UNIVERSITY OF NEVADA RENO

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GEOLOGIC ROADLOGS
RENO-STEAMBOAT SPRINGS
STEAMBOAT-VIRGINIA CITY-CARSON CITY-STEAMBOAT
STEAMBOAT-CARSON CITY-CARSON VALLEY-DAGGET PASS-LAKE TAHOE-MOUNT ROSE SUMMIT-STEAMBOAT
RENO-WADSWORTH-PYRAMID LAKE-RENO

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This information should be considered preliminary.
It has not been edited or reviewed.

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GEOLOGIC ROADLOG

RENO - STEAMBOAT SPRINGS

Mileage/
Cumulative

This roadlog begins at the University of Nevada old gymnasium parking lot. The university is built on early Quaternary, partially cemented, alluvial fan deposits of Peavine Mountain. Several deep drainageways that transported material from Peavine Mountain southwest to the Pleistocene Tahoe outwash flood plain have cut into this bajada complex that mantles the altered bedrock foothills of northwest Reno. Most of these old channels were incised during-and subsequent-to the Wisconsinan glacial stage. One steep-walled drainageway cuts through the university campus on the east margin of the parking lot. Many university buildings are constructed in this wash. Normally, major flooding is not a problem due to the light annual precipitation; however, serious flood damage occurred through the center of the campus along this drainageway in mid-February 1986.

0.0/0.0 Drive to the west entrance of campus at the old gymnasium and turn left (south) onto Virginia Street (U.S. 395). This route will take you from north to south through the center of the Truckee Meadows. The street crosses an old channel, then descends gradually down the intermediate-sloping, eroded, southwest facing front of the Peavine bajada complex.

0.4/0.4 Crossing over Interstate 80. From here south the low-gradient surface marks the northern margin of the Tahoe outwash flood plain. Roadcuts to the right along the Interstate expose grey-brown unconsolidated and interbedded cobble gravel and coarse sand of Wisconsinan Tahoe outwash starting at the base and continuing to within 10 to 12 feet of the surface. Above the outwash is fine to medium pebbly sand of Holocene age. This is reworked material derived from Peavine Mountain fan deposits that has spread as a thin veneer over the outwash. These Holocene deposits thin rapidly to a feather edge south of the Interstate 80.

0.5/0.9 Passing under the Reno arch.

0.2/1.1 Crossing the Truckee River. This is a perennial stream that drains Lake Tahoe and other valleys to the west and flows through a largely antecedent drainage north and eastward into Pyramid Lake, a distance of over 100 miles. Throughout the Truckee Meadows, the Truckee River is incised into

Wisconsinan outwash and Holocene silt and sand. After crossing the river, the surface rising ahead is cut on Illinoian, Donner Lake bouldery outwash.

0.1/1.2 Courthouse on the right. For the next few blocks the route ascends a moderately dissected slope on Donner Lake outwash, crosses a small summit, then proceeds down an erosional slope that is one of several moderately incised, but well-marked, east-trending drainages. The outwash in this area consists of strongly weathered, highly rounded boulders of andesite, metavolcanics, and plutonic rocks. The plutonic rocks are almost completely decomposed within the soil horizon. Giant boulders are common.

0.4/1.6 Thoma Street. Crossing a post-Illinoian fault on the northwestern margin of a north-trending, elongate graben in Donner Lake outwash.

0.5/2.1 Approaching Vassar Street. On the left, Donner Lake outwash is exposed in the embankment along Holcomb Street. This is inferred to be a fault scarp forming part of the eastern margin of the north-trending graben. Ahead, the nearly flat surface is underlain by the thin, western edge of Holocene silt and sand that covers much of the central Truckee Meadows.

0.2/2.3 Turn right on Mount Rose Street and proceed up the deeply weathered, upper depositional surface of the Donner Lake outwash floodplain. This surface is inferred to be over-steepened by Quaternary faulting and basin warping (Bingler, 1975).

0.1/2.4 Turn left on Lakeside Drive. For the next few blocks Lakeside Drive parallels an inferred fault that separates Donner Lake outwash on the right (hanging wall) from Holocene(?) reworked outwash on the left.

0.3/2.7 Cross Plumb Lane. Lakeside Drive continues to parallel the post-Illinoin fault that now becomes more defined by the bluff of Donner Lake outwash on the right, which forms the western margin of Virginia Lake.

0.2/2.9 Across the lake to the left, the east shore is also composed of Donner Lake outwash in the hanging wall of a down-to-the-west fault. Virginia Lake occupies a small graben arranged en echelon to the one previously mentioned at Vassar and Holcomb Streets.

0.2/3.1 Continue straight ahead along Virginia Lake.

0.2/3.3 Proceed up a slight slope on Lakeside Drive. This is the structurally complex southern end of the Virginia Lake graben. Several branching, post-Illinoian faults intersect here controlling the local topography.

0.5/3.8 Moana Lane intersection. Gentle slopes to the right are underlain by Peavine Mountain alluvial fan deposits. Here the fans grew outward from the Carson Range block (high mountains to the right and ahead) and are composed of altered andesite, and highly rounded pebbles reworked from the intraformational gravels in the Mio-Pliocene Kate Peak Formation.

Ahead and to the left are elongate, low-lying, fault-bounded (down-to-the-west faults) hills of Donner Lake outwash. Both sides of the road across the street have marshy areas. These are points where the water table intersects the ground surface probably controlled by the fault on the left at 11:00. (Notice the scarp below the white house).

Turn left on Moana Lane. Cross a fault escarpment and climb a hill that is underlain by Donner Lake outwash. Cross the summit and proceed down the depositional slope of the Donner Lake floodplain which has been oversteepened due to post-Illinoian faulting and by dissection of post-Illinoian streams draining the surface.

This stretch of west Moana Lane is the approximate center of a 4-5 square-mile area of thermal water wells, which produce water ranging from 160°F to 205°F drilled 100 to 300 feet down in the basin fill deposits. The hot water has been used for commercial and residential heating for almost 50 years. The Moana Hot Springs (located in NE/4,S26,T19N, R19E) are the locus of this geothermal anomaly, which is thought to be controlled by north-south-trending faults paralleling the front of the Carson Range to the west (Bateman and Scheiback, 1975, Bonham and Bingler, 1973). Several of these faults cut glacial deposits of Illinoian age. The heat source is presumed to be a cooling body of magma at an undertermined depth.

Those wells displaying an artesian head are located along a north-south-striking alignment, presumably a fault or fault trace. The surrounding wells do not have surface discharge and are generally of lower temperatures. These waters have probably diffused laterally underneath an impermeable clay zone that has been intersected by a bedrock fault which supplies the hot water. The highest water temperatures come from the contact zone between the Tertiary bedrock units and the overlying clay unit, which can measure up to 150 feet thick. Hot water is not generally found above this clay zone, and many cold water wells are drilled throughout this area.

0.6/4.4 To the right is the Moana municipal pool which is heated by geothermal water from a 500-foot well.

0.1/4.5 Turn right (south) on Virginia Street. This is the approximate boundary between the Illinoian Donner Lake outwash and the large Holocene floodplain-swamp-lacustrine complex, which lies directly to the right (east) and occupies much of the central and eastern Truckee Meadows. For the next few miles, land development along Virginia Street has completly obscured the subtle geology of the glacial outwash and fan deposits. (For more information refer to the Reno Geologic Map by Bonham and Bingler, 1973.)

0.2/4.7 Peckham Lane.

0.2/4.9 Reno-Sparks Convention Center on the left. Kumle Lane on the right. Approximately 0.7 mile to the west is the largest concentration of private homes heated with geothermal water from the Moana Hot Springs. The wells are generally 100-300 feet deep with water temperatures of 160°-185°F.

0.6/5.5 Intersection of S. McCarran Blvd. on the left.

0.6/6.1 Del Monte Lane and U.S. 395 North exit on the right. The route now leaves Donner Lake outwash deposits and crosses onto Holocene fan material (sand and gravel) deposited from streams issuing from the Carson Range and the large Evans Creek drainage to the west (right). You will be travelling on these Holocene fan deposits to the southern limit of the Truckee Meadows.

On the left, the Huffaker Hills emerge prominently from this Holocene surface. Composed of rhyodacite (andesite) flows of the Miocene Kate Peak Formation (13 m.y.), they are aligned in a north-northeast direction and are bounded by down-to-the-west faults in the basement rock that do not transect the Holocene deposits. The highest peak on the north end of the hills is Rattlesnake Mountain (elevation 5,011 feet). Beyond Huffaker Hills is the Virginia Range.

The principal drainage for the southern Truckee Meadows is Steamboat Creek, which originates to the south at Washoe Lake and flows northward into the Truckee Meadows and along the extreme eastern edge of the valley. The Truckee Meadows is underlain by a structural block that is bounded by Basin and Range faults on both the east and the west sides, and most recently has been tilted to the east in the late Pliocene through early Pleistocene. Present topographic evidence for this eastern tilting lies in the large fan-pediment surfaces being built on the west side of the basin, the sharp truncation of the eastern margin of the basin, and the fact that the surface drainage flows along the east edge of the valley.

2.9/9.0 If safe traffic conditions permit and a clear view is available, pull off to the right side of the road for a short summary of the Carson Range.

The Carson Range is a north-trending mountain block over 40 miles long, which splits off from the Sierran block about 30 miles south of here. It is bordered on the west by the Tahoe basin, on the northwest and north by the Truckee River canyon, and on the east by the Truckee Meadows, Washoe Valley, and the Carson Valley.

The highest peak in the Carson Range is Mount Rose (elevation 10,776 feet), a horst composed of Tertiary volcanic rocks of the Miocene Kate Peak Formation, which lies discordantly on Late Jurassic or Early Cretaceous granitic rocks.

To the south of Mount Rose is Slide Mountain (elevation 9,698 feet), exhibiting vertical scars. It is a mass of Jurassic or Cretaceous granitic rock.

From Mount Rose north, the rocks of the Carson Range are primarily Miocene Kate Peak andesite overlain by late Miocene or Pliocene basaltic rocks. South of Mount Rose, Jurassic-Cretaceous granodiorite is dominant.

In general, the Carson Range is horstlike - being flanked by impressive fault scarps on both the east and the west. Thompson and White (1964) found that...the warped and faulted block which forms the Carson Range has a structural relief with respect to bedrock of the basins on its east side of more than 8,000 feet. Considering the great depth of Lake Tahoe (1,600 feet) lying to the West, the structural relief on that side must be about as great.

On the north and northeast sides the range forms a partial dome [a domical fold or plunging anticlinal structure], which is broken by normal faults, most of which are antithetic, that is, the displacement is down on the mountain side of the faults (Thompson and White, 1964). The fault scarps face west toward the uplift. Along the north and northeast margins of the range, the faults are also roughly concentric and radial to the edge of the dome. Uplift has been primarily by flexure. Because most of these concentric faults have their downthrown sides toward the interior of the dome, the structural relief produced by faulting subtracts from that due to upwarping. The strata of the dome is stretched over a rising interior, causing the center to fail along normal faults and form grabens.

Farther south, along the east side, the domical boundary is replaced by great normal faults along which the range is uplifted with respect to the basins. In the interior of the range [north-trending] normal faults are abundant and the strata are complexly warped and tilted, but the overall structure is that of a faulted anticlinal uplift. (Thompson and White, 1964).

Thompson and White (1964) concluded that initial faulting in the northern part of the range accompanied or closely followed deposition of Miocene Kate Peak extrusive volcanic rocks, and during this same time Kate Peak intrusives were responsible for the uplift of Jurassic or Cretaceous age granodiorite and metamorphic rocks ("trapdoor fault blocks") in the interior of the range. Hudson (1987, verbal communication) says that the warping post-dates the Kate Peak Formation.

Thompson and White (1964) also postulated that voluminous intrusions at depth may be responsible for some of the larger structures of the Carson Range, including the northern domical structure, using as possible evidence a large bleached area 6 miles across the northern end of the range. According to Hudson (1987, verbal communication) this altered area predates any warping.

Structural movements continue to the present as indicated by earthquakes recorded in the area, by faulting of the late Miocene or Pliocene basalts and Quaternary alluvium on the north and north-east margins of the range, by down-cutting of the antecedent Truckee River Canyon and Thomas Creek Canyon by 400 feet since the first outpourings of the late Miocene or Pliocene basalts, and by the warping (or distributive faulting) and prominant boundary faults farther south along the east margin of the range. The warping and impressive boundary faults will be seen farther south in the first half of Route 2.

Arguments still exist over the date of major uplift of the eastern front of the northern Carson Block, especially since Mio-Pliocene volcanism.

Louderback (1904-1907, 1924) first produced evidence that more than 5,000 feet of post-Mio-Pliocene displacement occurred along the eastern front of the Carson Range at Mount Rose. He concluded that the entire Carson Range (hence the Sierra?) was uplifted as a block along that frontal fault in late Pliocene-early Pleistocene time. His interpretation has been further supported by Thompson and White (1964) and accepted by many others, including Hunt (1967), Burnett (1968), and Morrison (1965).

Other students of this problem, such as Hudson (1960) and Lydon (1962), agree that vigorous uplift took place here in the late Pliocene-early Pleistocene, but dispute the actual amount of vertical displacement. Lovejoy's (1964, 1966, 1968, 1969) field studies indicate...that there has been little significant faulting along the Sierra Nevada front at Mount Rose since Miocene-Pliocene volcanism. His studies of the volcanic units from Mount Rose to the Truckee Meadows postulate a relief between the two areas of over 5,000 (and perhaps as much as 8,000) feet in the early Pliocene.

Thompson and White (1964) recognized four periods of glaciation in the Carson Range. The three oldest are correlated with tills described by Blackwelder (1931) farther south in the Sierra Nevada.

The oldest and most extensive Sherwin glaciation is recognized by highly weathered till remmants that lack morrainal topography.

The next two younger tills are found within the major valleys. The older Tahoe till, the more extensive of the two, occurs only as lateral morraines and is characterized by granite boulders partially weathered to grus in a youthful A-C soil profile. The younger Toiga till has both lateral and end morraines preserved with unweathered granite boulders in an A-C soil profile. Fresh glacial morraines are present in some of the high cirques and are probably representative of the "little ice age" (Matthes, 1942).

0.6/9.6 Zolezzi Lane on the right.

0.6/10.2 A rhyolite dome is being quarried at the base of the Virginia Range at 9:00. Steamboat Hills ahead at 1:00.

0.7/10.9 Intersection of U.S. 395 (south to Carson City), State Route 341 (east to Virginia City), and State Route 431 (west to Lake Tahoe).

TURN RIGHT onto State Route 341 TO BEGIN ROUTE 1 (see page 8).

OR

CONTINUE STRAIGHT AHEAD on U.S. 395 TO BEGIN ROUTE 2 (see page 24.

GEOLOGIC ROADLOG - ROUTE 1

STEAMBOAT SPRINGS - VIRGINIA CITY - CARSON CITY - WASHOE VALLEY - STEAMBOAT SPRINGS

Mileage/
Cumulative

0.0/0.0 This route begins at the Steamboat Springs intersection of U.S. 395, State Route 431 (west to Lake Tahoe), and State Route 341 (east to Virginia City). TURN EAST ON STATE ROUTE 341 TO VIRGINIA CITY.

This is the approximate southern boundary of the Truckee Meadows.

0.2/0.2 The road abruptly leaves the Mount Rose fan-pediment deposits and descends into the floodplain of Steamboat Creek.

0.6/0.8 The light-colored pit at 9:00 at the base of the Virginia Range is being mined for lightweight aggregate. It is one of three pumiceous rhyolite (Pleistocene Steamboat Hills rhyolite) domes in this vicinity dated at 1.1 to 1.5 m.y. The other domes are dated at 3.0 m.y. They are believed to be related to the same magmatic heat source for the Steamboat geothermal area (at 2:00).

Ahead, the pastel, bleached zones on the slopes of the Virginia Range are hydrothermally altered andesites and rhyodacites (flows, breccias, pyroclastics) of the Miocene Alta and Kate Peak Formations. The alteration distribution is controlled by numerous north-south and east-west fracture zones.

0.8/1.6 Begin climb up Geiger Grade.

The Virginia Range is composed mainly of a thick (maximum 10,900 feet) section of Tertiary volcanic rocks consisting, at the base, of silicic ash-flow tuffs which are unconformably overlain by over 3,000 feet of andesitic flows, flow breccias, mud-flow breccias, and lacustrine sediments of the early Miocene Alta Formation (17-20 m.y.). Overlying the Alta Formation are andesitic to dacitic flows, stocks, and dikes of the Miocene Kate Peak Formation (dated from 12.3 to 14.9 m.y.), followed by the late Miocene or Pliocene Knickerbocker andesite and Lousetown Formation, and later Plio-Pleistocene scattered volcanics. About 17 m.y. ago hornblende andesite porphyry dikes and stocks of the Davidson diorite intruded the entire sequence up through the Alta Formation.

These volcanic rocks unconformably overlie about 1,300 feet of Lower Mesozoic(?) meta-andesite, meta-diorite, and meta-gabbro of the Peavine Sequence which has been folded and regionally metamorphosed (to at least greenschist facies) and thrusted during the Middle Jurassic over Lower Jurassic argillite and limestone of the Gardnerville Formation and Upper Triassic Oreana Peak Formation prior to the emplacement of Cretaceous(?) granitic plutons. Near the contacts with the plutons, more intense metamorphism has produced hornfels, schist, marble, and skarn of the amphibolite facies.

Structurally, the range consists of west-tilted blocks bounded by normal (dip-slip), northeast-to northwest-trending faults, which dip moderately or steeply to the east, and are step-faulted relatively down and to the east. The range is bounded on the north by the Truckee River Canyon (Olinghouse fault zone) and on the south by the Carson River Valley (Carson lineament). Both fault zones are northeast-trending lineaments having left-lateral movement.

Bedding in the Virginia Range dips at low to moderate angles westward toward the axes of the relatively down-dropped Truckee Meadows and Washoe Valley.

The predominent range-bounding fault on this western flank extends from the Truckee River south along the range for about 7 miles. It is characterized by a series of discontinuous scarps considered to be pre-Holocene in age because they cut mid-to late-Pleistocene alluvial fans. These scarps reflect the traces of steep to moderate antithetic (east-dipping) faults, which form longitudinal valleys along the range.

The Cenozoic deposits were laid down on a surface of low to moderate relief cut on the Mesozoic rocks. Repeated tilting and warping, accompanied by block faulting, took place from Miocene through Quaternary time along axes that trend northeast to northwest. Most of the deformation in the Virginia Range appears to post-date the Lousetown Formation. and the Knickerbocker andesite (Hudson, 1984).

There have been 3 periods of mineralization, associated with faulting and magmatism in the Virginia Range. In pre-Tertiary time where Mesozoic plutons came in contact with the country rock, veins and skarns yielding minor amounts of tungsten, lead, zinc, copper, iron, and precious metals were produced.

The second and major period of mineralization occurred during Miocene (12 to 14 m.y.) magmatism and the outpouring of lower Kate Peak Formation rocks. Major centers of mineralization during this period include the Geiger Grade area, and the Comstock, Washington Hill, Jumbo, Castle Peak, and Flowery districts. All of these areas were hydrothermally altered, but only where major faults were associated with the hydrothermal fluids do rich metal deposits occur. North- south trending fracture zones were formed mainly prior to and during mineralization. An east-west zone was formed after mineralization.

The third period of mineralization commenced 2.5 to 3 m.y. ago, after a period of structural quiescence and outpouring of the late Miocene or Pliocene Knickerbocker andesite and the Lousetown Formation. It is represented by the Pleistocene rhyolite domes (1.2 to 3.0 m.y.) on the western boundary of the range, the 1.14 m.y. old McClellan Peak basalt, and the active hydrothermal system at Steamboat Springs (3 m.y. to the present).

1.2/2.8 Note the clay pit on the right. Material from the pit was used for brick-making during the first half of the century. Most of the rocks in the pit are argillically altered andesites of the Alta Formation. The porphyritic plagioclase-biotite dacite in the center of the pit may be a feeder dike(?) for a flow of the Kate Peak Formation.

0.4/3.2 Passing altered rocks of the Miocene Alta and Kate Peak Formations. Alteration of these rocks occurred 12 to 14 m.y. ago.

0.2/3.4 Unaltered volcanic breccia of the Kate Peak Formation. The most common rock type in these abundant Kate Peak breccias (including tuff breccias, flow breccias, and lahars) is porphyritic dacite.

0.4/3.8 Note the landslide block across the canyon at 10:00.

0.2/4.0 Looking ahead, the next few roadcuts expose altered Alta Formation. Only Jeffrey and ponderosa pines grow on these altered areas.

0.7/4.7 Geiger overlook. Pull off the road and park. Rocks in this area are altered andesites of the Alta and Kate Peak Formations. The roadcut across from the parking area exposes hydrothermal breccias cross-cutting Alta andesites.

Walk down the path to the overlook for a panoramic view of Washoe Valley and Reno, with the Carson Range ahead (to the west). Looking from right (north) to left (south) on the skyline are Peavine Mountain (elevation 8,266 feet), Mt. Rose (elevation 10,776 feet), and Slide Mountain (elevation 9,698 feet). Below, near the highway is the light-colored sinter of the Steamboat Springs geothermal area. Note the numerous north-south-trending faults cutting the alluvial fan-pediment surface that spreads eastward from the Carson Range.

1.3/6.0 In the canyon ahead and to the right, the original Geiger Grade can be seen.

1.5/7.5 Geiger Grade historical marker on the right.

0.1/7.6 Entering Storey County.

0.2/7.8 The road now crosses an old erosion surface probably formed during Pliocene time.

1.6/9.4 Geiger Summit (elevation 6,799 feet). Here the bleached Alta and Kate Peak andesites are in contact. Outcrops ahead in the distance are unaltered flows of the Kate Peak Formation. The roadcuts ahead are mostly weakly altered flows of the Alta Formation.

0.4/9.8 Lousetown historical marker on the left. Rocks in the outcrop on the right are Alta Formation (porphyritic andesite).

0.3/10.1 More Alta andesite on the right.

1.1/11.2 On the hillside to the right, several resistant dikes of Kate Peak andesite jut above the ground surface.

0.4/11.6 Looking ahead (south), the surface of the east-dipping and north-south-trending Comstock fault forms the east side of Mt. Davidson (the highest peak on the right), a major break in the Virginia Range. The line of pits along the base of Mt. Davidson roughly defines the Comstock fault.

Beginning here, flows of the Alta Formation exposed in the roadcuts are commonly propylitized.

1.4/13.0 Entering Virginia City. The north end of the Comstock fault bends to the northeast here and cuts the drainageway on the right.

0.1/13.1 Roadside rest and picnic tables on the left. *Pull off the road and park.*

Abundant literature exists on the discovery and history of the Comstock Lode and Virginia City the surrounding areas, so only a brief summary will be given here. Excellent historical references for this area are:

Smith, G.H. (1943) *The History of the Comstock Lode, 1850-1920*: Nevada Bureau of Mines & Geology Bulletin 37.

Lord, E. (1883) *Comstock Mining and Miners*: U.S. Geological Survey Monograph 4; Howell-North Books, San Diego, Calif.

Galloway, J.D. (1947) *Early Engineering Works Contributory to the Comstock*: Nevada Bureau of Mines & Geology Bulletin 45.

The story of the Comstock Lode, the great silver and gold bonanza, began in 1849 south of Virginia City near the town of Dayton, an immigrant and Pony Express stop then known as Spafford Hall's Station. Passing immigrants began to pan the streams nearby in what came to be called Gold Canyon. For nearly a decade, transient miners washed the gravels of

Gold Canyon pocketing a total of around $600,000 as they gradually worked their way up the hill toward Mt. Davidson.

Early in 1859, lode gold and silver was discovered outcropping at both ends of the Comstock fault (about a mile apart), by two independant parties. Patrick McLaughlin and Peter O'Riley discovered rich black sands on the north end of the fault near Ophir Ravine. James Finney (or Fennimore), familiarly known as "Old Virginny", along with Jack Yount, Alec Henderson and John Bishop were the first to stake claims on the south end of the fault at Gold Hill. James Finney had also staked claims in Ophir Ravine in 1858, but hadn't developed them. Only after a few years of work was it apparent that these two strikes were located on the same vein along the eastern base of Mount Davidson, because surface exposure of the lode was poor.

Old Virginny was known as the best judge of placer ground in Gold Canon. Along with locating the first quartz claim on the Comstock, he was known for his generosity, good-will, and imbibing. The early miners at Virginia City acknowledged their debt to him and his efforts by naming the town after him.

The "Comstock" title was less formally established. Henry T. P. Comstock was the local loudmouth who became one of the original locators at Gold Hill by cutting himself in on McLaughlin and O'Riley's claim by insisting they were digging on his wood "ranch". He also claimed to be one of the original locators at Gold Hill.

As the 1859 miners washed the gravel for gold, they were impeded by a blue clay that clogged the equipment. They continued to dispose of it until some of the rock was secretly sent to an assay office in Grass Valley, California. The results showed that the miners had been throwing away rock worth $4,000 per ton in silver and gold. This news leaked-out and the "Rush to Washoe" was on.

The mining boom continued through 1878 as discoveries were made downward along the lode. The Crown Point bonanza, a concentration of gold and silver ore on the 1,000-foot level yielded $35 millions, and the Big Bonanza on the 1,400-foot level of the Consolidated Virginia Mine produced $105 millions.

Exploration continued as deep as 3,200 feet along the Comstock fault, but by the 1880's all mining, except for a few high-grade pockets on the East Vein zone, was largely confined to old stope fill and low grade ore in the upper levels. No bonanzas were found in 10 years of deep mining. The costs of pumping water to the surface and hauling low-grade ore such great distances to the surface contributed to the decision not to drill deeper. By World War II production had all but ceased.

In the late 1970's Houston International Minerals Corp.

renewed mining in the Consolidated Imperial pit. For the past few years United Mining Corp. has been mining underground and reworking dumps at the New Savage Mine, but late in 1985 production had stopped and United was looking for a buyer.

The main period of production, from 1863 to 1880, along with additional intermittant production to the present, has yielded over 190 million ounces of silver and 8 million ounces of gold.

Some of the Comstock mines are the deepest in the world. The lode had been developed to nearly 4,000 feet by inclined and vertical shafts from the Sierra Nevada to the Overman Mines, a distance of 3 miles. The mines were known for their extremely hot and humid working conditions, where miners commonly worked in temperatures of 100^{o}-125^{o}F. Rock temperatures as high a 167^{o}F were recorded from drill holes on the 3,000-foot level of the Yellow Jacket Mine. Hot water also plagued the lower depths of the Comstock mines. These problems taxed the mining companies financially and the miners physically. The moisture in the mines caused the layered rock to swell and crumble, and rotted the timbers. Rockfalls were a constant hazard. Air circulation was very poor. The build-up of carbon dioxide from organic sources, and gases from the incomplete combustion of nitroglycerine brought on symptoms in the miners that ranged from dizziness and nausea to blindness or insanity. Breathing the quartz dust brought on silicosis that often contributed to fatal pneumonia or tuberculosis. More men died from poor air circulation than from any other cause in the early years of Comstock mining.

The boom years of 1863 through 1880 brought about major engineering innovations to help solve some of the problems of deep underground mining. Some of these are still in use today, such as dynamite (giant powder) which replaced black powder in 1868, Burleigh mechanical drills which ran on compressed air which also helped to ventilate the mines, and the safety brake. The flat, woven wire rope developed by A.S. Hallidie of San Francisco in 1864 to hoist ore buckets to the surface is now used on the cable cars in San Francisco. Root blowers were introduced into the mines in 1865 for improved ventilation. The square-set timbering method was developed in 1860 by Philipp Deidesheimer, a young German engineer, especially for the type of soft, wet, crumbly rock encountered in the Comstock Lode fault zone. The clay was so expansive here that when the air would enter a newly dug hole the rock mass would immediately begin to swell and move, breaking timbers and filling the mine openings that weren't held back by stout timbering. The old Cornish pumps were developed to their maximum here on the Comstock, but they still couldn't keep up with the magnitude of water issuing from the depths of the mines.

Around 1863, Adolph Sutro, another German engineer, conceived the idea of a tunnel dug into the Flowery Range to drain the Comstock mines at the 1,650-foot level. The mines would benefit by being ventilated and drained of the constant flow of hot water, and Sutro hoped to profit by charging the mines to truck ore out of their lower levels through his tunnel. He also hoped to strike a rich vein for himself in the process of digging the tunnel. Initially, support from the mine owners, the banks, the Nevada Legislature (which in 1865 gave Sutro an exclusive franchise to the tunnel for 50 years), and Congress (which passed the Sutro Tunnel Act in 1866) was showered upon Sutro; however, it was withdrawn just 2 years later when the bankers (led by William Sharon) and mine owners decided Virginia City would lose its inflow of cash to the mills and related businesses at the other end of Sutro's Tunnel on the Carson River and in Carson City.

In 1869, the miner's rallied behind Sutro after a bad underground fire in the Yellow Jacket Mine killed many men. Money to build the tunnel was secured from a London bank and other European sources and the miners' union. Work finally began on the tunnel in October 1869.

The tunnel reached the Savage shaft in July 1878, almost 9 years after ground-breaking, but the Comstock mines had already progressed as much as 1,500 feet below the level which the tunnel was to drain, and the bonanza days were over. Had the tunnel been completed in the 1870's, it would have saved the mining companies millions of dollars in pumping costs alone.

The Sutro Tunnel stretches in a straight line from the eastern front of the Flowery Range (1 mile north of U.S. 50 and 2.25 miles northeast of Dayton) to a drift on the Savage shaft, a distance of 20,498 feet (almost 4 miles). It was 8 to 9 feet wide, and 7 feet high. In all, the tunnel cost $6.5 millions, including interest, to complete. It was never paid back in royalties after completion of the tunnel. Sutro quietly sold his stock in the tunnel shortly after it was finished, netting less than $1 million. He invested it in San Francisco real estate and became a multi-millionaire.

The Comstock Lode appears to be a stockwork zone, 65 to 130 feet wide at depth widening to over 600 feet near the surface. The ore-bearing zones are commonly 6 to 17 feet wide and are sandwiched between the East Clay and the West Clay, which are gouge zones from 10 to 40 feet wide created by post-mineral movement on the Comstock fault.

Most of the precious metals produced from the Comstock Lode came from the vein deposits associated with the Comstock fault system, which consists of the Comstock, Silver City, and Occidental faults. These faults dip about 45^{o} east, have a dip-slip of at least 2,500 feet (thompson, 1956), and form a major physiographic break in the Virginia Range. Movement on the faults is dip-slip with post-Miocene western rotation of the fault blocks, which has lowered the orignal dips. The Comstock and Occidental faults trend generally north-northeast. The Comstock fault can be traced northeastward from American Flat through Virginia City for 4 miles, and from there northward for another 4 miles. Geophysical studies indicate that it may continue northeastward for another 3 miles.

Two distinct periods of faulting occurred in this district. Movement on these major faults first occurred during the early middle Miocene (12 to 14 m.y.) along with alteration and mineralization associated with the intrusive and extrusive deposition of lower Kate Peak rocks. Dip-slip displacement on the Comstock and Silver City faults was about 1,300 feet, and movement on the Occidental fault was about 300 to 400 feet (after Hudson, 1986). The precious metals were deposited mainly in faults in the Alta Formation.

The second period of faulting commenced about 2.5 to 3 million years ago following the deposition of the late Miocene(?) Knickerbocker andesite and the upper member of the Kate Peak Formation. This post-Miocene dip-slip displacement is estimated to be about 2,000 to 2,500 feet on the Comstock fault zone, about 800 feet on the Silver City fault, and none to 200 feet on the Occidental fault. Numerous northerly-trending higher angle faults were formed at this time in the hanging wall of the Comstock fault with displacements of 30 to 410 feet. These post-mineral faults, along with the Comstock fault system, commonly display a right-lateral component of dip-slip motion, except on the Occidental fault near the Occidental shaft where a left-lateral component occurs.

Most ore bodies within the Comstock fault system occur near the surface with some cropping out. Rarely do they exceed 500 feet in vertical extent. Hanging wall ore bodies, as well as other slivers of ore bodies formed on the fault, have been displaced relatively downward by post-mineral offset on the fault. (The preceding geologic information is largely after Ashley, 1980; and Hudson, 1984 and 1986).

The relative position of the ore bodies is also controlled to some extent by cross faults cutting the Comstock system and trending N70°W. They are post-mineral in age, but some may have pre-or syn-mineral movement which helped to localize ore bodies (R. Carrington, personal comm.).

Mines in the Comstock Lode district can be placed in three main groups: The Bonanza group, Central group, and Gold Hill group (Becker, 1882). The Bonanza group includes the Consolidated Virginia, California (C&C), and Ophir Mines which are located near the north end of Virginia City. They exploited the Big Bonanza, the most productive single ore body in the district, and several smaller ore bodies at depths as great as about 2,970 feet. The Central group, including the Savage, Gould and Curry, Hale and Norcross, and Chollar-Potosi Mines, is located in the southern part of Virginia City. These mines exploited a number of ore bodies from the surface to depths of 1,683 feet. The Gold Hill group, including the Brown Point, Belcher, Yellow Jacket, and Imperial Mines, is located immediately west of Gold Hill. This series of shafts extends from Greiner's Bend on State Route 342 just north of Gold Hill a distance of 2,970 feet to the south-southwest. Many ore bodies of various sizes were mined here to depths of about 1,980 feet.

The ore bodies associated with the Comstock fault were generally tubular, but very irregular in longitudinal section. The best ore bodies occupied hanging wall fractures that diverged upward from the main fault (after Ashley, 1980).

Most of the mines of the Silver City district are located along the Silver City fault, beginning at a point about 0.7 mile due south of the townsite of Gold Hill and extending 2.4 miles down Gold Canyon to the mouth of the canyon just below Silver City. Ore bodies were found both in the Silver City fault zone and in northeast-trending cross faults. Ore bodies were lenses or shoots localized at points where veins branched or intersected; almost all of the ore was recovered from depths of 330 feet or less (Gianella, 1936).

Throughout the Comstock and Silver city districts the most abundant gangue material composing the veins is quartz. Parts of some veins in the Silver City district, however, are dominantly calcite. The main precious metal-bearing ore minerals of the Comstock Lode were argentite and electrum, with lesser amounts of polybasite; the ore also included abundant sphalerite, galena, chalcopyrite, and pyrite. Silver City district ores were relatively poor in base-metal sulfides, being mainly pyrite-gold with some native silver and electrum and minor argentite (Ashley, 1980).

0.2/13.3 Approaching the Carson Street intersection (no street sign).

OPTIONAL TRIP TO OPHIR DISCOVERY SITE. Turn right on Carson Street and proceed uphill for about 3 blocks to where the street makes an abrupt turn to the right. Stop. Just south of Carson Street begins the Virginia City pit where surface outcrops of the Comstock Lode were mined several hundred feet downward in 1859-1860, and again in the 1920's. RETURN TO THE CARSON STREET INTERSECTION and resume mileage at 13.3.

0.3/13.6 Virginia City Visitor's Bureau on the right. Here you may obtain maps, walking tours, photos and other information to help find your way to various points of interest in this historic town. Most of the buildings date from 1876. They were constructed after the great fire of 1875, which destroyed most of the city. Reconstruction was only partial because of the failing mines.

0.5/14.1 Junction with State Route 341 to the left. Proceed straight ahead on State Route 342.

On the right, the Loring Pit was mined by the Arizona Comstock Company during the Depression years (1930's) for low-grade silver ore valued at $2.00 to $3.00 per ton. 460,000 tons of ore were extracted yielding $1,437,000. In 1981, the Chollar raise was opened in the bottom of the pit by United Mining as a ventilation and escape shaft for its New Savage Mine (the portal for the mine is located to the east below F Street). Underground mining at the New Savage began in 1979. Production began in April 1983, and ended in April 1985 due to declining gold prices.

0.4/14.5 Descending Greiner's Bend. Alta andesite is exposed on both sides of the road. The headwaters of Gold Canyon originate in the canyon to the left. About 6 miles downstream is the town of Dayton where the first gold nuggets were discovered by passing emigrants. The lower 4 miles of Gold Canyon was the scene of placer mining for 10 years prior to the Comstock Lode discovery at Gold Hill in early 1859.

0.3/14.8 To the right, is the abandoned Houston International Minerals Corp. pit. Formerly the site of the Consolidated Imperial pit, Houston renewed mining here in 1979, but closed the mine in 1981 when they lost their battle with local townspeople to enlarge the pit and relocate Greiner's Bend. This pit also marks the original discovery of the south end of the Comstock Lode at Gold Hill by James Finney and his associates in 1859.

0.1/14.9 The red building off the road to the right is the Gold Hill depot for the famous Virginia & Truckee Railroad. Just beyond it is the Yellow Jacket shaft and the Crown Point Ravine.

0.1/15.0 Entering the town of Gold Hill.

0.2/15.2 Gray buildings of the Crown Point mill on the right.

0.4/15.6 Former United Mining Corp. offices on the right.

At 9:00, approximately 0.25 mile from the road, the north-northwest-trending Silver City fault intersects the north-northeast-trending Comstock fault in the vicinity of the Overman pit.

0.1/15.7 OPTIONAL SIDE TRIP TO AMERICAN FLAT. Take dirt road to the right, continue for about a mile avoiding side roads. Pass the Masonic cemetary, and the Caledonia Mine shaft above on the hill to the right. Some of the other great mines of the Comstock in this area are the Knickerbocker, Overman, Baltimore and Keystone. Most of these were in production as recently as 1942. Arrive at the ruins of the United Comstock Merger cyanide mill built around 1921, and the site of American City established in 1864. Around 1920, two Nevada engineers opened several mines in Gold Hill (United Comstock Mines Co.) and in Virginia City (Comstock Merger Mines Co.) as one of the final commercial ventures of the Comstock era. Several million tons of low-grade ore were found and the mill was built. The mines and mill operated for a few years until the price of silver dropped from over a dollar to $0.28 per ounce. The first power lines over the Sierra from California provided electricity for this mill. RETRACE ROUTE BACK TO JUNCTION WITH STATE ROUTE 342. TURN RIGHT. RESUME MILEAGE AT 15.7

0.1/15.8 New York Mine on the left. The north end of the Silver City fault is on the right side of the road at this point.

0.2/16.0 Headframe of the Keystone Mine is on the left. Hartford Hill is at 2:00. It is composed of early Miocene Santiago Canyon ash-flow tuff (21 m.y.). At the base of the hill are more open pits mined during the Depression.

0.6/16.6 On the right, at the base of Hartford Hill, is the Lucerne cut, a mineralized zone on the Silver City fault. It was the site of open-pit gold mining operations in the 1860's, early 1900's, and again in the 1940's and 1950's. Since the early 1920's, 200,000 tons of ore have yielded $1,200,000.

0.4/17.0 Entering Lyon County, and passing through Devil's Gate, composed of Miocene Alta andesite. Lower Mesozoic metavolcanics are exposed in the lower part of the roadcuts on the right.

0.1/17.1 Entering Silver City. This is the third of the largest communities on the Comstock Lode. Most of the gold and silver produced here came from within 300 feet of the surface on the Silver City fault, although some mines were explored to depths of over 800 feet. Most of the ore-producing veins on the fault varied from less than a foot to 3 or 4 feet. In several places, the ore was stoped to 40 feet or more. The veins were generally lenticular, pinching-out laterally and at depth.

0.2/17.3 Grosh brothers' monument on the right. Hosea and his brother Ethan Allen might have been the first to discover the Comstock, but they both died in 1857. They had good shows of silver on their "monster ledge" which was the Silver City fault, but it would never produce the riches that the Comstock fault did.

0.2/17.5 American Ravine on the right. The outcrops are Lower Mesozoic(?) metavolcanics.

0.2/17.7 On the right, the historical marker commemorates the McCones Foundries. Ahead, on the hillside to the right is the Dayton Mine and mill, erected in 1934. This marks the south end of the productive zone of the Silver City fault.

0.1/17.8 Junction with State Route 341 on the left. Proceed straight ahead. Gold Canyon bends to the southeast here. About 1.5 miles downstream are the Dayton placer gold workings.

0.4/18.2 Many mine shafts and prospect holes dot the landscape for the next few miles. The hills are composed mainly of early Miocene Santiago Canyon tuff. Prospectors were trying to locate a southern extension of the Comstock Lode.

Ahead and to the left is the Pine Nut Range. In the distance at 1:00 is the higher Carson Range.

1.6/19.8 Junction with U.S. 50. TURN RIGHT toward Carson City to continue roadlog, OR TURN LEFT for an OPTIONAL TRIP TO DAYTON AND SUTRO.

OPTIONAL TRIP TO DAYTON AND SUTRO. Travel east on U.S. 50. In about 1 mile, mounds of dredge tailings from placer operations near the mouth of Gold Canyon will be visible on the left. This is the general location of the first gold flakes discovered in 1849. 10 more years of panning up Gold Canyon led to the discovery of the Comstock Lode. Continue on to Dayton, originally called Spafford Hall's station on the California emigrant trail in the late 1840's. Note the historical marker (in front of the flea market) just before the junction of U.S. 50 and Dayton Valley Road. Turn right on Dayton Valley Road and travel one block to the Carson River bridge. Wagons camped under the cottonwoods for miles along the river in the mid-1800's. Return to downtown Dayton. Points of interest include the Dayton Historical Society Museum, the Dayton Museum, the Dayton City Park (west side of town), and the cemetary.

The site of Sutro is 3.5 miles east of Dayton on U.S. 50 (on the right side of the road). The entrance to the Sutro Tunnel can be reached by taking the gravel road leading north (left) from U.S. 50 at Sutro. It is at the base of the Flowery Range a mile to the northwest. END OF OPTIONAL TRIP TO DAYTON AND SUTRO. RETRACE ROUTE WEST ON U.S. 50 TO THE JUNCTION WITH STATE ROUTE 341 (to Virginia City). RESUME MILEAGE AT 19.8

You are presently traversing an old valley that was the main drainage way for this area before the Carson River cut its present canyon throught the north end of the Pine Nut Range (on the left).

0.5/20.3 Rocks exposed in the road cut are Tertiary mudflow breccias of the Kate Peak Formation.

0.1/20.4 In the hills at 2:00 is Portland Cement's now inactive gypsum mine and dumps located north of Mound House. In the foreground are light-colored gypsite deposits in Jurassic metasediments. The gypsum was milled for plaster from 1913 to 1920, with a total production of about $452,000. Local well water cannot be used for drinking because of the high concentrations of calcium, magnesium, and sulfate related to the gypsum deposits.

0.7/21.1 Mound House historical marker.

0.7/21.8 Entering Carson City.

1.0/22.8 The road crosses a basalt flow (Pleistocene? McClellan Peak Formation) that issued from a partially dissected vent about three miles to the northeast in the McClellan Peak area. McClellan Peak in the Virginia Range is a complex assemblage of Triassic metavolcanics, Cretaceous granodiorite, Oligocene-Miocene tuffs, and Tertiary-Quaternary andesites and basalts, some as young as 1.7 m.y. (Glancy and others, 1984).

1.1/23.9 Entering the historic town of Empire. Note fault scarps in the basin fill to the right (north) of the highway for the next mile. They bend southward and cross the highway in the vicinity of New Empire.

0.2/24.1 On the left, at the Akron Way intersection is the Carson River mills historical marker. CAREFULLY CROSS TRAFFIC TO GET TO THE MARKER if you want to take the OPTIONAL SIDE TRIP TO THE CARSON RIVER MILLS.

By the end of 1861, more than 76 mills with a total of 1,153 stamps had been built for the crushing and separating of Comstock ore in Virginia City, Six Mile Canyon, Gold Canyon, along the the Carson River from Empire to Dayton, and 7 more in Washoe Valley. They had a combined capacity for crushing 1,200 tons of ore daily, but there was no ore for half of them. Many had been built on speculation. After 1878, the mills closed down along with the failing Comstock mines.

After the discovery of the Comstock ore, experimenting commenced to devise a process that would efficiently release the gold and silver from the associated rock. The answer was found in the Washoe Process, developed chiefly by millman A. B. Paul, and in the Washoe Pan Mill, invented by a few ingenious California mill builders. The Washoe Process was a mechanical combination of two other processes used by the early Comstock miners. It accomplished in 6 hours what had formerly taken 4 to 6 weeks.

Originally, arrastras crushed the ore. This was followed by the Mexican patio process where the finely crushed ore, or "pulp", was mixed with water, quicksilver, salt, and copper sulfate. This mixture was then spread on an open floor, or patio, that was exposed to the sun's heat, and was turned with shovels or trampled by stock animals. Eventually, the sulfides were reduced to chlorides and then to the metallic state. The gold in the ore readily united with quicksilver to form amalgam.

The Carson River provided a steady source of power for the huge water wheels needed to drive the process, and wastes were discarded downstream.

In a typical 1870's Carson River mill (using the Washoe Process), the ore was delivered by the Virginia & Truckee Railroad and dumped into huge hoppers. It was then crushed into sand-sized particles by stamps. This material was mixed with salt, mercury, and water and heated in large, steam-heated pans. Large internal blades stirred the mixture for 6 to 12 hours until the precious metals became trapped in the mercury. This dough-like mass, called "charge", was then placed in "settlers" where the gold-silver amalgam settled to the bottom and was released and collected. Finally, the mercury was boiled off in retorts, and the bullion was collected.

During the stamping stage, much of the ore rock escaped being crushed into the optimum sand-size particles. These larger and smaller grains passed through the mill and were discharged into the river. Indeed, 95% of the rock produced went into the river as waste. The river was later dredged for its high gold and silver content.

The environmental impact of the milling operations on the Carson River was ghastly. The poisonous chemicals and rock waste were flushed down the river. Unknown amounts of mercury still lay trapped in the river bottom sediments and provide a continuing source of mercury pollution downstream. Beginning in 1980, 4 companies have sought permits to dredge the riverbed for its precious metals; however, in February 1986 they were finally turned-down by the Nevada Dept. of Conservation and Natural Resources after a 2-year study by the State Environmental Protection Division revealed high mercury levels in the river, expecially downstream and in Lahontan Reservoir. The levels exceed federal standards, and disruption of the sediments could cause problems. Certain persons are advised not to eat fish from this area.

OPTIONAL SIDE TRIP THE THE CARSON RIVER MILLS. (The road is rough. High-axle vehicles are recommended.) TURN RIGHT (south) on DEER RUN ROAD (0.2 mile east of the historical marker). The Empire graveyard is on the right. Travel 0.5 mile to the ruins of the Morgan Mill (on the right in a grove of trees). AT THE BRIDGE, TURN LEFT. DO NOT CROSS THE BRIDGE. 0.7 mile farther are the Brunswick Mill ruins. The dam across the river diverted water to the mill. DO NOT CROSS THE NEXT BRIDGE, KEEP LEFT along the edge of the river. 0.2 mile farther are the Merrimac Mill ruins (opposite side of the river). Note the mill extension across the river. This road is built on the right-of-way of the old Virginia & Truckee Railroad. 0.6 mile farther is a hand-excavated railroad cut dug by Chinese labor gangs employed by the railroad. KEEP LEFT THROUGH THE CUT. In another 1.4 miles the Santiago Mill ruins lie along the river below in the trees. The road bends to the north (left) and connects with U.S. 50 in 2 miles. END OF OPTIONAL TRIP TO THE CARSON RIVER MILLS. TURN LEFT (WEST) ON U.S. 50 and retrace route back to the historical marker at Akron Way. RESUME ROADLOG AT MILEAGE 24.1

The Carson River flows north between the Pine Nut Range on the east and Prison Hill on the west before it makes an eastward bend and enters Brunswick Canyon.

1.0/25.1 Entering New Empire. The Nevada State Maximum Security

Prison is located at the base of Prison Hill at 9:30. Hot springs are located along the fault at the northwest end of Prison Hill. Well-cemented Pleistocene(?) lacustrine sandstone was quarried at the north end of Prison Hill for buildings in Carson City, Reno, Virginia City, and the Brunswick Mill. Footprints and skeletal remains of bird and mammals are preserved in the sandstone, including those of the ground sloth, mammoth, horse, bison, deer, peccary, wolf, possibly sabre-tooth tiger, and many species of birds (after Moore, 1969).

1.7/26.8 Junction of U.S. 50 and Saliman Road. Note the Holocene fault scarp in the basin-fill at 3:00. The height of the scarp is 30 to 35 feet. Houses are built on the upthrown side. This northeast-trending fault scarp is located on the southern edge of the Carson lineament.

0.8/27.6 Junction of U.S. 50 and U.S. 395. TURN RIGHT (north) on U.S. 395. (Refer to ROUTE 2, mileage 19.4 to 0.0 for more detailed geologic descriptions from here to Steamboat Springs.)

3.8/31.4 Lakeview Summit (elevation 5,160 feet). Leaving Carson City. Entering Washoe County.

0.2/31.6 Descending into Washoe Valley. Ahead, on the right is Washoe Lake. Slide Mountain is at 10:00. A good view can be had of the landslide scar and debris flow of May 30, 1983.

5.6/37.2 At this point the 1983 debris flow crossed U.S. 395.

0.1/37.3 Passing the ruins of the Ophir Mill, one of the many mills that processed Comstock ore. It operated from 1861 to 1866 until the completion of the Virginia & Truckee Railroad offered more economical transportation to the more efficient Carson River mills. The historic townsite of Ophir is located about 0.25 mile to the left.

0.5/37.8 Note the granite boulders from an older debris flow from Slide Mountain.

0.9/38.7 Historic Winters Ranch on the right. It was built around 1861 with profits from the Comstock Lode.

0.8/39.5 Entering Old Washoe City. Founded in 1861, it soon become a major ore and lumber milling center for the Comstock mines.

1.6/41.1 Summit of Washoe Hill. Now descending into Pleasant Valley.

1.2/42.3 On the left, Galena Creek canyon splits the hills. This is the Galena mining district. Note entrance to the Commonwealth Mine, now being used as a teaching/experimental mine by the Mackay School of Mines at the University of Nevada at Reno.

1.0/43.3 Steamboat Hills on the left. The pastel rocks of the Geiger

Grade altered area are ahead in the Virginia Range.

3.0/46.3 Crossing the Steamboat Hot Springs terrace. Note the steam venting on the right.

1.1/47.4 Junction of U.S. 395 with U.S. 341 (on the right), and U.S. 431 (on the left). END OF ROUTE 1.

GEOLOGIC ROADLOG - ROUTE 2

STEAMBOAT SPRINGS - WASHOE VALLEY - CARSON VALLEY - KINGSBURY GRADE - LAKE TAHOE - MOUNT ROSE - STEAMBOAT SPRINGS

mileage/
cumulative

0.0/0.0 This route begins at the Steamboat Springs intersection of U.S. 395 south, Route 341 east to Virginia City (see Route 1), and Route 431 west to Mount Rose and Lake Tahoe. <u>HEAD SOUTH ON U.S. 395</u>.

Ahead and to the right is the Steamboat Springs geothermal area. The village of Steamboat and the Steamboat Springs spa are on the left.

The Steamboat Hot Springs system has the longest and most complex geologic history of any active geothermal area yet studied in detail in the world (White and others, 1964; Silberman and others, 1979). Other areas may have similar geologic histories, but lack the environments that preserve the evidence. Steamboat has been preserved because of the balance that has prevailed between structural uplift and erosion on the one hand, and inundation by volcanic products and alluvium on the other (White and others, 1964).

The following geologic descriptions are taken largely from White and others (1964), Thompson and White (1964), White (1968 and 1974), Bonham (1969), Garside (1979), Silberman and others (1979), Hudson (1985).

The oldest rocks in the Steamboat Springs area are pendants of Lower Mesozoic(?) metavolcanics (water-lain tuffs) and meta-sediments (sandstone, conglomerate, and limestone of the Lower Jurassic Gardnerville Formation) which have been intruded by granodiorite of Late Mesozoic (Cretaceous?) age. The granodiorite underlies much of the Steamboat area and has been hydrothermally altered in and adjacent to the thermal areas.

Erosional remnants of early Miocene Alta and Kate Peak Formations (soda trachyte flows) lie unconformably over the Mesozoic rocks (mainly granodiorite). Overlying the Alta and Kate Peak, in the vicinity of Sinter Hill, is the basaltic andesite of Steamboat Springs which has yielded K-Ar ages of 2.5 m.y.

Quaternary deposits at Steamboat include Pleistocene sediments and sinter overlying the basaltic andesite in the low-lying areas, and Holocene sinter occuring mainly on the

Main and Lower Terraces just west and east of U.S. 395.

Steamboat Springs is located near the north end of the Genoa Fault in a shatter zone of north-trending faults, and is the site of frequent earthquake swarms which are probably related to geothermal processes and are classified as low-risk. The thermal area occurs on a northeasterly-striking line of four known rhyolite domes known as the Steamboat Hills rhyolite. The largest dome is about 3.1 miles southwest of the Main Terrace and has yielded a K-Ar age of 1.14+-0.04 m.y. It was preceded and accompanied by extensive pyroclastic eruptions that mantled much of the adjacent area with rhyolite pumice. Three other domes, from 0.9 to 3.1 miles to the northeast, have yielded ages of from 1.2 to 3.0 m.y.

The hot-springs system formed in the early Pleistocene, prior to the eruption of the Steamboat Hills Basaltic Andesite flows in the Steamboat area. The source of the energy for the thermal convective system is most probably a rhyolitic magma chamber from which the rhyolitic domes were emplaced. In the approximately 3 million years of thermal activity here one would expect a greater volume of rhyolite to be extruded here than is actually present. White (1968) estimates that 3,000 km^3 of underlying magma would be required to cool over 3 million years to account for the continuous geothermal activity at present rates of heat flow. Put another way, about 10,001 km^3 of new magma, would have to have been provided each year for approximately 3 million years to supply the heat at the present rate of heat loss. This seems improbable.

In view of the complex histories of most large silicic volcanic systems and the fact that many of them culminated in ash-flow tuff eruptions and caldera collapse, the more probable explanation for Steamboat Springs is that the magma chamber lies at great depth and has had intermittant cycles of evolution.

The thermal waters at Steamboat are high in sodium, chloride, bicarbonate, and silicon dioxide, and have a significant lithium content. They also have anamalous amounts of arsenic, antimony, mercury, cesium, and boron. Mercury vapor is commonly detected in the steam from springs and wells, and is notable in some chalcedonic sinter. The relative abundance of these highly soluble elements which have a low crustal abundance coupled with the long life of the geothermal system suggest that the elements are not supplied to the system by rock leaching alone, but also by a continuing small (probably less than 5% of the total hydrothermal system) amount of enriched magmatic water.

Sinter at Steamboat Springs contains up to 0.22 ppm gold, 1.0 ppm silver, 280 ppm arsenic, 200 ppm antimony, 660 ppm mercury and 2.5 ppm thallium, while black siliceous muds deposited in present springs on the Main Terrace contain up to 10.0 ppm gold, 44.0 ppm silver, 1,384 ppm arsenic, 12,000 ppm antimony, 460 ppm mercury, 1,100 ppm thallium, 4 ppm tungsten, 570 ppm copper, 70 ppm lead, and 70 ppm zinc (Hudson, 1987, unpublished data).

Silica deposited from flowing springs occurs as silica gel often finely interlayered with algae. Gasses trapped under the silica gel lend a bubbly appearance to the gelatinous sinter with the porous texture preserved in the younger opaline sinter. The gasses may result in part from decomposition of algae. (Hudson, 1985).

Seasonal fluctuations and seismic activity creates wide variations in discharge rates. Individual springs have been active for decades while others start and stop over periods of weeks or months. Springs may deposit sinter for a time, and at other times the water may rapidly dissolve sinter, particularly at erupting springs. Open fissures on the Main Terrace are probably created by dissolution of sinter along fractures during low water conditions by sulfuric acid condensed on the walls of the fissures (White and others, 1964).

The Main Terrace is composed primarily of opaline sinter being deposited by the springs. With increasing age and depth the sinter changes in composition to chalcedonic sinter. A large area of chalcedonic sinter is present in Pine Basin to the southwest of the Main Terrace, and is believed to be the most extensive chalcedonic hot spring deposit of such sinter in the world.

The springs at Steamboat are near boiling, and exploration steam wells have reported temperatures as high as 369°F. Preferred estimated reservoir temperatures from chemical geothermometers are approximately 400°F (Mariner and others, 1974). Six steam wells, ranging in depth from 716 to 1,830 feet were drilled in the late 1950's and early 1960's by Nevada Thermal Power Company. Also, the U. S. Geological Survey drilled eight core holes totalling 3,316 feet. Several other wells have been drilled in the past for use by spas. In the late 1970's, Phillips Petroleum Company and Gulf Mineral Resources Company partnered in the drilling of 25 shallow temperature gradient holes and 14 intermediate temperature gradient holes. Based on those results, two deep tests were drilled, both capable of commercial production. The Steamboat No. 1 was drilled in 1979 to a depth of 3,050 feet and has a maximum temperature of 442°F. The Cox I-1 was drilled in 1981 to a depth of 3,471 feet and has a temperature of 350°F at 950 feet. Currently, Geothermal Development Associates has developed a small geothermal electric plant about 1 km northwest of the Main Terrace. (For those desiring a more detailed tour of the

Steamboat area, refer to White, 1985.)

1.2/1.2 Rocks in the roadcut are Lower Jurassic metasediments of the Gardnerville Formation, which includes shale, phyllite, argillite, quartzite, metatuff and metagraywacke, recrystallized limestone, conglomerate, hornfels, shist, and local interfingered skarn and tactite.

1.3/2.5 Entering Pleasant Valley. The Steamboat Hills which host the major part of the Galena mining district are on the right.

According to Thompson and White (1964) the Steamboat Hills trend northeast and have an anticlinal form produced by warping and tilting of fault blocks. On the southeast flank of the Steamboat Hills, north of Pleasant Valley, basal tuff-breccias of the Kate Peak Formation dip 45° to the southeast under the valley and reappear again on the southeast side of the synclinal structure in Pleasant Valley. The structural relief, as in the Carson Range, has been produced by a combination of normal faults dipping away from the hills, and tilting that more than compensates for antithetic faults dipping toward the hills.

At least three systems of normal faults have been recognized in the hills. One set strikes northeast, parallel to the axis of the hills; many of these are antithetic. A second set strikes northwest, nearly at right-angles to the first. The third set strikes nearly north and is prominent near Steamboat Springs; many faults of this set are antithetic in dipping toward the structural crest of Steamboat Hills, but their strikes are not parallel to the axis of the hills. Although faults of the three systems are not of distinctly separate ages, those of the north-striking system show evidence of being most active recently.

Several andesitic intrusions of the Kate Peak Formation, a dome of pumiceous rhyolite, and a vent for basaltic andesite, indicate that volcanism was active in the hills over a long span of time.

The Galena mining district encompasses the area around Pleasant Valley. The ore deposits occur in Lower Jurassic metasediments which have been intruded by Cretaceous granodiorite. These rocks are overlain unconformably by andesitic rocks of the Tertiary Alta and Kate Peak Formations.

The mining camp was founded in 1860. After lead-silver ore was discovered at the district's major mine, the Union or Commonwealth Mine, a mill and smelter were built. This operation proved unsuccessful and was abandoned. Several mining companies were in control of the Union-Commonwealth property up to 1957. Considerable development work was done, and small tonnages of lead, silver, zinc, and gold ore were shipped during the years 1906-1907, 1911-1942, and 1947-1956. The mine had substantial production from 1943 to 1945 during which 14,624 tons of lead-silver-zinc-copper ore was produced at a gross value of $232,000. Other mines in the area had minor production, but few records are available (after Bonham, 1969).

0.9/3.4 Crossing Galena Creek.

0.3/3.7 Entrance to the Commonwealth Mine at 9:00.

0.4/4.1 Crossing Steamboat Creek. Boulder deposits at the edge of the fields to the right are from the Brown's Creek (look right at about 10:00) flood of June 11, 1927. A thunderstorm caused the small Grass Lake reservoir located 4.5 miles upstream to fail.

0.3/4.4 Road cut exposures are volcanic breccias and related rocks of the Kate Peak Formation.

0.7/5.1 Approaching the summit of Washoe Hill (elevation 5,120 feet). Slide Mountain is at 12:00 and Mount Rose is at 1:00.

0.4/5.5 Eastlake Drive (on the left) follows the eastern shore of Washoe Lake. You are now crossing 4 north-south-trending faults. They die out about 1,000 feet to the right, and are concealed to the south under young alluvium of Washoe Lake. There is no consistancy to the up and down thrown sides. Rocks here are still Kate Peak Formation.

0.2/5.7 Entering Washoe Valley. Little Washoe Lake at 9:00, and Washoe Lake in the distance at 10:00.

Washoe Valley has an area of approximately 82 square miles and is a north-trending structural depression bounded on the west by the Carson Range and on the east by the Virginia Range. Faults bounding the basin on the west, at the foot of the Carson Range, have been active recently enough to displace late Pleistocene landslides east of Slide Mountain. Sediments are thickest (at least 1,800 feet) at the western margin of the basin. The boundary faults die out at the northern end of the basin, and there the Kate Peak Formation dips gently basinward. The floor of the valley is occupied by a shallow natural lake resulting from the saturated condition of the basin-fill sediments. The lake has dried completely during extreme drought once in the 1930's and almost completely in 1977. Ore was transported here from Virginia City across the north end of the lake by causeway to Ophir Creek for milling, prior to the completion of the Virginia & Truckee Railroad to Carson City.

0.25/5.95 Crossing the outlet of Little Washoe Lake into Steamboat

Creek. Steamboat Creek is entrenched in a narrow gorge 250 feet deep about 0.5 mile north of here on the west and northwest sides of Washoe Hill. This is partial evidence indicating that the north end of Washoe Valley was tilted eastward, or the axis of this part of the structural syncline was shifted eastward, in Late Quaternary time after entrenchment of the outlet had started. The faulted and uplifted beds 0.5 mile west of Little Washoe Lake also support this interpretation. The geologic history of this basin has been complex. Along with deformation of the northern end of the basin, old gravels and faulted lake beds cap surrounding hills. Erosion is destroying the connection between these isolated deposits. Washoe Valley has probably repeatedly contained larger lakes while Quaternary structural deformation competed with erosion and deposition. (after Thompson and White, 1964).

A series of Quaternary northeast-southwest-trending, antithetic faults parallel the road on the right and ascend en echelon toward the crest of the Carson Range.

0.15/6.1 Entering old Washoe City.

1.9/8.0 Bower's Mansion turn-off. Turn right onto old U.S. 395 (Franktown Road).

0.4/8.4 Davis Creek County Park to the right. Note the large white scar on Slide Mountain at 2:00.

Slide Mountain is composed mainly of Cretaceous granodiorite. The large landslide scar devoid of vegetation has been forming since prehistoric times. The slide involves approximately 125 million cubic yards of material that has moved downslope from an elevation of 9,400 feet to 5,000 feet. This slide probably moved in 1852 following a severe earthquake in the vicinity of Pyramid Lake (Slemmons and others, 1965).

Geologists can count at least 9 times in the past 100,000 years that slides and debris flows have let loose on Slide Mountain. The tenth and most recent landslide and resulting debris flow occurred on May 30, 1983.

The oversteepened and tectonically fractured granitic rocks, with joints roughly paralleling the slope, provide prime conditions for landslides. Unseasonably heavy precipitation and/or seismic shocks act as the trigger for the slides in this area. The slide mass ranges from rock-fall avalanche to debris flow. The degree of weathering, dissection, and alluvial cover indicate a pre-late Pleistocene age for the prehistoric landsliding. A large fault cuts the granodiorite on the east flank of Slide Mountain. Downthrow is to the west, with the granodiorite dipping 70° to the west. The longitudinal valley formed along the fault contains Hidden and Grass lakes, which are of glacial origin. Paralleling this fault farther east, another large fault bounds this part of the Carson Range, but has normal downthrow to the east.

0.2/8.6 Ahead, approaching an older debris flow leading from Slide Mountain. The slide debris to the right has a typical hummocky surface. This terrain was thought to be of glacial origin until the mid-1960's.

0.3/8.9 Ophir town site historical marker on the left. About 0.25 mile to the east of here on new U.S. 395 are the remains of the Ophir Mill (see Route 1, mileage 37.3).

0.2/9.1 Crossing the Ophir Creek mud and debris flow of May 30, 1983. Stop.

At 11:53 or 11:54 AM on May 30, 1983, a mass of rock, soil, and vegetation suddenly slid down the steep southeast-facing slope of Slide Mountain. The area of mass movement involved 40-50 acres and the movement was very swift. Much of the moving mass slid into the north half of Upper Price Lake, a small pond covering about 4-5 acres on Ophir Creek. The sudden movement of debris into the lake created a surge of water that rapidly exited the pond and flowed into Lower Price Lake, and the cumulative contents of both lakes, about 20-30 acre-feet of muddy water rushed down the steep (roughly 25% gradient) canyon of Ophir Creek below the lakes. The flood wave gouged debris from the canyon bottom and sides that consisted mainly of an unconsolidated heterogeneous mass of earlier land slide deposits. It incorporated this debris mixed with trees and vegetation that lined the canyon floor into an increasingly abrasive mixture of water and debris that gained momentum as it increased its mass during downstream transit. After about a mile, the channel gradient decreases to about 12-13 percent but most of the material continued to move and the mass progressivly increased as the bulldozing action persisted. After about 8-9 minutes of travel, this high-momentum debris wave, with a leading edge about 30 feet tall, reached the canyon mouth where the channel abruptly widened and flattened. At the canyon mouth, about 0.25 mile upstream from this roadway, after travelling about 2.5 miles at an average velocity of 18-20 miles per hour (25-30 feet per second), the boulder-laden flood wave encountered and destroyed 2 homes in its path. It overtook 4 of 5 people racing to escape its wrath, killed one and injured the other three. It then continued downstream across this roadway depositing large quantities of debris as the channel further expanded onto the fan and the gradient rapidly decreased. Maximum depth of fill across the road was about 9 feet. About 0.1 mile below this roadway, the moving mass destroyed one home and seriously damaged two others. Large boulder movement ceased just beyond this line of homes, but fine-grained, viscous run-out moved at least 0.2 mile farther to the edge of and onto the freeway, temporarily closing the southbound lanes. Find-grained runout continued to and along the west edge of the freeway for a least an hour. The mass movement of material from the slopes of Slide Mountain that began this disaster was probably triggered by increased hydraulic forces in the fractures and joints of the granodiorite bedrock. An abnormally heavy snowpack had been melting rapidly during several preceeding days of above-normal atmospheric temperature (Glancy and others, 1984).

0.2/9.3 Passing through an older debris flow.

0.6/9.9 Bowers Mansion County Park on the right.

The Mansion is built on the frontal fault system of the Carson Range, and is also the site of a geothermal anomaly. Hot water issues from springs along a recent fault. A well drilled along the fault in 1962 encountered 117°F water at 207 feet. This well now supplies the thermal water to the park's two pools.

0.8/10.7 Crossing Franktown Creek. On February 2, 1881 heavy rain on the snowpack caused a manmade dam on Franktown Creek about 2 miles above Franktown to fail. The resulting torrent destroyed most of the settlement and killed a few residents. Granitic boulders, gravel, and sand deposits dumped by the floodwaters are still visible along this road.

0.1/10.8 Franktown Road on the right. Continue straight ahead.

0.1/10.9 Franktown historical marker on the left. Franktown was another lumber and ore milling town that served the Comstock mines in Virginia City prior to the construction of the Virginia & Truckee Railroad.

2.8/13.7 Franktown Road on the right. Continue straight ahead. The road is built on Quaternary alluvial fan deposits that have issued from the Carson Range.

1.9/15.6 Cretaceous granitic grus is exposed on both side of the roadcut ahead. Miocene ash-flow tuff caps the granitic basement rocks here at about 5,000 feet. In the Virginia Range to the east (left), the base of the same unit is exposed high in the range, indicating displacements of 2,000 to 3,000 feet along the faults in the valley margin (Slemmons, 1975). To the west on the crest of the Carson Range, this unit occurs at elevations over 8,000 feet, showing the effects of warping or distributive faulting in this region (Moore, 1969).

0.1/15.7 Lakeview Summit (elevation 5,160 feet). This is the divide between Washoe Valley and Eagle Valley (ahead).

0.6/16.3 Entering Eagle Valley and Carson City.

Eagle Valley is another structural depression between the Carson Range on the west and the Virginia and Pine Nut Ranges on the east.

0.7/17.0 Large boulders in the borrow pit on the left were trucked here during clean-up operations of the 1983 Ophir Creek debris flow.

0.2/17.2 Crossing a northeast-trending Holocene fault scarp. Here the Sierran frontal fault zone intersects with the northwestern margin of the Carson lineament, a northeast-trending (N55oE) zone of faults stretching from Carson City to Fallon. It is thought to be a left-lateral compliment to the right-lateral northwest-trending Walker Lane fault zone. In the Carson City area the zone is about 4 to 5 miles wide with numerous fault scarps occurring along the southern margin of the Virginia Range (see Route 1, mileage 26.8). Both north and south margins of the lineament show evidence of Holocene movement (as recent as 300 years ago), while the central portion shows pre-Holocene movement (after Bell and Pease, 1980; Trexler and Bell, 1979).

1.3/18.5 Entering Carson City (elevation 4,675 feet).

0.9/19.4 Junction with U.S. 50 east on the left. Continue straight ahead on U.S. 395 south.

0.7/20.1 State Capitol and Legislative Building on the left.

0.7/20.8 On the right, note the roadcut at the base of the mountain. The stratigraphy on the north (right) end of the cut starting at the top consists of (1) recent surface deposits overlying a (2) lens of volcanic ash (probably mid-Pleistocene age and predating ancient Lake Lahontan deposits), which overlies (3) gravel, which overlies (4) Lower Mesozoic(?) metavolcanics.

0.3/21.1 The mountain at 9:00 is Prison Hill. The north end of the hill consists primarily of Lower Mesozoic(?) metavolcanic rocks. The southern part is Cretaceous granite. (For more information on the geology of Prison Hill see Route 1, mileage 25.1).

1.9/23.0 Junction with U.S. 50 (west). In the sand pit on the right, note the section of grus (decomposed granite) and coluvial deposits. Continue straight ahead on U.S. 395 south.

0.4/23.4 Crossing Clear Creek. Most of the streams draining east from the Carson Range have had portions of their gradients steepened by movement on Recent range front faults that cross their channels.

Begin climbing Indian Hill which separates Eagle Valley and Carson Valley (ahead). This hill consists of early Pleistocene terrace gravels of predominantly "metamorphic lithologies which were derived from older Quaternary or Tertiary sediments and granitic rocks to the west. The alluvial surface slopes northeast and represents a period of erosion and deposition that probably took place when the base level of Carson Valley was about 200 feet higher than present" (Glancy and others, 1984).

0.9/24.3 Turn right onto State Route 206 (Jack's Valley Road).

1.7/26.0 Crossing the Sierran frontal fault scarp which separates Cretaceous granodiorite of the Carson Range (on the west) from down-dropped Quaternary deposits on the east.

0.9/26.9 Descending into Jack's Valley. Looking west, the impressive Sierra Nevada frontal fault scarp (locally called the Genoa fault) rises more than 4,000 feet above the valley floor.

As you have seen, from Reno south to Carson City, the Sierra Nevada frontal fault is a diffuse zone of faults. South of Carson City, however, the frontal fault becomes strikingly prominent, consisting of fewer faults of greater vertical offset. In the Jack's Valley area vertical offset is as much as 7,994 feet, with an accompanying north-trending vertical escarpment of 4,000 feet.

2.0/28.9 Leaving Jack's Valley. The ponds on the left at the base of the hill are fed by geothermal water from the Hobo Hot Springs which span the west and south sides of the hill. The springs discharge 114oF water at the rate of 10 to 15 gallons of per minute.

0.2/29.1 Entering the Carson Valley, the vast expanse ahead and left.

Carson Valley is bounded on the west by the Carson Range (composed mostly of Cretaceous granodiorite and/or quartz monzonite), and on the east by the Pine Nut Range (rocks are varied and include granites, metasediments, sedimentary rocks, and volcanics that range in age from Lower Mesozoic through the Tertiary). The structural block underlying this valley tilts to the west. Older sediments are exposed along the eastern margin, and the steep frontal fault of the Carson Range bounds the western margin.

Like the Truckee Meadows and Washoe and Eagle Valleys to the north, Carson Valley experiences a rain-shadow effect from the Sierra. The west side of the valley is wet and the east side is dry. Carson Valley contains the headwaters of the east and west forks of the Carson River, high quality water that flows northeastward across Nevada to dead-end in the Carson Sink.

0.7/29.8 On the right is the Recent Genoa fault scarp.

0.2/30.0 At 3:00, the Genoa fault scarp follows the base of the Carson Range. This fault scarp is from 30 to 44 feet high, dips to the east at 36° to 50°, and stretches for about 10 miles in this area southward to Genoa. It was in existance in 1854 when the first settlers arrived in the area. A possible age of post-late Wisconsinan (post Tioga stage) is proposed based on the age of the old pine trees and lack of extensive erosion. The alluvium on both sides of the road is about 5,000 years old.

2.9/32.9 Entering Genoa, Nevada's oldest settlement.

0.4/33.3 Leaving Genoa. This is the site of debris flow which crossed the highway in August 1971.

0.5/33.8 Note the marshy, water-logged area of basin fill to the left, and the seeps above the valley floor just below the roadway. This will be elaborated on at the next mileage point.

0.5/34.3 Good exposure of the Genoa fault scarp in the gravel pit to the right. Detailed examinations of cross sections of the alluvial terraces nearby indicate that several events formed this scarp. In this area the Sierran frontal fault zone consists of two main splays which join south of Hobo Hot Springs to form the Genoa fault. Geologic and trenching studies by Pease (1979) indicate that both splays are less than several thousand years old. The Genoa fault scarp is geomorphically very young, and may be less than a few hundred years old according to Pease. Historical records indicate that it formed prior to 1854 (Lawson, 1912, Bell 1981). The fault plane here has an average strike of about N10°W, a rather uniform dip of 58° northeast, and an average plunge of 80° which suggests that about 10% of the displacement is a right-lateral component. The most recent displacements have produced triangular facets on the range front, and a youthful-appearing fault scarp with a vertical displacement of about 34 feet and a slope of about 38°. The displacements along this scarp have rejuvenated the valley to produce terraces on either side of the valley (after Slemmons, 1975).

The Carson River flows more than normally close to the foot of the Carson Range through an extensive marsh, indicating that depression of the valley floor has been so recent that debris washed from the Carson Range has not been able to fill the marsh and so force the river to meander eastward toward the center of the Carson Valley. Relief is only about 10 feet in the 3-mile wide flood plain.

The hot springs observed on this route issuing from along the margin of the Carson Range are directly related to the range-front faulting.

0.5/34.8 Walley's Hot Springs on the left. The resort features six hot mineral pools, saunas, and a fresh water swimming pool.

0.3/35.1 Exposure of the Genoa fault surface at 3:00. The granitic gouge contains slickensides. The dark rocks are Mesozoic metamorphics.

3.5/38.6 Junction with State Route 207 (new Kingsbury Grade). Turn Right.

0.9/39.5 You are now entering the Cretaceous granodiorite and quartz monzonite of the Carson Range. Except for an area around Glenbrook, this will be the dominant rock type for the route around Lake Tahoe.

7.2/46.7 Daggett Pass (elevation 7,334 feet). Begin descent into the Tahoe basin.

Lake Tahoe occupies a valley between the main crest of the Sierra on the west, and the Carson Range off-shoot of the Sierra on the east. It is about 22 miles long (from north to south) and 12 miles wide. The average depth of the water is 1,000 feet. The deepest measured depth is 1,645 feet. The maximum altitude of the lake surface is 6229.1 feet above mean sea level as mandated by law.

Lake Tahoe is commonly included in the Sierra Nevada geomorphic province; however, its formation is due to Great Basin-type faulting. The lithologic boundary of the Sierra Nevada extends eastward to the Carson Valley, while the structural boundary of the Great Basin extends westward to the crest of the Sierra on the west side of Lake Tahoe. The Tahoe basin is a down-dropped block, or graben, box-like in shape, and bordered by steeply-dipping faults between the two range crests. The floor of the basin is 4,700 feet above sea level, the same elevation as the surface of the Carson Valley to the east.

The Sierran block began to be faulted upward and tilted to the west about 6 million years ago. Faulting, volcanism, and uplift around the lake have progressed together from the late Tertiary (Mio-Pliocene) through Quaternary time. The lake basin was formed by faulting and volcanism about 2 million years ago.

Axelrod's studies of Mio-Pliocene age fossil plants in western Nevada and eastern California indicate a similar climate for both areas and a maximum elevation at that time of 2,000 to 3,000 feet. He suggested, therefore, that this area has been uplifted 5,000 to 6,500 feet, relative to the surrounding areas, since early Pliocene time. The boundary faults have been largely obscured by the more recent volcanic flows and glacial deposits; however, portions of the faults or fault zones can be traced in a number of areas surrounding the lake (refer to Burnett, 1972).

The first glaciation in the Sierra began around 3 million years ago (late Pliocene-early Pleistocene) after the range was uplifted to its present height.

There are four major groups of rocks present in the Lake Tahoe Basin: (1) pre-Cretaceous (Triassic and older) metamorphic rocks, (2) Jurassic and Cretaceous granitic intrusive rocks of the Sierra Nevada batholith, (3) Tertiary (Mio-Pliocene) and Quaternary (Pleistocene) volcanic rocks, and (4) Quaternary glacio-fluvial deposits.

The pre-Cretaceous (Triassic and older) rocks are metasediments or metavolcanics occurring as roof pendants on the granitic Sierra Nevada batholith. They are exposed on the western side of the basin.

Intrusive Jurassic and Cretaceous rocks of the Sierra Nevada batholith range in composition from monzogranite to quartz diorite (with granodiorite and quartz monzodiorite most abundant), and comprise most of the bedrock terrain in the Tahoe Basin. Quartz diorite, diorite, and gabbro are present in small bodies especially adjacent to the metamorphic rocks.

The darker more basic varieties of granite are the oldest intrusive rocks and are a result of the contamination of the granodiorite magma by basic wall rocks. This older group has been intruded by basaltic dikes and the younger, lighter-colored granodiorites.

Extensive flows of Tertiary and Quaternary volcanic rocks cover large areas in the northwestern part of the Tahoe Basin and to the north and south immediately outside of the basin. These volcanic rocks consist of mudflow breccias, and flows of andesite, basalt, and latite. The mudflows are crudely stratified, massive, thick-bedded, and are well to loosely consolidated. They erupted as a dense fluid and flowed many miles over gentle slopes. Most of the more extensive landslide areas in the northern part of the basin are formed in these mud-flow and tuff-flow breccia rocks and the sedimentary rocks derived from them. (Matthews, 1968). The andesite, basalt, and latite flows are more thinly bedded and display prominent cross-jointing. They are more resistant to weathering than the mudflows and support only a thin veneer of soil. Because water freely penetrates the joints, talus slopes form below these flows. Most of the vents for these flow rocks are buried by erupted material, but probably were localized in fault zones north of Lake Tahoe.

The centers of eruption on the north end of the basin are near Mt. Watson and Mt. Pluto. A great pile of Tertiary and Quaternary mudflow breccias and flows of andesite, latite, and basalt forms a dam across the outlet of the Tahoe Basin on the north, extending from the top of Martis Peak (elevation 8,642 feet) to the north shore of the lake, a distance of 4 miles. Stevens Peak on the south end of the Tahoe Basin is a volcanic pile 2,000 feet thick, which probably erupted through faults which formed the graben of the Upper Truckee River (on the south end of the lake).

Tertiary volcanic mudflow rocks around the north end of the Tahoe Basin have so far yielded K-Ar dates of from 1.3+-0.1 to 7.4 m.y. Thus, the majority of these volcanic mud flows appear to have erupted in late Pliocene time, with the overlying flows erupting just after the close of the Pliocene. These Tertiary volcanic rocks correlate in age and composition with formations eastward in the Carson and Virginia Ranges, and with the Mehrten Formation south of Lake Tahoe. The younger Quaternary flows correlate with the Pleistocene Lousetown Formation also found to the east. The Quaternary volcanic vents are marked by cinder cones.

During the Pleistocene epoch ice covered all but the highest peaks and ridges of the Sierra west of Lake Tahoe. Valley glaciers, almost 1,000 feet thick at their maximum, moved eastward down the canyons scouring loose rock and piling it up into lateral, medial, and terminal morraines. On the eastern side of the basin, in the Carson Range, only the shaded areas of the highest peaks developed glaciers. With the highest elevations in both ranges being equal, the difference in glaciation was directly related to the different amounts of snowfall each side of the basin received. Then, as now, the annual precipitation steadily decreased from west to east across the basin. This "rain shadow" effect is due to a combination of factors including air mass, moisture, and land forms. The western Sierran crest receives up to 90 inches of rainfall per year. The Carson Range receives only 20 inches per year; therefore, few examples of prime glacial features will be seen on this route along Tahoe's eastern shore.

Clues derived from relating dated volcanic rocks and landforms to associated glacial deposits, mapping fluctuating timberlines with tree ring measurements and Carbon-14 dating, and dating volcanic ash in soil horizons show that the Sierra harbored glaciers more than 3 million years ago. There were glacial advances again about 400,000 years ago and also about 130,000 years ago. A record of the advances and retreats of the glaciers is preserved in the morraines. Four major advances are known, and a fifth minor advance is represented by several rock glaciers which still may be active. The oldest glacial advances were the largest and extended farthest into the lowlands. However, morraines left by glaciers 60,000 to 20,000 years ago (the Tahoe, Tenaya, and Tioga glaciations of Pleistocene Wisconsinan age) are the best known of all the glacial deposits because they exhibit well-developed landscape features. Unfortunately, they are best developed in the southern half of the Sierra on the eastern slope.

The relative age of the morraines can be established by studying and comparing the amount of weathering each has sustained (Burnett, 1971). This is rather circumstantial evidence to be using, and it is further complicated by soil production on the moister western side of the Sierra vs. the dryer eastern side. Also, the number of morrainal advances and retreats were not uniform for all areas throughout the Sierra, which greatly scrambles the picture. Areas being compared in a glacial study may be so far apart or present such great contrasts that correlation on a regional scale is impossible.

The glacial history in this area is also represented by isolated patches of lake beds and shorelines that can be found up to elevations of 6,800 feet around Lake Tahoe. These deposits were laid down when the lake level was up to 600 feet higher than it is today. The older and larger glaciations (pre-Tahoe) caused the highest rises in lake level due to ice dams forming at the outlet of the lake which was, and is still, the Truckee River on the northwest end of the lake. The lake level rose at least 90 feet again during Tahoe glaciation. The frequence and level to which the lake was filled above its outlet by this process depended on thick glacial ice being released into the Truckee River outlet and the rate of meltwater build-up behind the ice dam.

Ice weighs less than water by one-tenth. The impounded water would build up until nine-tenths of the ice was covered and then the ice dam would begin to float. At this point, catastrophic floods of water would be released along the base of the ice. Evidence of these floods is found high on the walls of the Truckee River canyon from Tahoe City downstream to Verdi. Huge granite boulders east of Reno in the Truckee River floodplain and canyon beyond are also attributed to these episodes of flooding (refer to Route 3, mileage 10.5).

In the last 10,000 years, the climate has cooled enough three times for small glaciers to form in the Sierra. This period is called the "Little Ice Age" (Matthes, 1930). These cool periods were from:

1. 8500-7000 B.C. (9000-10,500 B.P.)
2. 1410
3. 1700-1750

3.1/49.8 Junction of Kingsbury Grade (State Route 207) and U.S. 50.

Turn right onto U.S. 50. The meadows along the left side of the road have been formed on decomposed granite sands which have been washed down to the lake level from streams draining the Carson Range on the right.

1.3/51.1 Elk Beach to the left. Round Mound (elevation 6,720 feet) at 11:00 is a resistant knob of granite.

2.2/53.3 Entering Zephyr Cove.

2.2/55.5 Entering Lakeridge. From here northward various expensive subdivisions have been constructed on extremely steep terrain of unstable decomposing granodiorite and quartz monzonite. Natural stream regimens there have been straightened and confined. Development of meadowlands along the lake shore has disturbed the low-velocity, settling-basin effect of the marshes, allowing silt and sand particles to wash directly into Lake Tahoe, diminishing the clarity of the water.

0.3/55.8 Cave Rock, straight ahead, is the eroded throat of a volcano which erupted in Tertiary (Miocene?) time. The rock is a porphyritic hornblende-sanidine latite. During the Pleistocene, caves were cut on the south side of the rock by wave action. The lake level was 140 feet higher then, due to glacial ice damming the outlet between Tahoe City and Truckee.

Looking to the left (west) across the lake is the white scar of the Emerald Bay rockslide-avalanche. Construction of Highway 89 (now located in the upper portion of the slide) probably precipitated the initial movement of the rock prior to a season of heavy precipitation in 1953. The highway undercut jointed blocks of granite stacked on each other in an area of steep topographic terrain. Again, following extreme precipitation during the winter of 1955-56, a much more extensive area failed (approximately 200,000 cubic yards), which nearly wiped-out the highway as the mass moved 450 feet downslope into Emerald Bay. Recurrance is very likely. Conditions contributing to the movement were a saturated rock mass and joint planes dissecting the granite rock at about 40° north, which is less than the topographic slope, and forms the sole or shear plane of the failure.

1.4/57.2 Vista point on the left.

0.6/57.8 Ahead, the prominent peak of dark rocks on the right side of the road is Shakespeare Point. It is part of a Tertiary lava flow with the same mineralogy as Cave Rock.

1.1/58.9 Glenbrook turn-off to the left. Keep to the right on U.S. 50. In the next mile the route passes through the following sequence of Lower Mesozoic(?) rocks: medium to dark gray metamorphosed tuff and flows, followed by dark gray hornblende diorite, followed by tan to pink gray biotite monzogranite.

1.4/60.3 Note the Miocene volcanic flow and vent (hornblende trachyte) rocks in the roadcuts for the next 1.5 miles. The rocks are mostly gray, except where hydrothermal solutions have bleached them to light pastel shades.

1.3/61.6 Spooner Junction. Turn left onto State Route 28. Spooner Summit (elevation 7,150 feet) is about 0.5 mile to the right.

0.3/61.9 Spooner Lake, on the right, occupies a fault-controlled sag pond area made deeper by a small earthen dam on the west end.

0.2/62.1 The route now passes from Miocene volcanics back into Lower Mesozoic(?) metamorphosed volcanics.

0.6/62.7 Spooner Meadow on the right.

0.1/62.8 Leaving Douglas County. Entering Carson City. Now passing back into Cretaceous granodiorite and quartz monzonite. The more resistant veins of quartz or feldspar stand out in relief in the roadcuts.

2.4/65.2 The road crosses a northeast-trending fault and parallels it for the next 0.3 mile. Down-drop is on the southeast side.

1.7/66.9 Leaving Carson City. Entering Washoe County.

0.5/67.4 The road crosses another northeast-trending fault which is occupied by Marlette Creek. Down-drop is on the southeast side. In the flat area to the right is Marlette Reservoir.

0.6/68.0 Sand Point ahead at 11:00.

0.7/68.7 Sand Harbor State Park on the left. The beautiful sandy beach surrounded by rounded granite knobs are a good example of the normal weathering of granite in this area.

Along joints in the granite, water enters and chemically and mechanically attacks the individual mineral grains, causing the rock to disintegrate. The knobs of granite in this area have not been fractured and are thus more resistant to erosion.

Much of the granite bedrock on the west side of the Tahoe basin was scraped clean of overlying debris and polished by moving ice and rock material of the Pleistocene glaciers, and today remains more impervious to the agents of chemical and mechanical weathering than the granite on the east side of the basin. In addition, weathering of the granite on the west is hindered because the elevations are higher, which keeps available water frozen more often, hindering its chemical and mechanical action. Also, vegetation is more scarce which eliminates the action of organic acids from forest litter on the rock minerals.

On the eastern unglaciated side of the basin, the granodiorite has been most affected by the combined action of water, atmospheric gases, and organic acids from decaying plant material.

Most of the minerals that make up the granitic rock are not chemically stable in the zone of weathering at or near the surface of the earth. The biotite is altered first by water and organic acids from decaying vegetation. These solutions seep into minute fractures in the rock, altering the biotite to chlorite, a slightly expanded mineral. This expansion shatters the surrounding mineral grains allowing more water to enter the rock (Wahrhaftig and others, 1965). The weak acid solutions also leach the calcium, potassium and sodium out of the feldspar grains, altering it to clay. The relatively stable quartz and hornblende grains are left unattached, and, eventually, the once solid granite is reduced to loose piles of coarse granite sand, called grus.

The minimum time required to form decomposed granite from fresh, massive rock has been estimated in the Tahoe basin by studying the degree of weathering adjacent to glacial moraines of various known ages. Assuming that all decomposed rock in areas undergoing glacial erosion would be removed by the great weight and abrasive action of glacial ice, any weathering on granite bedrock adjacent to the moraine must have taken place after the glacier receded. Granite beneath the 10,000-year-old Tioga stage moraines has been incompletely weathered to a maximum depth of about 1/16-inch, or about the thickness of one mineral grain. The Tahoe stage moraines are thought to be around 75,000 years old. Granite below these moraines is deeply weathered (up to 100 feet) to decomposed granite sand although many fresh residual blocks or "corestones" remain. Granitic rock adjacent to the pre-Tahoe moraines have been deeply and thoroughly weathered, and only a few residual corestones remain. (Matthews and Burnett, 1971).

0.2/68.9 The road crosses a fault trending north-northeast. Down-drop is on the southeast side.

0.6/69.5 Scenic overlook on the left.

1.0/70.5 The road crosses a northeast-trending fault. Down-drop is on the southeast side.

0.8/71.3 Entering Incline Village.

Most of the town is built on either steep, unstable decomposing granite; steep, unstable andesite flow rocks; old Lake Tahoe shoreline sediments; or alluvium washed down from the Mount Rose area to the north. Builders and buyers don't seem to mind the geologically unstable building sites.

3.2/74.5 Junction of State Route 28 and State Route 431 (Mount Rose Highway). Turn right onto State Route 431.

0.2/74.7 Crossing Second Creek. In August 1967, a mudflow washed down this creek destroying the only home in the area at that time. Now, many homes occupy the area, but no precautions have been taken for future mudslides.

2.7/77.4 Roadcuts on the left are in andesite. Volcanic rocks mantle the northern and northwestern portion of the Tahoe basin; therefore, the bedrock exposures will be alternating from the light, intrusive granodiorite to dark, extrusive andesites.

0.6/78.0 Scenic overlook on the right. Stop (watch for safe traffic conditions).

The human population has mushroomed in the Tahoe basin since the late 1940's. Along with the problems of smog from the car exhaust, and effective treatment and removal of all the waste products from the people, another major problem remains that of increased erosion and the resulting clouding of Tahoe's once clear waters by silt and increased organic nutrients, that has resulted in an enormous increase in algal growth in the lake. The building of roads and housing sites and resort areas have carved into the fragile forests and stream drainage systems on the mountain slopes. Shoreline meadows and marshes, that normally serve as the final settling basins or filters for the silt and organic debris brought down by streams, have been dried-out or filled-in to make golf courses or casino and town-sites. The natural ecosystem in this area of great climatic variation has been hard hit. Slow, winding streams have been cemented into straight narrow channels that funnel silt and organic nutrients directly into the lake in alarming amounts and with alarming speed.

The U. S. Geological Survey has studied the annual sediment yield from developed and undeveloped major drainage basins in the Incline Village area since 1970. The developed areas (mainly roadways and cleared building sites) have delivered 10 to 12 times more sediment (with accompanying concentrations of nitrogen and phosphorus) into Lake Tahoe than corresponding undeveloped areas.

Each year, between 42,000 and 64,000 tons of sediment containing high concentrations of organic nutrients from mature soils and forest mat are dumped into Lake Tahoe. 90% of this sediment comes from the 30% of privately-owned property around the basin. Only 10% is contributed by the 70% of land owned by state and federal governments.

The greatly increased amount of organic nitrogen and phosphorus now reaching the lake from sediment and sewage effluent is the food source for algae that grows almost anywhere in the shallows and is piled up in mats by wave action. This algae problem was first publicised in 1967 by Charles Goldman, professor of zoology and director of the Institute of Ecology at the University of California at Davis. He warned that the algae would turn the clear blue water to a turbid green if left unchecked. In 1969, the first recorded algal bloom occurred on the south shore of Lake Tahoe.

Leave overlook and proceed up the Mount Rose Highway (State Route 431).

2.5/80.5 Incline Lake on the left (through the trees). This lake was created by a small glacier descending out of Ginny Lake basin to the northwest. The glacier terminated just downstream from here.

0.8/81.3 Entering Tahoe Meadows to the right. Slide Mountain (elevation 9,698 feet) is visible ahead and on the right. Mantled near the peak with telephone, TV, and radio antennae, it is composed of granite.

1.4/82.7 Mount Rose Summit (elevation 8,990 feet). Mount Rose (elevation 10,776 feet) is to the south (left and ahead as the road curves). It is mantled with Miocene andesite of the Kate Peak Formation..

3.4/86.1 Scenic view turn-out on the right looks across Pleasant and Washoe Valleys to the Virginia Range. Virginia City is behind Mount Davidson (the highest peak on the horizon). Just ahead are good views of Reno and Sparks sprawling across the Truckee Meadows.

1.3/87.4 Sky Tavern ski resort on the left.

2.6/90.0 On the right, man-made terraces promote the growth of pine seedlings after logging and fire.

1.8/91.8 Galena Creek County Park on the left. The headwaters of this creek drain Mount Rose. Flash floods have occurred down this creek with almost annual regularity since the 1880's, mainly from November through January and in the mid-summer months. Until 1943, Galena Creek had a fairly stable channel, but it has since been cut deep and wide due to the effects of fire, clear-cutting, and natural erosion. The channel is now very unstable. People have been killed by these floods, and the property damage has been great. Several properties in the new Galena Forest Estates (to the right) are located in the historic flood zone. Lawsuits are pending.

1.3/93.1 The route finally leaves the granodiorite of the Carson Range and traverses a short section of andesite and dacite flows of the Miocene Kate Peak Formation.

0.6/93.7 Begin a steady descent through Tahoe (Wisconsinan) outwash and, farther down, Donner Lake (Wisconsinan-Illinoian?) outwash of the Mount Rose fan complex, composed of pediment and thin fan deposits from major streams draining Mount Rose. Clasts are predominently volcanic and granitic.

This outwash fan complex has been highly faulted in Cenozoic time, and is part of the Sierra Nevada frontal fault zone (along the east flank of the Carson Range) that extends from just south of the Truckee River in Reno south to Genoa. The faults in this zone are north-trending, dominantly normal (based on displaced Quaternary units), many are down-dropped on the west (antecedent), and are pre-Holocene and possibly pre-Wisconsinan in age (Bingler, 1974; Bonham and others, 1981). Fault plane solutions for present seismicity in this zone suggest a component of strike-slip movement (Van Wormer and Ryall, 1980).

0.9/94.6 The highway crosses a series of north-south trending faults, most of which are downdropped to the east. Note the Truckee Meadows and Huffaker Hills ahead at 9:00.

0.7/95.3 Callahan Road on the right. Continue straight ahead OR turn right for an Optional Tour of Recent Faulting In This Area.

OPTIONAL TOUR: Continue south on Callahan Road for the next mile, and note a series of north-trending, inferred, post-Wisconsinan fault traces approximately 1,000 feet to the right. Some break the Holocene alluvium. Other faults transect the Wisconsinan age fan material creating new drainage patterns and areas of ponding, and are filled with colluvium (reworked debris derived from the fan surface). In another 0.6 mile the road passes over a divide. Ahead is a new subdivision built in and around a large number of inferred post-Wisconsinan fault traces (after Bingler, 1975). Turn your vehicle around and return to State Route 431. END OF OPTIONAL TOUR. Turn right (east) on State Route 431.

In the next mile the road crosses 4 post-Wisconsinan fault scarps in Tahoe (100,000 years B.P.) outwash of the Mount Rose fan complex.

0.2/95.5 Ahead, in the left foreground is the western limit of the Steamboat Hills, here composed of faulted volcanic rocks (andesite and dacite flows) of the Miocene Alta and Kate Peak Formations. The abrupt western margin of the hills marks the fault scarp of a Quaternary horst block.

1.5/97.0 Lancers Hill at 9:00 is composed of Miocene Kate Peak andesite and dacite flows (with minor breccia and conglomerate). It is bounded on the east by a post-Wisconsinan fault which is down-dropped to the east. Looking north (to the left) of Lancers Hill are numerous low swales and small hills of fault-controlled origin. Most of the west and northwest facing embankments are fault scarps.

0.7/97.7 Crossing a north-south-trending fault which is down-dropped on the west.

0.2/97.9 The small area of red material on the right is mapped as a mud volcano by White and others (1964). The west side of the volcano is bounded by a fault crossing the highway from north to south and downdropped on the west. Immediately cross onto Wisconsinan-Illinoian(?) Donner Lake outwash of the Mount Rose fan complex.

0.5/98.4 Crossing a fault-controlled creek.

0.8/99.2 Junction of State Route 431 (Mount Rose Highway) and U. S. 395. Steamboat geothermal area on the right.

END OF ROUTE 2.

GEOLOGIC ROADLOG - ROUTE 3

RENO - PYRAMID LAKE - RENO

mileage/
cumulative

You may begin this roadlog at the Old Gymnasium entrance to the University of Nevada on N. Virginia Street (U.S. 395). (The geology of this immediate area is described in the beginning of this publication.)

0.0/0.0 Leave the campus at the Old Gym, turning left (south) on Virginia Street. Continue south a few blocks. Cross the overpass over Interstate 80 and immediately turn left (in front of the Nevada National Bank). Continue straight ahead (east) and onto Interstate 80.

The beginning of this route essentially spans the entire northern part of the Truckee Meadows from west to east, and roughly parallels the course of the Truckee River (on the right) to Pyramid Lake.

The Truckee Meadows is mainly a downwarped basin between east-dipping rocks of the Carson Range on the west, and west-dipping rocks of the Virginia Range on the east. The Steamboat Hills form the southern boundary. Faults along the eastern and western boundaries of the basin are mostly antithetic (downward movement is on the range side of the fault). The major structural break accounting for the "downdropped" nature of the basin does not occur at the range fronts, but is about a mile west of the eastern boundary of the basin where a west-facing fault scarp lies buried beneath about 2,800 feet of basin sediments.

Continuous basin deformation began in late Miocene-early Pliocene time and continues through the present. Faulting and warping that resulted in the present topography occurred mainly during the late Pliocene and early Pleistocene as evidenced by (1) east-tilted Mio-Pliocene sandstone of Hunter Creek exposed around the north and west margins of the basin, (2) fault displacements of Pliocene basalts and pre-Lake Lahontan alluvium in the Steamboat Hills area, (3) the large fan-pediment surfaces being built on the west side of the basin, (4) eastward-tilted and faulted Pleistocene glacial outwash deposits which are being buried by Recent alluvium in the eastern portion of the Truckee Meadows, and (5) a lateral shifting of streams in the Truckee Meadows to the extreme eastern border of the valley.

1.5/1.5 Passing U.S. 395 North and South bypass exits.

0.9/2.4 Leaving Reno. Entering Sparks.

2.0/4.4 McCarran Blvd. exit. Continue straight ahead. From the overpass, Rattlesnake Mountain can be seen on the right protruding above the southern Truckee Meadows.

0.6/5.0 Helm's gravel pit on the left is dug in Pleistocene Tahoe outwash. Most of Reno is built on Pleistocene Tahoe outwash. As you near the eastern edge of Sparks the route crosses Recent alluvium derived primarily from the Truckee River.

This low marshy area north and south of the highway is the Truckee Meadows from which the entire valley takes its name. The marshy character of the valley here may be due to recent uplift of the Virginia Range (straight ahead) temporarily ponding the waters, and/or an eastward tilt of the valley fault block. In December 1955, this section of the highway was closed due to flooding. Floodwaters came very near to the road surface again in February 1986.

1.0/6.0 Gravel pits ahead and to the left of the highway are in fan deposits of at least Tahoe age, based on the soil horizons. These deposits have supplied most of Reno's gravel needs for the past few years, but the quality is not superior. More pits in Tahoe outwash will be seen ahead.

1.5/7.5 Vista exit. Leaving Sparks and entering the Truckee River canyon which cuts through the Virginia Range on the right and the Pah Rah Range on the left.

Leaving Washoe County. Entering Storey County.

0.4/7.9 Lower Mesozoic(?) Peavine Sequence metavolcanics and metasediments (shales) are in the roadcut on the left, and on both sides of the road for the next 2-3 miles.

(The guard rail makes viewing of some of the features to the right impossible, but they will be mentioned anyway.) At 3:00 "reefs" of Lower Mesozoic meta-andesite breccias project slightly above the valley fill. Gravity anomalies indicate a sub-surface fault near here with approximately 1,000 feet of displacement.

The Army Corps of Engineers started deepening the river channel and removing the "reefs" in this area and farther downstream to lessen the effects of flooding in the eastern portion of the Truckee Meadows where the river enters this canyon.

The Truckee River follows the Olinghouse fault zone (a left-lateral, conjugate shear zone) from Sparks to Wadsworth, where it meets the Walker Lane fault zone. The river is probably an antecedent stream. It existed before warping and faulting uplifted the Virginia Range in Miocene through Quaternary time, but was able to downcut its valley at about the same rate that the range was being uplifted, therefore maintaining its course to the east.

A low pass (elevation 4,436 feet) north of Sparks through Spanish Springs Valley actually provides the shortest route for water from the Truckee Meadows to flow into Pyramid Lake. Lacustrine sediments in that area indicate intermittant damming of waters here due to tectonic movement along the west side of the Virginia Range. But the Truckee River was always able to drain the water eastward through the canyon (elevation at the mouth of the canyon is about 4,390 feet) before a spillover into Spanish Springs Valley occurred.

The Pah Rah Range will be on the left for almost the entire route. It is an L-shaped range bounded on the south by the Olinghouse fault zone, and on the east by the Walker Lane fault zone. Major faults in this southern portion of the range trend east-northeast. The range is composed of Oligocene through Pliocene andesitic basalts, tuffs, breccias, conglomerates, mudflows, and a few rhyolitic plugs, domes and flows overlying Lower Mesozoic metamorphic rocks.

On the right (south) is the Virginia Range. Along this route, the rocks are mainly pyroxene-hornblende andesite flows of the early Miocene Alta Formation which are overlain (farther along on this route) by Miocene Kate Peak Formation rocks (rhyolitic to andesitic flows, tuffs, mudflow breccias, and associated intrusives) interbedded with lenses of sedimentary diatomite, tuff, shale, and sandstone. In a very general way, the Virginia Range is a syncline. At the east and west ends of the Truckee Canyon Lower Mesozoic(?) Peavine Sequence metamorphic rocks are exposed. Progressively younger Tertiary volcanic rocks are found toward the central portion of the range near the highway. They range in age from Oligocene to Pleistocene. (For a more detailed geologic description of the Virginia Range, see Route 1, mileage 1.6).

1.0/8.9 River gauging station on the right. Lower Mesozoic(?) meta-volcanics are exposed along the river for the next 3 miles.

0.7/9.6 More "reefs" were removed from the Truckee channel in the next 1 to 1.5 miles. Rapids mark the end of the channel deepening.

0.9/10.5 Lockwood exit. Lagomarsino Canyon at 2:00. The type locality of the Lousetown Formation (Miocene basaltic flows) is about 8 miles up Lagomarsino Canyon.

At 1:00, on the east side of Lagomarsino Canyon is an abandoned tuffstone quarry. The rock exposed there is part of a Mio-Pliocene silicic air-fall tuff from a rhyolite dome complex on the north side of the river. It varies from rhyolitic pumiceous vitric tuff to lithic tuff breccia with some intercalated sandstone and diatomite. Blocks of tuff were used in constructing some of Reno and Sparks' older buildings, but could not compete with the price of cement or pumice cinder blocks.

On the west side of Lagomarsino Canyon just above the Harvey's Wagon Wheel sign is a thin, black layer of Pleistocene olivine basalt, the youngest volcanic rock recognized in this area. This flow started at a cinder cone 9 miles to the southeast and flowed down the ancestral Lagomarsino Canyon to the Truckee River, then eastward down the canyon for about 3 miles. The flow is less than 1 million years old, but has been well-dissected by erosion and faulting. Since the eruption, Lagomarsino Canyon has been deepened more than 150 feet. The Truckee has been deepened only about 70 feet at the mouth of Lagomarsino Canyon since the lava flowed.

At 1:00 to 2:00 is the Pliocene Mustang Formation (andesite flows). The lowest exposures of the flows are about 150 feet above the river indicating that the river has eroded at least 100 feet since the Mustang eruption.

Two river terrace levels are present in the canyon here. The higher one consists of boulder gravel of Pleistocene Donner Lake outwash resting on a channelled scabland-like surface cut on Pleistocene olivine basalt. On the lower terrace, Lake Lahontan sands are interbedded with and overlain by boulder gravel of Pleistocene Tahoe outwash. The scabland-like erosion of the Pleistocene basalt, the presence of large granitic boulders (from lithologies west of Reno) that were carried across the Truckee Meadows, as well as the occurrence of huge boulders of metavolcanic rocks (derived from short distances upstream) interbedded in the Tahoe outwash all point toward catastrophic floods that issued periodically down the Truckee River from Lake Tahoe during the Pleistocene.

The major rock types exposed for the next 8 miles are Miocene dacite flows, breccias, tuffs, and tuffaceous sedimentary rocks of the Kate Peak Formation, overlain by lenses of sedimentary rocks (tuffs and diatomites of the Truckee Formation?), which are, in turn, overlain by basaltic flows and breccias of the Miocene Lousetown Formation.

0.3/10.8 The large dome at 9:00 on the skyline is composed of Miocene Washington Hill rhyolite. The type section for this formation is about 3.5 miles south (to the right) of here at

Washington Hill.

1.1/11.9 Mustang exit. The Pliocene Mustang andesite is exposed to the right of the river where it lies unconformably over Miocene Kate Peak and Lousetown flows and associated sedimentary rocks.

0.7/12.6 Sanitary land fill for Reno and Sparks on the left.

0.8/13.4 At this point the canyon opens-up exhibiting vast expanses of Tertiary volcanic rocks.

1.3/14.7 White tuffs are exposed on both sides of the road. Note the landslide topography just above the river at 3:00.

0.7/15.4 Diatomaceous tuff in the roadcut on the left is contorted due to faulting. Down-dropped block is on the west.

0.4/15.8 Scenic view stop on right. CAREFULLY pull-off the highway and park. The small white houses at the bottom of the hill sit near a high water mark of ancient Lake Lahontan at an elevation of 4,313 feet. Truckee River delta and Lahontan lake deposits have been found as high as 4,380 feet in this part of the canyon. This is the western limit of the lake in the Truckee Canyon.

0.6/16.4 Patrick exit. Lahontan beach sands are being reworked to provide aggregate material for Reno.

0.5/16.9 Lake Lahontan sediments in roadcuts on the left. They are horizontal and varved and will be exposed in the canyon from here on.

The dark volcanic rocks on the left are Miocene basalts.

2.0/18.9 On the right is Sierra Pacific Power Company's Tracy power station. It is a steam generating plant with a generating capacity of approximately 300,000 kilowats. It is designed to run on either natural gas or fuel oil.

1.0/19.9 Tracy/Clark Station Exit.

Just after the Clark Exit, there are thick exposures of laminated Lahontan sediments that were deposited in the delta of the Truckee River where it fed into Lake Lahontan during maximum lake level. Gianella (1933) notes that the Lahontan Lake sediments were laid down as isolated patches in quiet water along the walls of the Truckee River Canyon, instead of completely filling the canyon, as might be expected.

Lake Lahontan, named during Clarence King's 1870's exploration of the Fortieth Parallel, was a large lake that existed mainly in western Nevada during the late

Pleistocene (beginning about 70,000 years ago). Locally, glaciers in the Sierra increased and decreased in extent with changes in the climate. When they were melting, many of the valleys in western Nevada were filled with the meltwater forming a large interconnecting lake called Lake Lahontan. The climate was wetter and cooler then which also contributed to the increased amount of surface water.

At its maximum, Lake Lahontan covered an area of over 8,400 square miles, and reached a maximum depth of 500 feet in the Pyramid Lake basin. The highest lake level reached an elevation of about 4,300 feet. The present-day remnants and formerly deepest areas of ancient Lake Lahontan are Pyramid, Walker, and Carson Lakes. They are fed by rivers running east from the Sierra. Other nearby basins that once held Lahontan waters, now only have water in them after heavy rains and during years of high precipitation. Still under investigation is the former extent of Lake Lahontan, along with the unsynchronized lake level maxima reached in the interconnecting valleys it filled, and the correlation of the high lake stands with the climatic and glacial ice fluctuations. Some of the evidence being used to uncover the complex history of the lake are old shorelines, lake sediment deposits, tree-ring and radiocarbon dating, and recent tectonic changes.

Today, ancient shorelines rim the mountains surrounding the lake's former basins. You will see them prominently displayed from Wadsworth north to Pyramid Lake. The longer the lake remained at a particular level the more prominent the shoreline or wave cut terrance became. Some local terraces are as much as 300 feet wide. Only one terrace is actually cut into rock. The lake level usually fluctuated too rapidly to accomplish more than just notching the pre-existing alluvium. (For more detailed investigations of Lake Lahontan in this area, refer to Russell, 1885; and Morrison, 1964, 1965, 1984.)

0.5/20.4 Outcrops on the left and right are Lahontan lake sediments.

0.6/21.0 The Eagle-Picher diatomite plant on the right produces absorbents, abrasives, filter materials, insulation, and filler used in many consumer products from its Celatom quarry in the basal section of the Miocene Desert Peak Formation about 7 miles to the east.

Diatomite is the white, siliceous skeletal remains of diatoms, which are microscopic, single-celled plants that grew in fresh water in this area during the Pliocene. They secreted siliceous frustules (shells) in a great variety of forms that accumulated in enormous numbers to form the deposits of diatomaceous earth you see today.

0.8/21.8 At 9:00 is an apparent left-lateral off-set of the white tuff of the Miocene Chloropagus Formation.

1.7/23.5 On the left, an artificial oxbow lake was created when the Truckee River was diverted to the south during construction of the freeway.

On the left near road level is the Miocene Pyramid Sequence (or Chloropagus and Old Gregory Formation) consisting of a thick basalt sequence (andesite, and dacite flows) with some interbedded rhyolitic tuffs and clastic deposits and occasional lenses of tuffaceous and diatomaceous sediments. Overlying this sequence are Miocene Kate Peak andesite and rhyolacite flows and volcano-clastic deposits. Locally, Miocene basalt and andesite flows cap the lower hills.

On the right are more Kate Peak rocks.

0.6/24.1 Derby Dam at 3:00. This small concrete and earthen dam diverts water from the Truckee River southeastward to the Lahontan Reservoir on the Carson River. Construction began on Derby and Lahontan Dams and the connecting diversion channels in 1903 as part of the Newlands Reclamation Project, the first U. S. Government project authorized under the Reclamation Act of 1902. The first water was diverted through the canal in 1906. In normal years, this project can provide year-round irrigation to over 90,000 acres, mainly in the Fallon area about 30 miles to the east.

Exposed high on the canyon wall above the dam is the base of the Miocene Desert Peak Formation. Several left-lateral(?) faults offset the base of the formation near the dam.

0.8/24.9 Thisbe-Derby Dam exit. On the left, the Miocene Pyramid Sequence crops out with Miocene Lousetown basalts capping the low hills. Kate Peak rocks are on the right.

1.2/26.1 High on the hills at 2:00 are the waste dumps of Eagle-Picher's Celatom Mine which supplies diatomite to their processing plant back at Clark Station. The white band in the canyon wall is volcanic tuff, not diatomite.

1.0/27.1 At 9:00, west-dipping Miocene Alta andesite is considerably altered (propylitized) where it is in contact with interbedded tuffs.

1.3/28.4 Painted Rock exit. The gray and tan rocks on the left are early to middle Miocene andesite flows and volcaniclastics of the Alta Formation. Farther along, the pink rocks are hydrothermally altered late Oligocene-early Miocene ash flow tuffs which unconformably overlie Mesozoic metasedimentary rocks. Hot solutions originating at depth altered the tuffs to bright pink and white clay minerals. The hills beyond these roadcuts on the left are composed of more Alta Formation which is overlain by Miocene basalts of the

Pyramid Sequence. Some of the hills are capped with Miocene basalt flows. Note the laminated Lake Lahontan sediments in the gullies.

0.1/28.5 On the left, quartz monzonite has intruded Mesozoic metasediments. Minor amounts of sheelite have been mined from the contact zone.

0.7/29.2 Rest area. On the left are Lake Lahontan sediments, and on the right are Miocene Pyramid Sequence volcanic rocks.

0.9/30.1 More Lake Lahontan sediments and terraces on the left.

1.2/31.3 Conical knob of Pleistocene age basalt on the left.

0.3/31.6 On the hillside to the left are the concrete remains of a 50-stamp mill for the Olinghouse (White Horse) gold mining district located 6 miles to the northwest. The area was first prospected in 1860. In 1906, the Nevada Consolidated Mining Company built a railroad linking the mines to this mill. The mill only operated for 3 months in 1906 and 1907 due to insufficient ore reserves.

TURN RIGHT onto PYRAMID LAKE-WADSWORTH EXIT. At the stop sign TURN LEFT onto U.S. 40. Entering the Pyramid Lake Indian Reservation.
The Truckee Range is in the distance at 2:00.

0.5/32.1 The Pah Rah Range is still on the left. The imposing mountain at 9:00 is composed mostly of Miocene Pyramid Sequence basalt and andesite flows, and mud flow breccias and agglomerates. The bottom of the hill is composed of darker Miocene Alta andesite.

This is the approximate intersection of the east-northeast trending Olinghouse fault zone and the northwest-southeast trending Walker Lane fault zone. The Olinghouse zone is probably an antithetic left-lateral conjugate sheer zone of the right lateral Walker Lane zone (after Bell, 1981 and 1984). The Truckee River follows the Olinghouse zone from Sparks east to Wadsworth, where it bends north to follow the Walker lane.

1.3/33.4 Just before entering Wadsworth TURN LEFT on State Route 447 to Nixon and Pyramid Lake.

0.4/33.7 The road ascends a large lake terrace scarp.

0.5/34.2 To the right, just above the green valley of the Truckee River, a large section of tan Lahontan lake bed and delta deposits can be seen.

1.4/35.6 The road on the left leads to the Olinghouse mining district located in the colorful hills straight ahead. The light-colored rocks are altered late Oligocene-early Miocene rhyolitic ash-flow tuffs, which are overlain by Pyramid Sequence volcanic rocks. Both formations have been intruded by Miocene granitic rocks. Gold at Olinghouse occurs as small high-grade pockets or shoots in quartz and calcite veins in fault zones in or adjacent to granodiorite porphyry dikes and intrusive masses which cut the Chloropagus Formation (andesites and basalts). The Cabin No. 2 Mine was the district's principal producer.

0.5/36.1 Entering Dodge Flat. The area on both sides of the road consists of a thin surface veneer of reworked and eolian deposits, which is underlain by deltaic lake plain sediments deposited by the Truckee River as it entered ancient Lake Lahontan. This broad surface is primarily related to the mid-Sehoo lake stand of Morrison (1964). It is characterized by the widespread occurrance of dentritic tufa.

Note the horizontal grooves of former Lahontan shorelines in the basal portion of the Truckee Range to the right. The dark rocks composing the southern end of the Truckee Range are Pliocene basalts.

Along the western (left) boundary of the flat, Lake Lahontan sediments are interbedded with alluvial deposits derived from the Pah Rah Range. The southern end of the Pah Rah Range consists mainly of Pliocene basalt and andesite flows.

The eastern (right) portion of Dodge Flat (and extending northward to the southern end of Pyramid Lake) is transected by segments of the Walker Lane. The Walker Lane is a zone of northwest-trending right-lateral strike-slip faults and parallel trending ranges extending from Pyramid Lake on the north at least as far south as Walker Lake. Geomorphic features marking this zone consist of rift-valleys, long linear ridges, subtle scarps, sag ponds and vegetation alignments.

1.9/38.0 At 10:00 northwest-trending faults offset pre-Lahontan fan deposits, which descend step-like from the Pah Rah Range and are tilted to the east.

0.2/38.2 Leaving Dodge Flat. On the west (left) along the Pah Rah range-front small scarps (under 10 feet) can be seen in Late Cenozoic alluvial fan deposits.

1.4/39.6 Note the large north-trending fault in pre-Lahontan fan deposits at 9:30.

1.6/41.2 A number of roads leading off to the right in this area afford good views of the stratigraphic section of Pleistocene Lake Lahontan. (Refer to Morrison's "South Overlook", 1965.)

The highest measured shoreline of ancient Lake Lahontan in this area is at an elevation of 4,395 feet (Mifflin and Wheat, 1979).

0.7/41.9 The road descends through "badland" topography. Note the complex assemblage of fluvial and pluvial deposits in the roadcuts for the next mile. The old bed of the Southern Pacific railroad parallels the route for the next few miles on the right. Rocks exposed here display faults with small vertical off-set.

0.9/42.8 Pyramid Lake battles historical marker on the right. STOP. Note the tufa deposits above the roadcut to the west, and behind the historical marker on the ledges below.

1.1/43.9 The road ascends a Sehoo age lake terrace. At the top of the hill PULL-OFF TO THE LEFT in the parking area. For a more detailed examination of the extremely well-developed tufa heads, walk to the east (right) side of the road. These late Sehoo age tufas have both lithoid and dendritic forms. Exposure and greater salinity during lower lake levels in Sehoo time are believed to have promoted rapid tufa growth here and in other favorable areas in ancient Lake Lahontan.

In 1885, Russell classified the tufa deposits of Lake Lahontan into three varieties: (1) lithoid, stony, and compact; (2) dendritic, coralline and branching; and (3) thinolite, showing crystal forms. The lithoid and dendritic varieties were (and are presently) deposited through the activity of blue-green algae along the lakeshore. Rocks or pebbles form the solid foundation for the algae to grow on.

OPTIONAL SIDE TRIP to the Narrows of the Truckee River. Take the dirt road on the right for a closer look at the "narrows" of the Truckee River. From this vantage point you can also see the deep down-cutting that the modern Truckee River has accomplished through Quaternary pre-and post- Lake Lahontan deposits. This deep incising is caused by the easily erodible nature of the unconsolidated lake, delta, and basin-fill deposits, and by upstream diversions of Truckee River water, factors which have resulted in the lowering of Pyramid Lake's base level, which has in turn steepened the local stream gradient of the Truckee River and added new impetus to its erosion of Late Quaternary deposits in this area, and redeposition of this new sediment load into Pyramid Lake at the present Truckee River delta.

About 5 miles downstream, a U. S. Geological Survey gauging station measures the flow of Truckee River water into Pyramid Lake. Remember that the lake receives essentially its total inflow from the Truckee River which originates at Lake Tahoe. It has been estimated that the normal flow at this point used to average about 680,000 acre-feet per year.

However, due to diversion of the water in Reno and at Derby Dam, the average inflow to Pyramid Lake over the past 25 years has been about 330,000 acre-feet per year. RETRACE ROUTE BACK TO MILEAGE POINT 43.9 and continue roadlog.

0.3/44.2 Note the horizontal lake terraces etched into the ancient Lahontan sediments on both sides of the road.

CAREFULLY pull off the road for a panoramic view of Pyramid Lake. (USE EXTREME CAUTION WHEN PULLING-OFF THE ROAD IN THE LAKE BASIN. SHOULDERS ARE OFTEN DEEP SAND.) The town of Nixon lies in the patch of green at 2:00. Behind Nixon, in the middle distance at 1:00, is Marble Bluff. Behind the bluff is the higher Lake Range. Anaho Island is directly ahead. Pyramid Island is to the right of Anaho near the eastern shore of the lake. The Truckee River runs north through Nixon and bends to the left before entering the lake at its present-day delta.

Due to the lowered lake level since 1867, much soft old lake and delta sediment from upstream has been eroded by the Truckee River and deposited at the mouth of the Truckee in the form of a new delta into Pyramid Lake.

0.3/44.5 Road to Little Nixon on the right. Continue straight ahead.

2.9/47.4 JUNCTION. TURN LEFT on State Route 446 to Sutcliff, OR CONTINUE STRAIGHT AHEAD on State Route 447 to Nixon for an OPTIONAL TRIP TO NIXON AND WINNEMUCCA LAKE.

OPTIONAL SIDE TRIP TO NIXON AND WINNEMUCCA LAKE. Travel for 0.6 mile and cross the Truckee River. The Nixon Trading post will be on the right ahead. Travel another 2 miles and Marble bluff will be ahead at 12:00. It is composed of metamorphosed limestone of the Lower Mesozoic Nightingale Sequence, which is covered with massive tufa deposits.

The drainage way along the south and east sides of the bluff is the Mud Lake Slough, the natural overflow channel from Pyramid to Winnemucca Lake, when Pyramid stood at higher levels. Until 1939, the Winnemucca basin contained water year-round. At its maximum historical level the lake had an area of about 90 square miles and maximum depth of about 80 feet. After 1911, inflow into Winnemucca Lake was intermittant. Because of upstream water diversions, the Truckee River incised (downcut) its present channel too deeply for water to flow eastward into the Mud Lake Slough and on to Winnemucca Lake. By 1939, Winnemucca Lake was no longer perennial. A valuable fish and waterfowl habitat has been lost.

Travel another 1.3 miles to the Marble Bluff viewpoint. To the right lies the southern part of Pyramid Lake, terminal basin for the Truckee River. In the foreground, the Truckee

River has cut through the ancient Lake Lahontan and more recent Pyramid sediments in its terminal floodplain, due to lowering of the lake level as discussed previously. A manmade channel was dug in the 1930's in a futile attempt to bypass the shallow natural delta channel to facilitate upstream spawning runs of Pyramid Lake fish. In the mid-1970's a smaller channel was again dug within the 1930's channel for the endangered Cui-ui and Cutthroat Trout in conjunction with the construction of the Marble Bluff diversion dam located a few hundred yards upriver. This dam and canal are succeeding in aiding the spawning runs, along with controlling further downcutting of the river channel in the delta area north of the dam. Upstream from the damsite, downcutting of the river channel is continuing (Glancy, 1984). END OF OPTIONAL TRIP TO NIXON AND WINNEMUCCA LAKE. RETRACE ROUTE 4.3 MILES BACK TO THE JUNCTION of State Routes 446 and 447. TURN RIGHT ON STATE ROUTE 447 and begin mileage at 47.4

The low terraces in this area are complex deposits of deltaic sediments. You are travelling across former lake bottom and delta sediments. The northern end of the Pah Rah Range is on the left. Most of the exposed rocks are late Oligocene-early Miocene rhyolitic ash-flow tuffs.

2.5/49.9 Note the high shorelines of ancient Lake Lahontan at 10:00.

0.6/50.5 Crossing Duck Lake playa. This small depression was formed by a Pyramid Lake shoreline barrier bar that dammed local drainage toward the north. A pond resulted that was fed by local runoff and probably by some ground-water seepage from Pyramid Lake during high stages. Historically, Duck Lake was a marshy area that provided waterfowl resources for the native Paiutes. This elevation is near the historical high level of the lake.

The level of Pyramid Lake represents a delicate balance between inflow and evaporation in this desert climate, and is known to have fluctuated substantially during historic times because of natural climatic change and man's intervention. Its level was about 3,860 feet in 1844 when discovered by Fremont. It may have reached a historic maximum of about 3,880 feet during the 1860's; it was at a level of about 3,876 feet when viewed by King in 1871, and at about 3,869 feet in 1909 (Hardman and Venstrom, 1941). The lake level began a steady decline when major water diversions began for the Newlands Irrigation Project at Derby Dam. According to U.S. Geological Survey data, it reached a historic low of about 3,784 feet in early 1967. The lake rose about 8 feet as a result of the abnormally great runoff of 1969, and has remained more or less stable during the 1970's because of changes in the Truckee River diversion management policy of the Department of Interior. During the back-to-back abnormally wet years of 1982-83, the lake level rose almost 20 feet (Glancy, 1984). It now stands at 3,815 feet (January 1987).

0.5/51.0 Tufa dome on the left.

0.2/51.2 The road cuts through the barrier bar that helped form Duck Lake.

0.9/52.1 Large tufa deposit on the left.

0.3/52.4 On the left, note the white band of calcium carbonate deposited on the rocks. This white band is present around the lake at about the same elevation (3,872 feet), but the width varies. It represents some natural equilibrium level of the lake. Fremont noted this white zone in 1844, when it was only about twelve feet above lake level. A similar zone occurs around Winnemucca Lake about 15 feet lower. Pyramid Lake has risen above this white line three times between 1860 and 1900.

0.3/52.7 Pull off road to the right for a closer look at the botryoidal tufa dome ("popcorn rocks") on the shoreline. The spheroidal form consists of concentric bands of thinolite.

Gianella (1933) stated that thinolite was a paramorph of calcite after aragonite, and may have been deposited at a time when the waters of Lake Lahontan were oversaturated with calcium carbonate. This over-or super-saturation of the lake water probably occurred during the dryer, interglacial periods when evaporation exceeded inflow. More recent studies of thinolite by Mifflin cause him to believe that thinolite forms (precipitates) when supersaturated thermal waters from hot springs (which are numerous in the Pyramid Basin) percolate up through the cold, calcareous lake bottom mud and water.

The alignment of tufa domes and mounds along fractures parallel to the trend of young (late Quaternary) faults here and at other localities around the lake basin suggests that the Walker Lake fault zone was active and was the focus of spring discharge (at least partly thermal) during Lake Lahontan time (after Born, 1972). Known active geothermal areas at Pyramid Lake include the Needles on the north end (three geothermal wells were drilled here by Western Geothermal, Inc. in the mid-1960's), Pyramid Island, and a hot spring on Anaho Island.

This locality also marks the former extent of the modern Truckee River delta during the Lake's lowest historic stand of the 1960's. At that time, the river was rapidly cutting down into and laterally eroding the freshly exposed lake deposits, particularly during periods of high river flow. The intense erosion formed a large prograding fluvial delta over the top of deeper-water lake sediments. For miles along the beaches in this area, similar complex sedimentary relationships telling of Pyramid Lake's dynamic past can be seen in vertical cross-section in the low cliffs just above water level.

1.2/53.9 At 3:00 on the opposite shore of the lake, the Marble Bluff diversion channel cuts a "V" just above water level to the right (south) of Marble Bluff. Ahead at 1:00, is a good view of Anaho and Pyramid Islands. In the distance at 12:00 the Needles can be seen jutting above the shoreline.

The color of Pyramid Lake changes constantly. Generally, this occurs because of changing intensity and angle of sunlight on suspended inorganic particles. But the most spectacular hues develop in late summer when the algae and tiny animals (mostly crustaceans) greatly increase their numbers forming "blankets" in the upper layers of water. The wind mixes this plankton layer with the deeper waters, creating striking green to turquoise hues that contrast with the pastels of the surrounding desert ranges.

1.3/58.7 An east-west trending fault crosses the road here. The road ascends a large, sandy escarpment of old lake deposits located at the mouth of Mullen Creek (ahead and to the left). Note the large tufa deposit on the right.

0.5/59.2 More tufa deposits on the right at 2:00.

0.7/59.9 The road was washed-out here by the February 1986 flooding of Mullen Creek.

0.7/60.6 <u>JUNCTION</u>. <u>TURN LEFT on State Route 445</u> to Reno.

0.2/60.8 <u>Pull off road to the left</u> for a final panorama of Pyramid Lake.

Pyramid Lake is currently about 25 miles long, 4 to 11 miles wide, and over 350 feet deep (just north of Pyramid Island). Geologically, it occupies the Pyramid Lake depression at the northern end of the Walker Lane fault zone and was formed during late Pliocene and early Pleistocene time. Coincident with this basin formation was the uplift of the Lake Range on the east and the Virginia Mountains on the northwest. Major uplift was due to faulting, and occurred after deposition of late Oligocene-early Miocene rhyolitic ash-flow tuffs and prior to the extrusion of late Miocene rocks (Bonham, 1969). The great vertical displacement that has occurred along the Walker Lane is exhibited by the regional position of Mesozoic rocks.

The Mesozoic basement in the Virginia Mountains and the Pah Rah Range is structurally depressed more than 4,000 feet relative to the Mesozoic basement in the ranges to the west.

Both ranges, however, constitute a topographically higher block than any of the nearby ranges to the west, due to (1) out-pourings of volcanic rocks several thousand feet in thickness making the area a highland by early Pliocene time and (2) to Plio-Pleistocene uplift of the area along the northwest trending boundary faults of the Walker Lane (after Bonham, 1969).

Anaho, the large tufa island directly east across the lake, has an elevation of 4,377 feet and was submerged over 10 feet when Lake Lahontan was at its maximum in this area. The island is separated from the eastern shore of the lake by a moat of shallow water, which threatens to become a land bridge if the level of the lake continues to decline.

Pyramid Island is the small pyramid-shaped tufa dome to the left of Anaho Island which gave Fremont the idea for naming the lake when he discovered it in 1841.

The lake water is brackish and contains about 5,000 parts per million of dissolved salts, about 75% of which consists of sodium chloride. The pH (alkalinity) of the lake is 9.15, which compares to a range of 6.5 to 8.5 for most lakes. These conditions are well-tolerated by the present fish population consisting of the famous Cui-ui lake sucker (Chamistees cujus), Cutthroat Trout (the original Lahontan Cutthroat Trout, Salmo clarki henshawi, has been extinct since the 1940's), and the Sacramento perch. The Cui-ui, a sucker fish with an extra fin, is found only in Pyramid Lake, although fossils of its Pleistocene ancestors are found in Klamath and Utah Lakes.

With the completion of the Derby Dam on the Truckee River in 1905 (and other large dams such as the flour mill, the Reduction Works, and the Electric Company in Reno), Pyramid Lake's Cutthroat Trout population began to dwindle. The dam did not include a fish ladder for upstream spawning runs. The fish would mill below the dam by the thousands only to be trapped, netted, dynamited, or hooked by "commerical fishermen". The diversion of Truckee River water continued to lower the lake level and so clog the delta with sediment that the trout that didn't get caught at the dam couldn't return to the lake after spawning. Restocking of the lake's fish population began in the 1950's.

From this vantage point it's easy to imagine Fremont's surprise at finding this expanse of water. He and his party of 24 men were traveling south from the Columbia River exploring the Great Basin before returning to the East when they arrived at a pass on the north end of the Lake.

0.6/61.4 Pull off road to left at the historical marker. Here at the summit of Mullen Gap the only lake terrace that was cut in to rock in the Lahontan Basin can be observed. Russell

(1885) called it the "thinolite terrace", which at that time stood about 150 feet above the lake, at an elevation of 4,200 feet. Looking behind the historical marker, it is a gray, rocky, horizontal band located about midway up the lichen-covered mountain in the background. Below, Mullen Creek served as a waterway for Lake Lahontan waters during high lake stands. Water flowed westward (right) into Warm Springs Valley, the western extent of Lahontan waters in this area. Note the large, sandy, table-like deposits of old lake sediments extending from the mouth of Mullen Creek toward Pyramid Lake.

0.3/61.7 For the next 4 miles the route follows Mullen Pass, an east-northeast trending structural lineament separating the Virginia Mountains on the north (right) and the Pah Rah Range on the south. Note the numerous Miocene intrusive dacite porphyry plugs to the left and right for the next several miles.

On the right, the Virginia Mountains are a northwest-trending block bounded on the northeast and southwest by northwest trending faults of the Walker Lane. North and northwest-trending faults, with predominantly dip-slip movement, occur within the range. Rocks in the northern 75% of the range are Miocene Pyramid Sequence basalt, andesite and dacite flows, flow breccias, mud-flow breccias, agglomerates, tuffs and associated intrusives. The southern end of the range is composed of late Oligocene-early Miocene (30 to 22 m.y.) rhyolitic ash-flow tuffs (with extensive propolytic alteration), and Miocene Pyramid Sequence basalt-flows, mudflows, agglomerates, tuffs, associated intrusives, and some intercalated sedimentary freshwater rocks. Alteration of these rocks by the hot fluids accompanying volcanic activity is responsible for their bright colors. The jagged conical formations are intrusive necks or fissures from which the other volcanic rocks issued.

On the left, the Pah Rah Range is more complexly faulted. Here, it's northern portion exhibits the northwest-trending fault pattern of the Walker Lane. The rocks are late Oligocene-early Miocene rhyolitic ash-flow tuffs and Miocene Pyramid Sequence basalt and andesite flows.

Lake Lahontan sediments cover the valley floor. During high lake stands, water spilled through here from Pyramid Lake into Warm Springs Valley ahead.

2.0/63.7 Crossing Mullen Creek. The road was washed out by February 1986 flooding.

1.5/65.2 In the foreground hills on the left, mine workings of the Pyramid district can be seen. Claims were located here as early as 1863, and the district was organized in 1866. Gold and silver ore assayed from $10 to $1,000 per ton, but little production occurred prior to 1878, when the Jones-Kincaid and the Monarch became the prinicpal properties. Between 1881 and 1889 the Franco-American (Blondin) Mine produced $87,000 in gold, silver and copper. From 1890 to the present, mining has been intermittant and on a small scale. In 1954, uranium was discovered in the district. Many claims were staked, and small scale production began in 1955.

The copper-lead-zinc-silver deposits of the district occur in northwest-trending veins in late Oligocene-early Miocene rhyolitic ash-flow tuffs. The ore is composed of pyrite, enargite, barite, galena and sphalerite in a gangue of quartz, calcite, and altered (sericitic) rhyolitic tuff. The presence of gold is minor, usually less than 0.05 ounces per ton. The uranium occurs in generally northeast-trending fault zones and is commonly localized along diabase dikes intruded into the ash-flow tuffs (after Bonham, 1969).

1.3/66.5 Light-colored Lake Lahontan sediments are exposed in the valley floor at 3:00. Warm Springs Valley is ahead and to the right.

1.1/67.6 Outcrops of late Oligocene-early Miocene ash-flow tuffs on the right and left.

0.6/68.2 Entering Warm Springs Valley. This valley is a down-dropped block bounded by northwest-trending faults believed to be part of the Walker Lane. The valley-fill, composed of Pliocene and younger (including Lake Lahontan) sedimentary and pyroclastic rocks, ranges in depth from 1,960 to 3,380 feet.

Leaving Warm Springs Valley. This is the western extent of Lake Lahontan sediments. The rocks on the right are Cretaceous intrusives (granites to gabbros). Rocks on the left are complexly faulted late Oligocene-early Miocene ash-flow tuffs and some Cretaceous(?) intrusives of the Pah Rah Range.

Extensive outcrops of Mesozoic basement (Cretaceous? intrusives) rocks occur in this area southwest of the Walker Lane boundary faults. They have been displaced upward at least 3,000 relative to the Mesozoic rocks in the Virginia Mountains block.

Erosional remnants of Tertiary rocks indicate that this area was formerly covered by some of the same Tertiary formations that cover the Virginia Mountains-Pah Rah Range block. Uplift occurred here after deposition of the late Oligocene-early Miocene ash-flow tuffs and prior to the extrusion of late Miocene rocks.

3.9/72.1 Hungry Valley straight ahead.

2.5/74.6 The route passes through Bacon Rind Flat, late Oligocene-early Miocene ash-flow tuffs crop-out on both sides of Rattlesnake Canyon on the left. These outcrops are remnants of flows that originated in the Pah Rah Range to the southeast.

The unnamed range on the right is composed of north-northeast and west-to northwest-trending faults in Cretaceous(?) intrusive rocks overlain by late Oligocene-early Miocene ash-flow tuffs.

3.8/78.4 Entering Spanish Springs Valley. Ahead, and to the right is Mount Rose and Slide Mountain in the Carson Range.

1.1/79.5 On the left at 10:00 is Sugarloaf Peak. It is composed of Miocene andesitic basalt, overlying Cretaceous(?) granite.

To the southeast (left), the surface of the Pah Rah Range is composed entirely of late Miocene basalts.

At the base of the hills on the right, light-gray decomposed granite is being mined for use mainly as landfill. Cretaceous(?) granites continue to outcrop in the hills to the right, along with pre-Lake Lahontan terrace, alluvial fan and pediment gravels and lacustrine deposits. These deposits are also found along the entire western margin of the Truckee Meadows (to the south).

3.2/82.7 The meadows of Spanish Springs Valley are kept green with the irrigation waters from the Orr Ditch which connects with the Truckee River ahead in Reno.

2.2/84.9 Truckee Meadows straight ahead. The route now passes through the Wedekind gold and silver mining district. Note the adits and dumps on the hills to the right.

George Wedekind was a piano tuner and week-end prospector who found his Wedekind Mine in 1896. He produced about $100,000 from his mine before selling-out to Governor John Sparks for $175,000. By 1901, about 50 shafts were sunk in the area. This also marked the main period of production with anywhere from $229,621 (unofficial smelter figures) to $107,091 (official production records) being produced. The surface ores reportedly contained rich silver chloride some gold, cerussite and anglesite (Bonham, 1969). There was a large flow of hot, acid water that was struck at 213 feet in 1903 that made mining difficult. The mill that was designed for surface oxide ore and not the sulfide ore that was present, also made mining here unprofitable. Mining was again attempted in the 1920's and 1930's, with lead, zinc, and silver oxides being encountered at 210 to 400 feet.

Cretaceous(?) granodiorite crops out on the north end of the district, but Miocene Alta Formation (pyroxene andesite flows) is the major rock unit exposed in the area. The flows are highly altered and have undergone extensive near-surface acid bleaching. Primary sulfides were reached at depths of about 50 feet and consisted of galena, sphalerite, pyrite, and argentite. Mineralization occurs in stockworks in northwest-and north-trending fracture zones.

Residential housing has encroached on the district, with a few "surprises" happening to unwary owners who have built too close to the old shafts.

0.8/85.7	Entering Sparks. Continue on Wedekind Road to the intersection with North McCarran Blvd.
0.3/86.0	TURN RIGHT onto North McCarran and continue straight ahead for 3.9 miles.
3.5/89.5	Downtown Reno at 9:00.
0.4/89.9	Intersection with North Virginia (U.S. 395) Street. TURN LEFT onto North Virginia Street.
0.5/90.4	Lawlor Events Center and the University of Nevada-Reno on the left.
0.4/90.8	Immediately past large blue spruce trees on left, turn left into the University of Nevada-Reno campus at the Old Gym. END OF ROUTE 3.

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