Teacher's Guide
TO CRATERS OF THE MOON

A Curriculum on Monument Geology, History and Ecology for Grades 5-6

NATIONAL PARK SERVICE
Department of the Interior

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A Curriculum on Monument Geology, History and Ecology for Grades 5-6

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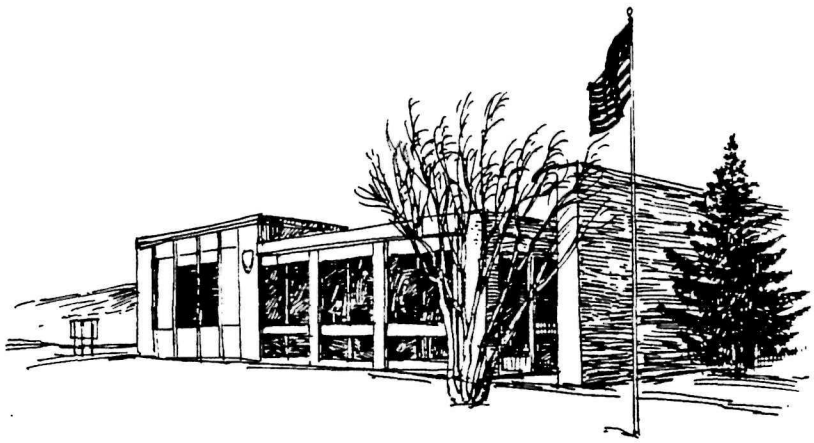


Field Trips

Craters of the Moon: An Educational Experience

Craters of the Moon was set aside as a National Monument by President Calvin Coolidge in 1924. In his proclamation declaring Craters of the Moon a National Monument, President Coolidge stated that the area contained "many curious and unusual phenomena of great educational value and has a weird and scenic landscape peculiar to itself." Preserved because of its geological significance, Craters of the Moon provides a unique opportunity to study a volcanic landscape. Although most of Craters of the Moon is covered by barren lava flows, it also supports a surprising diversity of plants and animals.

Reservations

Every weekday during May at least two school groups visit the monument. The ranger staff presents orientations for arriving groups at the Visitor Center. Orientation talks include a brief explanation of the significance of Craters of the Moon National Monument, as well as safety hazards your group may encounter. If you would like an orientation, we suggest making your reservation as far ahead as possible. Most field trips are scheduled between the first of May and Memorial Day because the unpredictable spring weather may prevent the opening of the Loop road until late April. As an alternative, you may want to consider scheduling your visit in September. Reservations can be made by calling (208) 527-3257.

Fee Waivers

School groups entering the monument for educational purposes are exempt from the entrance fee. The National Park Service does not collect entrance fees during the off season, generally from mid-September through mid-May. During the remainder of the year, school groups must obtain a fee waiver prior to their arrival at the monument to avoid being charged for admission. To obtain a fee waiver:

1. Make your request in writing to: Craters of the Moon National Monument, P.O. Box 29, Arco, Idaho 83213, Att. Fee Coordinator.
2. Use official school letterhead.
3. Explain how your trip to Craters of the Moon relates to the educational experience of your group. Please be specific.
4. Include the dates and the number of persons in your group.

Field Trips vs Recreational Activities

Craters of the Moon is an exceptional area for the study of volcanic activity along with the plants and animals native to Idaho's high desert. For this reason, we encourage schools to integrate their field trips with their classroom curriculum.

Facilities

In the winter, Labor Day to mid-June, the Visitor Center is open from 8:00 a.m. to 4:30 p.m. In the summer, from mid-June to Labor Day, the Visitor Center may have expanded hours. Exhibits at the Visitor Center include a five minute video on volcanic geology, as well as a wildlife display, and exhibits on geology and the history of Craters of the Moon. There is also a bookstore where books, postcards, posters, video cassettes, slide sets, and a limited selection of film are available. A complete listing of sales items and prices is available upon request. Restrooms are available at the Visitor Center, Caves Trail parking area, Devil's Orchard, and the Tree Molds parking area. Drinking water is not available once you leave the Visitor Center area. All visitors are advised to carry water whenever they plan to be in the field for more than an hour. Picnic facilities are available at the campground or the Visitor Center.

Student Conduct

The following regulations should be discussed with your group prior to their arrival at the monument. All the natural features within Craters of the Moon are protected. Collecting of rocks is strictly prohibited. Since walking or climbing on the fragile lava rock can cause irreversible damage, all visitors to the North Crater Flow, Spatter Cones, and Big Craters areas are required to stay on the paved walkways. If you have an opportunity to view the wildlife found at Craters of the Moon, use caution not to disturb the animals. Feeding, handling, or harassing wildlife is prohibited. All litter must be disposed of properly.

Safety

In order to have a safe educational visit, precautions must be taken. Since lava rock is sharp and any fall may result in an injury, running, pushing, or horseplay in general can lead to serious accidents. Because of the danger of falling, extreme caution and supervision is required around the Spatter Cones and Big Craters area. Keep students a safe distance from the crater's edge. Climbing on the bars and cables at the Spatter Cones is strictly prohibited. The caves, often totally dark with low ceilings, small crawlways and rocky floors, must be approached cautiously with safety a primary consideration. A reliable source of artificial light is needed for all caves. During the spring, when ice and snow can be found in the caves, extra caution should be used. If there is any question of safety, entrance into the caves should not be attempted. In the event of an accident, contact the nearest Ranger.

Group Size and Supervision

Group size should be limited to a maximum of 30 students. Groups larger than this have difficulty staying together on the trail and students may have difficulty hearing the group leader. If your group is larger than 30 students, plan to divide your group into smaller groups, providing each group with its own leader. The smaller the group, the more individual students will gain from the experience. There should be one adult for every six to eight students. Leaders and adults must remain with the group at all times.

Weather

The 7-mile Loop Drive through the park is closed from approximately November 1st to April 15th. The weather at Craters of the Moon is unpredictable. At an elevation of 5900 feet, cold, windy, or snowy weather is often possible even in late May. Cancelling a field trip at the last moment is awkward, but trips in snow and rain are rarely enjoyable or safe. There is no sheltered or indoor area groups can utilize. It is advisable to call ahead if bad weather seems a possibility.

What to Bring

Each member of your group should bring the following: lunch if you plan to eat at the monument, a water bottle, warm coat or jacket, sturdy shoes or boots (no sandals or open toed shoes), and one flashlight per person if you plan to visit the caves area. A camera with film is optional. All items should be labeled with the person's name, address, and phone number in case anything is lost.

Field Trips— Recommended Itinerary

Because most school groups visiting Craters of the Moon have the same amount of time available, the following sample itinerary may be useful.

10:30 a.m. Arrive at Craters of the Moon Visitor Center. Use the restrooms and tour the Visitor Center, viewing the exhibits and eruption video.

10:45 a.m. Front lawn of the Visitor Center. Orientation stressing monument geology and safety concerns. Plan to divide larger groups in half. The first group enters the Visitor Center while the second group receives an orientation. Then the two groups switch.

11:00 a.m. **North Crater Flow Trail.** This short (less than 1/4 mile) walk winds through a portion of the North Crater lava flow on a paved trail. A wide variety of flow formations can be seen, including aa and pahoehoe lava, blue dragon lava, pressure ridges, squeeze ups, and rafted blocks.

11:45 a.m. **Spatter Cones.** The Spatter cones are located directly off the parking area. These "miniature" volcanoes are thought to have formed during the latter stages of a fissure eruption as thick pasty globs of lava were thrown into the air and piled up around a vent.

12:00 noon **Big Craters.** The steep 1/4 mile long paved trail takes you to the crater's rim. Big Craters is actually a "cinder cone complex" consisting of nine nested cones made up of brown, red, and black

cinders. Big Craters is an excellent example of how a fissure eruption gradually shifts and changes.

12:30 p.m. Drive the loop road back to the campground or Visitor Center for lunch.

12:45 p.m. Lunch!

1:45 p.m. Last stop at the Visitor Center.

2:00 p.m. Leave Craters of the Moon.

Note: Visiting Indian Tunnel will add approximately one hour to this schedule.

Site Tours— North Crater Flow Trail

Background Information

The North Crater Flow Trail is one of most heavily visited trails in the park. The trail is fairly narrow making it difficult for a large group to gather in any one spot. It is important that you stay on the paved trail at all times. Walking on the lava in this area can easily break its fragile surface. Evidence of this damage can be seen along the trail. Because of the wide range of volcanic features found on the North Crater Flow Trail, it is an excellent first stop.

Trail Head Introduction

Most geologists agree that volcanic activity began at Craters of the Moon 15,000 years ago. Since then, there have been eight periods of volcanic activity. Each period lasted from a few years to a few hundred years. The quiet time between periods of volcanic activity could be as short as several hundred years or as long as 3,000 years. The average time between periods of volcanic activity is about 2,000 years. North Crater and the North Crater Lava Flow formed during the most recent eruptive period that ended approximately 2,100 years ago. Big Craters, the Spatter Cones, and the Blue Dragon Flow (Indian Tunnel, Boy Scout Cave, and the other lava tubes in the Caves Area) all formed during this same eruptive period. The following stops describe features that are encountered when following the trail in a clockwise direction.

Stop Number 1 Pahoehoe Lava

There are two general types of lava flows found at Craters of the Moon, pahoehoe (pah-hoy-hoy) and aa (ah-ah). Both of these words are Hawaiian since much of what we know about volcanic activity came from the study of active volcanoes in Hawaii. Pahoehoe is a smooth, pillowy lava that often forms ropes and coils. Pahoehoe means "ropy" in Hawaiian. Pahoehoe flows are very hot, up to 2,000 degrees Fahrenheit, and have been clocked flowing at speeds of more than 30 miles per hour. Pahoehoe flows are often seen flowing like glowing orange rivers. As the surface of a pahoehoe flow cools it forms a sort of "skin." The hot, fast-moving lava beneath pulls, pushes, and twists this cooler top layer into the weird ropes and coils. These ropes and coils can give you a hint to the direction the lava flowed. Pahoehoe is the most common type of lava flow found at Craters of the Moon.

Stop Number 2A
Triple Twist Tree

If you were to look at a cross section of a tree or the top of a stump, you would see the tree trunk is made up of a series of concentric rings. Since a living tree adds one growth ring each year, you can determine the age of the tree by counting the number of growth rings. A core sample taken from the triple twist tree, showed it to be at least 1,350 years old.

A molten lava flow destroys all plant life in its path. After the flow cools, new plant life slowly begins to return. This returning plant life provides scientists with one way to date lava flows. By comparing the amount of vegetation on one flow with the amount of vegetation on an adjoining flow, geologists can determine which of the two flows is older. To get an actual date on a lava flow, geologists can date a tree growing on the flow. In the case of the triple twist tree we know that the tree began growing after the last eruption, so the lava flow must be at least 1,350 years old.

Geologists can also use a method known as "radio-carbon dating." Samples of charred vegetation such as sagebrush, limber pine, or even pine cones can be dated using this method. To obtain dates far older than living vegetation or charcoal samples can provide, scientists can use "paleomagnetic measurements." As the lava cools, tiny magnetic crystals align themselves in the direction of the earth's current magnetic field. Each lava flow at Craters of the Moon reflects the direction of the magnetic field when the lava erupted and cooled. Scientists can correlate this information to the earth's changing pattern of magnetism and arrive at a date when the lava was deposited.

Stop Number 2B
Pressure Ridges and Squeeze Ups

Pressure ridges are a common feature of pahoehoe flows. They form as the flow's crust is pushed upwards by the pressure of the moving lava beneath. The arched crust generally cracks open, allowing molten lava to "squeeze up" to the surface like toothpaste out of a tube. Pressure ridges are usually a few feet high and about 100 feet long, but they can be as high as 50 feet and over half a mile long.

Stop Number 3
Aa Lava

Aa flows have a rough, jagged surface and are extremely sharp. In Hawaiian, aa means "hard on the feet." Most lava flows emerge as pahoehoe and somewhere down the slope change into aa as the lava cools, loses much of its gas, and becomes thicker. As the flow cools, it begins to slow down, moving as a mass of broken rubble. As compared to the fast moving pahoehoe flows, aa travels at speeds of about six miles per hour. The aa flow moves on top of a hidden molten core. As the clinkery outer surface slides down the front slope of the advancing flow, you can sometimes get a glimpse of the glowing interior. An advancing aa flow moves like a giant, slow moving tank or conveyer belt. Cooling lava rock that slides down the front of the flow is overridden by the advancing mass. Occasionally, a pahoehoe flow will burrow under an aa flow or emerge through a tunnel, leaving the appearance that an aa flow produced pahoehoe lava. Walking on an aa flow has been compared to walking on millions of cups and saucers stacked in a loose pile.

Stop Number 4
Blue Dragon Lava

The blue color comes from a thin outer layer of lava that contains titanium magnetite crystals. These abundant crystals reflect the intense blue light. One of the

youngest and largest lava flows in the park, the Blue Dragon Flow, gets its name from this blue lava. Robert Limbert, one of the park's earliest explorers, thought the name "Blue Dragon" was perfect. He compared the cracked and veined surface to the scales of a prehistoric reptile. Limbert also thought that squeeze ups looked like the legs and claws of a dragon.

Some of the lava is red where the blue lava has been broken and removed. This red coloration occurs because basaltic lava rock is high in iron, and as it cools, it often oxidizes or rusts. Metals such as iron rust when they come into contact with oxygen. Oxygen can be found in the air we breath, steam or water, and in the volcanic gases trapped within the cooling lava rock.

Stop Number 5
Rafted Blocks

Rafted blocks , or monoliths, are sections of a broken crater wall that have been carried along on top of an aa lava flow. Only aa flows are thick enough to "float" the blocks to their new locations. Although geologists can't be certain, they now believe that as many as four separate flows came from a vent at or near North Crater. The first, a particularly thick type of aa called block lava, flowed northward down the flank of North Crater into the valley between Sunset Cone and Grassy Cone located across the highway. The eruption was so violent that it destroyed the north flank of North Crater and possibly other cinder cones that might have stood in its path. As the eruption continued, two more aa lava flows rafted large blocks of the broken crater wall for several miles. Later, one more eruption produced a smaller pahoehoe flow. Viewed from the highway today, North Crater looks as if a giant "bite" was taken from it's northern side.

Stop Number 6
Block Lava

Block lava is a variety of aa lava characterized by large irregular blocks of very dense lava with smooth surfaces. Block flows are thicker than aa or pahoehoe, and when they are molten, they creep along at very slow speeds.

End of Trail
Summary

The eruptions at North Crater produced block, aa, and finally pahoehoe lava. Thick, slow-moving aa lava is capable of "floating" large sections of crater wall for several miles. Hot, fluid pahoehoe flows like a river of molten rock, crusting over to form pressure ridges and a ropy or wrinkled surface. As we have seen, lava can come in many different colors, from basic black, to blue, to rusty red. Why do we say that Craters of Moon has a violent past, a calm present, and an uncertain future? Remember that the last eruption at Craters of the Moon ended approximately 2,100 years ago and that the average time between periods of volcanic activity is 2,000 years. Geologists predict that the forces needed to produce a volcanic eruption are slowly building. This means a new eruption could occur at any time; next year, 300 years, or 1,000 years from now. It seems safe to say that more volcanic eruptions will occur in the not too distant future.

Site Tours—
Big Craters and Spatter Cones

Background Information

Big Craters and the Spatter Cones are two of the most interesting features in the

park. At one time, a number of trails crisscrossed the Spatter Cones and Big Craters. An extensive effort was made to rehabilitate this area. The importance of staying on the paved trails cannot be stressed enough. Extreme caution and supervision are required. The climb to the top of Big Craters is short (less than 1/4 mile) but steep. Be sure your groups stop to rest on the way up. To prevent members of your group from charging ahead, the group leader should stay in front. When at the top, keep a safe distance from the crater's edge. Do not let your students run down the side of these features.

The viewing area at the top of both Spatter Cones is limited. It is a good idea to divide large groups, allowing only five or six members of your group to approach at one time. Climbing on the bars and cables at the Spatter Cones is dangerous and strictly prohibited. **PLEASE DO NOT DROP ANY OBJECT, INCLUDING ROCKS, INTO THE SPATTER CONES.** Cleaning them out is dangerous and costly.

Parking Area
Introduction

The story of Craters of the Moon begins with the story of the Snake River Plain. The Snake River Plain is a vast expanse of lava that cuts across Southern Idaho like a giant smile. It extends from the Oregon border all the way to Wyoming. The Snake River Plain contains an assortment of lava flows, volcanoes, and volcanic features of varying ages. Although there are many theories on the formation of the Snake River Plain and its volcanic features, most geologists agree on the "Mantle Plume Theory" as the best explanation for the existence and location of the plain. Very briefly, the theory states that uneven heating within the core of the earth allows some material to become slightly hotter than the surrounding material. As the temperature of this material increases, it becomes less dense and buoyantly rises through the cooler, denser material surrounding it. This hot material, consisting of molten rock, is called magma. When magma erupts on the surface it is called lava. These plumes of magma are often referred to as "hot spots."

The Snake River Plain is surrounded by mountain ranges that were created through "Basin and Range" faulting. Basin and Range faulting occurs when the earth's crust is stretched and pulled in two different directions causing it to fracture. As the crust fractures, large blocks of the crust are uplifted, creating mountain ranges, and as large blocks are down-dropped, they create valleys. This pattern of mountain range - valley, mountain range - valley, can be seen in the areas surrounding the plain.

Basin and Range faulting is also thought to have created numerous fault zones, also known as rift zones, that run across the Snake River Plain in a north to south direction. These fault zones are made up of a series of long parallel surface and sub-surface cracks in the earth's crust. Craters of the Moon sits on top of one such rift zone, known as the Great Rift. Since rift zones represent weak areas in the earth's crust, it is common for them to be the site of volcanic eruptions.

Stop Number 1
Fissure-Type Eruptions

(Halfway to the top of Big Craters)
A typical eruption would begin as a section of the rift opens, creating a fissure. At first the lava is very fluid and charged with gas. As it erupts along the fissure it forms a long line of tall fountains called a "curtain of fire." This early stage of the eruption is often compared to shaking a can of soda and then "popping" the top. As the frothy lava shoots up into the air, it breaks apart and falls to the ground as cinders. As the eruption continues, sections of the fissure begin to seal off. All of the force of the eruption may be directed into one opening, creating a

fire fountain hundreds of feet high. Cinder cones are formed as cinders pile up around a vent. As most of the gas is released, the eruption becomes less violent and the fire fountains begin to die down. At this point the eruption changes. Massive amounts of lava pour from the remaining vents. These lava flows may continue to gush for months. Finally, when all the pressure is released, the eruption ends. In reality, however, there are very few, if any, "typical" eruptions. Cinder cones may form only to be torn apart by the opening of a new vent, or an eruption may simply end at any time.

Stop Number 2
Big Craters

Big Craters is a great example of how a fissure eruption gradually changes from a long curtain of fire to a single main vent. The fissure beneath Big Craters probably extended from the Spatter Cones to North Crater. Eruptions took place at many different points along the fissure. Big Craters is called a "cinder cone complex" because it's made up of as many as nine separate vents. Some of the smaller vents sit inside of larger ones. The cinders that make up Big Craters are varying shades of red, brown, and black. Some cinders are even iridescent purple and gold. Red cinders, like red lava rock, are the result of iron oxidization when the cooling cinders come in contact with steam. The iridescence is caused by a microscopically thin layer of volcanic glass that formed when the super hot cinders hit the cool air.

Stop Number 3
Spatter Cones

These "miniature" volcanoes form during the final stages of a fissure type eruption. As gases escape and pressure is released, the lava becomes thick and pasty. When these sticky globs of lava plop to the surface, they pile up to form spatter cones. Most spatter cones are much smaller than cinder cones. They are rarely more than 50 feet high. The steep sides of a spatter cone protect the ice and snow inside from the hot summer sun. One spatter cone, Snow Cone, has been known to hold ice all summer.

Parking Area
Summary

The Snake River Plain contains many different rift zones—one of which is the Great Rift. Rift zones are known for their spectacular fissure-type eruptions. The early stages of an eruption tend to be violent, as the gas charged lava forms fire fountains and cinder cones such as Big Craters. As much of the gas and pressure is released, the later stages are almost gentle, forming massive lava flows and spatter cones. Volcanic eruptions along the Great Rift have created 25 cinder cones, 60 separate lava flows, and numerous spatter cones.

Site Tours—
The Caves Area

Background Information

If you choose to visit any of the caves, special caution is advised. For safety reasons we advise that students remain in small supervised groups and not be allowed to explore the caves independently. There are five lava tube caves open to the public in the caves area. The largest is Indian Tunnel. Because of the limited time available, and ease of access, we generally recommend school groups visit only Indian Tunnel.

Each member of your group should have a dependable source of light such as a flashlight. Wear study shoes or boots. The caves are undeveloped and some hiking across broken lava is necessary. The ceilings are low and the footing uneven. Large holes in the 30 ft. ceiling of Indian Tunnel have created natural skylights. For safety reasons, when on the surface, teachers should not allow students to approach the skylights. Never allow any object to be dropped through a skylight, since the trail through Indian Tunnel runs directly under many of them. No running, pushing, or horseplay should be allowed in the caves area. The caves area has long been a favorite part of the park. The unique features of this area can be enjoyed safely by taking a few precautions. A brochure about the caves is available at the trail head.

Trail Head
Introduction

As the hot, fluid pahoehoe lava flows across the surface it forms rivers and channels. As the surface of the molten lava comes in contact with the cooler air, the surface of the lava starts to harden and the flow quickly "crusts" over. Hot lava continues to flow beneath the crust. When the eruption ends and the supply of lava stops, the lava drains out from beneath the crust leaving an empty tunnel or tube.

Stop Number 1
Dewdrop Cave

From here you can see the source of the Blue Dragon Lava Flow that formed the caves area. The Blue Dragon Flow erupted from a fissure at the base of Big Craters and the Spatter Cones. The Blue Dragon Flow is one of the youngest flows in the park.

Lava tubes are like a giant underground plumbing system for an eruption. They move the lava away from the vent and out onto the plain. Later eruptions often flow into existing lava tubes.

Many different events can cause a lava tube to collapse. Lava tubes often collapse during the final stages of an eruption as the lava begins to drain from the tube. If the lava drains from the tube while the roof is still soft and plastic, the roof may simply sink as it loses its support from the lava beneath. Another cause of collapse in lava tubes is the shrinking and cracking that occurs as lava cools. This cooling process can shatter the roof of a tube. Over long periods of time, the forces of erosion can also cause lava tubes to collapse. Water is a major force of erosion. As water seeps into cracks in the winter it repeatedly freezes and thaws. This freezing and thawing gradually widens the cracks. Bit by bit, the cracks grow wider, weakening the ceiling. Even the roots of trees and shrubs have been known to cause lava tubes to collapse. As plants begin growing in the protected cracks and crevices on the surface where soil and water collect, their roots can extend down through the roof of a tube. Each year as the roots grow longer and

thicker, they can weaken the roof to the point where it collapses.

Stop Number 2
Indian Tunnel

Being the largest lava tube in the caves area, Indian Tunnel is over 30 feet high, 50 feet wide, and approximately 800 feet long. Indian Tunnel contains many of the features common to all lava tubes. On the ceiling of the tube you can see lava stalactites formed as the river of lava pulled away from the ceiling, and molten material began to drip from the hot ceiling.

The amount of lava flowing in a tube fluctuates over the course of an eruption. If the activity at the vent increases, the amount of lava flowing into the tube may increase. This rise and fall of lava levels left marks on the walls of Indian Tunnel. If you look closely at the walls, you can see long linear ridges, called tide marks. These ridges show where the flowing river of lava temporarily held at a constant level long enough for deposits of lava to accumulate on the wall.

Since geologists cannot easily observe what happens inside a lava tube during an eruption, they can only speculate on how many features are formed. Most agree that during an eruption, lava tubes are often in a constant state of change. They can form only to be destroyed by the formation of new tubes. Tubes can even burst if the eruption pours more lava into the tube than the tube can hold, splitting it down the middle, like a loaf of bread in the oven.

Several forms of life can be found in Indian Tunnel today. In tubes with skylights, sunlight reaches into the cave and allows yellow and green mosses and lichens to grow on the moist, dimly lit walls. Small animals such as squirrels, chipmunks, and packrats make their home in the cave. Cavity nesting birds, such as violet-green swallows, find plenty of nesting cavities in the cracks of the rock that form the rim of the skylights. Great horned owls may also nest on the numerous ledges found in Indian Tunnel.

End of Indian Tunnel
Summary

Large eruptions that produce massive lava flows also produce lava tubes to move this great volume of lava away from the vent and out onto the plain. Rivers of pahoehoe quickly crust over, insulating the hot fluid lava beneath which continues to flow. Lava tube caves are left behind as the eruption subsides and the lava drains from beneath the hardening crust. The lava tubes in the caves area were all formed during the same eruption of the Blue Dragon Flow.

Chapter Two: Geology

Geology Summary for Teachers

Many Questions Arise

Craters of the Moon National Monument provides one of the best examples of basaltic volcanism in the world. Features typical of basalt eruptions—pahoehoe and aa flows, cinder cones, lava tubes, and spatter cones—are abundant and easily accessible. As one explores this bizarre landscape, many questions arise. Where is the volcano? Where did all this rock come from? How old is this area? Will the volcanoes erupt again?

The Snake River Plain

Craters of the Moon National Monument is located on the Snake River Plain. This crescent shaped expanse of volcanic rock stretches 400 miles from the Oregon border to Yellowstone. The age of the Snake River Plain can be traced from the most recent eruptions 2,000 years ago to the very oldest activity about 17 million years ago. Although both are volcanic in origin, the Eastern and Western Snake River Plain are considered geologically distinct.

Western Snake River Plain

Geologists believe the Western Snake River Plain was produced through the formation of a rift valley. A rift valley is a down-dropped area bounded by faults and fractures that are created when the earth's crust is pulled apart. This rifting on the Western Snake River Plain caused the crust to subside. The resulting depression then began to fill as upwelling lavas moved onto the surface through the crustal fractures. Wind and water also carried sedimentary deposits from the surrounding uplands into the subsiding area.

This rift valley originated about 17 million years ago and the last eruptions along the rift occurred between 1 million and 300,000 years ago. Because this landform continues to shrink as it cools, and because lava and sediments are periodically deposited on it, the area is in a state of continual subsidence. Although the Western Snake River Plain is still linked geographically to the Eastern Snake River Plain, geologists now find their origins to be distinctly different.

Eastern Snake River Plain

Volcanic eruptions vary according to how much silica the magma contains. Magma rich in silica is quite viscous and erupts very explosively. Magma with very high silica levels produces a rock called rhyolite. Magma with lower silica content generates much gentler eruptions of more fluid basaltic lava. There is evidence of both types of eruption on the Eastern Snake River Plain.

Calderas are massive craters up to 100 square miles in area formed when explosive eruptions empty magma chambers beneath the earth's crust, causing the surface to collapse. Calderas formed by rhyolitic eruptions are present on the Eastern Snake River Plain. Vestiges of numerous rhyolitic lava flows composed of small pieces of ash (ash flow tuffs) are also apparent along the margins of the Eastern Snake River Plain. They are all that is visible of a thick rhyolitic lava flow overlain by more recent basaltic lavas. These basaltic and rhyolitic lava flows have been measured by drilling to a depth of 2 1/2 miles. One half mile of basalt rests on more than two miles of rhyolite.

The rhyolitic volcanic deposits range in age from 10 million years on the western edge of the Plain, to 600,000 years at Yellowstone. Any theory about the origin of this area must explain the progressively younger ages of the rhyolitic deposits as you travel west to east, as well as the fact that later basaltic eruptions buried the rhyolite. Most geologists consider the *Mantle Plume Theory* the best explanation for the formation of the Eastern Snake River Plain.

Mantle Plume Theory

According to this theory, uneven heating caused by radioactive decay within the core of the earth causes some material to become hotter than that surrounding it. As this material heats up, it becomes less dense and rises through the cooler material of the earth's interior. These plumes, or "hot spots", produce many successive batches of rising magma. The rising magma eventually reaches the earth's crust and erupts onto the surface as lava.

The plumes remain stationary while the plates that make up the earth's crust move over them. Thus volcanic activity above a plume is expressed as a line of eruptions creating volcanic features which grow older the further they are from the hot spot. This relationship was first identified in the Hawaiian Island chain, and many geologists see the same pattern expressed on the Snake River Plain. Eruptions occurred 10 million years ago at Twin Falls, 5 million years ago at Arco, and finally, 600,000 years ago in Yellowstone.

The events that occur during an eruption associated with a mantle plume can be broken into two distinct stages.

Stage I
Rising basaltic magma formed within the earth's mantle reaches the crust. The heat of the collecting magma begins to melt the surrounding crustal rock, which is rich in silica, forming a pasty magma called rhyolite. The rhyolitic magma rises further, forming a second magma chamber within about 6 miles of the earth's surface.

Since gases within the thickened rhyolitic magma chamber cannot easily

escape, the eruptions tend to be devastating. These eruptions are so violent that they sometimes spew hundreds of cubic miles of ejected material into the atmosphere. By contrast Mount St. Helens produced less than 1/2 cubic mile of ejected material. As the magma chamber empties, there is nothing to support the crust above it. It collapses, forming a caldera up to 100 square miles in area.

Stage II
The intense volcanic activity associated with the mantle plume ebbs as the North American plate continues its movement southwestward, only to begin again at a new spot farther up the chain. Eventually the explosive rhyolitic activity is replaced by gentler basaltic eruptions. These basaltic eruptions arise from the original deep crustal basaltic magma chamber that formed during Stage I. Magma continues to rise and enlarge the chamber and pressure within it gradually increases. This pressure, coupled with the fractures in the earth's crust caused by regional crustal expansion, generate both the force and the pathways necessary for basaltic magma to move to the surface. The magma remains basaltic because there is little silica left in the crust to melt into it.

Upon eruption basaltic lava is very fluid and basaltic lava flows from these relatively calm eruptions spread out to cover the older rhyolite lavas. With each new eruption, less of the rhyolite is left exposed and, after millions of years, almost all of the rhyolite has been covered by basalt.

The Great Rift

Several volcanic rift zones traverse the Snake River Plain. Volcanic rift zones are weak areas where the earth's crust has been stretched and thinned and fissures have developed. Magma under pressure follows these fissures to the surface.

The most extensive system of fissures on the Snake River Plain is called the Great Rift, which passes through Craters of the Moon. This volcanic rift zone is 60 miles long and from 1.5 to five miles wide. It is characterized by short surface cracks, more than 25 cinder cones, and is the point of origin of over 60 lava flows. Geologists believe that the formation of the Great Rift is related to typical Basin and Range faulting.

Basin and Range

Basin and Range faulting is responsible for the topography of eastern California, Nevada, Utah, and southern Idaho and is typified by alternating uplifted mountain ranges and down-dropped valleys. Forces in these areas are pulling apart and thinning the earth's crust, producing a tremendous buildup of tension. When this tension becomes extreme, the earth's crust suddenly fractures. Large blocks of earth slip or rotate up and down, creating valleys separated by long mountain ranges.

The release of this tension has resulted in about 150 mountain ranges and valleys in the Basin and Range province, all aligned in a north/south direction and spaced at approximately 16 mile intervals.

There are Basin and Range mountain ranges to the north and south of the Snake River Plain. The block faults that occur at the edge of each are known as "border" or "range-front" faults, and extend beyond the base of the mountains and out beneath the lavas. The extension of the range-front faults onto the Eastern Snake River Plain is marked by zones of parallel cracks that may run for tens of miles, and are known collectively as volcanic rift zones.

The Great Rift is not a typical Snake River Plain volcanic rift zone, because it

cannot be readily identified as a continuation of a Basin and Range border fault. However, the distance from the Great Rift to the Lost River Mountains is slightly more than the 16 miles normally found between Basin and Range structures. Furthermore, gravity and seismic information indicates a fracture extending from the Great Rift into the Pioneer Mountains to the north. This leads some geologists to conclude that the Great Rift is an extension of a typical Basin and Range fault system.

The Great Rift is the conduit through which a tremendous amount of lava reached the surface to form the Craters of the Moon lava field.

Eruptions at Craters of the Moon

Most of the lava flows exposed at Craters of the Moon erupted between 2,000 and 15,000 years ago. These flows were deposited during eight eruptive periods, each separated by periods of relative calm. This cycle of eruptions interspersed with periods of calm is associated with the buildup of pressure as magma accumulates beneath the surface. Strain increases until the resistance of the earth's crust is overcome, magma rises to the surface, and an eruption takes place. As soon as the magmatic pressure dissipates, the eruption ceases until the pressure can build once more.

During a typical eruption at Craters of the Moon, the force of rising magma causes a section of the Great Rift to pull apart. As magma rises through the crack, gases contained within the magma expand. The frothy magma is very fluid and charged with gas. Eruptions begin as a long line of tall fountains along a crack that may extend more than a mile. These are called "curtain of fire" eruptions and produce downwind blankets of frothy cinders.

After hours or days, the initial expansion of gases decreases and the eruption becomes less violent. Some sections of the fissure seal off and the eruption becomes smaller and more localized. Cinders are still thrown into the air, but now they build up in piles around individual vents and form cinder cones.

As the amount of gas contained in the magma continues to drop, the volcanic activity again changes. Huge outpourings of lava flow from various fissures and vents. These lava flows typically continue for days to a few months, but may continue for years. They are the source of most of the rock produced during an eruption. The flows gradually subside and all activity stops.

What Does the Future Hold?

If what geologists tell us proves to be true, it is likely that there will be another eruption at Craters of the Moon. By studying the flows that make up the Craters of the Moon lava field, geologists have been able to determine an eruptive pattern that indicates the area is merely in a stage of dormancy. They believe that past eruptions conform to a predictable time schedule and that the eruptive cycle will begin again within the next 1,000 years.

Geology Summary for Students

Where is the Volcano?

Close your eyes and imagine a volcano. What do you see? A steep sided mountain that throws ash high into the air? Well, the volcanoes at Craters of the Moon are not like that at all!

The eruptions at Craters of the Moon are called fissure eruptions, because the lava here came out of cracks in the ground. Craters of the Moon is on a weak spot in the earth's crust called the Great Rift. The Great Rift is 53 miles long. All along it there are volcanic cones, lava flows, and open cracks in the ground. Eight times in the past 15,000 years, melted rock has risen from deep within the earth and erupted along the Great Rift. The eruptions may begin again. Geologists believe there will be another eruption at Craters of the Moon within the next 1,000 years.

Go with the Flow

What were the eruptions like? First a crack opened in the ground. Then frothy magma (melted rock inside the earth) burst from the crack and sprayed hundreds of feet into the air. The crack began to clog up. The eruption continued as isolated fountains of red hot lava (melted rock on the earth's surface.) The foamy lava cooled as it fell. Bubbly cinders piled up around the vents. They formed hills called cinder cones.

Gradually the eruption became less violent. The lava flowed quietly onto the surface from cracks in the ground. It spread out across the land. One lava flow at Craters of the Moon covers 100 square miles or over 12,000 football fields!

All Black Rock is Not the Same

You will see a lot of black rock at Craters of the Moon. But if you look carefully you will notice several different kinds.

As you walk across one of the cinder cones, listen to the crunch of the small rocks under your feet. Pick up a handful and look at them. They are very light and contain many air bubbles. These cinders erupted explosively and piled up around a volcanic vent. At the top of many of the cinder cones you will find a deep hole or crater. Lava erupted from these craters.

Most of the rock, though, is solid and relatively smooth. This rock emerged from fissures and flowed across the ground like water. Some of the lava was very hot and thin. It flowed quickly and formed rock with a wavy surface. In some places the the rock looks like coils of rope. This type of lava is called pahoehoe (pa-hoy-hoy), which means "ropy" in Hawaiian.

Cooler, thicker lava formed flows called aa (ah-ah). Aa does not flow as fast as pahoehoe. It breaks up as it flows, forming a very rough, jagged surface. Aa means "rough on the feet" in Hawaiian, and you will see why if you try to walk across it!

Strange Formations

You will see many things at Craters of the Moon unlike anything you have seen before. There are caves in the lava flows called lava tubes. How did they get there? The surface of the liquid rock hardens first. The lava keeps flowing underneath this crust. When the eruption ends, the lava under the crust flows out, leaving behind an empty tube.

There are miniature volcanoes called spatter cones. Thick, sticky lava burbles up along an opening in a fissure. Blobs of lava thrown into the air pile up around the crack. A steep walled cone forms.

Some of the rock at Craters of the Moon is not black, but blue! A thin layer of glass formed on the surface of this rock as it was cooling. The glass is shiny and blue.

In some places steep towers of rock rise above the lava like castles. These are pieces of a crater wall which was demolished by an eruption. Flowing lava then carried the pieces away like rafts on a river.

Although there are not many trees at Craters of the Moon, in places you can see molds of tree trunks. The trees were surrounded by red hot lava. The rock hardened around them, leaving behind a mold of the trunk. Then the trunk burned away from the heat of the lava.

All of these strange formations make Craters of the Moon a fascinating place to visit. Watch for them during your stay.

Words You May Hear at Craters Of The Moon

Aa
A type of lava flow having a rough surface with sharp, spiny projections. Aa means "hard on the feet" in Hawaiian.

Active Volcano
A volcano that is erupting or has erupted in recorded history.

Basalt
A fine grained, dark-colored rock rich in iron and magnesium and relatively poor in silica; the common lava of Hawaii and Craters of the Moon.

Blue Dragon Lava
A type of pahoehoe flow with a bright blue sheen on its surface. The blue color is produced by a thin veneer of crude "glass" that forms on the flow's surface.

Cinder
Small, very porous fragments of frothy rock ejected from a volcano.

Cinder Cone
A steep sided hill formed by the accumulation of cinders expelled from a volcanic vent.

Crater
A bowl- or funnel-shaped depression, generally in the top of a volcanic cone. The vent for volcanic material.

Fissure
A crack in the earth's surface from which volcanic material may erupt.

Lava
Magma which has reached the earth's surface.

Lava Tube
A hollow tunnel formed when the outer part of a flow has hardened and the inner, still molten material subsequently drains out.

Magma
Molten rock beneath the earth's surface.

Mantle Plume Theory
A theory which states that localized hot spots deep in the earth's mantle periodically release "plumes" of molten material which slowly rise to the surface. Hot spots are fixed and do not move. However, the crust of the earth slowly moves across them, generating volcanic activity.

Pahoehoe
A type of lava flow with a smooth, billowy surface. The Hawaiian term means "ropy."

Rafted Block (Monolith)
A large block of old cinder-cone walls which has been transported by a lava flow to a new location.

Shield Volcano
A volcano with a broad, low profile, the shape of a flattened dome, built up by repeated flows of very fluid lava. Common on the Snake River Plain, but not at Craters of the Moon.

Spatter
A thick, pasty clot of lava.

Spatter Cone
A low, steep-sided cone built of blobs of sticky lava that have piled up around a vent.

Tree Mold
An impression left in the lava of the charred surface of a tree. *(Shown at right.)*

Vent
A channel in the earth's surface from which volcanic material erupts.

Volcano
A vent in the surface of the earth through which magma, gases and ash erupt.

Volcanic Rift Zone
An array of volcanic fissures along which repeated eruptions occur.

What is Craters of the Moon Like?

A Snickers Bar
The earth's crust in the Craters of the Moon area is being pulled apart and thinned by forces within the earth. It is much like a Snickers Bar which you bend or stretch between your hands. Like the chocolate coating on the candy bar, the surface of the earth develops cracks called faults. It is one of these faults which has allowed magma to rise to the surface at Craters of the Moon.

A Pop Bottle
The magma underground is full of dissolved gases, like soda in a bottle of pop. It is dissolved gases that make a soda fizzy. We all know what happens when you shake up a bottle of pop and then take the top off. Volcanoes work the same way. The dissolved gases start to expand. Pressure builds and the volcano blows its top and erupts to release the pressure of the expanding gas.

Old Faithful
Lava erupted here in huge "fountains of fire." These fountains resembled the famous geyser Old Faithful but, instead of steam and water, they erupted melted rock.

Rice Krispies and Root Beer
The lava in a "fountain of fire" eruption is very frothy, like foam on a glass of root beer. The frothy bits of lava shower the ground and build up large cones of cinders. The cinders are light weight and contain many air bubbles, like Rice Krispies.

Hollywood Rocks
The light weight cinder rocks are like the foam rubber rocks that bounce down on cowboys in Hollywood westerns.

Maple Syrup
The lava that poured from the ground to form the many lava flows at Craters of the Moon was thin and watery, like maple syrup. In contrast, the lava associated with the eruption of Mount St. Helens in Washington was thick and sticky, like peanut butter.

Toothpaste
Lava in a fissure eruption oozes out of the ground like toothpaste being squeezed from a tube, and spreads out across the landscape like a river overflowing its banks.

A Frozen River
When a lava flow begins to cool, a crust forms on the surface which insulates the hot lava flowing beneath it. It's like the layer of ice that forms on a river in winter, with the water underneath it continuing to flow.

A MacDonald's Hot Apple Pie
The hot, sticky lava beneath a hardened crust is also like a MacDonald's Hot Apple Pie.

A Garden Hose
Lava flows beneath the solid crust of a lava flow like water through a garden hose. When the eruption stops, the lava drains out of the tube and leaves behind an empty chamber or cave.

Cow Patties
Spatter Cones form as blobs of sticky lava pile up around a volcanic vent. The squishy blobs of lava resemble something you might find in a cow pasture!

An Ice Chest
The lava rock is full of holes, like a hunk of Swiss cheese. These holes make the lava an extremely good insulator, like a giant styrofoam ice chest. The lava keeps the caves and spatter cones cool and preserves the ice that accumulates there in winter.

A Rusty Nail
The red color you see in some of the rock results from the same process that occurs when you leave your bicycle out in the rain. The iron in the rock rusts when it comes in contact with air and water.

A Marriage
The colorful patches on the rocks are a plant called lichens. They are composed of two separate living things growing together in a way that benefits both: fungus and algae. Fred Fungus and Alice Algae took a "lichen" to each other. They got married, but unfortunately their marriage has been on the rocks ever since.

A Parade
The plants growing on the lava change through time. This process is like a parade. The lichens come first, followed by small plants and shrubs, then limber pines, and finally sagebrush and grasses.

Activity 2A

Deep Time and You

Students make time lines showing significant events in Earth's history and their own lives.

Objectives:
- Students will be able to contruct a time line.
- Students will begin to comprehend the magnitude of geologic time.

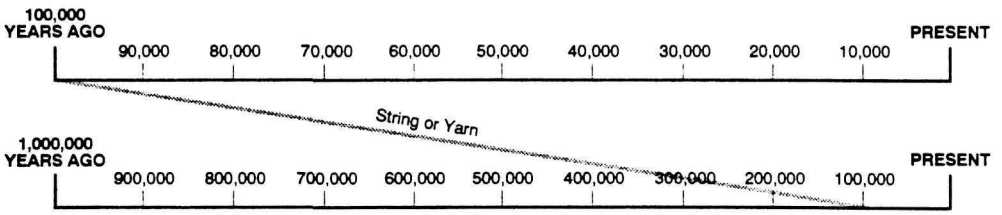
Duration:
1-2 hours

Background:
The Earth is about 4.5 billion years old, a number too large for people to conceptualize. If we were to shrink the Earth down to the size of a basketball and compress those 4.5 billion years into a few hours we would be able to observe radical changes. Continents would race around the globe, sink beneath the sea, rise up again, smash into other continents, build mountains, and erode back into the sea. Volcanoes would continually erupt and then quickly be weathered away. An astounding array of life would evolve and most of it would pass into extinction seconds later. Asteroids would occasionally slam into Earth. Indeed, the Earth would look like an extraordinarily dynamic little sphere before us.

But from our reference point, change of this magnitude is hard to appreciate. Yet if we begin to grasp the immensity of geologic time, we can begin to recognize the changing nature of Earth.

Materials:
- Adding machine tape (3 or 4 inches wide by about 100 feet)
- Pencils, pens, crayons
- String or yarn
- Use of a large indoor wall while your class is studying about Craters of the Moon

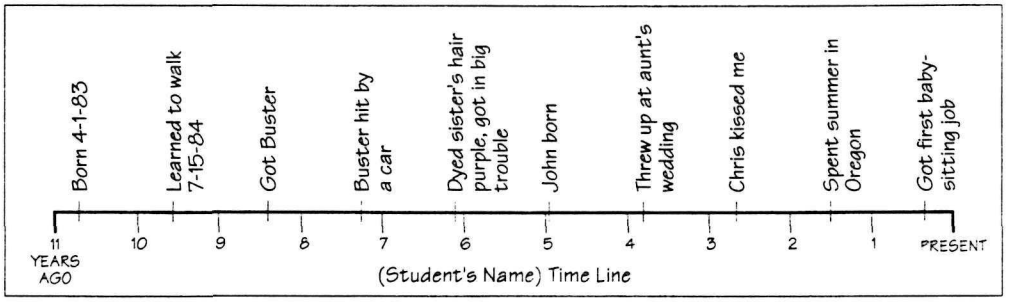
Procedure:
Students will construct time lines using adding machine tape. Completed time lines will be displayed on a wall for reference during the weeks you are studying Craters of the Moon. In subsequent Culural History and Ecology units, new time lines will be added to the existing ones on the wall. Time lines of different scales will be linked together with string or yarn to show temporal relationships. For example,



Part 1 - Personal Time Line

Have the students make a time line describing events in their own lives.
- Give each student a strip of adding machine tape about two feet long.
- Have them draw a straight line down the length of the tape.

- On the right side have them write "present."
- If the student is 10.5 years old, have them write "11 years ago" at the far left side of the tape.
- Then, let them divide the time line up into 11 equal increments.
- Finally, have them fill in significant parts of their life with text and pictures. Label it "Your Name's Time Line." For example,



- Save for future use.

Part 2 - Age of Earth Time Line

Have the students make a time line showing the age of the Earth.

- First, discuss the size of a billion. Quiz the students on what they were doing 10, 100, 1,000, etc. seconds ago. Let them guess; then tell them how long the time was in minutes, days, or years. They will be astounded at the size of a billion:

  10 seconds ago?
  100 seconds ago? ..... (1.3 minutes)
  1,000 seconds ago? ..... (16.7 minutes)
  1,000,000 seconds ago? ..... (11.5 days)
  1,000,000,000 seconds ago? ..... (31.7 years)

- Tell them the Earth is about 4.5 billion years old.
- Cut as long a piece of adding machine tape as your wall will accommodate.
- Have 2-3 students afix the time line near the bottom of the wall (other time lines will go above it) and mark off 5 equal lengths. Label the marks from left to right "5 billion years ago," "4 billion years ago," and so on. Label it "Earth's Time Line."
- At the 4.5 billion year old mark, write "the Earth is formed." Divide the most recent billion year division into 10 equal, 100,000,000 year increments.
- Later, your class can add more information to this time line.

Part 3 - Craters of the Moon Time Line

Have students make a time line showing events at Craters of the Moon.

- Assign several students to cut a time line about 15 feet long and divide it into 15 equal parts. It should be marked 15,000 years ago, 14,000 years ago, . . . present. Label it "Craters of the Moon Time Line." Place it two or three feet over the Earth's Time Line with right sides aligned. Allow enough room in between the strips for a "Life Time Line" you'll do later.
- Other students should make the following labels on separate small pieces of paper (illustrated if they wish) and when completed they should tape them at the appropriate place to the Craters of the Moon Time Line.

  2,000 years ago..... Broken Top
  2,100 years ago..... Blue Dragon Flow/Indian Tunnel
  2,200 years ago..... Trench Mortar Flat
  6,000 years ag ..... Big Cinder

7,400 years ago	Grassy Cone
12,000 years ago	Sunset Cone
2,300 years ago	North Crater
6,000 years ago	Big Cinder Butte
6,600 years ago	Silent Cone
2,100 years ago	Big Craters
1,500 years ago	Triple Twist tree on North Crater flow started growing

(Note: The relevance of the dates and places will grow as they build upon the time line in future weeks. Doing this excercise now will help to familiarize students with names of features they will see on their field trip.)

Activity 2B

The Earth, from Core to Crust

(adapted from Ranger Rick's "Nature Scope")

Students act out different parts of the Earth and then build models of the Earth showing its layers.

Objectives:

- Students will be able to name the parts of the Earth.
- Students will understand that the Earth is dynamic.

Duration:
2 to 3 hours

Background:
The Earth, like the life on its surface, is changing all the time. Parts of it are molten and slowly rise, cool, and sink back toward the Earth's core, like soup simmering over a fire. Continents drift around the globe creating the features we think of when we think of geology. But most of the Earth lies unseen between our feet and the other side of the world.

The Earth is made up of the crust, the mantle, and the core. Although geologists have only drilled a few miles into the Earth's crust, they have indirectly deduced much about the remainder of the planet's composition.

The Crust
What we walk on and see is the crust. It is wafer thin, only 3 to 22 miles thick. If the Earth were the size of a billiard ball, the crust would be as thick as a postage stamp stuck to its surface (think how thick the membrane of life would be that coats the Earth!). The crust is broken up into enormous sections the size of continents, called tectonic plates. Earthquakes and volcanoes are common along the margins of these moving plates. The volcanic activity at Craters, however, is not related to it lying on the edge of a continental plate. Rather, geologists theorize that a localized heat source in the mantle lies relatively near the surface in southern Idaho, resulting in the volcanism here.

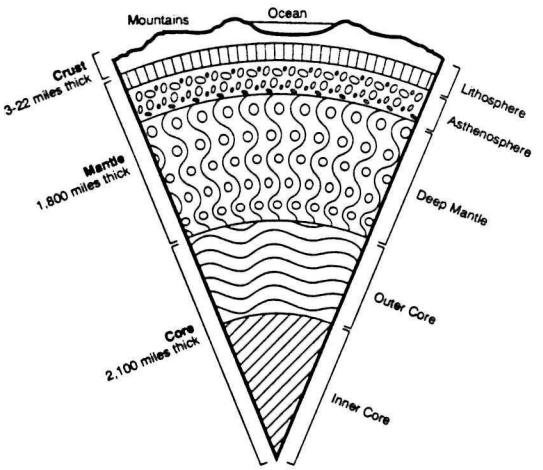
The Mantle
The mantle is about 1,800 miles thick and is under pressure and therefore denser and hotter than the crust. The mantle can be subdivided into three regions.

The Lithosphere. The lithospere is the outermost part of the mantle. It is just beneath the crust and both are cool and rigid and float upon the hotter layer below.

The Asthenosphere. This zone is hot enough to flow at a very slow rate of speed and acts as the sea upon which the lithosphere floats.

The Deep Mantle. Beneath the asthenosphere the rock becomes progressively more molten. Many geologists believe that huge convection currents mix this part of the mantle as it rises toward the asthenosphere, cools, and sinks back toward the core again.

The Core
Because of gravity, the densest materials are found near the Earth's center, mostly iron and nickel. The 2,100 mile thick core is under the pressure of 1,800 miles of mantle and is therefore very hot. Geologists believe this is the main source of heat for the geologic events we know about in the mantle. Based on how energy waves pass through the Earth, geologists know that the core is in two layers.



The Outer Core. The outer core is molten and responsible for Earth's magnetic field.

The Inner Core. The inner core is extraordinarily dense, solid metal.

Materials:
- Chalkboard
- Scissors
- Cardboard milk cartons or other similar boxes
- Small ziplock bags
- Masking tape
- Nontoxic paints or pens
- Clay or . . .
- Dough (for ingredients see recipe at end)
- Water
- Cardboard
- Glue
- Construction or butcher paper

Procedure:
Part 1 - Human Model of the Earth
Prepare slips of paper for your students with the following words (make adjustments for your class size):

Inner core, "heavy metal!" (1-2 slips)
Outer core, "molten metal!" (3-4 slips)
Deep mantle, "red hot rocks!" (6-7 slips)
Asthenosphere, "rolling stones!" (8-10 slips)
Lithosphere, "moving plates!" (12-14 slips)

Go outside and randomly issue the above paper slips to the kids. A fun way to have them assemble in groups is to have them loudly chant the words in quotation marks without showing each other their slips of paper. As they yell out their chant they listen for the same chant coming from others and then congregate with them.

Once they are in groups, tell them that they are going to build a human model of planet Earth. Earth is a dynamic thing, so they must make it come alive in their skit.

Explain briefly what characterizes each part of the Earth and then ask each group to come up with an appropriate movement while they chant "molten metal!," "rolling stones!," or whatever. Give them a few minutes to work this out.

Start with the core and add layers until you've completed the Earth with the lithosphere. Encourage them to come up with their very own ideas but if they need some direction, here are some suggestions for theatrics:

Inner core—Hand the inner core person or people a trillion pound weight and have them grunt "heavy metal, heavy metal" while under this massive weight. Or have them flex their muscles or lift weights while chanting to demonstrate the pressure they are under.

Outer core—These kids could weave in and out as they circle the inner core and chant "molten metal" to show that they are fluid. They could grit their teeth while they chant as they too are under lots of pressure.

Deep mantle—As they chant "red hot rocks" they could spin and revolve around the core in slow motion to show that they are molten.

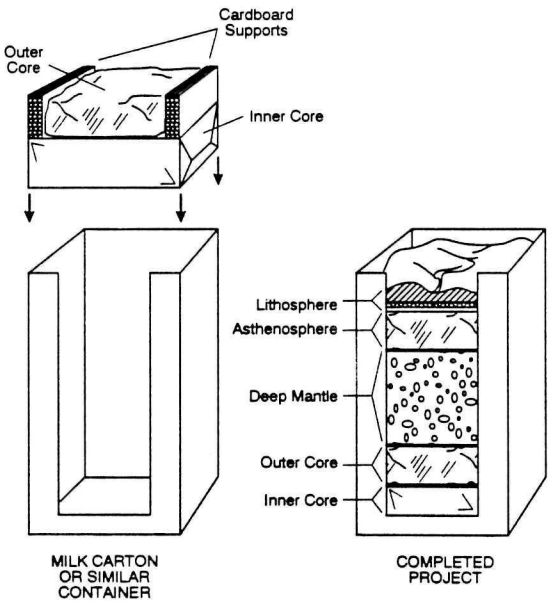
Asthenosphere—This layer is very viscous and the kids could demontrate it by keeping their feet planted while they sway, chant "rolling stones!," and face outward with their hands to show that they are holding up the lithosphere.

Crust/Lithosphere—Kids could link arms in groups of two or three and revolve around the Earth while chanting "moving plates!" to simulate the moving plates lithosphere and crust. One or two of the crust/lithosphere kids could simulate a volcano or earthquake.

Part 2 - Build a Cross Section of the Earth
Students will build a cross section model of Earth using materials that demonstrate the unique characteristics of its layers.

Divide the students into groups of about three to six kids. Have them work together as they construct a section of the Earth from the inner core to the lithosphere and crust.

The Container. Use a tall, narrow box like a milk carton to make the model. Cut out part of a panel as shown to serve as the window to the Earth's composition. Cover the box with paper so that it can be labelled and decorated.



Inner Core. Cut several pieces of corrugated cardboard so that they will fit in the bottom of the box. Stack and glue the pieces and wrap them in paper.

Outer Core. Fill a small ziplock bag or other waterproof bag with water. So that it won't rupture from the layers that will be added above it, make supports out of cardboard for the sides as shown. You can use crumpled plastic bags instead of water-filled bags if you feel water leakage will be a problem.

Deep Mantle. Use clay or dough (see recipe below) to make this layer. The dough can be painted with water colors or poster paints. If you want it to remain soft, the kids could enclose this layer in a zip-lock bag and sqeeze out the air before sealing it.

Asthenosphere. Use a different colored clay or dough to make this layer. Again, it could be sealed in plastic so it will remain soft.

Lithosphere. Cut a thin piece of cardboard to serve as the boundary between the crust and upper mantle. On the bottom side of it spread a thin layer of clay or dough for the upper mantle and on the top side spread a thin layer for the crust. Students can create mountain ranges in the crust.

Finishing touches. The kids could tape a nail and nickel on the box near the core to show that it is made of iron and nickel. With the information already provided, students could write a few words on the outside of the box about the characteristics and dimensions of the layers.

Dough Recipe

Two batches of the recipe will make enough dough for five models.

- 4 c. baking soda
- 2 c. cornstarch
- 2.5 c. cold water

Mix all ingredients in a saucepan and cook about 10 minutes over medium heat until the consistency of mashed potatoes. Remove from heat, empty onto a plate, and cover with a damp cloth. When cool, knead into a ball. Place in a sealed plastic bag and refrigerate until use.

Note: Earth's layers are not as distinct as illustrated here and by your models. There are transition zones and variations in densities within layers. The presence of Craters of the Moon not on the margins of continental plates demonstrates that the layers beneath our feet are far from uniform.

Activity 2C

The Creeping Hot Spots

Students learn about the Mantle Plume Theory, plate tectonics, and Idaho geography by experimenting with a map of Idaho.

Objectives:
- Students will be able to explain the basics of the Mantle Plume Theory.
- Students will understand that the crust slides over the mantle.
- Students will be able to name key cities and geologic features of Idaho.

Duration:
1 to 2 hours

Background:
The theory of plate tectonics explains much of Earth's geology. For example, California's famous San Andreas fault is formed where two tectonic plates come together and slide against each other. The tension that is created along the fault is periodically released, like a rubberband stretched to its breaking point, resulting in earthquakes.

Other geologic phenomenons require a combination of theories to be explained. For example, events creating the Snake River Plain that stretches across southern Idaho from Oregon to Wyoming cannot be described as easily as the San Andreas fault. A combination of "Rifting," "Basin and Range Faulting," "the Mantle Plume Theory," and Plate Tectonics are required to explain that big crescent. For a concise description of these theories and the likely sequence of events that made the Snake River Plain see pages 2.1 to 2.5.

The student activity that follows will require that you understand the basics of these theories.

Materials:
- One copy of the enclosed map of Idaho for each student
- Magic marker or highlighter for each student
- Candle and match (for teacher)
- One small Snickers candy bar for each student (optional)
- Maps of Idaho and neighboring states

Procedure:
Show the students the enclosed map, a copy of which they will soon receive. Emphasize that if Idaho were really this big, the crust would be about the thickness of the paper. Idaho is part of a massive piece of crust called the North American Plate and it slides as a unit over the Earth's mantle.

With the Idaho map you will demonstrate the Mantle Plume Theory, Rifting, and Plate Tectonics. The students will then repeat the demonstration on their own maps individually and in teams, adding information to their maps as they work.

Part 1 - Demonstrate Rifting

The Western Snake River Plain was created through the formation of a rift valley. The crust was pulled apart in that area, resulting in lava welling up to the surface. Imagine that the inner part of a Snickers bar is molten and under pressure and kept in place by the chocolate coating. If you were to twist or stretch the bar, "faults" and "fractures" would appear in the chocolate "crust" and its "molten" candy center would well up to the surface. This

is what happened in the Western Snake River Plain during the last 17 million years.

Locate the Western Snake River Plain on your map and weaken the area by punching several pencil holes through paper "crust." Then use your fingers to tug at the paper and create small tears and—*voilá*—you've created a rift valley.

As another way of demonstrating the process you may give each student a Snickers bar and let them pull and twist it to create faults and fractures before they eat it. You may wish to do this at the end of the class. Perhaps the Snickers bar could be used as a reward for demonstrating their knowledge to you about the formation of the Snake River Plain and geography of Idaho.

Part 2 - Demonstrate the Great Rift

In regards to the Western Snake River Plain, we spoke of rifting on a grand scale. A smaller example of rifting is the Great Rift, which runs 60 miles north-south and ranges from one to five miles wide. Here the crust was pulled apart, creating many fissures which allowed magma to escape. There are 25 cinder cones and 60 lava flows along the Great Rift.
Locate the line through Craters of the Moon on your map that represents the Great Rift. Punch pencil holes along the line and tear slightly to demonstrate the rifting here.

Part 3 - Demonstrate Mantle Plume Theory

Let the candle represent a hot spot in the mantle. Geologists think this heat source may have nuclear origins, like the heat generated in a nuclear reactor (it represents no threat to life because it is buried deep in the Earth). If you did "The Earth, from Core to Crust" activity you might want to get one of the models out to demonstrate the Mantle Plume Theory. Imagine some the of the deep mantle material squeezing upward toward the surface in a "plume." That hotter, deep mantle rock creates the heat necessary for the volcanic activity expressed at the surface.

Light the candle to symbolize the hot spot. Hold the crust (your map of Idaho) over the stationary candle high enough so that it won't scorch. From your reading of 2.1 to 2.5 you know that the Mantle Plume Theory applies only to the Eastern Snake River Plain and that 10 million years ago the Plume was located under what is now Twin Falls. You also know that the North American Plate has crept southwest over the eons and that 600,000 years ago the Plume or hot spot was active under Yellowstone.

As you describe this to the kids, lower the Twin Falls area to just the point of scorching and slowly move the crust (the map) southwest to form the Eastern Snake River Plain between Twin Falls and Yellowstone. You or a student can say, "10 million years ago, 9 million years ago," and so on as you slowly move the paper over the candle toward Yellowstone so that by the time you get there you're at "one million years ago." Let the scorching paper represent the creation of the Eastern Snake River Plain.

Part 4 - Student Maps

Issue your students copies of the provided maps. Have them label their maps with the following to improve their knowledge of Idaho geography. Then they should create the Western and Eastern Snake River Plain and the Great Rift (have them use a marking pen or highlighter instead of a candle for demonstrating the Mantle Plume Theory. Make sure they hold the pen stationary beneath the moving crust and count backward slowly from 10 million years ago until they arrive at Yellowstone).

Directions
East
West
North
South

Towns and Cities
Arco
Boise
Coeur d' Alene
Idaho Falls
Jackson
Lewiston
Missoula
Pocatello
Salmon
Sandpoint
Spokane
Twin Falls

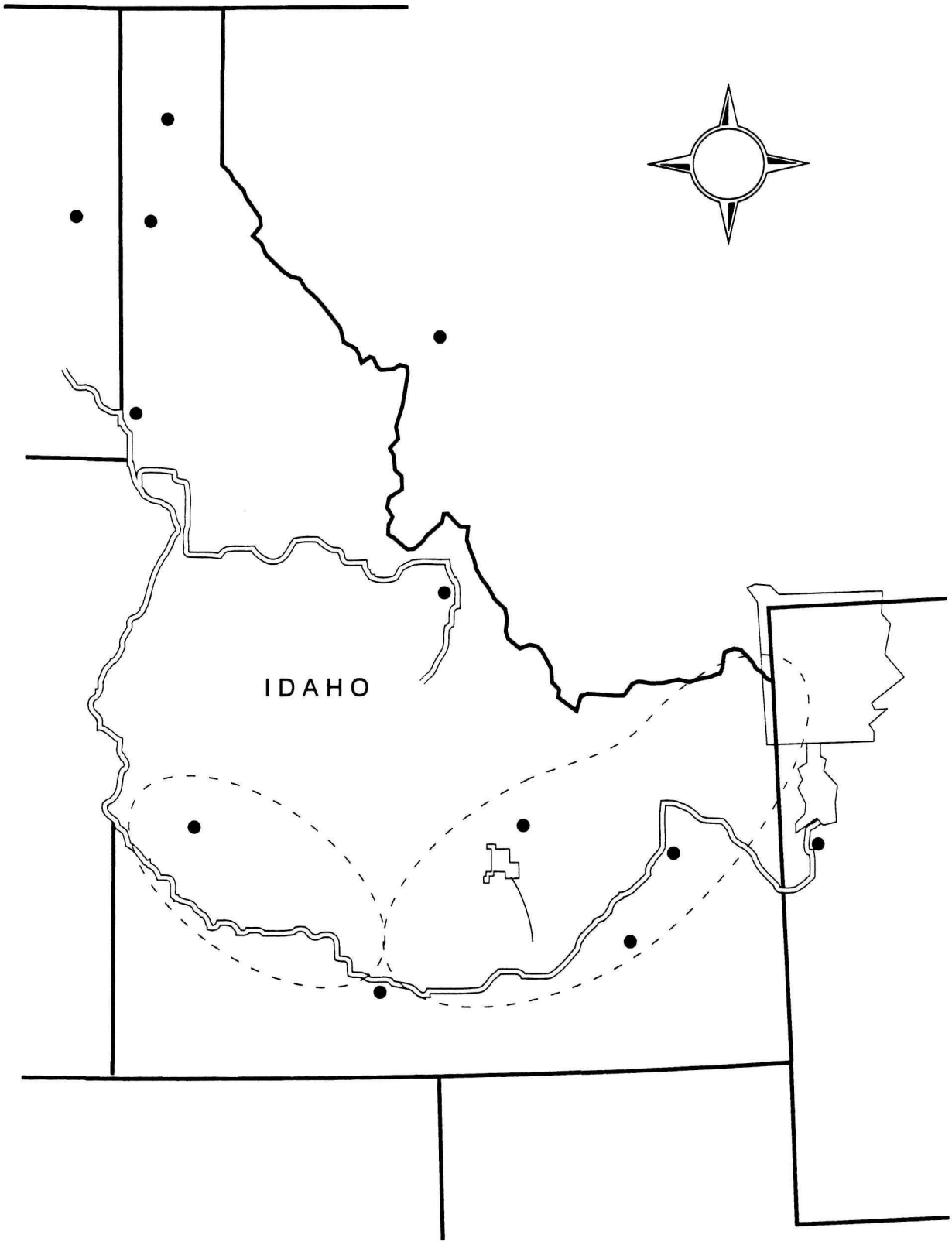
Rivers and Places
Yellowstone National Park
Craters of the Moon Nat'l Monument
Grand Teton National Park
Salmon River
Snake River
Western Snake River Plain
Eastern Snake River Plain
Great Rift

States and Countries
Montana
Nevada
Oregon
Utah
Washington
Wyoming
Canada

Note: Make sure the students understand that the above geologic processes happened concurrently over millions of years and that this explanation is a simplified version of reality.

Teacher's Answer Key:

Work Sheet 2C



Activity 2D

The Liquid Rock Race

Students learn about the properties of lava by experimenting with liquids having varying gas contents and viscosities.

Objectives:

- Students will be able to describe liquids in terms of their viscosity.
- Students will be able to explain how heat affects a liquid's viscosity.
- Students will understand how dissolved gas and pressure influence the behavior of an eruption.

Duration:
1 to 2 hours

Background:
When we think about the properties of liquid, water usually comes to mind. But there are many different liquids, each with unique freezing points, boiling points, and viscosities. A liquid's behavior can also be greatly modified by the presence of dissolved gases (e.g., champagne vs. wine).

Craters of the Moon was once a liquid sea of lava (although not all at once) until it "froze" and turned to a solid. Early eruptions were violent, like a corked bottle of champagne, while later eruptions were sedate, like wine being poured into a glass. Some lava raced across the land like heated olive oil, while other flows crept along like tons of tepid toothpaste.

Two basic types of lava made Craters: rhyolite and basalt. The principal difference between the two is the amount of silica (SiO_2) they contain. Rhyolitic lava's high silica content causes it to be quite viscous. That viscosity prevents gas within it from readily escaping as the magma rises to Earth's surface through a break in its crust. When lava can no longer contain the increasing gas pressure within, cataclysmic rhyolitic eruptions occur.

Basaltic eruptions are more gentle because gas bubbles to the surface before it generates explosive pressure. Boiling water does not cast large volumes of liquid into the air in violent fits and starts like, for example, a boiling vat of mud. The high viscosity of the mud causes it to behave like rhyolitic lava. Basaltic lavas are runnier, like maple syrup, while rhyolitic lavas are more like molasses.

Early volcanic activity in the Snake River Plain (up to 17 million years ago) consisted of calamitous rhyolitic eruptions that created enormous calderas up to 100 miles in area! At Craters this evidence has since been entirely hidden by the more recent, gentler, low-silica basaltic eruptions. All the rock you see at Craters is basalt.

Very hot basalt, whose top layered cooled like the "scum" at the surface of a mug of hot chocolate, became the smooth, ropy lava we call pahoehoe . Cooler lava that crept downhill and was slowly turned, twisted, and ground up into irregular chunks became aa.

Materials:

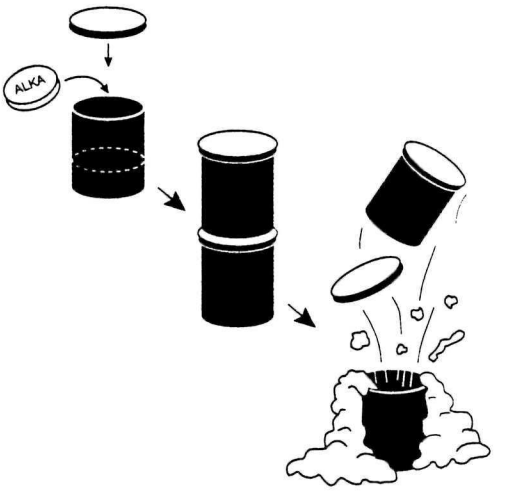
- Two empty film canisters (black with gray lid)
- Alka-seltzer tablets (about 30)
- Bunson burner, hot plate, or camp stove (optional)
- A pot for water (optional)

- Balloons, smallest available (one per 2-3 kids)
- Means to fill balloons part-way with water
- A bottle of carbonated mineral water
- Thermometer
- Watch with second hand
- Several liquids with different viscosities (e.g., water, cooking oil, honey, syrup, corn starch, molasses, water, or mayonnaise)
- A smooth surface such as a lunch tray or a dry erase board

Procedure:

Part 1 - Demonstrate Gas Pressure

As an attention grabber and to introduce volcanism and the effects of gas and pressure, prepare the following experiment. Fill a film canister 1/4 to 1/3 full of water. Drop an Alka-seltzer into the canister and put the lid on and place a second, empty canister on top of the first. You might do this surreptitiously and begin talking about gases, liquids, and solids. In a few seconds the increasing pressure within the canister will cause it to "erupt," blowing the cap and the empty canister into the air—getting everyone's attention. Alka-seltzer ooze may overflow the container just as lava might move down the slopes of a volcano.



Ask the students what happened. Gas was released when the Alka-seltzer came into contact with water. Gas occupies a greater volume than liquid or solid, so pressure increased within the canister until the lid could no longer contain it.

Show the class a bottle of carbonated mineral water or soda. Carbon dioxide (a gas at normal temperature and pressure) is dissolved in water. Shake it up and remove the cap. The liquid that bubbles out of the mouth of the bottle shows that the carbon dioxide within is quickly expanding now that its pressure has been released. The carbon dioxide expands, wreaking havoc just like the expanding gas in a rhyolitic volcanic eruption.

Ask the kids what happens to a pot of water sitting on a cold stove. Nothing much. What happens when you turn the heat on? The water approaches its boiling point and turns to gas. Where does the gas go? It escapes as steam. If you have a Bunson burner, a hot plate, or a camp stove you could boil water and demonstrate this to the class as you discuss it. What would happen if you screwed the lid on tight? Increasing temperature and pressure within the pot would eventually cause it to blow up, spraying scalding water all over!

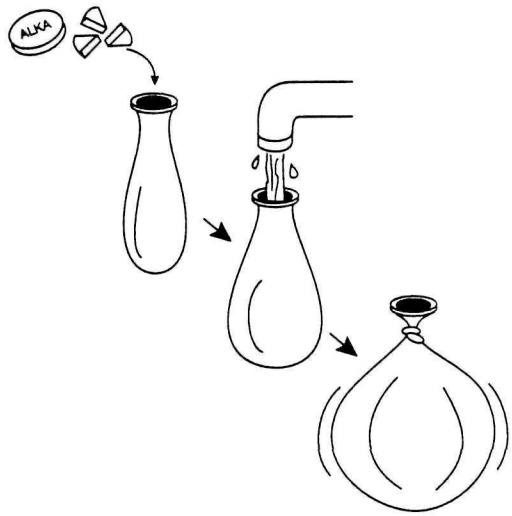
Ask the students what they know about the different states a substance can have: gas, liquid, solid. See what they know about water's three states: gaseous water, liquid water, and ice. Can they describe what happens to water when its temperature goes from –1 to +1 degrees C. (31 to 33 degrees F.)? From 99 to 101 degrees C. (211 to 213 degrees F.)?

Hold up a rock. Ask the class if it will melt. Yes, at a high enough temperature it would. After all, the rock at Craters was once liquid. Will it turn to

gas? In laboratory conditions under ultra-high temperatures its mineral parts would vaporize. But in nature the rock would not "boil" or reach its vapor point to any significant measure.

Part 2 - Alka-Seltzer and Balloon Experiment

Now it's time to let the students see for themselves the effects of gas and pressure. Go outside and give each of the students (or groups of 2-3 students) a small balloon and one or more Alka-seltzer tablets (you will need to experiment beforehand to see how much water and how many tablets result in the desired effects with your particular type of balloons).



Have the students first break up an Alka-seltzer tablet and stuff the pieces into the neck of a balloon. Then add a little water and quickly tie off the neck. They will see the balloon expand as the gas within the tablet is released, similar to expanding gas in rising lava. Some kids could experiment with more than one tablet and varying amounts of water in the balloon. You could also let students repeat the film canister experiment you did at the beginning of the lesson.

Part 3 - Viscosity Study

Place two lines on your smooth surface, labeling them A and B (see figure 1). You will measure the time it takes your liquids to go from A to B when the flat surface is held on an incline. Test each substance at different temperatures. For example, you could set one jar of honey in the sun or over a heating duct and another in a refrigerator until ready to do the experiment. Number the viscosities from least viscous (most runny) to most viscous (thickest) with "1" being the least viscous.

Using the following table, record the viscosity experiment data as a class or in small groups. Pretend that your liquids are actually different lavas at varying temperatures. Record whether your liquid contained lots of silica (high viscosity) or little silica (low viscosity).

Liquid	Temperature	Time	Viscosity Rating	Silica
(Sample)				
water	50°F	2 sec	1	low
water	90°F	2 sec	1	low
honey	50°F	30 sec	4	high
honey	75°F	8 sec	3	high
veg. oil	75°F	4 sec	2	med

How did temperature affect viscosity? Did your warm honey or molasses cool noticeably as it slid down the surface? If so, did it look different at the bottom than it did at the top? Did any of your materials get that ropy, pahoehoe look? If you used a refrigerator and had more time would any of your sugar-containing liquids crystallize and become like jagged aa lava?

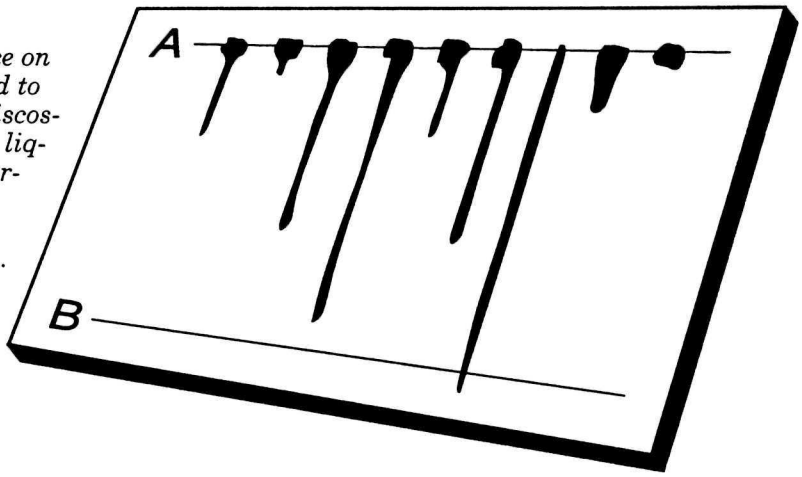


Figure 1
Smooth surface on an incline used to measure the viscosity of different liquids by measuring the time it takes them to go from A to B.

Chapter Three: History

Introduction

The Craters of the Moon lava field is a harsh and uninviting place. Summers are scorching and little rain falls. In winter the wind whips across the landscape, piling snow into huge drifts. Travel on foot across the rough, uneven rock is difficult in some places and nearly impossible in others.

The land has little practical value. Plant growth is sparse and game is limited. The lava does not lend itself well to grazing, hunting, farming, or mining. Therefore, early travellers avoided this area and only passed through it on their way somewhere else.

The Indians skirted the lava fields during their yearly migration in search of food. Emigrants on the Oregon Trail followed the edge of the lava flows as they travelled westward looking for farmland or gold. Not until a few individuals explored Craters of the Moon in the early 1900s did anyone venture onto the lava for pleasure. The enthusiasm of these early explorers laid the groundwork for the establishment of Craters of the Moon National Monument in 1924.

The Shoshoni Indians

The Shoshoni homeland in southern Idaho was an area with limited resources. To find enough food to survive, the Shoshoni travelled more than 1200 miles every year. The local and seasonal availability of various foods determined their movements.

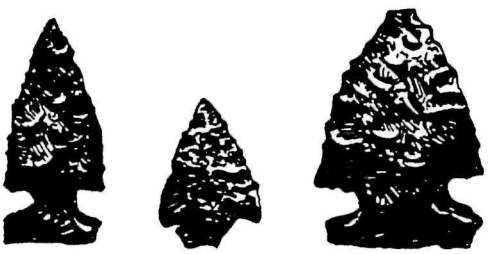
Their annual migration began each spring near Fort Hall where they grazed their horses on the luxuriant grasses. In early summer they headed north across the Snake River Plain for the Camas Prairie, near present day Fairfield. There they spent the summer digging camas bulbs. This onion-like plant was the staple of the Shoshoni diet until autumn.

They supplemented their diet of camas bulbs with strawberries, currants, grasshoppers, and pine nuts. They made bread from sunflower seeds and cakes from serviceberries. They also took rodents and an occasional large mammal, such as a bighorn sheep, mule deer or elk. But with the camas crop depleted, it was time to move again.

The Shoshoni spent fall on the Boise and Snake Rivers harvesting salmon. When the fish run ended, they returned to Fort Hall to fatten their horses on the last grass of the year. With their horses in peak condition, the Shoshoni set out to hunt buffalo and elk in what is now Wyoming and Montana.

They wintered along the Yellowstone River, subsisting on meat from the fall hunt. With the arrival of spring, they returned to Fort Hall and the cycle began once more.

Archaeologists have found ample evidence that the Indians struck out across the lava flows during their annual journey across southern Idaho. Evidence of their presence at Craters of the Moon includes more than 35 sites containing rock structures, pottery, arrowheads, worked stone, or tools.



Why did the Indians venture onto the harsh lava fields? The scarceness of water and rugged terrain made travel extremely arduous. A few waterholes exist, but they are not reliable. Perhaps they were hunting game—although mule deer, bighorn sheep, buffalo, and elk were probably never abundant on the lava. Maybe they sought tachylite, a dense form of basalt used for arrow points and stone tools. Or perhaps, like us, they were motivated by simple curiosity.

Whatever their reasons for visiting the area, the Shoshoni may actually have witnessed eruptions at Craters of the Moon. The most recent eruption here occurred 2,000 years ago. The Indians passed down legends indicating that their ancestors observed the fiery events that created this landscape:

The Angry Serpent
A Serpent trying to nap on the mountains above the Snake River was angered by lightning that disturbed its sleep. It coiled around and squeezed the mountain until pressure caused rocks to crumble, stones to melt, and fire to shoot out of the cracks. Liquid rock flowed from the fissures and the mountain exploded. The heat killed the slow-moving serpent and the hot rock roasted its flesh. Today, we see the ashes (cinders) and charred bones (pahoehoe lava) of the serpent on the landscape.

The Medicine Man
Fierce warriors living in caves and rock shelters drove the Indians from

their traditional lands in the forests. The Indians asked for help from the spirit world. In return for their promise that they would not harm wolves, foxes, bobcats, and cougars, the spirits lifted the tribe's medicine man to the top of a high mountain. When he reached the peak, the mountain ignited and burned fiercely. Nearby hills and cliffs melted and flowed into the valley. The valley filled with a lake of fire and the invaders were destroyed.

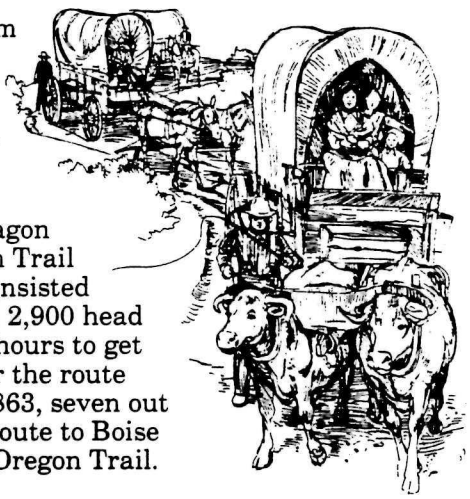
The routes which the Shoshoni used to move from one food source to another were later adopted by white travellers. Explorers and trappers, then emigrants and miners, crossed Shoshoni territory in the mid-1800s. Like the Indians before them, they avoided the rugged lava and travelled along its edges.

The Oregon Trail: Goodale's Cutoff

From the 1840s through the 1860s tens of thousands of emigrants passed through southern Idaho on their way to fertile farmland to the west or to the gold fields north of Boise. The traffic peaked in 1864 when 40,000 people travelled the Oregon Trail. The main trail followed the course of the Snake River, about 100 miles south of the monument.

John Jeffrey began promoting a spur trail which followed Shoshoni migration routes in 1852. He wanted to generate business for his Snake River ferry at the mouth of the Blackfoot River. This cutoff received some use from 1852-1854, but not until 1862 did a large percentage of Oregon Trail traffic choose the route.

The Northern Shosoni and Bannock tribes were growing resistant to emigrants' intrusion into their homeland. In August of that year, Bannock Indians ambushed a wagon train at Massacre Rock, killing 10 people. The increasing Indian hostility along the main trail resulted in demand for an alternate route safe from Indian attack.



An emigrant party asked a guide named Tim Goodale to lead them west from Fort Hall on the cutoff pioneered by Jeffrey. They hoped the alternate trail would be safer and enable them to reach the Salmon River gold fields more directly.

Goodale succeeded in leading the largest wagon train ever to cross any section of the Oregon Trail safely from Fort Hall to Boise. The group consisted of more than 1,095 people, 338 wagons, and 2,900 head of stock. It took this enormous train over 3 hours to get into or out of camp. Following this endeavor the route came to be known as Goodale's Cutoff. In 1863, seven out of every ten wagons reaching Fort Hall en route to Boise took Gooodale's Cutoff instead of the main Oregon Trail.

The 230-mile spur began at Fort Hall, then headed north toward Big Southern Butte, a conspicuous landmark on the Snake River Plain. From there it passed near the present town of Arco, wound through the northern part of Craters of the Moon, went southwest to Camas Prairie, and ended at Fort Boise. This journey typically took two to three weeks.

Goodale's Cutoff was a difficult route, and took its toll on the travellers and their wagons. The rugged lava restricted travel to one lane, so progress was slow. The path along the edge of the lava flows was circuitous and demanding. The emigrants typically passed through in late July, the hottest part of the summer.

Wood dried out in the desert air and shrank, causing wheels and boxes to come apart. Some pioneers wrote of finding pieces of broken wagons littering the trail. The impressions of some of these early travellers are preserved in diaries they kept of their trips. Julius Merrill, who crossed in 1864, described the lava landscape at Craters of the Moon:

> *"As far as the eye can reach there is nothing but this black volcanic rock. This region must have received some terrible scorchings and shakings years ago...The man whom Aesop described as being chained in a pool of water with an apple dangling above his head and being unable to quench either thirst or hunger was in a Paradise in comparison to him who drives a 'Bull team' across such places... Great must have been the relief of the volcano, powerful the emetic, that poured forth such a mass of 'Black Vomit.'"*

For nearly 50 years, migrating pioneers used Goodale's Cutoff. Later, miners moving ore to railroad depots and stage coaches carrying passengers to the towns of southern Idaho took the route. But the advent of the railroad and automobile led to the demise of Goodale's Cutoff as a wagon route.

Today, modern highways, including US 20, follow sections of Goodale's route. Now when people travel this road, they need not concern themselves with survival and can take time to appreciate the unique beauty of the harsh landscape. Most are unaware of an explorer who 70 years ago was the first white person to recognize the aesthetic value of Craters of the Moon.

Robert Limbert

The first documented exploration of the edge of the Craters of the Moon region occurred with Captain Benjamin Bonneville's mapping expedition in 1833-1834. The physical beauty of the area did not impress him. He wrote, "...nothing meets the eye but a desolate and awful waste; where no grass grows nor water runs, and where nothing is to be seen but lava."

Other explorers and geologists followed. None could match the enthusiasm and the daring exploits of Robert W. Limbert. Limbert came west in 1911 at the age of 26. He was a taxidermist by trade, and an avid outdoorsman. He explored the Craters of the Moon lava field many times and became a strong promoter of the area. He played a critical role in garnering public support for establishing Craters of the Moon National Monument.

Limbert's first major exploration of Craters of the Moon occurred in 1920 when he and a friend embarked on a 17 day, 80 mile trek across the lava. They carried bedding, an aluminum cook outfit, camera and tripod, binoculars, and two weeks of supplies. They also brought along a camp dog, a decision they were to regret. After three days of travel over the rough lava the dog's feet were cut and bleeding. For the remainder of the trip, Limbert and Cole had to carry the dog or wait for him to pick his way tortuously across the rugged rock.

Throughout the trip, Limbert photographed the volcanic landscape. He also named many of the natural features they encountered, including Big Cinder, Trench Mortar Flat, Echo Crater, and Yellowjacket Water Hole.

Limbert used his knowledge and experiences to promote the Craters of the Moon area. In 1921 he led 10 scientists and civic leaders into the lava fields and argued for protection of the area's volcanic features. He also wrote a series of newspaper and magazine articles. The most influential of these appeared in National Geographic in 1924. Limbert vividly described the spectacular and unusual landscape.

> *"Stretching to the southwest for a distance of about 11 miles, we saw perhaps one of the most remarkable lava flows in the world. Its color is a deep cobalt blue with generally a high gloss, as if the flow had been given a coat of blue varnish. The surface is netted and veined with small cracks, having the appearance of the scales of some prehistoric reptile."*

Limbert also sent President Calvin Coolidge a scrapbook with pictures and narration detailing his trips across Craters of the Moon. On May 2, 1924 President Calvin Coolidge created Craters of the Moon National Monument. He said:

> *" ... this area contains many curious and unusual phenomena of great educational value and has a weird and scenic landscape peculiar to itself..."*

About 1,500 people travelled over the gravel and cinder roads to attend the dedication ceremony on June 22, 1924.

Limbert continued to guide tours through the new monument. He even repeated his south to north traverse of the lava field with a group of friends. Their journey ended with an all-town welcome from the people of Arco, complete with a brass band.

Limbert believed that Craters of the Moon had the potential to attract large numbers of tourists. He never saw this dream realized, although today more than 200,000 people visit the monument each year. During his life, though, he made great strides in promoting the fantastic Craters of the Moon landscape as well as other areas in Idaho. Recognizing Limbert's importance to the creation of the Monument, the National Park Service dedicated the Visitor Center to his memory in 1990.

Conclusion

The Shoshoni Indians, emigrants on Goodale's Cutoff, and explorers like Robert Limbert, all contributed to the history of Craters of the Moon National Monument. What does the future hold for this strange volcanic landscape? What impact will we have on it and how will it affect people in the years to come?

The National Park Service is charged with preserving Craters of the Moon National Monument unimpaired for future generations. Park Service management of the area rests on sound scientific information and federal law. But ultimately the preservation of this monument, and every unit in the National Park System, depends on each of us. With parks facing increasingly complex threats, like deteriorating air quality, preserving park resources will require everyone's involvement. By helping to support and preserve Craters of the Moon National Monument, all of us can play a small role in its ongoing history.

Activity 3A

The People's Time Line

Students make a time line showing significant events in the cultural history of Craters of the Moon (see Deep Time and You in the Geology section).

Objectives:

- Students will be able to visualize the times of important cultural events in relation to other time scales at Craters of the Moon.

Duration:
1 hour

Background:
Craters of the Moon's human history is one of avoidance. The soil is sparse and poor and the minimal precipitation quickly disappears into the pourous lava. The few archeological sites at the Monument show that Native Americans travelled through the region but had no permanent dwellings there. Early settlers viewed the inhospitable land with morbid fascination as they headed for greener pastures in Oregon.

Most of what we know about Craters' human history occured in the last two hundred years, yet people have lived and died in the region for at least 15,000 years. In other words, 99% of our information on cultural history focuses on the last 1% of its time. As with geology, a time line can help to illustrate the relationships of events to time. The process can help to heighten the students' appreciation of cultural history.

Materials:

- Adding machine tape (3 or 4 inches wide by about 100 feet)
- Pencils, pens, crayons
- Use of a large indoor wall while your class is studying about Craters of the Moon

Procedure:
We recommend that you first conduct the Deep Time and You activity in the Geology section.

The People's Time Line

Have the students make a time line showing the cultural history of Craters of the Moon.

- Choose several students to make a time line about 15 feet long.
- Unlike the geology time line, let the range on this one be 1700 to 2000 A.D. (the geology time line counted backward from the "present.")
- Have the students break the 300 years up into equal-sized 10 year increments. Label it "The People's Time Line."
- When completed, afix the time line to your wall above the "Craters of the Moon Time Line," aligning the current year with "present" on the time lines beneath it.
- Other students should make the following labels on separate small pieces of paper (illustrated if they wish) and when completed they should tape them at the appropriate place on the People's Time Line.

Dates:	Events:
1924	President Calvin Coolidge sets aside Craters of the Moon National Monument.
1970	More than 90% of Craters is made a wilderness area—no roads or permanent structures can be built; people can only visit.
1833-34	Expedition where B.L.E. Bonneville says, "Nothing meets the eye but a desolate and awful waste, where no grass grows nor water runs, and where nothing is to be seen but lava."
1850s	Settlers use Goodale's Cutoff north of Craters of the Moon as an alternate route to the Oregon Trail to avoid attack by the Northern Shoshone Indians.
1862	Over 1,000 settlers travel to Oregon through Craters in the largest group of settlers ever to travel Oregon Trail at one time. Led by Goodale.
1901	First geologist, Israel C. Russel, studies Craters.
1923	Geologist Harold T. Stearns studies Craters.
1920	Robert Limbert walks 40 miles across Craters from south to north with a friend and a dog. The lava cuts the dog's feet; they have to carry him sometimes.
1879	Arthur Ferris and J.W. Powell explore Craters looking for water for cattle.
about 1862	Louis Arco establishes a ranch and trading post at Arco.
1969	Astronaut Alan Shepard and the crew of Apollo 14 come to Craters to see what the moon might be like to walk on.
early 1700s	Shoshone Indians get horses for the first time.
1884	Early explorer George Powell finds buffalo remains in "Buffalo Cave."
1926	Craters gets its first public outhouse!
1927	Craters gets its second public outhouse!
1927	Gas is 31 cents per gallon at the service station.
1927	Boy Scouts discover "Boy Scout Cave."
1929	Craters gets its first phone.
1952	Craters gets electricity.
1959	Visitor Center is built.

Place these last two dates on the "Craters of the Moon Time Line."

- 15,000 years ago, humans have been in southern Idaho for at least this much time.
- by 800 years ago, Shoshone began using bows and arrows.

Activity 3B

The Stuff We Use, Then and Now

Students contrast today's resource consumption with that of Native Americans and settlers.

Objectives:

- Students will be able to describe the difference between renewable and nonrenewable resources.
- Students will be able to identify the raw materials used to make most of the products they use.

Duration:
1 to 2 hours

Background:
Americans produce 154 million tons of garbage every year, or 3.4 pounds per person per day—which is a heck of a lot more than we did in the 1840s. Of course, then there were only 13 million Americans and today there are 250 million. Even so, our resource consumption and subsequent garbage production has grown much faster than our population. Landfills across the country are filling up and closing down with the waste we create, forcing us to reassess our garbage generating and disposal practices.

American settlers and the Native Americans they displaced didn't worry about waste disposal because the country was big, human numbers were small, and their garbage was largely decomposable and non-toxic. All that has changed. We have much more per person to get rid of today, and much of that (plastics, nylon, rubber, vinyl, polyester, and other petroleum products) requires hundreds of years to decompose. Common household waste such as paint and batteries contain toxic materials which can pollute ground water. Sea turtles and sea birds die from eating plastic and polystyrene floating on the ocean. Incinerated garbage can release toxic chemicals into the air. Despite the environmental costs of today's waste problems, we are in some ways as cavalier now about garbage disposal as we were 150 years ago.

How Long Litter Lasts

Material	Years
Cigarette butts	1-15
Wool socks	1-15
Orange peels	up to 2
Banana peels	up to 2
Nylon fabric	30-40
Leather	up to 50
Tin can	50
Plastic 6-pack holder	100
Glass bottle	1,000
Aluminum can	500
Plastic bottles	indefinitely
Styrofoam	indefinitely
Plastic film container	20-30
Plastic bags	10-20

By comparing today's consumption and waste practices with those of 150 years ago, we can better appreciate the consumption and waste issues we now face.

Materials:

- copies of the enclosed handouts

Procedure:
Students will list things they would take on a trip and categorize those things in various ways. They will make three lists, one for Shoshone Indians, one for Oregon Trail settlers, and one for a camping trip in the 1990s. Then they will answer questions about their lists on a provided worksheet.

See what the students know about renewable and nonrenewable resources. Renewable resources are made from living things which can replace themselves. Nonrenewable resources originate with non-living things and once used, cannot be replaced by nature in any time relevant to a human life.

See what your kids know about the raw materials used to make things. For example, hold up a running shoe. Do they know that the shoe is probably made out of oil (plastic, nylon, most rubber, and polyester)? Do they know what will happen to it once it's discarded (reside in a landfill for hundreds or thousands of years)?

To help your students understand consumption and waste issues, generate a list of things in your class with the students and have them categorize them as follows. Here are a few common examples:

Item	Made from: Renewable resource	Nonrenewable resource	Raw material	Reusable	Recyclable	Likely to be recycled	Decomposable
wooden desk	√		wood	Y	Y	N	Y
plastic chair		√	oil	Y	Y	N	N
magazine	√		wood	Y	Y	N	Y
computer		√	glass, oil, metal	Y	Y	N	N
paper	√		wood	N	Y	?	Y
cotton pants	√		cotton	Y	Y	N	Y
pile jacket		√	oil	Y	Y	N	N
PB sandwich	√		wheat, peanuts	N	N	N	Y
nylon jacket		√	oil	Y	Y	N	N
sandwich bag		√	oil	N	Y	N	N
plastic milk jug		√	oil	Y	Y	?	N

Definitions:

Reusable = can it be used over and over again?
Recyclable = can it be made into something else once it's served its original purpose?
Likely to be recycled = will it probably be recycled?
Decomposable = will it decompose in less than 10 years in ideal conditions?

When your kids get the hang of it, have them complete the following *"What to Take With You . . ."* work sheet—one or two for each of the three categories (copied back to back to save paper). You may want them to plan their trips in small groups. You may have to require that they do some research on what settlers and Native Americans used so their lists will be more complete. The following are some ideas you could share with them if they get stuck.

Shoshone Indians:

Pony
Arrow shafts
Buck skin pouch
Camas bulbs
Bow
Dog
Buffalo robe
Moccasins
Fire-making bow and spindle
Baskets
Dyes, paints
Otter skin water bag
Sinew from animal gut
Dried meat and berries
Obsidian
Flint knife
Spear
Tobacco
Tinder (for fire making)
Antler tine
Digging sticks

Oregon Trail settlers (courtesy John Campbell, 1863):

Oxen	Kettle	Whetstone
Wagon	Gold pans	Flour
Tent	Picks	Bacon
Candles	Shovels	Coffee
Soap	Axes	Tea
Matches	Bread pans	Yeast
Water keg	Wagon bucket	Salt
Coffee mill	Hand saw	Pepper
Plates	Drawing knife	Beans
Cups	Chisels	Vinegar
Silverware	Augers	Lard
Frying pans	Gimlets	Sugar
Butcher knives	Gold scales	Dried apples
Skillet	Files	Dried peaches
Water buckets	Hatchet	Rice
Tin pails	Hammer	
Rope	Nails	

Give the students the *"What to Take With You . . ."* handouts and the following instructions:

You're going to plan trips in three different times in history by making a list of all the stuff you would bring.

1) *List all the things you would take with you on an extended trip if you were a Shoshone Indian living here 200 years ago.*

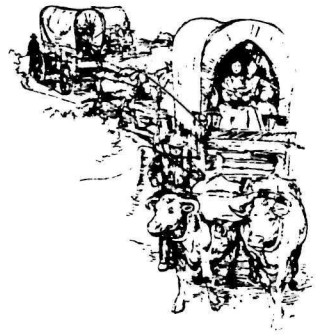
2) *Write down all the stuff you'd take with you if you were on the Oregon Trail 150 years ago.*

3) *List all the things you would need for a great family camping trip today.*

Be thorough and specific. After you've listed everything you'll need, go down the list and categorize your items as renewable, recyclable, decomposable, etc.

When they have completed the lists, give them the *"Stuff We Use, Then and Now"* work sheet to respond to. Remember, all one needs for survival is food, water, air, shelter, and clothes (in cold places).

Work Sheet 3B-1



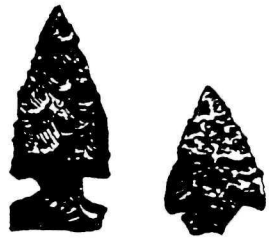
What to Take With You on a Trip if You Were an Oregon Trail Settler

Name_____

Number	Item	Renewable resource?	Nonrenewable resource?	Raw material	Reusable?	Recyclable?	Likely to be recycled?	Decom-posable?

Work Sheet 3B-2

What to Take With You on a Trip if You Were a Shoshone



Name_____

Number	Item	Renewable resource?	Nonrenewable resource?	Raw material	Reusable?	Recyclable?	Likely to be recycled?	Decom-posable?

Work Sheet 3B-3

What to Take With You on a Family Camping Trip

Name_____

Number	Item	Renewable resource?	Nonrenewable resource?	Raw material	Reusable?	Recyclable?	Likely to be recycled?	Decom-posable?

Work Sheet 3B-4

The Stuff We Use, Then and Now

Name: _____

How many items did you have for the:

Shoshone Indian trip? _____ Settler wagon trip?_____

Family camping trip? _____

What are the most common raw materials used by:

Shoshone Indians? _____

Settlers?_____

Today's campers?_____

Which group used the fewest nonrenewable resources?_____

Which group used the fewest reusable items? _____

Which group produced the most garbage? _____

The least garbage?_____

For your family camping list, put a star by the things you feel are most important in your life—the items you would want to part with last.

List the things you must have to *survive* (the list shouldn't be very long):

_____

_____

Go back through your lists and underline each of the things you would need for survival.

Did you star and underline the same items or were there differences? If so, does it seem strange to you that what you hold as most important in your life is not what you need for survival? Write two or three sentences about your thoughts on this.

_____

_____

_____

_____

_____

_____

Tell how your life would be different if we didn't use petroleum (oil) and the products it makes.

_____

_____

_____

_____

Activity 3C

Food for Thought

Students increase their awareness of food by studying their own diet and preparing and eating a Native American dish.

Objectives:

- Students will be able to list some of the positive and negative attributes of our way of producing food.
- Students will be able to prepare a simple Native American dish.

Duration:
2 hours

Background:
When we eat something, we are enjoying the fruits of photosynthesis. Every morsel of food we ingest was created by the sun, the Earth, water, and carbon dioxide. Each meal represents the beginning, growth, life, and death of plants and maybe animals. Seasonal weather variations can have drastic effects on this cycle, creating anxiety over the prospect of hunger. "Will there be enough to eat?" is a question that shaped human cultures and distribution worldwide.

Our relationship to food changed radically with the industrial revolution. Populations shifted from rural to urban, from food growing to food buying. The exploitation of abundant fossil energy (oil and coal) insulated us against hunger; if a crop failed at home, it could easily be imported from a thousand miles away.

Most Americans today do not know hunger. We expect grocery stores to provide a cornucopia of food year round. We have a feeble connection to preprocessed, canned, and boxed food grown on industrial farms by strangers in unknown places. Food that we ourselves didn't grow is more inclined to be wasted. Our relationship to food has grown as distant as the tropical fruits we import to North America.

While this century's food production practices have yielded advantages, they have also caused environmental perils. Pesticides make high crop yields and the ability to cheaply feed growing populations possible, but can have deleterious effects on wildlife, water, and people who eat the crop. Culinary diversity has increased with access to Central and South America, where hundreds of square miles of lowland tropical forests, among the most biologically diverse on Earth, are being replaced by heavily crop-dusted banana plantations. Attractive, convenient packaging makes food preparation easier but adds to our waste disposal problems. Unlike most of the world, we can afford to eat meat as a staple rather than a delicacy, which contributes to American's high rate of hypertension and heart disease. Our high meat diet exacerbates the impact we have on the natural world by requiring more land be taken from wildlife and used for beef production. For example, millions of acres of tropical forests have been felled to produce cheap beef for American hamburger franchises. The land required to provide food for one meat-eating person could provide enough food for 20 vegetarians.

Our relationship to food and its distribution and processing has changed radically. Appreciating the positive and negative aspects of these changes can heighten our awareness of food, where it comes from, how it's produced, and how it connects us to the natural world. Despite the changes during the last 100 years, the same sun and the same photosynthetic reaction that fed our ancestors feeds us.

We will be better Earth citizens if we are as conscious of our dependence upon nature as were our predecessors.

Materials:

- Honey
- Water
- Strawberries or raspberries
- Unbleached flour
- Baking powder
- Vegetable shortening
- Salt
- 2 to 4 10-inch cast iron skillets
- 2 to 4 mixing bowls
- 2 to 4 surfaces for kneading bread
- 2 to 4 quart saucepan
- 2 to 4 hot plates or burners

Procedure:

Generate a list of your students' favorite food on the chalkboard. If they suggest something like pizza, leave room underneath it for its ingredients (see below). In the next column, write the raw material it is made from. Next, write down where it came from, if you know. Record the food's packaging.

Then generate a list of foods local Indians might have eaten. The kids will likely guess the animals first. Encourage them to come up with other food they might have eaten such as: tule roots, camas bulbs, thistle shoots, squaw cabbage, clover, gooseberries, mushrooms, grasshoppers, crickets, caterpillars, ants, locusts (and their eggs, larvae, and chrysalides), salmon, rattlesnakes, sage grouse, and large mammals. Record the same information you recorded for our food.

Today's Food	Raw Material	Origin	Packaging
Pizza			cardboard box or foil
crust	wheat	Great Plains?	
sauce	tomatoes	southern states?	
toppings	beef	anywhere	
toppings	vegetables	many places	
Bananas	bananas	tropics	none
Corn (canned)	corn	maybe local	steel can
Hamburgers			styrofoam box
buns	wheat	Great Plains?	
burger	beef	anywhere	
sauces	tomatoes, mustard	southern states?	
condiments	vegetables	southern states?	
Hershey's bar			plastic and foil
sugar	sugar beet or cane	US or tropics	
chocolate	cocoa plant	tropics	

Indian Food	Raw Material	Origin	Packaging
Pemmican			
berries	berries	local	none
meat	deer, elk, bison		
Salmon	salmon	local	none
Breads	camas bulbs	local	none
Ant larvae	ants	local	none
Tule roots	tule plants	local	none

With the class, make a list of advantages and disadvantages of our modern food practices (see below). See what the kids can come up with.

A comparison of today's food production practices to those of Indians:

Advantages
- No starvation
- Ease of preparation
- Food gathering and production takes less time
- Gives us more time to pursue other endeavors
- Preservatives prevent food from spoiling
- Food is relatively inexpensive

Disadvantages
- High salt content of foods causes high blood pressure
- High fat and cholesterol cause heart disease
- Some food additives may cause cancer
- Pesticides poison the environment
- Herbicides poison the environment
- Many wild plants and animals cannot coexist with many farms and ranches
- Transport of foods from afar causes air pollution and contributes to the greenhouse effect
- Creating a demand for oil contributes to oil spills
- Irreplacable biological diversity is lost when forests and wetlands are removed to plant crops

What are the main differences in the way we procure foods? Perhaps the most fundamental difference is related to petroleum. Because of it, we can cheaply transport and process food. In effect, work that was once done by human muscle is now done by oil.

Now it's time to make an Indian snack. Allow a full hour. The following are recipes for pan bread and for fruit toppings to go with it. Ideally, go into the field with the kids and collect berries. This won't be possible for most classes, so just buy the berries and prepare them in class.

Divide the class into four to six groups. Three to five groups can work on bread while the remaining group works on a fruit recipe.

Bannock Bread

2 cups unbleached flour
4 teaspoons baking powder
1 teaspoon salt
1/2 cup vegetable shortening
1/2 cup water

Combine dry ingredients in a mixing bowl. Cut in shortening until mixture resembles coarse meal. Gradually mix in water to form a thick dough. Turn dough out onto a lightly floured surface and knead for 15 minutes, or until it is very smooth. Grease bottom and sides of a 10-inch cast-iron skillet. Press dough into the pan and cook, uncovered, on top of the stove over low heat for about 10 minutes on each side. Watch carefully so bread does not burn before center is cooked through. Place loaf on a rack to cool. Serves 6.

Whipped Raspberries and Honey

1 quart fresh raspberries
1/2 cup honey

Puree berries with honey until smooth. Chill and serve as a topping on bread. Serves 4 to 6.

Strawberries Poached in Honey Syrup

1/3 cup honey
2/3 cup water
1 quart fresh strawberries, washed and de-stemmed.

Place honey and water in a saucepan and boil rapidly for 5 minutes over medium-high heat. Reduce heat. Drop in the whole berries and simmer for 5 minutes. Turn off heat and allow berries to cool in the syrup. Serve warm or cold, ladling syrup over each portion. Serves 4 to 6.

Recipes from: Cox, B. and J. Martin. Spirit of the Harvest, North American Indian Cooking. 1991. Steward, Tabori, and Chang, New York. 255 pp.

As a follow up activity, you could have the students:

1) Write an Indian legend on how a certain food came to the Earth.
2) Write an essay on how their diet would be different without petroleum.

Activity 3D

Crater Writing

After the field trip to Craters, students use their field notebooks and knowledge they have gained through pre-trip activities to write two papers.

Objectives:

- Students will be able to write about Craters demonstrating what they learned about its geology, cultural history, and/or ecology.
- Students will be able to write in two different writing styles.
- Students will be able to identify objective and subjective writing.

Duration:
1-3 hours plus homework

Background:
In part because Robert Limbert could express his views on paper, Craters of the Moon National Monument was established. In several articles the explorer described the unique character of the land and promoted his view that it should be preserved in its natural state. Largely as a result of Limbert's written word, President Calvin Coolidge declared Craters of the Moon a National Monument in 1924.

Few skills are as important as writing—few are as complex and difficult to master, as well. Now that your students have visited Craters and studied its geology, cultural history, and ecology, have them reinforce what they learned by writing about it. If they put effort into the assignment and experience some frustration as they struggle with it, they will learn writing skills.

Two different writing styles are informal non-scientific and formal scientific. When Robert Limbert wrote about Craters of the Moon in his 1924 National Geographic article, he objectively described it in a formal scientific, irrefutable, and factual way. For example, "The district consists of some 63 volcanic craters, lava, and cinder cones, all at present extinct or dormant." Limbert also had a viewpoint. He thought Craters of the Moon was a beautiful place that should be preserved for posterity. In expressing this view in the same article, he expressed his opinion and used language that was less formal: ". . . its scenery is impressive in its grandeur."

Articles like Limbert's that occur in popular magazines usually convey a blend of scientific and non-scientific writing styles. The story is told, the place described, the incident reported, and the process explained. But the author reveals himself or herself by expressing a viewpoint and supporting that opinion through objective observation.

Authors of scientific journal articles, however, usually leave out obvious statements of opinion or emotive sentences. The language is straightforward, formal, and succinct; sentences are clear and declarative. The author's viewpoint is deemphasized and subtle. Likewise, model newspaper articles are written objectively, without editorializing. The writer's viewpoint may be difficult to determine or only surmised by omission of certain facts or emphasis of others.

The most frequently read part of newspapers are editorials and popular magazines are more popular than scientific journals. Readers prefer authors' viewpoints revealed. They like to agree or disagree and they like to know something about the human behind the by-line.

Much of our informational reading is heavily influenced by the author's opinion. Readers must make a conscious effort to separate the author's objectivity from subjectivity to fully comprehend what he or she is saying. Students' critical thinking skills are enhanced when they recognize these two different messages while reading an article.

Materials:

- paper • word processor (optional) • Student Journals

Procedure:

Tell your class that they will write two papers (1-3 pages long) on Craters of the Moon based on what they learned, what they experienced on their field trip, and what they research on their own. One paper will be formal scientific while the other will be informal non-scientific.

Part 1 - Work Sheet

On the next pages is a work sheet that will help the students grasp the difference between scientific and non-scientific writing, or, objective and subjective prose. Have them work on it first before they begin their writing assignments.

Part 2 - Formal Scientific

Formal scientific papers convey information in a concise manner. The author is anonymous in that his or her viewpoints are left out. Scientific papers should be irrefutable. If you say "North Crater is the most beautiful cone at Craters," others could disagree. If you say "North Crater's elevation is 6,244 feet," no one could disagree.

Have your students choose a very specific topic. You might require that they find additional information on their subject in at least two or three different sources. For example: an encyclopedia, a magazine, and a book. When they describe something not known to the general public, they must cite where they got the information using one of the standard literature cited styles (see the following literature cited section).

For this paper you could require the following format:

Title. The title should tell what the paper is about in fewer than ten words.

Introduction. The introduction, in which the author introduces the subject in a general manner, is one or two paragraphs long. A historical perspective might be offered. Why is the topic of interest? The introduction could ask or imply a question which is answered later in the paper.

Body of Paper. In three or four paragraphs the author explains his or her subject using an active rather than passive voice (see examples below). Students could use specific examples or observations they recorded in their Student Journals.

Examples of passive and active voice from Strunk and White, *The Elements of Style.*

Passive	Active
There were a great number of dead leaves lying on the ground.	Dead leaves covered the ground.
At dawn the crowing of a rooster could be heard.	The cock's crow came with dawn.
The reason he left college was that his health became impaired.	Failing health compelled him to leave college.
It was not long before he was very sorry that he had said what he had.	He soon repented his words.

Conclusion. Answer any unanswered questions in the conclusion. Do not present new information. The conclusion provides a closing to the paper so that the reader feels satisfied.

Literature Cited. There are many accepted styles for literature cited sections. All include pertinent information so that someone else can easily look up the reference. For example:

Limbert, R. W. "Among the 'Craters of the Moon'." *National Geographic.* March 1924, pp 303—338.

Part 3 - Informal Non-scientific

Students are most familiar with informal non-scientific writing. In this assignment encourage them to openly express their feelings and impressions. This paper will probably be easier for your students than the previous one. Following are three ideas for the informal non-scientific paper.

1. Students write a trip report like Robert Limbert did for his article. They may include their own impressions and feelings, but should support them with plenty of hard observations. If they felt Craters was ugly, they should provide stark examples of its ugliness before they say so. If Indian Tunnel was their favorite feature, they should use vivid descriptions to convince the reader why the tunnel was so great.

2. Students write a letter describing Craters to a blind person. This writing assignment forces the student to think of their visual observations in other terms. They have to use other senses—hearing, smell, touch, and taste—to describe the place and create a picture for the blind person.

3. Students write a letter to the editor or to a political leader expressing their view regarding a hypothetical threat to Craters. For example, pretend that Craters is being considered for a bombing range. If this were to happen, it would be off limits to the public and many of its geologic features would be damaged. Some plants and animals would be threatened. The range would create jobs, too. If you chose to use this scenario, students would have to adopt a pro or con position toward the proposal.

   For example, a student could be in favor of the range because she wants to fly jets when she grows up and would like to do so near her home town. She's visited Craters of the Moon and knows from first hand observations (which she vividly describes) that the place is not worth saving. Encourage diversity in their positions; urge some to play the devil's advocate.

Work Sheet 3D Answer Key:

1. S	2. NS	3. S	4. NS	5. S	6. NS
7. NS	8. S	9. S	10. NS	11. S	12. S
13. NS	14. S	15. S	16. NS	17. S	18. S
19. NS	20. NS				

Work Sheet 3D

Scientific vs. Non-Scientific Writing

Name_____

Robert Limbert explored Craters of the Moon in the 1920s and wrote an article about it for National Geographic in 1924. Some of his sentences from that article follow. They can be divided in two ways. Some sentences just tell the facts while others tell Limbert's opinion. Read each statement and decide which ones simply report what he saw and which sentences tell how he felt or what he believed. Label sentences that report the facts as **"S"** for scientific. Label sentences that report Limbert's feelings or opinions as **"NS"** for non-scientific.

1. S "The animal life consists principally of migrant birds, rock rabbits, woodchucks, black and grizzly bears . . ."
2. NS ". . . its scenery is impressive in its grandeur."
3. _____ "A glance at a map of Idaho shows that the southern part of the State, lying between Arco and Carey and north of Minidoka, is a vast region labeled desert or rolling plateau."
4. _____ ". . . this section is destined some day to attract tourists from all America, for its lava flows are as interesting as those of Vesuvius, Mauna Loa, or Kilauea."
5. _____ "The district consists of some 63 volcanic craters, lava, and cinder cones, all at present extinct or dormant."
6. _____ "That a region of such size and scenic peculiarity in the heart of the great Northwest could have remained practically unknown and unexplored is extraordinary."
7. _____ "The peculiar features seen on those trips led me to take a third trip across the region in the hope that even more interesting phenomenon might be encountered."
8. _____ "We also took with us an Airedale terrier for a camp dog."
9. _____ "After drinking our fill, we made the discovery that the water was full of innumerable little bright red wrigglers that looked like small shrimp. Each was about three-sixteenths of an inch long."
10. _____ "However, the water was good and one cannot afford to be squeamish in desert country."
11. _____ "It is the only water in this vicinity which can be depended upon the year round."
12. _____ "Along the slope there were evidences that bears had been digging for roots and rolling rocks for ants."
13. _____ "Think of the years of travel necessary to make that mark on the rock!"

14. _____ "Near here we built a signal fire that was seen by people watching for it 30 miles distant."

15. _____ "The crags had magnetic properties, and the compass needle could not be depended upon when near them."

16. _____ "As we stood on the edge and looked down, we tried to imagine the wonderful sight when the whole lava bed was glowing red."

17. _____ "From the ceiling hung clusters of immense ice stalactites, sometimes touching a few stalagmites of the same material below."

18. _____ "The floor was covered with ice so clear that when I first reached it I dipped down for a drink."

19. _____ "The dog was in terrible shape also; it was pitiful to watch him, as he hobbled after us."

20. _____ "To be frank, I had some very queer thoughts, chief of which was, Will anybody ever find me or shall I, like the [dead] sheep, lie here for years?"

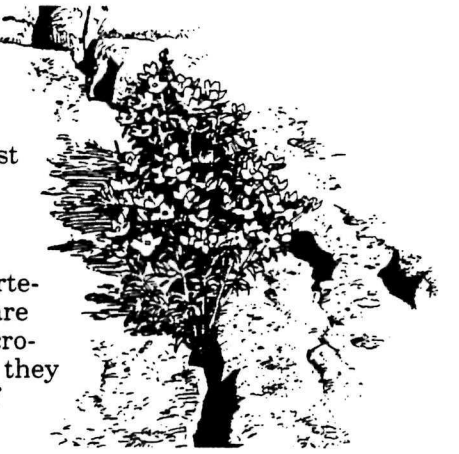
Chapter Four: Ecology

Life in the Lavas

Life at Craters of the Moon lives in the shadow of the Monument's volcanism—figuratively and literally. Over millennia the living landscape was periodically sterilized by new flows of molten rock. Each time life was set back, receding to the places where it was not incinerated. No sooner had the lava cooled, however, than windblown fungal spores and bacteria began to exploit the new landscape, setting the stage for the more visible life that would follow.

Life Gets Started

With a trace of windblown soil and a few nutrients added by microscopic organisms, inconspicuous plants begin their life. They start growing in the lava's nooks and crannies where living things compete for rare water just a few critical inches away from the desiccating winds and searing heat of the surface. Life hangs on at Craters, anchored by the microscopic root hairs of over 300 species of plants, each uniquely adapted to life in a place that, at first glance, appears lifeless.



Diversity Increases

Upon the plants, more than 175 species of vertebrates depend. Woven into this living fabric are thousands of species of invertebrates and microscopic organisms, each occupying niches only they can fill. With time comes the accumulation of soil in Craters' crevices and an increasing di-

versity of life. Biomass, or the total weight of all the living things in an area, also increases as a flow ages. Over aeons the land loses its volcanic identity to the ever more complex array of plants and animals that colonize the surface. At most of Craters, however, life is fresh and new; a mere 2,000 to 15,000 years have passed since an eruption cremated what lived before.

Life at Craters proceeds along a path defined by extreme heat and cold, a lack of water and soil, and competition between living things for limited resources. Every few thousand years the path abruptly ends beneath a wall of lava and life's clock is reset to zero.

Ecology

Studying the interrelationships along the way is the study of ecology. You and your class will examine Craters' ecology in the following activities and on your field trip. You will learn how living and nonliving parts of the Craters' ecosystem are interconnected and how plants and animals are adapted to their habitats. Through the study of ecology you will deepen your understanding of the way of life, its limitations, and our connections to it.

Activity 4A

Life Time Line

Students complete a time line showing the appearance and extinction of major types of fauna. Students also make forecasts into the future using time lines (see The People's Time Line in the History section).

Objectives:

- Students will be able to visualize the times of important evolutionary events in relation to geological and cultural history.
- Students will be able to name some of the animals that became extinct at Craters of the Moon.
- Students will use their imaginations to forecast future events and designate them on a time line.

Duration:
2 hours.

Background:
Of the millions, perhaps billions, of species that have lived on Earth, only a tiny fraction are alive today. Many (but not all) scientists think that mass extinctions were caused by asteroids crashing into Earth. The age of dinosaurs passed 65 million years ago and growing evidence shows that it coincided with an asteroid that struck the Earth in what is now the West Indies. Other extinctions were caused by changing weather regimes and competition with species that occupied similar niches. In all cases, however, a species becomes extinct because it cannot adapt to changing circumstances.

Earth is currently undergoing one of its most accelerated periods of extinction. Unlike all other known extinction phases, a single species, humans, is responsible. Species which are not able to adapt to human-caused changes are becoming extinct daily.

Perhaps if we become more knowledgeable about our evolutionary history, our concern for the species with which we share the Earth will grow.

Materials:

- Adding machine tape (3 or 4 inches wide by about 100 feet).
- Pencils, pens, crayons.
- String or yarn.
- Use of a large indoor wall while your class is studying about Craters of the Moon.
- Several picture books on prehistoric life.

Procedure:
We recommend that you first conduct the People's Time Line activity in the Cultural History section.

Part 1 - Life Time Line

Have the students make a time line showing the major biological features of several geologic periods.

- Choose several students to make a time line about 15 feet long.
- Label the right side "present" and the left side "500,000,000 years ago." Divide the time line into five 100,000,000 year increments. Divide each of these into ten 10,000,000 year increments.

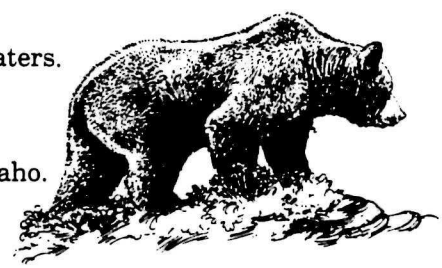
- Label it "Life Time Line" and afix it to the wall above the Earth's Time Line and below the Craters of the Moon Time Line.
- Teams of students (2-3 each) should make the following labels on separate small pieces of paper and tape them at the appropriate place to the Life Time Line. The students should label the range of time indicated on the Life Time Line.
- Teams should illustrate their geologic period with representative life forms by looking at various picture books on dinosaurs and prehistoric life.

Period	Time Span	Events
Quaternary	Present to 3 million years ago.	Humans evolve.
Tertiary	3 million to 63 million years ago.	Mammals are abundant and diverse and are the dominant animal life form.
Cretaceous	63 million to 135 million years ago.	Extinction of dinosaurs and ammonites (flat spiral shellfish) at end of Cretaceous. First flowering plants evolve.
Jurassic	135 million to 180 million years ago.	First birds and mammals evolve. Age of dinosaurs and ammonites.
Triassic	189 million to 230 million years ago.	First dinosaurs. Abundant conifers (pine-like trees). Abundant cycads (like giant ferns).
Permian	230 million to 280 million years ago.	Extinction of many marine animals, including trilobites.
Carboniferous	280 million to 345 million years ago.	First reptiles. Sharks and amphibians abundant. Large primitive trees and ferns.
Devonian	345 million to 405 million years ago.	First amphibians. Fishes abundant.
Silurian	405 million to 425 million years ago.	First land plants. First land animals.
Ordovician	425 million to 500 million years ago.	First fishes. Many invertebrates.

Part 2 - Craters Life Labels

Have the students make and illustrate the following labels and attach them to the People's Time Line.

- by 1920, bighorn sheep known to be extinct at Craters.
- by 1920, elk known to be extinct at Craters.
- by 1920, wolf known to be extinct at Craters.
- by 1920, grizzly known to be extinct at Craters.
- by 1840, bison known to be extinct in southern Idaho.

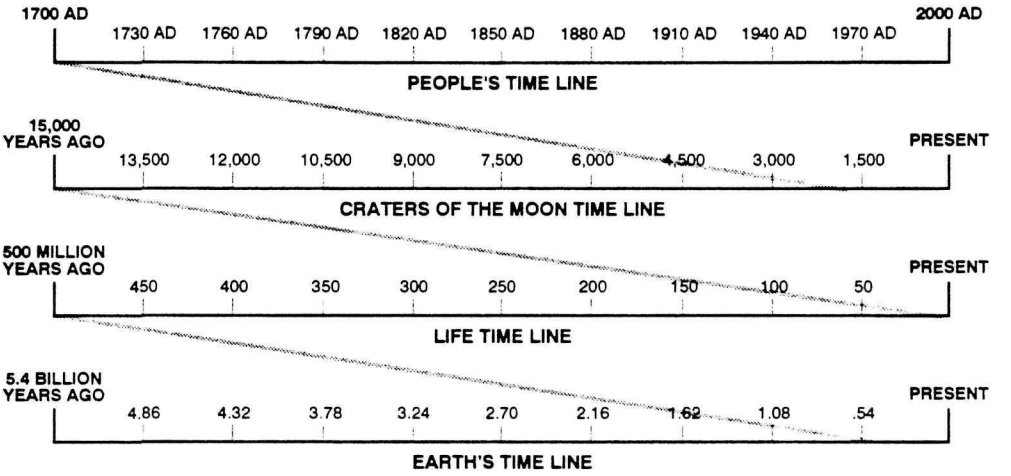


Part 3 - Future Time Line

Give each student about one or two feet of time line and instruct them to make a time line into the future using whichever time scale they want. For example, their time line could go from "Present" to "2 million years from now" or only "10 years from now." Students illustrate their time line with words and pictures explaining their predictions of the future.

Part 4 - Link Time Lines

Link the four time lines on your wall with string or yarn to show the temporal relationships between them. For example,



Place the personal time lines and the future time lines made by the students on the wall.

Activity 4B

Craters Ecosystem

Students learn about living and nonliving parts of ecosystems through one worksheet and two activities.

Objectives:

- Students will be able to define the living and non-living parts of an ecosystem.
- Students will be able to give examples of producers, consumers, and decomposers.
- Students will be able trace the path of energy through an ecosystem.

Duration:
1-2 hours

Background:
An ecosystem is the total of living parts (plants and animals) and nonliving parts (sunlight, air, water, soil) that support life in a unit of nature. We can refer to the Earth as one ecosystem or divide it into smaller units with similar characteristics (e.g., temperate forest, coral reef, and desert ecosystems). An aquarium or a cave could even be described in ecosystem terms.

Ecosystems are powered by the sun. Energy, in the form of sunlight, makes life as we know it possible. Air (specifically the oxygen, carbon dioxide, and nitrogen it contains), water, and the nutrients and minerals in soil make up the rest of the nonliving parts of an ecosystem. (Rock and dead organic matter will become soil in time.)

The living parts of an ecosytem can be divided into three categories:

1. Producers: Plants have chlorophyl and can produce their own energy in the form of carbohydrates (simple sugars) through photosynthesis.
2. Consumers: Animals must consume something else, either plants or other animals, to get their energy.
3. Decomposers: Many insects, microscopic animals, fungi, and bacteria get their energy by decomposing (or reducing) dead organic matter to its basic units, enriching the soil with nutrients.

Energy flows from the sun in the form of sunlight. While sunlight feels good on our skin, it doesn't feed our bellies. Plants, however, can take that sunlight and turn it into food! When we eat, we are in a way eating part sunshine. When we and other animals produce waste and eventually die, other, mostly microscopic, organisms may use the energy in our waste and dead bodies. This matter is reduced by decomposers and returned to the soil, where it may be used again by plants.

Energy is lost as it flows through an ecosystem. For example, not all the sunlight energy a plant receives is converted to chemical energy (i.e., carbohydrates). Some of it is wasted. Likewise, when mammals digest food they convert some of it to heat, which is irretrievably lost to the universe.

Matter, on the other hand, is conserved and recycled. The atoms that make up the molecules of living things have always been on Earth and will always remain here—as long as we don't blast them into space! The atoms and molecules in

your body may have been in a Tyrannasaurus rex 65 million years ago (and might be in a cockroach scientist 65 million years from now)!

ECOSYSTEM

- Living parts
  - plants
    - producers
    - decomposers
  - animals
    - consumers
- Nonliving parts
  - sunlight
  - air
  - water
  - soil

Materials:

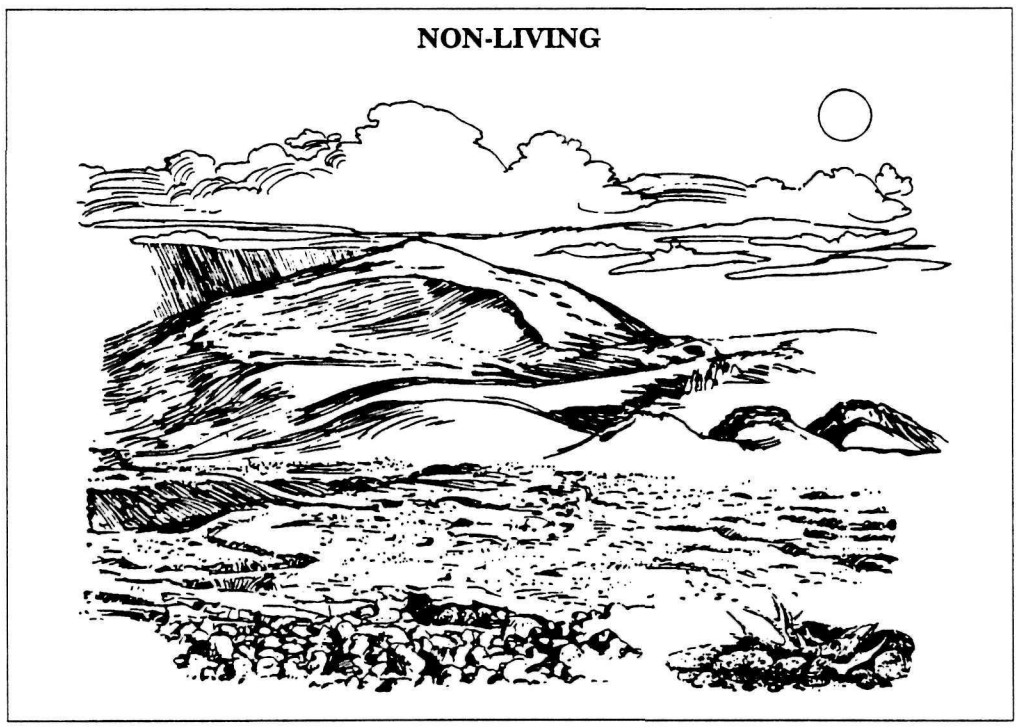
- Overhead projector
- Overhead transparencies made from enclosed illustrations

Procedure:

Part 1- Transparencies and Work Sheet

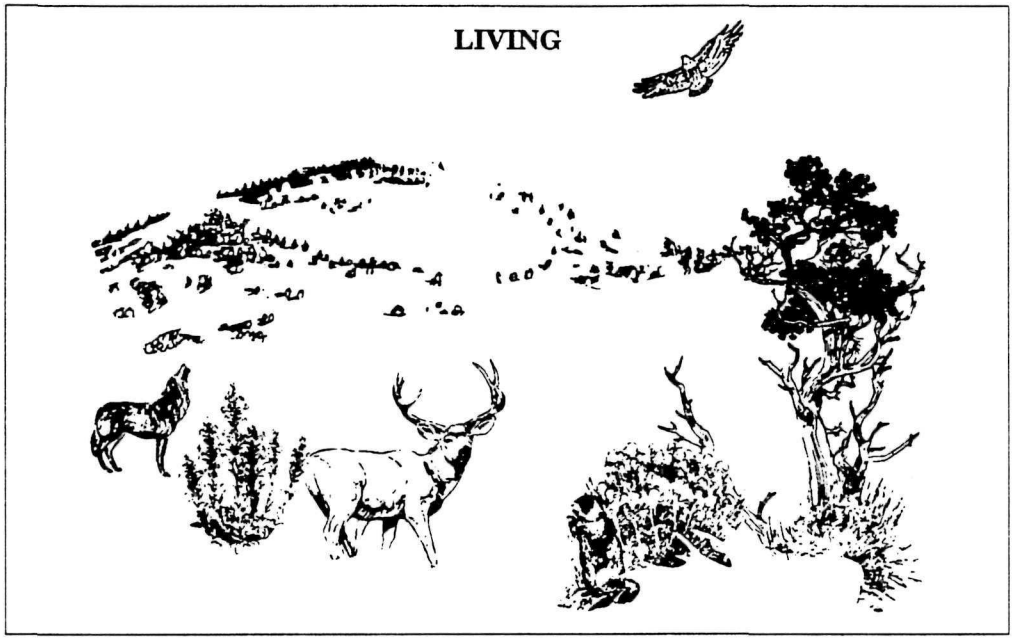
Make overhead transparencies of the two illustrations of ecosystems, one without life (Figure 1) and one with only living things (Figure 2), to explain the two basic parts of an ecosystem. Ask the students about the different parts in the nonliving illustration (sunlight, air, water, and soil).

Figure 1. *Illustration of Crater's ecosystem without plants and animals*



Switch transparencies and do the same with Figure 2. For now, just limit your discussion to plants and animals (not producers, consumers, and decomposers) so they won't get confused.

Figure 2. *Illustration of Crater's ecosystem with only plants and animals.*



To complete the ecosystem, overlay both transparencies at once.

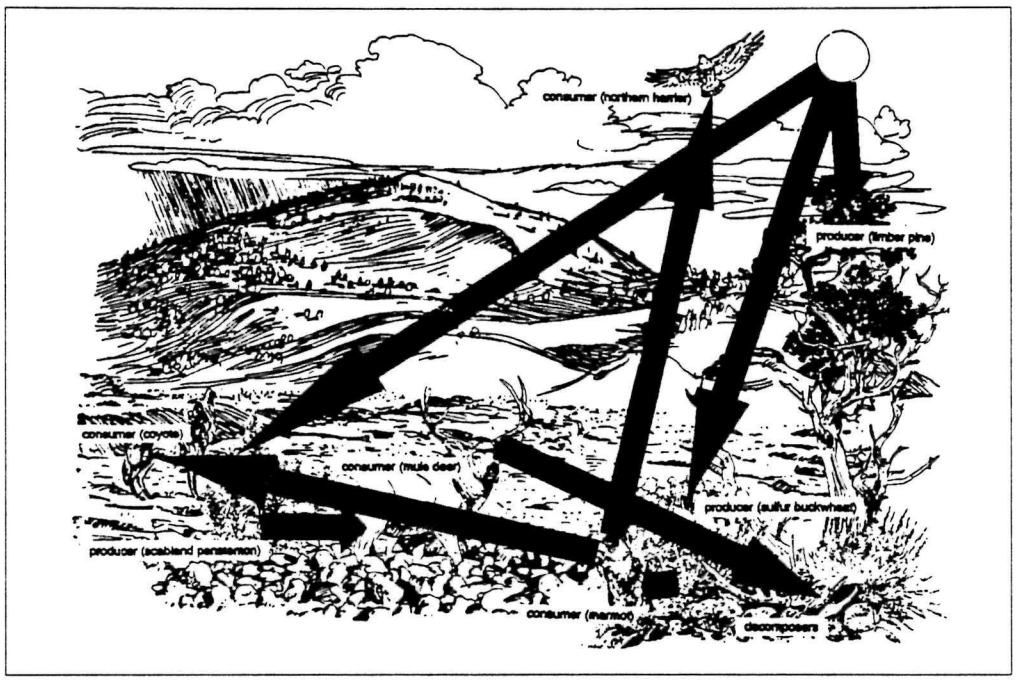
Figure 3. *Craters of the Moon Ecosystem.*

Once they get the idea that everything around them can be divided as living or nonliving, describe living things in more detail. Explain the relationship between producers, consumers, and decomposers (see Background section). Pass out the complete ecosystem illustration (Figure 3) and have them label its living and nonliving parts as follows:

- *Sunlight*
- *Producers*
- *Air*
- *Consumers*
- *Water*
- *Decomposers*
- *Soil (rock, mineral)*

Then draw arrows showing the path of energy through the ecosystem.

Figure 3. *Craters of the Moon Ecosystem. (Teacher's edition.)*



Part 2 - Building an Ecosystem.

As a fun way to reinforce their new-found ecosystem knowledge, go outside and do the following activity.

Tell the students that you're going to build an ecosystem with humans playing the different parts. Encourage them to be theatrical so their ecosystem will be dynamic and vital.

You will build an ecosystem in the shape of a circle with the sun at its core. Layer the kids around the ecoystem as you build it.

Start with the source of all our energy—the sun. Choose three or four kids and ask what sound the sun would make if it could make sound. Encourage them to come up with a sound of their own.

Living things are mostly made of water. Ask three or four students to stand around the suns in a circle after they have come up with a good sound for water.

Without air and the oxygen it contains, we'd be finished. Get three or four students to join the circle once they have decided what sound they'll make.

Soil, and the nutrients and minerals it contains, is necessary for plants. What sound will the three or four soils make when added to the ecosystem?

Of living things, plants (producers) are most abundant. Once you've got about four people to be producers put them in the circle. A good thing for producers to say is "grow, grow, grow!" since that is what they do under the sun.

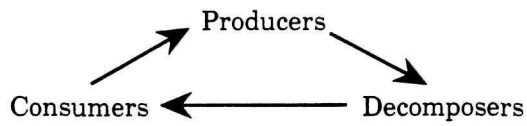
Consumers eat producers so they could say "munch, munch, munch!" You need two or three students for this.

Finally, all those producers and consumers would simply pile up and sit there when they die if not for the decomposers that cause them to "rot, rot, rot!" Finish off the circle with the decomposers.

See if all the participants know their "lines" by going through the ecosystem one by one. Don't let anyone get away with mumbling. If they're loud and obnoxious in the classroom when they shouldn't be, don't let them be quiet and shy now. Once they're ready with their parts, build the ecosystem by starting with the Sun and having the rest of the parts chime in one by one. You could have them revolve around the Sun to add a little motion to your ecosystem.

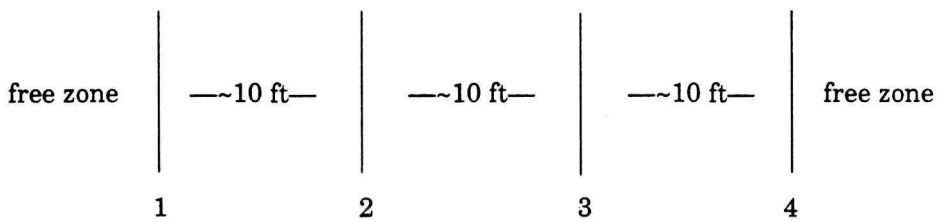
Part 3 - Rock, Paper, Scissors—Producer, Consumer, Decomposer

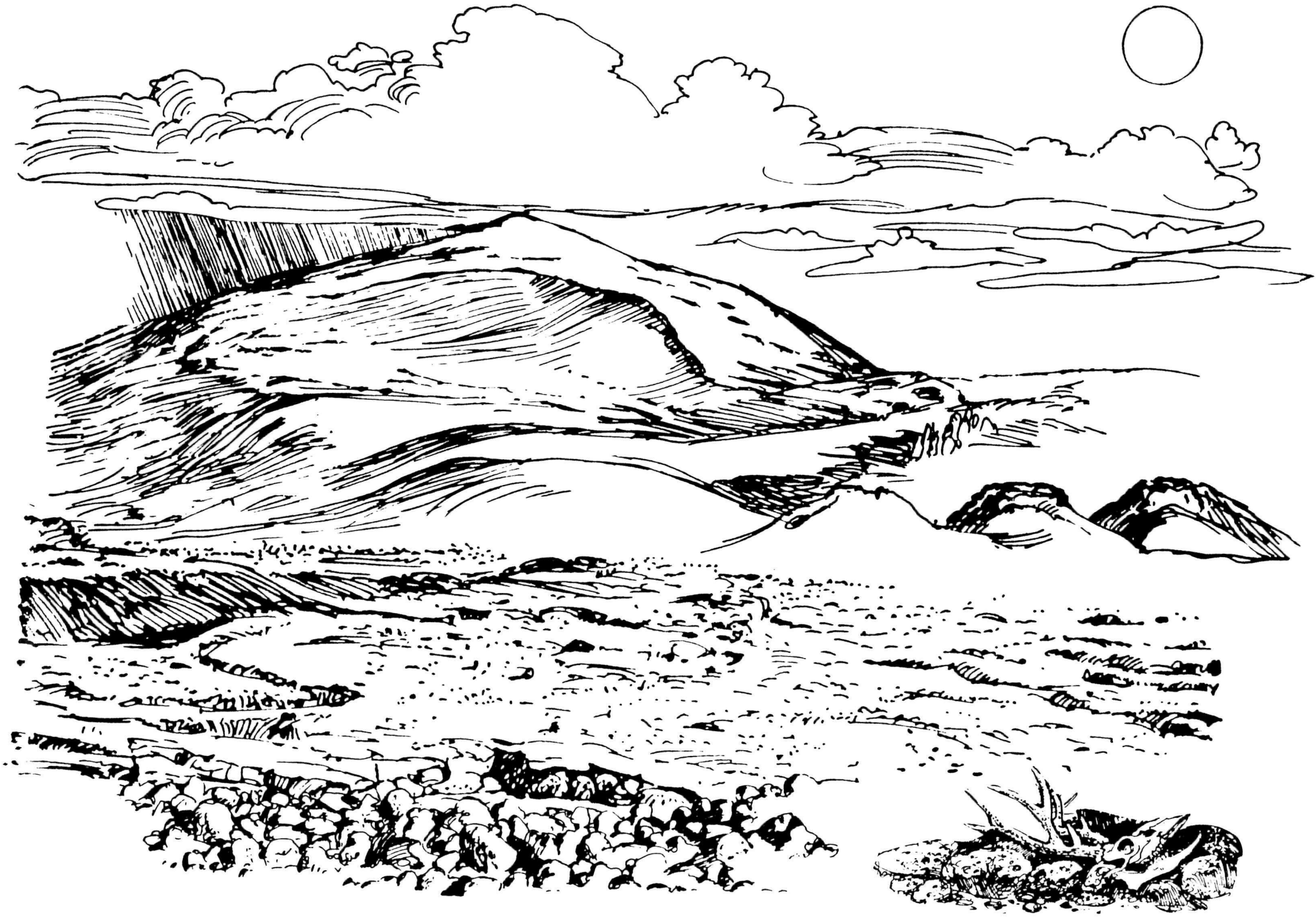
To test the students' knowledge of the relationship between producers, consumers, and decomposers, play this adaptation of rock, paper, scissors. Consumers get their energy from producers so you could say they are dominant over producers. Producers are able to utilize the nutrients made by decomposers, so producers are dominant over decomposers. When consumers die, decomposers use the energy in their bodies so decomposers are dominant.

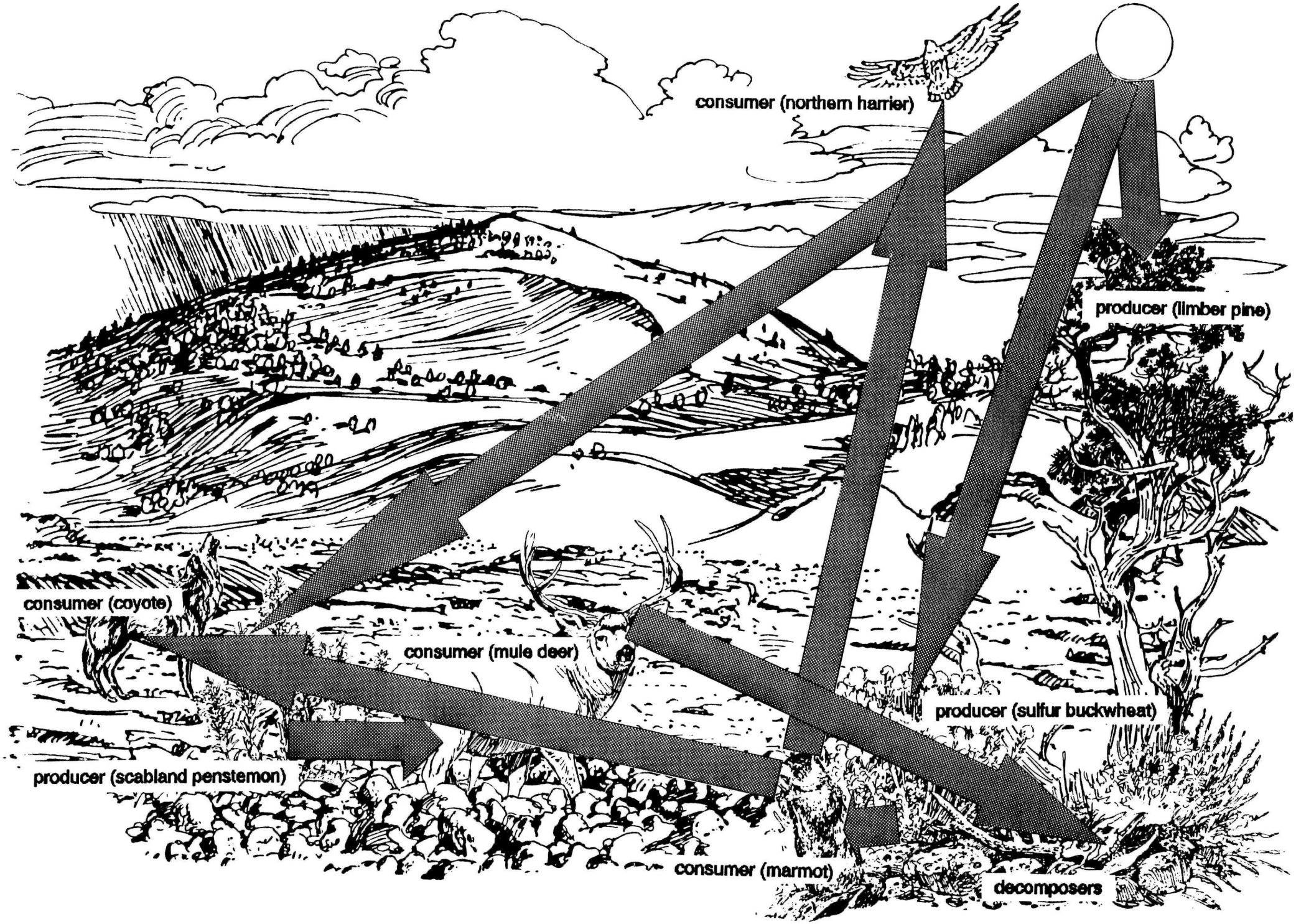


Kids will show with their hands what they are—producer, consumer, or decomposer. For example, producers could hold their arms up in the air for tree branches. Consumers could hold their hands up like bear or lion claws. To demonstrate decomposition and the break down of organic matter, decomposers could cover their stomach with their hands.

Make four lines on the ground as shown below. The kids will face away from each other on lines 2 and 3. They decide unanimously within each team which of the three to be. On your count of three they face inward showing their symbols. When you drop your arm, the dominant group rushes to tag the other team who runs to get to their free zone behind line 1 or 4. For example, if line 2 were consumers and line 3 were producers, when they faced each other they would see that the consumers (line 2) are going to chase the producers (line 3). When you drop your hand, they run toward line 4. If the producers get behind line 4 without being tagged, they're free. Hold your hand up a long time if necessary to give the kids time to figure out which way they should run. Ask them questions while your arm is raised. Have them give you examples of producers, consumers, and decomposers. There will be confusion at first so do the game enough times so most the kids understand the relationships between producer, consumer, and decomposer.






consumer (northern harrier)
producer (limber pine)
consumer (coyote)
consumer (mule deer)
producer (sulfur buckwheat)
producer (scabland penstemon)
consumer (marmot)
decomposers

Activity 4C

Adapting to a Brutal Land

Students match Craters plant adaptations to different habitat types and use their imaginations to create a species well adapted to a habitat of their design.

Objectives:

- Students will be able to name some adaptations plants have for living at Craters.
- Students will be able to match some common Craters plants to their appropriate microclimate.
- Students will be able to create their own species, well adapted to a student-designed habitat.

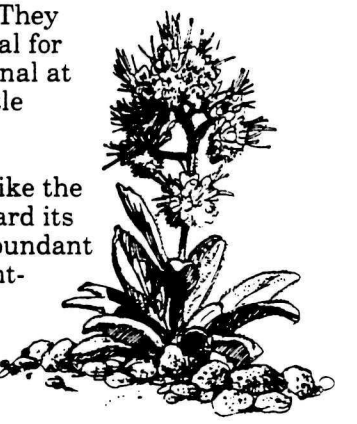
Duration:
2 hours

Background:
Every species has a unique set of adaptations that enables it to live in its environment. Some, like humans, starlings, and cheatgrass, have a wide tolerance to environmental constraints. Others, like Townsend's big-eared bats, three-toed woodpeckers, and the out-of-tune sticky tofieldia can survive only in the few niches where their unique habitat requirements are met. Most of Earth's biodiversity falls in the second category.

Over time, species adapt to changing environmental conditions structurally and behaviorally. Small, light-colored leaves covered with fine hairs are a structural adaptation some desert plants have to conserve water. Being nocturnal is a behavioral adaptation many desert animals adopt for the same reason. Humans have succeeded in exploiting every habitat on Earth because the structural adaptations of our big brains and our hands enabled us to make the myriad behavioral adaptations necessary to live in so many places.

Few environments are as hostile to life as Craters'. Temperatures range from 37 to 108 degrees F. and only about 17 inches of precipitation falls annually— mostly as snow. In spring it quickly melts off or seeps into the porous ground in time for summer winds and heat to evaporate every drop of moisture from the black landscape. Nevertheless, over 300 plant species cling to the nooks, crannies, and thin soils where life can exist at Craters. They go about enduring a permanent drought through tolerance, avoidance, and/or escape.

Some plants are extraordinarily tolerant of drought. They can withstand cell moisture levels that would be lethal for other plants. Sagebrush and bitterbrush are exceptional at extracting water from dry soils and living on very little moisture.



Plants can avoid drought with physical adaptations like the leaves of scorpionweed that funnel rain and dew toward its roots. Succulents like cacti collect water when it is abundant and retain it in their tissue. Rabbitbrush's small, light-colored leaves reduce evaporation.

Plants escape drought by living in the few places where water is actually plentiful. Others, like the dwarf monkeyflower, carry out their entire life cycle

during three moist weeks in the spring and survive as seeds during the rest of the year.

The diversity of life at Craters is possible because of its microclimates. The bottom of crevices and cracks may be 15 degrees F. cooler than the surface. Windblown soil called loess collects there, like dust in the corners of your home, creating a place for plants to grow. The well established soil on the north side of old cinder cones can support Douglas fir trees. Water-loving ferns can live in the midst of a desert by living near the melting ice and cool air of a cave and in deep crevices.

Materials:

- Copies of enclosed work sheet
- Clay for each student
- Construction paper, pipe cleaners, toothpicks

Procedure: Craters Adaptations

Start by having everyone tie their shoes without using their thumbs. The task was difficult because they weren't able to use one of our species' most useful adaptations—an opposable thumb.

Discuss adaptations with them and ask them to give examples. Generate a list of these on the board, like a bird's feather for flight; fur for warmth; claws for digging; down for lightweight insulation; keen sense of smell for detecting food and danger; fangs for injecting venom; an elephant's trunk for manipulating its environment; etc. See if they can come up with some behavioral adaptations too, like a wolf tucking its tail to show submissiveness; a robin singing to proclaim its territory; a sunflower following the path of the sun; a flower blooming at night to entice bats to pollinate it; a snake hissing when it feels threatened, and so on.

Once they have an idea what adaptation means ask them for examples of how plants are adapted to life at Craters. While they probably don't know much about plant adaptation at Craters, they likely know it's hot and dry in summer and cold and snowy in winter. Those conditions are what plants must adapt to. What is the basic growth form of plants that live in such places? Are they big and showy with delicate bright green leaves or bent and gnarled with pale leathery leaves? If the latter, why?

Your class may need some help with understanding the difference between north and south aspect slopes. In temperate latitudes, slope exposure has a profound influence on plant communities. Here in the northern hemisphere, the sun is always to the south so south facing slopes receive its direct rays. North facing slopes stay wetter because they are in the shade more of the year. The difference in soil moisture often means south facing slopes are pure sagebrush while water-loving trees grow on adjacent north facing slopes.

Students will rate different habitat types in terms of temperature and moisture, 1 being wettest. Then they will receive information on plant species and be asked to match them to the habitat type where they would most likely grow. Copy the following worksheet pages back to back to save paper and give them to the students.

Work Sheet 4C

Adapting to a Brutal Land

Name_____

Over 300 species of plants live at Craters despite it being hot and dry in summer and cold and snowy in winter. Each of them is adapted to living in a specific way in their environment. Some live only in cracks and crevices, some only on north sides of cinder cones, and some live in a variety of places. The reason for these differences are related to the plants' tolerance to temperature and available water.

Rate the following three habitat types from 1 to 3, wettest to dryest. Then, tell what plants would grow there by writing their corresponding numbers in the appropriate place in the third column.

Wettest to Dryest	Habitat Types	Plants Best Suited For Growing There
_____	Boise, Idaho	_____
_____	Brazilian rainforest	_____
_____	Mojave desert	_____

1) Barrel cactus—a succulent plant armed with spines. Can absorb water quickly and hold it in its fleshy tissue. Doesn't like to freeze. To three feet tall.

2) Strangler fig—starts out by growing on other tree's high branches to get more sunlight. Grows tendrils to forest floor for nutrients and water and then grows bigger and "strangles" the tree it started growing on. Likes warm, wet places.

3) Ponderosa pine—grows in soil moist from melting snow. Needles evaporate little water in dry summers.

4) Walking palm—huge dark green leaves for collecting sunlight at the bottom of a dark forest. The entire tree can move side to side over several years to find more light.

5) Black cottonwood—grows quickly along rivers in warm summer, but loses its leaves before the arrival of very cold winter.

6) Smoke tree—tiny light-gray leaves are resistant to drying out in wind. Has long root system to get water deep in the ground.

Rate the following Craters habitat types from 1 to 5, wettest to dryest. Then read through the plant descriptions and place them in the appropriate habitat type(s). Things are not black and white in nature; most plants can be found in more than one habitat type. Hint: You must know why it matters to a plant whether it lives on the north or south side of a mountain? Which side is drier and why?

Wettest to Dryest or Coolest to Hottest	Craters of the Moon Habitat Types	Plants Best Suited for Growing There
_____	North sides of cinder cones with deep soil	_____
_____	Surface of smooth, flat lava flows	_____
_____	South sides of cinder cones with little soil	_____
_____	Caves with light shining in and thawing ice	_____
_____	Cracks and crevices of lava flows	_____

1) Ferns—require shade and protection from drying winds.

2) Sagebrush—large leaves in spring and small leaves in summer help it to grow in full sun. Likes good soil but not shade.

3) Dwarf buckwheat—many small hairs on the surface of its leaves help keep it from losing water because it lives in hot country where its long roots find rare water. A very small plant.

4) Douglas fir—grows best in cool, moist mountains in good soil. Doesn't like full sun or growing by itself.

5) Moss—grows in the coolest, wettest places, never in full sun.

6) Syringa—drought tolerant plant that grows in small, sheltered areas in lava flows.

7) Limber pine—requires soil but can survive heat, wind, and lack of rain better than most pines.

8) Dwarf monkey flower—it grows up, produces seeds, and dies in three weeks during the spring. It survives only as seeds during summer and winter. Grows in full sun where few other plants can.

9) Gland cinquefoil—tougher than syringa, but still requires a crack or small pocket of soil to sink its roots.

10) Lichens—live almost everywhere, even where practically nothing else can. They're black, yellow, green, gold, or orange and live on rocks and trees.

11) Quaking aspen—a mountain tree whose broad leaves cannot tolerate heat and wind. Needs deep soils, shade, and moisture. Seldom grows alone.

Teachers' Habitat Type Answers
On the Craters plant-habitat matching you will find that the species can be matched with more than one habitat type. This is the way it is in nature; plants do not stop growing abruptly at habitat boundaries. Because it is not cut and dry students may find it frustrating. The point is that they realize that plants have different tolerances to water and temperature. A fern would never live on the barren, hot south slope of a cinder cone just as a syringa would never live in a dark, cool cave.

Wettest to Dryest	Habitat Types	Plants Best Suited For Growing There
2	Boise, Idaho	3, 5
1	Brazilian rainforest	2, 4
3	Mojave desert	1, 6

Wettest to Dryest or Coolest to Hottest	Craters of the Moon Habitat Types	Plants Best Suited for Growing There
2	North sides of cinder cones with deep soil	2, 4, 7, 10, 11
5	Surface of smooth, flat lava flows	10
4	South sides of cinder cones with little soil	2, 3, 8, 10
1	Caves with light shining in and thawing ice	1, 5, 10
3	Cracks and crevices of lava flows	1, 6, 7, 9, 10

Procedure: Adaptation Artistry (adapted from Project WILD)
Now that the students are adaptation experts with real life plant examples, let them use their imaginations to create their own well-adapted animals. They can draw them or use clay, construction paper, pipe cleaners, etc.

The students should be able to answer the following about their species:
- What is its habitat and how is their species well adapted to it?
- What does their animal eat; how does it get its food?
- How does it move?
- What is the animal's sex?
- What is the name of the species?

Their creation should be well-adapted to all the devious environmental constraints they will hopefully create for it.

As an example, one student made a "flapper." Flappers live on school cafeteria floors where they forage on food waste. They are camouflaged to look exactly like a pancake. When no one is looking they scoot across the floor to find more food or leave before the janitor comes. Unfortunately, in schools where students are learning to waste less food, flappers are becoming endangered.

Activity 4D

Craters Life Web

Students learn about the complexity of life and interrelationships between living things by constructing a Craters food web.

Objectives:

- Students will be able to describe several relationships between living things at Craters.
- Students will be able to trace the flow of energy through a food web.

Duration:
30 minutes to 1 hour

Background:
John Muir said, "When we try to pick anything out by itself, we find it hitched to everything else in the universe." For example, lichens accelerate the erosion of rock and tree trunks on which they grow, enriching nearby soil and improving growing conditions for syringa. Syringa creates shade and further enriches the soil when it dies and is decomposed by wind-dispersed fungi and bacteria. A host of insects colonize the crevice where the syringa grows. A spider eats the insects. A Clark's nutcracker hides a limber pine nut in the cool syringa crevice but is later caught by a Cooper's hawk. The pine nut germinates and finds the crevice to its liking and begins to grow, owing its future to all that came before it.

The story of life is about interrelationships, something of which we are largely ignorant. Our lack of ecological knowledge towers over what little we know of nature's ways. For example, the first step in understanding life is identifying the species and we don't know how many there are—not even to the nearest order of magnitude. The number could be could 10 or 100 million.

We do know that nothing lives in isolation. However, we often act as though life on Earth were a massive tool box, with many unnecessary minor nuts and bolts. In North America we once used the wonder pesticide DDT, but were ignorant of its effect on the rest of the food chain, where it caused egg shell thinning in predatory birds and tainted mothers' milk. Today, third world countries use DDT widely. How will long-term use of this and other pesticides affect the global environment? We condone the liquidation of ancient forests around the world by doing little to stop it. Is it mere poetry to refer to them as the lungs of the world and a treasure trove of biodiversity, or will their loss have catastrophic effects on Earth? How did the species that become extinct every day around the world fit into their ecosystem? Will their loss have far-reaching ecological effects or will it simply be an aesthetic loss? We don't know the answers to these questions—perhaps we can't know them, until it's too late.

To get a grasp of the complex interactions between living things, we can start by looking at a simple linear food chain: sun, dandelion, rabbit, and hawk. Sunlight is converted into chemical energy by green plants. Part of that energy is captured by herbivorous insects and vertebrates when they eat the plant. Carnivores then eat herbivores. In reality, however, the flow of energy through an ecosystem is more like a web. Species share energy back and forth in subtle ways. If we consider other relationships (i.e., plants that provide cover and nesting habi-

tat to animals; insects, birds, and bats that pollinate flowers; rodents that disperse seeds; animals that require shade created by plants; and so on), our web approaches a symbol of what nature is really like.

Materials:

- Ball of string 300-400 feet long
- Enclosed Craters species cards

Procedure:

Each member of your class will play one or more parts in a Craters food web. Have the kids sit cross-legged on the ground in a circle. Give each of them a slip of paper from the enclosed list of Craters species. Start a discussion on food chains and food webs.

What is the origin of all energy, the source of all food? The sun. Give the ball of string to the student who has the sun card. Now ask who needs the sun for its energy? There will be several kids with plant cards who should raise their hands. Plants use sunlight to make chemical energy (carbohydrates or simple sugars) through the process of photosynthesis. The sun holds onto the end of the string and passes the ball to the plant. Now who gets energy from the plant? It may be a rabbit or a deer that eats the plant, a hummingbird that sips its nectar, or a bee that collects its pollen. The plant holds onto the taught string that goes to the sun and passes the ball to the next person in the web. A predator might get its energy from the rabbit or hummingbird so the ball of string is passed to him or her. **Note: To prevent tangling the string, make sure each student passes the ball over the top of the web.**

When something dies it is reduced to its elemental form by decomposers like bacteria, fungi, and some insects. These decomposers help to enrich soil, which is critical to the needs of plants. The plants thrive and are then grazed and browsed by animals. When the animals and plants die, the decomposers complete the cycle.

If at some point you get stuck in making your food web—there's no clear relationship or your choices are limited—simply give the ball to someone that has already had it. They will hold two strands. Don't limit yourselves to what it says for each of the species; if they can think of some other relationship, use it. You could call it a "life web" and start talking about relationships other than food.

How do plants need insects? For pollination. How do swallows need dead trees? As places to nest. The ball should go in the direction where it is needed. Challenge your students to know what their species requires and speak up when the ball of string is at a species they need.

When everyone has at least one loop of string have the students carefully pull the web taught. While students are holding the web tell them that there are over 300 plant species and more than 175 amphibian, reptile, mammal, and bird species at Craters. There are thousands of species of insects, worms, and microscopic organisms. How many are represented here? Have we talked about all the possible relationships these organisms share? What if we had all the species with links representing all the relationships? It would require lots of string. The web might get so thick we couldn't see through it. Do we know about the many relationships between all the species? No way. What if we tug on one of the strings. In theory, each of you'd be able to feel it. Have one species become extinct by letting go of its string. What happens to the web? Have a few other species go extinct and see how the web is affected.

Before ending the activity you might want to read the following quote, attributed to Chief Seattle:

> *"This we know, the earth does not belong to man, man belongs to the earth. This we know, all things are connected like the blood that unites one family . . . Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself."*

To avoid tangles, have everyone lean forward and gently place their strands on the ground. The person with the end of the line can wind up the string as you wrap up the activity.

Materials 4D

For Life Web Participants

Copy both pages, cut slips apart, then distribute to participating students

Bacteria
Enriches soil by helping to decay dead things.

Bacteria
E. coli
Lives in people's guts where it helps break down food.

Fungi
Gets its energy and enriches soil as it breaks down dead wood.

House fly
Its larvae (maggots) get energy from food waste and dead animals and enrich soil.

Dermestid beetle
They get their energy by turning dead animals into compost.

Lava tube beetle
Scavenges insect remains in lava tubes. Bacteria and fungi break down its feces.

Wheat stem sawfly
Its larvae eat Great Basin wildrye. Sawflies are eaten by birds and other insects.

Great Basin wildrye
Eaten by many mammals.

Dwarf mistletoe
A parasite on limber pine trees that is sometimes eaten by deer and elk; produces berries that American robins and cedar waxwings eat.

Limber pine
Their seeds are eaten by Clark's nutcrackers and golden-mantled ground squirrels. They need soil to grow and nutcrackers to disperse their seeds.

Sagebrush
Has medicinal uses and is eaten by pronghorn and sage grouse.

Antelope bitterbrush
Important to deer and yellow pine chipmunks for food.

American robin
Eats berries and worms; requires trees to nest in.

Sage grouse
Eat and live in sagebrush; eaten by eagles.

Cedar waxwing
Eats many different types of berries; disperses the seeds of mistletoe; eaten by hawks.

Sharp-shinned hawk
Eats birds and requires trees to nest in.

Lewis mockorange
Needs sunlight and soil to live; Indians used its straight stems to make arrows.

Serviceberry
Deer and golden mantled ground squirrels eat and disperse its leaves and berries.

Golden currant
Yellow pine chipmunks and golden-mantled ground squirrels eat its berries.

Yellow pine chipmunk
Eats many seeds and fruits; eaten by hawks and other predators; likes to live near trees.

Golden-mantled ground squirrel
Eats many seeds and fruits; eaten by hawks and other predators.

Earthworm
Decomposes organic matter; eaten by robins and shrews.

Grasshoppers
Eats many grasses and feeds shrews.

Vagrant shrew
Only 2 inches long, it eats any animal smaller than itself; eaten by skunks and gopher snakes.

Striped skunk
Lives on bird eggs, small mammals, nuts and berries; nothing but great horned owls can eat it.

Sun
The source of energy for life on Earth. Plants make food with sunlight, water, carbon dioxide, and soil nutrients.

Great horned owl
The most powerful owl in North America; will eat many mammals, birds, and reptiles.

Golden eagle
Top of the food chain; eats rodents and large birds.

Pika
Makes hay bales out of grass and feeds on them during winter.

Grasses
Seeds and stems eaten by many animals. Needs soil to grow.

Human

Indian paintbrush
Grows best with other plants like sagebrush; hummingbirds pollinate its flowers.

Rufous hummingbird
Gets nectar from flowers; uses spider webs to make its nest.

Spider
Eats many different kinds of insects.

Gopher snake
Eats mostly rodents. Has to watch out for birds of prey.

Chapter Five:
Student Journal

Activity 5A

Students enhance their learning experience at Craters by using a Student Journal while on their field trip.

Objectives:

- Students will be able to determine the amount of time their bus journey would have taken had they walked or ridden a horse or wagon.
- Students will record their thoughts, art, observations, etc. in their personal field journal.
- Students will record the places they visited while on their tour of Craters.
- Students will draw a Craters ecosystem and label its living and non-living parts.

Duration:
For use by the students during their field trip to Craters.

Background:
The Student Journal is intended to focus the students' learning while they explore Craters of the Moon. It will help to reinforce the knowledge they have already gained through their classroom study of Craters geology, cultural history, and ecology. Upon returning to the school, the teacher can instruct the students to refer to their Journal notes for further Craters exploration. The Student Journal is for the students to keep and may be the only tangible thing they have from their visit to the Monument.

Materials:

- One pencil with eraser for each student.
- One Student Journal for each student.

Procedure:

Make back to back copies of the Student Journal on 8.5" X 11" paper, fold them in half, and staple together. Use different colored paper to make the Journals more appealing to children.

Go over the Journal with the students page by page before leaving on your field trip so the students will be prepared for the small amount of "book work" they must do once they are at Craters. You may wish to explain a grading policy to the students and/or tell them that their success on future assignments hinges on their thoughtful responses in their Journal.

The Student Journal

Page 1

Introductory page and Shel Silverstein's poem, *"Where the Sidewalk Ends."*

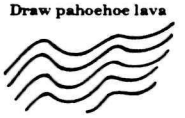
Page 2

Craters Travel Times. The students must get the odometer reading from their bus driver at the beginning of the trip and when they arrive at Craters to calculate the total days of travel the trip would take if they had to walk, ride horseback, or ride in a wagon.

Page 3

Craters Bingo. Encourage the kids to respond to each of the squares and get a "bingo blackout."

Following are the answers to Craters Bingo.

Draw pahoehoe lava 	**Most common lava you saw at Craters** Pahoehoe	**Number of plants growing in a 10 square foot plot out of:** **Solid rock**_____ **Rock cracks**_____	**A Craters fact you found fascinating**
Approximate elevation of Craters of the Moon 5,700 to 6,000 feet	**Why do plants grow better in cracks than solid rock?** Cracks retain more moisture and nutrients	**Draw aa lava** 	**The kind of rock found at Craters** Igneous (generally) Basalt (specifically)
Describe a mountain bluebird without using the word "blue" Color of the sky; azure; color of ice	**What is the name of a ranger you met?**	**When might Craters become volcanically active again?** Within 1,000 years	**Age of all Crater's visible lava** 2,000 to 15,000 years old
What your foot would look like after walking barefoot across aa lava? Hamburger, or draw a picture	**Name your favorite geologic feature**	**What is the Snake River Plain shaped like?** A smile or a crescent; or draw a picture	**What's easier on your bare feet, aa or pahoehoe?** Pahoehoe

Page 4

Field Observations. Following are three suggested ideas.

Idea #1.

From the North Crater Flow Trail have the students observe the differences-

between the North Crater (a young cone) and Grassy Cone (an old cone). From the trail, North Crater is close and to the south while Grassy Cone is about a mile to the west.

Have students generate a list of differences between these two cones, for example:

North Crater	**Grassy Cone**
Made of jagged, big rocks	Made of smaller rocks
Jagged outline	Smooth outline
Little vegetation	Covered with plants
Taller	Shorter

Then have them hypothesize why these two cones are different. If necessary, tell them that one cone is 2,300 years old (North Crater) while the other is 7,400 years old (Grassy Cone). Which is which and how do they know? You could instruct students to record their observations now and discuss it once you return to class.

The shape of Grassy Cone and the vegetation on its slopes indicate it has weathered longer and has had more time for soil to develop and plants to colonize its slopes.

You might also have the students hypothesize why trees grow on just one side of Grassy Cone. The forest grows only on the north side of Grassy Cone because we live in the northern hemisphere and the sun is always to the south of us. The cone casts a shadow northward, reducing evaporation on the north slope, thereby making life possible for water-loving trees.

Idea #2.
Choose an area where students can safely leave the path to closely observe plant life growing amongst the lava (e.g., caves area). Break them into teams and have them randomly choose a plot of lava, about 100 square feet in area, in which some plants are growing. Ask them to make a table as follows:

	Plants growing from crevices and cracks	**Plants growing out of bare, flat lava**
flowers	_____	_____
shrubs	_____	_____
trees	_____	_____

Beneath each column they would record the number of plants that are growing in the two categories.

Discussion and analysis could be saved for the classroom. What were their findings? Did crevices and cracks support more plant live? If so, how much more? Why would plants thrive better in crevices and cracks? (water and soil is retained there better than on bare rock because there is more shade and less wind).

Idea #3.
During the course of the day have the students make specific observations of their surroundings for an article they will write upon returning to class. Encourage them to use all of their senses. What did the area feel, sound, smell, and look like? How did their lunch taste that day? Challenge the students to create metaphors and/or similes for what they experience at Craters.

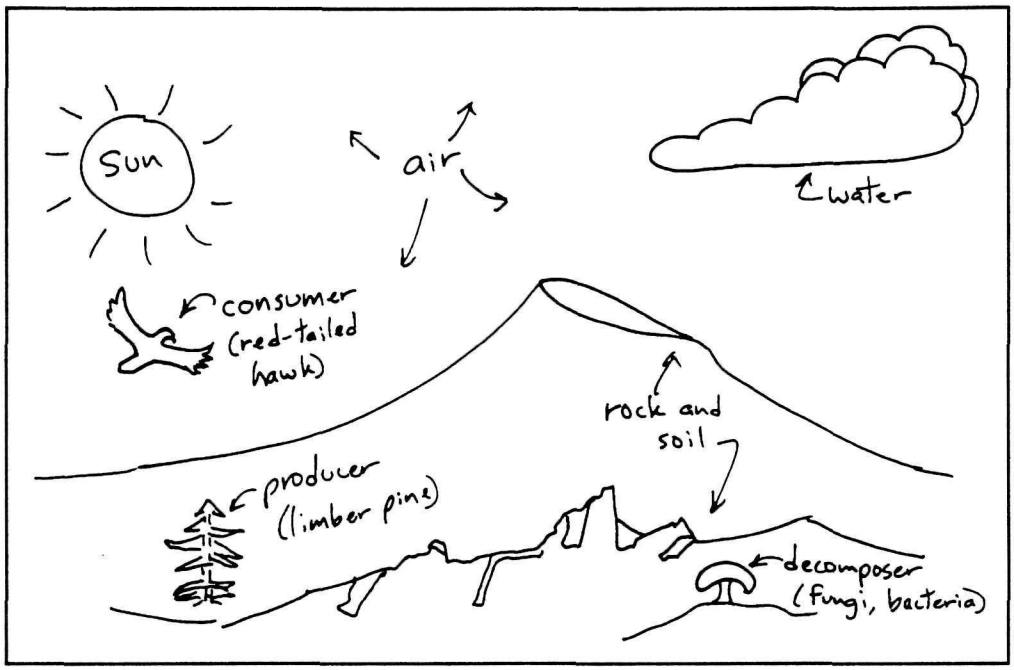
Instruct the students to keep a record of what they did and where they went. What geological observations did they make? What did they overhear other tourists saying about Craters? What birds and plants did they see? These specific notes could be used to write an article on their trip to Craters.

Pages 5 and 6

Ask students to circle those features and trails they visited to help them gain map reading skills. You could challenge the students to know where they are at all times.

Pages 7 and 8

Students draw a simple illustration of a Craters ecosystem and label it with its living and non-living parts. This activity will reinforce what they have already learned in your classroom using the Craters' curriculum. For example:



Page 9

The Notes page can be used for whatever purpose you want. For example, students could write haikus while sitting by themselves in Indian Tunnel (haikus are three lined, unrhymed Japanese poems consisting of 5, 7, and 5 syllables).

Alone with the birds
Their wings fill the air with joy
The same breeze cools us

Page 10

Encourage the kids to check off plants and animals they see at Craters. They can ask a ranger if they have questions on identification.

Back cover

The back cover is blank and can be used for more notes or sketches and artwork.

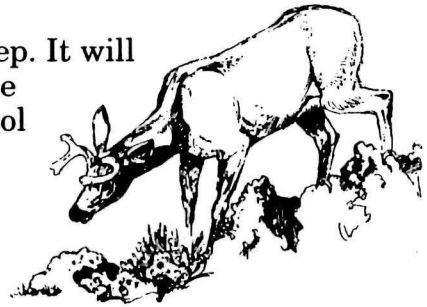
CRATERS OF THE MOON NATIONAL MONUMENT

Student Journal

Name_____ Date_____

Welcome to Craters of the Moon
We're glad you came!

This booklet is yours to keep. It will be a record of what we hope will be one of the best school field trips you ever take.



— Where the Sidewalk Ends —

There is a place where the sidewalk ends
And before the street begins,
And there the grass grows soft and white,
And there the sun burns crimson bright,
And there the moon-bird rests from his flight
To cool in the peppermint wind.

Let us leave this place where the smoke blows black
And the dark street winds and bends.
Past the pits where the asphalt flowers grow
We shall walk with a walk that is measured and slow,
and watch where the chalk-white arrows go
To the place where the sidewalk ends.

Yes we'll walk with a walk that is measured and slow,
And we'll go where the chalk-white arrows go,
For the children, they mark, and the children, they know
The place where the sidewalk ends.

—*Shel Silverstein*

Plants and Animals of Craters of the Moon

Place a check by the plants and animals you see at Craters.

PLANTS

- ❑ Indian paintbrush
- ❑ Scabland penstemon
- ❑ Antelope bitterbrush
- ❑ Sagebrush
- ❑ Rabbit brush
- ❑ Prickly pear cactus
- ❑ Syringa
- ❑ Limber pine
- ❑ Quaking aspen
- ❑ Douglas fir

MAMMALS

- ❑ Black-tailed jackrabbit
- ❑ Yellow-bellied marmot
- ❑ Pika
- ❑ Golden-mantled ground squirrel
- ❑ Yellow pine chipmunk
- ❑ Coyote
- ❑ Red fox
- ❑ Mule deer
- ❑ Pronghorn

REPTILES

- ❑ Gopher snake
- ❑ Western rattlesnake
- ❑ Western skink
- ❑ Western toad

BIRDS

- ❑ Northern harrier
- ❑ Golden eagle
- ❑ American kestrel
- ❑ Mourning dove
- ❑ Red-naped sapsucker
- ❑ Violet-green swallow
- ❑ Black-billed magpie
- ❑ Common raven
- ❑ Clark's nutcracker
- ❑ Mountain bluebird
- ❑ Rock wren
- ❑ American robin
- ❑ Western tanager
- ❑ Rufous-sided towhee
- ❑ Brewer's blackbird

OTHERS:

- ❑ _____
- ❑ _____
- ❑ _____
- ❑ _____
- ❑ _____
- ❑ _____
- ❑ _____
- ❑ _____
- ❑ _____

Notes:

Craters Travel Times

About 15,000 years ago the first people walked to Craters of the Moon. Just a few hundred years ago people travelled there on horses, then wagons. And now you're going there in a bus. See how long it would have taken to do the trip on foot or horseback.

	Bus odometer reading (miles)
End of trip:	_____
subtract	
Beginning of trip:	_____
equals	
Total miles:	_____

A walker, horse rider, or wagon goes about 2 miles per hour. To see how long this trip would have taken in the old days, take the total miles and divide it by 2 miles per hour.

_____ total miles ÷ 2 miles per hour

=_____ total hours of travel.

You only travel about 10 hours a day. To see how many days your trip would take, divide the total hours of travel by 10 hours per day.

total hours of travel ÷ 10 hours per day

=_____ total days of travel.

Try to get as many Craters bingos as possible by filling in the following squares

Draw pahoehoe lava	Most common lava you saw at Craters	Number of plants growing in a 10 square foot plot out of: Solid rock_____ Rock cracks_____	A Craters fact you found fascinating
Approximate elevation of Craters of the Moon	Why do plants grow better in cracks than solid rock?	Draw aa lava	The kind of rock found at Craters
Describe a mountain bluebird without using the word "blue"	What is the name of a ranger you met?	When might Craters become volcanically active again?	Age of all Crater's visible lava
What your foot would look like after walking barefoot across aa lava?	Name your favorite geologic feature	What is the Snake River Plain shaped like?	What's easier on your bare feet, aa or pahoehoe?

Craters of the Moon Ecosystem Art

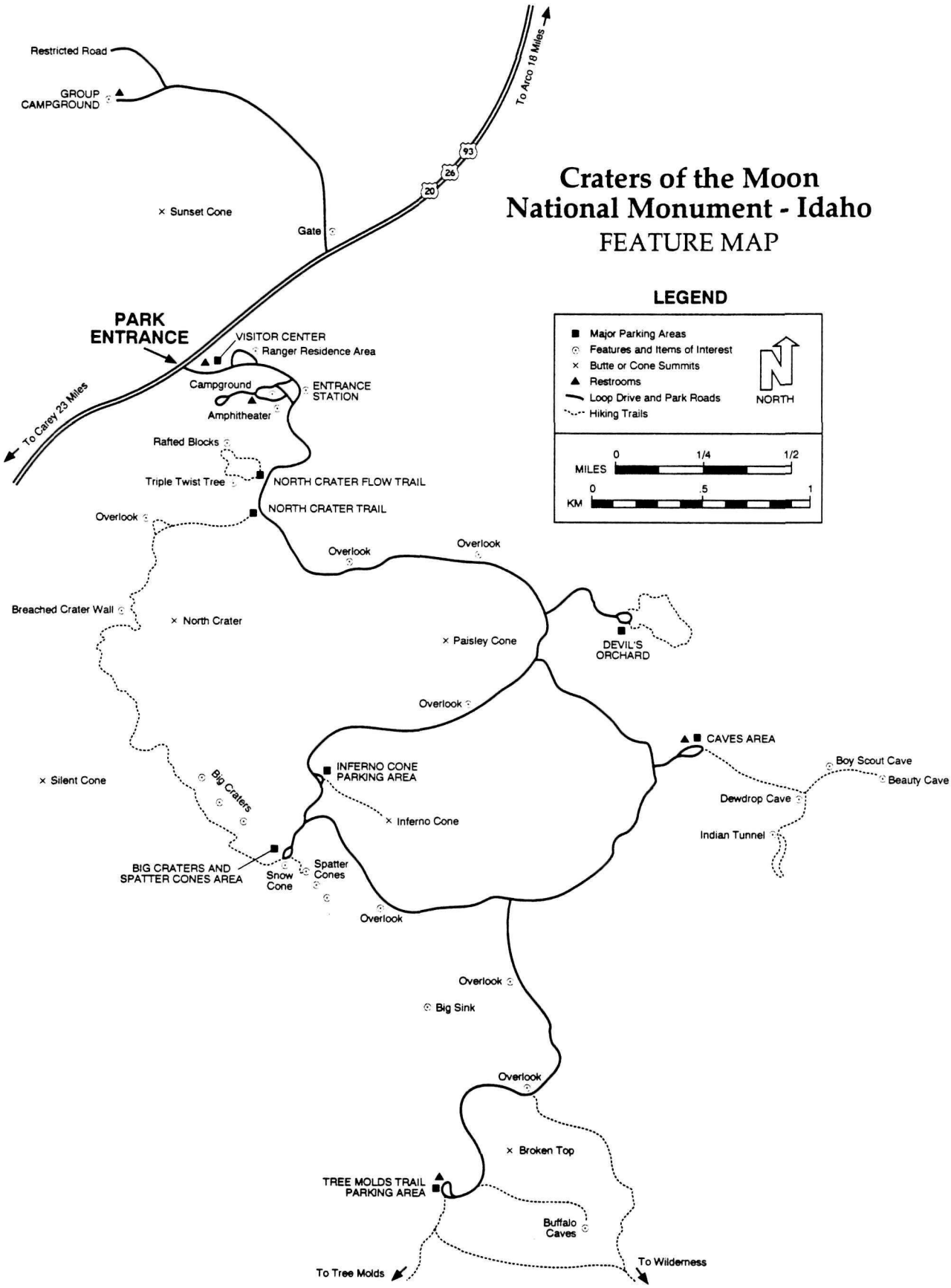
Draw a picture showing a Craters ecosystem. Label the following:

Air	Water	Rock and Soil	Sun
Producer	Consumer	Decomposer	

(Give examples for your producers, consumers, and decomposers)

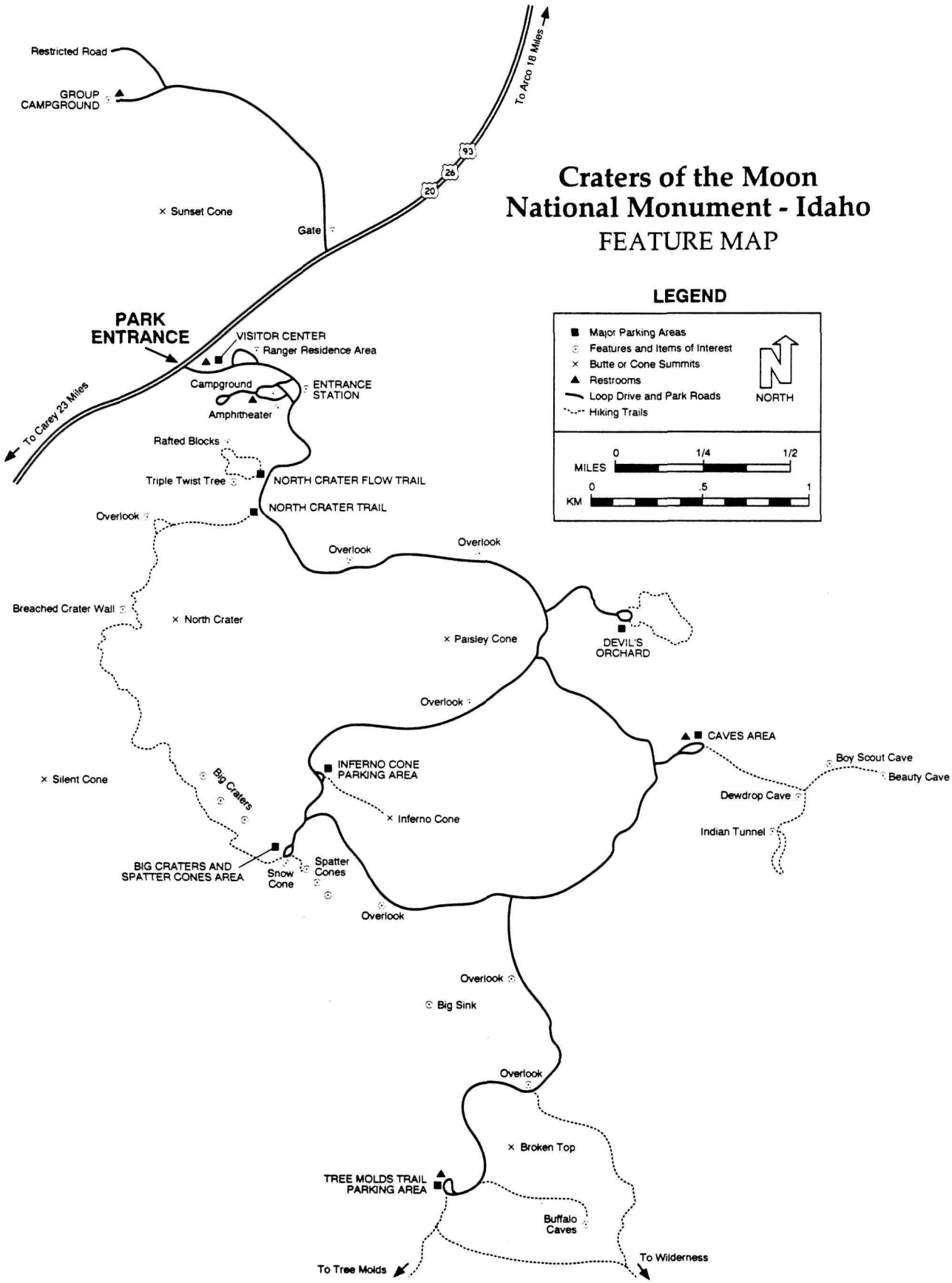
Field Observations:

On the following page circle the places you visited on your trip to Craters of the Moon.


Craters of the Moon
National Monument - Idaho
FEATURE MAP
LEGEND
Major Parking Areas
Features and Items of Interest
Butte or Cone Summits
Restrooms
Loop Drive and Park Roads
Hiking Trails
NORTH
MILES 0 1/4 1/2
KM 0 .5 1
Restricted Road
GROUP CAMPGROUND
To Arco 18 Miles
93
26
20
Sunset Cone
Gate
PARK ENTRANCE
VISITOR CENTER
Ranger Residence Area
Campground
ENTRANCE STATION
Amphitheater
To Carey 23 Miles
Rafted Blocks
Triple Twist Tree
NORTH CRATER FLOW TRAIL
NORTH CRATER TRAIL
Overlook
Overlook
Overlook
Breached Crater Wall
North Crater
Paisley Cone
DEVIL'S ORCHARD
Overlook
CAVES AREA
Boy Scout Cave
Beauty Cave
Dewdrop Cave
Indian Tunnel
Silent Cone
Big Craters
INFERNO CONE PARKING AREA
Inferno Cone
BIG CRATERS AND SPATTER CONES AREA
Snow Cone
Spatter Cones
Overlook
Overlook
Big Sink
Overlook
Broken Top
TREE MOLDS TRAIL PARKING AREA
Buffalo Caves
To Tree Molds
To Wilderness

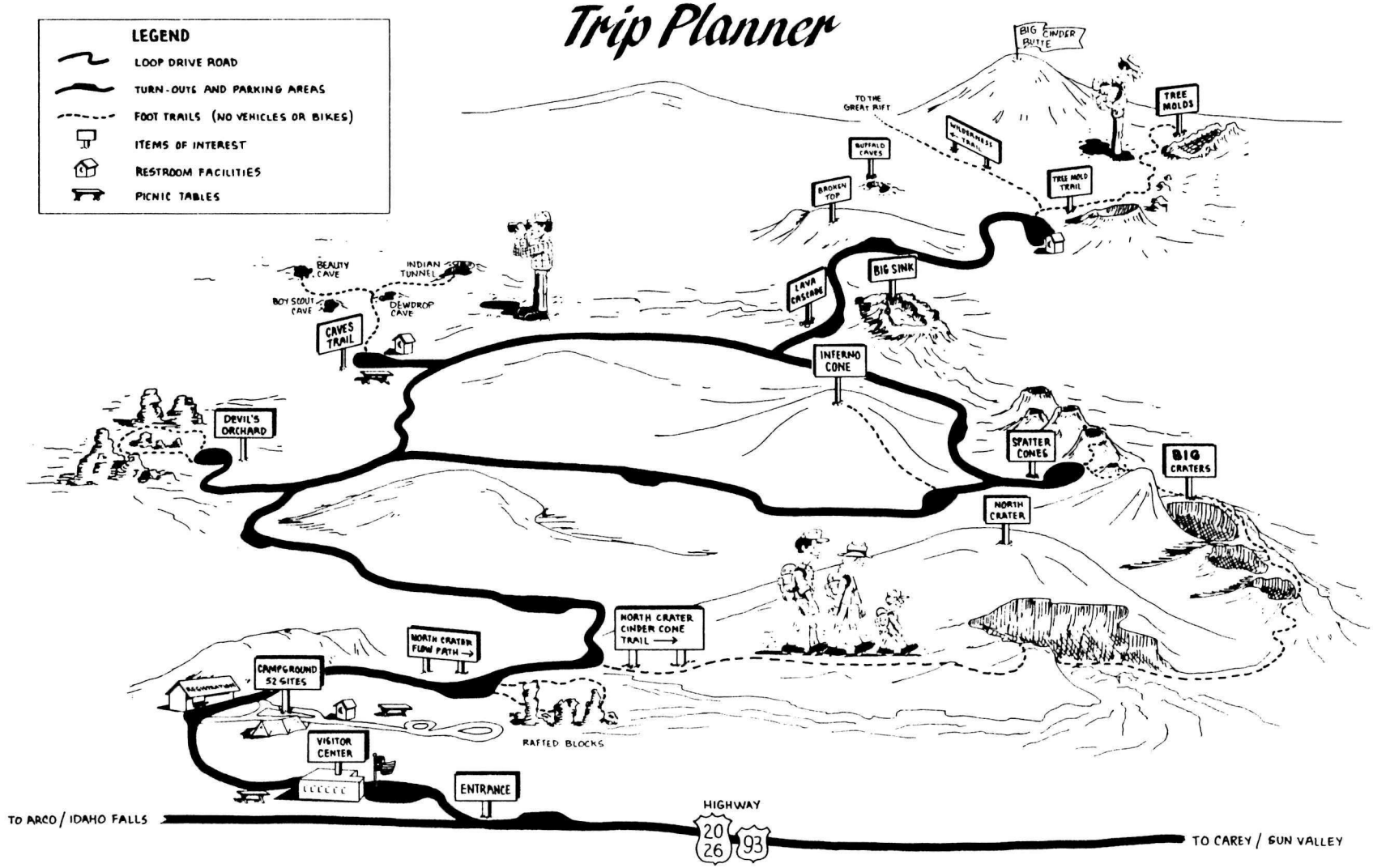
Appendix

Appendix One



Appendix Two

CRATERS OF THE MOON
NATIONAL MONUMENT, IDAHO
Trip Planner



Appendix Three:

Mailing List and Suggestion Form

Keeping in Touch

We have developed a mailing list to help us keep in touch with the teachers in our area. We notify teachers on the mailing list of annual teachers' workshops, new developments in our environmental education and outreach program, and special events. If you would like to be included on our mailing list, please complete this form and return it to the address below.

Please check appropriate responses:

_____ I would like a copy of the "Teacher's Guide to Craters of the Moon, A Curriculum on Monument Geology, History and Ecology for Grades 5-6."

_____ I would like a copy of the curriculum for high school students entitled, "Managing Critical Resources at Craters of the Moon National Monument."

_____ I do not require additional copies of the curriculum at this time, but please add me to the mailing list.

_____ I no longer wish to receive your mailings. Please remove my name from your mailing list.

Comments or Suggestions

We are always interested in making Craters of the Moon's Environmental Education Program better. Your comments and suggestions help us to do this. Please list your comments or suggestions on the reverse side of this form.

Your Name: _____

Address: _____

City, State, Zip: _____

School Name: _____

Grades taught: _____ Address shown is: ❑ school ❑ home

Return to: Craters of the Moon National Monument
Environmental Education Mailing List
P.O. Box 29
Arco, Idaho 83213

Phone (208) 527-3257
FAX (208) 527-3073