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The National Parks: Teaching the Geology of America

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by Lois Van Wagner

As a teacher of eighth-grade Earth Science I find that much of what I am teaching is best exemplified by one National Park or another. Many of the films and videos available for classroom use have location spots featuring the parks and even the texts use photographs, illustrations, and written material based on the National Parks. Since one of the purposes of the park system is to preserve in their natural state the various structures and landforms of geologic process and to develop interpretive materials for those formations there is a wealth of resources available for an Earth Science teacher.

My objectives in this unit are:

a. to present introductory geologic terminology and concepts;
b. to develop an understanding of those terms using specific examples found in the National Parks;
c. to develop an understanding in the student of the vastness and diversity of our geologic resources;
d. to provide activities and demonstrations to reinforce understanding of the scientific principles illustrated by geologic process;
e. to instill an appreciation of the value of the National Parks and a sense of pride in their collective ownership of the Parks.

In order to make the learning of the geologic information manageable and orderly I have divided the unit into four major headings; Vulcanism, The Mobile Crust, Erosional Forces, and Social Implications of the Parks. As sub-headings within these areas I have introduced terminology, selected representative parks, and developed classroom activities. As might be expected many of the parks could be outstanding representatives of several different processes and too there are many parks that are outstanding examples of specific processes which will not be used here. The scope of the unit (and of the school-year) simply cannot address all that the parks have have to offer nor all the parks that the System has to offer! I have attempted to develop my unit around the parks which are most familiar and popular, such as Yellowstone, Hawaii Volcanoes, Grand Tetons, and Yosemite. However, in order to be as geologically representative as possible I have included some of the lesser known parks, such as Lassen Volcanic, Craters of the Moon, and Great Sand Dunes. Additionally I have included some of my own particular favorites: Great Basin, Bryce Canyon, and Devil's Tower.

This unit addresses the middle school level student, specifically in an Earth Science curriculum, and will require approximately six to eight weeks to complete. The students should already have a basic knowledge of types of rocks and the concept of plate tectonics.

Vulcanism

Deep inside the Earth molten rock exists under tremendous pressure and extremely high temperatures. This molten rock or magma is able to move following the laws of pressure and convection. Because of this we sometimes are able to see this magma break out of its entrapping crust in the form of lava, cinders, ash and gases. The term lava includes substances of several Suite different descriptions and actions. One type called basaltic lava has a high percentage of water and is quite dark in color. It is thin and runny in composition and usually flows easily from a volcano in fairly level pools, however it can shoot upward in dramatic fountains. The other common type of lava has much less water and is light in color. It has the mineral silica in it and is often called granitic or silicic lava. This lava does not flow easily, it hardens in its vents until enough pressure is built up for it to burst explosively from its chamber. This violent explosion shatters and pulverizes the hardened lava into dust, ash, and cinders. The type of lava determines the type of volcanic cone manifested by the eruption. The smoothly flowing basaltic lava produces a gently sloping shield cone. The more violent eruptions of cinders, and ash build steep-sided cones called cinder cones. And if the type of eruptions alternates between cinders and basalt lava a composite cone is formed, also with sloping sides.

In addition to the dramatic displays of lava eruptions, the interior heat of the Earth can heat ground water and produce some very spectacular results. Because of the extremely high temperatures of magma-heated rock and the extremely high pressures caused by the weight of the overlying rock layers and water, the water in the porous rock can reach temperatures of 500°F without boiling (similar to the action of a pressure cooker). This superheated water is less dense than the newly arriving cool water in the system and moves upward, floating in a sense on the cold water. If it mixes with some cool water as it rises it may not boil at all, but flow out of its vents gently as a hot spring. If the opening of the hot spring is surrounded by soft, weathered soil it will make a fine mud which can bubble and pop like chocolate pudding on the stove. A third possibility is that the superheated water is restrained by narrow passages until the pressure becomes so great a small amount of the water bursts out, momentarily reducing the pressure on the remaining water which allows it to suddenly vaporize (boil), expand enormously and shoot out of the narrow opening in a rush as a geyser. As more water escapes the pressure on the remaining water decreases allowing more vaporization and more eruption of hot water and steam. This can go on for minutes, or hours, depending on the size of the underground system and the amount of water it holds.

Some other terms to become familiar with are: active, dormant, and extinct volcanoes. An active volcano has been defined by some sources as one that has erupted within the last 10,000 years. A dormant volcano maintains its potential for eruption but has not done so in historical memory. An extinct volcano is one which has lost its heat source and is never expected to erupt again.

Hawaii Volcanoes National Park is an outstanding example of a basaltic lava volcano area. Within this park we find the world's of the world's most active volcanoes, Kilauea, and the towering Mauna Loa with an elevation of 13,680 ft. above sea level. Hawaiian volcanoes are shield cones that have formed over a hot spot in the Earth's crust. This hot spot is fed by a plume of molten material rising from deep inside the mantle. Interestingly this plume is a stationary feature over which the Pacific crustal plate moves in a northwesterly direction. This resulted in the formation of a 1,500 mile chain of volcanic islands poking up from the ocean floor along a northwest-southeast axis. The most recent of these islands is Hawaii approximately 700,000 years of age. The most distant island is about 70 million years of age. In addition to the many islands there are an additional 2,000 miles of submerged seamounts attributed to the same source. And when scientists examined the ocean floor by means of submersibles they discovered the beginnings of a new island forming off the south-east coast of Hawaii. It is expected to break the surface in a mere 10,000 years!

Hawaii Volcanoes National Park is an ideal park to start with as its movies. Between the excitement of the fountaining lava and the glamour of the island itself the students are bound to be "caught" by the lesson. An excellent video resource is the television program "Discover; the World of Science" which has an entire program on Hawaii and features the Kilauea volcano in eruption, a very brave scientist walking on newly hardened lava, and information on Loihi, the next up-and-coming island in the chain.

Lassen Volcanic National Park is located in northern California and is part of the Cascade Range of mountains that have formed as a result of the subduction of the Juan de Fuca plate under the American plate. These mountains are set back about 100 miles from the subduction boundary and the magma rises over sixty miles from beneath the surface before it breaks through to form its cone. As the magma travels through this continental layer it is modified and its composition changes to a more granitic rock. This results in the formation of cinder or composite cones. Lassen has been active in this century, erupting with a series of spectacular displays in 1914 which continued on and off for a few years. In 1915 one explosion reached heights of seven miles and spread ash as far as 200 miles away.

Today the visitor to Lassen can see thermal steam, a cinder cone, and a caldera, the remains of a collapsed volcanic crater. The volcano which gives the park its name, Lassen Peak, stands at 10,457 feet and has not erupted since 1921 although it is still considered active.

Moving away from the Cascade Range across Idaho and into Wyoming we see a continuum of volcanic features protected by National Park status. These parks are Craters of the Moon, relatively unknown, and Yellowstone, perhaps the most famous of all the parks.

These two parks are related both by volcanic features and by possible geologic origin. It is believed that the entire Snake River Plain in Idaho formed over a hot spot which now lies beneath the northwestern corner of Wyoming. Although Yellowstone is now perched atop the hot spot's plume the most recent eruptions occurred just 2,000 years ago in Idaho at Craters of the Moon! This may be due to lingering reservoirs of magma still hot beneath the overlying layers. Scientists feel that the potential for further eruption still exists.

Craters of the Moon park is unique because of its basaltic flows ranging over 600 square miles emanating from a 48 mile long region of parallel fractures known as the Great Rift. These fractures trace a path which formed as the American plate moved in a southwesterly direction in that area.

Another interesting feature to be seen in this park are lava tube caves. These formed when molten lava moved across the land's surface like a river. The upper and side surfaces gradually cooled and formed tunnels through which liquid lava moved. As the lava source ran out of substance it left cooled and hardened passageways behind. These caves can be explored and studied with a flashlight and some courage.

Yellowstone, the premier of parks, illustrates so many geologic concepts that one could almost use it exclusively, but then we would miss the fun of learning about the other parks, and about the geologic history of other American regions. And so I have chosen to focus on only two specific concepts here, the Yellowstone caldera and the geothermal features of the park.

A visitor to Yellowstone today could spend a pleasant vacation there and never know that they were wandering inside a caldera with a good potential for eruption! Although surrounded by geysers and hot springs these things seem tamed and predictable (“Old Faithful” comes to mind). What is less well understood is that eruptions occurring over the last two million years have resulted in a huge caldera which occupies about one-third of the park’s area. The first of three major events was also the most cataclysmic with the release of 620 cubic miles of ash. A granitic-type of rock called rhyolite had accumulated in a blister-like magma chamber. After the material in the chamber had escaped by violent eruption the roof of the structure collapsed inward sinking many thousands of feet and encompassing a huge area forty miles long by thirty miles wide.

A second event occurred 1.2 million years ago and a third only 600,000 years ago. That eruption released about 250 cubic miles of ash (about 1,000 times that released by the eruption of Mt. St Helens). It is interesting to note that the events have been spaced approximately 600,000 years apart with the last eruption occurring just that length of time ago! It might be an interesting discussion to focus on how such and event might affect the student personally.

Some of Yellowstone’s most intriguing features are geothermals. Most of the children will be familiar with geysers and some may have heard of the hot springs. The mud pots or mud volcanoes are usually not known to them but do seem to catch their imaginations.

The mechanics of geothermal features have already been addressed so the children should be ready to review this as they view pictures (old calendars are great resources here), videos (several suggestions can be found in the Appendix), or filmstrips. Using the Yellowstone Park pamphlet map to locate the various geyser basins, mud pot areas, and hot springs and then relating those locations to the caldera boundaries is a valuable exercise.

The final park in our vulcanism study also represents the final stage in the vulcanism story. It is Devil’s Tower in the north-east corner of Wyoming. This structure is not actually a volcano but rather an igneous intrusion that cooled and hardened while still buried under many layers of sedimentary rock. Over many millions of years the softer outer rock eroded away revealing the harder inner plug. This central neck is distinguished by its column ar basalt jointing. The columns form when molten rock cools and shrinks into five or six-sided shapes. Some of the columns of Devil’s Tower are truly extraordinary as they can be 15 feet in diameter and extend upward 865 feet. Many of the students will remember that the movie “Close Encounters of the Third Kind” featured Devil’s Tower and they become quite excited discussing this particular formation. Brief clips from the film could be shown as reinforcement.

In the Appendix you will find several activities to use with students to enhance their understanding of appropriate science principles, and drawing and mapping.

The Mobile Crust

The relatively thin crust of the earth is constantly and slowly changing. The geologic record tells us much about these changes that have moved continents, formed mountain ranges, created seas, and carved canyons. One of the most complex concepts is that of crustal uplift. As the science of geology matured, and with the advent of seismographic studies and satellite imaging a new picture of earth came clear. Scientists began to study the interior of the earth, regions in the mantle and discovered convection currents, and thermal plumes. These gigantic movements inside the earth were resulting in movements of the surface of earth.

When a large layered area is lifted up into a plateau vertical cracks form called joints. When material is eroded away from parallel joints it leaves long narrow rows of rock called fins. And the layers themselves form horizontal weaknesses called bedding planes, which allows lateral erosion resulting in undercutting.

Other crustal bulges were found to be caused by the movement of magma up through cracks in the rock layers, sometimes forcing its way out of the confining rock, but sometimes not able to escape. The trapped magma by exerting its considerable pressure then might lift up a large blister in the crust called a dome.

As time goes by the magma in the dome can cool and harden. Softer layers of rock overlaying the batholith can wear away leaving concentric rings (or ovals) of mountains with a resistant central granitic core.

Another result of the stresses on the crust is faulting. Faults can be categorized by their relative movements. In normal faults the rocks above the fault line move down compared to those below the fault line. In thrust faults the rock above the fault line move upward, sometimes even overlapping the lower layers of rock. From these movements we derive both fault-block mountains, mountains formed by blocks of rock lifted up by a series of normal faults, and rift valleys, which form when the land between two normal faults sinks downward.

(figure available in print form)

If the lateral movement in the crust is slow and caused by exceptionally strong forces, or if the rock layers become extremely hot during compression, or if the rock is of a flexible nature rather than brittle it may bend and fold instead of break (fault). This is especially likely to occur along colliding plate boundaries. The result is often a series of parallel ridges or ranges.

(figure available in print form)

In the National Parks we can see excellent examples of crustal mobility. In Grand Canyon, Zion, and Bryce Canyon we see unique erosional forms that are the result of gradual uplift which began about thirteen million years ago. The upward movement was greatest at the southern end resulting in a northward downtilt. The total uplift is over 10,000 feet (and still growing!). Due to the angle of uplift the layers of rock take on the appearance of stair steps and have acquired the name “the Grand Staircase”.

(figure available in print form)

The Grand Canyon is the bottom step in the staircase. Its upper layer known as the Kaibab plateau is 225 million years old. If we examine the deepest regions of the canyon we would find incredibly ancient rock, some almost 2 billion years old. It is difficult for children to understand that the Colorado River cut down through rock layers in response to the land’s uplifting, that the river was only part of the canyon-cutting story. The melting snow, falling rain, alternating hot and cold, frost and ice all worked their efforts on the side walls to form the average nine-mile wide and 277 mile length of canyon. Since rain falling on the north side flows into the canyon and that falling on the south side flows away from the canyon the North Rim has been cut back twice as far as the South Rim.

Moving northward up the staircase we pass the Belted Cliffs, red and brown sandstones and shale, and the Vermillion Cliffs, some of the most richly colored beds of sandstone, shale, and limestone in Utah, which extend into Zion National Park.

Zion is renown for its massive White Cliffs, which inspired awe in the early settlers as well as the modern tourist. These towering cliffs of Navajo sandstone bear names like West Temple, Great White Throne, and Tabernacle Dome, all reflecting the majesty attributed to them by their names. These cliffs are among the tallest cliffs in the Staircase with heights up to 2,000 vertical feet. The Navajo sandstone is in reality not white, but rather the lower half is a light red and the upper half is tan. In bright sunshine the contrast of the two colors makes the tan area appear white.

Other interesting features seen in Zion are the swirling angular beds of rock that were formed from wind-blown sediments that accumulated between 135 to 165 million years ago, possibly carried in from a desert that lay to the west. The children will probably be most intrigued by Checkerboard Mesa, because of the name and the appearance of that formation. It is the result of erosion along both the bedding planes and vertical surface cracks. The chunks of rock that eventually fall off are fairly thin, usually six to thirteen inches thick, and the erosion is only “skin-deep”.

The final step in our journey up the “Grand Staircase” carries us over the Gray Cliffs, soft sandstones and shales that have been heavily eroded and on into the most delightful of parks, Bryce Canyon.

Bryce is not well known but to those who have seen pictures or who have had the opportunity to visit, it is unforgettable. It is the youngest of the series of steps, its oldest layers are only 100 million years old. During its geologic history the Bryce Canyon area has been a sea, a seashore, a coastal plain, and a lake bottom. The amazing shapes to be seen there now are a result of differential erosion, weaknesses in the sedimentary layers along bedding planes and vertical joints. The equally amazing coloration comes from the variety of minerals that have oxidized there. The reds of the Pink Cliffs come from iron oxidized to hemitite, the yellows from limonite, manganese oxide produces shades of blue, purple and lavender, and limestone provides areas of white. Unfortunately these colors are somewhat masked by a thin layer of reddish-brown clay but the visual effect is still astonishing.

The most extraordinary formations are the pinnacles. They begin when parallel joints are heavily eroded leaving narrow vertical fins of rock. These ridges are subjected to weathering from both sides and the softest areas of rock fall away forming first “windows” and finally isolated pinnacles. These pinnacles continue to erode into bizarre shapes that inspire fanciful names like Fairy Castle, Queen’s Garden, The Cathedral, the Alligator, and Queen Victoria.

Although Bryce and Zion both have examples of arches, there is a park dedicated to the preservation of an area even more rich in that particular formation. Arches National Park in Utah has more arches and windows than anywhere else in this country. The arch forms when an isolated fin of sandstone is attacked by water and frost, and undercutting of softer areas on the fin causes first perforation and then enlargement of the opening into a window. The pressure placed on the remaining unsupported rock creates a tensional force that results in the breaking away of huge arcs of rock and the formation of sometimes quite impossible-looking spans. As time passes these rock arches will collapse, but new ones will be forming as long as the plateau is there and erosion continues to cut away stone.

A quite different kind of uplift is seen in South Dakota in the Black Hills. Some sixty million years ago this area was pushed up by magma that worked its way close to the surface. It did not erupt but rather pushed up the overlaying layers in a blister-like formation and finally cooled and hardened into a dome. Over time the layers eroded forming mountain ridges and exposing the granitic dome. It was in a south-eastern face of this 6,000 foot mountain of granite that Gutzon Borglum carved his famous faces of the presidents. Begun in 1927 and completed in 1941 the sixty foot heads of Washington, Jefferson, Roosevelt, and Lincoln were brought forth from the rock with dynamite, jack-hammers, and drills to create the park now known as Mount Rushmore National Monument.

Outside the park we can find another characteristic of batholiths and domes. That is the presence of valuable minerals. The Homestake Mine was first mined in 1876 and since that time over one billion dollars worth of gold has been taken out.

Folded and faulted mountain ranges are the final chapter in the uplift story. Shenandoah and Great Smoky Mountains National Parks are examples of the results of continental collision. These are very old mountains formed before Pangaea broke up, formed 300-400 million years ago. The original mountain ranges were towering giants higher than our present day Rockies. Now of course time and the elements have worn the ridges down to their 2,000 to 3,000 foot levels and carpeted them with soil and lush vegetation. An important characteristic of folded mountains is still visible however, that is the many parallel ridges and the bent and twisted rock layers that are exposed here and there.

Fault block mountains tend to be rather dramatic as they often have sheer faces that rise steeply over a valley floor emphasizing the vertical height. And dramatic is surely a word that comes to mind when one describes the Grand Teton National Park. Here the mountains rise 7,000 feet above the valley floor. But that does not tell the whole story. In fact the rock along the western side of the Teton fault zone was lifted much more than that. And at the same time the eastern side of the fault sank, resulting in a total vertical movement of 30,000 feet along the fault! Erosion has removed all but the presently remaining 7,000 feet. These mountains are quite young geologically; the uplifting began only 8-10 million years ago. And the fault is still active, the mountains are still growing. The rocks at the base of the cliffs however are exceedingly old; 3 billion year old gneisses and schists.

One hundred fifty thousand years ago glaciers moved through the area carving the rugged peaks and laying down rows of moraines which would later act as dams to form Jackson Lake and Jenny Lake. The park has numerous glacial features and there is an active (though retreating) glacier between Grand Teton and Mount Owen.

Another unit that illustrates the effects of faulting is Great Basin National Park. This area is also a relatively young development, resulting from movement that began about 17 million years ago causing rifting. This rifting was the result of crustal plates pulling apart forming block mountain ranges separated by depressions called basins. This is termed basin and range and has a clear north-south orientation. Wheeler Peak is the highest point in the park and rises 7,000 feet from the valley floor. The predominant rock types are marble and quartzite, metamorphic rocks which indicate the stresses of the region. This park is one of the newest and is one of the System's "lesser-known parks", defined by the Park Service as a park that is located away from principle highways, often small in size, and even during peak seasons not heavily used. It has within its boundaries another former National Monument, Lehman Caves.

A practical way to demonstrate the formation of uplift features such as faulting, bedding planes, joints, domes, and arches is with layers of different colors of clay that have been rolled out into flat sheets and stacked to represent rock layers. In order to demonstrate folding a more flexible substance such as art foam is useful. It also can be obtained in various colors to show layering.

Erosional Forces

The forces of erosion are constantly at work changing the surface of the land. Erosion by water is the most common and wide-spread, tearing away river banks, washing over floodplains, eating away at subterranean caves and finally depositing its burden of sediments in new and distant locations in a variety of formations. Erosion by glacial ice is much more limited in range but its action is incredibly powerful. In areas affected by glacial erosion the entire surface of the land has been reworked. Wind erosion occurs in relatively dry areas where the absence of vegetative cover allows the surface soil to be moved by winds. Deserts, shorelines, and plowed fields are particularly susceptible to this. Over Earth's geologic history its surface has constantly been changed and revised by erosion and so we can look at formations in the parks as just a moment in time knowing that they are also destined to be worn away by the erosional agents of water, wind, and ice.

Surface water accumulating in the mountains as snowfall or in warmer areas as rainfall begins its journey down ward pulled by gravity. As small small streams and brooks join to form larger streams called tributaries, and those tributaries feed into the main channel we see a drainage system forming with the shape of an inverted tree with many branches. The area drained by this system is called the drainage basin. There are many changes in the appearance of the river as it flows down out of the mountains and onto flatter open plains. At its headwaters the river moves rapidly with a great deal of strength, cutting a steep-sided channel and carrying fairly large pieces of gravel and stone. The valley is generally V-shaped and there are often rapids and waterfalls. As the river reaches lower and flatter regions it may empty into an older established tributary that has been flowing for thousands of years referred to as a mature river valley. There would be a floodplain cut into the adjacent land and the river may have taken on a winding course marked by meanders, loops and bends in a river. As water moves through these winding channels it tends to wear away the banks on the outer side of the bend and deposit the sediment on the inner side of the bend. Over time the river may erode a short-cut through the river bank and establish a new channel. When this happens the old loop of the river, now cut off from the main stream, may continue its existence as an ox-bow lake.

When the mountain stream does not feed into an established river it may flow onto a flat plain where much of its water is absorbed or evaporated. When this happens the sediments that it was carrying are dropped in a fan shaped deposit called an alluvial fan. If the river empties into a large body of water such as a lake or ocean, it also is slowed sufficiently to cause most of the sediment load to drop and form a deposit called a delta.

Water sinking down into porous layers of rock and travelling through permeable layers of limestone as groundwater creates other spectacular formations. As rainwater falls through the air and enters the soil it combines with carbon dioxide to form mildly acidic carbonic acid. This weak acid moves through cracks and crevices in limestone rock dissolving away the sides enlarging the tiny openings into larger spaces forming caverns in the sub-surface rock. Extensive caves can form where groundwater reaches the watertable and then flows horizontally toward an outlet. As the water table drops, usually due to tectonic uplift, or deepening of a river valley which has served as an outlet, a new level of cave development may begin. In the cave which has been drained of its water the overlaying roof may collapse forming a sinkhole, or if the roof remains relatively intact calcite-rich water may seep through cracks resulting in the formation of stalactites, stalagmites, and columns. A third possibility is that most of the cave roof collapses leaving only narrow bands of rock called natural bridges crossing the river channel.

Glacial ice also has significant impact on the surface of the land. Valley glaciers form in mountains when the summer temperatures are not warm enough to melt the winter's accumulation of snow. This snow may build up year after year until its depth causes sufficient pressure to change the snow to ice. When this happens the bottom of the ice pack begins to flow downward moving over the landscape altering it. The ice moves through valleys widening them into a U-shape and plucking huge rocks from the bottom and sides of its path. It pushes large quantities of sand, silt, and gravel in front of it. When a glacier reaches a region which is warm its frontal edge melts releasing its load of sediments. If the glacier melts back it is said to be in retreat and the piles of debris it leaves behind is called a terminal moraine. Often these terminal moraines will block the outlet of a valley enough to create a lake. Or large chunks of glacial ice may have been forced into the ground as the glacier advanced and when the glacier retreats, the buried chunk of ice melts leaving a rounded depression filled with water called a kettlehole lake.

Some of the most beautiful features left by the last Ice Age are hanging valleys formed when trunk glaciers deepened their valleys more rapidly than tributary valleys. When the ice eventually melted the tributaries were left hanging high on the valley walls forming waterfalls.

If an advancing glacier moves down a valley that opens into the sea pieces of the forward edge may break off and fall into the sea forming icebergs. This process is called calving of icebergs. Continental glaciers,the very large sheets of ice once covering much of midwest and northeast United States and now covering Greenland and Antarctica, are the main source of icebergs.

Erosion by wind can best be compared to “sand-blasting”. Rocks are cut and polished to a smooth surface, and softer types of rocks will be cut away the most. The abrasive effect of the wind-blown sand is greatest at a height of about 20 inches. This action sometimes wears away the lower parts of a rock formation more than the upper, perhaps more resistant, portions. When this occurs a large cap rock sitting on a pedestal can result. A formation of this type carries the odd name of hoodoo.

Along shorelines and in the desert wind-blown sand can pile up in huge mounds called dunes. As the wind moves the grains of sand up and over its piled up mound a distinctive formation takes shape. The grains form a gentle slope on the side facing the wind (the windward side) and a rather steep slope on the side away from the wind (the leeward side). From this scientists can tell much about the source of ancient dune deposits.

All of these erosional and depositional features can be found in National Parks. If we return to Yellowstone we will find the Grand Canyon of the Yellowstone River cut in a steep V by the water of the Yellowstone River as it plunges over volcanic rock. The rushing water cuts down into its bed and the vertical walls collapse into the channel. The rock debris is tumbled and broken and then carried away by the power of the water. The Yellowstone River eventually meets the Missouri River and then the Mississippi River, and therefore is part of the Atlantic drainage system. This route would be interesting to trace out on a map of the United States indicating which states the rivers pass through. A complementary activity which would help clarify the concept of the Continental Divide would be to trace the path of the Snake River to the Columbia and on to The Pacific.

In another return visit we can look at the Snake River as it passes through Grand Teton National Park to find meanders and an ox-bow lake. Interestingly this river is not particularly old but because of the resistant character of the ridge rock in this area the land’s slope is not very steep and it is the rather low gradient that produces these meandering features. To the east of Jackson Lake the river curves southward, and along the north bank can be found Oxbow Bend, an old meander that has been cut off from the main stream. All along the river in this area as it moves through Antelope Flats the channel twists and bends and branches off into braids of flowing water as heads toward Jackson.

Another wonder of the Tetons is Jenny Lake. It is noteworthy because of a fairly recent formation that is developing there. On the west side of this beautiful lake Cascade Creek rushes through Cascade Canyon, over Hidden Falls and into the pond below. As the speed of the flowing water suddenly decreases the sediment load it is carrying is dropped to form a delta. Another location that this same process can be seen is in one of

Alaska's wilderness parks, Lake Clark National Park in southwest Alaska. Tributaries feeding into Twin Lakes carry an abundance of rock flour, silt and gravel the deposition of which is creating deltas out into the lake.

Death Valley National Monument is one of the driest (2 inches per year) and hottest (134°F in the shade) places in the United States but it also has been shaped and reshaped by the action of water. Its geologic formation is that of a basin formed by the down faulting of large blocks and uplifting of surrounding mountain ranges. One million years ago during the Pleistocene huge lakes filled the enclosed basins. One, Lake Manly, was 90 miles long and 585 feet deep. Evidence of its existence are the wave-cut terraces that surrounded the ancient shoreline and the abundance of precipitated salts, especially borax, that form thick plaza deposits.

About 11,000 years ago the climate changed and the inland lake evaporated. Today the rainfall is negligible most years, in fact at times several years will pass with no measurable rainfall at all. However on those rare occasions when significant rain does fall flooding can happen on a grand scale. Large amounts of sediments that have accumulated in the mountains are flushed out onto the flat dry plains below where they are dropped in a fan shaped pattern called an alluvial fan when the carrying waters sink into the absorbent sands.

Water, sinking into the ground elsewhere, sets in motion a different chain of events and results in quite different formations. To learn about these features we will look at three caves in the park system; Mammoth Cave, Wind Cave, and Jewel Cave. Mammoth Cave in Kentucky is a product of karst topography, a limestone region riddled with sinks, underground rivers, and caverns. It is the world's longest cave system, at 230 miles it is more than twice the length of the next longest system. What it lacks in delicate formations it compensates for with sheer enormity. One room, the Rotunda, is 142 feet long, 139 feet wide, and 40 feet high. Another, Mammoth Dome, is 192 feet long. The interconnecting caverns lay in at least four levels of depth and are spread beneath a surface area of about 16 square miles.

In order to see the more delicate features of caves we need to move on to South Dakota's Black Hills, just south of Mount Rushmore where both Wind Cave and Jewel Cave are located. Jewel Cave is noted for its many and varied calcite formations. Dogtooth spar is most abundant, sparkling like jewels along the walls of the caverns they have given this cave its name. Other formations are helictites, which grow upward as capillary action inside the minute hollow tubes of calcite draws mineral-rich water up in crooked, spiral shapes. Or soda-straws, which form when water saturated with dissolved limestone drips through tiny fissures in the ceilings of caves. Calcite is deposited in a tiny circle around the rim of the droplet and successive rings of crystals form a little hollow tube. It is from these soda-straws that larger hanging stalactites form, often because the hollow tube is blocked and the mineral-saturated water then flows down over the outside. Excess water dripping off of the stalactite will fall to the cave floor and build up into stalagmites. Other unusual features with fanciful names are "popcorn" (knobby nodules of calcite), "bacon" (orange and yellow-stained draperies of calcite formed when water trickled down an inclined ceiling), and "bubblegum" (unexplained bubbles of the mineral hydromagnesite with thicknesses of only 8 to 10 thousandths of a centimeter). Jewel Cave also has the unusual formation known as boxwork, but a near-by park, Wind Cave, has the world's most extensive display. The formation of boxwork can be said to have begun 60 million years ago when the Black Hills area was uplifted resulting in extensive cracking of the limestone layers there. These cracks formed networks of intersecting fractures that were filled with tightly packed calcite crystals deposited by the mineral-rich water that moved through the broken limestone rock. These veins of calcite were left exposed when the more soluble limestone was later dissolved away. In some places a very delicate touch of fine calcite crystals called frostwork edge the rims of the boxwork. Although Wind Cave and Jewel Cave are only about 20 miles apart and originate from the same geologic uplift, their specific formations are quite different and both warrant investigation.

A formation that can have several origins is the natural bridge. In some cases the bridge forms when most of the roof of a limestone cavern collapses. In other cases the rock is sandstone with streams meandering in loops around protruding fins. Over time the stream wears the fin of rock thin enough so that finally it breaks through gradually enlarging its shortcut channel. In Natural Bridges National Park we can find bridges in several stages of formation. Kachina Bridge is the newest and is still enlarging, Sipapu is a mature bridge with its abutments far enough apart so that the stream passing beneath it is no longer cutting in, and Owachomo is a very old bridge, only 9 feet thick and 180 feet across. Large blocks of Owachomo have fallen and its future life expectancy is only a few hundred years, considered to be just a brief moment in geologic time.

Many parks have fine examples of the influence of glacial ice, but two of the finest are Glacier and Yosemite. Glacier currently has about 50 small glaciers, but its landscapes tell of a time when ice must have covered most of the area. The valleys have the typical U-shape, two outstanding examples are McDonald Valley and St. Mary's Valley, both contain long finger lakes dug out by glacial movement and later dammed by moraines and outwash gravel. High in the north-east face of Garden Wall viewed from Many Glacier can be seen many cirques, deep basins formed by glaciers at the heads of valleys. In that same area Grinnell Glacier, the park's largest glacier, can be found. Other spectacular sights are the hanging valleys with their dramatic waterfalls. Avalanche Falls, St. Mary's Falls, and Grinnell Falls are all secondary valleys that had not eroded to the depth of their main valleys during the last Ice Age. A unique hanging valley can be seen at Trick Falls where the top of the falls passes over resistant rock beds but when stream levels are low the water issues from a limestone cave opening below, which is usually hidden from view by the upper falls.

Yosemite is one of the oldest parks and one of the most awe-inspiring. Granite peaks surround the Yosemite Valley, cut by hanging valleys with beautiful waterfalls emanating from them. Yosemite Falls at 1,430 feet, Ribbon Falls at 1,612 feet and Bridal Veil Falls at 620 feet feed into the Merced River which flows through the canyon. The level valley floor was laid down by an ancient glacial lake that formed when the terminal moraine of the retreating glacier trapped the water. Other signs left by the retreating glaciers are erratics, huge boulders transported by moving ice and then dropped when the ice melted back. Many erratics have been found on Glacier Monument at 1,500 ft. altitude that had been carried from a mountain 12 miles to the east. Arches are prominent features seen on many of the granite dome faces. They are caused by exfoliation the gradual weakening of thin layers of rock by the alternation of heat and cold resulting in constant expansion and contraction of rock materials which eventually fall off in large sheets. Because of the rounded, bulging formation of domes the collapse of the layers is in rounded arcs.

Exfoliation is the main action behind the formation of Half Dome. Contrary to popular belief the dome was not severed in half by a passing glacier. Rather it had been peeling away slowly and during the last Ice Age a glacier swept down the valley clearing away the debris and talus (broken rock at the base of a cliff) and removing more sheets of rock by plucking. But although the glacial ice reached within 500 feet of the top of Half Dome, it did not over-ride it cutting it in half.

A park found on America's east coast shows yet another face of the last Ice Age. Cape Cod National Seashore is underlaid by ancient granite, schist, and gneiss that were once connected to Africa before the land split apart 200 million years ago. The area's long and varied history can be studied in the layers deep below the present surface. That present surface is the result of glacial deposits of rock, gravel, and sand. The Upper Cape, the southern portion which juts eastward into the Atlantic Ocean, is a moraine ridge, and the Lower Cape, the northern portion that curls its fist toward Plymouth, is sandy outwash that accumulated between lobes of glacial ice. The retreat of the glacier 15,500 years ago left a lake bed later to be known as Cape Cod Bay. The area within the park boundaries on the east side of the Cape are eroding at a rate of 3 feet per year.

The sediment is moving northward and southward along the shoreline from a separation point in the area of Truro. In 4,000 to 6,000 years the northern part of Cape Cod will be an island cut off from the rest of the land by the sea. Over time it is expected that more islands will form and gradually become shoals unless a new ice age causes the sea-level to drop again.

In order to investigate the last glacial phenomenon we must again head north to Alaska, where in Glacier Bay we can observe the calving of icebergs. In this park the glacial movement is quite varied, in some areas retreating (Grand Pacific Glacier) and in other are as advancing (Johns Hopkins Glacier). In this inlet, on the west side of Glacier Bay frontal cliffs of ice 200 feet high are moving forward and breaking off into the sea. This activity keeps snips two miles away in order to prevent the risk of being swamped.

Two hundred years ago Glacier Bay lay under ice 4,000 feet thick. At that time a change in the climate resulted in a warming trend and the glacier began to retreat. As the ice melted it became a lighter burden on the land and the area began to rise at a rate of 1 1/2 inches a year. This rebound still continues today.

The final erosional events to be discussed are accomplished by the wind. In dry areas with little vegetation the soil surface is quite unstable. Loose sediments are picked up by the wind and hurled through the the air sometimes with incredible force. The result is a sand-blasting effect abrading the surface of any rocks or ridges in the way. In Arches National Park this unique type of erosion produces a very interesting and special formation called balanced rocks. This is a large rock resting precariously on its pedestal base. The upper portions of the formation are usually composed of rather resistant rock called cap rock and the base is a more friable composition which is susceptible to the power of the blowing sands. Balanced Rock is perhaps the most photographed of these but another one called Ham Rock is also noteworthy for its 55 foot height and 3,500 ton weight.

Wind also played its part in the formation of sand dunes. Two sites of interest are Indiana Dunes National Lakeshore, coastal dunes, and Great Sand Dunes National Monument, desert dunes. Indiana Dunes had their origin largely as a result of glacial action. Glaciers advanced and retreated in the Lake Michigan area depositing sediments which lake waves moved south along the western shore. Westerly winds then carried the sand eastward where it was deposited among the trees and vegetation as the flow of the wind was disrupted. Over time the partially buried trees died and the winds moved the dunes a bit further. Occasionally strong winds called blow-outs will remove the sand exposing the ancient dead tree stumps. The movement and deposition of sand is an ongoing process here.

Moving on to Colorado we can see some of the world’s tallest sand dunes in Great Sand Dunes National Monument. Here the sediments have been piled 700 to 800 feet deep by the strong prevailing winds from the southwest. Minerals from the San Juan Mountains are carried to the valley floor by streams, and in the spring and early summer winds of about 15 m.p.h. velocity pick these grains up and bounce them across the desert floor. When the winds hit the Sangre de Cristos Range they are slowed and they drop their burden of sand. Over time the grains of sand roll up the windward side of the dune in long gradual slopes and reaching their crest roll down the steep lee-ward side. In most dune areas this constant rolling would move the dunes forward in the direction of the prevailing winds, but here at Great Sand Dune there is an additional twist to the story. In winter the prevailing winds shift and come out of the east from the Sangre de Cristos Range reversing the direction of dune movement. The end result is a relatively stationary and high-piled group of dunes. These towering dunes first began their rhythmic growth when the climate warmed and dried after the retreat of the last Ice Age just 10,000 years ago making them among the youngest geologic features in our national parks.

There are many activities that could be adapted for use with this section of the unit. The use of a stream tray to study young and old rivers, alluvial fans and deltas is both visually reinforcing and fun. Students should also be continuing their booklets of geologic features and locating the representative parks they have been studying on the outline map of the United States. For detailed information on these and other activities see the Appendix. For further enrichment encourage the students to search for the landforms they have studied in additional parks of the National Park System. This could be accomplished by making available a variety of the pamphlets from the parks or by combining a list of all the National Parks with encyclopedia study.

Social Implications of the National Park System

In this unit we have been looking at one facet of the National Parks. Specific parks have been selected for their outstanding representation of particular geologic formations. But this is only part of the story. The students need to understand their role in the Park System. For many this over-view of the parks will be their first exposure to the idea of public lands (out-side of the neighborhood park). Some quotes from National Park booklets which tell the story of the formation of the National Park System can be found in Appendix II. These should be read to the students for their thought and discussion. Points for them to consider could include park ownership, selection of park areas, value of parks, and the mission of the park system. A particularly valuable resource for the teacher would be Joseph L. Sax's book *Mountains Without Handrails* .

Many of the more famous parks are in the western states and most of the students may feel they have little relevance to them due to the distance. But many of the newer parks are smaller, less well known , and closer than the children might think. A good exercise would be to investigate the parks within a one hundred or two hundred mile radius. They may be surprised to find how many there are. During the 1960s and 1970s many urban parks were established, such as Gateway National Recreation Area in New York City and Golden Gate National Recreation Area in San Francisco, with an eye to increasing accessiblity to heavily populated areas. Many of the National Historic Sites are also in densely populated areas.

With the increase in accessiblity comes problems that the park personnel must deal with. Although the park service has tried to spread the wealth of visitors over a larger number of parks by educating the people about the lesser-known parks, and to extend the visiting season where-ever possible to reduce summer density, still certain parks have continued to suffer from their mid-season (usually summer) overcrowding. In 1981 90% of all recreational visits were to 35% of the parks and 95% of the visits occurred during the summer season. [1] This leads to increased traffic, crowded facilities, and decreased enjoyment of the park for the visitor. Even activities that are encouraged in the park such as camping, hiking, or picnicking impact on it. Campers use downed trees and branches for their fires, hikers pack down the earth so plants cannot grow, animals in the areas are disturbed and scared away. Insensitive visitors pick the wildflowers, chop down living trees, break branches for firewood, remove fossils or artifacts, and litter. Some people want more active or noisy entertainments in the parks like motor boats, trail bikes, quads, dune buggies, snowmobiles, helicopter rides, and hang-gliding. Hunting and trapping are also allowed in some of the parks. The students should discuss how these activities might change the atmosphere of the park and whether some or all should be allowed. The use of quotes #5, 6, and 7 found in Appendix II could be helpful in getting a debate started.

Visitor-related problems have been increasing as visitation has increased. Interaction between man and wild animals is well known as a serious problem due to the many television treatments of the subject. Most of the students can join in a discussion of man and grizzley in Yellowstone. They may be less aware of problems with man and buffalo, elk, and any other large animal chosen for a backdrop for a family photograph. Other problem areas are dunes which appear immovable but in reality are quite fragile. In some areas fences and signs keep visitors off endangered formations. Another tactic used by the parks is to issue back-country hiking permits on a limited basis. This allows hikers to plan their treks knowing that the trails will not be overcrowded. And in areas that are heavily used, usually the shorter scenic trails, walking surfaces are designed for the abuse. In some areas trails are planned for handicap accessibility. All of these approaches are necessary in order to provide some form of access to visitors whether they are novices to the wilderness or true woodsmen and women looking for outdoor adventure.

Some of the most serious threats to the parks come not from inside but rather from outside the boundaries. One of the most publicized in recent years has been fire whether set by careless people or random lightning strikes. The park service has to deal with this problem virtually every summer in its western areas. The students may have seen the *Nature* program on PBS based on the fires at Yellowstone.

Another outside influence on parks is air pollution. Many of the western parks have reduced visibility due to nearby coal-burning plants and mining operations. Water pollution originating outside the park may affect animals and plants in rivers passing through the parks. And clear-cutting of forests can cause bank erosion which results in the silting of streams.

An interesting item for study is the possible effect of geothermal drilling outside of Yellowstone on the geysers and hotsprings inside the park boundaries. Or the drilling for oil outside of parks and its effect on wildlife in the area. Many of the national parks are adjacent to national forest areas that can be logged. How might that affect the parks?

In planning for visitors, roads, parking lots, concessions, and sanitary facilities are vital. All of these change the natural environment so that the areas we are trying to preserve from development and exploitation are in fact developed and exploited. Because the parks belong to the people and will only continue to be supported and grow as long as the people genuinely feel welcomed there (even if they will never make the trip to some of those distant places) the parks must continue to be designed to handle the crowds and encourage visitation. Because they are not isolated and in their natural state it will take careful planning and management to maintain a “natural” environment as close to the wild as possible. See Appendix II for discussion quote #8. The planning must take into account the increasing diversity of the American people and their varying level of wilderness expertise and understanding. For many the outdoor experience is foreign but tantalizing, the parks can facilitate the first steps into the wilds. Although putting more people on the trails may seem counter-productive, in reality it will increase the political base needed to insure the continued preservation of the existing parks and foster the growth of the whole National Park System.

Appendix I

Activity 1

Objective To acquaint the student with the shape and structure of various geologic features.

Materials white drawing paper
color pencils

Earth Science text

Procedure Have the student assemble a booklet of geologic features that are hand-drawn and colored. The drawings should be identified and labeled neatly. Some suggestions for specific illustrations follow but may vary depending on the text used as a resource and the teacher's level of emphasis on the subject. The drawings could be done gradually as the Unit develops, and the drawings should be done in sequence with the topics in the Unit and held for complete assembly into a book. Some of the students will have quite impressive collections that they can take great pride in. And the booklet serves as a great resource for review when test-time arrives.

Suggested illustrations:

Vulcanism	*Erosional Forces*
shield cone volcano	drainage basin
cinder cone volcano	young river valley (side view)
composite cone volcano	old river valley (side view)
Hawaiian Islands chain	river meanders
hot springs	ox-bow lake
geysers	alluvial fan
subduction zone	delta
flood basalts	cave formation
columnar basalt columns	stalactites
extinct volcanic central neck	stalagmites
caldera	columns
	sink holes
The Mobile Crust;	natural bridges
convection currents in the	glacial valley (side view)
mantle	cirques
dome	moraine
batholith	kettlehole lake
laccolith	hanging valley
normal fault	iceberg calving
thrust fault	balanced rock
fault block mountains	dune movement
rift valleys	arches (exfoliated)

folded mountains

pinnacles, fins

arches

Activity 2

Objective to familiarize the student with the diversity of the National Park System to familiarize the student with maps and map symbols

Materials National Park System Map and Guide (one for each group)

United States outline map (one for each student)
United States road map (one for each group)—optional
color pencils or markers drawing paper interpretive pamphlets from a wide variety of parks

Procedure Have the students work in groups to overview the National Park System Map. They should be looking for parks they have heard of, parks in neighboring states, parks in places they would like to visit, etc.

List on the blackboard the parks they will be studying in this Unit and have the students locate each and mark the locations on their U.S. outline map. In addition they might also locate parks that they might like to visit in the future or perhaps that they have been to already. Different colors could be assigned to each category to make the map more interesting. Have each child in each group select a park interpretive pamphlet. Working with the pamphlet have the student do the following exercises;

a. sketch the general outline of the park on drawing paper
b. locate with a symbol important geologic features
c. locate the visitor centers
d. locate the campgrounds and/or park hotels
e. using the U.S. road map, locate the park and indicate the roads that provide access to the park and the name and distance of the nearest small town and large city. Put this information on the student-drawn map.
f. the student could further embellish their map with tiny illustrations of representative plants and animals of their park (this information is found on the park pamphlet)
g. have the students show and explain their maps to each other.

National Parks list:

Hawaii Volcanoes	Great Basin
Lassen Volcanic	Lehman Caves
Craters of the Moon	Yosemite
Yellowstone	Lake Clark
Devil’s Tower	Death Valley
Grand Canyon	Mammoth Cave

Zion		Jewel Cave
Bryce Canyon	Wind Cave	
Arches		Natural Bridges
Mt. Rushmore	Glacier	
Shenandoah	Yosemite	
Great Smoky Mountains	Cape Cod	
Grand Tetons	Glacier Bay	
		Indiana Dunes
		Great Sand Dunes

Activity 3

Objective to understand the role of heat expansion in volcanic eruption

Materials	crayons (peeled pieces, 1 in.)	plaster of paris
	25 cm. string	plastic spoon
	scissors	water in beaker
	paper cup	safety glasses*

Procedure Have the students work in groups following the directions:

a. use the teacher-prepared* string to tie three one-inch pieces of crayon into a bundle
b. mix the plaster of paris and the water in the paper cup. It should be a soft mix and fill the cup about 2/3 full.
c. push the crayon bundle into the plaster so that it is centered and *not* touching the sides or bottom of the cup.
d. tap the cup gently to remove bubbles and set it aside to completely harden overnight.
e. when the cups of plaster have hardened tear off the paper, and cut off the string at the surface level
f. boil water in a pan* and carefully place the plaster cups into the water with tongs. The tops of the plaster cups should be above the water level.
g. observe the results (this will take some time, 20 min. or more)
h. describe what you have observed

Questions

1. What did you observe when the plaster was heated?
2. Why did we put a string in the plaster?
3. What would have happened if there was no string opening?
4. Compare this activity to what might be happening inside of a volcano as it erupts.

****Teacher notes Prepare the string by melting wax crayons in an aluminum pie plate over a heating tray. The pie plate can be saved and used from year to year or discarded. Take the precut lengths of string and roll them in the melted wax thoroughly. Remove them and let them cool on newspaper. Use extreme caution when melting wax as it is very flammable !***
Use an old pan to boil the water as the escaping wax is almost impossible to completely remove. *Safety note; The teacher should boil the water and lower the cups into it* . *Safety glasses for every student who wishes to get close should be required* .

Activity 4

Objective to understand viscosity and its affect on volcanic eruption

Materials hot plate safety glasses
cream of wheat cereal water
500 ml beaker spoon

Procedure Plug in and turn on the heating tray. Put on your glasses. Bring 250 ml of water to a boil. Add 5 teaspoons of cream of wheat. Stir and lower the heat to medium-low. Observe carefully. Watch the top surface and the side view through the glass. Notice the size and speed of the rising bubbles. Touch the cereal with the spoon to get an idea of its viscosity as the mixture cooks. Look for "crater" formation. Record all the data on the chart below. Do not burn the cereal!

Data:

	Thin cereal	Thick cereal
size of bubbles		
rate at which they		

rise

movement

of surface

other

observations

Important When you are through scrape all the cereal into the plastic garbage bag and place the beaker into hot soapy dishwater immediately. Clean work area right away before the cereal has time to harden on surfaces.

Questions

1. Define viscosity.
2. How did viscosity affect the movement of the cereal?
3. What kinds of lava can we compare the thin and thick cereal to?
4. How do each of the types of lava act when they erupt?

***Activity* 5**

Objective To understand how temperature affects viscosity and rate of flow

Materials

3 medicine cups with 5 ml of corn syrup; cold, room temp, and warm
3 medicine cups with 5 ml of molasses; cold, room temp, and warm
1 glass plate (plexiglass, or saran-wrap covered cardboard)
grease pencil
newspaper and two science books
stopwatch or clock with second hand
ruler

Procedure Use the following directions for both the corn syrup and molasses:

a. draw a line across the glass plate 10 cm from the end with the grease pencil.
b. open the newspaper and place the two science books and the glass plate flat on it.
c. pour the warm substance on the grease pencil mark all at once and quickly in order to have uniform results
d. quickly raise the plate edge onto the two books to make a slope.
e. immediately begin timing the number of seconds it takes for the substance to reach the bottom
f. put your data in the appropriate box on the data chart below
g. repeat steps c., d., e., and f. with the room temperature and the cold forms of both substances. Clean the plate between each run.

Data warm room temp. cold
liquid liquid liquid
travel time corn syrup

in seconds

(your data) molasses

(class average) molasses

Graphing On 1 cm. graph paper plot the class average data. Put temperature of the liquid on the vertical axis and travel time on the horizontal axis. Use two different colors to represent the two different liquids. Label everything.

Questions

1. How does temperature affect the viscosity of corn syrup and molasses?
2. How do corn syrup and molasses compare to basaltic and granitic lava?

Activity 6

Objective To understand the relationship between surface gradient, volume of flow and the

formation of river features.

Materials
Stream tray

buckets

blocks (to vary angle of gradient)

hoses of varying diameter

sand

food coloring for water

Procedure Set up the stream table with several inches depth of sand. Elevate one end to represent the headwaters and introduce the flow of water at that end. Prepare necessary hoses and buckets for overflow and begin the stream by siphoning water from the supply bucket. Once the flow is established introduce the food coloring (this makes any flow patterns more visible) to the supply bucket. Measure the length of the stream table and its elevation to calculate its gradient angle. After making observations, increase the gradient and compare results.
Using the same set-up make observations concerning effect of flow volume. Vary the flow volume by using different size hoses. Observe and compare results.

Enter data and results in the chart provided below.

Data:

Variables Observations Name of stream feature represented

First grad-

ient angle

Second grad-

ient angle

Low volume

flow

High volume

flow

Questions

1. Compare the size of the particles with the distance they were carried.

2. What effect does changing the gradient have on rate of flow?
3. What effect would the introduction of stones to the sand have?
4. Put stones in the stream tray sand to test your prediction. What happened?

Activity 7

Objective to understand the formation of stalactites and stalagmites

Materials

2 250 ml. beakers water
2 20 cm. pieces of yarn salt
styrofoam tray stirrer

Procedure Fill the two beakers with water. Stir in salt. Continue adding salt until no more will dissolve. Place the beakers about 10 cm. apart on the tray.
Tie the two pieces of yarn together about 2 cm. from the ends. Put each end of one of the yarns into a beaker.

Let the knotted end droop down slightly between the beakers.

Put the tray with the beakers in a place it will not be disturbed. Clean up your work space.

Make your observations on a daily basis for the first week and then once a week thereafter for a month. Record your observations.

Data: Observation
Day 1

Day 2

Day 3

Day 4

Day 5

Second Week

Third Week

Fourth Week

Questions

1. Did you observe stalactite formation? Explain.
2. Did you observe stalagmite formation? Explain.
3. How does the formation of stalactites in nature differ from your experiment?
4. How is the formation of stalactites in nature similar to that in your experiment?

Appendix II Selected Quotes for Class Discussion

#1 “Yellowstone National Park, established March 1,1872, was the first area so designated anywhere . . . .The remarkable Yellowstone Act withdrew some two million acres of public land in Wyoming and Montana territories from settlement, occupancy, or sale and dedicated it ‘as a public park or pleasuring ground for the benefit and enjoyment of the people.’ The law also provided for preservation of all timber, mineral deposits, natural curiosities and wonders within the park ‘in their natural condition.’ The twin purposes of preservation and public enjoyment . . . were there from the beginning.” [2]

#2 “The parks are the Nation’s pleasure grounds and the Nation’s restoring places, recreation grounds . . . . These great parks are, in the highest degree, as they stand today, a sheer expression of democracy, the separation of these lands from the public domain, to be held for the public, instead of being opened to private settlement.” J. Horace McFarland 1916. [3]

#3 “The act created the [National Park] Service ‘to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations . . . ..which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.” 1916. [4]

#4 “Using [his] authority, President Franklin D. Roosevelt signed executive orders on June 10 and July 28 consolidating all national parks and national monuments, all national military parks, 11 national cemeteries, all national memorials, and the parks of the National Capital under National Park Service administration.” 1933. [5]

#5 “The parks are indeed for people. Again and again our project staff has been reminded of that reality. Millions of children, the elderly, the handicapped and time-constrained, the sedentary who have ventured timidly into the outdoors for a glimpse of spectacular nature, all of these use, enjoy, are inspired and uplifted by the parks. They no less than hikers and climbers, backpackers and whitewater rafters and lovers of wilderness are fully entitled to share in the parks experience. All derive pleasure and sustenance from the parks, many in different ways, in different parts of the parks, with varying levels of services and accommodations. This report, like the parks themselves, is for all of them.” [6]

#6 “Sometimes the real issue is less the physical damage to resources caused by visitors than the effect they have in diminishing for others an experience rarely possible outside national parks.” [7]

#7 “To Congress [the preservationist] says don’t try to make the national parks all things to all people in every location. Do use the public lands to serve conventional recreational preferences, but save some places explicitly for what has been called—lacking any fully satisfactory term—reflective or contemplative recreation. Indeed, try to encourage more of such recreation, and for that reason try to accommodate conventional demands, as much as you can, at other places.” [8]

#8 “To fence the people out would surely preserve the parks, in an abstract sense,” Norman Newton, a noted landscape architect and author, observes. “But the parks are for people to enjoy; their justification is in their human values. Again and again one feels the insistence of that ultimate calculus.” [9]

YELLOWSTONE NATIONAL PARK

(figure available in print form)

Notes

1. Mellon, Richard King Foundation (Sponsor). *National Parks for a New Generation: Visions, Realities, Prospects* . Washington, D.C.: The Conservation Foundation, 1985, p. 213.
2. Division of Publications, National Park Service. *The National Parks: Shaping the System* . Washington, D.C., 1985, p. 10.
3. *Ibid* ., p. 12-13.
4. *Ibid* ., p. 18.
5. Ibid., p. 24.
6. Mellon, Richard King Foundation (Sponsor), p. xx.
7. *Ibid* ., p. 121.
8. Sax, Joseph L. *Mountains Without Handrails* . Ann Arbor: The University of Michigan Press, 1980, p. 105.
9. Mellon, Richard King Foundation (Sponsor), p. 119.

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Ash, Sidney and May, David. *Petrified Forest* . Holbrook, Arizona: Petrified Forest Museum Association, 1969.

Bezy, John. *Bryce Canyon* . 1980.

Crandall, Hugh. *Yellowstone* . 1977.

Eardley, A.J. and Schaack, James. Zion. 1971.

These books are profusely illustrated and explain much of the geology of the specific park in easily understood language. They are published by KC Publications, Las Vegas, Nevada. There are many other titles available in the series *The Story Behind the Scenery* : *Your National Parks* .

Geerlings, Paul. *Crossing the Volcano of Time* . Salt Lake City, Utah: Grand Canyon Publications, Inc, 1982.

Geerlings, Paul. *Down the Grand Staircase* . Salt Lake City, Utah, Grand Canyon Publications, Inc., 1981.

Geerlings' books are also well illustrated with the majority of the photographs focused on the plants and animals of the parks.

Kirkpatrick, Katherine and Rathbun, Elizabeth and Dennis, Robin and Gray, Ralph. *Adventures in Your National Parks* . Washington, D.C.: National Geographic Society, 1988.

This book focuses on children involved in exciting activities in the National Parks. Rafting, rock-climbing, canoeing, hiking, and biking are some of the adventures shown.

O'Neill, Catherine. *Natural Wonders of North America* . Washington, D.C.: National Geographic Society, 1984.

This book is not limited to the National Parks but does use numerous photographs from the parks. It also features children in many of its pictures.

National Park pamphlets, an integral part of this unit, are available from the park service's regional offices or by contacting the specific park directly.

Student Activity Workbook

Aten, Jerry. *Maptime . . . USA* . Carthage, IL.: Good Apple, Inc., 1982.

This activity book has reproducible games, maps, and worksheets, some of which apply directly to the National Parks and others which could be adapted for use with this unit. Grade level 4-8.

Teacher Bibliography

The National Parks: Index 1989 .

The National Parks: Lesser-Known Areas 1989 .

The National Parks: Shaping the System 1985 .

These books are all published by The Division of Publications, National Park Service, U.S. Department of the Interior, Washington, D.C. They are invaluable guides to the entire park system and its history.

Bailey, Ronald. *Planet Earth Glacier* . Alexandria, VA: Time-Life Books,1982.

Chorlton, Windsor. *Planet Earth Ice Ages* . Alexandria, VA: Time-Life Books, 1983.

Jackson, Donald Dale. *Planet Earth Underground Worlds* . Alexandria, VA: Time-Life Books, 1982.

Lewis, Thomas A. (Editor). *Planet Earth Volcano* . Alexandria, VA: TimeLife Books, 1982.

The Planet Earth series of books is an outstanding source of photographs and illustrations for use with your students. The series is especially good at providing interesting bits of information and short human-interest stories to explain geologic events. These volumes have become my “high use” books that the students regularly choose to read.

Ballard, Robert. *Exploring Our Living Planet* . Washington, D.C.: National Geographic Society, 1983.

Bennett, Ross, (Editor). *The New America’s Wonderlands* . Washington, D.C.: National Geographic Society, 1980.

This book is a good resource for many of the larger, well-known parks.

Bradley, Peter. “Great Basin National Park”, *Nevada* . June, 1987.

Because of its relative newness to the park system very little has been written in standard texts about this park. Nevada magazine has been an on-going source of information on this area.

Chronic, Halka. *Pages of Stone* . Seattle, WA: The Mountaineers, 1984.

This particular book is of the highest value in understanding the geologic events that took place in the development of the park formations.

Dunn, Margery (Editor). *Our Federal Lands* . Washington, D.C.: National Geographic Society, 1984.

This book gives brief sketches about 167 units in the park system.

Harris, Ann and Tuttle, Esther. *Geology of the National Parks* . Dubuque, IA: Kendall/ Hunt Publishing Co., 1977.

Extremely valuable resource for understanding park formations.

Harris, David and Kiver, Eugene. *Geologic Story of the National Parks and Monuments* . New York, NY: John Wiley and Sons, 1985.

Another very valuable resource for geologic information.

Martin, Paul (Editor). *Window on America* . Washington, D.C.; National Geographic Society, 1987.

Photographs and illustrations are presented by regions in this book.

Melham, Tom and Murie, Margaret and Ramsey, Cynthia and Sugar, James. *Alaska's Magnificent Parklands* . Washington, D.C.: National Geographic Society, 1984.

This book has outstanding maps and photographs of the Alaskan parks.

Mellon, Richard King Foundation (Sponsor). *National Parks for a New Generation: Visions, Realities, Prospects* . Washington, D.C.: The Conservation Foundation, 1985.

This book gives great insight into the problems of the National Parks.

Newhouse, Elizabeth (Editor). *National Geographic's Guide to the National Parks* . Washington, D.C.: National Geographic Society, 1989.

This book offers detailed information on 50 Scenic parks, and maps.

Sax, Joseph L. *Mountains Without Handrails* . Ann Arbor: The University of Michigan Press, 1980.

This book is particularly helpful in understanding park use.

Video Resources

Hawaii, Discover; the World of Science . Angier, John and Chedd, Graham, PBS.

This Land . Gordon, Douglas. Shell Oil Company Film.

Yellowstone on Fire . Nature, PBS, 1989.

Close Encounters of the Third Kind . Columbia Pictures.

Touring America's National Parks . Encounter Productions, Portland, OR 1986.

Grand Canyon; Amphitheater of the Gods . Reader's Digest and International Video Network. 1988.

Yellowstone; The First National Park . Reader's Digest and International Video Network.1988.

Yosemite; A Gift of Creation . Reader's Digest and International Video Network. 1988.