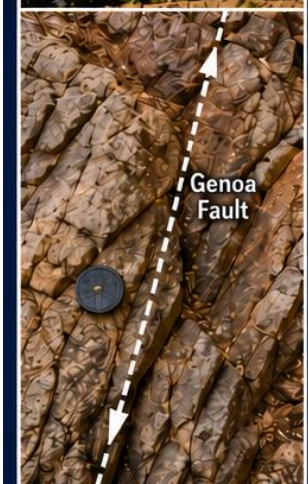



# 75th HIGHWAY GEOLOGY SYMPOSIUM

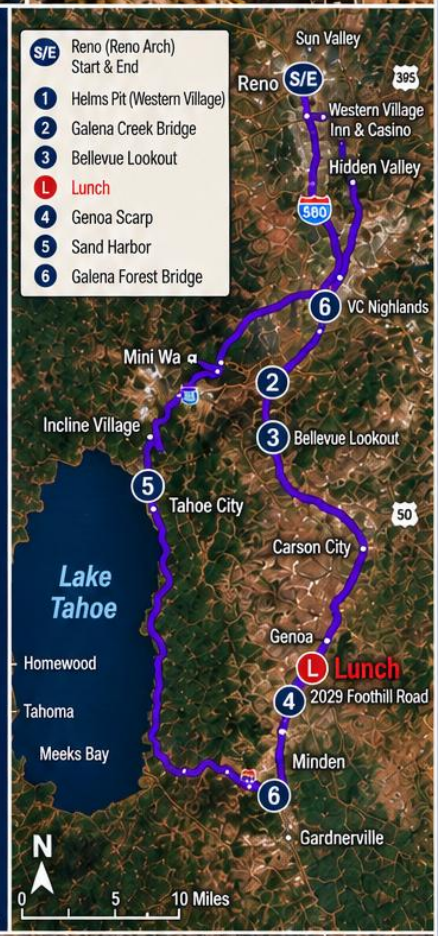
# FIELD TRIP GUIDE

***Faults, Floods, and Freeways:***

*The Geology and Engineering of the Reno–Tahoe Corridor*

**Reno, Nevada**

**October 1, 2026**




# Acknowledgments and Credits

This guide was prepared by the Steering Committee of the 75th Highway Geology Symposium for the October 1, 2026, field trip through the Reno–Tahoe corridor of western Nevada.

## Figure Credits

Unless otherwise captioned, geologic cross-sections and geophysical figures in this guide are reproduced or adapted from the following published sources, cited in full in the References section:

- Purkey, B.W. and Garside, L.J. (1995)
- Abbott, R.E. and Louie, J.N. (2000)
- Louie, J.N. et al. (2001), Southern California Earthquake Center Annual Workshop
- Stephenson, W.J. et al. (2013)
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- Glancy, P.A., and Bell, J.W., 2000, Landslide-induced flooding at Ophir Creek, Washoe County, western Nevada, May 30, 1983: U.S. Geological Survey Professional Paper 1617, 94 p.
- Birkeland, P.W. (1964), The Journal of Geology

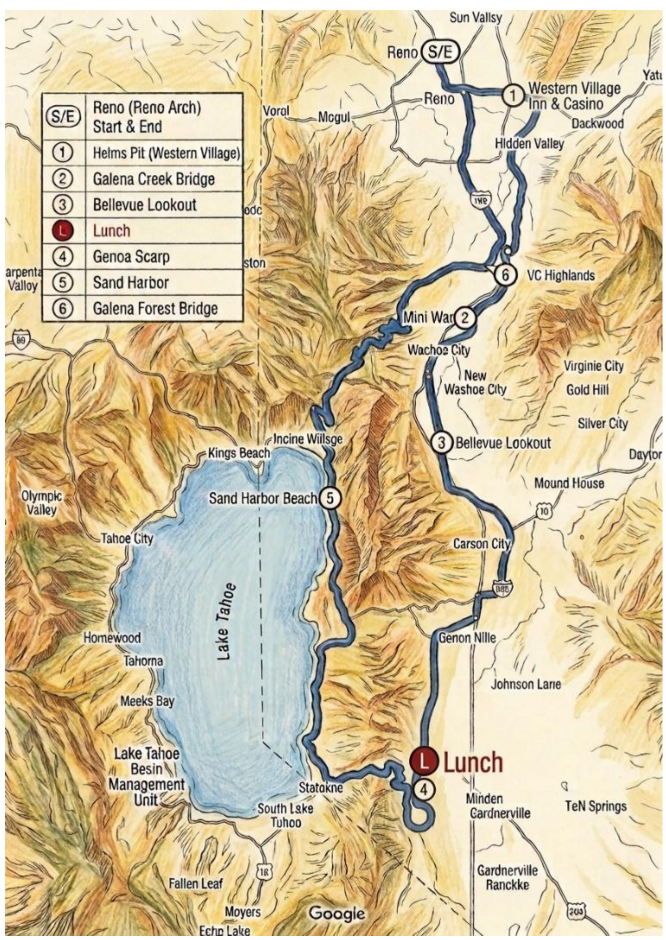
Construction and site photographs not otherwise credited were taken by HGS field trip committee members during pre-trip site visits.

# Contents

## Itinerary — Thursday, October 1, 2026

Sunrise 6:54 AM · Sunset 6:41 PM. Buses depart from the Reno Arch (Whitney Peak) at 7:30 AM and return by approximately 6:00 PM. Total drive time is roughly 5 hours 35 minutes; total stop time is roughly 4 hours 55 minutes.

| Stop | Location | Arrive | Depart |
|---|---|---|---|
| Start | Reno Arch, Whitney Peak | — | 7:30 AM |
| 1 | Helms Pit – Sparks Marina (Western Village Inn & Casino, Sparks) | 7:45 AM | 8:15 AM |
| 2 | Galena Creek Bridge (340 Galena Pines Rd, Reno) | 9:00 AM | 9:40 AM |
| 3 | Bellevue Lookout – Slide Mountain (Washoe Valley) | 10:00 AM | 10:30 AM |
| Lunch | Genoa Golf Club | 11:15 AM | 12:30 PM |
| 4 | Genoa Fault Scarp (Foothill Rd, Genoa) | 1:00 PM | 1:40 PM |
| 5 | Sand Harbor State Park, Lake Tahoe (bike trail) | 2:55 PM | 3:35 PM |
| 6 | Galena Forest Bridge, I-580 (Ormat geothermal field) | 4:45 PM | 5:25 PM |
| End | Reno Arch, Whitney Peak | 6:00 PM | — |




*Map of the field trip route and stop locations*

# Introduction: A Landscape Built by Faults

Today's route follows a roughly 130-mile loop south from Reno through Washoe Valley and Carson Valley to the shore of Lake Tahoe, then back north along the eastern base of the Carson Range. Along the way, the trip crosses one of the most active fault systems in North America outside of California's San Andreas system, the Walker Lane, and visits highway and bridge projects built directly on top of it.

The Reno–Tahoe region sits at the boundary between two great physiographic provinces. To the west, the Sierra Nevada rises as a tilted fault block, uplifted and tilted eastward along range front normal faults over the last several million years. To the east lies the Basin and Range province, a landscape of alternating mountain ranges and down dropped valleys produced by crustal extension. The ground here is literally being pulled apart. Reno, Washoe Valley, Carson Valley, and Lake Tahoe itself all occupy fault bounded basins (grabens and half grabens), as illustrated by the generalized geologic cross section through Lake Tahoe and Carson Valley (Figure 1). These basins lie within the broader transition zone commonly associated with the Walker Lane belt, which accommodates a significant share of the relative motion between the Pacific and North American plates.

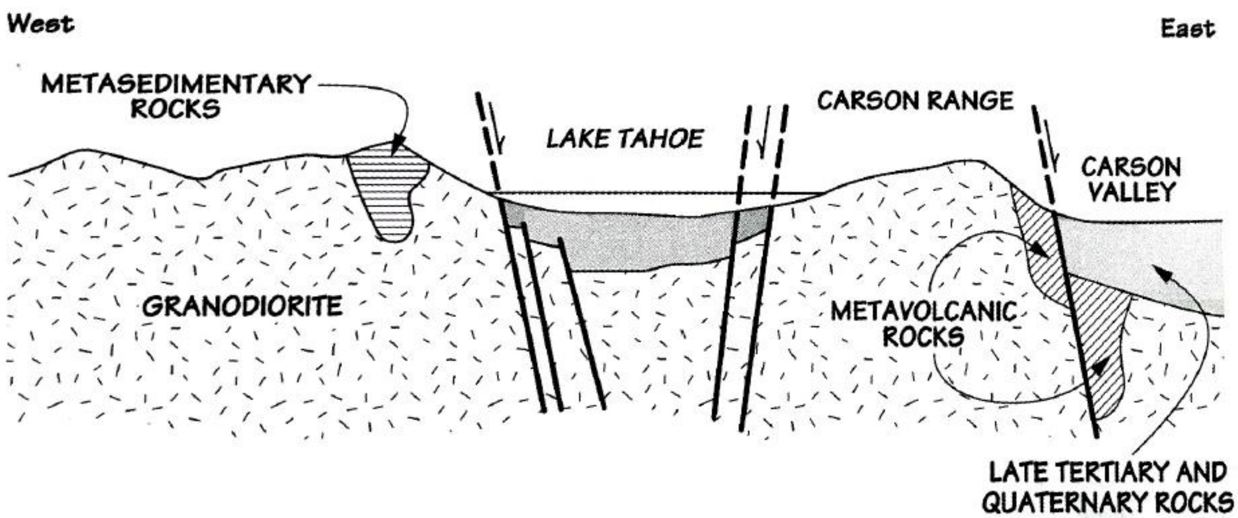



*Figure 1. Generalized west-to-east cross-section from the Sierra Nevada granodiorite, across the Lake Tahoe basin, to Carson Valley, showing the range-bounding normal faults that define this part of the Walker Lane. From Purkey & Garside (1995).*

Because these basins are actively subsiding while the surrounding ranges rise, they have filled with thousands of feet of Quaternary sediment, and the range-front faults that bound them remain capable of producing large earthquakes. The Genoa fault (Stop 4) and the faults beneath Lake Tahoe (Stop 5) are both examples of structures capable of magnitude 7 events. This same active, extending, faulted terrain is what today's stops are built on, and it is why bridges, roadcuts, and water systems in this corridor have to be designed with active faulting, steep topography, and seasonal flooding all in mind.

The trip also samples the region's more recent geologic history: a catastrophic 1983 landslide on Slide Mountain, the Pleistocene glaciation that carved and dammed the Tahoe–Truckee basin, and a 1997 flood that turned a gravel pit into Sparks Marina almost overnight. Together, the stops tell a story that runs from the Mesozoic to the present, and from bedrock geology to the highway engineering built in response to it.

# Drive to Stop 1 — Nugget Overpass and Sparks Tank Farm

As we leave the hotel, we jump on I-80 heading east toward our first stop, site of the Helms pit wall collapse and closure of I-80 westbound during the 1997 flood. Helms pit is now the Sparks Marina. As we travel east, I-80 parallels the Truckee River.

The Truckee River drains the Lake Tahoe basin and other valleys north of the lake. The river flows north out of the lake, then turns east toward Reno and continues its eastward course until taking a final bend northward to end in Pyramid Lake, a total distance of 121 miles. The route is largely fault controlled.

The home of the Pyramid Lake Paiute Tribe, Pyramid Lake is a remnant of Pleistocene or Pluvial (Ice-Age) Lake Lahontan. Nested between dry desert ranges, Pyramid is a terminal lake with no outlet. The Truckee River has cut a series of majestic canyons between Lake Tahoe and Pyramid Lake, mainly through thick flows of Tertiary basalt and andesite (Figure 2). Lapping onto these igneous rocks are light-colored layered sediments deposited by Lake Lahontan. Lahontan dried up only about 10,000 years ago, with its maximum stand reaching an elevation of almost 4000 ft. Figure 3 shows the surficial geology of the northern Truckee Meadows.

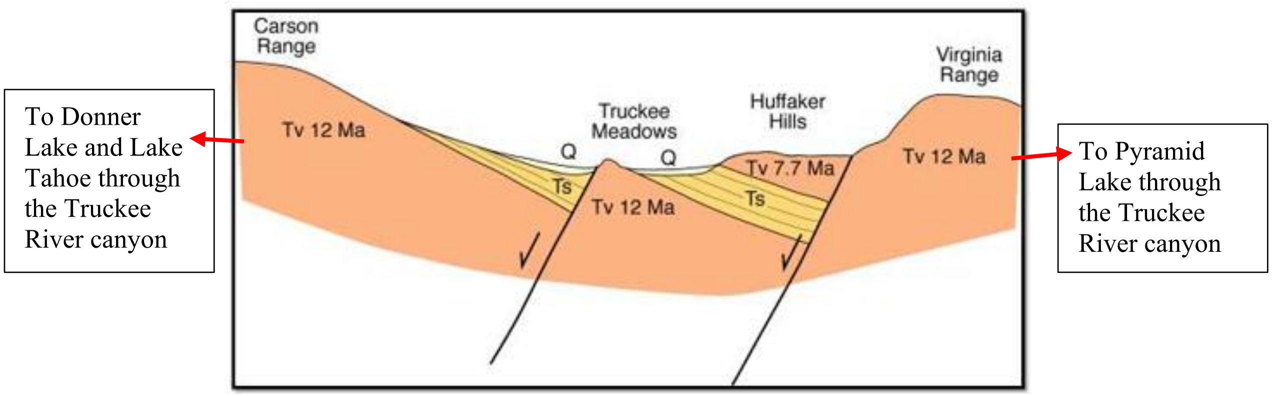



*Figure 2. Reno – Truckee Meadows Cross Section after C. Henry*

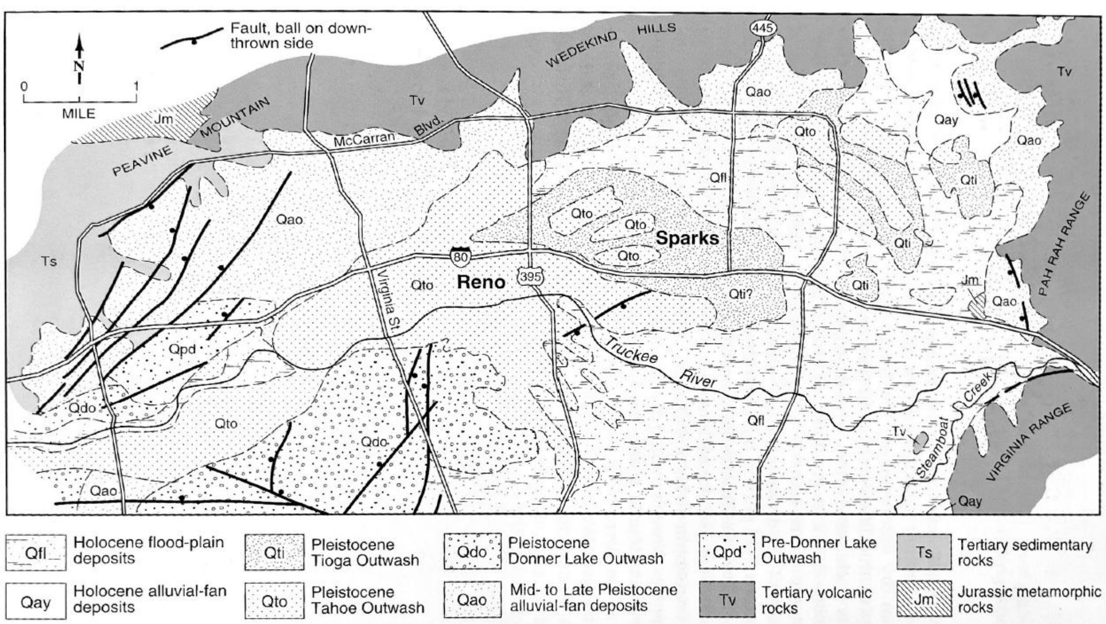



*Figure 3. Generalized surface geology of the northern Truckee Meadows, from Pukey and Garside (1995), after Bell and others (1984).*

On I-80 as we head toward the Sparks Marina (formerly Helms Pit) we will pass through two sides of the Nugget. The Nugget casino expanded under I-80 without altering the viaduct (Figure 4). To do so construction occurred around the bridge columns. One column is hidden in the aquarium.

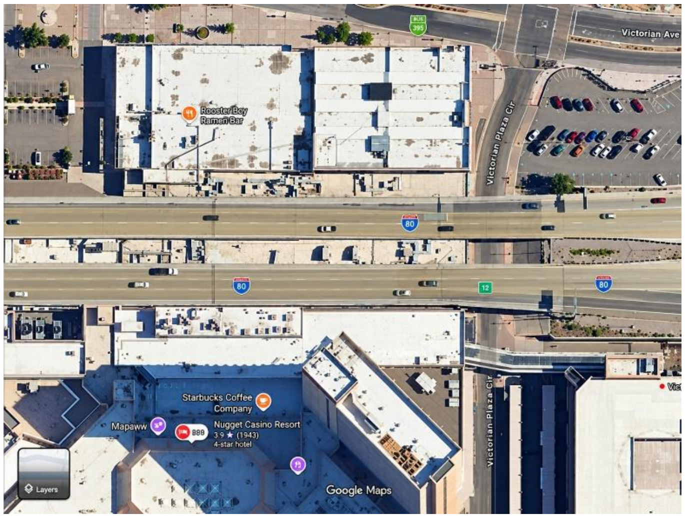



*Figure 4. Aerial view of the Nugget Casino and the Overpass, from Google Satellite View.*

Just east of the Nugget there are fuel tanks (Figure 5) which in the 1980s, and possibly earlier, leaked fuel that during the operation and drawdown of the water of the Helms aggregate quarry was drawn away from the Truckee River and to the pit, a piece of site history that set up the contamination and cleanup story at Stop 1.


*Figure 5. Fuel storage tanks east of the Nugget, visible from I-80 en route to Stop 1.*

## Stop 1 — Helms Pit / Sparks Marina

The site on which Sparks Marina Park is located was once a gravel pit owned and operated by Helms Construction Company (1968 to 1995). In 1987, petroleum products and solvents were discovered seeping into the 100 ft deep pit. Contamination was traced to a massive spill at the fuel-tank farm to the west. It was declared a Toxic Superfund Site and comprehensive cleanup was initiated. In 1996, the groundwater was reported free of petrochemicals and the property was turned over to the City of Sparks. Millions of dollars of spill mitigation money was made available to the city, which was used to construct the park and make the pit into a recreational pond. They also planned to fill the pit with water to a depth of 30 feet; however, in January 1997, the Truckee River overflowed its banks across the Truckee Meadows and filled Helms Pit (Figure 6 and Figure 7), creating Sparks Marina Park Lake, almost a half-mile wide. Cold, oxygen-deleted groundwater flows continually into the lake. In order to keep it at a desirable level, the city pumps 1 to 3 million gallons of water daily into the Truckee River.

The 1997 event was not a gentle overflow, the pit wall itself gave way, eroding into the adjacent I-80 shoulder as floodwater poured in. The photo below, taken during the event, shows the scale of the collapse relative to the interstate and the flooded industrial park beyond.

*Figure 6. The January 1997 flood breach: floodwater from the Truckee River undercut and collapsed the wall of Helms Pit, eroding the shoulder of westbound I-80.*

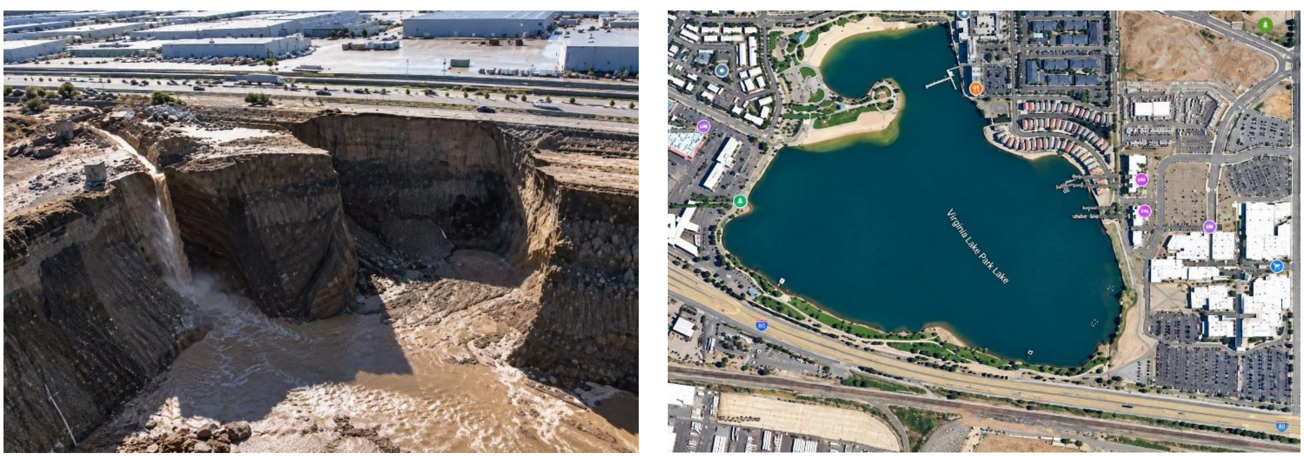



*Figure 7. (left) Closer view of the eroded pit wall at the moment of breach. (right) Sparks Marina in Google Satellite View.*

# Drive to Stop 2 — Basin and Range, Sierra Frontal Faults

Leaving the Sparks Marina, we travel south on Veterans Blvd. As we travel, we should note the structural geology of the Truckee Meadows. This valley is underlain by a down-dropped and down-warped structural block, which is bounded by basin-and-range faults on the east and the west sides. The east-dipping rocks of the Carson Range form the western boundary; the west-dipping rocks of the Virginia Range form the eastern boundary; and the Steamboat Hills (mostly intrusive igneous rocks) form the southern boundary. The faulting and tilting that formed this valley began at least 7 million years ago (late Miocene) and are still active.

Although faults are located along the eastern and western boundaries of the valley, the major structural breaks responsible for the down-warped nature of the valley run south-north along the middle of the valley. Sediments up to about 2,000 feet thick fill the eastern part of this basin (Abbott and Louie, 2000; Figure 8).

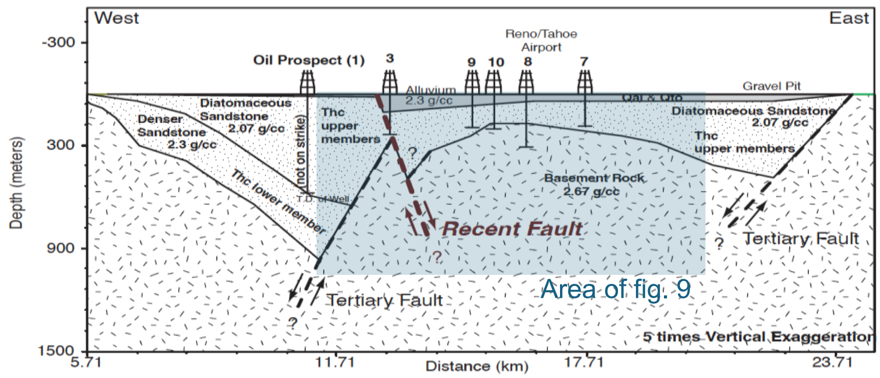



*Figure 8. West-to-east subsurface cross-section beneath the Truckee Meadows, from well and gravity data, showing the basin fill and a recent fault offsetting the diatomaceous sandstone and basement rock. From Abbott & Louie (2000).*

Eastward tilting of this underlying structural block began about 2 million years ago. The geologic and topographic evidence for this eastward tilting include (1) local tilted rock units that were laid down horizontally in early Pliocene time, (2) the large fan-pediment surfaces developed on the western side of the valley (note the deeply incised stream channels as erosion tries to keep up with uplift), (3) the sharp truncation of the eastern margin of the basin (Pleistocene outwash deposits from the Sierra Nevada are being buried by Holocene alluvium here), (4) the shifting of surface drainage to the eastern margin of the valley, and (5) the gentle eastward dips of Quaternary and underlying Tertiary stratigraphy seen in a 2009 USGS-UNR seismic-reflection line west-to-east along the Truckee River (Stephenson et al., 2013; Figure 9). Do you see evidence of fanning and growth faulting?

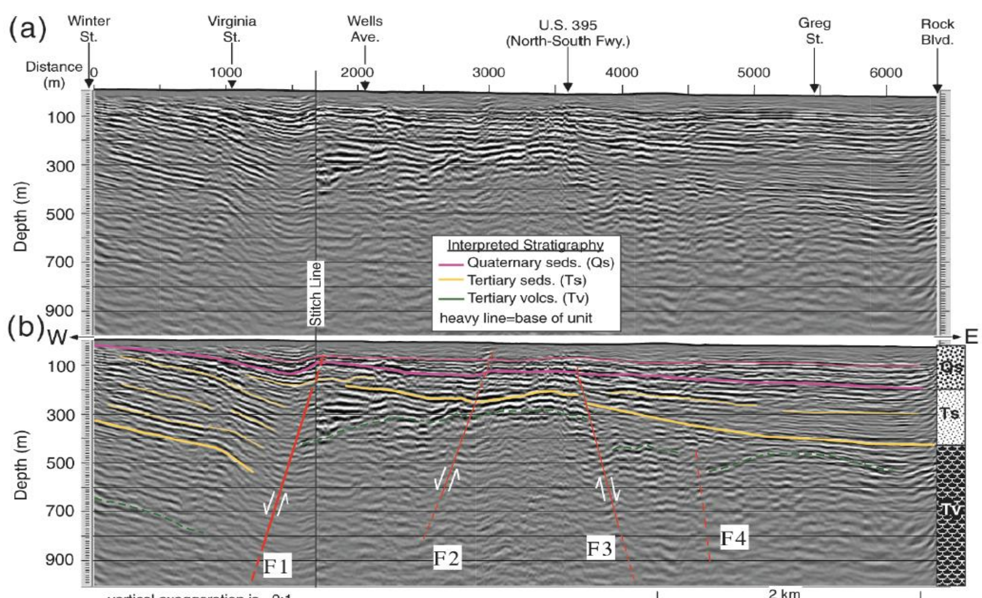



*Figure 9. Seismic reflection profile across Reno (Winter St. to Rock Blvd.) showing Quaternary, Tertiary sedimentary, and Tertiary volcanic units offset by faults F1–F4. (a) Uninterpreted, (b) interpreted from Stephenson et al. (2013).*

Despite the relatively shallow depths of soft sediments within the Truckee Meadows basin, < 4000 ft at maximum, there is evidence that the basin sediments still trap and amplify the waves that produce earthquake ground shaking. The Nevada Seismological Lab at UNR records basin shaking amplification factors of 5x to 10x when waves from regional large earthquakes enter the valley. Eckert et al. (2021) proposed localized amplifications exceeding 4x at 3 Hz for the Reno ShakeOut M6.3 scenario event from physics-based modeling of ground motions. However, an examination of recordings of local M3+ events by Seismo Lab Master of Science graduate Carter Dills (2026) did not find such amplification.

We might see wild horses on the east side of Veterans Blvd, while on the west, note the significant infilling of the wetlands to accommodate more development.

## Stop 2 — Galena Creek Bridge

From Veterans Boulevard we join Old US 395 heading south and turn off it to view Galena Creek Bridge (that is part of Interstate 580, replacing US 395) from its underside. This is a high impact transportation stop even for non-engineers because it visually explains how highways cross a deep valley with rugged terrain. It is a great spot for a quick photo (Figure 10), plus a short talk on wind, seismic design, and how construction access is managed in steep topography.

*Figure 10. View of the Galena Creek Bridge on I-580 from Pleasant Valley below. Mt. Rose in the background.*

Galena Creek Bridge with its dramatic tall piers is reportedly the tallest/longest concrete cathedral arch bridge in the world composed of two parallel cast-in-place concrete arches. The cathedral arch supports the bridge only at the crown; there are no intermediate spandrel columns. The structure serves as the centerpiece on a project that includes eight other cast-in-place concrete box girder bridges. The Nevada Department of Transportation (NDOT) had been planning for several decades to raise I-580 to full interstate highway standards for its entire length within the state. This segment extends the freeway from the Mt. Rose Highway to the Bowers Mansion cutoff in the Northern Washoe Valley.

Early geotechnical work on the route began in the year 2000. Louie of UNR and Ted Beeston of Black Eagle collaborated on shear-wave velocity measurements at the planned north and south arch thrust blocks, comparing volume-averaging surface-array measurements by Louie and his class against point downhole measurements by Bruce Redpath, Table 1 and Figure 11. The north abutments have significantly higher shear-wave velocity and thus shear strength compared to the south, as summarized in Table 1.

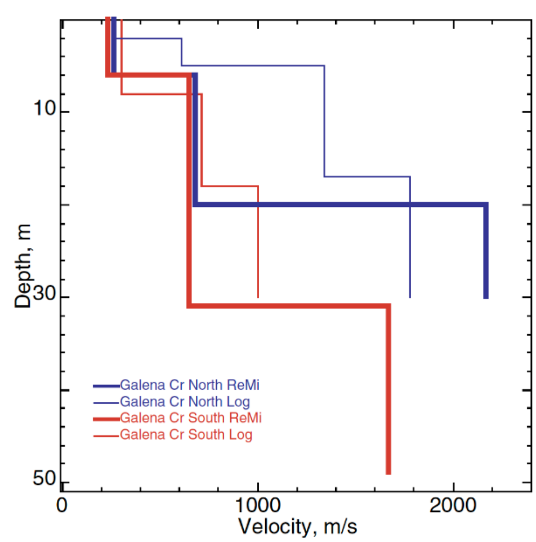



*Figure 11. Shear-wave velocity profiles from the north and south bridge abutments. From Louie et al. (2001).*

| Location | North ReMi | North Redpath | South ReMi | South Redpath |
|---|---|---|---|---|
| Vs100, ft/sec | 2076 | 3406 | 1551 | 1877 |
| ASCE 7-22 Class | C | BC* | C | C |

*Class B velocity, but engineering rock is at 16 ft depth, not <10 ft.

*Table 1. From Louie et al. (2001), Vs100 Values of 2001 Measurements, Louie of UNR with Ted Beeston of Black Eagle*

The origin of this difference in measured strength and seismic velocity was debated at the time, when seismic velocity data were costly and very few measurements had been made in northern Nevada. In the decades since, shear-wave velocity surveys have come to be commonly used in both the engineering and resource industries. Figure 12 shows a Terēan Inc. analysis of a survey conducted by the Truckee Meadows Water Authority (TMWA) that extends from the south abutment east to Old 395, courtesy of C. Kropf at TMWA. As is seen in many other surveys, shear-wave velocities can vary both vertically and horizontally by large factors, due to faulting and uneven deposition of volcanic flows. This survey assessed TMWA the possible locations for water-supply well rehabilitation.

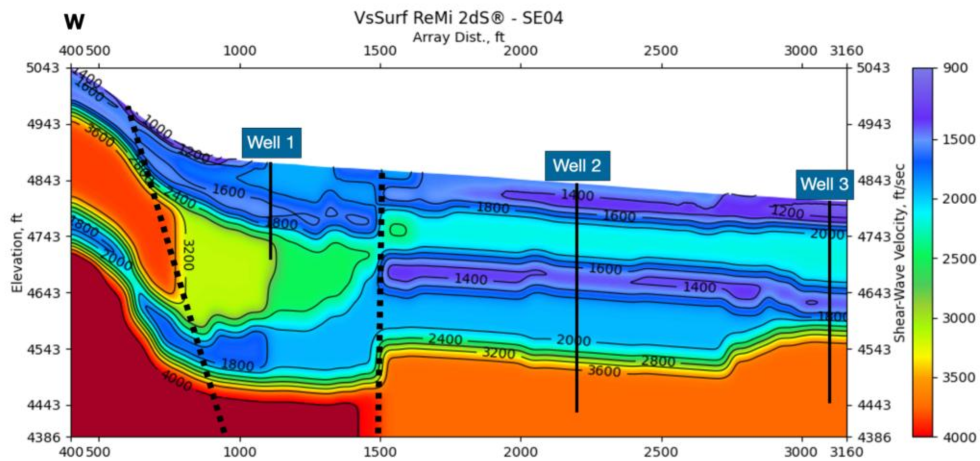



*Figure 12. Terēan analysis of TMWA survey from south abutment east to Old 395, courtesy C. Kropf, TMWA. V.E.=2x*

The Galena Creek Bridge consists of two parallel cast-in-place concrete arches with a span of 689 ft. Each arch has a width of 19.7 ft and a depth of 11.8 ft. The wall thickness is 1.6 ft. The arches are supported on thrust blocks founded on bedrock. Each arch supports a cast-in-place conventionally reinforced, two cell box girder, 62 ft wide and 8 ft 6 in. deep. Each box girder carries three lanes of traffic. The columns have overall cross-sectional dimensions of 19.7 ft by 9.8 ft with a wall thickness of 3.25 ft. These columns are supported by footings on piles (Figure 13 and Figure 14).

This approach required the use of traditional falsework, which was placed on a foundation created by filling the creek bed. About 523,000 cyd of earth cut from the nearby embankment were used to raise the level 140 ft (highest MSE/RSS wall in the world at the time). The fill measured approximately 385 ft wide at the base and tapered to approximately 210 ft wide at the top. A temporary 400-ft-long tunnel was built to protect the creek, with its walls set 30 ft on either side of the creek to minimize impact on the environment. The new approach required a four-month approval process, and work then began again in early 2007 to finish construction. Figure 15 and Figure 16 show the partly completed arch forms with the MSE/RSS walls in place during construction. The earthen fill was removed and used elsewhere in MSE walls along the route. Vegetation was restored after the bridge was completed.

Construction was started in 2003 but was delayed by a number of safety concerns, mainly associated with wind. In 2006, the original prime contractor found the planned construction method unsafe; the method was revised and a new contractor hired. Construction was completed in 2012. Afterward, NDOT collaborated with UNR to install and test instrumentation (for wind and seismic monitoring) on the main arch span.

*Figure 13. Bridge piers and falsework framing under construction, prior to placement of the arch spans.(NDOT)*

*Figure 14. Bridge pier reinforcement cage. (NDOT)*

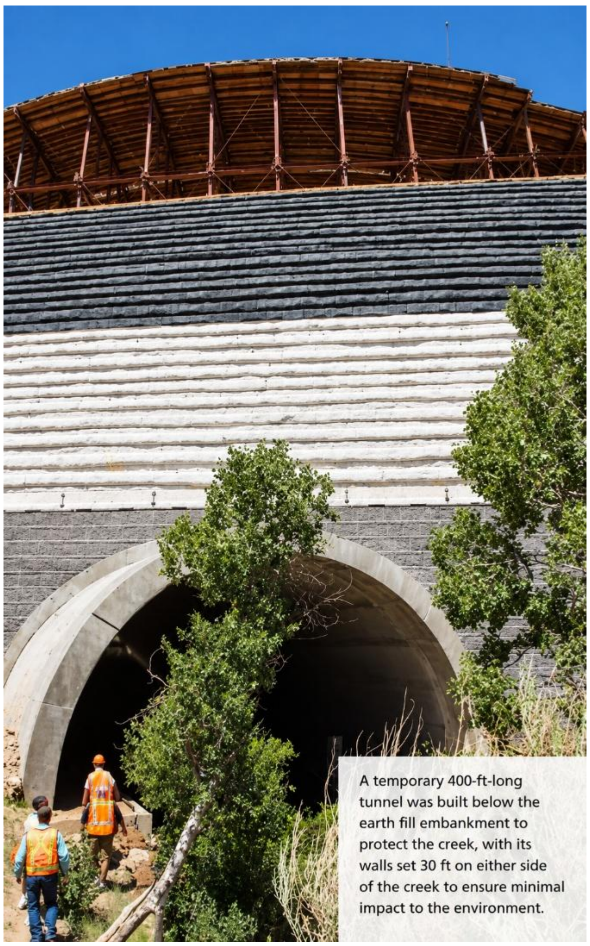



*Figure 15. MSE/RSS wall, creek tunnel, and forms for the arch. (NDOT)*

*Figure 16. Photo from Durski (ASPIRE The Concrete Bridge Magazine, Winter 2010) of the partly completed arch forms with the MSE/RSS walls in place during construction. (NDOT)*

## Drive to Stop 3 — The 1983 Slide Mountain Landslide

The route into Washoe Valley passes below Slide Mountain, site of one of the most dramatic landslide events in the region's recent history. On the morning of May 30, 1983, Memorial Day, following an exceptionally wet and heavy winter (snowpack around 200 percent of average, driven by a strong El Niño), a mass of roughly 1.4 million cubic yards of rock collapsed from the upper slopes of Slide Mountain into Upper Price Lake (Figure 19).

A hang-glider pilot who had launched from the Slide Mountain ski area minutes earlier watched the collapse from above and later described the impact as looking like an explosion that "blew the lake apart" (McLaughlin, 2005). The displaced water and debris, roughly 20 acre-feet, surged down Ophir Creek as a fast-moving flow of mud, rock, and boulders, at times 40 to 50 feet high, snapping mature trees and eventually reaching homes on the valley floor below. One resident, alerted by an unfamiliar rumbling sound from the creek, looked out a back window in time to see what he described as a wall of debris tearing through the landscape "like someone was tearing things up with a bulldozer" (McLaughlin, 2005). The flood destroyed several homes and killed one person (Figure 17, Figure 19, Figure 20, Figure 21, and Figure 22).

The event is documented in detail in USGS Professional Paper 1617 (Glancy and Bell) and remains a widely cited case study of how a rapid, high-volume landslide into a small alpine lake can generate a destructive flash flood far downstream with almost no warning. Perhaps Slide Mountain foreshadowed extremely destructive events such as the 2026 Nepal–Tibet floods of Aug. 26, 2026 (https://en.wikipedia.org/wiki/2026_Nepal–Tibet_floods).

*Figure 17. 1983 Ophir Creek debris flow aftermath in Washoe Valley. Historical photographs from the June 10 field trip working guide.*

A reasonable question to ask is whether slides such as in 1983 may have occurred in the geologic past, and what evidence we might find for them. Short of drilling, Louie of UNR and Dan Sturmer of the University of Cincinnati conducted in 2021 a geophysical profile of shear-wave velocity across the toe of the slide using the Terēan Deep ReMi® technique (Sturmer & Louie, 2023). They coupled that profile with another profile a mile south where there is no evidence of landslide deposits, bottom at right, as a control. The velocity sections (Figure 18) show that, below Slide Mountain, one third to one half of the 600-1300 ft basin thickness is filled with higher-velocity slide debris. The velocity of the slide debris is elevated by the presence of large boulders in a well-graded, tightly packed slide deposit. The velocity inversions below the slide deposits correspond to the

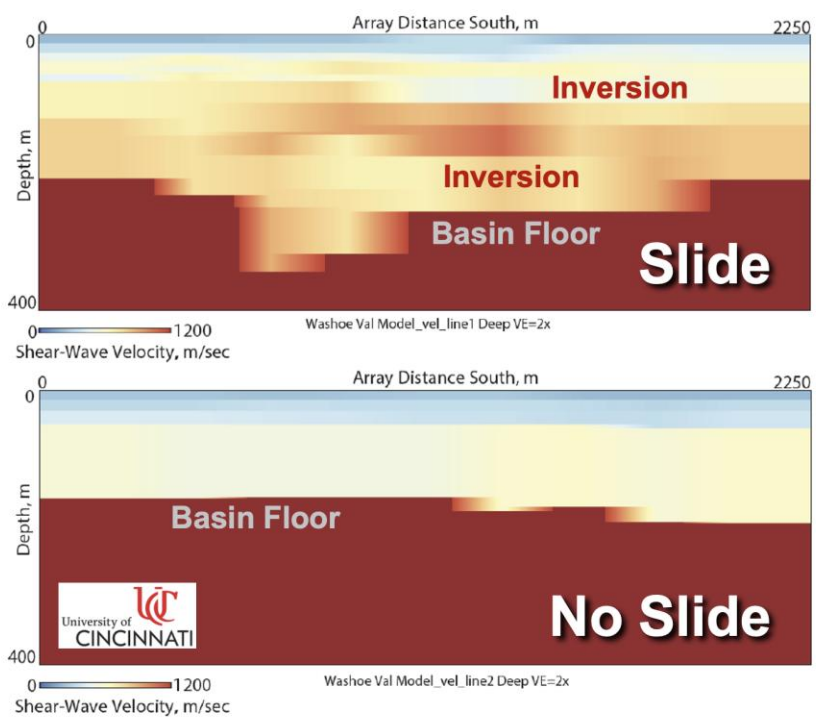



*Figure 18. ReMi® shear-wave velocity cross-sections through Washoe Valley, comparing a profile through 1983 landslide debris (top, showing a velocity inversion) against a profile with no slide material (bottom).*

loose fluvial sands and fine-grained lacustrine deposits of relatively slide-free intervals, with few boulders. At the control profile to the south, there is no basin fill having velocities elevated above the values expected of finer-grained Quaternary fluvial and lacustrine deposits. The surveys also hint at small grabens within the basin floor itself, additional evidence of the ongoing extension that shapes this valley.


Figure 19. Reno Gazette-Journal graphic illustrating the 1983 Slide Mountain event (RGJ, 2015).

Figure 20. Slide deposits on the floor of Washoe Val. (USGS photo).

Figure 21. Bouldery slide deposits 6 ft thick being cleared from Bowers Mansion Rd. (RGJ).

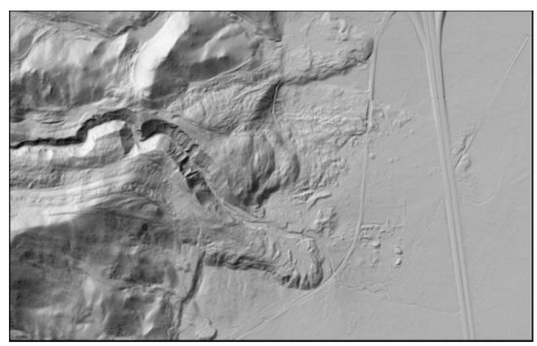


Figure 22. Lidar map showing bouldery lobes of the recent and three past slides running out from the mountain front into Washoe Valley, from Koehler (2022).

## Stop 3 — Bellevue Lookout, Washoe Valley

From Bellevue Lookout, roughly in the middle of Washoe Valley, the discussion turns to Walker Lane tectonics, the volcanic and sedimentary history of the Great Basin, the Sierran uplift, and how the 1983 Slide Mountain landslide is recorded in the valley's basin sediments.

## Volcanic and Quaternary history of Washoe Valley

The view from Bellevue Lookout records several overlapping chapters of western Nevada geology. Bedrock in and around Washoe Valley includes older granitic, metamorphic, volcanic, and sedimentary rocks, while the valley floor and range fronts preserve much younger deposits produced by alluvial fans, glaciers, landslides, debris flows, lakes, and wind. The nearby Steamboat Hills contain rhyolite lava and tuff about 1.2 million years old and basaltic andesite about 2.2 million years old, among the youngest volcanic rocks in western Nevada (Carlson et al., 2019).

The basin itself is equally important to the field trip story. Washoe Valley lies along the seismically active eastern front of the Carson Range (Figure 23). Quaternary faulting has displaced alluvial fan, debris flow, and glacial deposits, while repeated mass wasting from Slide Mountain has filled Ophir Creek canyon with a complex of at least five debris flow deposits, including the destructive 1983 event. Together, the faults, basin sediments, young volcanic rocks, and debris flow deposits show how tectonic extension, volcanism, erosion, glaciation, and mass wasting have acted together to shape the modern transportation corridor (Carlson et al., 2019).

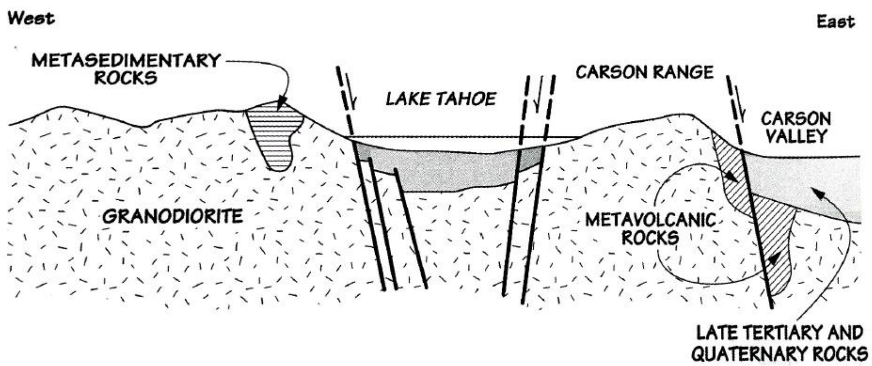



*Figure 23. Regional cross-section from the Sierra Nevada granodiorite through the Lake Tahoe basin to Carson Valley, showing the range-front normal faults visible from this vantage point. From Purkey & Garside (1995).*

As recently as 12,000 years ago, overflow from Washoe Lake went down Steamboat Creek to the Truckee River, which fed Pluvial Lake Lahontan. (Lake Tahoe also fed the Truckee River and Lake Lahontan.) Figure 25 shows the maximum extent of the lake 12,000 years ago at its maximum, and the glacier fields that fed it.

The Genoa fault forms the eastern front of the Sierra Nevada in this region (Ramelli et al., 1999). The Genoa is semi-continuous with the Mt. Rose fault system north from Washoe Valley (Figure 24). Altogether, the linked fault system could be 50 miles to even 60 miles long. If the entire length ruptured in one earthquake, its magnitude could be up to 7.5. The Genoa–Mt. Rose system is considered to pose the greatest earthquake hazard to the population and economy of the Reno-Tahoe-Carson metro area.

Eckert et al. (2021) constructed a physics-based model of a smaller, magnitude 6.3 scenario earthquake on a small portion of the fault system below south Reno. Their simulation included geotechnical, basin, and topographic effects on the propagation of the earthquake-shaking waves (Figure 26).

# Lunch — Genoa Golf Club

The group breaks for lunch at Genoa Golf Club, whose Lakes Course occupies the floor of Carson Valley along the Carson River, about three miles north of the historic town of Genoa. The property was carved out of a cattle ranch first homesteaded in the 1850s, and the Lakes Course itself was built in 1993, co-designed by PGA Champion Peter Jacobsen and John Harbottle III. Water comes into play on 14 of its 18 holes, with rolling fairways, wetlands, and the winding Carson River woven through the layout, a fitting lunch backdrop given the morning's discussion of basin sedimentation and active fault-bounded valleys.

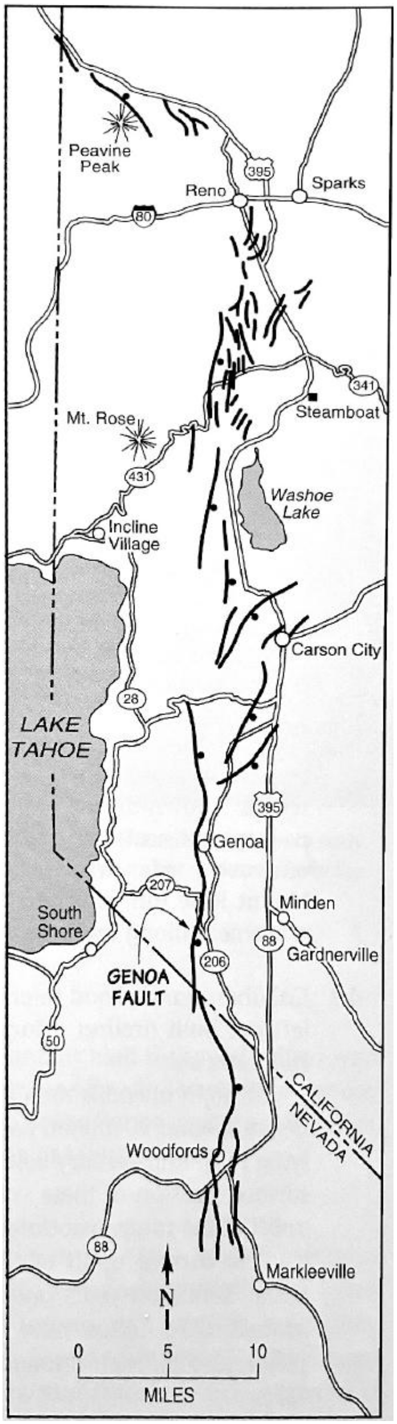



Figure 24. Diagrammatic map of the principal traces of the Genoa-Mt. Rose fault From Purkey & Garside (1995).

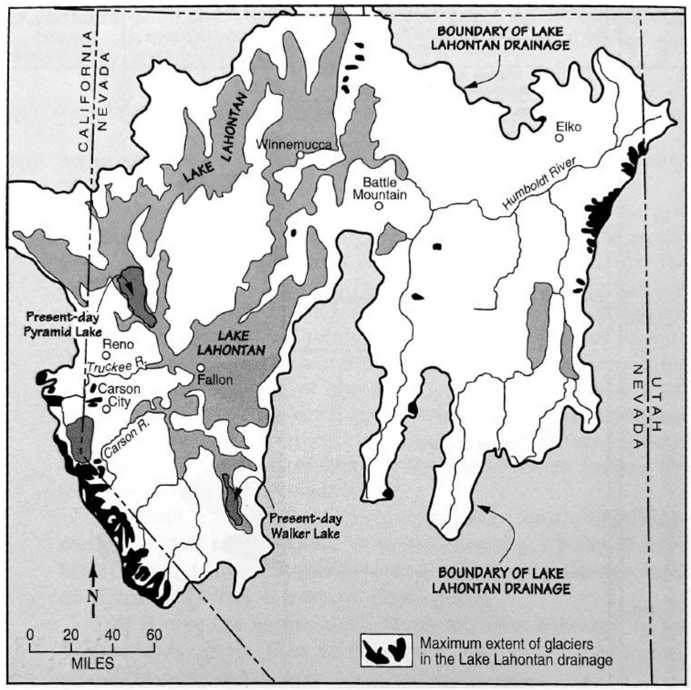



Figure 25. Pleistocene Lake Lahontan extent map.

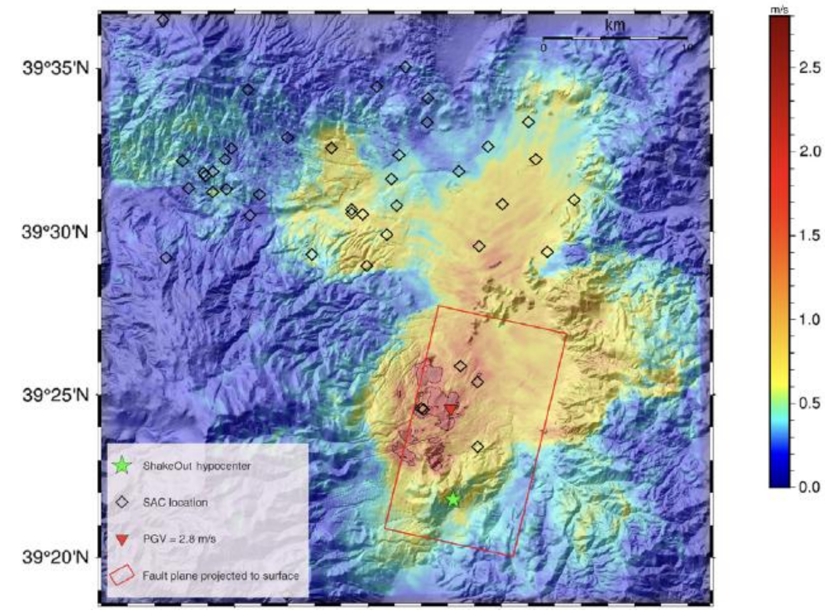



Figure 26. Physics-based scenario shake map for a M6.3 earthquake under south Reno, from Eckert et al. (2021). "Extreme" ground shaking at a particle velocity of over 1.5 meter per second is red and mostly located directly where the east-dipping rupture (red box) comes to the surface. Basin and topographic effects, modeled up to a frequency of 3.1 Hz, spread "Severe" shaking (yellow) northward into the Truckee Meadows basin.

## Stop 4 — Genoa Fault Scarp

At the Genoa fault scarp, a visible break in the landscape created by an active fault near Genoa in Carson Valley, the discussion turns to that fault system specifically and to how faults are characterized more generally across the Walker Lane. This fault scarp, with its last rupture just hundreds of years ago, is spectacularly exposed to the western wall of a gravel quarry formerly used by NDOT (Figure 27and Figure 28). Participants are invited to walk about 50 meters over rough ground to view the scarp closely.

This is one of the strongest stops on the trip for explaining how earthquakes shape the land, and why "where you build" matters as much as "how you build." Most visitors can recognize the feature quickly once it is pointed out — it reads as a simple step or ledge in the landscape, formed by repeated slip on the fault over many earthquake cycles.

*Figure 27. Looking north along the natural part of the Genoa fault scarp at Walley's. Photo by J. Louie.*

*Figure 28. A visible break in the landscape created by an active fault, located near Genoa in Carson Valley.*

Paleoseismic trenching across this scarp (Ramelli et al., 1999) exposed evidence of two large late-Holocene earthquakes on the Genoa fault, with normal-slip offsets of roughly 3–5.5 meters per event, comparable to the largest historical Basin and Range earthquakes, and equivalent to magnitude 7.2–7.5 (Figure 29). Radiocarbon dating placed the two most recent ruptures at about 500–600 and 2,000–2,200 years ago, and the fault's late Holocene slip rate of 2–3 millimeters per year is among the highest in the Basin and Range province.

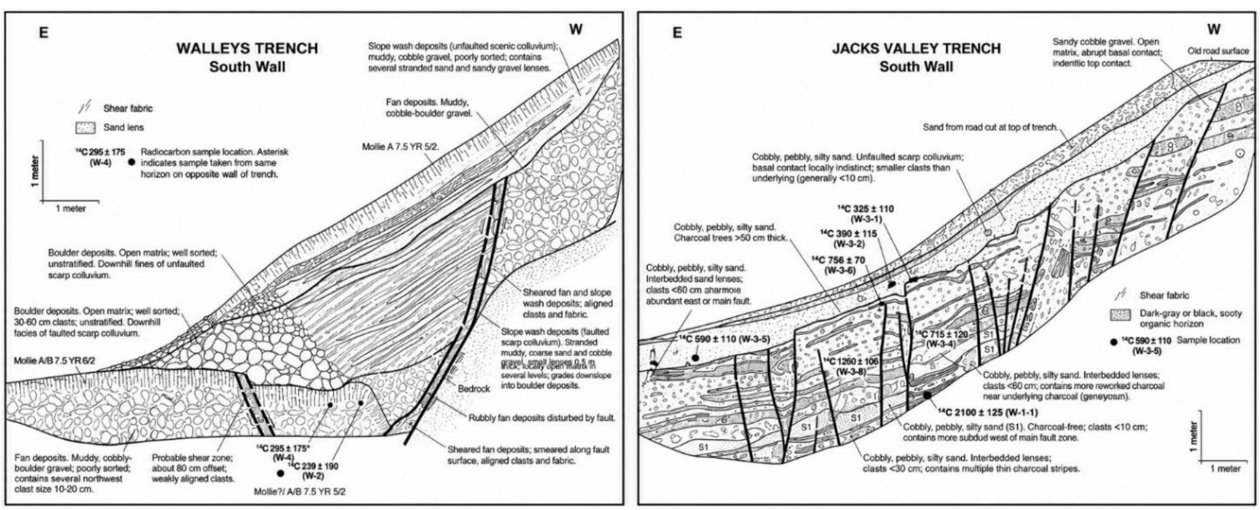



*Figure 29. Detailed trench logs of fault exposures at Walley's Hot Springs (left) and Jacks Valley (right). From Ramelli et al., 1999.*

## Drive to Stop 5 — Kingsbury Grade and Lake Tahoe

The climb up and over toward Lake Tahoe crosses the Carson Range along Kingsbury Grade, gaining elevation quickly and offering a preview of the Tahoe basin's steep, fault-bounded margins.

### Sidebar: Donner Lake Glaciation (background only — not a stop on this trip)

Although Donner Lake is not a field stop, its landscape provides useful regional context. Pleistocene glaciers repeatedly occupied the Tahoe-Truckee region, carving valleys and leaving moraines that locally dammed drainage. Donner Lake is a classic example of a basin whose modern form reflects this glacial history (Birkeland, 1964).

Glacial and ice-dam processes also affected the Truckee River system. Temporary blockage of drainage could raise lake levels and, when a dam failed. This released powerful outburst floods capable of transporting very large boulders downstream. This background helps connect the glacial landscape around Lake Tahoe with flood deposits observed farther east along the Truckee River corridor (Birkeland, 1964; Purkey and Garside, 1995).

### Geologic setting of the Lake Tahoe basin

Lake Tahoe and the surrounding mountains are underlain by Jurassic and Cretaceous granitic rocks (mostly granodiorite), which locally enclose small pendants of older Triassic and Jurassic metamorphic rock. In the Carson Range on the lake's east side, Miocene latite and trachyte, fine-grained volcanic rocks rich in alkali feldspar, intrude the granodiorite. Capping these older rocks are Early Miocene rhyolite ash-flow tuffs and younger Pliocene–Pleistocene basalt, along with associated lahar (volcanic mudflow) deposits.

Modern Lake Tahoe began forming roughly two million years ago after basalt and latite lava flows dammed its outlet near present-day Tahoe City. During Pleistocene and early Holocene glaciation, valley glaciers scoured the surrounding granitic bedrock; temporary damming of the lake's outlet by glacial ice periodically raised water levels and, when those ice dams failed, sent catastrophic floods as far downstream as modern Reno — the same process described in the Donner Lake sidebar. Figure 30 shows how the deep bathymetry of the bottom of Lake Tahoe has clear evidence of how a giant landslide originating on the west shore at McKinney Bay scattered huge blocks of slide debris all the way across the floor of the lake. Current thinking is that this giant slide occurred at about 250 ka.

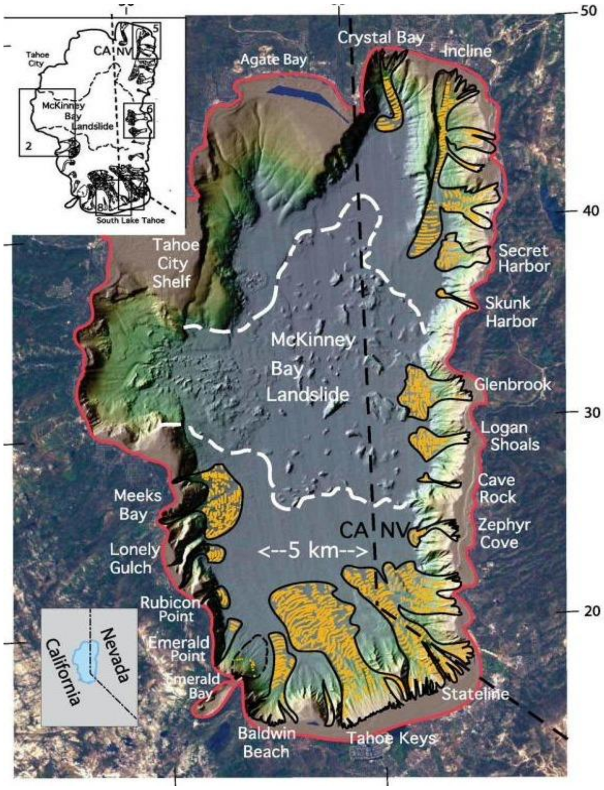
The lake occupies an active, fault-bounded half-graben that began forming about 3.7 million years ago. Although geographically part of the Sierra Nevada, the Tahoe basin is structurally a Basin and Range feature, shaped by the same regional extension responsible for Washoe and Carson Valleys. Five east-dipping normal faults cut the basin, at least three of which remain active and can produce magnitude 7.0 earthquakes; a rupture on either of two of these faults could generate a tsunami up to about 10 meters high in parts of the lake. Studies also show several faults in the western half of the basin capable of magnitude 6.3–6.9 events, with the potential to trigger further landsliding.

## Stop 5 — Sand Harbor State Park and the Tahoe East Shore Trail

Sand Harbor sits along Nevada State Route 28 between Incline Village and the town of Sand Harbor. Memorial Point Overlook nearby offers an easy, bird's-eye view of Lake Tahoe's famous color variations and the large granite boulders that line the shoreline. A short trail from the free parking area leads to the visitor center and the shore itself, with small interpretive posts along the way describing local flora, fauna, and fish habitat, and it is a popular, easily accessed fishing spot.

### Building a trail on a granite cliff

The Tahoe East Shore Trail, a paved multi-use path roughly three miles long, was built to give the public safer, dedicated access to this stretch of shoreline while relieving pressure on the Highway 28 corridor. At ten feet wide, the trail meets Americans with Disabilities Act standards, and it includes bike repair stations, racks, restrooms, and more than 25 interpretive panels covering the area's history, ecology, and geology. It begins at the intersection of Lakeshore Drive and Highway 28 and extends the existing Lakeshore path three more miles to Sand Harbor State Park, passing Hidden Beach and Memorial Point along the way, one segment of a larger trail planned eventually to circle the entire lake.



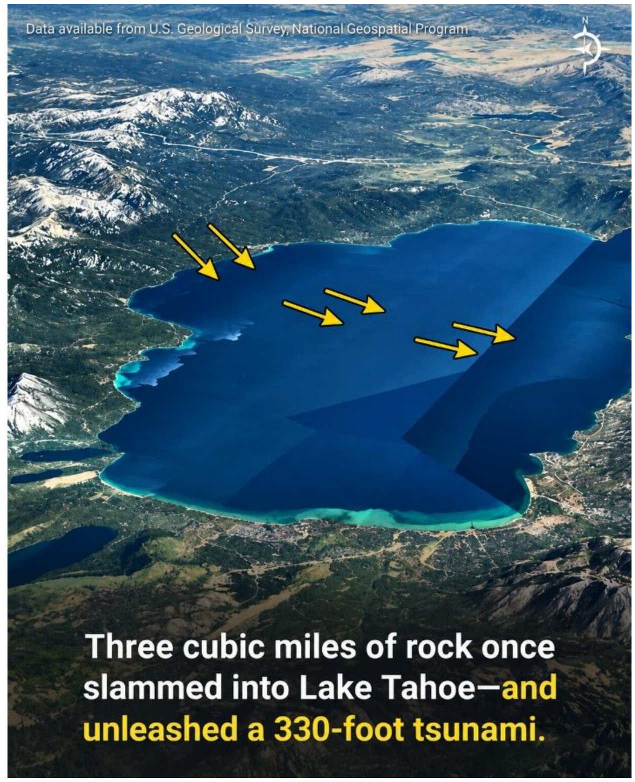




*Figure 30. (left) Lake-floor bathymetry showing the McKinney Bay landslide and other submerged slope failures around Lake Tahoe's margin — a reminder that large mass-wasting events, like the one at Slide Mountain (Stop 3), have also shaped the lake basin itself. From Moore et al. (2014). (right) Illustration suggesting how the catastrophic collapse of 1-3 cubic miles of the west Tahoe shoreline, forming McKinney Bay, could have resulted in a 300 ft high seiche (tsunami in a lake) and scattered blocks of the western shore across the bottom of the lake*

Constructing the East Shore Trail meant building a durable, ADA-accessible path directly into steep granite slopes above the lake (as in Figure 31), without closing the adjacent highway and under close environmental oversight. The Tahoe Regional Planning Agency (TRPA) monitored construction and aesthetics from a boat throughout the project. Figure 32 shows the north entrance to the lakeside part of the trail.

*Figure 31. A soil nail wall holds the active highway alignment above the new trail bed.*


*Figure 32. The finished trail: a cantilevered steel-surfaced boardwalk carries walkers and cyclists along the cliff face above Lake Tahoe's east shore.*

## Drive to Stop 6 — Mt. Rose Highway and the Mt. Rose Fan

The drive to the final stop climbs Mt. Rose Highway toward its summit, passing the site of a gabion wall failure, caused by ice jacking from insufficient drainage behind the gabions. Coming down from the Mt. Rose summit, the highway drops about 4,500 feet in elevation, crossing slopes with potential winter avalanche activity. Along the way, the view descending toward Reno has been compared to the view from "the cockpit of a plane coming in for a landing."

Historic low-angle aerial photography of this area, taken before it was developed, clearly shows fault traces picked out by subtle shadowing across the Mt. Rose alluvial fan, features now buried beneath homes and roads (Figure 33).


*Figure 33. Historic low-sun-angle aerial photograph showing fault traces delineated by shadowing along Mt. Rose Highway, before the area was developed. North is to the left.*

## Stop 6 — Galena Forest Bridge, Interstate 580

The Galena Forest Bridge on Interstate 580 was constructed over highly altered, unstable geothermal ground, with active fumaroles and boiling springs directly underneath. Figure 34 shows an aerial view of the bridge during its construction. The white ground is geothermally altered and weak.

At the Galena Forest Bridge, the field trip enters the Steamboat Springs geothermal field, where active faulting, hydrothermal alteration, geothermal production, and transportation infrastructure can be considered together. The material in this section was provided for the 2026 Highway Geology Symposium by Ormat and is used here as the primary description of the field and its operation.

### Geologic setting and geothermal resource

The greater Truckee Meadows area lies within the Walker Lane extensional zone along the eastern margin of the Sierra Nevada. In the Steamboat area, extension is accommodated by northwest striking right lateral oblique faults, east northeast striking left lateral oblique faults, and north south normal faults (Figure 35). The Steamboat Hills form an east-northeast trending intra-basin horst about 9.5 miles south of downtown Reno.

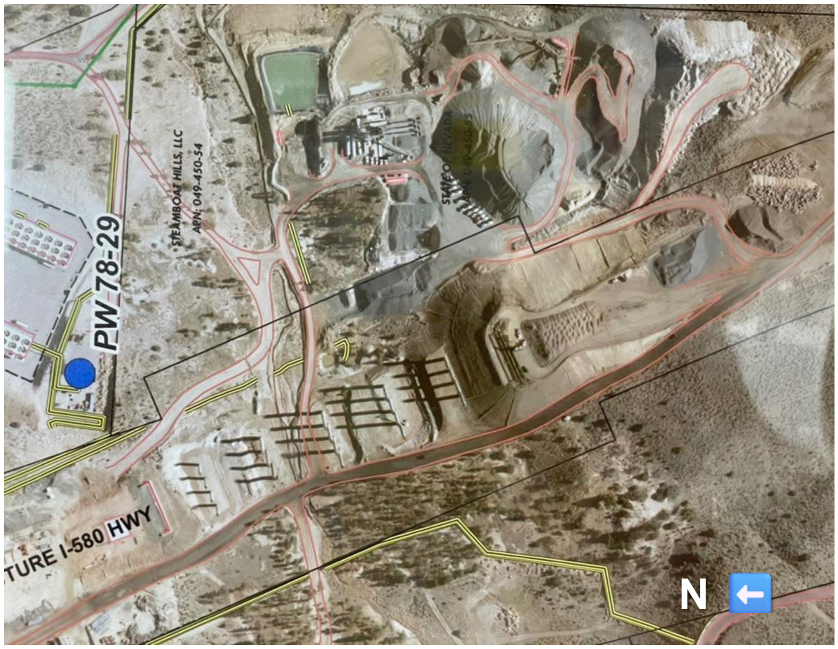



*Figure 34. Galena Forest Bridge piers during I-580 construction. North is to the left (courtesy of Ormat).*

The local geologic section includes Triassic metasedimentary rocks intruded by Cretaceous granodiorite, overlain by Miocene to Quaternary intermediate and felsic volcanic rocks, younger alluvium, and hydrothermal deposits (White et al., 1964). Fracture controlled permeability along northeast, north, and northwest striking faults provide pathways for geothermal fluids (Figure 35). Natural state upflow occurs in Upper Steamboat, with general northeast directed outflow toward Lower Steamboat.

Hydrothermal alteration is an important surface expression of this system. Near Pine Basin, hydrogen sulfide from deeply circulated geothermal fluids can oxidize to form sulfuric acid, producing strong argillic alteration and clay minerals such as kaolinite and smectite. Siliceous sinter and silica cemented alluvium in Lower Steamboat record cooling and degassing of thermal fluids along the outflow path.

## The Steamboat geothermal reservoir

Lower Steamboat is described as a highly permeable resource. Wells are generally about 700 to 2,000 feet deep, with most pumps set near 500 feet and production temperatures around 280°F. The Steamboat Hills resource is hotter. Some wells flow artesian while others are pumped, with well depths reaching about 3,000 feet, pumps set near 1,700 feet, and production temperatures of approximately 320°F to 340°F.

The reservoir cross section below (Figure 36) illustrates the hydraulic and thermal connection between Steamboat Hills and Lower Steamboat. It shows wells, faults, lithologic units, temperature contours, and the northeast directed movement of geothermal fluids through fractured rock.

## Steamboat Complex operations

According to the Ormat overview prepared for this symposium, the Steamboat Complex has 79 MW of geothermal generating capacity and 17 MW of solar capacity. The complex includes five operating plants, 24 production wells, and 10 injection wells. Reported resource temperatures range from 270°F to 325°F, and the land position covers approximately 1,468 acres of private and Bureau of Land Management leases. Power is sold under long-term agreements with SCAPPA and Nevada Power Company.

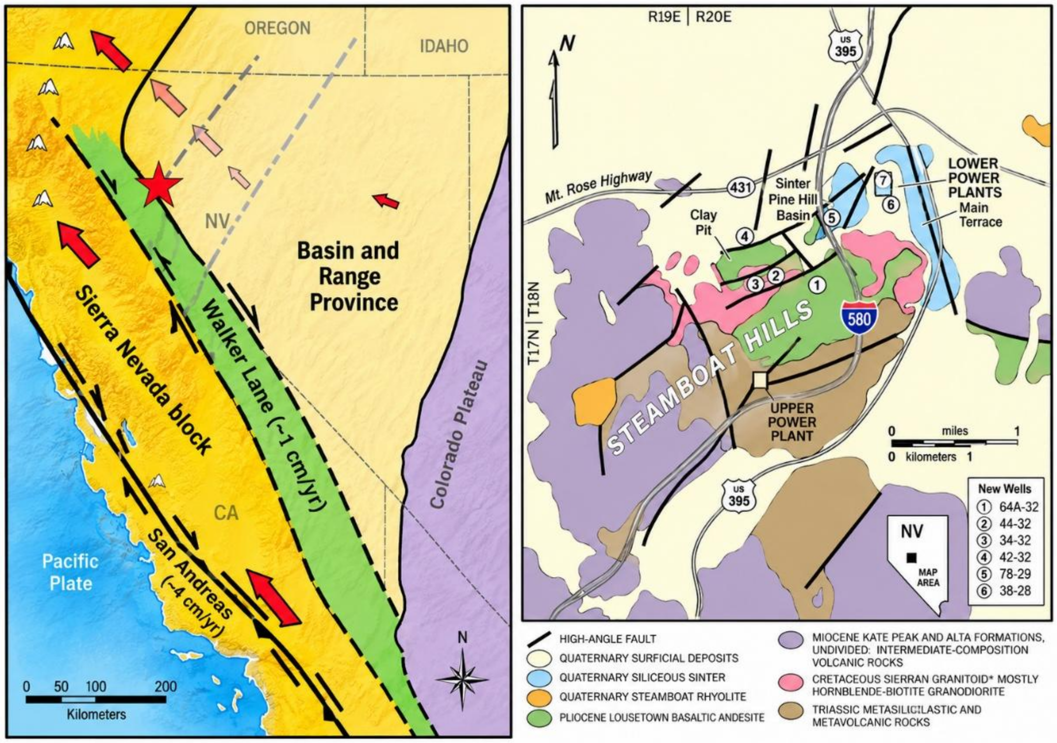



*Figure 35. Tectonic setting of Steamboat within the Walker Lane and geologic map of the Steamboat area. Source: Ormat material prepared for HGS 2026. Original figure sources: Faulds and Henry (2008) and Johnson and Hulen (2006).*

Two environmental features are particularly relevant in the field. Acidic geothermal soils in Pine Basin can stunt pine growth, providing a visible expression of near surface geothermal conditions. The Steamboat buckwheat is an endangered plant restricted to this valley and is actively protected during development and routine operations.

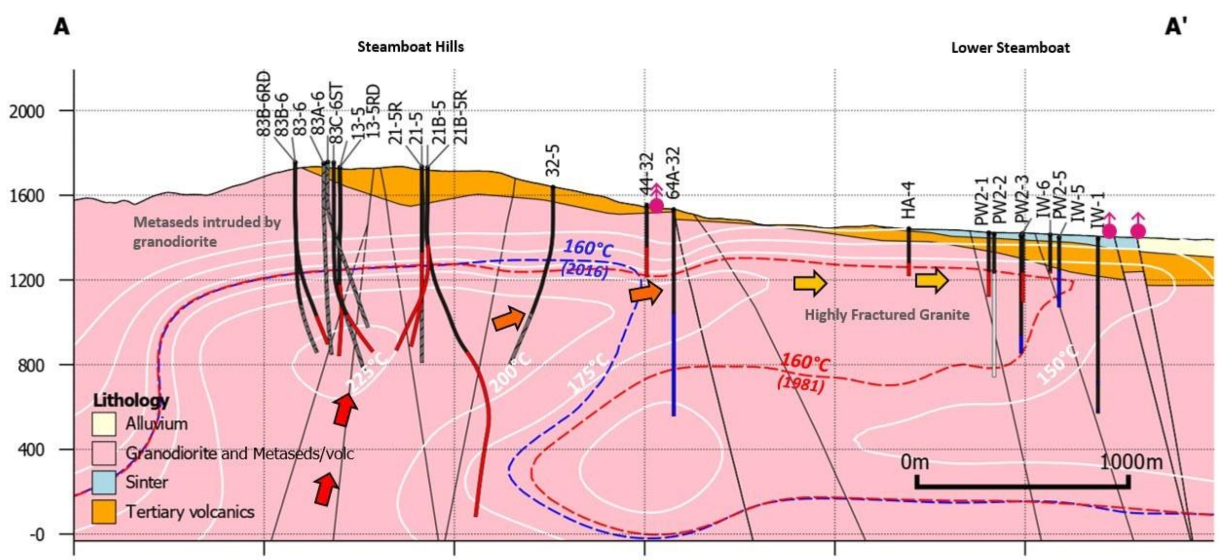



*Figure 36. Cross section showing the connection between the Steamboat Hills and Lower Steamboat reservoirs, natural state temperature isotherms, and cooling of outflow associated with production. Vertical scale is elevation in meters. Source: Ormat material prepared for HGS 2026.*

### How binary geothermal generation works

The Steamboat plants use binary geothermal technology (Figure 37). Hot geothermal fluid from production wells transfers heat to a separate motive fluid in heat exchangers. The motive fluid vaporizes and drives a turbine generator, then is condensed and recirculated through the closed power cycle. The cooled geothermal fluid is returned underground through injection wells. This separation allows heat to be extracted from the geothermal resource without sending the geothermal fluid through the turbine.

### What to observe at Stop 6

As the group views the Steamboat field, note the close relationship among fault-controlled permeability, hydrothermal alteration, production and injection infrastructure, and the I-580 transportation corridor. The stop provides a practical example of how the same active tectonic setting that creates geologic hazards can also create a renewable energy resource.

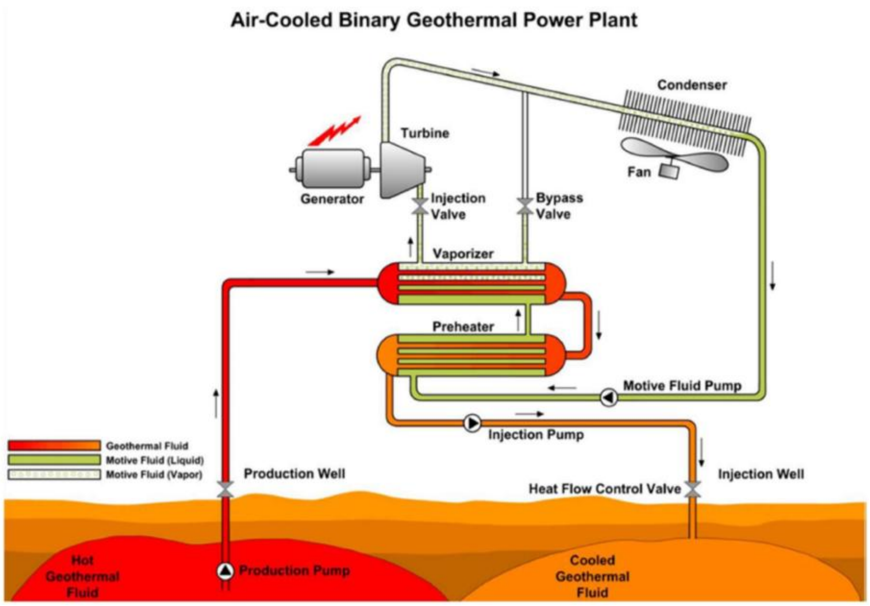



*Figure 37. Air cooled binary geothermal power plant process diagram showing production, heat exchange, power generation, condensation, and reinjection. Source: ProcessDiagrams.pdf supplied for the HGS 2026 field guide by Ormat.*

## Driving to the Hotel

From Galena Forest Bridge, the group descends I-580 north toward Reno, rejoining South Virginia Street near its junction with Mt. Rose Highway for the short drive back to the Reno Arch. Directly across that junction, NV-341 (Geiger Grade) climbs east toward Virginia City and the Comstock Lode, itself worth a full day's field trip, and a natural extension for a future symposium. Discovered in 1859 beneath Mount Davidson, the Comstock Lode was the first major silver discovery in the United States, and the resulting boom helped drive Nevada to statehood in 1864. Geologically, the deposit is a classic low-sulfidation, quartz-adularia epithermal vein system, roughly 12.5 to 13.7 million years old, in which silver and gold precipitated from hot, mineral-laden fluids circulating along the Comstock and related faults. Mining the lode to depths exceeding 3,000 feet, through hot, water-charged, and structurally complex ground, drove major advances in deep-mining and ground-support engineering, a fitting bookend to a day spent looking at how the region's active faulting continues to shape both hazard and infrastructure today.

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