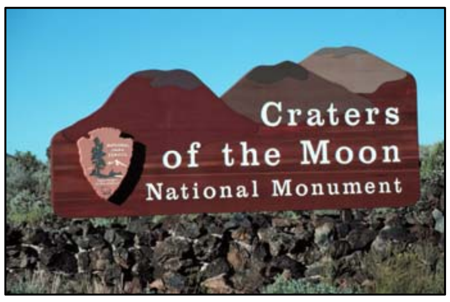
Geologic Points of Interest near the Visitor Center Area

Tiffany A. Rivera, Shaina M. Keane, and Douglass E. Owen



Before exploring Craters of the Moon geology, please be aware of the following rules, regulations, and safety concerns.

•UTM Coordinates

The points of interest on the accompanying pages are given in UTM coordinates. This point data was collected using a handheld GPS unit and collected using NAD83 Zone 12 Datum.

•North End Permits

We encourage the exploration of the North End of Craters of the Moon; however a day use permit is required and are available free of charge at the visitor center.

•Group Campsite

We offer a group campsite in the North End by reservation only. For groups up to 30 people we suggest camping here, rather than at multiple tent sites within the Lava Flow campground. Availability and reservations can be obtained by calling Park Headquarters. Cost is $30 per night.

•No Collecting

Many of the unique specimens you will see on your visit to Craters of the Moon may tempt you to collect them. All rocks must be left behind as there is no collecting permitted within Craters of the Moon without a research permit. Please leave specimens for future students and visitors to enjoy.

•Off-trail Travel

We prefer that our visitors stay on the trails as much as possible. However, to see exciting geology sometimes requires drifting from those trails. This is permissible in most areas throughout the park, but prohibited in three areas.

Please stay on trails at the following areas:

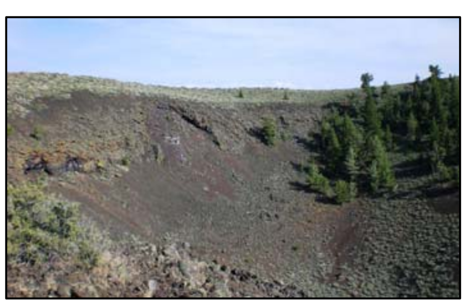
North Crater Flow Trail
Big Craters Trail
Spatter Cones Area

•Personal Safety

Visiting Craters of the Moon in the summer poses several different safety concerns. In summer months we suggest at least one gallon of water per person per day. It is also wise to wear sturdy shoes/boots and protect yourself from the sun by wearing a hat and sunscreen. If you would like to explore caves nearest to our seven-mile loop road, we recommend bringing along a flashlight. Exploration of other caves may require multiple sources of light, a helmet, and kneepads.

1 Grassy Cone Crater Complex N 4814659 E 290839

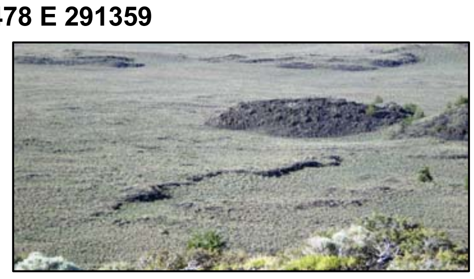
The crater complex at Grassy Cone goes unnoticed until the moment one approaches the crater rim. This view looking at the south crater wall shows the vent area for the most recent flow, roughly 7360 years ago. Grassy Cone's crater complex consists of five nested craters, each contributing to the building of the 100 meter high cone.



2 Grassy Cone Flow Lava Channel and Cones

N 4815239 E 291170 to N 4815478 E 291359

A well defined lava channel, identified by its levees, in the Grassy Cone Flow and ash layer can be seen from the crater area of Grassy Cone (upper photograph, see Point of Interest # 1). The channel is oriented approximately east-west for 400m. It is about 100m wide, and 3m deep. In the levees, multiple pulses of lava can be identified (lower photograph). The channel terminates just south of two cones that are surrounded by the Grassy Cone Flow.



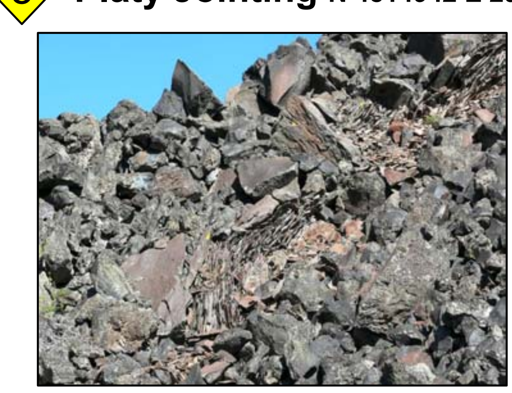
3 Sunset Cone Crater Complex N 4815989 E 292324

The main crater of Sunset Cone can be seen from US20 (left photograph); however, more spectacular views are from the crater rim (right photograph). Similar to Grassy Cone, Sunset Cone (ca. 12,000 years old) is composed of eight nested craters. The cone is roughly 140m tall and 1500m in diameter. These craters are accessible from the group campsite or from a small access road along the south side of the cone.

4 Overlook N 4815035 E 292352

The overlook of the North Crater and Highway Flows is just a short walk along an old road that angles off US20. It is best to reach this road by parking at the pullout along the highway and walking eastward toward the visitor center. Please use caution while walking along the highway. To the east, the Highway Flow fault scarp can be seen. Drapery features are present, in which the Highway Flow was still molten as faulting occurred, allowing the flow to droop over the fault scarp (upper photograph). Looking south from the overlook, boulders of the Highway Flow can be distinguished from the surrounding slabby pahoehoe of the North Crater Flow (lower photograph). The boulders are thought to have been ripped away from the massive interior of the Highway Flow as faulting occurred and later surrounded by the North Crater Flow. Finally, rafted blocks and volcanic necks can be viewed from this location (see Point of Interest #7).

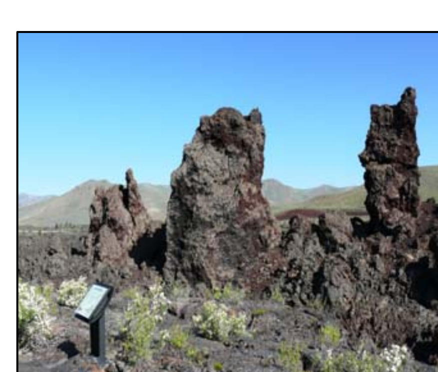
5 Platy Jointing N 4814942 E 292154 and N 4814965 E 292127



Platy jointing in the Highway Flow is a result of its high silica content allowing the flow to become extremely viscous during movement. This created an area of internal shear along the exterior of massive areas. This feature is most easily accessed by parking at the easternmost pullout along US20 and walking eastward toward the visitor center. Use caution when walking along US20. This feature is seen near mile maker 229.5

6 Monoliths N 4914915E 292817

The monoliths along the North Crater Flow Trail have been interpreted in two different manners. First, they may be rafted blocks, pieces of crater walls that were ripped away by a higher silica flow. Second, they are possibly volcanic necks, cooled conduits for a now missing cone (current map). As off-trail travel is prohibited along the North Crater Flow Trail, please view the monoliths from the way-side area.



7 Squeeze-Ups N 4814581 E 292861

If pressure is sufficient, lava can rise up the tension fracture typically found in the top of an inflated flow ridge and squeeze out onto the surface. The squeeze-ups seen here have then flowed down the sides of the flow ridge. As off-trail travel is prohibited on the North Crater Flow Trail, the best viewing area for this feature is from the North Crater Trail, as seen below.

8 Bomb Field N 4814543 E 292447

Many breadcrust bombs can be found along the North Crater Trail. These bombs form as the gaseous molten interior continues to expand inside a cooled crust. This stop presents several of varying sizes, as well as a spectacular view across the North Crater Flow.

9 Pumice Xenoliths N 4814207 E 292380

Pumice xenoliths in the vicinity of North Crater may be derived from material deposited when the Yellowstone Hotspot was beneath Craters of the Moon ca. 8mya. These xenoliths show that basaltic magma was interacting with the pumice, as basalt is strung through many of the pumice fragments. This alludes to assimilation of pre-existing rocks which would increase the silica content of the magma.

10 Granulite Xenoliths N 4814141 E 292369

Granulite xenoliths are present along the North Crater Trail. These xenoliths confirm that magma generation was occurring at greater depths, since geologists assume granulite is the composition of the lower crust beneath the eastern Snake River Plain.

11 Rhyolite Chips N 4814033 E 292197

An area just off the North Crater Trail contains many chips of what appear to be rhyolite. These are presumed to be xenoliths; however, a larger source for the chips could not be located. Rhyolite xenoliths could represent the deposits associated with Yellowstone eruptions prior to the formation of the Craters of the Moon lava field. Conversely, these chips may be derived from the Challis Volcanic Group which surfaced during the Tertiary; however it is uncertain if Challis Volcanics can be this evolved. More thorough investigation of these chips is needed (photograph at top of right column).

12 Andesite Xenolith N 4813983 E 292076

Two xenoliths of possible andesite were collected off of the North Crater Trail. Although the Snake River Plain exhibits dominantly bi-modal volcanism (rhyolite and basalt only), the presence of intermediate volcanics has been noted at nearby Cedar Butte. Andesite xenoltihs may reflect pockets of magma with varying composition due to higher amounts of crystal fractionation or may reflect an area beneath the Snake River Plain basalts which experienced a time of volcanism which created an intermediate composition. A third possibility is that these xenoliths represent underlying Challis volcanics. Since only two of these xenoliths have been found within Craters of the Moon, both have been collected for analyses, leaving collection localities marked by a prominent rock-pile.

13 Spatter-capped Cinder Mounds N 4814022 E 291991

The presence of spatter-capped cinder cones (upper photograph) led to the identification of a previously unmapped eruptive fissure (lower photograph). The cinder mounds have been interpreted as part of the North Crater complex; however the spatter capping these mounds must indicate an eruptive fissure nearby. Presently, this fissure is filled in by the Big Crater Flow. For more information on this fissure and other newly mapped features, please see the New Interpretation section.

14 Non-eruptive Fissures N 4813500 E 292385

A series of non-eruptive fissures have been identified on the west side of Big Craters. These fissures are parallel to, but offset from, the main eruptive vents for Big Craters. The longest and most prominent fissure is at least 25m long. This is the fissure mapped on the new 1:12,000 geologic map accompanying this publication. The non-eruptive fissures can be accessed easily from the Big Craters Trail.

15 Inferno Cone Vent N 4813146 E 293206

Many expect to find a vent at the top of Inferno Cone, but upon reaching the top, many are disappointed. The vent area for Inferno Cone lies to the south. As pyroclastics were emitted from the vent, the majority of the cinders were deposited to the north, although a smaller cinder cone was produced adjacent to the vent (right side of photograph). This may be due to strong winds blowing cinders to the north, an obstructed vent producing a fire hose effect, or a combination of both. The vent area is now filled in by the Blue Dragon Flow. To view this feature, park at the Spatter Cones then walk along the road back towards the loop-road. Off-trail travel at the Spatter Cones is prohibited; please enjoy this feature from the roadside.

New Interpretation of the Geology in Proximity to the Visitor Center: Evidence for a Missing Cinder Cone and Refined Mapping of Volcanic Features

Tiffany A. Rivera, Shaina M. Keane, and Douglass E. Owen

Refined Mapping of Volcanic Features

During the summer of 2007, detailed geologic field mapping of the area nearest the visitor center revealed several previously unmapped features and provided the opportunity to re-interpret the existing geology. Below is a description of our findings. For localities of these features, please refer to the accompanying geologic map and the Points of Interest section.

•Two Eruptive Fissures and a Series of Non-eruptive Fissures

The two eruptive fissures were found cutting the western flank of North Crater cinder cone (Figure 1). The eastern of the two is now partially filled by the North Crater pahoehoe flow, while the western fissure is completely filled by the Big Craters slab-lava flow. The eastern fissure is along strike with the Big Craters fissure system suggesting that the North Crater cinder cone must be older than Big Craters. Identification of the western fissure was by recognizing spatter capped cinder mounds. As spatter represents the waning stages of eruption, the presence of spatter here must indicate a fissure nearby. Several non-eruptive fissures are located along the west side of Big Craters (Figure 1). Although these fissures are not part of the eruptive system, they are parallel to the main eruptive fissures.

•Gravity Faults along Big Craters

Two gravity faults were recognized along the northwestern flank of Big Craters (Figure 1). The larger of the two stands out as it has been used as a game trail. The smaller mapped fault is topographically above the first; however it is less easily distinguishable. These features are nearly perpendicular to the fissure system and provide further evidence that slumping occurs along crater walls.

•Eastward and Westward Extenuation of the Highway Flow

We recognized that the Highway Flow (an a'a block lava of trachyandesite with local pahoehoe) extends both east and west beyond what is currently mapped. Within the western lobe, platy jointing is found in several areas. This feature is a result of internal friction at the base of the massive interior where the flow was unable to move naturally. Figure 2 shows the original mapping compared to more recent mapping.

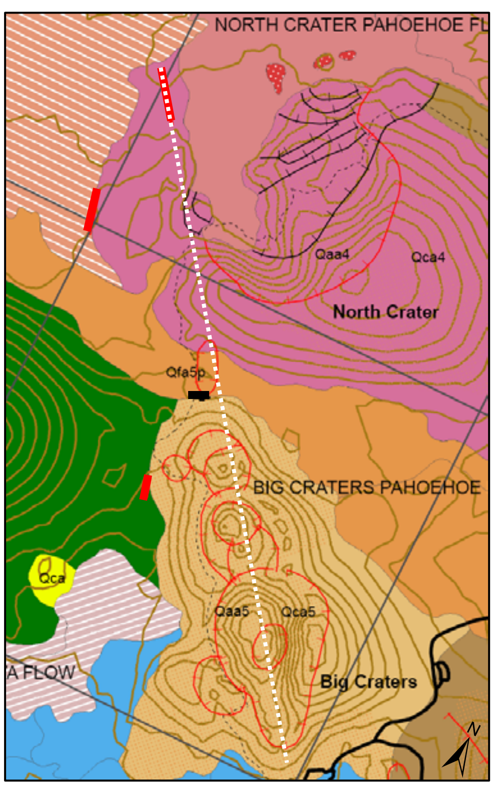


Figure 1. Newly mapped eruptive and non-eruptive fissures along the western flanks of North Crater and Big Craters cinder cones (solid red lines, exaggerated from map). White dashed line shows connection between Big Craters vent system and the eastern eruptive fissure found cutting North Crater cinder cone. Newly mapped gravity fault is shown as solid black line.

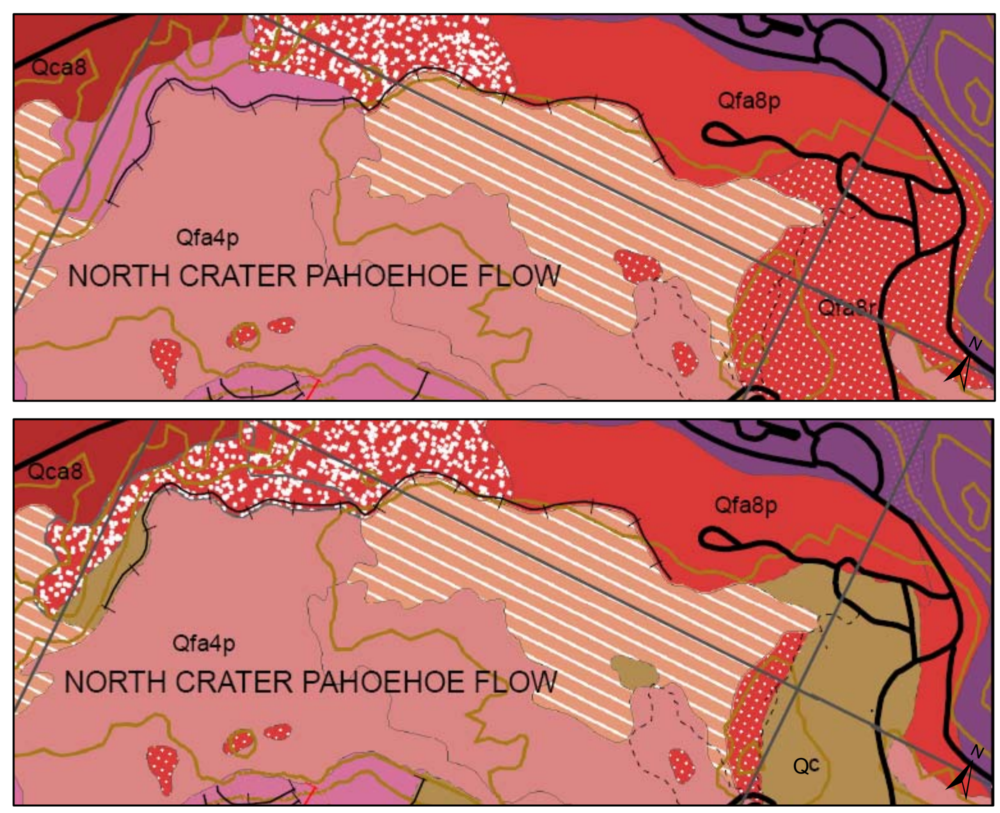


Figure 2. Upper map shows original interpretation of the Highway Flow. The block lava is shown as the red and white textured pattern in the upper part of the map and the pahoehoe section of the flow is shown as solid red extending to the east. Lower map shows new interpretation, including the extenuation of the Highway Flow both to the west and further to the east (symbology same as upper map).

Evidence for a Missing Cone

Previous workers have speculated that a large cinder cone (termed South Highway cinder cone) once existed between North Crater cinder cone, Highway US20, and the campground area. Recognition of a largely missing cinder cone agrees with work by Brossy, Jordan, and Champion (in press) showing the volume of material rafted from the North Crater cinder cone cannot be contained within the modern North Crater breach. These authors also collected paleomagnetic data from a South Highway cinder cone remnant on the north flank of North Crater cinder cone. Their data show that these two cones may be coeval. The northern rim of South Highway cinder cone acted as a topographical boundary for the Highway Flow, diverting most of the flow eastward along the cone (Caress and Owen, 2005). This project further reinterprets the existing geology to reflect the location of cone remnants and recreates a series of chronological events leading to the destruction of South Highway cinder cone. Figure 3 shows the location of South Highway cinder cone remnants.

•The campground hill area is the largest independent area of reinterpretation. This hill was previously mapped as a rafted block, as well as the cone remnant to the south. Inspection of these two areas show that loose cinders comprise the majority of these two areas. Extensive jostling occurs during rafting; it seems unlikely that such a large mass of loose cinders could have survived transport. The large amount of cinder material comprising these two areas leads us to believe that these rafted blocks are in situ pieces of the South Highway cinder cone wall (Figure 4).

•The rafted block in the North Crater pahoehoe flow has been reinterpreted as volcanic necks (Figure 5). These conduits may be one of several that contributed to the construction of South Highway cinder cone. This interpretation agrees with that of Maley, 1994. This was the only rafted block lacking loose cinders to be reinterpreted as part of South Highway cinder cone.

•The area immediately south of the Highway block lava flow presented again an area with a large volume of cinders. Moreover, the physical distance between North Crater cinder cone and this area did not seem feasible when considering the average size of the cinder cones within the Monument. Additionally, the welded cinders in this area do not resemble the material comprising North Crater cinder cone, but resemble the material seen in the campground hill area. These differences suggest that this is a remnant of South Highway cinder cone.

•The area on the northern side of North Crater cinder cone (Figure 3) also resembles the welded cinder material comprising the other possible South Highway cinder cone remnants. It was along this flank that the paleomagnetic cores were sampled by Brossy, Jordan, and Champion (in press). Their data suggests that South Highway cinder cone was coeval with North Crater cinder cone. These workers may have been the first to recognize the potential for a missing cinder cone.

•The area of South Highway cinder cone is measured as a minimum of 1300m long by 500m wide. The nearby North Crater cinder cone measures 1300m long by 750m wide. Inferno cone, whose vent is south of the cone itself, has a footprint area of 1300m by 1000m. The largest cinder cone, Big Cinder Butte, has a measured footprint of 3000m by 1500m – nearly three times the size of South Highway cinder cone. The measured area of South Highway cinder cone is consistent with other cinder cones in the Craters of the Moon lava field, providing more evidence for it's existence.

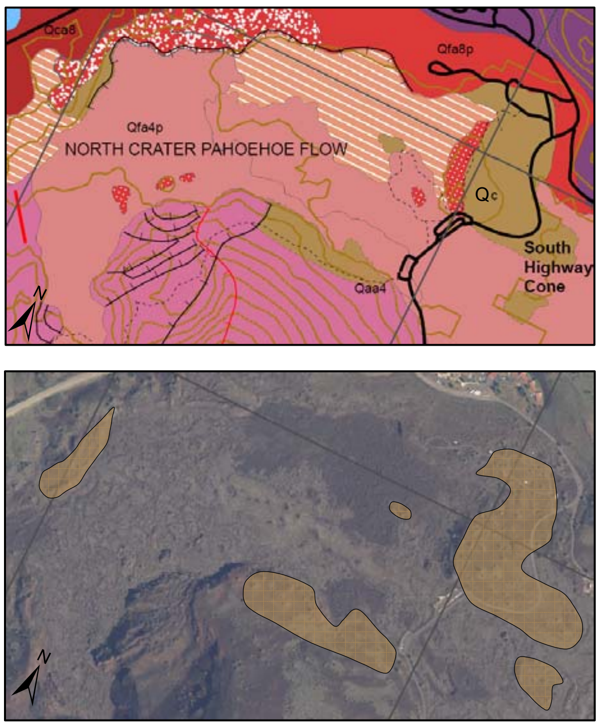


Figure 3. Map view and aerial interpretation of South Highway cinder cone remnants (in brown). The largest area for reinterpretation is in the campground area. Paleomagnetic data was taken from the remnant on the northern side of North Crater cinder cone. Minimum length of South Highway cinder cone was measured from the western remnant to the easternmost. Width was measured from the area of paleomagnetic cores to the fault scarp.

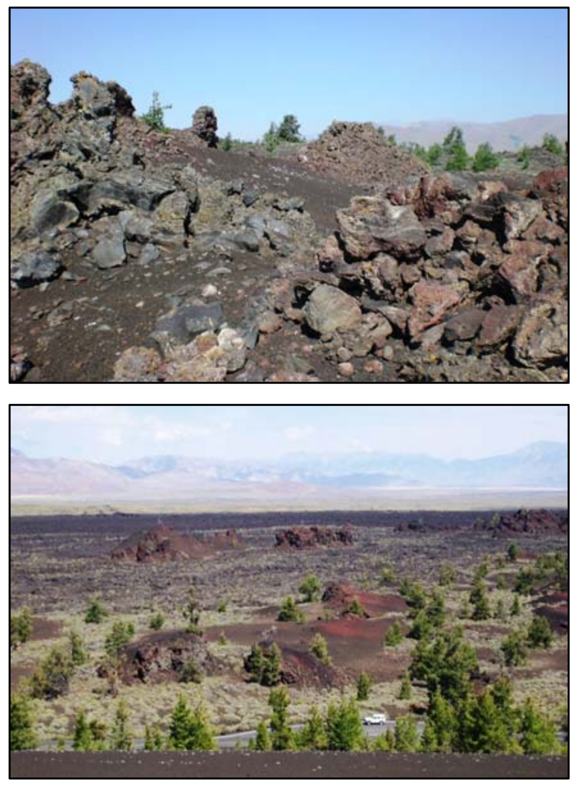


Figure 4. Reinterpretation of the campground hill (upper photograph) and large rafted block to its south (lower photograph, foreground) was based upon the extensive amount of loose cinder material comprising these previously mapped rafted blocks. Rafted blocks of welded cinders are visible in the background of the lower photograph.

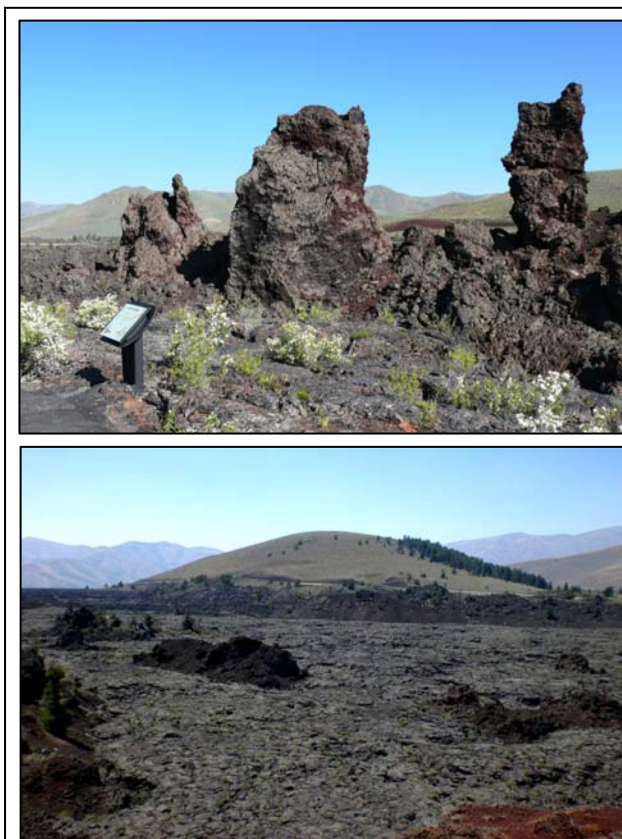
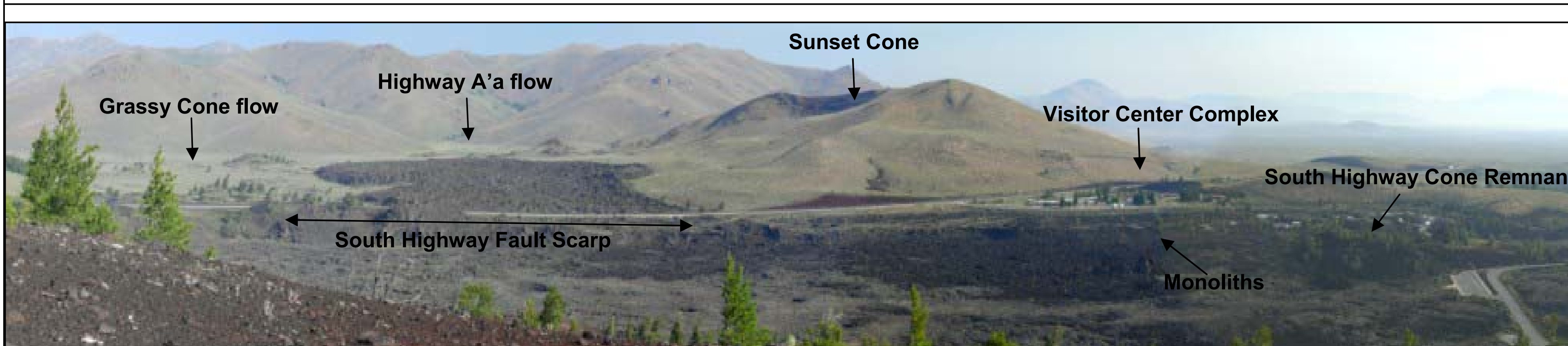


Figure 5. Previously mapped as rafted blocks, these monoliths (upper photograph) may be volcanic necks, or conduits, for the now largely missing South Highway cinder cone. The lower photograph shows rafted blocks composed of welded, rather than loose, cinders.

Sequence of Events

We present the following sequence of events from the creation to the destruction of South Highway cinder cone. This model is in partial agreement with one model proposed by Kuntz, et al. (1982). We believe that these events all happened relatively close in time although the exact amount of time for these events to happen is not constrained. Detailed absolute dating analyses on the flows and cinder cones are needed in order to examine the amount of time required to construct and destroy a moderately sized cinder cone.

•Construct North Crater and South Highway cinder cones
•Construct Big Craters cinder cone
  •A newly mapped eruptive fissure suggests that Big Craters is younger than North Crater cinder cone. This is also supported by the Big Craters pahoehoe flow (Qfa5p) onlapped onto the North Crater cinder cone. The amount of time by which Big Craters is younger has not been determined; however, we believe that these two cinder cones are relatively close in age (100 years or less).
•Eruption of Serrate and Devils Orchard Flows (not shown on map)
  •High silica flows capable of rafting away pieces of South Highway cinder cone. These flows most likely originated in the North Crater neighborhood although vent locations have not been found.
•Eruption of Highway Flow
  •Flow was channeled behind South Highway cinder cone; impingement against northern wall led to platy jointing.
•South Highway cinder cone and North Crater cinder cone began to be torn apart by the three flows mentioned above creating the rafted blocks strewn throughout the Devils Orchard and Serrate Flows. Either the Serrate or Devils Orchard Flow breached the northwest flank of North Crater cinder cone.
•Eruption of these high silica flows close in time emptied the underlying magma chamber, leaving a “hollow” area
•The empty chamber collapsed back into itself, creating the South highway fault scarp, and swallowing part of the South Highway cinder cone
•Collapse and addition of South Highway cinder cone material into the empty chamber led to the eruption of a lower silica North Crater pahoehoe flow from the previously breached wall of North Crater cinder cone.
•North Crater pahoehoe flows from the previously breached crater wall of North Crater cinder cone flowed around rafted blocks of North Crater and South Highway cinder cones, partially covered Serrate and Devils Orchard flows, and buried remaining evidence for the South Highway cinder cone.



Panoramic view across the North Crater pahoehoe flow taken from North Crater cinder cone

The Visitor Center area was first mapped by M. A. Kuntz et al. (1989) through a series of publications by the USGS. The USGS published four separate1:24,000 geologic maps that covered the northern portion of the Craters of the Moon lava field. These four quadrangles (GQ-1632, 1633, 1634, 1635) spanned to cover the boundaries of Craters of the Moon National Monument and Preserve. Detailed mapping of the visitor center area was undertaken by Tiffany A. Rivera, Shaina M. Keane, and Douglass E. Owen during the summer of 2007 as a continuation of the detailed Great Rift mapping that took place the previous three summers. The 1:12,000 map of the visitor center area will provide a more refined understanding of the volcanic history of the region. In addition, two pages regarding points of geologic interest and three pages on reinterpretation were published in the summer of 2007. The detailed descriptions with photos will allow visitors to conveniently locate and visit unique geologic features. The reinterpretation contributes to the understanding of the construction and destruction of cinder cones, events that have not been witnessed in recent history at Craters of the Moon.

ACKNOWLEDGEMENTS

Funding for this project came from The Geological Society of America’s GeoCorps America program. The authors would like to thank Craters of the Moon National Monument and Preserve Staff, Erika Colaiacomo and Celia Dubin for their field assistance, Mary Caress for her work on the Highway Flow, and Cooper Brossy for his knowledge of the North Crater neighborhood. T.A. Rivera would also like to thank Dr. Craig White, Boise State University, for his guidance, support, and for sharing his wealth of knowledge pertaining to unidentified basaltic features.

THE GEOLOGICAL SOCIETY OF AMERICA®

SCIENCE ▪ STEWARDSHIP ▪ SERVICE

REFERENCES

Brossy, C.C., Jordan, B.T., and Champion, D.E., in press, Reconstructing a breached cinder cone at Craters of the Moon National Monument: A geographic information systems approach, *in* Hughes, S., Orr B., Freiberg, D., and Boyack, D., eds., Proceedings of the Great Rift Science Symposium, Pocatello, Idaho, October 2005.

Brulet, B.R. and Chemtob, S.M., 2007, Geologic map of Echo Crater area: scale 1:12,000.
http://www.nps.gov/crmo/naturescience/upload/geomap_final_web.pdf
http://www.nps.gov/crmo/naturescience/upload/echo%20legend.pdf
http://www.nps.gov/crmo/naturescience/upload/geomap_final_web.pdf

Caress, M.E. and Owen, D.E., 2005, The Highway Flow in the Craters of the Moon lava field; a new interpretation of eruption history, Eos Trans. AGU. *86*(52), Fall Meet. Suppl., Abstract V53B-1565.

Kuntz, M.A., Champion, D.E., Spiker, E.C., Lefebvre, R.H., and McBroome, L.A., 1982, The Great Rift and the evolution of the Craters of the Moon lava fields, Idaho, *in* Bonnichsen, B. and Breckenridge, R.M., eds., Cenozoic Geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 423-437.

Kuntz, M.A., Lefebvre, R.H., Champion, D.E., Skipp, B.A., 1989a, Geologic map of the Inferno Cone quadrangle, Butte County, ID: U.S. Geological Survey Quadrangle Map GQ-1632, scale 1:24,000.

Maley, T.S., 1994, Field geology illustrated, 2nd ed.: Mineral Land Publications, Boise, Idaho, 704p.

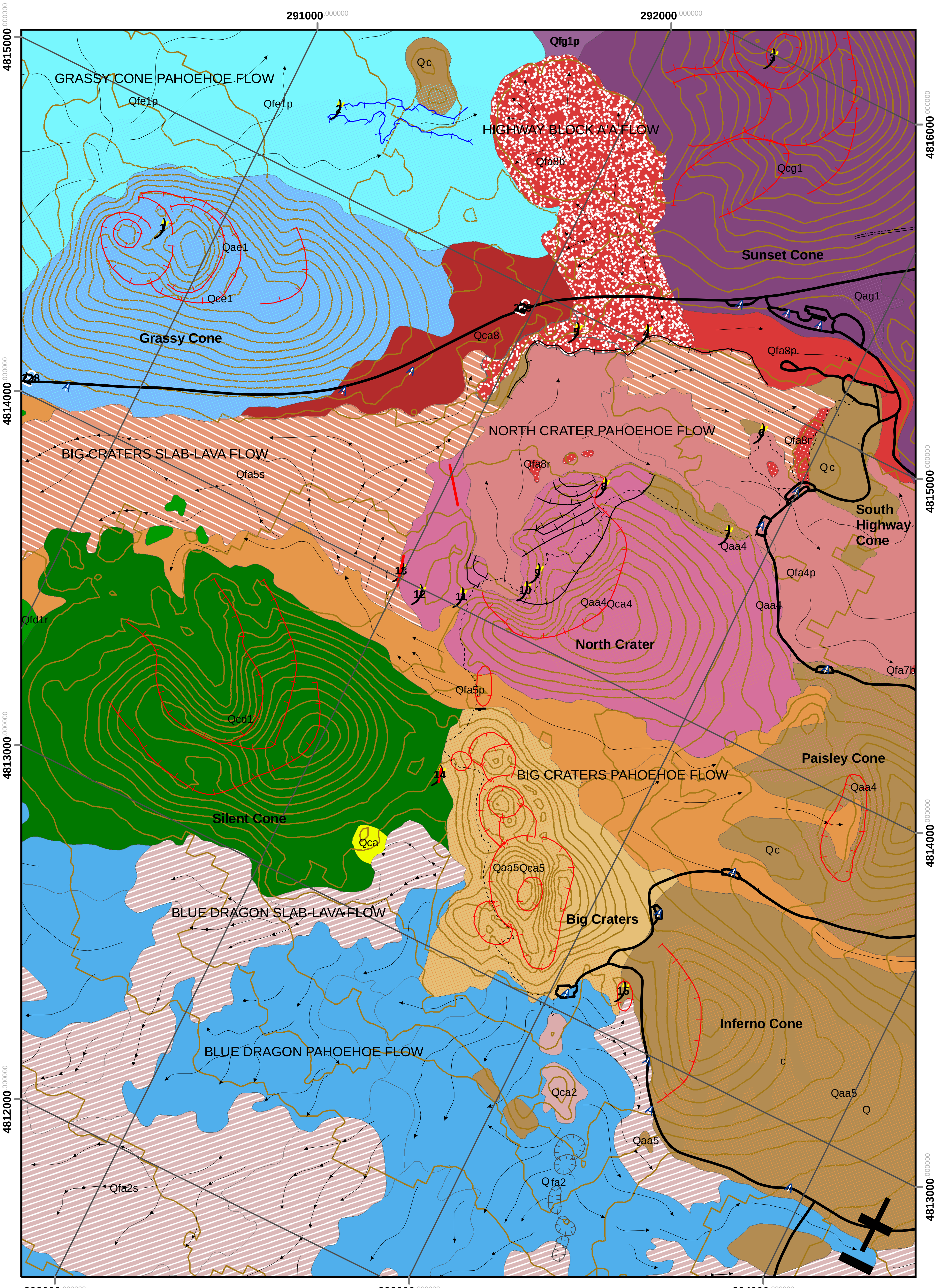
McCurry, M., Hackett, W.R., and Hayden, K., 1999, Cedar Butte and cogenetic Quaternary rhyolite domes of the eastern Snake River Plain, *in* Hughes, S.S. and Thackray, G.D., eds., Guidebook to the Geology of Eastern Idaho: Idaho Museum of Natural History, p. 169-179.

Murtaugh, J.C., 1961, Geology of Craters of the Moon National Monument, Idaho: Moscow, University of Idaho, M.S. thesis, 99p.

Wetherell, K. A., Clennon, R. P., Truitt, K. E., and Hansen, N., 2005, Geologic map of the Broken Top area: scale 1:12,000.
http://www.nps.gov/crmo/naturescience/upload/new_map2.pdf
http://www.nps.gov/crmo/naturescience/upload/legend.pdf

Geologic Map of the Visitor Center Area
Craters of the Moon National Monument and Preserve

Tiffany A. Rivera, Shaina M. Keane, and Douglass E. Owen



SCALE 1:12,000

0 0.25 0.5 1 Kilometers

0 0.25 0.5 1 Miles

CONTOUR INTERVAL 10 METERS

TRUE NORTH
MAGNETIC NORTH
14

APPROXIMATE MEAN DECLINATION, 2006

Source: ESRI Data & Maps Geologic Quadrangle 1632
Projected Using North American Datum 1983
1000 m Universal Transverse Mercator grid, zone 12
Created in ArcGIS 9 using ArcMap for
Craters of the Moon National Monument
and Preserve, 2007

Description of Map Units

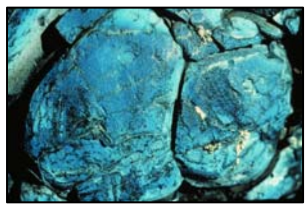
Volcanic units in the vicinity of the visitor center, Craters of the Moon lava field; Units arranged by age; youngest unit is located at the top left and become progressively older down to the right

GEOLOGIC UNITS

Blue Dragon Flow (2,076±45) and related deposits

Qfa2

Pahoehoe basalt-hawaiite flow
Dominantly tube-fed flows characterized by dark and light blue glassy, vesiculated surfaces. The flow is comprised of two lobes that moved from fissure-controlled vents at the Spatter Cones (Qca2) and the southern part of Big Craters cinder cone (Qca5).



Qfa2s

Slab-lava flow
Slabby pahoehoe flows from degassed, highly viscous lava which encountered rough and/or steep topography; sourced through rootless vents.

Qca2

Spatter Cones
Agglutinated spatter and cinders formed around central vents at the southern end of Big Craters cinder cone (Qca5). Southern end of fissure system marked by spatter ramparts and pit craters.

Qfa4p

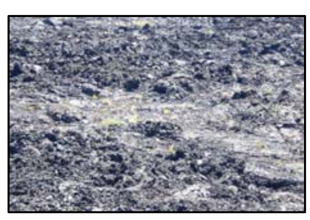
North Crater pahoehoe basalt-hawaiite flow (nd, ~2,400)
Surface-fed flow with blue glassy crust and highly vesiculated. Flow contains xenoliths of gneissic, rhyolitic, and pumaceous rocks.

Big Craters Flow (2,400±300) and related deposits

Qfa5p

Qfa5s

Pahoehoe hawaiite flow and slab-lava flow
Surface-fed flows originating from vents near the northern margin of Big Craters cinder cone (Qca5) consisting of two flows: Big Craters Northeast and Big Craters Southwest (Murtaugh 1961). Characterized by elongated vesicles (spiny pahoehoe) and glassy surface. Slab-lavas formed when flow encountered rough and/or steep topography.



Qca5

Qaa5

Big Craters cinder cone and ash deposits
Complex consists of minimum nine nested craters suggesting a complex history. Fissure on northern flank sourced Big Craters flows (Qfa5s and Qfa5p). Non-eruptive fissures on western flank are parallel to, but offset from main eruptive fissures. Accumulations of ash on the east flank of Big Craters and the west flank of Inferno Cone (Qc) are less than 1m thick.

Highway Flow and related deposits (nd)

Qfa8b

Block-a'a trachyandesite flow
Surface-fed flow from vent area between Grassy and Sunset cinder cones (Qce1 and Qcg1, respectfully). Flow fronts are as high as 15m and 2-10m of flow are exposed at the South Highway cinder cone (Qc) fault scarp (see New Interpretation section).

Qfa8p

Pahoehoe trachyandesite flow
Surface-fed glassy flow found in the campground area. Unit consists of slab lava locally.

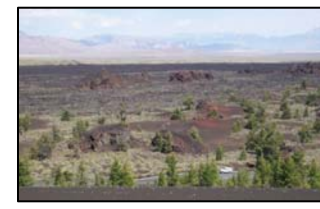
Qfa8r

Rafted Blocks
Source is most likely North Crater cinder cone (Qca4) and South Highway cinder cone (see New Interpretation section).

Highway Flow and related deposits continued

Qca8

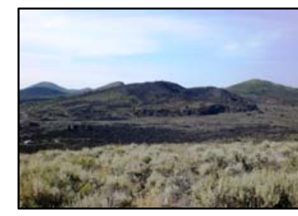
Cinder Mounds
Irregular-shaped mounds less than 8m high and 100m in diameter. Origin is unknown but may be related to eruptions associated with North Crater cinder cone (Qca4) or South Highway cinder cone (see New Interpretation section).



Qca4

Qaa4

North Crater Cinder Cone and ash deposits
North side of cone cut by normal faults which created slumped blocks. North wall of crater is breached as a result of collapse and rafting by more viscous lavas. Cone was source for North Crater flow (Qfa4p) and believd to have collapsed in association with the eruption of the Highway Flow (Qfa8) and other high-silica lavas. Cone is about 130m high and 1000m in diameter. Ash and lapilli accumulated on the eastern flank of North Crater cinder cone and on Paisley Cone (Qc) are less than 1m thick.



Silent Cone Flow (nd) and related deposits

Qfd1r

Rafted Blocks
Broken wall blocks sourced from the northwestern part of Silent Cone cinder cone (Qcd1). Blocks close to the cinder cone are surrounded by Big Craters flow (Qfa5p and Qfa5s) and Blue Dragon flow (Qfa2).

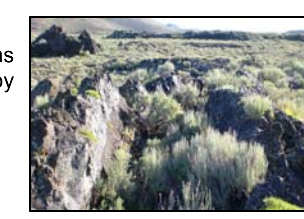
Qcd1

Silent Cone cinder cone
Complex consists of three nested craters and is open to the northwest from collapse and faulting. Cone is about 150m high and 1500m wide.

Grassy Cone Flow (7,360±60) and related deposits

Qfe1p

Pahoehoe basalt flow
Surface- and tube-fed flow which was highly inflated. Flow is dominated by inflation pits and pressure ridges.



Qce1

Qae1

Grassy Cone cinder cone and ash deposit
Cone consists of five nested craters and is source area for Grassy Cone flows (Qfe1p). Cone is about 110m high and 1500m in diameter. Well-bedded ash and lapilli lie on the Grassy Cone flow (Qfe1p) and up to 1m thick near the cone.

Sunset Cone Flow (12,010±150) and related deposits

Qfg1p

Pahoehoe basalt-hawaiite flow
Surface- and possible tube-fed flows from vents near the Sunset Cone cinder cone (Qcg1). Local unmapped patches of a'a exist where the flow moved over steeper slopes.

Qcg1

Qag1

Sunset Cone cinder cone and ash deposit
Cone is a complex of eight nested craters which indicate a complicated eruptive history. Cone is 140m high and 1500m in diameter. Well-bedded ash and lapilli on east flank of Sunset Cone (Qcg1) up to 2m thick are mapped.

Qc

Cinder cones (Holocene and latest Pleistocene)
Cinder cones having no known associated lava flows; absolute ages of cones are undetermined. In this map, this unit includes Paisley, Inferno, and South Highway cones, along with unnamed cones in the northern part of the Monument.

Qca

Colluvium and alluvium (Holocene and Pleistocene)
Colluvium at base of steep slopes

MAP SYMBOLS

Paved Road
Unpaved Road
Contour Line
Hiking Trail
Flow Direction

Contact – Dashed where approximated
Scarp – Gravity fault; hachures point to area of lower elevation
Crater – Rim at volcanic vent; hachures point to area of lower elevation
Eruptive and Non-eruptive Fissures
Lava Channel

Pit Crater – Typically circular depressions formed by collapse; hachures point to area of lower elevation
1 **Geologic Point of Interest**
P **Parking area**
229 **Mile Marker**

For information concerning references and methodology, refer to the New Interpretation section.