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by Ted Konigsmark

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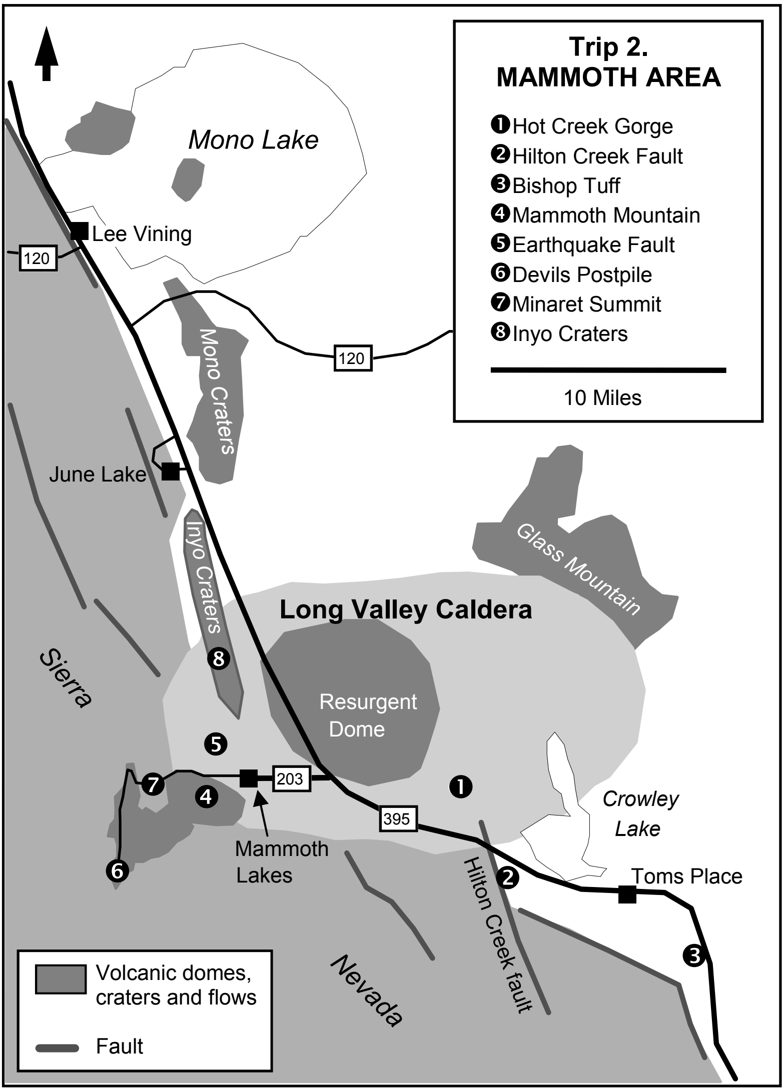

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Mammoth Lakes
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Hilton Creek fault
Volcanic domes, craters and flows
Fault

Trip 2

MAMMOTH AREA

Volcanoes, Domes and Craters

The Mammoth area is one of the most volcanically active areas in the lower 48 States. From Bishop to Mono Lake, you are never out of sight of volcanoes, domes, craters, fumaroles, hot springs, and many different types of volcanic rocks, including rhyolite, andesite, basalt, obsidian, pumice, tuff, and welded tuff. During this trip, you'll see examples of all of these volcanic features and volcanic rocks.

Much of this volcanic activity is associated with the Long Valley Caldera, the remains of a huge volcano that erupted 760,000 years ago. Most of the remaining volcanic activity is associated with the Inyo and Mono Craters, a trend of domes and craters that extend from the Long Valley Caldera north to Mono Lake.

All of the volcanic features in this area lie along the fault zones that define the eastern escarpment of the Sierra Nevada and appear to be related to the uplift of the Sierra. The volcanism began four million years ago, about the same time that the uplift began, and has continued up to the present time. During uplift, the earth's crust was stretched, faulted and broken along the mountain front and magma from deep within the crust made its way upward along the broken rocks in the fault zones.

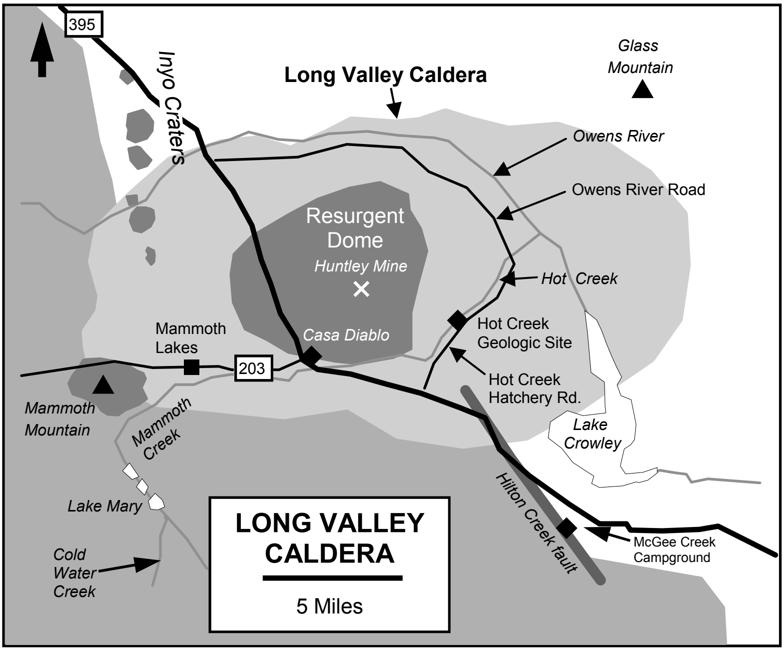
The early volcanic activity was mainly basaltic. However, the composition changed over time and most of the later volcanic rocks are rhyolitic. Rhyolite magma, which has a high content of silica, is stiff and does not flow easily. Depending on the water content and other conditions, rhyolite magma can form volcanic rocks that look quite different. If the magma is rich in water, the magma may erupt as tuff and frothy white pumice. If there is less water and the magma cools slowly, the magma may form a stiff, pasty rhyolite flow. If there is no water, and the magma chills rapidly, the magma may form a black obsidian flow. Many of the volcanic features in the Mammoth area are made up of combinations of rhyolite, obsidian, tuff, and pumice that were formed during different phases of the same eruption.

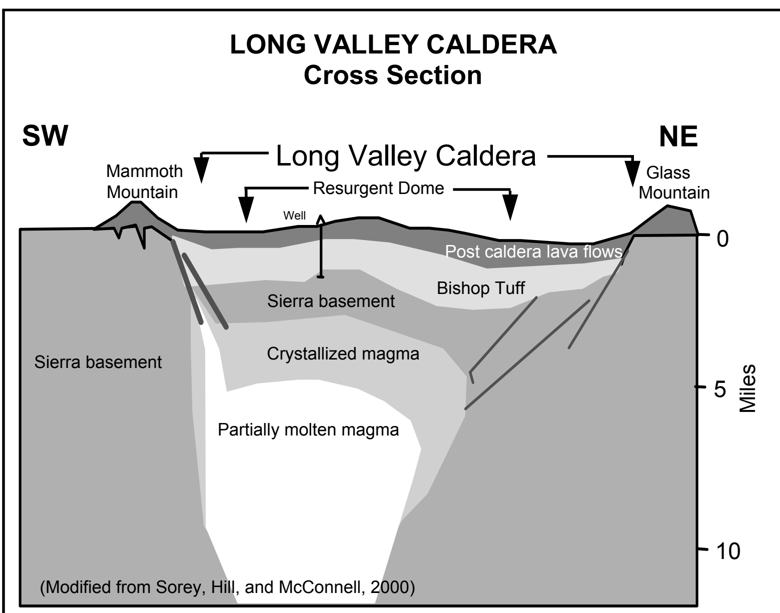
Long Valley Caldera

The Long Valley Caldera is a large oval depression, about 20 miles across, that lies north and northwest of Lake Crowley. The caldera was formed during the eruption of the Long Valley volcano 760,000 years ago. During this eruption, 150 cubic miles of superheated ash was expelled from the volcano. Half of this ash was thrown into the air and formed a column of ash eight miles high. The larger fragments of ash fell back to the ground near the volcano and the smaller fragments were carried by the jet stream as far east as Kansas and Nebraska. The other half of the eruption consisted of clouds of ash that flowed down the flanks of the volcano. The fragments of this ash were suspended by the gas emitted from the ash. Some of these ash flows extended north from the caldera, but most of the flows went south down the Owens Valley and reached as far as Big Pine. The air-fall ash and ash flows that were deposited during the eruption of the Long Valley Caldera are known as the Bishop Tuff. The Volcanic Tableland that covers much of the Owens Valley from Lake Crowley to Bishop is formed from numerous ash flows in the Bishop Tuff.

Following the eruption of the Long Valley volcano, the magma chamber under the volcano was nearly empty, so the volcano collapsed into itself, forming the large depression of the Long Valley Caldera. Immediately after the eruption, the caldera was about two miles deep. However, much of the erupted ash fell back into the depression, filling about two-thirds of the caldera. After the eruption, more magma arrived in the magma chamber and pushed up a dome in the center of the caldera. This *resurgent dome* now rises 1,500 feet above the valley floor. Some of the magma under the caldera later erupted to form rhyolite domes and volcanoes in and along the edges of the caldera. Mammoth Mountain is one of these volcanoes. The Long Valley Caldera is still volcanically active. A large magma chamber under the caldera provides the heat for numerous hot springs, hot creeks, and fumaroles in the caldera. From time to time, the magma moves, causing earthquakes, faults, and renewed uplift of the resurgent dome.

During the last of the glacial episodes, a large lake occupied the depression of the Long Valley Caldera. Shorelines of this lake can be seen around the edges of the caldera. The resurgent dome was an island in this lake. The lake was dammed by the Bishop Tuff at the south end of Lake Crowley. Owens Gorge was formed when this Pleistocene lake cut through the dam and then carved a steep gorge through the ash flows of the Bishop Tuff.


395
Inyo Craters
Long Valley Caldera
Glass Mountain
Owens River
Owens River Road
Resurgent Dome
Huntley Mine
Hot Creek
Hot Creek Geologic Site
Hot Creek Hatchery Rd.
Mammoth Lakes
203
Casa Diablo
Mammoth Mountain
Mammoth Creek
Lake Crowley
Lake Mary
Cold Water Creek
Hilton Creek fault
McGee Creek Campground
LONG VALLEY CALDERA
5 Miles


LONG VALLEY CALDERA
Cross Section
SW
NE
Long Valley Caldera
Mammoth Mountain
Resurgent Dome
Glass Mountain
Well
0
Post caldera lava flows
Bishop Tuff
Sierra basement
Crystallized magma
Sierra basement
5
Miles
Partially molten magma
10
(Modified from Sorey, Hill, and McConnell, 2000)

➊ *Hot Creek Gorge*

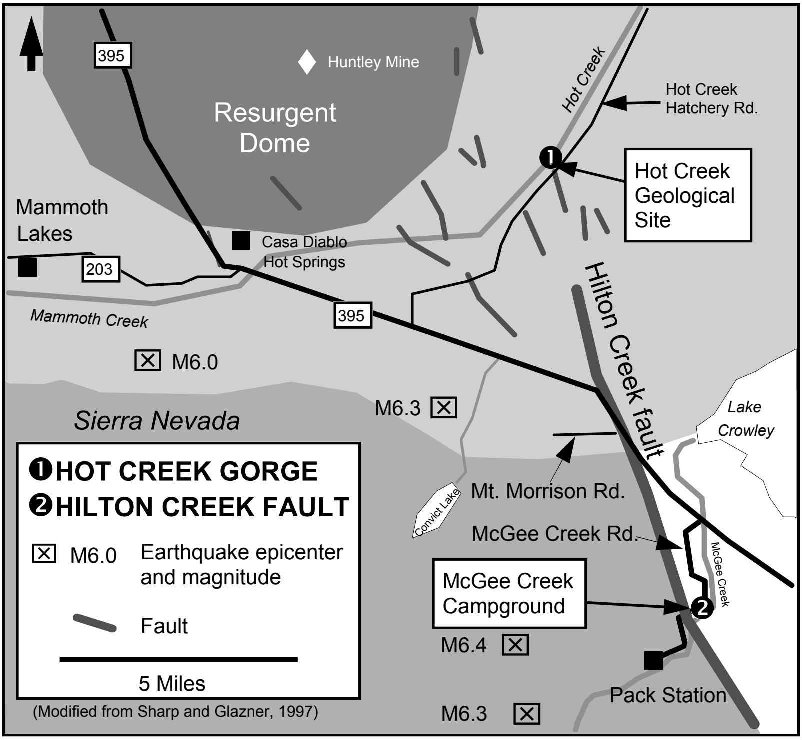
There are many hot springs and geothermal areas in the Mammoth and Mono Lake areas. Most of these were formed when surface water or groundwater from the eastern slope of the Sierra Nevada was heated by magma at shallow depths. One of the best known of these geothermal areas is Hot Creek Gorge, which lies within the Long Valley Caldera.

Hot Creek Geological Site **-** *From the junction Hwy. 395 and Hot Creek Hatchery Rd. drive 3.5 mi. E on Hot Creek Hatchery Rd. to the Hot Creek Geological Site; the site has a good viewing area and several paths to the bottom of the gorge.*
Hot Creek lies at the bottom of a 100-foot gorge that cuts across the southeast flank of the resurgent dome. The creek flowed through this area prior to uplift of the resurgent dome, and the gorge was cut as the creek maintained its established course during uplift of the dome.

The water in Hot Creek has its source in the Mammoth area where a number of snow-fed creeks combine to form Mammoth Creek. Mammoth Creek then flows eastward into the Long Valley Caldera. In the caldera, much of the cold water soaks into the ground and is heated by the magma under the caldera. Near Casa Diablo, this hot groundwater mingles with the surface water from Mammoth Creek. The creek then changes its name to Hot Creek, and continues to flow eastward through Hot Creek Gorge. Further east, Hot Creek leaves the gorge, spreads out on the floor of the eastern part of the caldera, and eventually makes its way into the Owens River and Lake Crowley.

The temperature of the water in Hot Creek can rise dramatically after earthquake activity. Many of the earthquakes in this area are caused by movement of magma under the caldera, and the moving magma provides new sources of heat for the groundwater that flows into Hot Creek. Hot Creek is a popular swimming area, but test the water before you plunge in, particularly after an earthquake!

The rocks in the walls of Hot Creek Gorge are a rhyolite lava flow that erupted from a vent on the southern rim of the Long Valley Caldera about 300,000 years ago. The lava flow is about three miles long and 500 feet thick. Along the creek, the rhyolite has been bleached, oxidized, and altered to white clay by the hot water in many places. Hydrothermal alteration of rhyolite is common in volcanic areas, and can result in large deposits of clay. The kaolinite deposits at the Huntley Mine in the center of the resurgent dome were formed in this manner.

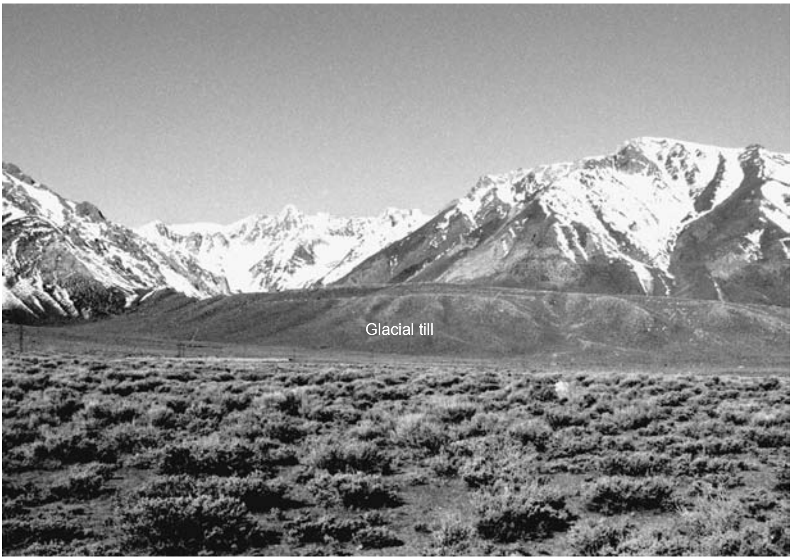


Hot Creek Gorge at the Geological Site. The Sierra Nevada is on the horizon.

❷ *Hilton Creek Fault*

The Hilton Creek fault is one of the many faults that make up the Frontal fault system of the Sierra Nevada. The fault begins south of Hilton Creek, cuts through the McGee Creek Campground, and then continues north into the Long Valley Caldera, where it splays into a number of small faults and dies out. This fault is of special interest because it has been recently active and this activity seems to be related to the current volcanism in the Long Valley Caldera. In May of 1980, a series of four earthquakes (M6.0 to M6.4) occurred within a few miles of the Hilton Creek fault. The earthquakes were accompanied by a number of surface ruptures along the fault. Most of these ruptures were less than a mile long and had vertical movements less than six inches. There were also a large number of ruptures in the southern part of the resurgent dome and these ruptures are on trend with the Hilton Creek fault. It appears that magma under the caldera is intermittently making its way upward along fractured rocks in the fault zone. The 1980 faulting in this area is the most significant earthquake activity on the east side of the Sierra Nevada since the 1872 Owens Valley earthquake. One of the best places to see the Hilton Creek fault is at the McGee Creek Campground.

> ***McGee Creek Campground -*** *From Hwy. 203 and Hwy. 395, drive S 8 mi. on Hwy. 395; turn right on McGee Creek Rd. and go 2 mi. to the McGee Creek Campground.*
>
> During the Pleistocene glacial episodes, a glacier flowed down McGee Creek and extended about a mile beyond the mountain front. When the glacier melted, it left behind the huge pile of terminal, recessional, and lateral moraines that can easily be seen from Highway 395. McGee Creek Road climbs up this pile of glacial material. The McGee Creek Campground lies in a flat valley along McGee Creek, and is flanked by two large lateral moraines. The flat floor of the valley was formed from glacial outwash sediments. At the campground, the flat valley floor and the flanking lateral moraines are cut by a 50-foot high scarp formed by the Hilton Creek fault. The scarp appears as a steep embankment at the west end of the campground, and provides a neat windbreak for the campground. On the hillside above the campground, you can see where the fault scarp cuts through the lateral moraines. McGee Creek Road continues beyond the campground and makes a jog where it crosses the fault scarp on the northern lateral moraine. The outwash plain and lateral moraines at the McGee Creek Campground were deposited during the last glacial episode. The faulting must have occurred after this glacial episode. It is rare for a fault scarp of this magnitude to be preserved, and it is rare for a fault scarp to cut glacial material that is this young.



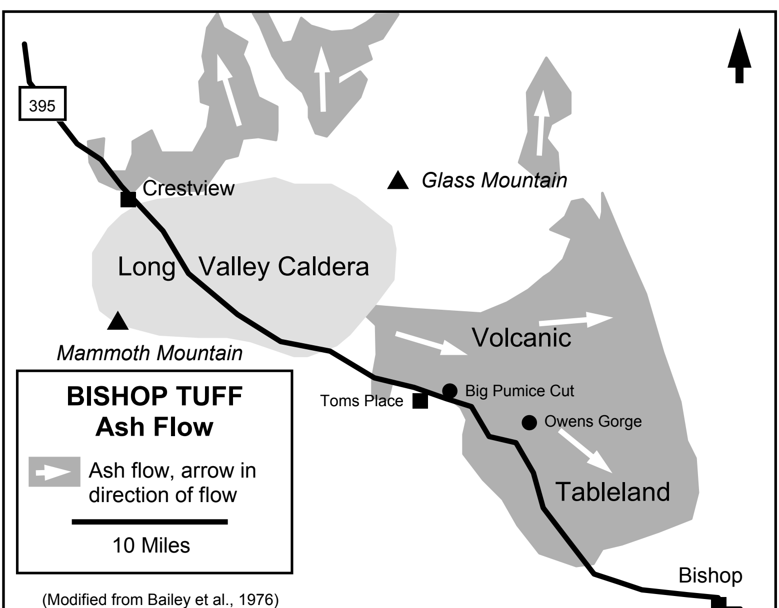
This view of the eastern front of the Sierra at McGee Creek shows the large pile of glacial till left by the McGee Creek glacier. The till appears as the low flat-topped ridge in the center of the photo. The Hilton Creek fault lies along the mountain front and cuts through some of this glacial material.

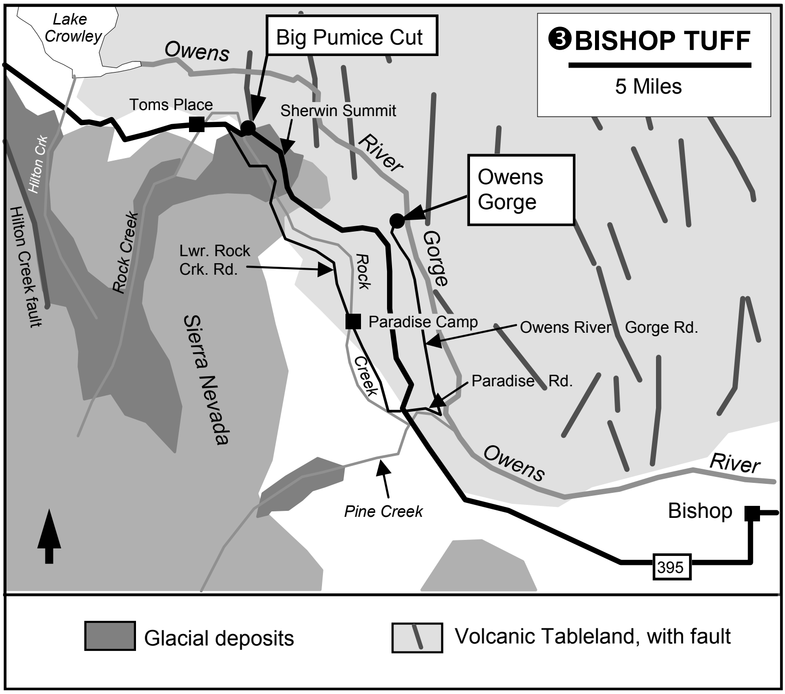
The Hilton Creek fault scarp lies at the west end of the McGee Creek Campground. The thin horizontal line of snow follows the top of the fault scarp. To the right, the scarp crosses McGee Creek Road and then climbs up the north wall of the valley.

❸ *Bishop Tuff*

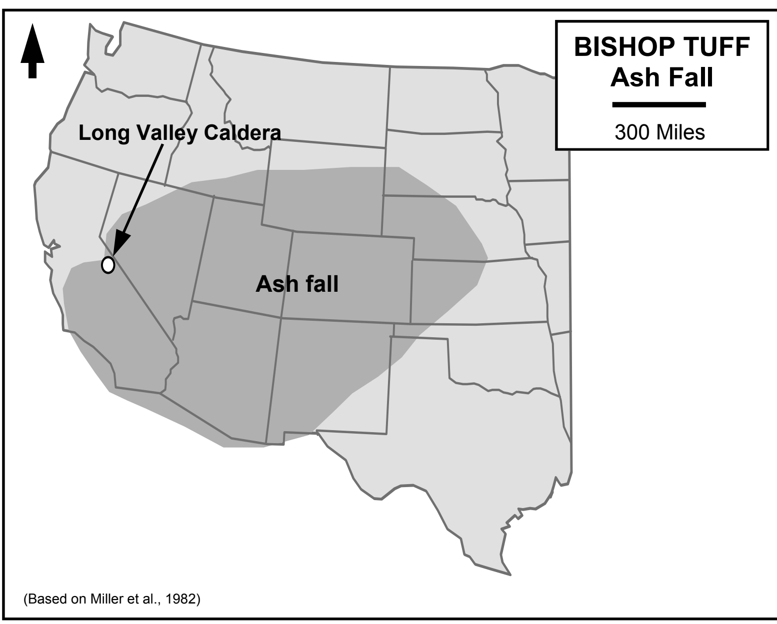
The volcanic ash that was deposited during eruption of the Long Valley volcano is referred to as the Bishop Tuff. There are many exposures of the Bishop Tuff in the vicinity of the Long Valley Caldera. However, the most extensive exposures are southeast of the Long Valley Caldera, where the tuff extends for 20 miles across Owens Valley and as far south as Bishop and Big Pine.

The Bishop Tuff includes several different units. At the base is a layer of unconsolidated white ash and pumice, about ten to fifteen feet thick, that was thrown into the air at the beginning of the eruption and fell to the ground near the volcano. This air-fall ash is overlain by a series of ash flows that streamed down the flanks of the Long Valley volcano during its eruption. The ash flows are as much as 500 feet thick. Where the ash flows were thick, mainly in the center of the flow, the hot ash fused together to form welded tuff. The welded tuff is extremely hard and forms the rough, desolate Volcanic Tableland that lies between Bishop and the Long Valley Caldera. Where the ash flows were thin, mainly along the margins of the flow, the ash was not welded, and consists of white unconsolidated tuff. You will see the air-fall tuff and the unconsolidated ash-flow tuff at the Big Pumice Cut south of Toms Place, and the welded tuff and Volcanic Tableland during the trip to Owens Gorge.





❸BISHOP TUFF
5 Miles
Lake Crowley
Owens
Big Pumice Cut
Toms Place
Sherwin Summit
River
Owens Gorge
Hilton Crk
Hilton Creek fault
Rock Creek
Lwr. Rock Crk. Rd.
Rock
Gorge
Sierra Nevada
Paradise Camp
Owens River Gorge Rd.
Creek
Paradise Rd.
Owens
River
Pine Creek
Bishop
395
Glacial deposits
Volcanic Tableland, with fault



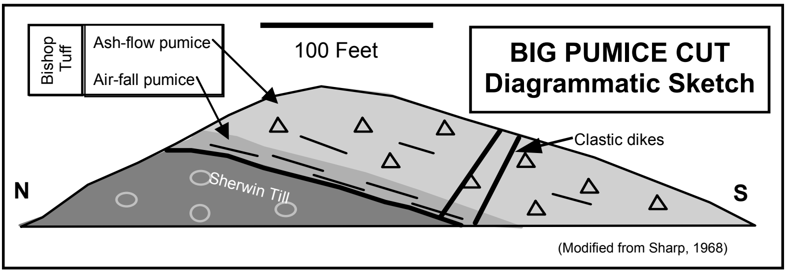
BISHOP TUFF Ash Fall
300 Miles
Long Valley Caldera
Ash fall
(Based on Miller et al., 1982)

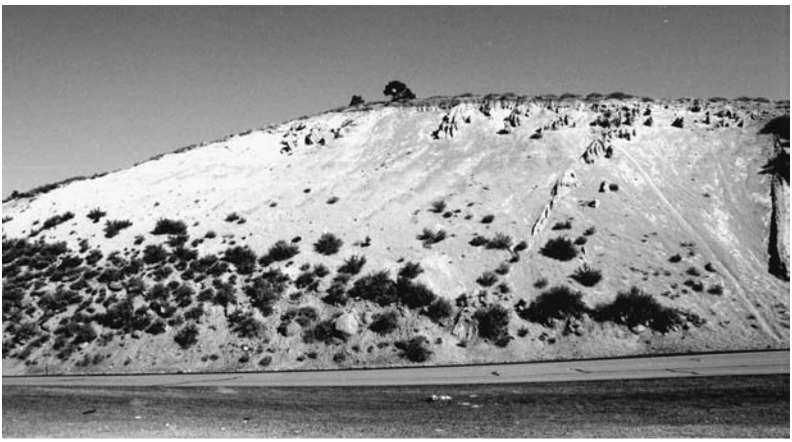
Big Pumice Cut – *From Toms Place go S on Hwy. 395 1 mi.; park in the large pullout on the W side of the highway immediately S of Lower Rock Creek Rd. The Big Pumice cut is on the E side of Hwy. 395.*

The Big Pumice cut is a large roadcut along Highway 395 that exposes the unconsolidated rocks that were deposited along the western edge of the ash flows that form the Bishop Tuff. The white tuff and pumice in the roadcut erodes rapidly, so there are few good, clean exposures. However, there is still much to see.

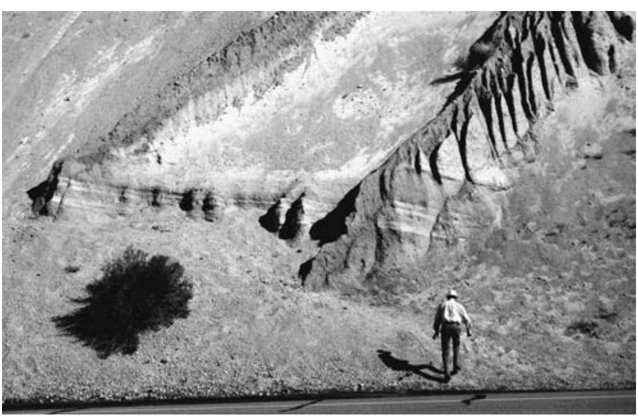
Before the Bishop Tuff was deposited, much of the Sierra mountain front south and west of this area was covered by the Sherwin Till. The Sherwin Till was deposited about 800,000 years ago, during the second oldest glacial episode in the Sierra Nevada. When the Bishop Tuff was deposited, it covered the Sherwin Till in this area. You can see the Sherwin Till at the north end of the Big Pumice cut, where the brush is growing. The till is composed of partially decomposed boulders and other poorly sorted glacial debris. In the roadcut, note that the Bishop Tuff lies on top of the Sherwin Till and that the contact between the till and the tuff slopes gently to the right. Since the tuff was deposited on top of the till, the Sherwin till is obviously older than the tuff. This roadcut is one of the few places that the age relationship between the Sherwin Till and the Bishop Tuff can be seen, and was the subject of a technical publication by Sharp in 1968.

The lowermost 15 feet of the Bishop Tuff that overlies the Sherwin Till consists of a layer of pumice and ash. This is the material that had been thrown into the air at the beginning of the eruption of the Long Valley volcano. This air-fall pumice is mainly fine-grained and forms well-bedded layers. In this roadcut, these layers follow the surface of the underlying Sherwin Till and slope gently to the right. The remainder of the tuff in the roadcut is mainly coarse, poorly-sorted pumice. In clean exposures, very faint near-horizontal layering can be seen. This pumice was deposited as a series of ash flows. The faint layering probably represents different pulses during the flow. These rocks were at the edge of the ash flow and never became welded. You will see that these rocks are quite different from the welded tuffs at the Gorge Overlook. In the center of the roadcut, several near-vertical clastic dikes cut through the Bishop Tuff. These dikes consist of sand and gravel that has fallen into cracks in the tuff from the overlying surface rocks. The sand and gravel in these dikes is harder than the pumice, so the dikes are quite prominent in the outcrop.





The Sherwin Till is exposed on the lower brush-covered slope to the left. Note the large boulders in the till. The till is overlain by the white rocks of the Bishop Tuff in the upper part of the roadcut.



Two clastic dikes cut through the Bishop Tuff in the center of the Big Pumice cut. The banded layer between the dikes is air-fall pumice and the overlying white rocks are ash-flow pumice.

Owens Gorge **-** *From Toms Place drive 11 mi. S on Hwy. 395; turn E on Paradise Rd. and drive 1 mi.; turn N on Gorge Rd. and drive 6 mi. to the Upper Power Plant; park near the closed gate.*

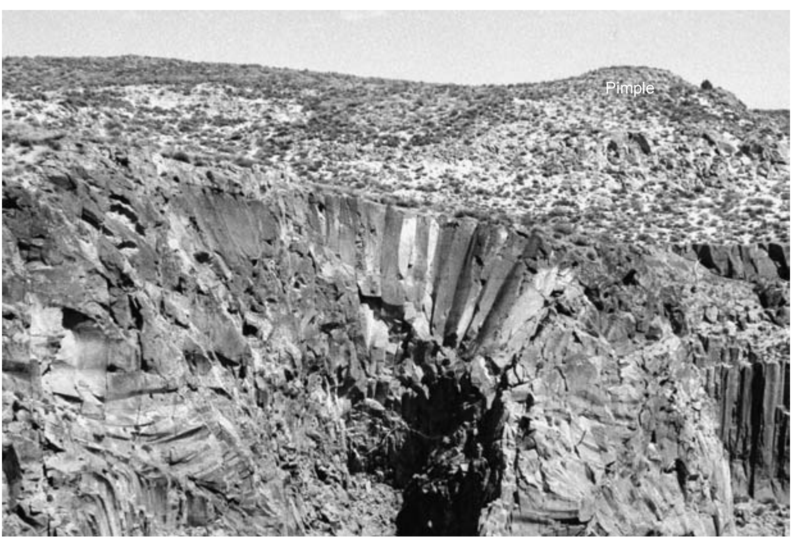
As you drive along Gorge Road to the Upper Power Plant, you are driving on the Volcanic Tableland. The tableland is an extremely hard surface that resists erosion and is formed from welded tuff. The welded tuff is part of the Bishop Tuff, and the tableland represents the upper surface of the thick ash flows that were deposited during eruption of the Long Valley volcano. The ash flows were several hundred feet thick in this area, and the hot ash cooled slowly. The tuff fragments were welded together as the ash cooled. During the cooling period, gas that had been trapped in the ash flows was expelled to the surface through vents. These vents now appear as scattered small conical hills on the tableland, and are locally known as pimples. You can see many of these pimples along Gorge Road.

When the ash flows were first deposited in this area, the surface of the tableland sloped gently south from the Long Valley volcano to Big Pine. Since then, Bishop and Big Pine have dropped over 2,000 feet relative to Long Valley. Some of this downward movement was by down-warping of the ground and some by faulting that took place along a number of small faults. These faults cut across the tableland, and each fault offsets and drops the surface of the tableland 20 feet or so. Most of the faults are on the east side of the Owens Gorge, so they are not apparent along Gorge Road.

From the pullout near the Upper Power Plant you can get a good view of the Owens Gorge and the welded tuff that is exposed in the walls of the gorge. The tuff has well-developed columnar joints that form large vertical columns along the steep walls of the gorge. In some places, the joints are not vertical, but form spectacular radiating columns. These columns formed around the gas vents in the flow. The vents represented a cooling surface to the flow, and the columns formed perpendicular to that cooling surface. These vents formed the pimples on the surface of the flow.

The welded tuff is very hard and erodes into steep cliffs. In fresh exposures, the rock is mostly pink, but the rock is brown on weathered surfaces. If you look at the rock with a magnifying glass, you will see small fragments of pumice, clear fragments of feldspar and quartz, and many small pieces of other nondescript volcanic rocks. In the walls of the gorge, you can see evidence of multiple ash flows. Some white pumice is also found within the flows near the Upper Power Plant.

Owens Gorge at the Upper Power Plant is cut into the hard welded ash flows of the Bishop Tuff. The top of the Bishop Tuff forms the Volcanic Tableland. Columnar joints in the welded tuff form pillars that line the walls of the gorge.



Radiating columnar joints in the Bishop Tuff are exposed in the wall of Owens Gorge near the Upper Power Plant. The joints formed around a vent where gas escaped from the ash flow. The “pimple” on the surface of the ash flow was also formed by the escaping gas.

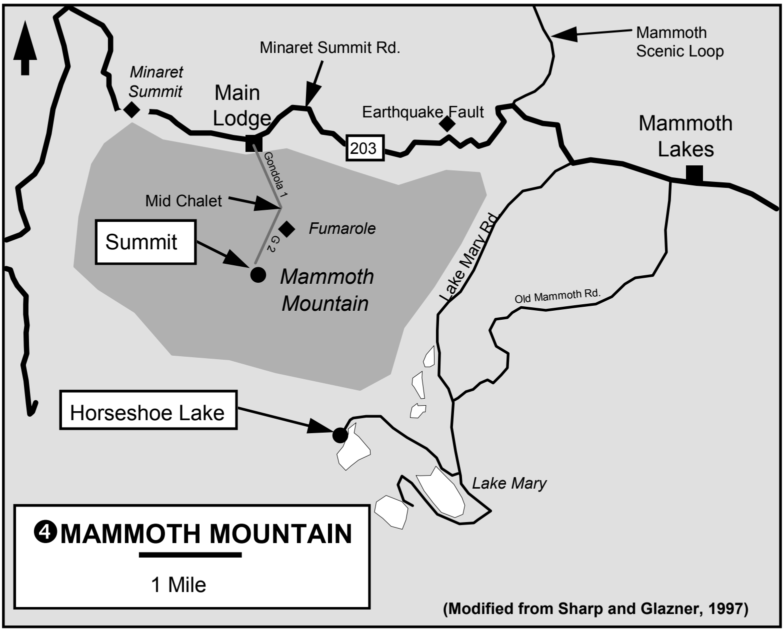
❹ *Mammoth Mountain*

Mammoth Mountain is a volcano that lies along the southwestern rim of the Long Valley Caldera. The volcano began to take shape 200,000 years ago and was built up over the next 160,000 years by a series of a dozen or so eruptions of rhyolite and andesite interspersed with layers of tuff, scoria, and pumice. The last of these eruptions was about 40,000 years ago.

Summit **-** *From the main ski lodge at Mammoth Mountain take the gondola to the top, then hike 0.25 mi. to the S summit; go in the summer when there is no snow.*

You can see some of the volcanic rocks that make up Mammoth Mountain along the short hike from the summit gondola station to the south summit of the mountain. Most of the rocks along the trail are purple and gray andesite with crystals of quartz, feldspar, biotite, and hornblende. Some of these rocks have been altered by hot steam and fluids that have destroyed the biotite and hornblende and turned the feldspar into clay. From the summit, you can see across the Long Valley Caldera to Glass Mountain, just beyond the east side of the caldera.

Now that you have enjoyed the view from the summit, there is something else that I should tell you. You are standing on top of an active volcano. In May of 1980, a number of earthquakes were recorded at Mammoth Mountain. These earthquakes were caused by surges of magma in a magma chamber that lies below the mountain. In 1989, another swarm of earthquakes was caused by upward intrusion of a dike of magma that lies one to two miles below the mountain. Large volumes of gas are still being expelled from the magma below Mammoth Mountain. In most volcanoes, this gas would make its way upward and come out of a vent at the summit. However, at Mammoth Mountain impermeable rocks above the magma chamber stop this upward flow. The gas is, instead, forced to rise along the flanks of the volcano, and some escapes from fumaroles on the flanks of the mountain. Gondola 2 passes near one of these fumaroles on its way to the summit. Other gas rises around the base of the volcano, where it locally permeates the ground. Following the 1980 earthquakes, there was an increase in water temperature and flow at most of the fumaroles on Mammoth Mountain. After the 1989 earthquakes, there was an increase in CO_2 gas derived from the magma. The earthquakes and CO_2 gas emissions at Mammoth Mountain have been under intense study by the U.S. Geological Survey for many years. For an update on the volcanic activity for the Long Valley Caldera, go to their website: http://quake.wr.usgs.gov/VOLCANOES/LongValley.

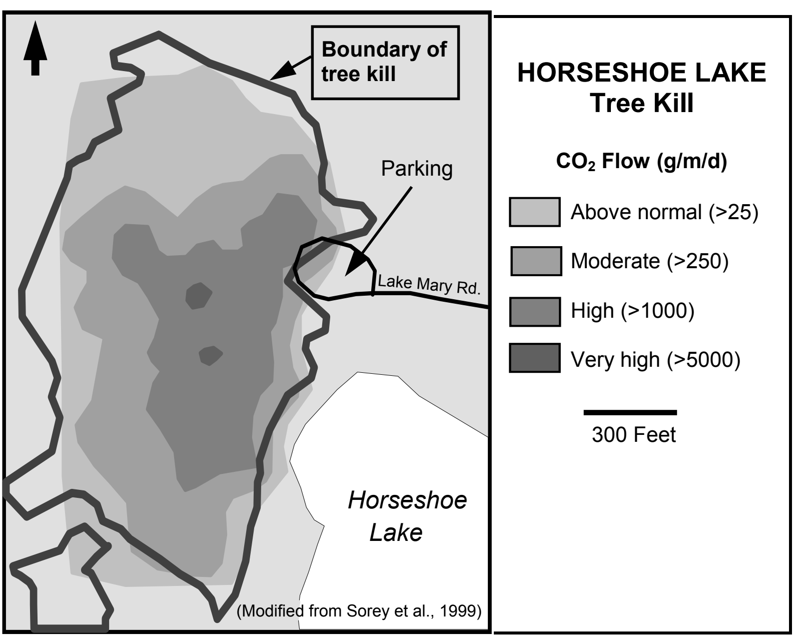


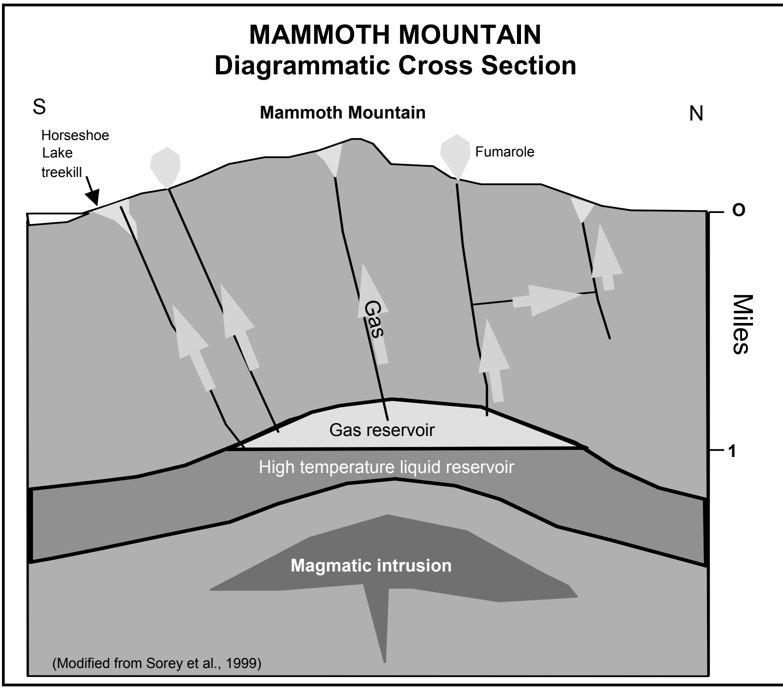
A steep cliff of the andesitic volcanic rocks that form Mammoth Mountain can be seen from the gondola to the summit. The reflections in the upper right are from the window of the gondola.

Horseshoe Lake - *Drive to the end of Lake Mary Road; park in the parking lot for the abandoned Horseshoe Lake campground.*

From the parking lot at Horseshoe Lake, you can see a large area of dead trees. In 1990, the Forest Service first noticed that the trees were dying in this area. Soon, it was recognized that this tree kill was due to abnormally large concentrations of CO_2 in the soil. Chemical analysis of the gas indicated that the gas was coming from a magmatic source rather than from groundwater. The swarm of earthquakes that occurred at Mammoth Mountain in 1989 was attributed to movement of magma below Mammoth Mountain. The gas was probably released from the magma at that time. Earthquakes related to movement of magma have occurred periodically since 1989, so the problem has not yet passed.

When the CO_2 gas was released from the magma during the 1989 earthquake, some of the gas escaped from fumaroles. However, most of the gas simply percolated upward through the ground around the base of the mountain. Since CO_2 is heavier than air, the gas can build up to abnormally high concentrations in low spots on the ground. High concentrations also occur when the CO_2 is trapped under heavy snow cover and not allowed to dissipate.





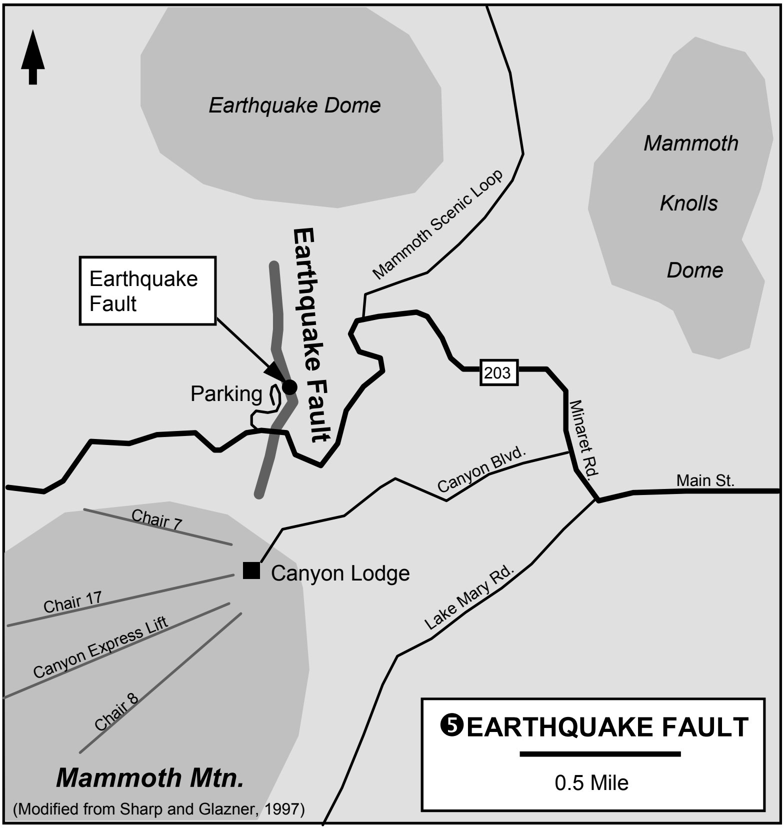
These trees near the parking lot at Horseshoe Lake have been killed by excess CO_2 that has permeated the soil. The CO_2 is coming from a magma reservoir that lies below Mammoth Mountain.

❺ *Earthquake Fault*

The earthquake fault is on the north slope of Mammoth Mountain and at the south end of the Inyo Craters. Despite its billing, the earthquake fault is not a fault and it is unlikely that it was caused by an earthquake. In fact, no one really knows how the crack was formed. Take a look and see if you have any ideas.

> ***Earthquake Fault*** *- From the junction of Mammoth Scenic Loop and Hwy. 203 drive W on Hwy. 203 1 mi. to the earthquake fault turnoff; take the short drive to the parking area.*
>
> From the parking area you can take a short walk to the earthquake fault and then go along the fault for some distance. The fault is a large open crack, up to 10 feet wide and 50 feet deep, that extends north-south for somewhat less than a mile. The crack occurs in a rhyolite lava flow, one of the many flows that make up Mammoth Mountain. If you look at the irregularities in the rocks on either side of the crack, it appears that that there is no offset along the crack, but that the sides were simply pulled apart. No one really knows how the crack was formed. It doesn't appear to be a fault because

The earthquake fault is a deep crack in a rhyolite flow on the north flank of Mammoth Mountain. The origin of the crack is not known, but it is doubtful that the crack was formed by an earthquake.



the sides are not offset. The crack was not caused by cooling of the lava flow because the flow occurred over 50,000 years ago. Any crack formed at that time would have been filled long ago. One possibility is that the crack formed when the lava flow was bent by a deep-seated intrusion of magma at the south end of the Inyo Craters. There has been a great deal of volcanic activity along the Inyo Craters during the last 2,000 years. If the crack had occurred in most other types of rock, it probably would not have survived long. However, the rhyolite flow is hard, brittle rock, and does not erode rapidly.

From the viewing area, the earthquake fault extends south to Highway 203, which goes across the crack. Immediately south of the highway the crack continues as a shallow trench, and then dies out as it heads for the ski area near Canyon Lodge.

❻ *Devils Postpile*

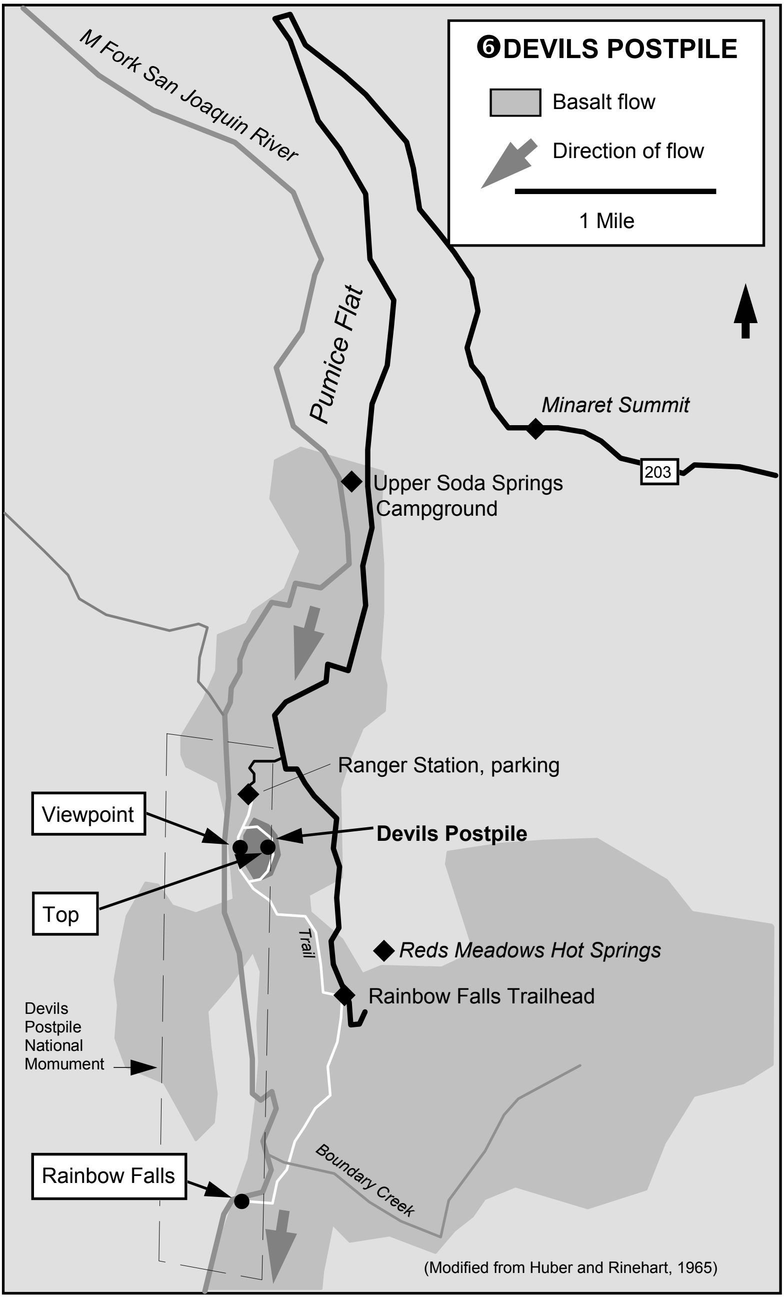
The Devils Postpile is the most spectacular and best-known example of columnar jointing in California. The basalt that forms the postpile came from vents on the valley floor near the Upper Soda Springs Campground about 100,000 years ago, during the Tahoe glacial episode. After leaving the vent, the lava flowed down the valley of the Middle Fork of the San Joaquin River about 2.5 miles. At that point it encountered an obstruction in the valley, perhaps a glacial moraine, and ponded in back of the obstruction until it reached a thickness of 400 feet - much thicker than most basalt flows.

It took an unusual set of geologic circumstances to form the long curved columns at Devils Postpile. The lava was thick and homogeneous, with no flow banding. There was little gas in the flow, so few vesicles were formed. This thick mass of lava cooled very slowly. As it cooled, it contracted evenly, and formed very regular contraction joints. Typically, contraction joints break lava flows into six-sided columns that are perpendicular to the cooling surface. In a tabular flow, these columns are usually vertical. However, the thick Devils Postpile flow was not tabular, but pinched out along the sides of the valley. The columns at Devils Postpile thus curve toward the edges of the valley.

Shortly after the lava flow, glaciers moved down the river valley and overrode the basalt. The glaciers also quarried the basalt along the columnar joints, and eventually removed much of the flow from the central part of the valley. Devils Postpile represents a small remnant of the original flow that clings to the east side of the valley. After glaciation, many of the basalt columns subsequently broke from the side of the flow and accumulated in the large pile seen at the base of the cliff.

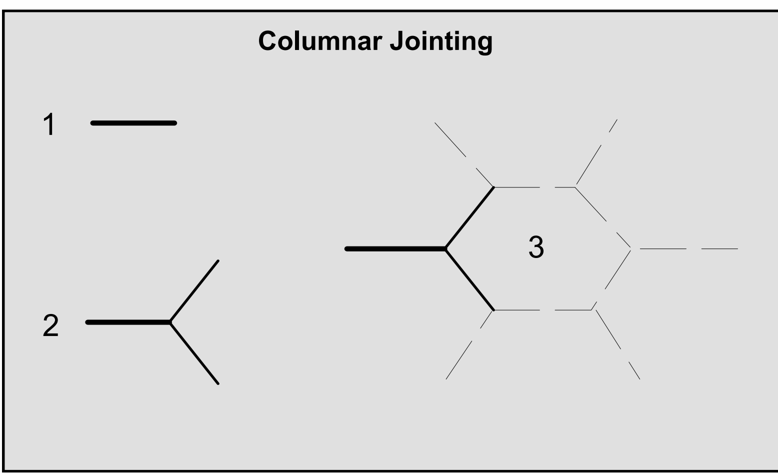
Viewpoint - *From Minaret Summit drive 7 mi. W on Hwy. 203 to the Devils Postpile Ranger Station; from there take the short hike to the Devils Postpile viewpoint. Accessible mid-June to mid-Oct. In summer, take the shuttle from Mammoth Mtn. Inn 7AM to 7PM daily. For details, phone 760-934-2289 or check website www.nps.gov/depo.*

From the base of the Devils Postpile you can see the tall basalt columns exposed in the cliff on the east side of the river valley. In the center of the postpile, the columns are near vertical, but along the edges, the columns are curved so that they lie at a steep angle. Individual columns are as much as 60 feet long, and many are two to three feet in diameter. Note that most of the basalt columns have six sides, but you can also find columns with three, four, five, and seven sides. This is typical for most basalt flows. The basalt is dark gray, fine grained, and has phenocrysts of plagioclase and olivine.

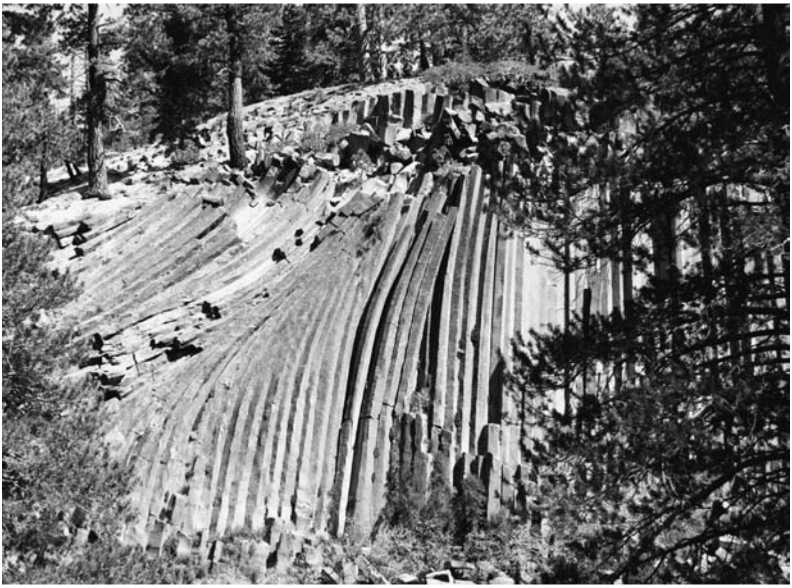

❻DEVILS POSTPILE
Basalt flow
Direction of flow
1 Mile
M Fork San Joaquin River
Pumice Flat
Minaret Summit
203
Upper Soda Springs Campground
Ranger Station, parking
Viewpoint
Devils Postpile
Top
Trail
Reds Meadows Hot Springs
Rainbow Falls Trailhead
Devils Postpile National Momument
Rainbow Falls
Boundary Creek
(Modified from Huber and Rinehart, 1965)

Top - *From the viewpoint, take the short loop trail to the top of the postpile.*
After this short hike, you will be standing on top of the Devils Postpile lava flow. The tops of the basalt columns have been polished and striated by the Pleistocene glaciers and look like polished tiles on a rounded dance floor. The striations indicate the direction of movement of the glacier.

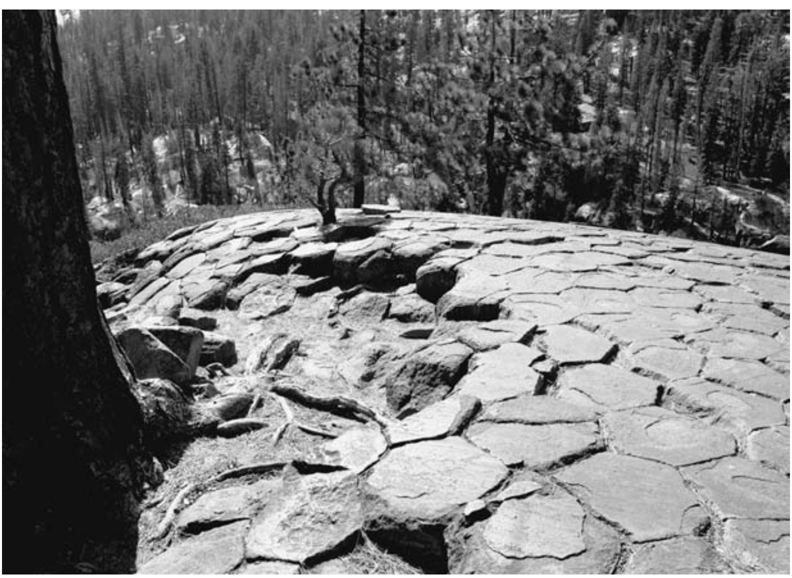
Rainbow Falls - *Take the trail from Devils Postpile (4 mi. RT) or from Rainbow Falls trailhead (2 mi. RT); a stairway and short trail lead to the bottom of the falls.*
At Rainbow Falls, the Middle Fork of the San Joaquin River drops 101 feet over a cliff of the same lava flow that formed Devils Postpile. It appears that two separate geologic steps were needed to make these falls:
1) When the last glacier melted at the end of the last ice age, the Middle Fork of the San Joaquin River flowed downstream from the Devils Postpile on the west side of the lava flow. The basalt cliff along the western edge of the lava flow was formed by river erosion when the river occupied this course.
2) Later, upstream from Rainbow Falls, the river was diverted eastward and began to flow on the top of the lava flow. The river then plunged over the edge of the flow, forming Rainbow Falls. At the base of the falls, the river returned to its original channel and continued to flow south.



1. As the lava cooled, it shrank, and small contraction cracks began to form.
2. After the cracks extended about ten inches, they branched to form an angle of about 120°. This provided the maximum stress relief.
3. After each new crack extended another ten inches, it branched again, forming six-sided columns.



Devils Postpile is one of the most spectacular examples of columnar jointing of a basalt lava flow in California.



At the top of Devils Postpile, the basalt columns have been polished by glaciers to resemble a curved tiled dance floor. Striations on the polished surface indicate the direction of movement of the glacier.

❼ *Minaret Summit*

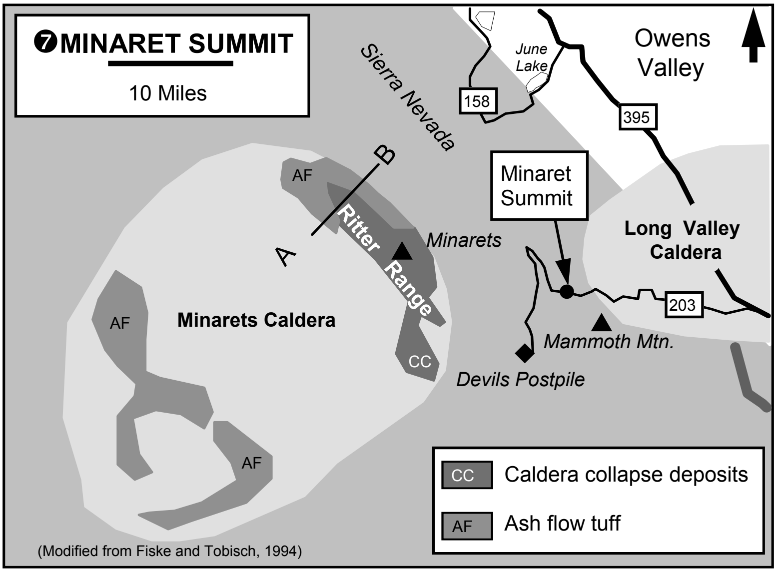
The Minaret Summit is a low point along the Sierra Nevada drainage divide. Moisture-laden winter storms from the west are funneled through this divide and directed toward Mammoth Mountain. Mammoth Mountain soaks up the moisture from these storms in thick blankets of snow and then sends the dehumidified air on to Owens Valley and Nevada. Mammoth Mountain thus accumulates large amounts of snow during the winter, whereas most of the other peaks east of the Sierra crest get little moisture and little snow. Mammoth Mountain is ideally situated to capture the winter snow from the west, and still provide easy access from the protected eastern slope of the Sierra.

Minaret Summit - *From Old Mammoth Rd. and Hwy. 203 drive 5 mi. W on Hwy. 203 to the Minaret Summit; take the short turnoff to the view area.*

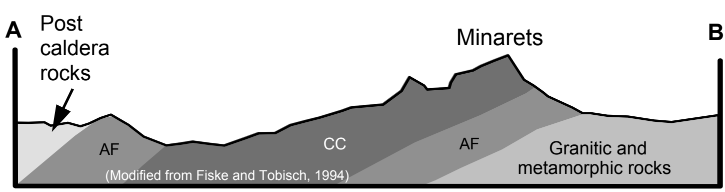
From Minaret Summit, you can get an excellent view of the Minarets, which appear as a series of sharp rugged spires that dominate the horizon six miles to the west. The Minarets are formed from metamorphosed Cretaceous volcanic rocks, and the weathering and erosion of these dark volcanic rocks has given the Minarets its distinctive topography. In a 1994 publication, Fiske and Tobisch showed that these volcanic rocks are composed largely of pyroclastic flows and were formed along the western margin of a large Cretaceous caldera. The Minarets Caldera is similar in size to the nearby and more recent Long Valley Caldera.

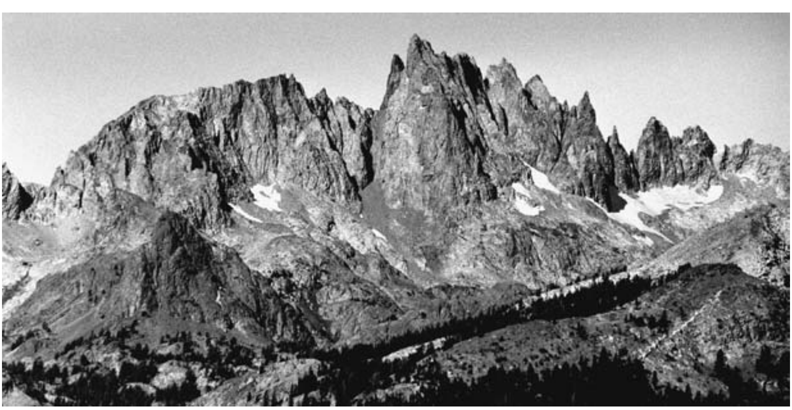
The Minarets Caldera is part of the large Ritter Range roof pendant, which consists of 30,000 feet of dark metamorphosed Cretaceous volcanic rocks that have been only slightly deformed. This roof pendant is a remnant of the Cretaceous volcanic rocks that once covered the Sierra Nevada batholith. The volcanic rocks were formed at the surface while the plutons of the Sierra Nevada batholith were being intruded at depth. During Cretaceous time, this part of the Sierra must have been somewhat similar to the present-day Andes, where numerous volcanoes erupt at the surface as plutons are formed at depth.

After the volcanic rocks of the Ritter Range were deposited, some were reheated to high temperatures by the underlying granite magma of the Sierra Nevada batholith. Where this has occurred, the volcanic rocks have been altered and new minerals have been formed. One of the most common of these minerals is garnet, which occurs as small red crystals in the metamorphosed volcanic rocks. Rocks altered by heating in this manner are called hornfels and are common in the Ritter Range.



Diagrammatic Cross Section





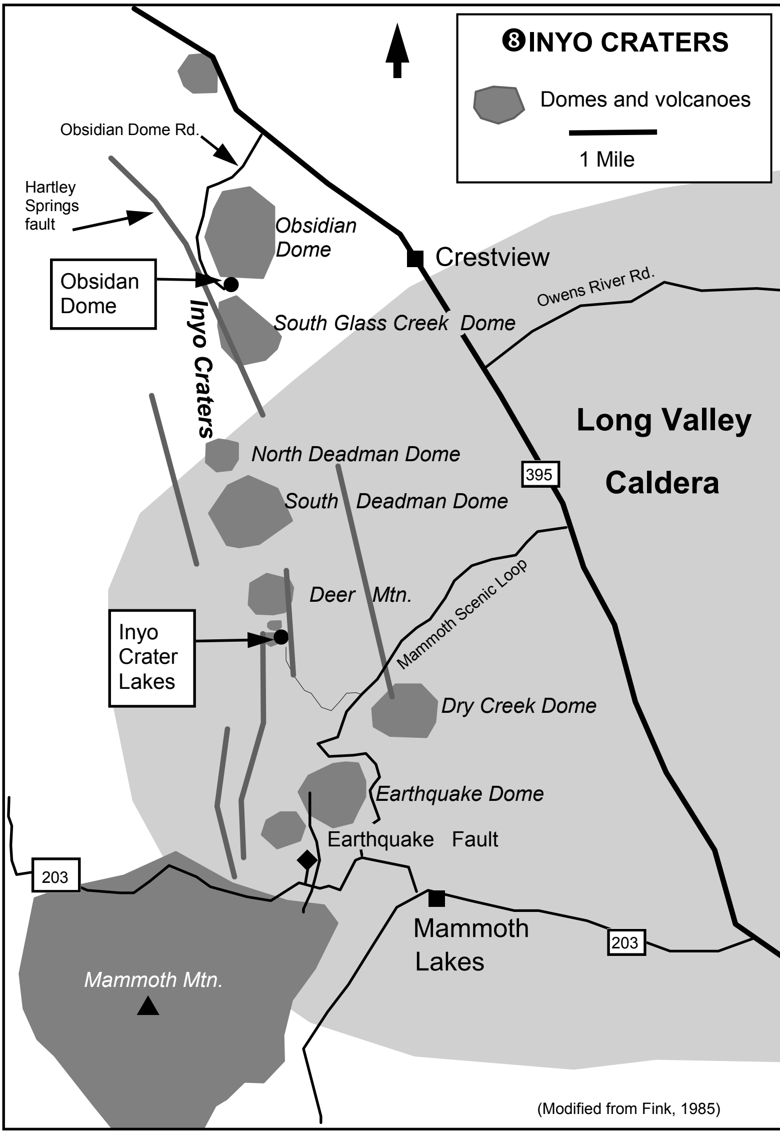
The Minarets consist of dark metamorphosed Cretaceous volcanic rocks that were formed along the east side of the Minarets Caldera.

❽ *Inyo Craters*

The Inyo Craters are a six-mile-long chain of craters, domes, flows, explosion pits, faults, and cracks that extend from Mammoth Mountain north to Obsidian Dome. This volcanic trend crosses the rim of the Long Valley Caldera without any apparent change. It also crosses the Hartley Springs fault, one of the major frontal faults of the Sierra Nevada, without effect. All of the volcanic activity along this trend is quite recent. The oldest volcanic activity was the formation of the North Deadman Dome several thousand years ago. The most recent activity occurred approximately 500 to 600 years ago and resulted in the formation of Obsidian Dome, South Glass Creek Dome, South Deadman Dome, Dear Mountain, and the Inyo Crater Lakes at the south end of the trend.

Inyo Crater Lakes - *From the junction of Hwy. 203 and Mammoth Scenic Loop drive N on the Mammoth Scenic Loop 2.5 mi.; turn W at the "Inyo Craters" turnoff and follow the unpaved road 1 mi. to the parking area; hike 0.3 mi. to the craters.*
There are three craters in this group. The hike from the parking area takes you to the two smaller craters. Each of these is about 600 feet across. The southern crater is about 200 feet deep and the northern crater about 100 feet deep. Both are filled by small lakes. The third crater of the group is at the top of Deer Mountain, immediately to the north. These craters were formed about 500 years ago when magma, rising along a dike, encountered groundwater. The

This pit at the southern Inyo Crater Lake was formed by an explosion of steam when rising magma encountered groundwater near the surface.



groundwater turned to steam, forming *phreatic* explosions that blasted the craters from the country rock. No volcanic rocks erupted from the craters at the time of the explosions. The walls of the craters consist of near-horizontal layers of tuff and lava flows that came from other earlier eruptive centers. If the steam had vented slowly rather than explosively, there would have been fumaroles at this locality rather than craters.

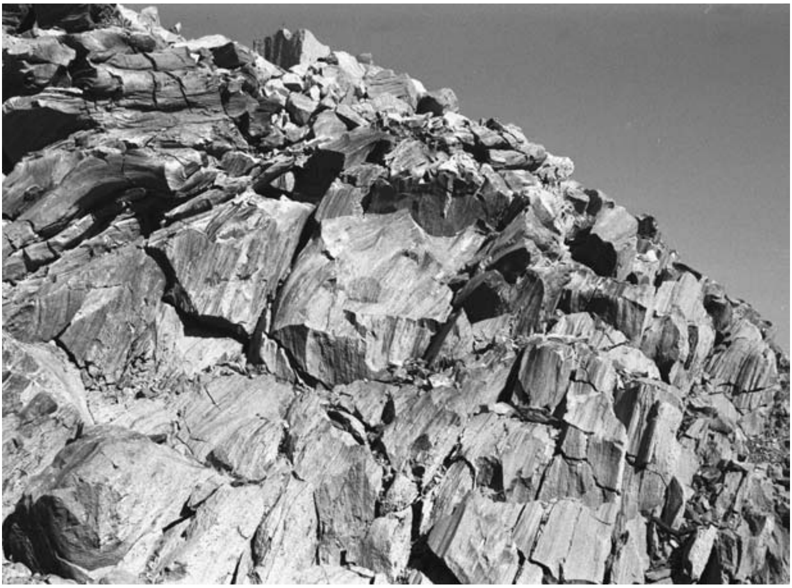
Obsidian Dome - *From the junction of Hwy. 158 and Hwy. 395 go S 3.7 mi. on Hwy. 395; turn W on Obsidian Dome Rd.; go 1.5 mi. to the parking area for Obsidian Dome.*

Obsidian Dome is a small dome near the north end of the Inyo Craters. The dome was formed when viscous rhyolite magma oozed from a vent about 600 years ago. At the beginning of the eruption, volcanic tuff was ejected from the vent and carried northeast, where it formed a blanket several feet thick near the vent.

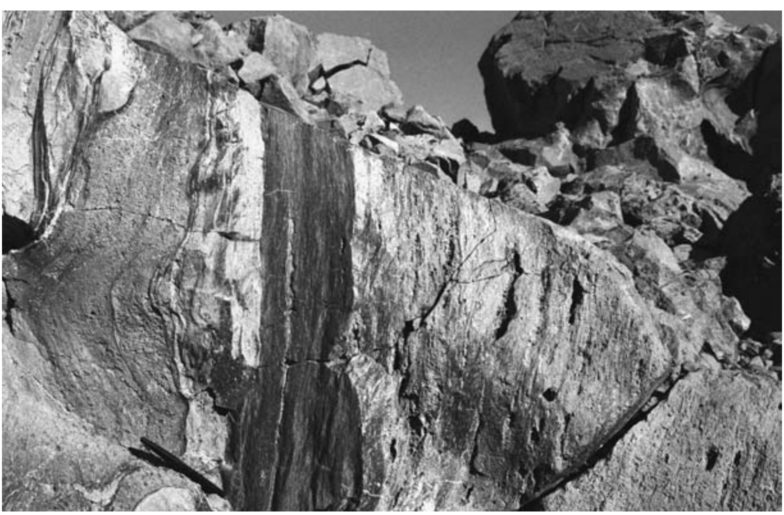
To see the rocks that form the dome, hike up the short gated road to the abandoned rock quarry at the top of the dome. The rocks along the road and at the top consist of layers of obsidian, stony rhyolite and pumice. The obsidian looks like black glass and breaks into hard sharp fragments with curved surfaces. The stony rhyolite is dull and colored gray, orange and pink. The pumice is light gray, foamy, and very light weight. Blocks of pumice quarried at Obsidian Dome were used as decorative rock.

The obsidian, stony rhyolite, and pumice at Obsidian Dome are essentially the same composition and were formed from viscous rhyolitic magma. The differences in composition are due mainly to the amount of gas in the magma and the cooling history of the magma. The obsidian formed from gas-poor rhyolitic magma that chilled so fast that crystals did not have time to form. Crystallization was slow because the magma was viscous and the elements had trouble combining into crystals. The stony rhyolite formed from magma that cooled more slowly, and small crystals had time to form. The pumice formed from frothy layers of gas-rich magma that chilled rapidly.

Obsidian is common in young rhyolite eruptions. However, obsidian is a supercooled liquid, and over time obsidian crystallizes into stony rhyolite. Thus, old obsidian flows are rare. The process by which obsidian changes to stony rhyolite is referred to as *devitrification*. Devitrification begins at the surface of the obsidian, which is exposed to weathering, and works toward the interior. Old obsidian flows have a rind of devitrified glass. The older the flow, the thicker the rind, assuming the same climatic conditions. If the rate of devitrification is known, then the age of the obsidian can be determined. Many of the obsidian flows along the Inyo and Mono Craters have been dated using this method.



This obsidian flow at Obsidian Dome has near-vertical flow banding and is broken into large blocks that formed as the obsidian cooled. Note the striated surfaces that were formed like grooves in toothpaste squeezed from a tube.



In this close up view of the flow you can see bands of black obsidian, gray rhyolite, and white frothy pumice. The pen at lower left provides scale.