

A SHORT
GEOLOGY OF CRATERS OF THE MOON
AND THE SNAKE RIVER PLAIN

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Craters of the Moon
National Monument

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Introduction

While Craters of the Moon National Monument contains some of the best examples of volcanic features in the world, it is really just a small portion of the much larger geologic region known as the Snake River Plain. Craters of the Moon is significant because it represents the site of the most recent eruptions on the entire Plain, but to fully comprehend what happened here, you must first understand the origins of the Snake River Plain. To accomplish this, we will look at the geology of southwestern Idaho, Yellowstone and Craters of the Moon.

The Snake River Plain

The Snake River Plain is an area of immense lava deposition located in a 400 mile arc that stretches across all of southern Idaho. The width of this landscape ranges from as little as 30 miles to as much as 125 miles. It is composed mainly of two types of lava; basalt and rhyolite. The Plain contains such volcanic features as calderas, volcanic rift zones, shield volcanoes, cinder cones, eruptive fissures, lava flows, spatter cones, lava tubes and volcanic domes.

The age of the Snake River Plain can be traced from the most recent eruptions of 2,000 years ago to the very oldest activity that took place about 17 million years ago. The story of what took place between these events has only recently been partially unraveled by geologists. As more and more information is collected, it is becoming apparent that the formation of the Snake River Plain will be one of the most interesting geologic stories ever to be put together.

A few years ago, the Snake River Plain was considered as an extension of the Columbia River Plateau of Washington and Oregon. Although the lavas of the Columbia River Plateau may mix with the lavas of the Snake River Plain in western Idaho, geologists now consider these two provinces very distinct geologic units. Furthermore, geologists have been able to find enough different geologic characteristics between the western and eastern Snake River Plain to necessitate discussing the Plain's geology as two separate entities.

Western Snake River Plain

The western Snake River Plain is believed to have been

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

This rift valley originated about 17 million years ago northwest of Twin Falls and has continued to slowly expand to the northwest ever since. The last volcanic eruptions along this rift occurred between approximately 300 thousand to 1 million years ago. Because this landform continues to shrink as it cools and because more and more lava and sediments are periodically deposited on this segment of the Plain, the area is in a state of continual subsidence. Even today, the local terrain is still adjusting to these influences in an attempt to attain a state of equilibrium.

To the south of where geologists have located the point of origin of the Western Snake River Plain, a new geologic story of the formation of the Eastern Snake River Plain begins. This is an area of lava deposition that traces its origins to a very different geologic phenomenon.

Eastern Snake River Plain

The eastern Snake River Plain is primarily composed of thick rhyolite lava flows overlain by basaltic lavas. It is defined as an area that begins to the north of Twin Falls and continues to the Yellowstone area on the Wyoming-Montana border. Although they are now mostly covered by recent basaltic lava flows, vestiges of numerous calderas (massive craters that were formed when explosive eruptions emptied magma chambers beneath the earth's crust causing the area to subside or collapse) and their associated rhyolitic ash-flow tuffs (lava flows composed of small pieces of ash) can be found along the margins of the entire length of the eastern Plain.

The ages of the caldera formation and rhyolitic volcanics on the eastern Plain range from 10 million years on the western edge to 600 thousand years at Yellowstone. The most recent basaltic flows occurred at Craters of the Moon about 2 thousand years ago. The basaltic and rhyolitic lava flows of the Plain have been measured by drilling to a depth of 2 1/2 miles. It was found that 1/2 mile of basaltic lava rested on more than 2 miles of rhyolitic lava. Since this drilling did not reach the bottom of the rhyolite deposits, the exact depth of the lavas is not known, but it certainly indicates the massive amount of lava deposited.

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Formation of the Eastern Snake River Plain

Although both geologists and laymen still refer to all of the lava fields of southern Idaho as the Snake River Plain, the more we learn about this area, the more it appears that the western and eastern sections of the plain are two very distinct and separate geologic structures. Since Craters of the Moon is located on the eastern Snake River Plain, we will now limit our discussion to this area.

The mechanics of the forces that created the eastern Snake River Plain are still disputed by geologists. However, as more data has been collected and certain geologic principles have been better defined, most geologists have come to consider the Mantle Plume Theory as the best explanation of the formation of the eastern Snake River Plain.

Mantle Plume

The Mantle Plume Theory was developed in the early 1970's as an explanation for the creation of the Hawaiian Islands. Put as simply as possible, the theory states that uneven heating within the core of the earth allows some materials to become slightly hotter than the substance that surrounds it. When the temperature of this material increases, it becomes less dense and buoyantly rises through the cooler, denser material of the earth's interior. It is thought that these plumes or "hot spots" remain active for approximately 100,000 years and produce many successive batches of rising material.

The hot material rises toward the surface like a tennis ball rises when released underwater. When this hot "ball" of molten material reaches the crust of the earth, it eventually pushes itself through and then erupts onto the surface as molten lava. Because the plume remains stationary while the plates that make up the earth's crust continue to move over it, the volcanic activity on the continents is expressed as a line of eruptions. In the ocean, it tends to form chains of volcanic islands.

Characteristically, eruptions derived from hot spots can be traced from older, early eruptions to younger, more recent eruptions. This relationship is clearly identified in the Hawaiian Island chain and many geologists see this same pattern in the age of rhyolitic volcanics expressed on the

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eastern Snake River Plain. These eruptions began 10 million years of age at Twin Falls or even earlier at 17.5 million years ago on the border of Oregon and Nevada if you agree with geologists that believe the plume first expressed itself in this area. Eruptions are younger farther northeast; 5 million years at Arco and Idaho Falls and, finally, 600 thousand years in Yellowstone.

The Mechanics of an Eruption Associated with a Mantle Plume

The cycle of events that occur in association with an eruption resulting from the presence of a mantle plume is thought to produce a very specific sequence of lava deposition: a very thin layer of basalt lava at the bottom, a thick layer of rhyolitic lava in the middle and a thin layer of basalt at the top. This has been determined by checking the cores of drill holes on the eastern Snake River Plain, where geologists have established that a layer of basalt overlies a massive layer of rhyolite. They were not able to drill deep enough to confirm the presence of the bottom layer of basalt, but if deeper drillings are made, geologists expect to find that it is present. This layering of different lava types is the result of the various stages of a typical eruption.

Stage I

Geologists theorize that a certain set of events occur as the molten ball of rising magma reaches the crust of the earth. As the rising blob of hot material first comes in contact with the crust, it continues to rise, but, because the crust is usually less dense than the rising magma, its upward movement soon begins to slow. A small amount of magma may actually reach the surface of the earth and be ejected as basaltic lava. But, at this point, most of the magma becomes trapped within the crust.

Stage II

As more and more basaltic magma collects at or near the crust (mantle boundary), heat from the magma begins to partially melt rocks of the lower part of the crust. When this occurs, large amounts of silica contained within this crust mix with the magma. This increase in silica produces a very thick, pasty magma.

The rhyolitic magma continues to collect and eventually a magma chamber is formed. A magma chamber is any large reservoir within the earth's crust that contains a body of

magma. As more and more gas-charged magma collects in the chamber from the increasing amounts of partial melting of the crust, pressures eventually build to a point where the resistance of the containing crust is overcome. This time, the resulting eruption of rhyolitic lava no longer resembles the earlier, relatively calm expulsion of basaltic lavas. The gasses contained within the thick magma cannot easily escape and, as a result, gas pressure continues to build until it is released all at once in a huge explosion.

These eruptions were gigantic. When they occurred, hundreds of cubic miles of ejected material (Mount St. Helens produced only 0.5 cubic miles of ejected material) was spewed into the atmosphere and onto the earth's surface. As the magma chamber beneath the surface was emptied, there was nothing left to support the crust and so it collapsed, forming a huge depression up to 30 miles in diameter known as a caldera.

Geologists have found evidence that many calderas have developed on the Snake River Plain. After millions of years, however, all but a few of the more recently formed calderas (in the Yellowstone area) have been filled by subsequent rhyolitic and basaltic flows.

Stage III

As the North American Plate continued its movement to the southwest, the intense volcanic activity associated with the hot spot would gradually ebb only to be renewed at a new location. But in the area the plume had moved through, the very explosive rhyolitic activity was replaced by a reoccurrence of basaltic eruptions. These basaltic eruptions were caused by the residual heat that remained in the crust after the hot plume moved on.

Again, the magma generated by this residual heat is not buoyant enough to initially overcome the resistance of the earth's crust and remains trapped beneath the surface in magma chambers. This time, however, there is little silica left in the surrounding crustal rock. Most of it was melted during the formation of earlier rhyolitic magma chambers that produced the silica-rich rhyolite lava, but now the magma remains basaltic.

Once more, the sequence of rising magma filling and enlarging the magma chamber, the gradual increase in pressure within the chamber and, finally, the buildup of pressures great enough to force the magma to erupt onto the surface takes place. The basaltic lava begins to cover the older rhyolite lavas. With each new eruption of basalt, less of the rhyolite is left exposed and, after millions of years have passed, all of the surface area may be covered by basalt. This has happened at Craters of the Moon.

Craters of the Moon and the Great Rift

As pressure builds in the underground magma chambers, it is common for an eruption to occur at a site where the crust is weakest. On the Snake River Plain, this often occurs where volcanic rift zones are found. Volcanic rift zones are locations where the earth's crust has been pulled apart. Characteristic of volcanic rift zones are fractures or cracks that are found both on and below the surface. Volcanic rift zones represent weak areas in the earth's crust and magma under pressure follows the cracks and fissures within the rock to the surface.

There are several volcanic rift zones that traverse the Snake River Plain, but the most extensive and best studied is the Great Rift that runs through Craters of the Moon National Monument. This rift zone is approximately 60 miles in length and varies from between 1 1/2 to 5 miles in width. The area can be recognized by the presence of short cracks, the alignment of more than 25 cinder cones, and as the site of origin for more than 40 different lava flows that make up the Craters of the Moon Lava Field. The reason for the existence and location of the Great Rift has not been fully studied, but geologists believe that it is related to typical Basin and Range faulting common in areas adjacent to the Snake River Plain.

Basin and Range structure is a term for alternating uplifted mountain ranges and down-dropped valleys. This type of topography is very common in parts of California, Nevada, Utah and southern Idaho. Geologists know that the earth's crust is unusually thin in this region and they believe this is the result of forces pulling the crust in opposite directions. This stretches and thins the crust while producing a tremendous buildup of tension. When this tension becomes extreme, the earth's crust suddenly fractures. Then, depending on which theory you support, large blocks of earth simply slip down, creating a valley, or the blocks rotate to a position where one end of the block is higher than the other. Either way, a valley between two mountains is created.

Since the tension on the earth's crust in this region is fairly uniform, the release of this tension occurs in a very uniform manner over the entire area. The result is about 150 mountain ranges and valleys spread over the Basin and Range Province, all aligned in an approximately north/south direction. Typically, valleys are about 16 miles wide and mountains and valleys occur at 16 mile intervals. This series of valley and mountain range structures is known as Basin and Range topography.

While there are mountain ranges to the north and south of the Snake River Plain that have been identified as Basin and Range structures, there are no such features on the plain itself. But the block faults that occur at the edge of each Basin and Range mountain range are known as "border faults" and extend beyond the base of the mountains and out beneath the lavas. The extension of the border faults onto the plain is expressed in zones of parallel cracks that may run for tens of miles. These zones provide weak areas in the crust where lava can easily rise to the surface. These are the series of cracks we know collectively as volcanic rifts zones.

The Great Rift is not the typical volcanic rift zone found on the Snake River Plain because it cannot be readily identified as a continuation of one of the faults at the base of a Basin and Range mountain range. The distance from the Lost River Mountains to the east, however, is just slightly more than the normal 16 miles between Basin and Range structures. Gravity and seismic information indicates the presence of a fracture extending into the Pioneer Mountains (the Pioneers are part of the Idaho Batholith, an intrusion of igneous rock, and not a Basin and Range Mountain) just to the north of Craters of the Moon. This leads some geologists to believe that, although no Basin and Range mountain range formed because of the presence of the very large and stable Idaho Batholith, the Great Rift itself is probably a typical Basin and Range fault line.

Whatever the reason for its formation, the Great Rift is the conduit through the crust that allowed the tremendous amount of lava that makes up the Craters of the Moon Lava Field to reach the surface. The story of these eruptions is the geologic history of Craters of the Moon.

Eruptive History of Craters of the Moon

Most of the lavas that are exposed at Craters of the Moon formed between 2,000 and 15,000 years ago. All were basaltic eruptions that are typical of the volcanic activity produced by the residual heat that remains after the mantle plume has moved into another area. Geologists believe that these lavas were all deposited during eight "eruptive periods." These eruptive periods were all of about 1,000 years or less in duration and were separated by periods of relative calm that lasted for a few hundred to more than two thousand years.

The basis for establishing this geologic sequence comes from paleomagnetic and radiocarbon data. For paleomagnetic studies, geologists took cores of rock from many of the flows and determined how the magnetic minerals (ie. iron particles) it contained were aligned. Since the lava was molten when erupted, the magnetic minerals it contained lined up with the

earth's magnetic field and were frozen in place when the rock cooled and solidified. Since geologists have plotted the constant movement of the earth's magnetic poles and its exact position for much of recent geologic history, the alignment of the iron-bearing in the lava could be matched up to the time when these lavas would have been deposited. This match up suggests the age of the lavas within about 100 years.

Another method used by geologists to determine the age of Craters of the Moon flows involved radiocarbon dating techniques. When the lavas flowed across vegetated ground, they converted sagebrush, grass, pines and other plants to charcoal. Geologists who studied the Craters of the Moon lava field obtained this charcoal by excavating beneath the flows at the margin of the lava field. The charcoal contains carbon-14, the radioactive isotope of carbon, whose age can be determined by standard radiometric methods. Again, this data can be used to determine the age of the lava flow to within about 100 years.

This dating of various flows identified a sequence of eruptions interspersed by periods of calm. This cycle is associated with the build up of tension within the earth's crust from expansion and the continual accumulation of magma beneath the surface. Both forces exert an increasing strain on the crust until the resistance of the earth's crust is finally overcome. When this happens, an eruption takes place. As soon as the magmatic pressure dissipates, the eruption ceases until the pressures can build once more.

A Typical Eruption

What took place during a typical eruption at Craters of the Moon can be determined from information obtained through research on the Monument and from the observation of similar eruptions in Hawaii and Iceland. A scenario might go like this:

A combination of various forces would eventually cause a section of the Great Rift to pull apart, resulting in a reduction of the pressure to which magma is subjected by the weight of the overlying earth's crust. As this pressure decreases and, as magmatic pressures increase, a crack forms and magma rises in the crack toward the surface. As magma rises, gases contained within the magma begin to expand. As more and more gas expands, the magma turns to a froth as it rises to the surface through the cracks. At first, the lava is very fluid and charged with gas. Eruptions begin as a long line of tall fountains that can extend for as much as a mile or more in length. These eruptions along a crack or series of cracks produce a "curtain-of-fire" type of eruption. Much of the material produced in the curtain-of-

fire stage is in the form of cinders that contain many gas bubbles.

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

As the amount of gas contained in the magma continues to drop, the volcanic activity again changes. Now huge outpourings of lava are pumped out of the various fissures or from the vents of cinder cones in the form of lava flows. These lava flows may continue to gush for months or possibly years. Long-term eruptions of lava flows from a single vent become the source of most of the material produced during an eruption. As gas pressure continues to fall and the source of magma is depleted, the flows gradually subside and finally, all activity stops.

While this would describe a typical eruption, this cycle could often be disrupted. Cinder cones would sometimes form only to be filled by material from a nearby fountain. Cones and other formations could be ripped apart when new vents opened. If the molten magma came in contact with ground water, huge quantities of steam would be released and explosive eruptions would be renewed. Or the eruption could simply stop at any point. There may actually be no such thing as a "typical" eruption.

The Future

It has been 2,000 years since there was any volcanic activity at Craters of the Moon. Is it still likely that there will be another eruption at Craters of the Moon? If what geologists tell us proves to be true, then the answer is yes.

By studying the flows that make up the lava fields of Craters of the Moon, geologists have been able to determine an eruptive pattern that indicates the area is merely in a dormant stage at the present time. They believe that past eruptions conform to a very predictable time schedule and feel that the eruptive cycle will begin once again.

If the geologists are correct, then the components that have lead to volcanic eruptions at Craters of the Moon in the past are still in place today. They predict the next eruption will occur within the next 1,000 years.