Guide for the Earth Science Week Field Trip, October 17 and 18, 2015

Nevada Bureau of Mines and Geology Educational Series E-57

Fire and Ice—Geology of the Mount Rose Quadrangle, Lake Tahoe, and the Carson Range

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The field trip starts at 9:00 am each day at the Galena Creek Visitor Center, located off Mt. Rose Highway (NV431), which we will refer to as MRH throughout this guidebook. From Reno, take I-580/US395 South, then take exit 56 toward North Lake Tahoe, merge onto MRH, and go 5 miles west to Galena Creek Park.

When you merge onto MRH, to the left are the Steamboat Hills, where two geothermal power plants are located. About 4 miles up MRH (just past Timberline Drive) you will pass a glacial moraine of Whites Creek (large ridge to right); this is evidence of one of the largest glaciers to come down the east flank of the Carson Range. Five miles up MRH, **turn right to the Galena Creek Visitor Center**. The Visitor Center has bathrooms, informative displays, and a gift shop; it's worth a look and opens at 9 am.

Mount Rose Geology Overview

The geologic history of the Mount Rose area spans nearly 200 million years and includes multiple episodes of volcanism, faulting, and erosion by rivers, glaciers, and landslides. Below is a summary of the geology of the Mount Rose area starting with the oldest rocks and events and continuing through to the most recent geologic activity.

The oldest rocks in the Mount Rose area are Jurassic metamorphic rocks. Locally, these metamorphosed volcanic and sedimentary rocks are preserved in only a few locations, and on this trip we will only get a glimpse of a small outcrop on the west face of Slide Mountain. The next oldest rocks are Cretaceous granitic rocks, which are common throughout the Carson Range and Sierra Nevada. These granitic rocks represent the deep magma bodies of a chain of ancient volcanoes that were active along the west coast of North America about 100 million years ago. Intrusion of the magma bodies caused the metamorphism of the overlying, or host, Jurassic rocks. Today, most of these ancient volcanic and metamorphic rocks are long since eroded away and only the granitic rocks (the cooled remnants of the magma bodies that fed these volcanoes) are left. The granitic rocks we see today originally formed at depths of 5 to 15 km below the ancient ground surface, but the old volcanoes did not stand at absolute elevations of 5 to 15 km above the modern elevation; rather the old mountains have eroded and the granite that formed deep underground has been uplifted to the surface.

A younger episode of volcanism swept across the region during the middle Miocene to Pliocene, 18 to 3 million years ago, and lingered into the Pleistocene, as recently as 1 to 2 million years ago. This period of volcanism deposited the volcanic rocks that we see today sitting directly on the Cretaceous granite. Volcanic rocks are exposed in many locations throughout the Mount Rose area; where they cap the top of Mount Rose, they contrast greatly with the much lighter underlying granitic rocks. The known ages of volcanic rocks in the Mount Rose quadrangle span from 13 to 5 million years old. The majority of these volcanic rocks were erupted from a single volcano that was active 7 to 6 million years ago, centered in the Gray Creek area in the northwest quarter of the Mount Rose quadrangle. This volcanic center is marked by a pattern of radial dikes and large areas of hydrothermal alteration.

The landscape we see today is largely the result of Basin and Range extension, which began in this region about 12 million years ago and continues to today. At this latitude, Basin and Range extension stretches from Salt Lake City to the west side of Lake Tahoe, a distance of more than 800 km. Prior to Basin and Range extension, the Salt Lake City and Tahoe areas were about 50% closer, but have spread laterally away from each other. This extension is accommodated by north- to northeast-striking normal faults, one of which bounds the eastern front of the Carson Range. Reno, Carson City, Minden, and Gardnerville are all located on the down-dropped side of this fault. Another north-striking fault bounds the west side of the Tahoe basin and drops the floor of this basin down to the east relative to the crest of the Sierra Nevada. The floor of Lake Tahoe is at a similar elevation to Carson City. Numerous smaller intervening faults that are parallel and synthetic to the large range-bounding faults cut through the mountain ranges. Many of these faults can be seen on the Mount Rose geologic map, including those cutting through the volcanic rocks capping Mount Rose.

The Carson Range fault system and the Tahoe basin faults are still active today as evidenced by earthquake scarps that cut young glacial and alluvial deposits. One of the primary faults in the northern part of the Tahoe basin, the Incline Village fault, is exposed in the Mount Rose map area. The fault follows much of the course of Third Creek and runs through the town of Incline Village. Both the Carson Range fault system and the Incline Village fault system experienced major earthquake ruptures about 300 to 500 years ago.

In addition to the faulting that has created the elongate north-south mountain ranges and basins we see today, glaciers, rivers, and landslides have also been shaping the landscape. Nearly all the major creeks that drain out of the northern Carson Range in the Mount Rose area were filled with glaciers at multiple times during the last several hundred thousand years. One of the largest moraines is visible along the range-front at the mouth of Whites Creek. Other well preserved moraines are in Galena Creek, Third Creek, Bronco Creek, and Gray Creek. The upper reaches of many of these drainages are U-shaped in cross-section, indicating glacial erosion. Valleys carved only by rivers tend to be more V-shaped in cross-section. There have been no large glaciers in the Carson Range for more than 10 thousand years, but there may have been small glaciers as recently as about 200 years ago. On this trip, we will visit young moraines below the northeast side of Tamarack Peak near the summit of Mount Rose Highway.

The Lake Tahoe basin probably formed during the past 3 million years. During this time, the level of the lake has fluctuated dramatically due to a combination of changing climate conditions and elevation of the outlet. Lava flows, landslides, and glaciers have blocked the outlet of Lake Tahoe from time to time, increasing the lake level far above its modern elevation. Periods of extended drought have also dropped the lake well below the current outlet. Several old shorelines are exposed near Incline Village. Some of the best examples are the prominent benches visible along Stateline Point, which we will see at the last stop on this field trip.

Table 1. Generalized Geologic Units of the Mount Rose Area

Geologic unit (abbreviated list)	Age	Years before present (very approximate)
Qg_1 – Young glacial deposits	Holocene	200 yr?
Qg_2 – Last glacial maximum (“Tioga”)	Pleistocene	20 thousand
Qg_3 – Earlier glacial maximum (“Tahoe”)	Pleistocene	50 or 150 thousand
Tv – Volcanic rocks	Miocene	5 to 15 million
Kgd – Granitic rocks (granodiorite)	Cretaceous	100 million

PDF Maps

Everyone who has access to a tablet or a smartphone with GPS capability is encouraged to download the PDF Maps app. It is available for Apple and Android platforms and it is free. The PDF copy of the Mount Rose geologic map is free to download (http://pubs.nbmg.unr.edu/Prel-geol-Mount-Rose-quad-p/of2014-07.htm) and can be uploaded to this app. The users will then be able to locate themselves on the map and follow along with the details of the geology while hiking or as a passengers in a vehicle.

http://www.avenza.com/pdf-maps

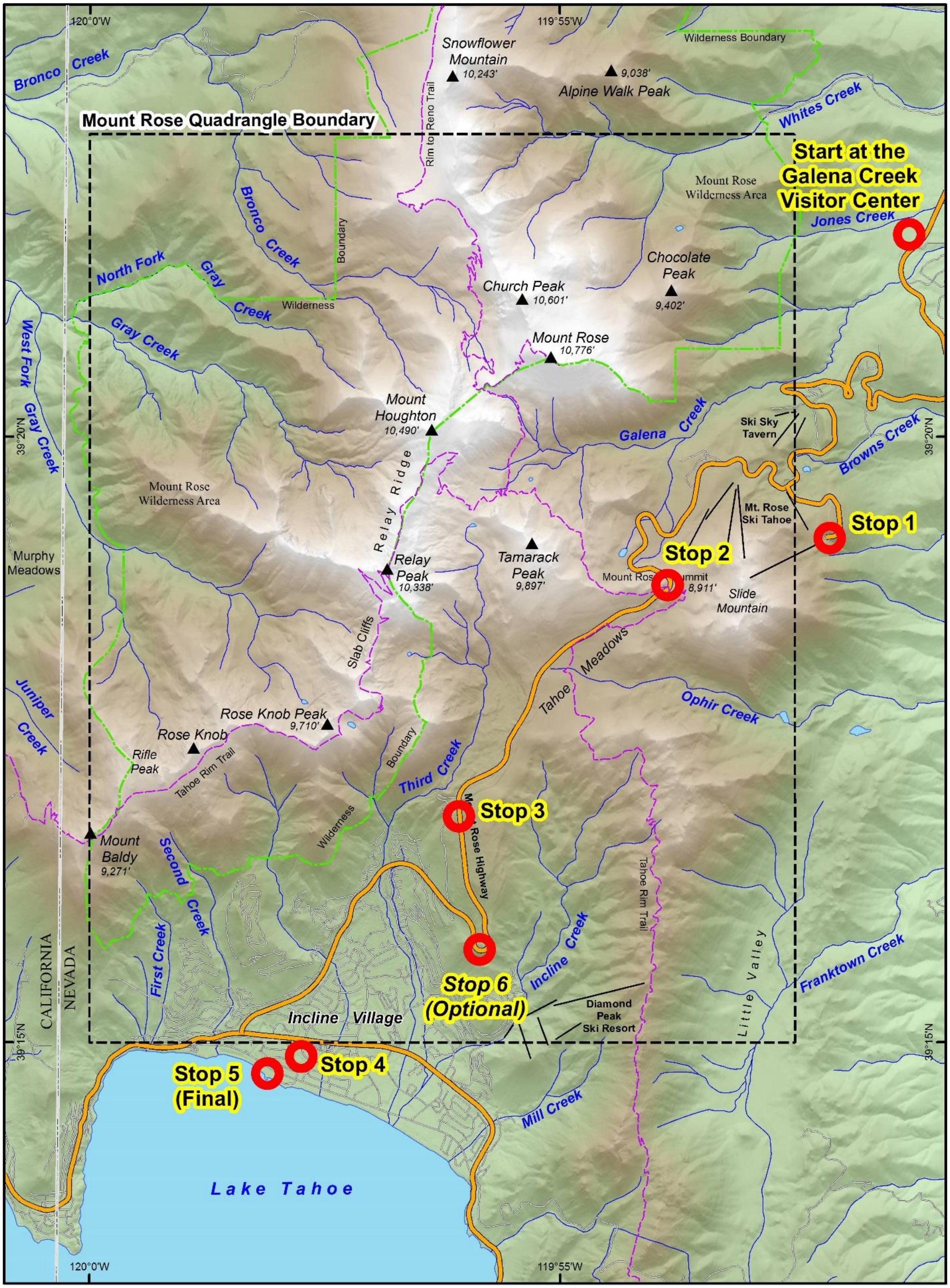

Figure 1. Field trip map.

Road Log

ZERO miles at the right turn from Galena Creek Visitor Center onto MRH (fig. 1). For almost 1 mi, MRH crosses the Galena Creek glacial outwash/alluvial fan.

0.7 – MRH begins to climb the range front. Bedrock-cored, right-lateral moraines of Galena Creek indicate that glaciers (Qg_3 and older) came down at least this far. For the next 3 mi, MRH is on volcanic rocks (Tv) dropped down to the east by a large fault.

1.9 – MRH bends to the right and parallels Browns Creek, the drainage to the left. Browns Creek glaciers spilled over the large fault escarpment ahead and to the left, but did not extend down as far as those in Galena Creek.

3.4 – Passing Sunridge and Reindeer Lodge, MRH is still on volcanic rocks, which can be seen through the trees to the right.

3.8 – Just past the Tannenbaum Event Center (on left), MRH crosses a large range-front fault (the Little Valley fault) and enters Kgd granitic rocks (covered by glacial deposits here). The volcanic rocks behind us are faulted down to the east by >1.5 km.

4.6 – For the next 0.2 mi, MRH is on a younger glacial outwash terrace (Qgo_2).

4.8 – At the sharp left bend, MRH climbs older glacial moraines (Qgm_3) that are about 60 m (200 ft) higher than the Qgo_2 terrace.

5.1 – Sky Tavern, on the right, is a publicly owned ski area that hosts a junior ski program and mountain-bike races.

5.5 – Kgd is highly fractured because it is bounded by two faults.

5.8 – Top of the range-front escarpment; this is where Browns Creek glaciers spilled over.

6.3 – Qg_2 moraines of Browns Creek. Qg_2 surfaces have many boulders, relative to the older Qg_3 surfaces we will see later.

6.5 – Left turn toward Mt. Rose ski area, Winters Creek Lodge (NV 878 S)

7.1 – Again, Kgd is bounded by two faults and is highly fractured.

7.6 – U-turn at Winters Creek Lodge parking lot (a note for another day: there's a very nice trail (~1 mile roundtrip) that loops around the top of the knob on the right; the trailhead is by picnic tables at the far end of the parking lot).

7.8 – Start back down NV878 and park on the right by the guardrail (east) for **STOP 1**. The large pullout where we will park offers a great view, but the view from the smaller pullout just below is even better and is where we will gather.

8.2 – View of Mt. Rose to the right (northwest).

8.7 – Intersect MRH.

ZERO miles at the **Left turn on MRH**

0.3 – Over the next 0.5 mi, road cuts expose thin Qg_3 deposits on Kgd, which has thin aplite dikes. The Qg_3 surfaces have fewer boulders than the Qg_2 surfaces we saw earlier due to weathering.

0.9 – Mt. Rose ski area, Main Lodge, on left.

1.5 – We won't stop here, but the pullout on the right provides a nice view of the faulted volcanic rocks capping Mount Rose (fig. 2).

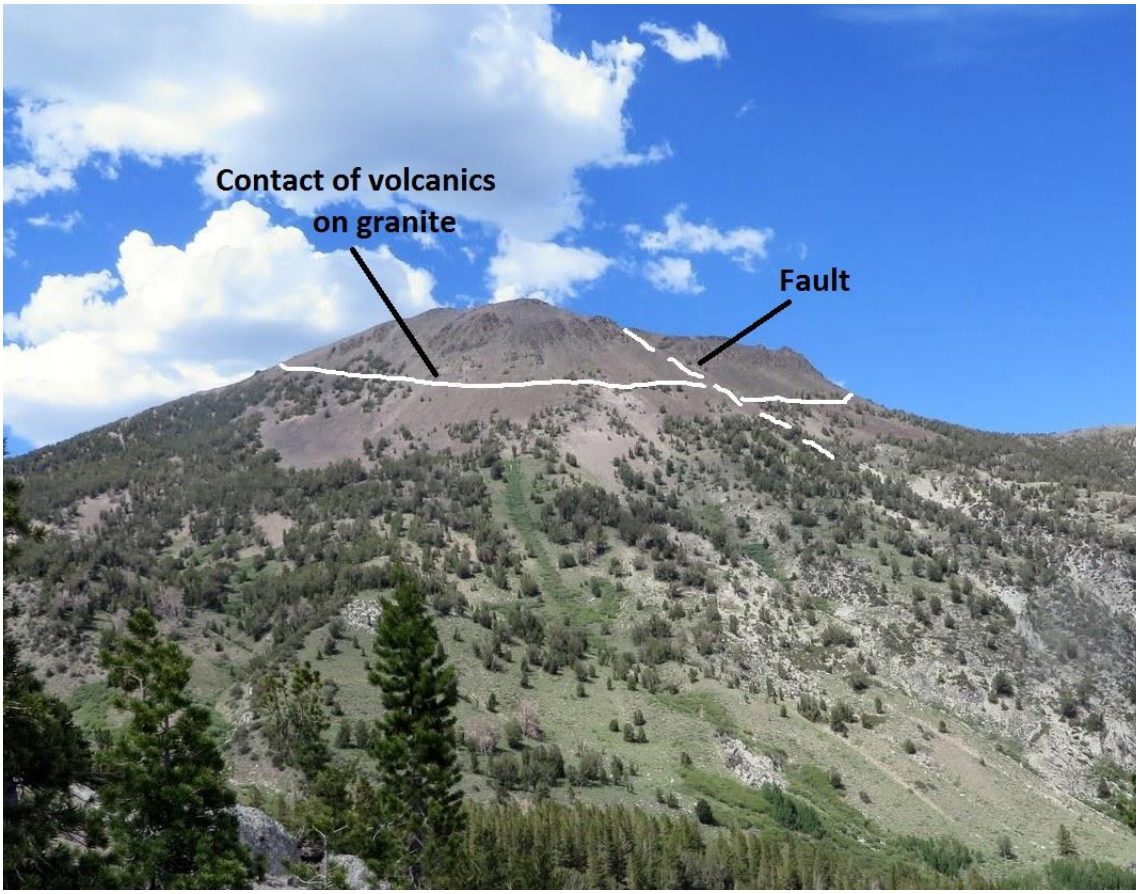

Figure 2. Photo of Mt. Rose showing capping volcanic rocks and the largest of several faults cutting the volcanic rocks. The capping andesite is 7 million years old. *Photo by Nick Hinz.*

2.8 – Ahead is Kgd (to left) faulted against Tv (to right; fig. 3); in the road cut just past this fault, fractures in Kgd parallel the fault.

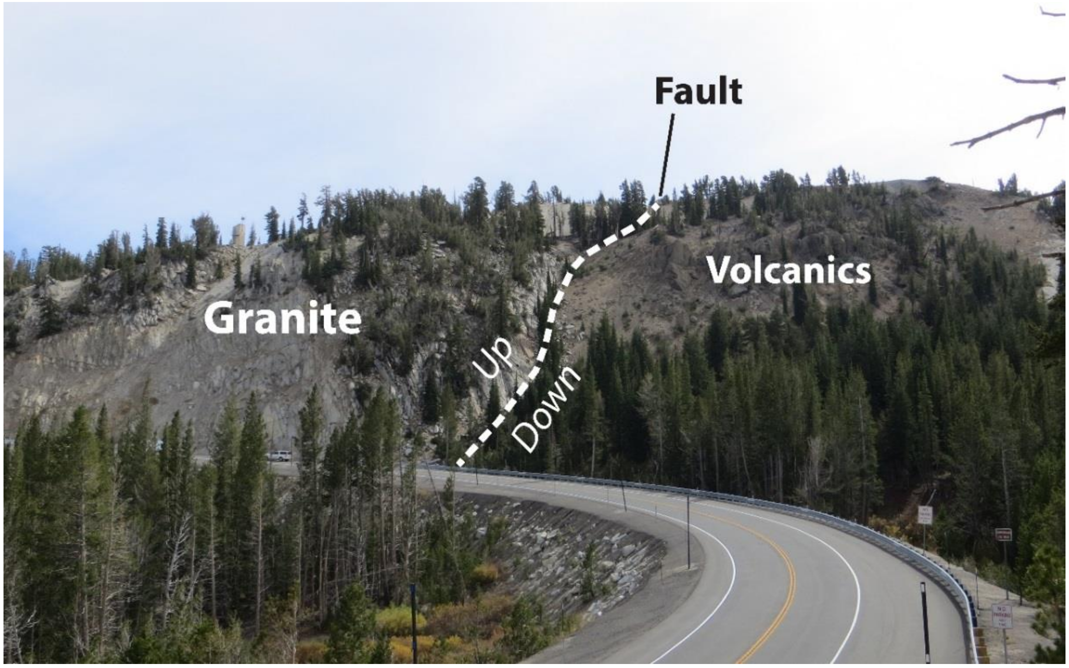

Figure 3. Photo at mileage 2.8 looking at a fault offsetting volcanic rocks against granodiorite. *Photo by Alan Ramelli*

3.3 – Park on the right at the Mount Rose Trailhead for **STOP 2**. We will hike along the Mount Rose trail (~2 mi round trip, fig. 4). Take water and lunch.

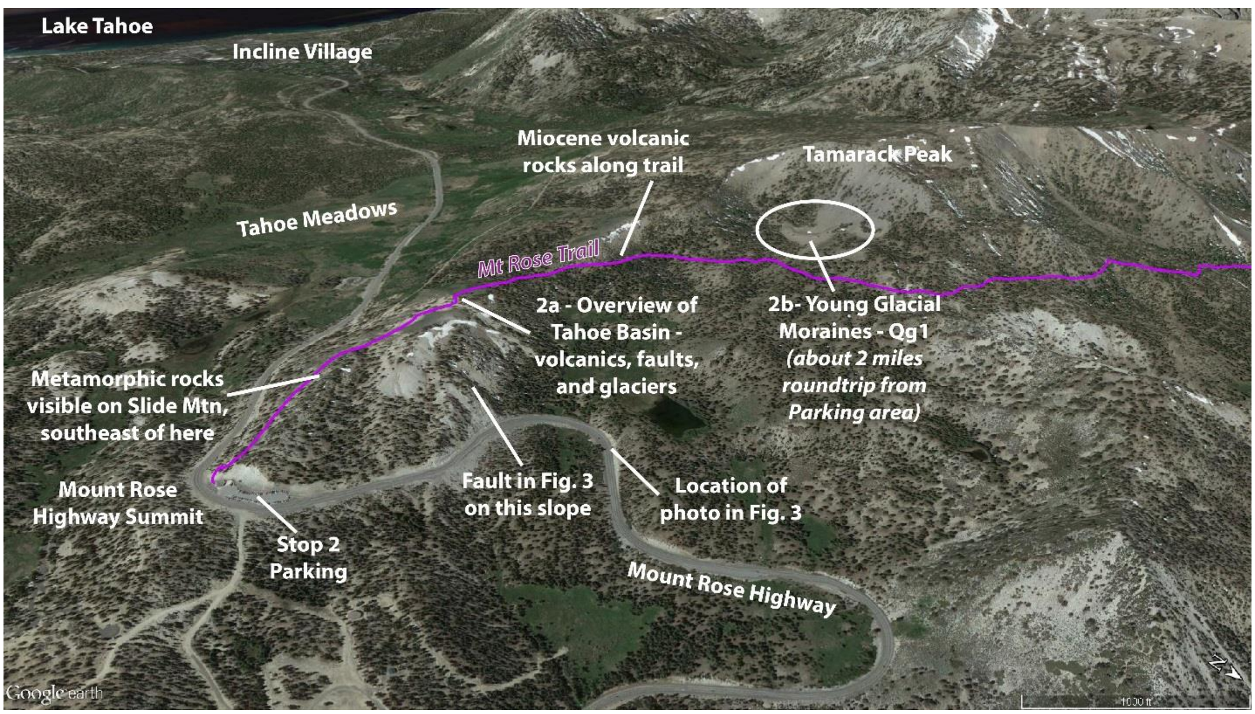

Figure 4. Stop 2 map, Google Earth image looking southwest. Stop 2b (our turnaround point) is at 39.3167º N, 119.9141º W.

ZERO miles at Mount Rose Trailhead and continue west on MRH, which drops down toward Tahoe Meadows (aka Sheep Flat), a popular recreation area.

0.5 – Watch for the flashing light that indicates a reduced speed limit during times of heavy recreational use.

0.7 – Tahoe Meadows trailhead on left. An interpretive loop trail here is a great short hike for another day.

1.5 – At the west edge of Tahoe Meadows, MRH enters the Lake Tahoe basin. For the next 1.5 mi, MRH parallels Qg_2 moraines of Third Creek.

3.1 – Park in the large pullout on the right with the "brake check area" sign for **STOP 3** (fig. 5). We will shuttle cars to a pullout 1 mi further down MRH.

For Stop 3, we will walk 0.1 mi back up MRH, then 0.5 mi down the old highway to look at contrasting weathering of different-aged glacial moraines. From there, we will continue walking down the old highway, then veer left on a flume trail, look at volcanic rocks, and end at a pullout further down MRH (total walking distance ~1.5 mi). This requires shuttling cars down to the 2nd pullout, or shuttling drivers back to the 1st pullout.

4.1 – Shuttle pickup at pullout on right, just past the bear-crossing sign.

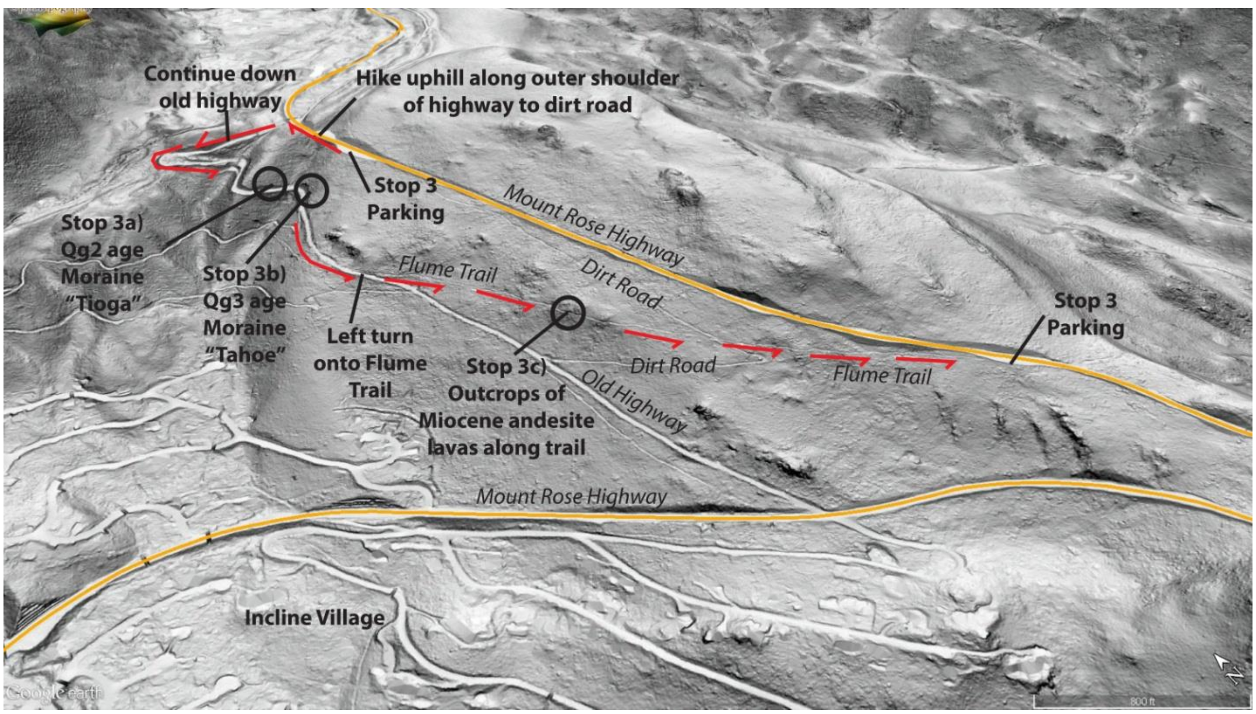

Figure 5. Stop 3 map, LIDAR image looking northeast. Go left on a flume trail at 39.2782º N, 119.9377º W. *Credit: Tahoe Basin LiDAR, 2011, www.opentopograpy.org*

ZERO miles at the pullout and continue west on MRH

0.4 – Scenic overlook on left (we won't stop here now, but this is an optional stop for the end of the day); the road cut on the right (opposite the overlook) exposes W-dipping basaltic andesite that is 5.5 million years old, and represents one of the youngest known volcanic rocks in the Mount Rose area.

1.4 – The first road cut stabilized with gabions (rock-filled wire baskets) is in the same Qg_3 moraine we saw at Stop 3.

1.9 – MRH crosses Third Creek.

4.0 – **At the roundabout, take the 2nd exit**, going east on Hwy 28 toward Incline Village.

4.3 – The outfield of Preston Field (on left) is cut into old lake deposits (beach sand and gravel) deposited by an older, higher stand of Lake Tahoe. We'll discuss these Qlo deposits at Stop 4.

4.6 – Crossing the Incline Village fault, which forms an E-facing scarp several meters high.

4.8 – **Turn right on Southwood Blvd**. The Incline Village fault scarp is behind the old Incline School on the right.

5.0 – **Turn right on Mays Blvd, then turn right into the Village Shopping Center**. Park near Village Market/Post Office for **STOP 4** (fig. 6). Follow the trail behind the market.

Figure 6. Stop 4 map, Google Earth image, with north at the top.

ZERO miles as you leave the Village Shopping Center and turn right on Mays Blvd.

0.3 – **Turn right on Lakeshore Blvd**.

0.35 – **Turn left into Burnt Cedar Beach**, turn left again, drive through the first parking area, continue left around the concession buildings to the east part of the park, and walk out to the point for **STOP 5**. We will look at older lake shorelines and discuss past levels of Lake Tahoe.

(Note: during summer months, generally from late May to late September, Burnt Cedar Beach is not open to the public).

The field trip ends here. The drive to return to Reno takes approximately 45 min. There are several ways to return to MRH. A recommended route is to go east on Lakeshore Blvd for 1.6 mi, then turn left on Country Club and go 3 mi, then turn right onto MRH; this will take you past several lakeside mansions, Incline and Ski Beaches, and the Tahoe Science Center, which is well worth a visit on another day. A somewhat shorter route is to go west on Lakeshore Blvd, turn right on Hwy 28, then left on MRH at the roundabout; however, the intersection with Hwy 28 can get backed up due to people trying to turn left. A third option is to go east on Lakeshore for 1.2 mi and turn left on Village Blvd; this will take you through central Incline Village and is a good option if you intend to stay for dinner (we'd be glad to offer restaurant recommendations if you ask).

On your return, the Scenic Overlook that we passed earlier is a worthwhile stop, especially for those who haven't been here before.

STOP DESCRIPTIONS

Stop 1: Overlook from Slide Mountain

At Stop 1, you are looking down the steep eastern face of Slide Mountain. This large escarpment was created by one of the largest active faults in the western Basin and Range Province, the Carson Range fault system (CRFS). To the south, the CRFS consists of a single large fault (Genoa fault) that bounds the west side of Carson Valley. At Washoe Valley, below you to the right, the CRFS includes two main faults: the Washoe Valley fault, which bounds the west side of Washoe Valley, and the Little Valley fault, which forms a smaller valley perched within the range. At Slide Mountain, the Little Valley fault is the main fault of the system and forms the large escarpment below you. To the north, the CRFS splays into a myriad of faults across the Truckee Meadows (Reno area).

- Sierra Nevada/Basin and Range Province transition

- Clarification of "Mount Rose"

- Slide Mt. landslides

Stop 2: Mt. Rose Trail (2 mile round trip)

-View of metamorphic rocks from the Mount Rose trail on the west side of Slide Mountain.

2a – Overview presentation and discussion of:

<u>Volcanic rocks</u>: Volcanic rocks capping the ridges were erupted from the 6–7 million year old volcanic center in Gray Creek. The capping andesite on Mount Rose summit is 7 million years old.

<u>Faults</u>: Faults in Tahoe basin, Tahoe geologic map, faults cutting Mt. Rose, Incline fault

<u>Glaciation</u>: Tahoe Meadows ice cap, Third Creek glacier; glacial erratics—large erratics can be found along the trail

-Volcanic rocks exposed along the trail—these were erupted from the 6–7 million year old volcanic center in Gray Creek

2b – Young moraine; Little Ice Age and Neoglacial period

Figure 7. Looking east down Galena Creek, a U-shaped canyon carved by glaciers. *Photo by Nick Hinz.*

Figure 8. Two-meter-high fault scarp along the Incline Village fault, near Tahoe Meadows. *Photo by Alan Ramelli.*

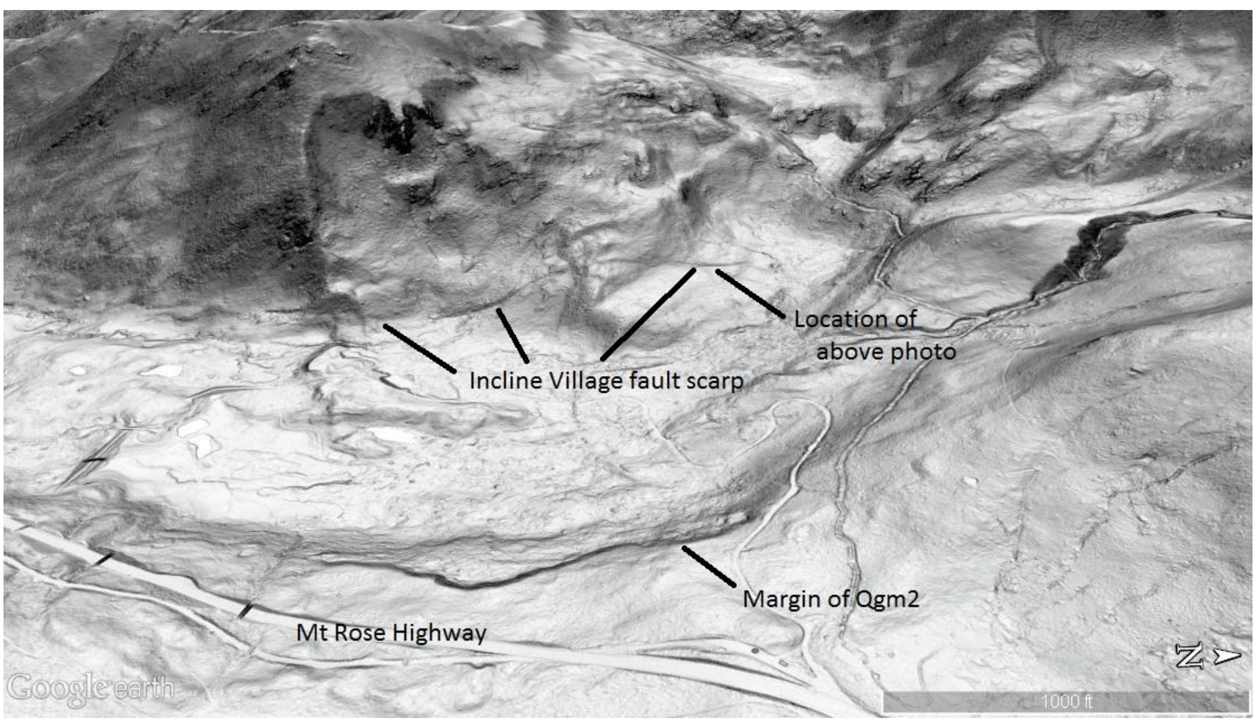

Figure 9. LIDAR image of western Tahoe Meadows area, looking west. *Credit: Tahoe Basin LiDAR, 2011, www.opentopograpy.org*

Figure 10. Young moraine at Stop 2b, looking southeast. *Photo by Alan Ramelli*

Stop 3: Glacial moraines and volcanic rocks

– Contrast of clast weathering and discussion of glacial ages; optional short car shuttle to look at volcanic rocks.

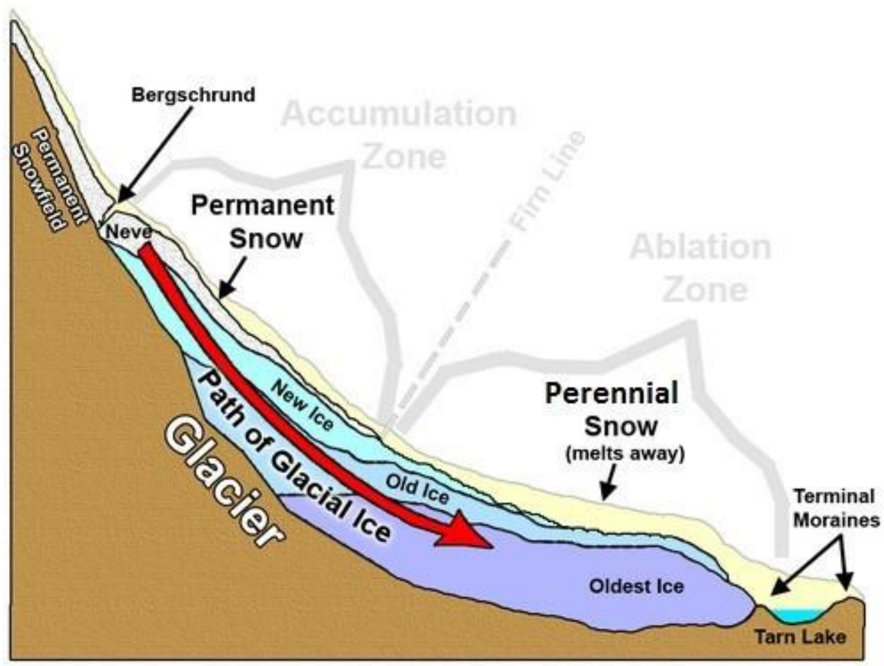

Figure 11. Glacier cross section.

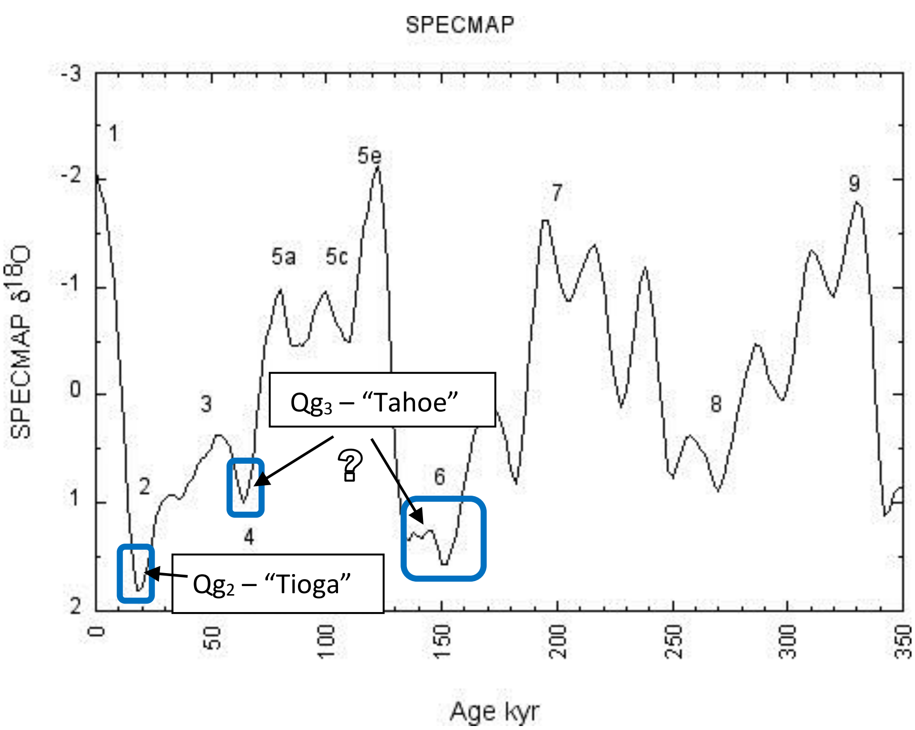

Figure 12. Oxygen isotope curve and glacial stages. The Last Glacial Maximum ("Tioga") occurred during Stage 2; an older glacial maximum ("Tahoe") correlates with either Stage 4 or 6, but its greater extent suggests Stage 6.

Stop 4: Incline Village fault at old elementary school

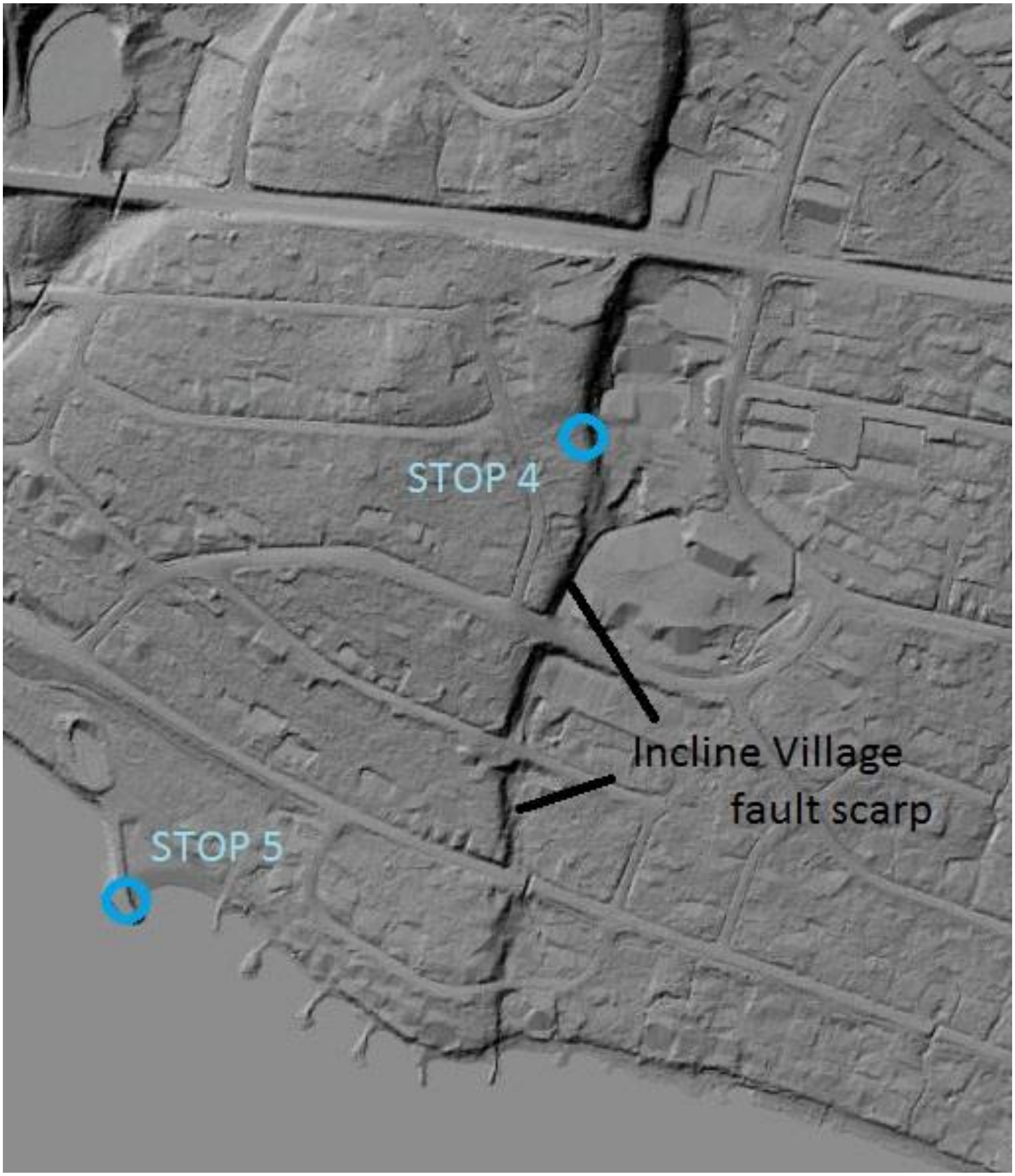

Figure 13. Vertical LIDAR image of Incline Village fault scarp; north is up. *Credit: Tahoe Basin LiDAR, 2011, www.opentopograpy.org*

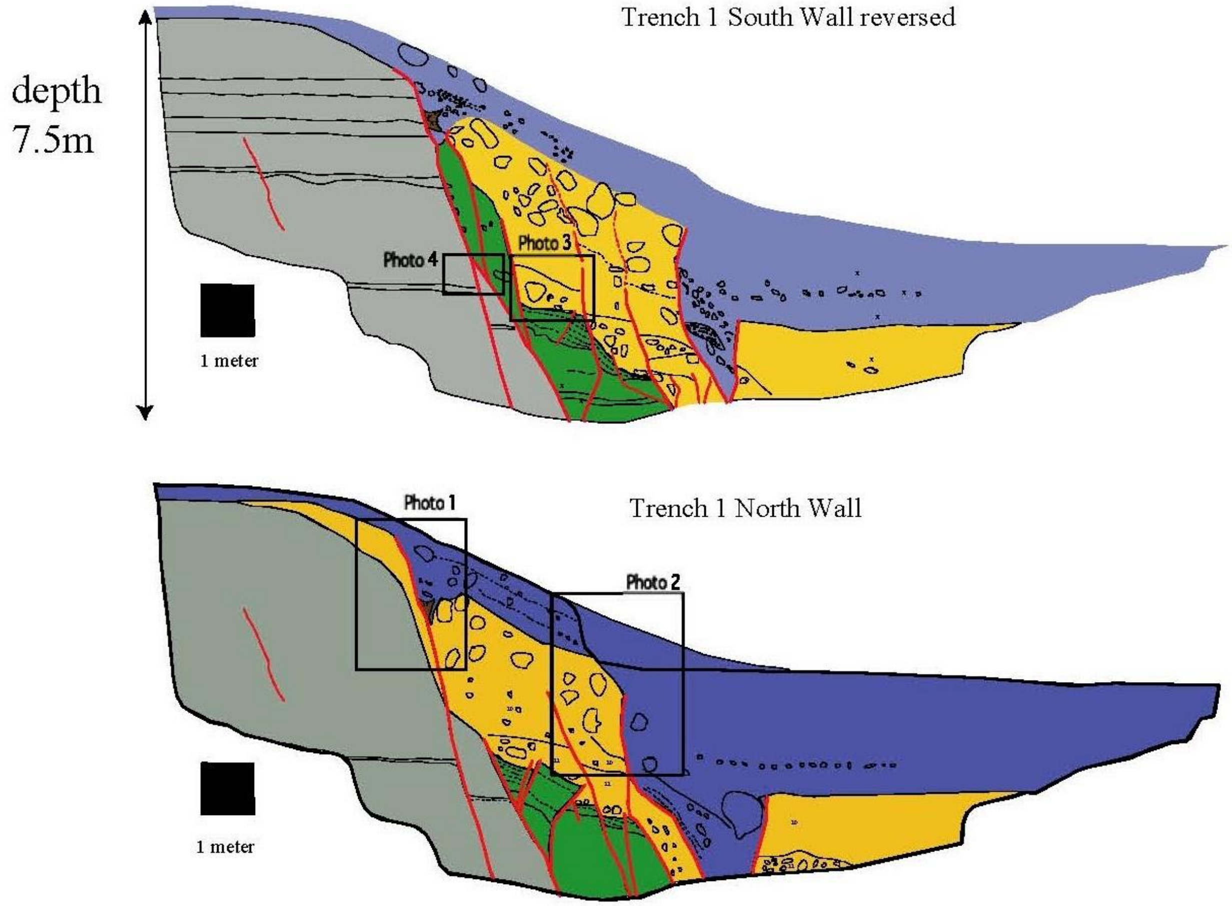

Figure 14. Incline Village fault trench logs, from work by Gordon Seitz (now with the California Geological Survey) in 2004. By excavating trenches across fault scarps, we can determine when earthquakes occurred and estimate how big they were. This trench exposed Pleistocene shallow lacustrine sands (Qlo) faulted against scarp-derived deposits. Gray – Qlo lake deposits; Blue – most recent earthquake deposits; Yellow – deposits from the next oldest earthquake; Green – deposits from an older earthquake. Photo locations refer to photos in Seitz's report that are not shown here.

Stop 5: Lake Tahoe overlook at Burnt Cedar Beach

- Shoreline benches and lake history (known and unknown)

Figure 15. Looking west at Stateline Point from Burnt Cedar Beach. The prominent benches were cut by older and higher lake stands. *Photo by Alan Ramelli*

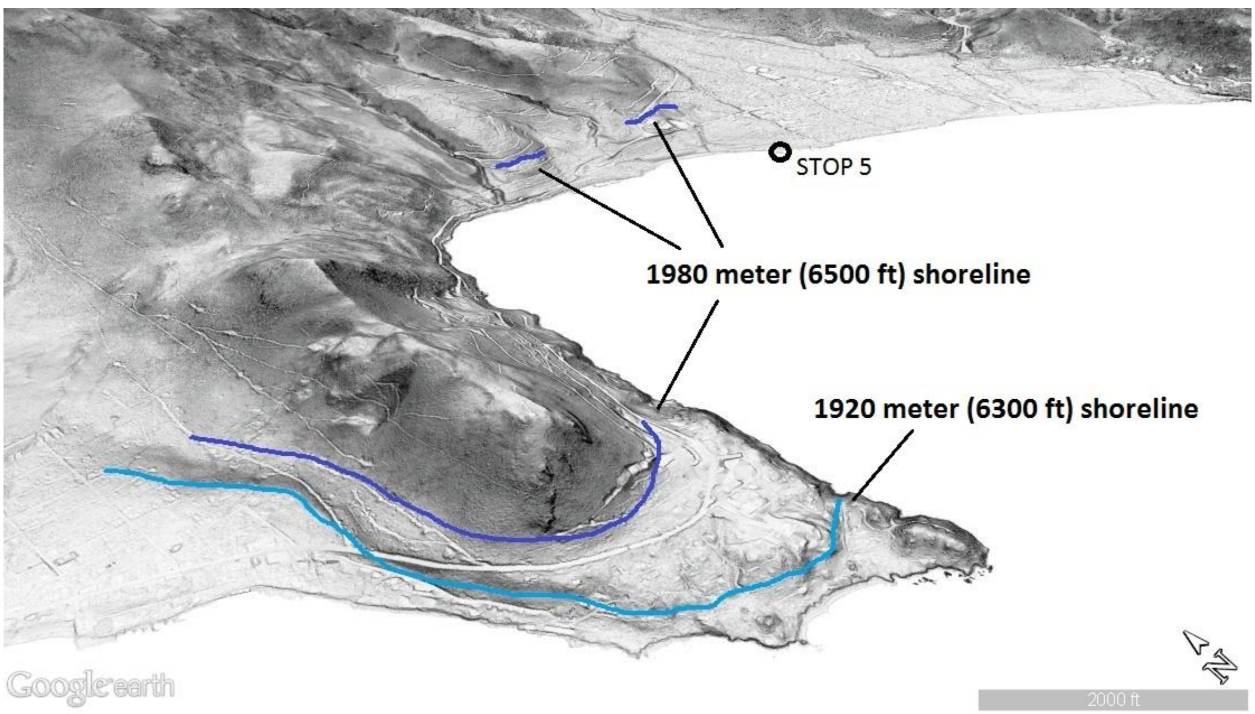

Figure 16. Oblique LIDAR image of Stateline Point showing shorelines in above photo, looking northeast. The modern elevation of Lake Tahoe, which is controlled by a small dam at Tahoe City, is 1899 meters. *Credit: Tahoe Basin LiDAR, 2011, www.opentopograpy.org*

Glossary

Ablation - Occurs when more glacier ice is lost by melting and evaporation each year than is added by snowfall.

Alluvial fan - A fan-shaped pile of sediment that forms where a rapidly flowing mountain stream enters a relatively flat valley. As water slows down, it deposits sediment (alluvium) that gradually builds a fan.

Andesite - Fine-grained, generally dark-colored, igneous volcanic rock with more silica than basalt. Commonly with visible crystals of plagioclase feldspar. Generally occurs in lava flows, but also as dikes. The most common rock in volcanic arcs.

Aplite - A light-colored igneous rock with the same mineral composition as granite minus the dark-colored minerals: quartz, plagioclase feldspar, and potassium feldspar, but with a fine-grained, almost sugary texture. Commonly occurs as dikes.

Basalt - A dark, fine-grained, extrusive (volcanic) igneous rock with a low silica content (40% to 50%), but rich in iron, magnesium and calcium. Generally occurs in lava flows, but also as dikes. Basalt makes up most of the ocean floor and is the most abundant volcanic rock in the Earth's crust.

Basin and Range Province - That part of the southwestern United States and northwestern Mexico that is typified by elongate north-south trending arid valleys bounded by mountain ranges which also bound adjacent valleys.

Boulder - Any loose rock (sediment) larger than 256 millimeters (10 inches).

Cretaceous - A geologic period ranging from 65 to 145 million years ago.

Dike - A sheet-like or tabular-shaped igneous intrusion that cuts across the sedimentary layering, metamorphic foliation, or other texture of a pre-existing rock.

Erratic - A rock that differs from the size and type of rock native to the area in which it rests. Usually refers to large rocks deposited by glaciers.

Fault - A fracture in the Earth along which one side has moved relative to the other. Sudden movements on faults cause earthquakes.

Fault Scarp - A steep slope or cliff formed when movement along a fault exposes the fault surface.

Fluvial - Term used to describe river or stream-related features or processes. **Fluvial deposits** are sediments deposited by the flowing water of a stream.

Fracture - Any break in rock along which no significant movement has occurred.

Glacier - A long-lived sheet or mass of ice made of recrystallized snow. Glaciers move downhill due to the stress of their own weight.

Granite - A coarse-grained intrusive igneous rock with at least 65% silica. Quartz, plagioclase feldspar and potassium feldspar make up most of the rock and give it a fairly light color. Granite has more potassium feldspar than plagioclase feldspar. Usually contains biotite, but also may have hornblende.

Granitic - A general term for intrusive igneous rocks that look similar to granite but may range in composition from quartz-diorite to granite. All granitic rocks are light colored; feldspar and quartz are visible in hand specimen.

Granodiorite - An intrusive igneous rock similar to granite, but contains more plagioclase than potassium feldspar.

Grus - Coarse sand and gravel that forms from weathering of granitic rocks

Holocene - An epoch of the Quaternary Period beginning 10,000 years ago and continuing today.

Hydrothermal Alteration - A mineralogical change due to invading hot fluids, a process that often emplaces veins of ore minerals.

Isotope - Different forms of a single element that have the same number of protons but different numbers of neutrons in their nuclei. Some radioactive isotopes are unstable and shed nuclear particles over time until they become stable. For instance, unstable isotopes of uranium break down to become lead.

Joint - A narrow crack in rock along which there has been no significant movement of either side. Joints commonly form in parallel sets.

Jurassic - A geologic period ranging from 145 to 200 million years ago.

LIDAR - A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. High-resolution digital elevation maps generated by LIDAR have led to significant advances in geomorphology (the branch of geoscience concerned with the origin and evolution of the Earth surface). LIDAR can detect subtle topographic features, even under a vegetation canopy.

Magma - Molten rock. Magma may be completely liquid or a mixture of liquid rock, dissolved gases and crystals. Molten rock that flows out onto the Earth’s surface is called lava.

Magma chamber - A body of molten rock and solid crystal mush beneath the Earth’s surface. When this chamber cools and solidifies, it is called a pluton.

Metamorphic rock – A rock that has undergone chemical or structural changes produced by increase in heat and/or pressure, or by replacement of elements by hot, chemically active fluids.

Miocene - An epoch that includes the time interval of about 23.7 to 5.3 million years ago.

Moraine - A hill-like pile of rock rubble located on or deposited by a glacier. An **end moraine** forms at the terminus of a glacier. A **terminal moraine** is an end moraine at the farthest advance of the glacier. A **lateral moraine** forms along the sides of a glacier (a right-lateral moraine is on the right side of the glacier, as you’re looking downslope).

Normal Fault - A fault that drops rock on one side of the fault down relative to the other side.

Outwash - Glacial outwash is the deposit of sand, silt, and gravel formed below a glacier by meltwater streams and rivers.

Pleistocene - The earliest epoch of the Quaternary Period, beginning about 2 million years ago and ending 10,000 years ago. Commonly known as the **"Ice Age,"** a time with episodes of widespread continental glaciation.

Pliocene - The latest epoch of the Tertiary Period, beginning about 5 million years ago and ending 2 million years ago.

Pluton - A large body of intrusive igneous rock that solidified within the crust.

Scarp - A cliff or steep slope formed by faulting, erosion, or landslides. (=escarpment).

Till - Unsorted, unstratified rock rubble or debris carried on and/or deposited by the ice of a glacier.

Weathering - Weathering includes two surface or near-surface processes that work in concert to decompose rocks. Both processes occur in place. No movement is involved in weathering. **Chemical weathering** involves a chemical change in at least some of the minerals within a rock. **Mechanical weathering** involves physically breaking rocks into fragments without changing the chemical makeup of the minerals within it. Mechanical weathering includes processes such as water in cracks freezing and expanding, or changes in temperature that expand and shrink individual minerals enough to break them apart.