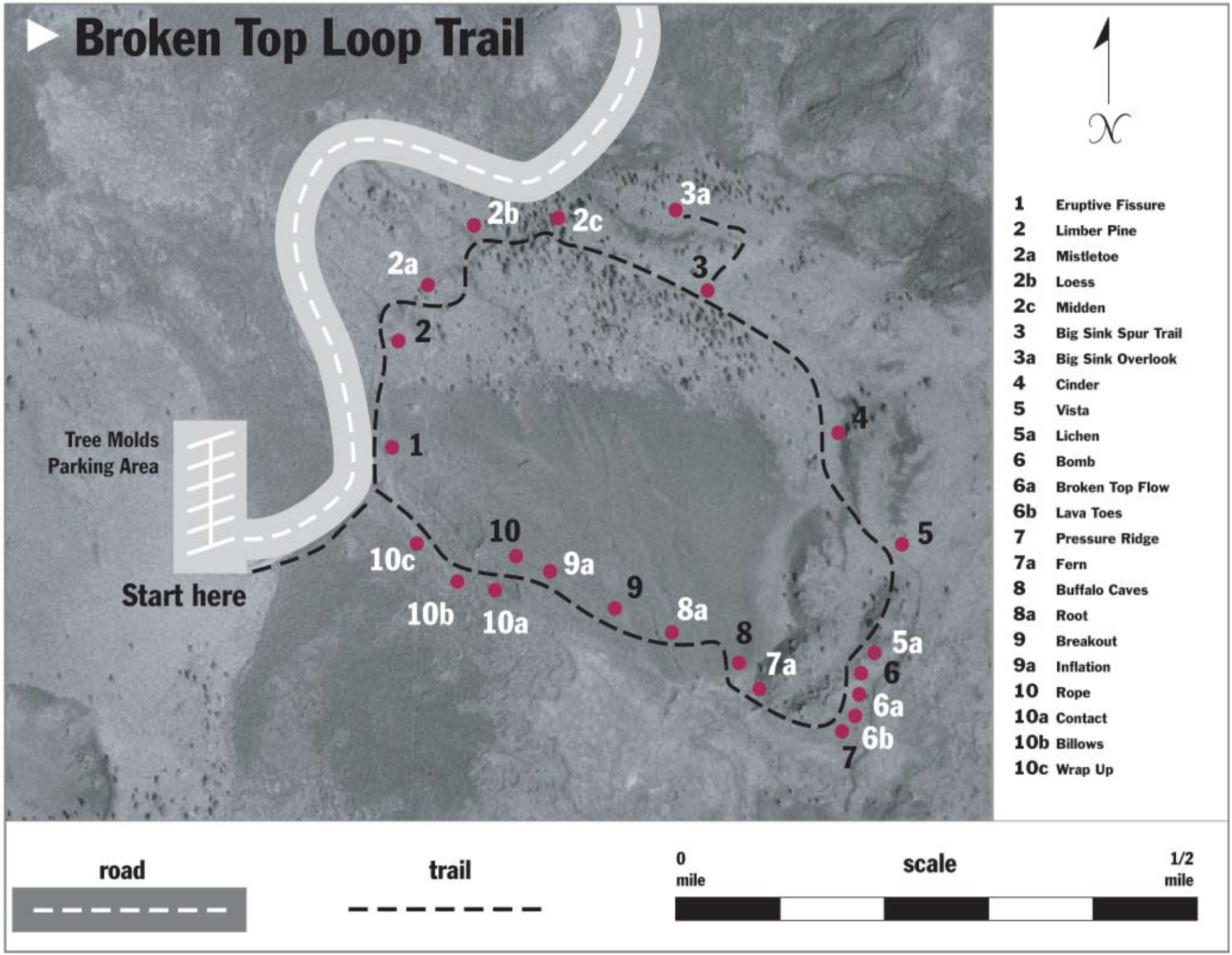
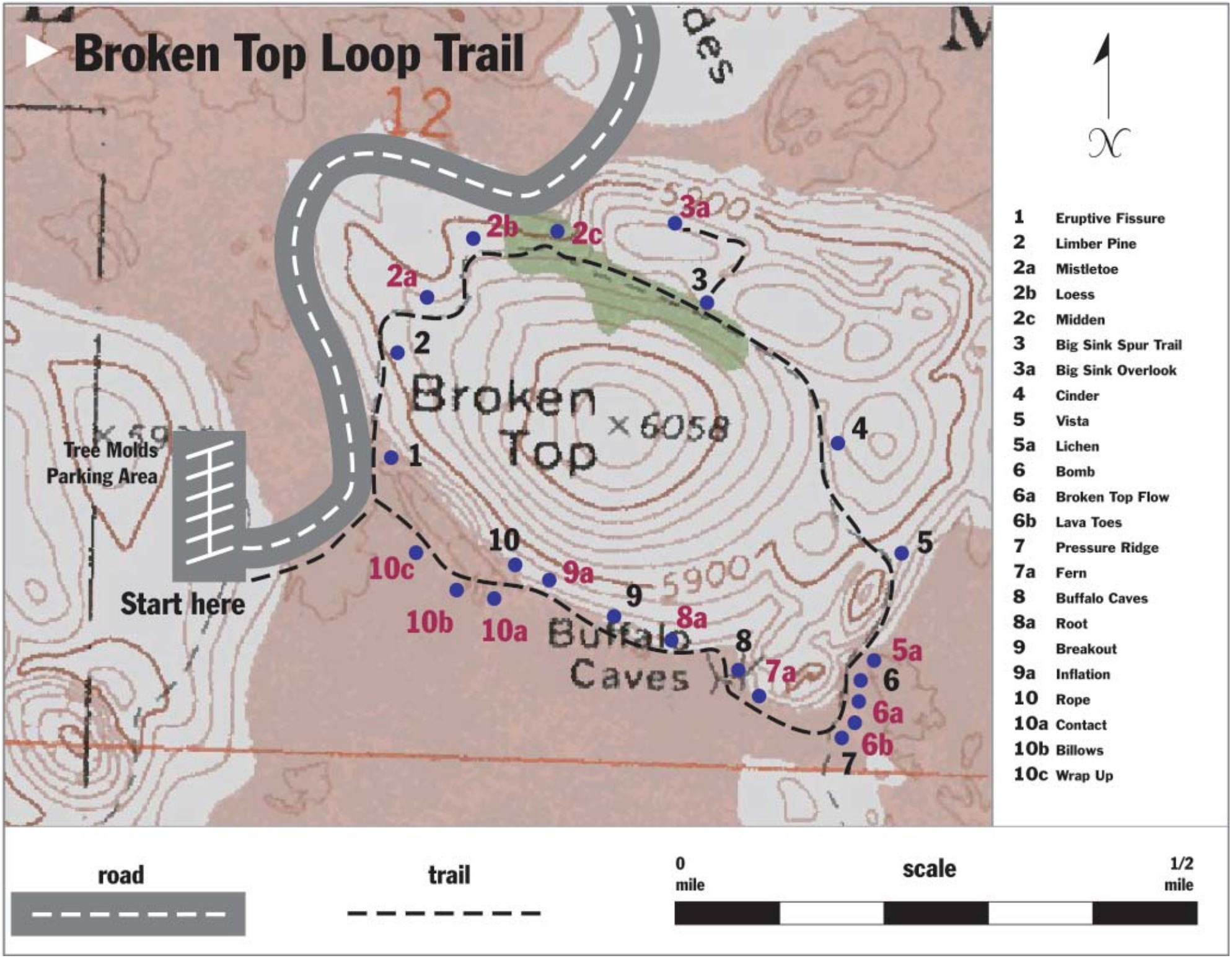
MAPS

Orthographic version
Topographic version


Broken Top Loop Trail
Tree Molds
Parking Area
Start here
1
2
2a
2b
2c
3
3a
4
5
5a
6
6a
6b
7
7a
8
8a
9
9a
10
10a
10b
10c
1 Eruptive Fissure
2 Limber Pine
2a Mistletoe
2b Loess
2c Midden
3 Big Sink Spur Trail
3a Big Sink Overlook
4 Cinder
5 Vista
5a Lichen
6 Bomb
6a Broken Top Flow
6b Lava Toes
7 Pressure Ridge
7a Fern
8 Buffalo Caves
8a Root
9 Breakout
9a Inflation
10 Rope
10a Contact
10b Billows
10c Wrap Up
road
trail
0
mile
scale
1/2
mile


Broken Top Loop Trail
12
Broken Top
x6058
Buffalo Caves
5900
Tree Molds Parking Area
Start here
1 Eruptive Fissure
2 Limber Pine
2a Mistletoe
2b Loess
2c Midden
3 Big Sink Spur Trail
3a Big Sink Overlook
4 Cinder
5 Vista
5a Lichen
6 Bomb
6a Broken Top Flow
6b Lava Toes
7 Pressure Ridge
7a Fern
8 Buffalo Caves
8a Root
9 Breakout
9a Inflation
10 Rope
10a Contact
10b Billows
10c Wrap Up
road
trail
0 mile
scale
1/2 mile

APPENDIX I

GEOLOGY OF CRATERS OF THE MOON NM
(simple version)

Craters of the Moon

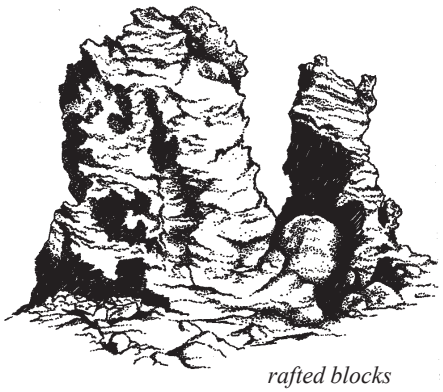
National Monument
U.S. Department of the Interior

Geology

Big Cinder Butte

WHAT MAKES CRATERS OF THE MOON SO SPECIAL GEOLOGICALLY?

Craters of the Moon is an outdoor classroom in which to study volcanic geology. It is the largest and most complex of the late Pleistocene (the last Ice Age) and Holocene basaltic lava fields of the Eastern Snake River Plain. In the past 15,000, years eight major eruptive periods formed the Craters of the Moon Lava Field. During this time the Craters of the Moon Lava Field grew to cover 618 square miles. In contrast, most of the other lava fields on the Eastern Snake River Plain (including the Kings Bowl and Wapi Lava Fields) represent single eruptions. The Craters of the Moon Lava Field consists of up to 60 lava flows and 25 cones.



rafted blocks

WHAT IS THE GREAT RIFT?

The Great Rift is a long line of fractures in the Earth's crust. It begins at the base of the Pioneer Mountains (north of the park's visitor center) and extends for over 50 miles to the southeast. The Craters of the Moon Lava Field is the northernmost of the 3 lava fields found along the Great Rift. The Craters of the Moon Lava Field formed from magma (molten rock below the surface of the earth), which pushed up along the Great Rift. The magma that formed the Kings Bowl and Wapi Lava Fields also came up along the Great Rift, but originated in a different magma chamber.

TIMELINE OF GEOLOGIC EVENTS

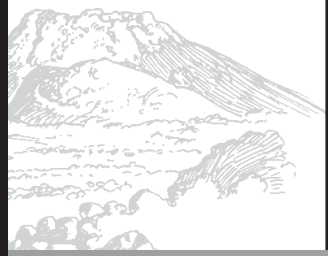
*The Yellowstone Hotspot was beneath Craters of the Moon. This time was characterized by violent eruptions and formation of huge craters called **calderas**. Some calderas are 10 to 40 miles wide.*

~8 MILLION TO 10 MILLION YEARS AGO

Numerous basaltic eruptions produced a 4,000-foot-thick sequence of lava flows.

6 MILLION TO 15 THOUSAND YEARS AGO

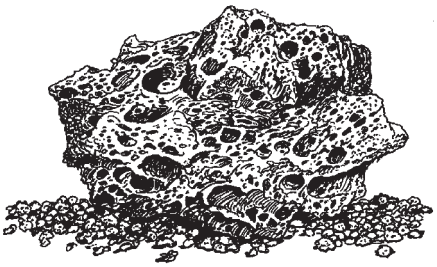
The Craters of the Moon Lava Field formed during eight major eruptive periods. The Wapi and Kings Bowl lava fields formed about 2,200 years ago.



15 THOUSAND TO 2 THOUSAND YEARS AGO

WHAT IS THE YELLOWSTONE HOTSPOT?

The Yellowstone Hotspot is a column of hot rock flowing up from the Earth's upper mantle. The hotspot has a plume shape, just like the wax in a "lava lamp."



cinder

The column flows upward until it hits the overlying North American Plate, which is colder. The plate consists of the crust and the uppermost mantle. Periodically, blobs of iron-rich basaltic magma rise up into the crust from a depth of about 50 miles. In the crust, these molten blobs melt overlying rocks and form sponge-like magma chambers. About 100 times in the past 16.5 million years, catastrophic eruptions of huge volumes of granitic magma have taken place along the Eastern Snake River Plain. Although some of the mountain ranges that existed on the Eastern Snake River Plain before the hotspot may have been blown away by the eruptions, it is more likely that they were swallowed up as the floor of the caldera sank during the violent explosions. The hotspot itself is stationary. Rather, it is the North American Plate that has been moving in a southwesterly direction over the hotspot. The plate's movement has produced the progressively younger trend of eruptions to the northeast. Imagine the burn mark left by a candle as a sheet of paper is moved across the flame.

WHAT KINDS OF LAVA ARE FOUND AT CRATERS OF THE MOON?

Molten rock on the Earth's surface is called ***lava***. Of the 60 lava flows visible on the surface of the Craters of the Moon Lava Field today, 20 have been dated. The oldest is about 15,000 years old and the youngest about 2,000.

Some lava flows are very dense and have a surface of angular blocks—***block lava***. Others have a rough, jagged, or clinkery surface—***áa lava.*** Still others have a smooth, ropy, or billowy surface—***pahoehoe lava***.

áa lava

HOW LIKELY IS ANOTHER ERUPTION AT CRATERS OF THE MOON? WHAT WILL THIS ERUPTION BE LIKE?

The interval between eruptive periods in the Craters of the Moon Lava Field averages 2,000 years and it has been more than 2,000 years since the last eruption. The area's geologic record suggests that future eruptions will begin along the central portion of the Great Rift in the Craters of the Moon Lava Field, but they may well travel to the northern part of the monument in the proximity of the loop drive. The nature of the area's volcanism suggests that slightly over one cubic mile of lava will be erupted during the next eruption period. Initial flows, based on past performance, will probably be relatively non-explosive and produce large-volume pahoehoe flows. Eruptions from potential vents on the northern part of the Great Rift may be comparatively explosive, produce significant amounts of cinder, lava bombs, and spatter, destroy cinder cones by both explosion and collapse, and build new ones.

erupting cinder cones

Only time will tell for sure.

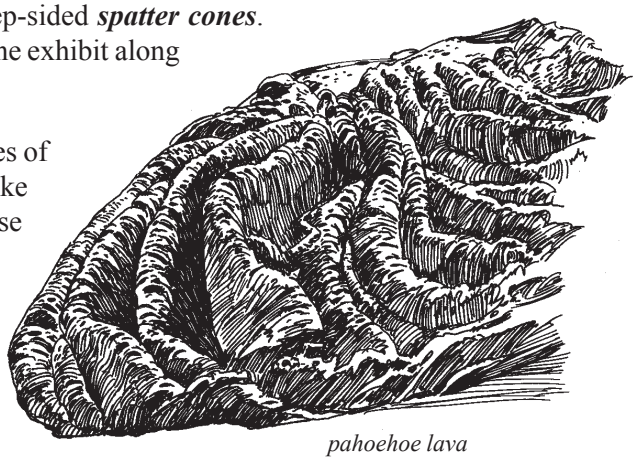
WHAT KIND OF FEATURES ARE BUILT BY ERUPTIONS?

When magma emerges at the Earth's surface along a segment of a rift, it often begins by producing a curtain of fire and a line of low eruptions. As portions of the segment become clogged the fountains jet higher. If magma emerges at the surface highly charged with gas it sprays high in the air, like taking the cap off a shaken bottle of soda pop. The highly gas-charged molten rock cools and solidifies during flight and rains down to form cinders. When enough cinder piles up, a ***cinder cone*** is formed. If you look closely at cinders you will see that they are laced with gas holes and resemble a sponge or a piece of Swiss cheese. Cinders are very lightweight because of these gas holes. The fire fountains that produced many of the Craters of the Moon cinder cones were probably over 1,000 feet high. Big Cinder Butte, the tallest cinder cone at Craters of the Moon, is over 700 feet high.

Lava tubes are hollow spaces beneath the surface of solidified lava flows. They are formed by the withdrawal of molten lava after the formation of the surface crusts. Indian Tunnel in the northern area of the park has a 40-foot-high ceiling and is 800 feet long. Bear Trap Cave, which lies between the Craters of the Moon and Kings Bowl Lava Fields, is about 15 miles long, but is not continuously passable.

Some vents along the rift eject very fluid particles (spatter) that accumulate to form steep-sided ***spatter cones***. Stop and visit the Spatter Cone exhibit along the loop drive.

During some eruptions, pieces of crater walls are carried off like icebergs by lava flows. These wall portions are known as ***rafted blocks***. The monoliths on the North Crater Flow Trail across from the visitor center are excellent examples of these volcanic formations. Go to Devils Orchard to see more examples of rafted blocks.



pahoehoe lava

For further information, check out the following websites:

WWW.NPS.GOV/CRMO/

WWW2.NATURE.NPS.GOV/GRD/PARKS/CRMO/

WWW.ID.BLM.GOV/CRATERS/

HTTP://VULCAN.WR.USGS.GOV/VOLCANOES/IDAHO/CRATERSMOON/DESCRIPTION_CRATERS_MOON.HTML

HTTP://IMNH.ISU.EDU/DIGITALATLAS

APPENDIX II

GEOLOGY OF CRATERS OF THE MOON NM
(more technical version)

GEOLOGY

OF CRATERS OF THE MOON NATIONAL MONUMENT

Compiled and interpreted from current literature by
Doug Owen, Park Geologist

BRIEF CHRONOLOGY OF GEOLOGIC EVENTS

- Between approximately 8 and 10 million years ago the Yellowstone Hotspot was beneath Craters of the Moon. This time was characterized by violent rhyolite eruptions and caldera formation.
- Between 6 million and 15,000 years ago numerous basaltic eruptions produced a 4,000-foot-thick sequence of lava flows.
- Between 15,000 and 2,000 years ago the Craters of the Moon Lava Field formed during eight major eruptive periods. During this time the Craters of the Moon lava field grew to cover 618 square miles. The Wapi and Kings Bowl lava fields formed contemporaneously about 2,200 years ago.

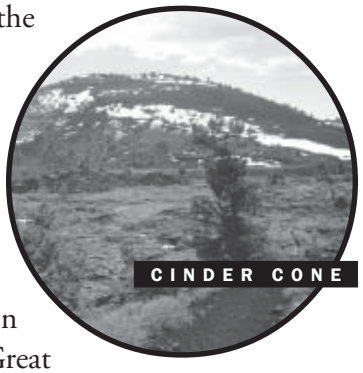
DESCRIPTION

The Craters of the Moon Lava Field, a composite field, is made up of about 60 lava flows and 25 cones. It is the largest and most complex of the late Pleistocene (the last Ice Age, from 1 million to 10,000 years ago) and Holocene (10,000 years ago to the present) basaltic lava fields of the Eastern Snake River Plain. The flows of the Craters of the Moon Lava Field have parent magma similar to that in the rest of the plain, but exhibit a wide range of chemical compositions. This wide range is caused in one of two ways: (1) by crustal contamination from assimilating older rocks, which produces lava with silica (SiO_2) ranges of ~49% to 64%, or (2) by crystal fractionation, which produces lava with silica ranges of ~44% to 54%.

In the past 15,000 years eight major eruptive periods formed the Craters of the Moon Lava Field. In contrast, most of the other lava fields on the Eastern Snake River Plain (including Kings Bowl and Wapi) represent single eruptions. Although these eruptions were widely scattered in space and time, they share nearly identical chemical composition (producing lava with silica ranges of ~45% to 48%). The typical Eastern Snake River Plain basalts are classified as diktytaxitic olivine tholeiite lavas or simply olivine basalts.

What makes Craters of the Moon so special geologically?

Craters of the Moon is an outdoor classroom in which to study volcanic geology. The Craters of the Moon Lava Field is the largest basaltic, dominantly Holocene (dating from the past 10,000 years) lava field in the lower 48 states. It has nearly every type of feature associated with basaltic systems and park trails give convenient access to most of them. So, short of travelling to Alaska or Hawaii, this is one of the best places in the United States to study this type of volcanism.


CINDER CONE

What is the Great Rift?

The Great Rift is a system of crustal fractures. It begins at the base of the Pioneer Mountains (north of the park's visitor center) and extends for over 50 miles to the southeast. The Craters of the Moon Lava Field is the northernmost of the 3 lava fields found along the Great Rift. The Wapi Lava Field is the southernmost. The Craters of the Moon Lava Field formed from magma (molten rock below the surface of the earth), which pushed up along the Great Rift. The magma that formed the Kings Bowl and Wapi Lava Fields also came up along the Great Rift, but originated in a different magma chamber. The Great Rift and other volcanic rifts on the Eastern Snake River Plain are generally parallel to but not necessarily collinear with basin and range faults north and south of the plain.

What is the Yellowstone Hotspot? When did it form? How did it move?

Many geologists think the Yellowstone Hotspot formed just 17 to 18 million years ago; a few think it is much older. More and more evidence is pointing to the hotspot having formed in the Earth's upper mantle at a depth of about 125 miles, rather than being a mantle plume from the core/mantle boundary. The hotspot has a plume shape, just like the wax in a "lava lamp," but the plume is probably not completely molten. It is a column of hot rock, which may have been produced by radioactive decay, in which some of the molten rock flows upward. The column flows upward until it hits the overlying North American Plate, which is colder. The plate consists of the crust and the uppermost mantle. Periodically blobs of iron-rich basaltic magma rise up into the crust from a depth of about 50 miles. In the crust these molten blobs melt overlying silica-rich rocks and form sponge-like magma chambers of partly molten rhyolite.


SPATTER CONE

About 100 times in the past 16.5 million years catastrophic eruptions of huge volumes of rhyolitic magma have taken place along the Eastern Snake River Plain. These eruptions often produced huge craters called calderas; some are 10 to 40 miles wide. Many of the approximately 100 calderas overlapped and may be broken down into 7 to 13 volcanic centers. Although some of the mountain ranges that existed on the Eastern Snake River Plain before the hotspot may have been

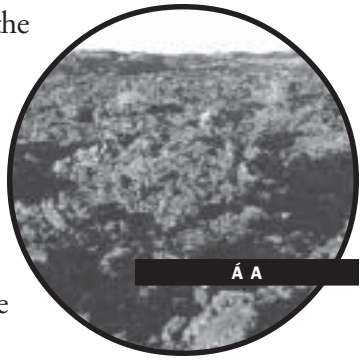
blown away by the eruptions, it is more likely that they were swallowed up as the floor of the caldera sank during the violent explosions.


BLOCK

The hotspot itself is stationary. Rather, it is the North American Plate that has been moving in a southwesterly direction over the hotspot. The plate's movement has produced the progressively younger trend of rhyolitic eruptions to the northeast. Imagine the burn mark left by a candle as a sheet of paper is moved across the flame.

If the Yellowstone Hotspot was here so long ago and is now so far away, why have the eruptions continued?

Recent seismic data suggest that the Yellowstone Hotspot left behind a slab of basalt 6 to 10 miles thick. This slab is poised in a mid-crustal position and some of it is thought to contain partial melt. It is believed that this slab represents the slag left in the bottom of the numerous magma chambers spawned by the hotspot. This region is experiencing basin and range type faulting, which is stretching or pulling apart the crust. The Lost River Range north of the town of Arco is good evidence that these forces are still active. In 1983 these forces caused a magnitude 7.3 earthquake, during which Mount Borah rose up about 1 foot and the entire Lost River Valley in that vicinity dropped about 8 feet. On the Eastern Snake River Plain, instead of producing mountain ranges, the tensional forces have created decompression melting, which results in dike emplacement and periodic eruption of molten rock onto the surface. As long as these forces continue to act, more eruptions will eventually occur.


ÁA

What kind of lava is found at Craters of the Moon?

Molten rock on the surface is called ***lava***. Of the 60 lava flows visible on the surface of the Craters of the Moon Lava Field today, 20 have been dated. The oldest is about 15,000 years old and the youngest about 2,000. Some lava flows were very dense and had a surface of angular blocks—***block lava***. Others had a rough, jagged, or clinkery surface—***áa lava***. Still others had a smooth, ropy, or billowy surface—***pahoehoe lava***. Three special kinds of pahoehoe may be observed in the Craters of the Moon Lava Field: (1) ***slabby pahoehoe***, is made up of jumbled plates or slabs of broken pahoehoe crust; (2) ***shelly pahoehoe***, which forms from gas-charged lava, contains small open tubes, blisters, and thin crusts; and (3) ***spiny pahoehoe***, which is very thick and pasty, contains elongated gas bubbles on the surface that form spines. Both slabby and spiny pahoehoe are transition phases to áa.


PAHOEHOE

What are volcanic bombs?

Four kinds of bombs are found at Craters of the Moon, all of which start off as globs of molten rock thrown into the air. If the glob gets twisted during its flight it is called a ***spindle bomb*** and typically extends from a few inches to several feet in length. If it is very tiny and twisted it is called a ***ribbon bomb***. When a glob forms a crust as it flies through the air and if the gases inside continue to expand and crack that crust, it is called a ***breadcrust bomb***. The outer surface texture is similar to bread rising in the oven. If the glob does not completely solidify during flight, so that it goes splat and flattens on landing, it is called a ***cow-pie bomb***. Some cow-pie bombs are over 10 feet long.

What are lava tubes?

Lava tubes are hollow spaces beneath the surface of solidified lava flows. They are formed by the withdrawal of molten lava after the formation of the surface crusts. Indian Tunnel in the northern area of the park has a 40-foot high ceiling and is 800 feet long. Bear Trap Cave, which lies between the Craters of the Moon and the Kings Bowl Lava Fields, is about 15 miles long, but is not continuously passable.

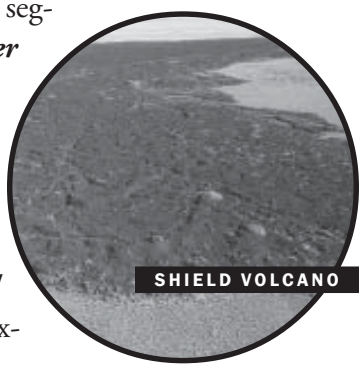
What kind of features are built by eruptions?

Most of the Craters of the Moon lava flows are pahoehoe and were fed through tubes and tube systems, although there are some sheet flows. At Craters of the Moon structures representing both inflation and deflation of the lava surface can be seen along with hot and cold collapses of the roofs of lava tubes. Inside lava tubes one can see lava stalactites, remelt features, and lava curbs. In other places lava flows formed ponds, built levees, and produced lava cascades. Some lava flows produced small mounds (***tumuli***) or elongated ridges (***pressure ridges***) on their crusts. In some places ***squeeze-ups*** formed when pressure was sufficient to force molten lava up through tension fractures in the top of pressure ridges or cracks in the solidified crust of lava ponds. ***Pressure plateaus*** were produced by the sill-like injection of new lava beneath the crust of an earlier flow that has not completely solidified.

When magma emerges at the surface along a segment of a rift, it often begins by producing a curtain of fire and a line of low eruptions. As portions of the segment become clogged the fountains jet higher. If magma emerges at the surface highly charged with gas it sprays high in the air, like taking the cap off a shaken bottle of soda pop. The fire fountains that produced many of the Craters of the Moon cinder cones were probably over 1,000 feet high.

Big Cinder Butte, the tallest cinder cone at Craters of the Moon, is over 700 feet high. The highly gas-charged molten rock cools and solidifies during flight and rains down to form ***cinder cones***. If you look closely at cinders you will see that they are laced with gas holes and resemble a sponge or piece of Swiss cheese. Cinders are very lightweight because of these gas holes.

Some vents along the rift ejected very fluid particles (***spatter***) that accumulated to form steep-sided ***spatter cones***. Along eruptive fissures where a whole segment erupted, spatter accumulated to produce low ridges called ***spatter ramparts***. ***Hornitos***, also known as rootless vents, are similar in appearance to spatter cones. Hornitos form from spatter ejected from holes in the crust of a lava tube instead of directly from a feeding fissure. Craters of the Moon also has collapses known as ***sinks*** or ***pit craters***. During some eruptions pieces of crater walls were carried off like icebergs by lava flows. These wall chunks are known as ***rafted blocks***; the monoliths on the North Crater Flow Trail are excellent examples of these volcanic formations.


SHIELD VOLCANO

How many volcanoes lie on the Eastern Snake River Plain? What is the most common type? What was the average volume of material erupted?

The most common type of volcano is a shield volcano. Shield volcanoes are gently sloping, like a knight's shield lying on the ground, or like a flattened dome built by fluid lava flowing away from the vent. There are believed to be about 8,000 on the Eastern Snake River Plain and an average volume of 1.2 cubic miles of material erupted from them.

Why has Crater of the Moon Lava Field had multiple eruptive periods when most other areas have not?


SQUEEZE UP

One hypothesis is that basin and range faulting is having a hard time moving into the Idaho Batholith, a mass of granitic bodies that covers over 15,000 square miles in central Idaho. Stress that would otherwise be released in the Idaho Batholith is possibly being accomodated along the Great Rift, thus resulting in more volcanic activity here.

How likely is another eruption at Craters of the Moon? What will this eruption be like?

Very likely. The recurrence interval for eruptive activity in the Craters of the Moon Lava Field averages 2,000 years and it has been more than 2,000 years since the last eruption. We are now at the end of a normal repose interval. The constancy of the most recent volcanic output rate suggests that slightly over one cubic mile of lava will be erupted during the next eruption period.

In the past, eruptions in the Craters of the Moon Lava Field have generally shifted to the segment of the Great Rift with the longest repose interval. Therefore, the next eruptive period should begin along the central portion of the Great Rift in the Craters of the Moon Lava Field, but may well propagate to the northern part of the monument in the proximity of the loop road. Initial flows, based on past performance, will probably be relatively non-explosive and produce large-volume pahoehoe flows. Eruptions from potential vents on the northern part of the Great Rift may be comparatively explosive and may produce significant amounts of ***tephra*** (airfall material ejected from a volcano), destroy cinder cones by both explosion and collapse, and build new ones. Only time will tell for sure.

SUGGESTED READING

Smith, Robert B. and Siegel, Lee J. Windows into the Earth. Oxford University Press, 2000 (242 pp).
Read chapters 1 and 2 for a description of the Yellowstone Hotspot and the development of the Eastern Snake River Plain. Written for the layperson.

Kuntz, Mel A., Champion, Duane E., Spiker, Elliot C., and Lefebvre, Richard H. "Contrasting magma types and steady-state, volume-predictable, basaltic volcanism along the Great Rift, Idaho." Geological Society of America Bulletin, vol. 97, pp. 579-594.
Good technical summary paper that includes speculations on future eruptive activity.

Decker, Robert and Decker, Barbara. Volcanoes In America's National Parks. W.W. Norton & Company, New York, 2001 (256 pp).
Good general reference book on volcanic parks in the U.S.; Craters of the Moon is on pages 190 to 195. Written for the layperson .

WEBSITE INFORMATION SOURCES

National Park Service
www.nps.gov/crmo/

NPS Geological Resources Division
www2.nature.nps.gov/grd/parks/crmo/

Bureau of Land Management
www.id.blm.gov/craters/

U.S. Geological Survey
http://vulcan.wr.usgs.gov/volcanoes/idaho/cratersmoon/description_craters_moon.html

Digital Atlas of Idaho
http://imnh.isu.edu/digitalatlas

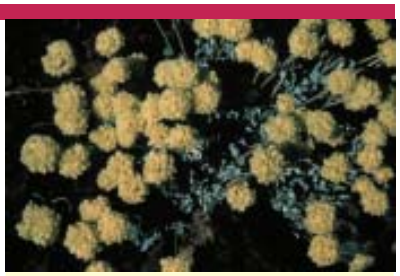
APPENDIX III

SOME COMMON PLANTS OF CRATERS OF THE MOON

Antelope Bitterbrush — This shrub is a major food source for wildlife at Craters of the Moon. It is the primary food source for the deer. Because our soils are young (i.e., dominantly brought in by the wind since the ice age) and there is so little rain to leach nutrients and carry them below the root zone, the nutrients are available for the shrub to take them up. This uptake makes the shrub very nutritious, so nutritious in fact that the deer here often have twins or triplets instead of just a single fawn, as is the norm elsewhere. In spring, after the shrub flowers, each of the small fruits that form contain a drop or two of purple juice. This juice is a source of water for small animals and you will often see chipmunks up in the shrubs eating the fruits. Later, inside each of the fruits, a nice size black seed develops that many of the small animals also eat. In a very dry year, as an adaptation to survive, the shrub will drop its leaves to conserve water and not grow them back until after a good rain. The leaves of this shrub and most other desert shrubs are smaller than those found on shrubs in a more humid climate. Smaller leaves have a smaller surface area from which to lose water to the air. The buds for next year's leaves are an important food source during the winter for animals such as the rabbits.

Mule deer often have twins or triplets at Craters of the Moon because the antelope bitterbrush here is so nutritious.

Ask students who have been to more humid climates to compare the size of the leaves of this shrub to shrubs in that more humid climate.



Dwarf Buckwheat — This small, low-growing, whitish-colored plant ubiquitous to the cinder areas in the park is one of the plants most often asked about by visitors. A 10- or 20-power hand lens makes it easier to see the wool-like hairs that reflect light and help create dead air space next to the plant tissue. Cinders can be heated to over 150^{0}F by the sun, so reflecting light and keeping the soil immediately below the plant cooler is a real advantage for survival. Both the hairs and the color of the foliage help to do this. The dead air space created by the hairs helps to reduce moisture loss to wind. This plant is highly competitive for water and puts out a remarkably extensive root system. Roots from a single small plant have been measured to extend as far as 110 cm vertically and horizontally. The even spacing between plants is caused by the competition between plants for water and not, as many visitors think, because they were planted that way by man (*we have not planted any of them*). The typical life span of the plant is unknown, but observations have indicated that it is many years. Living multiple years gives it a big advantage over plants that have to come up from seed every year. The longer life span allows it to establish an extensive root system. Also, the plant maintains its foliage under the snow and does not have to waste energy growing new foliage the following spring. In the spring this plant puts out pom-pom like flowers.

Hand lenses are available for sale at the Visitor Center bookstore.

Rockspirea — This plant has grayish-red bark and wedge-shaped leaves with a toothed margin. The flowers are borne in dense terminal clusters that make the shrub look like a mass of cream- or coral-colored foam when it is in bloom.

Rubber Rabbitbrush — This plant has gray-green linear leaves and produces a burst of yellow when it flowers in the late summer and fall. It is a prodigious pollen producer and affects many people who suffer from allergies. The plant is a host for numerous insects. It contains a natural latex and was chewed by the Indians to help quench thirst, much like people use chewing gum today.

Sagebrush — This pungent-smelling shrub has grayish-green wedge-shaped leaves with 3 prominent teeth at the end. It is not the same as the herb called sage. Today the plant is generally considered to be toxic, but the Indians used it stop internal bleeding, boiled it to produce an antiseptic, because of the plant's strong bacteriostatic quality. Sage requires a deep soil profile and usually is found on older deposits where there has been more time for soil to accumulate. One of sagebrush's adaptations to living in the desert is that it also grows larger leaves in the spring to make more food when moisture is more readily available. Then, as the soil dries out, the large leaves are replaced by small leaves to reduce water loss through evaporation. Smaller leaves have less surface area to lose moisture from and is a common characteristic of desert plants.

Sagebrush (close-up).

Scorpionweed — This fascinating plant has hairs that are easily seen under low magnification. The hairs do several things that enable this plant to survive here. They reflect light to help keep the plant cooler (which often makes the leaves appear as if they have frost on them), they help create a dead air space next to the plant tissue that prevents the loss of moisture to the wind. The hair also serve as traps for dew. Students may have also noticed that the veins on the leaves all point toward the center of the plant; this helps roll any moisture that accumulates or falls on the plant back toward its tap root. The plant gets its name from the seed bodies that form, which look like the hooked tail of a scorpion.

Scorpionweed (close-up). Note the hairs on the leaves.

Ask students beforehand if they see any plants that remind them of a funnel.

Sulfur Buckwheat — This plant is somewhat shrubby and forms mats of red and green leaves (this is probably the best clue for students to look for in order to recognize the plant). Flowering stalks are much taller than on the dwarf buckwheat, but still are usually less than 10 inches tall.

Syringa — This flower, also called Lewis mockorange, is the state flower of Idaho. The shrub has gray-brown bark and bright green oval leaves that are borne opposite each other on the branches. The flowers are very fragrant and measure about 1 inch in diameter. The petals are white.

Fern bush — This shrub has very distinctive leaves that are pinnately dissected and remind many people of ferns. The leaves are sticky to the touch, the oils being a strategy to reduce moisture loss. The Native Americans found that these same oils had a very beneficial quality, i.e., they are a natural insect repellent, and would rub the aromatic leaves of this plant over their skin. The flowers are about 1/2 inch in diameter with 5 creamy white petals.

APPENDIX IV

COMMONLY SEEN PLANTS OF CRATERS OF THE MOON (list)

Commonly Seen Plants

Craters of the Moon
NATIONAL MONUMENT

Compiled by Doug Owen, Park Naturalist

yellow flowers

Common name	Scientific name	Family
☐ Arrow-Leaved Balsamroot	Balsamorhiza sagittata	Sunflower
☐ Hawksbeard	Crepis (3 species)	Sunflower
☐ Mountain Dandelion	Agoseris glauca	Sunflower
☐ Salsify	Tragopogon dubius	Sunflower
☐ Groundsel	Senecio (5 species)	Sunflower
☐ Buckwheats	Erigonum (11 species)	Buckwheat
☐ Desert Parsley	Cymopterus terebinthinus	Carrot
☐ Gland Cinquefoil	Potentilla glanulosa	Rose
☐ Leopard Lily	Fritillaria atropurpurea	Lily
☐ Wayside Gromwell	Lithospermum ruderale	Borage
☐ Hairy Golden-Aster	Heterotheca villosa	Sunflower
☐ Sukdorf's Monkeyflower	Mimulus suksdorfii	Snapdragon
☐ White Stem Stickleaf	Mentzelia dispersa	Loasa
☐ Yellow Wood Violet	Viola orbiculata	Violet
☐ Blazingstar	Mentzelia laevicaulis	Loasa
☐ Prickly Pear cactus	Opuntia polyacantha	Cactus
☐ Mullein	Verbascum thapsus	Snapdragon

red / purple / blue flowers

☐ Indian Paintbrush	Castilleja chromosa	Snapdragon
☐ Dwarf Monkeyflower	Mimulus nanus	Snapdragon
☐ Wild Onion	Allium (8 species)	Lily
☐ Scarlet Gilia	Gilia aggregata	Phlox
☐ Wire Lettuce	Stephanomeria tenuifolia	Sunflower
☐ Joe Pye Weed	Eupatorium occidentale	Sunflower
☐ Hoary Aster	Machaeranthera canescens	Sunflower
☐ Fernleaf Fleabane	Erigeron compositus	Sunflower
☐ Blue Penstemon	Penstemon cyaneus	Snapdragon
☐ Lupine	Lupinus (4 species)	Pea
☐ Anderson Larkspur	Delpinium andersonii	Buttercup
☐ Scorpionweed	Phacelia hastata	Waterleaf
☐ Blue-eyed Mary	Collinsia parviplora	Snapdragon
☐ Rockcress	Arabis (5 species)	Mustard
☐ Spiney Skeleton Plant	Stephanomeria spinosa	Sunflower

Common name	Scientific name	Family
☐ Bitterroot	Lewisia rediviva	Purslane
☐ Sego Lily	Calochortus nuttallii	Lily
☐ Cryptantha	Cryptantha (8 species)	Borage
☐ Scabland Penstemon	Penstemon deustus	Snapdragon
☐ Lava Phlox	Leptodactylon pungens	Phlox
☐ Dusty Maiden	Chaenactis douglasii	Sunflower
☐ Western Yarrow	Achillea millefolium	Sunflower
☐ Slender Woodland Star	Lithophragma tenella	Saxafrage
☐ Ground Smoke	Gayophytum (5 species)	Primrose
☐ Coyote Tobacco	Nicotiana attenuata	Nightshade

white flowers

☐ Limber Pine	Pinus flexilis	Pine
☐ Douglas Fir	Pseudotsuga menziesii	Pine
☐ Quaking Aspen	Populus tremuloides	Willow
☐ Rocky Mtn. Juniper	Juniperus scopulorum	Cedar

trees

☐ Antelope Bitterbrush	Purshia tridentata	Rose
☐ Rubber Rabbitbrush	Chrysothamnus nauseosus	Sunflower
☐ Fern Bush/Tansy Bush	Chamaebatiaria millefolium	Rose
☐ Sagebrush	Aretmisia (6 species)	Sunflower
☐ Syringa	Philadelphus lewisii	Hydrangea
☐ Squaw Currant	Ribes cereum	Currant
☐ Golden Currant	Ribes aureum	Currant
☐ Serviceberry	Amelanchier alnifolia	Rose
☐ Rockspirea	Holodiscus dumosus	Rose
☐ Choke Cherry	Prunus virginiana	Rose
☐ Dwarf Goldenweed	Haplopappus nanus	Sunflower

shrubs

☐ Christmas Fern	Polystichum scopulinum	Fern
☐ Brittle Bladder Fern	Cystopteris fragilis	Fern
☐ Male Fern	Dryopteris felix-mas	Fern

ferns

☐ Dwarf Mistletoe	Arceuthobium cyanocarpum	Mistletoe
☐ Great Basin Wildrye	Elymus cinereus	Grass
☐ Bottle Brush/Squirreltail Grass	Sitanion hystrix	Grass
☐ Cheat Grass	Bromus tectorum	Grass
☐ Indian Rice Grass	Oryzopsis hymenoides	Grass
☐ Gray-Green Thistle	Cirsium canovirens	Aster
☐ Tumbleweed	Salsola kali	Goosefoot
☐ Sandberg Bluegrass	Poa secunda	Grass
☐ Needlegrass	Stipa (5 species)	Grass

grasses, etc.

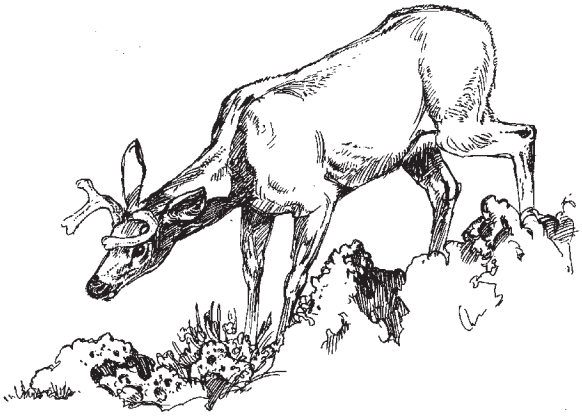
APPENDIX V

WILDLIFE CHECKLIST

Craters of the Moon

National Monument
U.S. Department of the Interior

Wildlife Checklist



At first glance, Craters of the Moon seems a lifeless place. The young lava flows and cinder cones are indeed inhospitable. During summer as little as one inch of rain may fall. This moisture drains quickly into the porous rock and out of reach of animals. Air temperatures soar into the 90's and the lava surface may reach over 150° F. Drying winds of over 20 miles per hour are common in summer.

Despite the harsh conditions, many creatures eke out a living here. Animals escape the summer heat in different ways. Most, like the mountain lion, venture forth in search of food only at night. Others, like the pika, are active at dusk and dawn. Those that are out during the day often seek shelter in the hottest hours. Marmots take more extreme measures to escape heat. They enter a hibernation-like state called estivation, during which their metabolism and body temperature drop. They estivate until cooler, moister conditions return.

Since there are no streams and few water holes in the lava fields, animals must get the moisture they need directly from their food. Mule deer munch bitterbrush leaves. Violet-green swallows snatch insects from the air. Rattlesnakes inject their venom and swallow their prey, such as chipmunks, whole. Each of these foods contains water essential to life.

The following list should assist you in identifying the animals you see during your visit. Even if you do not see animals, be alert to evidence of their presence: tracks, trails, nests, burrows, gnawed cones and twigs, fur, feathers, bones, droppings, calls, and smells.

All animals have been classified in one of two categories:

I: Quite common at some time during the year and may include resident, migrant, or breeding animals.

II: Has been observed within the monument only infrequently. Sightings of these animals should be reported at the visitor center.

Reptiles and Amphibians

- ☐ Gopher Snake – I
- ☐ Rubber Boa – I
- ☐ Western Rattlesnake – II
- ☐ Western Garter Snake – II
- ☐ Western Yellow-Bellied Racer – II
- ☐ Long-nosed Leopard Lizard – II
- ☐ Sagebrush Lizard – II
- ☐ Desert Horned Lizard – II
- ☐ Short-Horned Lizard – II
- ☐ Western Skink – I
- ☐ Western Toad - II
- ☐ Boreal Chorus Frog – II

Mammals

- ☐ Dusky Shrew – II
- ☐ Vagrant Shrew – II
- ☐ Merriam's Shrew – II
- ☐ Little Brown Myotis – I
- ☐ Long-eared Myotis – II
- ☐ Long-legged Myotis – II
- ☐ Small-footed Myotis – II
- ☐ Fringed Myotis – II
- ☐ California Myotis – II
- ☐ Big Brown Bat – II
- ☐ Hoary Bat – II
- ☐ Townsend's Big-eared Bat – II
- ☐ Pika – I
- ☐ Pygmy Rabbit – I
- ☐ Mountain Cottontail – II
- ☐ Snowshoe Hare – II
- ☐ White-tailed Jackrabbit – I
- ☐ Black-tailed Jackrabbit – II
- ☐ Least Chipmunk – II
- ☐ Yellow-pine Chipmunk – I
- ☐ Yellow-bellied Marmot – I
- ☐ Columbian Ground Squirrel – II
- ☐ Great Basin Ground Squirrel – II
- ☐ Golden-mantled Ground Squirrel – I
- ☐ Red Squirrel – I
- ☐ Northern Pocket Gopher – II
- ☐ Great Basin Pocket Mouse – I
- ☐ Ord's Kangaroo Rat – II
- ☐ Western Harvest Mouse – II
- ☐ Deer Mouse – I
- ☐ Bushy-tailed Woodrat – I
- ☐ Montane Vole – I
- ☐ Long-tailed Vole – II
- ☐ Sagebrush Vole – II
- ☐ Western Jumping Mouse – II
- ☐ Muskrat – II
- ☐ Beaver – II
- ☐ Porcupine – II
- ☐ Coyote – I
- ☐ Red Fox – I
- ☐ Kit Fox – II
- ☐ Black Bear – II
- ☐ Raccoon – II
- ☐ Short-tailed Weasel – II
- ☐ Long-tailed Weasel – I
- ☐ Badger – I
- ☐ Western Spotted Skunk – II
- ☐ Striped Skunk – II
- ☐ Mountain Lion – II
- ☐ Bobcat – II
- ☐ Elk – II
- ☐ Mule Deer – I
- ☐ White-tailed Deer – II
- ☐ Pronghorn – I
- ☐ Moose - II

APPENDIX VI

BIRD CHECKLIST

Craters of the Moon

National Monument
U.S. Department of the Interior

Bird Checklist

Birding Watching at Craters of the Moon

While stark, barren lavas are the focal point of the 1100-square mile monument, other habitats are well represented: limber pine forest; pockets of Douglas fir and aspen; extensive tracts of sagebrush, other shrubs, and grasses; and a few small riparian zones and wetlands. These attract a variety of birds, and the monument's proximity to other ecosystems — marshes, mountains, forests, and lakes — brings a wide spectrum of migrants and accidentals to the area. A surprising 184 species of birds have been reported at Craters of the Moon.

Few birds remain during the harsh winter. However, some are far northern species, difficult to find in the U.S. and therefore of interest to birders. Spring migrants reach a peak in May, and as summer progresses, more than 80 species may nest. By mid-August, southbound migrants are visible, pausing here to rest and forage.

Sightings by visitors are important additions to our wildlife records. Please report unusual bird sightings at the visitor center or write to:

Craters of the Moon National Monument
Resource Management Division
P.O. Box 29
Arco, ID 83213

Codes

These codes reflect the likelihood of finding a given species in appropriate habitat throughout a given season.

A	Abundant	Hard to miss
C	Common	Seen most days, easy to find
F	Fairly Common	Seen annually, but not daily
U	Uncommon	A few are seen most years
O	Occassional	Not present most years
X	Accidental	Not expected; 3 records
H	Hypothetical	An unverified record exists
R	Rare	Scarce, not seen yearly

Sp	Spring	late March-early June
S	Summer	early June-late August
F	Fall	late August-November
W	Winter	November-March
*	Nesting species	Has nested at Craters of the Moon

Checklist

	Grebes	Sp	S	F	W
	Pied-billed Grebe	O	O		
	Eared Grebe	O	O	O	
	Western Grebe	X	X		
	Pelicans and Cormorants	**Sp**	**S**	**F**	**W**
	American White Pelican			X	
	Herons and Egrets	**Sp**	**S**	**F**	**W**
	Great Blue Heron	O	O		
	Vultures	**Sp**	**S**	**F**	**W**
	Turkey Vulture	C	C		
	Ducks and Geese	**Sp**	**S**	**F**	**W**
	Snow Goose	O			
	Canada Goose	U	R		
	Gadwall	F			
	American Wigeon	F			
	Mallard *	F	O		
	Northern Shoveler	U			
	Cinnamon Teal	U	U		
	Northern Pintail	F			
	Blue-winged Teal		X		
	Green-winged Teal		X		
	Tundra Swan	F			
	Hawks, Eagles, Falcons	**Sp**	**S**	**F**	**W**
	Osprey			R	
	Bald Eagle			R	R
	Northern Harrier *	U	F	R	
	Sharp-shinned Hawk *	U	U	U	
	Copper's Hawk *	O	O	O	
	Northern Goshawk			O	
	Swainson's Hawk.	O	R		
	Red-tailed hawk *	U	U		
	Rough-legged Hawk				U
	Ferruginous Hawk *	O	O		
	Golden Eagle *	U	U	U	U
	American Kestrel *	F	F	U	
	Merlin	O	X	O	
	Peregrine Falcon	O		O	
	Prairie Falcon *	R	U	U	R
	Gallinaceous Birds	**Sp**	**S**	**F**	**W**
	Chukar *		O	O	
	Gray Partridge *		O	O	
	Ring-necked Pheasant	X		X	
	Ruffed Grouse			O	
	Greater Sage Grouse *	U	U	U	U
	Blue Grouse *		U	U	
	Wild Turkey		X		
	Rails and Cranes	**Sp**	**S**	**F**	**W**
	American Coot	C	C	C	
	Sora			X	
	Sandhill Crane	O		O	

	Shorebirds	Sp	S	F	W
	Killdeer	R	R	R	
	Spotted Sandpiper	O	O		
	Long-billed Curlew		O		
	Common Snipe			O	
	Wilson's Phalarope			X	
	Ring-billed Gull	O			
	Herring Gull		O		
	California Gull	O			
	Forster's Tern		O		
	Black Tern		O		
	Doves and Pigeons	**Sp**	**S**	**F**	**W**
	Rock Dove *	U	F	F	R
	Band-tailed Pigeon		O		
	Mourning Dove *	C	C		
	Owls	**Sp**	**S**	**F**	**W**
	Great Horned Owl *	U	U	U	U
	Snowy Owl				X
	Burrowing Owl		O		
	Long-eared Owl *	R	R	O	
	Short-eared Owl *	R	U	R	
	Northern Saw-whet Owl *	R	R	R	R
	Nightjars	**Sp**	**S**	**F**	**W**
	Common Nighthawk *		F		
	Common Poorwill *		U		
	Swifts	**Sp**	**S**	**F**	**W**
	White-throated Swift	O			
	Hummingbirds	**Sp**	**S**	**F**	**W**
	Black-chinned Hummingbd	R	R		
	Calliope Hummingbird	R	U		
	Broad-tailed Hummingbird		O		
	Rufous Hummingbird *	R	F		
	Kingfishers	**Sp**	**S**	**F**	**W**
	Belted Kingfisher	O			
	Woodpeckers	**Sp**	**S**	**F**	**W**
	Lewis' Woodpecker *	R	U		
	Red-headed Woodpecker		X		
	Red-naped Sapsucker *	F	R	U	
	Williamson's Sapsucker	R			
	Downy Woodpecker *	R	R	R	R
	Hairy Woodpecker *	U	U	U	U
	Northern Flicker *	C	C	C	U
	Flycatchers	**Sp**	**S**	**F**	**W**
	Olive-sided Flycatcher *		U		
	Western Wood-pewee *		U		
	Willow Flycatcher		X		
	Hammond's Flycatcher	R			
	Gray Flycatcher		O		
	Ducky Flycatcher *	R	F		
	Cordilleran Flycatcher		O		

Checklist

	Flycatchers (continued)	Sp	S	F	W
	Say's Phoebe *	U	U		
	Ash-throated Flycatcher	X			
	Western Kingbird	R		R	
	Eastern Kingbird		O		
	Shrikes	**Sp**	**S**	**F**	**W**
	Loggerhead Shrike *	R	U	R	
	Northern Shrike				U
	Vireos	**Sp**	**S**	**F**	**W**
	Plumbeous Vireo *	R	R	R	
	Cassin's Vireo *	R	U		
	Warbling Vireo *	U	U		
	Jays and Crows	**Sp**	**S**	**F**	**W**
	Steller's Jay	O		O	
	Pinyon Jay			O	O
	Clark's Nutcracker *	C	C	A	C
	Black-billed Magpie *	R	R	U	R
	American Crow *	U	R		
	Common Raven *	C	C	C	C
	Larks	**Sp**	**S**	**F**	**W**
	Horned Lark		R	F	F
	Swallows	**Sp**	**S**	**F**	**W**
	N. Rough-winged Swallow	R			
	Tree Swallow		O		
	Viloet-green swallow *	F	A	U	
	Barn Swallow *	C	C	F	
	Chickadees	**Sp**	**S**	**F**	**W**
	Black-capped Chickadee *	C	C	F	R
	Mountain Chickadee *	C	C	F	F
	Nuthatches	**Sp**	**S**	**F**	**W**
	Red-breasted Nuthatch	U	U	U	R
	White-breasted Nuthatch	R	R	R	
	Creepers	**Sp**	**S**	**F**	**W**
	Brown Creeper	R		R	R
	Wrens	**Sp**	**S**	**F**	**W**
	Rock Wren *	C	C	R	
	House Wren *	U	U	R	
	Winter Wren	R		R	R
	Dippers	**Sp**	**S**	**F**	**W**
	American Dipper			X	
	Kinglets, Gnatcatchers	**Sp**	**S**	**F**	**W**
	Golden-crowned Kinglet	R	R	R	R
	Ruby-crowned Kinglet	C	U	C	
	Blue-gray Gnatcatcher *	R	R	R	
	Thrushes	**Sp**	**S**	**F**	**W**
	Western Bluebird		X		
	Mountain Bluebird *	C	C	F	
	Townsend's Solitaire	R		R	
	Swainson's Thrush	R		R	
	Hermit Thrush	U		U	
	American Robin *	C	A	F	
	Varied Thrush	O			
	Thrashers, Mockingbirds	**Sp**	**S**	**F**	**W**
	Gray Catbird	O	O		
	Sage Thrasher *	R	U	F	
	Brown Thrasher		X	X	
	Starlings	**Sp**	**S**	**F**	**W**
	European Starling *	C	C	C	U
	Pipits and Wagtails	Sp	S	F	W
	American Pipit			O	
	Waxwings	**Sp**	**S**	**F**	**W**
	Bohemian Waxwing			O	U
	Cedar Waxwing	U	R	U	

	Warblers	Sp	S	F	W
	Tennessee Warbler	X		X	
	Orange-crowned Warbler *	U	F	R	
	Nashville Warbler			X	
	Yellow Warbler *	U	F		
	Yellow-rumped Warbler	C	U	F	
	Townsend's Warbler	R		R	
	American Redstart	X			
	Northern Waterthrush	X		X	
	MacGillivray's Warbler *	U	F	R	
	Wilson's Warbler *	U	F	R	
	Yellow-breasted Chat	X		X	
	Tanagers	**Sp**	**S**	**F**	**W**
	Western Tanager *	F	U		
	Sparrows	**Sp**	**S**	**F**	**W**
	Green-tailed Towhee *	C	F	U	
	Spotted Towhee *	C	C	U	
	Chipping Sparrow *	U	F		
	Brewer's Sparrow *	A	A	C	
	Vesper Sparrow *	F	F	F	
	Lark Sparrow	R	U		
	Black-throated Sparrow		X		
	Sage Sparrow	R	R		
	Lark Bunting *		R		
	Savannah Sparrow	O	O		
	Grasshopper Sparrow *	U	U		
	Fox Sparrow *	U	U		
	Song Sparrow *	F	F	F	
	Lincoln's Sparrow	O			
	White-throated Sparrow			X	
	White-crowned Sparrow	F	U	F	
	Golden-crowned Sparrow			X	
	Dark-eyed Junco	C	F	F	
	Snow Bunting				U
	Cardinals and Allies	**Sp**	**S**	**F**	**W**
	Black-headed Grosbeak *	U	U		
	Lazuli Bunting *	F	C	F	
	Blackbirds and Orioles	**Sp**	**S**	**F**	**W**
	Red-winged Blackbird *	F	F	F	
	Western Meadowlark *	F	F	U	
	Yellow-headed Blackbird *	C	C	C	R
	Brewer's Blackbird	C	A		
	Common Grackle		X		
	Brown-headed Cowbird *	C	C		
	Bullock's Oriole *	U	U		
	Baltimore Oriole	X			
	Finches	**Sp**	**S**	**F**	**W**
	Gray-crowned Rosy-Finch	R			U
	Black Rosy-Finch				R
	Pine Grosbeak			O	
	Cassin's Finch *	C	A	U	
	House Finch	U	R	U	
	Red Crossbill		O	O	
	Hoary Redpoll				X
	Common Redpoll				R
	Pine Siskin *	F	C	F	U
	American Goldfinch	R		R	
	Evening Grosbeak	U	U	U	
	Weaver Finches	**Sp**	**S**	**F**	**W**
	House Sparrow *	C	C	C	

APPENDIX VII

WEATHER INFORMATION

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Average Max. Temperature (F)	28.9	34.1	41.5	53.4	64.5	74.4	84.3	82.7	71.6	59.1	40.4	29.9	55.4
Average Min. Temperature (F)	10.3	14.3	20.4	28.2	36.9	44.6	51.9	50.2	40.9	31.3	20.5	11.3	30.1
Average Total Precipitation (in.)	2.17	1.61	1.28	1.04	1.74	1.27	0.69	0.85	0.87	0.90	1.36	1.80	15.58
Average Total SnowFall (in.)	22.5	17.8	9.8	4.6	2.2	0.0	0.0	0.0	0.5	1.7	10.9	19.6	89.5
Average Snow Depth (in.)	20	26	19	3	0	0	0	0	0	0	2	11	7

Percent of possible observations for period of record.
Max. Temp.: 95.2% Min. Temp.: 95.5% Precipitation: 96.6% Snowfall: 95.7% Snow Depth: 91.9%

APPENDIX VIII

GLOSSARY OF TERMS NOT DEFINED IN THE TEXT

aa — a Hawaiian term for lava flows typified by a rough, jagged, spinose, clinkery, or fragmental surface.

cinder — a fragment of lava from an erupting volcano, often very porous and filled with gas holes.

cinder cone — a steep, conical hill formed by the accumulation of cinders and other loose material expelled from a volcanic vent by escaping gasses.

Ka — one thousand years.

lava — magma or molten rock that has reached the surface of the earth.

loess — wind-blown silt.

Ma — one million years.

magma — molten rock below the surface of the earth.

pahoehoe — a Hawaiian term for lava typified by a smooth, billowy, or undulating surface.

pyroclast — an individual particle ejected during a volcanic eruption.

spatter — an accumulation of very fluid pyroclasts.

symbiotic — the intimate living together of two dissimilar organisms in a mutually beneficial relationship.

vent — the opening at the earth's surface through which gasses and other volcanic materials issue.