Craters of the Moon National Monument and Preserve

GRI Ancillary Map Information Document, Craters of the Moon Lava Field 24k Map

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Craters of the Moon National Monument and Preserve

cotm_geology.pdf

Version: 5/6/2014
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Craters of the Moon National Monument and Preserve, Idaho

Document to Accompany Digital Geologic-GIS Data

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This document has been developed to accompany the digital 24k scale geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Craters of the Moon National Monument and Preserve, Idaho (CRMO).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park contact:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park.
(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.
GRI Digital Maps and Source Map Citations

Multiple digital geologic-GIS maps were produced for this park – a compiled map clipped to the quadrangles of interest for the park, and four 7.5’ quadrangle component maps. The GRI digital geologic-GIS maps for Portions of the Craters of the Moon Lava Field, Idaho (COTM):

The GRI compiled park extent and vicinity map,

**GRI Digital Geologic Map of Portions of the Craters of the Moon Lava Field, Idaho (GRI MapCode COTM)**

Source maps used in the compiled map are listed with each 7.5’ quadrangle component map.

Individual GRI 7.5’ component maps and their source map,

**GRI Digital Geologic Map of the Fissure Butte Quadrangle, Idaho (GRI MapCode FIBU)**


**GRI Digital Geologic Map of the Inferno Cone Quadrangle, Idaho (GRI MapCode INCO)**


**GRI Digital Geologic Map of the North Laidlaw Butte Quadrangle, Idaho (GRI MapCode NLBU)**


**GRI Digital Geologic Map of The Watchman Quadrangle, Idaho (GRI MapCode THWA)**


Additional information pertaining to each source map is also presented in the GRI Source Map Information (COTMMAP) table included with the GRI geology-GIS data.
Map Unit List

The geologic units present in the digital geologic-GIS data produced for Craters of the Moon National Monument and Preserve, Idaho (CRMO) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qca - Colluvium and alluvium). Units are listed from youngest to oldest. Information about each geologic unit is also presented in the GRI Geologic Unit Information (COTMUNIT) table included with the GRI geology-GIS data. Some source unit symbols, names and/or ages may have been changed in this document and in the GRI digital geologic-GIS data. This was done if a unit was considered to be the same unit as one or more units on other source maps used for this project, and these unit symbols, names and/or ages differed. In this case a single unit symbol and name, and the unit’s now recognized age, was adopted. Unit symbols, names and/or ages in a unit descriptions, or on a correlation of map units or other source map figure were not edited. If a unit symbol, name or age was changed by the GRI the unit’s source map symbol, name and/or age appears with the unit’s source map description.

Cenozoic Era

Quaternary Period

Snake River Group, Craters of the Moon Lava Field

Lava Flows of Period A

Broken Top flow
- Qfa1p - Broken Top flow, pahoehoe basalt flow
- Qca1 - Broken Top flow, Broken Top cinder cone
- Qaa1 - Broken Top flow, volcanic-ash deposits

Blue Dragon flow
- Qfa2p - Blue Dragon flow, pahoehoe basalt-hawaiite flow
- Qfa2s - Blue Dragon flow, slab-lava flows
- Qca2 - Blue Dragon flow, spatter cones and related eruptive-fissure deposits

Trench Mortar Flat flow
- Qfa3p - Trench Mortar Flat flow, pahoehoe basalt-hawaiite flows
- Qfa3s - Trench Mortar Flat flow, slab-lava flows
- Qca3 - Trench Mortar Flat flow, The Watchman cinder cone, cinder mounds and spatter-rampart deposits
- Qaa3 - Trench Mortar Flat flow, volcanic-ash deposits

North Crater flow
- Qfa4p - North Crater flow, pahoehoe basalt-hawaiite flow
- Qca4 - North Crater flow, North Crater cinder cone
- Qaa4 - North Crater flow, volcanic-ash deposits

Big Craters flow
- Qfa5p - Big Craters flow, pahoehoe hawaiite flows
- Qfa5s - Big Craters flow, slab-lava flows
- Qca5 - Big Craters flow, Big Craters cinder cone
- Qaa5 - Big Craters flow, volcanic-ash deposits

Serrate flow
- Qfa6b - Serrate flow, block-a'a trachyandesite flow
- Qfa6s - Serrate flow, squeeze-out flows
- Qfa6r - Serrate flow, rafted blocks

Devils Orchard flow
- Qfa7b - Devils Orchard flow, block-a'a trachyandesite flow
- Qfa7r - Devils Orchard flow, rafted blocks
Highway flow
- Qfa8p - Highway flow, pahoehoe trachyandesite flow
- Qfa8b - Highway flow, block-a'a trachyandesite flow
- Qfa8r - Highway flow, rafted blocks
- Qca8 - Highway flow, cinder mounds

Lava Flows of Period B
Vermillion Chasm flow
- Qfb1p - Vermillion Chasm flow, pahoehoe basalt flow
- Qfb1a - Vermillion Chasm flow, a'a flow
- Qfb1s - Vermillion Chasm flow, slab-lava flows
- Qcb1 - Vermillion Chasm flow, cinder-mound and spatter ramparts deposits
- Qab1 - Vermillion Chasm flow, volcanic-ash deposits

Deadhorse flow
- Qfb2p - Deadhorse flow, pahoehoe basalt flow
- Qcb2 - Deadhorse flow, spatter-rampart deposits
- Qab2 - Deadhorse flow, volcanic-ash deposits

Devils Cauldron flow
- Qfb3p - Devils Cauldron flow, pahoehoe basalt-hawaiite flow
- Qfb3s - Devils Cauldron flow, slab-lava flow

Black top Butte flow
- Qfb4p - Black Top Butte flow, pahoehoe hawaiite flow
- Qfb4s - Black Top Butte flow, slab-lava flow
- Qcb4 - Black Top Butte flow, Black Top Butte cinder cone
- Qab4 - Black Top Butte flow, volcanic-ash deposits

Lava Flows of Period C
Indian Wells North flow
- Qfc1a - Indian Wells North flow, a'a trachyandesite flow
- Qfc1z - Indian Wells North flow, squeeze-out flows
- Qfc1r - Indian Wells North flow, rafted blocks

Indian Wells South flow
- Qfc2a - Indian Wells South flow, a'a trachyandesite flow
- Qfc2z - Indian Wells South flow, squeeze-out flows
- Qfc2r - Indian Wells South flow, rafted blocks

Sawtooth flow
- Qfc3a - Sawtooth flow, a'a trachyandesite flow
- Qfc3s - Sawtooth flow, slab-lava flows
- Qfc3z - Sawtooth flow, squeeze-out flows
- Qfc3r - Sawtooth flow, rafted blocks
- Qcc3 - Sawtooth flow, Big Cinder Butte cinder cone
- Qac3 - Sawtooth flow, volcanic-ash deposits

South Echo flow
- Qfc4p - South Echo flow, pahoehoe basalt flow
- Qcc4 - South Echo flow, spatter rampart deposits

Sheep Trail Butte flow
- Qfc5p - Sheep Trail Butte flow, pahoehoe basalt flow
- Qfc5a - Sheep Trail Butte flow, a'a flow
- Qfc5z - Sheep Trail Butte flow, squeeze-out flows
- Qcc5 - Sheep Trail Butte flow, Sheep Trail Butte cinder cone
- Qac5 - Sheep Trail Butte flow, volcanic-ash deposits

Fissure Butte flow
- Qfc6p - Fissure Butte flow, pahoehoe basalt flow
CRMO GRI Map Document (24k Map)

Qfc6a - Fissure Butte flow, a'a flow
Qcc6 - Fissure Butte flow, Fissure Butte cinder cone and related spatter-rampart deposits

The Sentinel flow
Qfc7p - The Sentinel flow, pahoehoe basalt flow
Qfc7a - The Sentinel flow, a'a flows
Qfc7z - The Sentinel flow, squeeze-out flows
Qfc7r - The Sentinel flow, rafted blocks
Qcc7 - The Sentinel flow, The Sentinel cinder cone
Qac7 - The Sentinel flow, volcanic ash deposits

Lava Flows of Period D
Silent Cone flow
Qfd1p - Silent Cone flow, pahoehoe trachyandesite flow
Qfd1a - Silent Cone flow, a'a flow
Qfd1r - Silent Cone flow, rafted blocks
Qcd1 - Silent Cone flow, Silent Cone cinder cone

Carey Kipuka flow
Qfd2a - Carey Kipuka flow, a'a hawaiite flow
Qfd2z - Carey Kipuka flow, squeeze-out flow

Little Park flow
Qfd3p - Little Park flow, pahoehoe hawaiite flow
Qfd3a - Little Park flow, a'a hawaiite flow
Qfd3z - Little Park flow, squeeze-out flows
Qfd3r - Little Park flow, rafted blocks

Little Laidlaw Park flow
Qfd4a - Little Laidlaw Park flow, a'a hawaiite flow
Qfd4z - Little Laidlaw Park flow, squeeze-out flow

Lava Flows of Period E
Grassy Cone flow
Qfe1p - Grassy Cone flow, pahoehoe basalt flow
Qfe1a - Grassy Cone flow, a'a flows
Qfe1r - Grassy Cone flow, rafted blocks
Qce1 - Grassy Cone flow, Grassy Cone cinder cone
Qae1 - Grassy Cone flow, volcanic-ash deposits

Lava Point flow
Qfe2a - Lava Point flow, a'a basalt flows
Qfe2z - Lava Point flow, squeeze-out flows
Qfe2r - Lava Point flow, rafted blocks

Lava Flows of Period G
Sunset flows
Qfg1p - Sunset flows, pahoehoe basalt-hawaiite flows
Qcg1 - Sunset flows, Sunset Cone cinder cone
Qag1 - Sunset flows, volcanic-ash deposits

Carey flow
Qfg2p - Carey flow, pahoehoe basalt-hawaiite flow
Qfg2a - Carey flow, a'a flows

Lava Flows of Period H
Crescent Butte flow
Qfh1p - Crescent Butte flow, pahoehoe basalt flow
Qch1 - Crescent Butte flow, Crescent Butte cinder cone
Little Prairie flow
  Qfh2p - Little Prairie flow, pahoehoe basalt flow
  Qfh2a - Little Prairie flow, a'a flows

No Name flow
  Qfh3p - No Name flow, pahoehoe basalt flow

Surficial Deposits
  Qca - Colluvium and alluvium

Volcanics of Indeterminate Age
  Qc1  - Cinder cones of indeterminate age

Volcanics older than the Craters of the Moon Lava Field
  Qbs  - Pahoehoe basalt flows
  Qc2  - Older cinder cones

Tertiary Period

Intrusive Rocks
  Tg  - Biotite granite of Big Cottonwood Creek
  Tqm - Hornblende quartz monzonite of Little Cottonwood Creek

Challis Volcanics
  Tcw - Welded tuff
  Tclb - Lava flows and interbedded tuff breccia
  Tclb - Tuff breccia

Paleozoic Era

Mississippian Period

Sedimentary Rocks
  Mcb - Copper Basin Formation
**Map Unit Descriptions**

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

** Source unit symbols were changed by the GRI to be more descriptive. The source author characterized each flow by a symbol (e.g. fa1) but then only differentiated flow types by texture patterns on the paper map. The GRI added a descriptive age symbol (e.g. Q) and a letter at the end of the symbol (e.g. p for pahoehoe or a for a’a) to differentiate the flow type in the GIS data. For example, the Quaternary Broken Top flow, pahoehoe basalt flow was resymbolized as Qfa1p.

**Qfa1p - Broken Top flow, pahoehoe basalt flow (Holocene)**

fa1 - Broken Top flow and related vent and ash deposits, Pahoehoe basalt flow (Holocene)
Surface-fed flow from obscure vents and short fissures, arcuate cracks, and small, spatter-encrusted vents on east and southeast flanks of Broken Top cinder cone (ca1). Vents probably formed during partial collapse of Broken Top cinder cone. Flow is hummocky, rough-surfaced, and cut by widely spaced polygonal joints. A lighter color and relative abundance of grass and low bushes distinguish the Broken Top flow from underlying Blue Dragon pahoehoe flow (fa2). Unit also includes inclined slabs of basalt, as thick as 5 m, and accumulations of agglutinated spatter that lie on northeast-, east-, and south-facing slopes of Broken Top cinder cone. Only distal parts of two lobes of flow occur in The Watchman quadrangle. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

fa1 - Broken Top flow, Pahoehoe basalt flow (Holocene)
Pahoehoe basalt flow- Surface-fed flow from obscure vents and short fissures, arcuate cracks, and small, spatter-encrusted vents on east and southeast flanks of Broken Top cinder cone (ca1) in the Inferno Cone quadrangle (Kuntz and others, 1989). Only distal parts of two lobes of flow occur in this quadrangle. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

**Qca1 - Broken Top flow, Broken Top cinder cone (Holocene)**

c1 - Broken Top flow and related vent and ash deposits, Broken Top cinder cone (Holocene)
West flank of cone mantled by agglutinated spatter (aa1) from eruptive fissure on west side of cone. West flank of cone is cur by northwest-trending fissures and normal faults having less than 1 m displacement. Bulk of cone may have formed by eruptions from fissure of west side of cone, possibly at same time as eruptions from eruptive fissures in Trench Mortar Flat. Arcuate scarps on east and south sides of cone are generally concentric with apex of cone and probably formed by collapse during eruption of Broken Top flow. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

**Qaa1 - Broken Top flow, volcanic-ash deposits (Holocene)**

aa1 - Broken Top flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Ash and fine spatter from fissure vent on west side of Broken Top cinder cone. Deposit less than 1 m thick. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).
Qfa2p - Blue Dragon flow, pahoehoe basalt-hawaiite flow (Holocene)

fa2 - Blue Dragon flow, Pahoehoe basalt-hawaiite flow (Holocene)
Tube-fed flow characterized by fresh, iridescent, dark- and light-blue, glassy, vesicular surfaces. Flow erupted from fissure-controlled vents in the vicinity of the Spatter Cones (ca2) and the south end of Big Craters cinder cone (ca5) in the adjoining Inferno Cone quadrangle (Kuntz and others, 1989a). Only distal parts of eastern lobe occur in this quadrangle. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

fa2 - Blue Dragon flow and related vent deposits, Pahoehoe basalt-hawaiite flow (Holocene)
Chiefly tube-fed flow characterized by fresh, iridescent, dark- and light-blue, glassy, vesicular surfaces. Flow consists of two lobes that moved east and west from fissure-controlled vents near the Spatter Cones (ca2) and the south end of Big Craters cinder cone (ca5). Fissure system is marked by spatter cones and pit craters. Lava tubes, skylights, and rootless vent complexes define medial and distal parts of tube systems that fed eastern and western lobes. Lava ponds rimmed by levees (popularly termed "sinks") are perched above openings on the tube system between Big Craters cinder cone (ca5) and Broken Top cinder cone (ca1). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

fa2- Blue Dragon flow, Pahoehoe basalt-hawaiite flow (Holocene)
Tube-fed pahoehoe flow characterized by fresh, iridescent, dark- and light-blue, glassy, vesicular surfaces. Flow erupted from fissure-controlled vents in the vicinity of the Spatter Cones (ca2) and the south end of Big Craters cinder cone (ca5) in the adjoining Inferno Cone quadrangle (Kuntz and others, 1989a). Only distal parts of the western lobe of flow occur in this quadrangle. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

fa2- Blue Dragon flow, Pahoehoe basalt-hawaiite flow (Holocene)
Tube- and surface-fed flow characterized by fresh, iridescent, dark- and light-blue, glassy, vesicular surfaces. Flow erupted from fissure-controlled vents in the vicinity of the Spatter Cones (ca2) and the south end of Big Craters cinder cone (ca5) in the Inferno Cone quadrangle (Kuntz and others, 1989a). Lava tubes, skylights, and rootless vent complexes define tube systems that fed eastern lobe of unit in this quadrangle. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qfa2s - Blue Dragon flow, slab-lava flows (Holocene)

fa2 - Blue Dragon flow and related slab-lava flows, Slab-lava flows (Holocene)
Formed near rootless vents from degassed, more viscous lava erupted late in eruptive sequence and where degassed, more viscous, lava traversed rough topography or flowed down relatively steep slopes. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

fa2 - Blue Dragon flow, Slab-lava flows (Holocene)
Formed where degassed, more viscous lava erupted from rootless vents and where partially congealed pahoehoe flows traversed rough topography or flowed down relatively steep slopes. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qca2 - Blue Dragon flow, spatter cones and related eruptive-fissure deposits (Holocene)

c2 - Blue Dragon flow and related vent deposits, Spatter Cones and related eruptive-fissure deposits (Holocene)
The Spatter Cones are accumulations of agglutinated spatter and cinders as high as 20 m and 100 m
across. Cones formed around central vents along eruptive fissure system at south end of Big Craters cinder cone (ca5). Fissure system is source for most of Blue Dragon flows. South end of eruptive fissure system is defined by small, low spatter ramparts and pit craters. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfa3p - Trench Mortar Flat flow, pahoehoe basalt-hawaiite flows (Holocene)

fa3 - Trench Mortar Flat flow and related vent and ash deposits, Pahoehoe basalt-hawaiite flows (Holocene)
Surface-fed, thin, shelly flows that were erupted from northern part of the Trench Mortar Flat set of eruptive fissures southeast of Big Cinder Butte cinder cone (cc3). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

fa3 - Trench Mortar Flat flow and related vent and ash deposits, Pahoehoe basalt-hawaiite flows (Holocene)
Surface-fed, thin, shelly flows erupted from southern part of the Trench Mortar Flat set of eruptive fissures that are northwest of The Watchman cinder cone (ca3). (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qfa3s - Trench Mortar Flat flow, slab-lava flows (Holocene)

fa3 - Trench Mortar Flat flow, Slab-lava flows (Holocene)
Formed where distal and marginal parts of Trench Mortar Flat pahoehoe flow, shown in The Watchman (Kuntz and others, 1989b) and Inferno Cone (Kuntz and others, 1989a) quadrangles, continued to move after crust had congealed. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

fa3 - Trench Mortar Flat flow and related vent and ash deposits, Slab-lava flows (Holocene)
Formed where distal and marginal parts of Trench Mortar Flat pahoehoe flow, shown in The Watchman (Kuntz and others, 1989b) and Inferno Cone (Kuntz and others, 1989a) quadrangles, continued to move after crust had congealed. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qca3 - Trench Mortar Flat flow, The Watchman cinder cone, cinder mounds and spatter-rampart deposits (Holocene)

c3 - Trench Mortar Flat flow and related vent and ash deposits, Cinder mounds (Holocene)
Spatter and ash form cinder mounds adjacent to a relatively large central vent at Yellowjacket Waterhole. Spatter ramparts (unmapped) as much as 3 m high, 20 m wide, and 100 m long flank some fissures. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

c3 - Trench Mortar Flat flow and related vent and ash deposits, The Watchman cinder cone, cinder mounds, and spatter-rampart deposits (Holocene)
Deposits that flank eruptive fissures on northwest and southeast sides of The Watchman cinder cone consist mostly of agglutinated spatter and cinders. Spatter and ash form a cinder mounted to south of a relatively large central vent near Little Prairie Waterhole. Spatter ramparts (unmapped) as high as 5 m and as wide as 50 m flank some eruptive fissures in Trench Mortar Flat. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).
Qaa3 - Trench Mortar Flat flow, volcanic-ash deposits (Holocene)

aa3 - Trench Mortar Flat flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Ash and fine lapilli erupted from fissure vents in Trench Mortar Flat. Most deposits at north end of Trench Mortar Flat occur as accumulations less than 1 m thick on southwest side of cinder cones to the northeast (downwind) of source vents. Deposits near Yellowjacket Waterhole occur as thin veneer less than 1 m thick on Trench Mortar Flat flow (fa3). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

aa3 - Trench Mortar Flat flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Ash and lapilli erupted from fissure vents in Trench Mortar Flat. Deposits occur as thin veneer less than 1 m thick on Trench Mortar Flat pahoehoe flow near vents at Bearsden Waterhole and Little Prairie Waterhole. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qfa4p - North Crater flow, pahoehoe basalt-hawaiite flow (Holocene)

fa4 - North Crater flow and related vent and ash deposits, Pahoehoe basalt-hawaiite flow (Holocene)
Surface-fed flow that has iridescent, light-blue, highly vesicular, glassy crust. Flow contains rare inclusions of gneissic rocks, partly fused dacitic to rhyolitic rocks, and holohyaline clots of pumice. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qca4 - North Crater flow, North Crater cinder cone (Holocene)

c4 - North Crater flow and related vent and ash deposits, North Crater cinder cone (Holocene)
North side of cone is cut by northwest-dipping normal faults that created slumped blocks. Crater is open to north as a result of cone collapse and rafting away of remnants of crater walls by viscous lava flows. Cone was source vent for North Crater flow (fa4). Most of cone is believed to have formed and collapsed during eruption of Highway (fa8), Devils Orchard (fa7), and Serrate (fa6) flows. Cone is about 130 m high and 1 km in diameter. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qaa4 - North Crater flow, volcanic-ash deposits (Holocene)

aa4 - North Crater flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Ash and fine lapilli from vents in North Crater cinder cone (ca4). Deposits are discontinuous, less-than-1-m-thick blankets that accumulated downwind on eastern flanks of North Crater Cone (ca4) and Paisley Cone (ga) and, locally, on the Devils Orchard flow (fa7). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfa5p - Big Craters flow, pahoehoe hawaiite flows (Holocene)

fa5 - Big Craters flow and related vent and ash deposits, Pahoehoe hawaiite flows (Holocene)
Surface-fed flows that extend east and west from eruptive-fissure and cinder-mantled vents at the north end of Big Craters cinder cone (ca5). Unit includes Big Craters Northeast and Big Craters Southwest flows of Murtaugh (1961). Flow is characterized by olive-gray (5Y4/1), glassy crusts and elongated,
stretched vesicles. Rock is denser and medium dark gray (N4) in interior. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

fa5 - Big Craters flow, Pahoehoe hawaiite flows (Holocene)
Surface-fed flow that extends east from eruptive-fissure and cinder-cone vents at the north end of Big Craters cinder cone (ca5) in the Inferno Cone quadrangle (Kuntz and others, 1989a). Only distal parts of flow occur in The Watchman quadrangle. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

Qfa5s - Big Craters flow, slab-lava flows (Holocene)
fa5 - Big Craters flow and related vent and ash deposits, Slab-lava flows (Holocene)
Formed where partly congealed pahoehoe flows traversed rough topography, such as the underlying, corrugated surface of the Serrate flow (fa6). (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qca5 - Big Craters flow, Big Craters cinder cone (Holocene)
ca5 - Big Craters flow, Big Craters cinder cone (Holocene)
Cone consists of at least nine nested cones that indicate a complicated eruptive history. Inner walls of southernmost crater are mantled by thin flows and agglutinated spatter. Cone is about 100 m high, 800 m long, and 500 m wide. Vents at base of south and west flanks of cone were sources for some Blue Dragon flows (fa2). Fissure on north flank of cone was source vent for Big Craters flows (fa5). (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qaa5 - Big Craters flow, volcanic-ash deposits (Holocene)
aa5 - Big Craters flow, Volcanic-ash deposits (Holocene)
Ash and fine lapilli from vents at Big Craters cinder cone (ca5). Accumulations occur downwind on east slope of Big Craters cinder cone and on west and east flanks of Inferno Cone cinder cone (c). Layers of unmapped ash, less than 1 m thick, occur on Big Craters flows (fa5) near vents. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qfa6b - Serrate flow, block-a’a trachyandesite flow (Holocene)
fa6 - Serrate flow, Block-a’a trachyandesite flow (Holocene)
Surface-fed, jagged, block-a’a flow. Presumed source vent at or near North Crater cinder cone (ca4). Flow is nearly identical to Devils Orchard (fa7) and Highway (fa8) flows in terms of petrographic, chemical, and field characteristics, but age relations with these units are unknown (Kuntz and others, 1982). (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

fa6 - Serrate flow, Block-a’a trachyandesite flow (Holocene)
Surface-fed flow that extends about 11 km east-northeast from a presumed source vent at or near North Crater cinder cone (ca4) in the Inferno Cone quadrangle (Kuntz and others, 1989a). Only distal part of flow occurs in this quadrangle. Flow fronts are steep and as high as 5 m. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).
Qfa6z - Serrate flow, squeeze-out flows (Holocene)

fa6 - Serrate flow, Squeeze-out flows (Holocene)
Squeeze-out flows- Extensive lobes at base of steep margins of Serrate block-a'a flow. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

fa6 - Serrate flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe that occur at the base of steep margins of block-a'a flow. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qfa6r - Serrate flow, rafted blocks (Holocene)

fa6 - Serrate flow, Rafted blocks (Holocene)
Broken wall blocks of a shattered cinder cone, probably North Crater cinder cone (ca4). Rafted blocks are as long as 300 m and as high as 30 m. When viewed from a distance of more than several km, the Serrate block-a'a flow has a notched, serrated profile due to the arrangement of rafted blocks. Rafted blocks project through younger Big Craters flow (fa5). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

fa6 - Serrate flow, Rafted blocks (Holocene)
Broken wall blocks derived from a shattered cinder cone, probably North Crater cinder cone (ca4) in the Inferno Cone quadrangle (Kuntz and others, 1989a). Rafted blocks have lengths of as much as 300 m and heights of as much as 30 m. When viewed from a distance of more than several kilometers, the Serrate block-a'a flow has a notched, serrated profile due to the arrangement of rafted blocks. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qfa7b - Devils Orchard flow, block-a'a trachyandesite flow (Holocene)

fa7 - Devils Orchard flow, Block-a'a trachyandesite flow (Holocene)
Presumed source vent is at or near North Crater cinder cone (ca4). Flow is covered by less than 0.1 m of ash and cinders (aa4) immediately east of Paisley Cone (c). Exact age relations of unit with Serrate (fa6) and Highway (fa8) flows are unknown (Kuntz and others, 1982). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfa7r - Devils Orchard flow, rafted blocks (Holocene)

fa7 - Devils Orchard flow, Rafted blocks (Holocene)
Broken wall blocks of a shattered cinder cone, probably North Crater cinder cone (ca4). Rafted blocks are as long as 300 m and as high as 20 m. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfa8p - Highway flow, pahoehoe trachyandesite flow (Holocene)

fa8 - Highway flow, Pahoehoe trachyandesite flow (Holocene)
Surface-fed, glassy flow in the area of the campground at Craters of the Moon National Monument. Locally, unit consists of slab lava. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).
Qfa8b - Highway flow, block-a’a trachyandesite flow (Holocene)

fa8 - Highway flow, Block-a’a trachyandesite flow (Holocene)
Surface-fed flow that extends 1 km north from a presumed source vent at or near North Crater cinder cone (ca4). Flow is extremely rough surfaced and contains furrows, spires, and blocks that produce local relief of as much as 10 m. Flow fronts are as high as 15 m. Flow is 2-10 m thick where exposed in cross section on an arcuate scarp about 0.25 km north of North Crater cinder cone. Exact age relations of unit with Serrate (fa6) and Devils Orchard (fa7) flows are unknown. See Kuntz and others (1982) for discussion of origin of this unit. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfa8r - Highway flow, rafted blocks (Holocene)

fa8 - Highway flow, Rafted blocks (Holocene)
Source probably North Crater cinder cone (ca4). A large area just southeast of the headquarters area for Craters of the Moon National Monument consists of numerous rafted blocks. Because the area between these blocks is largely modified by trails, roads, camping areas, and other human activity, the map is generalized in this area. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qca8 - Highway flow, cinder mounds (Holocene)

ca8 - Highway flow, Cinder mounds (Holocene)
Irregular-shaped, low mounds, less than 8 m high and less than 100 m in diameter. Origin of deposit unknown but possibly related to eruptions during collapse of North Crater cinder cone (ca4). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfb1p - Vermillion Chasm flow, pahoehoe basalt flow (Holocene)

fb1 - Vermillion Chasm flow, Pahoehoe basalt flow (Holocene)
Surface-fed, partly shelly flow from eruptive fissures at Vermillion Chasm and from eruptive fissures that extend as far as 2 km southeast of Vermillion Chasm. Unit consists of thin (mostly < 1 m), shelly flows near source vents and thicker, more dense pahoehoe in distal parts of unit. In medial parts of unit, flows split along long, continuous surface furrows and cracks and moved as separate sublobes. Flow cut by noneruptive fissures in southeast part of flow. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfb1a - Vermillion Chasm flow, a’a flow (Holocene)

fb1 - Vermillion Chasm flow, A’a flow (Holocene)
Formed from late-stage, degassed lava erupted from vents at northern part of Vermillion Chasm eruptive-fissure system. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfb1s - Vermillion Chasm flow, slab-lava flows (Holocene)

fb1 - Vermillion Chasm flow, Slab-lava flows (Holocene)
Occur where distal lobe of Vermillion Chasm pahoehoe flow continued to move after crust had congealed. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).
Qcb1 - Vermillion Chasm flow, cinder-mound and spatter ramparts deposits (Holocene)

cb1 - Vermillion Chasm flow, Cinder-mound and spatter ramparts deposits (Holocene)
Deposits flank eruptive fissures in Vermillion Chasm area. Fissures are marked by ash-mantled furrows as wide and as deep as 10 m. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qab1 - Vermillion Chasm flow, volcanic-ash deposits (Holocene)

ab1 - Vermillion Chasm flow, Volcanic-ash deposits (Holocene)
Volcanic-ash deposits- Erupted from fissure vents in and southeast of Vermillion Chasm. Deposits occur as thin (< 2 m thick) mantle on flanks of spatter rampart deposits. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfb2p - Deadhorse flow, pahoehoe basalt flow (Holocene)

fb2 - Deadhorse flow, Pahoehoe basalt flow (Holocene)
Surface-fed, shelly, thin (< 1 m thick) flow from eruptive fissures northwest of Black Top Butte cinder cone (cb4). Thin, glassy crusts that are highly weathered impart a dusty, brownish-gray color to flow. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qcb2 - Deadhorse flow, spatter-rampart deposits (Holocene)

cb2 - Deadhorse flow and related vent and ash deposits, Spatter-rampart deposits (Holocene)
Flank Deadhorse eruptive fissures and related open cracks. Fissure system is about 11 km long and extends from southeastern margin of Vermillion Chasm pahoehoe flow (fb1), through Black Top Butte cinder cone (cb4), to the southeastern margin of the Craters of the Moon lava field beyond the eastern edge of this quadrangle. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qab2 - Deadhorse flow, volcanic-ash deposits (Holocene)

cb2 - Deadhorse flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Erupted from fissures at the northern end of Deadhorse eruptive-fissure system. Deposit occurs as a thin (< 1 m thick) mantle on northern part of spatter ramparts of Deadhorse eruptive fissures (cb2). (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfb3p - Devils Cauldron flow, pahoehoe basalt-hawaiite flow (Holocene)

fb3 - Devils Cauldron flow, Pahoehoe basalt-hawaiite flow (Holocene)
Chiefly surface-fed flow. Unit erupted from a low, broad lava dome, Devils Cauldron, that is beyond the eastern edge of this quadrangle and 1 km east of Black Top Butte cinder cone (cb4). (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).
**Qfb3s - Devils Cauldron flow, slab-lava flow (Holocene)**

fb3 - Devils Cauldron flow, Slab-lava flow (Holocene)
Represents late-stage eruption of degassed, more viscous lava from northernmost vent at Devils Cauldron, 1 km east of Black Top Butte cinder cone (cb4), beyond the eastern edge of this quadrangle. (GRI Source Map ID 922) ([Fissure Butte 7.5' Quadrangle](Fissure Butte 7.5' Quadrangle)).

**Qfb4p - Black Top Butte flow, pahoehoe hawaiite flow (Holocene)**

fb4 - Black Top Butte flow and related vent and ash deposits, Pahoehoe hawaiite flow (Holocene)
Surface-fed, thin (<2 m thick) flow from vents at the southern end of Black Top Butte cinder cone (cb4), just beyond eastern edge of this quadrangle. Flow mostly covered by Devils Cauldron pahoehoe flow (fb3). (GRI Source Map ID 922) ([Fissure Butte 7.5' Quadrangle](Fissure Butte 7.5' Quadrangle)).

**Qfb4s - Black Top Butte flow, slab-lava flow (Holocene)**

fb4 - Black Top Butte flow and related vent and ash deposits, Slab-lava flow (Holocene)
See "Lava Flow Morphology" section of the report for slab-lava flow description. (GRI Source Map ID 922) ([Fissure Butte 7.5' Quadrangle](Fissure Butte 7.5' Quadrangle)).

**Qcb4 - Black Top Butte flow, Black Top Butte cinder cone (Holocene)**

cb4 - Black Top Butte flow and related vent and ash deposits, Black Top Butte cinder cone (Holocene)
Cone consists of at least three nested cones. Craters are filled by lava ponds and indented by pit craters. Cone is about 75 m high, 600 m wide, and 1 km long. (GRI Source Map ID 922) ([Fissure Butte 7.5' Quadrangle](Fissure Butte 7.5' Quadrangle)).

**Qab4 - Black Top Butte flow, volcanic-ash deposits (Holocene)**

ab4 - Black Top Butte flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Occur as thin mantle (< 1 m thick) on west, north, and northeast parts of Black Top Butte cinder cone. (GRI Source Map ID 922) ([Fissure Butte 7.5' Quadrangle](Fissure Butte 7.5' Quadrangle)).

**Qfc1a - Indian Wells North flow, a'a trachyandesite flow (Holocene)**

fc1 - Indian Wells North flow, A'a trachyandesite flow (Holocene)
Surface-fed flow containing numerous lobes having steep fronts. Only a small part of the flow occurs in this quadrangle. Flow ridges, furrows, and cracks suggest a source at or near the northwest side of Big Cinder Butte cinder cone (cc3). (GRI Source Map ID 923) ([Inferno Cone 7.5' Quadrangle](Inferno Cone 7.5' Quadrangle)).

**fc1 - Indian Wells North flow, A'a trachyandesite flow (Holocene)**
Bulbous, steep-sided flow that contains numerous lobes. Flow ridges, furrows, and cracks suggest a source vent at or near the northwest side of Big Cinder Butte cinder cone (cc3) in the adjacent Inferno Cone quadrangle (Kuntz and others, 1989a). (GRI Source Map ID 925) ([North Laidlaw Butte 7.5' Quadrangle](North Laidlaw Butte 7.5' Quadrangle)).
Qfc1z - Indian Wells North flow, squeeze-out flows (Holocene)
fc1 - Indian Wells North flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe at the base of steep margins of Indian Wells North a'a flow. (*GRI Source Map ID 925*) (North Laidlaw Butte 7.5' Quadrangle).

Qfc1r - Indian Wells North flow, rafted blocks (Holocene)
fc1 - Indian Wells North flow, Rafted blocks (Holocene)
Broken wall blocks of a shattered cinder cone, probably Big Cinder Butte (cc3). Rafted blocks are as long as 200 m and as high as 20 m. (*GRI Source Map ID 923*) (Inferno Cone 7.5' Quadrangle).

Qfc2a - Indian Wells South flow, a'a trachyandesite flow (Holocene)
fc2 - Indian Wells South flow, A'a trachyandesite flow (Holocene)
Bulbous, steep-sided, flow fronts as high as 20 m. Unit may be an earlier phase of the Indian Wells North a'a flow (*fc1*). Flow ridges, furrows, and cracks suggest a source at or near Big Cinder Butte cinder cone (cc3) in the Inferno Cone quadrangle (Kuntz and others, 1989a). (*GRI Source Map ID 925*) (North Laidlaw Butte 7.5' Quadrangle).

Qfc2z - Indian Wells South flow, squeeze-out flows (Holocene)
fc2 - Indian Wells South flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe at the base of steep margins of the Indian Wells South a'a flow. (*GRI Source Map ID 925*) (North Laidlaw Butte 7.5' Quadrangle).

Qfc2r - Indian Wells South flow, rafted blocks (Holocene)
fc2 - Indian Wells South flow, Rafted blocks (Holocene)
Broken wall blocks of a shattered cinder cone, possibly Big Cinder Butte (cc3) in the adjacent Inferno Cone quadrangle (Kuntz and others, 1989a). Rafted blocks are typically 100 m long and about 15 m high. (*GRI Source Map ID 925*) (North Laidlaw Butte 7.5' Quadrangle).
Qfc3a - Sawtooth flow, a'a trachyandesite flow (Holocene)

fc3 - Sawtooth flow, A'a trachyandesite flow (Holocene)
Long (21 km), steep-sided flow that contains numerous lobes having steep fronts. Flow erupted from Big Cinder Butte cinder cone (cc3) in the Inferno Cone quadrangle (Kuntz and others, 1989a). Only medial and distal parts of flow occur in this quadrangle. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

fc3 - Sawtooth flow and related vent and ash deposits, A'a trachyandesite flow (Holocene)
Surface-fed, long, steep-sided flow that contains numerous lobes having steep fronts. Only proximal parts of flow occur in this quadrant, distal parts of flow are in adjacent quadrangles. Flow is mantled by as much as 2 m of unmapped ash in its proximal parts. Flow issued from source vent at south end of Big Cinder Butte cinder cone (cc3). Unit includes Big Cinder Butte Northwest a'a flow, a short (< 1 km long), blocky flow on northwest flank of Big Cinder Butte cinder cone. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfc3s - Sawtooth flow, slab-lava flows (Holocene)

fc3 - Sawtooth flow and related vent and ash deposits, Slab-lava flows (Holocene)
Tumbled, rafted slabs and crusts of pahoehoe(?) lava. Most slab-lava flows occur as late-stage streams of lava that are between major lobes of the Sawtooth a'a flow. Some slab-lava flows appear to be remobilized areas of the Sawtooth a'a flow. The surface of some slab-lava flows is broken into polygonal plates that are tens to hundreds of meters in longest dimension. Lesser amounts of ash occur on slab-lava flows than of a'a flow. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

Qfc3z - Sawtooth flow, squeeze-out flows (Holocene)

fc3 - Sawtooth flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe from rootless vents at the base of steep margins of the Sawtooth a'a flow. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

fc3 - Sawtooth flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe from rootless vents at base of steep margins of Sawtooth a'a flow. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

Qfc3r - Sawtooth flow, rafted blocks (Holocene)

fc3 - Sawtooth flow, Rafted blocks (Holocene)
Broken wall fragments of Big Cinder Butte cinder cone (cc3) in the Inferno Cone quadrangle (Kuntz and others, 1989a). Blocks are found in medial but not distal parts of the Sawtooth a'a flow. Blocks typically have lengths of 30-70 m and heights of 10 m or less. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

fc3 - Sawtooth flow and related vent and ash deposits, Rafted blocks (Holocene)
Broken wall blocks derived from central part of Big Cinder Butte cinder cone (cc3) near vent area and also from southern flanks of cone. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

**Qcc3 - Sawtooth flow, Big Cinder Butte cinder cone (Holocene)**

cc3 - Sawtooth flow and related vent and ash deposits, Big Cinder Butte cinder cone (Holocene)

Inner walls of crater are mantled by agglutinated spatter and thin lava flows. Cone is about 240 m high, 1 km wide, about 3 km long, and has a volume of about 0.2 km³. Stearns (1928) reported that Big Cinder Butte ranks among the largest, purely basaltic cinder cones in the world. East and southeast flanks of cone are cut by aligned, elongated, and circular craters that are part of Trench Mortar Flat eruptive-fissure system. Cone is open to southeast. Cone is source vent for Sawtooth and Big Cinder Butte northwest flows (fc3) and possible source vent for Indian Wells North (fc1) and Indian Wells South (fc2) flows of the North Laidlaw Butte quadrangle (Champion and others, 1989). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

**Qac3 - Sawtooth flow, volcanic-ash deposits (Holocene)**

ac3 - Sawtooth flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)

Ash and lapilli from vents at Big Cinder Butte cinder cone (cc3). Deposits as thick as 1 m occur on inner crater walls of Big Cinder Butte cinder cone, and thicker (<5 m), but discontinuous, deposits occur on south and west flanks of cone. Ash is coarser on steep eastern and northern flanks of cone and finer on western flanks. Sawtooth and Big Cinder Butte Northwest flows (fc3) are mantled by unmapped ash deposits. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

**Qfc4p - South Echo flow, pahoehoe basalt flow (Holocene)**

fc4 - South Echo flow and related vent deposits, Pahoehoe basalt flow (Holocene)

Surface-fed flow mostly less than 1 m thick. Largely covered by unmapped ash and lapilli. Flow erupted from fissures about 1 km southeast of Echo Crater cinder cone (c). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

fc4 - South Echo flow and related vent deposits, Pahoehoe basalt flow (Holocene)

Surface-fed flow mostly less than 1 m thick. Largely covered by unmapped ash and lapilli. Flow erupted from fissures about 1 km northwest of The Sentinel cinder cone (cc7). (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

**Qcc4 - South Echo flow, spatter rampart deposits (Holocene)**

cc4 - South Echo flow and related vent deposits, Spatter rampart deposits (Holocene)

Spatter ramparts flank eruptive fissures between Echo Crater cinder cone (c) and The Sentinel cinder cone (cc7) in The Watchman quadrangle (Kuntz, Lelebre, and Champion, 1989). Largely covered by ash and vegetation. Fissures were source vents for South Echo flow (fc4). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

cc4 - South Echo flow and related vent deposits, Spatter rampart deposits (Holocene)

Spatter ramparts flank eruptive fissures northwest of The Sentinel cinder cone (cc7). Largely covered by
tephra and vegetation. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).

Qfc5p - Sheep Trail Butte flow, pahoehoe basalt flow (Holocene)
fc5 - Sheep Trail Butte flow and related vent and ash deposits, Pahoehoe basalt flow (Holocene)
Surface-fed flow that extends 1-2 km south of source vents at Sheep Trail Butte cinder cone (cc5). (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfc5a - Sheep Trail Butte flow, a'a flow (Holocene)
fc5 - Sheep Trail Butte flow and related vent and ash deposits, A'a flow (Holocene)
Forms medial and distal parts of Sheep Trail Butte flow, indicating that pahoehoe converted to a'a after 1-2 km of travel from source vent. Flow lacks monoliths that are typical of most other a'a flows of the Craters of the Moon lava field. Isolated exposures about 2 km east of Purple Butte are correlated with main part of unit by similarities in field, petrographic, and paleomagnetic characteristics. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfc5z - Sheep Trail Butte flow, squeeze-out flows (Holocene)
fc5 - Sheep Trail Butte flow and related vent and ash deposits, Squeeze-out flow (Holocene)
Bulbous masses of pahoehoe along steep margins of Sheep Trail Butte a'a flow. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qcc5 - Sheep Trail Butte flow, Sheep Trail Butte cinder cone (Holocene)
cc5 - Sheep Trail Butte flow and related vent and ash deposits, Sheep Trail Butte cinder cone (Holocene)
Cone consists of five nested cinder cones and associated craters that indicate a complicated eruptive history. Cone is about 30 m high, 750 m long, and 800 m wide. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qac5 - Sheep Trail Butte flow, volcanic-ash deposits (Holocene)
ac5 - Sheep Trail Butte flow and related vent and ash deposits, Volcanic-ash deposits (Holocene)
Associated with youngest eruptions that formed younger, nested cinder cones along axis of Sheep Trail Butte cinder cone (cc5). Deposit occurs as thin (< 1 m thick) mantle on younger cone deposits. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfc6p - Fissure Butte flow, pahoehoe basalt flow (Holocene)
fc6 - Fissure Butte flow and related vent deposits, Pahoehoe basalt flow (Holocene)
Surface-fed flow from eruptive fissure northwest of Fissure Butte cinder cone (cc6). Flow largely mantled
by lapilli and ash. *(GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle)*.

**Qfc6a - Fissure Butte flow, a'a flow (Holocene)**

fc6 - Fissure Butte flow and related vent deposits, A'a flow (Holocene)

Two areas of a'a; one is on west side of Fissure Butte cinder cone (cc6), where a'a lava formed at margin of Fissure Butte pahoehoe flow, and the other is east of cinder cone, where a'a formed in major distributary channel. *(GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle)*.

**Qcc6 - Fissure Butte flow, Fissure Butte cinder cone and related spatter-rampart deposits (Holocene)**

cc6 - Fissure Butte flow and related vent deposits, Fissure Butte cinder cone and related spatter-rampart deposits (Holocene)

Cone is elongated east-west, about 150 m high, about 2.5 km long, and about 1 km wide. Northern part of cone joins with spatter rampart deposits that are along eruptive fissure to northwest of cinder cone. Fissures are marked by ash-mantled furrows as wide as 10 m and as deep as 5 m. *(GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle)*.

**Qfc7p - The Sentinel flow, pahoehoe basalt flow (Holocene)**

fc7 - The Sentinel flow and related vent deposits, Pahoehoe basalt flow (Holocene)

Surface-fed flow from vents in craters and at the base of The Sentinel cinder cone (cc7). Vents are mainly in The Watchman quadrangle (Kuntz and others, 1989b). Flow is dominantly pahoehoe in proximal parts and partly a'a in distal parts. Flow is mantled by unmapped lapilli and ash near vents. *(GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle)*.

**fc7 - The Sentinel flow, Pahoehoe basalt flow (Holocene)**

Surface-fed pahoehoe flow from vents in craters and at the base of The Sentinel cinder cone (cc7), which are in adjacent The Watchman quadrangle (Kuntz and others, 1989b). Only proximal parts of flow west of source vents occur in this quadrangle. Dominantly pahoehoe in proximal parts and partly a'a in distal parts. Flow is mantled by lapilli and ash near vents. *(GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle)*.

**fc7 - The Sentinel flow, Pahoehoe basalt flow (Holocene)**

Surface-fed pahoehoe flow from vents in craters at the base of The Sentinel cinder cone (cc7) in adjacent The Watchman quadrangle (Kuntz and others, 1989b). Flow is dominantly pahoehoe in proximal parts and dominantly a'a in distal parts. Only western lobe of flow occurs in this quadrangle. Mantled by unmapped lapilli and ash near vents. *(GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle)*.

**fc7 - The Sentinel flow and related vent and ash deposits, Pahoehoe basalt flow (Holocene)**

Surface-fed flow from The Sentinel cinder cone (cc7). Flow is dominantly pahoehoe in proximal parts and partly a'a in distal parts. Flow is mantled by lapilli and ash near vents. *(GRI Source Map ID 926) (The Watchman 7.5' Quadrangle)*.
Qfc7a - The Sentinel flow, a'a flows (Holocene)

fc7 - The Sentinel flow and related vent deposits, A’a flows (Holocene)
Contain many lobes having steep flow fronts. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

fc7 - The Sentinel flow, A’a basalt flow (Holocene)
Consists of many small lobes with steep flow fronts. A’a formed from pahoehoe in distal parts of flow. (GRI Source Map ID 925) (North Laidlaw Butte 7.5’ Quadrangle).

Qfc7z - The Sentinel flow, squeeze-out flows (Holocene)

fc7 - The Sentinel flow and related vent deposits, squeeze-out flows (Holocene)
Bulbous masses of pahoehoe at the base of steep margins of a’a phase of The Sentinel flow. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

Qfc7r - The Sentinel flow, rafted blocks (Holocene)

fc7 - The Sentinel flow and related vent deposits, Rafted blocks (Holocene)
Broken wall blocks of The Sentinel cinder cone (cc7) in The Watchman quadrangle (Kuntz and others, 1989b). Rafted blocks are typically 30-80 m long and less than 20 m high. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

Qcc7 - The Sentinel flow, The Sentinel cinder cone (Holocene)

cc7 - The Sentinel flow and related vent deposits, The Sentinel cinder cone (Holocene)
Cone is a composite of at least four smaller cinder cones, which indicates a complicated eruptive history. Cone is 65 m high and 1 km long. Only southernmost flanks of cone occur in this quadrangle; most of cone is in The Watchman quadrangle (Kuntz and others, 1989b). (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

cc7 - The Sentinel flow and related vent and ash deposits, The Sentinel cinder cone (Holocene)
Cone is composite of at least four smaller cinder cones, which indicates a complicated eruptive history. Cone is 65 m high and 1 km long. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

Qac7 - The Sentinel flow, volcanic ash deposits (Holocene)

ac7 - The Sentinel flow and related vent deposits, Volcanic-ash deposits (Holocene)
Erupted from vents at northern part of The Sentinel cinder cone (cc7). Deposits occur as thin (< 2 m thick) mantle on flanks of cone. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

Qfd1p - Silent Cone flow, pahoehoe trachyandesite flow (Holocene)

fd1 - Silent Cone flow and related vent deposits, Pahoehoe trachyandesite flow (Holocene)
Surface-fed flow having numerous distributory lobes. Source vent is Silent Cone cinder cone (cd1). Only distal parts of flow are exposed; proximal parts are covered by Big Craters (fa5) and Blue Dragon (fa2) flows. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).
Qfd1a - Silent Cone flow, a’a flow (Holocene)

fd1 - Silent Cone flow and related vent deposits, A’a flow (Holocene)
Flow contains bulbous lobes. Unit occurs as distal part of Silent Cone pahoehoe flow. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qfd1r - Silent Cone flow, rafted blocks (Holocene)

fd1 - Silent Cone flow and related vent deposits, Rafted blocks (Holocene)
Broken wall blocks derived from northwestern part of Silent Cone cinder cone (cd1). Blocks near Silent Cone cinder cone are surrounded or partly surrounded by younger Big Craters (fa5) and Blue Dragon (fa2) flows. Some of the larger blocks, having lengths of as much as 300 m, appear to consist of several coalesced blocks. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qcd1 - Silent Cone flow, Silent Cone cinder cone (Holocene)

cd1 - Silent Cone flow and related vent deposits, Silent Cone cinder cone (Holocene)
Consists of three nested craters that suggest a complicated eruptive history. Cone is collapsed, faulted, and open to the northwest. Cone is about 150 m high and 1.5 km wide. Silent Cone may have been source vent for the Carey Kipuka (fd2), Little Park (fd3), and Little Laidlaw Park (fd4) flows, all within the North Laidlaw Butte quadrangle (Champion and others, 1989). (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qfd2a - Carey Kipuka flow, a’a hawaiite flow (Holocene)

fd2 - Carey Kipuka flow, A’a hawaiite flow (Holocene)
Steep, bulbous flow fronts as high as 10 m. Only isolated kipukas of flow are exposed. Source vent is unknown but may be Silent Cone cinder cone (cd1) in the Inferno Cone quadrangle (Kuntz and others, 1989a). (GRI Source Map ID 925) (North Laidlaw Butte 7.5’ Quadrangle).

Qfd2z - Carey Kipuka flow, squeeze-out flow (Holocene)

fd2 - Carey Kipuka flow, Squeeze-out flow (Holocene)
Bulbous mass of pahoehoe at base of a steep margin of the Carey Kipuka a’a flow. (GRI Source Map ID 925) (North Laidlaw Butte 7.5’ Quadrangle).

Qfd3p - Little Park flow, pahoehoe hawaiite flow (Holocene)

fd3 - Little Park flow, Pahoehoe hawaiite flow (Holocene)
Surface-fed, pahoehoe flow that is mostly covered by Indian Wells South (fc2) and Blue Dragon flows (fa2). Source vent unknown but may be Silent Cone cinder cone (cd1) in the adjacent Inferno Cone quadrangle (Kuntz and others, 1989a). (GRI Source Map ID 925) (North Laidlaw Butte 7.5’ Quadrangle).
Qfd3a - Little Park flow, a'a hawaiite flow (Holocene)

fd3 - Little Park flow, A'a hawaiite flow (Holocene)
Blocky flow with steep, bulbous flow fronts as high as 10 m. Source vent is unknown but may be Silent Cone cinder cone (cd1) in the adjacent Inferno Cone quadrangle (Kuntz and others, 1989a). (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

Qfd3z - Little Park flow, squeeze-out flows (Holocene)

fd3 - Little Park flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe at base of steep margins of a'a flow. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

Qfd3r - Little Park flow, rafted blocks (Holocene)

fd3 - Little Park flow, Rafted blocks (Holocene)
Broken wall blocks of a shattered cinder cone, possibly Silent Cone cinder cone (cd1) in the adjacent Inferno Cone quadrangle (Kuntz and others, 1989a). Most blocks are less than 50 m long and less than 10 m high. Some blocks consist of two or more coalesced blocks. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

Qfd4a - Little Laidlaw Park flow, a'a hawaiite flow (Holocene)

fd4 - Little Laidlaw Park flow, A'a hawaiite flow (Holocene)
Blocky flow having prominent lobes and steep, bulbous flow fronts as high as 10 m. Source vent is unknown but may be Silent Cone cinder cone (cd1) in the adjacent Inferno Cone quadrangle (Kuntz and others, 1989a). Flow lacks rafted blocks that are typical of most a'a flows of the Craters of the Moon lava field. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

Qfd4z - Little Laidlaw Park flow, squeeze-out flow (Holocene)

fd4 - Little Laidlaw Park flow, Squeeze-out flow (Holocene)
Bulbous masses of pahoehoe at base of steep margins of a'a flow. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

Qca - Colluvium and alluvium (Holocene and Pleistocene)

Qca - Colluvium and alluvium (Holocene and Pleistocene)
Unit includes alluvium at stream mouths and colluvium at base of steep slopes. Mapped only where deposits are relatively thick. Very thin, discontinuous deposits of eolian sediment that partly cover older flows of the Craters of the Moon lava field and bedrock in the northwest corner of this quadrangle are not mapped. See Scott (1982) for a more detailed map and description of surficial deposits. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).
Qfe1p - Grassy Cone flow, pahoehoe basalt flow (Pleistocene to Holocene)

fe1 - Grassy cone flow and related vent and ash deposits, Pahoehoe basalt flow (Holocene to Pleistocene)
Surface- and tube-fed flow. Proximal parts covered by black, brown, olive, and red ash. *(GRI Source Map ID 923)* *(Inferno Cone 7.5' Quadrangle)*.

fe1 - Grassy cone flow, Pahoehoe basalt flow (Holocene to Pleistocene)
Pahoehoe basalt flow- Surface- and tube-fed flow. Small area in northwest part of quadrangle is part of extensive flow to north. *(GRI Source Map ID 925)* *(North Laidlaw Butte 7.5' Quadrangle)*.

Qfe1a - Grassy Cone flow, a’a flows (Pleistocene to Holocene)

fe1 - Grassy cone flow and related vent and ash deposits, A’a flows (Holocene to Pleistocene)
Flows contain prominent corrugated surfaces. A’a occurs within pahoehoe flow in areas where pahoehoe collapsed and (or) flowed over steep slopes. *(GRI Source Map ID 923)* *(Inferno Cone 7.5' Quadrangle)*.

Qfe1r - Grassy Cone flow, rafted blocks (Pleistocene to Holocene)

fe1 - Grassy cone flow and related vent and ash deposits, Rafted blocks (Holocene to Pleistocene)
Broken wall blocks derived from Grassy Cone cinder cone (ce1). Blocks are typically less than 100 m long and less than 10 m high. *(GRI Source Map ID 923)* *(Inferno Cone 7.5' Quadrangle)*.

Qce1 - Grassy Cone flow, Grassy Cone cinder cone (Pleistocene to Holocene)

ce1 - Grassy Cone flow and related vent and ash deposits, Grassy Cone cinder cone (Holocene to Pleistocene)
Consists of five nested craters that suggest a complicated eruptive history. Cone is about 110 m high and about 1.5 km wide. Cone is source vent for Grassy Cone flows (fe1). *(GRI Source Map ID 923)* *(Inferno Cone 7.5' Quadrangle)*.

Qae1 - Grassy Cone flow, volcanic-ash deposits (Pleistocene to Holocene)

ae1 - Grassy cone flow and related vent and ash deposits, Volcanic-ash deposits (Holocene to Pleistocene)
Well-bedded ash and lapilli from vents at Grassy Cone cinder cone (ce1). Deposits lie on Grassy Cone flow (fe1) and are as much as 1 m thick near cone. Thin, discontinuous, unmapped deposits also occur on bedrock to north and west of Grassy Cone cinder cone. *(GRI Source Map ID 923)* *(Inferno Cone 7.5' Quadrangle)*.
Qfe2a - Lava Point flow, a'a basalt flows (Pleistocene to Holocene)

fe2 - Lava Point flow, A'a basalt flows (Holocene)
Flows have steep, bulbous flow fronts. Unit consists of three isolated exposures that are separated from one another by Sawtooth (fc3) and Sheep Trail Butte flows (fc5). The three exposures are correlated by similarities in field, petrographic, and paleomagnetic characteristics. Only distal parts of flows are exposed. Source vent is unknown. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

fe2 - Lava Point flow, A'a basalt flow (Holocene)
Flow has steep, bulbous flow fronts and rough, corrugated surfaces. Only small parts of extensive flow occur in quadrangle. (GRI Source Map ID 925) (North Laidlaw Butte 7.5' Quadrangle).

** The Lava Point flow was attributed as a Holocene-age unit in the text on the source maps but upon studying relationships with other flows and the correlation of map units, the GRI found that truly the unit is Pleistocene to Holocene in age.

Qfe2z - Lava Point flow, squeeze-out flows (Pleistocene to Holocene)

fe2 - Lava Point flow, Squeeze-out flows (Holocene)
Bulbous masses of pahoehoe at the base of steep margins of the Lava Point a'a flow. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qfe2r - Lava Point flow, rafted blocks (Pleistocene to Holocene)

fe2 - Lava Point flow, Rafted blocks (Pleistocene to Holocene)
Broken wall blocks of an unknown cinder cone. Blocks are typically 20-50 m long and 5-20 m high. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

Qc1 - Cinder cones of indeterminate age (Holocene and latest Pleistocene)

c - Cinder cones (Holocene and latest Pleistocene)
A group of cinder cones along the Great Rift that have no identifiable associated lava flows; thus, exact ages cannot be assigned to them. Age of cones in map unit is older than flows of eruptive period C. In this quadrangle, unit includes Split Butte and Two Point Butte cinder cones and a smaller, unnamed cinder cone in the northwest part of quadrangle. (GRI Source Map ID 922) (Fissure Butte 7.5' Quadrangle).

c - Cinder cones (Holocene and latest Pleistocene)
A group of cinder cones along the Great Rift that have no identifiable associated lava flows; thus, exact ages cannot be assigned to them. Age of cones in map unit encompasses nearly the entire time span of Craters of the Moon lava field. In this quadrangle, unit includes Paisley Cone, Inferno Cone, Half Cone, Echo Crater, and other unnamed cinder cones. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

** Two unnamed cinder cones along the Great Rift that have no identifiable associated lava flows; thus, exact age cannot be assigned to them. (GRI Source Map ID 926) (The Watchman 7.5' Quadrangle).
Qfg1p - Sunset flows, pahoehoe basalt-hawaiite flows (latest Pleistocene)

fg1 - Sunset flows and related vent and ash deposits, Pahoehoe basalt-hawaiite flows (latest Pleistocene)
Surface- and tube(?)-fed flows from vents in and near Sunset Cone cinder cone (cg1). Unit includes Sunset Northwest and Sunset Northeast flows of Murtaugh (1961). Flows are covered by an unmapped layer, less than 2 m thick, of olive, orange, and brown lapilli northwest, north, and northeast of Sunset Cone. Local, small patches of a’a lava (unmapped) occur where pahoehoe flows collapsed or moved over steep slopes. Sunset Northwest flow erupted from obscure vents now represented by lava mounds, deeply mantled by cinders and ash, that are just northwest of Sunset Cone. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qcg1 - Sunset flows, Sunset Cone cinder cone (latest Pleistocene)

cg1 - Sunset flows and related vent and ash deposits, Sunset Cone cinder cone (latest Pleistocene)
Cone is a complex of eight nested cones that indicate a complicated eruptive history. Cone is about 140 m high and about 1.5 km in diameter. Cone is source vent for Sunset Cone (fg1) and Carey flows (fg2). (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qag1 - Sunset flows, volcanic-ash deposits (latest Pleistocene)

ag1 - Sunset flows and related vent and ash deposits, Volcanic-ash deposits (latest Pleistocene)
Well-bedded ash and lapilli from vents at Sunset Cone cinder cone (cg1). Only thickest (0.5-2 m) deposits on east (downwind) flanks of Sunset Cone and on bedrock slopes north of Sunset Cone are mapped. Thin (< 0.5 m), discontinuous deposits on Sunset Cone flows (fg1) are not mapped. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qfg2p - Carey flow, pahoehoe basalt-hawaiite flow (latest Pleistocene)

fg2 - Carey flow, Pahoehoe basalt-hawaiite flow (latest Pleistocene)
Surface- and tube(?)-fed flow that extends 50 km to the southwest; thus, only proximal parts of flow are shown in this quadrangle. Carey flow is believed to have erupted simultaneously with Sunset Cone flows (fg1) on the basis of similarities in field, petrographic, paleomagnetic, and chemical characteristics (Kuntz and others, 1982; Kuntz, Champion, and others, 1986). Sunset Cone cinder cone (cg1) is believed to be source vent for unit. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qfg2a - Carey flow, a’a flows (latest Pleistocene)

fg2 - Carey flow, A’a flows (latest Pleistocene)
Rough-textured flows having prominent corrugated surfaces and many individual lobes. Flow fronts are
steep and as high as 5 m. Flows lack rafted blocks that are typical of other a'a flows of the Craters of the Moon lava field. A’a appears to have formed where pahoehoe flow moved over steep slopes. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

fg2 - Carey flow, A’a basalt-hawaiite flow (latest Pleistocene)
Rough-textured flow with prominent corrugated surfaces. Flow lacks rafted blocks typical of most a’a flows in the Craters of the Moon lava field. (GRI Source Map ID 925) (North Laidlaw Butte 7.5’ Quadrangle).

Qfh1p - Crescent Butte flow, pahoehoe basalt flow (latest Pleistocene)

fh1 - Crescent Butte flow and related vent deposits, Pahoehoe basalt flow (latest Pleistocene)
Small, surface-fed pahoehoe flow from crater in Crescent Butte cinder cone (ch1). Flow is mantled by vegetation and thin colluvium. (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

Qch1 - Crescent Butte flow, Crescent Butte cinder cone (latest Pleistocene)

ch1 - Crescent Butte flow and related vent deposits, Crescent Butte cinder cone (latest Pleistocene)
Western flank of cone is mantled by ash from Trench Mortar Flat eruptive fissures. Cone is about 120 m high and 1 km in diameter; source vent for the Crescent Butte flow (fh1). (GRI Source Map ID 923) (Inferno Cone 7.5’ Quadrangle).

ch1 - Crescent Butte flow and related vent deposits, Crescent Butte cinder cone (latest Pleistocene)
Only eastern flank of cone occurs in this quadrangle; most of cone and associated Crescent Butte flow (fh1) shown on Inferno Cone quadrangle (Kuntz and others, 1989a). (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

Qfh2p - Little Prairie flow, pahoehoe basalt flow (latest Pleistocene)

fh2 - Little Prairie flow, Pahoehoe basalt flow (latest Pleistocene)
Surface- and tube(?)-fed flow that is covered by low bushes and grass and mantled by a thin blanket of ash. Source vent is unknown. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

fh2 - Little Prairie flow, Pahoehoe basalt flow (latest Pleistocene)
Surface- and tube(?)-fed flow that is covered by low bushes and grass. A thin blanket of ash occurs on western margin and fine ash and eolian sediment occur on eastern margin of flow. Source vent unknown. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

Qfh2a - Little Prairie flow, a’a flows (latest Pleistocene)

fh2 - Little Prairie flow, A’a flows (latest Pleistocene)
Occur in distal part of Little Prairie pahoehoe flow. Covered by low shrubs and grass, fine ash, and thin, discontinuous eolian sediment. Source vent unknown. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).
fh2 - Little Prairie flow, A'a flow (latest Pleistocene)
Occurs in distal part of pahoehoe flow. Covered by low shrubs and grass, fine ash, and thin, (< 1 m thick) eolian sediment. Source vent unknown. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).

Qfh3p - No Name flow, pahoehoe basalt flow (latest Pleistocene)

fh3 - No Name flow, Pahoehoe basalt flow (latest Pleistocene)
Surface- and tube-fed flow that is covered by a thin, discontinuous mantle of eolian sediment. Unit is possibly correlative with Little Prairie pahoehoe flow (fh2) on the basis of similarities in rock type, paleomagnetic data, and distribution of units with respect to the Great Rift. Source vent unknown. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

Qbs - Pahoehoe basalt flows (Pleistocene)

Qbs - Pahoehoe basalt flows (Pleistocene)
Typically brownish-gray (5 YR/1) to dark-gray (N3), slightly weathered flows that are partly covered by unmapped, discontinuous deposits of eolian sediment. In this quadrangle, unit consists of flows from vents in the North Laidlaw Butte quadrangle (Champion and others, 1989) and in three kipukas in the west-central part of quadrangle. Rock is typically holocrystalline, diktytaxitic, and porphyritic to aphyric. Crystals of olivine and plagioclase are typically as large as 1-2 mm. Plagioclase, olivine, clinopyroxene, an equant opaque mineral, and a bladed opaque mineral constitute the matrix, and crystals range in size from 0.1 to 1 mm. Brown glass is charged with tiny crystals of opaque minerals. (GRI Source Map ID 922) (Fissure Butte 7.5’ Quadrangle).

Qbs - Pahoehoe basalt flows (Pleistocene)
Typically brownish-gray (5 YR/1) to dark-gray (N3), slightly weathered flows that are partly covered by unmapped, discontinuous eolian deposits. Flows originated from large crater vents at Bowl Crater, Snowdrift Crater, and Big Blowout Butte; from smaller, elongated, slot-shaped vents at Hollow Top, Blowout Reservoir, Bullshot Reservoir, and Turnbull Butte; and from eruptive fissures. Rock is typically hypocrystalline, diktytaxitic, and porphyritic to aphyric. Crystals of olivine and plagioclase are typically as large as 1-2 mm. Plagioclase, olivine, clinopyroxene, an equant opaque mineral, and a bladed opaque mineral constitute the matrix, and crystals range in size from 0.1 to 1.0 mm. Brown glass is charged with tiny crystals of opaque minerals. (GRI Source Map ID 925) (North Laidlaw Butte 7.5’ Quadrangle).

Qbs - Pahoehoe basalt flow (Pleistocene)
Typically brownish-gray (NYR4/1) to dark-gray (N3), slightly weathered flow that is partly covered by unmapped, discontinuous eolian deposits of eolian sediment. In this quadrangle, unit consists of flow from vents in Huddles Hole, a kipuka surrounded by Blue Dragon pahoehoe flow (fa2). Rock is typically hypocrystalline, diktytaxitic, and porphyritic to aphyric. Crystals of olivine and plagioclase are typically as large as 1-2 mm. Plagioclase, olivine, clinopyroxene, an equant opaque mineral, and a bladed opaque mineral constitute the matrix, and crystals range in size from 0.1 to 1 mm. Brown glass is charged with tiny crystals of opaque minerals. (GRI Source Map ID 926) (The Watchman 7.5’ Quadrangle).
Qc2 - Older cinder cones (Pleistocene)

Qc - Cinder cones (Pleistocene)
A group of cinder cones off the axis of the Great Rift that have no identifiable, associated lava flows. Locally covered by vegetation and thin (< 1 m thick), unmapped deposits of eolian sediment that distinguish them from Holocene and Pleistocene cones (c). In this quadrangle, unit includes Purple Butte and other unnamed cinder cones. (*GRI Source Map ID 922*) (*Fissure Butte 7.5' Quadrangle*).

Qc - Cinder cone (Pleistocene)
Red, brown, and black cinders and ash. Covered with vegetation and thin (< 1 m thick) unmapped eolian deposits. (*GRI Source Map ID 925*) (*North Laidlaw Butte 7.5' Quadrangle*).

Qc - Cinder cones (Pleistocene)
A group of cinder cones off the axis of the Great Rift that have no identifiable, associated lava flows. Locally covered by vegetation and thin (< 1 m), unmapped deposits of eolian sediment that distinguish them from Holocene and Pleistocene cones (c). (*GRI Source Map ID 926*) (*The Watchman 7.5' Quadrangle*).

Tg - Biotite granite of Big Cottonwood Creek (Eocene)

Tg - Biotite granite of Big Cottonwood Creek (Eocene)
Medium- to coarse-grained, massive, biotite granite consisting of orthoclase, quartz, and subordinate amounts of plagioclase (An5-20) and biotite. Hornblende, magnetite, and rutile are accessory minerals. Granite intrudes rocks of Challis Volcanics (Sidle, 1979). Contacts of unit partly from Sidle (1979) and from interpretation of aerial photographs. (*GRI Source Map ID 923*) (*Inferno Cone 7.5' Quadrangle*).

Tqm - Hornblende quartz monzonite of Little Cottonwood Creek (Eocene)

Tqm - Hornblende quartz monzonite of Little Cottonwood Creek (Eocene)
Weakly-foliated, medium-grained, equigranular, quartz monzonite consisting of plagioclase (An10-20 and An30-50), orthoclase, quartz, and hornblende. Magnetite and pyrite are accessory minerals. Quartz monzonite intrudes rocks of Challis Volcanics (Sidle, 1979). Contacts of unit partly from Sidle (1979) and from interpretation of aerial photographs. (*GRI Source Map ID 923*) (*Inferno Cone 7.5' Quadrangle*).

Tcw - Welded tuff (Eocene)

Tcw - Challis Volcanics, Welded tuff (Eocene)
Gray, welded ash-flow tuff containing pink, brownish-gray, and orange pumice fragments. Rests unconformably on lava flows and tuff breccia (unit Tclb). Unit about 60 m thick (Sidle, 1979). Contacts of unit partly from Sidle (1979) and from interpretation of aerial photographs. (*GRI Source Map ID 923*) (*Inferno Cone 7.5' Quadrangle*).

Tclb - Lava flows and interbedded tuff breccia (Eocene)

Tclb - Challis Volcanics, Lava flows and interbedded tuff breccia (Eocene)
Gray to black, banded, porphyritic rhyodacite lava flows near base of unit and interbedded, greenish,
weakly to well-foliated tuff breccia containing glassy fragments of earlier flows in upper part of unit. Unit as thick as 600 m (Sidle (1979). Contacts partly from Sidle (1979) and from interpretation of aerial photographs. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

**Tctb - Tuff breccia (Eocene)**

**Tctb - Challis Volcanics, Tuff breccia (Eocene)**
Greenish, grayish, tuff breccia containing angular lithic fragments. Lava flows and thin beds of crystal-lithic tuff are common interbeds. Unit interfingers with lava flows of unit Tclb. Unit as thick as 400 m (Sidle, 1979). Contacts partly from Sidle (1979) and from interpretation of aerial photographs. (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).

**Mcb - Copper Basin Formation (Upper and Lower Mississippian)**

**Mcb - Copper Basin Formation (Upper and Lower Mississippian)**
Interbedded claystone, siltstone, sandstone, and minor conglomerate. Claystone is dark gray to black, weathers gray, locally laminated, and locally contains pebbles of chert and quartzite as much as 3 cm in diameter. The trace of fossil Helminthoida is present on some bedding surfaces. Siltstone is medium to dark gray, locally laminated. Sandstone is olive gray to medium gray, very fine to fine grained, impure, quartzitic, and locally contains pebbles of argillite, quartzite, and chert. Sole markings are common in places. Conglomerate is medium dark gray, weathers light gray. Clasts consist of pebbles and cobbles as large as 8 cm in diameter of argillite, quartzite, and chert, in a sandy matrix. Entire sequence folded and locally sheared and brecciated (B.A. Skipp, U.S. Geological Survey, written commun., 1984). Outcrops on western edge of quadrangle interpreted to be outer-fan turbidites and basin-plain deposits of the Scorpion subplate of Nilsen (1977). (GRI Source Map ID 923) (Inferno Cone 7.5' Quadrangle).
GRI Source Map Information

** Convert this topic to Chapter Without Text! If there is only one source map, elevate the source map block to this topic level and delete this topic!

Fissure Butte 7.5' Quadrangle


Correlation of Map Units

Extracted from: Fissure Butte 7.5' Quadrangle.
Index Map

Extracted from: Fissure Butte 7.5' Quadrangle.

Map Legend

- **Contact**—Dashed where approximately located, particularly between flow units of a named flow; dotted where concealed. Relative ages of flows along contact indicated by Y, younger; O, older
- **Flow line**—Linear flow features and lava tubes; arrow shows flow direction
- **Skylights in lava tubes**
- **Lava channel**—Large channel; arrow shows direction of flow
- **Flow ridges, furrows, and cracks**—Ridges are generally perpendicular to direction of flow movement and furrows and cracks are generally parallel to direction of flow movement
- **Crater**—Crater rim on volcanic vent; hachures point toward central depression. Hachures not shown on smaller craters
- **Cone**—Vent for small lava cones, cinder cones, and spatter cones
- **Eruptive fissure**—Fracture through which lava erupted, generally bordered by spatter ramparts
- **Noneruptive fissures**—Fractures in rock through which lava has not erupted. Width generally less than 3 ft (1 m)
- **Rootless vent**—Secondary source of lava not directly related to conduits that brought magma to the surface from deep magma reservoir; chiefly openings along lava tubes
- **Lava pond**—Levees surrounding lava pond; hachures point away from pond
Figure 1

Figure 1.—Index map showing location of the Fissure Butte quadrangle, Craters of the Moon National Monument, Craters of the Moon lava field, the Great Rift, and companion Geologic Quadrangle Maps.

Extracted from: Fissure Butte 7.5’ Quadrangle.
Figure 2

Figure 2.—Index map of southern Idaho showing location of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift.

Extracted from: Fissure Butte 7.5' Quadrangle.
This map is one of four maps (fig. 1) that depict the volcanic geology of the northern part of Craters of the Moon lava field in the Snake River Plain of southern Idaho (fig. 2). The Snake River Plain, a region of late Tertiary and Quaternary basaltic volcanism, contains many volcanic rift zones, the most spectacular being the Great Rift, the northern part of which contains the source vents for the flows of the Craters of the Moon lava field. The Great Rift is a northwest-trending fracture system, 85 km long and 2-8 km wide, that extends nearly across the entire width of the Snake River Plain (fig. 2). The Great Rift is defined by an array of cinder cones, shield volcanoes, lava cones, eruptive fissures, noneruptive fissures, and fresh-appearing lava flows.

Two other lava fields, the Wapi and Kings Bowl fields, are along the southern part of the Great Rift (fig. 2). The geology of the entire Great Rift and of the three lava fields is depicted on a 1:100,000-scale map by Kuntz and others (1987). The Craters of the Moon lava field consists of more than 60 lava flows and flow units, more than 25 cinder cones, and 8 eruptive fissure systems. The lava field covers an area of about 1,600 km$^2$, contains more than 30 km$^3$ of lava, and is the largest dominantly Holocene basaltic lava field in the coterminous United States (Kuntz and others, 1982; Kuntz, Champion, and others, 1986).

Radiocarbon and paleomagnetic data and our field studies (Kuntz and others, 1987; Kuntz, Champion, and others, 1986; Kuntz, Spiker, and others, 1986) reveal that lava flows of the Craters of the Moon lava field were emplaced in at least eight eruptive periods, designated as H, the oldest, through A, the youngest. Eruptive period H began about 15,000 years ago, and eruptive period A ended about 2000 years ago. Each eruptive period was about 1,000 years or less in duration and was separated by intervals of quiescence lasting a few hundred to more than 2,000 years. The lava flows of the Craters of the Moon lava field belong to the Snake River Group of Pleistocene and Holocene age.
The map of the Fissure Butte quadrangle can be used separately, but a more complete picture of the volcanic geology of the Great Rift and of the Craters of the Moon National Monument can be obtained by also studying the three companion maps shown in figure 1. The Fissure Butte quadrangle depicts the volcanic features along the southern part of the northern segment of the Great Rift, including most of the source vents for lava flows formed in eruptive periods B and C. Also shown on this map are the complex relations of various flow units of the Sheep Trail Butte, Fissure Butte, and The Sentinel flows. Also shown are important cinder cones along the Great Rift, including Split Butte, Fissure Butte, Sheep Trail Butte, and Black Top Butte. Eruptive fissures and noneruptive fissures are also shown. A few small areas of lava flows that are older than flows of the Craters of the Moon lava field also occur in this quadrangle. These older flows, like the flows of the Craters of the Moon lava field, are also part of the Snake River Group of Pleistocene and Holocene age.

Many of the names of lava flows (for example, Vermillion Chasm flow) on this map are those used by Stearns (1928) and Murtaugh (1961), but new names have been applied to some flows. The “Correlation of Map Units” shows all map units depicted on the four maps of this study, but only the units in this quadrangle are colored. The named Holocene flows of the Snake River Group mapped in this quadrangle are informal units.

The map symbols consist of letters and numbers arranged in the following order: the first letter of each symbol refers to the type of deposit (f, flow; c, cinder and spatter deposits near vent areas; and a, ash deposits); the second letter refers to the eruptive period of the deposit (A, the youngest, through H, the oldest); the number indicates the stratigraphic order of deposition within the eruptive period (1, the youngest, 2, the next oldest; and so on). Overprinted patterns designate various types of flow deposits, specifically slab-lava, a’a, and “squeeze-out” flows. Patterns and (or) colors also are used to distinguish cinder-spatter and ash deposits.

Lava Flow Morphology

Five morphologic types of lava flows occur in this quadrangle: pahoehoe, slab lava, a’a, squeeze-out, and block a’a flows. Pahoehoe is further subdivided into surface-fed and tube-fed varieties (Holcomb, 1980, 1981).

Surface-fed pahoehoe flows cover small areas. They are typically less than 10 m thick, cover less than 20 km$^2$, and contain less than 0.1 km$^3$ of rock. They consist of shelly pahoehoe (Swanson, 1973) near vents and contain numerous channels and lava gutters that distributed lava to the advancing flow fronts. Congealed lava ponds are present in some flows. These flows probably were fed by lava fountains and by sporadic overflow from one or more vents along eruptive fissures. On the basis of his study of Hawaiian eruptions, Swanson (1973) stated that surface-fed pahoehoe flows form during short-lived eruptions that last hours or a few days and (or) for which the lava supply was variable. The Trench Mortar Flat pahoehoe flow is an example of a surface-fed pahoehoe flow.

Tube-fed pahoehoe flows cover areas of 30-300 km$^2$. They are typically 10-12 m thick and have volumes of as much as 4 km$^3$. Holcomb (1980) noted that tube-fed pahoehoe flows develop broad dendritic distribution systems that originate from rootless vents along master lava tube systems. Swanson (1973) observed that tube-fed pahoehoe flows reflect fairly constant supplies of lava for periods of days, weeks, or months from central vents of cinder cones. The proximal parts of tube-fed flows are characterized by lava-tube systems having elongated, sinuous depressions, rootless vents, and “skylights”. The distal parts of the flows are characterized by hummocky and billowy surfaces, tumuli, pressure plateaus and collapse depressions. The Blue Dragon flow is an excellent example of a tube-fed pahoehoe flow.

Slab lava consists of jumbled, rafted plates and slabs of flow crust that form a jagged, rough-surfaced flow. Slab lava occurs as local phases of pahoehoe flows where partly congealed crust was broken and disturbed, such as localities where pahoehoe moved over rough, underlying topography or where degassed, more viscous lava was erupted locally, such as at rootless vents. Surfaces of slab-lava flows are typically corrugated, having prominent flow ridges and longitudinal furrows and cracks that are generally perpendicular and parallel, respectively, to the direction of flow movement. The Blue Dragon flow contains many lobes of slab lava.
Squeeze-out lava forms bulbous lobes of pahoehoe that are steep-sided, short, relatively thick, and stubby. They were extruded from rootless vents at the base of the steep margins of a’a and block a’a flows. Squeeze-out flows consist of numerous lobes and ridges in interdigitating, dendritic patterns that form rough topography. Squeeze-out flows are prominent features along the northern margin of the Serrate flow.

A’a lava forms rough-surfaced, thick, narrow, relatively long, small- to intermediate-volume flows. Flow thickness is typically 15-20 m, the width less than 5 km, the length as much as 25 km, and the volume generally less than 1 km$^3$. The proximal parts of the flows contain central channels that are locally anastomosed. The distal parts of the flows consist of bulbous, steep-sided lobes having arcuate flow ridges that are generally perpendicular to the direction of flow and having longitudinal furrows and cracks generally parallel to the direction of flow. The surface of a’a flows has several meters of relief because of a covering of rubble consisting of angular, spinose blocks and irregular masses of cooled crust. Much of the Sawtooth flow consists of a’a.

Block-a’a lava forms thick, lobate masses with features identical to a’a flows but with the additional characteristic of containing large, angular, smooth-sided blocks of solid, massive lava. Prominent flow ridges and longitudinal furrows and cracks are typical of block-a’a flows. The Highway, Devils Orchard, and Serrate flows are of the block-a’a type.

Well-documented studies of Hawaiian eruptions (Holcomb, 1980; Peterson and Tilling, 1980) suggest that nearly all Hawaiian basaltic lava erupts as pahoehoe and, as it cools, some may change to a’a as it flows away from the vent. Factors in the transition from pahoehoe to a’a are cooling, degassing, and, locally, turbulence. These factors determine the critical relations between viscosity and rate of shear strain needed to produce a’a (Peterson and Tilling, 1980). Viscosity is a measure of the stiffness of the lava; rate of shear strain is the speed at which the lava deforms. Typically, a’a forms when the original pahoehoe lava continues to move and deform after it has become highly viscous. This process produces stiff clots, masses, and fragments in certain parts of the flow. Continued movement, causing aggregation, fracture, and grinding together of these fragments, completes the transition to a’a lava.

Several flows in this quadrangle are believed to have erupted as a’a or to have been converted from pahoehoe to a’’a after travel of only a few hundred meters from their respective vents, because they consist of lava whose chemical composition suggests high initial viscosity, and because the flows are a’’a or block-a’’a along most or all of their length. These flows are the Highway, Devils Orchard, Serrate, and Silent Cone flows.

An intermediate stage in the transformation from pahoehoe to a’’a is the formation of slab lava, which forms when the chilled crust of a pahoehoe flow is fractured, forming plates that are jumbled, tilted, and rafted on the surface of the underlying, moving flow. Slab-lava is a common type of flow in composite lava flows of the Craters of the Moon lava field, being particularly conspicuous in the Blue Dragon, Big Craters, and Trench Mortar Flat flows.

Some types of lava flows are intergradational and, as shown in the “Correlation of Map Units,” several types comprise a composite named flow. The various flow types in a composite flow are considered to be phases of the flow that formed nearly simultaneously under locally variable physical conditions. As examples of composite flows, small lobes of slab lava are part of the Blue Dragon flow, which is predominantly tube-fed pahoehoe. The Serrate flow is dominantly block a’’a but also contains rafted blocks and squeeze-out flows around its margins. Several flows in the Craters of the Moon lava field consist of pahoehoe in proximal parts and a’’a in distal parts.

**Other Volcanic Rock and Vent Deposits**

Rafted blocks are fragments of bedded, oxidized, mostly agglutinated cinders and ash derived from the walls of shattered, disrupted cinder cones. Because of their relatively low density, rafted blocks were transported on the surface and within lava flows of relatively high viscosity and density, such as a’’a flows and block a’’a flows. Rafted blocks are as much as 300 m long and as much as 30 m high. Rafted blocks are common in the Devils Orchard, Serrate, Silent Cone, Indian Wells North, and Sawtooth flows. Rafted blocks are termed “monoliths” in earlier literature about Craters of the Moon National Monument.

Cinder cones and cinder mounds are accumulations of black, brown, red, orange, and tan bombs,
lapilli, coarse ash, and interbedded, fresh to strongly oxidized lava flows that build up around a central vent or a series of vents along an eruptive fissure. Many cinder cones in Craters of the Moon National Monument are composite and consist of nested cones that formed during pulsating eruptions from closely spaced vents along short segments of eruptive fissures.

Spatter ramparts are low, narrow accumulations of brown, red, orange, and tan agglutinated spatter and loose lapilli and ash that are along one or both flanks of eruptive fissures. Spatter ramparts are typically less than 5 m high and less than 50 m wide.

Ash deposits are blankets of black, brown, and red ash and fine spatter that occur downwind, typically to the east or northeast, of source vents. Most ash deposits are less than 1 m thick.

Chemical, Macroscopic, and Microscopic Characteristics of Various Rock Types

Chemical compositions of lava flows in each eruptive period are given in Kuntz and others (1985). Rock names assigned to the lava flows in the Craters of the Moon field (“basalt,” “hawaiite,” “trachyandesite”) are those suggested by Cox and others (1979). The classification is based on the weight percentages of Na₂O + K₂O versus SiO₂ (see fig. 3). Note that most chemical analyses plot within the fields for basalt, hawaiite, and trachyandesite. The name basalt-hawaiite is given to rocks whose rock analyses lie close to the line between basalt and hawaiite.

Basalt, hawaiite, and trachyandesite have unique physical characteristics and microscopic features. The lava type, color, vesicle size and shape, mineralogical composition, and textural features for each type of rock are summarized in the following paragraphs. Petrographic descriptions of lava flow types were made from standard petrographic examination of thin sections. Olivine composition was estimated optically by the curvature of the isogyre as viewed along an optic axis. The composition of plagioclase was determined by measurement of extinction angles of albite lamellae in crystals in which both 001 and 010 crystallographic planes were oriented vertically. The chemical composition for some minerals in the lava flows was determined using the electron microprobe by Leeman and others (1976) and by Stout and Nichols (1976). Colors and numerical designation of hues for the volcanic rocks were assigned using the “Rock Color Chart” of the Geological Society of America (1975). Colors of rocks in cinder cones and volcanic ash deposits are extremely variable; thus general terms are used to describe the colors of these deposits.

Basalt is typically dark gray (N3) and medium dark gray (N4) and contains nearly spherical vesicles. It typically occurs as tube-fed pahoehoe flows, which contain minor amounts of slab lava or as surface-fed, shelly pahoehoe. Porphyritic basalt contains phenocrysts of olivine as large as 5 mm in diameter, plagioclase laths as long as 2 cm, and rare skeletal crystals of an equant opaque mineral, which is probably titanomagnetite. Olivine composition is typically Fo₅₀₋₆₅ and plagioclase composition is typically An₄₅₋₅₅. The matrix of basalt consists of granules and skeletal crystals of olivine, plagioclase laths, intersertal clinopyroxene, an equant opaque mineral, possibly titanomagnetite or spinel, an acicular to feathery opaque mineral, and opaque-charged, brown glass. Basalt is typically hypocrystalline and diktytaxitic textures are common.

Hawaiite is typically medium dark gray (N4) to brownish gray (5YR4/1) and has vesicles that are slightly elongated and stretched. Hawaiian occurs as surface-fed pahoehoe flows containing significant amounts of slab lava and as pahoehoe flows that have distal phases of a’a lava. Petrographically, hawaiite is similar to basalt, except that, in hawaiite, plagioclase phenocrysts are more common than olivine phenocrysts. Olivine composition is Fo₄₅₋₅₀ and plagioclase composition is typically An₄₀₋₅₀.

Trachyandesite is typically olive gray (5Y4/1), has extremely elongated, stretched vesicles, and occurs as a’a and block-a’a flows. Trachyandesite flows are extremely fine-grained and locally contain xenolithic clots of gneiss; felsic, hypocrystalline volcanic rocks; and holohyaline pumice. Xenocrysts of rounded, embayed, skeletal crystals of anorthoclase, dark-green clinopyroxene, plagioclase, rare zircon, and aggregates of these minerals are seen in thin sections. The matrix of trachyandesite typically consists of slender, skeletal olivine crystals (Fo₃₅₋₄₀), slender laths of plagioclase (An₃₅₋₄₀), spindles and needles of greenish-brown clinopyroxene, and opaque-charged, brown glass.
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Extracted from: Fissure Butte 7.5’ Quadrangle.

**Inferno Cone 7.5’ Quadrangle**

Kuntz, Mel A., Lefebvre, Richard H. and Champion, Duane E., 1989, Geologic Map of the Inferno Cone
Quadrangle, Butte County, Idaho: U.S. Geological Survey, Geologic Quadrangle Map GQ-1632, scale
1:24,000. (GRI Source Map ID 923).
## Correlation of Map Units

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Index Map

Extracted from: Inferno Cone 7.5' Quadrangle.
Map Legend

**Y** Contact—Dashed were approximately located, particularly between flow units of a named flow; dotted where concealed. Relative ages of flows along contact indicated by Y, younger, O, older

**Fault** Ball and bar on downthrown side

**Scarp** Barbs point to area of lower elevation. Also known as the “Highway fault.” See Kuntz and others (1982) for discussion

**15 Strike and dip of beds**

**Flow line**—Small channels, gutters, and lava tubes; arrow shows flow direction

**Skylight in lava tube**

**Lava channel**—Large channel, arrow shows direction of flow

**Flow ridges, furrows, and cracks**—Ridges are generally perpendicular to direction of flow movement and furrows and cracks are generally parallel to direction of flow movement

**Crater**—Crater rim on volcanic vent; hachures point toward central depression (hachures not shown on smaller craters)

**Pit crater**—Generally circular depression formed by collapse; walls are steep to vertical

**Cone**—Vent for small lava cones, cinder cones, and spatter cones

**Eruptive fissure**—Fracture through which lava erupted, generally bordered by spatter ramparts

**Noneruptive fissures**—Fractures in rock through which lava has not erupted. Width generally less than 3 ft (1 m)

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**Lava pond**—Levees surrounding lava pond; hachures point away from pond

*Extracted from: Inferno Cone 7.5' Quadrangle.*
Figure 1

Figure 1.—Index map showing location of Inferno Cone quadrangle, Craters of the Moon National Monument, Craters of the Moon lava field, the Great Rift, and companion Geologic Quadrangle Maps.

Extracted from: Inferno Cone 7.5’ Quadrangle.
Figure 2

Figure 2.—Index map of southern Idaho showing location of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift.

Extracted from: Inferno Cone 7.5’ Quadrangle.
Introduction

This map is one of four maps (fig. 1) that depict the volcanic geology of the northern part of Craters of the Moon lava field in the Snake River Plain of southern Idaho (fig. 2). The Snake River Plain, a region of late Tertiary and Quaternary basaltic volcanism, contains many volcanic rift zones, the most spectacular being the Great Rift, the northern part of which contains the source vents for the flows of the Craters of the Moon lava field. The Great Rift is a northwest-trending fracture system, 85 km long, 2-8 km wide, that extends nearly across the width of the Snake River Plain (fig. 2). The Great Rift is defined by an array of cinder cones, shield volcanoes, lava cones, eruptive fissures, noneruptive fissures, and fresh-appearing lava flows.

Two other lava fields, the Wapi and Kings Bowl fields, are along the southern part of the Great Rift (fig. 2). The geology of the entire Great Rift and of the three fields is depicted on a 1:100,000-scale map by Kuntz and others (1987). The Craters of the Moon lava field consists of more than 60 lava flows and flow units, more than 25 cinder cones, and 8 eruptive fissure systems. The lava field covers an area of about 1,600 km², contains more than 30 km³ of lava, and is the largest dominantly Holocene basaltic lava field in the coterminous United States (Kuntz and others, 1982; Kuntz, Champion, and others, 1986).

Radiocarbon and paleomagnetic data and our field studies (Kuntz and others, 1987; Kuntz, Champion, and others, 1986; Kuntz, Spiker, and others, 1986) reveal that lava flows of the Craters of the Moon lava field were emplaced in at least eight eruptive periods, designated as H, the oldest, through A, the youngest. Eruptive period H began about 15,000 years ago, and eruptive period A ended about 2000 years ago. Each eruptive period was about 1,000 years or less in duration and was separated by intervals of quiescence lasting a few hundred to more than 2,000 years. The lava flows of the Craters of the Moon lava field belong to the Snake River Group of Pleistocene and Holocene age.
The map of the Inferno Cone quadrangle can be used separately, but a more complete picture of the volcanic geology of the Great Rift and of the Craters of the Moon National Monument can be obtained by also studying the three companion maps shown in figure 1. The Inferno Cone quadrangle depicts the volcanic features that are most easily accessible, via roads and trails, to visitors to Craters of the Moon National Monument, including the Spatter Cones, Lava Cascades, Buffalo Caves, Inferno Cone, North Crater, Big Craters, Devils Orchard, and the skylights and lava tubes (popularly termed “caves”) of the Caves Trail.

Many of the names of lava flows (for example, Blue Dragon flow) on this map are those used by Stearns (1928) and Murtaugh (1961), but new names have been applied to some flows. The “Correlation of Map Units” shows all map units depicted on the four maps of this study, but only the units in this quadrangle are colored. The named Holocene flows of the Snake River Group mapped in this quadrangle are informal units.

The map symbols consist of letters and numbers arranged in the following order: the first letter of each symbol refers to the type of deposit (f, flow; c, cinder and spatter deposits near vent areas; and a, ash deposits); the second letter refers to the eruptive period of the deposit (A, the youngest, through H, the oldest); the number indicates the stratigraphic order of deposition within the eruptive period (1, the youngest; 2, the next oldest; and so on). Overprinted patterns designate various types of flow deposits, specifically slab-lava, “squeeze-out”, and a’a flows. Patterns and (or) colors also are used to distinguish cinder-spatter and ash deposits and rafted blocks.

Lava Flow Morphology

Five morphologic types of lava flows occur in this quadrangle: pahoehoe, slab lava, a’a, squeeze-out, and block a’a flows. Pahoehoe is further subdivided into surface-fed and tube-fed varieties (Holcomb, 1980, 1981).

Surface-fed pahoehoe flows cover small areas. They are typically less than 10 m thick, cover less than 20 km\(^2\), and contain less than 0.1 km\(^3\) of rock. They consist of shelly pahoehoe (Swanson, 1973) near vents and contain numerous channels and lava gutters that distributed lava to the advancing flow fronts. Congealed lava ponds are present in some flows. These flows probably were fed by lava fountains and by sporadic overflow from one or more vents along eruptive fissures. On the basis of his study of Hawaiian eruptions, Swanson (1973) stated that surface-fed pahoehoe flows form during short-lived eruptions that last hours or a few days and (or) for which the lava supply was variable. The Trench Mortar Flat pahoehoe flow is an example of a surface-fed pahoehoe flow.

Tube-fed pahoehoe flows cover areas of 30-300 km\(^2\). They are typically 10-12 m thick and have volumes of as much as 4 km\(^3\). Holcomb (1980) noted that tube-fed pahoehoe flows develop broad dendritic distribution systems that originate from rootless vents along master lava tube systems. Swanson (1973) observed that tube-fed pahoehoe flows reflect fairly constant supplies of lava for periods of days, weeks, or months from central vents of cinder cones. The proximal parts of tube-fed flows are characterized by lava-tube systems having elongated, sinuous depressions, rootless vents, and “skylights”. The distal parts of the flows are characterized by hummocky and billowy surfaces, tumuli, pressure plateaus and collapse depressions. The Blue Dragon flow is an excellent example of a tube-fed pahoehoe flow.

Slab lava consists of jumbled, rafted plates and slabs of flow crust that form a jagged, rough-surfaced flow. Slab lava occurs as local phases of pahoehoe flows where partly congealed crust was broken and disturbed, such as localities where pahoehoe moved over rough, underlying topography or where degassed, more viscous lava was erupted locally, such as at rootless vents. Surfaces of slab-lava flows are typically corrugated, having prominent flow ridges and longitudinal furrows and cracks that are generally perpendicular and parallel, respectively, to the direction of flow movement. The Blue Dragon flow contains many lobes of slab lava.

Squeeze-out lava forms bulbous lobes of pahoehoe that are steep-sided, short, relatively thick, and stubby. They were extruded from rootless vents at the base of the steep margins of a’a and block a’a flows. Squeeze-out flows consist of numerous lobes and ridges in interdigitating, dendritic patterns that form rough topography. Squeeze-out flows are prominent features along the northern margin of the
Serrate flow.

A’a lava forms rough-surfaced, thick, narrow, relatively long, small- to intermediate-volume flows. Flow thickness is typically 15-20 m, the width less than 5 km, the length as much as 25 km, and the volume generally less than 1 km³. The proximal parts of the flows contain central channels that are locally anastomosed. The distal parts of the flows consist of bulbous, steep-sided lobes having arcuate flow ridges that are generally perpendicular to the direction of flow and having longitudinal furrows and cracks generally parallel to the direction of flow. The surface of a’a flows has several meters of relief because of a covering of rubble consisting of angular, spinose blocks and irregular masses of cooled crust. Much of the Sawtooth flow consists of a’a.

Block-a’a lava forms thick, lobate masses with features identical to a’a flows but with the additional characteristic of containing large, angular, smooth-sided blocks of solid, massive lava. Prominent flow ridges and longitudinal furrows and cracks are typical of block-a’a flows. The Highway, Devils Orchard, and Serrate flows are of the block-a’a type.

Well-documented studies of Hawaiian eruptions (Holcomb, 1980; Peterson and Tilling, 1980) suggest that nearly all Hawaiian basaltic lava erupts as pahoehoe and, as it cools, some may change to a’a as it flows away from the vent. Factors in the transition from pahoehoe to a’a are cooling, degassing, and, locally, turbulence. These factors determine the critical relations between viscosity and rate of shear strain needed to produce a’a (Peterson and Tilling, 1980). Viscosity is a measure of the stiffness of the lava; rate of shear strain is the speed at which the lava deforms. Typically, a’a forms when the original pahoehoe lava continues to move and deform after it has become highly viscous. This process produces stiff clots, masses, and fragments in certain parts of the flow. Continued movement, causing aggregation, fracture, and grinding together of these fragments, completes the transition to a’a lava.

Several flows in this quadrangle are believed to have erupted as a’a or to have been converted from pahoehoe to a’a after travel of only a few hundred meters from their respective vents, because they consist of lava whose chemical composition suggests high initial viscosity, and because the flows are a’a or block-a’a along most or all of their length. These flows are the Highway, Devils Orchard, Serrate, and Silent Cone flows.

An intermediate stage in the transformation from pahoehoe to a’a is the formation of slab lava, which forms when the chilled crust of a pahoehoe flow is fractured, forming plates that are jumbled, tilted, and rafted on the surface of the underlying, moving flow. Slab-lava is a common type of flow in composite lava flows of the Craters of the Moon lava field, being particularly conspicuous in the Blue Dragon, Big Craters, and Trench Mortar Flat flows.

Some types of lava flows are intergradational and, as shown in the “Correlation of Map Units,” several types comprise a composite named flow. The various flow types in a composite flow are considered to be phases of the flow that formed nearly simultaneously under locally variable physical conditions. As examples of composite flows, small lobes of slab lava are part of the Blue Dragon flow, which is predominantly tube-fed pahoehoe. The Serrate flow is dominantly block a’a but also contains rafted blocks and squeeze-out flows around its margins. Several flows in the Craters of the Moon lava field consist of pahoehoe in proximal parts and a’a in distal parts.

Other Volcanic Rock and Vent Deposits

Rafted blocks are fragments of bedded, oxidized, mostly agglutinated cinders and ash derived from the walls of shattered, disrupted cinder cones. Because of their relatively low density, rafted blocks were transported on the surface and within lava flows of relatively high viscosity and density, such as a’a flows and block a’a flows. Rafted blocks are as much as 300 m long and as much as 30 m high. Rafted blocks are common in the Devils Orchard, Serrate, Silent Cone, Indian Wells North, and Sawtooth flows. Rafted blocks are termed “monoliths” in earlier literature about Craters of the Moon National Monument.

Cinder cones and cinder mounds are accumulations of black, brown, red, orange, and tan bombs, lapilli, coarse ash, and interbedded, fresh to strongly oxidized lava flows that build up around a central vent or a series of vents along an eruptive fissure. Many cinder cones in Craters of the Moon National Monument are composite and consist of nested cones that formed during pulsating eruptions from closely spaced vents along short segments of eruptive fissures.
Spatter ramparts are low, narrow accumulations of brown, red, orange, and tan agglutinated spatter and loose lapilli and ash that are along one or both flanks of eruptive fissures. Spatter ramparts are typically less than 5 m high and less than 50 m wide.

Ash deposits are blankets of black, brown, and red ash and fine spatter that occur downwind, typically to the east or northeast, of source vents. Most ash deposits are less than 1 m thick.

**Chemical, Macroscopic, and Microscopic Characteristics of Various Rock Types**

Chemical compositions of lava flows in each eruptive period are given in Kuntz and others (1985). Rock names assigned to the lava flows in the Craters of the Moon field (“basalt,” “hawaiite,” “trachyandesite”) are those suggested by Cox and others (1979). The classification is based on the weight percentages of Na$_2$O + K$_2$O versus SiO$_2$ (see fig. 3). Note that most chemical analyses plot within the fields for basalt, hawaiite, and trachyandesite. The name basalt-hawaiite is given to rocks whose rock analyses lie close to the line between basalt and hawaiite.

Basalt, hawaiite, and trachyandesite have unique physical characteristics and microscopic features. The lava type, color, vesicle size and shape, mineralogical composition, and textural features for each type of rock are summarized in the following paragraphs. Petrographic descriptions of lava flow types were made from standard petrographic examination of thin sections. Olivine composition was estimated optically by the curvature of the isogyre as viewed along an optic axis. The composition of plagioclase was determined by measurement of extinction angles of albite twin lamellae in crystals in which both 001 and 010 crystallographic planes were oriented vertically. The chemical composition for some minerals in the lava flows was determined using the electron microprobe by Leeman and others (1976) and by Stout and Nichols (1976). Colors and numerical designation of hues for the volcanic rocks were assigned using the “Rock Color Chart” of the Geological Society of America (1975). Colors of rocks in cinder cones and volcanic ash deposits are extremely variable; thus general terms are used to describe the colors of these deposits.

**Basalt**

Basalt is typically dark gray (N3) and medium dark gray (N4) and contains nearly spherical vesicles. It typically occurs as tube-fed pahoehoe flows, which contain minor amounts of slab lava or as surface-fed, shelly pahoehoe. Porphyritic basalt contains phenocrysts of olivine as large as 5 mm in diameter, plagioclase laths as long as 2 cm, and rare skeletal crystals of an equant opaque mineral, which is probably titanomagnetite. Olivine composition is typically Fo$_{50-65}$ and plagioclase composition is typically An$_{45-55}$. The matrix of basalt consists of granules and skeletal crystals of olivine, plagioclase laths, intersertal clinopyroxene, an equant opaque mineral, possibly titanomagnetite or spinel, an acicular to feathery opaque mineral, and opaque-charged, brown glass. Basalt is typically hypocrystalline and diktytaxitic textures are common.

**Hawaiite**

Hawaiite is typically medium dark gray (N4) to brownish gray (5YR4/1) and has vesicles that are slightly elongated and stretched. Hawaiite occurs as surface-fed pahoehoe flows containing significant amounts of slab lava and as pahoehoe flows that have distal phases of a‘a lava. Petrographically, hawaiite is similar to basalt, except that, in hawaiite, plagioclase phenocrysts are more common than olivine phenocrysts. Olivine composition is Fo$_{45-50}$ and plagioclase is typically An$_{40-50}$.

**Trachyandesite**

Trachyandesite is typically olive gray (5Y4/1), has extremely elongated, stretched vesicles, and occurs as a‘a and block-a‘a flows. Trachyandesite flows are extremely fine-grained and locally contain xenolithic clots of gneiss; felsic, hypocrystalline volcanic rocks; and holohyaline pumice. Xenocrysts of rounded, embayed, skeletal crystals of anorthoclase, dark-green clinopyroxene, plagioclase, rare zircon, and aggregates of these minerals are seen in thin sections. The matrix of trachyandesite typically consists of slender, skeletal olivine crystals (Fo$_{35-40}$), slender laths of plagioclase (An$_{35-40}$), spindles and needles of greenish-brown clinopyroxene, and opaque-charged, brown glass.

*Extracted from: Infemo Cone 7.5' Quadrangle.*
References


Extracted from: Inferno Cone 7.5' Quadrangle.

North Laidlaw Butte 7.5' Quadrangle

### Correlation of Map Units

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**Extracted from:** North Laidlaw Butte 7.5' Quadrangle.
Index Map

Extracted from: North Laidlaw Butte 7.5' Quadrangle.

Map Legend

- **Contact**—Dashed where approximately located, particularly between flow units of a named flow. Relative ages of flows along contact indicated by Y, younger; O, older
- **Flow line**—Small channels, gutters, and lava tubes; arrow shows flow direction
- **Lava channel**—Large channel, arrow shows direction of flow
- **Flow ridges, furrows, and cracks**—Ridges are generally perpendicular to direction of flow movement and furrows and cracks are generally parallel to direction of flow movement
- **Crater**—Crater rim on volcanic vent; hachures point toward central depression (hachures not shown on smaller craters)
- **Cone**—Vent for small lava cones, cinder cones, and spatter cones
- **Eruptive fissure**—Fracture through which lava erupted, generally bordered by spatter ramparts
- **Neronruptive fissures**—Fractures in rock through which lava has not erupted. Width generally less than 3 ft (1 m)
- **Rootless vent**—Secondary source of lava not directly related to conduits that brought magma to the surface from deep magma reservoir; chiefly openings along lava tubes
- **Lava pond**—Levees surrounding lava pond; hachures point away from pond

Extracted from: North Laidlaw Butte 7.5' Quadrangle.
Figure 1

Figure 1.—Index map showing location of the North Laidlaw Butte quadrangle, Craters of the Moon National Monument, Craters of the Moon lava field, the Great Rift, and companion Geologic Quadrangle Maps.

Extracted from: North Laidlaw Butte 7.5' Quadrangle.
Figure 2

![Map of southern Idaho showing location of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift.](map)

Figure 2.—Index map of southern Idaho showing location of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift.

*Extracted from: North Laidlaw Butte 7.5° Quadrangle.*
Figure 3

![Figure 3](image_url)

**Figure 3.**—Na$_2$O + K$_2$O versus SiO$_2$ plot for analyzed rocks from Craters of the Moon, Wapi, and Kings Bowl lava fields. Line A–B separates alkaline from subalkaline fields (Irvine and Baragar, 1971). Nomenclature from Cox and others (1979). Major-element data from Kuntz and others (1985).

*Extracted from: North Laidlaw Butte 7.5' Quadrangle.*

**Report**

**Introduction**

This map is one of four maps (fig. 1) that depict the volcanic geology of the northern part of Craters of the Moon lava field in the Snake River Plain of southern Idaho (fig. 2). The Snake River Plain, a region of late Tertiary and Quaternary basaltic volcanism, contains many volcanic rift zones, the most spectacular being the Great Rift, the northern part of which contains the source vents for the flows of the Craters of the Moon lava field. The Great Rift is a northwest-trending fracture system, 85 km long and 2-8 km wide, that extends nearly across the entire width of the Snake River Plain (fig. 2). The Great Rift is defined by an array of cinder cones, shield volcanoes, lava cones, eruptive fissures, noneruptive fissures, and fresh-appearing lava flows.

Two other lava fields, the Wapi and Kings Bowl fields, are along the southern part of the Great Rift (fig. 2). The geology of the entire Great Rift and of the three lava fields is depicted on a 1:100,000-scale map by Kuntz and others (1987). The Craters of the Moon lava field consists of more than 60 lava flows and flow units, more than 25 cinder cones, and 8 eruptive fissure systems. The lava field covers an area of about 1,600 km$^2$, contains more than 30 km$^3$ of lava, and is the largest dominantly Holocene basaltic lava field in the coterminous United States (Kuntz and others, 1982; Kuntz, Champion, and others, 1986).

Radiocarbon and paleomagnetic data and our field studies (Kuntz and others, 1987; Kuntz, Champion, and others, 1986; Kuntz, Spiker, and others, 1986) reveal that lava flows of the Craters of the Moon lava field were emplaced in at least eight eruptive periods, designated as H, the oldest, through A, the youngest. Eruptive period H began about 15,000 years ago, and eruptive period A ended about 2000 years ago. Each eruptive period was about 1,000 years or less in duration and was separated by intervals of quiescence lasting a few hundred to more than 2,000 years. The lava flows of the Craters of the Moon lava field belong to the Snake River Group of Pleistocene and Holocene age.
The map of the North Laidlaw Butte quadrangle can be used separately, but a more complete picture of the volcanic geology of the Great Rift and of Craters of the Moon National Monument can be obtained by also studying the three companion maps shown in figure 1. The North Laidlaw Butte quadrangle depicts the volcanic geology of bulbous a’a lava flows primarily of eruptive periods C and D, including the Indian Wells North, Indian Wells South, Sawtooth, The Sentinel, Carey Kipuka, Little Park, and Little Laidlaw Park flows. Part of the lava tube system that fed the western lobe of the Blue Dragon pahoehoe flow during eruptive period A occurs in the northwest corner of the quadrangle. Most of the map area is covered by lava flows and associated crater vents and eruptive fissures that formed earlier than the Craters of the Moon lava field. These flows, like the flows of the Craters of the Moon lava field, are also part of the Snake River Group of Pleistocene and Holocene age.

Many of the names of lava flows (for example, the Blue Dragon flow) are those used by Stearns (1928) and Murtaugh (1961), but new names have been applied to some flows. The “Correlation of Map Units” shows all map units depicted on the four maps of this study, but only the units present in this quadrangle are colored. The named Holocene flows of the Snake River Group mapped in this quadrangle are informal units.

The map symbols consist of letters and numbers in the following order: the first letter of each symbol refers to the type of deposit (f, flow; c, cinder and spatter deposits near vent areas; and a, ash deposits); the second letter refers to the eruptive period of the deposit (A, the youngest, through H, the oldest); the number indicates the stratigraphic order of deposition within the eruptive period (1, the youngest; 2, the next oldest; and so on). Overprinted patterns designate “squeeze-out” flows and a’a flows.

### Lava Flow Morphology

Three morphologic types of lava flows occur in this quadrangle: pahoehoe, a’a, and squeeze-out flows. Pahoehoe is further subdivided into surface-fed and tube-fed varieties (Holcomb, 1980, 1981).

Surface-fed pahoehoe flows cover small areas. They are typically less than 10 m thick, cover less than 20 km$^2$, and contain less than 0.1 km$^3$ of rock. They consist of shelly pahoehoe (Swanson, 1973) near vents and contain numerous channels and lava gutters that distributed lava to advancing flow fronts. Congealed lava ponds are present in some flows. These flows were probably fed by lava fountains and by sporadic overflow from one or more vents along eruptive fissures. On the basis of his study of Hawaiian eruptions, Swanson (1973) stated that surface-fed pahoehoe flows form during short-lived eruptions that last hours or a few days and (or) in which the rate of lava supply may vary. The proximal parts of The Sentinel flow are surface-fed pahoehoe.

Tube-fed pahoehoe flows cover areas of 30-300 km$^2$. They are typically 10-12 m thick and have volumes of as much as 4 km$^3$. Holcomb (1980) noted that tube-fed pahoehoe flows develop broad dendritic distribution systems that originate from rootless vents along master lava-tube systems. Swanson (1973) observed that tube-fed pahoehoe flows reflect fairly constant supplies of lava for periods of days, weeks, or months from central vents or cinder cones. The proximal parts of tube-fed flows are characterized by lava-tube systems having elongated, sinuous depressions, rootless vents, and “skylights”. The distal parts of the flows are characterized by hummocky and billowy surfaces, tumuli, pressure plateaus and collapse depressions. The Blue Dragon flow is chiefly tube-fed pahoehoe.

Squeeze-out lava forms bulbous lobes of pahoehoe that are steep-sided, short, relatively thick, and stubby. They were extruded from rootless vents at the base of the steep margins of a’a flows. Squeeze-out flows consist of numerous lobes and ridges in interdigitating, dendritic patterns that form rough topography. Squeeze-out flows are common along the steep margins of the Sawtooth, Little Park, and Little Laidlaw Park a’a flows.

A’a lava forms rough-surfaced, thick, narrow, relatively long, small- to intermediate-volume flows. Flow thickness is typically 15-20 m, the width less than 5 km, the length as much as 25 km, and the volume generally less than 1 km$^3$. The proximal parts of most a’a flows contain central channels that are locally anastomosed. The distal parts of the flows consist of bulbous, steep-sided lobes having arcuate flow ridges that are generally perpendicular to the direction of flow and having longitudinal furrows and cracks generally parallel to the direction of flow. The surface of a’a flows has several meters of relief.
because of a covering of rubble consisting of angular, spinose blocks and irregular masses of cooled crust. The Indian Wells North, Indian Wells South, Sawtooth, Little Park, and Little Laidlaw Park flows are excellent examples of a’a flows.

Well-documented studies of Hawaiian eruptions (Holcomb, 1980; Peterson and Tilling, 1980) suggest that nearly all Hawaiian basaltic lava erupts as pahoehoe and, as it cools, some may change to a’a as it flows away from the vent. Factors involved in the transition from pahoehoe to a’a are cooling, degassing, and, locally, turbulence. These factors determine the critical relations between viscosity and rate of shear strain needed to produce a’a (Peterson and Tilling, 1980). Viscosity is a measure of the stiffness of the lava; rate of shear strain is the speed at which the lava deforms. Typically, a’a forms when the original pahoehoe lava continues to move and deform after it has become highly viscous. This process produces stiff clots, masses, and fragments in certain parts of the flow. Continued movement, causing aggregation, fracture, and grinding together of these fragments, completes the transition to a’a lava.

The a’a flows in this quadrangle are believed to have erupted as a’a or to have been converted from pahoehoe to a’a after travel of only a few hundred meters from their respective vents, because they consist of lava whose chemical composition suggests high initial viscosity, and because the flows are a’a along most of their length.

Some types of lava flows are intergradational and, as shown in the “Correlation of Map Units,” several types comprise a composite named flow. The various flow types in a composite flow are considered to be phases of the flow that formed nearly simultaneously under locally variable physical conditions. Examples of composite flows are the Sawtooth and Little Laidlaw Park flows, which consist of a’a and squeeze-out flows, and the Little Park flow, which consists of pahoehoe in proximal parts and a’a in distal parts.

Other Volcanic Rock and Vent Deposits

Rafted blocks are fragments of bedded, oxidized, mostly agglutinated cinders and ash derived from the walls of shattered, disrupted cinder cones. Because of their relatively low density, rafted blocks were transported on the surface and within lava flows of relatively high viscosity and density, such as a’a flows. Rafted blocks are as much as 300 m long and as much as 30 m high. Rafted blocks are termed “monoliths” in earlier literature about Craters of the Moon National Monument. The Indian Wells North, Indian Wells South, and Little Park flows contain rafted blocks.

Chemical, Macroscopic, and Microscopic Characteristics of Various Rock Types

Chemical composition of the lava flows in each eruptive period are given in Kuntz and others (1985). Rock names assigned to the lava flows in the Craters of the Moon field (“basalt,” “hawaiite,” “trachyandesite”) are those suggested by Cox and others (1979). The classification is based on the weight percentages of Na₂O + K₂O versus SiO₂ (see fig. 3). Note that most chemical analyses plot within the fields for basalt, hawaiite, and trachyandesite. The name basalt-hawaiite is given to rocks whose analyses lie close to the line between basalt and hawaiite.

Basalt, hawaiite, and trachyandesite have unique physical characteristics and microscopic features. The lava type, color, vesicle size and shape, mineralogical composition, and textural features for each type of rock are summarized in the following paragraphs. Petrographic descriptions of lava flow types were made from standard petrographic examination of thin sections. Olivine composition was estimated optically by the curvature of the isogyre as viewed along an optic axis. The composition of plagioclase was determined by measurement of extinction angles of albite twin lamellae in crystals in which both 001 and 010 crystallographic planes were oriented vertically. The chemical composition for some minerals in some flows was determined using the electron microprobe by Leeman and others (1976) and by Stout and Nichols (1976). Colors and numerical designation of hues for the volcanic rocks were assigned using the “Rock Color Chart” of the Geological Society of America (1975). Colors of rocks in cinder cones and volcanic-ash deposits are extremely variable; thus general terms are used to describe the colors of these deposits.
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Trachyandesite is typically olive gray (5Y4/1), has extremely elongated, stretched vesicles, and occurs as a'a and block-a'a flows. Trachyandesite flows are extremely fine grained and locally contain xenolithic clots of gneiss; felsic, hypocrystalline volcanic rocks; and holohyaline pumice. Xenocrysts of rounded, embayed, skeletal crystals of anorthoclase, dark-green clinopyroxene, plagioclase, rare zircon, and aggregates of these minerals are seen in thin sections. The matrix of trachyandesite typically consists of slender, skeletal olivine crystals ($\text{Fo}_{\text{35-40}}$), slender laths of plagioclase ($\text{An}_{\text{35-40}}$), spindles and needles of greenish-brown clinopyroxene, and opaque-charged, brown glass.

Extracted from: North Laidlaw Butte 7.5' Quadrangle.

References


Kuntz, M.A., Champion, D.E., Spiker, E.C., and Lefebvre, R.H., 1986, Contrasting magma types and


Extracted from: North Laidlaw Butte 7.5' Quadrangle.

The Watchman 7.5' Quadrangle

## Correlation of Map Units

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<th>Volcanic Package</th>
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*Note: Numbers indicate map units in Table of Geologic Unit Correlation Maps (Q3-22, Q3-23, and Q3-24)*

Extracted from: *The Watchman 7.5' Quadrangle.*
Index Map

Extracted from: The Watchman 7.5' Quadrangle.

Map Legend

- **Contact**—Dashed where approximately located, particularly between flow units within a named flow; dotted where concealed. Relative ages of flows along contact indicated by Y, younger; O, older
- **Flow line**—Linear flow features and lava tubes; arrow shows flow direction
- **Skylights in lava tubes**
- **Lava channel**—Large channel, arrow shows direction of flow
- **Flow ridges, furrows, and cracks**—Ridges are generally perpendicular to direction of flow movement and furrows and cracks are generally parallel to direction of flow movement
- **Crater**—Crater rim on volcanic vent; hachures point toward central depression
- **Cone**—Vent for small lava cones, cinder cones, and spatter cones
- **Eruptive fissure**—Fracture through which lava erupted, generally bordered by spatter ramparts
- **Non-eruptive fissures**—Fractures in rock through which lava has not erupted. Width generally less than 3 ft (1 m)
- **Rootless vent**—Secondary source of lava not directly related to conduits that brought magma to the surface from deep magma reservoir; chiefly openings along lava tubes

Extracted from: The Watchman 7.5' Quadrangle.
Figure 1

Figure 1.—Index map showing location of The Watchman quadrangle, Craters of the Moon National Monument, Craters of the Moon lava field, the Great Rift, and companion Geologic Quadrangle Maps.

Extracted from: The Watchman 7.5' Quadrangle.
Figure 2

Figure 2.—Index map of southern Idaho showing location of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift.

Extracted from: The Watchman 7.5' Quadrangle.
This map is one of four maps (fig. 1) that depict the volcanic geology of the northern part of Craters of the Moon lava field in the Snake River Plain of southern Idaho (fig. 2). The Snake River Plain, a region of late Tertiary and Quaternary basaltic volcanism, contains many volcanic rift zones, the most spectacular being the Great Rift, the northern part of which contains the source vents for the flows of the Craters of the Moon lava field. The Great Rift is a northwest-trending fracture system, 85 km long and 2-8 km wide, that extends nearly across the width of the Snake River Plain (fig. 2). The Great Rift is defined by an array of cinder cones, shield volcanoes, lava cones, eruptive fissures, noneruptive fissures, and fresh-appearing lava flows.

Two other lava fields, the Wapi and Kings Bowl fields, are along the southern part of the Great Rift (fig. 2). The geology of the entire Great Rift and of the three lava fields is depicted on a 1:100,000-scale map by Kuntz and others (1987). The Craters of the Moon lava field consists of more than 60 lava flows and flow units, more than 25 cinder cones, and 8 eruptive fissure systems. The lava field covers an area of about 1,600 km², contains more than 30 km³ of lava, and is the largest dominantly Holocene basaltic lava field in the coterminous United States (Kuntz and others, 1982; Kuntz, Champion, and others, 1986).

Radiocarbon and paleomagnetic data and our field studies (Kuntz and others, 1987; Kuntz, Champion, and others, 1986; Kuntz, Spiker, and others, 1986) reveal that lava flows of the Craters of the Moon lava field were emplaced in at least eight eruptive periods, designated as H, the oldest, through A, the youngest. Eruptive period H began about 15,000 years ago, and eruptive period A ended about 2000 years ago. Each eruptive period was about 1,000 years or less in duration and was separated by intervals of quiescence lasting a few hundred to more than 2,000 years. The lava flows of the Craters of the Moon lava field belong to the Snake River Group of Pleistocene and Holocene age.
The map of The Watchman quadrangle can be used separately, but a more complete picture of the volcanic geology of the Great Rift and of the Craters of the Moon National Monument can be obtained by also studying the three companion maps shown in figure 1. The Watchman quadrangle depicts volcanic features in the northeastern part of the Craters of the Moon National Monument, especially the intermediate and distal parts of the eastern lobe of the Blue Dragon pahoehoe flow. This map is important because it shows the lava tube rootless vent system that fed the voluminous eastern lobe of the Blue Dragon flow. Also shown on the map are fissure vents and noneruptive fissures of Trench Mortar Flat, The Watchman and The Sentinel cinder cones, distal parts of the Serrate flow, and older Craters of the Moon flows in the Little Prairie area. Lava flows that formed earlier than the Craters of the Moon lava field occur along the eastern margin of this quadrangle. These latter flows, like the flows of the Craters of the Moon lava field, are also part of the Snake River Group of Pleistocene and Holocene age.

Many of the names of lava flows (for example, the Blue Dragon flow) on this map are those used by Stearns (1928) and Murtaugh (1961), but new names have been applied to some flows. The “Correlation of Map Units” shows all map units depicted on the four maps of this study, but only the units in this quadrangle are colored. The named Holocene flows of the Snake River Group mapped in this quadrangle are informal units.

The map symbols consist of letters and numbers arranged in the following order: the first letter of each symbol refers to the type of deposit (f, flow; c, cinder and spatter deposits near vent areas; and a, ash deposits); the second letter refers to the eruptive period of the deposit (A, the youngest, through H, the oldest); the number indicates the stratigraphic order of deposition within the eruptive period (1, the youngest, 2, the next oldest; and so on). Overprinted patterns designate various types of flow deposits, specifically slab lava, “squeeze-out”, and a’a flows. Patterns and (or) colors also are used to distinguish cinder-spatter and ash deposits and rafted blocks.

**Lava Flow Morphology**

Five morphologic types of lava flows occur in this quadrangle; pahoehoe, slab lava, a’a, squeeze-out, and block a’a flows. Pahoehoe is further subdivided into surface-fed and tube-fed varieties (Holcomb, 1980, 1981).

Surface-fed pahoehoe flows cover small areas. They are typically less than 10 m thick, cover less than 20 km², and contain less than 0.1 km³ of rock. They consist of shelly pahoehoe (Swanson, 1973) near vents and contain numerous channels and lava gutters that distributed lava to advancing flow fronts. Congealed lava ponds are present in some flows. These flows were probably fed by lava fountains and by sporadic overflow from one or more vents along eruptive fissures. On the basis of his study of Hawaiian eruptions, Swanson (1973) stated that surface-fed pahoehoe flows form during short-lived eruptions that last hours or a few days and (or) for which the lava supply was variable. The Trench Mortar Flat pahoehoe flow is an example of a surface-fed pahoehoe flow.

Tube-fed pahoehoe flows cover areas of 30-300 km². They are typically 10-12 m thick and have volumes of as much as 4 km³. Holcomb (1980) noted that tube-fed pahoehoe flows develop broad dendritic distribution systems that originate from rootless vents along master lava-tube systems. Swanson (1973) observed that tube-fed pahoehoe flows reflect fairly constant supplies of lava for periods of days, weeks, or months from central vents or cinder cones. The proximal parts of tube-fed flows are characterized by lava-tube systems having elongated, sinuous depressions, rootless vents, and “skylights”. The distal parts of the flows are characterized by hummocky and billowy surfaces, tumuli, pressure plateaus and collapse depressions. The Blue Dragon flow is an excellent example of a tube-fed pahoehoe flow.

Slab lava consists of jumbled, rafted plates and slabs of flow crust that form a jagged, rough-surfaced flow. Slab lava occurs as local phases of pahoehoe flows where partly congealed crust was broken and disturbed, such as localities where pahoehoe moved over rough underlying topography, or where degassed, more viscous lava was erupted locally, such as at rootless vents. Surfaces of slab-lava flows are typically corrugated, having prominent flow ridges and longitudinal furrows and cracks that are generally perpendicular and parallel, respectively, to the direction of flow movement. The distal parts of
the Trench Mortar Flat flow consist of slab lava.

Squeeze-out lava forms bulbous lobes of pahoehoe that are steep-sided, short, relatively thick, and stubby. They were extruded from rootless vents at the base of the steep margins of a’a and block-a’a flows. Squeeze-out flows consist of numerous lobes and ridges in interdigitating, dendritic patterns that form rough topography. The Serrate flow contains squeeze-out lobes along its northern margin.

A’a lava forms rough-surfaced, thick, narrow, relatively long, small- to intermediate-volume flows. Flow thickness is typically 15-20 m, the width less than 5 km, the length as much as 25 km, and the volume generally less than 1 km³. The proximal parts of the flows contain central channels that are locally anastomosed. In their distal parts, a’a flows consist of bulbous, steep-sided lobes having arcuate flow ridges that are generally perpendicular to the direction of flow and having longitudinal furrows and cracks generally parallel to the direction of flow. The surface of a’a flows has several meters of relief because of a covering of rubble consisting of angular, spinose blocks and irregular masses of cooled crust. The most prominent a’a flows in the Craters of the Moon National Monument occur in adjacent quadrangles, but the distal parts of the Little Prairie flow consist of a’a.

Block-a’a lava forms thick, lobate masses having features identical to a’a lava, but it also contains large, angular, smooth-sided blocks of solid, massive lava. Prominent flow ridges and longitudinal furrows and cracks are typical of block-a’a flows. The Serrate flow is a block-a’a flow.

Some types of lava flows are intergradational and, as shown in the “Correlation of Map Units,” several types comprise a named composite flow. The various flow types in a composite flow are considered to be phases of the flow that formed nearly simultaneously under locally variable physical conditions. Examples of composite flows are the Blue Dragon flow, which is predominantly tube-fed pahoehoe but also has small lobes of slab lava and the Serrate flow, which is dominantly block-a’a but also contains rafted blocks and squeeze-out lobes around its margins. The Little Prairie flow consists of pahoehoe in proximal parts and a’a in distal parts.

Well-documented studies of Hawaiian eruptions (Holcomb, 1980; Peterson and Tilling, 1980) suggest that nearly all Hawaiian basaltic lava erupts as pahoehoe and, as it cools, some may change to a’a as it flows away from the vent. Factors in the transition from pahoehoe to a’a are cooling, degassing, and, locally, turbulence. These factors determine the critical relations between viscosity and rate of shear strain needed to produce a’a (Peterson and Tilling, 1980). Viscosity is a measure of the stiffness of the lava; rate of shear strain is the speed at which the lava deforms. Typically, a’a forms when the original pahoehoe lava continues to move and deform after it has become highly viscous. This process produces stiff clots, masses, and fragments in certain parts of the flow. Continued movement, causing aggregation, fracture, and grinding together of these fragments, completes the transition to a’a lava.

Several flows shown in this quadrangle are believed to have erupted as a’a or to have been converted from pahoehoe to a’a after travel of only a few hundred meters from their respective vents, because they consist of lava whose chemical composition suggests high initial viscosity, and because these flows are a’a or block a’a along most or all of their length. The Serrate and Little Prairie flows are examples of such composite flows.

An intermediate stage in the transformation from pahoehoe to a’a is the formation of slab lava, which forms when the chilled crust of a pahoehoe flow is fractured, forming plates that are jumbled, tilted, and rafted on the surface of the underlying, moving flow. Slab-lava is a common type of flow in composite lava flows of the Craters of the Moon lava field, being particularly conspicuous in the Blue Dragon and Trench Mortar Flat flows.

Other Volcanic Rock and Vent Deposits

Rafted blocks are fragments of bedded, oxidized, mostly agglutinated cinders and ash derived from the walls of shattered, disrupted cinder cones. Because of their relatively low density, rafted blocks were transported on the surface and within lava flows of relatively high viscosity and density, such as a’a and block-a’a flows. Rafted blocks are as much as 300 m long and as much as 30 m high. The Serrate flow contains many rafted blocks. Rafted blocks are termed “monoliths” in earlier literature about Craters of the Moon National Monument.

Cinder cones are accumulations of black, brown, red, orange, and tan bombs, lapilli, coarse ash,
and interbedded, fresh to strongly oxidized lava flows that build up around a central vent or a series of vents along an eruptive fissure. Many cinder cones in Craters of the Moon National Monument are composite and consist of nested cones that formed during pulsating eruptions from closely spaced vents along short segments of eruptive fissures. An example of a composite cinder cone in this quadrangle is The Sentinel cinder cone.

Spatter ramparts are low, narrow accumulations of brown, red, orange, and tan agglutinated spatter and loose lapilli and ash that are along one or both flanks of eruptive fissures. Spatter ramparts are typically less than 5 m high and less than 50 m wide. Spatter ramparts occur along the Trench Mortar Flat eruptive fissures approximately 1 km northwest of The Watchman cinder cone.

Ash deposits are blankets of black, brown, and red ash and fine spatter that occur downwind, typically to the east or northeast, of source vents. Most ash deposits are less than 1 m thick.

**Chemical, Macroscopic, and Microscopic Characteristics of Various Rock Types**

Chemical compositions of lava flows in each eruptive period are given in Kuntz and others (1985). Rock names assigned to the lava flows in the Craters of the Moon field (“basalt,” “hawaiite,” “trachyandesite”) are those suggested by Cox and others (1979). The classification is based on the weight percentages of Na$_2$O + K$_2$O versus SiO$_2$ (see fig. 3). Note that most chemical analyses plot within the fields for basalt, hawaiite, and trachyandesite. The name basalt-hawaiite is given to rocks whose rock analyses lie close to the line between basalt and hawaiite.

Basalt, hawaiite, and trachyandesite have unique physical characteristics and microscopic features. The lava type, color, vesicle size and shape, mineralogical composition, and textural features for each type of rock are summarized in the following paragraphs. Petrographic descriptions of lava-flow types were made from standard petrographic examination of thin sections. Olivine composition was estimated optically by the curvature of the isogyre as viewed along an optic axis. The composition of plagioclase was determined by measurement of extinction angles of albite twin lamellae in crystals in which both 001 and 010 crystallographic planes were oriented vertically. The chemical composition for some minerals of the lava flows was determined using the electron microprobe by Leeman and others (1976) and by Stout and Nichols (1976). Colors and numerical designation of hues for the volcanic rocks were assigned using the “Rock Color Chart” of the Geological Society of America (1975). Colors of rocks in cinder cones and volcanic ash deposits are extremely variable; thus general terms are used to describe the colors of these deposits.

**Basalt** is typically dark gray (N3) and medium dark gray (N4) and contains nearly spherical vesicles. It typically occurs as tube-fed pahoehoe flows that contain minor amounts of slab lava or as surface-fed, shelly pahoehoe flows. Porphyritic basalt contains phenocrysts of olivine as large as 5 mm in diameter, plagioclase laths as long as 2 cm, and rare skeletal crystals of an equant opaque mineral, which is probably titanomagnetite. Olivine composition is typically Fo$_{50-65}$ and plagioclase composition is typically An$_{45-55}$. The matrix of basalt consists of granules and skeletal crystals of olivine, plagioclase laths, interstitial clinopyroxene, an equant opaque mineral that is possibly titanomagnetite or spinel, an acicular to feathery opaque mineral, and opaque-charged, brown glass. Basalt is holocrystalline to hypocrystalline and diktytaxitic textures are common.

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**Trachyandesite** is typically olive gray (5Y4/1), has extremely elongated, stretched vesicles, and occurs as a’a and block-a’a flows. Trachyandesite flows are extremely fine grained and locally contain xenolithic clots of gneiss; felsic, hypocrystalline volcanic rocks; and holohyaline pumice. Xenocrysts of rounded, embayed, skeletal crystals of anorthoclase, dark-green clinopyroxene, plagioclase, rare zircon, and aggregates of these minerals are seen in thin sections. The matrix of trachyandesite typically...
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Extracted from: The Watchman 7.5' Quadrangle.

References


Extracted from: The Watchman 7.5' Quadrangle.
**GRI Digital Data Credits**

This document was developed and completed by Derek Witt (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Stephanie O'Meara (Colorado State University).

The information in this document was compiled from GRI source maps, and intended to accompany the digital geologic-GIS map(s) and other digital data for Craters of the Moon National Monument and Preserve, Idaho (CRMO) developed by Derek Witt and Stephanie O'Meara (Colorado State University) (see the [GRI Digital Maps and Source Map Citations](#) section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS map(s)).

GRI finalization by Stephanie O'Meara (Colorado State University).

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).