Guide for the Earth Science Week Field Trip, October 15 or 16, 2011

Nevada Bureau of Mines and Geology Educational Series E-51

"Life's A Beach"

In Search of Ancient Shorelines and Volcanoes in the Grimes Point and Lahontan Mountains Area

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2011

National Earth Science Week (ESW) 2011 encourages people everywhere to explore the natural world and learn about the geosciences. The Nevada Bureau of Mines & Geology (NBMG) welcomes you to participate in its fourteenth annual Earth Science Week field trip. In keeping with the National ESW theme, "Our Ever-Changing Earth," this year's trip will focus on the Cenozoic geology of the region around Grimes Point and the Lahontan Mountains, including evidence for a large Pleistocene lake in the area; volcanism related to crustal extension in the Basin and Range Province of the western United States; hydrothermal (hot water) activity associated with volcanism; tilting of volcanic and sedimentary rocks related to faulting and extension; and production of electricity using geothermal power, related to hot water that gets close to the surface along extension-related faults. Many of the features we will explore are related to ongoing geologic processes that continue to alter the face of the Earth. Frequent reference will be made to recently published NBMG geologic maps of the Lahontan Mountains Quadrangle and the Grimes Point Quadrangle, by NBMG geologist John Bell and others (complete citations in reference list). We will **leave from** the Fox Peak gas station, on the north side of U.S. Highway 50, 0.5 mile east of downtown **Fallon, at 9:00 a.m.** each day. Field trip participants wanting a tour of the **Great Basin Science Sample and Records Library (GBSSRL)**, the new building for information, publication sales, geologic and topographic maps, and geological samples of the Nevada Bureau of Mines and Geology, can meet there, **2175 Raggio Parkway, Reno, NV 89512** (on the west side of the Desert Research Institute campus) at 7:15 a.m. We will **leave the GBSSRL location in Reno at 7:45 a.m.**

Stops will include the following:

Stop 1. On the west side of Sehoo Mountain, where we will examine beach deposits from the shore of Pleistocene Lake Lahontan and collect tufa-coated Pliocene basalt. Shorelines of Lake Lahontan, expressed as wave-cut terraces or beach deposits, are visible throughout the area.

Stop 2. Eagles House, where we will examine and collect unaltered and altered Miocene rhyolite. Crystals in the unaltered rhyolite include quartz, biotite, sanidine,and hornblende.

Stop 3. Near Eagles House, where we will examine and collect Miocene tuff that was silicified and pyritized then later oxidized to make the rock commonly known as "Nevada wonderstone."

Stop 4. Also near Eagles House, where we will examine and collect breccia (containing silicified and oxidized fragments of Miocene lacustrine siltstone) and calcite.

Stop 5. At Grimes Point, where we will examine (but not collect) petroglyphs carved by prehistoric humans along the shore of the receding Lake Lahontan a few thousand years ago.

Stop 6. Near Grimes Point, where we will examine and collect pebbles of banded, silicified, oxidized Miocene air-fall tuff that were naturally polished by stream and wave activity along the shores of Lake Lahontan.

Stop 7. At a green hill between Salt Wells Mountain and Rainbow Mountain, where we will examine and collect silicified, celadonite-altered Miocene pumice and conglomerate.

Stop 8. On the east side of Rainbow Mountain, where we will collect celadonite-, calcite-, and quartz-bearing amygdaloidal basalt and dacite.

Stop 9. If time permits (anticipating returning to Reno by 5:00 p.m.), we will stop on our way west, out of Fallon, at Soda Lake, probably the youngest volcano within the borders of Nevada. Volcanic bombs at Soda Lake contain crystals of olivine, clinopyroxene, plagioclase, and magnetite.

Please see the glossary for definitions of geological terms and for chemical formulas of common minerals that can be found on today's trip.

Items to have for the field trip:

- Water – lots of it, a gallon per person
- Food for lunch and snacks
- Sunscreen and hat
- First aid kit
- Walking stick and gloves
- Camera and binoculars
- Bag, bucket, or box for samples
- Insured vehicle with high clearance (doesn't need to be 4-wheel drive) and spare tire.

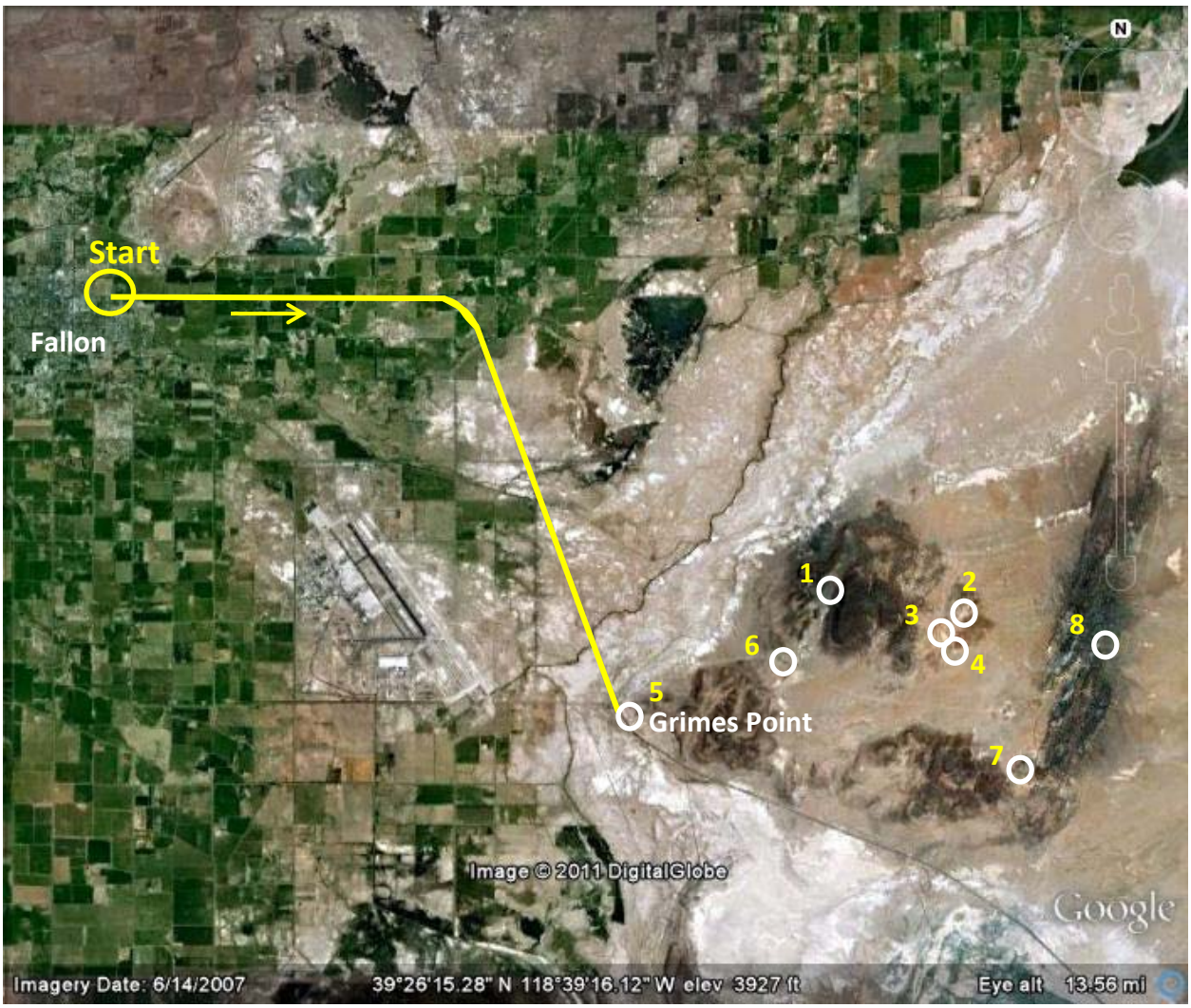

Figure 1. Route from Fallon to Grimes Point (Stop 5) and other stops.

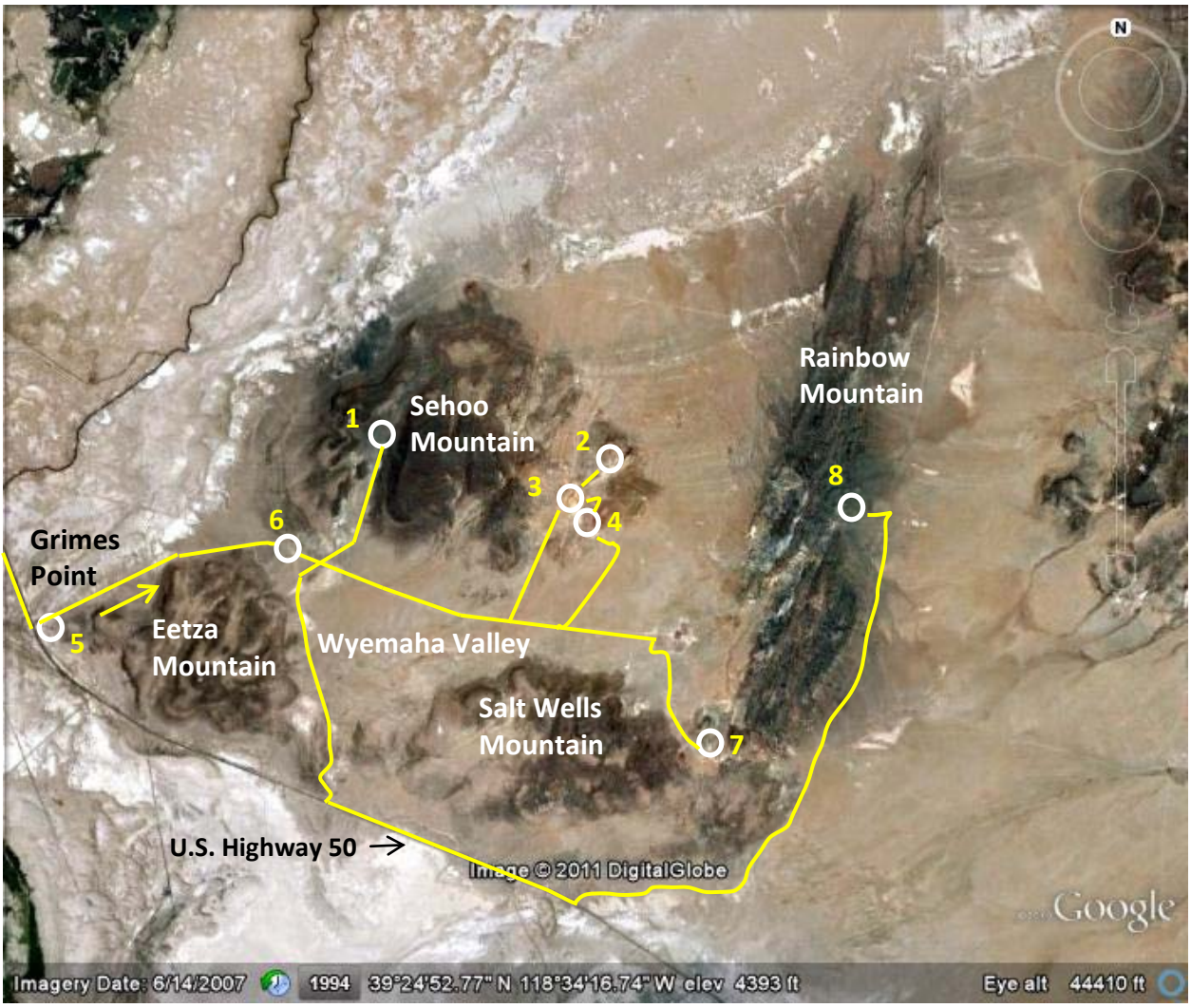

Figure 2. Location of stops in the Lahontan Mountains area.

Figure 3. Location of Stop 1 (39˚25.263´N, 118˚36.081´W).

Figure 4. Location of Stop 2 (39˚25.150´N, 118˚34.187´W), Stop 3 (39˚24.858´N, 118˚34.561´W), and Stop 4 (39˚24.801´N, 118˚34.331´W).

Figure 5. Location of Stop 5, Grimes Point (39˚24.081´N, 118˚38.838´W).

Figure 6. Location of Stop 6 (39˚24.572´N, 118˚36.815´W).

Figure 7. Location of Stop 7 (39˚23.334´N, 118˚33.368´W).

Figure 8. Access road to Stop 8, takes off U.S. Highway 50 a short distance east of the Salt Wells Road (39˚22.335´N, 118˚34.519´W).

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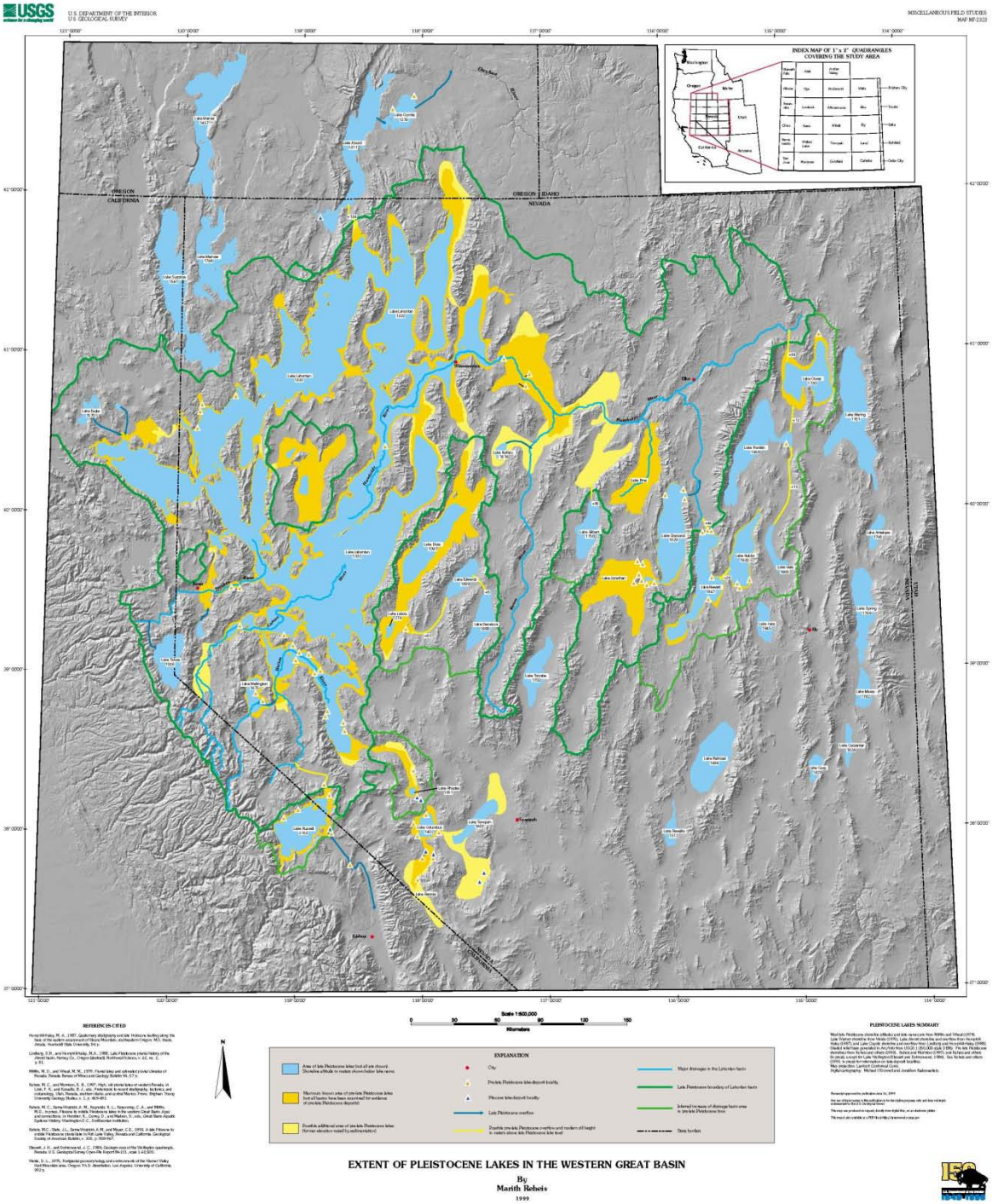
Figure 9. Location of Stop 8 (39˚24.757´N, 118˚32.307´W).


U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
MISCELLANEOUS FIELD STUDIES
MAP MF-2323
INDEX MAP OF 1° x 2° QUADRANGLES COVERING THE STUDY AREA
OREGON
CALIFORNIA
OREGON
IDAHO
NEVADA
Lake Lahontan
Lake Bonneville
Lake Clark
Lake Dixie
Lake Ely
Lake Gilmore
Lake Gosiute
Lake Hatch
Lake Hubbs
Lake Jim
Lake Lucin
Lake Mason
Lake Millard
Lake Mono
Lake Pahute
Lake Parker
Lake Pilot
Lake Pinto
Lake Pleasant
Lake Rogers
Lake Russell
Lake Sarcobatis
Lake Shoshone
Lake Spring
Lake Stanley
Lake Steens
Lake Tecopa
Lake Thomas
Lake Tonopah
Lake Tule
Lake Uinta
Lake Vernon
Lake Wasatch
Lake Waterman
Lake Wells
Lake Wheeler
Lake Wilson
Lake Zeno
Lake Zonia
Lake Zumwalt
Lake Zyzzx
Lake Cowan
Lake Dunn
Lake Gale
Lake Gilbert
Lake Gordon
Lake Hall
Lake Hitchcock
Lake Hoover
Lake Jackson
Lake Jones
Lake Lane
Lake Lewis
Lake Lisbon
Lake Lucerne
Lake Lyman
Lake Mackay
Lake Marion
Lake Mason
Lake Mellen
Lake Mohave
Lake Mojave
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Lake Newark
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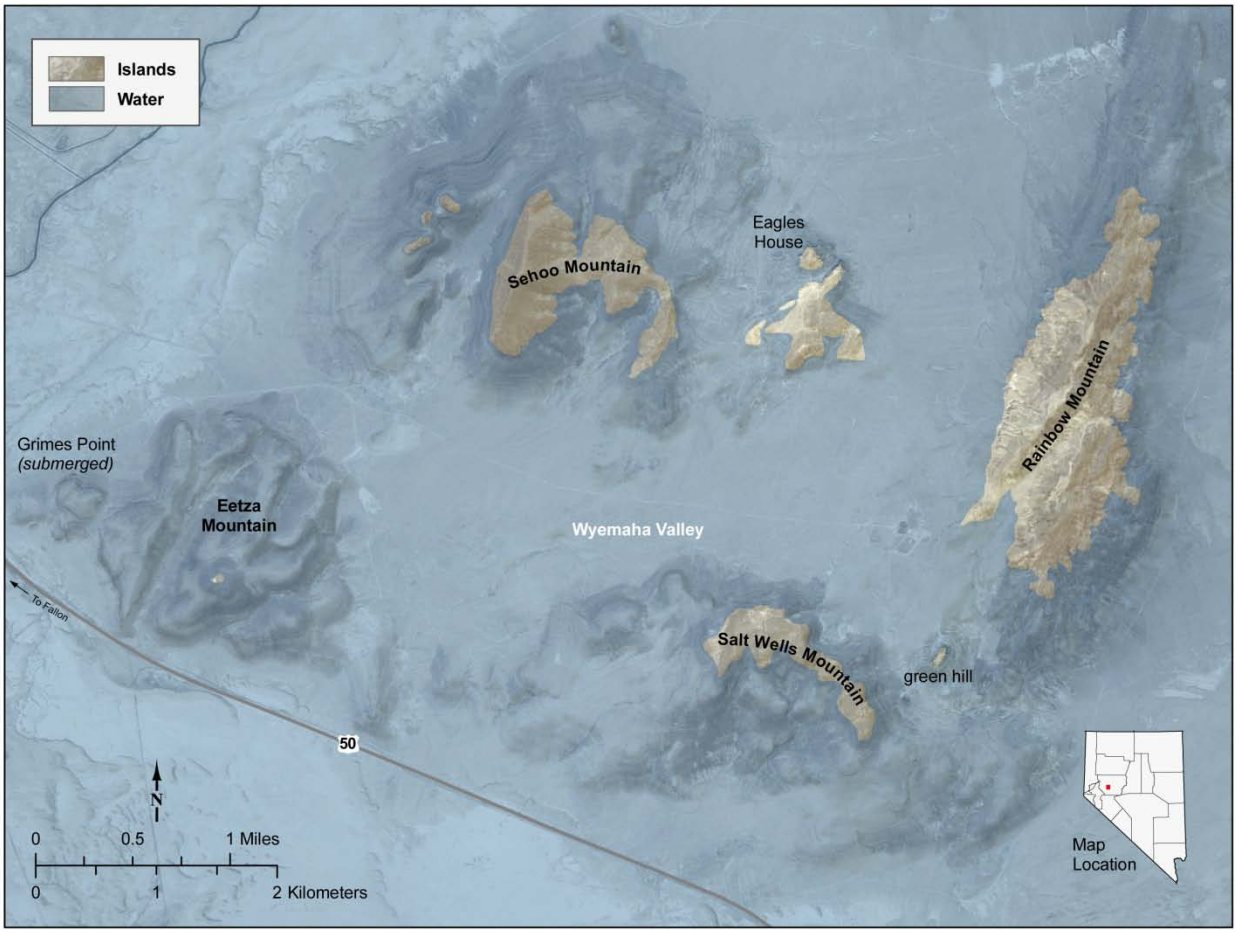

Figure 11. Islands in Pleistocene Lake Lahontan approximately 15,000 years ago, when the lake was at an elevation of approximately 1336 meters (4383 feet). See figure 2 for the locations of field-trip stops. Cartography by Matthew T. Richardson on base map from the U.S. Geological Survey.

ROAD LOG

Mile 0.0. The road log begins at Fox Peak gas station, on the north side of U.S. Highway 50, 0.5 mile east of Maine Street in downtown Fallon. Drive east on Highway 50. See figures 1, 2, 3, 5, and 6 for maps of the route to Stop 1.

Mile 9.4. Left turn (east) onto road to Grimes Point. We will return to the picnic tables and bathroom facilities at Grimes Point during lunch, at Stop 5 (figure 5).

Mile 11.7. Left turn (north) at fork in road – see figures 2, 3, and 6 for maps to Stop 1. We pass Stop 6 on our way to Stop 1.

Mile 12.6. At the Y in the road, stay right onto the higher road.

Mile 12.7. **Stop 1.** See how geologists figure out where the high stand of Lake Lahontan was approximately 15,000 years ago. This stop is on the west side of Sehoo Mountain. We will examine beach deposits of the middle Sehoo Alloformation (deposited on the shore of Pleistocene Lake Lahontan) and collect tufa-coated Pliocene olivine basalt. A short hike uphill to the west crosses unconsolidated beach gravel composed predominantly of rounded cobbles of basalt, beach gravel that is cemented by tufa, a wave-cut terrace, colluvium composed of angular blocks of basalt, and a basalt flow in outcrop. Vesicles and amygdules in the basalt, which are flattened by the weight of the overlying lava, record a slight dip (non-horizontal) to the basalt flow. The basalt contains crystals of plagioclase, olivine, and clinopyroxene.

This high stand peaked about 15,000 years ago according radiocarbon dates on shells, tufa, and a camel bone. The lake mostly dried up probably within 1000 years of this high stand. A series of small lakes then existed intermittently until about 1500 years ago.

The tufa here comes in several varieties. Lithoid tufa is the rather dense and sometimes layered tufa cementing the gravels. Dendritic tufa is the most common type and is what drapes the outcrops. It generally has branching texture. Dendritic tufa that forms “heads” resembling coral is sometimes referred to as “coralline” tufa. Thinolite is a rare type of tufa consisting of a mass of crystals originally formed as aragonite that mostly recrystallized to calcite. Dendritic and most of the lithoid tufa formed in association with algal mats. These usually formed in less than six meters of water, and due to fluctuations in water depths, were at times exposed to the air. Thinolite and some lithoid tufa formed by inorganic precipitation. These probably formed offshore in six to 30 meters of water when the salinity, temperature, and pH were right.

For anglers who may be wondering what the fishing was like during the last high stand, the bones of carp, bullhead, and Lahontan Tui chub have been found in sediments of that age at Hidden Cave near Grimes Point.

Figure 12. Gravel from the beach deposits of the middle Sehoo Alloformation, Stop 1.

Figure 13. Gravel along the beach of Lake Lahontan, Stop 1.

Figure 14. Tufa-cemented gravel, Stop 1.

Figure 15. Tufa-cemented gravel, Stop 1.

Figure 16. Basalt at Stop 1; lizard for scale.

Figure 17. Tufa-coated cobbles of basalt, Stop 1.

Figure 18. Horizontal wave-cut terrace below outcrop of gently dipping basalt, Stop 1.

Figure 19. Lichen growing preferentially on the north side of a basalt block, Stop 1.

Figure 20. Prominent shorelines are generally more visible on the west side of hills than on the east side, looking south from Stop 1.

After Stop 1, return (south) on the same road.

Mile 13.7. Turn left (east), away from Grimes Point.

Mile 15.1. Turn left (north) toward the orange hill (which is Stop 3). We will drive past Stop 3 on our way to Stop 2 (figure 4).

Figure 21. View of the orange hill at Stop 3, looking north, on the way to Stop 2.

Mile 15.7. Stay to the right at the Y in the road.

Mile 16.0. Stay to the left at the Y in the road.

Mile 16.05. Stay to the right at the Y in the road.

Mile 16.2. Stay to the left at the Y in the road.

Mile 16.6. **Stop 2** (Eagles House). Hike to outcrops of unaltered, pink rhyolite and altered green rhyolite. The rhyolite contains small (1 mm size crystals of quartz, biotite, sanidine, and hornblende). The alteration mineral that gives the rock a green color is probably celadonite. The rhyolite is either a shallow intrusion (into surrounding tuffs and mudstones) or a lava dome. Flow banding in the rhyolite is locally vertical.

A pumice deposit about 1 mile (2 km) northeast of Eagles House may have been deposited when this rhyolite erupted. The Fallon Concrete Products Co. began mining the pumice in 1951 as light-weight aggregate for concrete and building blocks. Production was curtailed because of the limited extent of the deposit and an increase in cohesiveness of the pumice at depth.

Figure 22. Rhyolite at Stop 2, lizard for scale.

Figure 23. Horned lizard (aka horned toad, horny toad, or horned frog) at Stop 2.

Figure 24. Rhyolite at Stop 2, containing small crystals of quartz, biotite, sanidine, and hornblende.

Figure 25. View to the south from the top of Eagles House, Stop 2. The ridge in the center of the photo is more rhyolite. The orange-colored, west-dipping tuff and sediments on the hill on the right is at Stop 3. Stop 4 is at the base of the hill in the upper left.

After Stop 2, return south to Stop 3; drive east, then north and park on the east side of the hill.

Mile 17.3. **Stop 3**. The rock capping the orange hill is a rhyolitic tuff. It was altered by hot waters that deposited pyrite and quartz. Rainwater penetrated the rock and oxidized the pyrite to form liesegang bands of red hematite and orange and brown goethite. Rockhounds call rock with liesegang banding "wonderstone." Other wonderstones typically develop in sandstones and rhyolite flows. Some of this wonderstone was worked into stone tools by Native Americans. The silicification of this rock made it similar in hardness and strength to chert (flint) and obsidian. A few arrowheads of this rock are on display in the Wigwam Restaurant in Fernley. Given its proximity to the rhyolite at Eagles House, the alteration of the tuff may have been caused by water heated by magma associated with the rhyolite intrusion or lava dome. Sandstone below the tuff is also oxidized and liesegang banded.

After Stop 3, drive in a north-to-east-to-south loop to Stop 4.

Mile 17.5. **Stop 4**. The rock here is an unusual breccia with blocks of silicified (converted to quartz and with pore spaces in the rock filled with quartz), liesegang-banded siltstone. The breccia is cut by veins of calcite, which here is uncharacteristically black or dark gray in color. Tufa (deposited from Lake Lahontan) locally drapes the surface of the outcrop. The brecciation and veining may be related to the Eagles House rhyolite. In recent years, boulders of the breccia have been quarried for dimension stone.

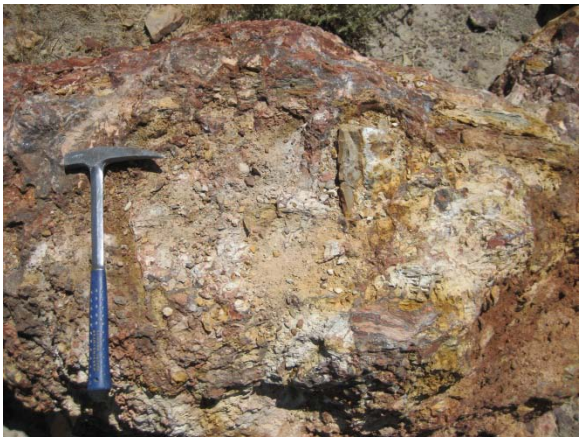

Figure 26. Breccia with silicified and oxidized fragments of Miocene lacustrine siltstone, cut by veins of black calcite, Stop 4.

After Stop 4, drive south, heading to Stop 5 (see figures 2, 4, and 5 for maps). The green hill to the southeast is Stop 7.

Mile 18.5. Turn right (west) toward Stop 5.

Mile 22.5. Turn left (southeast) into the picnic area at Stop 5.

Mile 22.7. **Stop 5**. This is our planned lunch stop. The U.S. Bureau of Land Management has constructed a path along which you can view petroglyphs. Do not disturb the petroglyphs or collect rocks at this site. Intermittent lakes were probably close to this elevation at the times that these petroglyphs were carved into the rock. The oldest known human mummy in North America, dated at about 10,600 years before present, came from Spirit Cave nearby.

Figure 27. Some petroglyphs at Stop 5 appear to depict traditional Nevada food, like this carving of snake and eggs.

Figure 28. Petroglyphs on boulder of basalt at Stop 5. The boulders are coated with rock varnish, a thin layer of dark brown to black iron and manganese oxides.

After Stop 5, drive back up the dirt road to Stop 6.

Mile 24.8. **Stop 6**. Collect pebbles of wonderstone.

Figure 29. Nevada wonderstone pebbles at Stop 6. Erosion broke pieces of the rock from its outcrop (probably at Stop 3), and streams carried pebbles to the shore of Lake Lahontan. The pebbles were tumbled and polished by the streams and by wave action along the shore of the lake. The high degree of polish is due to a combination of the silicification of the rock (making it hard and resistant to mechanical breakage) and the wave action on the lake shore.

After Stop 6, continue east to Stop 7 (see figures 2 and 7 for maps.)

Mile 27.6. Turn right (south) at the fence. Inside the fenced area is a small clay operation, where montmorillonite (bentonite) has been mined from claystone or altered tuff in the Miocene sedimentary and volcanic rocks.

Mile 27.8. Turn left (east), following the fence.

Mile 28.0. Turn right (southeast).

Mile 28.4. Turn right (south), about 150 meters before the green hill, and around the west side of the green hill.

Mile 28.8. **Stop 7**. These rocks, silicified pumice and conglomerate, have been hydrothermally altered to mostly quartz and

potassium feldspar. The green color is due to small amounts of celadonite, similar to the green rhyolite on the south side of Eagles House. It is possible that the alteration is connected to the silicification seen at Stops 3 and 4, or there could be a buried intrusion, similar to the Eagles House rhyolite, at depth closer to Stop 7.

Figure 30. Graded bedding in conglomerate at Stop 7. A layer of cobbles (below the handle of the hammer) is capped by a layer of pebbles (at the hammer), which is capped by a layer of sand (above the top of the hammer).

After Stop 7, follow the route back toward Stop 6 (see figures 2, 6, and 7).

Mile 32.5. Turn left (southwest) onto a dirt road near the gravel quarries.

Mile 33.8. Turn right at the Y in the road, not left into a gravel pit.

Mile 33.9. Turn left onto a major dirt road that services a nearby quarry.

Mile 34.4. Turn left (southeast) onto U.S. Highway 50. Be careful, because cars speed along this highway, and you'll be turning left in 2.0 miles, shortly after the Salt Wells Road.

Mile 36.4. Turn left (north) off of Highway 50 (see figure 8 for a detailed map). The road is sometimes marked with small red flags. Be careful on this dirt road. It is washed out in several places, but you can drive around the difficult spots.

Mile 38.0. Be careful – washout.

Mile 38.9. Continue straight (north) at the Y in the road. Shortly after the intersection, drive west around the bad washout at this location (39˚23.338´N, 118˚32.461´W).

Mile 40.6. Turn left (west) toward the small canyon (see figure 9 for a detailed map).

Mile 40.9. **Stop 8**. The Miocene volcanic rocks here (basalt and dacite) dip more steeply (approximately 30 degrees from the horizontal, down to the west) than the Pliocene basalt that we sampled at Stop 1. The tilting of the volcanic and sedimentary rocks (also visible at Stop 3) is the result of crustal extension. Originally horizontal lake sediments, tuffs, and lava flows are tilted either like a stack of books that are pushed over or like a landslide above a curved fault surface.

After Stop 8, retrace the route back to Highway 50 (see figures 9 and 8). Slow down and drive around the washouts at Miles 41.5, 42.4, 42.8, and 43.8.

Figure 31. Amygdaloidal basalt at Stop 8. Amygdules are gas bubbles that have been filled with minerals deposited by hot water. Here the amygdules are filled with quartz, calcite, and celadonite.

A major fault marks the break in slope along the east side of Rainbow Mountain (the mountain to the west of the road). This fault ruptured the ground surface along a distance of 12 miles (20 km) at 4:13 a.m. on July 6, 1954, causing the magnitude 6.6 Rainbow Mountain earthquake. A second earthquake (magnitude 6) at 3:09 p.m. on the same day extended the rupture south of U.S. Highway 50. The second event, referred to as the Fourmile Flat earthquake, reportedly

raised a cloud of dust on the Fourmile Flat playa and damaged Highway 50. A third event, referred to as the Stillwater earthquake (magnitude 6.8), occurred at 10:51 pm on August 23 and extended the rupture northward. These three events, felt over an area of 130,000 square miles, resulted in a discontinuous and locally en echelon series of small scarps over a distance of 70 km. These earthquakes were followed by the Fairview Peak (magnitude 7.2) and Dixie Valley (magnitude 7.1) earthquakes on December 16 of the same year.

The scarp from the 1954 earthquake had up to 0.8 meter of vertical displacement and up to 1 meter of right lateral, horizontal displacement at Rainbow Mountain, but it has been eroded and is barely visible today. Just west of the road, about 4 miles north of Stop 8, the scarp, which is visible as a gentle eastward slope over a short distance of a few meters, marks the displacement in the otherwise relatively flat alluvium. However, the 5-meter scarp at Fairview Peak (BLM site south of Highway 50, east of here) is spectacularly visible. The Earth Science Week field trip in 2005 visited this site, and directions are given in the Nevada Bureau of Mines and Geology Educational Series publication E-44 (http://www.nbmg.unr.edu/dox/e44.pdf).

Mile 42.8. Slow down and watch for the bad washout. Drive west around the washout at this location (39˚23.338´N, 118˚32.461´W).

Mile 45.3. Turn right (west) on Highway 50, heading back to Fallon (see figures 1 and 2).

Across the playa to the south is the Salt Wells geothermal power plant owned by Enel North America. The plant has a capacity of 23.6 megawatts and came on line in 2009. Wells drilled for this power plant have permitted depths of 760 meters. Hot water from several thousand meters below the surface has moved up along a fault to produce a shallow reservoir of hot water at this location.

Mile 59.2. For those interested in an additional stop on the way home, reset your odometer at the Fox Peak gas station.

Mile 0.0. From the Fox Peak gas station, drive west on U.S. Highway 50, through downtown Fallon (see figure 33 for a map to Soda Lake).

Mile 0.5. Cross Maine Street, the main street in Fallon.

Mile 4.7. Turn right (north) on Soda Lake Road.

Mile 6.7. Turn left (west) on Cox Road.

Mile 7.5. Turn right (north) onto a dirt road up the slight rise to the rim of the Soda Lake volcano.

Mile 7.9. **Stop 9**. Soda Lake is a Holocene basalt maar (pronounced “mar,” a volcano formed when magma reached so close to the surface that the groundwater boiled). It cuts through Lake Lahontan sediments and is probably the youngest volcano within the borders of Nevada (less than 10,000 years old and maybe as young as 1500 years old). Volcanic bombs contain large (greater than 1 mm to as much as 1 cm) crystals of abundant clear and white plagioclase and green olivine (peridot, the gem variety) and less common black, vitreous clinopyroxene. The rock contains small grains of magnetite and is slightly magnetic.

Little Soda Lake, visible nearby to the southwest of Soda Lake, is also a maar. You can now declare that **you have been to maars** (pronounced “Mars”). Coincidentally, most of the rocks below the surface of Mars are basalt, and the red color of Mars is from hematite, formed from oxidation of iron minerals in the basalt.

About two miles northeast of Soda Lake, the Soda Lake Numbers 1 and 2 geothermal power plants, which came on line in 1987 and 1991, respectively, have a combined capacity of 26.1 megawatts. Magma Energy Corporation recently drilled two production wells here with permitted depths of 1830 m and 1980 m. Most geothermal resources in Nevada are associated with faults that moved during Basin-and-Range crustal extension, although there could be a connection between the hot water in the geothermal reservoir and young magma at Soda Lake.

Figure 32. Basalt bombs erupted from Soda Lake, Stop 9.

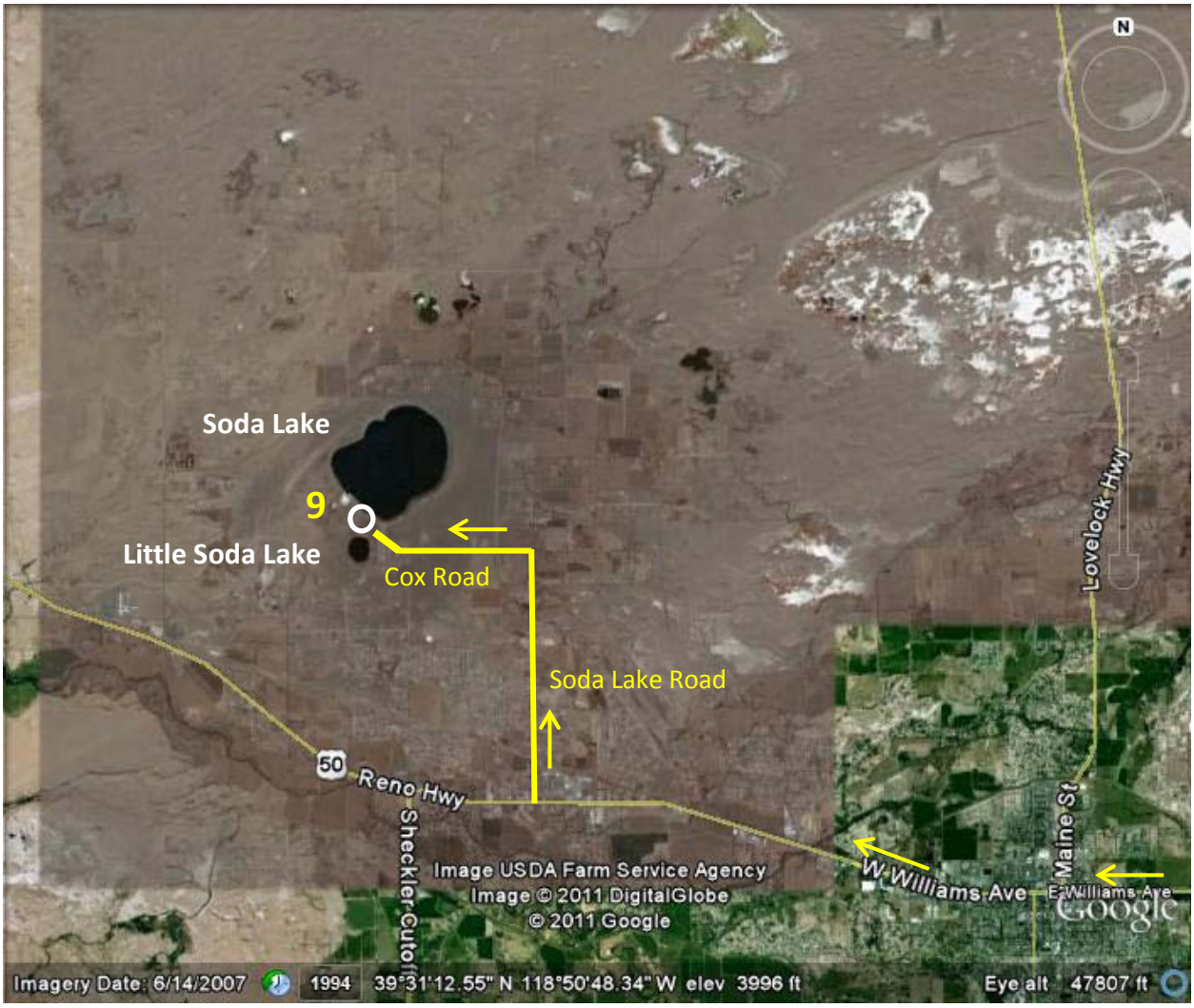

Figure 33. Location of Stop 9, Soda Lake (39˚31.085´N, 118˚52.825´W).

GLOSSARY

Geologic Time Scale for This Area

Era	Period	Epoch	
Cenozoic	**Quaternary**	**Holocene**:	11,700 years ago to present
		Pleistocene:	2.6 million to 11,700 years ago.
	Tertiary	**Pliocene**:	5.3 million to 2.6 million years ago
		Miocene:	23.0 to 5.3 million years ago
		Oligocene:	33.9 to 23.0 million years ago
		Eocene:	55.8 to 33.9 million years ago
		Paleocene:	65.5 to 55.8 million years ago

Minerals and their Chemical Formulas

Apatite, $Ca_5(PO_4)_3(OH,F)$, occurs as small (less than 1 mm) crystals in many igneous rocks

Aragonite, $CaCO_3$, generally white, yellowish, or gray, orthorhombic, slightly harder and denser than calcite but less stable and less common

Biotite, $K(Mg,Fe)_3AlSi_3O_{10}(OH,F)_2$, black flakes of mica

Calcite, $CaCO_3$, generally white or clear, but sometimes black or other colors, rhombohedral cleavage, softer than steel or glass, fizzes when dissolved in acid, as described in the following chemical reaction:

$CaCO_3 + 2H^+$ (acid) = Ca^{2+} (calcium in solution) + H_2O + CO_2 (carbon dioxide released into the air)

Celadonite, $K(Mg,Fe^{2+})(Fe^{3+},Al)Si_4O_{10}(OH)_2$, green clay mineral

Clinopyroxene, $Ca(Mg,Fe)Si_2O_6$, black or dark green, hard mineral common in basalts

Goethite, FeOOH, orange, rust-colored mineral, usually coating other rocks

Hematite, Fe_2O_3, red; also occurs as small (generally less than 1 mm long) black crystals in igneous rocks, in a solid solution with ilmenite, $FeTiO_3$

Hornblende, $Ca_2(Mg,Fe)_4Al(Si_7Al)O_{22}(OH,F)_2$, black prisms, common in many igneous rocks

Magnetite, Fe_3O_4, black, magnetic, generally in a solid solution with ulvospinel, Fe_2TiO_4

Monazite, $CePO_4$, occurs as small (less than 1 mm) crystals in many igneous rocks, commonly contains many of the light rare earth elements in these rocks

Montmorillonite, $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$, part of the **smectite** group of clay minerals, also called **bentonite**, generally white or cream-colored but can be dark brown, red, or black, depending on impurities; because of its property of swelling when wet, it is used in drilling muds in oil fields

Olivine, $(Mg,Fe)_2SiO_4$, olive green (oxidized to brown or yellowish brown) mineral common in basalts

Opal, $SiO_2 \cdot nH_2O$, generally white

Plagioclase, a feldspar solid solution dominantly between the end members albite, $NaAlSi_3O_8$, and anorthite, $CaAl_2Si_2O_8$, with lesser amounts of $KAlSi_3O_8$; with cleavage and striations from twinning within the crystals, clear when unaltered, commonly white when altered partially to clay minerals

Pyrite, FeS_2, brass-colored, metallic luster; black when very fine grained or powdered; oxidizes to goethite

Quartz, SiO_2 (silica), clear or white with conchoidal fractures (like glass, with no cleavage planes); scratches steel and glass

Sanidine, a feldspar solid solution dominantly between the end members potassium feldspar, $KAlSi_3O_8$, and albite, $NaAlSi_3O_8$, with lesser amounts of anorthite, $CaAl_2Si_2O_8$, clear to white; with cleavage

Titanite, $CaTiSiO_5$, occurs as small (less than 1 mm) crystals in many igneous rocks

Xenotime, YPO_4, occurs as small (less than 1 mm) crystals in many igneous rocks, commonly contains many of the heavy rare earth elements in these rocks

Zircon, $ZrSiO_4$, occurs as small (less than 1 mm) crystals in many igneous rocks

Rock Types

Intrusive igneous rock types have chemically equivalent extrusive (volcanic) rock types. With increasing silica concentrations (from lowest in gabbro to highest in granite), the common igneous rocks are:

Intrusive		Extrusive
Gabbro	=	**Basalt**
Diorite	=	Andesite
Granodiorite	=	**Dacite**
Granite	=	**Rhyolite**

Pumice is a highly vesicular (lots of holes) and therefore low density volcanic rock, composed dominantly of glass but may also contain crystals. It is pyroclastic (erupted from a volcanic explosion and deposited from the air, rather than flowing as lava). **Tuff** is composed mostly of small (millimeter sized and smaller) shards of volcanic glass, also derived from a volcanic explosion. The glass shards, crystals, and occasional rock fragments erupted into the air are termed "ash." Pumice and tuff generally are rhyolitic or dacitic in chemical composition.

An **amygdule** (spelled amygdale by the British) is a gas cavity or vesicle in an igneous rock, which has been filled with secondary minerals. Amygdaloidal basalt is common in this area, with the amygdules filled with quartz, calcite, and locally a mixture of celadonite and quartz. **Bombs** (solidified pieces of formerly liquid magma, blown out of a volcano and shaped while in flight through the air) of basalt occur at Soda Lake, which is a **maar** (a low-relief volcanic crater formed by shallow explosive eruptions, generally involving ground water that boiled when it was heated by the magma).

Unconsolidated sediments in the area include fine-grained clay and silt (deposited in lakes), sand (deposited in streams and dunes), **diatomite** (composed of microscopic silica fossils deposited in lakes), gravel (deposited on the shores of lakes and in stream channels), **alluvium** (a mixture of clay, silt, sand, and gravel, generally deposited by streams), and **colluvium** (a mixture of soil material and rock fragments deposited by rainwash, sheetwash, or slow downslope creep on the sides of hills). Sediments classified by size of particles include **clay** (less than 1/256 mm in diameter), **silt** (1/256 to 1/16 mm), **sand** (1/16 to 2 mm), granule (2 to 4 mm), pebble (4 to 64 mm), cobble (64 to 256 mm), and boulder (greater than 256 mm). **Gravel** consists predominantly of rounded rock fragments larger than 2 mm. An **alloformation** is a mappable stratigraphic unit that is defined on the basis of its bounding discontinuities.

Sedimentary rocks are consolidated sediments. With increasing grain size, these include **claystone** (mudstone or shale), **siltstone**, **sandstone**, and **conglomerate**. **Tufa**, a type of limestone that forms in or along the shores of lakes, is composed primarily of the mineral calcite. It forms where ground water from springs interacts with lake water or where alkaline lake water evaporates. **Caliche**, another variation of limestone, is calcite-cemented soil, alluvium, or colluvium, formed primarily when calcite precipitates from evaporating rainwater in an arid environment. **Chert** is a dense, silica-rich sedimentary rock generally formed in deep oceans but also in shallow lakes where abundant silica was available from volcanic ash.

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