

Excerpt from
Geologic Trips, Sierra Nevada

by Ted Konigsmark

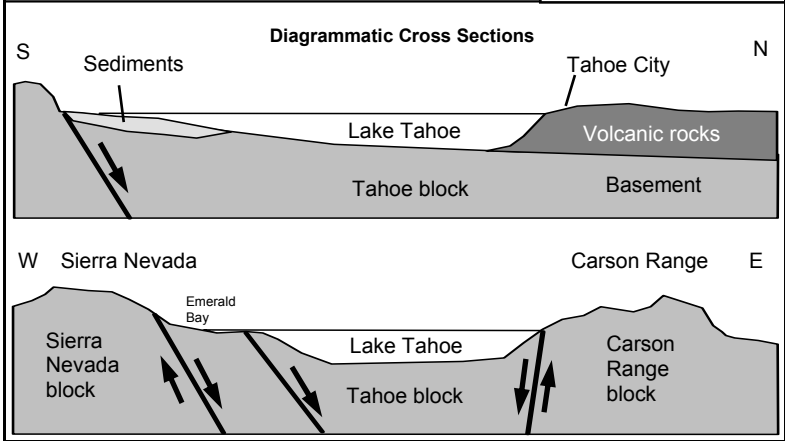
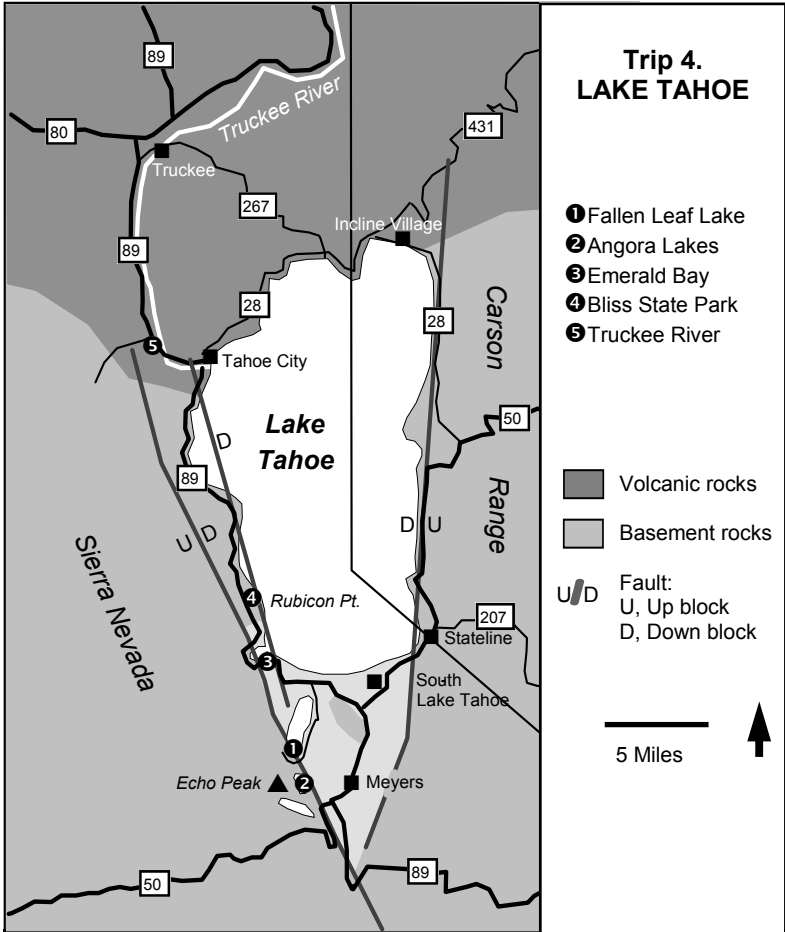
ISBN 0-9661316-5-7

GeoPress

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Trip 4

LAKE TAHOE

Faults, Glaciers, and Lakes

Lake Tahoe is the largest and deepest lake in the Sierra Nevada, and certainly one of the most scenic. On this trip we'll take a look at how the lake was made, and how glaciers played an important role in the formation of many of the other lakes and scenic features in the Tahoe area.

The first step in the formation of Lake Tahoe began during the Plio-Pleistocene uplift of the Sierra Nevada. When the crust in the Tahoe area was uplifted and stretched, it broke into several large blocks. One of these blocks, the Tahoe block, dropped about 5,000 feet along a series of large faults that splayed and opened to the north. As the Tahoe block dropped, the adjacent Sierra Nevada and Carson Range blocks were uplifted, forming a deep valley between the Sierra Nevada and the Carson Range. This valley sloped to the north and was drained by a north-flowing river. The second step in the formation of the lake occurred when the north part of this valley was filled with a thick pile of volcanic rocks that formed a dam in the river valley. The waters of Lake Tahoe are held in place by this dam. The volcanic rocks at the north end of Lake Tahoe extend from Tahoe City and Incline Village north to Sierraville, and from Truckee east to Floristan.

The water for Lake Tahoe is supplied mainly by rivers and creeks along the south and west sides of the lake that are fed from the abundant snow in the Sierra Nevada. Since more water is supplied to the lake than the lake can hold, the level of the lake depends on the height of the dam at the outlet. Presently, the lake is 1,645 feet deep. However, during Pleistocene glaciation, the level of the lake moved up and down as much as 600 feet as glaciers and moraines dammed the outlet and then receded and/or were breached.

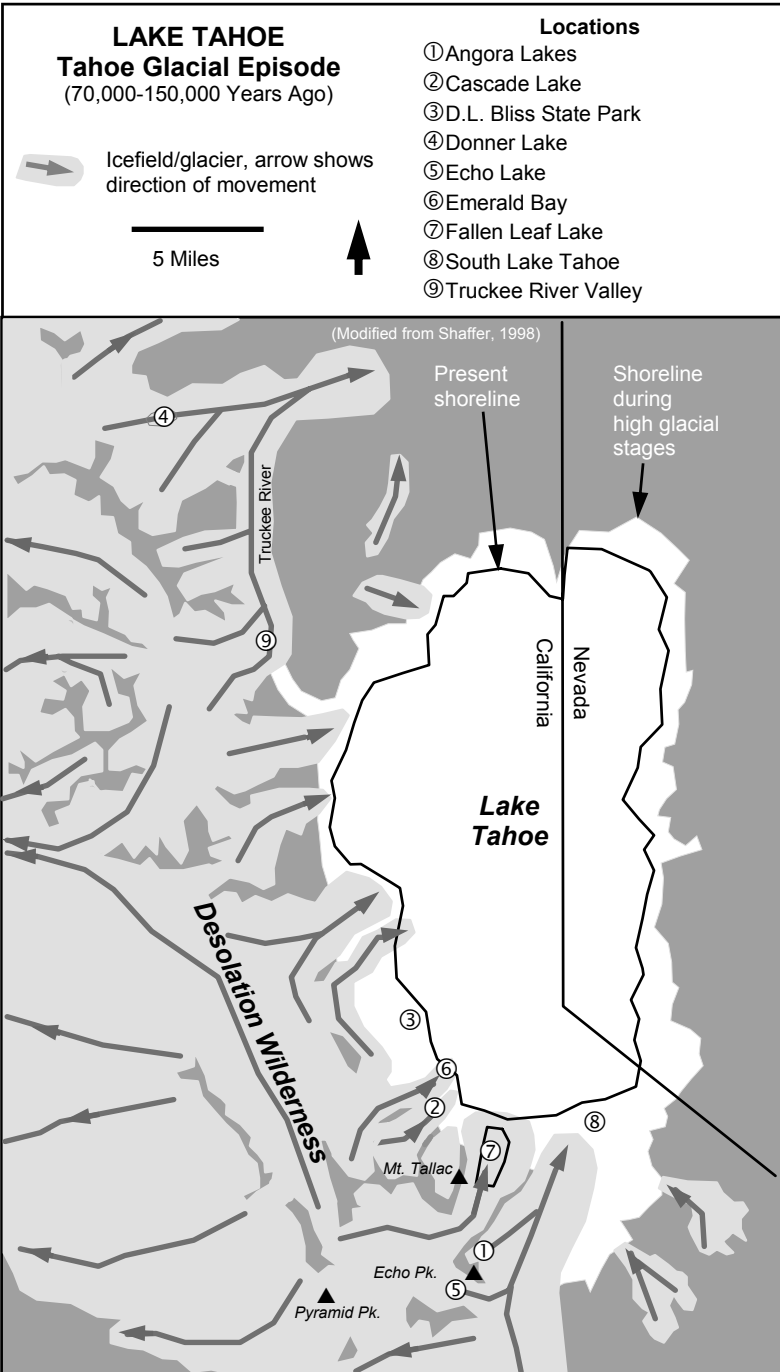
Glaciers have had a profound influence on the landscape along the western margin of Lake Tahoe. Most of the moisture from Pacific storms was trapped by the mountains west of the lake, so there are few glaciers on the east side of the lake. Lake Tahoe itself was never covered by glaciers. Like Mono Lake and Owens Lake, Lake Tahoe was the terminus of the glaciers and a depository for glacial debris and water.

Glaciers left their mark on the landscape in many ways. They carved cirques and glacial valleys in the high country. They entered the lake and dumped their glacial debris into the lake. They also left behind polished granitic rocks and exotic blocks that can be found in many places around the lake.

All four of the major Sierra glacial episodes were present in the Tahoe area. During each episode, a thick icefield covered the high Desolation Wilderness area west of the lake. This icefield stripped the Desolation Wilderness of its weathered rock and soil cover and exposed large areas of fresh granitic and metamorphic rocks. The moving ice in the icefield also scooped out numerous small lake basins and carved dozens of jagged peaks in the Desolation Wilderness. From the icefield, a number of glaciers extended east down the steep fault scarps that formed the western side of the Tahoe basin. As the glaciers moved down the canyons and into Lake Tahoe, they gouged out lake basins, formed cliffs, and steepened the walls of the valleys. The glaciers also carried a large amount of rock material and dumped it into the western and southern part of the lake. Some of this glacial material was deposited as lateral, terminal, and recessional moraines. You can see these moraines today at Fallen Leaf Lake, Angora Lake, Cascade Lake, and Emerald Bay.

Much of the work done in the early glacial episodes was covered and reworked during the later glacial episodes. Thus, most of the moraines that we see today were formed by the large Tahoe glacial episode, 70,000 to 150,000 years ago, and the younger but smaller Tioga episode, 19,000 to 26,000 years ago.

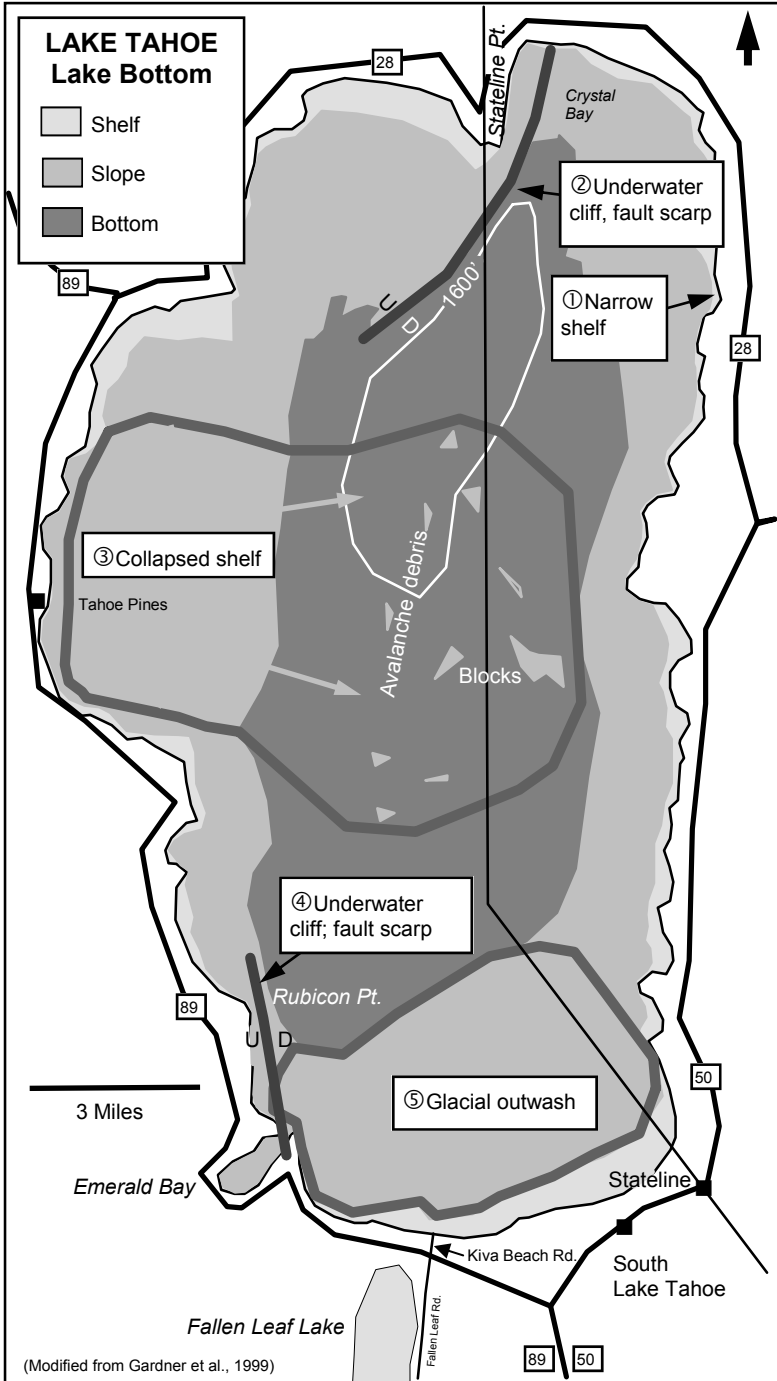
The Truckee River serves as the outlet for Lake Tahoe. The overflow water leaves the lake at the outlet just south of Tahoe City. From there, the water flows north to Truckee, and then east to Reno. During glacial episodes, glaciers filled the Truckee River valley from time to time and blocked the outlet of the lake. When this happened, the lake rose as much as 600 feet and covered much of the low area south of the present lake. The communities of South Lake Tahoe and Meyers are built on sediments that were deposited when the lake was at these higher levels. Shorelines that were formed at the high lake levels can be seen in a number of places around the lake basin. When the dams of glacial ice suddenly broke, it must have been quite a sight. But more about that later, during the trip to the Truckee River.



The Bottom of the Lake

Unfortunately, from a geologic standpoint, the beautiful blue waters of Lake Tahoe hide the bottom of the lake and some of the interesting geology that could otherwise be seen on the lake bottom. In order to get an understanding of this geology, the U.S. Geological Survey recently published a detailed bathymetric map and report that describes the bottom of the lake (Gardner et al., 1999). Based on this study, the central part of the lake has a relatively flat bottom that slopes gently to the north and is at depths of 1,500 to 1,645 feet below the present shoreline. The margins of the lake are made up of sediments brought into the lake by rivers and glaciers. These sediments typically form a shallow shelf from the shoreline to water depths of about a hundred feet. Below this shelf, there is a steep slope that has gullies, trenches, ridges, cliffs, mounds, blocks, and fans. Here are some of the geologic features described in the USGS study:

- ① The entire east side of the lake has a narrow shallow shelf and then a steep slope to the flat bottom of the lake. Very little sediment has entered the lake from this side, so only a narrow bench of sediment has built up along the shoreline.
- ② Immediately east of Stateline Point, at the north end of the lake, there is an underwater cliff that is 1,400 feet high. The cliff probably represents a fault scarp. Crystal Bay is on the down-thrown side of the fault and the water in Crystal Bay is up to 1,500 feet deep.
- ③ On the west side of the lake, near Tahoe Pines, a five mile section of the shelf of the lake has collapsed. The glacial sediments that made up the shelf broke off and formed an underwater avalanche. This avalanche carried the sediments into deep water and deposited them in an irregular fan that is five miles wide, six miles long, and as much as 660 feet deep. The fan includes large blocks and mounds of avalanche material that traveled almost across the lake before settling on the flat bottom. One of these blocks is nearly a mile long, half a mile wide and 400 feet high.
- ④ East of Rubicon Point there is a 1,400-foot underwater cliff. The cliff is likely the scarp of one of the boundary faults of the Tahoe block.
- ⑤ The south margin of the lake from Fallen Leaf Lake to Stateline is formed from glacial-outwash sediments deposited in front of glaciers. This steep gullied slope is interrupted in at least two places by large blocks of sediment pushed to the margin of Lake Tahoe by large glaciers.



❶ **Fallen Leaf Lake**

Fallen Leaf Lake was formed by glacial moraines. The east and west sides of the three-mile-long lake are bounded by lateral moraines and the lake is separated from Lake Tahoe by a series of recessional moraines. Fallen Leaf Lake is 150 feet above Lake Tahoe and drains into Lake Tahoe through Taylor Creek, which cuts through these recessional moraines. If there were no lateral and recessional moraines, there would be no Fallen Leaf Lake.

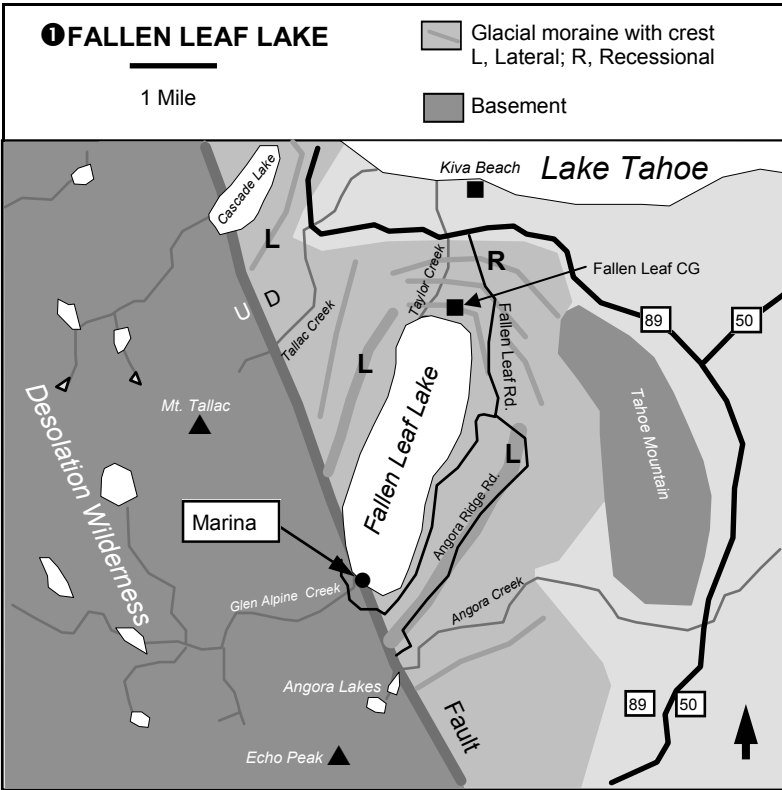
The south end of Fallen Leaf Lake lies at the base of one of the large faults along which the Tahoe block was downfaulted several thousand feet. The lake sits in a pile of glacial debris that was carried down the scarp of this fault by Pleistocene glaciers. This glacial debris fills in much of the southern part of the Tahoe basin. As the lake was filled in, the glaciers rode over the older glacial material and continued to dump their debris into the lake.

The glacier that formed Fallen Leaf Lake began in a thick icefield that covered the Desolation Wilderness west of Fallen Leaf Lake. From this icefield, the glacier flowed down the valley of Glen Alpine Creek and formed numerous small lakes and falls as it tumbled down the steep slope into the Lake Tahoe basin. From the marina at Fallen Leaf Lake, you can see how this glacier formed the lake.

Marina - From the junction of Hwys. 50 and 89 in South Lake Tahoe drive 3 mi. N on Hwy. 89; turn left on Fallen Leaf Rd. and drive 5.5 mi. to the marina.

The marina at Fallen Leaf Lake lies near the base of one of the large faults that form the southwest border of the Lake Tahoe basin. You can't see the actual fault, but you know that it is there because the marina and the south end of Fallen Leaf Lake are underlain by young lake and glacial sediments, and the granitic basement rocks can be found along Glen Alpine Creek immediately west of the marina.

Fallen Leaf Campground lies on the recessional moraines that can be seen at the far end of the lake. This recessional moraine is composed of a series of linear ridges that cut across the valley. The high ridge on the southeast side of the lake is a large lateral moraine that formed between the Glen Alpine glacier and the Angora glacier. This moraine is up to 900 feet high. The ridge along the northwest side of the lake is the lateral moraine that formed between the Glen Alpine and Tallac Creek glaciers.



Fallen Leaf Lake from Angora Ridge Road.

② Angora Lakes

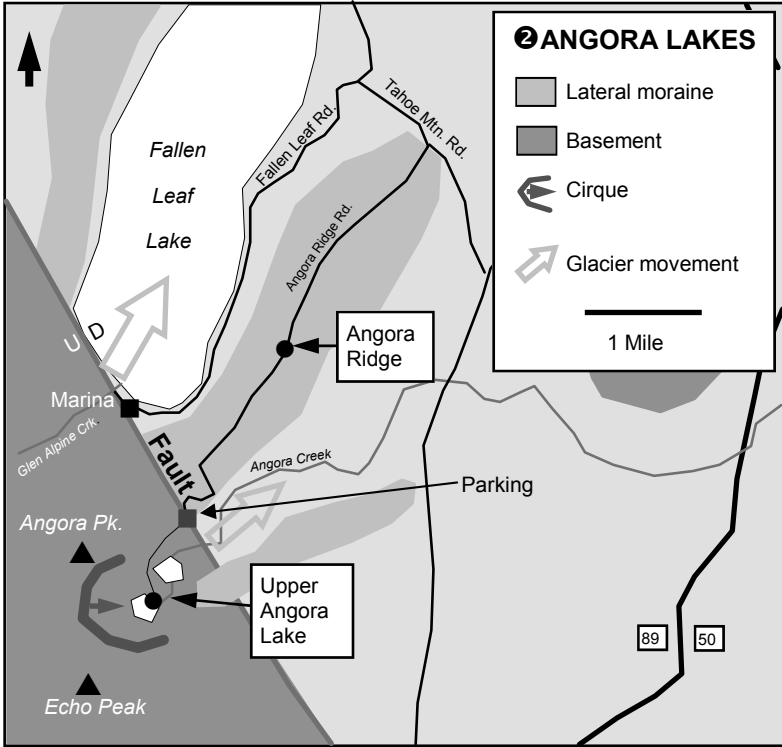
Although the Angora Lakes lie only a mile south of Fallen Leaf Lake, they are quite different. Fallen Leaf Lake lies on the downthrown side of the boundary fault for the Tahoe basin, whereas the Angora Lakes are on the upthrown side of the same fault, about 1,000 feet above Fallen Leaf Lake. Another major difference is that the Angora Lakes have been carved out of the granitic basement rocks of the Sierra Nevada by glacial erosion. In contrast, Fallen Leaf Lake sits in a pile of glacial debris—very scenic glacial debris. During the drive from Fallen Leaf Lake to Angora Lakes, you climb the lateral moraine on the south side of Fallen Leaf Lake and then ride along the crest of this moraine for about a mile. The road ends in a meadow on the high side of the boundary fault for the Tahoe basin. From there, it is a short hike to the Angora Lakes.

Angora Ridge - *From the junction of Hwy. 50 and Fallen Leaf Rd. drive S on Fallen Leaf Rd. 2.0 mi.; turn left on Tahoe Mountain Rd. and drive 0.4 mi.; turn right on Angora Ridge Rd. and drive 2 mi.; park at one of the pullouts on the ridge just beyond the fire lookout.*

The high ridge that you have been driving along is a lateral moraine that was formed between the Glen Alpine and Angora glaciers. You can see the glacial till that makes up the moraine all along the ridge. Some of the boulders are quite large, and these are mixed with rounded rocks of all sizes, as well as sand, silt, and clay. From the ridge, you can look down 900 feet onto Fallen Leaf Lake. When the glaciers were active, they were at least as high as this lateral moraine. The lateral moraine makes a convenient ramp to get to the Angora Lakes. If it were not for this lateral moraine, these lakes would not be easily accessible by car.

Upper Angora Lake - *From the fire lookout continue 1 mi. to the parking lot at end of Angora Ridge Rd.; hike along the closed road 0.5 mi. to Upper Angora Lake.*

Upper Angora Lake lies in a glacial cirque on the east side of Angora Peak and the north side of Echo Peak. The steep semicircular wall of the cirque and the basin for Upper Angora Lake were excavated from Angora and Echo Peaks as meltwater from the Angora glacier alternately froze and thawed the jointed granite. Note the steep granite cliffs at the base of the cirque at the far side of the lake. Upper Angora Lake is one of hundreds of cirque lakes formed in the Sierra high country during the ice ages. Lower Angora Lake was formed when the Angora glacier excavated some of the weaker jointed granite along Angora Creek. This lake is partly dammed by a moraine left during retreat of the last Angora glacier.



Upper Angora Lake is a cirque formed by a glacier that covered the east side of Angora Peak. While enjoying the view of the lake and Angora Peak, top center, have a lemonade at the Angora Lakes Resort. Lemonade has been a tradition of the resort for over half a century.



③ Emerald Bay

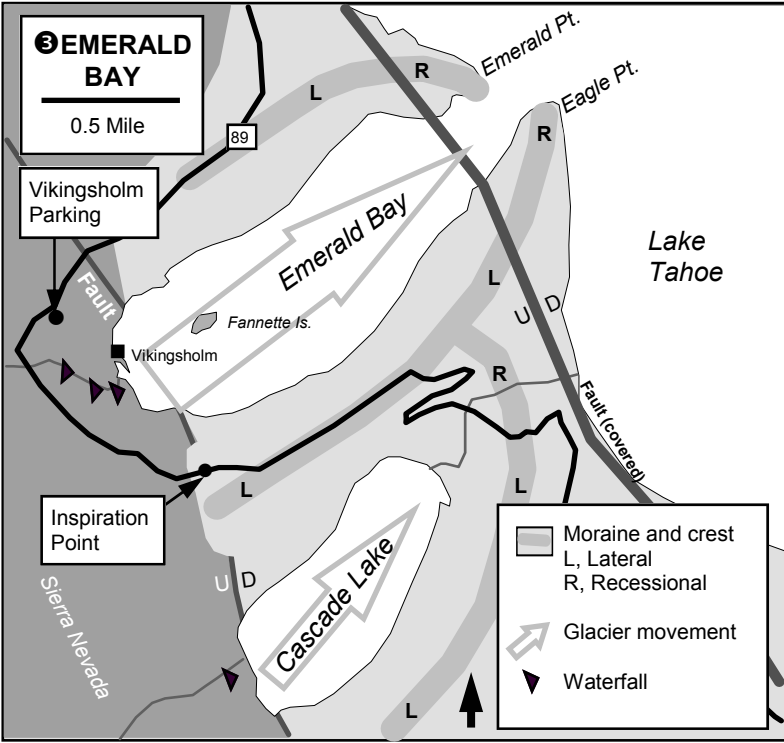
Scenic Emerald Bay is geologically similar to Fallen Leaf Lake. However, the recessional moraines at Fallen Leaf Lake formed a dam for the lake, whereas Emerald Bay enters Lake Tahoe through a narrow gap in its recessional moraine. The glacier responsible for Emerald Bay began in the Desolation Wilderness icefield and scooped out the basins for Velma Lakes and Eagle Lake on its way to Lake Tahoe. When the glacier reached Lake Tahoe, it crossed a large fault on the west side of the Tahoe basin and abruptly entered the lake. Upon entering the lake, the glacier began to melt and dump its load of glacial debris along the shoreline. At the end of the last glacial episode, the glacier retreated and left the large lateral moraine that now forms the southeast side of Emerald Bay and the recessional moraine that nearly closes the mouth of the bay. Eagle Point and Emerald Point are on this recessional moraine.

Inspiration Point - From Fallen Leaf Rd. drive N on Hwy. 89 5 mi. to the Inspiration Point parking area on the S side of Emerald Bay.

One mile south of Inspiration Point, Highway 89 begins to climb the large lateral moraine on the south side of Emerald Bay. The road then follows the crest of this moraine to Inspiration Point. From the crest of the moraine there are good views of Emerald Bay to the north and Cascade Lake to the south. Cascade Lake is formed by lateral and recessional moraines deposited by a glacier that moved down Cascade Creek. At Inspiration Point, the highway crosses a fault. The Sierra Nevada was uplifted on the west of this fault and the Tahoe basin subsided on the east side. This same fault forms the head of Cascade Lake and Fallen Leaf Lake. The fault dies out rapidly to the north, and the downfaulting of the Tahoe block is transferred to another fault that lies in Lake Tahoe just east of Rubicon Point.

Vikingsholm Parking - From Inspiration Point drive 1 mi. N to the Vikingsholm parking area. Vikingsholm, a Scandinavian-style mansion built in 1929, is a one-mile hike from the Vikingsholm parking area; guided tours in the summer. Emerald Bay is in Emerald Bay State Park (530-525-7277).

From here there is an excellent view of Emerald Bay and the recessional moraine at the mouth of the bay. The head of the bay lies in the granitic rocks of the Sierra Nevada batholith, and there are good exposures of these granitic rocks at the Vikingsholm parking area. Fannette Island is a small roche moutonnée of basement rock that was overridden by the Emerald Bay glacier. As shown on the Tahoe location map (p. 140), the bay lies on a sliver of basement rock between two of the large boundary faults on the west side of downdropped Tahoe block.



The low ridge at the mouth of Emerald Bay is a recessional moraine. The bay is connected to Lake Tahoe through a narrow gap in this moraine. Fannette Island in the center of the bay is an outcrop of granite that rises 150' from the water.

④ **Bliss State Park**

Most of the granitic rocks in the High Sierra are fresh and hard, since they were scoured and cleaned by glaciers during the Pleistocene glacial episodes. However, the granitic rocks at D. L. Bliss State Park are deeply weathered. The weathered rocks were preserved here because this area lies between the Emerald Bay glacier to the south and the Meeks Bay glacier to the north, and this area was never covered by glaciers.

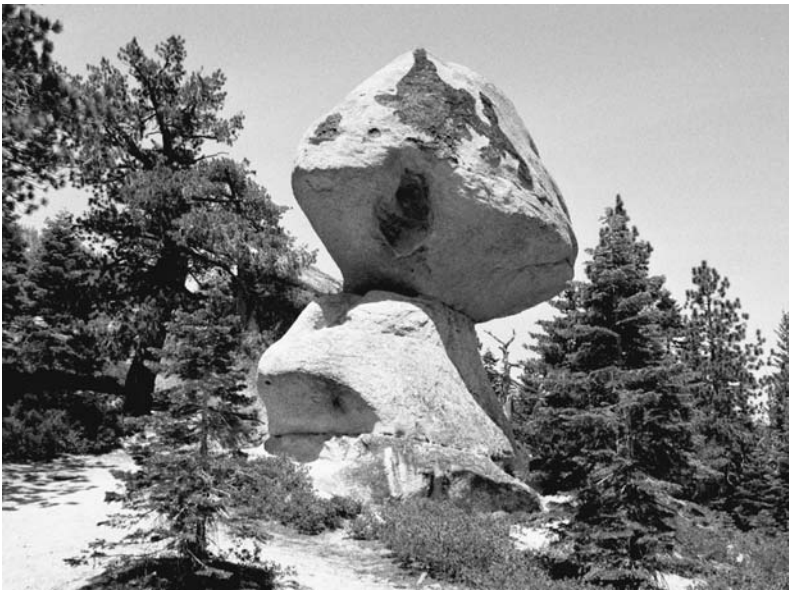
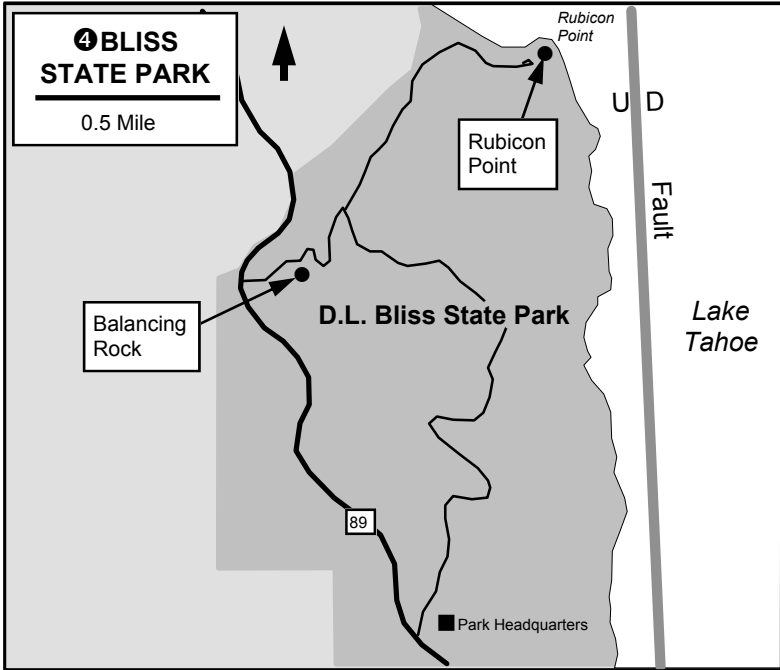
The deep weathering of these granitic rocks has produced a number of large rounded boulders that can be seen throughout the park. This weathering has been taking place for several million years. As in the Alabama Hills, the weathering follows the joints in the granite, and the granite along the joints slowly decomposes and is washed away. Granite that is cut by intersecting joints develops rounded ledges and boulders, depending on the joint pattern. Many of these rounded boulders can be seen in the roadcuts along Highway 89 just south of the park entrance. However, the most impressive example of a large rounded boulder is in the park, at Balancing Rock.

Balancing Rock - *The entrance to D.L. Bliss State Park (entrance fee) is on Hwy. 89 2 mi. N of the Vikingsholm Parking area; from the park entrance drive 2 mi. to the Balancing Rock Nature Trail; hike the 0.5 mi. loop trail; easy. For information, phone 530-525-7277 or visit the website www.parks.ca.gov.*

There are many good examples of rounded granite boulders and ledges along the Balancing Rock nature trail. However, the highlight along the trail is Balancing Rock, a 130-ton granite boulder perched on a granite base. The boulder is separated from the base by a large near-horizontal joint, and the granite along that joint is in the process of weathering. In fact, you can see a hole through this joint if you look at the right angle. The height of Balancing Rock gives an indication to the amount of weathering that has occurred in this area. The original granite surface was once at least as high as the top of the rock.

Rubicon Point - *From Balancing Rock, drive 1 mi. east to Rubicon Point parking area.*

Rubicon Point is a 600-foot high granite promontory that lies at the south end of Rubicon Bay. Immediately east of Rubicon Point, the shoreline drops 1,411 feet vertically to the bottom of Lake Tahoe. This steep underwater cliff is a fault scarp, one of the many faults that were responsible for the downdropping of the Tahoe block. The fault scarp is preserved because it was not covered by younger glacial debris.



Balancing Rock in D. L. Bliss State Park is a large rounded boulder of granitic rock formed by deep weathering along jointed granite.

⑤ **Truckee River**

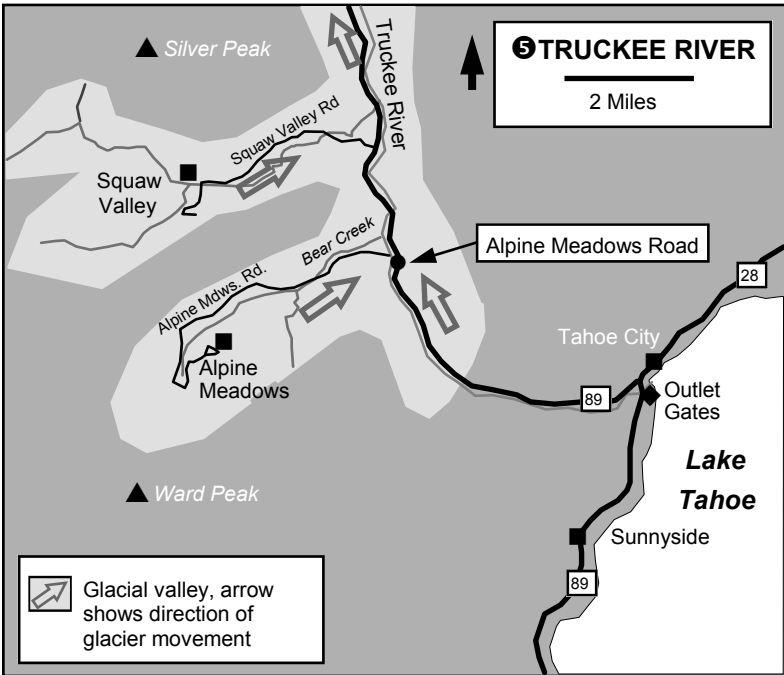
The water level of Lake Tahoe remains constant at 6,229 feet. This level is maintained because more water enters the lake than is lost by evaporation. The excess water flows into the Truckee River through the Outlet Gates, just south of Tahoe City. From the Outlet Gates, the Truckee River flows north through a narrow, deep, 12 mile-long river valley as it drops 400 feet on its way to Truckee. This section of the river cuts through the volcanic rocks that form the northern dam for the lake.

The water level of Lake Tahoe has not always been constant. Ever since the volcanic rocks began to dam the lake, the level of the lake has risen as the outlet was blocked by eruptions of new volcanic material and has fallen as the volcanic rocks were eroded by the river. The level of the lake also fluctuated during the Pleistocene glacial episodes, rising as much as 600 feet when glaciers blocked the Truckee River valley and falling during interglacial episodes. Ice does not make a very good dam. When the water level behind an ice dam reaches about 9/10's the thickness of the ice, the ice begins to float and the dam is undermined by the water. When this happens, the dam fails catastrophically and huge amounts of lake water are suddenly released down the river valley. This happened repeatedly along the Truckee River during Pleistocene glaciation. Large boulders, as much as ten feet in diameter, were carried by these floods along the Truckee River as far as Reno.

Alpine Meadows Road - From the junction of Hwys. 89 and 28 in Tahoe City drive 3.5 miles N on Hwy. 89 to Alpine Meadows Road; park.

From its intersection with Highway 89, Alpine Meadows Road goes west up the Bear Creek valley to the community of Alpine Meadows. During the Pleistocene glacial episodes, the Bear Creek glacier flowed down this valley and then north along the Truckee River valley where it was joined by other glaciers and continued to Truckee. When these glaciers melted, they left behind lateral moraines and other piles of glacial debris. On the east side of this road intersection, you can see some of this glacial material along the side of the valley. The moraines are composed of a great variety of poorly sorted volcanic and igneous rocks in a jumbled mass.

At Layton State Park you can see the Outlet Gates for Lake Tahoe. The park is on the south side of the HW 89 bridge across the Truckee River. The outlet was first dammed in 1870 with rock and timber. The present dam was built in 1910. The park is also the site of the North Lake Tahoe Historical Society Museum (530-583-1762).



The Truckee River valley one mile south of Alpine Meadows Road. During the Pleistocene glacial episodes, glaciers periodically blocked this valley and formed a dam that raised the water level of Lake Tahoe as much as 600 feet.