Managing Critical Resources at Craters of the Moon National Monument

A Curriculum for High School Students

WINNER NPS AWARD OF EXCELLENCE

Prepared by:

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Lyn Benjamin and **Patti Moore**
for their work done researching and writing the curriculum.

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NATIONAL PARK SERVICE
Department of the Interior

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Planning a Field Trip to Craters of the Moon

Using this Curriculum

This curriculum is designed to familiarize high school students with the natural resources at Craters of the Moon National Monument and how the National Park Service manages them.

The curriculum is divided into 7 chapters which focus on areas of concern to park managers. Each chapter contains background information, study questions, and activities to be completed at the monument and in the classroom.

Individual chapters and activities can stand alone as learning units. Feel free to select the combination which best suits your needs. You may also consider splitting your class into small groups and assigning them a variety of activities from different chapters. The activity durations listed represent actual time on location, and do not include driving time within the monument.

Most of the activities in the curriculum will be most effective for groups of 30 students or less. In many cases, you will want to divide the group into smaller groups to accomplish the field work described. Please plan to bring one adult leader for every 6-8 students. The better prepared the adult assistants are, the more productive an educational experience your students will have. If the group you are bringing is considerably larger, contact us and we will work with you to design an effective experience for your students.

Certain activities require the presence of a Craters of the Moon staff member. This will be noted in the activity description. Reservations are required for activities involving a park ranger, and should be made well in advance of your visit. Certain activities require special supplies or equipment, such as plant identification materials or historic photographs, which are not included with the curriculum. These materials are available in a kit at the monument, and may be borrowed upon your arrival, or prior to your visit if demand is not too great. To make reservations or borrow the support kit, contact the National Park Service at (208)527-3257. We are anxious to offer any assistance you need in planning and implementing a successful field trip. Please feel free to call us.

Visiting the Craters of the Moon

When to Visit

The 7-mile Loop Drive through the monument is closed from approximately November 1st through April 15th. The weather at Craters of the Moon, which is located at 5900 feet, is unpredictable. Cold, windy, or snowy weather is possible even in late May. Cancelling a field trip at the last moment is awkward, but trips in poor conditions are not enjoyable or safe. There is no indoor area for groups to utilize.

Most schools visit between May 1st and Memorial Day. After Memorial Day, the monument staff is too busy to assist visiting groups. You may still plan a visit, but should incorporate only activities which do not require National Park Service participation. Groups may also consider visiting in the fall between Labor Day and mid-October.

What to Bring

The weather may be cool, windy and/or damp at any time of year. Make sure your students are adequately prepared for a full day in the out-of-doors. Students should bring a warm jacket, sturdy shoes or boots, rain gear if the weather is threatening, and a flashlight if you plan to visit the caves area. You cannot purchase food at the monument, so make sure everyone packs a lunch if you plan to eat here.

Fees

The monument charges an entrance fee from early June through mid-September. Groups visiting for educational purposes are exempt from this entrance fee. If you plan to visit during that time period, write to the Chief Ranger, Craters of the Moon National Monument, P.O. Box 29, Arco, ID 83213 on your school stationery describing the purpose and date of your visit. You will receive a fee waiver in return, which you can show at the entrance station the day of your visit.

Facilities

The Visitor Center is open from 8:00 a.m. to 4:30 p.m. from Labor Day through June 1st, and 8:00 a.m. to 6:00 p.m. during the summer. The Visitor Center offers a five minute video on volcanic geology, as well as displays on the geology, history, and ecology of the monument. There is also a store which sells books, postcards, posters, videos, slides, film, and other items. A complete list of sales items and prices is available upon request. There are restrooms at the Visitor Center, and at the Caves Area, Devil's Orchard, and Tree Molds parking lots. There is no drinking water beyond the Visitor Center. Picnic facilities are available in the campground and outside the Visitor Center.

Student Conduct

Please discuss the following regulations with your students before your arrival. All the natural features within Craters of the Moon are protected. Collecting rocks and other objects is prohibited. Because climbing on the fragile lava rock can cause irreversible damage, all visitors to the North Crater Flow, Spatters Cones, and Big Crater must stay on the paved walkways. Dispose of all litter properly.

Safety

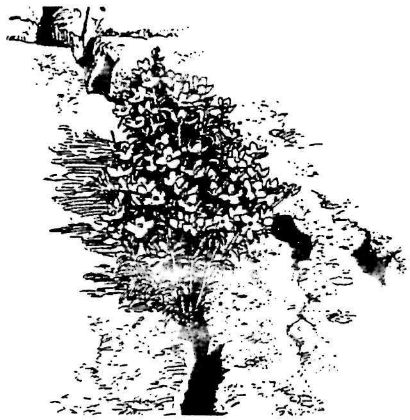
By far the most common cause of injury at Craters of the Moon is falling on the sharp, abrasive lava rock. Instruct your students to exercise caution and avoid any running, pushing, horseplay or other activities which could cause falls and lead to serious injury. Particular care is required in the caves, due to the lack of light, low ceilings, uneven floors, occasional ice, and small crawlways. First aid is available at the Visitor Center should anyone in your group get hurt.

Activities Chart

The following chart lists the activities you will find in this guide. The chart shows a description of the activity, whether a support kit is necessary, if ranger assistance or on-site visitation is required, and what materials you will need to provide.

Activity	Description	Support Kit Needed?	Ranger Assists?	Time On Site	Materials Needed
2A What's Happening to the Spatter Cones?	Students compare the contemporary scene with historic photos to determine what impact people have had on the Spatter Cones.	Yes	No	1 hour	Pencils, paper, camera, support kit with historic photos
2B Document Human Impact	Students compile a report documenting human impact on the volcanic features of the monument.	No	No	2 hours	Pencils, paper, camera, monument maps, activity 2B work sheet
2C What's the Plan?	Students develop a plan to correct the most serious problem of human impact at the monument.	No	No	None	Pencils, paper, flip charts, markers, word processor (optional), activity 2C work sheet
2D Now Hear This!	Students develop a handout encouraging monument visitors to help preserve fragile resources.	No	No	None	Copies of brochures, pencils, paper, word processor (optional)
3A Complete a Cave Resource Report	Students explore a lava tube and document features on a Cave Resource Report.	No	No	2 hours	Pencils, Cave Resource Report forms, clipboards, flashlights, long pants, hats, camera
3B Debate on Denying Cave Access	Students break into two groups and conduct a formal debate on whether access to certain caves should be denied.	No	No	None	2 flip charts, markers
4A Visit Air Quality Monitoring Sites	Students visit air quality monitoring sites to find out how data is collected and what it reveals.	No	Yes	2 hours	Pencils, activity 4A work sheets 1 and 2
4B How Clean is Your Home?	Students compare the results of pH tests of the soil, surface water, and precipitation at the monument and their home town.	No	No	2 hours (optional)	Soil and water samples from both locations, pH testing kit, beakers, distilled water, pencils, activity 4B work sheet
5A Assessing Stream Health	Students assess physical and chemical stream quality on a stream at the monument and one near home.	Yes	Yes	3 hours	Support kit with Hach Kits and thermometers, activity 5A work sheets, pencils
6A Habitat Inventory	Students compare environmental conditions and plant communities in six different habitats.	Yes	Yes	3 hours	Support kit with geologic map, compass, psychrometer, distilled water, balance, soil thermometer, field guides and plant lists. School brings pencils, activity 6A work sheets, measuring tape, surveyors tape, stakes, and cameras.
6B Reading on Kipuka Research	Students answer questions following a reading about research on the distribution of plant and animal species on the monument's kipukas.	No	No	None	Reading material, pencils, paper
6C Mule Deer Census	Students assist in the annual spring mule deer census and interpret the data they gather.	No	No	3 hours	Activity 6C work sheets 1 and 2, pencils, binoculars and a spotting scope, hiking gear
6D Exotic Plant Monitoring and Removal	Students monitor the presence of exotic plants in a disturbed area of the monument and assist in removing them.	Yes	Yes	2 hours	Activity 6D work sheets, pencils, work gloves, stakes, surveyors tape, field guides in support kit
6E Wildlife Management Questionnaire	Students conduct research and interviews to determine how wildlife management differs among federal land management agencies.	No	No	None	Telephone, telephone books, pencils, paper, library vertical files

Chapter 1



What is Resource Management?

Preserving The Priceless And Irreplaceable

The National Park System of the United States preserves our shared heritage as a nation: superlative natural features, remains of prehistoric cultures, and sites that commemorate the pivotal events and influential people that shaped our destiny. Craters of the Moon National Monument is one of the more than 350 areas under the custodianship of the National Park Service. The National Park Service has two overriding goals - to preserve in pristine condition the natural and cultural resources entrusted to its care, and to enable visitors to enjoy those resources in safety and comfort.

The National Park System benefits the American people in many ways. The parks teach us about the birth and development of our country. They are ideal locations for scientific study of natural objects, organisms, and processes. They help us to comprehend the natural forces shaping our world and the living things that share it. As relatively pristine relicts of the North American wilderness, they provide a baseline of comparison for the changes we have wrought on our environment. They secure islands of habitat critical to the survival of many plant and animal species, such as the Florida panther and the grizzly bear. And finally, they allow us to retreat from civilization and sense the grandeur of wild spaces. They provide spectacular settings to gather with family and friends for recreation and renewal.

What's Special At Craters?

President Calvin Coolidge established Craters of the Moon National Monument in 1924, to preserve a "remarkable fissure eruption together with its associated volcanic cones, craters, rifts, lava flows, caves, and natural bridges" for its unusual scientific and educational value. The significance of the monument lies in the relatively young age of the lava flows and the diversity of volcanic features in a small geographic area.

The volcanic features do not stand alone, but are part of a delicately intertwined ecosystem. Volcanic eruptions from 15,000 to 2,000 years ago laid a rugged foundation for life. Windblown soil collected on the lava flows, enabling plants to grow. The plants provide food for various animals which are, in turn, food sources for others. Clean air and water are critical to these living things. Indians, pioneers, and explorers in the past and today's tourists have also left their mark on the landscape.

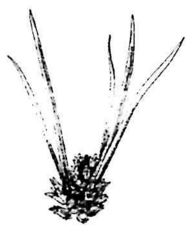
The resources of Craters of the Moon National Monument, then, are many. They include volcanic features, soil, fauna, flora, air, water, and archeological and historical remains. The National Park Service strives to maintain the health and balance of all of the strands of this intricate web.

Volcanic features

The monument contains part of the Great Rift, a volcanic rift zone that extends south from the Pioneer Mountains for 60 miles. Eruptions occurred intermittently along the Great Rift from 15,000 until 2,100 years ago, and are likely to begin again within the next 1,000 years. These eruptions produced vast flows of pahoehoe and a'a lava and a variety of other volcanic features: cinder cones, rafted blocks, spatter cones, lava tubes, bombs, collapse depressions, squeeze-ups, pressure ridges, and tree molds.

Soil

There is very little soil on the recent lava flows of the monument. Soil forms primarily from the accumulation of wind-blown particles in cracks in the lava. Given sufficient time, these cracks fill in completely, allowing soil to build up on the surface. Older flows and cones are covered with soil supporting a climax community of shrubs and grasses.



Flora

Although much of the monument surface consists of barren lava flows, plant communities are surprisingly diverse. The varied lava types, microhabitats within lava flows, changes in elevation and topography, and riparian areas all contribute to habitat diversity. The monument's flora reflects the geologic setting. Plant succession is well illustrated on lava deposits of different ages. In all, there are more than 300 species of vascular plants, including Phacelia inconspicua, an endangered species in Idaho. More than 25 species of exotic plants have been identified in the monument and are of special concern to managers.

Fauna

The animal life at Craters of the Moon also shows remarkable diversity. A total of 148 bird, 8 reptile, 2 amphibian, and 51 mammal species have been recorded. Five of the mammal species - grizzly bear, gray wolf, bison, porcupine, and bighorn sheep - have disappeared from the monument. The most common animals are the horned lizard, mourning dove, sage grouse, magpie, raven, Clark's nutcracker, common nighthawk, mountain bluebird, great horned owl, golden eagle, yellow pine chipmunk, golden mantled ground squirrel, pocket gopher, packrat, badger, coyote, mule deer, pronghorn antelope and several rabbit and bat species. There are subspecies of pika, Great Basin pocket mouse, and yellow pine chipmunk which live only in the vicinity of the Great Rift. Four species at Craters of the Moon are federal category 2 candidate species. This means that they may be endangered or threatened, but the US Fish and Wildlife Service has insufficient data to list them. They are the ferruginous hawk, Townsend's big-eared bat, lynx, and blind leiodid cave beetle.

Air

The National Park Service monitors the air at Craters of the Moon for various pollutants: acid deposition, particulates, airborne radioactivity, and ozone. It is important to establish current conditions so that changes in air quality can be documented and counteracted. Air quality is critical to visitor health and enjoyment of scenic vistas. Clean air is also necessary to maintain healthy living things and pure water, and to preserve historic and prehistoric objects.

Craters of the Moon has some of the clearest air in the continental United States. The Environmental Protection Agency uses this location as a baseline reference for visibility - how far the eye can see. Visibility is 174 miles or more about 10% of the time. Even so, there is evidence that air quality at the monument is beginning to deteriorate. Preserving the pristine quality of the air in the face of increasing external threats is a primary focus at Craters of the Moon.

Water

Surface water is extremely scarce at Craters of the Moon. Little Cottonwood Creek flows out of the Pioneer Mountains in the north end of the monument. Four springs and two wells in the Little Cottonwood drainage provide drinking water for the monument. In addition, there are scattered water holes in the lava flows. The insulating properties of the rock and downward movement of cold air through the lava tubes keep temperatures low and maintain ice in some caves year round.

Archeological and Historical Sites

In the 1960s and again in 1992 and 1993, archeologists from Idaho State University examined the monument for evidence of prehistoric occupation. They found that archeological sites are most likely in areas where water, caves, or a big sagebrush plant community occur. More than two thirds of the sites are near a water hole. Some of the sites contain projectile points, pottery shards, scattered stone flakes and/or stone tools.

Altogether, archeologists have identified 39 archeological sites at Craters of the Moon. Starting with a cluster of large sites at the base of the Pioneer Mountains, the sites become smaller, fewer, and more thinly scattered as one proceeds south onto the lava along the Great Rift. Except for sites near Little Cottonwood Creek and at the base of the Pioneer Mountains, the sites represent short periods of occupation. The distribution of the sites supports the theory that native hunters and gatherers came into the central and southeastern sections of the monument from the northwest, then moved south along the Great Rift, where travel was relatively easy.

A section of the Oregon Trail called Goodale's Cutoff passes through the north end of the monument. Guide Tim Goodale led the largest wagon train ever to travel any section of the Oregon Trail through the area in 1864. It consisted of 338 wagons, 1095 people, and 2900 head of stock. In the years following Goodale's successful trip, seven out of every 10 wagons heading west from Fort Hall chose the route bearing his name.

How Do We Manage?

The National Park Service brings together many specialists to protect these diverse resources. Together they identify problems, collect information, and take action. Ultimately, the goal of this process of resource management is to minimize human impacts. This is achieved through a 5 step process.

Research

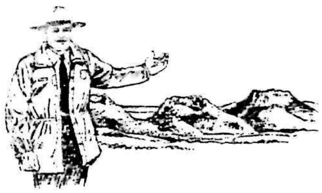
Scientists inventory the resources, determine ecological relationships, document impacts, and provide information on how undesirable change may be prevented.

Public Involvement

Because this is public land, the National Park Service seeks citizen input before taking any significant actions.

Implementation

Managers use the facts researchers provide to evaluate options and to select a path of action. Then, they monitor the results.



Education

To gain understanding and support, rangers explain resource problems and possible solutions to the public. They stress how the cumulative actions of park visitors and neighbors may have long-term consequences.

Protection

Park rangers enforce regulations which protect natural features. They seek to keep the natural environment in pristine condition while still allowing visitors to enjoy it.

The challenge of resource management is to maintain the health and viability of monument resources, while facilitating visitor use and enjoyment of the area. Only with public understanding and cooperation can the National Park Service preserve the irreplaceable resources at Craters of the Moon.

Chapter 2

Degradation of Geologic Resources

Geologic History

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 a'a flows, cinder cones, lava tubes, 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?

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 in the west to Yellowstone National Park in the east. The age of the Snake River Plain can be traced from the most recent eruptions 2,000 years ago to the oldest activity roughly 17 million years ago. Geologists consider the eastern and western sections of the Snake River Plain to have different geologic histories. This discussion will focus on the eastern Snake River Plain.

Volcanic eruptions vary according to how much silica (SiO_2) the magma contains. Magma rich in silica is viscous and erupts explosively, producing a rock called rhyolite. Rhyolitic eruptions may create massive craters called calderas, which form when an eruption empties a magma chamber beneath the Earth's crust, causing the surface to collapse. The Island Park Caldera just east of Yellowstone is an example of a rhyolitic caldera. Magma with lower levels of silica generates gentler eruptions of more fluid basaltic lava, such as that seen at Craters of the Moon. There is, therefore, evidence of both types of eruptions on the eastern Snake River Plain.

Vestiges of numerous rhyolitic lava flows and calderas are apparent along the margins of the eastern Snake River Plain. They are all that is visible of a thick layer of rhyolite that is overlain by more recent basalt flows. In a typical section of the Snake River Plain, 2 kilometers of basaltic rock and sediments lie on top of a layer 8 kilometers thick, believed to consist of rhyolitic rocks.

The rhyolitic volcanic deposits on the Snake River Plain vary in age. Eruptions occurred about 10 million years ago at Twin Falls, five million years ago at Arco, and finally, 600,000 years ago in Yellowstone National Park. Any theory about the origin of this area must explain the progressively younger ages of the rhyolitic deposits from southwest to northeast, as well as the fact that later basaltic eruptions buried the rhyolite. Most geologists consider the Mantle Plume Theory as the best explanation for the formation of the eastern Snake River Plain.

Mantle Plume Theory

According to this theory, uneven heating within the core and lower mantle of the Earth causes some material to become hotter than that surrounding it. The hotter material becomes less dense and rises through the cooler rock of the Earth's interior. These plumes, or "hot spots", produce many successive batches of rising magma. The rising magma may eventually reach the Earth's crust and erupt 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 volcanic features which grow older the farther they are from the hot spot. The volcanic events associated with a mantle plume occur in two distinct stages.

Stage I:

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

Since gases within the thick rhyolitic magma cannot easily escape, the eruptions tend to be devastating, sometimes spewing hundreds of cubic miles of material into the atmosphere. By contrast, Mount St. Helens ejected less than 1/2 cubic mile of rock. As the magma chamber empties, there is nothing to support the crust above it. It collapses, forming a caldera that may be 100 square miles in area!

Stage II:

The intense volcanic activity associated with the mantle plume ebbs as the plate continues its movement, only to begin again at a new spot farther up the chain. Eventually, gentler basaltic eruptions replace the explosive rhyolitic activity. These basaltic eruptions arise from the original deep crustal basaltic magma chamber that formed at the base of the Earth's crust during Stage I. Magma continues to rise and enlarge the chamber and pressure within it gradually increases. The pressure forces the magma toward the surface through fractures in the Earth's crust. The magma remains basaltic because there is little silica left in the crust to melt into it.

Upon eruption, basaltic lava is very fluid. Lava flows from these relatively calm eruptions spread out on the surface to cover older rhyolite. With each new eruption, less rhyolite is left exposed and, after millions of years, basalt covers nearly all of the rhyolite, like frosting on a cake.

The Great Rift

A hot spot provided the magma for the eruptions at Craters of the Moon. The Great Rift provided the pathway for the magma to reach the surface. The Great Rift is the most extensive of several volcanic rift zones which traverse the Snake River Plain. Volcanic rift zones are weak areas where the Earth's crust has stretched and thinned and fissures have developed. Magma under pressure follows these fissures to the surface.

The Great Rift, which passes through Craters of the Moon, 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 for 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 crust suddenly fractures. Large blocks of earth slip or rotate up and down, creating valleys separated by long mountain ranges. There are 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.

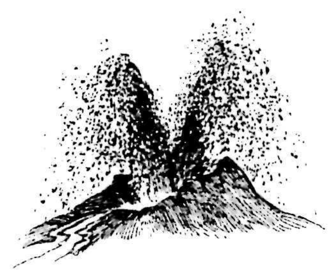
There are basin-and-range mountain ranges to the north and south of the Snake River Plain. The block faults that occur at the edge of each are known as "border" or "range-front" faults. These faults may extend a short distance beyond the base of the mountains and out beneath the lavas. They are marked by zones of parallel cracks in the basalt lava flows that may run for tens of miles.

The Great Rift 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 Range is slightly more than the 16 miles normally found between basin-and-range structures. Furthermore, gravity and seismic information indicate 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 basin-and-range fault system.

Geologists have suggested that the release of strain which occurs during basin-and-range faulting may result in magma production along connected volcanic rift zones as the decompression causes melting. If so, then periods of major faulting near the margins of the eastern Snake River Plain may correlate with periods of volcanism on collinear rift zones. The volcanic rift zones associated with basin-and-range faults would be long-lived and self-perpetuating. Techniques for dating faults and volcanic deposits are not yet accurate enough to fully investigate this idea.

Eruptions at Craters of the Moon

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



During a typical eruption at Craters of the Moon, rising magma forces a section of the Great Rift to pull apart. As magma rises, 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 bubbly cinders and ash.

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 they build up in piles around individual vents and form cinder cones such as North Crater, Big Craters, and Inferno Cone.

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. Hot, thin lava containing relatively little silica forms smooth-surfaced pahoehoe flows. Cooler lava, or lava containing slightly more silica, forms coarse, uneven a'a flows.

If what geologists tell us proves to be true, 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 discovered an eruptive pattern that indicates the area is merely in a stage of temporary dormancy. They believe that past eruptions conform to a predictable time schedule and that the eruptive cycle will begin again sometime within the next 1,000 years.

Protecting Geologic Features From Harm

The landscape at Craters of the Moon National Monument is deceptively fragile. A first glance convinces you that it would be virtually impossible to do damage to all that sharp, angular lava. The truth, of course, is just the opposite. The lava breaks down quickly under feet, bikes and vehicles. Because the interior of many lava flows is red in color, human-caused erosion of the darker lava surface is immediately obvious. Look, for example, at the trail to the top of Inferno Cone or the pahoehoe surface along the North Crater Flow trail. This damage is irreversible.

Of course, natural forces are constantly at work breaking down the rock. The contraction and expansion of water in cracks as it freezes and thaws pushes the rock apart. So do the roots of trees and shrubs gradually working their way into crevices. The lava rock will break down eventually on its own. The point is whether the National Park Service should permit humans to accelerate the process.

Not only the rocks themselves, but also the plants growing on them, are subject to destruction. There is little soil and limited plant growth on the lava flows. Nothing grows on the surface of the rock except lichens. Lichens hundreds of years old may be only inches wide. If destroyed, it may take decades for them to reestablish themselves. Trampling may also kill wildflowers and other plants.

The National Park Service strives to keep as much of Craters of the Moon open to the public as possible. However, sometimes the level of human impact is too great, and protective action becomes necessary. What is an acceptable level of human impact? There is no clear answer to the question. Preservation of irreplaceable resources has to balance visitor use. At present, there are two areas in the monument which are closed to off-trail travel due to the exceptionally fragile nature of the rocks and heavy human use: the Spatter Cones and the North Crater Flow. How would you handle this complex problem?

Degradation of Geologic Resources

1. Briefly describe the Mantle Plume Theory which explains the volcanic activity at Craters of the Moon. What physical evidence supports this theory?
2. What is the Great Rift?
3. What is Basin and Range faulting?
4. How old are the lava flows at Craters of the Moon?
5. List three features typical of basalt eruptions and describe how they form.
6. Is the lava landscape at Craters of the Moon as indestructible as it appears to be? What kind of activities may damage it?
7. Why does damage to the geologic features at Craters of the Moon not disappear with time?
8. How do you feel about not being allowed to go off of the trail at the Spatter Cones and on the North Crater Flow?
9. Should Craters of the Moon visitors have access to all areas of the monument?
10. What constitutes an acceptable level of human impact?
11. What can visitors do to help the National Park Service preserve the geologic features at Craters of the Moon National Monument?

What's Happening to the Spatter Cones?

By comparing the contemporary scene with a series of historic photographs, students recognize the impact people have had on these fragile features, and what corrective measures the NPS has taken.

Objectives:
Students will be able to describe human impact on the Spatter Cones and what measures the NPS has taken to alleviate the problem. They will formulate and express opinions about what level of human impact is acceptable at the Spatter Cones and in natural areas in general.

Duration:
1 hour at the Spatter Cones, 1 hour in the classroom

Materials:
Historic photographs of Spatter Cones (available in support kit at the monument), pencil and paper, camera (optional), activity 2A work sheet

Background Information:

The Spatter Cone chain represents the very essence of Craters of the Moon — volcanism. These "mini-volcanoes" formed when blobs of molten lava were thrown a few feet into the air during the last gasp of an eruption. The hot clots of lava fell on top of one another and became welded together to form small cones around a central vent.

Ironically, as rugged as the Spatter Cones look, they are very fragile. Although erosion is a natural process, the accelerated destruction of these cones began when the very first visitor climbed to the top to take a look inside. It wasn't long before the effect of thousands of footprints became evident. Faced with this problem, managers at Craters of the Moon undertook a number of steps.

When rangers compared photographs taken in the 1920s to present conditions, the problem was easy to recognize. On some of the cones, more than two feet of rock had worn from the rim. On others, entire sections of the crater wall had collapsed. Visitors had worn numerous trails into the flanks of every cone.

The staff contacted other parks with volcanic landscapes to see if they had similar problems. Most managers reported that they also had experienced difficulty preventing people from hiking across the steep slopes of cones. As deep ruts began to appear on the cones, most of these managers solved their problem by closing sensitive areas to visitor travel and allowing certain volcanic formations to be viewed only from a distance.

The first priority at the Spatter Cones was to repair past damage. The Park Service removed old cement stairways, asphalt trails, and pipe railings. They covered the scars with rock collected at the base of the cones.

The second priority was to prevent further damage. Several options were considered:

- Do nothing and accept the deterioration.

- Close the area to all visitor use.
- Construct a viewing platform.
- Allow limited access.

Managers decided to allow limited access. Visitors are now encouraged to look inside several cones adjoining the parking area, but stringent controls prohibit access to the other cones.

The maintenance crew removed unneeded trails and improved access to areas where use is encouraged. They stabilized the new trail with buried timbers and added railings and retaining walls to make it safe and prevent it from widening.

With little experience to guide this effort, the Park Service made mistakes. The safety railings around the Snow Cone had to be rebuilt three times. The first railing, constructed of metal pipe and wire mesh fencing, looked like a plumber's nightmare. The second railing, made of wooden poles, resembled a corral for very small horses. Finally the crew completed an enclosure of lava rock pilings with cable strung between them. This was the only barrier that was not a visual intrusion.

These efforts were coupled with a new regulation restricting off-trail travel in the area, and with educating visitors about the fragile nature of the cones.

Since completion of this project, the deterioration of the Spatter Cones has greatly slowed. Visitors have shown their support with positive comments and a willingness to stay on established trails.

Procedure:

1. A packet of historic photos is available in the support kit at the Visitor Center. Break into small groups, each of which receives one of the historic photos. From the Spatter Cones parking lot find a vantage point which most nearly matches the one from which your photograph was taken. You must remain on the trails. Even scientists must obey regulations when studying the monument, because their footprints are the same as everyone else's. Either sketch or photograph what you see.

2. After returning to school, prepare a report incorporating the photos or drawings. The report should answer the questions on the following page.

Observations of the Spatter Cones at Craters of the Moon

1. How many years have passed since the original photographs were taken?

2. What changes can you observe?

3. Could some of the degradation have been prevented? How?

4. How do you feel about the changes which have taken place?

5. If you were Superintendent of Craters of the Moon, how would you protect fragile or damaged features?

Document Human Impact at Craters of the Moon

Students observe and catalog human impact on the volcanic features of the monument and compile a report documenting what they have seen.

Objectives:
Students will be able to recognize areas where human activity has harmed monument resources and be able to articulate in writing their ideas about acceptable levels of impact in the monument.

Duration:
2 hours at Craters of the Moon and 1 hour at school.

Materials:
Pencil, paper, camera (optional), maps of the monument, activity 2B work sheet

Background Information:

Signs of people at Craters of the Moon are abundant. Inferno Cone provides one of the most striking examples of visitor impact on geologic features. The boots of one hiker after another have gradually compacted the cinders and turned a narrow trail into a broad one that mars the cone from bottom to top. The Park Service has tried different techniques to monitor and rehabilitate the area. Maintenance crews have raked the scarred cinders. Managers have driven stakes into the ground to measure the rate of change in the ground level through time, but either visitors removed the stakes or they disappeared into the cinders. At one time, the staff even brought in a rototiller to churn up the compacted ground. All of these efforts at repairing the damaged cone and slowing the rate of further deterioration have failed.

Other areas are also showing wear and tear. The North Crater Flow Trail and Caves Trail each lead large numbers of visitors across the lava flows. Unfortunately, not all of these people stay on the trails, and the areas where they have ventured onto the lava are often highly visible. Foot traffic can break the outer crust of the lava, revealing the rust-colored rock beneath the gray surface. In several spots in the monument it is apparent that vehicles have driven across cinder fields. The wheel ruts are marked by differences in color from the surrounding cinders and sometimes by different plant growth. Wandering visitors have also worn trails into the cinders in some places, especially the campground and Big Craters areas. However, not all of the trails winding across the cinder fields are the result of people. Many mark the paths of mule deer moving through the monument on their annual migrations.

Another obvious human impact students may watch for is litter.

The process of monitoring for impacts is ongoing, and is essential to the prompt identification of problem areas or progressive degradation. The information which your students gather is invaluable because they may notice things the monument staff has not. If your students have produced good quality work, please submit it to the monument for our review.

Procedure:

1. Watch for evidence of human impact on the lava flows and other geologic features as you travel through Craters of the Moon National Monument. These would include erosion on cinder cones, broken surfaces (especially red in color) on the lava flows, bike or car tracks in the cinders, "social" trails in areas where maintained trails do not exist, places where plants have been trampled, and litter. Some areas where you are likely to see such impacts include the campground, Inferno Cone, Big Craters, the Spatter Cones, the North Crater Flow Trail, and the Caves Trail. You will also be able to spot damage as you drive around the road.

2. Record your observations either verbally, in drawings, or through photographs. Number the drawings, descriptions, or photos and mark these numbers on a map of the monument for later reference.

3. After returning to school, compile a report detailing your observations. This will be especially effective if you have taken photographs. Include references to your marked map. As part of your report, answer the questions on the following page.

Report on Human Impacts Observed At Craters of the Moon

1. In how many locations did you observe damage?

2. What did it look like and what caused it?

3. Is the damage reparable?

4. Did you see evidence of impact even where human use has been restricted (the Spatter Cones area or North Crater Flow)?

5. How do you think that degradation to the geologic features at Craters of the Moon can be prevented or lessened?

6. Do you think the National Park Service should close certain areas in order to protect especially fragile features like the Spatter Cones or certain caves, even though the monument also exists for the enjoyment of the people?

What's the Plan?

In small work groups, students identify the most serious human impact on volcanic features at Craters of the Moon and develop a plan to correct the problem.

Objectives:
Students will be able to cooperate and share ideas when faced with solving a complex resource management problem. They will be able to articulate specific steps to solve one of the real problems facing managers at the monument.

Duration:
1 class period for work group preparation and 1 for presentations to classmates

Materials:
pens, paper, a word processor (optional), a quiet room, flip charts, markers

Procedure:

1. Break into small work groups. Select one person to record the ideas the group formulates.

2. Discuss and list what each group member thinks is the most significant example of degradation at Craters of the Moon. As a group, select the problem which you feel is the most pressing.

3. Discuss the various approaches which might be used to solve this problem. Select one of these approaches and develop a plan for implementing this solution. Be specific in describing the steps involved. Decide how you will present your results to the rest of the class, and then each group in turn will make its presentation.

Now Hear This!

Students develop a handout for Craters of the Moon visitors compelling them to play an active role in preserving fragile monument resources.

Objectives:
Students will be able to articulate what activities pose a threat to volcanic features at Craters of the Moon and steps visitors can take to aid in the preservation of those resources.

Duration:
1-2 hours in class

Materials:
Copies of existing information handouts and brochures distributed at Craters of the Moon (call to request these), paper, pens, word processor (optional)

Background:
One of the techniques park managers employ to protect natural features is to educate the public about their significance and fragility. If people understand and appreciate an area, whether it is a national monument or their own home, they will want to ensure its preservation.

Procedure:
Design a handout to be distributed to visitors at Craters of the Moon. You can focus on a particular area or feature (such as the caves or the Spatter Cones) or your information can be general and apply to the entire monument. Attempt to convince your readers that what they are seeing is special and that it is important that they protect it from harm. Describe activities that are potentially harmful and ways they can be avoided. Use photographs and/or illustrations. If you do really outstanding work, the National Park Service may display your handout at the monument!

Chapter 3

Cave Management

The Indian Tunnel System

About 2,100 years ago magma poured from a fissure where the Spatter Cones now stand. Sheets of red-hot lava raced down slope, in some places forming swift channels. The rivers of liquid rock sometimes crusted over, and the movement of lava continued below a hardened surface. These tubes transported enormous quantities of lava from the eruption source to the edge of the flow.

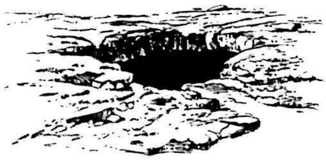
The volume of liquid rock was so great that the tubes could not contain it all. Lava burst through the roof of the tube system and formed huge ponds on the surface. Eventually, the flow of lava inside the tubes subsided and lava beneath the hardened surface of the ponds drained back into the tubes. With no lava to support the crust, the ponds collapsed, forming a series of bowl-shaped depressions called sinks.

From the sinks area, the flow advanced to the southwest. Lava tubes more than 30 feet high formed in the thicker sections of the flow, while many smaller tubes branched off to distribute lava to an ever-widening flow front. When the eruption waned, the lava drained from the tubes, adding a new layer to the lava fields beyond. Eventually the flow, called the "Blue Dra-Flow," covered an area of 100 square miles.

The lava tubes which make up the Indian Tunnel system all formed during the eruption of the Blue Dragon Flow. They represent a network of interconnected passageways which helped distribute the lava from its source up to 18 miles away.

Tube Formation

The formation of tubes is a complex process dependent on the chemical and physical properties of the lava, eruption rate, and topography. In the simplest method of tube formation, the surface of the pahoehoe, exposed to the cool air, hardens. Lava continues to flow beneath this crust. As the lava sup-



ply diminishes, the conduit drains, leaving a hollow lava tube.

Often, though, rather than flowing as a broad sheet, lava becomes restricted in channels. Lava channels usually form in the fastest moving part of a flow along older lava channels and tubes, stream beds, rifts, or other depressions.

Once a channel stabilizes, a roof may form in a variety of ways. A scum may develop and fuse to the channel sides. This crust thickens through overflows on the surface and accretion of cooled lava on its underside. A crust may develop on channel edges and merge like a zipper in the center of the channel. In some channels, crustal plates form, tear loose, and drift along the surface of the flow. Eventually they fuse to one another and the channel sides, forming a roof. In turbulent lava flows splashing, spattering, and overflow along the channel form lava levees. These may continue to build until they arch over the channel and join.

Destiny of Caves

The roof of a lava tube shrinks as it cools, causing numerous cracks that weaken the roof and may cause it to collapse. A roof that collapses while still hot and in a semi-plastic state will sag, creating a bowl-like depression. A roof that has completely hardened will fracture and tumble into a pile of broken rubble on the tube floor. If a tube roof survives the cooling process, it is very stable and may stand for many thousands of years.

Lava Tube Features

Curbs

Ridges on the walls indicate places where the draining river of lava temporarily held at a constant level. Lava deposits built up on the walls like a bathtub ring.

Stalactites

Lava stalactites are not created by water, but in the birth of a lava tube. The receding lava river may leave molten rock on the ceiling, or the heat within the tube may cause it to remelt. The molten rock drips and hardens, forming numerous small lava stalactites.

Mineral deposits

There are mineral deposits on the ceilings of many lava tubes, primarily sulfate compounds. Geologists are not in total agreement about the source of these minerals. They were deposited by either volcanic gases during the eruptions, percolating surface water since the eruptions ceased, or a combination of these two processes.

Ice and water

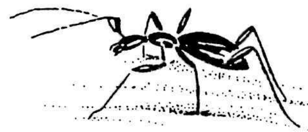
During the spring months, runoff from melting snow seeps through the porous cave roofs. At night, the temperature drops and dripping water freezes into ice stalactites and stalagmites. In most cases, the summer heat destroys these ice formations, but in a few caves, ice remains all year. Caves with an impermeable rock or ice floor collect water from seepage and condensation, creating permanent water holes.

Plants

Most plants cannot survive without sunlight. With its many ceiling collapses, Indian Tunnel provides suitable habitat for lichens and mosses on the cave walls. In older tubes, soil builds up on the cave floor beneath openings and other plants may grow.

Wildlife

Due to the lack of water, food, and light in most caves, animal life is scarce. However, there are some creatures which take advantage of the shelter the caves provide. The lava tubes are home to the blind leiodid cave beetle, an insect whose range is restricted to lava tubes in southern Idaho. While several bat species live in the monument, it is unusual to see them in the caves along this trail. You may see other winged creatures, though. Violet-green swallows, mountain bluebirds, great-horned owls, and rock doves all use the rocky ledges around cave entrances as nesting sites. Bushy-tailed woodrats commonly build their nests in lava tubes. A variety of other birds, squirrels, chipmunks, foxes, snakes, and other creatures occasionally enter the caves.



Archeological artifacts

Several archeological sites are located near caves. Indian Tunnel derives its name from the rock circles and scattered artifacts found near one of the entrances.

Preserving the Caves for the Future

The lava tubes are subject to freeze-thaw action, wind and water erosion, and invasion by plant roots, but the greatest threat to the caves comes from people. The caves area is the most heavily visited part of the monument. Because the resources they contain are irreplaceable, it is critical that the caves receive adequate protection. The National Park Service has a Cave Management Program which guides decisions about the type of use to be permitted in each cave in the monument. The program is designed to maximize both access to caves and protection of their resources.

The first step in the cave management process is collecting information. In the summer of 1993, a student intern spent 3 months visiting nearly 80 different lava tubes. He inventoried the contents of each cave, noting any significant plants, animals, ice, water, archeological and historic artifacts, rock formations, mineral deposits, or safety hazards. He sketched maps of the caves, photographed their entrances, and used a Global Positioning System (GPS) device to obtain the exact coordinates and elevation of the cave. A GPS device receives and differentiates multiple satellite signals to accurately determine ground location to within 10 meters.

Based on this information, the National Park Service has limited access to a few of the lava tubes at Craters of the Moon. The reasons for the closures vary. Arco Tunnel can be entered only after receiving a permit. An unprepared caver could easily become lost in the complex network of passages in this cave. Groups interested in visiting Arco Tunnel can get the key at the Visitor Center after filling out a permit and receiving a cave map. This enables the National Park Service to see that those venturing into Arco Tunnel have adequate equipment and knowledge to complete the trip safely.

Crystal Pit, like Arco Tunnel, has a locked gate. It is permanently closed not only to park visitors; access of park staff and researchers is also severely limited. There is no way to enter this cave except by rapelling into it and landing on the floor, which is covered with delicate crystal formations. It is thus impossible to enter the cave without causing permanent damage.

There are several caves in the monument which are closed to protect groups of Townsend's big-eared bats. This bat is a Category 2 species under the Endangered Species Act, meaning that listing as endangered or threatened may be appropriate but there is insufficient data to support such action. Townsend's big-eared bats are very sensitive to any disturbance.

The rest of the lava tubes in the monument are open to the public. Those along the Caves Trail area can be easily visited. Indian Tunnel, the largest lava tube, is accessible without a flashlight and receives thousands of visitors each year. The other caves in the area are dark and cooler, require some scrambling, and are more challenging to visit. Most of the lava tubes away from the Caves Trail are in rugged terrain requiring long hikes across the lava, and receive very few visitors.

The National Park Service will provide information upon request about all of the caves except those that are closed to the public. Only a handful of caves are closed to protect visitors, delicate mineral deposits, or sensitive wildlife.

Cave Management

1. How do lava tubes form?

2. How many lava tubes are there at Craters of the Moon?

3. Describe 3 types of resources found in lava tubes and give an example of each.

4. Why should the caves be protected?

5. How is protection of the caves accomplished at the monument?

6. Do you believe the National Park Service is justified in closing certain caves to the public? Why or why not?

Complete a Cave Resource Report

Students will thoroughly explore a lava tube, and document critical features on a Cave Resource Report.

Objectives:
Students will be able to list 6 different types of resources found in lava tubes and give an example of each. They will be able to describe the method the National Park Service uses to determine whether a cave should be open or closed to public use.

Duration:
2-3 hours, depending on the cave(s) chosen

Materials:
Pencil, copy of the Cave Resource Report for each student, clipboards or some other portable hard surface to write on, flashlight or headlamp, long pants, hat, and a camera (optional)

Background Information:
The Cave Resource Report is a tool for monitoring change over time. By periodically collecting this information and comparing the results with earlier reports, the National Park Service can document and respond to damage to cave resources through closures or some other action. Therefore, the reports your students collect are of use to the monument staff, regardless of whether a Cave Resource Report has already been done for a given cave. Upon completion of this activity, please submit your completed cave resource reports to the National Park Service for review.

Procedure:

1. Split into small groups of 5-8 people to facilitate cave travel and select one or more caves to explore. There are four caves along the Caves Trail in close proximity to each other and well suited to this exercise: Boyscout, Surprise, and Beauty Caves and Indian Tunnel.

2. As you tour the cave, use your flashlight to examine the cave for unique features. These might include signs of animals, plants, water, ice, historic or prehistoric artifacts, mineral deposits, rock formations, etc. Look carefully - you may see something no one has noticed before.

3. Make notes on the Cave Resource Report. Include a rough map of the cave and a description of the cave entrance. You may also carry a camera and take a photograph of the cave entrance as well as anything significant you discover in the cave. Attach your photographs to the final report.

4. Submit your completed reports to the National Park Service. Your observations, if done well, may be helpful to the monument.

SAFETY INFORMATION

The only lava tube suitable for large groups (more than 15 people) is Indian Tunnel. If your group is going to enter the other caves, you should break up into smaller groups and have a responsible and experienced adult in charge of each.

It is critical that each student be properly equipped, especially in caves other than Indian Tunnel. Each must have a good quality flashlight or headlamp, long pants, and a hat. For extensive exploration, knee pads and a helmet are recommended. Bike helmets are perfect for this purpose.

If you are considering a spring field trip, check with the monument on snow and ice conditions in the caves. It is not possible to enter the caves after heavy winters until mid- to late May.

Cave Resource Report

Inventory Team Members

Cave Name

Descriptive Location (including entrance orientation, cairn size/location, landmarks, and how located)

Detailed Description of Major Features (including hydrologic, archeologic, historic, geologic, faunal, floral, or other resources)

Hazards (both within cave and/or in reaching cave and any additional equipment needed)

Map Or Sketch (including location of all major features, hazards, and photo

Map Or Sketch (including location of all major features, hazards, and photo points listed above)

Recommended Use Restrictions

Justification for Recommended Use Restrictions

Prepared By____ Date_____________

Debate on Denying Cave Access

Students break into two groups and develop and present arguments in a structured debate in favor of and against restricting access to certain caves.

Objectives:
Students will be able to verbally articulate arguments for and against denying visitors access to certain caves at Craters of the Moon. They will develop and be able to express a personal opinion on the topic.

Duration:
1-2 hours of class time

Materials:
Magic Markers, 2 flip charts

Procedure:

1. Split the class into two teams, perhaps combining groups that visited caves together.

2. Each group will represent one side of the issue of whether or not the National Park Service should deny the public access to certain caves in the monument. They will have 20 minutes to develop their arguments. The group should select one person to be the team scribe and record ideas on a flip chart. They must decide among themselves who will present each argument. Make sure that everyone takes a turn to speak, rather than having just one spokesperson for each group.

   While the groups are working, the teacher should circulate among them and make sure they are on track. Some suggestions for points they may want to make appear in the table at right.

3. The teacher will act as an impartial facilitator during the debate. Give each team 2 minutes to present each of their arguments and the other team 30 seconds to rebut. Team one should present their first argument, followed by team 2's rebuttal. Then team two presents their first argument, followed by team 1's rebuttal. They continue to alternate until both sides have presented all of their arguments.

4. Take two confidential votes following the debate. Which team did they think most powerfully and effectively argued their case? Then have them vote on their personal beliefs, regardless of which team they were on. Do they think that the National Park Service should deny access to certain areas at Craters of the Moon (and other National Parks and Monuments) to protect fragile resources?

Pro Denying Access to Caves

- Only those caves with resources so fragile that they would be irreparably harmed if entered are closed.
- There are dozens of other caves open to visitors, while less than ten are closed.
- The National Park Service has a mandate to preserve resources in the monument "unimpaired." This takes precedence over giving visitors access to every part of the monument.

Anti Denying Access to Cave

- The National Monument is public land, it belongs to us, and as US citizens we have a right to enter any part of it we please.
- The federal government should not exert control over the actions of private individuals as long as they are not hurting anyone.
- The Park Service should focus on educating the public to use the caves with care instead of penalizing everyone because of the careless actions of a few individuals.

Chapter 4

Air Quality

National Parks are like the canaries miners used to take into mines; if the bird died they knew that bad air threatened their lives. Pristine natural systems serve the same function for humanity as the coal mine canary. They respond to environmental degradation and warn us that we are at risk.

The amended Clean Air Act of 1977 expresses our nation's desire to preserve, for its own sake, the ability to see long distance panoramas in our remaining wild lands, and to preserve ecosystems, plants and animals. The law established a program to prevent any significant deterioration of the air quality in areas of special scenic value, called "Class I" areas. The Craters of the Moon wilderness is one such area and thus enjoys the most stringent degree of air quality protection.

The National Park Service (NPS) must prevent deterioration in air quality beyond specified limits and protect monument resources from air pollution-related damage. Air pollution can impair park resources in numerous ways, including leaching nutrients from soil, acidification of water, damage to plants, discoloration and accelerated weathering of physical features, and reduced visibility. It is crucial that the airshed be managed to prevent irreversible damage to the entire ecosystem. Yet it is quite a different undertaking than managing other resources, since the source of problems often lies outside the park boundary.

After the passage of the 1977 Amendments to the Clean Air Act, the Park Service undertook an extensive program of monitoring air quality at selected sites in the National Park system. To most visitors, the air at Craters of the Moon seems fine; why monitor at all? Air quality monitoring provides an opportunity to detect and correct dangerous pollution trends before they harm fragile resources. Craters of the Moon is one site in a nationwide network which monitors acid deposition and ozone. Monument personnel also collect data on visibility, airborne particulates, airborne radioactivity, and operate a National Oceanic and Atmospheric Administration weather station. Weather data is important because weather directly affects air quality through moisture, clouds, and transport and dispersion of pollutants and particles. Monitoring serves two basic functions. Initially, it provides baseline information. Then ongoing monitoring allows scientists to document change from that baseline through time.

Let us examine the causes and potential impact of the various pollutants monitored here and what the data has revealed to date.

Sources of Air Pollution at Craters of the Moon

There are several emission sources in southern Idaho which may affect air quality at Craters of the Moon. The Idaho National Engineering Laboratory (INEL), a Department of Energy nuclear research center employing more than 10,000 people, lies 15 miles from the monument. The INEL has several facilities with air quality permits from the State of Idaho, 14 permits as of 1990. These facilities are operated in compliance with permit conditions. Visibility-reducing particles and release of airborne radioactivity are of potential concern.

Large mineral and chemical plants are located in the Pocatello area, 60 miles southeast of the monument. In addition to general industrial air pollution, the fluorides emitted as a result of fertilizer production are a potential threat.

Mining practices and agricultural activities also degrade air quality. Burning stubble off fields is a common practice, and the dust generated by plowing fields and use of dirt roads may all result in lower visibility. Natural and man-caused wildfires also take their toll. Emissions from sources outside Idaho may also cross state borders and reach Craters of the Moon.

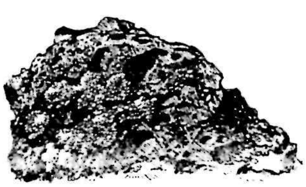
Visibility

In order to appreciate and understand the geological phenomena for which the park was established, one must be able to clearly view the Great Rift, vast lava fields, and other geologic features. Therefore, good visibility is of primary importance at Craters of the Moon. The monument has some of the clearest air in the continental United States. On some fall days, you can see 243 miles, the theoretical maximum possible.

Two instruments measure visibility at Craters of the Moon. An automatic 35mm camera photographs Big Southern Butte daily at 9:00 a.m., noon, and 3:00 p.m. Scientists analyze these photos for the contrast between a dark distant object (Big Southern Butte) and the adjacent sky, assuming that the contrast will be higher when the air is clean and free of light-scattering particles. Based on their analysis, they assign a standard visual range, a measure of the clarity of the atmosphere, to each photo. In addition, a particulate sampler filters suspended particles from the air as a measure of how much dust, soot and other non-gaseous pollutants are present.

Standard visual range values at Craters of the Moon have decreased over the last 10 years. The degradation is significant because it detracts from the visitors' enjoyment of scenic vistas. This finding was a shock to the National Park Service, which had always considered Craters of the Moon to be a pristine airshed. While natural sources such as smoke from lightening-caused fires may be responsible for some of the deterioration, most of the air pollution at Craters of the Moon stems from people.

Biomonitoring



Biomonitoring measures the biological effects of air pollution on plants and animals. Research on several species has occurred at Craters of the Moon. In 1988, a botanist conducted a study of the lichens in the monument. He found slight indications of pollution damage in the campground area and along the state highway. Overall, however, he concluded that lichens show "no evidence of even moderate levels of air pollution" at Craters of the Moon.

Ozone

What is Ozone?

Ozone is a form of oxygen and is the principal component of modern smog. In nature, oxygen atoms tend to pair up in molecules of pure oxygen known as O_2; all animal life and, indirectly, most plant life, requires O_2 to live. Ozone (0_3) is also oxygen, but in groups of three atoms per molecule. Ozone, formed from emissions from forests fires and from lightning, occurs naturally in very small amounts in the air we breathe. Normally, only one O_3 molecule is present for every 50,000,000 O_2 molecules in our air (in scientific terms, .02 parts per million). At this level, ozone is not harmful to life.

However, ozone can form in other ways and in dangerous amounts. The reactants necessary for the formation of ozone are also found in dry cleaning fluid, house paint, cleaning solvents, breweries, bakeries, petroleum refineries, furniture plants, and gas stations - all products or processes we deem necessary to our quality of life. More important, the fossil and organic fuels we burn - in our cars, power plants, factories, and refineries - generate hydrocarbons and nitrogen oxides, two of the key ingredients in the formation of ozone. These compounds rise into the lower atmospheric layer, or troposphere, where sunlight transforms them into ozone. In populated areas, ozone levels can rise to over ten times normal background levels. Such levels are dangerous to human, animal, and plant life. Nor are the dangers limited to cities; ozone continues to form as its ingredients drift downwind, and even higher concentrations may occur miles from the sources of the chemical precursors.

The Dangers of Ozone

In humans and animals, excessive ozone irritates the mucous membranes of the respiratory system, and can reduce resistance to infection. It aggravates chronic diseases such as bronchitis, asthma, and emphysema, and may hasten death in persons already ill. Even healthy people can suffer a temporary reduction in lung capacity after exposure to levels of ozone currently considered safe. The effect can last up to a week, and is worst for people such as athletes, who breathe the dangerous chemical deep into their lungs.

In plants, ozone causes a wide spectrum of disease, decline, and even death. In 1984, a Congressional study determined that "Ozone causes about a 6 to 7 percent loss of U.S. agricultural productivity"; another source estimated the losses at one to two billion dollars annually. "So far, no monetary figure has been placed on ozone damage to forests, but the eventual price tag could be staggering", said the World Resources Institute in 1986.

Ozone is also known to damage paints, plastics, textiles, and some rubber products, though the exact extent is difficult to determine.

Since the installation of the Craters of the Moon ozone monitor in September of 1992, the national ambient air quality standard for ozone of .12 ppm level has not been exceeded here. At times, the equipment has recorded levels close to .08 ppm; recent evidence indicates that some sensitive plant species may exhibit injury at that level.

"Good" Ozone

Ironically, in another way ozone is beneficial. In a higher atmospheric layer known as the stratosphere, ten to thirty miles above the Earth's surface, ozone is naturally present in high concentrations in what is called the ozone layer. At that altitude, ozone is formed when intense sunlight strikes ordinary oxygen molecules; the ozone produced is converted back into oxygen by yet more sunlight. This continual process absorbs much of the sun's harmful radiation, thereby protecting virtually all life on Earth.

The ozone layer has been seriously damaged by chlorofluorocarbons (CFCs) such as freon, which are widely used as refrigerants, aerosol propellants, in the manufacture of styrofoam, and in industrial cleaning processes. CFCs drift up into the stratosphere, decompose under ultraviolet (UV) radiation and release chlorine molecules that destroy enormous amounts of ozone;

one molecule of chlorine can destroy up to 100,000 ozone molecules. This deterioration has created a "hole" in the ozone layer. The resulting increase in UV exposure at the Earth's surface may cause skin cancer and cataracts in humans as well as vegetation damage.

It would be helpful if the excess tropospheric ozone could drift up into the stratosphere and repair the depleted ozone layer. However, the stratosphere and the troposphere are separated by a natural barrier called the tropopause. Here the temperature difference between the atmospheric layers traps the excess ozone, much as temperature inversions sometimes trap smog over cities. The excess ozone cannot move upward through it.

Acid Rain

What is Acid Rain?

All rainfall is by nature somewhat acidic. Decomposing organic matter, the movement of the sea, geothermal activity, and volcanic eruptions all contribute to the accumulation of acidic chemicals in the atmosphere. The principal factor, however, is atmospheric carbon dioxide, which causes a slightly acidic rainfall even in the most pristine of environments. Distilled water, with a pH of 7.0, is considered to be neutral. Uncontaminated precipitation has a pH of about 5.7. In the northeastern US it is not unusual to have rainfall with a pH of 4.0 — which is 1,000 times more acidic than distilled water! More than 200 lakes in the Adirondack Mountains of New York have reportedly become too acidic to support fish life.

There is no doubt that man-made pollutants accelerate the acidification of rainfall. The burning of fossil fuels in power plants, paper mills, other industries, building heating, and vehicles produces sulfur dioxide (SO_2) and nitrogen oxides (NOx). These pollutants combine with water in the atmosphere to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3). They often travel hundreds of miles before falling as acidic rain, snow, dust, or gas. All these wet and dry forms of acid deposition are known loosely as "acid rain."

Effects of Acid Rain

There is increasing concern that acid rain is causing serious, irreversible changes in our environment. The environmental effects of acid rain fall into four categories: aquatic, terrestrial, materials, and human health. Since the impacts of acid rain are complex and develop slowly, the extent of the impacts in these categories is difficult to quantify.

Aquatic Effects:

The adverse effects of acid rain are most apparent in aquatic systems. The most common impact appears to be on reproductive cycles. When exposed to acidic water, female fish and amphibians may fail to produce eggs or produce eggs that do not develop normally. Low pH levels also impair the health of fully developed organisms.

Acid rain plays a role in the mobilization of toxic metals. These metals remain inert in the soil until acid rain moves through the ground. The acidity of this precipitation is capable of dissolving and "mobilizing" metals such as aluminum, manganese, and mercury. Transported by acid rain, these toxic metals can then accumulate in lakes and streams, where they threaten aquatic organisms.

The extent of damage acid rain causes depends on the total acidity deposited and the sensitivity of the area receiving it. An ecosystem's ability to resist change in pH is called its buffering capacity. The concentration of dissolved carbonates determines the alkalinity of the soil. Alkaline soils may neutralize acidic deposition. Calcareous rock (rock containing calcium, calcium carbonate, or lime) like limestone is very alkaline, buffering acid more readily than noncalcareous rock such as granite. In lakes that have little buffering capacity, acid rain may change the pH enough to kill sensitive plants and animals. Areas with acid-neutralizing compounds in the soil can experience years of acid rain without problems, whereas areas with little acid-buffering capacity are very vulnerable to damage from acid rain.

Terrestrial Effects

We know less about acid rain's effects on forests and crops than we do about effects on aquatic systems. The most extreme form of damage some have attributed to acid rain is the phenomenon known as "die-back". Dieback is a term applied to the unexplained death of whole sections of once-thriving forests. Dieback has occurred in areas of central Europe and the Appalachian Mountains of the US. Many scientists believe that air pollution is a contributing factor to this mortality. Pollutants may cause physiological changes in trees that lessen their resistance to diseases and to damage from freezing. There is, however, little direct evidence linking acid rain to forest dieback.

Scientists do agree that acid rain can lead to other, less extreme effects on soil and forest systems. It can leach nutrients from soil and foliage while inhibiting photosynthesis. Acid rain can also kill certain essential microorganisms. The toxic metals it mobilizes when passing through the soil can be harmful not just to aquatic life, but to trees and crops as well.

Material Effects

Acid rain can also damage man-made materials; we are all familiar with photographs of statues that are losing their features and shape with acid rain cited as the culprit. The problem is far more than aesthetic. Building materials, too, can be degraded by acidity. Limestone, marble, carbonate-based paints, and galvanized steel all are eroded and weakened by the kind of dilute acids found in acid deposition. The Acropolis in Greece, the Coliseum in Italy, and the United States Capitol building, all are deteriorating due to the effects of air pollution.

Since materials naturally deteriorate with time, it is difficult to differentiate acid rain damage from normal weathering, or to identify the damage caused by specific pollutants. Consequently, the precise role acid rain plays in the deterioration of materials is still unknown.

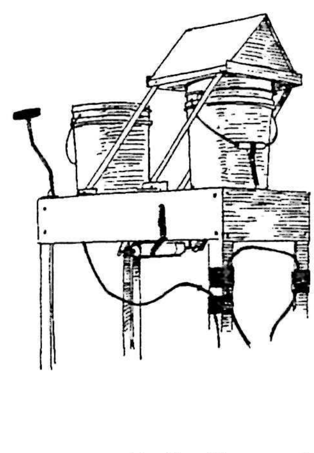
Human Health

So far, health problems resulting from direct contact with acid rain are unknown. Research is needed to confirm whether inhaling acidic particles in acid fog carries some health risk.

Is There Acid Rain at Craters of the Moon?

Since 1980, Craters of the Moon has operated a National Atmospheric Deposition Program (NADP) site. The NADP is a national interagency program for monitoring acid precipitation, with over 200 sites across the country.

Once a week a park ranger collects a sample of the rain or snow which fell during the previous week. Precipitation falls into clean plastic containers which are covered to protect them from contamination during dry weather and uncovered automatically during rainfall. After measuring the acidity on a portion of the sample, the ranger seals the bucket and sends it to a central laboratory. There samples from throughout the country are analyzed. Scientists test them for pH and identify individual chemicals in each sample.



For 1989, the mean annual pH at the monument was 4.95 with a range of 4.01 to 6.59. If one accepts the definition that any reading below 5.6 constitutes acid rain, Craters of the Moon does sometimes experience precipitation that is slightly acidic. Precipitation data indicates no significant change in mean annual pH during 1982-7.

Radioactivity

The Department of Energy operates an environmental surveillance program to monitor the direct (air and water) and indirect pathways (soil, foodstuffs, animals) by which radioactive materials from Idaho National Engineering Laboratory operations might reach the public. Airborne particulate radioactivity is monitored by a network of 23 air samplers, 12 located within the INEL, seven near the Site boundary, and four at more distant locations like Craters of the Moon. With the exception of Craters of the Moon National Monument, the distant locations are sufficiently remote from the Site to ensure that detectable radioactivity is primarily due to natural background radiation or sources other than INEL operations. Craters of the Moon is close enough that radioactive particles from Site operations are occasionally detected at low concentrations. Public exposure to radiation from the INEL, through both direct and indirect pathways, is well below Environmental Protection Agency safety standards.

How Can You Help?

A pen is the most effective tool at your disposal to assure clean air for the future. Write to your government representatives at all levels and let them know how you feel about topical environmental issues. There are many public and private organizations dedicated to environmental concerns such as the reduction of air pollution, and any of them would be grateful for your interest. Some publish newsletters featuring articles about what you can do to help protect the environment.

Experts agree there is only one way to save the ozone layer - stop producing ozone depleting CFCs! This must be done as soon as possible. Because many CFCs remain in the stratosphere for up to 100 years, any action taken today to stop production of these chemicals will not result in reduced ozone depletion for decades. Environmentally safe styrofoam now exists. Pump-style dispensers have widely replaced aerosol sprays. Purchase these products and not their destructive counterparts. The use of freon in refrigerators, freezers and ice arenas continues to be a problem.

Don't forget the actions we can take in our daily lives that make a difference! Use car pools or mass transit where available. Otherwise, drive a fuel-efficient car and keep it properly tuned. Walk or ride a bicycle when traveling short distances. Find ways to make your home more energy-efficient. Store and dispose of hazardous materials properly. Select nature- friendly products when you shop. Reuse and recycle.

If a geographically isolated site like Craters of the Moon is beginning to be affected by air pollution, the time to take action to protect our air is now.

Air Quality

1. What types of pollution does the National Park Service monitor at Craters of the Moon National Monument?

2. What evidence does this monitoring provide that the air quality at the monument is declining?

3. What pollution sources in southern Idaho have the potential to impact the relatively pristine air at Craters of the Moon?

4. Describe the sources and impacts of acid rain and ozone.

5. What actions can we take in our own lives to help assure clean air for the future?

Visit Air Quality Monitoring Sites

Students visit air quality monitoring sites with a park ranger and obtain information on how data is collected and what it reveals.

Objective:
Students will be able to list the types of pollution monitored at Craters of the Moon, describe the collection techniques used, and summarize what the data collected indicates about air quality at the monument.

Duration:
2 hours

Materials:
Pencil, activity 4A work sheets 1 and 2, park ranger

Procedure:

1. Make arrangements with the National Park Service before you visit the monument. We will provide a ranger to show you the data collection sites and talk to your group if you arrange it well in advance.
2. Accompany the ranger on a hike from the campground to the air quality monitoring site. There you will have the opportunity to observe the particulate sampler, visibility monitoring camera, and acid deposition sampler.
3. Return to the Visitor Center, where the ranger will explain the ozone monitor located there.
4. Complete the work sheet on the next page, recording information on the different instruments used to collect data and the nature of the information collected. This will include an ozone monitor, particulate sampler, visibility camera, and acid deposition collector. Ask the ranger the questions on page 2 of the work sheet.

Air Quality Data Collection at Craters of the Moon

Type of Pollution	Collection Method	Summary of Data to Date
Ozone		
Acid Rain		
Particulates		
Visibility		

Air Quality Data Collection at Craters of the Moon

1. How many years has the National Park Service been collecting data at Craters of the Moon?

Acid Rain	__________
Ozone	__________
Particulates	__________
Airborne Radioactivity	__________
Visibility	__________

2. What are the sources of pollution which may be affecting air quality here?

3. What is the National Park Service doing to address sources of air pollution within monument boundaries?

4. What can the National Park Service do to address sources of pollution outside monument boundaries?

5. Will monitoring continue at Craters of the Moon? Is any expansion in the monitoring program anticipated?

Air Quality Data Collection at Craters of the Moon

1. How many years has the National Park Service been collecting data at Craters of the Moon?

Acid Rain	since 1980
Ozone	since 1992
Particulates	since 1974
Airborne Radioactivity	since 1973
Visibility	since 1982

2. What are the sources of pollution which may be affecting air quality here?

There are several potential sources of air pollution in southern Idaho which may affect air quality at Craters of the Moon. The Idaho National Engineering Laboratory, a Department of Energy nuclear research center employing more than 10,000 people, lies 15 miles from the monument. High level radioactive waste that contains acids is heated to convert the waste from liquid to solid. The acids are burned off and nitrogen oxides are released in a yellowish plume through a tall stack - 725 tons in 1988. In addition to the nitrogen oxides, visibility impacts and release of airborne radioactivity are potential concerns.

Two large mineral and chemical plants are located in the Pocatello area, 60 miles southeast of the monument. In addition to general industrial air pollution, the fluorides emitted as a result of fertilizer production are a potential threat.

Mining practices and agricultural activities also degrade air quality. Burning stubble off fields is a common practice, and the dust generated by plowing fields and use of dirt roads can also be significant. Natural range and forest fires also can decrease air quality.

3. What is the National Park Service doing to address sources of air pollution within monument boundaries?

In order to reduce pollution generated inside the monument (and because dead wood for collection is scarce and precious to the soil), wood fires are not permitted in the campground. The Park Service recently replaced oil furnaces in the buildings at Craters of the Moon with electric forced air heating. The monument owns three motor scooters, highly fuel efficient, which rangers use to get around the monument during the summer.

In addition, the Park Service attempts to educate visitors about the threat deteriorating air quality poses to monument resources in our guided walks, exhibits, and publications. This includes this curriculum as well as the recently completed trail guide and exhibits at Devil's Orchard.

4. What can the National Park Service do to address sources of pollution outside monument boundaries?

Through procedures outlined in the National Environmental Policy Act and the Prevention of Significant Deterioration Program of the Clean Air Act, the National Park Service comments on activities which have the potential to threaten air quality. This would include, for example, any proposal to build industrial facilities in the vicinity of the monument.

The National Park Service also establishes cooperative agreements with emitters, such as the Idaho National Engineering Laboratory, in an effort to meet the needs of both organizations while still protecting the Craters of the Moon airshed.

We also work with other agencies to coordinate monitoring efforts and data comparison.

5. Will monitoring continue at Craters of the Moon? Is any expansion of the monitoring program anticipated?

The monitoring program will continue. The monument may expand its existing program to become a UV-B radiation monitoring site. It has been predicted that the depletion of ozone will be accompanied by a corresponding increase in the amount of UV-B radiation reaching the Earth's surface. This could result in increased occurrence of skin cancer, reduced agricultural yields of some sensitive crops, and changes in species composition of ecosystems.

How Clean is Your Home?

Students conduct pH tests on the soil, surface water, and precipitation at Craters of the Moon and at a site in their own community.

Objectives:
Students will be able to explain the use of the pH scale as a tool to measure acidity. Based on data collected, they will be able to describe how the acidity of soil, water and precipitation at Craters of the Moon compares to their home environment.

Duration:
1 hour in the classroom. The monument can provide water, precipitation and soil samples upon request. Groups may also collect their own samples while visiting the monument. This would take about 2 hours; collecting surface water will require a trip to a stream in the north end of the monument or a hike to Boy Scout Cave.

Materials:
Samples of soil, surface water, and precipitation from Craters of the Moon and from home area, pH test strips or other measurement method, paper and pencils, beakers.

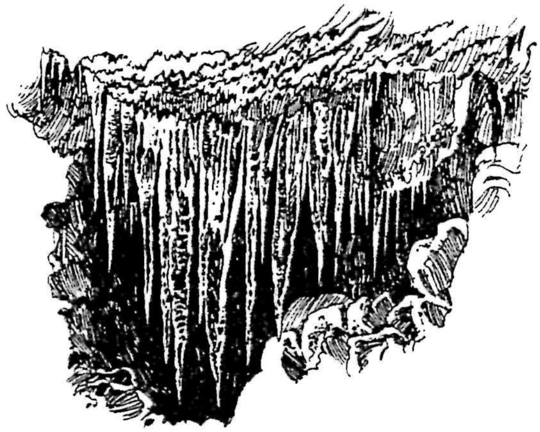
Background Information:
It is the concentration of hydrogen ions (H^+) that determines the acidity of a liquid. This concentration is described using a pH scale. The scale ranges from 0.0 (most acidic/ highest H^+ concentration) to 14.0 (most basic/ lowest H^+ concentration). A solution with a pH of 7.0 is neutral. The pH scale is a negative logarithmic scale in base 10. This means that a solution with a pH of 4.0 is ten times more than acidic than a solution with a pH of 5.0, and one hundred times more acidic than a solution with a pH of 6.0.

Procedure:

1. For each sample you have you will need a small (100ml) beaker. Put your samples in and label them carefully.
2. To collect a precipitation sample at home or school, cut a plastic soda bottle in two and invert the top half so it is resting on the lower half like a funnel. Before collecting your sample, clean and rinse the bottle with distilled water. Make sure you keep it free of contaminants such as insects or dirt. Set it in a spot where it will gather rain water and test the rain water as soon as possible after collection.
3. For very dry soil samples you will need to add moisture. Use a neutral-pH distilled water. Always check the pH of the distilled water before using it.
4. Test the pH of each sample and record the results on the chart provided on the following page.
5. Is there a difference in pH between the samples from your home and Craters of the Moon? If there is, try to explain the difference. Are there potential sources of pollution near your home? What are the prevailing winds?

How Clean is Your Home?

Sample Type	Home Area pH	Craters of the Moon pH
Surface Water Sample		
Precipitation Sample		
Soil Sample		



Water Quality

Water is extremely scarce at Craters of the Moon. Little Cottonwood and Leech Creeks, which flow from springs in the foothills of the Pioneer Mountains, are the only two streams in the Monument. They disappear below ground at the edge of the lava flows. Throughout the rest of the Monument, water exists only in scattered water holes and ice caves.

Water holes appear to form when water percolating downward meets an unusually non-porous layer of lava, where the water may collect into a pool. If the temperature in these locations is below freezing, the water turns to ice. Ice, too, forms an impermeable layer that traps water above it. These water holes provide oases for animals living in the volcanic desert. Early explorers of the lava fields located water by watching for concentrations of birds circling in the air above water holes.

Ironically, deep below the parched surface of the lava beds lies an enormous reservoir of fresh water, the "Snake River Plain aquifer." The Snake River Plain aquifer is a huge underground body of water covering 10,000 square miles, stretching from the town of Hagerman upstream to near St. Anthony. The aquifer is made up of water which is stored in a series of lava flows erupted over the past 15 million years. The lava flows are separated by layers of broken rock and cinders as well as sand, gravel, and clay which mark the location of ancient lakes and rivers. In addition, the lava is cracked, leaving large spaces through which water can flow. These rock layers act like a giant sponge, with a storage capacity of 200 million acre feet!

Farmers depend on the aquifer to irrigate over one million acres annually. Most farms also depend on wells for domestic and stock water. In addition, over 41 communities serving 127,000 people utilize the aquifer for municipal water supplies, either from wells or springs.

The aquifer lies approximately 1,000 feet below the surface and flows slowly, following the gradual slope of the Snake River Plain. Streams entering the lava plain, rain, and snow melt all disappear into the porous rock. The water then makes its slow journey southwestward, eventually cascading from the canyon walls into the Snake River at Thousand Springs.

Water Quality Research at Craters of the Moon

In 1992, researchers began an Aquatic Resources Assessment at Craters of the Moon. The study collected baseline data on water and ice in the Monument. It also documented the physical condition of the streams and chemical content of the water in streams, water holes, ice caves, and wells. In addition, researchers examined the invertebrate animal life of streams, and they reviewed historical documents for any trends in water quantity. This study established what existing conditions are, and created guidelines for ongoing monitoring to detect any significant changes.

The study indicates that minerals may be leaching from the mine tailings at the abandoned Martin Mine into the water of Little Cottonwood Creek. Samples from the spring box on Little Cottonwood Creek, upstream from this area, demonstrate that the springs come from a surface source and not from groundwater as previously thought. Sampling of water in several ice caves showed that the water may come from atmospheric condensation and not from percolation of ground water, as had been previously assumed.

Water Quality

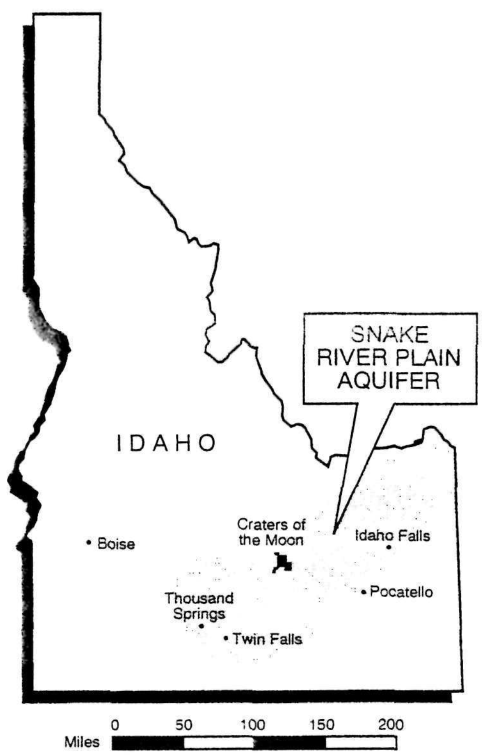
1. It is theorized that water in the Snake River aquifer moves at a rate of approximately five to ten feet per day. Using the map below, calculate how long it would take for water to travel from Craters of the Moon to Thousand Springs. (Remember, there are 5,280 feet in one mile.)

2. Given what you know about the geology of the Snake River Plain, explain why massive irrigation has been necessary to turn sagebrush desert into rich potato farmland.

3. Using your map of the Snake River Plain aquifer, predict possible contamination sources. Indicate both the geographical source and the nature of the contamination.

4. Describe the types of surface water present at Craters of the Moon.

5. What did the water resource study conducted in 1992 indicate about sources of water at the monument?



Assessing Stream Health

Students will assess physical stream quality and complete chemical tests on the water of a creek at Craters of the Moon and a stream near their school.

Objective:
Students will demonstrate correct procedures for testing 3 chemical indicators of water quality and for assessing the physical condition of a stream. They will be able to describe the difference in water quality between streams at Crater of the Moon and near their school.

Duration:
1 hour in the classroom, 3 hours at the stream for each location

Materials:
Pens, pencils, activity 5A work sheet, water quality testing kits (Hach Kits), thermometers

Background Information:
The chemical tests of water quality the National Park Service uses to monitor Little Cottonwood Creek include measurements of water temperature, dissolved oxygen, and pH. These tests indicate a variety of things about the health of the stream environment.

Temperature

Temperature directly affects many of the physical, biological, and chemical characteristics of a stream: the amount of oxygen that can be dissolved in water, the rate of photosynthesis, and the metabolic rate of aquatic organisms. Aquatic organisms have adapted to survive within a certain range of water temperatures. Very high or low temperatures may exceed the tolerance limit for some aquatic life. Because warm water holds less oxygen than cool water, increasing temperature can negatively affect the whole aquatic ecosystem. Temperature also affects aquatic life's sensitivity to toxic wastes, parasites and disease. Fish become more vulnerable because they are in a weakened condition from lack of dissolved oxygen, or under stress from higher water temperature.

Dissolved Oxygen

Dissolved oxygen is essential for the maintenance of healthy lakes and rivers, since most aquatic plants and animals need a certain level of dissolved oxygen for survival. Waters with consistently high dissolved oxygen are healthy and stable aquatic ecosystems, capable of supporting many different kinds of organisms.

Much of the dissolved oxygen in water comes from the atmosphere. Waves on still water and tumbling water on fast-moving rivers mix atmospheric oxygen into the water. Algae and rooted aquatic plants also deliver oxygen to water through photosynthesis. In lakes, rooted plants are more abundant than in rivers. This results in a daily variance in dissolved oxygen levels due to photosynthesis. Dissolved oxygen levels are at their highest in the afternoon and lowest just before dawn, sometimes endangering fish life.

Water temperature, volume of water moving down a river, build-up of organic wastes, and fertilizers in run-off all affect the level of dissolved oxygen in a system. Depletions in dissolved oxygen can cause major shifts in the types of organisms present in a stream. Aquatic insects that are sensitive to low oxygen levels, such as mayfly nymphs and caddisfly larvae, will be replaced by creatures tolerant of these lower levels.

pH

The pH scale is a measure of the degree of acidity or alkalinity of a substance. Most aquatic organisms have adapted to life in water of a specific pH and may die if the pH shifts even slightly. Increased amounts of nitrogen oxides and sulfur dioxide, primarily from automobile and coal-fired power plant emissions, are converted to nitric and sulfuric acids in the atmosphere. These acids combine with moisture and fall to the earth as acid rain or snow. Acid rain has acidified thousands of lakes in the northern hemisphere to the point where they are devoid of life. (For more detail on this phenomenon, see Chapter 4 on Air Quality).

Procedure:

1. Before visiting the monument please contact the National Park Service *for information on appropriate sites for this activity. One of our staff* members will unlock the gate on the road into the north end of the monument, where the streams are located, and accompany your group to the monitoring location.

2. Split the class into small groups and assign each group a small reach of stream. Students then complete the "Survey of the Physical and Chemical Condition of a Stream" work sheet, rating characteristics of the upper banks, lower banks and channel bottom as poor, fair, good, or excellent. The lower bank is the intermittently submerged portion of the channel from the normal high water line to the water's edge during the summer low flow period. The upper bank extends from the break in the general slope of the surrounding land to the normal high water line. Terrestrial plants and animals normally inhabit this area. The same procedure can be repeated on a stream at home and the results compared.

3. Each group should also complete tests for temperature, dissolved oxygen, and pH and enter the results on the work sheet. The instructions for each of these tests are as follows:

Temperature Testing Procedure

1. Lower the thermometer four inches below the surface of the stream.

2. Keep the thermometer in the water until it reaches equilibrium (approximately two minutes).

3. Record the temperature in degrees centigrade.

4. Repeat the test once in the same location.

5. Record your results.

Dissolved Oxygen Testing Procedure (Using a Hach water testing kit)

It is important to sample away from the shore, and just below the surface of the water. Use an extended rod sampler with a wire basket, or collect your sample from a bridge. (There is no bridge available at the monument, but may be on your home stream.)

1. Remove the stopper and immerse the dissolved oxygen bottle beneath the surface.

2. Allow the water to flow over the bottle for a few minutes, and make sure no air bubbles are present when you take the bottle from the river. Add the contents of pillow #1 (manganous sulphate powder) and insert the stopper, making sure no air is trapped inside. Shake vigorously to fully mix. If oxygen is present a brownish-orange precipitate will form. If air bubbles form after the first shake, discard the sample and begin again.

3. Allow the sample to stand until the precipitate settles halfway. When the top half clears, shake again and allow the sample to settle.

4. Add pillow #3 (sulfuric acid powder) to the sample and shake. The precipitate will dissolve and the water will turn yellow.

5. Pour the sample to the top of the measuring tube; pour the contents into the square mixing bottle. Repeat once.

6. While swirling the bottle, use the dropper to add the titrant to the prepared sample. Count the number of drops needed to change the sample from yellow to a clear solution. Each drop equals 0.5mg/l of dissolved oxygen. Record your results.

pH Sampling Procedure (Using a Hach water testing kit)

Collect the water sample away form the bank just below the surface of the stream. Measure the sample immediately, because changes in temperature can affect the pH value.

1. Rinse each test tube with the water sample.

2. Fill both viewing tubes with the water sample to the first line.

3. Add 6 drops of the Wide Range 4 pH indicator solution into one tube and swirl to mix. This is your prepared sample.

4. Place the tube of the prepared sample into the right opening of the comparator wheel. Place the other tube into the left opening.

5. Hold the wheel up to a light source and rotate the wheel until the color on the wheel matches the color of the prepared sample.

6. When the colors match, read the pH value of the sample through the window and record the value.

Survey of the Physical and Chemical Condition of a Stream

Stream Name____

Group Members____

Water Temperature__________ pH Level________ Dissolved Oxygen________

	Excellent 4 points	Good 3 points	Fair 2 points	Poor 1 point
Upper Channel Banks				
1. Landform Slope				
2. Mass Wasting Hazard				
3. Debris Jam Potential				
4. Vegetative Bank Protection				
Lower Channel Banks				
5. Channel Capacity				
6. Bank Rock Content				
7. Obstructions to Flow				
8. Cutting				
9. Deposition				
Channel Bottom				
10. Angularity				
11. Brightness				
12. Consolidation of Bottom Material				
13. Aquatic Vegetation				
Total Points				

To attain an overall score for stream health, total the points and divide by 13.

Score________________

Instructions:

1. The gradient of the banks above the stream. Excellent - side slopes on the channel are less than 30% on both banks. Good - Side slopes up to 40% on one or both banks. Fair - Side slopes up to 60% on one or both banks. Poor - Steep slopes over 60%. Steep slopes provide larger volumes of soils for downstream sedimentation.

2. The potential of banks to slide into the creek channel. Excellent - no evidence of mass wasting. Good - Evidence of infrequent and/or very small slumps. Fair - Frequency and/or magnitude of the mass wasting increases to the point where normal high water aggravates the problem. Poor - Frequent and/or very large slides are readily apparent.

3. Floatable objects deposited on the stream banks. Excellent - debris may be present, but there is no chance the stream will float it away. Good - The debris offers some bank protection, but is small enough to be floated away in time. Fair - There is noticeable accumulation of debris of all sizes and the stream is large enough to float it away. Poor - heavy accumulations of debris are present; high flows would dislodge most of the material.

4. Amount of plant cover on the banks. Excellent - plants cover 90% of the ground. Good - 70-90% cover. Fair - 50-70% cover. Poor -less than 50% of the ground is covered.

5. The ratio of channel width to channel depth (width/depth). Excellent - ratio less than 7. Good - ratio 8 to 15. Fair - ratio 15 to 25. Poor - ratio greater than 25.

6. The percentage of rocks comprising the banks. Excellent - rocks make up 65% or more of the volume of the banks. Good - Rocks 40-65% of bank volume. Fair - Rocks 20-40% of bank volume. Poor - rocks make up less than 20% of the bank volume.

7. The quantity and stability of materials obstructing the flow of water. Excellent - logs, rocks, and other obstructions are firmly embedded and produce a pattern of flow. Good - Obstructions cause only minor bank and bottom erosion. Fair - Moderately frequent, unstable obstructions cause noticeable seasonal erosion of the channel. Poor - obstructions are so frequent they are indivisible; they are unstable and cause a shift of sediments in all seasons.

8. Erosion of bank material due to a bend or obstruction in the stream channel. Excellent - little or no cutting is evident. Good - Some intermittent cutting along channel outcurves and at prominent constrictions. Fair - Significant bank cutting occurs frequently. Poor - nearly continuous bank cutting.

9. The amount of deposition of fresh sediments. Excellent - very little or no deposition of fresh silt, sand or gravel. Good - Some fresh deposits on bars and behind obstructions. Fair - deposits of fresh, coarse sands and gravels observed with moderate frequency. Poor - extensive deposits of fresh silt, fine sand and small gravel.

10. The shape of the rocks, which become rounded as they spend more time in tumbling water. The more angular the rock, the more stable the channel bottom. Excellent - very angular. Good - somewhat angular. Fair - Sub-angular. Poor - rounded.

11. Cleanliness of the rocks. Rocks in motion do not collect algae or become stained. Excellent - less than 5% of the total bottom should be "bright", meaning the rocks are clean. Good - 5 to 35% bright. Fair - 50/50 mix of the rocks appear to be bright. Poor - bright, freshly exposed rocks predominate 2/3 or more of the bottom.

12. Consolidation of bottom material. Excellent - an array of sizes are tightly packed and wedged with much overlapping. Good - Moderately tight packing of particles protected by overlapping rocks. Fair - Moderately loose without any pattern of overlapping. Poor - rocks in loose array, moved easily by less than high flow conditions.

13. Aquatic Vegetation. Excellent - clinging plants are abundant from bank-to-bank. Good - Plants are quite common in the slower portions of the stream, but thin out or are absent in swift water. Fair - Plants are found but their occurrence is spotty. Poor - Clinging plants are rarely found.

Chapter 6

Life on the Lavas: Preserving the Balance

A Harsh Environment

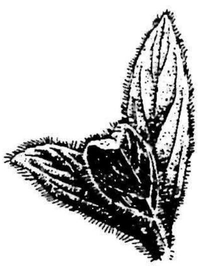
Living things at Craters of the Moon must overcome daunting challenges if they are to survive. In addition to the scant soil on the cinder cones and lava flows, plants contend with considerable environmental stress. Summer brings blazing heat and winter frigid cold. In volcanic soils, the temperature beneath the surface quickly responds to changes in air temperature. Scientists have detected changes in soil temperature three inches below the surface within one hour of a change in air temperature. The marked difference in daytime and nighttime summer temperatures, if extreme, can shock a plant's root system. This coupled with the abnormally high surface temperatures reached as the black soil absorbs heat from the sun—more than 150 degrees Fahrenheit—creates conditions potentially deadly for plants.

Average annual precipitation is only 17 inches, much of which occurs as snow. Rainwater and snow melt sink quickly into the porous lava and out of the reach of plant roots. By the summer growing season little moisture is available. The irregular cavities in the cinders partially offset this by temporarily retaining small amounts of water. The air is dry and southwesterly winds, averaging a daily 12 mph in the summer, further rob plants of precious moisture. All of these factors make it difficult for plants to establish themselves in this volcanic landscape.

Despite these barren conditions, Craters of the Moon is home to a surprising array of plants and animals: more than 300 plant, 20,000 insect, 2 amphibian, 8 reptile, 148 bird, and 44 mammal species! These living things have unique structural and behavioral adaptations which enable them to survive the environmental extremes of the lava desert.

Plant Adaptations: Evaders and Resisters

Desert plants have two fundamental strategies for coping with lack of water—evasion and resistance. Drought evaders avoid dry conditions by growing at times or in places which provide adequate moisture. Mosses and ferns, for example, escape drought by growing near persistent water supplies such as ice caves or in moist crevices on the lava flows. Aspen and Douglas-fir trees grow only on sheltered slopes or along streams. The tiny dwarf monkeyflower carries out its full life cycle during the few moist weeks in early summer, surviving as a seed the rest of the year.



Most of the plants in the monument, however, must be able to endure blistering heat, extreme drought, and desiccating wind. They resist rather than evade environmental extremes. Various structural features enable these plants to locate water and to conserve moisture. The tissues of sagebrush and antelope bitterbrush, for example, can withstand extreme dehydration without permanent cell damage. They are also able to extract water from very dry soils. Like many desert plants, the bitterbrush has tiny leaves, which expose less surface area to the drying heat and wind. White hairs on the leaves and stems of plants like scorpionweed reduce surface evaporation by inhibiting air flow, reflecting sunlight, and trapping moisture as it leaves the plant. Succulent plants such as pricklypear cactus can store water for later use. The showy blossom of the blazing star opens only at night rather than exposing itself to intense sunlight.

Animal Adaptations

Animals at Craters of the Moon must cope with the same environmental extremes as the plants. Most are nocturnal and avoid heat and intense sunlight. Those that remain active during the day retreat to rocky burrows in the lava or other shady locations during the hottest hours. Some creatures have more sophisticated mechanisms for reducing body temperature. Jackrabbits, for example, radiate heat from their ears when air temperature climbs higher than body temperature. Blood flow through the large surface area of the ears dissipates body heat. Marmots take more extreme measures. When conditions become too hot and dry, they go into a state of deep stupor called aestivation, during which their metabolism and other body functions drop for weeks at a time.

Animals living on the lava flows have essentially no access to water and must get their moisture directly from their food. This is true regardless of whether they are consuming plants, insects, or larger animals.

Two animals at Craters of the Moon have developed distinct subspecies which are darker in color than their relatives elsewhere, the pika and pocket mouse. This adaptation protects them from predators, since it makes them more difficult to see against the dark surface of the lava.

In addition to surviving the rigors of summer, each animal must have a strategy to survive the sub-zero temperatures, deep snow, and lack of food during the winter months. Migration and hibernation are both effective ways to escape extreme winter conditions. Most of the bird species present during the summer overwinter elsewhere; the western tanager, for example, spends its winters in Mexico and Central America. There are animals that migrate shorter distances on foot. The Craters of the Moon mule deer herd moves down slope onto the desert where the snow is not as deep during the winter. Ground squirrels, marmots, bears, and other animals spend the cold months in a state of deep sleep. Marmots, for example, experience a drop in body temperature from 98 degrees to just 34 degrees Fahrenheit and their heart rate plummets from 80 to just 4 beats per minute. This is a very effective way to conserve energy and survive on stored fat until warm weather returns.

There are animals, though, that are active in winter. Some, like the pocket gopher, mountain vole, and pika, actually remain beneath the snow layer. The small open space between the snow and the ground is warmer than the surface and affords some protection from predators. Pikas assure an adequate food supply for themselves by storing stacks of dried grasses collected during the summer in their rocky dens. Food storage is a strategy also adopted by red squirrels. They store limber pine cones near rocks and fallen logs all summer long, and dig through the snow to find this food cache.

It took thousands of years for this community of plants and animals adapted to the rigorous conditions at Craters of the Moon to become established. The formation of soil on the barren rock was the necessary first step in their colonization of the lava.

Soil Formation: Prerequisite for Life

Soil formation proceeds in different ways on cinder cones and lava flows. On cinder cones, wind, water, and changing temperatures break large cinders into smaller and smaller pieces. Meanwhile, the wind carries in fine particles of dust and soil, which mix with the top layer of cinders and provide many of the components needed for plant growth. However, there is no nitrogen within newly deposited cinders, so only plants capable of getting nitrogen from some other source can grow. Certain algae and bacteria are able to absorb nitrogen directly from the atmosphere. This unique characteristic allows algae and bacteria to take hold on cinder fields. When they die, their bodies decompose and provide nitrogen for the plants that follow.

In contrast to loose cinder piles, lava flows have a hard skin of volcanic glass and an interior riddled with cracks and vesicles. Soil formation on the lava flow begins with the growth of lichens. Lichens are a combination of organisms: an algae that obtains nutrients by secreting an acid which dissolves rock, and a fungus that absorbs water and protects the algae from the drying effects of the sun. This mutually beneficial relationship provides everything needed for lichens to colonize bare rock.

Lichens break off small fragments of rock, which the wind blows into the many crevices of the lava flow. There, these particles combine with larger deposits of wind-borne dust and build rudimentary soil. Eventually enough soil builds up in the cracks for plants to sprout. Once plants begin to grow in the newly created soils of the cinder cones and lava flows, a process of ongoing change called succession has begun.

Plant Succession

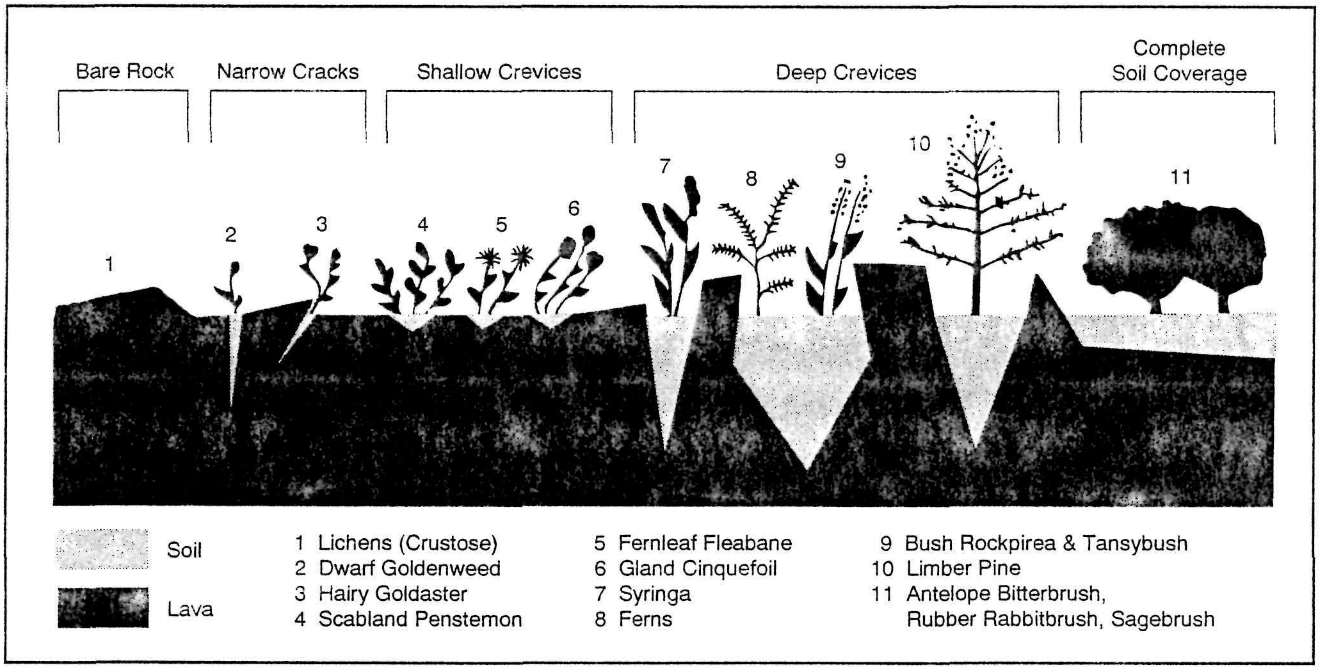
Succession is the orderly stage-by-stage replacement of one plant community by another. Each community in turn alters its environment by adding organic matter to soil, increasing its ability to hold water, and by providing shade. Eventually this results in conditions that favor the survival of a new group of plants. Succession proceeds differently on the lava flows than on the cinder cones, but the final "climax" community is identical.

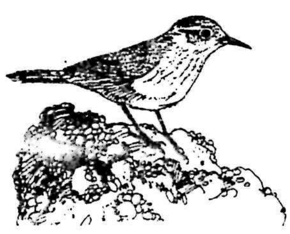
Once enough soil has accumulated on cinders, small herbs such as dwarf buckwheat, scorpionweed, bitterroot, and dwarf monkeyflower begin to grow. As time progresses, the remains from these plants mix with the cinders to produce a richer, deeper soil able to support more complex plants. Plant succession then occurs differently on north and south facing slopes. North-facing cinder slopes receive less direct sunlight and are sheltered from the prevailing winds. Therefore, snow stays longer, and these slopes remain cooler and wetter than southern exposures. These conditions initially favor limber pine and

bitterbrush. As more organic matter accumulates, increasing water retention in the soil, Douglas-fir replaces the pine.

On south-facing slopes, bitterbrush and other shrubs replace the pioneer herb gardens as the soil slowly builds. Limber pines are interspersed with the shrubs, but disappear as the plant cover becomes more dense, since pine seedlings cannot survive in the shade of the bushes. By growing rapidly upward, bitterbrush can withstand partial burial by wind-drifted cinders. The upreaching branches intercept dust particles, gradually adding soil and creating conditions favorable for sagebrush and grasses to grow. As erosion begins to level out steep slopes and the soil deepens and matures, a sagebrush-grassland covers the cinders. Succession has proceeded from cinder garden herbs to bitterbrush/limber pine and finally to sagebrush- grassland.

Succession is essentially at a standstill on the surface and in the shallow cracks of fresh lava flows. It is in the wind-deposited soils of the deep crevices that lava flow succession begins. There plants such as tansybush, syringa, and bush rockspirea find protection from direct wind and sun. Dead leaves and stems from these plants, plus airborne debris, accumulate and the crevices eventually fill in, creating conditions like those in the shallow cracks. More drought-resistant species replace the original deep crevice plants. These new plants flourish, creating a layer of soil around them. Only when the crevices and cracks have filled with soil can a complete plant cover develop. Wide expanses of lava then gather a layer of soil in which extensive tracts of sagebrush-grasses thrive. Thus, succession on the lava flows proceeds from deep crevice drought evaders to shallow crevice drought resisters to sagebrush-grassland.

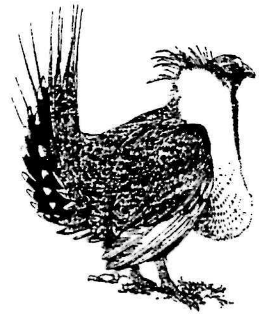




Each successional plant community has its own set of animal inhabitants. Barren lava flows conceal the nests of rock wrens, a grayish-brown bird sometimes seen bobbing up and down among the rocks. They raise their young in the a'a lava where they can retreat into cool crevices in the heat of the day. Great-horned owls find the high ledges in lava tubes or cinder cone cliffs ideal sites to nest, protected from attack by other birds. Pikas and yellow-bellied marmots also live in lava outcrops.

Limber pine stands host animals that feed on pine nuts, like the yellow pine chipmunk and the larger golden-mantled ground squirrel. The Lewis' woodpecker and Clark's nutcracker both use dead pines to build their nests, and nutcrackers are highly dependent on pine nuts for survival.

Douglas-fir groves shelter animals not normally found in the high desert: chickadees, red- breasted nuthatches, brown creepers, and golden-crowned kinglets and forest mammals like red squirrels and porcupines.



The sagebrush-grassland community holds the greatest abundance of animal life. Pronghorns and coyotes occasionally wander through, and the northern harrier, American kestrel, and sage thrasher are all abundant. Sage grouse move to the foothills just north of the monument in springtime. In winter they return to the sagebrush flats to escape deep winter snows. The sage grouse has feathered toes which enable it to walk on top of the snow and feed on an unlimited supply of sagebrush leaves.

Life on the Lavas: Preserving the Balance

1. List 5 factors limiting the growth of vegetation at Craters of the Moon. Are there similar factors which limit plant growth in your home environment?

2. What two basic strategies do plants use to survive in desert conditions? Give examples of plants at Craters of the Moon that use each of these strategies.

3. Give 3 examples of behavioral adaptations animals at Craters of the Moon employ to survive the hot, dry summers. Give 3 examples of behavioral adaptations they use to survive the rigors of winter.

4. In your own words explain what is meant by succession. How might you observe examples of succession at Craters of the Moon?

5. How has the geology of Craters of the Moon affected the distribution of plant communities that live there?

Habitat Inventory

Students compare environmental conditions and plant communitities in 6 different habitats.

Objectives:
Students will be able to explain how the type of lava, age of the deposit, and slope affect plant communities.

Duration:
3 hours on site, one class period to discuss results

Materials:
Pencils, activity 6A work sheets, measuring tapes, surveyors tape and stakes, camera and film. A geologic map to age lava flows and field guides and plant lists to assist with plant identification, air and soil thermometers, sling psychrometer, distilled water, and balance to weigh fuel moisture sticks are available in the support kit at the Visitor Center.

Background Information:
Many variables affect the distribution of plants at Craters of the Moon: the type of lava; age of the volcanic deposit; degree of soil development; and the impact of wind, snow accumulation, and slope. The interaction of these factors results in a mosaic of plant communities. In 1982-3, scientists completed a vegetation map of the monument which identified 26 vegetation types. The vegetation types are based on the most conspicuous species and on those species covering the most ground in an area. This exercise will expose students to 6 distinctly different vegetation types identified in the mapping study. Together these 6 habitats account for 71.3 percent of the monument.

Type 1: Douglas Fir/Mountain Snowberry (.1 percent of monument)
This type is found on relatively steep, north-facing slopes of older cinder cones. Douglas fir is the dominant tree with occasional limber pines present. Generally, more than 50% of the soil surface is devoid of vegetation, but it is covered by a layer of litter. The dominant understory shrub is mountain snowberry. Common chokecherry is widespread, especially in areas of bright light. Willow species are also present. Common forbs include broadleaf bluebell, sharpleaf valerian, and sticky cinquefoil. Common grasses include Sandberg bluegrass, Idaho fescue, and slender wheatgrass.

Type 2: Antelope Bitterbrush/Great Basin Wildrye (.4 percent of monument)
Found on slopes of medium-aged and older cinder cones. The dominant shrub in this type is antelope bitterbrush. Other common shrubs include rubber rabbitbrush, mountain snowberry, and Wyeth eriogonum. Wax currant and mountain big sagebrush occur as scattered individuals. Common forbs include arrowleaf balsamroot, Holboell rockcress, sulfur buckwheat, and stoneseed. Desert parsley forms a relatively dense understory, especially where grass density is low. The most conspicuous

grass is great basin wildrye, although bluebunch wheatgrass occurs in much higher densities than wildrye in many areas of this type.

Type 3: Mountain Big Sagebrush/Bluebunch Wheatgrass (5.2 percent of monument)

Occurs on older lava flows and south slopes of medium aged and older cinder cones, which have more highly developed soils. The type is widespread in the monument and diverse in composition. The dominant shrub is mountain big sagebrush and bluebunch wheatgrass is the most common grass. Antelope bitterbrush is common and in some areas occurs in higher densities than sagebrush. Mountain snowberry and saskatoon serviceberry are common in moister sites, as are nettle-leaf horsemint and onion grass.

Type 4: Low Density Lava Flows (57.8 percent of monument)

These flows of a'a, pahoehoe, and block lava are generally the youngest in the monument and have relatively low plant cover. Shrubs provide less than five percent of the total cover and include tansybush, ocean spray, mockorange, and dwarf goldenweed. On more favorable microsites, antelope bitterbrush and lava phlox are common. Common forbs include scabland penstemon, desert parsley, fernleaf fleabane, sulfur buckwheat, thistle, narrowleaved skeletonweed, and sticky cinquefoil. The most common grasses are Sandberg bluegrass and squirrel tail.

Type 5: Limber Pine/Antelope Bitterbrush (5.6 percent of monument)

This type is found on young to medium-age cinder cones. Antelope bitterbrush is the dominant shrub, with rubber rabbitbrush and wax currant also common. Mountain big sagebrush occurs on more favorable sites. Common forbs include sulfur buckwheat, dwarf buckwheat, dwarf monkeyflower, and deceptive groundsmoke. Grasses include Thurber needlegrass, squirrel tail, and Sandberg bluegrass. Bluebunch wheatgrass is limited to more favorable microsites.

Type 6: Cinder Gardens (2.2 percent of monument)

A cinder surface and low total plant cover (generally less than five percent in mid-summer) separate this community from all others. It is dominated by dwarf buckwheat, which is conspicuous due to its persistent leaves. Species common into mid-July include silverleaf phacelia, bristly cryptantha, hoary aster, Douglas chaenactis, thorn skeleton plant, and narrowleaved skeletonweed. In June, when growing conditions are most favorable, dwarf monkeyflower, Sukdorf's mimulus, dwarf onion, and bitterroot lewisia are common. Some areas of this type are devoid of higher plants due to extremely harsh conditions.

Procedure:

1. Divide the class into six groups and assign each to one of the six areas shown on the map. The groups should work simultaneously to conserve time. If you are travelling by bus, drop off each group and then have the bus return to pick them up in the same order, so each group has an equal amount of time to complete their work. If you are travelling by car, each group can car pool to their location, and the entire group can reconvene at a specified time.

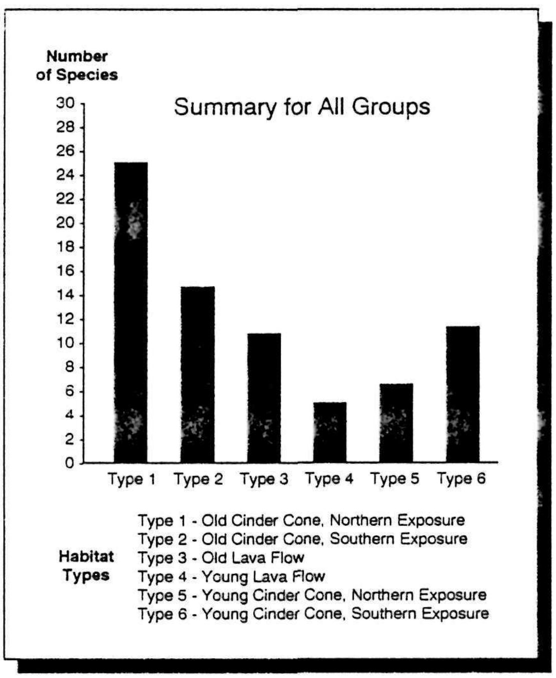
3. In each habitat, mark out an area 10m by 15m using stakes and surveyors tape. Photograph the site for later reference during the discussion at school.

4. Complete the activity 6A work sheet, recording environmental conditions and plants observed. If students are unable to identify certain plants with the resource materials provided, they may simply include a description.

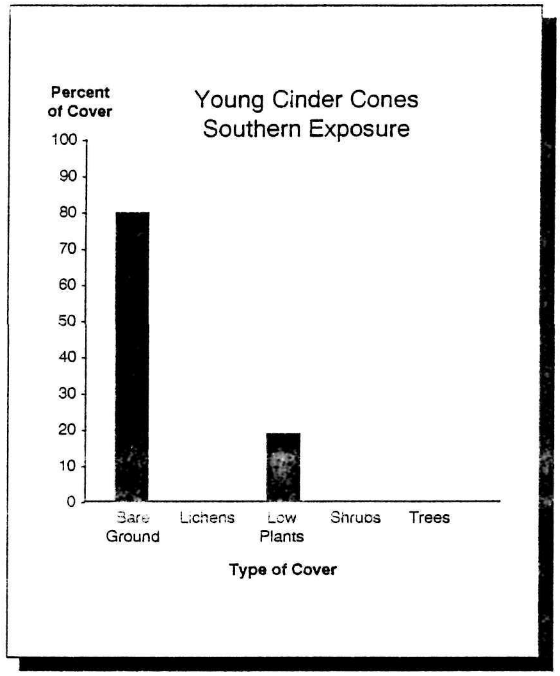
5. After returning to school, quantify your results. You may post the following chart on the wall and have each group complete their portion.

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Soil Surface Temperature						
% of Shaded Ground						
Soil Moisture						
Age of Volcanic Deposit						
# of Species						
# of Plants						

6. Then have students prepare a series of graphs to display the above data. These can be done in a large format and posted so that everyone can compare results in a group discussion. Assign each group to do two graphs. The first should show percentage of different types of plant cover for their habitat type. Have them post one or more of the photos they took of their habitat type with this graph. Here is an example of such a graph:



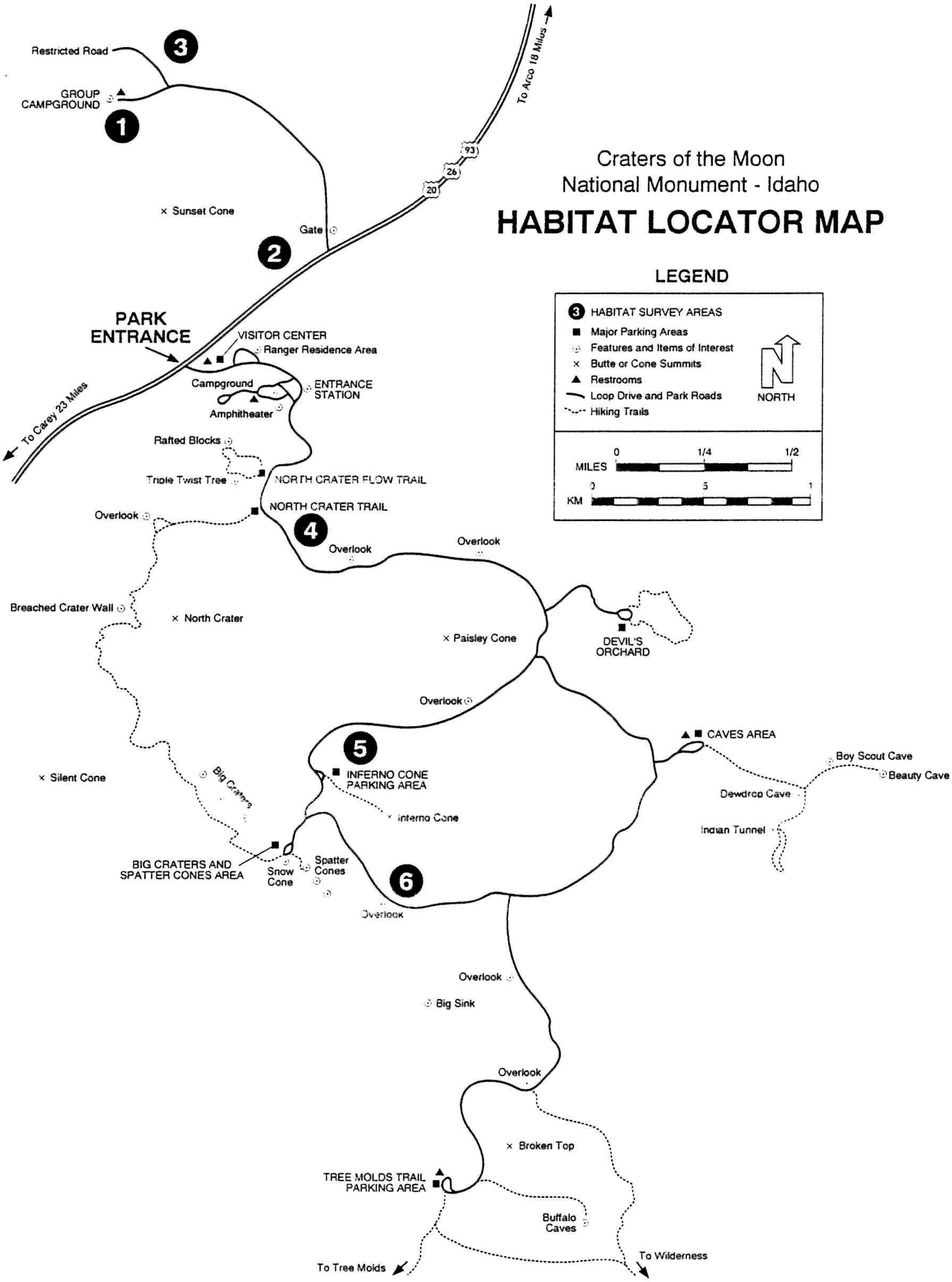
The other should summarize data for all groups on one variable (soil surface temperature, percent of shaded ground, soil moisture, lava age, number of species, or number of individual plants). Assign one variable to each group so there is no overlap. Here is an example of one such graph:



7. Have students assign their habitat type a name based on the plants they found to be most numerous or conspicuous there. You may then share with them the descriptions of their habitat types from the vegetative mapping project (included in the background information above.)

8. Have students write down answers to the following questions. Then lead a group discussion of their results. What factors appear to determine the types of plants found in an area? Which habitat type is most diverse? Least diverse? How does the age of a lava deposit affect the plants found there? Why do plant communities change through time? How does northern versus southern exposure affect plant communities? Why?

ACTIVITY 6A
MAP



Habitat Inventory for Craters of the Moon

Names of Observers____

Date ______________________________ Time of Day__________________

Habitat Type:

_______ #1 Old cinder cone, northern exposure
_______ #2 Old cinder cone, southern exposure
_______ #3 Old lava flow
_______ #4 Young lava flow
_______ #5 Young cinder cone, northern exposure
_______ #6 Young cinder cone, southern exposure

Environmental Conditions:

________Soil surface temperature
________Estimated percent of shaded ground
________Fuel moisture stick weight
________Relative humidity
________Air temperature
________Direction of slope
________Age of volcanic deposit

Describe the soil in terms of color and texture.

How many different species of plants are present? It does not matter if you can name them all; simply differentiate species from one another and count types.

How many individual plants are present within your study plot?

Identify the five most numerous species in your transect. What are they?

____
____
____
____
____

Estimate percentages for the following types of ground cover:

________Bare ground
________Lichens
________Low growing plants (forbs, herbs, ferns, mosses, etc.)
________Shrubs
________Trees (estimate canopy cover)

Instructions for Measuring Environmental Conditions

1. **Soil Surface Temperature**
   Using the thermometer with the long stem attached, insert the stem in the soil just below the surface. Wait for 1 minute and then record the temperature.

2. **Estimated Percent of Shaded Ground**
   Look at the ground in your plot and estimate how much of the ground surface is in shade.

3. **Fuel Moisture Stick Weight**
   You will find a rack with a fuel moisture stick on it at your site. Pick up the fuel moisture stick by the hook and lay it on the scale from the support kit you picked up at the Visitor Center. **Make sure you do not touch the wooden part of the stick, as the oils in your skin will throw off your results.** Make note of the weight. The fuel moisture sticks weigh 100 grams when dry and provide a relative measure of how much moisture is in the soil:

< 105 grams = very dry	105-107 grams = dry
107-110 grams = moderate	110-115 grams = moist
> 115 grams = wet	

4. **Relative Humidity**
   A psychrometer is a reliable instrument for determining relative humidity and temperature. Air is passed over a dry mercury thermometer and a second, identical thermometer that is covered by a wetted muslin wick. The wet bulb always reads lower than the dry bulb because of the cooling effect of the evaporating water. The drier the air, the lower the reading. The two temperature readings are recorded. The relative humidity is then calculated from a psychromatic table, provided in the support kit.

   Wet the wick with distilled water. **Be careful not to touch the wick, as the oil in your skin will destroy its ability to absorb water.** Then swing the psychrometer at the end of its chain for 1 minute. **Be careful not to hit anyone or anything!** Read the wet bulb immediately and then the dry bulb. Repeat the procedure until two or more wet bulb readings are the same. Consult the psychromatic table to determine the relative humidity. Enter the dry bulb reading as your air temperature.

5. **Direction of slope**
   If your site is on a slope, use the compass in the support kit to determine what direction the slope faces. If it is on flat ground, write "flat" on the inventory sheet.

6. **Age of Volcanic Deposit**
   Use the map of the lava deposits in the support kit to determine the age of the lava at your site.

Reading on Kipuka Research

This reading will introduce students to some broad themes in ecology and their application through research at Craters of the Moon. Students will answer study questions on this topic following the reading.

Objective:
Students will be able to describe the impact of kipuka size and remoteness on species number and population size.

Duration:
1 hour in the classroom

Materials:
Reading material, pen, paper

Background Information:
Although Craters of the Moon is not an island, there are landforms present called kipukas which have island-like characteristics. Kipukas form when a lava flow surrounds, but does not cover, a piece of ground, often the top of an older cinder cone. Kipuka is the Hawaiian word for island. Kipukas are of particular scientific interest because they preserve relatively pristine remnants of native vegetation, only minimally affected by fire and grazing. A 1962 presidential proclamation added Carey Kipuka (180 acres) to the monument, on the basis of its scientific value for ecological studies.

Island biogeography is a theory used in ecological studies to explain and predict population composition of island communities. The theory of island biogeography holds that the number of species living on an island is directly related to the size of the island and its distance from other land. Smaller habitats can support fewer species than larger ones and greater isolation leads to reduced immigration. In considering the application of this theory the nature of the barrier becomes important. On true islands, water represents a nearly impassable barrier for most terrestrial species. Habitat islands, on the other hand, are surrounded by only partially impassable barriers, like lava flows, thus reducing the effect of isolation.

In 1982 a scientist conducted research on 14 kipukas in the Craters of the Moon lava field to test the equilibrium theory of island biogeography. Individual kipukas covered 0.16-3.6 hectares (a hectare is 10,000 square meters) and were isolated from the "mainland" by 70-1800 meters of lava. Researchers trapped small mammals and lizards and sampled vegetation on each kipuka. A summary and possible explanation of the study results follows.

Procedure:
1. Read the summary of the kipuka study at Craters of the Moon and then answer the questions on the activity 6B work sheet.

Patterns in the Distribution of Plants and Animals on Lava Flows and Kipukas in Southeastern Idaho

Excerpts from a Masters Thesis by Steven H. Lovejoy 1980

The equilibrium model of the theory of island biogeography (MacArthur & Wilson 1967) postulates that the number of species on an island is the result of an equilibrium between two counterbalancing forces: extinction and immigration. Because populations fluctuate in size, below a certain level the population—and possibly the species in a localized area—will become extinct. The smaller the island, the more likely extinction becomes, due to smaller population size. Reestablishment of the species depends on immigration of new individuals into the area, which varies with how isolated the island is. The data collected in this study can be used to test two predictions derived from the equilibrium model.

Species-Isolation Effect
The first prediction is that for a set of kipukas of similar size, the more isolated kipukas will have lower rates of colonization, and therefore fewer species, than kipukas closer to the mainland.

This prediction is not true for plant species on kipukas. This is probably because the persistence of individuals of perennial species is long relative to immigration rates. The isolation effect would be important only in systems where short-lived plants predominate. In addition, the lava apparently does not provide a broad enough barrier to prevent plant dispersal.

This prediction is also not true for animals species. The location and numbers of small mammals captured permits a rough evaluation of how significant a barrier to dispersal the lava is. Four species made up 96% of all small mammal captures. The deer mouse, by far the most common species trapped in any habitat, comprised 83% of all captures. Bushy- tailed woodrats nest and breed on the lava and their distinctive urine markings were seen at the perimeter of every kipuka. Mountain cottontail ranges widely over lava, for we saw cottontails and rabbit scat on lava far from any kipuka. I observed least chipmunk a number of times on lava and trapped them more often than any species except deer mice. Although the lack of vegetation on the lava may limit population sizes of these animals, it apparently does not restrict their presence or ability to disperse. These four species have a very low probability of extinction on kipukas, because there is a permanent pool of potential colonists in the lava nearby to move into vacancies in the favorable kipuka habitats. Obviously, there will be no isolation effect if lava is not a barrier to the animals, and none was observed.

It is much less likely that the other species trapped—Great Basin pocket mouse, Townsend's ground squirrel, montane vole, and western harvest mouse—actually reside on lava. In no instance did I see or capture any of these species on lava. On the other hand, they were not very common on kipukas either. I captured only 24 individuals of these four species, in most cases one per kipuka. Given the high trapping intensity on kipukas, it is fair to assume that single individuals are immigrants to the kipukas rather than representatives of established populations.

Although seven individuals are not enough for a firm conclusion, a weak isolation effect was apparent for these immigrants. It is suggestive that four of the immigrants were captured in an area sandwiched between two major species sources and another less than 100m from the mainland. Both of the immigrants caught on isolated kipukas were ground squirrels, which appear to disperse better than the other three rare species.

Isolation seemed to play no role in the number of reptile species present on a kipuka. But, in light of the abundance of the desert short-horned lizard on mainland close to the lava's edge, its total absence on kipukas suggests that lava is more of a barrier to the dispersal of this slow-moving reptile than for its quicker relatives.

Density-Isolation Effect

One interesting and unexpected isolation effect does exist: the density of animals increases, rather than decreases, with isolation. There are several possible explanations for this phenomenon. Perhaps animals nest in lava but forage communally on a the richer food sources of a nearby kipuka. Trapping the kipuka but not the lava would produce the impression of high density when, in reality, animals that resided elsewhere were being counted. The fact that the isolated kipukas show almost no trapping-out effect supports this hypothesis. Generally when trapping small mammals, the number of individuals captured declines steeply from the first to succeeding days. If animals trapped were coming from outside of the trapping area this decline wouldn't occur.

Another possible mechanism for increased density on isolated kipukas involves predation. Predation pressure on kipukas is likely to be intermittent, particularly on small kipukas. These kipukas are probably not large enough to support a snake population, individual coyote, or other large predators. So, in between periods of intense predation, kipukas may enjoy periods of total release from predation pressure. During these lulls, small mammal populations may build up to densities that greatly exceed densities on less isolated kipukas, where predators may forage more frequently.

Species-Area Effect

For most species, the larger a kipuka the higher the number of individuals of any species that can live there. If the MacArthur-Wilson model is correct, larger populations sizes will result in noticeably lower rates of extinction, and therefore higher numbers of species. The second prediction of the MacArthur-Wilson model, then, is that larger kipukas will have larger numbers of species. This prediction is true for both plant and animals species on kipukas.

The MacArthur-Wilson model is also relevant in accounting for the number of small mammal species on kipukas. The relevance of the MacArthur-Wilson model is apparent in an analysis of minimum area requirements necessary for maintenance of populations. Of the small mammal species observed on kipukas for which lava poses an impediment to dispersal, three species had established populations.

None of these was on a kipuka less than three hectares in size. The species involved did not appear to be restricted to a particular type of habitat unavailable on smaller kipukas, nor was the increase in environmental heterogeneity on kipukas of larger size important to the individual species. Instead it is possible that these species need an area of at least three hectares in this ecosystem to support a large enough number of individuals to maintain a population. Perhaps those species without populations on the study kipukas have minimum area requirements greater than three hectares.

There are alternative explanations for the absence of certain small mammal species. There might be a lack of suitable habitat on kipukas for some species. For instance, Ord's kangaroo rat is generally associated with sandy soils for digging, and only one trapped kipuka met this criterion. If a species were absent from the mainland immediately adjacent to the lava flow, there would be no source of immigrants to colonize kipukas. Lava might be a very effective, perhaps impenetrable barrier to some species. Probably the observed distribution of small mammal species is the result of a number of such mechanisms operating together.

Summary of Results

1. Contrary to the prediction of the MacArthur-Wilson model, the number of plant species on a kipuka did not depend on how isolated it was. Lava probably poses a scant barrier to plant dispersal, so that the persistence of individuals of perennial species is long relative to immigration rates.

2. Contrary to prediction, the number of small mammal species on a kipuka did not depend on how isolated the kipuka was. Data indicate that, although lava restricted the dispersal of some species, it did not restrict others. These other species made up over 96% of all small mammal captures. Considering only the 24 captures of individuals of those species that lava did restrict, there was an isolation effect.

3 The number of plant species on a kipuka depended on the size of the kipuka, as predicted by the MacArthur-Wilson model.

4. The number of small mammal species on a kipuka depended on the size of the kipuka, as predicted by the MacArthur-Wilson model. Considering only those small mammal species restricted by lava heightened the species/area effect.

6. More isolated kipukas had higher densities of small mammals than less isolated kipukas. There are two plausible explanations for this result. Faunas of small, more isolated kipukas may have had longer periods of release from predation pressure. Or small mammals on isolated kipukas may nest in the lava but forage on kipukas, so that trapping just the kipuka reveals an artificially high density.

7. Many small mammal species appeared to have a minimum space requirement in order to establish a population. Of the species for which lava is a barrier, there appeared to be three populations established on kipukas. No populations existed on kipukas less than three hectares in size. Other species often encountered in mainland habitats may have been absent from the kipukas studied due to minimum area requirements greater than the size of the largest study kipukas.

Questions on the Island Biogeography Study at Craters of the Moon

1. What two predictions does the MacArthur-Wilson model make about the relationships between species number, area size, and area isolation?

2. Did the researcher's results support or contradict these predictions?

3. What explanation is offered for these results?

4. What is the third, unexpected effect that was observed? What explanation is given for these results?

5. What kind of barrier does lava provide to plant dispersal? Animal dispersal?

Mule Deer Census

Students will assist monument staff with the seasonal mule deer census and will learn how to interpret the data they gather.

Participating in this activity requires an early morning trip to the monument; ideally a class might spend the night so they could hit the trail soon after sunrise. Deer censuses are conducted annually April-early June and August-early September. Participating in the census provides an excellent hands-on experience for small groups (20 or less) of interested students. The data students collect may actually be incorporated into the National Park Service census statistics for the year.

Objective:
Students will be able to describe the unique ecology of the Craters of the Moon deer herd, the deer monitoring program, and the significance of the data they collected.

Duration:
3 hours at the monument, 1-2 hours in class to analyze and discuss data

Materials:
Activity 6C work sheets 1 and 2, pencils, binoculars and a spotting scope, hiking gear

Background Information:

Deer Herd Migration

In 1980, researchers began a study of the Craters of the Moon mule deer. Biologists collected information about the reproduction, mortality, distribution and movement of the herd. Prior to this research, it was not known how many deer lived within the monument's boundaries, if the population was increasing or decreasing, and whether the herd was healthy.

To answer these questions, researchers captured 100 deer and marked them with colored ear tags. These brightly colored streamers allowed researchers to identify each deer. They also attached radio collars to twenty deer to help track their day-to-day movements. By observing the deer over the next three years, researchers recorded 2,381 deer sightings and completed a life history on each animal. The analysis of this research provided some surprising information.

Specifically, researchers had not anticipated the unique dual migration pattern they found. The deer have a traditional fall/spring migration with movement between summer and winter ranges and a second migration that takes place during the summer. The dual migration works like this. Each year as the snow melts, more than 400 deer leave their wintering grounds at lower elevations to arrive at the monument in late April or early May. About one-half of the herd heads into the northern section of the monument where there is a good supply of herbs and shrubs. Rainfall in March and April is plentiful and small creeks, ponds or puddles provide water for this group of deer. The remainder of the herd goes to the southern part of the monument. In this area, because of the porous lava, no standing water exists. There is plenty of nutritional antelope bitterbrush, however, and when the deer eat this plant they are getting both food and the moisture they need.

When summer arrives temperatures rise and the rain stops. Springs that run year-round continue to provide water for the northern deer herd. In the southern area of the monument, however, the vegetation begins to dry out and the deer find it difficult to get enough water.

Researchers determined the exact conditions, usually in July or August, when the lack of water reaches a critical point for these deer. This happens during any 12-day period in which daytime temperatures are more than 80 degrees Fahrenheit and nighttime lows don't drop below 50 degrees Fahrenheit. These sustained high temperatures dehydrate plants to a point where they no longer provide enough moisture to assure the southern deers' survival. Then, the southern herd moves rapidly north. The deer population in the northern end of the monument doubles in as little as two weeks. The deer find themselves living in a situation comparable to a house with several people living in each room. They must endure these crowded conditions until rain comes and some of the deer move south again. If it doesn't rain, the entire deer herd remains in the northern end of the monument until fall. Then they return to their winter range. Scientists now see this dual migration as a specific adaptation of the deer herd to the Craters of the Moon environment—one that allows them to survive despite extremely hot summers and a marginal water supply.

Monitoring the Deer Herd

The deer monitoring program provides a yearly measure of mule deer population size, herd productivity, and overwinter fawn survival. The information gathered allows the National Park Service to gain an understanding of year to year variation in the population and to identify long-term changes. Deer censuses are conducted in the spring and late summer each year. As soon as deer begin to arrive in the monument in April, the staff begins to document the sex and age of all deer seen. Sampling continues through the month of May and the first two weeks of June until at least 100 and preferably 200 animals have been classified.

The late summer census takes place between August 15 and September 15. Park staff conduct six early morning censuses from a vehicle along the 3.9 mile section of dirt road that runs from Highway 26 into the northern section of the monument, where most of the deer reside at that time. The censuses begin 10 minutes after sunrise and take 1-2 hours. The ranger carefully scans the terrain along the road with binoculars or a spotting scope, and records all deer visible. The deer are classified as either adult males, yearling males, females, or fawns.

Deer killed by automobiles on the highway and by hunters around the park boundary provide an estimate of population trends independent of the late summer census. Information on the date, number, sex, and age of these animals is recorded as a check on the roadside censuses.

Procedure:

1. Conduct an early morning walking tour on the wilderness trail. You can go as far as the lava trees, a 3 mile round trip, or if time is limited, hike the 2 mile round trip to Buffalo Caves. Ask at the Visitor Center for more detailed information about these trails. You may want to divide into small groups and hike several different trails. Groups could, for example, hike to the tree molds, the lava trees, and the North Crater Trail. Small group size is a distinct advantage for this activity, because the quieter and more attentive the students are, the more likely they are to observe deer.

2. Use the "Mule Deer Census Form" to record your data. You will classify all deer seen as adult males, adult females, yearlings, or unknown. Yearlings may be differentiated from adults based on body size and the ratio of ear length to lower jaw length. Deer with ears longer than the lower jaw are yearlings; those with ears the same length or shorter than the

lower jaw are adults. Use a spotting scope or binoculars to obtain a profile view when aging the deer.

3. When data collection is complete, make the calculations on work sheet 2 "Calculating Overwinter Fawn Survival," to determine what percentage of fawns survived the winter. Determining overwinter fawn survival is the primary objective of the spring census. For example, in the late summer of 1982, there were 94 fawns per 100 adult females and in the spring of 1983, there was a classification ratio of 73 yearlings per 100 adult females. Overwinter survival is then indexed as 73/94 x 100 or 88 percent. (This procedure will overestimate overwinter survival fawns depending on the winter mortality of adult does. The more adult does that die in winter, the greater will be the overestimation.)

4. Most groups are unable to visit the monument in September to participate in the more extensive census conducted at that time. Park staff analyze the data collected in August and September to determine an estimate for population size and relative size, sex, and age classes of deer. If you are interested in more extensive statistical analysis of the deer census data, the monument will provide you with data from the most recent fall census on request. Sample data from 1993 is included here for your use if you prefer. Complete the "Analysis of Fall Mule Deer Census Data."

Mule Deer Census Form

Date______________________

Previous Winter (check one): Mild____ Average____ Severe____

Time: Begin__________ End_________

Observers:____

Weather:

Temperature_________ Wind Speed_________ Cloud Cover______________

Number Of Deer Observed			
Adult Males	Adult Females	Yearlings	Unknown

Ratio: _________ : 100 : _________ : _________

Total Number of Deer Observed_________________

Calculating Overwinter Fawn Survival

Number of Previous Fall Fawns:.. ___________

Number of Previous Fall Does:.. ___________

Fawns per 100 Does **(F ratio)** .... ___________
(number of fawns divided by number of does times 100)

Number of Spring Yearlings.. ___________

Number of Spring Does.. ___________

Number of Spring Yearlings per 100 Does **(Y Ratio)**.................. ___________
(number of yearlings divided by number of does times 100)

Overwinter Survival .... ___________
(as a percentage of fawn population Y ratio divided by F ratio)

Analysis of Fall Mule Deer Census Data

1. **Number of deer per census**
   The average number of deer seen per census is the yearly index to population trend. Calculate the mean for the total number of deer in each sex and age class for the six samples collected in the fall of this year. (Add the number of deer seen in the six samples for each age class and divide by six to get the mean.)

2. **Sex and age ratios**
   Combine the data from the six censuses and calculate the ratio of adult males, yearling males, and fawns per 100 females. To accomplish this, divide the total number in each age class by the number of females and multiply by 100. For example, consider a series of six censuses which yielded a total of 75 deer that included 10 adult males, 4 yearling males, 25 females, and 31 fawns. The classification would be calculated as follows:

$$\frac{10 \text{ adult males}}{25 \text{ females}} \times 100 = 40 \text{ adult males to}$$

$$\frac{4 \text{ yearling males}}{25 \text{ females}} \times 100 = 16 \text{ yearling males to}$$

$$\frac{25 \text{ females}}{25 \text{ females}} \times 100 = 100 \text{ females to}$$

$$\frac{31 \text{ fawns}}{25 \text{ females}} \times 100 = 124 \text{ fawns}$$

   Disregard deer of unknown sex and age classes when making these calculations.

3. **Estimating the Number of Deer in the Craters Herd**
   During research conducted in 1980-82, biologists estimated the size of the deer herd both through the census procedure still in use, and by marking and recapturing deer. The relationship between the average daily standard census totals and mark-recapture population estimates was quantified and enables us to continue to estimate the size of the deer population based on our census figures.

   Where y = mark-recapture population estimate and x = average daily standard census total, the regression equation relating y and x is $y = 7.295x + 19.056$. To estimate the late summer total deer population, (y), substitute the average daily standard census total for x in this equation and solve for y. For example, if the average daily standard census total (x) is 50. Then

$$y = (7.295)(50) + 19.056 = 384 \text{ deer}$$

4. The 95 percent confidence interval on this estimate is given by the following equation, where y = late summer deer population (from calculation in #3) and x = average daily census total (from calculation in #1).

$$y \pm 12.706\sqrt{43.22\left(1.33 + \frac{(x - 58.8)^2}{277.26}\right)}$$

So the 95 percent confidence interval on y in this example is

$$384 \pm 12.706\sqrt{43.22\left(1.33 + \frac{(50 - 58.8)^2}{277.26}\right)}$$

which is equivalent to 384 +/- 106.0. In other words, there is a 95 percent confidence that the total number of deer lies between 278 and 490.

Summary of Standard Deer Censuses 1992

Sex and Age Class	Census 1	Census 2	Census 3	Census 4	Census 5	Census 6
Adult Males	5	0	0	3	2	4
Yearling Males	1	3	0	3	0	2
Females	25	24	17	15	25	14
Fawns	24	14	10	13	19	7
Unknown	0	0	0	0	0	0
Total	**55**	**41**	**27**	**34**	**46**	**27**

Summary of Standard Deer Censuses 1993

Sex and Age Class	Census 1	Census 2	Census 3	Census 4	Census 5	Census 6
Adult Males	0	1	0	0	0	0
Yearling Males	0	0	0	0	0	0
Females	11	8	2	0	7	6
Fawns	6	9	2	0	7	4
Unknown	0	0	0	0	0	0
Total	**17**	**18**	**4**	**0**	**14**	**10**

Results of the Fall Mule Deer Census Calculations

	1992	1993
Mean Number of Deer for the Six Fall Censuses:		
Adult Males	2.3	0.17
Yearling Males	1.5	0.0
Females	20.0	5.7
Fawns	14.5	4.7
Total Sample	38.33	10.5
Sex and Age Rations:		
Adult Males	11.7	2.9
Yearling Males	7.5	0.0
Females	100.0	100.0
Fawns	72.5	82.4
Late Summer Total Deer Herd Estimate	299	96
95% Confidence Interval on Mule Deer Population Size	299 +/- 141	96 +/- 261

Exotic Plant Monitoring and Removal

Students monitor the presence of exotic plants in a disturbed area of the monument, and assist the National Park Service in removing them.

Objective:
Students will be able to define what an exotic plant is, describe how exotics can threaten natural ecosystems, and explain the National Park Service approach to managing exotic species.

Duration:
1 hour classroom preparation, 2 hours at the monument, 1 hour after return to school

Materials:
Park ranger, activity 6D work sheets, pencils, work gloves, stakes and surveyors tape, plant field guides (available in support kit at the Visitor Center)

Background Information:
Exotic species are ones that humans intentionally or inadvertently introduced into an area outside of the species' natural range. Most exotic plant species have only minor impacts on natural ecosystems. A small group of exotic plants, however, can be extremely disruptive. They may damage historic and archeological resources, interfere with natural processes, and threaten the survival of naturally evolved plant communities and individual native species.

The National Park Service has as a goal the maintenance and restoration of not only individual species but all the components and processes of naturally evolving ecosystems. Therefore, controlling exotic species that have substantial impacts on park resources is a high priority. Low priority is given to species that cause little damage or are virtually impossible to control.

Exotic plants are especially common in areas where construction, road building, or other human activity disturbs the soil. They often have a competitive edge over indigenous plants when they invade an altered site. Therefore, most of the exotic plants at Craters of the Moon are concentrated along the highway, and the dirt road and streams in the northern part of the monument.

The following are the most widespread exotic plants that occur within the monument:

bull thistle	*cow parsnip*	*field pennycress*
Canadian thistle	*common mullein*	*common burdock*
western salsify	*dandelion*	*Russian thistle*
cheatgrass	*diffuse knapweed*	*spotted knapweed*

Most of these plants are in isolated pockets and are not currently a threat to native ecosystems. Others, like cheatgrass and field pennycress, are so widespread that control efforts would have little success.

Common mullein is one of the most conspicuous exotic plants at Craters of the Moon. The plant was originally imported from Europe for its ornamental qualities, but soon escaped the confines of the home garden. Mullein quickly expanded its range over most of the temperate areas of North America. Common mullein is an example of how difficult it can be to eradicate a non-native species once it has become established.

In the 1980s the monument staff, faced with extensive stands of these plants, decided to fight back.

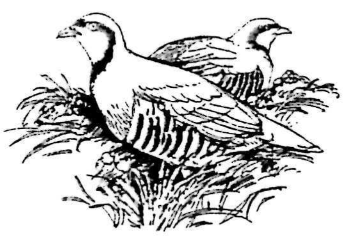
Round 1. Staff pulls mullein out by the roots. Mullein expands even more rapidly because it grows well in the disturbed site left behind.

Round 2. Staff clips seed heads from plants. Mullein quickly grows two new seed heads to replace each lost one.

Round 3. Staff cuts the plant's stalk where it joins the root with a spade or applies a herbicide directly to the mullein. Mullein sprouts the following year from seeds that remain viable for up to fifty years.

Round 4. Staff analyzes the results of their efforts for the last three years. No headway has been made in eradicating the mullein.

The National Park Service is still trying to prevent the spread of mullein into new areas, but it is a daunting task which will require concerted effort over a long period of time. Although complete eradication is likely impossible, the monument is having some success eliminating mullein along the highway corridor.



Exotic Animals

Exotic animal species have also invaded the monument and upset the natural balance of the ecosystem: the European house sparrow, European starling, chukar, grey partridge, and domestic pigeon. The starling and sparrow, both introduced from Europe, compete aggressively with native birds for the limited nesting holes in trees. If the number of starlings and house sparrows continues to grow, native cavity nesters like the bluebird may be severely affected.

Game managers introduced chukars into Idaho from Asia to provide another upland game bird for hunting. Because harsh winters greatly reduced the population, it has not become a threat to native species. There is anecdotal evidence that the number of domestic pigeons in Indian Tunnel is rapidly increasing, and that the nesting pigeons are displacing native violet-green swallows. Resource managers at the monument hope to establish a system to monitor the domestic pigeons and assess what impact they are having. If the impact on the violet-green swallows is serious, the monument will explore options for their removal.

Procedure:

1. Contact the National Park Service to set up a date when a member of the staff can accompany your group and lead the exotic species eradication section of this exercise.

2. As preparation in the classroom, discuss what exotic plants are, the threat they may pose to native ecosystems, and why the National Park Service seeks to eradicate them.

3. Upon arrival at the monument you will travel by dirt road into the "North End" of the monument, where exotic species are most heavily concentrated. The Park Service has marked a permanent location for the monitoring grid. Mark off one square meter at the marked location.

4. Complete the activity 6D "Exotic Species Work Sheet." They may refer to the plant identification materials and field guides available in the support kit at the Visitor Center to assist in identifying plants. Your school may want to consider using the same grid location from year to year to assess whether any change in plant community composition is occurring through time.

5. If time permits, the park ranger can guide your group in removing exotic plants in a small area.

6. Upon your return to school, have the students complete the questions on the back of the "Exotic Species Work Sheet."

This project has real value to the monument, both in terms of providing data on trends in exotic species populations through monitoring, and through assisting with eradication efforts. Please emphasize to your students that this is not just an exercise, but a real project of benefit to the park and we appreciate their assistance.

Exotic Species Work Sheet

Group Members____

Describe any signs of soil disturbance. Is it natural or caused by people?

Using the identification materials provided, look for the following types of exotic plants and mark down how many of each are present in the test plot. If you do not see any of a particular type of plant, enter a zero.

Bull thistle ________________________________

Canadian thistle ____________________________

Western salsify _____________________________

Cheatgrass _________________________________

Common Mullein _____________________________

Dandelion __________________________________

Diffuse Knapweed ____________________________

Field Pennycress _____________________________

Common Burdock _____________________________

Russian thistle _______________________________

How many species of native plants are present? (It does not matter if you know their names; simply count the different types).

How many individuals of native plants are growing in the test plot?

1. What is an exotic species?

2. What are some ways that exotic species can have a negative impact on the natural ecosystems they invade?

3. Why does the National Park Service eradicate certain harmful exotic species? Do you believe that it is a worthwhile way of spending tax dollars? Why or why not?

4. Do you know of any exotic plants or animals present in your home environment? There are probably hundreds!

5. There have been many historical examples of the introduction of non-native species into island communities, with devastating results for indigenous species. Australia, New Zealand and Hawaii all provide interesting case studies. Choose one area that interests you and write a one page research paper documenting the effects of the arrival of a non-native species on an island.

Wildlife Management Questionnaire

Students will research, by interview and/or readings, how wildlife management policies differ among federal agencies, and make a presentation to the rest of the class based on their research.

Objective:
Students will be able to describe differences in wildlife management polices between the Bureau of Land Management, US Forest Service, and National Park Service.

Duration:
2 hours in the classroom

Materials:
Telephone, telephone books, pencil, paper, library vertical files

Background Information:

Idaho contains more federal land than any other state in the lower 48 except Nevada - more than two thirds of the state. These public lands are managed by various agencies of the federal government, each of which has a unique mission.

The US Forest Service (USFS), an agency of the Department of Agriculture, is responsible for the wise use of the nation's forested lands. National Forests are managed for a variety of services and products: timber, range, outdoor recreation, watersheds, fish and wildlife. The Forest Service strives to conserve resources and to sustain the yield of forest products and services indefinitely. There are 14 National Forests completely or partially in Idaho, totalling more than 28 million acres.

The National Park Service, an agency of the Department of the Interior, manages four areas in Idaho: Craters of the Moon National Monument, Hagerman Fossil Beds National Monument, Nez Perce National Historical Park, and City of Rocks National Reserve (more than 66,000 acres in all). It is the NPS mission to preserve and protect wildlife and other park resources, while encouraging visitors to use and enjoy the parks. Because the emphasis in National Parks is on preservation, rather than conservation of resources, activities which are permitted on other federal lands are prohibited in most parks and monuments: hunting, trapping, grazing, mining, logging, and others.

The Bureau of Land Management (BLM), an agency of the Department of the Interior, controls lands not suitable for agriculture or inclusion in National Parks or Forests. In Idaho more than 22% of the state (12 million acres of land) is under BLM jurisdiction. Like the Forest Service, the BLM emphasizes multiple uses of the land. Livestock grazing and outdoor recreation are predominant on BLM lands.

Procedure:

1. Break the class into 3 groups. Then assign each group to contact an office of either the Bureau of Land Management, Forest Service, or the National Park Service to acquire answers to the following set of

questions. The students may request written information and/or interview an agency representative. Alternatively, they may conduct research in the school or town library to find pertinent information. They will use the information they gather to prepare an oral presentation on the policies of their agency for the rest of the class.

2. Once students have completed gathering information, have each work group prepare a 10 minute presentation for the class. In order to ensure everyone's participation, you may divide the questions evenly among group members and have each person responsible for researching and presenting their subset of questions.

3. Following the presentations, lead a discussion on the similarities and differences in wildlife management between agencies. Which approach do they believe to be most valuable? Do they think the National Park Service is correct in prohibiting certain activities in parks?

Wildlife Management Questionnaire for Federal Agencies

1. What is the agency's mission?

2. What is the agency policy on hunting and trapping? Why are they or are they not permitted?

3. Is grazing permitted on the land the agency manages? Why or why not?

4. Are domestic pets permitted on hiking trails? Why or why not?

5. Is any kind of predator control conducted on agency lands? Why or why not?

6. Does the agency have any plans to reintroduce species of animals once present but extirpated by human activity (such as wolves, grizzly bears, or bighorn sheep?) If so, is there controversy over the issue? What groups favor or oppose reintroduction?

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