DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC QUADRANGLE MAP
INFERNO CONE QUADRANGLE, IDAHO
GQ–1632

DESCRIPTION OF MAP UNITS

[Note: Capitalization and lack of capitalization of geographic names on this map does not necessarily indicate formal or informal geographic nomenclature. All named flows are informal stratigraphic units]

SNAKE RIVER GROUP (HOLOCENE AND PLEISTOCENE)

Lava flows of the Craters of the Moon lava field

Lava flows of eruptive period A

Broken Top flow and related vent and ash deposits (Holocene)

fa1 — **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). 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

ca1 — **Broken Top cinder cone**—West flank of cone mantled by agglutinated spatter (aa1) from eruptive fissure on west side of cone. West flank of cone is cut by northwest-trending fissures and normal faults having less than 1 m displacement. Bulk of cone may have formed by eruptions from fissure on 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.

aa1 — **Volcanic-ash deposits**—Ash and fine spatter from fissure vent on west side of Broken Top cinder cone. Deposit less than 1 m thick

Blue Dragon flow and related vent deposits (Holocene)

fa2 — **Pahoehoe basalt-hawaiite flow**—Chiefly tube-fed flow characterized by fresh, irridescent, 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)

fa2 — **Slab-lava flows**—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

ca2 — **Spatter Cones and related eruptive-fissure deposits**—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 defined by small, low spatter ramparts and pit craters

Trench Mortar Flat flow and related vent and ash deposits (Holocene)

fa3 — **Pahoehoe basalt-hawaiite flows**—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)

ca3 — **Cinder mounds**—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

aa3 — **Volcanic-ash deposits**—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 north-east (downwind) of source vents. Deposits near Yellowjacket Waterhole occur as a thin veneer less than 1 m thick on Trench Mortar Flat flow (fa3)

North Crater flow and related vent and ash deposits (Holocene)

fa4 — **Pahoehoe basalt-hawaiite flow**—Surface-fed flow that has irridescent, light-blue, highly vesicular, glassy crust. Flow contains rare inclusions of gneissic rocks, partly fused dacitic to rhyolitic rocks, and holohyaline clots of pumice

ca4 — **North Crater cinder cone**—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

aa4 — **Volcanic-ash deposits**—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 (c) and, locally, on the Devils Orchard flow (fa7)

Big Craters flow and related vent and ash deposits (Holocene)

fa5 — **Pahoehoe hawaiite flows**—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

fa5 — **Slab-lava flows**—Formed where partly congealed pahoehoe flows traversed rough topography, such as the underlying, corrugated surface of the Serrate flow (fa6)

ca5 — **Big Craters cinder cone**—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)

aa5 — **Volcanic-ash deposits**—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

Serrate flow (Holocene)

fa6 — **Block-a'a trachyandesite flow**—Surface-fed, jagged, block-a'a flow. Presumed source vent at or near North Crater cinder cone (ca4). Flow fronts are steep and as high as 5 m. 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)

fa6 — **Squeeze-out flows**—Extensive lobes at base of steep margins of Serrate block-a'a flow

fa6 — **Rafted blocks**—Broken wall blocks of a shattered cinder cone, probably North Crater (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)

Devils Orchard flow (Holocene)

fa7 — **Block-a'a trachyandesite flow**—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)

fa7 — **Rafted blocks**—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

Highway flow and related vent deposits (Holocene)

fa8 — **Block-a'a trachyandesite flow**—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 a 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

fa8 — **Pahoehoe trachyandesite flow**—Surface-fed, glassy flow in the area of the campground at Craters of the Moon National Monument. Locally, unit consists of slab lava

fa8 — **Rafted blocks**—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

ca8 — **Cinder mounds**—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)

Lava flows of eruptive period C

Indian Wells North flow (Holocene)

fc1 — **A'a trachyandesite flow**—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)

fc1 — **Rafted blocks**—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

Sawtooth flow and related vent and ash deposits (Holocene)

fc3 — **A'a trachyandesite flow**—Surface-fed, long, steep-sided flow that contains numerous lobes having steep fronts. Only proximal parts of flow occur in this quadrangle, 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

fc3 — **Slab-lava flows**—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 on a'a flow

fc3 — **Rafted blocks**—Broken wall blocks derived from central part of Big Cinder Butte cinder cone (cc3) near vent area and also from southern flanks of cone

cc3 — **Big Cinder Butte cinder cone**—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 km^3. Stearns (1928) reported that Big Cinder Butte ranks among the largest, purely basaltic cinder cones in the world. East and southeast flank 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)

ac3 — **Volcanic-ash deposits**—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

South Echo flow and related vent deposits (Holocene)

fc4 — **Pahoehoe basalt flow**—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)

cc4 — **Spatter rampart deposits**—Spatter ramparts flank eruptive fissures between Echo Crater cinder cone (c) and The Sentinel cinder cone (cc7) in The Watchman quadrangle (Kuntz, Lefebvre, and Champion, 1989). Largely covered by ash and vegetation. Fissures were source vents for South Echo flow (fc4)

The Sentinel flow (Holocene)

fc7 — **Pahoehoe basalt flow**—Surface-fed flow from vents in craters and at the base of The Sentinel cinder cone (cc7), which are in adjacent The Watchman quadrangle (Kuntz, Lefebvre, and Champion, 1989). 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

Lava flows of eruptive period D

Silent Cone flow and related vent deposits (Holocene)

fd1 — **Pahoehoe trachyandesite flow**—Surface-fed flow having numerous distributary 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

fd1 — **A'a flow**—Flow contains bulbous lobes. Unit occurs as distal part of Silent Cone pahoehoe flow

fd1 — **Rafted blocks**—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

cd1 — **Silent Cone cinder cone**—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)

Lava flows of eruptive period E

Grassy Cone flow and related vent and ash deposits (Holocene to Pleistocene)

fe1 — **Pahoehoe basalt flow**—Surface- and tube-fed flow. Proximal parts covered by black, brown, olive, and red ash

fe1 — **A'a flows**—Flows contain prominent corrugated surfaces. A'a occurs within pahoehoe flow in areas where pahoehoe collapsed and (or) flowed over steep slopes

fe1 — **Rafted blocks**—Broken wall blocks derived from Grassy Cone cinder cone (ce1). Blocks are typically less than 100 m long and less than 10 m high

ce1 — **Grassy Cone cinder cone**—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)

ae1 — **Volcanic-ash deposits**—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

Lava flows of eruptive period G

Sunset flows and related vent and ash deposits (latest Pleistocene)

fg1 — **Pahoehoe basalt-hawaiite flows**—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

cg1 — **Sunset Cone cinder cone**—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)

ag1 — **Volcanic-ash deposits**—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

Carey flow (latest Pleistocene)

fg2 — **Pahoehoe basalt-hawaiite flow**—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

fg2 — **A'a flows**—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

Lava flows of eruptive period H

Crescent Butte flow and related vent deposits (latest Pleistocene)

fh1 — **Pahoehoe basalt flow**—Small, surface-fed, pahoehoe flow from crater in Crescent Butte cinder cone (ch1). Flow is mantled by vegetation and thin colluvium

ch1 — **Crescent Butte cinder cone**—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)

Cinder cones of indeterminant age

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 the Craters of the Moon lava field. In this quadrangle, unit includes Paisley Cone, Inferno Cone, Half Cone, Echo Crater, and other unnamed cinder cones

SURFICIAL DEPOSITS

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

BEDROCK IN MOUNTAINS NORTH OF THE SNAKE RIVER PLAIN

Intrusive rocks (mapped by William C. Sidle)

Tg — **Biotite granite of Big Cottonwood Creek (Eocene)**—Medium- to coarse-grained, massive, biotite granite consisting of orthoclase, quartz, and subordinate amounts of plagioclase (An_{5-20}) 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

Tqm — **Hornblende quartz monzonite of Little Cottonwood Creek (Eocene)**—Weakly foliated, medium-grained, equigranular, quartz monzonite consisting of plagioclase (An_{10-20} and An_{30-50}), 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

Volcanic rocks (mapped by William C. Sidle)

Challis Volcanics (Eocene)

Tcw — **Welded tuff**—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

Tclb — **Lava flows and interbedded tuff breccia**—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

Tctb — **Tuff breccia**—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

Sedimentary rocks (mapped by Betty A. Skipp)

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 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-plan deposits of the Scorpion subplate of Nilsen (1977)

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

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

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)

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

INTRODUCTION

This map is one of four maps (fig. 1) that depict the volcanic geology of the northern part of the 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 Rifts 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 km^2, contains more than 30 km^3 of lava, and is the largest dominantly Holocene basaltic lava field in the conterminous 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 2,000 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, 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 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 cinders cones. The proximal parts of tube-fed flows are characterized by lava-tube systems having elongated, sinuous depression, 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 were pahoehoe moved over rough, underlying topography or were 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 consist 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 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.

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 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 built 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 $Na_2O + K_2O$ verses 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 analyses lie close to the line between basalt and hawaiite.

Basalt, hawaiite, and trachyandesite have unique physical characteristics and microscopic features. The lava flow type, color, vesicle size and shape, mineralogical composition, and textural features for each type of rock are summarized in the following paragraphs. Petrographic description 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 Nicholls (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 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, as 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. 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 composition is typically An_{40-50}.

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 (Fo_{35-45}), slender laths of plagioclase (An_{35-40}), spindles and needles of greenish-brown clinopyroxene, and opaque-charged, brown glass.

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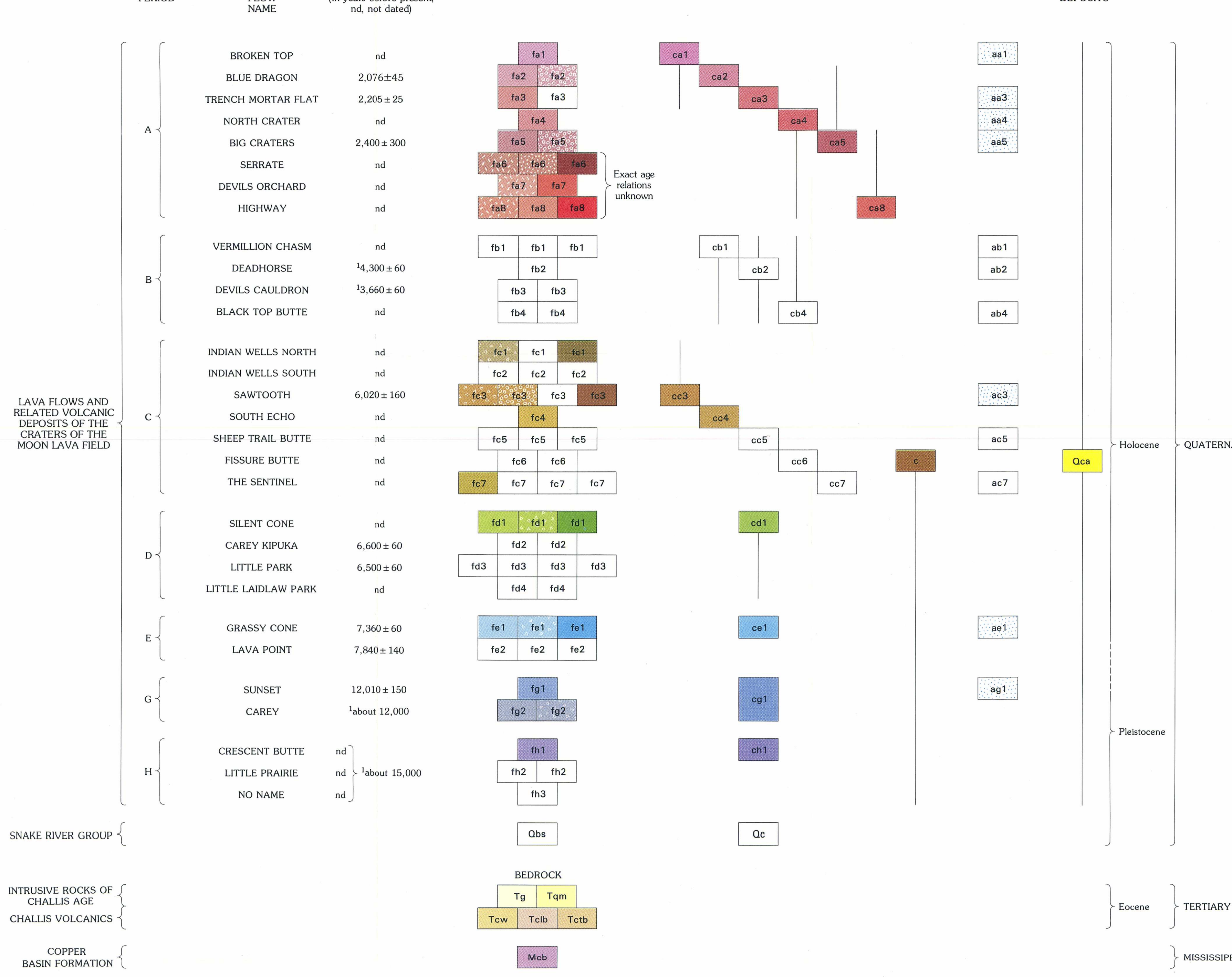
CORRELATION OF MAP UNITS

[Uncolored boxes indicate map units found in companion Geologic Quadrangle Maps GQ–1633, GQ–1634, and GQ–1635]



[1]See Kuntz, Champion, and others (1986); Kuntz and others (1982); and Kuntz, Spiker, and others (1986) for discussion and interpretation of radiocarbon ages.

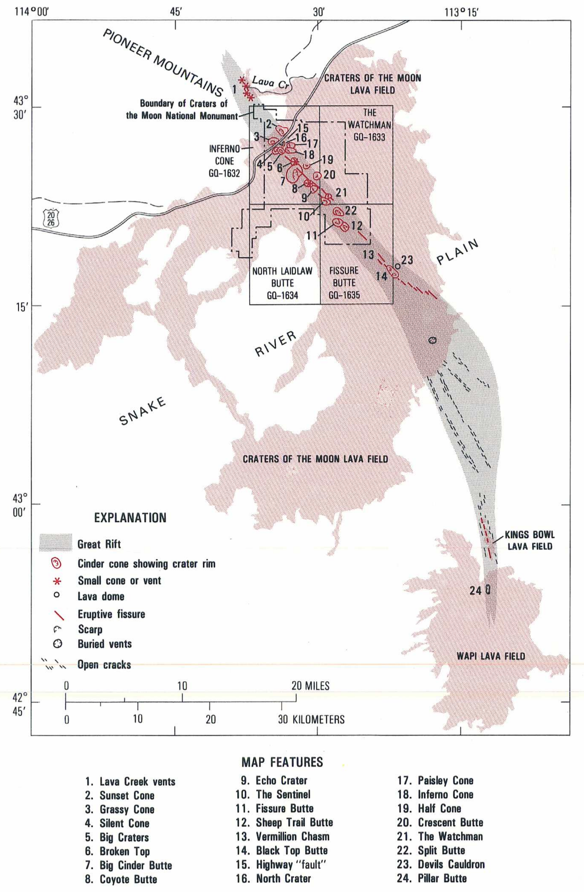


Figure 1.—Index map showing location of Inferno Cone quadrangle, Craters of the Moon National Monument, Craters of the Moon lava field, the Great Rift, and companion Geologic Quadrangle Maps.

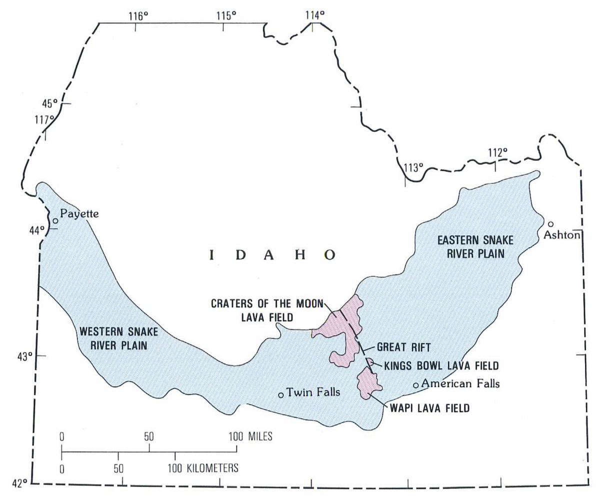


Figure 2.–Index map of southern Idaho showing location of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift.

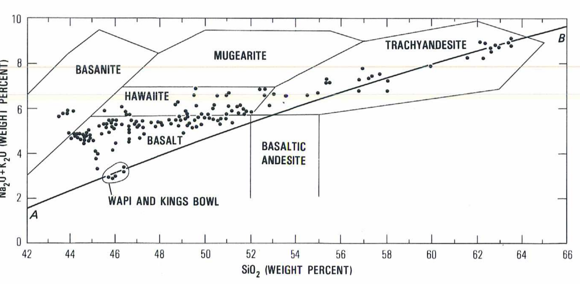
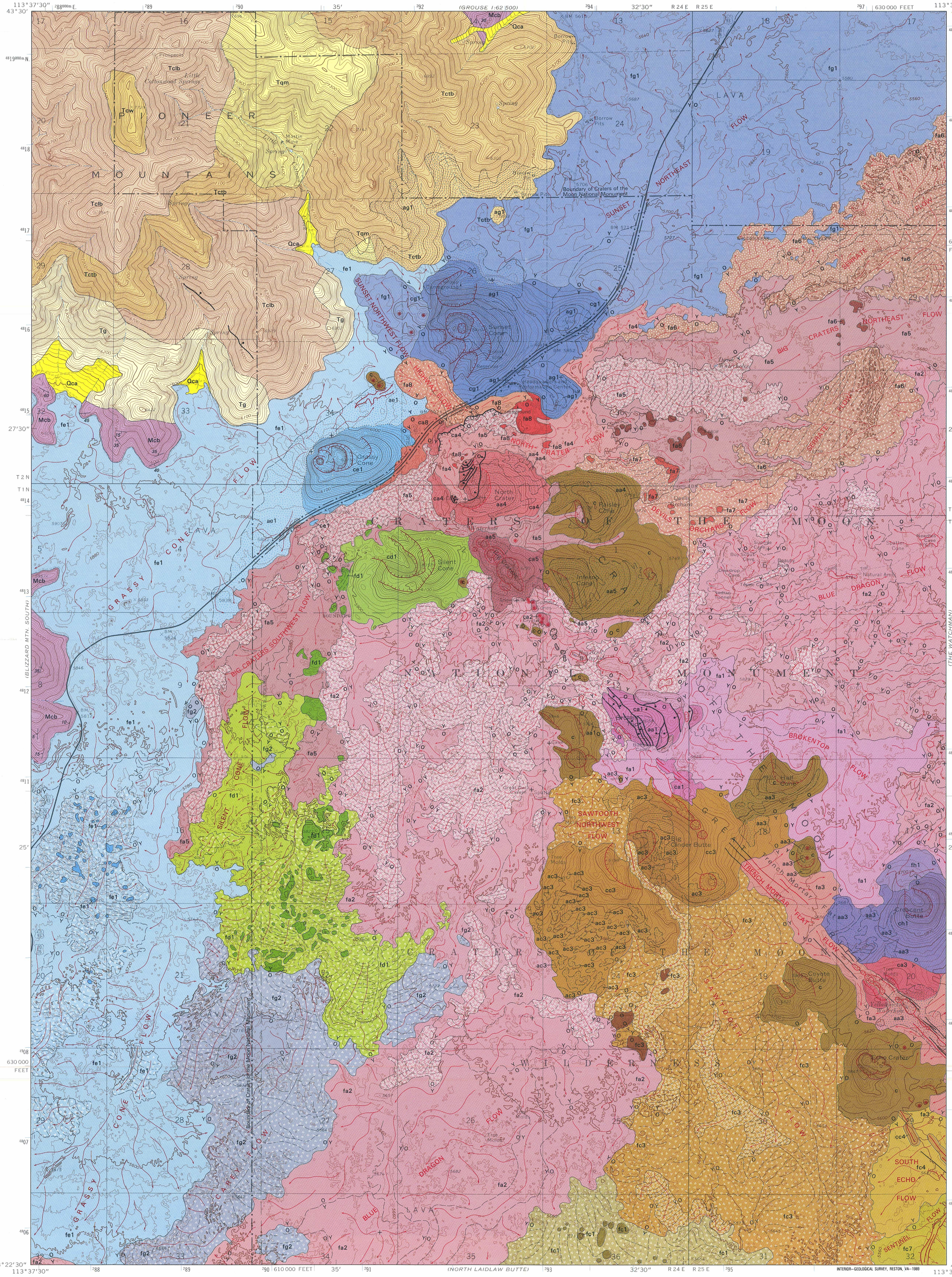


Figure 3.—Na_2O+K_2O versus SiO_2 plot for analyzed rocks from Craters of the Moon, Wapi, and Kings Bowl lava fields. Line *A–B* separates alkaline from subalkaline fields (Irwin and Baragar, 1971). Nomenclature from Cox and others (1979). Major-element data from Kuntz and others (1985).



Base by U.S. Geological Survey, 1972
10,000-foot grid based on Idaho coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

APPROXIMATE MEAN DECLINATION, 1989

SCALE 1:24 000
1 ½ 0 1 MILE
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology mapped in 1975 and 1978-80; assisted by L. A. Morgan, 1978 and 1979

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GEOLOGIC MAP OF THE INFERNO CONE QUADRANGLE, BUTTE COUNTY, IDAHO

By Mel A. Kuntz, Richard H. Lefebvre, Duane E. Champion, and Betty A. Skipp

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