Medicine Lake Volcano and Lava Beds National Monument

Siskiyou and Modoc Counties

JULIE M. DONNELLY-NOLAN, Geologist

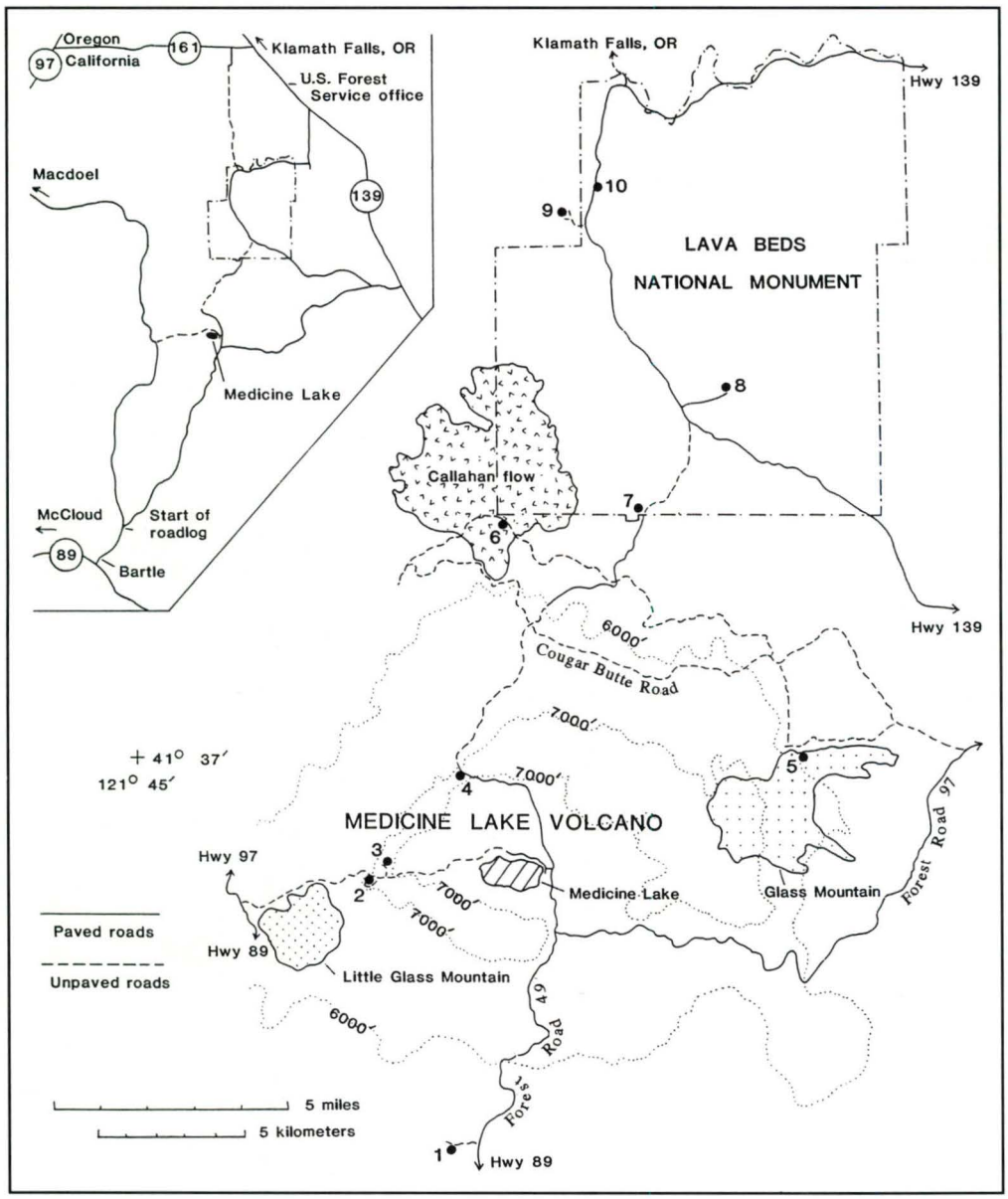
Photo 1. View from Mt. Hoffman south across Little Glass Mountain toward Mount Shasta. *Photo by D.L. Wagner.*

Originally published in the 1987 Geological Society of America Centennial Field Guide, Cordilleran Section, this field guide has been updated for CALIFORNIA GEOLOGY. The trip can be completed in one day or extended to investigate other features such as those suggested at the end of this guide. One of these side trips is described in this issue: "Captain Jack's Stronghold (The Geologic Events that Created a Natural Fortress)"....editor.

LOCATION

Medicine Lake volcano is in the Modoc Plateau physiographic province in northeastern California, about 30 miles (50 km) northeast of Mt. Shasta. It is a Pleistocene and Holocene shield volcano whose products cover about 900 square miles (2,500 km^2); volume is estimated to be 180 cubic miles (750 km^3) (Dzurisin and others, 1991). Lava Beds National Monument is on the northern flank of the volcano. The monument encompasses mostly basaltic and some andesitic lavas. Higher on the volcano, basaltic lavas are mostly absent. Andesite dominates, but high-silica lavas are present including the spectacular late Holocene rhyolites and dacites of Glass Mountain, Little Glass Mountain (Photo 1), and the Medicine dacite flow (Anderson, 1941). A wide variety of volcanic and tectonic phenomena can be seen at Medicine Lake volcano. Many features are young and well exposed, making it an ideal place for a field trip to see the range of volcanic activity from basaltic to rhyolitic (see map).

Medicine Lake sits at an elevation of 6,676 feet (2,005 m) within a 4.5- by 7.5-mile (7- by 12-km) caldera; the highest point on the caldera rim is 7,913 feet (2,398 m) and the plateau surrounding the volcano is about 4,000 feet (1,200 m) in elevation. The volcano is traversed by numerous roads, and access is good although most roads are unpaved. Four-wheel-drive vehicles are unnecessary for this trip and for access to most of the volcano, but high clearance is recommended. It is wise to call ahead for road and weather conditions. Call the Doublehead Ranger District, Tulelake, California (Modoc National Forest) for information about the eastern half of the volcano including the caldera and the campgrounds at Medicine Lake. Call the Shasta-Trinity National Forest headquarters in Redding, California for the southwestern part of the volcano, and the Klamath National Forest headquarters in Yreka, California for the northwestern part.



Location map for field trip to Medicine Lake Volcano and Lava Beds National Monument. Inset shows major highways in the area. Trip goes from south to north.

Campgrounds are available at Lava Beds National Monument. Be advised that campgrounds can fill up on holiday weekends. Depending on the weather and the depth of winter snowfall, it may not be possible to drive across the caldera in early summer. It is recommended this field trip guide be followed between the Fourth of July and early October. Roads may be open and clear in June and into early November, but be sure to contact the local Forest Service or Park Service office to find out. Lava Beds National Monument is open all year.

The weather is unpredictable from day to day at high elevations. Temperatures commonly drop to freezing even during summer nights at Medicine Lake. A typical summer day will reach 90°F (32°C) at lower elevations and 70-80°F (21-27°C) on the upper part of the volcano, with occasional isolated thunderstorms in the afternoon. Food and gas are not available along this route; water is available only at Medicine Lake and at the Visitor Center and campground in Lava Beds National Monument.

Wear gloves and eye protection when examining and climbing on young, glassy, high-silica flows. You will need lights (and something warm to wear) for Stop 8 and any other caves you visit; flashlights may be borrowed from the Visitor Center in Lava Beds National Monument after entrance fees are paid. Remember not to collect samples in the monument. Watch out for rattlesnakes at lower elevations, particularly in the monument. Be aware that each year new roads open and old ones

close. Obtain Forest Service maps for the area (a new series of 7.5-minute topographic maps is also available).

I have written this as a one-day trip. It is designed to show a variety of rock types and morphologic features. If each stop takes half an hour, the whole trip should take about 10 hours. Many other stops are possible, and I have listed a few below if you wish to make it a multiple-day trip. A few other stops are described in Donnelly-Nolan and others (1981). The classic geologic reference is Anderson (1941), which contains a useful, although generalized map. Some petrologic references include Condie and Hayslip (1975), Mertzman (1977a, 1977b), Grove and Baker (1984), and Grove and others (1988).

The turnoff to Medicine Lake is on Highway 89 about 16.5 miles (26.5 km) east of McCloud and about 20 miles (32 km) east of Interstate 5. Driving east, the turnoff is just past the Bartle store; there is a small sign on your left. Turn north onto a good paved road that goes through the site labeled Bartle on the map. Continue north about 4 miles (6.5 km) to a junction with another paved road (Forest Road 49) on the right; a sign points toward Medicine Lake. Turn right. Trip mileage begins at this intersection. (Note that the left-hand road, Forest Road 15, continues north as a good paved road past Little Glass Mountain and across the northwest flank of Medicine Lake volcano, then turns west and connects with Highway 97 at Macdoel.)

ROADLOG

mile km

Odometer readings are in miles (kilometers are in parentheses).

0.0

Junction of paved roads 4 miles (6.5 km) north of Highway 89 and Bartle. Turn right and head northeast across Pliocene high-alumina basalt known as the Warner Basalt (Anderson, 1941). Note the thick red soil. It is better developed than any soil you will see on the younger lavas of Medicine Lake volcano. After about 9 miles (14.5 km), the road drops over an east-facing fault scarp onto young Medicine Lake basaltic lavas. The road crosses a lava tube that begins at Giant Crater and can be traced for at least 14 miles (23 km), making it one of the longest known lava tubes (Photo 2) (Greeley and Baer, 1971). Continue driving north.

17.6 (28.2)

There is a sign and parking area on the left for Jot Dean ice cave. As you continue across this Holocene basalt that erupted from Double Hole Crater, note the deflation that took place after the lava formed a "high-water mark," crusted over, and then let the crust down as it flowed away via one or more tubes.

18.4 (29.4)

Turn left onto the good gravel road. The road sign points to Grasshopper Flat. Follow the road west for 0.5 miles (0.8 km) to the large spatter cone (volcanic material explosively ejected from and built up around a vent) on your left. Stop and park off the road.

18.9 (30.2)

Stop 1. Double Hole Crater. Walk south across the thin pahoehoe (smooth) high-alumina basalt to the crater. Note the small surface tubes and

mile km

pahoehoe toes. Climb this large spatter cone and look at the welded spatter. This stop gives you an opportunity to see one of the several types of vents for the many basaltic flows of Medicine Lake volcano (Photo 3). Other vent types include much smaller spatter cones aligned to form spatter ramparts, cinder cones, and pit craters (Stop 7). With the exception of the Lake Basalt (Anderson, 1941) in the caldera, which has an unusual texture and may repre-

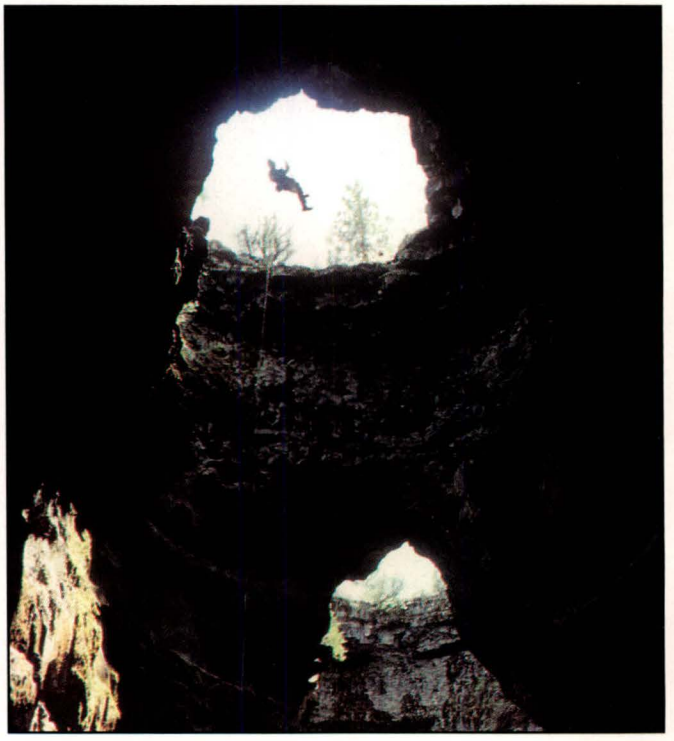


Photo 2. A caver rappels 60 feet (18 m) into the Mossy Carpet entrance to Catwalk Cave, a part of the Gaping Holes lava tube system which is contained in the basalt erupted from Giant Crater. *Photo by Bruce W. Rogers.*

Photo 3. A 30-foot- (9-m-) high spatter cone similar to those found near Stop 1. *Photo by Bruce W. Rogers.*

mile km

sent some form of cumulate, you will not cross basalt again until you reach the north flank of the volcano. The basalt at Double Hole Crater is part of the Giant Crater lava field of early Holocene basalt and basaltic andesite that erupted from several nearby vents including Giant and Chimney craters (Donnelly-Nolan and others, 1991). The initial eruptions were contaminated with crustal material (Baker and others, 1991), followed by more than 1 cubic mile (4 km^3) of high-alumina basalt that flowed south 27 miles (43 km) via lava tubes. Return to the paved road.

19.4 (31.0) Turn left and continue north on paved Forest Road 49 toward Medicine Lake.

25.6 (41.0) Junction with a good paved road on your right. Continue straight ahead to the north, but note that the road to the right (Forest Road 97) goes down the east side of the volcano and joins Highway 139.

27.2 (43.5) Turn left onto the paved road. A sign points to Medicine Lake.

27.5 (44.0) Turn right. Drive around the north side of the lake, past the campgrounds. Pavement ends at the west entrance to Medicine Campground. Continue west.

mile km

29.2 (46.7) Forest Service ranger station. Continue straight ahead. Travel on this road is rough and slow.

31.5 (50.4) Base of Little Mount Hoffman cinder cone. The road forks. Go straight ahead, put your vehicle in low gear, and drive to the top of the cinder cone. If it is early in the summer and there are snowdrifts around the base of the cone, there may be snowdrifts across the road to the top. Rather than backing down this rather steep and exposed road, you may want to walk to the top. The view from the top is worth it.

32.1 (51.4) **Stop 2. Little Mount Hoffman Lookout.** The view from the top of this cinder cone is spectacular. Below you is the late Holocene rhyolite of Little Glass Mountain. Behind the glass flow, Mt. Shasta dominates the western skyline. To the south, on a clear day you can see Lassen Peak; to the north are Mt. McLoughlin and, still farther away, Mt. Scott on the eastern rim of Crater Lake caldera. To the east you can see the dome of Glass Mountain on the eastern rim of Medicine Lake caldera. Drive back down to the base of Little Mount Hoffman.

32.7 (52.3) At the road junction go straight ahead (east), back toward Medicine Lake.

32.9 (52.6) Turn left. Follow the narrow dirt road about 0.3 miles (0.5 km) to the first wide spot on the left where several cars can be parked.

33.2 (53.1) **Stop 3. Cracks.** Cross the road and walk about N30°E into a logged area. You will see large cracks in the ground. Continue walking northeast about 100 yards (100 m) to the largest crack, about 30 feet (10 m) deep and 30 feet (10 m) wide. This set of cracks developed over a rhyolite dike (Fink and Pollard, 1983) during emplacement of Little Glass Mountain and several domes of identical composition farther to the northeast. Note that the ragged edges of the cracks could be fit back together in an east-west sense. The walls of the cracks expose the interior of a fountain-fed andesite flow. You can easily see the agglutinated (welded by volcanic glass) texture and angular lithic (rock) fragments typical of this type of flow. The andesite erupted from the glaciated

mile km

cinder cone just south of the parking spot. Retrace the route 0.3 miles (0.5 km) to the road junction.

33.5 (53.6)

Turn left and retrace the route to Medicine Lake. I recommend stopping for lunch at one of the campgrounds or at the picnic area at the east end of the lake.

37.3 (59.7)

Turn left onto the paved road, away from Medicine Lake.

37.6 (60.2)

Turn left onto the main paved road, Forest Road 49. Continue north across the caldera floor and around the east and north sides of the late Holocene Medicine dacite flow. Drive west up the northern wall of the caldera. Stop at the wide spot in the road just before the road turns north and crosses the caldera rim.

40.6 (65.0)

Stop 4. North rim of caldera. Below you to the south is the Medicine dacite flow and beyond that, Medicine Lake. The muted topography of the caldera is partially a result of glaciation that has stripped the tops of lava flows and rounded off cinder cones. Medicine Lake appears to sit in a bed of glacial clay that prevents the water from draining into the permeable volcanic rocks. The caldera does not seem to be primarily the result of ash-flow eruptions although a small andesitic ash flow did erupt from the caldera in late Pleistocene time (see Stop 9). The best explanation seems to be Anderson's (1941) suggestion that the caldera resulted from voluminous eruption of andesite lavas around the rim of the caldera. This roadcut exposes one of these andesites; another was exposed in the cracks at Stop 3. Follow the road over the north rim.

40.9 (65.4)

Pavement ends at this intersection. Continue straight ahead. Road is rough and slow.

45.1 (72.2)

Intersection of major dirt roads. Turn right on Cougar Butte Road. Continue east on main gravel road to the first major road on the right.

51.4 (82.2)

Turn right and proceed south. The good dirt road becomes a narrow track in pumice. When you arrive at the pumice mining area, drive toward the front of

mile km

the big rhyolite flow you can see sparkling ahead of you. The roads in the mining area are continually changing. Currently, as you continue south you come to a major haul road—watch for large trucks. Turn left onto this road, then turn right very soon onto a narrow dirt track that goes around the front of the big rhyolite lobe you can see above you. Park at the edge of the flow where a big pile of obsidian blocks prevents access to a bulldozer road that climbs the flow.

53.4 (85.4)

Stop 5. Glass Mountain (Photo 4). Beware—the glass is very sharp. Walk up the bulldozer cut and examine the rhyolite. Pieces vary from black aphyric obsidian to pumiceous, lighter-colored samples, and samples with interesting textures that show evidence of breakage, oxidation, and flowage while still hot. On your left, under the rhyolite lobe, is the dacite that is the first part of the Glass Mountain flow (Anderson, 1933; Eichelberger, 1975). Go out onto the dacite and see the abundant basaltic andesite inclusions. Two mixing events are suggested: first, a basaltic

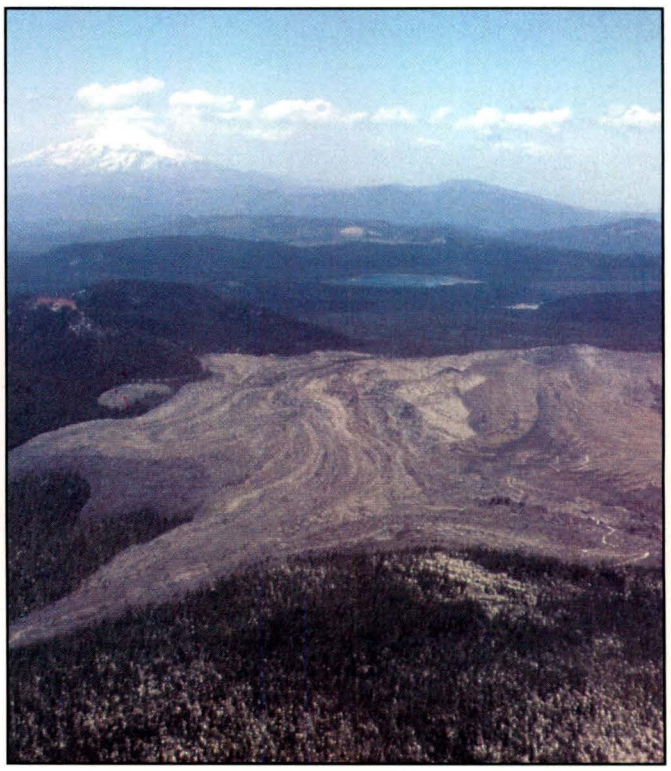


Photo 4. Aerial photo of Glass Mountain, looking to the west. Note Medicine Lake at upper right center and Mount Shasta to top left of center. *Photo by Bruce W. Rogers.*

mile km

component is mixed into rhyolite magma and homogenization to dacite takes place; second, basaltic andesite magma is injected into the dacite, forming blobs that chill against the host silicic magma and perhaps cause the eruption. For further discussion of this stop, see Donnelly-Nolan and others (1981) and Eichelberger (1981).

Glass Mountain lava erupted from a N30°W-trending dike along which are 13 vents. According to Eichelberger (1975), three of the vents contributed to the Glass Mountain flow. The other 10 vents produced small domes and flows, nine of which are north, and one south, of the main flow. Based on carbon-14 dating, the Glass Mountain eruption occurred about 850 years ago (Donnelly-Nolan and others, 1990). There are large trees growing in pumiceous zones on the flow, indicating that 200 years is too young. Heiken (1978) discusses both Glass Mountain and Little Glass Mountain tephra deposits, concluding that the former feature is younger. Return to your vehicle and retrace your route north through the pumice mining area and onto the main road. Continue north to Cougar Butte Road.

55.4 (88.6)

Turn left onto Cougar Butte Road.

55.7 (89.1)

Turn right onto the first good road on your right. This road goes generally northwest down the north flank of the volcano. Continue on it until you intersect a paved road.

61.2 (97.9)

Drive directly across the paved road (Forest Road 49) onto a narrow dirt road. If you turn left at this intersection you will return directly to Stop 4 and to Medicine Lake. (If you turn right, you will go directly to Stop 7 and Lava Beds National Monument.) Drive straight ahead, staying on this old railroad grade for about 3 miles (5 km). You will drive directly into a late Holocene basaltic andesite flow shown on Anderson's 1941 map as the Callahan flow. The road cuts through the base of the flow's vent, Cinder Butte, which was quarried for roadbed material for the railroad grade. Slow down and look for the first parking area on your left that can hold several vehicles.

mile km

64.3 (102.9)

Stop 6. Callahan Flow. Rather than being on the surface, the road cuts into the flow giving you a three-dimensional view of the sometimes blocky, sometimes smooth-surfaced flow morphology (Photo 5). Here you can look into the center of a small flow lobe. Because this part of the flow appears to have cooled in place, paleomagnetists chose this location for sampling. Note the 1-inch- (2.5-cm-) diameter core holes. The flow has a carbon-14 age of 1,110 ± 60 years (Donnelly-Nolan and Champion, 1987).

There is a very nice view to the north and northeast across the sparsely vegetated flow. To the north are several normal faults (east side down) trending north toward Klamath Falls. To the northeast you can see some of the cinder cones

Photo 5. Road cut in the Callahan Flow at Stop 6. Cinder Butte, the source of the flow, is in the background. *Photo by D.L. Wagner.*

mile km

and flows of Lava Beds National Monument; you are just outside the southwest corner of the monument. Turn around and return to the paved road.

67.4 (107.8)

Turn left onto paved Forest Road 49. Drive north just past the pavement's end at the southern boundary of Lava Beds National Monument. On your left is the parking area for Mammoth Crater.

69.0 (110.4)

Stop 7. Mammoth Crater. Follow the short paved path west to a view of Mammoth Crater. This crater vented a large volume of basalt and basaltic andesite. It is one of several vents including Modoc Crater and Bearpaw Butte that produced the late Pleistocene unit referred to by Donnelly-Nolan and Champion (1987) as the basalt of Mammoth Crater. This unit covers about two-thirds of the monument and extends beyond monument boundaries to the east and west; its volume is estimated to be more than 1 cubic mile (4 km^3). This unit is analogous to basalt erupted at Giant Crater and related vents on the south side of the volcano (see Stop 1). The earliest eruptions appear to have produced basaltic andesite lavas that built up around the vents; later, more-fluid basalt flowed via lava tubes as far as 15 miles (25 km). You will see one of these tubes at Stop 8. Continue driving north on the dirt road to a paved road shown on the 1986 Modoc National Forest map as Road 10.

71.6 (114. 6)

Turn left on this paved road (the main road through Lava Beds National Monument). Proceed north to the first paved road on the right. A sign points to Skull Cave.

72.0 (115.2)

Turn right and drive east to Skull Cave.

73.1 (117.0)

Stop 8. Skull Cave. You will need flashlights and/or lanterns to explore the cave. Flashlights may be borrowed at the Visitor Center, 1.5 miles (2.4 km) south on the main monument road. Even if you don't have lights and can't explore the cave, the entrance in itself is an impressive experience. Skull Cave is part of a large tube that transported lava to the northeastern corner of Lava Beds National Monument. Going into the cave, take the stairs to ice at the bottom, two levels below. At least three lava tubes are stacked one on top of the other at this location. This is one place where the Law of Superposition fails because tubes are often used more than once and the inner lava is youngest. Thus, younger lava can be under older lava. Return to the main monument road.

mile km

74.2 (118.7)

Turn right and drive north about 4 miles (6.5 km) where you will go northwest across a Holocene aa (rough) basalt flow referred to as the basalt of Devils Homestead. Ahead of you is the fault scarp called Gillem Bluff (Photo 6). The road turns north following the fault. Look for a road on your left with a sign stating the road is not maintained for public use.

78.8 (126.1)

Turn left. The road soon becomes dirt. Follow it west, then north to the first right-hand turn.

79.2 (126.7)

Turn right and drive about 0.2 mile (0.3 km) north, keeping left at the next

Photo 6. East-side-down normal faults at Howitzer Point along Gillem Bluff. The drained lakebed of Tule Lake, lower right, has been farmed since the early part of this century. The white and gray area at the bottom of the scarp at the extreme right of the photograph is the western margin of the remaining arched roof of Skull Cave. *Photo by Bruce W. Rogers.*

mile km

intersection and parking next to the shallow gully on your left.

79.4 (127.0)

Stop 9. Andesitic Ash-Flow Tuff. Walk into the gully. Brownish-red andesitic ash-flow tuff forms low outcrops on both sides. The estimated thickness of the tuff here, prior to some quarrying, was 5 or 6 feet (fewer than 2 m). This small patch of partially welded andesitic tuff is one of many on the north and west sides of Medicine Lake volcano. It is also present in a few small patches on the east side. The spatial distribution of the tuff indicates that it erupted at or near the center of the volcano. The largest pumice and lithic fragments are in the single outcrop in the caldera, suggesting a source in the caldera.

The absence of this unit on the caldera rim, together with indications of hydrothermal alteration at the caldera outcrop, suggests that the ash erupted through an ice cap on the volcano and was deposited in the caldera on the only exposed ground surface, where a fumarole had melted the ice. Coarse gravels and dry channels cut in the tuff on the northwest flank of the volcano indicate that meltwater from the interaction of the ash flow and the ice formed a catastrophic flood (Donnelly-Nolan and Nolan, 1986). The tuff has not been dated directly, but the probable presence of an ice cap, and evidence from younger lava flows (some of which have been glaciated), points to a late Pleistocene age, predating the latest glaciation. Sarna-Wojcicki and others (1991) estimate an age for the andesite tuff of about 160,000 years based on correlation with a tephra layer in Tule Lake sediments. Stratigraphically, the tuff is of major importance as the volcano's only marker bed. Anderson (1941) recognized the andesitic ash-flow

mile km

tuff but interpreted its typical exposure in the bottoms of gullies to indicate that it was one of the volcano's oldest units. Recent mapping (Donnelly-Nolan, unpublished) shows that the tuff is younger than about 90 percent (by volume) of Medicine Lake volcano. Retrace your route to the main paved road through Lava Beds National Monument.

80.0 (128.0)

Turn left. Drive along Gillem Bluff and turn right into parking area.

80.8 (129.3)

Stop 10. Devil's Homestead Overlook. Directly below you is the basalt of Devil's Homestead, erupted from spatter vents at Fleener Chimneys farther south along the Gillem Bluff fault scarp. To the south is a panorama of Lava Beds National Monument and the shield shape of Medicine Lake volcano, with the north flank dotted with cinder cones. To the north, the fault scarp of Gillem Bluff continues directly north forming the western margin of Tule Lake basin.

This trip can easily be expanded to 2 or more days. In Lava Beds National Monument alone, many more stops can be made. I suggest Captain Jack's Stronghold for an interesting example of geohistory (Waters, 1981 [see Waters, this issue]), Fleener Chimneys, Black Craters, a climb to the top of Schonchin Butte, and Valentine Cave (Photo 7 and cover photo) for a nice, clean cave with lots of interesting flow features. At the monument Visitor Center you'll find publications

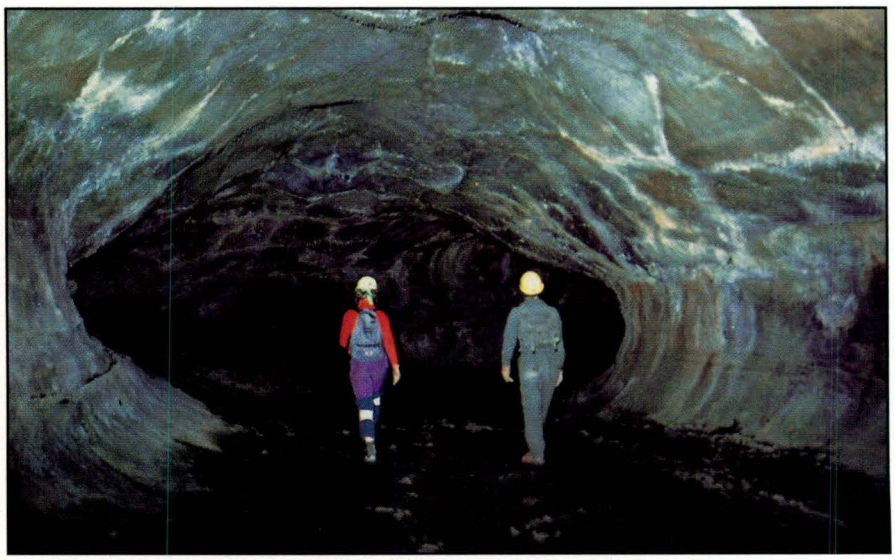


Photo 7. Two visitors explore Valentine Cave, a well-preserved cave deservedly popular with Lava Beds National Monument visitors. *Photo by Bruce W. Rogers.*

for sale, interesting displays, and directions to the nearly 300 caves in the monument. In the middle of the Visitor Center parking lot is the entrance to Mushpot Cave where topical films are shown, including one that describes lava tube formation.

Medicine dacite flow and Little Glass Mountain contain interesting suites of inclusions ranging from gabbro to basalt, andesite, and granite (Mertzman, 1981; Grove and Donnelly-Nolan, 1986). Little Glass Mountain also displays some very interesting flow features that have been described by Fink (1981); directions are in Donnelly-Nolan and others (1981). A drive down the east side of the volcano (see directions to the paved road between Stops 1 and 2 of this roadlog) offers a scenic overlook where you can view the Burnt Lava flow and High Hole Crater (southern analogs of the Callahan flow and Cinder Butte) to Lassen Peak in the distance. Farther east are roads that take you to the south side of the Glass Mountain flow. After descending the volcano, you can stop at the railroad tracks to view the Warner Basalt. Park at the railroad crossing and walk a short distance north along the tracks to the first good exposure. East of the railroad tracks and west of Highway 139 is a turnoff to paved Forest Road 10 that enters Lava Beds National Monument from the southeast.

Julie M. Donnelly-Nolan is a geologist in the branch of Igneous and Geothermal Processes at the U.S. Geological Survey in Menlo Park, California. She has worked at Medicine Lake volcano since 1979, doing detailed geologic mapping and geochemical studies. Her previous field area was the Geysers-Clear Lake area of northern California, where she worked on the geothermal system and the volcanic rocks. While obtaining her Ph.D. at the University of California, Berkeley, she worked at the Division of Mines and Geology.

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TEACHER FEATURE

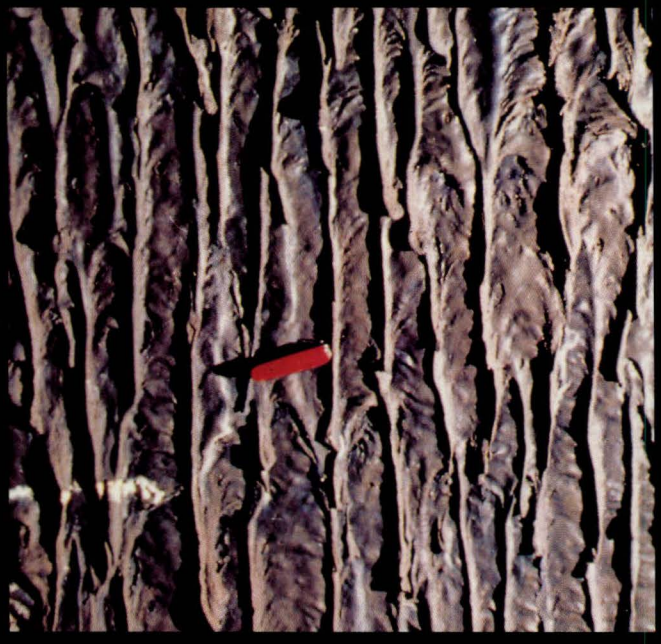
Going Down the Tubes

Photos by Bruce W. Rogers

Most of us have not had the opportunity to watch magma, or lava, flowing out of a volcanic vent, but most have seen pictures of the fiery red rivers racing down volcanoes. It is difficult to study lava flows up close while they are still hot. When they cool and harden, however, they leave a record of what happened during the eruption.

To explore a lava tube is to explore the inside of a lava flow (cover photo). As the flowing lava cools, a rocky crust forms on the surface, and a lava tube forms as the lava drains. When part of the roof caves in, it forms collapse pits or collapse trenches, in some places creating an entrance to the tube, in others a blockage.

The cascade in this photo (right) formed when lava flowed from one tube into a lower, older tube.



Inside many lava tubes, lava dripped or ran down the walls and formed dripstone...

...or dripped from the ceiling and formed lavacicles. Lavacicles are also called lava stalactites because they resemble stalactites found in limestone caves. Lava stalagmites are sometimes found where lava dripped onto the floor after it solidified.

Pull outs occur where still-hot lava peeled away from the wall, exposing older linings of harder lava.

The walls of lava tubes are marked by different lava flow levels. There are benches as in the cover photo and the photo to the right, and balconies as in the photo below, where the flow level stayed the same long enough for the lava to cool along the walls. Sometimes benches grow together across the tube and the lava beneath drains away, forming a tube within a tube. A tube-in-tube can also form when a new flow courses down an older tube, cools, and forms a smaller tube.

For more details on lava tubes, refer to *Geology of Some Lava Tubes, Shasta County* and *Hat Creek Lava Tubes as Fallout Shelters,* MINERAL INFORMATION SERVICE (CALIFORNIA GEOLOGY), 1963, v. 16, no. 3.

Also, U.S. Geological Survey Bulletin 1673, *Selected Caves and Lava-Tube Systems In and Near Lava Beds National Monument,* is available through:

Books and Open-File Reports Section
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Federal Center
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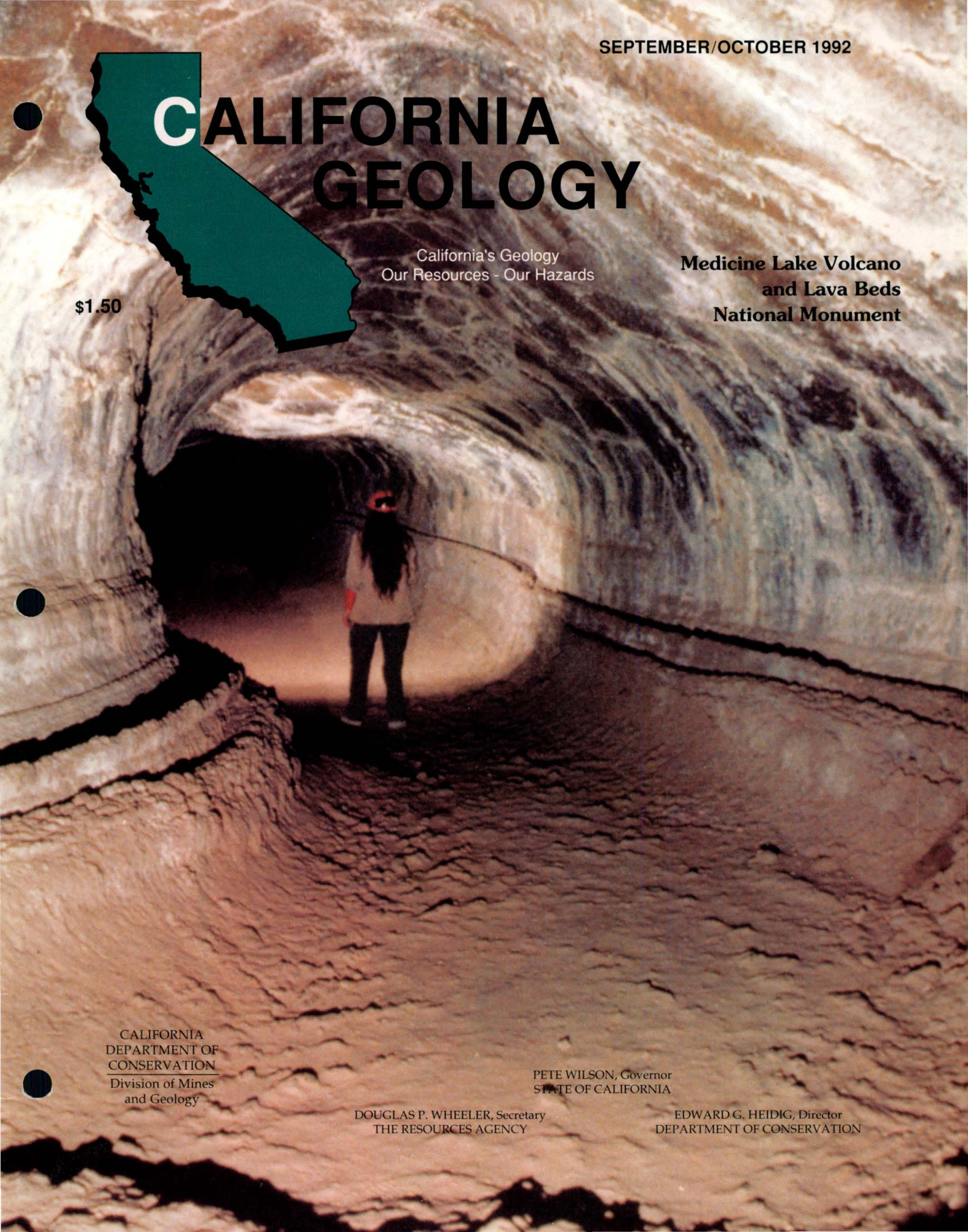

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Technical Editor: Elise Mattison
Copy Editor: Lena Tabilio
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Publications Supervisor: Jeff Tambert

Division Headquarters: 801 K Street, 12th Floor, MS 12-30
Sacramento, CA 95814-3531
916-445-1825

Publications and Information Office: 801 K Street
14th Floor, MS 14-33
Sacramento, CA 95814-3532
916-445-5716

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Cover Photo: Valentine Cave, a lava tube in Lava Beds National Monument, Siskiyou County, California. Lava benches on the walls mark the level of lava that once flowed through the tube. *Photo by Bruce W. Rogers.*