Geologic Points of Interest of Broken Top Area

Andrew J. Tveter, Emerald K. Shirley and Douglass E. Owen

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

•No Collecting

You may want to collect many of the unique rock formations you will see on your visit to Craters of the Moon but all rocks must be left behind as there is no collecting permitted within the monument without a research permit. Please leave all rocks for future students and visitors to enjoy.

•Off-trail Travel

We prefer that our visitors stay on the trails as much as possible. However, seeing 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. Trails will have a description on the display panel at each trail head. Protect yourself from the sun by wearing a hat and sunscreen. If you would like to explore the cave area or Buffalo Caves we recommend bringing along a flashlight and a sweatshirt. Exploration of other caves may require multiple sources of light, a helmet, and kneepads. Please check with the Visitor Center before you go into any unmarked cave.

1 Water Hole

This water hole lies inside the drained central portion of a lava pond rimmed by levees that sit above the main tube system for the Blue Dragon Flow. It represents a perched water table over ice. A rock cairn on the levee marks its location.

2 Shelly Pahoehoe

The blisters, bridges and small open tubes of this shelly pahoehoe, a highly vesicular, extremely gas infused lava, flowed from Broken Top Crater during its last eruption. Thicknesses of the shells range from 7-30 cm. Watch your step, this terrain is very unstable and hard on the ankles!

3 Granulite Xenolith

Xenoliths are fragments of older rocks ripped loose and transported to the surface during volcanic eruptions. This xenolith is granulite and represents lower crustal rocks of Archean Age (3 billion+ years old). As xenoliths are assimilated into the melt they alter the chemistry of the melt and account for some of the chemical variability found in Craters of the Moon basalts. The Xenolith sits on the east side of the fissure east of Big Cinder Butte. It is set within a boulder made up of cinder cone material.

4a Tilted Southeast Flanks

After the eruption hiatus between the original formation of the Broken Top cone approximately 2,200 years ago and the re-eruption of Broken Top post Blue Dragon Flow (2,100 years ago), the re-inflation of the cone and subsequent outpouring of the Broken Top Flow tilted up these small flank eruptions that vesiculation indicates were originally laid down close to horizontally.

4b

5 Big Sink Overlook

From this overlook you can see a large depression, a former lava pond. As the pond cooled, levees formed around the perimeter. At various times, lava broke out forming rivers or streams of lava, the “Lava Cascades.”

6 Tree Molds

Tree molds are formed when lava flows around or bulldozes down a tree and before the tree is consumed by fire the lava solidifies. This can leave a cylindrical mold of the tree and/or a tire track like pattern of charred wood preserved in the lava Molds can preserve trunks, limbs and root structures. This specific tree mold (top photo), known locally as Grandpa, is 2.2 meters deep, 0.9 meters in diameter, preserves nine limbs and one Emerald. The lower photo shows tree molds from which the direction of lava flow can be determined, The lava wrapped around the trunks of the trees, freezing and accumulating on the up-flow side. The lava in the photo was flowing towards the lower left of the picture

7 3 Eruptive Fissures

On the west side of the Broken Top following the loop trail, you will cross three eruptive fissures, which abut the flank of the cone. Abundant spatter indicates that the three fissures were eruptive. These fissures are interpreted to be part of the trench mortar flat event as they are aligned with main Trench Mortar Flat fissures.

8 Broken Top Fissures

The fissures seen here are interpreted to be part of the Trench Mortar Flat event because of their alignment and similar character of the ejecta. Tracing the fissures up the side of the cone, they transition from being eruptive near the base to non eruptive higher up.

9 Gravity Faults

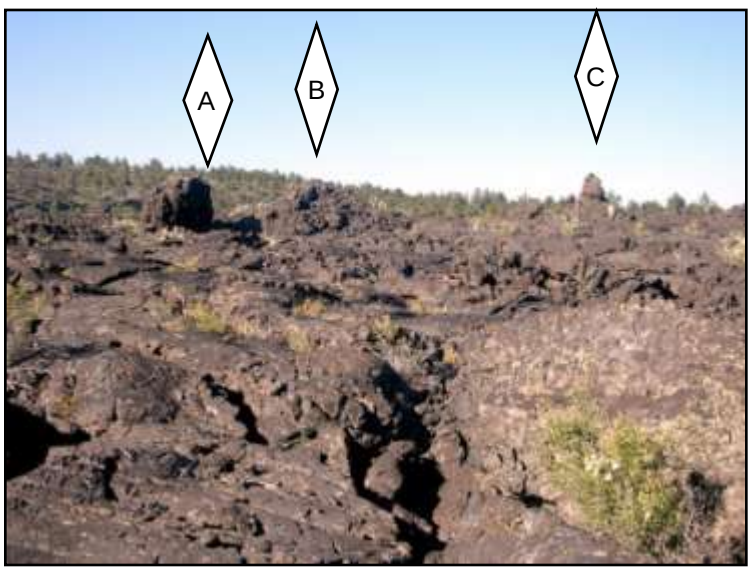
The NE side of Big Cinder Butte displays a group of gravity faults. These faults are the result of slopes being in excess of the normal angle of repose for a cinder cone (~30°), resulting in slope failure under the tug of gravity. They exhibit vertical displacement and are often arcuate indictive of slumping. The photo below is one of three faults on the over steepened nose of ca1 material.

10 Drained Tumulus

A tumulus is created when the upward pressure of slow-moving molten lava within a flow swells or pushes the overlying crust upward. This specific tumulus was created when the first pulse of the Broken Top Flow pushed up the cooled crust of the top of the flow. The flow then drained the tumulus creating a void beneath.

11 Small Kipukas

A Kipuka is an older area surrounded by a younger lava flow creating an island of the older landscape. These three small kipukas (A, B & C), seen west of the Broken Top Trail, are pieces of the buried Sawtooth NW flow. They are blocks of spatter that were carried by lava from their source, near Big Cinder Butte, to their current location. Many other small kipukas were observed in the field and the largest ones are marked on the map.



12 Buried Rafted Block

This buried block next to the trail reveals itself nicely because of the stark contrast between the black lava flow and the red oxidized cinder cone material of the small rafted block. Close examination will reveal there are some bands of oxidized tachylyte-basaltic glass.

New Interpretation of Broken Top Eruption of the Great Rift and Refined Mapping of Volcanic Features

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New Interpretation

Detailed mapping of the area around Broken Top cone during summer 2009 allowed for the refining of the sequence of events associated with Broken Top, elucidation of more features than previously mapped and also correlation with the Trench Mortar Flat event. Our detailed investigation suggests that there were two distinct pulses to the creation and inflation of the Broken Top flow pressure plateau on the west side of Broken Top cone.

Aerial photographs and ground observation reveal that the main vent for the Broken Top flow is in the southeastern portion of the cone on the opposite side of the cone from the eruptive fissure, which built the cone. The main lobe of the flow traveled east and around Half Cone and terminated near Crescent Butte. Our emphasis was investigation of the smaller lobe that flowed westerly and formed a prominent pressure plateau (Figure 1). A pressure plateau forms by the sill-like injection of lava beneath a previously formed crust that inflates the crust upward, often tilting up the edges at a steep angle that then serve as levees (Figure 2). Examining the textures exposed in inflation clefts along the edge of the plateau reveals evidence for two distinct pulses of inflation. The upper 15-40 cm is well vessiculated with horizontal zones of bubbles representing the initial outpouring as a relatively shallow sheet flow followed by much more uniform and massive zone all the way to the bottom suggesting a rapid and continuous inflation without any distinct surges or pulses to produce new vessiculated zones. The aerial extent of the western lobe probably means that the whole formation event took a few hours or at most a few days.

The western lobe of the Broken Top flow seems to have been largely sourced from the Buffalo Cave area and dominantly flowed in a southerly direction based on aerial photos and ground observations. Lava stalactites and curbs present at Buffalo Caves (Figs. 3 & 4) also support the interpretation of southerly flow from the vent area based on the direction that the lava stalactites on the curbs are bent and the way accreted material is attached to the curbs. The complicated multi-levels of Buffalo caves (Fig. 5) probably formed when the tube issuing from the vent area became clogged, but the eruption and formation of the plateau continued. New tubes are often stacked above the clogged one during an eruption (Gansecki, C., et al., 2003).

The steep inclined edges of the pressure plateau that helped contain what was in essence a lava lake leaked, resulting in the formation of a large number of lava toes. In contrast to the surface of the plateau, which spalled or flaked off its glass in the initial cooling process, the lava toes frequently have a pale-blue glassy surface. These toes flowed out on top of the Blue Dragon flow (easily seen in the area near post #10 on the loop trail), indicating that the Broken Top flow is younger than the Blue Dragon. Blue Dragon is approximately 2,100 years old (2,076 +/- 45; Kuntz,et al, 1989, Map GQ-1632).

Figure 1. Broken Top cinder cone; pressure plateau below cinder cone, toes are obscured by cloud shadow

Figure 2. Pressure plateau tilting up at a steep angles near the edge. Edges of the plateau serve as levees.

Figure 3. Bent Lava Curb in Buffalo Caves

Figure 4. Bent Lavasicle in Buffalo Caves

Figure 5. Complicated multi-levels of Buffalo caves.

Previous mapping of the Broken Top flow (Weatherall, et al, 2005) only showed a small U-shaped section of well developed pressure plateau to the west of Broken Top cinder cone. Detailed mapping of the area delineates a much larger and more complex pressure plateau system encompassing most of the area between Broken Top and Big Cinder Butte cones. Two zones with numerous inflation pits are shown on the 1/3,500 scale detail maps. These zones likely represent where the broken Top Flow encountered elevated topography associated with now largely buried flow fronts of the Sawtooth NW flow. As the inflating flow chills and solidifies against these highs it steps back and continues to inflate. Small Kipukas such as Figure 6, where the flow fronts are well exposed, but surrounded by the Broken Top flow have the same appearance and characteristics as the Sawtooth NW flow fronts mapped as yellow lines on the main map.

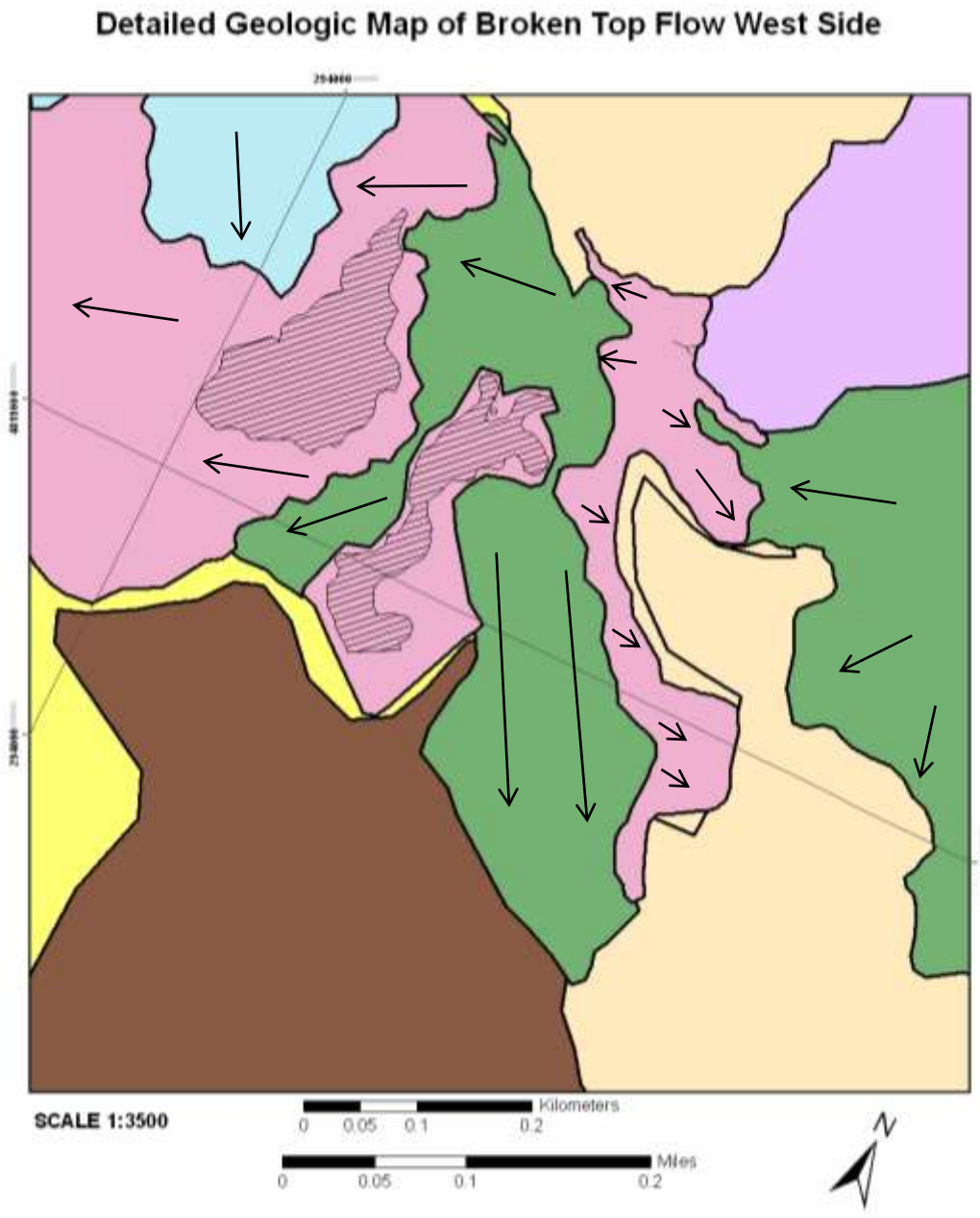
Field observation and aerial photography reveals that towards the close of the eruption of the western lobe there was a significant breakout of lava onto the surface of the plateau, likely representing the clogging/collapse of one or more of the main distributor tubes within the plateau that forced the lava back onto the surface.

The Trench Mortar Flat event that created the fissures that run NW-SE across Trench Mortar Flats happened 2180 +/- 70 BP based on C-14 dates from charcoal found in tree molds on the flat (Kuntz, et al., 2007). These fissures run from the flank of Watchman in the south up onto the flank of Broken Top (Figure 7). There is also a prominent zone of gravity faults near the eruptive fissure that spawned Broken Top cone where the over-steepened slope failed and was slumping into the eruptive fissure. Later this fissure was in filled by a lobe of the Blue Dragon flow, which issued from the Spatter Cones Big Craters area. In turn the Blue Dragon was buried in places by the Broken Top flow.

Figure 6. Small Kipuka made up of cinder cone materials resembling materials found in Sawtooth NW Flow Fronts.

Figure 7. Fissures from Trench Mortar Flat Event running up Broken Top

Map 1, arrows show lava flow direction



Sequence of Events:

•Sawtooth Northwest flow ~6,020 BP

•Broken Top cinder cone ~slightly before or contemporaneous with Trench Mortar Flat Event ~2,200 BP

•Hiatus of ~100 years

•Blue Dragon Flow ~2,100 BP

•Re-inflation of Broken Top tilting up flank eruptions

•Broken Top Flow some time after Blue Dragon flow, perhaps only a few years
- •Broken Top flow starts as sheet flow and inflates rapidly creating a pressure plateau
- •Broken Top flow has late stage breakout onto the surface, probably after clogging of distributary lava tube feeding the plateau

The Broken Top 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 Broken Top area was undertaken by Kathryn A. Wetherell, Rachel P. Clennon, Kimberly E. Truitt, and Nichole Hansen during the summer of 2005. More refined mapping was requested by the Park Service and Andrew J. Tveter, Emerald K. Shirley and Douglass E. Owen under took this task during the summer of 2009. The 1:12,000 map of the Broken Top area will provide a more refined understanding of the volcanic history of the region. Furthermore, two pages concerning points of geologic interest and three pages of reinterpretation were published in the summer of 2009. The indepth descriptions and color photos will let visitors and students locate these exceptional geologic features with ease. The reinterpretation contributes to the understanding of the events that created the landscape of Craters of the Moon National Monument and Preserve.

ACKNOWLEDGEMENTS

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http://www.nps.gov/crmo/naturescience/upload/legend.pdf

Geologic Map Broken Top Area
Craters of the Moon National Monument and Preserve

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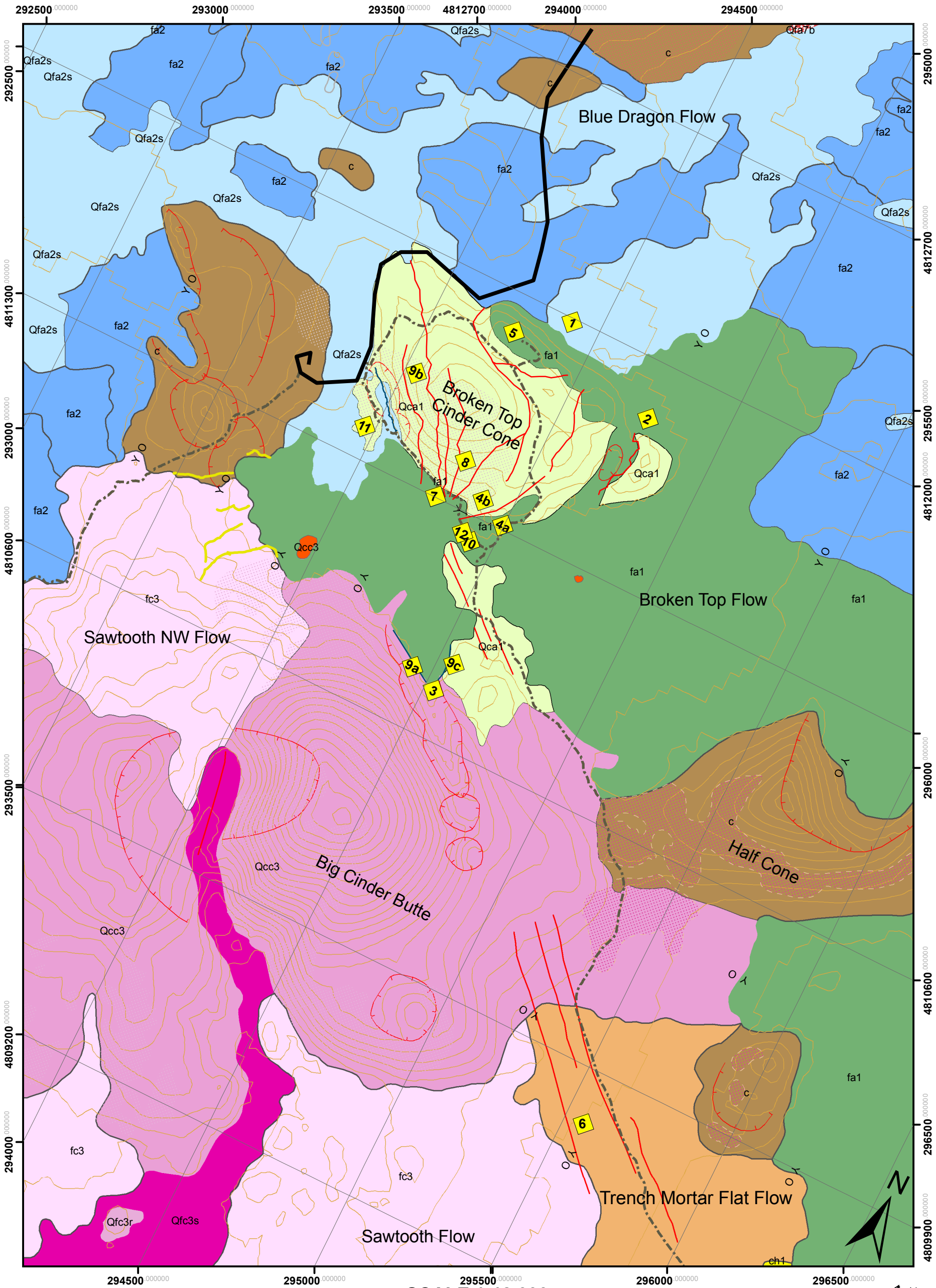
2009



Source: ESRI Data & Maps
Geologic Quadrangles - 1632, 1633, 1634, 1635
Projection: 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

SCALE 1:12,000

Kilometers
0 0.25 0.5

Miles
0 0.125 0.25 0.5

CONTOUR INTERVAL 10 METERS

TRUE NORTH
MAGNETIC NORTH
14

APPROXIMATE MEAN DECLINATION, 2006