



Lake Tahoe from Eagle Rock, west shore Lake Tahoe, California

Guide for the Earth Science Week Field Trip, October 7, 2023

Nevada Bureau of Mines and Geology Educational Series E-72

Earth, Wind, and Fire

The dynamic evolution of the eastern Sierra Nevada
and western Great Basin, Nevada and California

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2023



University of Nevada, Reno



Nevada Bureau
of Mines
and Geology

Suggested Citation:

Micander, R., Burke-Ruhl, G., Dee, S., Henry, C.D., Kozloski, R., and Koehler, R.D., 2023, Earth, wind, and fire—the dynamic evolution of the eastern Sierra Nevada and western Great Basin, Nevada, and California (Guide for the Earth Science Week field trip, October 7, 2023): Nevada Bureau of Mines and Geology Educational Series 72, 32 p.

Front cover photograph by Rachel Micander.

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Logistics

The field trip starts at the Great Basin Science Sample and Records Library / Publication Sales and Information Office, which we will refer to as the **Gold Building** throughout this guidebook. To navigate to the Gold Building from downtown Reno, take US-395 North to Exit 71 for Dandini Boulevard. Follow Dandini Boulevard east, veer right onto Raggio Parkway, and the Gold Building will be on your left. The address is **2175 Raggio Parkway, Reno, NV 89512**.

Please plan to arrive at the Gold Building parking lot by **8:00 am**. Following some introductory comments, route plans, and discussion, we will depart by **8:30 am**. We will mostly be traveling on paved highways and roads and some gravel parking areas with some short hikes interspersed throughout our day. Due to the nature of where we are going on this trip, carpooling will be particularly important.

Since parking is anticipated to be tight in many places we will not be maintaining a caravan as we have in years past. We will provide locations for each of our stops in Google maps. Please work your way to these stops and park smartly and wisely, where legal to do so. Once parked, please meet up with the rest of the group, and once we reach critical mass, we will begin our discussions.

Please pack a lunch and snacks, and bring plenty of water, sturdy shoes, appropriate gear, camera, hand sanitizer, and a smile.

Introduction

This year, Earth Science Week is celebrating the theme “Geoscience Innovating for Earth and People”. In keeping with the theme, our 2023 field trip will take us on a tour of the Truckee and north Lake Tahoe areas, and the Truckee River west of Reno. We will discuss some aspects of the geosciences that are helping our mountain communities work towards healthier and increasingly sustainable lifestyles, while implementing environmental problem-solving in the Lake Tahoe Basin and beyond. We will discuss the geology and ecosystems in these regions, past mining and logging activities, landscape evolution, and natural hazards. We will also learn about microplastics in Lake Tahoe, which provides drinking water to downstream communities, and research that is being done to study these substances.

Our first stop will be at Summit Haus on Donner Pass off of Old Highway 40, near Donner Ski Ranch and Sugar Bowl resort. Here we will discuss the tectonic history and evolution of Donner Summit, Donner Lake, the Basin and Range Province, and the paleovalleys that traveled through this region prior to Sierra Nevada uplift. This location provides us with an excellent view of the old railroad and snowsheds—we will discuss the history of the area before moving on. Our next stop will be at Eagle Rock along the west shore of Lake Tahoe. We will hike up to the top of this fairly young (geologically speaking) volcanic edifice and discuss the geomorphology and glaciation of the region along with landslides and tsunamis that have impacted Lake Tahoe in the past. From here, we will travel to the Gatekeepers Museum located at the outlet of Lake Tahoe, where we will have lunch and discuss the hydrology of the lake along with the various plant and animal species found in the Lake Tahoe Basin. Following lunch, we will journey over the Dollar Point fault on the north shore of the lake before heading over Brockway Summit and descending into Martis Valley. We will stop at the Truckee River Legacy Trailhead in Glenshire, where glaciations, terraces, faulting, and land development will be reviewed. Finally, we will make our way back down the Truckee River canyon wrapping up our tour at Mayberry Park. Here, we will discuss floodplains along the Truckee River, sandstone and other sedimentary deposits, and the history of the ditches that supply water to the Truckee Meadows.

Approximate schedule

- 8:00 am – Meet at the Gold Building
- 8:30 am – Depart from the Gold Building parking lot
- 9:20 am – **Stop 1:** Donner Pass/Summit Haus
- 10:20 am – Depart Donner Pass/Summit Haus
- 11:00 am – **Stop 2:** Eagle Rock
- 12:20 pm – Depart Eagle Rock
- 12:40 pm – **Stop 3:** Truckee River outlet/Gatekeepers Museum
- 2:00 pm – Depart Truckee River outlet/Gatekeepers Museum
- 2:40 pm – **Stop 4:** Truckee River Legacy Trail/Glenshire Trailhead
- 3:20 pm – Depart Truckee River Legacy Trail/Glenshire Trailhead
- 3:50 pm – **Stop 5:** Mayberry Park, west Reno

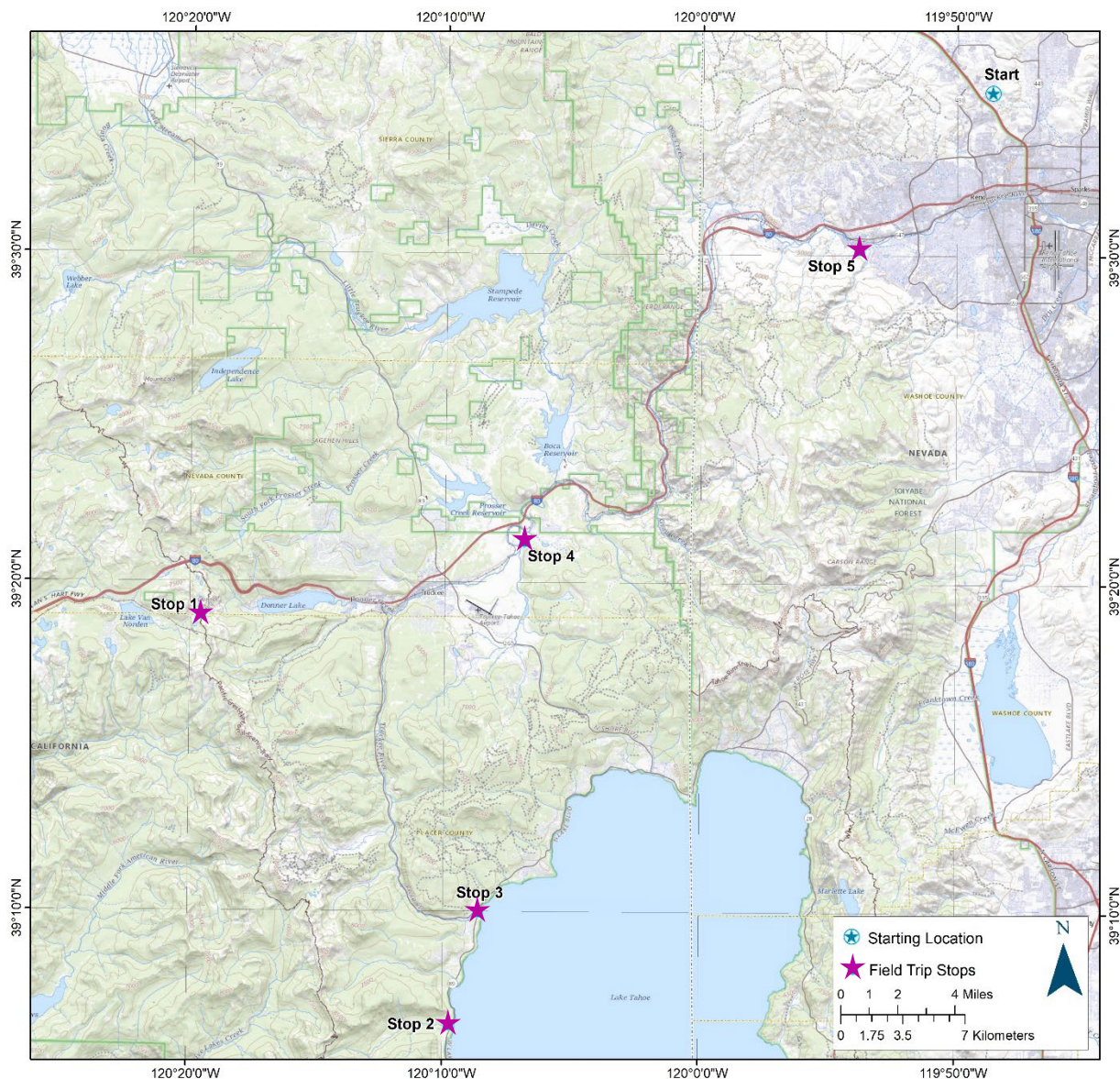


Figure 1. Overview map of starting location and field trip stops.

Points of interest along Old Highway 40 as we make our way to the Sierra crest

Lake Van Norden and Summit Valley



Figure 2. Top: Anglers targeting catfish at Lake Van Norden (photo circa 1950). Bottom: Lake Van Norden occupied a significant portion of Summit Valley when full (photo circa 1955). Photos courtesy of Donner Summit Historical Society.

The headwaters of the South Yuba River originate near Donner Pass and flow west, eventually merging with other forks of the Yuba River, joining the Sacramento River, the delta, and finally into the San Francisco Bay and Pacific Ocean. What a life this river must have! However, before making its epic journey down canyon, carving through granite cliffs and ancient river valleys, it flows into Summit Valley and the now mostly dry Lake Van Norden. Prior to the construction of a dam as early as 1874, the valley was simply a meadow with streams flowing freely through it. The dam was enlarged in 1916 to provide more water and electricity to downstream communities, including orchards being planted in the Central Valley. When full, the lake held 5,600-acre feet of water, providing all sorts of outdoor recreation for the community in Summit Valley and beyond (fig. 2). Every spring, Lake Van Norden would fill with snowmelt, and water was let out each summer to sustain flows in the South Yuba River, generating electricity downstream. The lake all but emptied during the late summer and fall, allowing for native grasses to grow and sheep to graze before winter.

In 1976, the California Division of Safety of Dams and Pacific Gas and Electric (PG&E) (which now owned the dam) explored options to

further enlarge the dam. However, the original dam was constructed on unstable glacial till and PG&E determined it was not cost-effective to fix the dam. As a result, the dam was notched to hold only 150-acre feet of water, returning much of the valley to a meadow. Currently, conservation efforts are underway to return this wetland to its original, biologically diverse state.

Road cut/parking lot near Sugar Bowl Resort

Keep your eyes peeled for a large road cut and parking lot on your left as we drive east on Old Highway 40 from Soda Springs towards Donner Pass. The reddish diagonal layer is an ancient soil (paleosol) overlying granitic rock (120 Ma) of the Sierra Nevada batholith. There is a white tephra layer overlying the paleosol and granite (fig. 3). To the south, Mount Disney and the Palisades at Sugar Bowl Resort are visible. The rocks capping Mount Disney are from a volcanic debris avalanche, while the Palisades are composed of pyroclastic flows.



Figure 3. Looking north along Old Highway 40 at ancient soils and volcanic ash (tephra) layers overlying ~120 Ma granitic rock. Geologist for scale. Photo: R. Micander

STOP 1 [39.316314°N, -120.3263438°W](#) [Donner Pass/Summit Haus](#)



SPECIAL NOTES: As with most stops on this year's field trip, parking will be tight. Please do **not** park inside or in front of cones next to buildings. Feel free to park in the gravel area at stop 1 and **not** on the paved path. We may need to double park. There is some parking along the road as well.

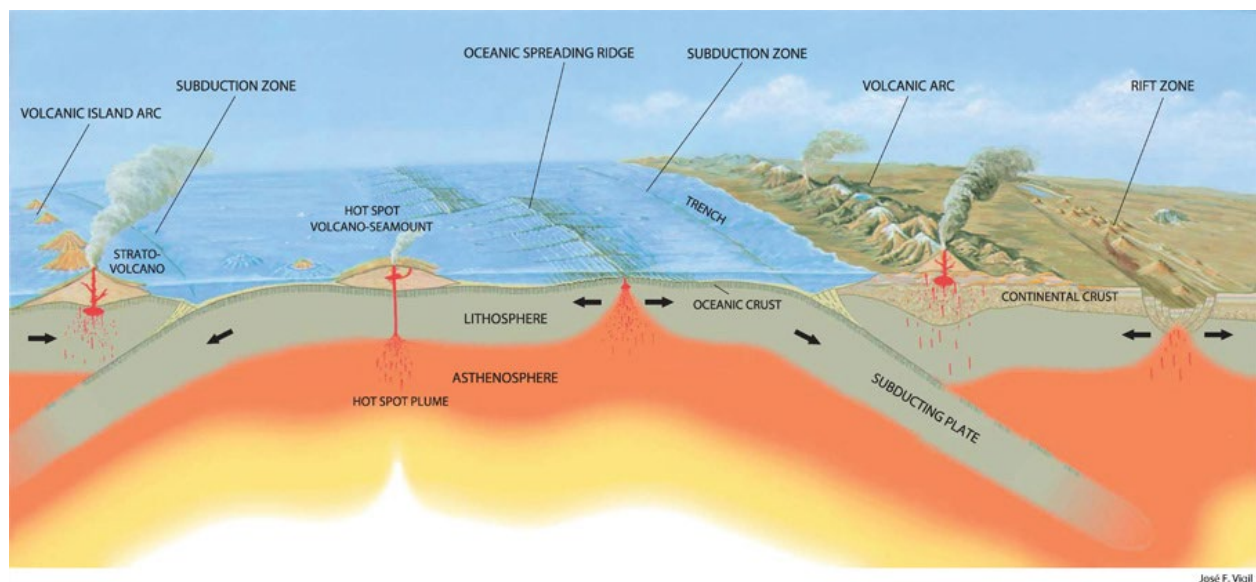
Figure 4. Looking east towards Donner Lake from Donner Pass. The high mountains in the background are the Carson Range of the Great Basin. The town of Truckee sits just beyond the east end of Donner Lake. Reno and the Truckee Meadows are located behind the Carson Range. Photo: R. Micander

Geographic Overview

As we stand on this outcrop above Donner Lake, take a moment to look around you at the surrounding peaks and terrane. We are more or less standing on the Sierra crest with the Great Basin stretching out to the east of us and the Sierra Nevada mountains and foothills to the west. The mountains far to the east are the Carson Range—Reno and the Truckee Meadows are beyond this range, obscured from view. The high point in the Carson Range is Mount Rose (10,785'). There are two ridges on either side of Donner Lake—the ridge to the north is unnamed and Schallenberger Ridge is on the south side of the lake. Donner Peak and Mount Judah are the high points south of our location and Mount Stephens is the high point directly to the northeast. From here, we have an excellent view of the old railway grade and snowsheds below.

Geologic History

Our parking area provides a good view of the major geologic features around Donner Pass. The rocks we can see are all igneous, that is formed from magma or molten rock that either solidified deep beneath the earth as plutons or erupted in volcanoes to form a variety of volcanic rocks. Both plutonic and volcanic rocks are present here, and both have an origin related to plate tectonics (fig. 5). We are on the North American plate, which consists of the North American continent all the way to the east coast of the U.S. and halfway into the Atlantic Ocean. The part that makes up the continent is called a continental plate, and the part that underlies the ocean is an oceanic plate. Over the last few hundred million years, other tectonic plates to the west dove beneath this western continental part of the North American plate in a process called subduction. Until about 3 million years ago, an oceanic Farallon plate was subducting beneath us. Before that, other tectonic plates, including some that were parts of continents, subducted beneath North America. As the subducting plate moves down beneath the overriding plate and into the mantle, the plate is heated, releases a lot of water and other volatiles, which react with the very hot mantle (1,000°C) to generate magmas. Those magmas rise, interact with the crust, and either solidify at depths of several kilometers or rise to the surface and erupt as volcanoes.



José F. Vigil

Figure 5. Block diagram illustrating plate tectonics and the three types of plate boundaries. The uppermost part of the Earth is made up of several rigid plates that move as units relative to one another. Divergent boundaries occur where two plates move away from one another (rift zone, oceanic spreading ridge). These include mid-oceanic ridges in which molten basalt wells up to replace the diverging crust. Convergent boundaries occur where one plate dives beneath another. A volcanic arc, a chain of volcanoes, forms at the overriding plate above the down-going plate. Transform faults occur where two plates move parallel but in opposite directions from one another. Image from Oregon Department of Geology and Mineral Industries, modified from an image by José F. Vigil and Robert I. Tilling, courtesy of U.S. Geological Survey.

The parking area is cut into the type of igneous rock that solidified at depth. Specifically, the rock is 114-million-year-old granodiorite of the geologically famous Sierra Nevada batholith. A batholith is a large body of intrusive igneous rock which formed beneath the Earth's surface from magma. Batholiths are often composed of a collection of plutons (smaller bodies of magma which cool slowly underground) that coalesce in the subsurface. These batholiths also generally form over tens of millions of years. This part of the Sierra Nevada batholith is a good example, with individual plutons in this area forming between 120 and 90 million years ago. Granodiorite is a type of granite or granitic rock, which is a very common type of rock rich in silica (SiO_2) and consists of the minerals quartz, feldspars, biotite (black mica), and hornblende. The magma that formed this granodiorite was probably at about 750°C . You can call the rock here either granodiorite or granite, and the trip leaders will happily identify the rocks and minerals for you. Geologists are like physicians. They come up with lots of odd sounding names to confuse non-geologists and allow us to earn the big bucks.

After the batholith formed, what is now the Sierra Nevada was part of a highland that continued eastward through Nevada and into western Utah. Continuing with the big names, this highland is called the Nevadaplano, a takeoff or play on words on the Altiplano of the Andes. West-flowing river systems with headwaters in central Nevada traversed the Nevadaplano carving paleovalleys into the highland over the course of tens of millions of years. The material eroded by these rivers was transported into the Pacific Ocean, which was located in the Great Valley (California's Central Valley) at the time. We are standing just east of one of these major paleovalleys (fig. 6).

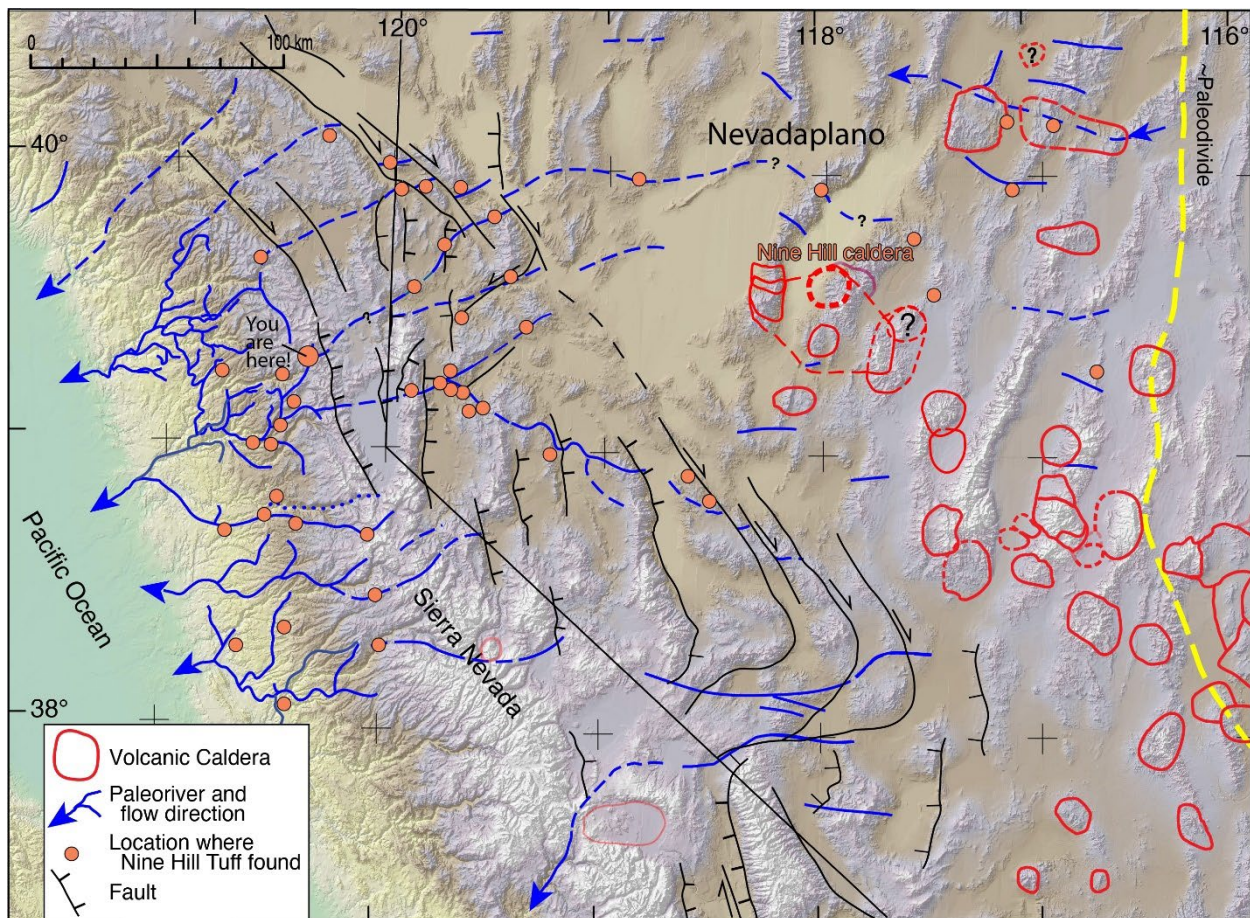


Figure 6. Map showing calderas (supervolcanoes) in central Nevada, ancient river systems that drained the high Nevadaplano to the Pacific Ocean (in the Great Valley until about 25 million years ago), and the Nine Hill Tuff, which erupted from the labeled caldera. The Nine Hill Tuff flowed down the river valleys and likely destroyed much of what was in its path.

This leads us to the first of two major volcanic episodes that affected this region. The dark cliff partway up the ridge above Old 40 Bar and Grill is the Nine Hill Tuff, a type of volcanic rock called an ash-flow tuff. Ash-flow tuffs are a mix of originally hot magmatic particles including pumice, volcanic gas, and older rock fragments that form from giant, very explosive volcanic eruptions. Beginning about 45 million years ago, ash-flow tuffs began to erupt from giant volcanoes called calderas (or “supervolcanoes”) in a belt through central Nevada (fig. 6). Ash-flow tuff eruptions are less dense than water but denser than air. Therefore, they flow down river valleys somewhat like water does, but as huge, very hot volcanic clouds. The eruptions of Mount Saint Helens, Pinatubo, and Vesuvius that destroyed Pompeii in AD 79 are similar but were very small compared to the Nevada eruptions. The Nine Hill Tuff erupted from a caldera in the Clan Alpine Mountains east of Fallon and flowed through here all the way to the Pacific Ocean in the Great Valley. You may have heard the term supervolcano applied to the volcanoes of Yellowstone National Park, which has three. Nevada had as many as 100.

The rocks that cap the ridge of Donner Ski Ranch, above the Nine Hill Tuff, are volcanic rocks that formed during the second, younger volcanic episode. The rocks that make up the higher part of the ridge are lavas and tuffs that erupted from nearby volcanoes between about 7 and 13 million years ago. These volcanoes mostly erupted basalt and andesite. Basalt is low in silica, and andesite has a silica content midway between basalt and granite. A type of andesite lava caps Boreal Ridge, and the Donner Ski Ranch ridge consists of andesite tuffs and sedimentary rocks that were eroded from the volcanic rocks. More of these rocks are exposed on Mounts Disney, Lincoln, and Judah in an arc to the south.

The volcanoes that produced these rocks were part of the ancestral Cascade volcanic arc, which was here until about 3 million years ago. The Lake Tahoe–Reno region had many volcanoes like Mount Shasta, Mount Saint Helens, and Lassen Peak. Due to changes in plate tectonics, the southern end of the active Cascade arc is now at Lassen Peak (~165 km to the north). The active Cascade arc continues from Lassen Peak through Mount Shasta, Mount Hood near Portland, Mount Rainier near Seattle, and into southern British Columbia.

All volcanoes are hazardous, and the Lake Tahoe–Reno area 3 million years ago would not have been the great place to live that it is now. Lava flows can cook anything they run into, but explosive eruptions are even more hazardous. The 1980 eruption of Mount Saint Helens, where about 1 km³ of magma erupted explosively, took many lives, and decimated a large area around the volcano, is a good example of the hazards volcanoes can pose. Volcanic debris flows form when hot volcanic rock interacts with water to make a hot slurry that flows rapidly, as much as 50 mph, down the flanks of volcanoes (fig. 7). Since debris flows travel much more rapidly than lavas do, they can inundate an area with very little warning.



Figure 7. Debris-flow deposit composed of very large volcanic blocks in a matrix of smaller blocks (near Mount Houghton, Nevada). This was transported as a slurry of heated water and variably hot blocks, so it was contemporaneous with volcanic activity. We can tell the deposit was hot because the large block directly above the person has radial cooling joints, which form as hot material cools and shrinks. Most cooling joints are vertical like at Devils Postpile National Monument near Mammoth, California. The joints in this photo radiate from the middle of the block to its edge (red arrows) because the initially hot block cooled inward from its edge. Photo: C. Henry

Mafic inclusions

As you walk around at this stop, take a moment to search for rounded bits of dark rock within the lighter colored granitic rock (fig. 8). These are mafic inclusions that formed in the early stages of pluton development. When the pluton was first forming, the magma (or melt) was more mafic (mafic meaning dark in color, resulting rock composed of darker, heavier minerals). When the granitic melt was injected into the pluton, bits of the mafic rocks that had already started to solidify were incorporated into the melt and preserved as the mafic inclusions we see today.



Figure 8. A mafic inclusion in granodiorite. Photo: Wikipedia

Quaternary geology: faults and glaciation

Three periods of glaciation have been recognized in this part of the Sierra Nevada: the Tioga, Tahoe, and Donner Lake (fig. 9). However, only the two youngest (Tioga and Tahoe) are well understood. Valley glaciers flowed to the west and east from ice caps along the Sierra crest, including a large ice cap that sat just to the west of our location at Donner Pass. East-flowing glaciers carved the valley now occupied by Donner Lake and parts of the town of Truckee. The cliff faces we are standing on were formed by the glaciers sliding eastward and eroding away the volcanic and plutonic bedrock. Many of the ridges we see around Donner Lake are glacial moraine deposits left behind by the glaciers after they receded. The younger Tioga glaciation deposited moraines in the low ridges that dam the east end of Donner Lake. The older Tahoe glaciation had larger, more extensive glaciers with thicker ice that deposited moraines to higher elevations including the prominent ridge on the north side of Donner Lake with homes built on the moraine crest. These glaciers also left behind striations and polish on the granitic rocks we are standing on and placed glacial erratics across the landscape.

The landscape to the east of the overlook is shaped by relatively young tectonic faults that downdropped the valleys to the east. These faults are largely north-trending normal faults (fig. 10) with some component of strike-slip displacement. One such normal fault is located between Donner Pass and the west end of Donner Lake. This fault has downdropped the contact between the volcanic rocks and the underlying granodiorite several hundred feet on the east side of the fault.

Human History in Donner Pass

The area as a whole is commonly referred to by locals as Donner Summit. At a more detailed level, Donner Pass proper is only the section through which Old Highway 40 runs between Boreal Ridge and Mount Judah, topping out at an elevation of 7,056 feet. Just to the north, where Interstate 80 crosses the Sierra crest at an elevation of 7,240 feet between Boreal Ridge and Castle Peak, is called Euer Saddle, and is referred to as Donner Summit by CalTrans and other public agencies.

Native American people have inhabited the Donner Summit area for thousands of years, as evidenced by the petroglyphs along Old Highway 40 (Donner Summit Historical Society, 2016). Starting in the late 1840s, the various emigrant trails were blazed as waves of Euro-Americans migrated westward, looking for routes across the Sierra Nevada in their pursuit of gold and better opportunities. The route known as the Truckee Trail, part of the greater California Trail network, was pioneered by the Stephens-Townsend-Murphy Party in 1844, the first known emigrant party to cross the Sierra Nevada (Richards, 2004). The route proved difficult, with many treacherous river crossings in the boulder-strewn canyons, but the pioneers were fortunate to have the help and guidance of a local Paiute chieftain known as Captain Truckee, for whom the settlers named the river. Captain Truckee was the grandfather of native activist Sarah Winnemucca (Zanjani, 2001; Gradydon, 1986).

The pass and lake are named for the unfortunate Donner Party that was stranded nearby during the winter of 1846. Already seriously delayed on their journey, the party became stranded in heavy snows near present day Donner Lake. Running dangerously low on supplies, the party sent out a few of their members to cross the pass and return with help. By the time they were rescued, only 45 of the 81 people who went into winter quarters survived, some having resorted to cannibalism (Stewart, 1963).

The Sierra Nevada would continue to prove a daunting barrier to east-west travel for many years, only being conquered in 1868 by the construction of the Central Pacific Railroad. Over nearly three years of sustained blasting and construction, a workforce of primarily Chinese laborers built a series of tunnels through the granitic rocks at top of the pass, the longest, Tunnel #6, measuring 1,659 feet long. The laborers also worked to lay track, clear obstacles, and build retaining barricades and snowsheds, which were vitally important to keep the tracks clear of heavy winter snows (Gilliss, 1870). The concrete sheds you see today were mostly built in the early 1900s, replacing older wooden sheds, which were prone to collapse or catching fire (Schrantz, 2019). In 1925, a second tunnel was cut through the rock several miles to the south in order to supplement the original Tunnel #6. This was officially named Tunnel No. 41, but was also referred to simply as the Big Hole, and was both longer and straighter than the original railroad tunnel. Both tunnels remained in operation until 1993, after which Tunnel #6 closed and the Big Hole became the sole train route through Donner Pass (Fullwood, 2005).

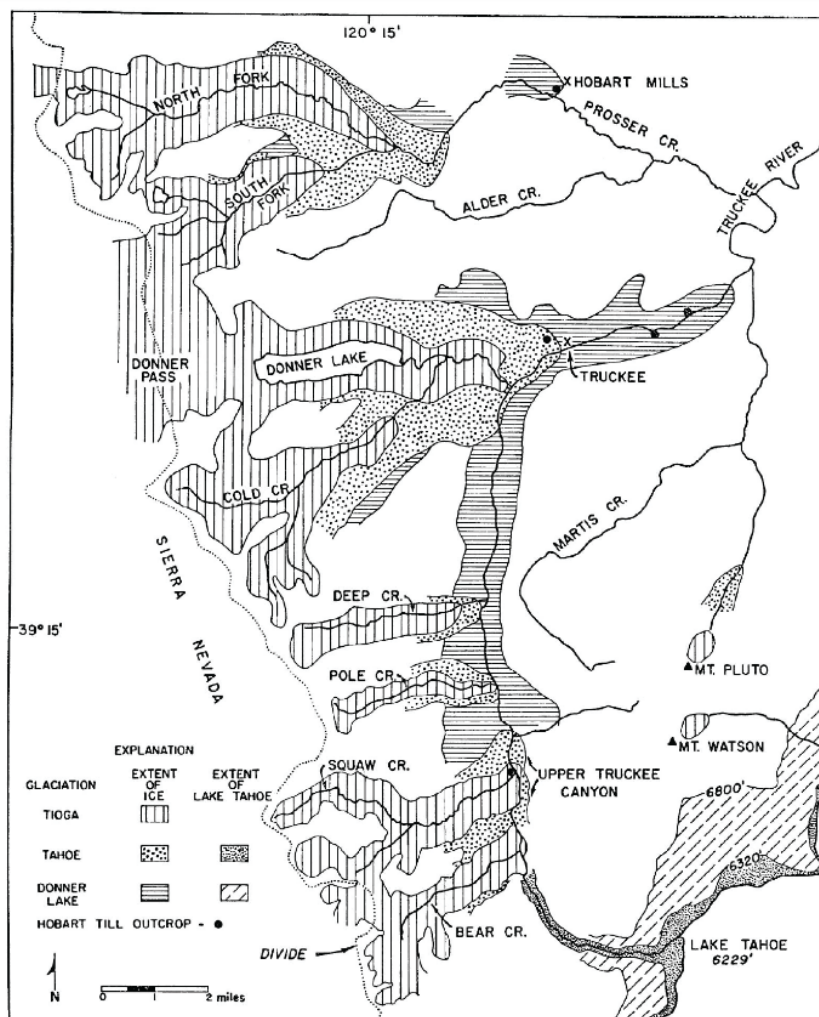


Figure 9. Original mapping of the extent of Sierra Nevada glaciers from Birkeland (1964).

Points of interest as we wind down Old Highway 40 towards Donner Lake and through the Truckee River canyon on Highway 89

Geology in Action

As we wind down Donner Pass, keep your eyes out for a large rockfall that closed this section of Old Highway 40 for quite some time this year (2023). New pavement shows us where the rocks fell from the cliffs and the fresh granitic rock face can be seen on the cliff wall to your left. For those climbers among us, this particular rock face is known as the Road Cut.

Glaciers and Floods

As we leave Truckee and head south towards Tahoe City, imagine glaciers coming down various tributary valleys to the west (right) and intersecting the Truckee River canyon. Olympic Valley is an excellent example of the U-shaped valleys and features carved from these glaciers. The glaciers did more than carve out valleys, though. During periods of time, the glaciers would dam the flow of the Truckee River with ice. These dams would occasionally burst, resulting in glacial outwash floods that carried massive amounts of water and sediment down the canyon. We will see evidence of these floods at Stop 4.

STOP 2 [39.1083674°N, -120.161674°W](#) [Eagle Rock Trailhead](#)

SPECIAL NOTES: Please park where you can. There is some trailhead parking at Eagle Rock proper, but other parking can be found in the neighborhoods and side streets nearby. Please respect driveways and no parking signs. Once we all reconvene at the Eagle Rock Trailhead, we will embark on a 15- to 20-minute steep hike up a well-maintained trail (but watch out for roots!). Please note as we near the top of Eagle Rock, the terrane becomes uneven—watch your step!

Geographic Overview

We are standing along the edge of the Lake Tahoe Basin, which is the western-most basin of the Basin and Range Province. The Sierra Nevada rise behind us, and the Carson Range bounds the eastern edge of the basin. Cave Rock is visible across the lake for those keen-eyed viewers. Beyond the Carson Range to the east are the Carson Valley, Washoe Valley, and Truckee Meadows—just a few of a series of valleys separated by mountain ranges that span far to the east across Nevada and some of Utah, ending at the Wasatch Range east of Salt Lake City. The base of Lake Tahoe is roughly the same elevation as the base of the Carson Valley, giving visitors an idea of how much water fills this basin. Here at Eagle Rock, we are standing along the sides of McKinney Bay—a large bay on Lake Tahoe’s west shore that we will discuss later.

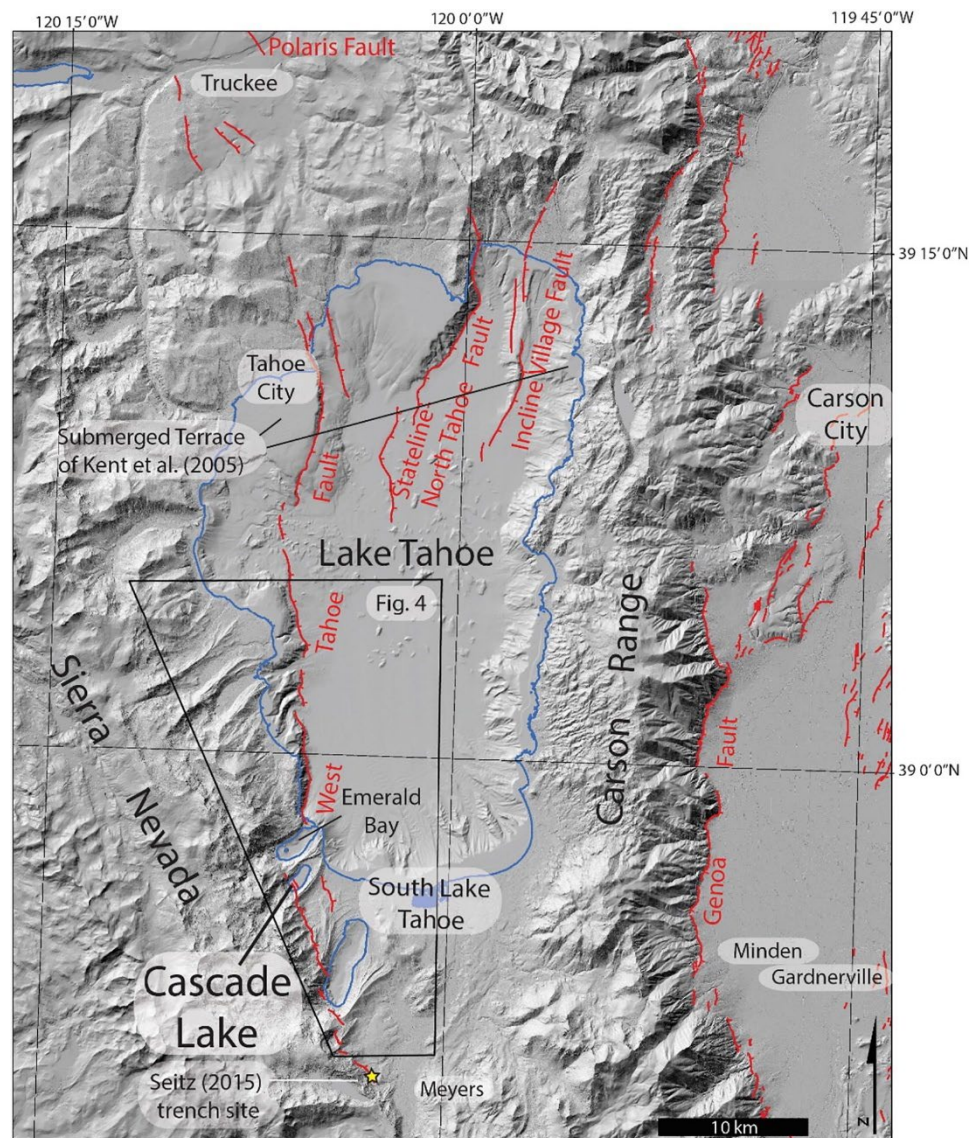
Geology

The Quaternary geologic history of Lake Tahoe has been influenced by active faulting, volcanism, and glaciations. The lake basin was originally formed by active faulting along its western and eastern margins during the last 2–3 million years, and actually occupies a tectonic half-graben, a valley formed by tectonic down dropping due to extension of the crust. The area around Tahoe City is a topographic low point in the Tahoe basin as well as the outlet of the Truckee River, which flows to Pyramid Lake. Quaternary volcanism temporarily dammed parts of the Truckee River below the outlet causing the lake level to fluctuate. These included basaltic flows near the town of Truckee and andesitic mudflow breccias near the outlet in Tahoe City. Lake levels also fluctuated due to periodic glaciations, which led to valley glaciers extending across the river, rising the height of the lake. Catastrophic failures of these ice dams caused massive floods (known as jökulhlaups) which rapidly lowered the lake level. These floods transported massive boulders downstream, which were deposited on Truckee River terraces in the Verdi area.



Figure 10. (above) Fault block diagrams showing movement along strike-slip and normal faults. Image credit: U.S. Geological Survey

Figure 11. (right) Map of Quaternary faults in the Lake Tahoe Basin (Pierce et al., 2017) Lake Tahoe and Cascade Lake shorelines shown are blue; active faults are red.



In front of us is a major underwater fault system known as the West Tahoe-Dollar Point fault zone. This fault system is largely a normal fault with some strike-slip displacement. Tectonic slip on the fault system is driven by the northward migration of the Sierra Nevada relative to the Carson Range effectively pulling the Lake Tahoe Basin apart. This fault extends north towards Tahoe City, where it continues on land just east of Dollar Point. Slip on the fault has dropped the basin down to the east from where we are standing. A similar system of faults, collectively known as the Sierra Nevada frontal fault system, bounds the eastern side of the Carson Range and extends up into the Reno area.

Glacial Activity

We are standing at the mouth of Blackwood Creek canyon, which is a classic U-shaped glacially carved valley, as are many of the valleys along the west shore of Lake Tahoe, including Ward Creek canyon and Emerald Bay. Looking to the south, we can see glacial moraine crests extending from these valleys into the Lake Tahoe Basin, giving a sense of the extent of ice. The major glaciations recorded by these moraines are the younger Tioga glaciation and the older Tahoe glaciation. Relatively new analytical techniques allow geologists to date the length of time boulders deposited on the crests of these moraines have been exposed at the surface. The technique is called ^{10}Be terrestrial cosmogenic nuclide surface exposure dating. Results from a recent study on the moraine crests on the west shore of Lake Tahoe found that the glacial maximum for the Tioga glaciation occurred ~22,000 years ago and the Tahoe glacial maximum occurred at ~120,000 years ago (Pierce et al., 2017). If you look around the top of Eagle Rock, you can find granite boulders that were deposited by the glacial ice. This granite was plucked from the crest of the Sierra Nevada located several kilometers to the west.

Landslides, Tsunamis, and Seiches, Oh My!

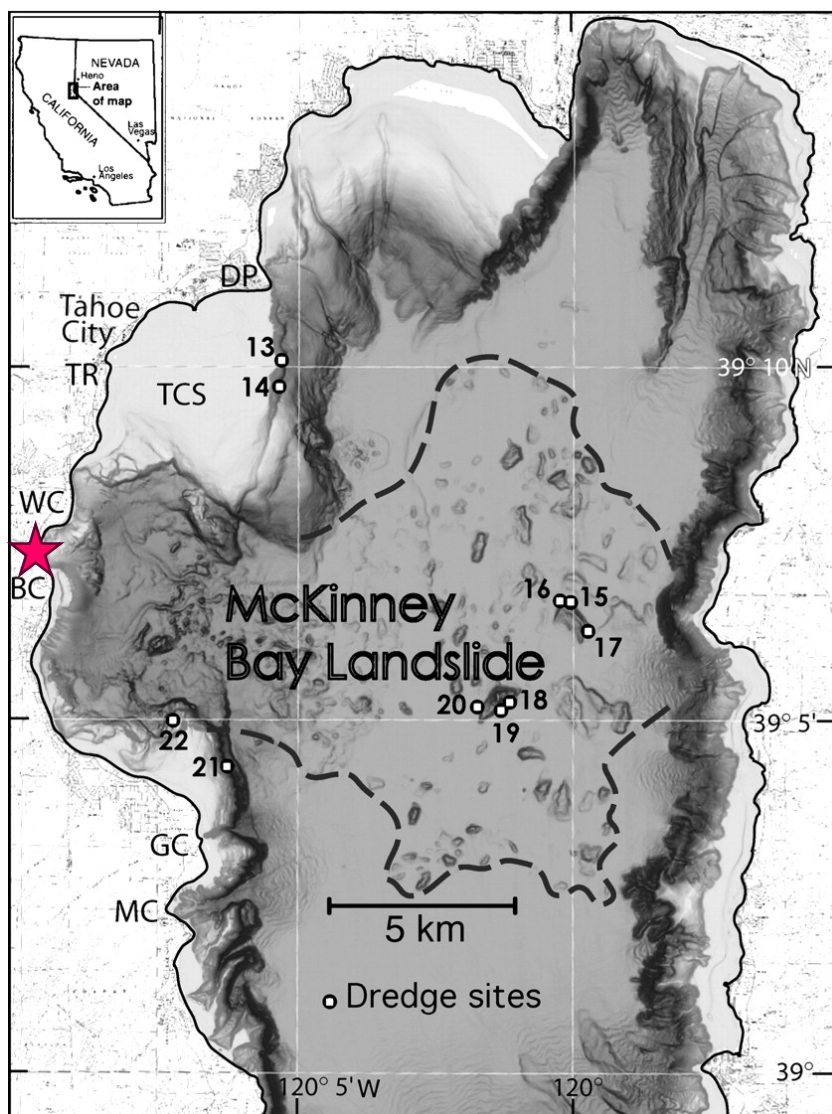


Figure 12. Bathymetric features within Lake Tahoe showing the McKinney Bay landslide, with its head and alcove on the west and block-studded toe on the east side of lake. Large blocks from the landslide are seen strewn across the center of the lake. Tahoe City shelf (TCS) is generally less than 15 m deep. Red star indicates our approximate location. Abbreviations for geographic locations are Dollar Point (DP), Truckee River outlet of lake (TR), Ward Creek (WC), Blackwood Creek (BC), General Creek (GC), and Meeks Creek (MC). Figure from Moore et al., 2006.

Eagle Rock is located along McKinney Bay—a large bay on the western shores of Lake Tahoe. The bay is interpreted to be the result of a large landslide that likely occurred during Holocene times, after the Tioga glaciation. The glacial moraines that would have been deposited at the ends of both Blackwood Creek canyon and Ward Creek canyon are missing here, indicating they were likely wiped out by a landslide. Furthermore, bathymetric images and past studies both show evidence of landslides in the form of large blocks scattered across the lake floor (fig. 12) and tsunami generated boulder ridges evident along the Tahoe City shelf. The landslide and missing moraines are rather poorly understood, but that is sometimes the nature of geology.

As previously discussed, there are multiple young north-south faults in the vicinity of Lake Tahoe, which experience small to medium-sized earthquakes (Schweickert et al., 2000, Kortemeier et al., 2018). Studies have shown that a sudden displacement of 4 meters along one of these faults could result in a magnitude 7 earthquake and potentially generate lake waves ranging from 3 to 10 meters in height (Ichinose et al., 2000). Since Lake Tahoe sits within an enclosed basin, the waves could oscillate back and forth for some time—a phenomenon known as a seiche.

Prior to the McKinney Bay landslide, the shelf on the west side of Lake Tahoe, underlain by loosely compacted lacustrine sediments, was approximately 5 km wide and extended roughly 16 km northward from Meeks Bay to Tahoe City. In their 2006 paper, Moore et al. estimate that between 7 and 15 thousand years ago, a section of this shelf, approximately 6 kilometers in length, experienced a rapid downslope movement into the lake, generating significant waves. In addition, Moore et al. (2006) concluded that the remaining 4 kilometers of the shelf to the

north (Tahoe City shelf, figure 12) and the southern area are also susceptible to landslides. These shelf regions sit on potentially unstable lake beds and are flanked by steep cliffs.

A moderate earthquake along one of the major faults within the Lake Tahoe Basin could potentially trigger a landslide or slope collapse. Such an event might lead to a tsunami with wave heights reaching tens of meters, resulting in extensive damage and flooding around Lake Tahoe and posing a threat to the approximately 50,000 residents living within the Lake Tahoe Basin. Additionally, these waves could potentially surpass the dam and outlet areas of the lake, leading to flooding downstream through the Truckee River canyon into the Reno area (Birkeland, 1968).



Figure 13. Tuff breccia beds and a glacial erratic on top of Eagle Rock. Photo: R. Micander

Bedrock at Eagle Rock

You may be wondering what exactly it is that you are standing on at this location. This rather impressive chunk of rock is Eagle Rock, a volcanic rock that is younger than the columnar basalt outcrops we can see to the northwest. There is evidence that Eagle Rock may have been underwater at some point and may have been a phreatic eruption that took place around 2 million years ago.

Eagle Rock is interpreted to be a tuff cone that formed approximately 2.08 million years ago. It originated from an explosive volcanic vent that started its activity either underwater or on water-saturated ground, ultimately erupting through stream and/or beach gravels (Kortemeier et al., 2018). Over time, extensive erosion has taken its toll on the tuff cone. It was shaped and scoured by glaciers from both the Tahoe and Tioga periods that moved through Blackwood Creek canyon. The evidence of glacial scouring is apparent in the solidly cemented planar surface of the tuff, and the presence of numerous granitoid glacial erratics (fig. 13) resting upon the tuff breccia (Schweickert and Lahren, 2002).

Eagle Rock may have also been shaped by massive tsunami runup waves or seiches generated by the McKinney Bay landslide. This intense water action could have resulted in the removal of a substantial portion of the tuff cone (Schweickert et al., 2000; Schweickert and Lahren, 2002; Kortemeier et al., 2018). Eagle Rock is primarily composed of basaltic tuff breccia, containing numerous juvenile clasts as well as occasional clasts of rounded andesitic pebbles and cobbles. The presence of abundant lapilli coated with a layer of fine ash indicates their transport through a wet eruption cloud and subsequent deposition in a subaerial environment (Kortemeier et al., 2018). Inward-dipping layers of tuff breccia (as depicted in figure 10) are present in many locations at Eagle Rock. These layers are thought to have been deposited within the volcanic vent itself. Multiple vertical basaltic dikes are present in the central part of the vent area and some are brecciated. In addition, a small basalt flow is exposed at the summit of Eagle Rock and was dated to be approximately 2 million years old (Kortemeier et al., 2018).

Human History in the Lake Tahoe Basin

Indigenous people have lived in and around the Lake Tahoe Basin for many thousands of years. Today, there are four major groups throughout northern Nevada; the Northern (Numu) and Southern (Nuwu) Paiute, the Western Shoshone (Newe), and the Washoe (Wa She Shu). It is from the Washoe that the name Tahoe originates, being a mispronunciation of the word “Da ow”, meaning “the lake”. The native peoples who lived in this region practiced a hunter-gatherer lifestyle, with food staples consisting of pine nuts, roots, fish, and game (Davenport, 2019).

The first confirmed sighting of Lake Tahoe by Euro-Americans was by Captain John C. Fremont and his cartographer Charles Preuss on February 14, 1844, spotting it from the summit of Red Lake Peak near Carson Pass. This was during his second western expedition, only about two weeks after he and his party were forced to abandon their army howitzer at a place near Sonora Pass now appropriately called Lost Cannon Peak. To this day, the legend of the lost Fremont Cannon has left an indelible mark on the annals of Nevada sports history (Vogel, 2021). The first known Euro-Americans to actually set foot on the shores of Lake Tahoe were members of the aforementioned Stephens-Townsend-Murphy Party (Richards, 2004).

Development in the Lake Tahoe Basin increased significantly following the discovery of gold on the Comstock Lode and the rise of Virginia City. There were already some ranching and lumbering operations, the latter of which concentrated in Glenbrook, but these would gradually expand and become more consolidated as the mining boomtowns created enormous demands for resources. Water was one of the first resources to be so managed, both for domestic usage and to support other industries. Starting in 1871, the Virginia and Gold Hill Water Company (VGHWC) hired civil engineer Hermann Schussler to design a system to deliver fresh water to the communities in the Virginia Range. What he built was a large inverted siphon system, the first in the United States, to bring water from reservoirs in the Carson Range, down through Washoe Valley, and then up to the mining towns. Such a system works by having the pipes completely full of liquid, so that by the time the water reaches the lowest point of the pipeline, there is enough pressure behind it to force the fluid back uphill on the other side—provided the endpoint is at a lower elevation than the starting point. At its peak, this interconnected system could deliver up to 2.2 million gallons of water per day to Virginia City. Today, many remnants of the water system built by the VGHWC survive and are popular recreation spots. One need only visit Marlette Lake, Spooner Lake, or the Flume Trail to see some of the company’s legacy (Boughton, 1997; American Society of Civil Engineers, 2023; Straka, 2007; Alonzo, 2021a).

Intensive logging to support mining operations and urban growth, as well as livestock grazing and other human disturbances, denuded the forests around the lake, and are the reasons why most trees in the basin are second-generation growth, with relatively few remaining old-growth stands (Barbour, 2002). The Carson and Tahoe Lumber and Fluming Company (CTLFC), founded by D.L. Bliss and his partners, became the chief driving force for the growth of the timber industry in the area. Under their guidance, the CTLFC would consolidate lumber interests, build the first railways up to Tahoe, and purchase the VGHWC. Although it is hard to imagine now, it was common to see great rafts of logs being driven across the lake by steamer ships bound for the sawmills at Glenbrook (Boughton, 1997; Straka, 2007).

Even during peak mining and timbering times, the potential of Tahoe as a scenic tourist and residential area was appreciated. During the late 19th and early 20th centuries, many wealthy families, particularly from San Francisco, would build summer homes around the lake, such as the still surviving Hellman-Ehrman Mansion in Sugar Pine Point State Park (California Department of Parks and Recreation, 2023). In a different vein, interest grew to try and preserve the unique beauty of Tahoe itself, and several attempts were made in the early 20th century to turn the lake and surrounding areas into a national park, but none of these proposals ever made it through Congress. A population and building boom following the end of World War II, the establishment of a more robust casino gaming industry, the completion of the nearby Interstate system, and hosting the 1960 Winter Olympics

all contributed to the Lake Tahoe region's ever-growing fame. For better or worse, these events helped push the Lake Tahoe Basin towards becoming the tourist mecca it is today (Boughton, 1997).

Conservation efforts continued throughout the 20th and into the 21st century, with new state parks and protected areas being created at various times and through assorted state or federal means. In recent years, much more public attention towards protecting and maintaining the lake and broader Sierra Nevada region has developed, especially in the face of more serious environmental challenges like over-tourism and climate change.

STOP 3 [39.166357°N, -120.143659°W](#) [Truckee River outlet/Gatekeepers Museum](#)

General Overview

At this stop we will visit Fanny Bridge and the dam and outlet of the Truckee River from Lake Tahoe. The Gatekeepers Museum is a historical heritage site of Lake Tahoe and run by the North Lake Tahoe Historical Society. Built to house the Watermaster of Fanny Bridge in the early 1900s, the tiny cabin is now home to an interesting collection of local artifacts. The museum highlights a few different exhibits that educate on the history of Lake Tahoe. It focuses on historical photos of the Lake Tahoe shoreline from 1916, Washoe history, an extensive collection of Native American baskets from more than 85 tribes, boating history, as well as history of the 1960 Olympics.

The land surrounding the Gatekeepers Museum is operated by the State of California as part of the Tahoe State Recreation Area. We will have the opportunity to wander around the Lake Tahoe outlet dam and view the historical photographs and signs describing the history of the dam. We will also be able to walk out to the beach to take in the vistas of the lake and discuss the hydrology of the lake. “Fanny Bridge” gets its name from the many tourists who visit the site and lean over the railing to see (and feed) the large Lahontan cutthroat and brown trout that congregate below the dam.

The dam is 18.2 feet high and 109 feet long, and regulates flow through a gated spillway (17 bays) with a maximum release capacity of 2,100 cubic feet per second. Throughout its history, proponents of the dam lobbied for water rights with early plans to divert the water to San Francisco and later plans to provide irrigation to western Nevada (the Newlands Project), which included a canal along the Truckee River and several diversion dams. The later project still provides the primary source of water for the Reno and Carson City areas; however, the water supply is supplemented by other water storage reservoirs.



Figure 14. Photographs of the Truckee River outlet from Lake Tahoe including the dam and locks (left) and the outlet of the lake during a low water year (right). Photo: R. Koehler.

Lake Tahoe's Physical Hydrology

Lake Tahoe is the largest Alpine Lake in North America, and at 1,645 feet deep, it is the second deepest lake in the U.S. (Tahoe Environmental Research Center [TERC], 2023). As discussed at previous stops, Lake Tahoe was formed by a combination of seismic activity, volcanism, and glaciation. The Upper Truckee River is by far the largest tributary, contributing over 25 percent of the total inflow. However, the lake is fed by a total of 63 streams, which transport snowmelt, precipitation, and groundwater discharge into Lake Tahoe.

The Truckee River is the only outflow from Lake Tahoe. The river flows at Tahoe City through the Lake Tahoe Dam (which began operation in 1913) and passes through the cities of Truckee, Reno, and Sparks before terminating in Pyramid Lake. The Lake Tahoe Dam controls the top six feet of Lake Tahoe and adds an additional 744,600 acre-feet of storage capacity (U.S. Bureau of Reclamation 2023). Periodic droughts in the early to mid-1900s spurred attempts by downstream water users to dredge, cut, and blast the lake's outlet to allow the release of additional water from below the lake's natural rim (Murphy and Knopp, 2000). Ultimately, when the lake level dropped so low that no water could leave Lake Tahoe, water was pumped over the dam to supply Nevada farmers, and later Boca Reservoir was constructed as an alternate water source.

Why is Lake Tahoe so clear?

The clarity of Lake Tahoe is greater than any other large lake in the world (TERC, 2023), but why is this and how long can we expect this clarity to last? Clarity refers to the ability for light to penetrate deep into a water body. As light interacts with water molecules and floating particles it is scattered and absorbed. Floating sediment and algae particles have the strongest effect on light scattering and clarity reduction (Smith and Kuchnicki, 2010).

Lakes are essentially impoundments of water that gradually fill as they accumulate sediment and other materials and are converted to marshes or meadows. The life span of some lakes may be as short as a few weeks, or they may persist through geologic time periods (Dodds and Whiles, 2020). From the viewpoint of the successional stages of lakes, Lake Tahoe is still young, well oxygenated, and nutrient poor (oligotrophic). In most cases, lakes move past this nutrient-limited state as erosion processes and organic content in the lake increases. The addition of nutrients in a water body stimulates the growth of algae and aquatic plants, resulting in a decline in clarity. Over the past 2–3 million years, Lake Tahoe has largely been protected from sedimentation and nutrient delivery by its unique geologic and hydrologic position. Lake Tahoe is very large relative to the size of its watershed, which reduces the impact of sediment delivery (Smith and Kuchnicki, 2010). Because the lake's surface is so large, over 36% of the precipitation that falls in the watershed enters the lake directly as snow or rain (Smith and Kuchnicki, 2010). Additionally, the Lake Tahoe Basin is dominated by low nutrient granitic soils (Natural Resources Conservation Service, 2003). However, over the past 150 years, the impacts of human activities and development within the basin have caused the clarity of Lake Tahoe to decline and have increased the speed of nutrient enrichment or eutrophication of the lake. Significant activities including land disturbance, urban development, plastic pollution, and climate change are discussed below.

How has human development impacted water quality?

Lake sediments form from material carried in from the watershed as well as organic materials from the lake ecosystem. These materials, deposited in layers in chronological order and preserved in the low temperature/low oxygen environment of the lake bottom, can serve as a record of past events and lake conditions. Studies of Lake Tahoe's sediments (Goldman and Byron, 1986; Heyvaert, 1998) identified two distinct periods of disturbance and sediment deposition characterized by thick organic deposits. The first disturbance layer coincides with the Comstock era (1870s–1890s) clear-cutting, and the second and larger disturbance layer is connected to the post-1960s explosion of urban development and population growth in the Lake Tahoe Basin.

During the Comstock era, intensive logging and road construction dramatically increased the volume of sediment that was deposited into Lake Tahoe. Heyvaert (1998) estimated that during the Comstock, the deposition of sediment into Lake Tahoe increased 7–12 times compared to pre-Comstock levels. The network of logging roads, trails, and flumes that supported the removal of timber from the Lake Tahoe watershed also acted as conduits, directing overland runoff and erosion into tributary streams (Murphy and Knopp, 2000). During this period, essentially all of the accessible and valuable timber in the basin was harvested, leaving an estimated sixty percent of the watershed clear-cut (Murphy and Knopp, 2000). Sedimentation levels in Lake Tahoe decreased sharply following the cessation of large-scale logging, before increasing again with the surge of urban development in the decades that followed.

Despite the destruction of Tahoe’s forests, the lake became a tourist destination in the late 1800s and by 1901, a tourist railroad was developed between the transcontinental railroad station in Truckee and Tahoe City. Further travel was provided to locations around the lake via steamers. By the 1920s, an automobile road system circled the lake and year-round communities began to take hold. Development of the gambling industry (1930s) and ski resorts after the 1960 winter Olympics spurred rapid and unregulated development that surpassed the capacity of local sewer disposal systems (Murphy and Knopp, 2000). In many areas, sewer effluent was sprayed directly onto the land (Strong, 1984), resulting in increased nutrient content in runoff and tributary streams. In 1968, sewage began to be exported from the basin and by 1975 almost all wastewater generated in the Lake Tahoe Basin was exported.

Another factor in the increase of sediment and nutrient delivery to Lake Tahoe is the loss of wetlands and meadows. These vital ecosystems act as filters for surface water by slowing flood waters and capturing sediment and nutrients. Since 1900, approximately 75 percent of marshes and 50 percent of meadows in the Lake Tahoe Basin have been degraded (Elliott-Fisk et al., 1996). Although many small wetlands and riparian areas were lost or degraded during Comstock logging and subsequent overgrazing, the Truckee Marsh (the largest wetland in the Lake Tahoe Basin) remained intact until the 1950s. The Tahoe Keys project filled and altered 750 acres of natural and intact marsh and replaced it with residential development. Although the marsh remains the largest in the basin, its hydrologic function has been compromised. However, restoration of wetlands, meadows, and riparian areas has been a priority in the Lake Tahoe Basin, with over 713 acres restored or enhanced since 2007 (Tahoe Regional Planning Agency [TRPA], 2023). This includes efforts by the California Tahoe Conservancy to restore over 250 acres of the Upper Truckee Marsh. These projects will reduce sediment and nutrient transport to Lake Tahoe over time.

Concerns about the effects of human disturbance on Lake Tahoe began to take shape in the late 1950s when the pioneering UC Davis limnologist Charles Goldman began conducting studies of algae growth. In 1967, Goldman published his essay “Bad News from Lake Tahoe”, which explained the effects of land use changes and accelerated nutrient enrichment (eutrophication) to the general public. Since that time, the effects of human activities and land use changes on Lake Tahoe’s water quality have been studied consistently by a coalition of research universities and governmental agencies, formalized as the Lake Tahoe Interagency Monitoring Program in 1980. Land use regulation and water quality protections were implemented through the establishment of the Tahoe Regional Planning Agency in 1969 and the establishment of the Lake Tahoe Total Maximum Daily Load (TMDL) by the Environmental Protection Agency in 2011. The TMDL acts as an upper limit for sediment and nutrient delivery to the lake and provides a mechanism for ensuring that new development projects are designed to protect water quality.

What are the future challenges facing Lake Tahoe?

Climate change

The water column in Lake Tahoe is stratified, or separated into layers, with cold deep water sitting below sun-warmed surface layers. These temperatures become inverted in the winter when surface waters become cooler and denser than deep waters, causing the lake to “mix” or “turn over”, with some deep waters moving to the surface and some surface waters becoming trapped in the deep zones. Deep-water sediments can act as reservoirs for nutrients (mainly phosphorus and nitrogen) but in oligotrophic lakes they ordinarily are not considered to be significant sources of nutrients compared to surface inputs (Beutel and Horne, 2018). However, the release of nutrients from sediments is accelerated in warm, low-oxygen environments (Beutel and Horne, 2018). When the lake does not turn over, deep waters are not cooled and oxygenated by winter surface waters. This low oxygen environment promotes the growth of specialized bacteria that release nitrogen from sediments as ammonia. For this reason, the depth and extent of lake mixing has a profound effect on lake clarity and water quality (TERC, 2023).

Deep mixing brings warm, nutrient rich water to the surface, which can promote algal growth, and delivers cold, oxygen-rich water to deep environments, which promotes aquatic life throughout the water column (TERC, 2023; Beutel and Horne, 2018). The depth of mixing is driven by the intensity of surface water cooling in the winter. In many years, Lake Tahoe experiences only a partial mixing of the water column. For example, in the mild winter of 2022, Lake Tahoe mixed to a depth of 330 feet, which was the second shallowest mixing event on record. However, in response to the record winter of 2023, Tahoe mixed fully to a depth of 1,475 feet (TERC, 2023)

Since 1970, Lake Tahoe surface water temperature has increased by 2.1°F with a rate of warming of 0.39°F per decade (TERC, 2023). Mid-lake surface water temperatures from a depth of 5 feet have been measured monthly from research vessels and buoys since 1968. Measurements of deep-water environments (1,320 ft) also show a warming trend (TERC, 2023). As the climate warms, Lake Tahoe could become more stable and experience shallower and less frequent mixing events (Beutel and Horne, 2018). Ultimately, this would cause deep waters to become warmer and less oxygenated, allowing for increased release of nutrients from lake sediments. When mixing does occur, it will therefore likely carry a larger supply of nutrients such as phosphorus, ammonia nitrogen, and iron to surface waters.

Plastic pollution

Plastics are ubiquitous in our world and, along with climate change, addressing plastic pollution is among the major challenges of our time. Plastic pollution has been widely documented in oceans, lakes, and rivers around the world, and despite its protected status and relatively isolated location, Lake Tahoe is no exception. In 2022, scientists studying microplastic pollution (plastic particles less than 5 mm in size) in 38 lakes around the world found that Lake Tahoe had the third-highest concentration of microplastics in the water column, exceeding the concentration of microplastics found in some of the oceans’ most affected locations (Nava et al., 2023). The plastics found were small fragments that have broken free from degrading plastic items (such as food and beverage packaging, recreational equipment, and buoys) and synthetic fibers (which may be sourced from textiles, ropes, and nets).

Flora and fauna



Figure 15. Mountain chickadee, a common songbird of the Lake Tahoe Basin. Photo: R. Micander.

Situated on the western margin of the Great Basin, the Lake Tahoe Basin and surrounding areas are home to diverse wildlife. Fish, birds, bears, and rodents are common here as well as many varieties of wildflowers, fungi, trees, and other plants. Black bears are commonly seen, especially when salmon are spawning. More reclusive are mountain lions and pikas, who live in the higher elevations around the lake. Kokanee salmon and Lahontan cutthroat trout are some of the fish you might see in the lake, and several rodents including squirrels, chipmunks, marmots, and beavers are frequently seen here. Birds include the mountain chickadee (fig. 15), willow flycatcher, eagles and hawks, woodpeckers, western tanager, and many, many others. While we could easily spend all day discussing the variety of species native to the Lake Tahoe Basin, we will only discuss a few of the more unique species and share a little about some of the invasive and non-native populations that have established themselves here.

Native fish

The Lahontan cutthroat trout were extirpated in the Lake Tahoe waters since the early 20th century by a combination of over fishing and introduction of other fish species, which could out-compete them. While more intensive stocking programs began in 2019, they remain extremely rare, especially in larger sizes.

Other smaller, native fish include the Tahoe sucker, Mountain whitefish, Lahontan redbreast, Tui chub, Paiute sculpin, and others. All have seen population declines due to invasive species.

Non-native fish species

The Mackinaw (Lake) trout was introduced after depletion of the Lahontan cutthroat trout, and now out-compete them in the lake, making reintroduction efforts difficult. The rainbow and brown trout were introduced to the lake and are now regularly stocked by the California Fish and Game according to the Nevada Department of Wildlife (NDOW).



Figure 16. Kokanee salmon during spawning season. Photo courtesy of the Tahoe Daily Tribune.

The kokanee, landlocked cousins of the sea-going sockeye salmon, were introduced to Lake Tahoe in 1944 by biologists working on the lake's north shore. These salmon quickly adapted to the alpine environment, joining brown trout, rainbow trout, and Mackinaw among the most prominent game fish in Lake Tahoe. Each autumn, mature kokanee return to the streams from which they were hatched, select a mate, spawn, and die. Adult males develop a humped back and a hooked jaw, which will help them battle the territory and secure a mate. Both sexes turn from their usual silvery-blue color to a bright red (fig. 16). Although most U.S. Forest Service wildlife programs focus on land animals or birds, the Lake Tahoe Basin Management Unit has created a unique educational program to view the kokanee salmon in their natural habitat at Taylor Creek, just north of South Lake Tahoe. Kokanee salmon can typically be seen in Taylor Creek throughout the month of October. However, this spawning event has been threatened in years past due to drought and low water levels.

Other non-native warmwater game fish such as bass, bluegill, crappie, and catfish can be found in shallow, marina areas and some streams, particularly in the Tahoe Keys.

Invasive invertebrates and plants

Asian clams were first discovered in 2002, and now can be found in the southern part of the lake. Crawdads, or crayfish, were first introduced in Marlette Lake in 1895. Marlette Lake drains into Lake Tahoe, and crawdads are now a common sight along rocky shorelines area-wide. Crawdads are edible, and many people set traps to catch and cook them.

Curlyleaf pondweed and Eurasian watermilfoil are more prevalent in shallow, warmer areas, like the Tahoe Keys. Attempts at removing these invasive water plants have included placing large mats, distributing herbicides, and even deploying radiation.

Beavers

Beavers were reintroduced to the basin starting in the 1930s and 1940s. Their reintroduction helped expand wetlands, reduce sediment and nutrient loads in the streams, all of which help maintain Lake Tahoe's water quality (Muskopf, 2007).

Sugar pines



Figure 17. A large sugar pine towers over the Lake Tahoe Basin. Photo courtesy of <https://sugarpinefoundation.org/>

The largest species of pine trees in the world, sugar pines were dubbed the "king of the conifers" by John Muir, and are some of the largest trees found in the Lake Tahoe Basin (Filmer, 2015). Their cones are generally 14–24 inches and can be seen hanging from the ends of branches. The needles are fairly short, only 3–5 inches, and come in bundles of five. Sugar pines are found on the western side of the forest up to 7,500 ft. in elevation. They are important for their longevity, their wood, and their cones. Native American people used the sweet tasting sap as a food additive and medicine. The seeds are a nutritious

food source—a type of edible pine nut, which were commonly roasted or pounded into cakes and stored for the winter. The blackish brown nuts were also used as decorative beads in jewelry. Early European settlers used sugar pines for timber as the wood is renowned for being lightweight (despite its massive volume), knotless, and very straight. Sugar pine lumber is used to make storage containers, wide knotless boards, and piano and organ keys.

Snow plants

One of the more striking and unique plants of the Lake Tahoe Basin and eastern Sierra Nevada is the snow plant (*Sarcodes sanguinea*). The scientific name of the snow plant translates roughly to "the bloody flesh-like thing" and keen-eyed forest visitors would be hard-pressed to miss this stunning plant when it is in bloom. Snow plants have no chlorophyll and are parasitic—deriving their sustenance and nutrients from fungi that attach to roots of trees. They have a symbiotic relationship with the tree: the roots provide fixed carbon to the fungus, and in return, the fungus provides mineral nutrients, water, and protection from pathogens to the tree. Snow plants can be found growing out of pine needles and other forest litter on the surface of the ground, near a conifer shortly after the snow melts (fig 18). Sometimes, they can be seen popping out of the snow. These truly are a delight to see and are found only in Nevada, California, and Oregon in the U.S.



Figure 18. Snow plants. Photo: R. Micander

Points of interest as we work our way out of the Lake Tahoe Basin and into Martis Valley

Dollar Point fault

Take note of the elevation we gain as we drive towards Kings Beach. You will notice that we cross over a large rise in the road before it starts to head back down towards lake level. This rise is the footwall of the Dollar Point fault—a normal fault that extends underneath Lake Tahoe.

Brockway Summit

Exiting the Lake Tahoe Basin, we cross over Brockway Summit, which intersects the Tahoe Rim Trail. The pass itself is 7,199 feet above sea level.

Martis Valley

As we drive down the mountain, the trees and boulders give way to a large valley. This is Martis Valley. Notice the multiple flat areas and terraces in this valley. Those flat areas represent various levels and ages of glacial outwash. These terraces are inset into one another and break Steno's law of superposition—the upper terraces are the oldest while the bottom terraces represent younger rocks.

STOP 4

39.3542114°N, -120.1174115°W

Truckee River Legacy Trail/Glenshire Trailhead

SPECIAL NOTES: There are several parking spaces in the paved parking lot at the trailhead. Depending on how busy it is, there should be enough room. However, if there is not, please park legally and carefully along the road, where possible. Once we convene, we will take a short 5 minute (0.1 mile) walk on a paved trail to a viewpoint overlooking the Truckee River and Martis Valley.

General Overview

Here, we will take a short walk to an overlook on the Truckee River Legacy Trail, a community bike/walking path that extends 4.6 miles from Glenshire to the Truckee River Regional Park near downtown Truckee. A cut section of a large tree that was felled in 2015 sits at the trailhead and provides an interpretive history lesson based on tree rings. The trail sits at the transition between the White and Ponderosa pine forests of the Sierra Nevada and the sagebrush dominated vegetation of the high desert. During the spring and summer months, common yarrow, blue flax, and stinging nettle are all visible along the trail. In the late summer and early fall months, the small wildflowers give way to rabbitbrush. Observant attendees may be able to spot some small clusters of lupine still blooming.

From the overlook, we will view the various mountain peaks along the skyline including Donner Pass, Northstar Resort, and Palisades Tahoe Resort. A historic ice dam along Martis Creek is visible at the bottom of the hill. We will discuss the glacial history of the Sierra Nevada and view several different levels of glacial outwash terraces present along the margins of the river. Also visible are the volcanic deposits that rim the canyon adjacent to the river.

Terraces along the Truckee River were influenced by several major late Pleistocene glaciations in the Sierra Nevada. From the overlook, we can see several glacial cirques along the crest of the Sierra Nevada that were the source for the glacial ice. These glaciers extended down their respective valleys to the vicinity of the town of Truckee and provided tremendous water flow to the Truckee River. The downstream extent of the glaciers was first described in detail by Birkeland (1964) (fig. 9). During deglaciation, massive flows of water carved terraces east of Truckee. The terraces that can be viewed from the overlook include terraces associated with the Donner Lake, Tahoe, and Tioga glaciations (Pierce et al., in prep). As mentioned previously, the age of the Donner glaciation is unknown; however, the ages of the Tahoe and Tioga glaciations are thought to be around 120,000 years and 22,000 years, respectively (Pierce et al., 2017).

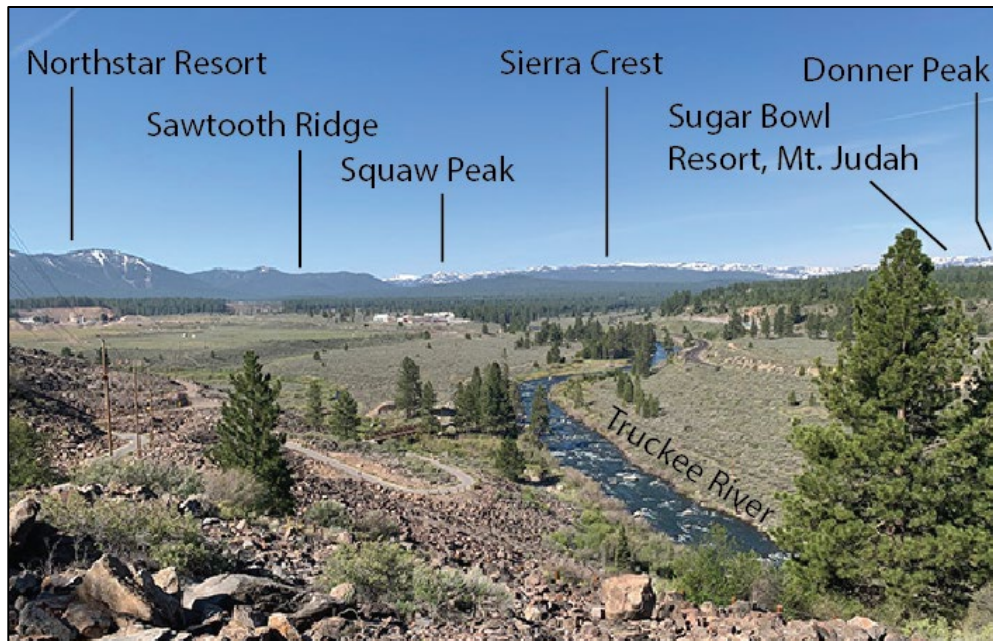


Figure 19. Overlook from the Truckee River Legacy Trail showing several different levels of glacial outwash terraces along the Truckee River and several prominent mountains along the skyline. Photo: R. Koehler.



Figure 20. Views of volcanic bedrock along the margin of the Truckee River from the trail. Photos: R. Koehler.



Figure 21. Yellow rabbitbrush in bloom alongside mountain mahogany along the Truckee River Legacy Trail. Pine trees can be seen in the background. Take a moment while we visit this site: are these pine trees gentle Jeffrey or prickly Ponderosas? Photo: R. Micander

distinguished by examining their cones. Ponderosa pine cones feature outward-pointing barbs, while Jeffrey pine cones have inward-pointing barbs, which can be remembered as "gentle Jeffrey and prickly ponderosa." Additionally, Jeffrey pine bark emits a delightful scent commonly described as reminiscent of vanilla or butterscotch.

Native Plant Species

As previously mentioned, several species of wildflowers and shrubs can be seen at this location. The flora has transitioned from predominantly Jeffrey and Ponderosa pines, white and red firs, and some sugar pines to the brushy sagebrush steppe dominated by rabbitbrush, mountain mahogany, dryland wildflowers, and some pines. The transition of flora is the result of the rain shadow created by the Sierra Nevada. Storms break up as they move across the mountains, resulting in diminishing amounts of precipitation as they move east. Along the Truckee River, healthy riparian corridors can be observed between Truckee and Reno.

Ponderosa and Jeffrey pines are two closely related pine species that inhabit the eastern Sierra Nevada and parts of western Nevada. Due to their similarities, they are collectively referred to as "yellow pines". Ponderosa pines (*Pinus ponderosa*) have a broader distribution, ranging from Baja California to British Columbia in the western U.S., while Jeffrey pines (*Pinus jeffreyi*) are primarily confined to the eastern Sierra Nevada and associated mountain ranges (Tingley et al., 2005). Complicating matters, these two species occasionally interbreed, resulting in hybrid offspring.

Although these two species of pine may appear identical to the untrained observer, they can be

Land Development and Transfer Plans

As the focus of this year's Earth Science Week is taking a broader perspective on how various disciplines affect our lives, this stop is an excellent place to consider the question of land usage. In the American West, we live in regions where the questions on how best to utilize land is a constant presence. Here in Martis Valley, some of those land-use issues have not only bubbled to the surface, but have sparked drastic back and forth legal battles for years over the interests of property owners, public conservatorship, safety issues, and environmental protections, sometimes collectively known as the Martis Valley Wars. This has led to potential new legal questions and frameworks, which could influence how such decisions are made in the future.

Points of interest as we travel down to Reno along the Truckee River canyon

Wildfires and Habitat Degradation

As we make our way down the Truckee River canyon towards Reno, evidence of large and devastating fires can be seen along the canyon walls. Some areas have started to recover following these intense fires, and other areas remain scarred with cheatgrass outcompeting the native plant species, such as sagebrush. Cheatgrass is a highly aggressive and invasive plant species that establishes itself following wildfires, taking up natural resources that the native plants need to re-establish themselves. In addition, prolonged drought, pollution, and attacks by species like pine beetles are weakening forests and leading to increased ecological pressure in these environments. These factors in part lead to more frequent and severe wildfires, which devastate the landscape. As human development and recreation increasingly stretches into these forest lands, the risk of wildfires and subsequent risk to habitat, life, and property continues to climb.

Hydropower in Truckee in Truckee River Canyon

Driving eastbound through the Truckee River canyon, you will see assorted flumes and canals on the hillsides, most of which are maintained for run-of-river hydroelectric generators. Originally, there were four such power plants along this stretch of river. Beginning near the Floriston exit, you will see the remains of one such flume on your left. This flume leads to the remains of the Farad Power Plant, which shut down in 1989. Difficult to see from the road, the old plant can be easily visited by taking the Farad exit and walking the short distance back up the Tahoe-Pyramid Trail. Of the three still operating hydro plants, all owned and operated by the Truckee Meadows Water Authority, the most readily spotted is the Fleish Plant near the California–Nevada state line, seen from Interstate 80 on the east side of the river, where overflow water from the flume creates a scenic waterfall (fig. 22). The other two operating generators are the Verdi Plant, and the Washoe Plant near Mogul (Truckee Meadows Water Authority, 2021; DePuy, 2021).



Figure 22. View of the Fleish Power Plant, water flume, and Steamboat Ditch/Flume along Interstate 80. Photo: Google Street View Image.

Lawtons Hot Springs and the River Inn

Originally known as Granite Hot Springs, this site was used as a convenient watering stop for the railroad, whose workers would also take the opportunity to soak in the warm waters. The property was sold in 1884 to Summer Lee Laughton, who intended to build up the site as a resort. Over the years, and many misspellings of his name, the area would come to be called Lawtons Hot Springs, and would become a popular rest stop and tourist destination throughout the early 20th century. The resort itself went through several different owners and names, eventually coming to be called the River Inn, and expanding to include amenities like a restaurant, hotel, gambling hall, swimming pool, RV park, and golf course. But problems arising from contamination leaking from its sewage system and mounting financial burdens to its creditors, the River Inn closed in 1978 (Moreno, 2021; Reno Evening Gazette, 1978). Since its closure, various companies and individuals have tried to redevelop the land, with all such plans falling apart for one reason or another. By the mid 2000s, the property had sat derelict for many years, with the most notable uses of it being as a training ground for local SWAT teams, and as a monitoring station for groundwater temperatures during the 2008 Mogul Earthquake Sequence (Hart, 2018; Ruhl et al., 2016). The property was sold in 2020 to a new private owner, with plans to make it a personal residence.

STOP 5 **[39.5266878°N, -119.8848303°W](#)**
[Mayberry Park, west Reno](#)

Geographic Overview

Mayberry Park is nestled in amongst the riparian corridor of the Truckee River and the warehouses of west Reno. Peavine Peak towers to our north, measuring 8,269 feet above sea level. To the south are a series of ancient river terraces, the Hunter Creek canyon (a tributary to the Truckee River), and the northern slopes of the Carson Range. A smaller, somewhat prominent ridge called Chalk Bluff sits between us and Interstate 80. Chalk Bluff is primarily composed of diatomite, interbedded with ash layers, all displaced by numerous tiny faults. The roadcut into Chalk Bluff along Fourth Street provides an excellent location for roadside geology and for undergraduate geology students to interpret lacustrine sediments and structures made from faulting.

Geology

Before about 3 million years ago, the greater Reno area looked very different than it does today. The Carson Range, Peavine Mountain, the Virginia and Pah Rah ranges, and the valleys between all these mountains did not exist. The mountains and valleys are a result of a major episode of faulting at about 3 million years ago that dropped the Truckee Meadows and the valley between Peavine Mountain and the Carson Range down relative to those mountains.



Figure 23. Photomicrographs of Nevada diatoms from Cryderman et al., unpublished.



Figure 24. Fish fossil preserved in diatomite. Photo: D.D. LaPointe.

At Mayberry Park, we can see the remnants of what used to be present in the Reno area. The Reno area was also part of the ancestral Cascade volcanic chain seen at Stop 1. A 16-million-year-old andesite volcano was centered around the south and west flanks of Peavine Mountain and westward into California and the Bald Mountain Range. A 12-million-year-old andesite volcano was present along the north flank of the Carson Range and westward to Verdi Peak. The prominent, white knob on the steep slopes south of the Truckee River west of the park is part of another hot, volcanic debris-flow deposit.

A big change occurred about 12 million years ago, when an episode of faulting generated a wide, shallow basin that was filled with a large, freshwater lake. A diverse assemblage of sedimentary rocks, somewhat inappropriately called the sandstone of Hunter Creek, accumulated in the lake. Although some sandstone and conglomerate are present near the base of the sequence, they are minor components (Bell and Garside, 1987; Ramelli et al., 2011; Hinz et al., 2018). The most common rock type is diatomite, or diatomaceous siltstone. Diatomite consists of billions and billions of tiny shells grown by diatoms, a single cell type of microscopic algae that can live in either fresh or salt water. The shells are generally less than 0.2 mm across (less than 1 hundredth of an inch), so not visible to the naked eye. However, photomicrographs show that they are really pretty (fig. 23). Unlike most water-living organisms that make their shells out of calcite or its cousin aragonite (CaCO_3), diatoms make their shells out of silicon dioxide, SiO_2 . Silicon dioxide can occur in several forms, including the well-known quartz, but diatom shells are opal! Not as pretty as some of northwestern Nevada's famous fire opal, but a lot easier to find around Reno. The lake also had fish and plants growing around the shore. These are now represented as fish and leaf fossils. Fish fossils are especially common in diatomite deposits east of Reno (fig. 24).



Figure 25. Diatomite as seen in a roadcut along West Fourth Street. Photo: C. Henry.

The 3-million-year-old episode of faulting dismembered the lake and faulted and tilted the sediments including the diatomite. Diatomite underlies much of suburban northwest Reno but is so soft that it mostly does not make good rock exposures except in some of the small canyons. Roadcuts along West Fourth Street west of McCarran Boulevard nicely display faulted and tilted diatomite, but it is not the easiest place to visit because of traffic and lack of sidewalks (fig. 25).

The overall dimensions of the basin and lake are not well known. Similar diatomite and related sedimentary deposits are present around Boca

Reservoir to the west and in many places east of Reno. However, whether these were part of a single contiguous basin or separate basins separated by faults and highlands is unknown. Diatomite is mined at several locations in Nevada, including east of the Tahoe-Reno Industrial Center and northeast of Bradys Hot Springs along Interstate 80. Its primary use is as a water filter, but it is also used as a filler in food, medicines, paint, and plastic, and as kitty litter. NBMG has had Earth Science Week field trips to some of the mines to learn about the geology and uses of diatomite and to collect fish fossils.

Irrigation Ditches in Truckee Meadows

While irrigation canals and aqueducts were built almost since the first Euro-Americans settled in the Truckee Meadows, the system of water transport conduits known simply as the “ditches” today began in earnest in 1861 with the digging of the Pioneer Ditch, with many more being dug in subsequent years. The ditches that remain today, each owned and managed by a different private company, still transport water to irrigate some of the remaining agricultural land in the greater Reno-Sparks area, as well as for private lawn and garden usage in certain residential neighborhoods (Tingley et al., 2005; Kennedy/Jenks Consultants, 2003).

Stemming from the gradual growth of urban areas around them, many of the ditches have taken on a role in helping convey storm runoff, though that was not part of their original purpose. In the early 2000s, an agreement was formalized between the City of Reno, Washoe County, and the private ditch companies, where the governments pay the companies for upkeep and repairs in return for channeling stormwater runoff. However, simply due to their ages, many of the ditches experience seepage, overflow, and even breaches, leading to flooding in residential areas during periods of heavy precipitation (Damon, 2017). Assorted plans to update or improve the ditches have been put forward. Though some of these proposals, such as piping and covering of sections of the Steamboat Ditch, have run into friction from other residents, given that the ditches now also play prominent roles as scenic parts of the urban landscape of Reno (Alonzo, 2021b). At this stop you can easily see three ditches. On the east end of the park is Hunter’s Crossing footbridge, downstream of which is the concrete intake for the Lake Ditch. The Last Chance Ditch is immediately on the south side of the river, opposite the park, and crossed by the adjacent Tom Cooke Trail on the west end of the park. If you hike up the Tom Cooke Trail, it eventually intersects with the Steamboat Ditch Trail, running besides its namesake.

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