Water Temperature:**
Use the thermometer in your kit to measure the temperature of the water.

Water Temperature = __________________________ degrees Fahrenheit

**pH:**
Use the cabbage water and jars to test the acidity of the water.

What color is the water? ________________________________

Is the water more acidic or more basic? ________________________________

**Rate of Flow:**
To calculate the rate of flow, you will be timing how long it takes a stick (or an orange) to float downstream. Pick one group member to put the orange in the creek and have him or her stand on the bank upstream. Pick a second person to retrieve the orange at the bottom and have them stand somewhere downstream. Measure the distance between the person putting the orange in and the person retrieving the orange.

What is the distance? ____________ ft.

Have the upstream person place the orange in the water. As soon as the orange is in the water, start the stopwatch. Stop the stopwatch when the orange reaches the retrieving person. Remember, the retriever should wait for the orange to come all the way down to his or her location. Try to collect the orange. A net could come in handy.

How long did it take to float downstream? ______________ sec.

Divide distance by time to figure out the rate of the water.

\[
\frac{\text{distance}}{\text{time}} = \text{ft. per sec}
\]
Getting There:
This site is unmarked and is difficult to find. We recommend meeting a ranger.

From the North: Take route 209S to just south of Milford, turn left onto route 206 and cross the bridge. (No toll in this direction.) Make the first right onto the Old Mine Road (1 mile.) Take Old Mine Road south, crossing route 560 after 7 miles. 6.66 miles south of the intersection with route 560, the road will fork - go to the left. 1.2 miles past the fork, you will see an old farm complex on the left; the barn has red knobs on the roof. Make a left on the third dirt road after this farm (0.8 miles past the farm).

From I-80: Take exit 1 in New Jersey and get onto the Old Mine Road. Travel north on the Old Mine Road to the bridge over Flatbrook Creek. Turn right after the bridge. Haney’s Mills is 3.2 miles north on the right hand side.

Take Along Tips for Teachers:

- The limestone rock formations you are observing next to the creek were formed in a very shallow tidal area.
- The mud dried, hardened, and cracked and was later covered by a new layer of mud that also dried, hardened and cracked. This process was repeated often.
- These formations are referred to as desiccation columns. Notice that many of them contain veins of calcite.
**Glossary**

**A**

**Acid:** a chemical compound that tastes sour and forms a water solution that turns litmus paper red.

**Acidity:** the quality, state, or degree of being acid.

**Adapt:** to adjust to the environment.

**Adaptation:** a characteristic of an organism that helps it survive in its habitat.

**Alien (as in alien species):** foreign; not native

**Anticline:** a fold that bends upward

**Aquatic:** growing, living or done in water

**Asteroid:** Orbiting small bodies believed to be either fragments of a disintegrated planet or of matter that never completed the planet forming process.

**B**

**Base:** a chemical substance (like lime or ammonia) that reacts with an acid to form a salt and turns red litmus paper blue.

**Bedding:** layers in rocks and deposits.

**C**

**Cast:** a fossil formed when minerals fill in a space in a rock where an organism or some evidence of its passing once was.

**Cemetery:** a place where dead people are buried.

**Chemical Weathering:** weakening of rock in which the composition of the rock is changed

**Cleavage:** the tendency of a rock or mineral to split readily in one or more directions.

**Compound:** a substance that is made up of more than one element.

**Conglomerate:** a rock formed of fragments.

**Controversy:** a disagreement about something about which there is a great difference of opinion.

**Convex:** rounded like the outside of a ball or circle.

**Crater:** 1. a hollow in the shape of a bowl around the opening of a volcano or geiser. 2. a hole (as in the surface of the earth or the moon) formed by an impact (as of a meteorite).
Crystal: a repeating pattern of particles that make up minerals.

Dessication Column: cracked mud that has turned to rock
Dip: to slope downward.
Direction: the path along which something moves, lies or points.
Dolomite: 1. a mineral. 2. a rock name for formations composed largely of the mineral dolomite.
Drift: any material laid down directly by ice or deposited in lakes, oceans or streams as a result of glacial activity.

Ecosystem: the whole group of living and nonliving things that make up an environment and affect each other.
Eminent Domain: a right of a government to take private property for public use.
Epitaph: a brief statement on a tombstone in memory of a dead person.
Erode: to eat into, wear away or destroy by wearing away.
Erosion: the act of eroding; the state of being eroded.
Erratic: a stone or boulder, glacially transported from one place and left in an area with a different bedrock composition.
Exotic: introduced from a foreign country or area.

Facies Fossil: a fossil that is a good indicator of a past environment.
Flow Rate: the speed that water is flowing.
Fold: 1. a part doubled or laid over another part. 2. bend.
Fossil: a trace or print of the remains of a plant or animal preserved in earth or rock.

Gap: a break in a mountain where a river flows through or once flowed through.
Geologist: a person who is an expert in geology.
Geology: 1. a science that deals with the history of the earth and its life, especially as recorded in rocks. 2. the geological features of an area.
Glacial: 1. very cold. 2. the geological features of an area.
Glacier: a huge amount of ice moving slowly down a slope or over a wide area of land.
Gneiss: a metamorphic rock commonly formed by metamorphism of granite.
Grain: a small hard particle.
Granite: a very hard gray or pink igneous rock, much used for buildings and monuments. Granite is made of crystals of several different minerals and is formed when lava cools slowly.

Habitat: a place where an organism lives.
Hardness: a mineral's ability to resist being scratched on a smooth surface.
Hypothesis: 1. a well formed guess. 2. a prediction.

Ice Wedging: the process of breaking something apart that occurs when water freezes and expands.
Igneous: a type of rock formed from the cooling of melted rock material.
Index Fossil: a fossil that is useful in dating and relating rocks.
Insect: a small, often winged animal that has six jointed legs and a body formed of three parts.

Joint: a break or fracture in a rock.

Kettle: a depression in ground surface formed by melting of a block of ice buried or partially buried by glacial drift, either outwash or till.
Lake: a body of water surrounded by land.
Landslide: the slipping down of a mass of rocks or earth on a steep slope.
Larvae: a wingless form (as a grub or caterpillar) in which many insects hatch from the egg.
Layers: one thickness of something laid over another.
Limestone: a sedimentary rock composed largely of mineral calcite.

Magma: hot melted rock and gases deep inside the earth.
Marble: metamorphic rock or granular texture, with no rock cleavage, and composed of calcite, dolomite or both.
Metamorphic: a type of rock formed when heat and pressure change other rocks.
Mineral: a substance that is the same throughout and which has a crystalline structure.
Model: to follow as a pattern or example.
Moh’s hardness scale: a scale used to measure the hardness of rock.
Mold: an imprint in a rock where an organism or some evidence of an organism once was.
Moraine: a mound of rocks, gravel and sand deposited by a glacier.

Observation: the gathering of information by noting facts or occurrences.

Parameter: any of a set of properties whose values determine the characteristics or behaviors of something.
PH: a number used to describe acidity or alkalinity on a scale whose values run from 0-10, with 7 representing neutrality. Numbers less than 7 indicate acidity and numbers greater than 7 indicate alkalinity.
Physical Weathering: the weakening of rock by processes that do not change its composition.

Plate: one of the large, drifting sections which make up the earth’s surface.

Plate tectonics: movement and interactions of the rigid plates that make up the earth’s surface.

Plucking: the process by which a glacier picks up rocks by freezing around them and then pulling them along.

Polygon: a shape that has three or more straight sides.

Pothole: a deep round hole (as in a stream bed or road).

Ridge: a range of hills or mountains.

Rock: a mixture of one or more minerals cemented together.

Sandstone: a sedimentary rock made of sand that is held together by a natural cement.

Scratch Test: a test used to determine the hardness of a rock or mineral.

Sedimentary: a type of rock that is made from the weathered pieces of rock that have been transported, deposited and stuck together.

Shale: a sedimentary rock with a very fine grain.

Siltstone: a sedimentary rock made of fine grains of silt.

Soil composition: the different items that make up soil.

Soil: a combination of weathered rocks and minerals, dead plants and animals, water and air.

Squatter: a person who settles on land that they do not own.

Stream: a body of water (as a brook or a river) flowing on the earth.

Striae/Striations: scratches, or small channels, carved by glacial action. Striations along bedrock surfaces are oriented in the direction of ice flow across that surface.

Syncline: a fold that convexes downward.

Talus: an apron of rocks at the base of a rock outcrop, formed when pieces break off the rock face and fall into a pile.
Temperature: a measure of how hot or cold a place or object is.
Theory: 1. an explanation of something based on observation and reasoning. 2. an idea or opinion about something. 3. a general rule used to explain experiences or facts.
Till: unsorted material deposited by a glacier.
Trace Fossils: fossilized scat, tracks, burrows and other evidence of where an organism once was.

Valley: an area of low land between ranges of hills and mountains.
Valley Glacier: a smaller glacier that's movement is controlled by the terrain.
Volcano: a type of mountain that has an opening at the top through which lava, ash or other types of volcanic rock flows.

Weathering: the process of wind, water, ice, chemical changes or other factors that break rock into pieces or wear rock away.
Suggested Readings

Activity Books

Teacher Resource Books
Children's Literature


Web Sites

USGS Geology in the Parks