Interpretive Guide to Cave Area

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Geoscientists-in-the-Park Summer 2015

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Preface

The purpose of this interpretive guide is to assist park rangers with organizing their cave walk programs and more generally, with understanding the geology of Craters of the Moon National Monument from the regional scale to small-scale features in the lava flows present in the cave area. The guide is organized into three main sections: potential cave walk stops, potential cave walk topics, and relevant historical quotes. The potential stops include photos, interpretive opportunities, and interpretive techniques. Rangers are encouraged to select 8-10 stops, depending on feedback from their coach, and one or two topics to discuss at each stop. All the material presented in the potential stops index is based on the tangibles present along the cave trail and does not represent all possible topics that pertain to the monument as a whole. Please ensure that all topics relate to the cohesive development of a relevant idea (i.e. your theme). The potential cave walk topics and historical quotes are intended to add to the ranger's overall understanding of the resources present along the cave trail.

We hope that future rangers and volunteers find this guide helpful in crafting successful cave walks and in understanding the geologic processes that formed the caves themselves and shaped the surrounding landscape. Effective interpretation of the cave area, the most popular attraction at Craters of the Moon, is vital for solidifying the visitors' appreciation of our "weird and scenic landscape".

We appreciate Douglass Owen, Ted Stout, Todd Stefanic, and Jim Bromberg for introducing us to the geology and natural resources present at Craters of the Moon, and Sandra Gladish for her ongoing interpretive coaching and mentorship. We would also like to acknowledge our fellow rangers Jack Davisson, Aaron Ellig, Patra Foulk, Audrey Ledford, Sue Morris, Mia Russell, Jennifer Slaughter, Kathleen Slocum, and Kathleen Whitacre for bringing their unique perspectives to the table and sharing their own knowledge of history, geography, and wildlife biology.

Potential Stop Index

1.) Trailhead near parking lot.

Cave trailhead.

Possible topics include:

Great Rift – The Great Rift is a 52-mile long series of fissures that formed due to extension and subsequent thinning and cracking of the crust. This extension is occurring throughout the Basin and Range province, and has resulted in the formation of the alternating mountain ranges and basins throughout southern Idaho, Nevada, Utah, Arizona, New Mexico, and southeastern California, as well as smaller lava flows in those states. There have been eruptions of lava along parts of the Great Rift due to the forces of Basin and Range extension paired with hot rock left behind by the Yellowstone hotspot when it was present beneath Craters of the Moon (approximately 10 mya). The Great Rift area produced at least 60 lava flows and 25 cinder cone volcanoes. The first volcanic eruption along the Great Rift occurred about 15,000 years ago, with eruptions occurring at intervals of roughly 2000 years since that time. Volcanic activity along rifts can also be found in Hawaii, Iceland, and eastern Africa.

Interpretive Technique: You could incorporate Stearns' quote about fissure eruptions: "Up to the time of the discovery of the Great Rift, volcanic phenomena that accompany a fissure eruption were not known to exist in this country."

Basalt – Basalt is the most common variety of volcanic rock. It forms from cooled lava of a composition usually rich in metallic minerals (iron and magnesium), and poor in silica (quartz).

As the crust thins and pulls apart along the Great Rift, the pressure on pockets of hot rock beneath the surface decreases, allowing the material to rise, expand, move faster with greater ease, heat up further, and eventually melt.

Interpretive Technique: You could incorporate some quotes about "black vomit", "unvarying mass of black rock", or others that directly relate to the basalt (see quotes section at end of document or Historic Context Statements book) at this point.

Cinder Cones – Cinder cones are small volcanoes that form from the deposition of pyroclastic material (fragmented lava) as it shoots into the air from a central vent and falls back down, collecting around the vent. Lava can contain lots of trapped gases (called 'volatiles' in geology; water vapor, carbon dioxide, and sulfur gas among others), and when these gases expand, the foamy lava blows apart and erupts as "fire" or lava fountains. As the foamy lava flies through the air, it cools and forms cinders, which accumulate around the vent. In Craters of the Moon, the prevailing winds were so strong that the cinders were blown downwind and accumulated there, so most of our cinder cones have formed downwind of the vent (oblong to the northeast because the prevailing wind blows from the southwest). Cinder cones occur in many volcanically-active regions, including Hawaii and Iceland. We have 25 cinder cones in the monument.

2.) Slabby pahoehoe near parking lot and cave guide box.

Slabby pahoehoe near parking lot.

Cave guide box.

Possible topics include:

Pahoehoe Lava – The Hawaiian term pāhoehoe (pa-hoy-hoy) describes lava that flowed as a liquid resulting in a relatively smooth or ropy appearance. This type of lava predominates here at Craters of the Moon but different varieties of pāhoehoe described as shelly, spiny, and slabby display very different textures due to their increasing levels of viscosity:

Shelly pāhoehoe is characterized by thin egg-shell like layers of lava.
Spiny pāhoehoe displays a wood like texture due to the taffy-like stretching of its outer pores.
Slabby pāhoehoe has large slabs of hardened lava that sheared off the surface as the molten interior flowed.

A'a Lava – The Hawaiian term ʻaʻā (ah-ah) describes lava that has a relatively stony and rough surface. The lava here is transitional between slabby pāhoehoe and true ʻaʻā. Although chemically identical, pāhoehoe lava may transition into ʻaʻā when it cools slightly and thickens. A'a lava flows are "cool" lava flows of temperatures of approximately 1700 degrees F. The cooler temperature causes the lava to become more viscous (more sticky) and resistant to flowing. The cooling chunks of lava are incorporated into the active lava flow, resulting in a jagged, chunky, jumbled appearance. A'a lava also forms from flowing down steeper slopes, which assists with mixing the partially-cooled parts of the lava and causes the lava to flow faster and shear itself apart.

Interpretive Technique: You could show a picture of active a'a flow here, or use analogies, such as comparing a'a to cookie crumbles or its flow motion to tractor treads.

Cave Guide Box - Show visitors the cave guide box and explain that they can take a guide for detailed diagrams of the cave interiors if they plan to explore other caves after the tour.

3.) Transition area between slabby and spiny pahoehoe.

Slabby pahoehoe between spiny pahoehoe flows.

Possible topics include:

Pahoehoe Lava – Pahoehoe lava flows look smooth because they were flowing at temperatures exceeding 1800 degrees F and were less viscous (less sticky). Pahoehoe flows are also often found on more gentle slopes, or flatter topography. The pahoehoe here is also part of the Blue Dragon Flow, which originated from fissures near the Spatter Cones. It is one of the youngest lava flows in the park, at around 2000 years old. The holes and small spaces found in lava rock are called vesicles, and are places where there were once gas bubbles in the lava flow. In the case of the spiny pahoehoe, the gas bubbles became elongated as the surface of the flow was stretching while it cooled.

Interpretive Technique: You could show a picture of an active pahoehoe flow, or use an analogy such as comparing pahoehoe to warm honey or chocolate syrup.

Life on the Lava – Ask visitors where they see the vegetation (in cracks). You can play the seed on the rock vs. seed in the crack game, or "forecast" a later discussion of why at a later stop. Ask visitors if they see or hear any animals, or see anywhere that an animal might live, or something an animal might eat. Give some statistics of numbers of species of plants, mammals, birds, and invertebrates to show biodiversity.

4.) Pressure ridge.

Pressure ridge along trail.

Possible topics include:

Pressure Ridge Formation – Pressure ridges form within lava flows where a surface of semi-solid, semi-cooled lava is squeezed and forced upward by more molten lava underneath. This usually occurs when a lava flow encounters a topographic obstacle and cannot continue flowing with ease. The tops and/or sides of a pressure ridge often crack, and steam or lava may be released or drained from those cracks. There are some nice examples in the caves area, as well as along the North Crater Flow Trail and Broken Top Loop.

Shoshone Serpent Legend – The pressure ridge resembles lava that was pushed up by a large snake as it moved along underground. The Shoshone believed that there was a giant serpent responsible for the formation of Craters of the Moon.

Interpretive Technique: Ask a visitor to read the following Shoshone legend:

Long, long ago, a huge serpent, miles and miles in length, lay where the channel of the Snake River is now. Though the serpent was never known to harm anyone, people were terrified by it. One spring, after it had lain asleep all winter, it left its bed and went to a large mountain found in the area now known as Craters of the Moon. There it coiled its immense body around the mountain and sunned itself. After several days, thunder and lightning passed over the mountain and aroused the wrath of the serpent. A second time flashes of lightning played on the mountain, and this time the lightning struck nearby. Angered, the serpent began to tighten its coils around the mountain. Soon the pressure caused the rocks to begin to crumble. Still the serpent tightened its coils. The pressure became so great that the stones began to melt. Fire came from the cracks. Soon liquid rock flowed down the sides of the mountain. The huge serpent, slow in its movements, could not get away from the fire. So it was killed by the heat, and its body was

roasted in the hot rock. At last the fire burned itself out; the rocks cooled off; the liquid rock became solid again. Today if one visits the spot, he will see ashes and charred bones where the mountain used to be. If he will look closely at the solidified rock, he will see the ribs and bones of the huge serpent, charred and lifeless.

Life on the Lava – Plants and animals can survive on the lava by living in cracks and cavities in the flows. The cracks and cavities in the lava trap cool air, soil, and moisture, and also provide shelter from the sun and wind.

Interpretive Technique: Ask visitors where they see the vegetation growing. You can play the seed on the rock vs. seed in the crack game, or "forecast" a later discussion of why at a later stop. Ask visitors if they see or hear any animals, or see anywhere that an animal might live, or something an animal might eat. Give some statistics of numbers of species of plants, mammals, birds, and invertebrates to show biodiversity. You can also bring an infrared thermometer and have a volunteer check surface temperature vs. the temperature found at the bottom of one of our cracks.

Ethnobotany – Discuss the ethnobotany of whatever plants are visible at each stop (plants will change throughout the season).

Interpretive Technique: See Doug's ethnobotany guide for examples.

5.) Pahoehoe area near lava tube sign.

Ropy pahoehoe lava with Lava Tube sign. Note small lava tubes to the right of the sign and toward top of flow.

Possible topics include:

Ropy Pahoehoe Texture – Ropy pahoehoe forms when the surface of the pahoehoe flow cools and begins to solidify into a crust, but the molten lava beneath is still flowing. The flowing lava carries the partially-cooled surface crust with it, folding it up as it goes.

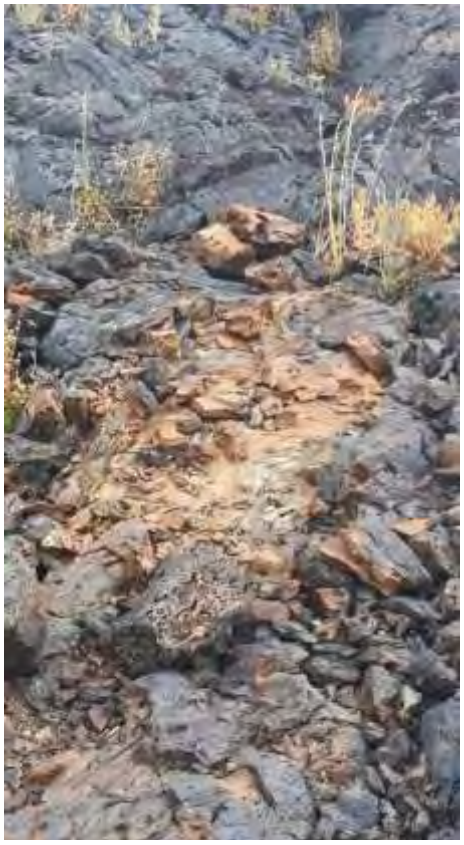
Interpretive Technique: Use an analogy such as the "skin" on the top of a pot of thick soup, or "scum" on cooling hot chocolate.

Different Colors of Lava –
Blues and purples – These colors are caused by the Blue Dragon phenomenon (possible explanations below).
Grays and browns – The natural variation in color is due to the metallic minerals in basalt. The lava can be gray, black, or brown.
Reds/oranges – These colors are due to oxidation of the iron-bearing minerals within the basalt. Many of the rust-colored areas are where the lava surface has been broken, allowing it to be exposed to the elements. This can also be evidence of visitors going off trail and breaking the lava by walking on it, which is why it is important to stay on the trails to preserve the rock.

Blue Dragon Flow – This flow is one of the youngest lava flows in the park (~2000 years old), erupted from the Spatter Cones and Big Craters area. There are several theories regarding the blue color: 1) high concentration of titanium in lava (does not appear to be supported by chemical analyses), 2) veneer of volcanic glass that scatters light to make it look blue/purple. The flow is called "Blue Dragon" due to the blue glass and the spiny pahoehoe texture resembling "prehistoric reptile" scales. There is oxidation damage to this lava flow along the sides of the trail from visitors walking on the lava.

Wildlife – This stop contains examples of small caves. Pikas use small cavities to escape from the heat because they cannot survive in temperatures above 80 degrees F for more than six hours.

Blue glass on Blue Dragon flow.



Damage to lava from oxidation.

Lava Tubes – Basaltic lava, especially pahoehoe, often flows in underground channels like a river. Basaltic lava is typically around 2000 degrees F, so the air feels very cold to the lava and the exterior of the flow, the part in contact with the air, begins to cool. The lava tube forms either when the sides of the lava flow begin to cool and solidify, eventually meeting to form the top, or when the uppermost crust of the flow cools first and accumulates, creating a bridge over the lava flow. The lava tube acts like the frozen surface of a river in the winter. The molten lava is still flowing inside, but it is insulated from the outside environment and thus can flow longer distances without cooling than it would otherwise. Small lava tubes are also formed underneath pahoehoe crust after the lava drains out. The small lava tubes provide good habitats, nesting sites, or food storage for small animals like squirrels, chipmunks, rabbits, pika, marmots, and packrats. Lava tubes are fragile features, and the final stage of any lava tube is collapse.

6.) Pahoehoe flow, near obvious coils/folds or blue veneer on lava flow.

Pahoehoe flow midway from Lava Tube sign to Dewdrop cave.

Possible topics include:

Blue Dragon Flow – This flow is one of the youngest lava flows in the park (~2000 years old), erupted from the Spatter Cones and Big Craters area. There are several theories regarding the blue color: 1) high concentration of titanium in lava (does not appear to be supported by chemical analyses), 2) veneer of volcanic glass that scatters light to make it look blue/purple. The flow is called "Blue Dragon" due to the blue glass and the spiny pahoehoe texture resembling "prehistoric reptile" scales. There is oxidation damage to this lava flow along the sides of the trail from visitors walking on the lava.

Jeffries'/Goodale's Cutoff (if good view of Pioneer Mountains) – In the late 1800s, tension built between the emigrants (also known as 'pioneers', but we will call them emigrants because they were new to the area) and Native Americans due to overgrazing, waste dumping, and general overuse of resources and lack of respect for the land that was being crossed. Native Americans started to attack emigrants on their way west. A local guide, Tim Goodale, was hired to lead emigrants along an alternative route now known as Goodale's Cutoff. Although the route is known as Goodale's Cutoff, a man named J.J. Jeffries original pioneered the route in 1852 using pre-existing Native American trails. The longest wagon train that ever crossed the Oregon Trail (over 300 wagons) took Goodale's Cutoff along the Pioneer Mountains where U.S. 93/26/20 is now. Fred Dykes (1989) estimates that 2,400 travelers used Jeffries'/Goodale's Cutoff in 1854, or 40% of Oregon Trail travelers.

Goodale's Cutoff and Emigrant Perspectives – Emigrant perspectives of the Great Rift region were not positive, as it was difficult to travel and especially difficult to find water.

Interpretive Technique: You can use emigrant quotes included at the end of the document, or others from the Historic Context Statements book.

Shoshone Serpent Legend – The Shoshone believed that there was a giant serpent responsible for the formation of Craters of the Moon.

Interpretive Technique: Ask a visitor to read the Shoshone legend if you have not done so yet.

7.) Large cooling crack (Dragon's teeth) on south side of trail; fern growing in cracks across from crack.

Cooling crack beside trail.

Possible topics include:

Cooling Crack Formation – Cooling cracks are abundant on the spiny pahoehoe lava flows in the caves area. They form as the lava is cooling, contracting, and shrinking, so the cooling cracks themselves are quite old but can be widened by repeated freezing and thawing of water or ice in the cracks during winter. The jagged edges on either side of the cracks resemble dragon teeth, and the "teeth" match up like puzzle pieces on either side.

Plant Adaptations – The ferns are growing in overhang microenvironments created by lava tubes and lava tube collapses. Microenvironments are formed by the trapped moisture, soil, and cool air found within well-insulated lava cracks. The cracks also shelter plants from extreme heat and strong wind.

Interpretive Technique: Have visitors play the "seed on lava vs. seed in crack" game by asking them to pretend they are seeds trying to survive and grow in the lava. If they were a seed, where on the lava would they choose to grow?

Christmas ferns growing in overhang area along trail adjacent to cooling crack.

8.) Dewdrop Cave

Entrance to Dewdrop Cave.

Possible topics include:

Lava Tube Caves – This is an example of a smaller lava tube cave. The federal government defines "caves" as follows: *…any naturally occurring void, cavity, recess, or system of interconnected passages which occurs beneath the surface of the earth or within a cliff or ledge … which is large enough to permit an individual to enter, whether or not the entrance is naturally formed or manmade.*

Plant Adaptations - Lichens and mosses can grow in lava tube caves because the cave environment is darker and more humid while still allowing enough light through skylights and cracks for photosynthesis.

Weather or Climate – The temperature is lower and the humidity is higher inside the cave.

Safety – If visitors are going into Dewdrop, Boy Scout, or Beauty cave, they will be on their own and will need flashlights and protective clothing, such as a hat or hard hat. Warn visitors about darkness, low ceilings, and ice in Boy Scout Cave and Beauty Cave. Show visitors where to walk to find the other two caves, and mention that Dewdrop is a good stopping point for a short rest or a break from the sun or heat for the walk back.

Geology – Cold collapses create cave entrances. Cold collapses form when the roof of a lava tube cools completely and then collapses in a brittle manner.

9.) Hot/Cold collapse site near sign.

Cold collapse.

Hot collapse.

Possible topics include:

Hot Collapse vs. Cold Collapse – The hot collapse is behind the sign. Hot collapses forms when the roof of a lava tube is still hot and sags into the hollow space beneath like a deflated soufflé after molted lava has drained out. The cold collapse is across the trail from the sign. Cold collapses form when a lava tube has cooled completely after lava has drained out. Eventually gravity will cause the unstable tube to collapse into the empty space in a brittle manner. Frost wedging contributes to the instability and eventual collapse of lava tube caves.

Interpretive Technique: Use analogies for hot/cold collapses, such as deflated soufflés or warm brownies for hot collapses and peanut brittle or hard candy for cold collapses.

10.) Native American rock rings.

Rock rings near entrance to Indian Tunnel.

Possible topics include:

Native American Use of CRMO and Caves – Migratory (moving to different locales based on the seasons) tribes temporarily inhabited area for at least the past 2000 years, possibly leaving the only eyewitness accounts of the most recent eruption. Lava flows may have covered older artifacts. Tribes came through the region in pursuit of game, as well as medicinal plants and rock materials for making tools (specifically tachylyte). Artifacts and archeological findings include rock rings, hunting blinds, windbreaks, grinding tools, projectile points, pottery, sharpening and flaking tools, and the flakes that were chipped off of tools and points. The presence of rock rings outside of Indian Tunnel gave the cave its name.

Interpretive Technique: Quiz visitors on purpose of rock rings and explain that the purpose of them is unknown. Have a visitor read the serpent legend if it has not yet been told.

11.) Indian Tunnel entrance above stairs.

Indian Tunnel entrance.

Possible topics include:

Lava Tubes – Basaltic lava, especially pahoehoe, often flows in underground channels like a river. Basaltic lava is typically around 2000 degrees F, so the air feels very cold to the lava and the exterior of the flow, the part in contact with the air, begins to cool. The lava tube forms either when the sides of the lava flow begin to cool and solidify, eventually meeting to form the top, or when the uppermost crust of the flow cools first and accumulates, creating a bridge over the lava flow. The lava tube acts like the frozen surface of a river in the winter. The molten lava is still flowing inside, but it is insulated from the outside environment and thus can flow longer distances without cooling than it would otherwise. Small lava tubes are also formed underneath pahoehoe crust after the lava drains out. The small lava tubes provide good habitats, nesting sites, or food storage for small animals like squirrels, chipmunks, rabbits, pika, marmots, and packrats. Lava tubes are fragile features, and the final stage of any lava tube is collapse.

Safety – Mention a safety warning here about taking off sunglasses, getting out flashlight if they have one, and using three points of contact when going down stairs and getting into cave.

12.) Inside of Indian Tunnel near first skylight.

Floor of Indian Tunnel beside skylight.

Possible topics include:

Plant Adaptations – Lichens and mosses can grow in lava tube caves because the cave environment is darker and more humid while still allowing enough light through skylights and cracks for photosynthesis.

Temperature Difference in Cave – The temperature is lower and the humidity is higher inside the cave thanks to the insulative properties of lava rock.

Lava Tube Formation – Basaltic lava, especially pahoehoe, often flows in underground channels like a river. Basaltic lava is typically around 2000 degrees F, so the air feels very cold to the lava and the exterior of the flow, the part in contact with the air, begins to cool. The lava tube forms either when the sides of the lava flow begin to cool and solidify, eventually meeting to form the top, or when the uppermost crust of the flow cools first and accumulates, creating a bridge over the lava flow. The lava tube acts like the frozen surface of a river in the winter. The molten lava is still flowing inside, but it is insulated from the outside environment and thus can flow longer distances without cooling than it would otherwise. Small lava tubes are also formed underneath pahoehoe crust after the lava drains out. The small lava tubes provide good habitats, nesting sites, or food storage for small animals like squirrels, chipmunks, rabbits, pika, marmots, and packrats. Lava tubes are fragile features, and the final stage of any lava tube is collapse.

Different Cave Formations –
Lava curbs (bathtub rings) – These features are horizontal ridges or indentations on the walls that show the level of the lava flow as it was receding like water draining from a bathtub, or rings of coffee on the inside of a coffee cup showing how the amount of coffee in the cup decreased.
Lava stalactites – These features can form from lava dripping from the ceiling, or from remelting by hot new flows.
Lava stalagmites – These features are rare due to the fact that lava tube floors are usually molten during cave formation. On rare occasions the edge of floor may harden enough to sustain lava dripping from above to create a stalagmite formation.

Mineral deposits – Cave deposits mostly contain sulfur and calcium. The minerals form or grow very slowly due to the weathering of basalt by water. Some of the minerals found in the caves are also found on Mars (jarosite, thenardite, calcite).

Native American Use of CRMO and Caves – Migratory (moving to different locales based on the seasons) tribes temporarily inhabited area for at least the past 2000 years, possibly leaving the only eyewitness accounts of the most recent eruption. Lava flows may have covered older artifacts. Tribes came through the region in pursuit of game, as well as medicinal plants and rock materials for making tools (specifically tachylyte). Artifacts and archeological findings include rock rings, hunting blinds, windbreaks, grinding tools, projectile points, pottery, sharpening and flaking tools, and the flakes that were chipped off of tools and points. The presence of rock rings outside of Indian Tunnel gave the cave its name.

Interpretive Technique: Quiz visitors on purpose of rock rings and explain that the purpose of them is unknown. Have a visitor read the serpent legend if it has not been told yet.

Wildlife – Violet-green swallows, mountain bluebirds, rock doves/pigeons, ravens, and great horned owls use caves (especially near skylights) for nesting.

Interpretive Technique: Show photos of aforementioned wildlife.

Snake River Plain Aquifer and Hydrology of Basalt– Basalt rock is porous (due to its vesicles, or gas bubbles) and can hold water. Rain and snow melt can also seep through cracks in cave roofs and lava flows to replenish the Snake River Plain aquifer. The Snake River Plain aquifer contains as much water as Lake Erie. It is a "sole-source" aquifer, meaning that 50% of the area's water needs are supplied by this aquifer. In the Craters of the Moon area, the water table of the aquifer is about 1,000 feet below the surface.

Interpretive Technique: Use the "rock porosity" demonstration. Pour water or have a visitor pour water onto the cave floor or a porous lava rock to see how quickly it drains or filters down.

Lava stalactites at the bottom of the staircase into Indian Tunnel.

Calcium precipitation on rock in Indian Tunnel.

Secondary minerals forming in Dewdrop Cave.

Lava curbs or bath tub rings etched into Indian Tunnel walls.

Good boulder to stand on when leading a large group. Boxed area denotes a good rock for rock porosity demo.

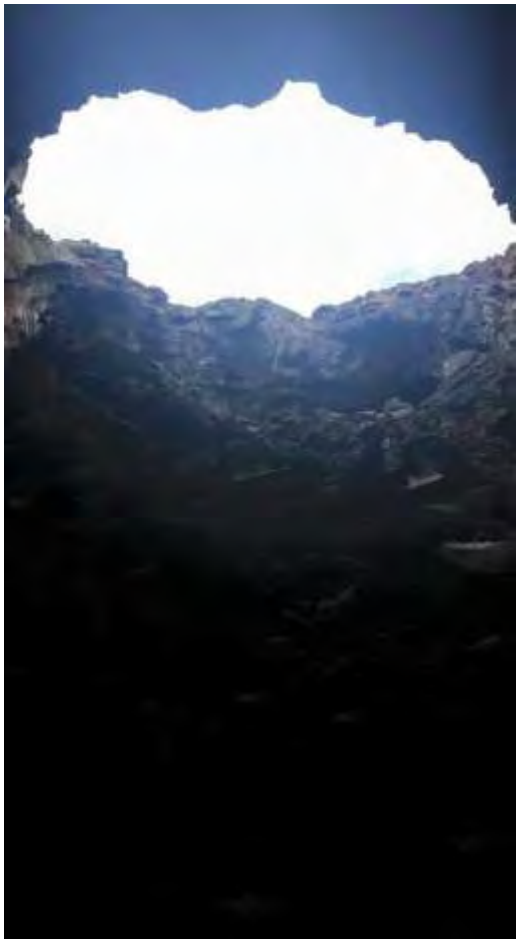
13.) Middle dark portion of Indian Tunnel between first and second skylights.

Possible topics include:

Wildlife – Pika use cool cracks and crevices to escape from the heat because they cannot survive in temperatures above 80 degrees F for more than six hours. The Idaho blind cave beetle is endemic to Idaho. They are blind because they are adapted to darkness. Bushytail woodrats (pack rats) build nests in lava tubes. The contents of their nests (rocks, artifacts, etc.) can reveal information about the history of an area. Bats use dark caves to sleep during day and hibernate in the winter. They are susceptible to White-Nose syndrome, which is why visitors obtain cave permits. We want to protect the bats because they are helpful for pest control and pollination of night-blooming plants. For example, Little Brown Bats (Myotis lucifugus) can eat 1200 mosquitoes in an hour. Squirrels, chipmunks, marmots, rabbits, foxes, snakes, and other animals will also enter caves occasionally.

Interpretive Technique: Show photos of aforementioned wildlife.

14.) Indian Tunnel floor near second skylight or top of collapse under second skylight (depending on group fitness level).



Cave floor near second skylight.

Top of cold collapse in second skylight.

Possible topics include:

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Interpretive Technique: Use the "rock porosity" demonstration. Pour water or have a visitor pour water onto the cave floor or a porous lava rock to see how quickly it drains or filters down.

History of CRMO Monument – Robert Limbert first came to the Great Rift region in 1918 and loved the area enough to record his journey in articles and pictures. In 1924, Limbert contacted President Calvin Coolidge about Craters of the Moon and asked for it to be declared a national monument. Coolidge declared the area a national monument two months later, calling it a "weird and scenic landscape peculiar to itself."

Conclusion – This a good place to summarize your program, connect your program to the National Park Service mission, and end the tour. Check to see if visitors need assistance leaving the cave, and provide if necessary. Otherwise, you may choose to lead any willing and able bodied visitors through the rest of the cave informally.

14.) Next dark portion of tube leading to cave exit.

Lava curb, lichen, and moss in second dark tube.

Geology – Point out the lava curb.

Lichens and Mosses - Mosses are adapted to go dormant when there is not enough water. The dead-looking black moss can actually be resuscitated (turns green again) by pouring water on it – makes a good demonstration for visitors! Lichens are a relationship between algae and a fungus where the algae provide the food via photosynthesis and the fungus provides structure, protection, and nutrients from the rock. Lichens are pioneer species that are often the first to inhabit new terrain and begin the process of soil formation from rocks. Lichens are also good indicators of air quality; they are especially susceptible to sulfur compounds in the air. There are over 90 species of lichen in the park.

Potential Topics

Geology

Geography – Southern Idaho, Pacific Northwest, Basin and Range geography, the Basin and Range province, what area the Basin and Ranger covers, what major landforms make up the Basin and Range province, local geography (Pioneer Mountains and Lost River Range Mountains, Three Buttes rhyolite domes, shield volcanoes, Snake River Plain, Snake River

Volcanology – Different types of volcanoes (shield, cinder cone, rhyolite dome, no stratovolcanoes here), why and how volcanoes erupt, compare and contrast with Yellowstone, Hawaii,, Iceland, and other planetary bodies in the solar system, Blue Dragon Flow, explanation of lava textures (a'a vs. pahoehoe), explanation of pressure ridges and cooling cracks, explanation of lava tubes

Geologic Hazards – Specifically related to local geology, such as earthquakes, lava flows, pyroclastic materials, landslides and slope stability

Mineralogy – Basalt is made of metallic minerals (which then contributes to rich volcanic soil when they are weathered down; iron, magnesium, calcium, etc.), feldspar, and a little bit of quartz, our lava has more quartz than Hawaii so our lava is more viscous (stickier and more resistant to flowing)

Petrology – Basics of basalt, low-silica (low quartz) volcanic rock; typical of rift zones, oceanic hot spots (such as Hawaii), and flood basalt provinces (such as Columbia River basalts); where our basalt comes from and how it forms

Geochemistry – Volcanic gas geochemistry is a monitoring method, increase of gas emissions before eruption, mention that lava has volcanic gases (volatiles) like sulfur gases, water vapor, and carbon dioxide, and that iss why you can get curtains of fire and lava fountaining with fissure eruptions and cinder cones; also can tell there was gas because of gas bubbles in rocks (vesicles)

Tectonics – Plate tectonics; brief overview of three types with emphasis on divergent continental boundaries; what features you would expect to see: cinder cones, basaltic lava flows, fissures, shield volcanoes; ultimate fate of divergent continental boundaries: continent rifts apart to form new ocean basin, examples of other divergent boundaries: mid-ocean ridges, Iceland, East African rift zone, Red Sea, Basin and Range province of US

Structural Geology – Normal faulting, horst and graben (Basin and Range) structures in mountains and valleys to northeast

Sedimentology – Loess is the only sediment; it is windblown in from the Pioneer Mountains, no other sedimentary rock types in most of the park except in the North End

Geochronology and Thermochronology – Carbon-14 dating with charred wood remains, Argon dating, and thermoluminescence (TL) used to determine the ages of lava flows

Geophysics and Seismology – Monitoring of seismic activity in area, seismicity or earthquakes precursor to future eruptions

Paleontology – Some bones from animals have been found in caves, tree molds/lava trees and charred wood preserve evidence of past life.

Planetary geology – Lava flows found on almost all other solar system bodies, caves at CRMO being used for research into lava tube caves on Mars, secondary minerals found in caves at CRMO are some of same minerals detected on Mars (jarosite, thenardite, calcite; significant because some of these minerals can be formed by biochemical processes, suggesting that there could be past and/or present life on Mars)

Hydrology and Hydrogeology – Porosity of basalt, Snake River Plain basaltic aquifer, source for agriculture and municipal use, volcanic rock provides good filtration for water

Nuclear Geology and Radioactive Materials – All rocks are radioactive to some degree; heat in lava and magma comes from radioactive isotopes that give off heat

Mining and Mining Claims – Lead, silver, and gold mining in North End of the monument in the Pioneer Mountains area 1880's-1920's, "Martin Mine" with nine claims on Little Cottonwood Creek; buildings were torn down

Soils –Soil was created by the grinding force of continental glaciers during the Pleistocene epoch, that same force pulverizing rock into dust, which then is blown by wind onto the lava fields. Soil formation is a long process, especially in an arid environment, and especially with the cracked surface of the lava which causes the water to travel vertically through cracks instead of running off and eroding the surface. The little soil that does exist at Craters accumulates between cinders and in cracks in the lava.

Speleology – A cave is any natural crack or crevice large enough to fit a human.; different formations that can be found within lava tube caves, such as lava curbs or bath tub rings, lava drips or lava stalactites, and lava stalagmites

Climatology

Seasonal Average Temperatures – Found on weather and climate handout in Visitor Center

Precipitation – Average annual precipitation (rain) is 15.38 inches, average annual snowfall is 88.3 inches

Seasonal Storms - Winter snow and summer rains account for majority of precipitation

Weathering (Natural vs. Anthropogenic) – Natural weathering very slow due to high desert environment, anthropogenic "weathering": stepping on lava and breaking surface, exposure of iron-rich minerals in basalt to air as a result of breaking results in oxidation, wearing down glassy surface, crushing cinders by walking and driving over cinders creates dust and destroys cinders and volcanic glass in cinders

Wind direction, Wind speed – Prevailing wind direction is southwest, cinder cones generally pile to northeast of vent due to wind direction, plants are also shielded from wind on northeast side of cone resulting in more vegetation; drying winds are a daily occurrence, especially in the afternoon, and may reach 15 to 30 miles per hour

Temperature on the Lava – Highest recorded temperature of lava is 178 degrees F, dark material absorbs heat

Elevation – Above 5280 ft., baseline elevation used in website climate summary is 5910 ft

UV index – Can get "very high"; 8+ on UV Index scale

Humidity – High desert, low humidity

Desert Climate – Arid and hot, very little precipitation, air temperatures in the 90s in the summer months

Climate Change – Pika are struggling as temperatures increase; pika populations are being monitored as sentinels of climate change; drier vegetation, higher temperatures, and stronger thunderstorms result in increased wildfires.

Air Quality and Pollution – Health of lichens are good indicators of air quality, pure air in caves and many parts of park, increased vehicle emissions and pollution damage lichens as explained by Devil's Orchard sign

Dark Skies for Astronomy – Far from urban areas, so little light pollution from nearby cities or towns, not much traffic on the road at night either, park installed light pollution-friendly lighting (lights that point down) throughout park in order to maintain clear, dark skies

Biology

Biodiversity – Give numbers of mammals (61), birds (220), amphibians (4), reptiles (10), invertebrates (1000+), and plants (752), talk about why we can have certain kinds of animals and insects here, such as pika and the endemic blind cave beetle

Primary Succession – The process of vegetation returning to an area after a major disturbance event, such as a wildfire or eruption; can be observed in the Cave Area where vegetation has started to repopulate the lava, and many other places in the park

Botany – Specifically adaptations to the lava, like plants growing in cracks, growing in shaded areas of collapsed lava tubes, microenvironments created by lava flow features, also have extensive root systems (shallow and deep), have fuzzy and sticky leaves to prevent evaporation of water, leaves often light-colored to absorb less heat, note types of plants that can be pointed out while walking depending on the time of the year

Mosses, Lichens, and Fungi – Mosses are adapted to go dormant when there is not enough water, the dead-looking black moss can actually be resuscitated (turns green again) by pouring water on it (makes a good demonstration for visitors); lichens are a relationship between algae and a fungus where the algae provide the food via photosynthesis and the fungus provides structure, protection, and nutrients from the rock; lichens are pioneer species that are often the first to inhabit new terrain and begin the process of soil formation from rocks; lichens are also good indicators of air quality; they are especially susceptible to sulfur compounds in the air; there are over 90 species of lichen in the park; there are some species of mushrooms which can be found in shaded areas, cracks, and caves

Entomology – Butterflies, moths, endemic cave beetle, native bees, grasshoppers, and flies are common; mosquitos are not found due to lack of water for spawning as well as consumption by bats; bats eat lots of flying insects

Herpetology – Types of reptiles: rattlesnakes, gopher snakes, blue-tailed skinks, lizards; how snakes do not like slithering over the lava but will hide in cracks and stick to sagebrush areas

Ornithology – Lots of birds roost in or near caves including pigeons, mountain bluebirds, ravens, violet green swallows, great horned owls; many tropical birds (example: violet green swallow) come up in the summer and return to Central America during the winter

Mammology – Mammals that make use of lava tubes and caves such as pikas, pack rats, bats, marmots, rabbits, squirrels, chipmunks, foxes, coyotes

High Desert Environment – Desert climate paired with high elevation, preserves volcanic features at CRMO due to slow weathering rate

Hunting and Grazing – Native Americans hunted game animals through Great Rift area, grazing of emigrant livestock led to tensions between Native Americans and emigrants, resulting in Goodale's Cutoff

Invasive Species – Cave pigeons, cheat grass; invasive species are bad because they outcompete native plants and animals, use resources

Diseases Transmitted from Humans to Wildlife and Vice Versa – White-nose syndrome can be transmitted to people's clothing and gear, then transmitted by humans to bats in other caves (need for cave permit process); hantavirus, don't touch rodents (live or dead) or their nests in caves

Agriculture – Loess and the aquifer contribute to Idaho's famous potatoes

History

Native Americans (Shoshone-Bannock) – Use of caves as shelter, food storage, transportation through lava fields, use of rocks such as tachylyte, tensions with emigrants due to overgrazing and misuse of land, use of plants for medicinal purposes (ethnobotany)

Artifacts and Structures, Archaeology – Specifically artifacts found in cave area such as rock rings, buffalo bones found in Buffalo Cave with tool marks on bones, projectile points, pottery fragments, etc., maybe talk about how people here used tachylyte as opposed to obsidian because it was the resource available in our lava fields

Linguistics and Language Families – Shoshone language has about 500 speakers remaining with teaching in schools, Bannock language has about 6 speakers, all old, no instruction, is considered a dead language, Shoshone and Bannock are two different language families (Northern Shoshone and Northern Paiute respectively)

Oral Traditions, Folklore, Religion – Serpent legend and medicine man legend were probable eyewitness accounts of most recent eruptions

Ethnobotany – Restrict this to plants found along the cave area trail; examples are antelope bitterbrush, buckwheat, fern bush, lava phlox, limber pine, hot rock penstemon, scorpionweed, wire lettuce, syringa/mock orange, gland cinquefoil, rabbitbrush

Fur trappers, Pioneers, Gold Rush, Tim Goodale and Goodale's Cutoff – Lots of good quotes that could be used (see end of document and/or Historic Context Statements book)

Tensions and Conflicts between Europeans and Indigenous Peoples – Tensions between emigrants and Native Americans due to overgrazing and using up natural resource; use for explanation of why Goodale's Cutoff exists, Massacre Rock represented the culmination of those tensions

Fort Hall Indian Reservation – The Shoshone-Bannock, whose ancestors roamed this area, now live at the Fort Hall Indian Reservation

Early Explorers (Limbert and Cole), Geologists like Russell and Stearns – Paved the way for CRMO to become a monument, lots of good quotes (see end of document)

Calvin Coolidge – Why Coolidge declared Craters of the Moon monument, the wording of founding legislation ("weird and scenic landscape")

Mission 66 – Trails and modern buildings added during Mission 66 renovation

Astronauts – Trained in geology before Apollo missions to Moon, could show picture of Engle and Cernan in a cave

Expansion in 2000 by Clinton Administration – Approximately 700,000 acres added to monument, a large portion of which was subsequently named a National Preserve by Congress.

Collaboration with Bureau of Land Management – Brief explanation, and can specifically mention that BLM manages many caves on the BLM monument and preserve, some of which are open to the public and are marked on travel map available at VC, but are very difficult to get to, and are completely wild

National Park Service Mission

Land Use – Recreation such as hiking, backcountry camping (by permit), biking on North End administrative use road (by permit)

Natural Resources – Plants, animals, rocks/scenery/landscape, clean air, dark skies, wilderness, cultural resources

Conservation vs. Preservation – Conservation: using the resources, but trying to do so in a sustainable way (ex. BLM-style of land/resource management), preservation: limiting use of resources so they are used as little as possible (ex. NPS-style of land/resource management)

Communal Ownership of Park Lands – National parks belong to everyone in the United States

Stewardship – We are guardians of the land, not gardeners

Interpretation → Appreciation → Preservation

Scientific Research – Biologic, geologic research conducted at park, maybe give some examples: NASA research, biology researchers currently in park, pika researchers who were in park, use by school groups for science education

Environmental Impacts from NPS Agency and Visitors, Mitigating impacts – Accidental destruction of limber pine in attempt to mitigate dwarf mistletoe impact, visitors walking on lava results in damage to rock (physical and chemical), poor air quality due to vehicle emissions affect lichen health

Rules and Regulations – No collecting, no pets on trails, must have cave permits to enter caves, no feeding wildlife, stay on trails

Visitor Concerns, Commentary, and Suggestions – Ask if visitors have questions or comments

Daily Programs Offered and Future Events – Give rundown of daily program schedule for remainder of day and/or following day depending on time, and any special events

Relevant Historical Quotes

Fur Traders

Wilson Price Hunt: "dreary desert of sand and gravel"

Alexander Ross: "a most dreary looking place"

Peter Skene Ogden: "cursed country", "crossed over the plain considered by all the greatest impediment in the route between this and the Flat Head Post"

J.H. Stevens: "a barren desert, destitute of every species of vegetation, except a few scattering cedars, and speckled with huge round masses of black basaltic rock", "entered a tract of country entirely covered with a stratum of black rock", "had spread over the earth's surface to the extent of 40-50 miles", "was doubtless lava which had been vomited forth from some volcano, the fires of which are now extinct"

Explorers

John Kirk Townsend: "one of the most arid plains we have seen, covered thickly with jagged masses of lava, and twisted wormwood bushes", "juxtaposition of enormous masses formed many large and dark caves"

Capt. Benjamin Bonneville, as recounted by Washington Irving: "the volcanic plain in question forms an area of about 60 miles in diameter, where nothing meets the eye but a desolate and awful waste; where no grass grows nor water runs, and where nothing is to be seen but lava"

Sir Archibald Geikie (prominent Scottish volcanologist of the time): "plain had once been a great lake or sea of molten rock which surged along the base of the hills, entering every valley, and leaving there a solid floor of bare black stone," he thought it was a fissure eruption because there were no "visible cones or vents from which these floods of basalt could have proceeded", his experience at CRMO "lifted the mist from my geological vision"

Israel Russell: “To lovers of nature and all who rejoice in scenes of natural wildness unmodified…the plains of southern Idaho present exceptional attractions”, “many pleasing variations in color, ranging from deep red through brown and purple to lusterless black”
Limbert: “immense rolls and folds of fantastically formed lava…colored blue, black, and brown”, “color is a deep, cobalt blue, with generally a high gloss, as if the lava flow had been given a blue varnish” (and many others)

Stearns: “Up to the time of the discovery of the Great Rift, volcanic phenomena that accompany a fissure eruption were not known to exist in this country”

Hunt as recounted by Washington Irving: “It is a land where no man permanently resides; a vast, uninhabited solitude with precipitous cliffs and yawning ravines, looking like the ruins of the world; vast tracts that must ever defy cultivation and interpose dreary and thirsty wilds between the habitations of man”

Oregon Trail Settlers

(some very long excerpts from journals in Historic Context Statements book p.83-85 for Oregon Trail)

Julius Merrell: “It was a desolate, dismal scenery. Up or down the valley as far as the eye could reach or across the mountains and into the dim distance the same unvarying mass of black rock. Not a shrub, bird nor insect seemed to live near it. Great must have been the relief of the volcano, powerful the emetic, that poured such a mass of black vomit."

Unnamed traveler: “area would grow no grains or vegetables”

Sources

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