ROADSIDE GEOLOGY AND MINING HISTORY
OWENS VALLEY AND MONO BASIN
2019

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With annotations and adaptations from David Jessey and Robert Reynolds (2009) and Steve Kipshie (2001)

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Key words: Owens Valley, Mono Lake, Mono County, Inyo County

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INTRODUCTION

Points of interest in this guidebook are described in the text with the notation (#00) correspond to points on the road and geologic maps of this guide with an orange triangle. Several images are also duplicated from DNG CD 98-001 “California Gold Mines: A Sesquicentennial Photograph Collection”. These are noted in the photos of this guide as “1998, CGS.”

Mine Production Statistics

All mine production values are from county reports. Most of those values were presented in dollars. They have been converted in this guide to ounces using the assumption that between 1849 and 1949 the average value of gold produced from the gold mines in California was $25.00 per ounce.

Mileage Markers

Whenever possible, this field guide is keyed to highway mileage posts with the denotation "MP."

Maps

This road guide has two sets of maps. There are four regional maps printed at a scale of 1:50,000. These are compiled from 1:250,000 California Geological Survey (CGS) topographic maps. The geology for these maps is from the USGS digitized 1:750,000 scale map of California. These maps are designed to be printed on a 36 inch-wide plotter. The regional maps are designed to be printed at a page size of 36 inches by 44 inches.

The second set of maps is produced at a various scales. These use maps from my Geologic Mosaic which is a compilation of mapping av various scales These maps also contain mine and mineral occurrence site locations from the MRDS dataset of USGS and the MAS data set from the former Bureau of Mines.

All maps are available in .PDF format.

Acknowledgements:

I have used the guidebook “Geologic Guidebook to the Long Valley-Mono Craters Region of the Eastern Sierra, Second Edition by Steven R. Lipshie (2001) extensively through this guidebook. I have also used the guidebook Landscape evolution at an active plate margin: a field trip to the Owens Valley by David R. Jessey and Robert Reynolds (2009). Citations and adaptations are used by permission.

Contents

Map 01: Bridgeport to Conway Summit

Bridgeport (#001, T3N, R25E, Sec. 33).

The seat of Mono County, this town has a beautifully restored courthouse building.

Figure 1. County Courthouse, Bridgeport

Travertine Hot Springs (#002; T2N, R25E, Sec. 34).

About 13 miles north of Conway Summit, turn east onto an access road near the Caltrans yard. Proceed up the dirt road to the hot springs. These springs are administered by the BLM and are a popular visitor attraction. Small pools have been made to facilitate bathers. The quantity of hot water varies unpredictably and does not seem to be associated with variations in precipitation levels.

The large linear mounds, on the crests of which some springs emanate, are composed of a rock similar to limestone called travertine. The very colorful oxblood-colored banding has made this a popular decorative stone in the past. Many fireplaces in southern

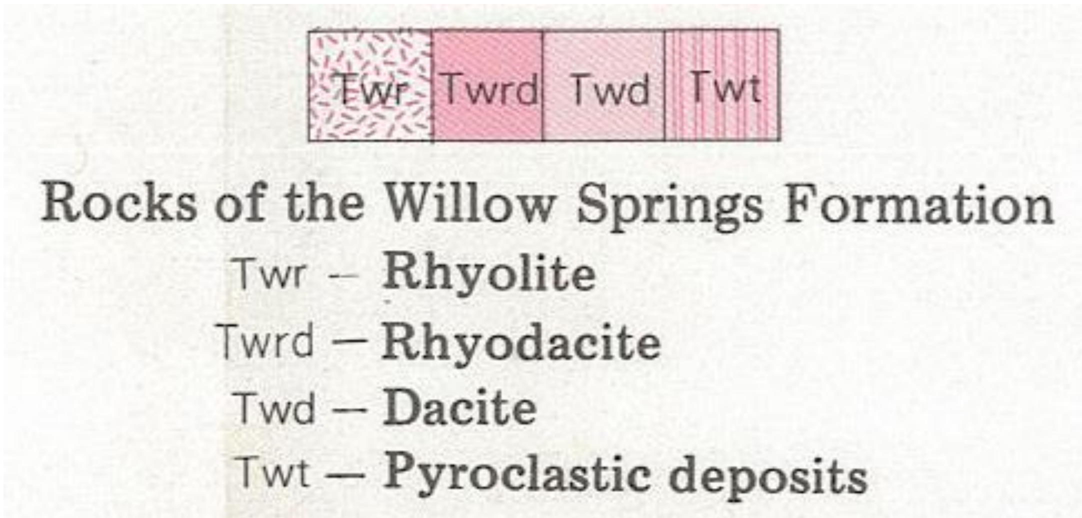
California fireplaces are so adorned. Many tons of stone were removed from a quarry here years ago.

More recently, attempts have been made to tap the geothermal potential here. Under a federal lease, a few holes have been drilled, but because of drilling problems the potential has never been fully assessed. There have been difficulties in abandoning these wells owing to the mush-like nature of the rocks.

The hills surrounding Travertine Hot Springs support Utah juniper (Juniperus osteosperma) and single-leaved pinyon pine (Pinus monophylla). The nut of the single-leaved pinyon was the single most important food resource in the dietary regimen of the Paiute of the Deep Springs, Fish Lake, and Owens valleys, and their harvest was highly influential in the lives of these native Californians. Entire families or villages would move to the pinyon woodlands and set up camp in early fall. Because of its importance to their winter diet, every effort was made to maximize the harvest. The nuts were much more easily handled if left on the trees until brown and open, but this both shortened the harvest and increased the likelihood of predation by birds and other animals. To avoid this, the Paiute harvested the cones while still green, and then roasted them to simulate the natural ripening process. More information on the Native American use of this and other resources of eastern California can be found in Clarence A. Hall's Natural History of the White-Inyo Range, Eastern California (see bibliography).

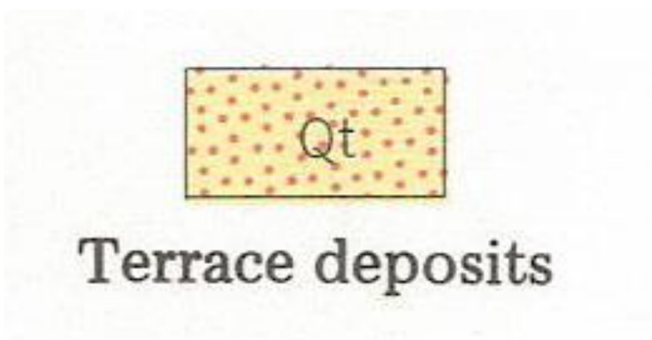
Other common plants in this area are Great Basin Sage (Artemesia tridentata), antelope bush (Purshia tridentata), and Mormon or desert tea (Ephedra viridis). Mormon tea was often used by the Native Americans to make a soothing or medicinal tea, occasionally with antelope bush in the tea as well. Also keep your eyes open for Clark's nutcrackers (chunky gray birds with black wings and black central tail feathers, about 12 inches long), major competitors with the Paiute for pine nuts, mountain bluebirds, and yellow billed magpies.

Chesterman and Gray (1975) mapped the area of Travertine Hot Springs as Miocene-Pliocene Willow Springs formation (Twd). The springs are at the conjunction of two faults.

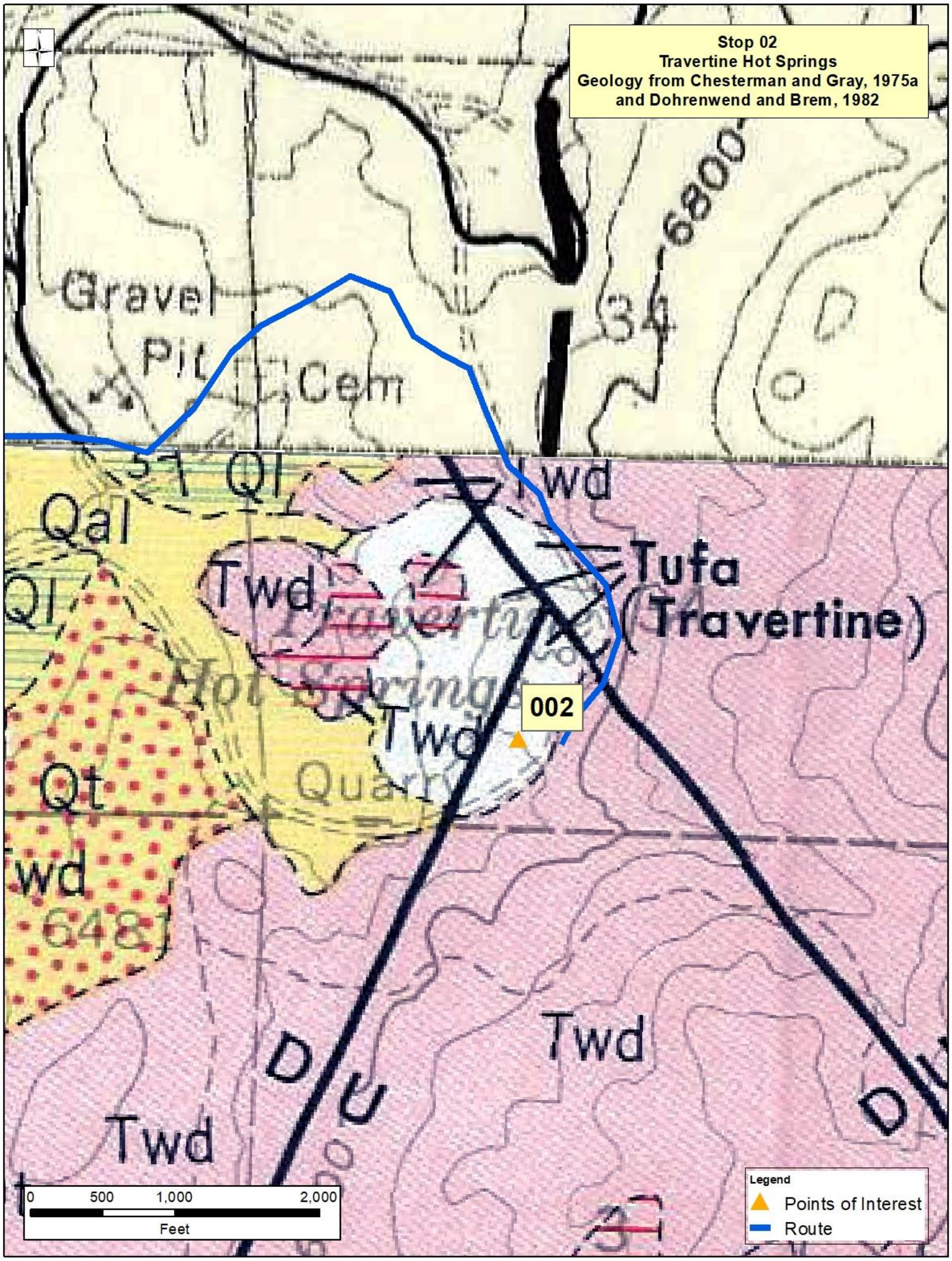


Miocene-Pliocene Willow Springs Formaton. From Chesterman and Gray, 1975

To the southwest of the springs are some Holocene River Terrace Deposits (Qt).



Holocene Terrace deposits. From Chesterman and Gray, 1975.



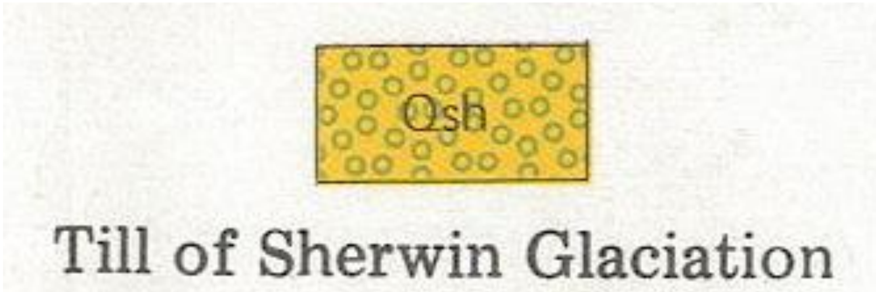
Geologic map of Travertine Hot Springs. From Chesterman and Gry, 1975 and Dohrenwend and Brem, 1982.

Dogtown (#003; T4N, R25E, Sec. 23).

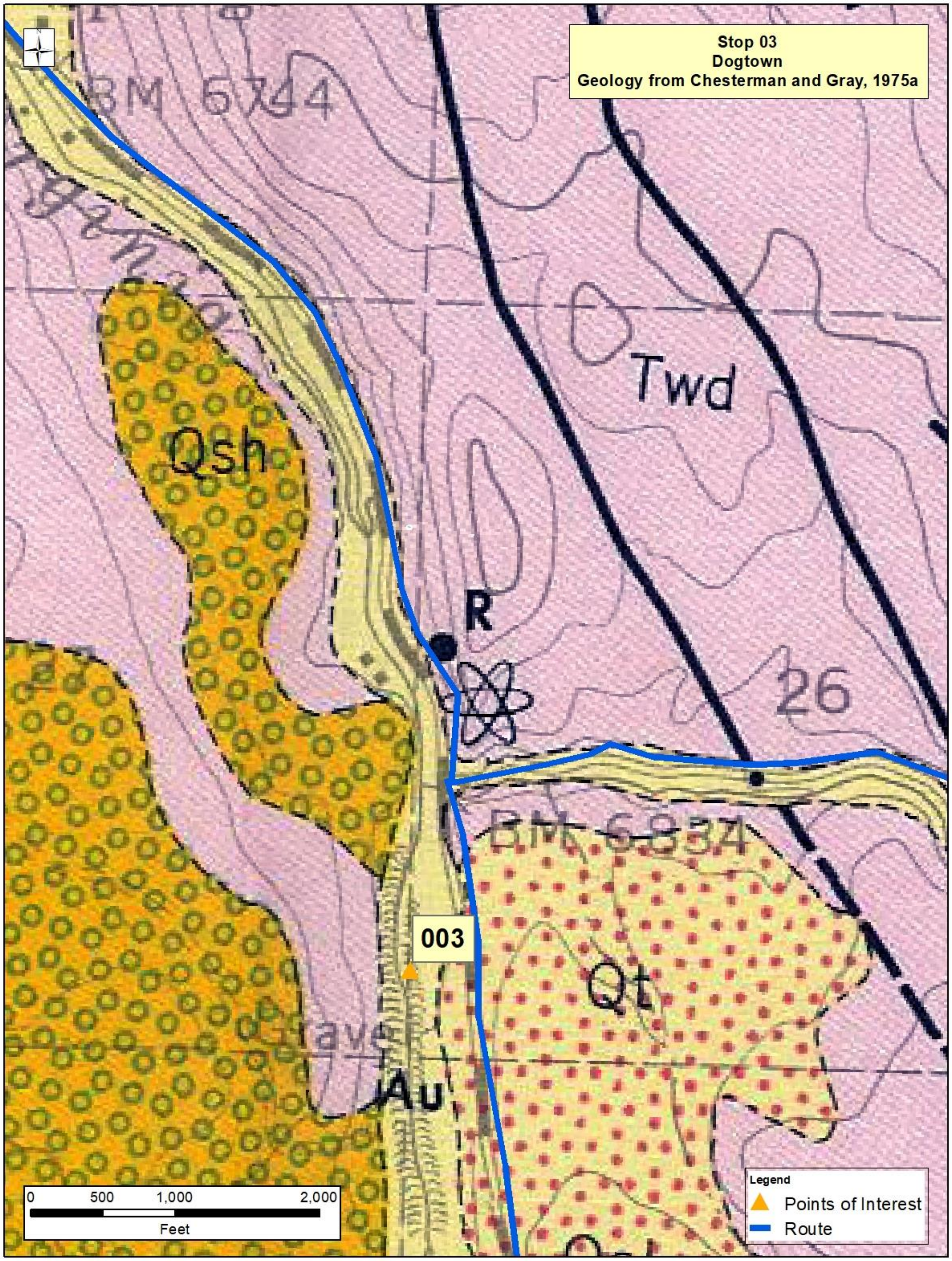
Dogtown. Photo by Gregg Wilkerson, 2008.

This is a gold placer camp. Placer tailings are plainly visible on the Virginia River and gold can still be obtained from these tailings. Along the road from Bodie to Mono Lake, we will travel through pinyon-juniper woodland which we saw up close at Travertine Hot Springs until we get to the lower altitude around Mono Lake. In this area we see typical Great Basin Sagebrush. Rabbitbrush (Chrysothamnus nauseosus) is one of the local dominants in this area and is the yellow flowered plant which can be seen along this and many roadsides in fall. This widespread member of the Aster family has eight subspecies, so can appear very different in different places; it is an extremely common constituent of desert habitats of all types. There is also great basin sage, antelope bush, and Mormon tea along the road.

Chesterman and Gray (1975) mapped the area of Dogtown as having Tertiary Willow Springs formation (Twd) and Holoene River Terrace Deposits (Qt), and Pleistocene Sherwin Till (Qsh). The gold-bearing gravels are in the Holocene river sediments. There is also a radioactive anomaly in the Willow Springs formation north of Dogtown.



Pleistocene Sherwin Till. From Chesterman and Gray, 1975.



Geologic map of Dogtown. From Chesterman and Gray, 1975.

SIDE TRIP TO BODIE

Take this side trip from Dogtown.

Cinnabar Canyon (#004; T.4N, R.26E, Sec. 19)

This is the site of a mercury mining operation. It is a hot spring deposit in volcanic ash layers. It is north of the Bodie-Dogtown Road, two miles east of Dogtown.

Map 02: Bodie and North Cinnabar Canyon

Map 03: Bodie State Park

Bodie Ghost Town and State Park (#005; T4N, R25E, Sec. 8,9,16 and 17).

About seven miles north of Conway Summit, or six miles south of Bridgeport, turn east onto Route 270 toward Bodie State Park. On the right side of the road as we go along is a riparian habitat typical for this area. It is filled with willows, now going dormant, and quaking aspens. Also going dormant are large areas of a native rose, Rosa woodsii, also called interior rose. The red fruit of this plant is rose hips, a good source of vitamin C. Locals often gather these when ripe, either to make tea or rose hip jelly. The low growing shrub which surrounds Bodie is silver sagebrush, Artemesia Cana, a more localized member of the same genus as the very widespread great basin sage which we saw at Travertine Hot Springs.

Bodie Mill. Photo by Gregg Wilkerson, 2008.

Bodie is remarkable in its preservation as a late 1800s ghost town. The town was privately owned until the early 1960s when bought by the state and made a state park. The town is now kept in a state of "arrested decay," meaning that the natural decay of the buildings is arrested, but no reconstruction is done. The state will attempt to keep a building standing, but if it falls down it stays down.

Bodie sprung up around gold mines in an area of altered volcanic rocks of Tertiary age. Many millions of dollars in gold ingots were shipped from Bodie's mills in the late 1880s, making it one of California's premier gold producing areas of the time. Most of the claims within the productive area were patented and become private land. There remains a substantial amount of Public Lands in the vicinity of Bodie, much under mining claims. Recent efforts to reestablish gold mining near Bodie has met with opposition and a recent congressional action has withdrawn mineral claims for 5,000 acres within the "Bodie Bowl". As a result of the Desert Protection Act of 1994, the mining claims at Bodie were appraised at $65 million. Negotiations with the trustee for the claims and State Parks Department and conservation groups resulted in purchase of the claims for $6 million. No economic developments of the mineral deposits at Bodie are now planned.

Map 04: Mono Lake

Conway Summit Vista Point (#006; T3N, R25E, Sec. 35 and 36).

Near Conway Summit is a roadside vista that gives a good view of Mono Basin. On the north side of Mono Lake is the Black Point volcanic cone. Note the wave-cut shorelines on the flanks of the cone. This was an underwater eruption that occurred while Lake Russell was full or nearly so.

North of Conway Summit is a meadow on the west side of the road in which numerous quaking aspens (Populus tremuloides) can be seen in various stages of going dormant. Quaking aspens are dependent on ready access to water, and are characterized by clonal growth. It is these trees which are giving the red/orange/yellow covering which can be seen along the east side of the Sierra, at high altitudes or along stream beds. The pine with these is lodgepole pine, Pinus contorta ssp. mariana.

Mono Townsite (#007; T. 3N, R.26E, Sec. 30)

This was a pre-Bodie placer camp in Rattlesnake Gulch was founded in the 1850's.

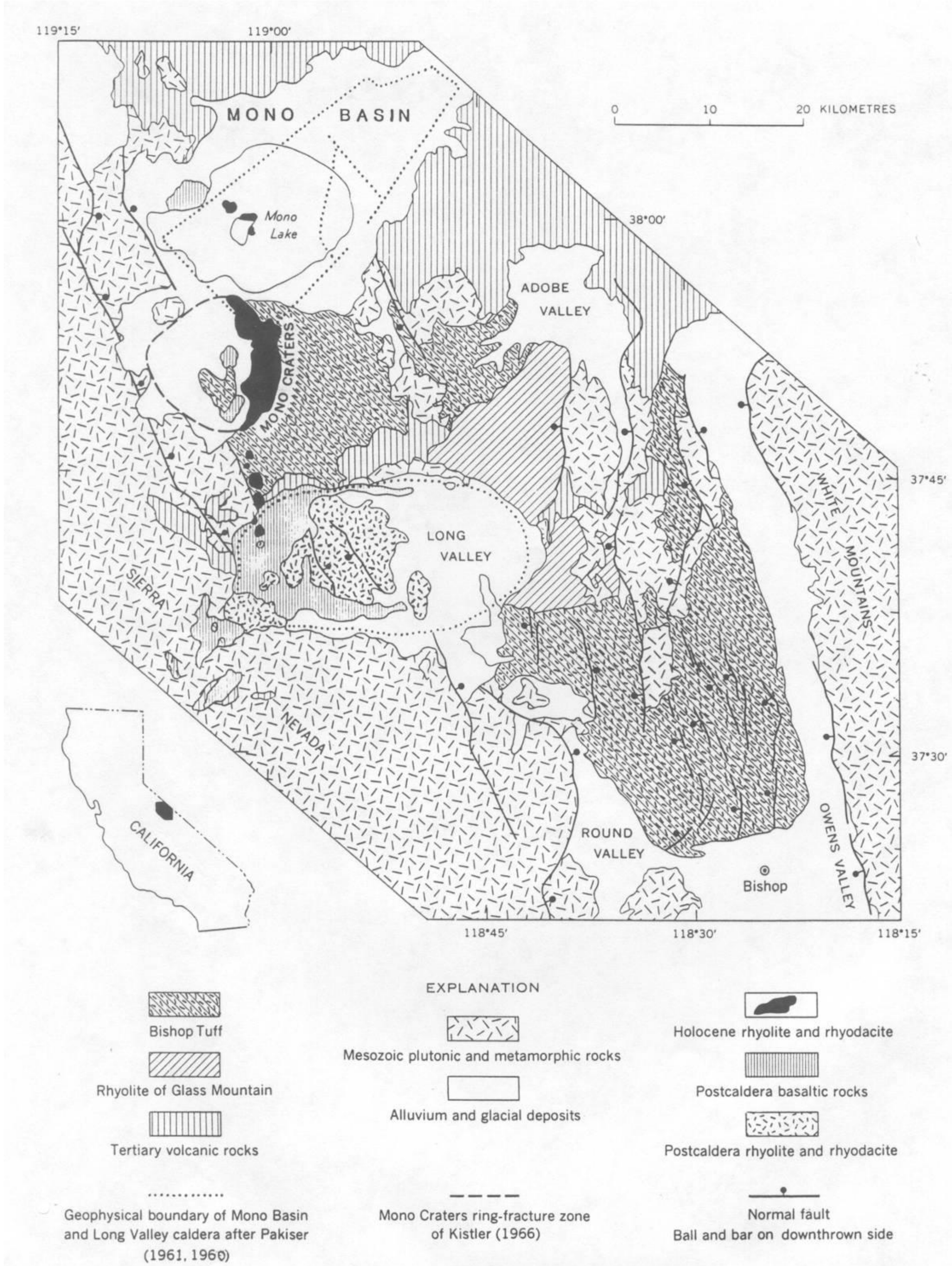
Lundy Canyon and Lake (#008; T2N, R25E, Sec. 14).

About 5.2 miles north of Lee Vining (#010), turn west onto Lundy Lake Road. Go another 12 miles. At this point, lateral glacial moraines of Tahoe (65, 0000 years) and Tioga age are displaced by a near-vertical fault. The scarp aligns perfectly with the range front fault described at Lee Vining. Lundy Canyon is the site of the Bodie Hydroelectric Plant. It was built to provide power to the mine and mill in 1870, and was the first hydroelectric power plant in California.

The Goleta, Spartain and Sterling mines on the north side of Lundy Creek near the mouth of the canyon are massive sulfide deposits containing copper, lead and zinc.

Brine Shrimp Hatchery (#009; T2N, R26E, Sec. 31).

The saline waters of Mono Lake are suitable for introduced oceanic organisms. The organism attracts birds. Mono Lake supports the second largest breeding colony in the world of California gulls, perhaps up to 10-15% of the world population of this species. Because they often nest on Negit and Pahoa Islands, their breeding patterns are significantly disturbed by land bridging of the islands during low water levels. Other birds which nest at Mono Lake include snowy plovers and caspian terns. Because its historical stability and high productivity have made Mono Lake a predictable source of superabundant food for birds, it is one of the major migratory stopover areas in the world for eared grebes, supporting about 750,000 individuals in and average year. The grebes undergo molt and accumulate fat reserves at the lake during their post breeding migration. It also provides one of the world's largest concentration points for Wilson's phalaropes, with an estimated 80,000 individuals using the lake every year, as well as a temporary stopping off point for an estimated 50-65,000 red-necked phalaropes.



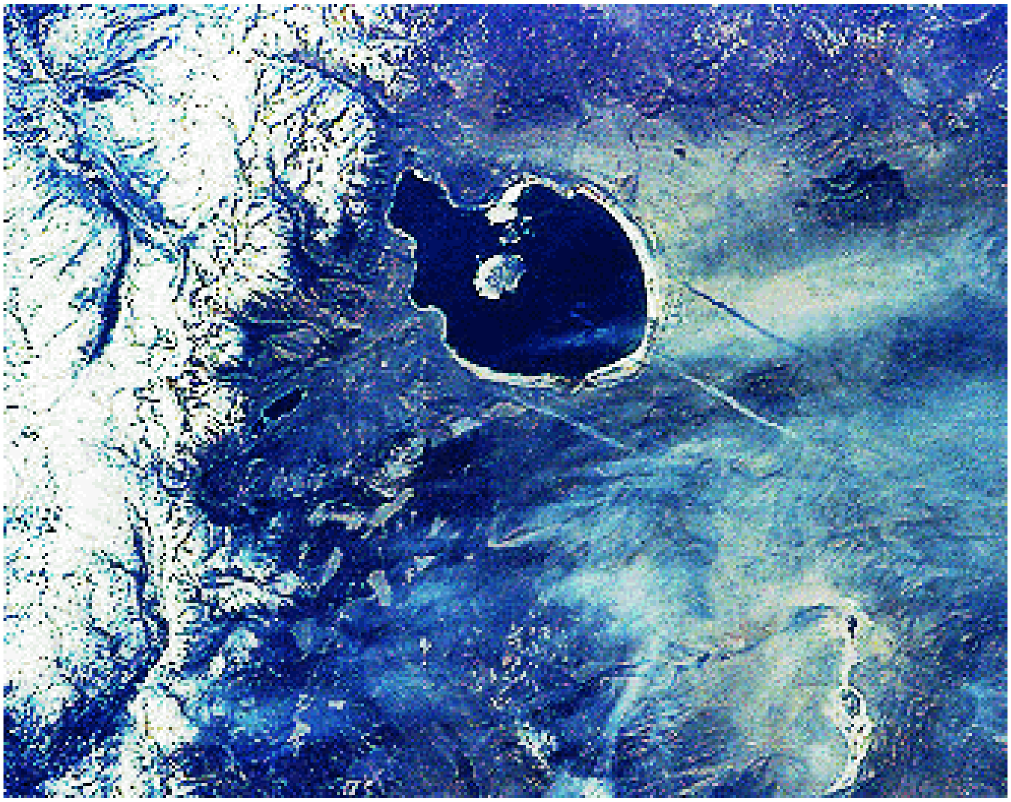
Geologic map of the Long Valley-Mono basin area (from Bailey, 1989).

Mono Lake Visitor's Center (#013; T.1 and T.2, R.26E and R.27E)

Lake. Photo by Gregg Wilkerson, 2008.

To the north of SR 120 is Mono Lake. Like Owens Lake, Mono Lake has shrunk considerably since the turn of the century due to diversions of Sierra Nevadan streams to the LA aqueduct. Over the past 20 years, much controversy has been raised over the issue of a declining Mono Lake. At low water levels a land bridge forms to Negit Island allowing predators access to migratory bird colonies.

Mark Twain spent six years in eastern California and Nevada during the 1860's, and his book Roughing It chronicles, among other things his visits to Mono Lake and Lee Vining, including a near-fatal trip he and his friend took to Pahoa Island.



Satillite view of Mono Lake. From NASA.

During much of the Pleistocene, Mono Basin was filled to overflowing with water. This ancient lake is called ancestral Lake Russell. The lake reached 7,200 ft elevation at its highest level. A prominent wave-cut bench surrounds Mono Basin at 7,000 ft. Water quantities sufficient to fill Lake Russell were due to increased levels of precipitation and, to a lesser degree, glacial meltwater.

On September 28, 1994, the State Water Resources Control Board voted 5-0 to amend water licenses held by the Los Angeles Department of Water and Power (LADWP) to allow the lake level to rise to 6,392 feet from its current level of 6374.8 feet. Since 1940, Mono Lake levels have been affected by diversions from tributary streams by the LADWP, causing the lake level to fall approximately 45 feet between 1941 and 1982, accompanied by a significant increase in salinity. Mono Lake is a closed saline water body which is highly productive biologically, supplying both food (brine shrimp and brine flies) and nesting habitat for abundant bird life. The major bird species which use Mono Lake (California gulls, eared grebes, Wilson's and northern phalaropes, and snowy plovers) are sensitive to changes in the availability of suitable nesting habitat and food availability.

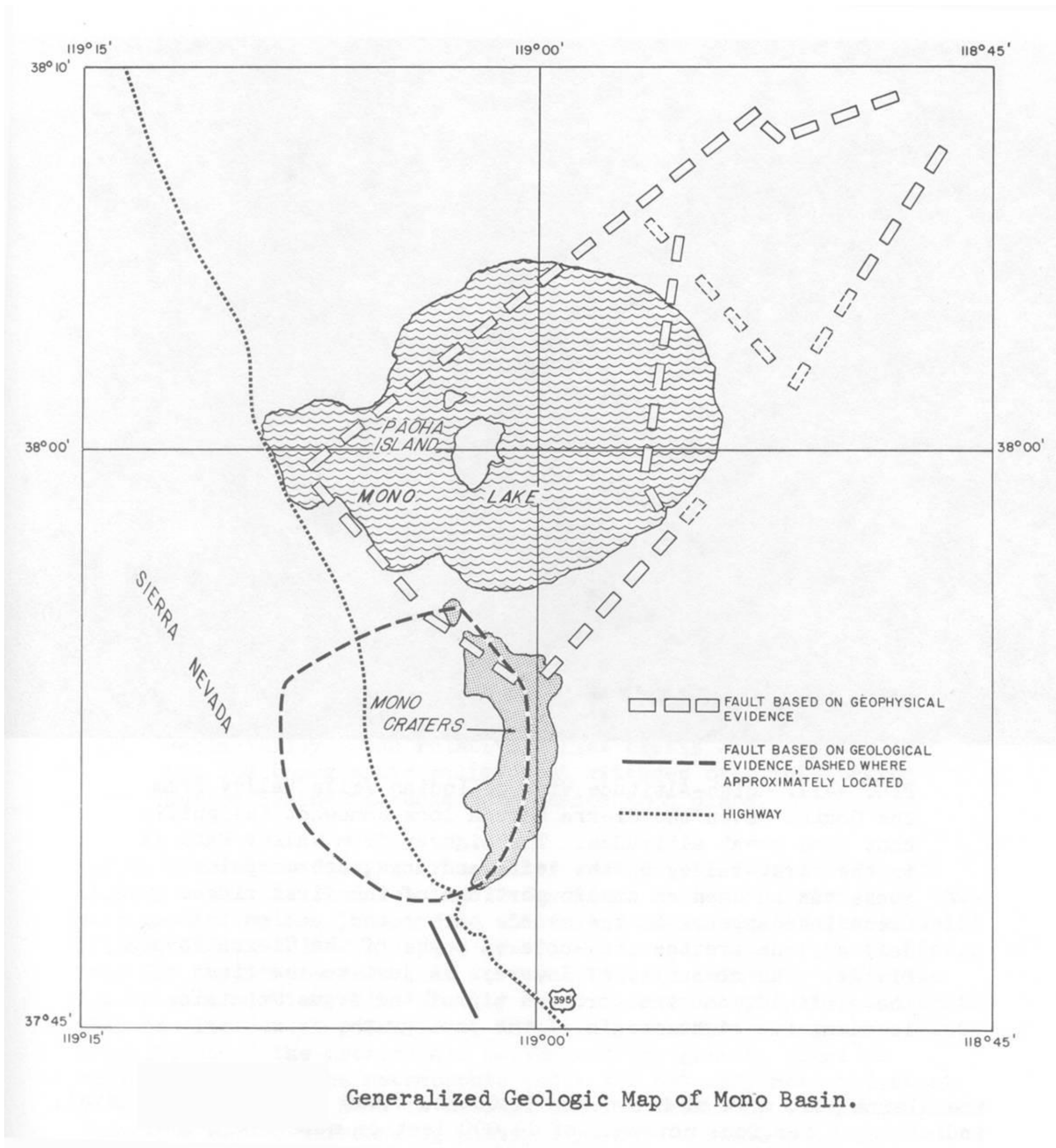
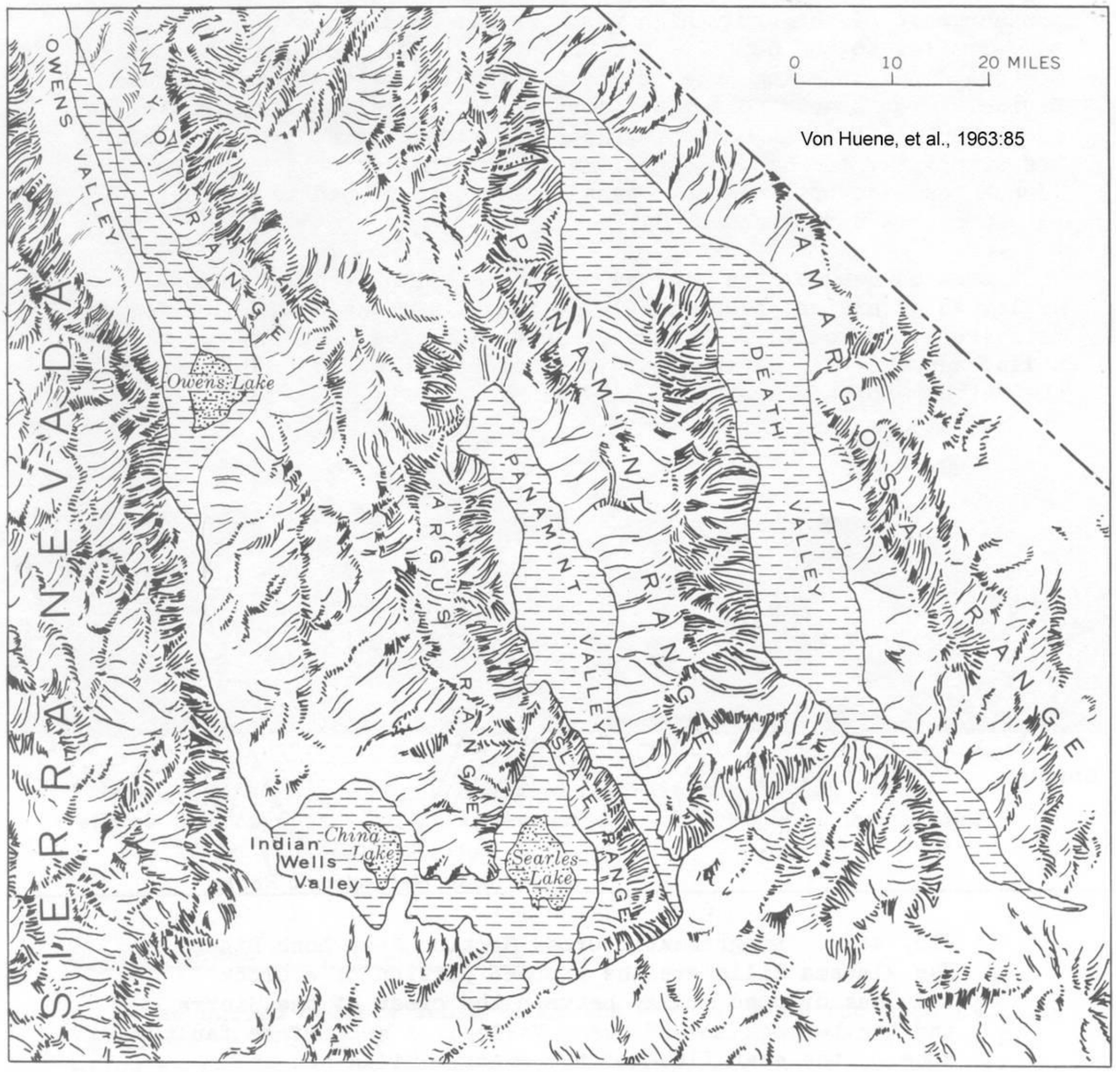


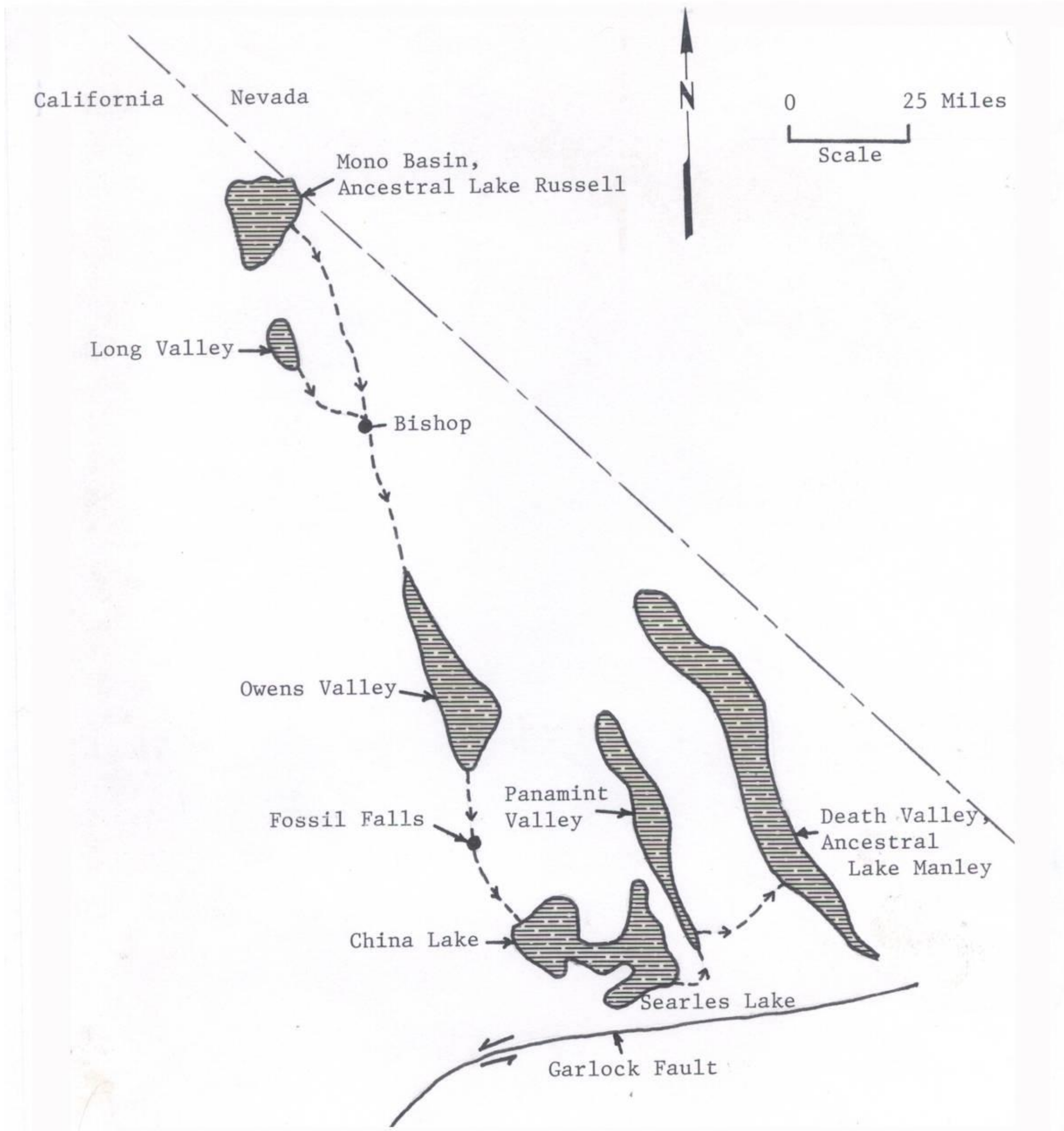
Illustration is from Von Huene, et al, 1963:77

The Pluvial Lakes of California

In the Pleistocene, Mono Lake overflowed via the Owen's River into Owens Lake (Lake Crowley is a 20th century invention of LADWP). Owens Lake overflowed into China Lake. China Lake overflowed into Searles Lake (Pamamint Lake) and Searles Lake overflowed into Lake Manley (Death Valley).



Generalized Map of Ice-Age Lake Overflow System.



Meltwater from Pleistocene alpine glaciers in the Sierra Nevadas filled many of the structural lows within the "basin and range" province. The lakes overflowed, creating streams now abandoned.

Negit and Pahoa Islands (#011 and #012, T.2N, R27E, Sec.30.)

From the Visitor's Center there is a good view of these islands. Negit is composed chiefly of volcanic cones and flows that predate the 220 year old 6,456 ft. shoreline. One small basalt flow on the island lacks the 6,456 ft shoreline, suggesting an age less than 220 years (Stine, 1984). The recent eruption has been compared to "Krakatoa East of Java".
Paoha Island is composed of uplifted lake bed sediments in a broad arch, possibly related to a shallow intrusive body. High temperature thermal springs near the island led to geothermal exploration in the 1970s. An exploration well was slant-drilled toward Pahoa

Island from the south shore of Mono Lake. No unusual temperature gradients were found, suggesting localized geothermal systems concentrated along faults and fractures. Pahoa Island has a wave-cut shoreline representing the historical (1919) Mono Lake highstand of 6,428 ft. But the island lacks evidence of the 220 year old 6,456 ft shoreline, suggesting uplift occurred between the late 1700s and late 1800s (Stine, 1984)

There used to be a Sanitarium on Negit Island. It had domed roofs with celestial motifs to aid recovery. During WWII, Pahoa Island was the site of nuclear blast simulations using conventional explosives

Lee Vining (#010; T1N, R26E, Sec. 9).

Lee Vining Park. Photo by Gregg Wilkerson, 2008.

Return westward on the dirt road to US 395. Turn north. The steep hill behind Lee Vining is a fault scarp and part of the Sierran Frontal fault zone. A short distance up the scarp can be seen the 7,000 foot Lake Russell shoreline. At its maximum, Lake Russell overflowed through the east side of Mono Basin, through Benton, and eventually into Owens Valley.

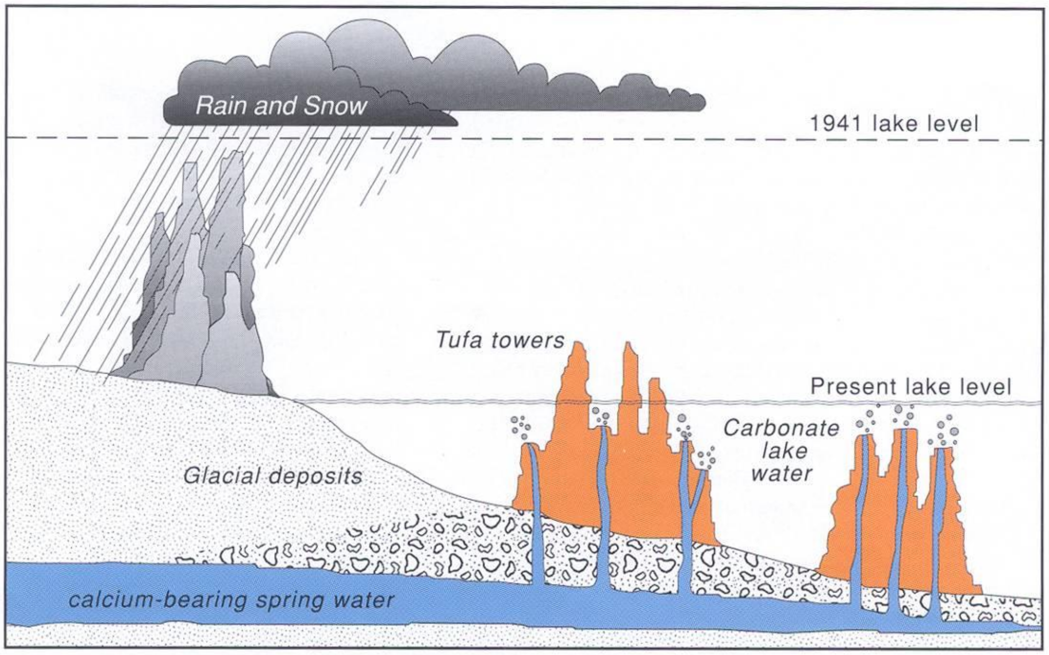
The Museum at Lee Vining has an interesting upside-down house.

Tufa Towers

(#015; T.1N, R.27E, Sec. 16.)

Mono Lake Tufa Towers. Photo by Gregg Wilkerson, 2008.

As we make our way back to SR 120, note the spectacular tufa towers near the Mono Lake shoreline. Having had no outlet since glacial (ancestral Lake Russell) times, Mono Lake has shrunk from its maximum largely due to evaporation. As a result, lake water has become increasingly saline and high in carbonates. Subaqueous fresh water springs, with calcium-rich water, occur on the lake bottom. The calcium and carbonate ions combine to form calcium carbonate, or limestone, around the spring. The towers grow until reaching the lake surface. The large numbers of towers at roughly the same elevation suggest a long-standing lake level at that elevation. The size and distribution of the towers are related to glacial stages and the corresponding high and low lake levels.



Origin of tuff towers from submarine hot springs.

CALCAREOUS TUFA FORMATIONS

Searles Lake and Mono Lake

TED RIEGER, Writer and Photographer

Photo 1. Tufa spires at South Tufa Area, Mono Lake Tufa State Reserve. Narrowed diameters on two spires at left indicate a former lake surface where tufa was reduced, possibly by waves or solution in lake water. *Photos by author.*

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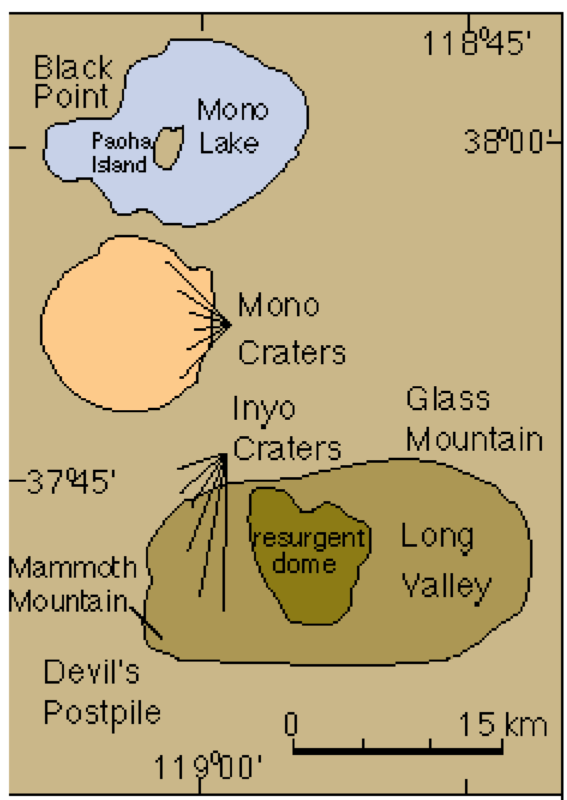
Mono Craters (T.1 and 2.N, R27E).

The prominent gray buttes south of SR 120 are Mono Craters. The "craters" are actually rhyolitic domes ranging in age from 600 to 35,000 years. The domes are aligned roughly north-south along



Location of main features of the Long Valley and Mono-Inyo Craters Volcanic Field. Based on Bailey (1983 and 1989).

a semi-circular ring fracture pattern that extends westward into the Sierra Nevada Range. This ring fracture pattern may portend a caldera similar to Long Valley. If so, Mono Craters would be on the caldera's east rim.

Mono Craters, photo by R.F. Hopson

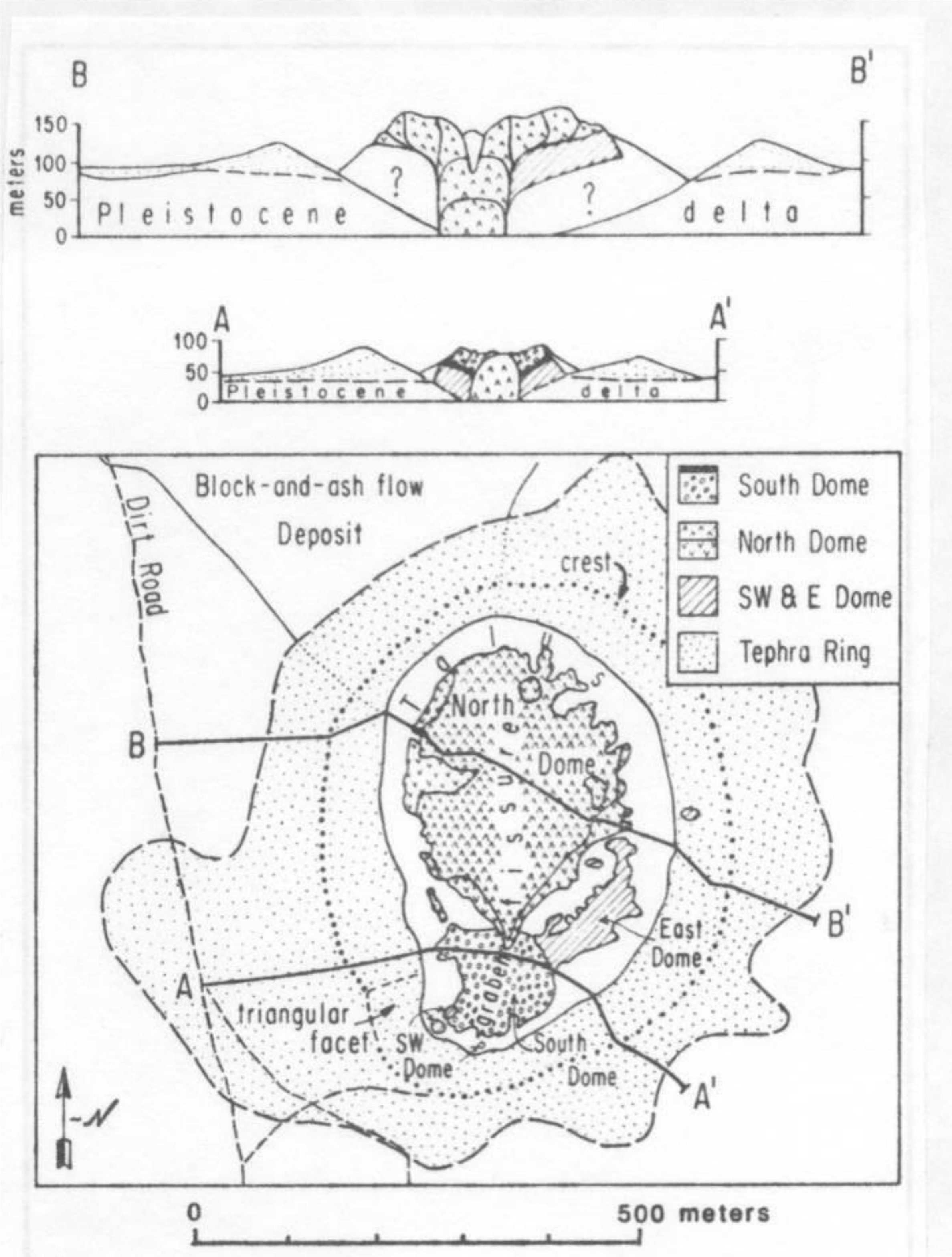
Von Huene, et al., 1963:104

General View of Mono Craters, Looking East.

Panum Dome or North Dome (#014; T.1N, R.27E, Sec.19).

About 3.1 miles from the US 395 turnoff, turn north from Route 120 onto an unpaved road marked "Panum Crater." At 600 years of age, Panum Dome is the youngest dome in the Mono Craters chain (Sieh and Bursik, 1986. Panum Dome is composed of obsidian flows surrounded by a precursory cone of airfall tephra. The tephra ring is about 2 mile in diameter.

The rocks of Panum Crater are the products of two eruptions from this vent (Sieh and Bursik, 1986. The previous eruption resulted in a similar dome. The earlier dome apparently exploded, sending an avalanche of large pumice blocks toward Mono Lake. Our next stop will be to look at this pumice block avalanche.



Generalized geologic map and cross sections of Panum Dome (from Sieh and Bursik, 1986).


Pumice and Obsidian at Panum Dome. Photo by Gregg Wilkerson, 2008

Pumice block avalanche at Panum Dome

(#014 T.1N, R.27E, Sec.18).

Leave the Panum Dome parking lot on a dirt road to the northwest. Proceed to the well-traveled dirt road that parallels the lake shoreline. Turn right (east) and go 0.4 mile. This is the toe of the block avalanche. Carved into the avalanche here is a wave-cut shoreline covered with beach cobbles (figure 15). The shoreline's elevation is 6,456 ft. Since no wave-cut benches occur higher on the 600 year old avalanche, we can assume this elevation is the highest lake level reached during the past 600 years (Stine, 1984. In fact, the 6,456 ft shoreline, radiocarbon dated at 220 years, is the highest level reached in the past 2,000 years (Stine, 1984). There are shoreline deposits on Pahoa Island that match those on the flanks of Panum Dome. But there are or corresponding shoreline features on Negit Island. This may indicate Negit Island is younger than the last shoreline-making episode.

Von Huene, et al., 1963:105

Plug Dome at North End of Mono Craters Chain. Mono Lake is along the upper margin. This dome has not grown out of its precursory crater.

Miner’s Memorial

At the junction of Highway 395 and 120 is the Miner’s Memorial. “On this site is the grave of the unknown prospector, a reminder of the great sacrifice made by our ancestors who explored and settled the western frontier and especially to the memory of each and all pioneers of Mono County who’s resting place is known only to God. May they rest in peace”

Map 05: June Lake Loop

U.S. Pumice Mine

(#017; T.1S, R.27E. Sec 21)

This mine produces block pumice that naturally fractures in blocks less than 3 inches in the shortest dimension. This peculiarity made to deposit locatable under the 1872 General Mining Law. Most pumice was exempted from the General Mining Law by the Materials Act of 1955.

Mono Basin and (A)eolian Buttes (T1S, R26E, Sec. 13 and 14).

South of the Lee Vining-Benton Junction, a sign along US 395 points out: "Eolian Buttes; the oldest volcanic formation in Mono Basin." Eolian Buttes is actually an outcropping of Bishop Tuff beautifully sculptured by wind erosion. At 710,000 years of age, the Bishop Tuff is far younger than the several million year old Tertiary age volcanic rocks of the Bodie Hills and Cowtrack Mountain areas.

Glaciation	Age (years)
Neoglacial	2-3,000
Tioga	10-20,000
Tenaya	25-40,000
Tahoe	60-130,000
Mono Basin	87,000
Donner Lake	250,000
Casa Diablo	400-500,000
Sherwin	750,000
McGee	2.5-3.2 million

Major Sierran glaciations. Those referred to in this report are highlighted. Ages are from Malcolm Clark, USGS, Personal Communication, 1990

June Lake (#018; T2S, R26E, Sec. 11).

To the south of June Lake rises a glacial lateral moraine of Tahoe and Tioga age. The lakes around the loop were formed by glacial scouring action. June Lake is drained by Reverse Creek which flows westward toward the mountains. This relationship is an anomaly found nowhere else in the Sierra Nevada Range. There have been several attempts to explain Reverse Creek. The most plausible explanation is the differential erosion by glaciers of rocks of differing hardness.

Reverse Creek (#020; T.2S. R.26E, Sec.25)

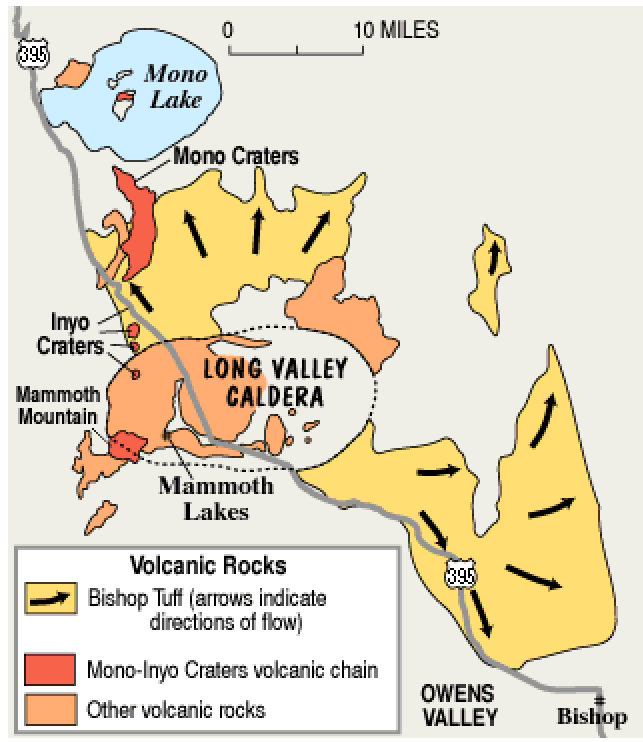
The water direction flows in the reverse direction of most streams in this area due to damming by the moraines

Silver Lake Resort **(#021; T.2S, R.26E, Sec. 8).** A great river of ice coming from the Sierra Nevadas split, partly occupying the Reverse Creek drainage and partly in this valley containing Silver and Grant Lakes. At this location, glacial ice may have this valley to a level 1000 ft above the floor. Polished granitic surfaces testify to the great erosional power of glaciers. Subdued actuate terminal moraines from receding Tioga glaciers can be seen in Grant Lake on the north end of the June lake Loop.

Grant Lake (#022; T.1S, R.26E, Sec. 21)

This lake is contained within lateral moraines and a terminal moraine forms its natural dam.

Map 06: Long Valley Caldera



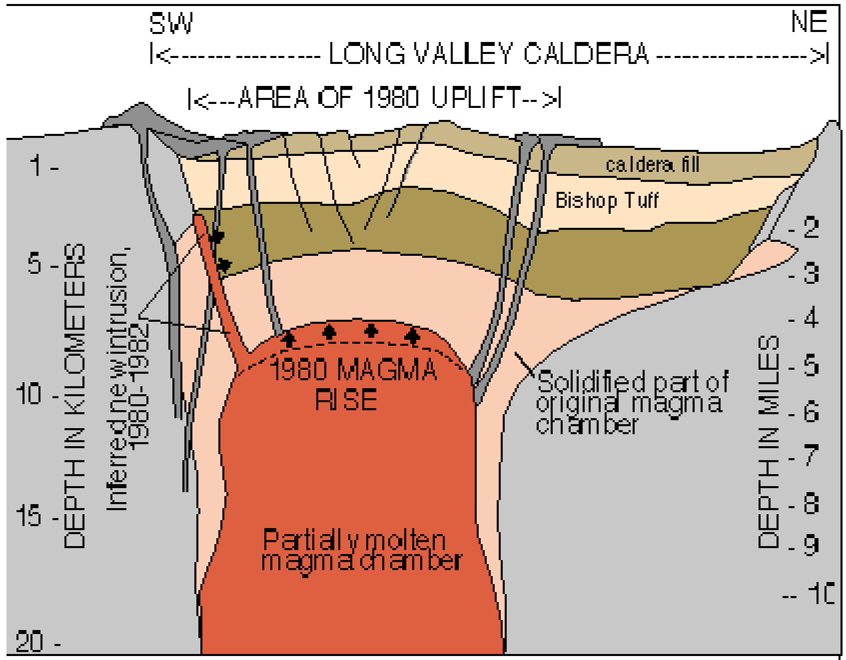
Long Valley Caldera

(Map 04-C, T. 1, 2 and 3 S, R. 27, 28, 29, 30 E)

Long Valley is completely bounded by faults in a semicircular pattern and filled with more than 10,000 feet of sediment. Geophysical and hydrological evidence suggest the collapse caldera is underlain by a shallow intrusive body. Eruptions of rhyolite and basalt since the collapse have formed a resurgent dome surrounded by several "moat" flows (Bailey, 1989).

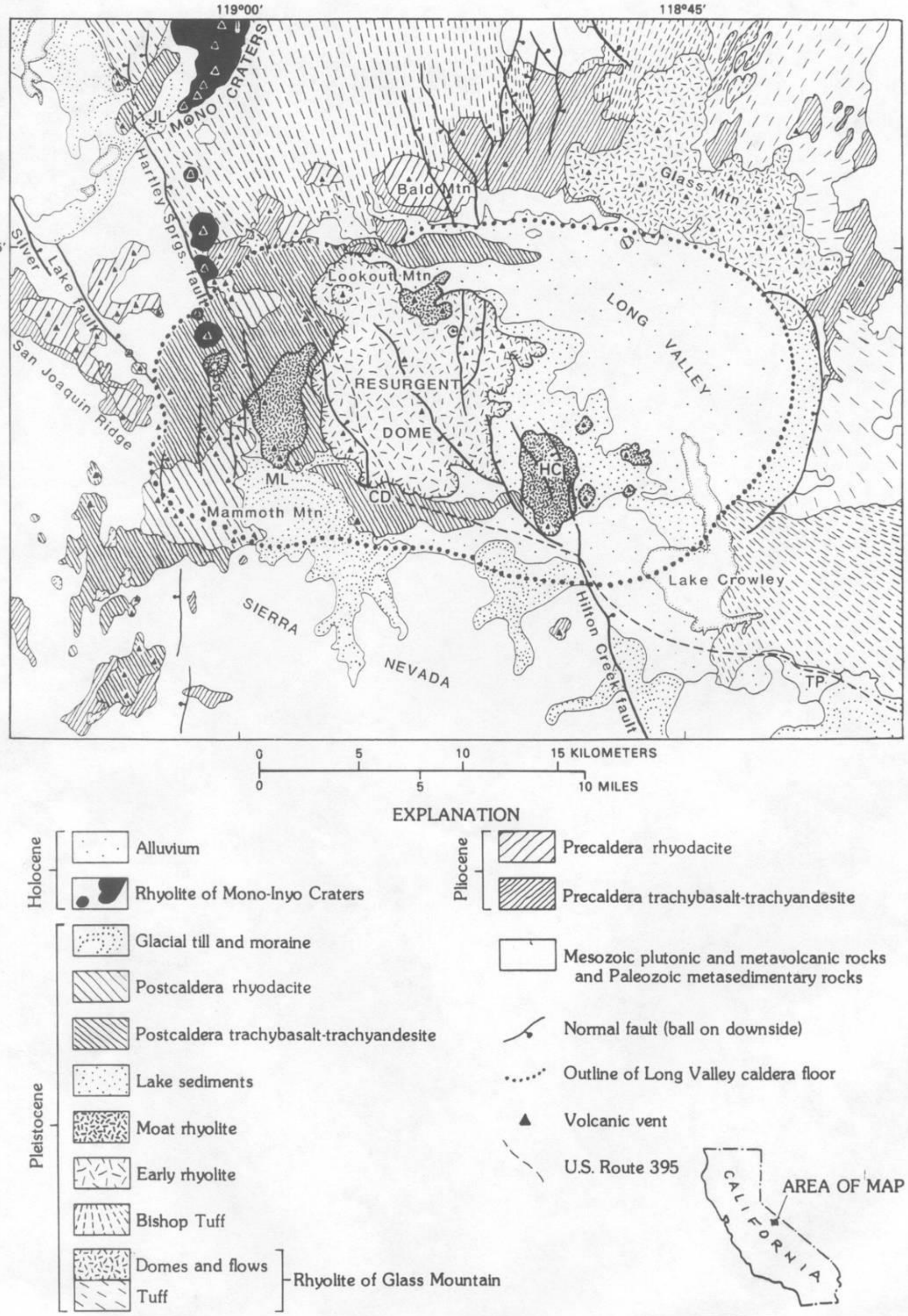
Long Valley Caldera is a depression in eastern California that is adjacent to Mammoth Mountain. The valley is one of the largest calderas on earth, measuring about 32 kilometers long (east-west) and 17 kilometers wide (north-south). The elevation of the floor of the caldera is 6,500 feet (2,000 m) in the east and 8,500 feet (2600 m) in the west. The elevation of the walls of the caldera reach elevations of 9,800-11,500 feet (3000-3500 m) except in the east where the wall rises only 500 feet (150 m) to an elevation of 7,550 feet (2,300 m) (http://en.wikipedia.org/wiki/Long_Valley_Caldera, April 3, 2007).

Long Valley was formed 760,000 years ago when a huge volcanic eruption released very hot ash that later cooled to form the Bishop tuff that is common to the area. The eruption was so colossal that the magma chamber under the now completely destroyed volcano was significantly emptied to the point of collapse. The collapse itself caused an even larger secondary eruption of pyroclastic ash that burned and buried thousands of square miles. Ash from this eruption blanketed much of the western part of what is now the United States. Geologists call topographic depressions formed in this manner calderas. (http://en.wikipedia.org/wiki/Long_Valley_Caldera, April 3, 2007).



Cross-section through the Long Valley caldera showing inferred subsurface relations of the magma chamber and 1980-1982 new intrusion of magma along the south wall of the caldera. Based on Bailey (1983).

The old caldera keeps us on our toes by periodic earthquake swarms in the Mammoth Lakes area. In May, 1980, a sequence of damaging M 6.0 earthquakes was accompanied by nearly two feet of uplift in the resurgent dome area (Bailey, 1989. This activity led the USGS to conclude that a major volcanic eruption was imminent. The eruption did not occur, but the warning upset the local economy, particularly real estate, for some time. Long Valley has since quieted, although micro-earthquake swarms continue. On May 6-7, 1990, a swarm of 300 earthquakes occurred over a 24 hour period, the largest of M 3.5. This activity may be evidence for movement of magma in a chamber beneath the resurgent dome.



Geologic map of the Long valley caldera (from Bailey, 1989).

West Side of Long Valley Caldera

Crestview and Glass Creek

(#019; T.2S, R.27E, Sec. 28).

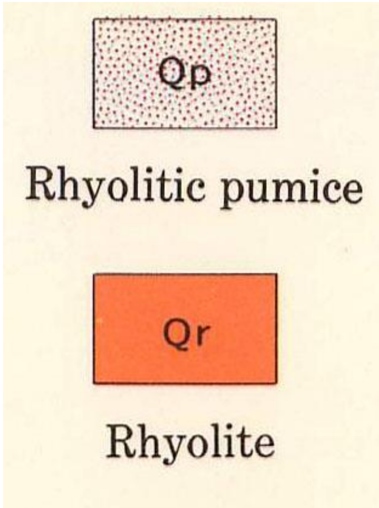
At Crestview is a road leading up Glass Creek to ***Obsidian Dome (#023)***, a spectacular volcanic glass formation. Glass Creek gets its name from the obsidian pebbles in its streambed.

Map 07: Obsidian Dome

Obsidian Dome (#023; T.2S, R.27E, Sec. 20).

This dome is less than 600 years old. It is a beautiful mass of black volcanic glass, rhyolite and pumice. Mineral collecting is not permitted by the Forest Service in this area or critical environmental concern. Jumper Campground is 0.3 miles northwest of the dome. On the road to the Dome we drive up Deadman Creek and in Section 33 cross an unusual olivine-bearing quartz latite (Qoq). Normally olivine and quartz do not coexist.

The obsidian (Qr) is rhyolitic and surrounded by rhyolitic pumice (Qp) of Hubart and Rinehart, 1986.



North rim of Long Valley Caldera

Continuing south on US 395, the highway climbs a grade near Crestview. This grade marks the ***northern rim of the Long Valley Caldera (#024)***. Very fresh-appearing obsidian domes (Inyo Domes) to the west of US 395 were quietly erupted about 600 years ago. Enter Mammoth Scenic Loop, despite its name, was built to provide an escape route for Mammoth Lakes in case of natural disasters such as earthquakes and volcanic eruptions. After about 3 miles, turn right onto a dirt road leading to a parking area for Inyo Craters (Site 8-1, see discussion below).

Map 08: Inyo Craters

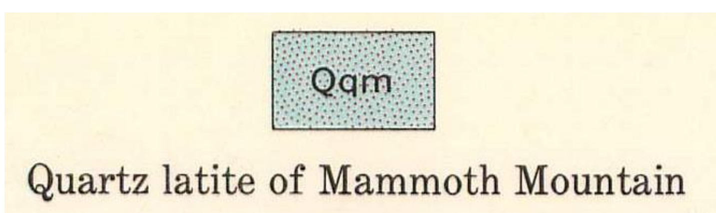
Inyo Craters (#025; T.3S, R.27E, Sec. 17)

Mono and Inyo Domes. , photo by R.F. Hopson

From the parking lot, a quarter-mile walk takes us to the craters. There are three craters here, all aligned a northerly axis. We are viewing the two southern craters, termed "North" and "South." These pits are about 600 ft in width and 180 ft deep. The craters are the result of violent steam explosions. Rising molten magma contacted groundwater causing phreatic explosions. The three explosions occurred at roughly the same time, possibly within hours or days (Bailey, 1989. An age of 710 years for the craters is based on age-dating of a shattered log in South Crater. Rhyolitic volcanos may have three stages of growth (see figure above). Stage 1 has explosive eruptions which form as shallow crater rimmed by a tephra ring. Stage 2 witnesses the emplacement of a rhyolite dome in the crater which may fill the crater and engulf the tephra ring. If extrusion continues, the dome may form a colulee in Stage 3 which spills over the tephra ring as a thick stubby lava flow (Putnam, 1938)

South Crater is one of three phreatic explosion craters termed Inyo Craters. The craters formed about 700 years ago when rising molten rock contacted groundwater, causing great steam explosions.

Notice the difference in water color between the two pits. Bailey (1989) attributes the yellowish color of South Crater to suspended sulfur. The brown color of North Crater is due to organic material. These craters and the Inyo Domes to the north align along what may be a fracture zone responsible also for Mono Craters. Mono Craters may also be situated on the eastern rim of a ring fracture system that extends westward into the Sierra Nevada Range. Stop #026 is atop Quartz Latite of Mammoth Mountain (Hurbert and Rinehart, 1965).

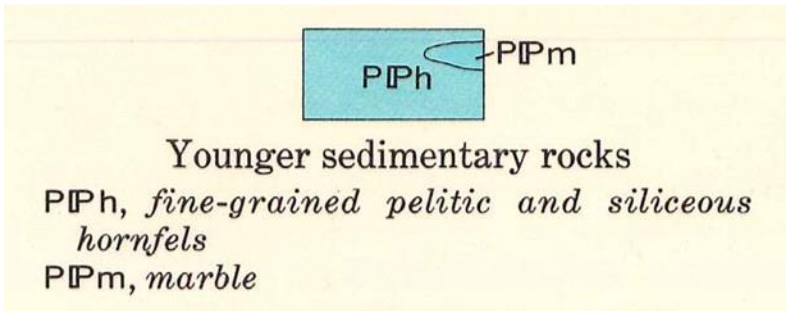


Map 09: Devil's Post Pile

Minaret Summit and Vista Point (#028; T.3S, R.26E).

Below Minaret Summit is the deeply glaciated valley of the Middle Fork San Joaquin River. This river formerly drained large areas to the east. Uplift along Sierran frontal faults over the past 3 million years has beheaded the stream from its eastern beginnings

(Bailey, 1989). On the western horizon are the Minarets, Mt. Ritter, and Banner Peak. This range is composed of Cretaceous age metavolcanic rocks that weather to crags and spires. Michael Minaret is shown in the photo. This stop is near a roof pendant of Permian-Pennsylvanian marine rocks (PlPm).



Minaret Summit. Photo from [https://farm6.staticflickr.com/5506/14590421601_d27e41c3c6_b.jpg accessed June 15](https://farm6.staticflickr.com/5506/14590421601_d27e41c3c6_b.jpg), 2019

On the western horizon are the Minarets. The rocks composing these mountains are various types of metamorphosed volcanic rocks of Cretaceous age that weather to crags and spires.

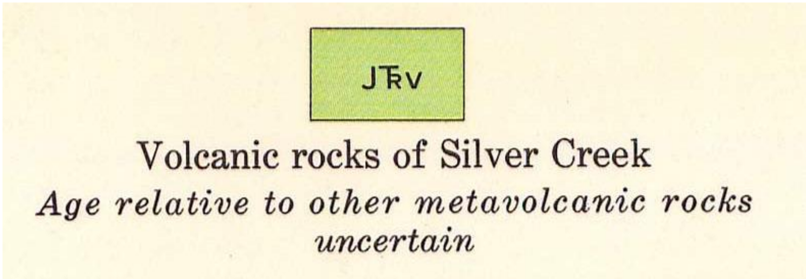
To the southeast is Mammoth Mountain, covered with ski lifts. This volcano sits on the rim of Long Valley Caldera and is about 400,000 years old (Sharp, 1965). Long Valley Caldera collapsed about 710,000 years ago covering this region with pinkish Bishop Tuff. The tuff composes the Volcanic Tableland near Bishop.

Mammoth Mountain is currently dormant. But ongoing micro-earthquake swarms focused beneath the mountain keep seismologists on their toes. Emissions of gas and steam from vents in the mountain result in a semi-permanent cloud during winter.

Continue on down the hill toward Devils Postpile, 1,660 below.

This feature is on the “Scenic Drive” to Mammoth Lakes on Route 203. Along this route is a point of interest called "Earthquake Fault." The large linear chasm exposed here is neither a fault nor is it known to be associated with earthquake activity. It is an open crevice in a lava flow that has split apart laterally, a type of displacement not normally associated with faulting. The crevice is deep enough to trap snow in the bottom year round.

The “Scenic Drive” on Highway 203 road was built to provide an escape route for Mammoth Lakes in case of natural disasters such as earthquakes, landslides and volcanic eruptions. The series of damaging M 5-6 earthquakes in May of 1980 led the USGS to issue an alert advising that a volcanic eruption was imminent. This over-reaction was believed to have been a ploy to get additional funding for the USGS. Although no eruption occurred, the alert had adverse affects the local economy. Signs on café doors read “Geologists not welcome”. On the switchback leading down from the Minarets to Devil’s Post Pile we cross through the Jurassic-Triassic Silver Creek volcanics



Devil's Post Pile National Monument (#030; T.4S, R.26E)

Devil's Post Pile. Photo by Gregg Wilkerson, 2008.

This National Monument is on the floor of the Middle Fork San Joaquin River. A short walk brings us to the "postpile," a spectacular columnar-jointed basalt flow. Under certain conditions, lava flows shrink as they cool, forming hexagonal vertical jointing. Although columnar jointing is common in basalt flows, Devil's Postpile is unique in the perfectly formed, uniform, and long columns. Because lava flows cool gradually from the ground up, such uniform column development over much of the flow's thickness is very unusual.

The age of this flow is 100-200,000 years (Bailey, 1989). Since the time of its eruption, the valley has been glaciated several times, the latest being the Tioga glaciation of 10-20,000 years ago. Evidence for ice overriding the basalt flow can be seen by taking a short hike to the top of the flow. Here, hexagonal columns were polished and striated by the heavy, rock and sand-laden glacial ice. Many columns fell in the May, 1980 earthquakes.

Six-sided columns polished by glacial ice at Devil's Post Pile (Photo by Mark Milliken)

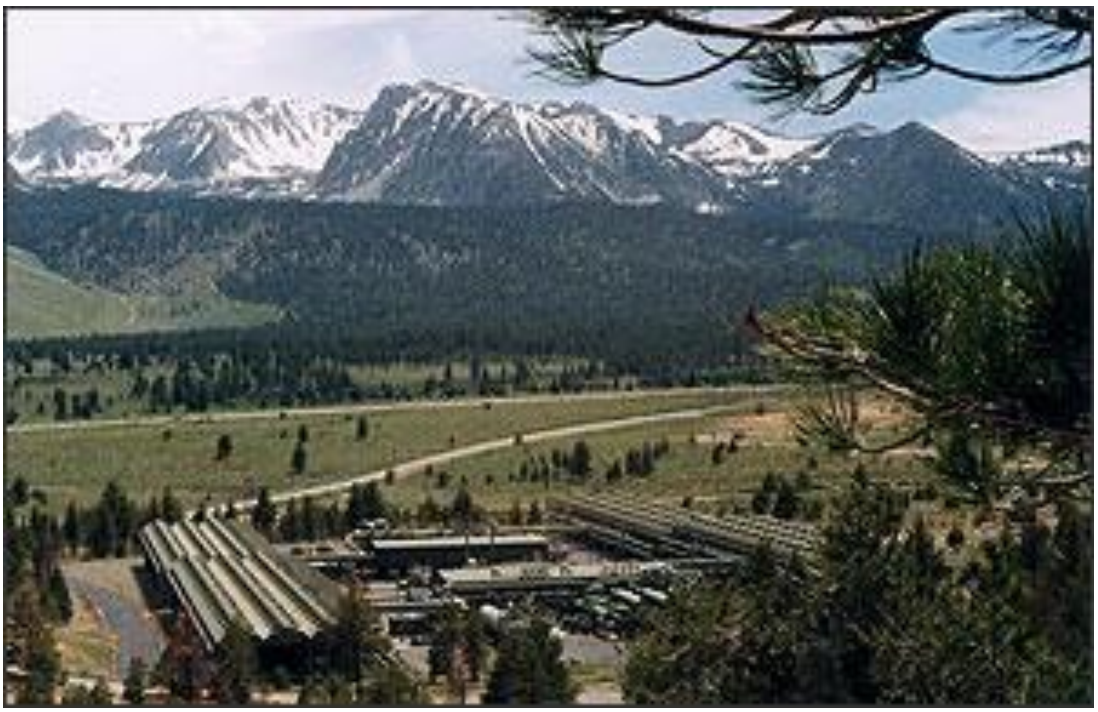
North of Devil's Post Pile is ***Minaret Falls (#029)***.

Minaret Falls

Casa Diablo Hot Springs and Pacific Lighting Geothermal Power Plants (#031; T.3S, R.28E, Sec. 32)

Turn off US 395 at the Mammoth Lakes (SR 203) exit. Turn right at the stop sign. We are at Casa Diablo Hot Springs. Turn left immediately and proceed 3 miles to the Mammoth Pacific geothermal generating plant.

There are 3 power plants at this site. A 10 megawatt plant is on private land and two 15-megawatt plants are on Forest Service property. The electricity is generated from geothermally heated groundwater. The reservoir is about 600 ft deep with a temperature



Casa Diablo Geothermal Plan. Photo by Gregg Wilkerson, 2008

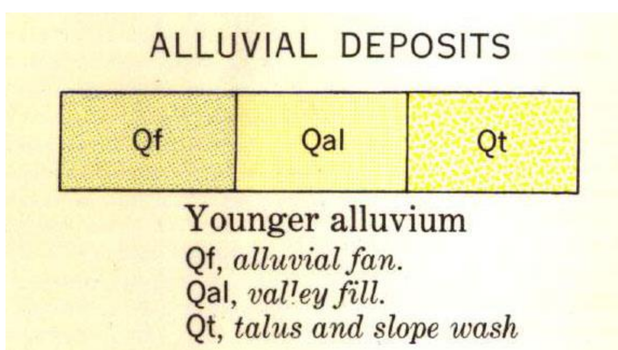
of 340 degrees F. (there has been some concern of late over dropping reservoir temperature. Monitoring wells are being drilled). Hot water heats isobutane in heat exchangers, then is reinjected back into the reservoir. The isobutane passes through generator turbines and then is condensed by large air cooling fans. This process greatly reduces steam plumes. Interestingly, some local residents are opposed to geothermal steam plumes, but not to the denuding of forests to make ski areas.

To the west of us is the town of Mammoth Lakes with Mammoth Mountain in the background. Mammoth Mountain is a volcano that sits on the rim of Long Valley Caldera and is about 400,000 years old (Sharp, 1976). It erupted some 300,000 years after the collapse of Long Valley caldera. The volcano is currently dormant, but ongoing micro-earthquake swarms focused beneath the mountain keep seismologists on their toes. Emissions of gas and steam from vents in the mountain result in a semi-permanent cloud during winter.

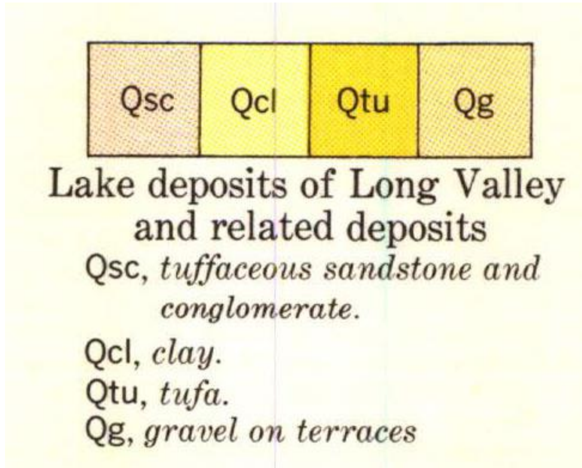
Map 10: Hot Creek Loop

Hot Creek. Photo by Gregg Wilkerson, 2008.

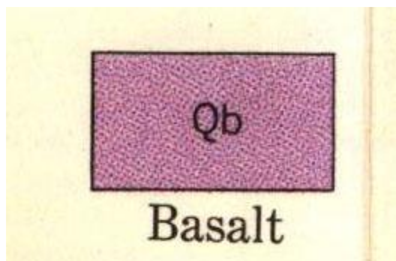
The major rock types encountered in the Hot Creek Loop area as mapped by Rinehart and Ross (1964) are:



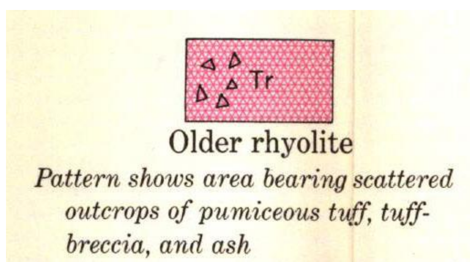
Quaternary Alluvial Deposits



Quaternary Lake Deposis of Long Valley



Pleistocene Basalt



Pliocene older rhyolite

The origin of Hot Creek was described by Maloney (1993):

Hot Creek has eroded a canyon some thirty meters deep across the Hot Creek rhyolite flows located in the southeastern moat of Long Valley Caldera. Maloney (1987) showed that the canyon formed by headward erosion resulting from spring sapping along hydrothermally altered fractures in the rhyolite, and the capture of Mammoth Creek. This analysis ignored the continuing uplift of the central resurgent dome. Reid (1992) concluded that the downward erosion of the canyon must have kept pace with the uplift. Long Valley Lake occupied the caldera until 100,000 to 50,000 years before present. The elevation of the shoreline, determined by trigonometric leveling, is 2,166 m where the creek enters the canyon and 2,148 m on the downstream side of the rhyolite. The slope of the strand line is about equal to the stream gradient. The hill was lower and the stream gradient less at the time of stream capture. Rotational uplift increased the stream gradient which increased the rate of downward erosion and formed the V-shaped canyon (Maloney, 1991, abstract)

East Side of Long Valley Caldera

Hot Creek (#032; T.3S, R.28-29E).

This is a popular recreation area with several hot springs which feed the creek. It has been closed by the Forest Service because some swimmers have been scalded.

Hot Creek Kaolinite Mine (#033; T.3S R.28E, Sec. 15).

This is a site of intense hydrothermal alteration of volcanic material is associated with faulting.

Lipshie (2001:76-77) describes this site this way: The kaolinite mine is operated by Standard Industrial Minerals, which has local headquarters at its mill in Laws, north of Bishop. The company has been quite accommodating to geologists in the past, and to maintain this good relationship you should reciprocate their courtesy and consideration. If you plan to visit this stop, contact the company in Laws and let them know when you would like to visit and then get their permission. The mine operators don't object to visitors, but when the mine is being actively worked, they would prefer to have visitors come on week-ends, when they won't interfere with the mining operations. If you visit the pit, respect their equipment and other property. (Adding this last statement should be unnecessary, but unfortunately it isn't, Lipshie, 2001:76-77)

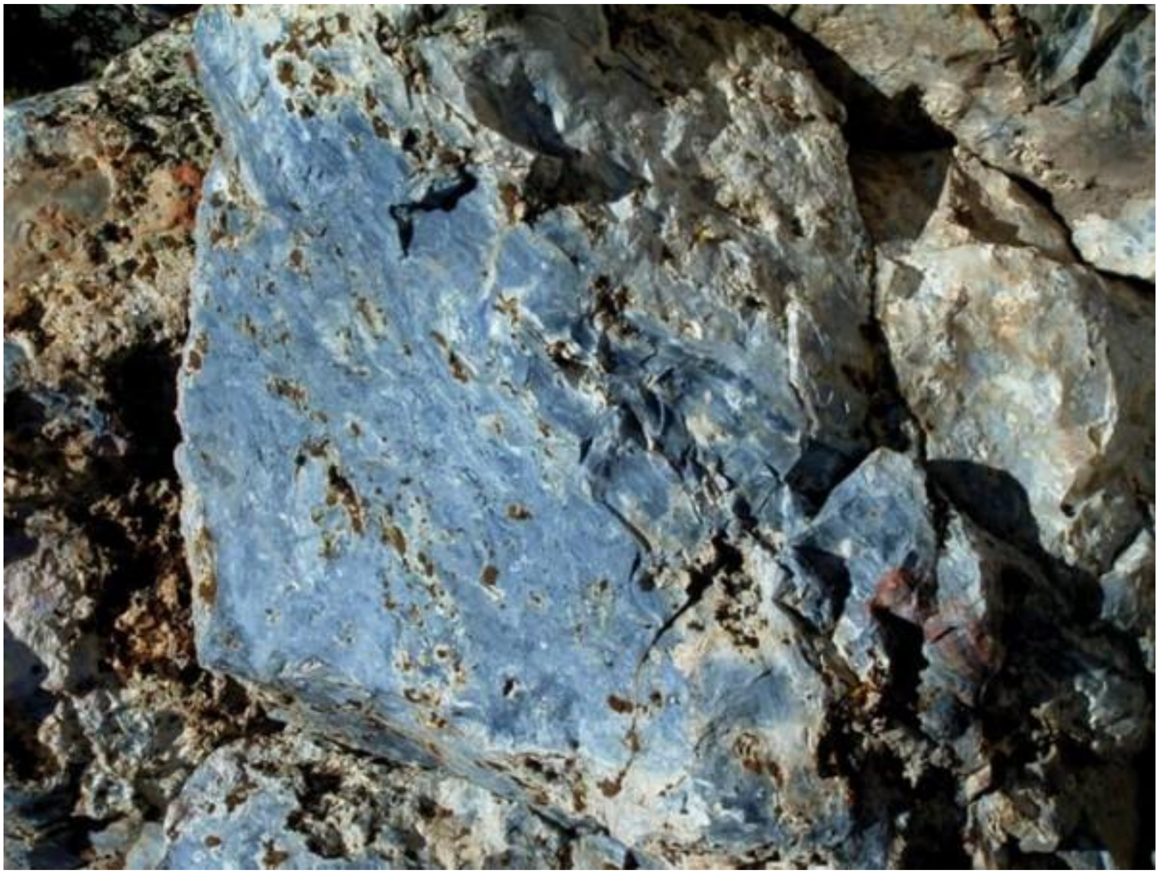
The kaolinite of Little Antelope Valley formed by hydrothermal alteration of Pleistocene tuffaceous lakebeds and, to a lesser extent, older rhyolite. The degree of alteration is partly a function of porosity, the more porous tuffaceous lakebeds (30 to 45 percent porosity) being more pervasively altered than the rhyolite (about 10 percent porosity) (Cleveland, 1962, p. 20). The clay deposit occurs on the east side of a north-trending graben. Hydro-thermal fluids probably migrated upward along north-trending normal faults that cut the resurgent dome. Alteration to kaolinite occurred before depo-sition of the youngest lakebeds (Cleveland, p. 21). The clay has relict bed-ding where derived from tuffaceous lakebeds and relict flow banding where derived from older rhyolite; these relict features are quite evident in the pit walls. The clay is cut by numerous thin veins of opal (not gem quality, unfortunately), and the deposit has a caprock of opaline claystone that ranges in thickness from 3 in. (8 cm) to 20 ft (6 m). Traces of alunite are also present locally but are not economically significant (Lipshie, 2001:76-77).

The Huntley Prospect first began production of kaolinite clay in 1952, and in its first seven years of operation the mine produced 16,300 tons of clay (Cleveland, 1962, p. 7). The mine, formerly owned by Huntley Industrial Minerals of Bishop, was acquired by Standard Industrial Minerals of Youngstown, Ohio (western regional office in Reno), in 1962. The company got a patent on 180 acres of their claim in 1976. Kaolinite is hauled by truck from here to the company mill at Laws, where it is ground into powder and shipped to customers. Kaolinite from this prospect has been put to many uses: as filler in paint, plastic, rubber, and paper; whitener in paint and Portland cement; and an additive in paper coating, ceramics, insecticides, pharmaceuticals, and stucco (Cleveland, p. 25-26; Standard Industrial Minerals, undated fact sheet; Lipshie, 2001:76-77).

Blue chert *(*#145; T.3S, R.28E, Sec. 23)

This site is described by Lipshie (2001:78-80) as follows: This low knoll consists mostly of siliceous sinter deposits formed by chemical precipitation of silica around hot springs. If you collect samples here, please try to collect in moderation; don't try to cart off the entire deposit. Many such knolls are scattered throughout this vicinity, but they generally are much smaller than this one, typically measuring about 50 ft (15 m) across and standing 3 to 10 ft (1 to 3 m) above the surrounding lake sediments. At this particular locality, the chert has a particularly striking grayish blue (5 PB 5/2) color; at other localities, the color is typically light bluish gray (5 B 7/1). The deep blue color seems to be restricted to this knoll, as far as I can tell. I don't know why this attractive coloration is found only at this outcrop but assume that it is related to chemical conditions that were unique to this locality during the precipitation of the deposits (Lipshie, 2001:78-80).

Long Valley chert deposits generally are massive and well indurated, as at this outcrop, but some deposits in the caldera are thinly laminated and poorly to moderately indurated. Some sinter masses contain subangular pebbles of rhyolite about 0.4 in. (1 cm) across. The widespread occurrence of siliceous sinter masses on the margin of the caldera indicates that hot spring activity was once much more widespread than it is today, especially around the southern and eastern margins of the resurgent dome (Lipshie, 2001:78-80).



Blue chert of Long Valley Caldera. Photo from http://a52.idata.over-blog.com/600x450/3/02/18/95/actu-8/Actu-9/Actu-10/actu-13/Dossier-16/Dossier-23/bluechert---geology-csupmona.edu.jpg accessed June 15, 2019

Two samples of blue chert from this locality were dated by the $^{230}Th/^{234}U$ disequilibrium method, and ages of ≥260,000 years and ≥310,000 years were determined (Sorey and others, 1991, p. 232). This indicates that the blue chert deposit probably formed around 300,000 years ago. Siliceous sinter from a chert deposit along Little Hot Creek was also dated by the same method, and ages ranging from >210,000 years to >310,000 years were found (Sorey and others, 1991, p. 233). The radiometric ages suggest that a surge of hot spring activity occurred along the eastern margin of the resurgent dome around 300,000 years ago. This activity would have been synchronous with the eruption of the 0.3-m.y.-old moat rhyolite east of the resurgent dome (Lipshie, 2001:78-80).

The blue chert is currently being considered as a candidate for an open-pit gold mine. In the early 1980's, gold mineralization was identified in the chert deposit, and in 1994, Royal Gold, Inc., of Denver began an intensive exploration program that involved extensive drilling. They found that gold mineralization is widespread in the sedimentary and pyroclastic deposits that underlie the site. They also concluded that mineralization by hydro-thermal fluids occurred about 400,000 years ago, before the extrusion of the 0.3-m.y.-old moat rhyolite (Steininger, 1999, p. 320). Note that this age is older than the age determined by Sorey and others (1991) for the chert, which also was deposited by hydrothermal fluids; this inconsistency remains to be resolved (Lipshie, 2001:78-80).

Chemical analyses by Royal Gold determined that the deposit has an average gold content of 0.018 ounce per ton of ore, which translates to an estimated reserve of 1.3 million ounces of gold (Steininger, 1999, p. 321). If that low level of gold content is representative of the entire deposit, the company would need to mine over 55 tons of ore to produce one ounce of gold. The base of the upper, oxidized zone of the gold deposit extends in places to depths in excess of 300 ft (90 m), with depths averaging 150 ft (45 m) (Steininger, p. 321). Two-thirds of the gold deposit is within the oxidized zone (Steininger, p. 321), and the company proposes to extract the ore by open-pit mining. The proposed mining operation has aroused environmental concerns, and local opposition is likely to hinder or halt development of the proposed open-pit mine. From a personal standpoint, I am rather fond of the blue chert and would greatly regret its obliteration by a mining (or any other) operation (Lipshie, 2001:78-80).

Sandia Laboratory's Research Well (#034; T.3S, R.28E, Sec.21; 37° 40' 47" N, 118° 54' 31" W).

The Department of Energy conducted a research program to study geothermal energy development in the resurgent dome of Long Valley Caldera. Drilling began on June 15, 1998 and ended September 15, 1998.
The well cores several hundred feet every other year. Plans were to drill to 25,000 feet or until the temperature reached 400°C. The Sandia program tested drilling technology in high temperature regimes. Drilling was done every odd-numbered year, with scientific analysis of data done on even years.

The Sandia Labs website relates that:

A scientific drilling effort has been proposed to deepen an existing 2-km deep hole to a target depth of between 3.5 and 4.0 km. The borehole is located near the center of the resurgent dome of Long Valley Caldera in east-central California. Deepening the well has been accomplished by continuous H-size coring (2.5" diameter core) to the target depth. The ICDP with 80% matching funds from the California Energy Commission (CEC), the U.S. Department of Energy (DoE), and the U.S. Geological Survey (USGS) supported the project. Long Valley Caldera has shown sustained unrest since 1980 characterized by recurring earthquake swarms, inflation (dome-shaped uplift) of the resurgent dome, and increased levels of fumarolic activity accompanied by high concentrations of carbon dioxide (CO_2) gas in the soils around Mammoth Mountain on the southwest margin of the caldera. The existing 2-km-deep hole is located directly over the center of inflation in the resurgent dome (total uplift since 1979 is 60 cm and the current uplift rate is 2-3 cm/y) and at the northern margin of the earthquake swarm activity (http://www.icdp-online.de/contenido/icdp/front_content.php?idcat=710; April 3, 2007).

Sandia Laboratory Well. Photo from ICDP, 2007

Scientific goals of the drilling were to shed light on the nature of processes at midcrustal depths in areas of active deformation by drilling into the seismogenic volume beneath the resurgent dome and

- obtaining a complete core section for studies of the petrology, fracture state, and pore fluids,
- determining the temperature profile below the hydrologic convective regime that appears to control temperature shallower than 2 km,
- determining the state of stress within the seismogenic volume, and
- Modeling present-day hydrothermal conditions.

In the long term, the hole is being used as a geophysical observatory with a number of down-hole instrument packages to track processes occurring directly above the inflating magma chamber driving unrest in the caldera (http://www.icdp-online.de/contenido/icdp/front_content.php?idcat=710; April 3, 2007).

Sorley and others (1991) said this about the hydrothermal activity in Long Valley:

Data collected since 1985 from test drilling, fluid sampling, and geologic and geophysical investigations provide a clearer definition of the hydrothermal system in Long Valley caldera than was previously available. This information confirms the existence of high-temperature (> 200°C) reservoirs within the volcanic fill in parts of the west moat. These reservoirs contain fluids which are chemically similar to thermal fluids encountered in the central and eastern parts of the caldera. The roots of the present-day hydrothermal system (the source reservoir, principal zones of upflow, and the magmatic heat source) most likely occur within metamorphic basement rocks beneath the western part of the caldera. Geothermometer-temperature estimates for the source reservoir range from 214 to 248°C. Zones of upflow of hot water could exist beneath the plateau of moat rhyolite located west of the resurgent dome or beneath Mammoth Mountain. Lateral flow of thermal water away from such upflow zones through reservoirs in the Bishop Tuff and early rhyolite accounts for temperature reversals encountered in most existing wells. Dating of hot-spring deposits from active and inactive thermal areas confirms previous interpretations of the evolution of hydrothermal activity that suggest two periods of extensive hot-spring discharge, one peaking about 300 ka and another extending from about 40 ka to the present. The onset of hydrothermal activity around 40 ka coincides with the initiation of rhyolitic volcanism along the Mono-Inyo Craters volcanic chain that extends beneath the caldera's west moat (Sorley and others, 1991, abstract))

Fish Hatchery (#036; T.4S, R.28E, Sec.12)

This facility is operated by the California Department of Fish and Game and supplies fish to all of the eastern Sierra Nevada.

Whitemore Hot Springs (# 037; T4.S, R.29E, Sec. 6)

This hot spring is the site of a now-abandoned resort.

Convict Lake (#035; T. 4S, R.28E, Sec. 23)

This lake is formed by terminal and lateral moraines. It is formed by faulting.

The story of Convict Lake is told at http://www.convictlake.com/history-5.htm (April 4, 2007):

The year was 1871. The Civil War had ended only six years before. The country was still suffering the effects of this divisive time in its history. The Eastern Sierra was a wild and lawless place. It was populated by miners, outlaws, rustlers, gangs comprised of former Confederate and Union soldiers and wild bands of Indians. Of course, a few honest ranchers and citizens were in the area as well! It was a quite a Sunday on September 17, until 29 desperate prisoners overpowered the guards of the Nevada State Penitentiary in Carson City, NV, stole weapons and horses, and made their escape. These convicts were some of West's worst the characters; murderers, rapists, train and stage robbers, and horse thieves. Once the prisoners had broken out, they split up. One group of 13 headed south. Along the way they robbed several locals and stole more weapons, horses and provisions. Six of this band separated and continued south to escape the posse they were sure was following them. Their leader was a convicted 22 year old murderer named Jones. He had lived and worked in Mono and Inyo Counties for some time and was familiar with the territory. One of the other convicts was named Roberts, an 18 year old convicted stage robber. He had grown up in Long Valley, near Crowley Lake. Because Jones and Roberts knew the area, their plan was to cross over the Sierra Mountains to the western slope where they would be safe from pursuit. Hell bent for leather, they headed towards the Mammoth area, always fearful that a posse was on their tail. Unknown to them the original posse chasing them got tired and gave up within 2 days. They were only being trailed by a resident they had robbed along the way who was set on getting his stolen horses and guns back.

Of course the convicts didn't know they were almost in the clear! Sometime during the day of September 19th, a rider was catching up to the convicts. They feared it was the posse and planned an ambush. Instead of the law, they ambushed an innocent 18 year Pony Express rider named Billy Poor. It was his first time delivering the mail. Once they had him, they couldn't let him go because he would tell others about them. They couldn't hold him hostage because he would slow them down. Jones, with Morton standing by, cold bloodily shot and killed young Billy Poor just north of Bridgeport. Capturing and killing Billy Poor was a huge mistake because now the Convicts had murdered a local Mono County citizen. They had violated the community and the citizens were bent on revenge! Not realizing what they had brought down on themselves, they continued their flight south towards Benton Crossing, a settlement just east of here at the foot of the White Mountains, with plans to turn westward toward what was know as Monte Diablo Creek and Lake; then across the Sierra Nevada to safety. By Friday morning, September 22 a new posse of 10 men, lead by Sheriff Robert Morrison, and guided by an Indian deputy named Mono Jim, was hot on their trail. By Friday evening the posse caught up with the convicts camped by, what was then called, Monte Diablo Creek. They decided to spend the night at a nearby ranch and to confront the convicts in the morning.

The convicts had little to eat for some days, and awoke very early that fateful Saturday morning. Jones, the ring leader, and 2 others went toward Monte Diablo Lake, what is now Convict Lake, to look for food. All they could find were Rose Hip berries, which, if you either take a horseback ride with us or a hike, you will see them, still growing all along the North Shore of the lake.

While Jones and the two others were looking for food, the posse went up Monte Diablo Creek towards the eastern end of the deep cut where Convict Lake now lies. The Convicts were waiting in hiding on the south side of the creek. In the first exchange of gunfire, the convict named Roberts was shot in both his shoulder and foot and crawled off into the undergrowth. The other two convicts, named Morton and Black kept firing, which drove the posse, except Sheriff Morrison, back into the woods. All of a sudden, Morrison had a clear shot at Black, he pulled the trigger, the pistol cap exploded, but the gun didn't fire. Black turned and shot Morrison in the side. Then he walked up to Morrison and shot him in the back of the head, killing him instantly. Morton and Black then took some pistols and horses left behind by the fleeing posse and headed up the canyon to get away.Soon they came upon the Indian Deputy Guide named Mono Jim. He mistook them for the posse and called out to them. It was a fatal mistake! They chased him down and Morton shot him through the eye, killing him straight away. Morton, Black and Roberts hooked up and fled south towards Bishop. It was never known how Jones and the other two Convicts escaped the shootout. Jones, the leader who, by killing Billy Poor, brought the local posse's hornet's nest onto them, disappeared and was never heard from again.

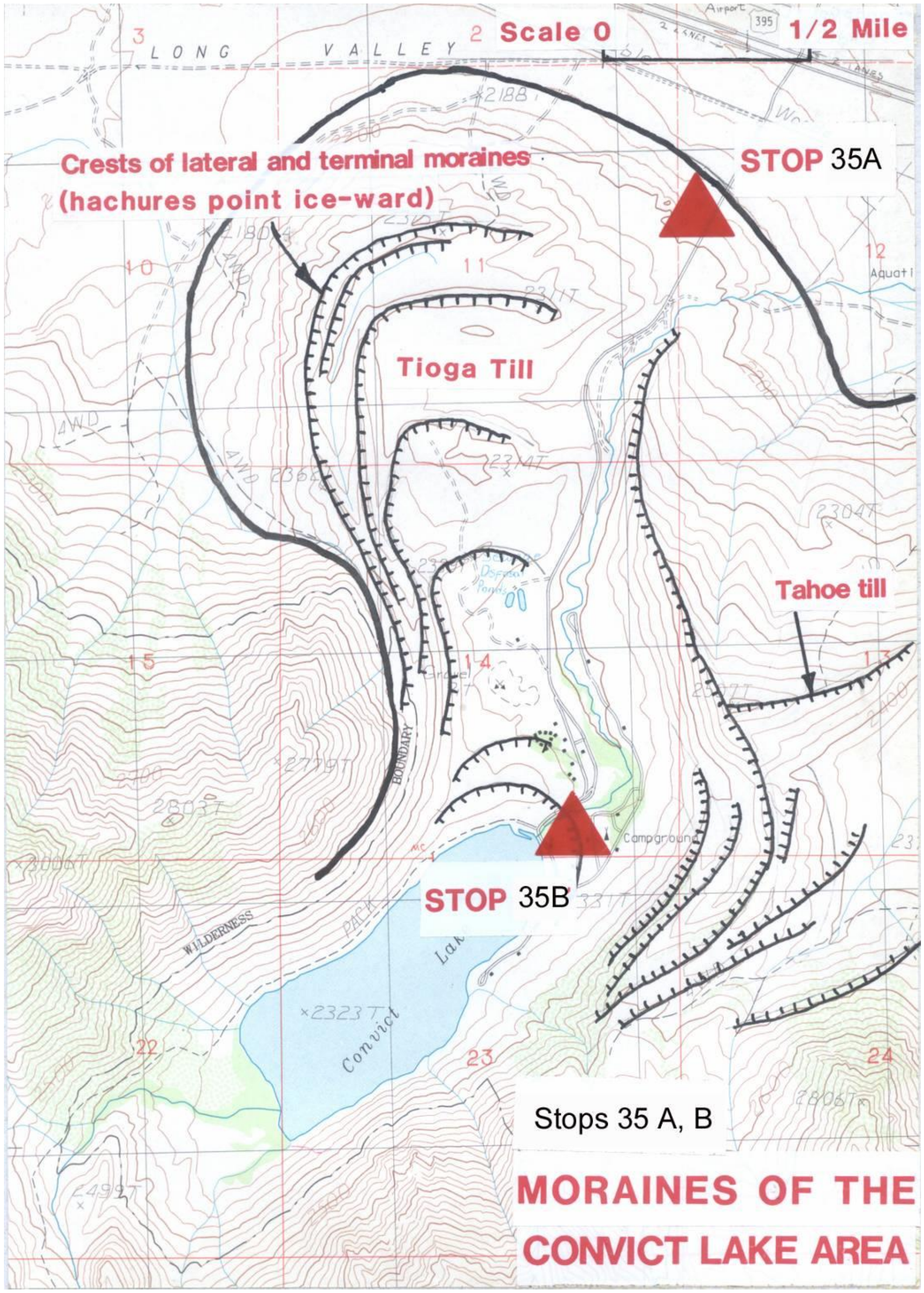
The other two with him were eventually captured on the east side of the White Mountains, the range you can see from Convict across the Caldaria to the East, and returned to prison in Carson City. A new posse formed to track down and take revenge on Morton, Black and Roberts for killing Sheriff Morrison and Deputy Mono Jim. It was September 27th when they finally captured Morton and Brown just north of Bishop. Roberts was nowhere to be found. Black was wounded during the capture, but survived. Morton and Brown claimed Roberts had killed Morrison, which caused the posse to resume their search for Roberts. Two days later they caught up with Roberts. When he confronted Morton, it was obvious to the posse that Morton and Black had killed Morrison and Mono Jim and that Jones, with Morton, had killed Billy Poor.

On October 1st the prisoners were loaded on a wagon and started for the trip back to the jail in Carson City. All of a sudden the wagon was surrounded by a large group of vigilantes. Without any resistance, the guards turned over the prisoners to the vigilantes. They took the convicts to a nearby cabin and held a trial. After only a short deliberation, the votes were taken. The "jury" agreed that Morton and Brown should be hung at once and that Roberts, the boy stage robber, would be sent back to jail. By November 15th, 18 of the original 29 convicts had been captured, Morton and Brown were hung, and Jones and 9 others were still at large. The escape had caused a great deal of controversy and dispute throughout southern Nevada, both Inyo and Mono Counties in eastern California.

Even today we can see the results from this historical event. Monte Diablo Creek and

Lake were re-named to Convict Creek and Lake. The 12,000 foot plus mountain overlooking Convict Lake was re-named Mount Morrison in honor of the slain Sheriff. The smaller mountain in front of Morrison was named Mono Jim after the slain Deputy guide. There are also several other less well know, and somewhat disputed, outcomes from this momentous adventure. And as students of history know, sometimes actual events are confused with wishful thinking; hence the birth of Urban Legends.The young boy, Billy Poor who was murdered in cold blood by Jones was greatly missed by his family and neighbors. In his honor, it is claimed, a sandwich was invented: The Poor Boy.

If you have the opportunity, enjoy summer lunch at the Convict Lake Restaurant to experience this fabulous sandwich in honor of one of Mono Counties' heroes. (Some locals even insist that the Hero Sandwich was also named after Billy; go figure!)



The song, "I Shot the Sheriff, I didn't Shoot the Deputy?" supposedly has its roots in the Convict Lake shootout! When the vigilantes took Morton and Brown to hang, they said anything and everything they could to save their rotten hides.

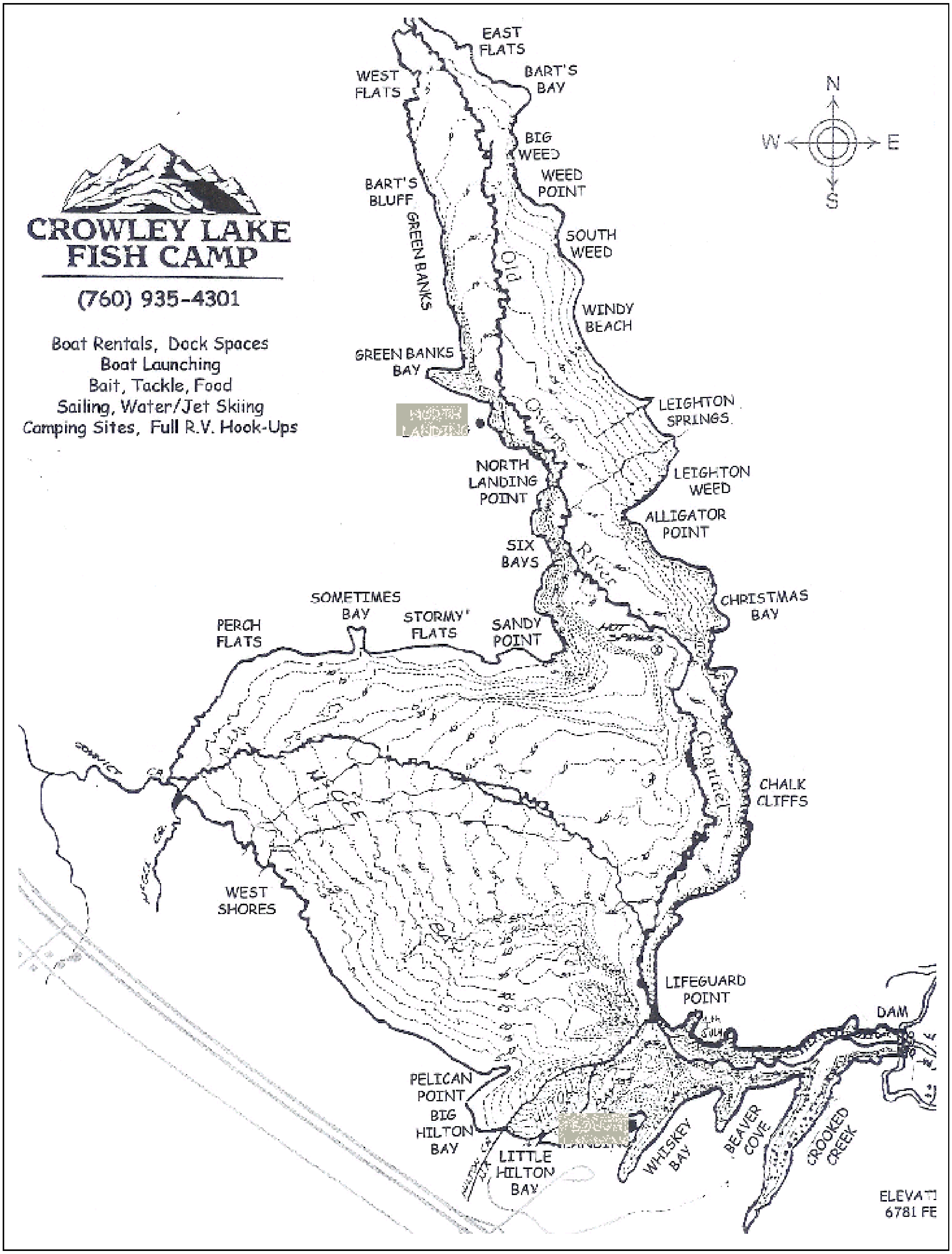
They kept pleading and whining that they were innocent. It is told that many years later when Bob Marley heard this story, it became his inspiration for this ageless song.

So you see, the name Convict Lake has some very deep roots in facts, and maybe even in a little fiction.

Convict Lake lies in a U-shaped depression carved by the latest glaciers of Tioga age. Glacially scoured Laurel Mountain in the background is composed of highly distorted Ordovician marine rocks.

Lake Crowley and Owens Gorge (#037; (T.4S, R.29E)

This lake is formed by a dam that blocks the outlet to Owen’s River Gorge. It was an important site in the Owens Valley water wars. On December 6, 2006 the LA Department of Water and Power was ordered to divert 5% of the annual flow of the Owens River out of the aqueduct and back into Owens Gorge to support the trout fishery.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BIG WEED
WEED POINT
BART'S BLUFF
GREEN BANKS
SOUTH WEED
Old Owens River Channel
WINDY BEACH
GREEN BANKS BAY
LEIGHTON SPRINGS
NORTH LANDING POINT
LEIGHTON WEED
ALLIGATOR POINT
SIX BAYS
CHRISTMAS BAY
SOMETIMES BAY
STORMY FLATS
SANDY POINT
PERCH FLATS
CHALK CLIFFS
WEST SHORES
LIFEGUARD POINT
DAM
PELICAN POINT
BIG HILTON BAY
LITTLE HILTON BAY
WHISKEY BAY
BEAVER COVE
CROOKED CREEK
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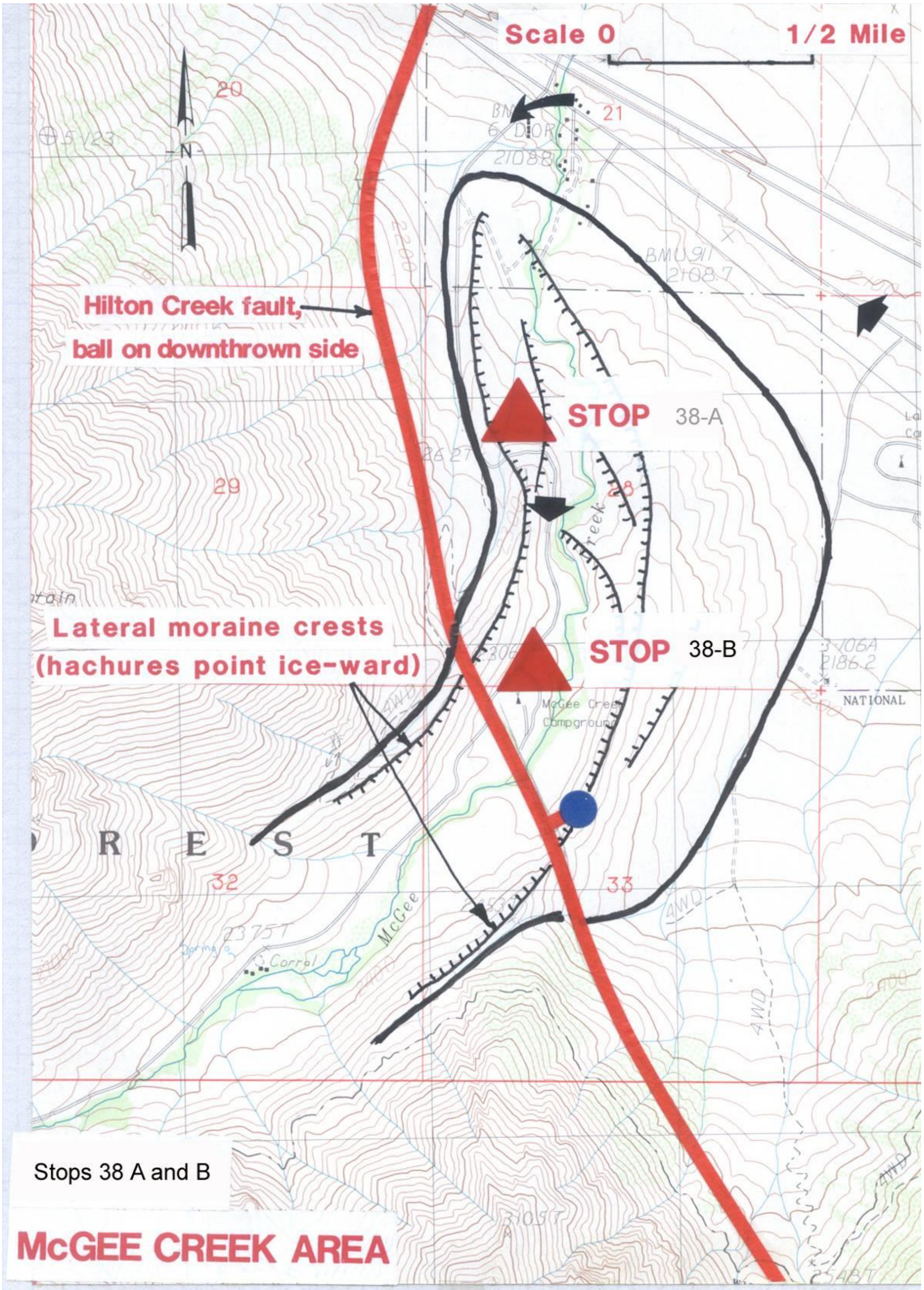
McGee Creek Lateral Moraine (#038; T.4S, R.29E, Sec. 28)



Fault scarp offsetting Tahoe age glacial moraines along McGee Creek. The scarp is about 60 feet high and aligns perfectly with the Sierran range front.

Below the McGee Creek Campground, we are standing on the crest of a lateral moraine of Tioga age. The relatively young age of the till is suggested by the large number boulders exposed on the surface. Glacial ice filled the valley of McGee Creek to at least this elevation during the Tahoe and Tioga glaciations. This stop affords a panoramic view of eastern Long Valley and Crowley Lake. Crowley Lake dates back to 1941 when Long Valley Dam was built. Crowley Lake was named after Father John J. Crowley who promoted tourism in the eastern Sierra Nevada region after LADWP's acquisition of water rights depressed local economies. Father Crowley was killed in an automobile accident near Olancha in 1941. Continue up this road to the McGee Creek Forest Service campground.

FIG. 4-30. Detail of Fault That Cuts Moraine at Mouth of McGee Canyon. Von Huene, et al., 1963:102

Hilton Creek Fault at McGee Creek (#038; T4S, R29E, Sec.33)

The base of a □50 ft high fault scarp is at a grove of aspen trees at the south of the campground. The fault plane is perfect alignment with the range front, and is sub-parallel to the Wheeler Crest fault. The western lateral moraine has been cut with surgical precision. As with other faults we've looked at, there was probably more than one seismic event associated with this displacement. Even so, the very planar fault scarp surface on the western lateral moraine suggests rapid movement over a relatively short time.

At the Forest Service campground in McGee Creek, high above and to the south is Esha Canyon, a "hanging valley". In alpine glaciation terms, a hanging valley once contained a tributary glacier feeding a much larger main glacier. Upon retreat of the ice, the tributary valley floor was left high, or hanging, above the main valley floor.

Earthquakes associated with this fault were undoubtedly large in magnitude, and modern day repetitions could be catastrophic. No major movement has occurred along this fault in historic times. Clark (1981 found the latest Tioga tills (10,000 years) to be offset over 50 ft. Older Tahoe tills (60,000-130,000 years) have been offset about 400 ft. Movement along the Hilton Creek fault during the May, 1980 seismic events has been the subject of some debate. Clark and others (1980 carefully mapped surface disturbances along the fault which they contribute to actual fault displacement. Other less analytical work suggests the ruptures are a form of slope failure brought on by ground shaking during the earthquakes. Hilton Creek fault continues northwest-ward from McGee Creek for about two miles before being terminated by a west-trending fault near US 395. Range-front debris chutes have been vertically displaced from their talus cones. Continue north on US 395. As we pass the Mammoth Lakes airport note the low hills to the north. These are small rhyolitic domes of the resurgent dome. To the south can be seen the world-famous loop moraines of Convict Lake. The large number of boulders on the till surface suggests a very young till of Tioga age. To the east of the low-lying loop moraines is a 1000 ft high lateral moraine of Tahoe age. Far fewer boulders are present on the Tahoe till suggesting greater age. McGee Mountain towers above Convict Lake to the southeast. On the crest is located the 2.5-3.2 million year old McGee till, thought to be the oldest Sierra Nevada till found to date.

White streaks can commonly be seen on the sides of rhyolitic cones in the resurgent dome. These are excavations of kaolinite clay deposits. In places the clay has been covered with reddish rhyolitic debris by the Forest Service as part of a "beautification" project. Local hydrothermal alteration along faults led to opalization and kaolinization of the rhyolites (Lipshie, 1976).

Southwestward view up McGee Creek valley showing displacement of glacial tills by the Hilton Creek fault. Displacement seen here, about 50 feet, is within 10,000 year old Tioga tills.

The USGS web site has a nice photo of the Hilton Creek Fault (reproduced on previous page). The caption to that photo says: Aerial view of a glacial moraine along McGee Creek that has been offset about 15 m by part of the Hilton Creek fault system. Note cars in parking lot (lower left) for scale. The Hilton Creek fault is much larger than suggested by this relatively small offset--its scarp in places is about 1,100 m tall and forms part of the eastern front of the Sierra Nevada. The northern part of the fault terminates in Long Valley caldera, about 5 km NNE from this site.

Tom's Place (#039; T.4S, R.30E, Sec.33)

At Tom's Place Highway 395 marks a lithologic contact between Bishop Tuff to the northeast and Mesozoic granite to the southwest.

Map 11: Sherwin Pass to Tungsten Hills (Round Valley)

Sherwin Summit Road Cut (#040; T.4S, R.30E, Sec.34)

This site is at the junction of Lower Rock Creek Road and Highway 395. It is a famous road cut is visited by hundreds of geologists every year. Geologists have had a great debate dating back to 1931 as to which was older, the Bishop tuff or Sherwin till. The argument was finally settled in 1957 when this excavation revealed the contact, showing the till as older. (Despite this road cut, there were still doubters who claimed the till was not Sherwin). Note the resistant clastic dikes within the Bishop Tuff. Cracks in the tuff opened up allowing surficial debris to fall in and become partially cemented.

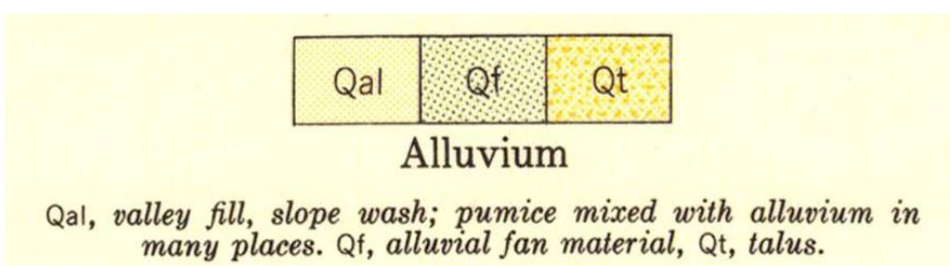
Sherwin Pass sandstone dikes

The great age of the Sherwin till is suggested by the advanced state of weathering exhibited by the boulders (grus). Although older than the 710,000 year Bishop Tuff, there is precious little evidence (such as overlying basalt flows) to determine a maximum age for the Sherwin till. Lipshie (1976 discusses an outcrop in Rock Creek Gorge where Sherwin Till is lying on a much older and heavily oxidized till. The older till may be the 2.5-3.2 million year old McGee till, the oldest known Sierran glacial till (more about which later)

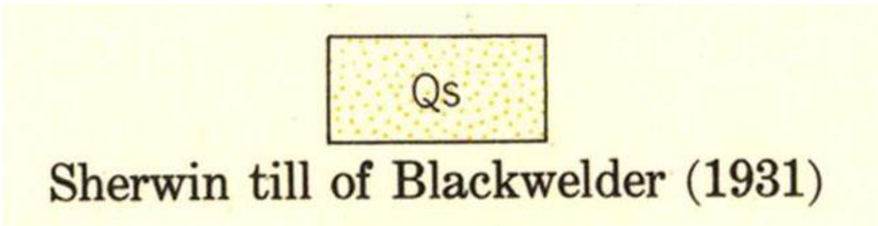
The famous Sherwin Summit roadcut on US 395 where Bishop Tuff (BT) overlies darker Sherwin Till (ST).

Here at Sherwin Summit we see a glacial till overlain by the 740,000 year-old Bishop Tuff. So we know the till is older than 740,000. Elsewhere this same till overlays (is younger than) a basalt flow with a K/Ar age of 3.2 million years. Therefore, this till's age is bracketed between 740,000 and 3.2 million years before present. The Sherwin date of 750,000 is arrived at by correlation to a major Midwestern glaciation (Kansan).

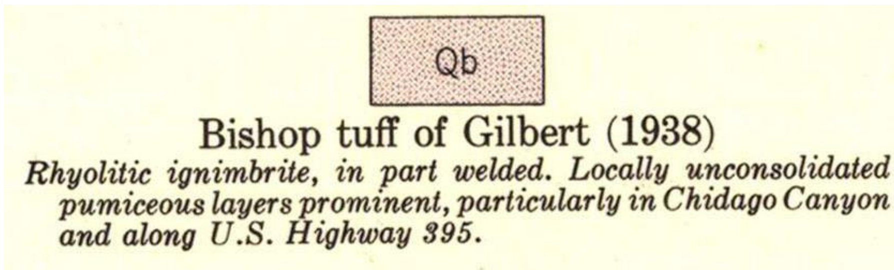
The mapping of this area by Rinehart and Ross (1956) is reproduced below. The main geologic units are:



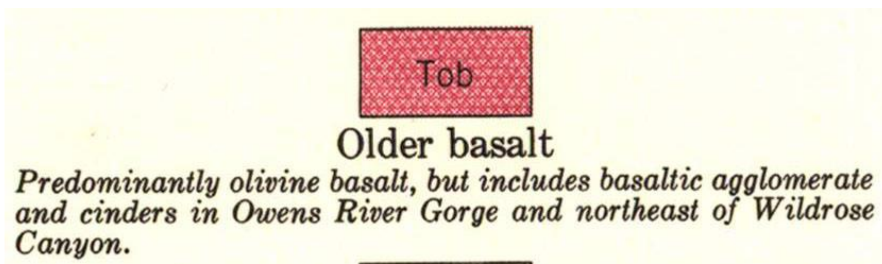
Recent Alluvium



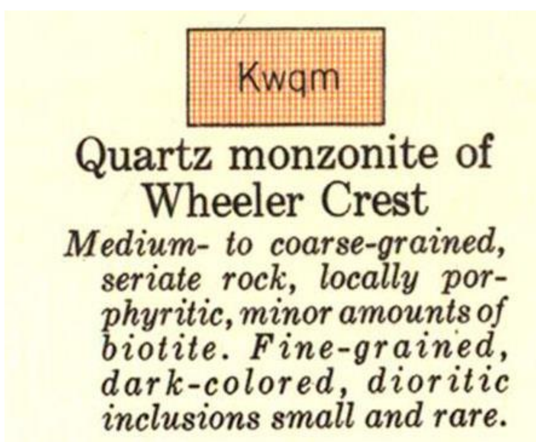
Pleistocene Sherwin Till



Pleistocene Bishop Tuff



Tertiary Older Basalt



Cretaceous Quartz Monzonite of Wheeler Crest

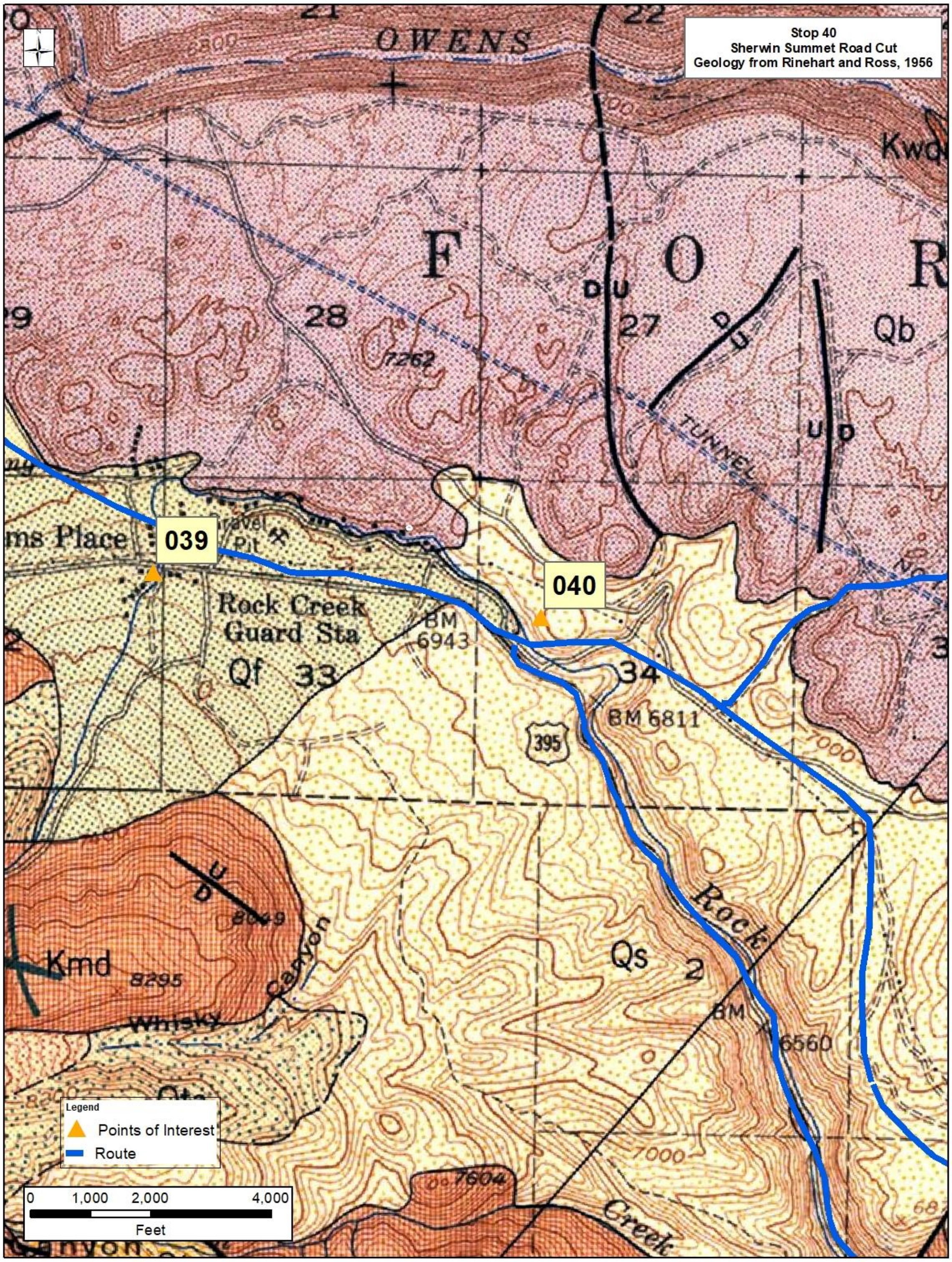
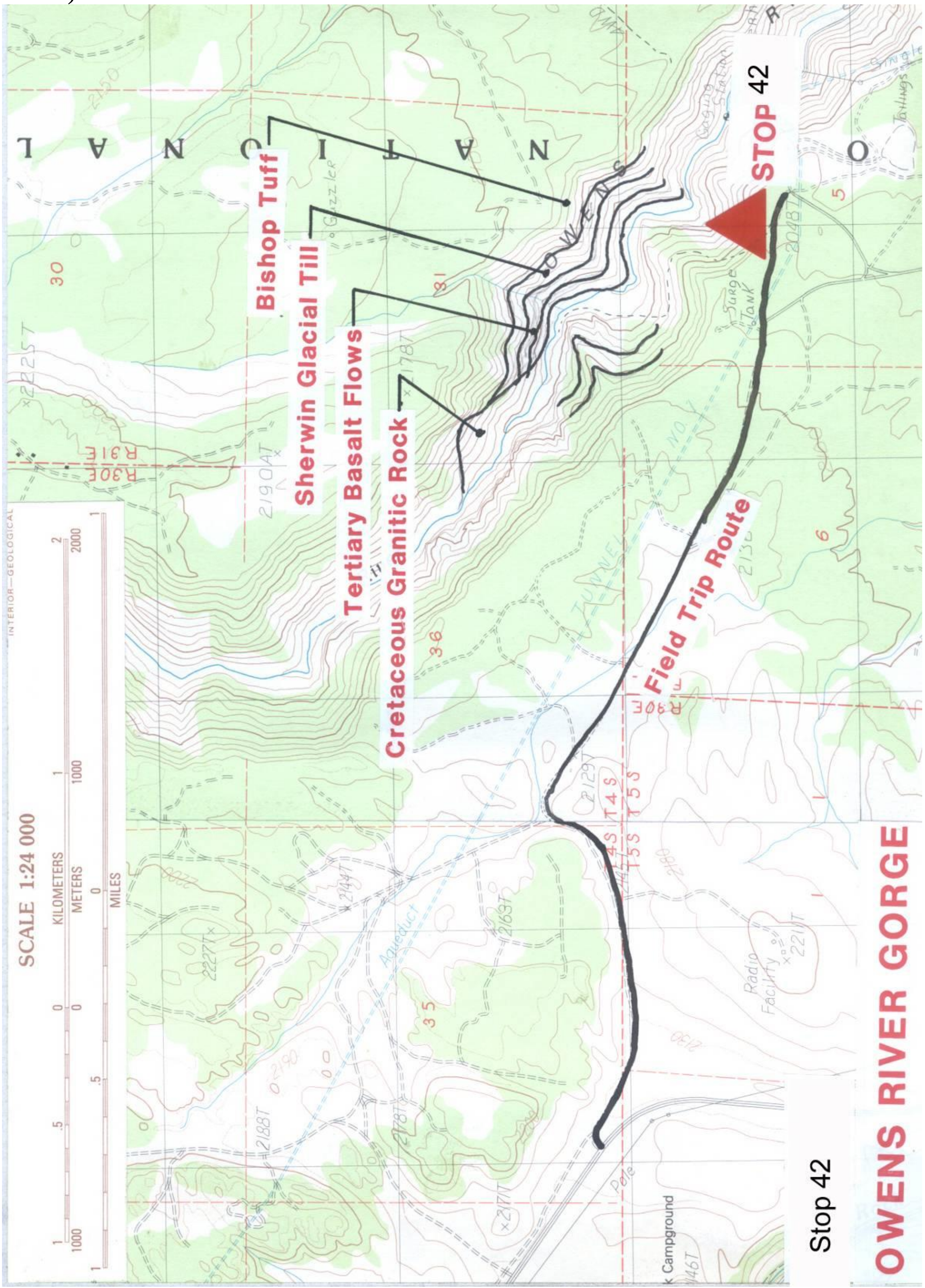
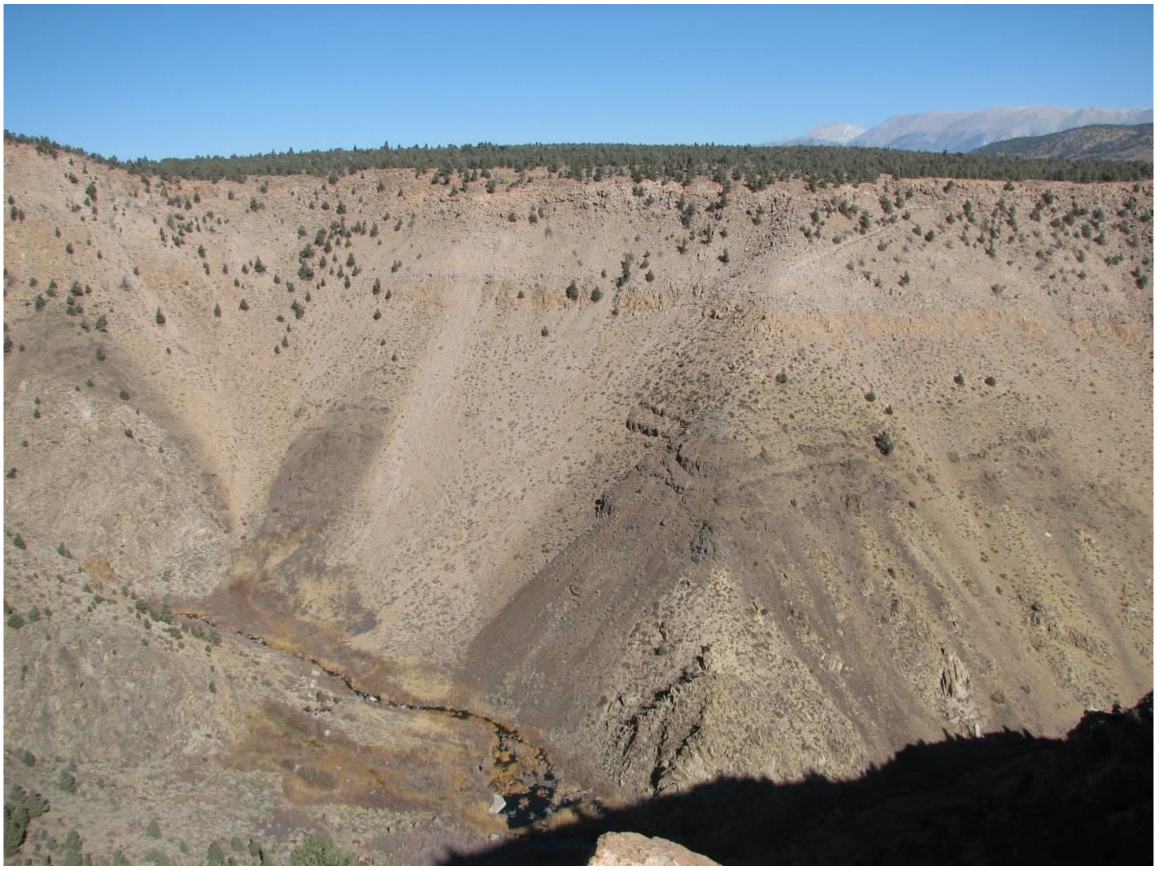


Figure 2. Geologic map of Stop 40. Sherwin Grade Road Cut. Geology by Rinehart and Ross, 1956.

Owens Gorge Overlooks (#042; T.5S, R.31E, Sec.5 and #043; T.4S, R.31E, Sec.36)





From the ***Sherwin Pass site (#039)*** continue east on the four lane US Highway 395 for 3/4 mile. Turn left (north) onto a dirt road. To your left is an outcrop of Bishop Tuff. To your right is a featureless hill (7246 ft elevation) with a microwave tower on top. This hill is the type location for the Sherwin till. The till-tuff relationship is not at all clear with these exposures. This location is typical of the relationship, and it's easy to see why the age debate went on for so many years.

After about 2.5 miles on the dirt road, we come to a LADWP surge tank. Here the road forks into three directions; take the middle fork. Proceed another 0.3 mile and park at the Owens Gorge overlook.

Walk a short distance from the road and view spectacular outcrops of the Bishop Tuff in the gorge walls. About 730,000 years ago, the Long Valley Caldera collapsed, accompanied by a cataclysmic volcanic eruption (Bailey, 1989. The resulting ash falls and incandescent flows formed the Bishop Tuff. The tuff is found buried in Owens Valley at least eight miles south of Bishop at depths of 700 feet. Bishop Tuff outcrops are found as far north as Mono Basin.

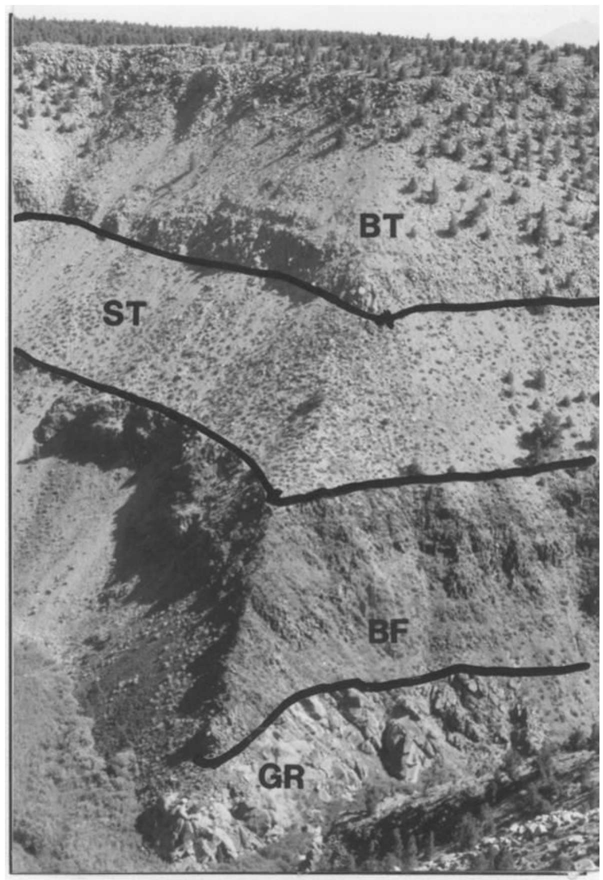
Bishop Tuff is composed of several different "modes," ranging from air fall pumice to welded tuff. These different modes are reflected in the various colors seen on the cliff wall. Evidence suggests that the entire Bishop Tuff thickness was deposited over a period of days. Small fumarolic mounds dot the surface of the tuff. These mounds may have been near high temperature gas vents, causing the tuff to become more indurated and less susceptible to weathering. The spectacular radiating fan-shaped jointing on the southern gorge wall may be related to a gas vent. Older dark colored volcanic flows underlie the Bishop Tuff.

The imposing Sierran escarpment (Wheeler Crest) dominates the western view. The Wheeler Crest escarpment is actually a huge fault scarp. Recent faulting is suggested by fault scarps in fans at the base of the escarpment. To the south is Round Valley, a closed depression bordered by Bishop Tuff on the east. At the mouth of Pine Canyon are prominent glacial moraines of Tahoe (60,000-130,000 years) and Tioga (10,000-20,000 years) glaciations. Glacial moraines of these ages are present in most canyons along the Sierran front northward to Truckee and beyond.

North on Sherwin Grade (old US 395) are outcrops of Bishop Tuff lying upon Cretaceous age quartz monzonite basement rocks at the descent down into Rock Creek gorge. As the road once again starts climbing, one passes from granitic basement rocks across a fault and into Sherwin glacial till. Turn right onto US 395 and pull into the parking area after few hundred feet.

On the north wall can be seen a "layer cake" succession of rock units that have had great importance to the understanding of Eastern Sierra Nevada region geology. The Triassic age Wheeler Crest Quartz Monzonite forms the gorge bottom. Overlying the granitic rocks are 60 ft of basalt flows dated at 3.2 million years and having a source less than one mile north (Bailey, 1989).

Overlying the basalt flows is an outwash gravel related to the Sherwin till. Overlying the gravel is the multi-colored Bishop Tuff. The cliff-forming resistant lowermost welded tuff overlies the gravel. The basalt flows occupied paleo-valleys in the granitic surface. Looking up the gorge, we see the irregular granitic paleo-topography filled in with the basalt. A pre-basalt relief of several hundred feet is apparent. If you look closely/y, normal faults cutting the entire section and offsetting the Bishop Tuff can be seen.

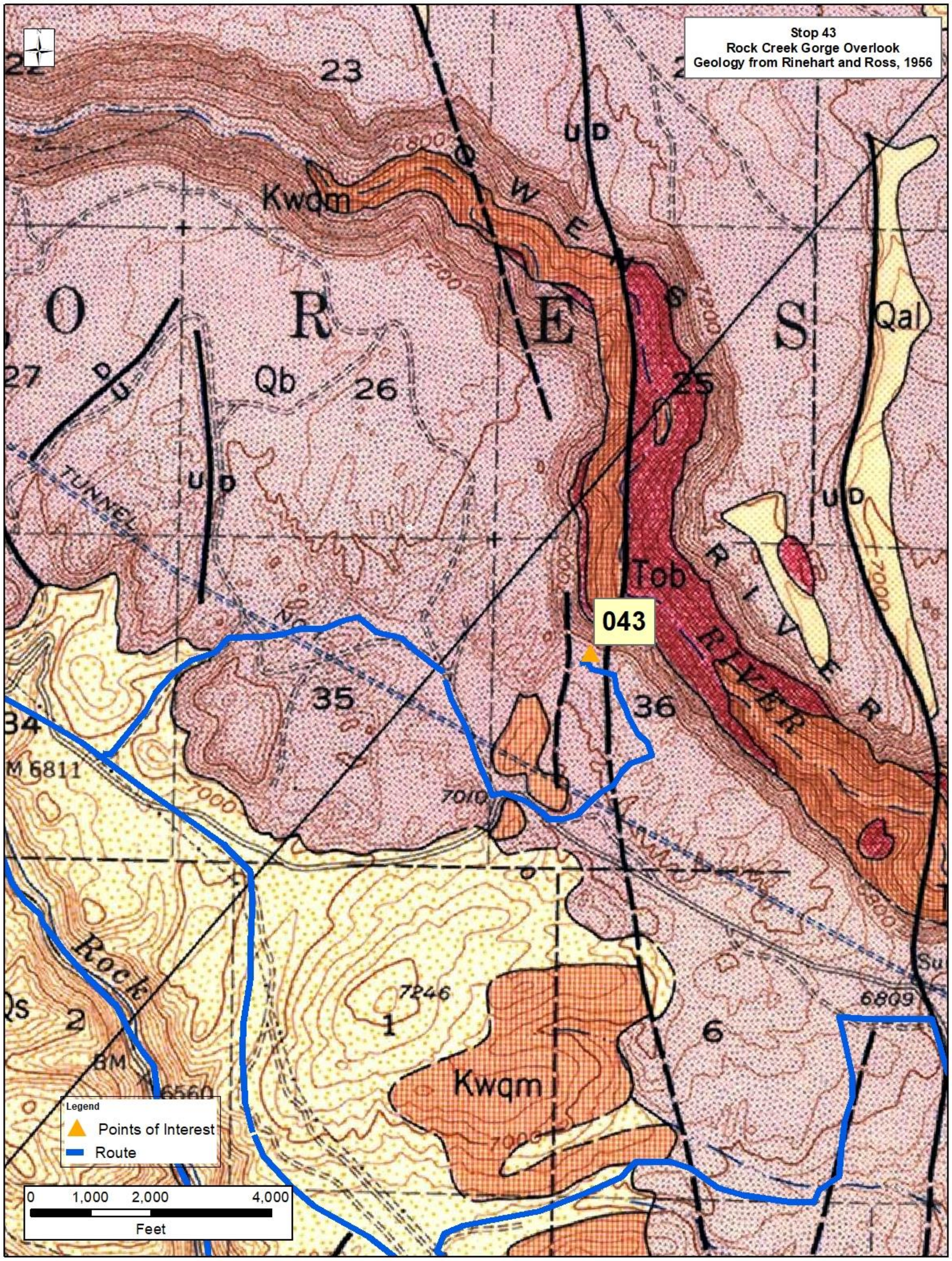


Owens River gorge. Granitic rocks are overlain by basalt, Sherwin Till, and Bishop Tuff.

Owens Gorge was created when the Pleistocene glacial Lake Crowley overflowed Long Valley and spilled out onto the Volcanic Tableland. The river's course was controlled by faulting and folding of the Bishop Tuff. Lipshie (1976) gives a good historical background on this region.

Rock Creek Gorge Overlook (#041; T.5S, R.30E, Sec. 13)

Interestingly, the very similar Rock Creek Gorge flows virtually parallel to the Owens River Gorge, but they seem to be unrelated. There is no evidence suggesting that Rock Creek Gorge ever drained Long Valley. Equally interesting is the fact that Rock Creek Gorge terminates in the closed depression of Round Valley.



Geologic map of Owens Gorge Overlook. From Reinhart and Ross, 1956.

Sherwin Grade

The old highway along Rock Creek has several very fine exposures of till and Bishop Tuff.

Pine Creek Scheelite Mine and Roof Pendent (#044 - Mill at T.7S, R.30E, Sec. 5, S1/2; #045 - Mine at T.5.S, R.30E, Sec. 5, N1/2)

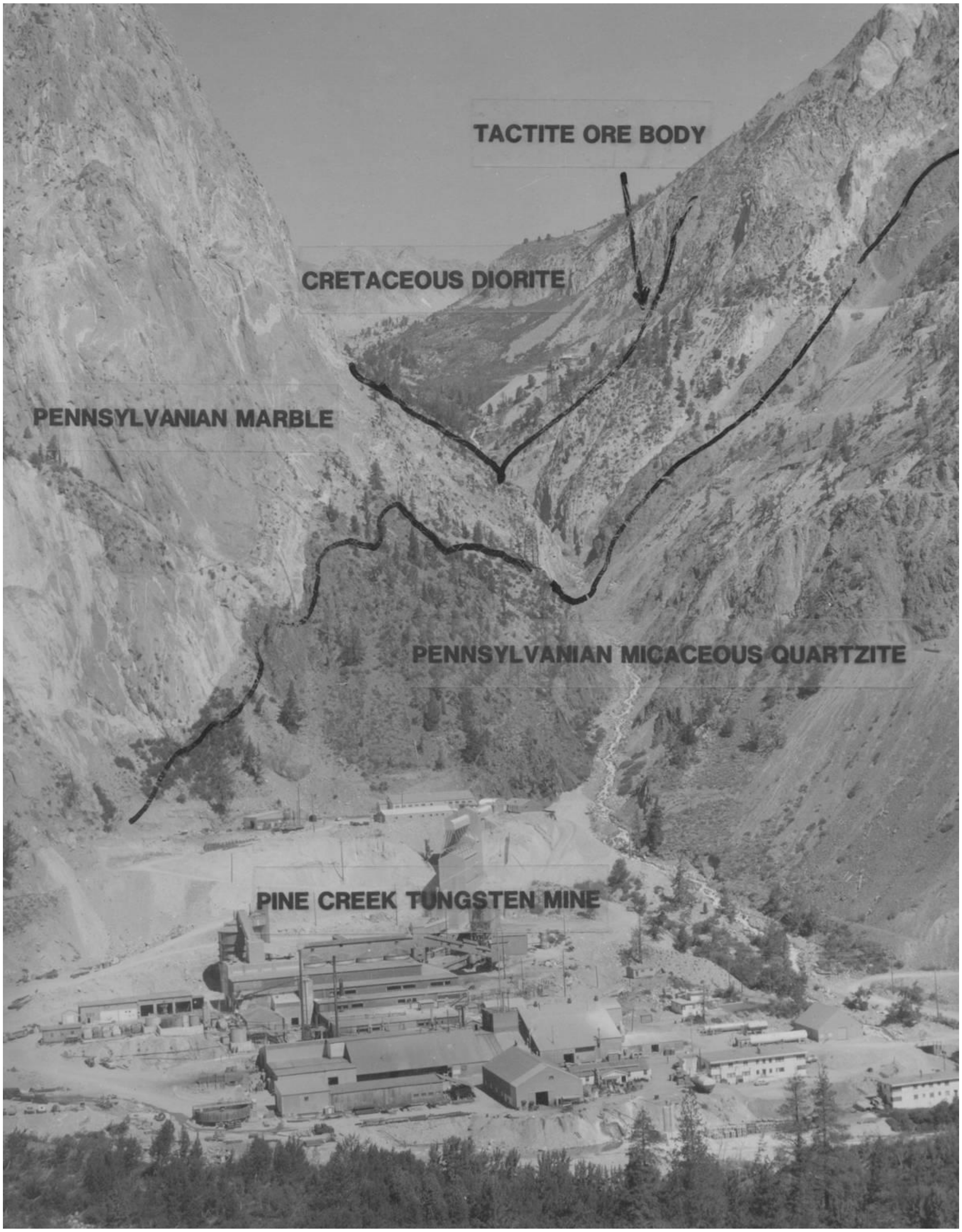
The following discussion of the Pine Creek mine is from Bruce Bilodeau. The Pine Creek Tungsten mine offices, mill and main adit to the mine are located at the confluence of Pine and Morgan Creeks at an elevation of 8,100 feet in Pine Creek Canyon. The mine workings are underground, about two miles farther up Morgan Creek, extending from an elevation of 8,100 feet to the surface at 12,000 feet. The ore contains the tungsten-bearing mineral scheelite ($CaWO4$). Operated by Union Carbide Corporation, it is the largest tungsten mine in the United States. The Pine Creek mine and the Climax mine near Leadville, Colorado accounted for about 93 percent of all domestic tungsten production in 1977 (Stafford, 1980).

Pine Creek Tungsten Mine from http://www.accesscom.com/~mjcarter/New%20scenics/image-html/Pine_Creek_Tungsten_Mine.html, April 10, 2007.

The Pine Creek orebody occurs at the northern end of the Pine Creek pendent. The pendant is a raft of metasedimentary and metavolcanic rock intruded by Sierran granitoids (Fig. 2). It is almost 11 kilometers long and one-and-a-half kilometers wide, extending from Mt. Tom to Wheeler Crest. The southern one-third is mostly unmineralized metavolcanic rock. The northern two-thirds is metasedimentary rock divisible into three distinct units. The oldest unit is composed of pelitic hornfels, micaceous quartzite, and vitreous quartzite. The next youngest is light gray marble, which in turn is overlain by a unit of micaceous quartzite. They are folded into a tight syncline, whose limbs are nearly vertical at the north end and shallow to the south. The rocks have been correlated with those in the Mt. Morrison pendant to the north, which have been dated by fossils as Pennsylvanian and Permian (?) (Bateman, 1965).

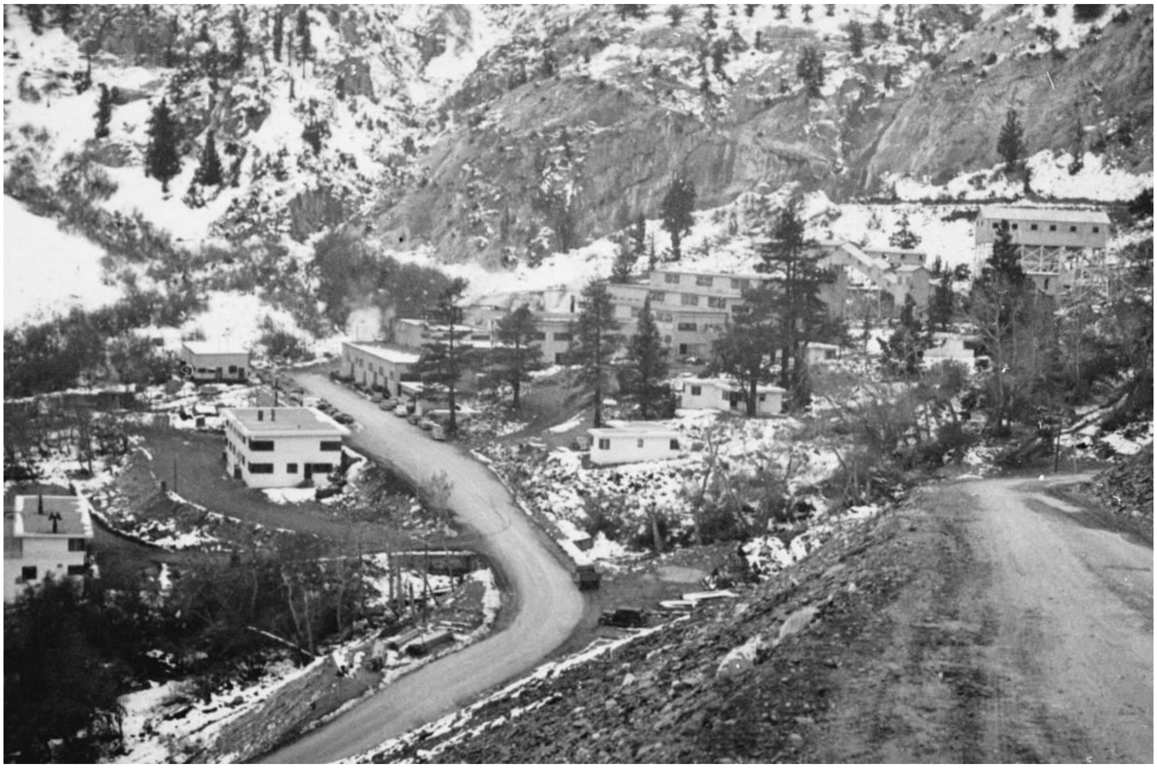
The pendant is in contact with three granitic intrusives. The two most important are the Tungsten Hills quartz monzonite, dated as Triassic (Bateman, l978) and the Wheeler Crest quartz monzonite, 96 m.y. (Kistler and others, 1965). Most of the tungsten mineralization in the Bishop District is thought to be related to the Tungsten Hills quartz monzonite because of its close association to the Pine Creek ore body and numerous other tungsten deposits (Bateman, 1965). An older body of quartz diorite has little or no associated tungsten mineralization.

The Pine Creek ore deposit occurs along the western margin of the pendant, at the northernmost contact between the marble unit and the Tungsten Hills quartz monzonite.



It is a contact metasomatic deposit of a scheelite-bearing garnet-pyroxene rock called tactite. The scheelite usually occurs in the tactite as disseminated crystals up to one cm in diameter. When illuminated with a black light, the tactite often shows bands and swirls of these crystals. In a few places, the scheelite occurs in seams tens of centimeters wide, almost 90 percent pure.

Tactite occurs only along the northernmost 1,000 meters of the contact between the quartz monzonite and the marble. Bateman (1965) believed the formation of tactite was controlled by three factors.



Pine Tree Mine (CGS Collection)

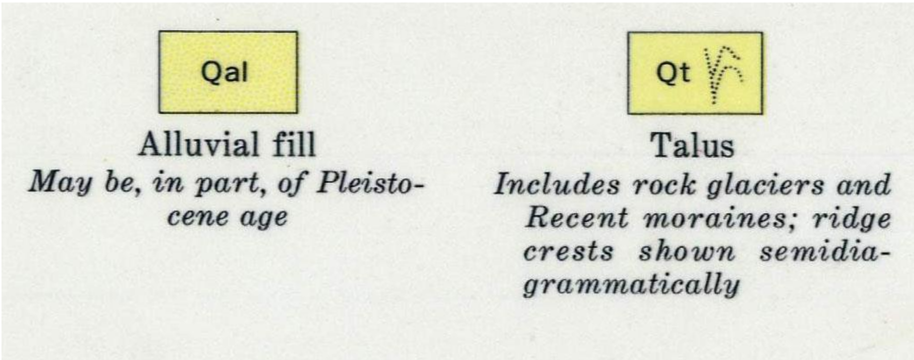
First, it usually formed from a rock rich in calcium, preferably clean marble. Second, it also commonly formed in embayments into the intrusive contact. Third, and probably the most important factor allowing the formation of tactite is an abundance of fractures in the marble, enough to pass the mineralizing fluids.

The skarn commonly has quartz monzonite in contact with a narrow band of quartz. The quartz is adjacent to the tungsten-bearing tactite. The tactite grades into white, bleached marble, which is in contact with the unmineralized gray marble. Relative thicknesses of each of these units may vary considerably. The quartz and tactite may also contain significant amounts of molybdenite and copper sulfides which, when abundant, are mined for their own sake.

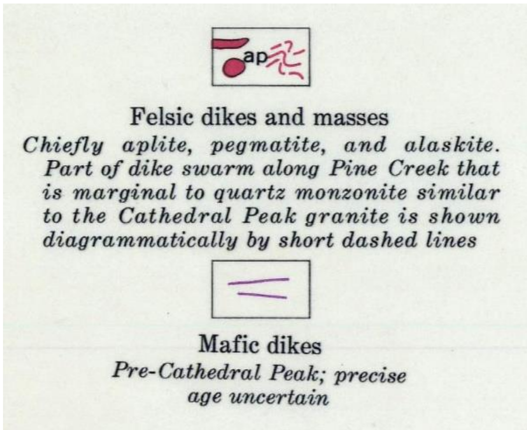
Tungsten mining first began at the Pine Creek mine in 1918. Because of fluctuations in the tungsten market, operations only lasted a few years. The demand for tungsten increased in the mid-1930's and at the same time ultraviolet light was introduced as a prospecting tool for tungsten minerals. Subsequently, numerous tungsten deposits were discovered in the Bishop area. The Pine Creek mine was acquired and reopened by the U.S. Vanadium Company in 1936. This company later changed its name to Union Carbide Corporation. In 1948, an access tunnel was completed 1,500 feet below the previous main level. The ore was shipped by aerial tramway to the present mill. In 1967, a two-mile tunnel was completed from the present mill site to the main workings. Known as the "Easy Going Drift," it provided easy access to the active parts of the mine. A small ore body was accidentally discovered only a short distance in from the portal, while drilling this tunnel. It is called the "Bend" orebody.

On the road to the Pine Creek Mill is the site of the old mining town of ***Sheelite (#046).***

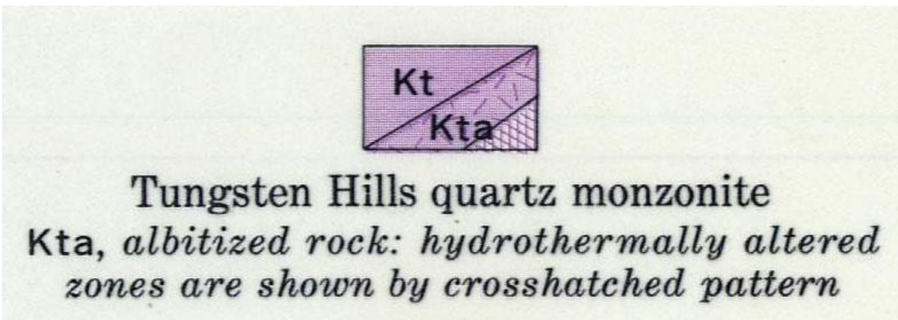
A geologic map of the area of the Pine Tree Mine and points of interest #045, #045 and #046 is provided below. The major geologic unitson thi map are



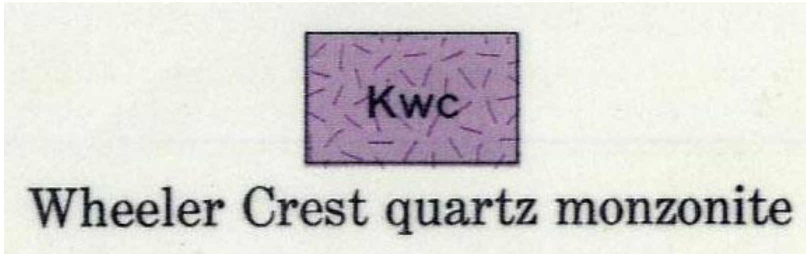
Quaternary alluvium and talus deposits



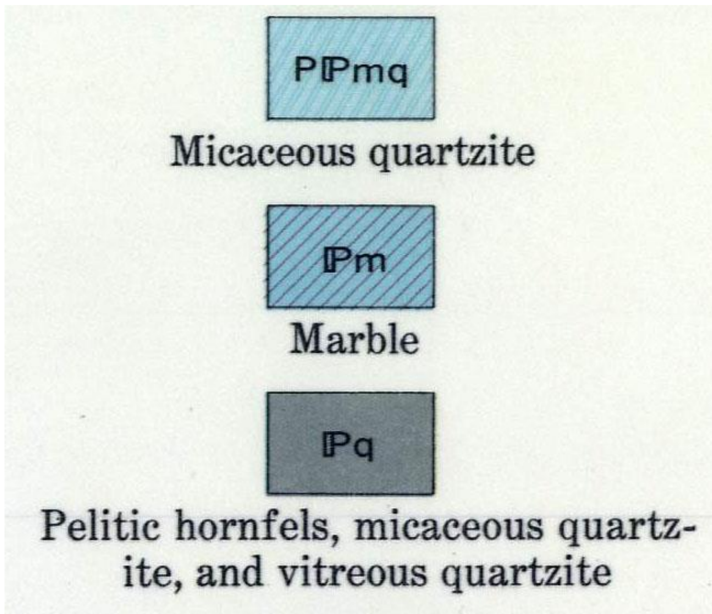
Felsic and mafic dikes



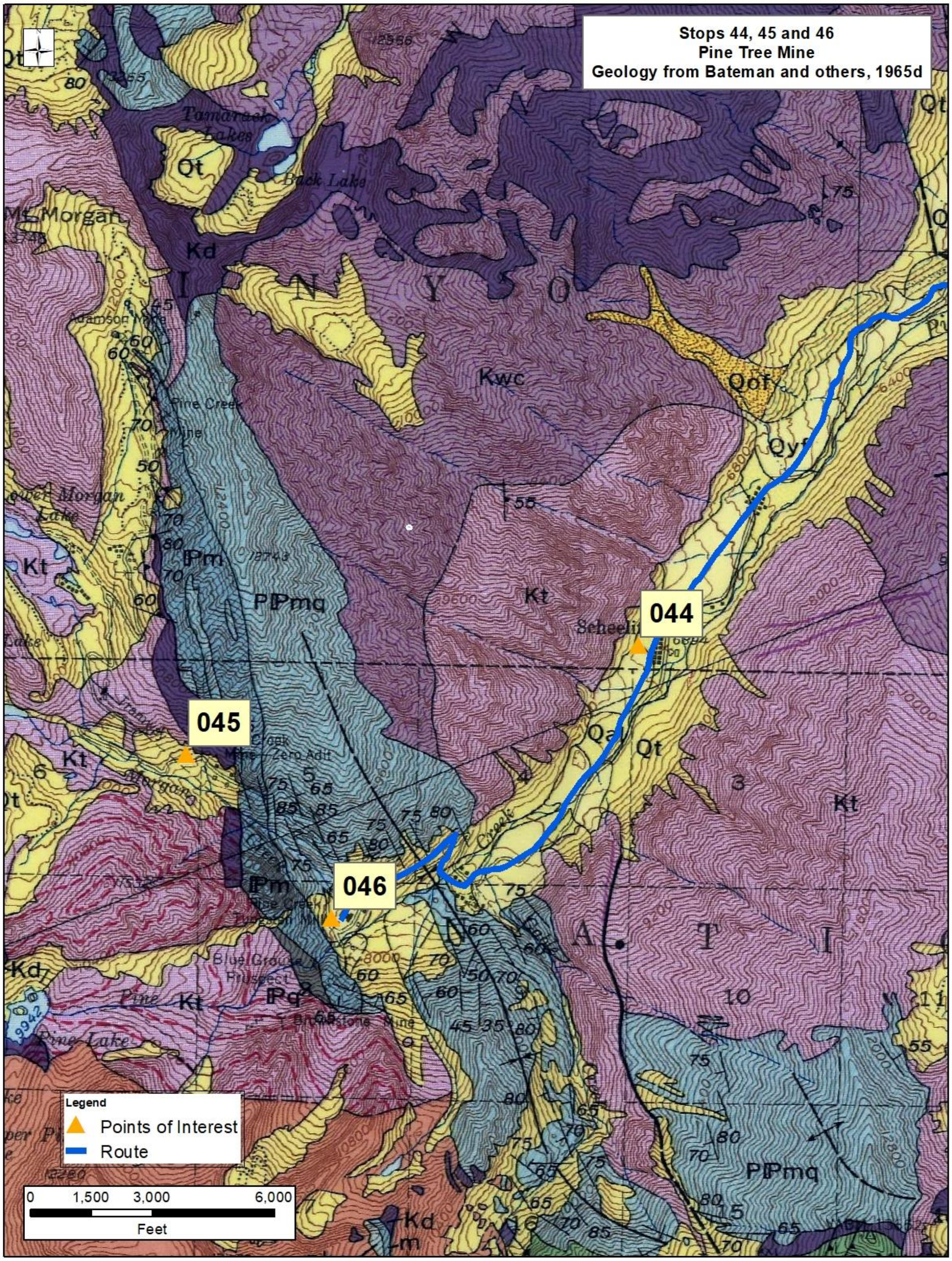
Cretaceous Tungsten Hills Quartz Monzonite



Cretaceous Wheeler Crest Quartz Monzonite



Permian and Pennsylvanian Units



Geologic map of the Pine Tree Mine. From Bateman and others, 1965d

Tungsten Hills and Round Valley (T5-6S, R31E)

A view of Round Valley can be had at the turnout north of the "Elevation 5,000 ft) sign on Highway 395. The spectacular Sierran escarpment dominates the western and southern views. To the southwest we see Pine Creek and the prominent glacial lateral moraines emanating from the valley.

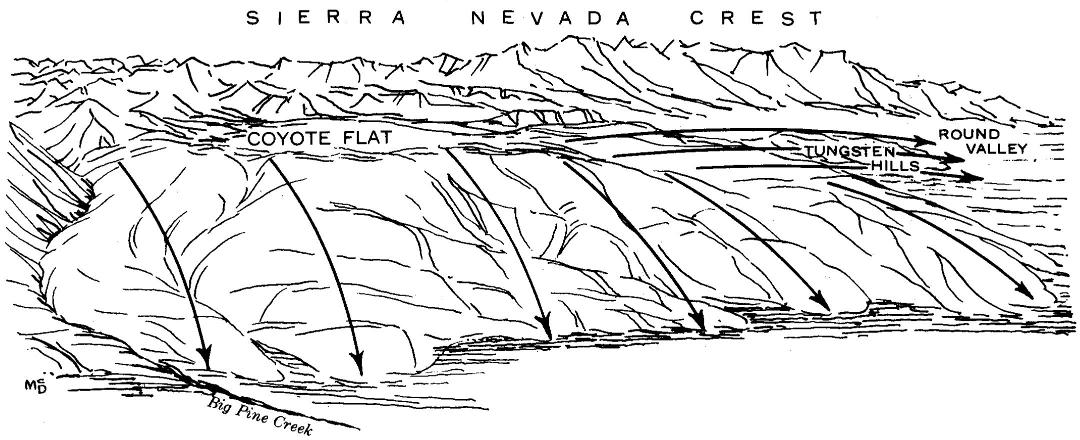
These well-preserved moraines of Tahoe age (See Table 1) are present in most canyons along the Sierra Nevada front northward to Truckee and beyond. Not visible from here are the smaller and younger moraines of Tioga age nestled within the Tahoe tills. The Tioga glaciation was not as extensive and the Tahoe. The ***Tungsten Hills (#047)*** to the south are covered with dozens of mine workings. In addition to the hard-rock mines, there are several placer tungsten deposits in Round Valley. Iron staining in one of the open pits of the Tungsten Hill mines is shown in the photo on the previous page.

Decline at one of the Tungsten Hill Mines.

Table 1. Names and ages of major Pleistocene glacial tills of the eastern Sierra Nevada Range.

Till	Age (years before present)
Hilgard	11,000
Tioga	20,000
Tenanya	26,000
Mono Basin	87,000
Donner Lake	250,000
Casa Diablo	400,000
Sherwin	730,000
McGee	1,500,000
Deadman's Pass	3,000,000

The Tungsten Hills are part of a broad arching feature west of Bishop named the Coyote Warp (Von Huene et al., 1963:72).



Sketch of Coyote Warp.

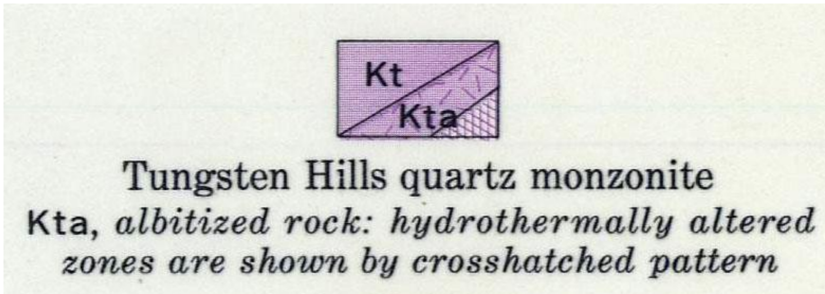
Illustration from Von Huene et al., 1963:72

The geology of the Tungsten Hills is summarized by Lipshie (2001:10):

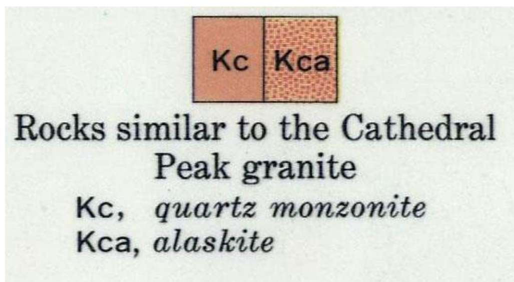
The Tungsten Hills are aptly named, because the first tungsten ore to be reported from the Bishop mining district was found there. The discovery occurred in 1913 at the Jackrabbit Mine (Bateman, 1965, p. 125), about 2 miles (3 km) north of here. The hills consist mostly of Tungsten Hills Granite, for which Bateman (1992, p. 164) reported a Triassic age, based on U-Pb ages of 197 and 202 m.y. (Table 2 indicates that, according to the 1998 geologic time scale, the Triassic-Jurassic boundary has an age of 206 m.y., which means that the unit should be considered Early Jurassic in age—yet another complication!) Bateman considered the K-Ar (biotite) ages of 74 to 77 m.y. reported by Kistler and others (1965, p. 162) to have been reset, presumably by later intrusive or tectonic activity. Evernden and Kistler (1970, p. 33) also reported K-Ar ages of 80 m.y. from biotite and 83 m.y. from hornblende for the Tungsten Hills intrusion. However, Hurley and others (1965, p. 170) concluded from Rb-Sr dating that the Tungsten Hills plutonic rocks lay on the 180-m.y. isochron, which would indicate a Jurassic age for the unit (Lipshie, 2001:10).

The age-dating story gets even more murky if we refer back to Bateman's earlier discussion of field relationships, in which he (1965, p. 86) reported that the Tungsten Hills unit is younger than various other plutonic rocks, including the Lamarck Granodiorite and Round Valley Peak Granodiorite. But the Lamarck Granodiorite has a U-Pb age of 90 m.y. and K-Ar ages of 86 and 90 m.y. on hornblende and 79 and 85 m.y. on biotite (Bateman, 1992, p. 146), which indicates a Cretaceous age for the granodiorite. Similarly, the Round Valley Peak Granodiorite has a U-Pb age of 89 m.y. and K-Ar ages of 84 m.y. on hornblende and 89 m.y. on biotite (Bateman, 1992, p. 151), which again indicates a Cretaceous age. So we are left with a dilemma: the reported field relationships contradict the U-Pb age-dating. One possibility is that rocks identified as Tungsten Hills Granite may actually comprise a number of plutons with ages that span the Mesozoic. Another possibility, of course, is that either the radiometric dating or the interpretation of field relationships is wrong. As with most geologic controversies, time and further research should resolve the issue (Lipshie, 2001:10).

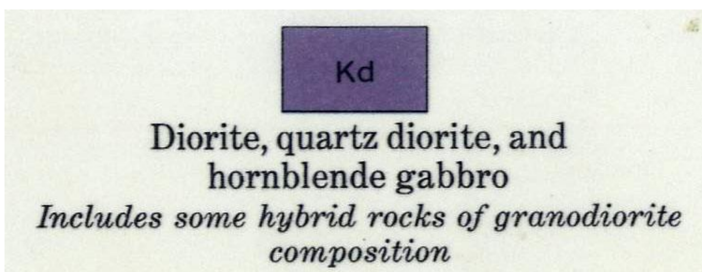
The area of the Tungsten hills was mapped by Bateman and others (1965am 1965b). The major units depicted on Map 12 are:



Cretaceous Tungsten Hills Quart Monzonite



Cretaceous Granite of Cathedral Peak



Cretaceous Diorite, Quartz Diorite and Hornblende Gabbro

Knopf's Knob (#144; T.7S, R.32E, Sec. 17)

The description of this point of interest, below, is quoted from Lipshie, 2001:3-4. This unique outcrop is north of Bishop Creek Road. It consists of granite intruded and partially fused by olivine-augite basalt dike.

Please refrain from collecting samples here unless you intend to use them for *bona fide*, serious scientific studies.

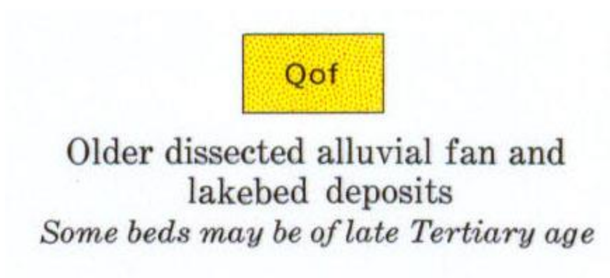
The outcrop here, first described by Adolph Knopf (1918, p. 74-75), is extraordinary in that columnar jointing has developed in the granite, as well as in the basalt (Fig. 3).

Columns generally have four to six sides and are between 4 and 7 ft (1.2 and 2 m) long and about 1 ft (0.3 m) across. At the granite-basalt contact, the columns are normal to the contact, although they commonly curve as they extend away from it (Knopf, 1918, p. 75).

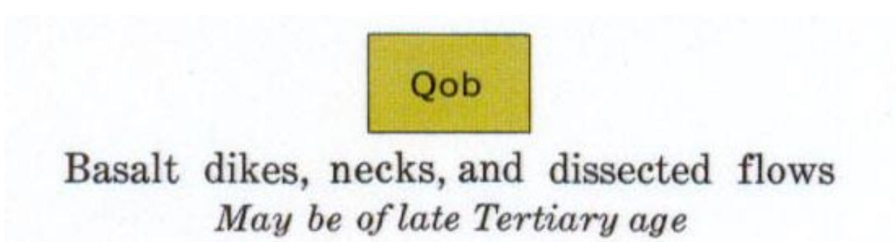
The Pleistocene (?) basalt dike, which is up to 15 ft (5 m) thick, locally contains corroded xenocrysts of quartz and minor feldspar; xenocrysts are surrounded by brown glass containing tridymite crystals. In the granite, quartz and feldspar grains are shattered (presumably by thermal stresses) and cut by glass veinlets near the dike contact. The glass is brown (basalt-derived) near the contact, becoming colorless (granite-derived) about 1 to 2 mm into the plutonic rock. Knopf (1938), who labeled the granitic unit as granodiorite, and Bateman (1965, p. 151), who called it quartz monzonite, have described the unusual petrographic relationships of the rocks at this outcrop.

The granite was formerly described as quartz monzonite (see Mileage 5.6, below), but has since been renamed in accordance with the IUGS (International Union of Geological Sciences) classification of plutonic rocks (Streckeisen, 1973). Bateman (1992, p. 164) has changed the name of the plutonic rock unit seen at "Knopf's Knob" from Tungsten Hills Quartz Monzonite (Bateman, 1965, p. 80) to Tungsten Hills Granite. The widespread adoption of the IUGS classification, which displaced the old petrographic nomenclature (Williams and others, 1954), has led to wholesale changes in the names of plutonic rocks of the Sierra Nevada. It has also left some of us who learned the old classification system in school feeling somewhat befuddled by the new names. As an added bonus, the age of the Tungsten Hills Quartz Monzonite/Granite has been changed from Cretaceous (Bateman, 1965) to Triassic (Bateman, 1992).

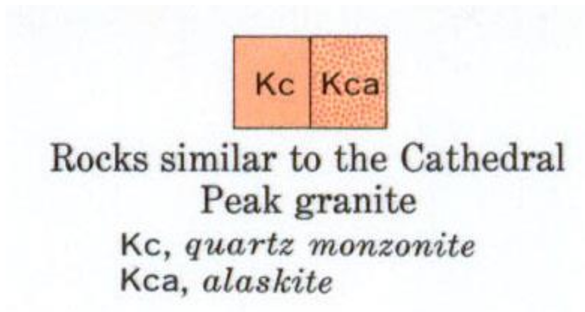
The area of Knoph's Knob was mapped by Bateman and others (1965). The major units on the map, below are:



Quaternary Lake Beds and dissected alluvial fans



Pleistocene Basalt



Cretaceous Granite of Cathedral Peak

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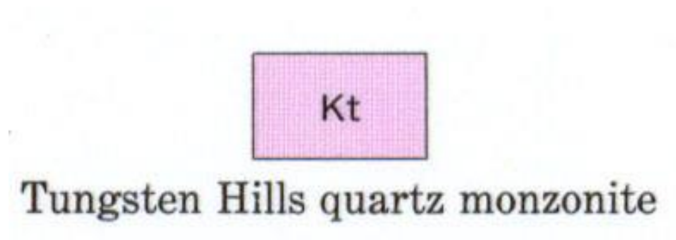
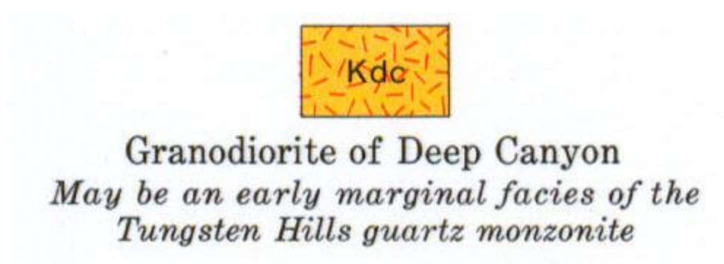
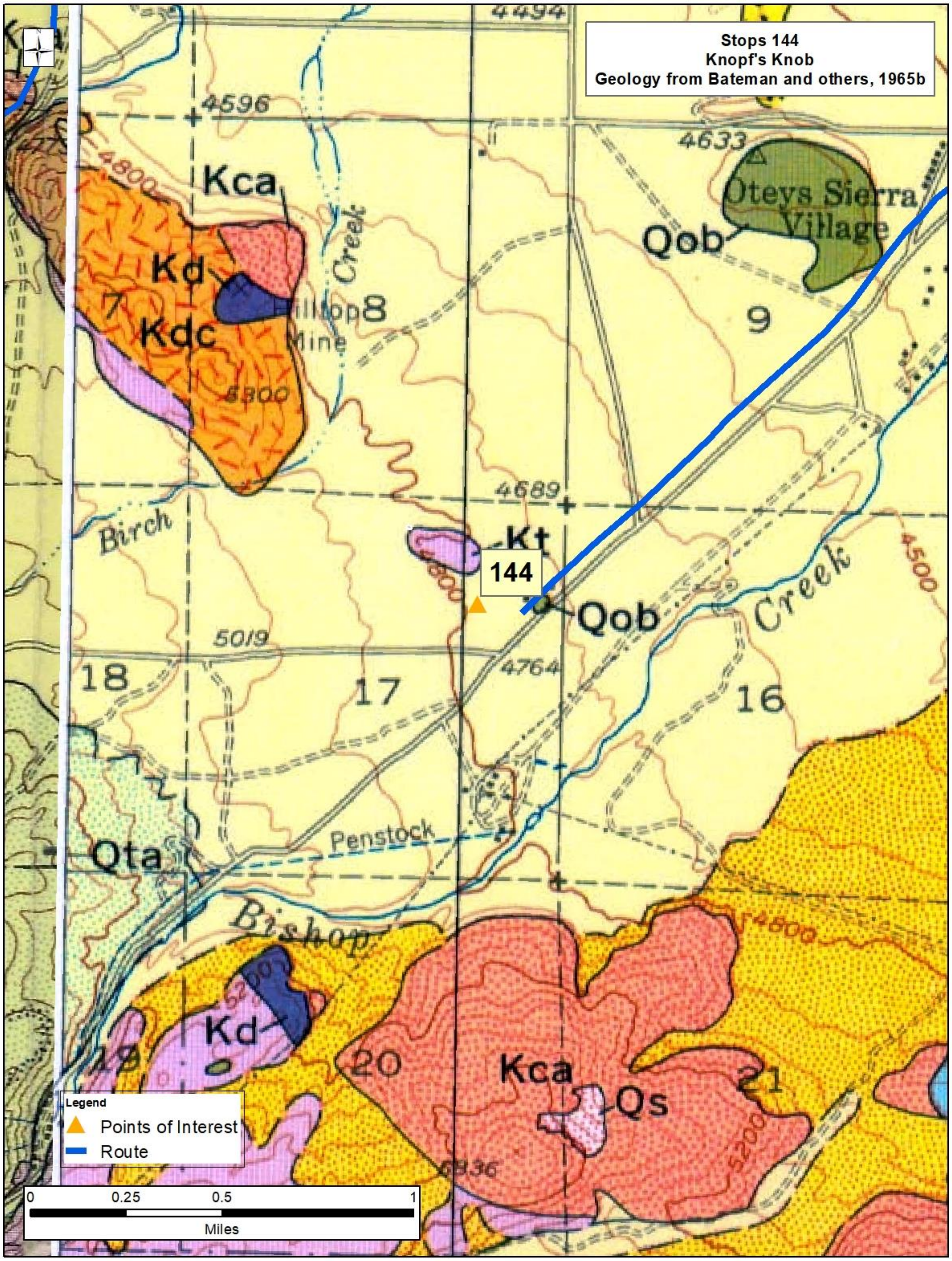


Cretaceous Tungsten Hills Quartz Monzonite



Cretaceous Granodiorite of Deep Canyon



Geologic map of the area surrounding Knopf's Knob. Geology from Batemen and others, 1965b.

Map 13: Bishop and Bristlecone Pine Forest

Volcanic Table Lands (#049; T.5-6S, R.22-33E)

Volcanic Tablelands. View is north from the Tungsten Hills

The "Tablelands" cover 325 square miles, dominating the landscape of northern Owens Valley. The underlying rock is 740,000 years old Bishop Tuff, a volcanic rock believed to have been ejected from the Long Valley Caldera during its collapse. The tuff also is found buried in Owens Valley at least eight miles to the south at depths of 700 feet.

Von Huene, et al., 1963:96 Tilted Fault Block at Rawson Creek.

The Bishop Tuff is composed of a lower air fall pumice layer and an upper "welded" layer. The welded layer ("ignimbrite") resulted from a very hot and fast "fiery cloud." Another term commonly used for this type of eruption is a "nuee ardente." Temperatures were high enough to melt glass. Individual mineral grains were welded together forming a relatively hard and brittle rock.

Local warping of the land surface here has caused deformation of the Bishop Tuff. To the east a short distance can be seen tilted slabs of Bishop Tuff faulted against each other (Fig. 1) Being very brittle, the tuff resists bending or folding, preferring to break. These faults are characteristic of the Volcanic Tablelands and locally control drainage. Fish Slough is an example of a fault-controlled stream.

Fish Slough (#050-A , T.6S, R.33E, Sec. 6 and #050-B; T.5S, R.32E, Sec. 13)

This is an area of critical environmental concern (ACEC) co-managed by BLM and several other agencies. ACEC's are designated to "recognize, maintain, and enhance the area's unique resource values." Other resource values include cultural history and a great diversity of unique and protected plants and animal life, including the diving beetle.

Aerial photograph of Volcanic Tablelands showing faults. Bishop and Owens River are just below the lower margin; the view is north toward the end of Owens Valley. Von Huene, et al., 1963:97

Fish Slough ACEC is easy to find, in east-central California at the north end of the Owens Valley, 5 miles north of Bishop. You can drive to the ACEC via graded dirt roads from U.S. Highway 395 and U.S. Highway 6. No visitor services are provided in this isolated desert environment, so travelers are advised to be prepared.

Fish Slough is a desert wetland ecosystem fed by the only three natural springs left on the Owens Valley floor. The flora includes 270 vascular plant types from 52 families. It is home to the rare and endemic Fish Slough Milkvetch (Astragalus lentinginosis var. piscinensis) and a much less common relative of the rabbitbrush than the rubber rabbitbrush we have been seeing, this one with white flowers (Chrysothamnus albidis).

The following is extracted from http://thesierraweb.com/generalinfo/fishslough.cfm (April 3, 2007):
Fish Slough is a lush oasis in an arid landscape known as the Volcanic Tableland. The wetland and part of the Volcanic Tableland totaling 36,000 acres is designated as an Area of Critical Environmental Concern (ACEC) to recognize, maintain, and enhance its unique resource values.

You will discover the ACEC is a special place. The marsh creates a rich environment supporting diverse plant and animal life, including several unique and sensitive species. Nestled between the towering White Mountains to the east and Sierra Nevada to the west, the unusual geological features that give rise to the springs make a colorful landscape of cliffs and terraces with warm pastel hues that are especially striking in the early morning and evening hours. Prehistoric and historic peoples were also drawn to this habitat for the special resource values we recognize today. Several agencies manage the ACEC under a Cooperative Management Plan, with the help of volunteers from the Eastern Sierra Audubon Society.

A Land Formed by Cataclysm

Violent geologic events are the natural forces underlying Fish Slough's subtle beauty. Glowing hot rhyolite ash flowed like a scorching avalanche out of the Long Valley Caldera 760,000 years ago, destroying every living thing in its path and blanketing the landscape several hundred feet deep for miles around. This pyroclastic flow then fused to create the porous white, pink and tan rock called Bishop tuff that makes up the Volcanic Tableland.

Later, faulting action warped and cracked the gentle slope of the Tableland, lifting some parts and dropping others. The smooth surface broke into blocks that that eroded into jagged or oddly curving forms. The small round bumps that dot some parts of the Tableland are the result of fumaroles of hot water and steam that vented from the cooling ash flow and hardened the tuff so that it resisted erosion.

Pick up a piece of Bishop tuff and notice how light it is. Air pockets in the hot ash flow became small holes that allow water to pass through quickly. Water, wind and earthquakes continue to change the landscape you see today. One of the most active fault scarps runs along the east side of Fish Slough. Rising abruptly from the edge of the Tableland, the East Side Bluff is more than 5 miles long and 300 feet high!

Water in the Desert

The Volcanic Tableland lies at the meeting place of the Great Basin Desert to the north and the Mojave Desert to the south. The geologic forces that created the Tableland also created an oasis in these arid lands. The faulting action that lifted the East Side Bluff threw a huge block of land at its base down to the level of the water table, so that a rich wetland was formed.

Look closely into the bottoms of the pools at the north end of Fish Slough. The upwelling bubbles you may see are springs that feed the pools and replenish the marsh. Three perennial, free-flowing freshwater spring systems merge their waters to flow south toward the Owens River. The springs and their outflow are surrounded by wet marshlands. These, in turn, are bordered by seasonally wet alkali meadows, frosted with a white crust of minerals left by evaporating water.

Because of the water in Fish Slough, there is a greater abundance of life here than in the surrounding desert. What differences in life can you see between Fish Slough and the Volcanic Tableland?

Lives in the Balance

Water is the key to the varied life found in Fish Slough. Outside the marsh, Great Basin and Mojave Desert plants survive extreme heat and cold with very little water. These hardy plants include shadscale, Parry saltbrush, four-wing saltbush, spiny hopsage, bud sage, Indian ricegrass, and desert trumpet. Seeds of annual plants lie dormant until a wet springtime when the Volcanic Tableland suddenly blooms with brilliant colors, including vast sweeps of the bright yellow Venus blazing-star.

This high desert habitat is home for many animals. You might see some of the more common ones: coyotes, black-tailed jackrabbits, white-tailed antelope squirrels, gopher snakes, rattlesnakes, desert spiny lizards, sage sparrows, rock wrens and mourning doves. The boulders and cliffs of the fault scarps offer excellent hunting, perching and nesting sites for golden eagles and prairie falcons.

Notice the change in the vegetation and animal life as you look from the high desert over to the marshland. The seasonally saturated alkali meadows support a rare community of plants adapted to the high alkalinity and varying water levels. At water's edge the vegetation changes to a type that is even more water-dependent. Bulrushes, cattails, sedges, willows and cottonwoods are a few of the plants that thrive here.

You can find creatures here that depend on the marsh for at least part of their life cycle. Green-Winged and Cinnamon Teals, Mallards, Ruddy Ducks, Pintails and Gadwalls frequent the marsh, especially during spring and fall. Great Blue Herons, American Bitterns, Northern Harriers, Common Yellowthroats and Marsh Wrens also use the wetlands, and this oasis in the desert attracts rare migrating birds far from their usual home. You may also see raccoons or striped skunks wading in the shallows, or deer coming to drink.

Protected Plants

The terms "endangered" and "threatened" are applied to plants and animals that are protected because of their uniqueness, special habitat needs, and potential threat of extinction. One plant, the **Fish Slough milk vetch** (*Astragalus lentiginosus var. piscinensis*), is federally listed as a threatened species. You cannot find this low-growing perennial forb anywhere in the world except the alkali meadows of Fish Slough. It was discovered in 1974 by Mary DeDecker, a local botanist. Nearby you may find the white flowers of the **alkali mariposa lily** (*Calochortus excavatus*), a BLM Sensitive Species that also has very limited distribution.

Five other rare plant species depending on the life giving waters of Fish Slough are **alkali cordgrass** (*Spartina gracilis*), **hot spring fimbristylis** (*Fimbristylis thermalis*), **Great Basin centaurium** (*Centaurium exaltatum*), **King's ivesia** (*Ivesia kingii var. kingii*), and **silverleaf milk vetch** (*Astragalus argophyllus var. argophyllus*). You may be able to find and photograph these in the marsh and alkali flats.

Desert Fishes

Move closer to the water's edge. Spend a few moments sitting quietly and gazing into a clear pool. What kinds of life forms can evolve and thrive in an isolated desert wetland?

The endangered **Owens pupfish** is a small fish observed in vast numbers throughout the Owens Valley in 1859 by U.S. Army Captain J. W. Davidson and still abundant in 1916 in the north end of the valley. However, Owens pupfish numbers and habitat were dwindling. Water diversions and wetland drainage were responsible, along with the introduction of predatory fish. By 1948 the species was believed extinct - but in 1964 a small population was rediscovered in Fish Slough.

Owens pupfish feed on insect larvae and other small aquatic creatures and can survive in warm, salty water with low oxygen levels. The males will fight aggressively to defend the small territories where they display their blue and silver breeding colors to attract a mate. A photo of a pupfish is shown below.

The **Owens speckled dace** is a subspecies of speckled dace now found in very few sites within the Owens River drainage. It was thought to be gone from Fish Slough but was rediscovered here in 2002. Biologists hope to reintroduce the once-abundant **Owens sucker** and **Owens tui chub** to parts of the slough that are safe from non-native fish. Owens tui chub became endangered mainly because of interbreeding with other chubs that were imported as bait. Non-native species such as large-mouth bass and crayfish prey on the smaller natives, while mosquito fish compete with them. Non-native animals can disrupt the fragile natural balance of this complex wetland environment.

Of the many small aquatic invertebrates, the **Fish Slough springsnail** is unique. This diminutive snail, barely larger than the head of a pin, is found in specific freshwater locations in the Fish Slough wetland - and nowhere else in the world.

Early Occupants

Fish Slough's abundant resources naturally attracted Native Americans to the area. Food sources included various wetland and desert scrub plant resources, waterfowl, deer, pronghorn, rabbits, freshwater mollusks, and the native desert fishes. Fish were caught by using plant derived poisons and fishing nets, and by dragging baskets through the water. Indian ricegrass, a major food source, was harvested and carried in durable baskets

woven from willow. Duck eggs could be gathered and carried with temporary baskets woven on the spot from bulrushes.
Mysterious Rock Art

You can find many prehistoric rock art sites in the Fish Slough ACEC. These carvings, called petroglyphs, were made by Native Americans prior to white settlement. Notice the unusual geometric symbols and designs of the petroglyphs. Their meaning has many interpretations, often associated with shamanic or hunting magic. One theory speculates a relationship may exist between these carvings and hunting rituals since game trails are found near many petroglyphs sites. However, this is a mystery that may never be solved.
Over the centuries many Native American cultures have used Fish Slough; most recently, the Owens Valley Paiute Indians. Besides petroglyphs, other prehistoric sites in the ACEC include temporary camps, semi permanent village sites, and lithic scatters - the scraps left from stone tool making.

New Settlers in the Deepest Valley

During the 1860s ranchers and miners began to occupy the present day areas of Bishop and Laws. These and other new settlers homesteaded land in America's deepest valley along creeks, rivers and springs. Part of the Fish Slough wetland was pioneered by Phillip Keough in 1890, who set up a stage stop near the northwest spring.
In the last quarter of the 19th century the Fish Slough Road became a main wagon route connecting Bishop and Laws to the prosperous mining camps of Benton Hot Springs, Bodie and Aurora. Freight and supplies were transported on this route, which also served as a cattle driveway. Dust-covered settlers routinely traveled this rutted and sandy road to Bishop from as far north as Reno and Carson City.
In the 1920s and 1930s the City of Los Angeles bought riparian lands in the Owens Valley, including Fish Slough, in order to acquire water rights and supply water to a growing city. As a secondary result, intensive agricultural uses and private land development were precluded here. After the remnant population of Owens pupfish was discovered in the 1960s, the City of Los Angeles Department of Water and Power and the California Department of Fish and Game established the Fish Slough Native Fish Sanctuary. Since then the wetland has become increasingly recognized for its unique qualities and ecological significance.

Pumice Mines (#051; T5S, R33E, Sec.19, 29 and 32)

The pumice mines north of Bishop can be reached from Highway 6. On the way to these deposits you will pass the railroad site and museum of ***Laws (#052)***.

The combination of stresses already existing in this area, such as summer drought, winter cold and fairly low nutrient value of the pumice make recovery of vegetation systems in this area slow and difficult at best. On the areas where the unusable pumice has been discarded, the disturbance and lack of soil nutrients supports only the growth of weedy species such as Russian thistle or tumbleweed (Salsola tragus). These introduced annuals become brittle with age, and eventually are blown off their root systems and tumble along the ground distributing their seeds. They have become major pests in many parts of the west; however, in the lack of consistent disturbance, local natives can often out-compete them. On older pumice piles in this area, a few of the natives can be seen re-entering the vegetation type, but recovery is slow. LADWP has bought up much of the land in this and other areas of the Owens Valley in order to have access to the water rights. Along the road can be seen the remains of dead trees, probably many of them remnants of old homestead plantings, such as Lombardy poplar or cottonwoods, which have died as the lowering water table has eliminated their access.

The Van Loon Pumice deposit is an older air-fall tuff-pumice that lies below the Bishop Tuff.

Van Loon Pumice Mill

ALTERNATE ROUTE: LEE VINING TO BISHOP VIA BENTON

From Lee Vining, go south on Highway 395 to Highway 120 (Benton Junction). Turn east and go toward Benton. Panum Crater and Mono Lake are to the North

Mono Mills (#016; T.1S. R. 27E, Sec. 2)

The pines which we are seeing in this area are Jeffrey pines (Pinus jeffreyi). Principally a California species, (it goes just north into the Klamath Mountains of southern Oregon and into the northern mountains of northern Baja California, but is otherwise restricted to California), Jeffrey Pines can form large single-species stands such as the one were are going through here. Native Americans used the roots of the plant for weaving in baskets and containers. Distinguishable from its close relative Ponderosa pine (Pinus ponderosa) where they occur together because the scales on the end of the cones turn under, as opposed to outward on 'prickly ponderosa,' it also has reddish bark both inside and out, and is said to smell of vanilla, particularly when it is warm. It seems more tolerant of marginal soils than other pines, as can be seen in this area where it is the only tree colonizing the Coulee (pumice) on the south side of the road. Also occurring with Jeffrey pines in this area is the rare Mono County endemic Mono Lake lupine, Lupinus duranii, which can be seen this time of year as a low lying grayish plant with palmately (round) compound leaves. In 1881, need for lumber, timber and fuel in Bodie led to the construction of a narrow guage railroad from Mono Lake to Bodie. Jeffrey pines in this area were harvested and milled in the Mono Mills and shipped across the lake for use in booming Bodie. Clear cutting was the rule, and in large areas one can see numerous similar sized, young Jeffrey Pines interspersed with numerous large stumps. For several miles it is rare to see any of the large, older trees which are common in less disturbed sites. In 1880, Bodie had used 5,000,000 feet of lumber, supplied by Mono Mills and four lumber mills around Bridgeport.

Big Sand Flat (#053; T. 1S, R. 28 E, Sec.9)

This is an area of fine pumice sand.

Bitter Spring (#054, T.1S, R.28E, Sec. 1)

Sulfate waters from volcanic action give this spring a bitter taste**.**

Indian Meadows (#055; T. 1S, R. 30 E, Sec. 30)

Black Lake (#056; T1.S, R.32E, Sec. 32).

Black Lake, a small saline lake which can be seen at the bottom of the hills as we approach Sagehen Summit, is the home to two rare local endemics, Inyo County Star Tulip (Calochortus excavatus) and the endangered Owens Valley Checkerbloom (Sidalcea covillei). Both are thought to be threatened by overgrazing and the lowering of the water table in this area.

After going over Sagehen Summit, we enter a different, more desert, vegetation type. The most apparent new constituent is the cholla or teddy bear cactus (Opuntia echinocarpa) Other changes which are not so apparent immediately are that the Mormon tea is a different species, and the addition of several more desert species such as Mojave Indigo bush (Psorothamnus arborescens var minutifolius), whose flowers were originally used to dye blue jeans. The dye itself is a clear or yellow color; the blue appears only on contact with oxygen. This is why jeans were blue on the outside, but white on the inside.

Benton Hot Springs (#057; T.2S, R.31E, Sec.2)

These hot springs are at the site of an Indian Reservation.

Benton Hot Spring (from website).

One of the oldest surviving towns in Mono County, Benton was once a thriving, silver mining town, with up to 5,000 inhabitants. It was established in 1852 as a stop over for travelers heading south from the nearby mining towns of Bodie and Aurora. (http://historicbentonhotsprings.com/history.htm, April 7, 2007)

In 1862, mining began in the nearby Blind Spring Hills and the town boomed. Today, there are a small number of old structures left in Benton, as well as the cemetery. If you yearn to experience yesteryear, then come and enjoy our interesting buildings, old mining and farming equipment, and our natural hot springs, while you step back in time to a more gentle atmosphere. (http://historicbentonhotsprings.com/history.htm, April 7, 2007)

Blind Springs Valley Pumice Deposits (#058; T.2S, R.31E, Sec. 14, 23).

The Benton Pumice Beds lie in a block faulted trough between the White and Sierra Nevada Mountains. Between these two regional structures is an uplifted block expressed topographically as the Benton Mountain Range. The Tertiary history of this region is dominated by the 570,000 year old Bishop Tuff which was deposited following the eruption of the Long Valley Caldera (Sorey et. al, 1978; Krauskopf and Bateman, 1977).

Tuff beds within the Tulare Formation of the western San Joaquin Valley, 250 miles to the southwest have been suggested as correlative with the Bishop Tuff (Milliken, 1990). The rise of resurgent domes within the 6-mile wide caldera and volcanism in the Inyo Craters and Mono Craters volcanic chains has resulted in widespread pumice distributions in this area. The most recent pumice/obsidian eruption was about 10,000 years ago (Bateman, 1992). The best exposures of the pumice are in an area 0.75 miles west of Blind Springs Hill. The pumice is Quaternary ejecta material which came from the rhyolitic volcanoes in the Glass Mountain-Volcanic Tablelands area of Mono County. The pumice beds occur in two distinct layers separated by an unconformity. The upper layer is 0 to 11 ft. thick and consists of coarse subangular pumice fragments, some of which are over 1.75 inches in diameter. The lower bed is medium to coarse grained with subangular fragments up to 1.0 inch in size. The lower bed is 0 to 9 feet thick. Overburden at the Blind Springs Hill deposit varies from 0 to 15 feet. There are approximately 1 million cubic yards of material in the deposit that can be mined. The layers which have been mined for pumice are members of the Tuff of Taylor Canyon (Krauskopf and Bateman, 1977). The pumice from these deposits was used in the manufacture of stone-wash and acid-wash textiles (Wilkerson and Hoffer, 1995).

Benton (#059; T.1S, R.32E, Sec. 32)

Benton was a camp on the Owens Valley Railroad.

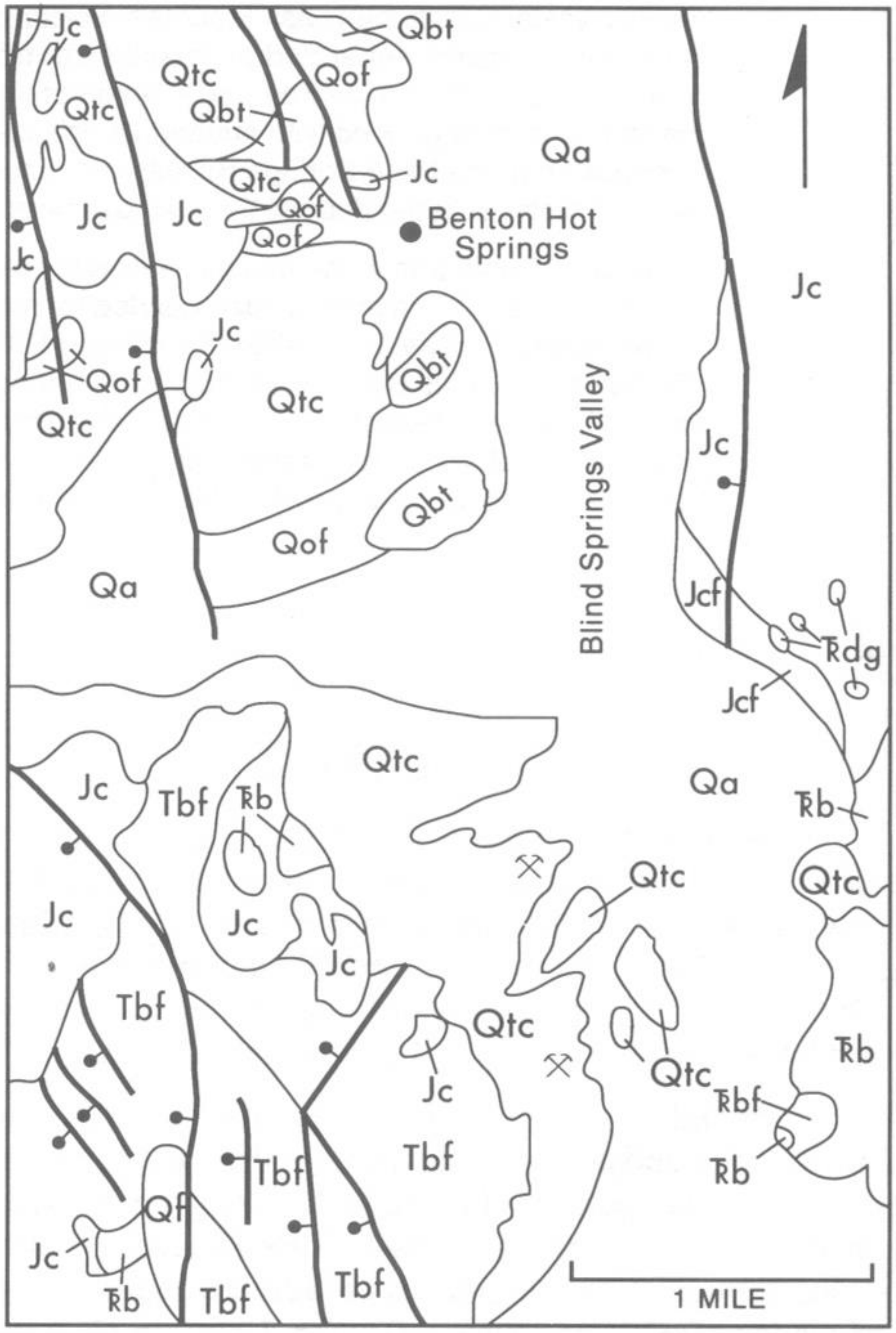
Commanche Mine (#060; T.2S, R.32E, Sec. 17)

This is a silver-copper mine.

Hammil (Site) (#061; T.3S, R.32E, Sec 24)

Califant Valley (#062; T.5S, R.33E. Sec. 9)

The geology of this area is summarized in Unruh, Jeffrey, James Humphrey and Andrew Barron. 2003.



Geologic map of Blind Springs Valley. Adapted from Krauskopf and Bateman, 1977. Qa = alluvium, Qf = fanglomerate, Qof = older fanglomerate, Qbt = Bishop Tuff, Qtc = tuff of Taylor Canyon, Tbf = basalt flows, Jc = granite of Casa Diablo Mountain, Jcf = fine grained granite of Casa Diablo Mountain, Tb = granodiorite of Benton Range, Tbf = fine grained granodiorite of Benton Range.

From Wilkerson and Hoffer, 1995

Califant Valley Powerhouse (#063; T.5S, R.33E, Sec. 15 and 16)

Map 14: Bishop to Big Pine

Bishop (#064; T. 7S, R.33e, Sec. 6)

Bishop is a city in Inyo County, California, USA. The population was 3,575 at the 2000 census. The town was named after Bishop Creek, flowing out of the Sierra Nevada: the creek was named after Samuel Addison Bishop, a settler in the Owens Valley (http://en.wikipedia.org/wiki/Bishop%2C_California, April 5, 2007).

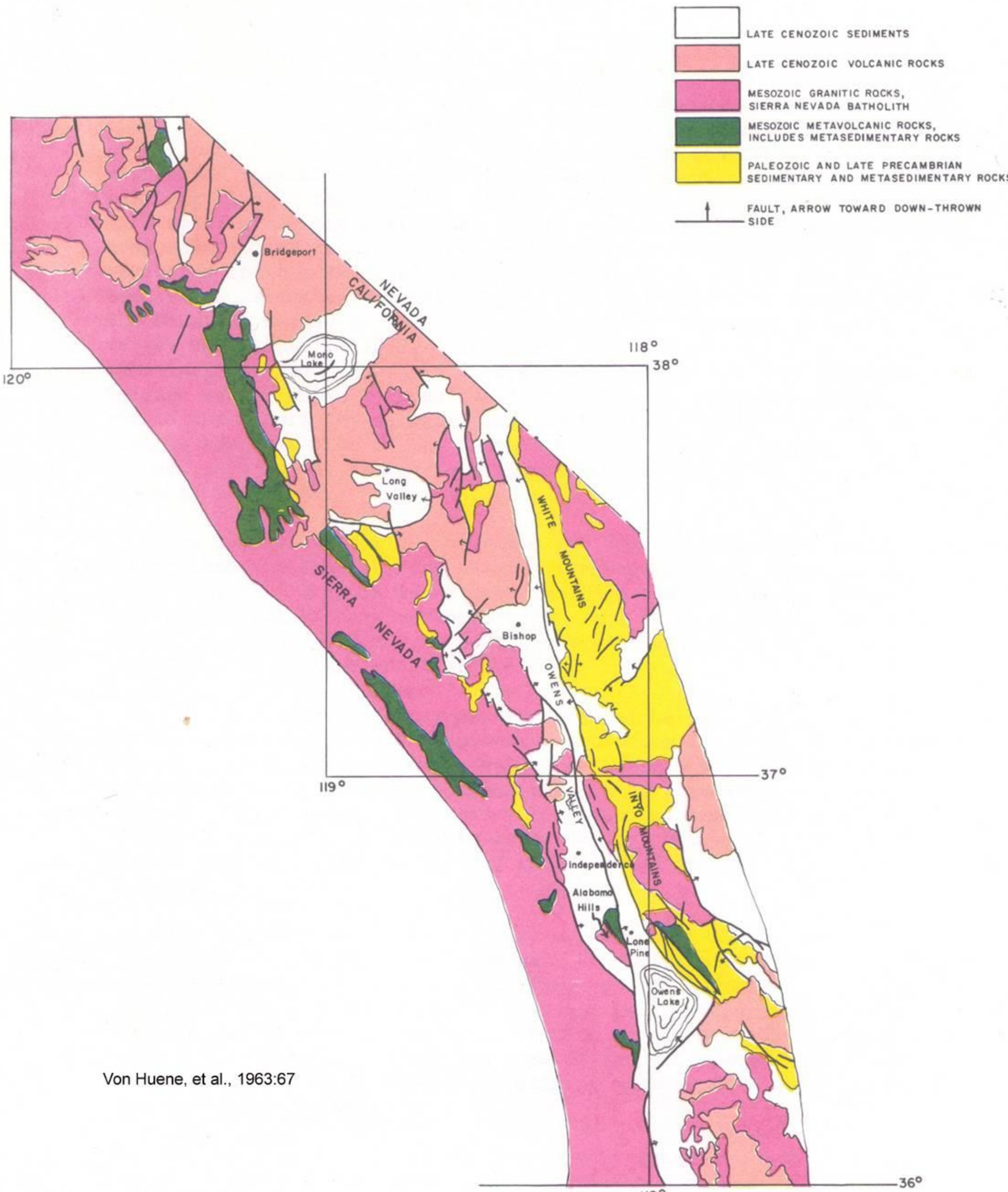
Bishop is also dubbed the "Mule Capitol of the World" and a week long-festival called Mule Days has been held since 1969 on the week of Memorial Day, celebrating the contributions of Pack-Mules to the area. The festival attracts a large number of tourists, primarily from the Southern California area (http://en.wikipedia.org/wiki/Bishop%2C_California, April 5, 2007).

Bishop was the home of Galen Rowell, and his wife Barbara, before their untimely death at the Eastern Sierra Regional Airport. Stuntman and NASCAR driver Stanton Barrett also calls Bishop home. Matt Williams, former Major League Baseball 3rd baseman and slugger, was also born in Bishop (http://en.wikipedia.org/wiki/Bishop%2C_California, April 5, 2007).

Owens Valley

Owens Valley is a down-dropped block between the Sierra Nevada to the west and the Inyo-White Mountain chains to the east

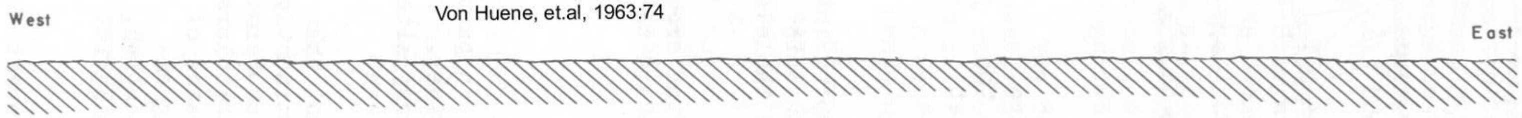
In the 1970's a popular model to explain the relationship between the Sierra, Owens Valley, and the Inyo-White Mountains proposed that the valley is the result of regional arching.



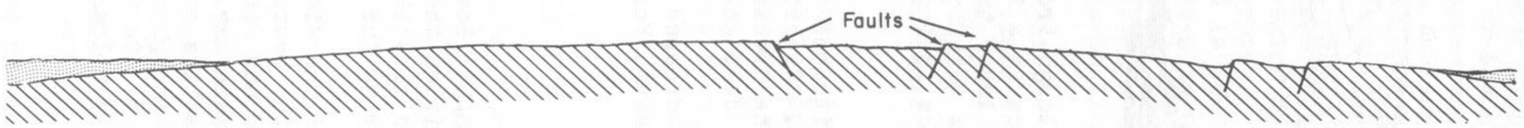
Von Huene, et al., 1963:67

Generalized Geologic Map of Owens Valley Region.

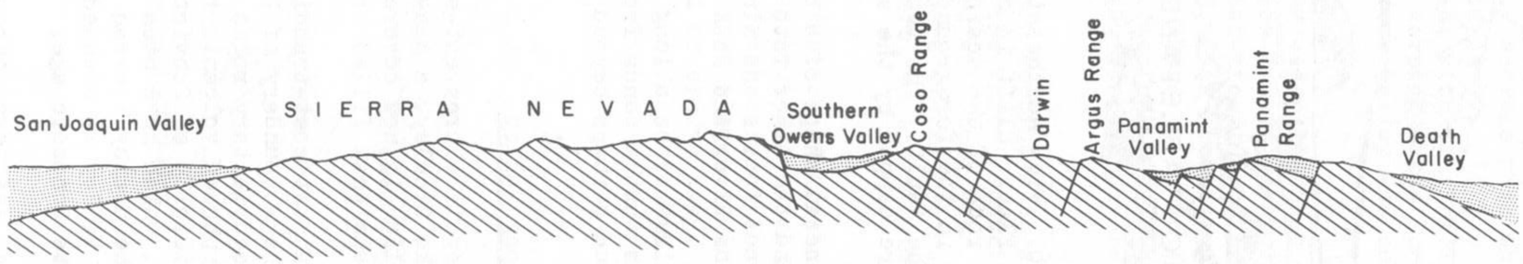
Von Huene, et.al, 1963:74



(a) Several million years ago the present Sierra Nevada area was part of a gently rolling plain.

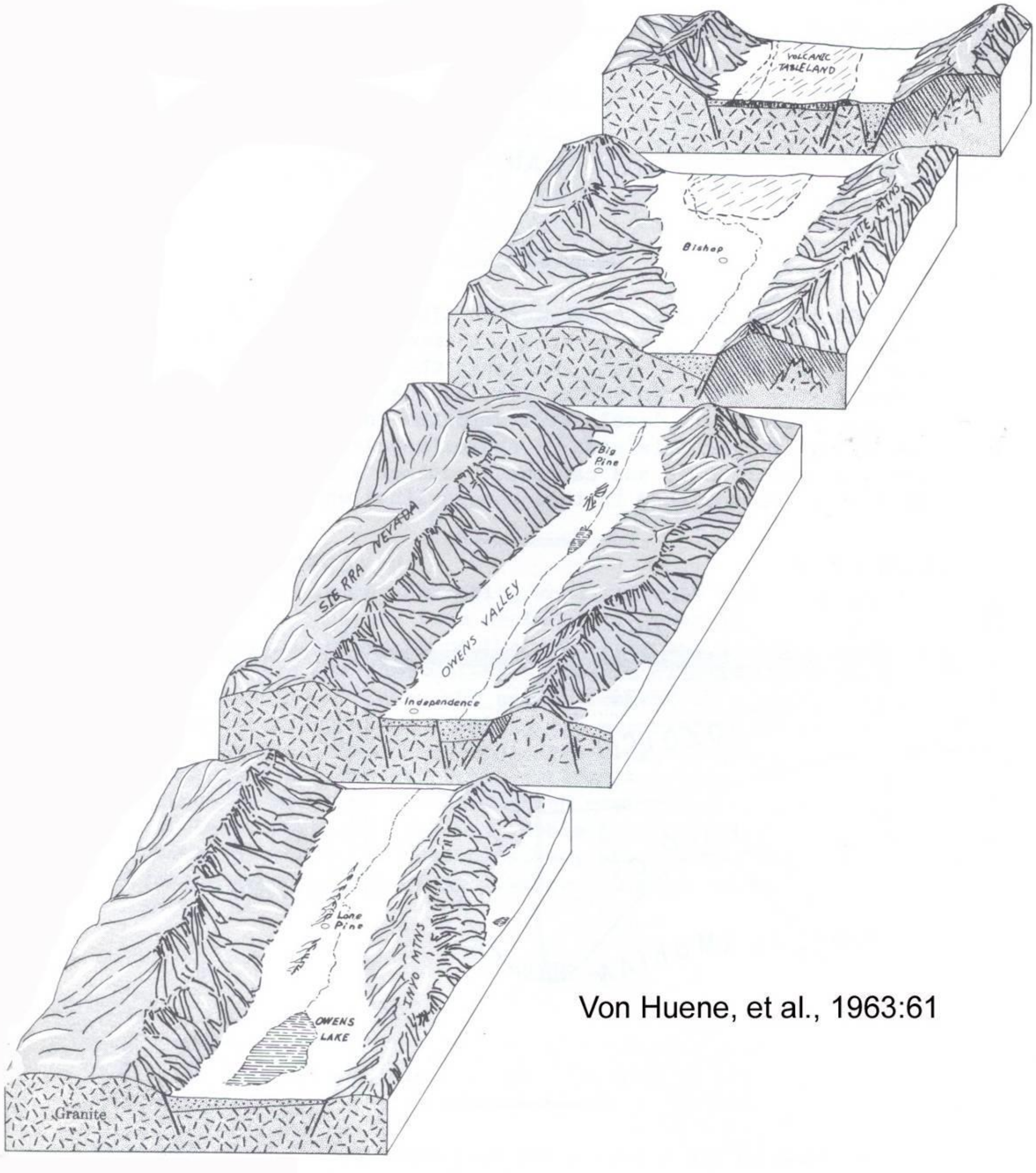


(b) Then the earth's crust began to bend upward and form a great arch. The arching caused the crust to stretch and resulted in faulting along the crest and east flank.



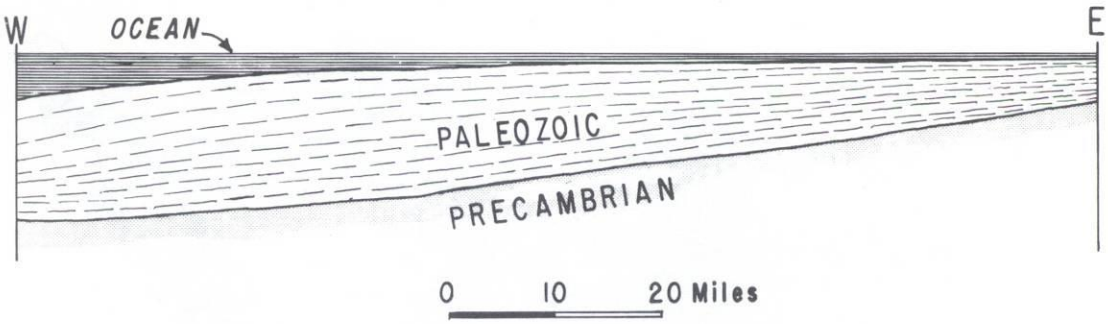
(c) Sinking of a strip of ground along the crest of the arch formed Owens Valley. The west flank of the arch became the Sierra Nevada; perhaps because it was composed of granite, it retained its unity as a single, enormous, westward-tilted block. The east flank of the arch broke into a series of eastward-tilted blocks, which became the ranges east of Owens Valley.

Development of Owens Valley According to Arching Hypothesis.

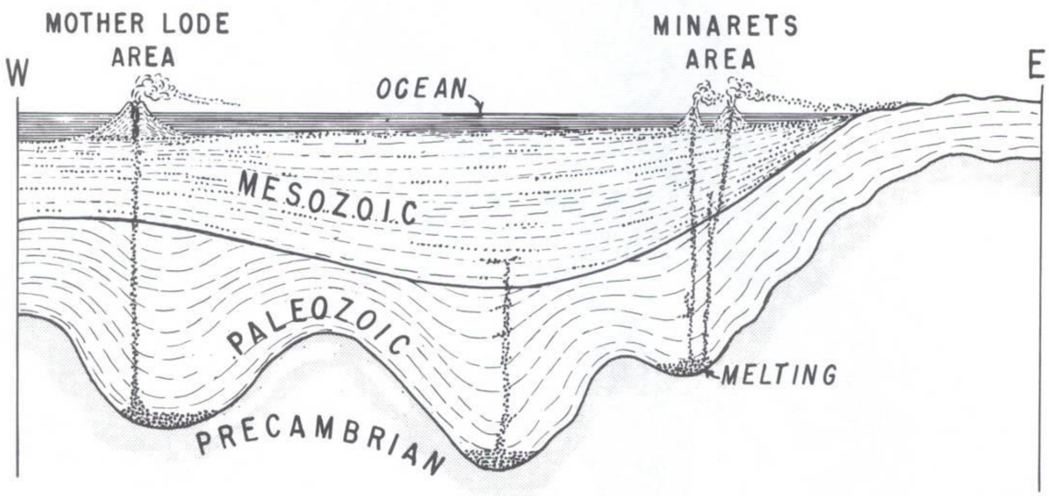


Von Huene, et al., 1963:61

Generalized Block Diagram of Owens Valley.



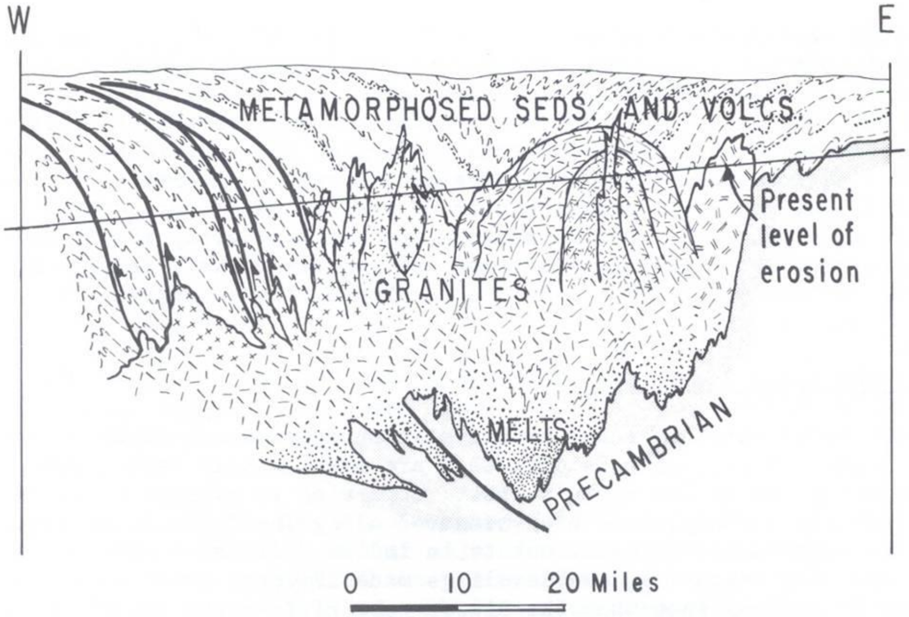
(a) Beginning in late Pre-Cambrian time the region was submerged beneath the ocean, along with most of the rest of the western United States. Although the sea floor was flexed periodically and lifted above sea level at least once, it lay generally below sea level until sometime in the Permian or Triassic. During this span of approximately 400 million years, a variety of clastic and carbonate sediments more than 20,000 feet thick accumulated in this geosynclinal environment.



Von Huene, et al., 1963:62

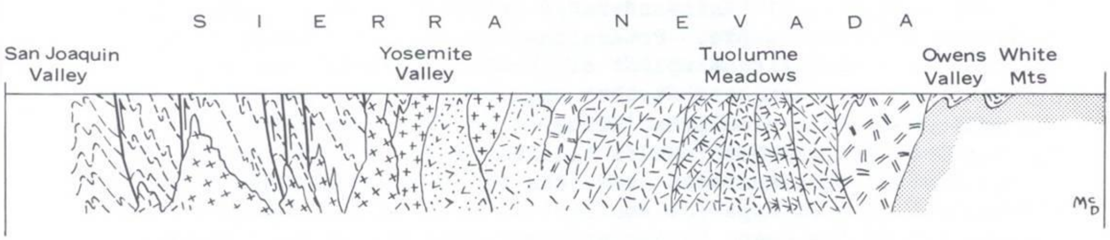
(b) Sometime in the Triassic the sediments were folded, faulted, lifted above sea level, and eroded. Then a long narrow trough began to bow down and to collect debris. The sinking of the trough was accompanied by volcanism, and vast quantities of lavas and ash were extruded. Some of this material flowed or fell directly into the trough, which was near or below sea level most of the time, but large volumes were deposited on land. Much of this material was then eroded and washed into the sinking trough.

Diagrammatic Summary of Early History of Sierra Nevada and Owens Valley Regions.



(c) Beginning in the Jurassic, when volcanic and sedimentary deposits had collected to a depth of at least 50,000 feet, the strata that had piled up on the sea floor and in the trough were tightly folded and faulted. As a result of downbuckling some of the strata were brought into an environment of elevated temperature and pressure where mobilization occurred. The mobile material worked upward into the overlying, strongly deformed volcanic and sedimentary rocks, where it crystallized to form a sequence of granitic plutons, which were emplaced during a span of at least 60 million years. Other hypotheses for the origin of these plutons have been proposed, but the one shown here is strongly supported by field studies and experimental work with granitic melts.

Von Huene, et al., 1963:63



(d) After the granitic plutons crystallized, the trough began to rise. Continuous uplift and erosion stripped away most of the overlying metamorphic rocks, exposing the plutons. Erosion probably kept pace with uplift, and before basin-and-range deformation took place the land was reduced to a broad rolling plain—the same plain that later was broken into the fault blocks that form the Sierra Nevada, Owens Valley, the White, Inyo, Coso, and Argus Mountains, and the desert ranges and basins farther east.

Keough Hot Springs (#065; T.8S, R.33E, Sec 17).

Associated with the East Sierra Fault system, this is a popular recreation spot.

Keough Hot Springs (http://www.keoughshotsprings.com/; April 11, 2007)

Klondike Lake (#066; T.8S, R.33E, Sec. 36).

This is an important site for waterfowl and other wildlife.

Owen's Valley Caltech Radio Astronomy Telescopes (#067; T8S, R34E, Sec. 19).

One of these dishes is 90 feet and the other 150 feet in diameter. The following information is taken from http://www.ovro.caltech.edu/ (April 7, 2007):

The Owens Valley Radio Observatory (OVRO) is the largest university-operated radio observatory in the world. The observatory is located near Bishop, California, approximately 250 miles north of Los Angeles on the east side of the Sierra Nevada. For reference, its coordinates are 37°14'02" latitude, 118°16'56" longitude at 1222 meters above sea level. The major instruments at the observatory are:

Millimeter-Wavelength Array
The newly completed millimeter-wavelength array consists of six high-accuracy radio telescopes, each 10.4 meters (34 feet) in diameter. The individual telescopes can be moved to observing stations along a T-shaped railroad track and pointed toward the same object in space. By combining the detected signals through a process called interferometry, extremely high-definition pictures can be produced. As in all interferometry, the degree of detail achieved depends upon the distance between the telescopes; for example, a single dish with a diameter of 300 meters (about one fifth of a mile) would be required to match the resolution that can be obtained with these new instruments. This array was moved to Westguard pass

in 2007.

40-M Telescope

An intensive program of microwave background observations is currently underway at OVRO using the 40-meter (130-foot) telescope. According to the Big Bang theory, the universe began some 15 billion years ago with an enormous explosion of primeval matter, and has been expanding and cooling ever since. The remnant heat radiation of this explosion can now be detected as very weak radio noise coming from all directions in space. A fundamental problem is how the once homogeneous, expanding gas gave rise to the current, lumpy distribution of stars and galaxies. Observations of this "microwave background" provide information about the conditions of the early universe and help determine how the original expanding ball of gas condensed into the celestial bodies we see today.

Solar Array

New receivers and signal processing equipment have transformed the 27-meter (90-foot) telescopes into a powerful interferometer for studying the Sun. Solar temperatures range from about 5,500 degrees Celsius at the solar surface to two million degrees at a higher level known as the corona. In the corona, strong magnetic fields guide and constrain ionized gas. Solar flares occur when the energy stored in the tangled magnetic fields explosively releases. Electrons in these fields generate radio emission at wavelengths dependent on the strength of the field. The solar interferometer can be tuned rapidly to many different wavelengths so magnetic fields of different intensities can be seen almost simultaneously. Scientists can then determine the way in which these fields emerge, strengthen, and entangle themselves, perhaps fire, and then decay.

Graduate student research with the instruments at Owens Valley has been extensive. Long-term commitments of observing time have been available to students enabling more innovative and comprehensive projects than would have been possible at a national observatory. Typically 5-7 graduate students are supported with fellowships and have done a significant fraction of their Ph.D. research with the observatory instruments. Projects have ranged from purely observational research with the existing instrumentation to the design, development, and use of new instrumentation.

Big Pine Indian Reservation (#069; T.9S, R.34E, Sec. 17 and 20).

The reservation is the site of an ongoing groundwater study. The area has eroded boulders that are the size of automobiles with giant ventifacts.

Giant Sequoia at Big Pine Triangle County Park (#068; T.9S, R.34.E, common corner sections 7,8,16 and 17)

This planted tree is 150 years old.

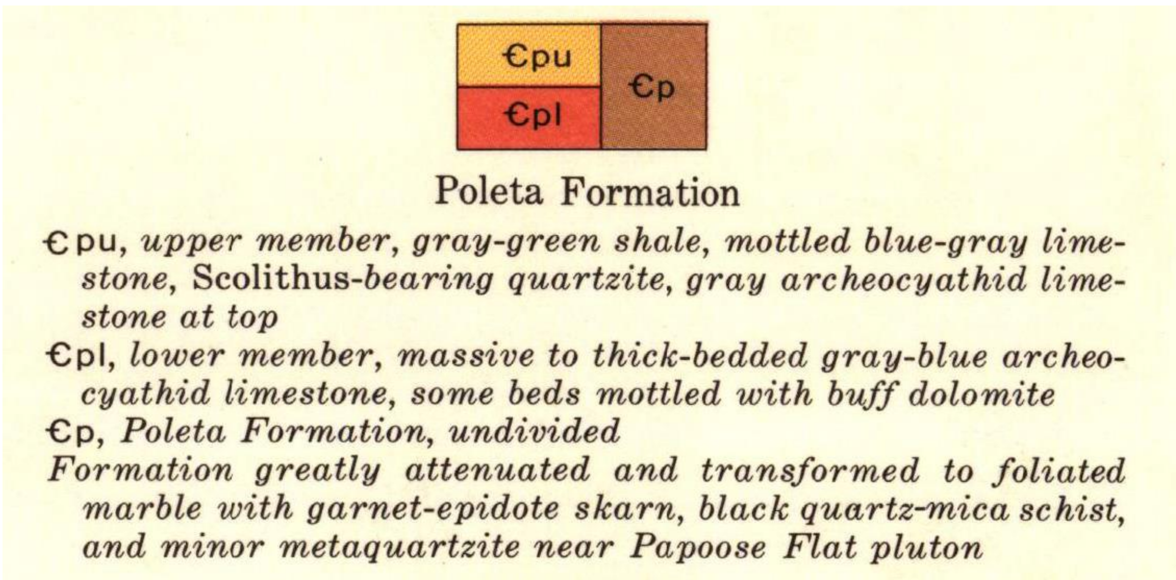
Wilkerson Spring (#069; T.9S, R.34E, Sec. 10)

The home of the authors' great granduncle and his magic elixir.

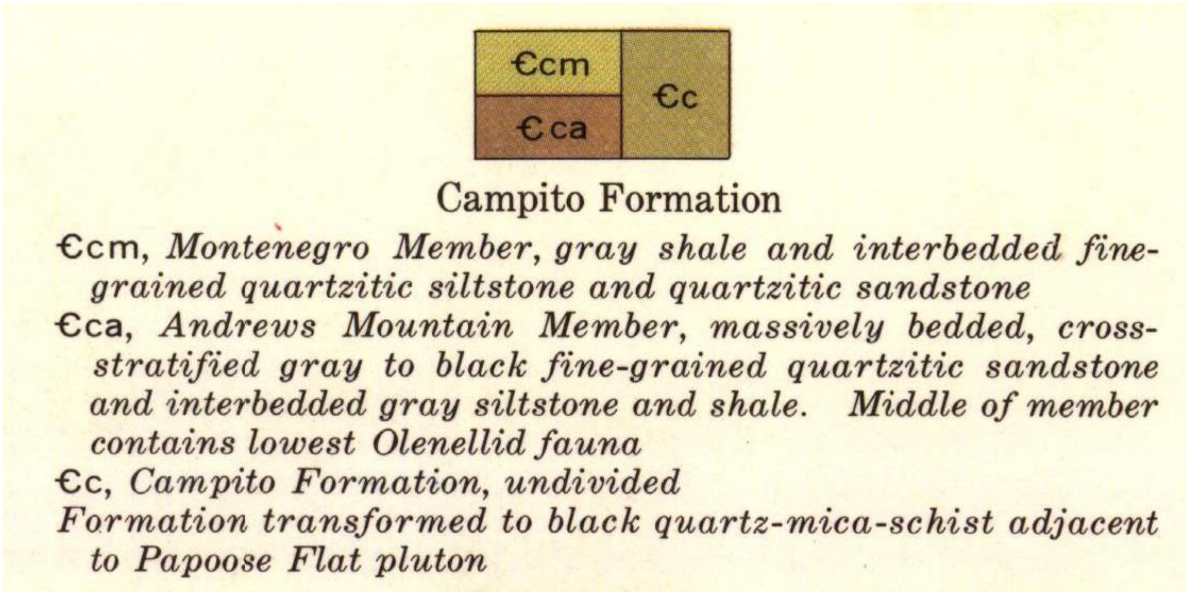
Side trip to Bristlecone Pine National Forest and the Bancroft High Altitude Research Station

Map 14.1 Big Pine to Papoose Flat

This side trip begins at the Big Pine city campground at the intersection of Highways 394 and 108. From the campground head east toward Westguard Pass. Drive 2.7 miles to the Big Pine Community Pit (#070), then on another 14.5 miles on alluvial materials. This brings us the mouth of Cedar Flat Canyon (#219) where we cross several range-front faults. The rocks here are Cambrian Poleta Formation (Nelesen, 1966).



At the Toll House (site) we pass on to Cambrian Campito Formation. We are un this unit until we get to Poleta Folds Junction (#220). There we pass back into Poleta Folds Formation.



The Della B prospect is 0.8 miles north of Papoose Flat Junction. This is a uranium occurrence (Rains and others, 1983).

Map 14.2 Bristlecone Pine National Forest

Point #220 is the turn off to Bristlecone Pine National Forest. At the Junction we have returned to Campeto Formation (€ca, cm or c). On the old road (abandoned), to the east, Point #221 we return to Poleta Formation , and at Point #222 go back to Campito Formation. The more recent paved road is entirely in Poleta Formation

At Point #223 is a contact between Campito Formation and Triassic volcanic rocks (Trvl). Here we enter Reed Flat. We pass the Mexican and Reed Flat mines. The Mexican is a lead-zinc deposit with galena and sphalerite. The Reed Flat produced silver. Drive 0.2 miles past the Reed Flat mine to a road junction. Turn right to go to the Schulman Grove and Visitor's Center (#224)

At Goat Springs Junction (#225) the road to the right goes up to the Bristlecone Pine National Forest. The road to the left goes on the Bancroft White Mountain Research Station. From Goat springs junction we go north for 1.6 miles across Older Alluvvium Cambrian Campito Formation and Triassic volcanics and marine rocks to Wyman Creek Junction (#226). We turn right here and go west across the Precambrain Reed Dolomite to see more Bristlecone Pine growing on the Reed Dolomite unit.

Bristlecone Pine National Forest (#071; T.6S, R.35E, Sec. 17)

The Bristlecone Pine National Forest is east of Big Pine and north of Westguard Pass off of Highway 168.

For eons the bristlecones (Pinus longaeva & aristata) have flourished atop the arid mountains of the Great Basin, from Colorado to California, enduring extreme hardships and silently adjusting to their environment. Their exquisite beauty was known to few. Their great age was known to not know until 1953.
(http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

First we must go back to 1932 when Edmund Schulman began his career in dendrochronology as an assistant to A.E. Douglass of the Laboratory of Tree-Ring Research, University of Arizona. Schulman had a background in astronomy and, like his mentor, he related cosmic events to the science of tree-ring dating. For the next 20 years he conducted climatic research throughout the western states. At that time our records of climatic conditions in western America were relatively short, with sensitive tree-ring records showing only a few centuries. Schulman thought it imperative that he/science push the chronology further into the past
(http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

During the years 1939-1953 Schulman's focus was on conifers in the lower forest zones, the habitat of the piñon and Douglas-fir. The longer records of the Giant Sequoia (Sequoiadendron giganteum) were not used because of the semi-humid region they grow in. Then he learned that certain species of trees in the upper-forest zones, growing under stressful conditions, showed sensitive records of drought in their growth-ring sequences, much more so than the rings of trees living in lower zones that can be unreliable due to ground water, etc. The short, distorted and dwarfed trees of the upper tree lines were now his focus. He discovered a Douglas-fir 600 yrs. old in Mesa Verde National Park, Colorado, an 800 year old bristlecone on Mt. Evans in Nevada, and a piñon pine of 975 yrs. in Utah. With all this data, a picture of the past climatic events began to emerge (http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

From 1215 to 1299 A.D. a severe drought took place and probably caused the Pueblo people to seek areas with adequate food, leaving their long-established homes. Following this calamity, the period (1300-1396) was shown to be one of extreme rainfall, probably a time of great floods. Schulman began to see a 200 year cycle of flood and drought, and he formed a theory relating this cycle with sunspot phenomena that were observed to be in decline during this same period. But the hypothesis was put aside due to insufficient data (http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

In 1953, Schulman was working with his colleague Frits W. Went of Cal Tech when they found a limber pine (Pinus flexilis) in Sun Valley, Idaho, with 1700 growth rings. A very promising find! Returning to Pasadena with their collected data, they made a detour to the White Mountains acting on a rumor that old trees existed there. Knowing such hearsay seldom proved to be true, the trip up the mountain was made anyway, and became fateful. Here they found a multiple-stemmed bristlecone fully 36 feet (10.9m) in circumference that had been named "Patriarch" by a local ranger. Although after taking samples, they found it to be only 1500 years old with typical ring growth of the upper tree line. But at this point they knew that the bristlecones were better recorders of drought conditions than the limber pines. Even more exciting were the old trees found nearby on even drier sites. The return home was filled with excitement for next year's field trip (http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

Back in the laboratory, extensive analysis of the collected samples and data proved the "rumor" true and Schulman was then convinced it was the bristlecone stands he needed to explore. During the following two years of 1954 and 1955, an extensive search from California to Colorado was carried out by Dr. Schulman and his assistant C.W. Ferguson. They found the oldest trees at elevations of 10,000 to 11,000 feet (3048 to 3354m), often growing in seemingly impossible locations. These trees showed large areas of die back (deadwood) and thin strips of living bark. The trees growing in the most extreme conditions, with scant soil and moisture, seemed to be the oldest! Several trees in the 3,000 to 4,000+ year range were discovered. All but one were found in the White-Inyo Range, so Schulman devoted his attention to this area. The first tree proven over four thousand years old he aptly named "Pine Alpha". Later in 1957 "Methuselah" was found to be 4,723 years old and remains today the world's oldest known living tree (http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

Ancient at Schuleman Grove (From https://bonsaitonight.com/2017/08/22/ancient-bristlecone-pine-forest/ accessed June 12, 2019)

For several months after his discovery Schulman was known to be awed by these trees, often speaking with amazement about their ability to live so long with so little. He wrote: "The capacity of these trees to live so fantastically long may, when we come to understand it fully, perhaps serve as a guidepost on the road to understanding of longevity in general.

(http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

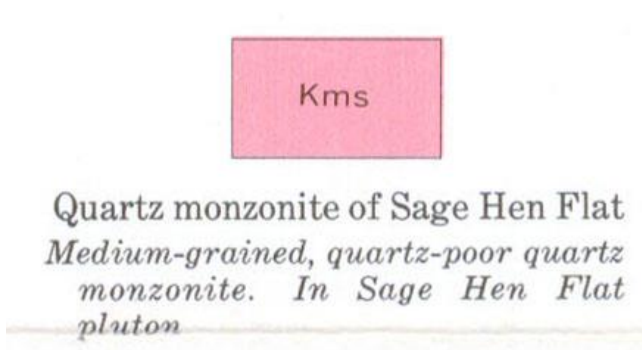
Data by Schulman and his colleagues was reported in National Geographic (1958) bringing worldwide attention to the White Mountains. Sadly though, Edmund Schulman died shortly before his article was published, struck down by a heart attack at age 49. That same year the U.S. Forest Service established the 28,000 acre Ancient Bristlecone Pine Forest, naming a very special area, Schulman Memorial Grove, in honor of his contribution to the world. (http://www.sonic.net/bristlecone/Schulman.html, April 5, 2007).

After exploring the Bristlecones (#229), return to Wyman Creek Junction (#226) and head north toward the Bancroft Station.

Map 14.3 Big Prospector Meadow to Bancroft High Altitude Research Center

Point #227 is Big Prospector Meadow. The road to the northeast goes to the Golden Siren Gold Mine. The host rock is marble. See U.S. Geological Survey Professional Paper 110, 1918, P. 119 and U.S. Bureau of Mines Open File Report MLA 94-83, 1983, TABLE 4, No. 93, P. 48 (Cited in MRDS, 2011).

Turn right at Big Prospector Meadow Junction and go 2.3 miles northwest across Quartz Monzonite of Sage Hen Flat (Kms) to the White Mountain Research Station and Crooked Creek Laboratory (Nelson, 1966).



White Mountain High Altitude Research Station (#072 observatory, #073 Barcroft laboratory; T.4S, R.34E, Sec. 20)

The White Mountain Research Station is a multi-campus research unit (MRU) of the University of California Office of Research, with a campus office located at UC San Diego. WMRS includes a base station near the town of Bishop (Owens Valley Lab; elevation 4000') , a montane station at Crooked Creek (elev. 10,200'), an alpine station at *Barcroft* (elev. 12,500'), and a high alpine summit lab on White Mountain Peak (elev. 14,250'). The combination of facilities, geologic exposure, high elevation and winter access make the station uniquely valuable for scientific study and educational purposes (http://www.wmrs.edu/. April 7, 2005)

Return to Big Prospector Meadow Junction (#227) and proceed northwest and north to the Patriarch Tree Junction (#288). From there take the right fork and go 0.9 miles to the Patriarch Tree (#073). On this journey we cross a short section of Precambrian Deep Springs Formation….

pЄd

Deep Spring Formation

Interbedded quartzite, shale, limestone, and dolomite; quartzite fine grained and light gray to brown, shale gray, limestone thin bedded and blue gray, dolomite gray to brown. Metamorphosed near intrusive bodies to coarse-grained quartzite, mica schist, gray to white calcite and dolomite marble, and calc-silicate hornfels

… and then Precambrian Reed Dolomite (Krauskopf, 1971)

pЄr

Reed Dolomite

Massive, fine-grained, white to light-gray in southwest corner of quadrangle. Elsewhere metamorphosed to massive, coarse-grained, white to buff marble; rare thin interbeds of mica schist and calc-silicate hornfels

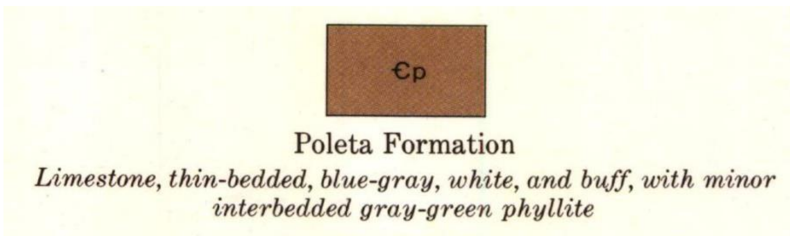
Patriarch Tree Campground (#073; T.5S, R.34E, Sec. 12)

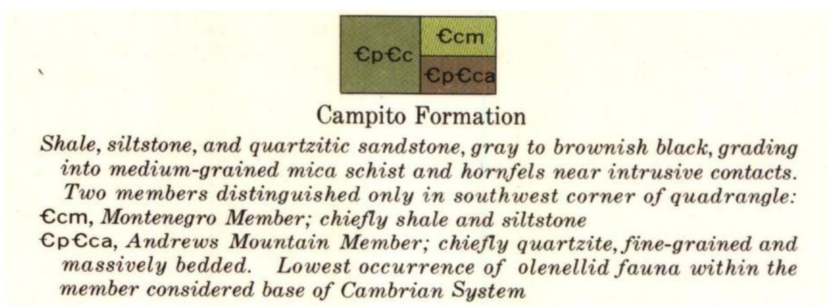
The Bristlecone Pine trees at this campground are the highest elevation grove in the White Mountains. Near the campground is the oldest living Bristlecone pine, named Methuselah.

Patriarch Tree. Photo by Janet Westbrook.

Return to Patriarch Tree unction (#228). Turn left and go toward the northwest 1.6 miles over Deep Springs Formation Reed Dolomite and Older alluvium to the Eva Belle Mine Junction (#229). A trail leads right from this junction down to the Eva Bell Mine Site (#184). Gregg Wilkerson mapped this area in 1976 for his summer field project. The mine is at a juncture of two faults (See Appendix 1).

From the Eva Belle Mine Junction go north-northeast across Cambrian Poleta and Campeto Formations.





Point #230 is a contact between Older alluvium to the southeast and Granodiorite of Mt Barcroft (Jgb) to the northwest (Krauskopf,, 1971). We will remain on this unit at the Barcroft Library Research Station (#072) and the Observatory (#073).

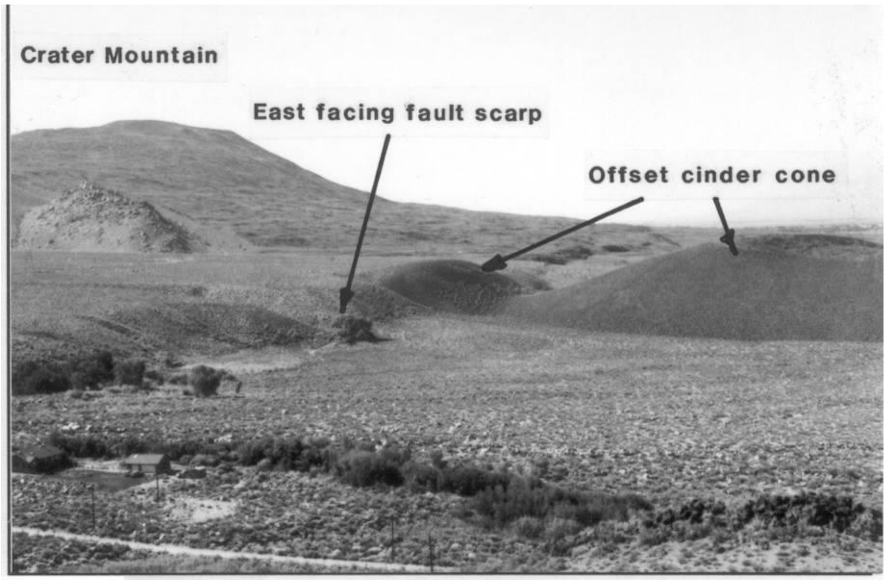
White Mountain High Altitude Observatory (#073)

Barcroft Laboratory, White Mountain High Altitude Research Station (#072). After visiting the Observatory and Barcroft station, return to Big Pine.

Map 15: Big Pine to Aberdeen

Crater Mountain (#074; T.10S, R.34E, Sec. 6).

This mountain looks like a large volcano. It is really a small volcano that sits atop a large mass of granodiorite. The lava has covered this mass and so the volcano looks large. The Crater Mountain eruption is 290,000 years old. Parts of the underlying granitic hill crop out from beneath the basalt as "islands." The largest island is Fish Spring Hill where mining operations have scarred the hillside. Fresh appearing east-facing normal faults can be seen on the flank of Crater Mountain. A prominent north-south fault displaces the 314,000 year old Fish Springs cinder cone. Crater Mountain has a series of lava tubes that are important habitat for bats.



Offset cinder cone along a fault north of the Poverty Hills. The cone has been offset about 60 feet.

Crater Mountain is a volcano rising 2,000 feet above Owens Valley. But looks can deceive. The basaltic vent and flows are perched atop a ±1,200 foot high granitic hill. The dark linear lines near the base are faults.

Map 16: Fish Springs Mining District

Fish Springs Hill Mines (Cleveland Mines) (#075; T10S, R34E. Sec. 17)

These mines worked shear zones with gold-quartz mineralization.

Birch Creek Arrastra (#076; T.10S, R.34E, Sec. 20)

This mill site dates to the 1930's. The mill here has an unusual arrastra. It is driven by a Dodge truck rear end and powered by a Model A motor.

Sites #075 (Cleveland Mine) and #076 (Birch Creek Arrastra) are in a graben. The boundary faults for this graben run approximately north-south. The eastern fault is on the west side of the Poverty Hills, and the western fault on the eastern escarpment below the American Perlite rhyolite dome.

American Perlite Mine and Overlook (T#077; T.10S, R.34E, Secs 19 and 30).

American Perlite Mine with view to northeast

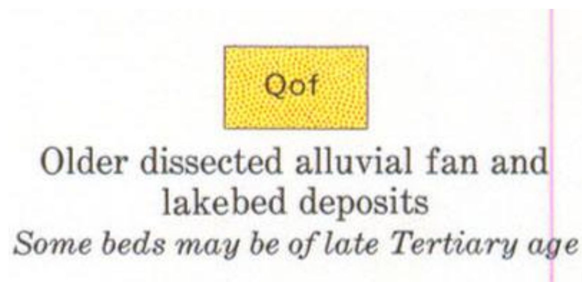
From Highway 395, turn west onto Fish Springs Road. After 2 mile, turn left onto Tinemaha Road and continue through the campground. Drive west up to the mine and park at an overlook just east of the mine operation. The hill being mined is composed of perlite. Unlike silica-poor basalt lava whose low viscosity results in extensive flows, rhyolite is high in silica, resulting in a higher viscosity. Upon eruption, rhyolite flows like toothpaste out of tube, forming localized domes. This dome is estimated to be 1 million years old. The perlite ore is crushed to sand sized particles and shipped to processing plants for "popping." Its expansive properties allow its use as absorbent, dehydrator, soil additive, lightweight concrete, insulation, paint fillers, stucco, ceiling and roofing material, tile cleaner, and cattle feed supplement. American Perlite mines 50,000 tons of ore annually from this dome. On the alluvial fans immediately to the east is a lush band of vegetation. Given the semi-arid climate, this lushness is an anomaly. The vegetation is concentrated within a wet area updip from a west-facing normal fault. Groundwater from the Sierra Nevadas seeps downdip through the alluvial fans. The fault may have elevated basement granitic rocks, putting them in contact with fan gravels, causing a groundwater barrier. Groundwater ponds up behind the fault, eventually reaching the surface to form an oasis.

Much of this vegetation is introduced, and there is an old pear orchard, apparently abandoned but still producing a few pears. Other native vegetation includes typical riparian and wetland species including willow and wild roses.

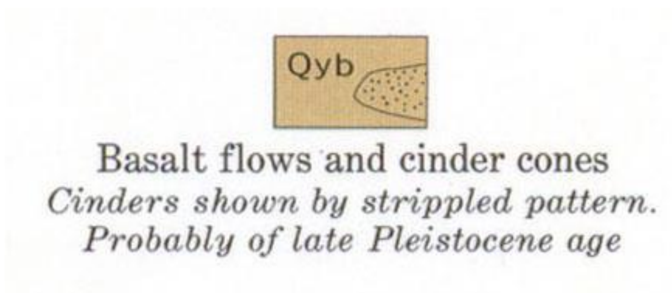
This west-facing fault extends from Crater Mountain in the north to Red Mountain in the south, a distance of over four miles. The fault displaces Crater Mountain basalts, but not the 340,000 year old (Bierman and others, 1991 Red Mountain cinder cone. This relationship suggests the Crater Mountain flows are older than the fault, and that Red Mountain is younger than the fault. Hence, Red Mountain is younger than Crater Mountain. Crater Mountain is 290,000 years old, however, suggesting just the opposite relationship. Taking the age dating error ranges into account could put Red Mountain older than Crater Mountain.

This perlite dome was formerly known as the Fish Springs Perlite deposit (Norman and Stewart, 1951:105). It is 7 miles south of Big Pine and 3 miles west of Fish Springs at the eastern end of a conspicuous hill near the base of the Sierra Nevada. The hill is elongate in plan and trends in an easterly direction. It rises about 100 feet above its base of outwash alluvial material. The hill is composed almost wholly of glassy volcanic rocks. The rock at the top is pumiceous perlite, which grades downward into a more or less flat-lying zone of slightly pumiceous perlite about 40 feet in thickness. The perlite rests upon brecciated obsidian, which rests upon a dense, glassy, perlitic vitrophyre. The only overburden is the highly pumiceous perlite, and much of it will expand. The perlite rock was mined in an open cut by a small power shovel loading into trucks which hauled the perlite to a crushing and screening plant at Loco, a siding on the Southern Pacific Railroad 21 miles north of Little Lake. At the crushing plant, the perlite rock was crushed in an impact crusher and elevated to a trommel where two products are separated, minus-12 mesh to plus-50 mesh and minus-50 mesh, and stored in a 24-ton, two-compartment bin. The oversize fragments return to the crusher for further crushing. Crushed perlite rock was bulk loaded into railroad cars and trucks. The mill could process 30 tons in an 8-hour day in 1951 (Norman and Stewart, 1951:105). The perlite expands when roasted, and was used for potting soils. Now it is used in various ceramic products.

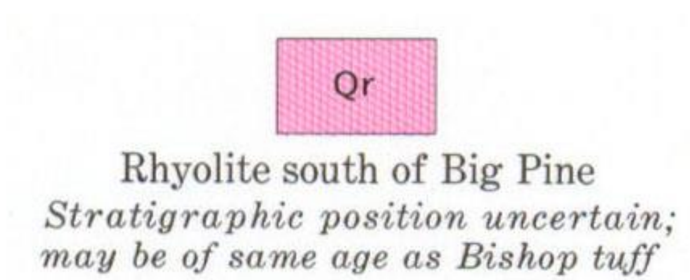
The area of Map 16 was mapped by Bateman and others, 1965a and Nelson, 1966a. In the map below, the major geologic units are:



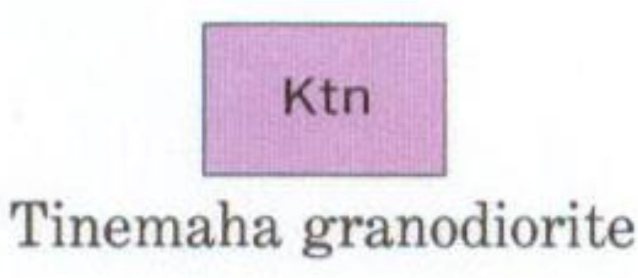
Pleistocene Lake and Fan Deposits



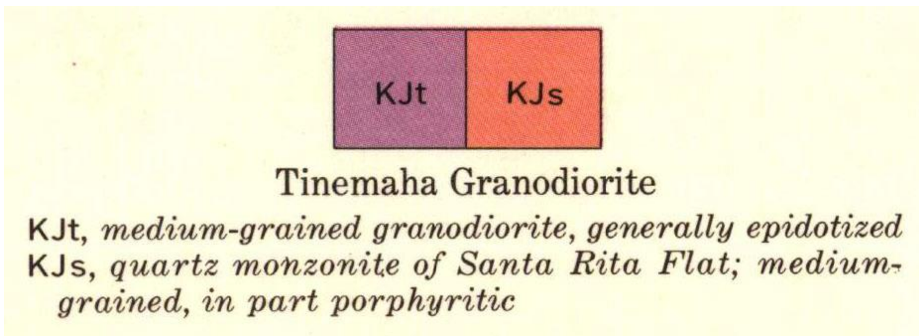
Pleistocene Basalt



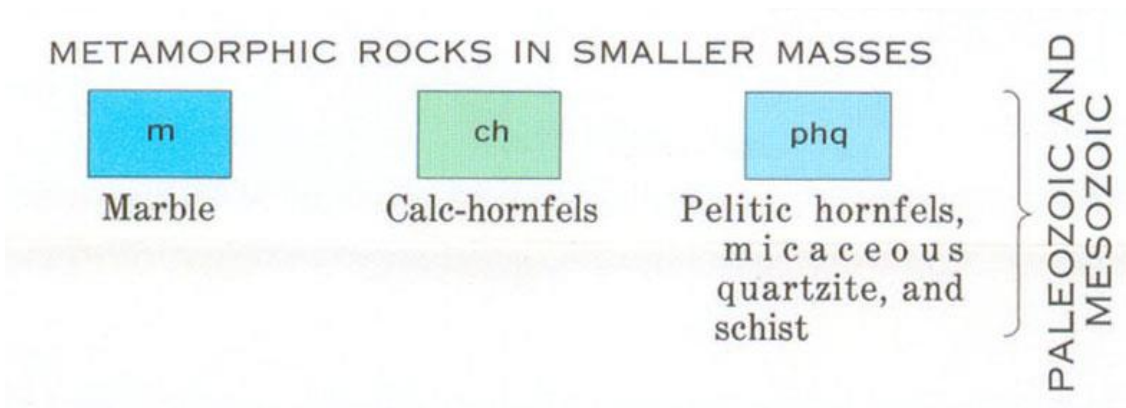
Pleistocene Rhyolite



Cretaceous Tinemaha Granodiorite



Cretaceous Tinemaha Granodiorite



Paleozoic Metamorphic rocks

Red Mountain (#105; T.11S, R.34E, Sec. 4 and 5).

One can speculate that the Red Hill eruption occurred coincident with or shortly after the major seismic event associated with fault displacement. Further to the east is another fault, discussed earlier, that offsets the Fish Springs cinder cone. This east facing fault combined with the west facing fault discussed above, form a broad, low relief horst, or uplifted block, about 12 miles wide and oriented north-south. As the block has risen due to vertical displacements on the these two faults, Birch Creek has managed to maintain a rate of erosion equal to or greater than the rate of uplift, thereby deepening its channel and becoming incised.

This horst is in alignment with the granite high beneath Crater Mountain, suggesting the two are related. This may be a rising block of granite bounded by deep-seated faults forming conduits for basaltic lava to rise and be extruded. Alternately, the block could be sitting still while Owens Valley drops around it.

Tinemaha Reservoir and Viewpoint (#081; T.10S, R.34E, Sec. 23, 24, 25 and 26).

About 17.5 miles north of Independence, turn east from US 395 onto an unpaved road leading to the wildlife viewpoint parking area. Walk a short distance to the viewpoint. The hill we are on is an uplifted block of Paleozoic metamorphic and Cretaceous granitic rocks similar to those that compose the Poverty Hills to the west. There has been some mining interest in the Poverty Hills, but no known commercial mines. The "New Era" mine, SW across US 395, is actually a trespass on federal lands; the operator claims to be extracting platinum from groundwater. No positive results have yet been seen from the operation.

From the Tule Elk overlook, you can see the riparian corridor of the Owens River to the north, with the marshy area just north of the reservoir. Before the dam was built, this whole area consisted of marshy areas such as this. This reservoir and that marshy area currently provide bird habitat for ospreys, blue herons, great egrets, and double-crested cormorants, many of which can be seen today. On a snag sticking up from the inlet toward the inlet can be seen a large nest in the top of the tree, probably an osprey nest. During fall migrations, numerous ruddy ducks and other migrants can be seen here as well.

The vegetation looks a lot like the vegetation which we've been seeing all along, although we have seen numerous. This is because similar environmental forces are at work on all of them: summer drought, winter cold, and in many places low nutrient or high salinity soil. This is the result of convergent evolution, which is to say that those plants which have similar adaptations are able to survive under these conditions. One thing that you will notice is that many of the plants which we have seen appear dead, or to be just sticks. A common drought adaptation is drought deciduousness--the plant loses its leaves during the driest part of the year in order to reduce loss of water through transpiration from the leaves. Another common adaptation to heat and drought is grayish hairs on the leaves. The hairs help to reduce the wind drying of the leaves; the gray colors help to reflect the sun and thus reduce temperature stress on the plants. Small leaves are also common, often with thick coverings which reduce evapotranspiration. Finally most of these plants are fairly low growing and widespread, in order to make the best use of the limited resources. You will notice that riparian species even in the same areas do not share these characteristics: often they will have large, soft, bright green leaves. Their more or less limitless access to water enables them to carry on photosynthesis all the time, as well as using evapotranspiration for cooling. Ancestral Lake Owens (Eastern Side of Owens Lake): In order to deal with excess salinity such as exists here, many plants evolve to isolate salt in vacuoles within its cells, or exude it from their leaves. Atriplex (saltbush), of which we have seen numerous species does this, as does salt grass (Distichilis spicata), which is a major constituent of the yellow vegetation surround the lake, as well as the grass growing among some of the shrubs. Tamarisk (salt cedar), an extremely invasive introduced weed which can be seen around older settlements in this area, uses this ability to outcompete other species in its area by dropping concentrated salt from its leaves, increasing the salinity content in its immediate area, and making it uninhabitable for most other species.

As we drove up the dirt road to the parking area, you may have noticed white lake bed sediments and an overlying black, blocky basalt flow. This Tinemaha Reservoir flow has been dated at 640,000 years).

New Era Mine (Buckeye or Never Rest) (#082; T. 10 S., R. 34 E., Sec. 27)

This is one of the gold mines in the Poverty Hills. It is ***in*** the Fish Springs district on the east slope of the Poverty Hills about 2 miles south of Fish Springs. The orebody is in a mineralized, decomposed monzonite porphyry dike which strikes north, dips 35" E. and may be as much as 60 feet in width. The value of the ore ranges from $4 to $10 per ton (1951 dollars). In 1951, W. C. Hove, was milling ore averaging $6 per ton. The main haulage level is a 1000-foot adit, driven S. 45" W. which intersects a GO0 inclined shaft at the 165-foot station. The shaft, sunk N. 45º E. near the outcrop of the dike, has levels at 30,100, and 150 feet with approximately 1000 feet of lateral workings. There are also some open cuts west of the shaft. The value of ore produced by the present operator through October 1947 has been $800 from 250 tons. Mr. Hove estimated that there was equal production from previous operations. The ore was trammed to the crude-ore bin, then passed to a Sturtevant jaw crusher where the ore was crushed. The fine ore was placed in two 34-ton cyanide tanks and leached in a 60-hour cycle. The equipment includes a 125-cubic-foot Ingersoll Rand compressor. All equipment is electrically driven by power purchased from the City of Los Angeles. Water is pumped from a 100-foot well. The property was idle in 1951 (Norman and Stewart, 1951:47, Site #70 of Plate 2).

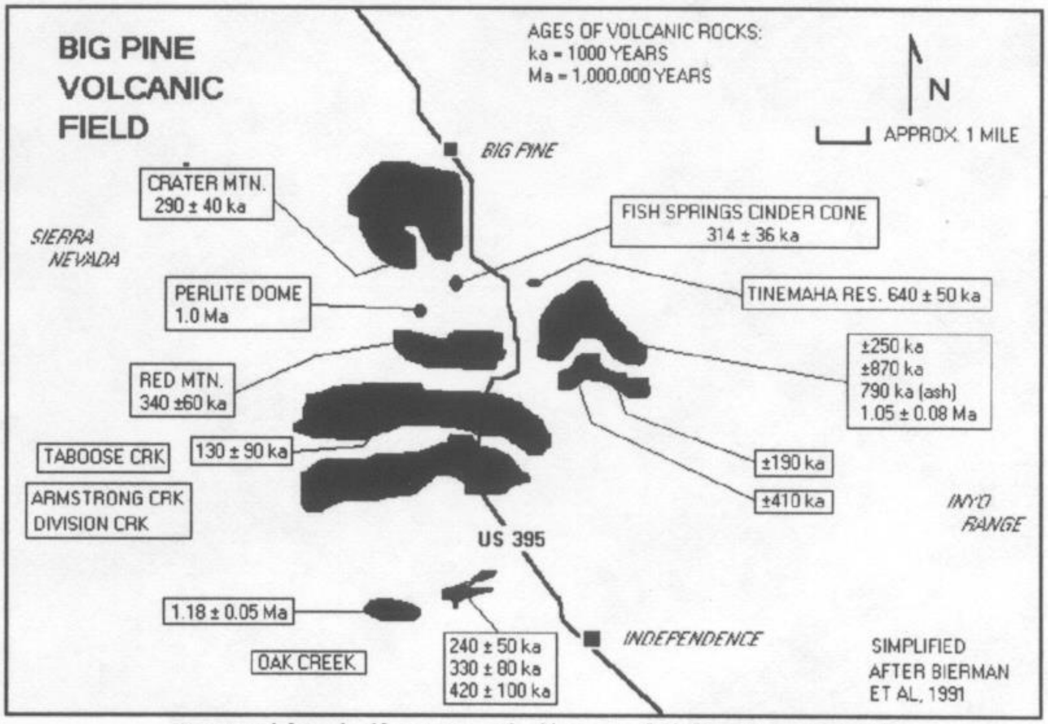
In the 1980's and early 1990's there was a project here to extract platinum from groundwater. The groundwater came from a well on the east side of Highway 395. It was pumped to the New Era mine site where a processing plant was built. It had several electrolyte cells. A cathode electrolytic plating material was collected and fired. The ashes where sent to Europe for processing.

Big Pine Volcanic Field (#083; T. 10 and 11S, R. 34 and 35 E)

Continuing south on US 395, we enter the Big Pine volcanic field about 10 miles north of Independence. Basalt flows have issued from faults along the bases of the Sierra Nevada and Inyo ranges. Ages of the flows range from 130,000 to 1.18 million years, almost a full order of magnitude age spread. These lava flows make good habitat for seldom seen Tule elk herds. The field is near the site of ***Aberdeen (#084***).

Big Pine Volcanic Field, Looking Northeast. The fault along which Crater and Red Mountains are located cuts from lower right to upper left corner. This scarp faces the mountains, whereas the one farther east faces the valley.

Big Pine Volcanic Field. From Van Huene et al., 1963:83.

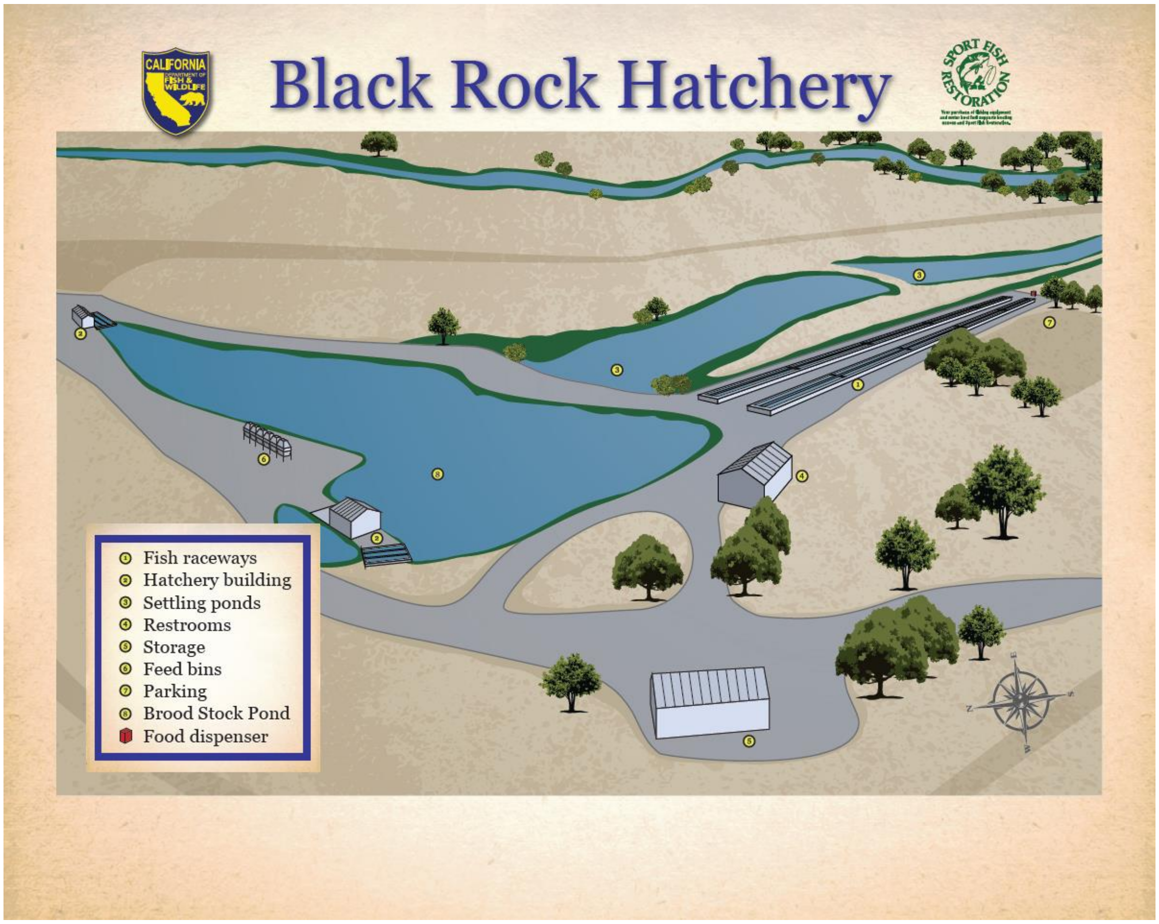


Generalized diagram of flows within the Big Pine volcanic field. Ages range from 130,000 to 1.18 million years.

Map 17: Aberdeen to Independence

Black Rock Fish Hatchery (#084; T.12S, R.24E, Sec. 2)

Black Rock Hatchery is located near the town of Independence in the Owens Valley of the Eastern Sierra-Nevada range. Black Rock Hatchery raises trout for stocking waters in the surrounding area. Many blue-ribbon trout streams are nearby.



From California Department of Fish and Wildlife

Mt. Whitney Fish Hatchery (#086; T.13S, R.34E, Sec. 2)

It was constructed in 1916 in a French Tudor design. The facility originally produced trout fingerling for planting throughout the state. The facility now is used for brood stock and produces 15 million golden, brown and rainbow trout eggs annually.

The ponds in front of the building contain quantities of large brood stock and wild fowl for visitors to view and feed. (Take nickels for the feed dispensing machines (the ducks also like the feed).
(http://www.livermont.com/Independence/Points_Of_Interest/PointsInterest.htm, April 7, 2007)

Independence (#087; T.13S, R.35E, Sec. 17 and 18)

Independence, California is the heart of the Owens Valley. A small rural community of approximately 800 people is the county seat for Inyo County; the second largest county in California. Independence offers: history, natural resources, recreational activities, with many things to do and places to go.

"The small town of Independence, Inyo County seat, boasts a stately courthouse, charming old Winnedumah Inn, Eastern California Museum, Mary Austin home, tennis court, swimming pool, nearby Mount Whitney Fish Hatchery, and an old fashioned 4th of July celebration. Drive West 12 miles up into Onion Valley for campgrounds and trail head into Sierra Nevada backcountry. Manzanar, five miles south on Highway 395, site of a WWII Japanese -- American relocation camp, is a new National Historic Site." (http://www.livermont.com/Independence/Index.htm, April 7, 2007).

Map 18: Independence to Lone Pine

Fort Independence Indian Reservation (#088; T.13S, R.35E, Sec. 6)

The following is from http://www.fortindependence.com/native.aspxm (April 7, 2007):

In the early 1850's, the United States Army established the Fort Independence military camp on what is known today as the Fort Independence Indian Reservation. The Army diverted water, grew crops and started wood lots to provide for the soldiers. This drew many native people to the surrounding area around the camp because of the food and supplies that were there. By this time, many farmers and ranchers had been diverting water for crops thereby reducing the amount of water the native plants and grasses so intimately depended on. Living off the land was becoming increasingly harder and forced the native people to work for the settlers in order to provide for their families.
When the military left the valley, the native people of the area held various allotments adjacent to the Fort and eventually assumed control of the land. The Fort Independence Reservation was officially established through executive orders Number 2264 and 2375 in 1915 and 1916, respectively. This provided the Tribal members with 360 acres of land adjacent to Oak Creek in Independence California. In 2000, the Tribe received an additional 200 acres through the California Indian Land Transfer Act for a total of 560 acres.

Although the Reservation was established in 1915, the formal Tribal government was established in 1965. A group of allottees and descendants of original allottees came together and developed the Articles of Association which is still in use today with no major amendments. The Articles are similar to the Constitution of the United States and lays the framework for additional laws and regulations. The allottees also developed enrollment and assignment ordinances to govern the membership and assignment of tribal land for individual and commercial use. The membership consists of 136 tribal members of which approximately half live on the Reservation and the rest reside elsewhere in the Unites States from coast to coast.

Independence Dike Swarm (#089, T.13S, R.34E, Sec. 20 and 21)

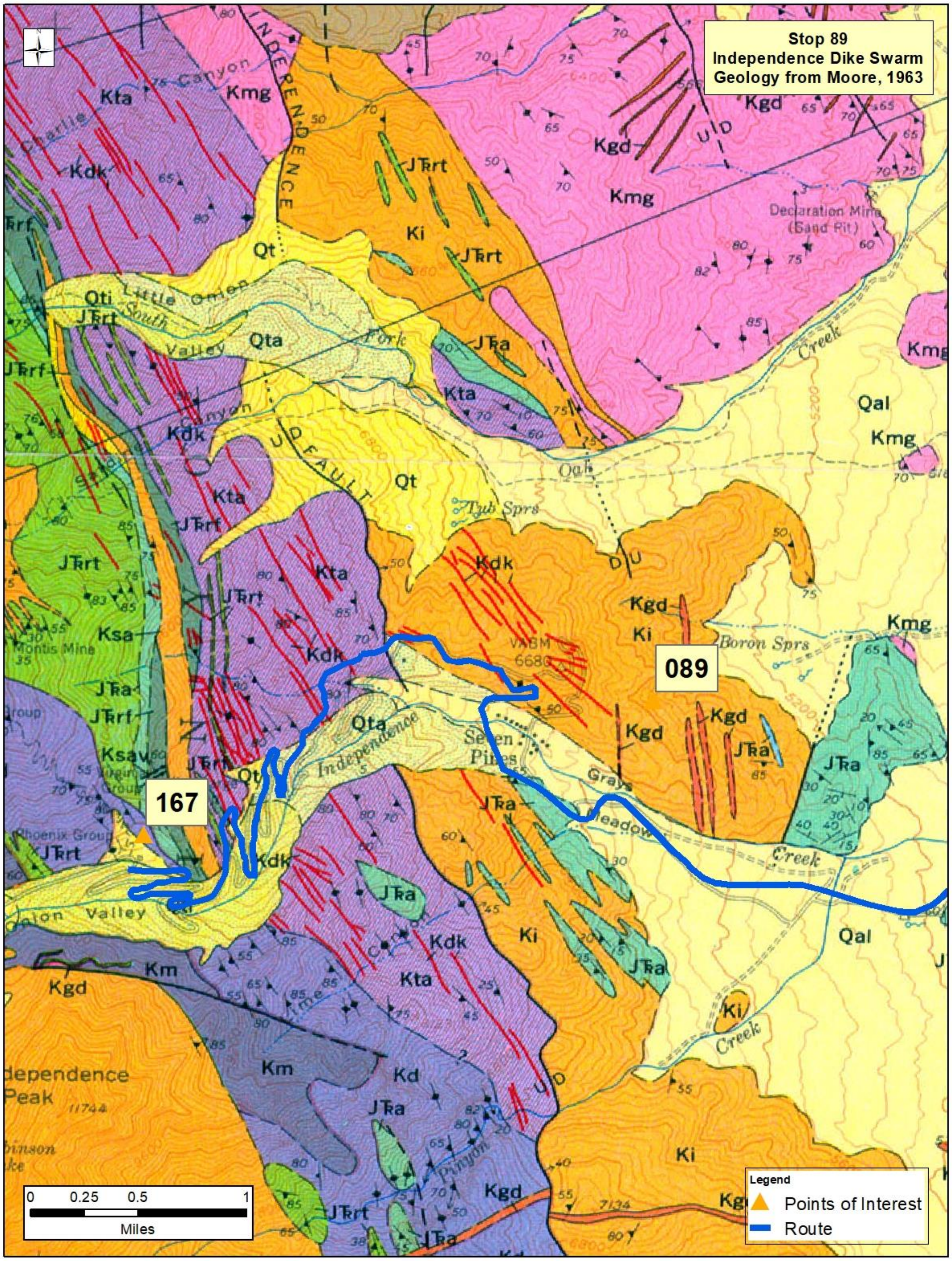
Between Independence and the Kearsarge Mine (#167) are exposures of the Independence Dike Swarm.

Independence dikes. Photo from https://c2.staticflickr.com/6/5159/6923501078_1a8f1e1ac6.jpg Accessed June 23, 2019

The following information about the Paleozoic Independence Dike Swarm is taken from Carl Brian and others (http://www.geosci.unc.edu/Petunia/IDS_Web_Site/FTG.html; April 7, 2007):

The Independence Dike Swarm (IDS) has attracted widespread attention since its first published description [54] years ago (Moore and Hopson, 1961; Smith, 1962). Mapping by J. G. Moore and C. A. Hopson revealed a dense set of northwest-striking dikes in the high country of the central Sierra Nevada northwest of the town of Independence, and G. I. Smith found a similar swarm near Searles Lake. It soon became clear that these swarms were continuous (Smith, 1962). Additional field work and geochronology by Chen and Moore (1979) and James (1989) extended the swarm both north and south of the type locality. The swarm is now recognized to extend over 600 km along strike, from the northern Sierra Nevada and White Mountains to southeasternmost California (Fig. 1).

Several aspects of the swarm make it a valuable stratigraphic and temporal marker in regional tectonic studies. In particular, the IDS crosses several tectonic province boundaries, individual dikes consistently strike northwest, and the Jurassic part of the swarm intruded during a brief interval around 148 Ma. Many tectonic studies of southern and eastern California use these properties to advantage (e.g. Smith, 1962; Karish et al., 1987; Glazner et al., 1989; Dunne and Walker, 1993; Schermer, 1993; Martin et al., 1993; Dunne et al., 1994; Schermer and Busby, 1994; Ron and Nur, 1996).



Portion of the Independence Dike Swarm. From Mooore, 1963.

Manzanar (#090; T.14S, R.35E, Sec. 10)

In 1942, the United States government ordered more than 110,000 men, women, and children to leave their homes and detained them in remote, military-style camps. Manzanar War Relocation Center was one of ten camps where Japanese American citizens and resident Japanese aliens were interned during World War II.

This land has been a War Relocation Center, an apple farming community, a cattle ranch, and home of the Owens Valley Paiute. Together, these occupations illustrate Manzanar's long history of recurring human settlement, inhabitation, injustice and displacement.

Alabama Gates (#091; T.14S, R.36E, Sec. 31)

The Alabama Gates are a famous site in the Los Angeles-Owens Valley "Water Wars". On November 16, 1924 Mark Watterson led 60 to 100 people to occupy the Alabama Gates, closing the aqueduct by opening the emergency spillway. Renewed negotiation ended the occupation.

In 1983, a teenager, still angry about the Owens Valley wars, damaged the Alabama gates again. The judge sentenced him to attend college.

Los Angeles County Aqueduct

The following is from http://wsoweb.ladwp.com/Aqueduct/historyoflaa/whoeverbrings.htm (April 7, 2007):

By delivering the Owens River water to Los Angeles, Mulholland had made it possible for the city to prosper. Mulholland said, "Whoever brings the water brings the people." But as Los Angeles grew, it was the demand of the people that brought the water. The 1920s brought unprecedented growth, and homes and businesses spread across the Los Angeles basin.

There were several years of lower than normal snowfall in the Eastern Sierra. Local water use on privately owned land in the Owens Valley was increasing. By the spring of 1923 both the City and the Owens Valley were facing water shortages.

The City lacked a dam and a storage reservoir to control the flow of the Owens River above the aqueduct intake at Independence. The best site, Long Valley, had remained in Fred Eaton's hands and Mulholland had rejected Eaton's asking price for the land.

Between Long Valley and the Independence intake, miles of irrigation canals diverted water to farms and ranches.

In order to increase supply, the City began pumping groundwater. Farmers in the Independence area filed injunctions in an attempt to halt falling water table levels. In Bishop and Lone Pine, residents became alarmed by the City's purchases of properties north of Independence for the acquisition of groundwater rights.

Wilfred and Mark Watterson were Inyo County's financial leaders. Owners of the Inyo County Bank, the Wattersons organized valley residents into a unified opposition through the formation of an irrigation district.

The City of Los Angeles moved to acquire options on the McNally Ditch, the area's major canal, before its owners joined the irrigation district.

A series of escalating confrontations ensued. Farmers illegally diverted water, leaving the canal empty. The City purchased land and water rights indiscriminately, leading to accusations of "checker boarding." An environment of frustration and uncertainty prevailed. Area farmers felt vulnerable, unsure of the intentions of their neighbors. The growing position of many valley residents was that Los Angeles should buy out the entire area. On May 21, 1924, the first violence of the dispute erupted. Forty men dynamited the Lone Pine aqueduct spillway gate. No arrests were made. Eventually, the two sides were entirely stalemated.

The City believed the wholesale purchase of the district was unnecessary to meet its water needs. Instead, on October 14th, the City proposed a plan that would leave 30,000 acres in the Bishop area free of City purchases. The City also offered to help promote the construction of a state highway to the area, thereby creating a local tourist industry.

The Wattersons and the directors of the Owens Valley Irrigation District rejected the proposal, insisting on outright farm purchase and full compensation for all the townspeople.

On November 16, 1924 Mark Watterson led 60 to 100 people to occupy the Alabama Gates, closing the aqueduct by opening the emergency spillway. Renewed negotiation ended the occupation.

Finally, the conflict became completely centered on the issues of farm purchases and reparations to the townspeople. Attacks on the aqueduct began again in April 1926 and by July 1927 there had been 10 instances of dynamiting.

The controversy was at its height when suddenly valley resistance was undermined. The Wattersons closed the doors of all branches of the Inyo County Bank. The Wattersons were not only bankrupt, later they were tried and convicted of thirty-six counts of embezzlement.

In the face of the collapse of both resistance and the Owens Valley economy, the City sponsored a series of repair and maintenance programs for aqueduct facilities that stimulated local employment. The City of Los Angeles also continued to purchase private land holdings and their water rights to meet the increasing demands.

Five important reservoirs were constructed from 1921 to 1929: Tinnemaha on the Owens River, Upper San Fernando (Van Norman), Stone Canyon, Encino, and Hollywood. The water system of Los Angeles expanded by hundreds of miles of new mains and thousands of new service connections.

In 1928 William Mulholland left the DWP, shaken by the tragedy of the St. Francis Dam, 40 miles north of Los Angeles. On March 12th of that year, Mulholland inspected the dam, the construction of which he had supervised. Hours later it collapsed, killing 450 people in the ensuing flood. He accepted full responsibility and resigned.

Map 21: North Owens Lake

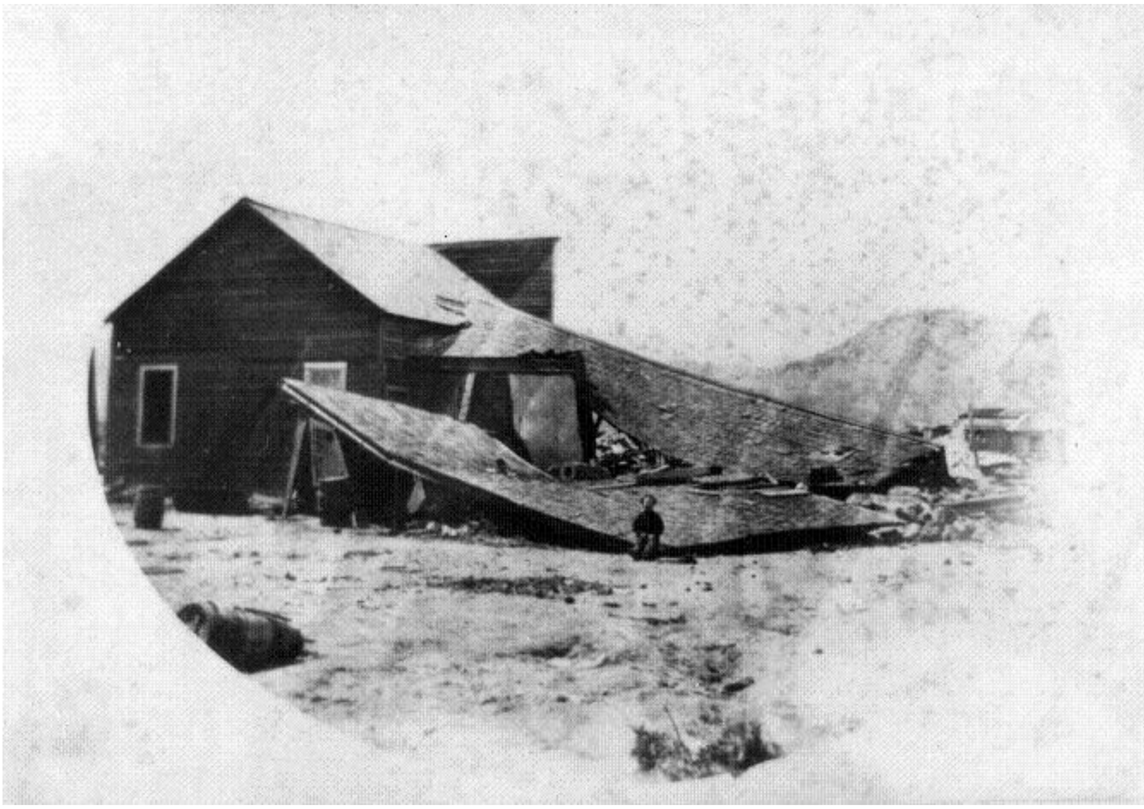
This map shows the Keeler-Cerro Gordo-Salt Tram-Burgess-Swansee Loop and the side trip to the Owens Lake Overlook.

Map 22: Lone Pine

Graves of the Earthquake Victims, Lone Pine Earthquake, 1872
(#092; T.15S, R.36E, Sec.30)

Adobe home damaged by 1872 Owens Valley Earthquake at Lone Pine. From https://www.sierranevadageotourism.org/images/otc/input/content/350/sieADC3FF3C413624523.jpg. Accessed June 23, 2019

About a mile north of downtown Lone Pine is a well-maintained cemetery for the 1872 earthquake victims. The cemetery is fittingly located on top the main 1872 fault scarp on the west side of US 395.



Lone Pine after the earthquake.

On March 16, 1872 at 2:30 A.M. the small community of Lone Pine, California was violently awakened by an earthquake. The magnitude of the quake was about the same as the "Big One" in San Francisco in 1906. It literally leveled the town of Lone Pine. Of the 80 buildings, built of mud and adobe, only 20 structures were left standing. Diaz Lake was formed by this quake.

Twenty-six people lost their lives that day in the disaster. A mass grave, located just north of Lone Pine, on the up-thrust block of the main fault that caused the quake commemorates the site.

The landscape bears the scars of the 1872 earthquake. From Lone Pine to Big Pine remnants of the disaster are still in evidence. In the alley way behind La Florista, the local flower shop and nursery stands "The Old Adobe Wall" the only known remaining example of pre-earthquake architecture in Lone Pine. The wall is 21 inches thick, 148 inches long and 80 inches high. The bottom layer of the wall is three foot thick and built of heavy stone, the rest of the structure is adobe brick and rubble with brick mortar.

The wall is what is left of a general merchandising store and living quarters that was owned by Charles and Madeleine Meysan who came to Lone Pine in 1869 from a French

Camp near Columbia. It is believed that the building was near 100 feet long, with the store in front and living area in the back. The Meysans had 10 children and prospered in Lone Pine. All was well until that early morning of March 16, when the adobe building the family was living in literally shook to pieces. The quake claimed the life of their daughter Alice. Shortly afterward, Meysan constructed a new building made of wood.

La Florista now occupies this building. The wall remained in the possession of various members of the Meysan family until September 30, 1921 when Eugenie Dunn sold it to O.W. Dolph. On December 22, 1931 the City of Los Angeles purchased the property.

The wall remained undisturbed for another forty years until one day a woman by the name of Elodie Drew, a granddaughter of Charles Meysan, received a phone call, the person on the other end wanted to bulldoze the wall. Elodie said "I guess I sounded pretty mad, because they went and put up a fence around the wall".

On August 6, 1971 the protection for the wall erected by the City of Los Angeles, Department of Water and Power was finished. Recently a dedication was held by the E. Clampus Vitus. For more information on the Charles Meysan family there are two splendid articles by Elodie Drew in the "Saga of Inyo Country".

Lone Pine Earthquake of 1872 (T.15S, R36.E, Sec 20).

The 1872 Lone Pine earthquake may have been as intense as the M 8.3 San Francisco earthquake of 1906. Some 27 people were killed and many more injured, making a sizable impact on Lone Pine's population at the time. The dead were buried in a mass grave on the 1872 fault scarp north of town. Most casualties resulted from collapsing adobe buildings. Wood frame structures fared better. Detailed work by Lubetkin and Clark (1987 on scarp profiles and weathering character led them to conclude that only 3-7

feet of vertical displacement occurred here in 1872. They claim the height of this scarp may be the cumulative effect of three major seismic events, including the 1872 event.

Most geologic reports have described the 1872 Lone Pine earthquake as exceeding M 8.0 and one of three "Great" earthquakes in California's history (the other two being 1906 San Francisco and 1857 Fort Tejon). The 1872 Lone Pine earthquake, however, had a surface rupture of slightly more than 40 miles, between Owens Lake and Big Pine. Moreover, vertical displacements were less than seven feet. These characteristics are very similar to those of the 1992 M 7.3 Landers earthquake. There is thus some thought that the size of 1872 Lone Pine event may have been similar to 1992 Landers earthquake (Pierre St. Amand, Personal Communication, 1992).

BLM Geologist Cheryl Seth of the Bishop Resource Area points out the Sierran frontal fault. Light colored sheared and altered granitic rocks on the left are faulted against darker fan gravels.

Alabama Hills (#094; T.15S, R.36E, Sec. 29, 30)

The geology of the Alabama Hills is summarized by Larie Kenneth Richardson (http://www.angelfire.com/extreme4/lkrwork/book1.htm, April 7, 2007):

Previously the metamorphic rocks in the northeastern portion of the Alabama Hills were mapped as a single unit (encompassing Triassic metasediments and metavolcanics). The following pre-metamorphic sequence is proposed to explain this pattern seen in the geologic map.

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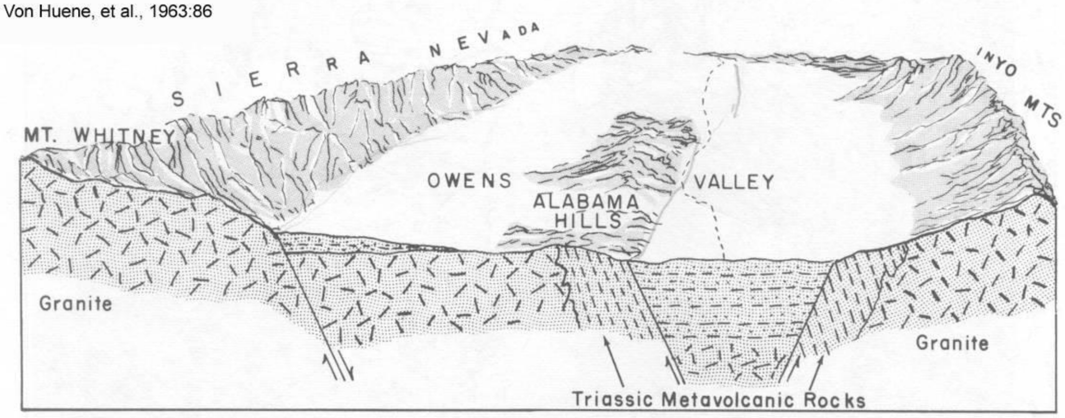
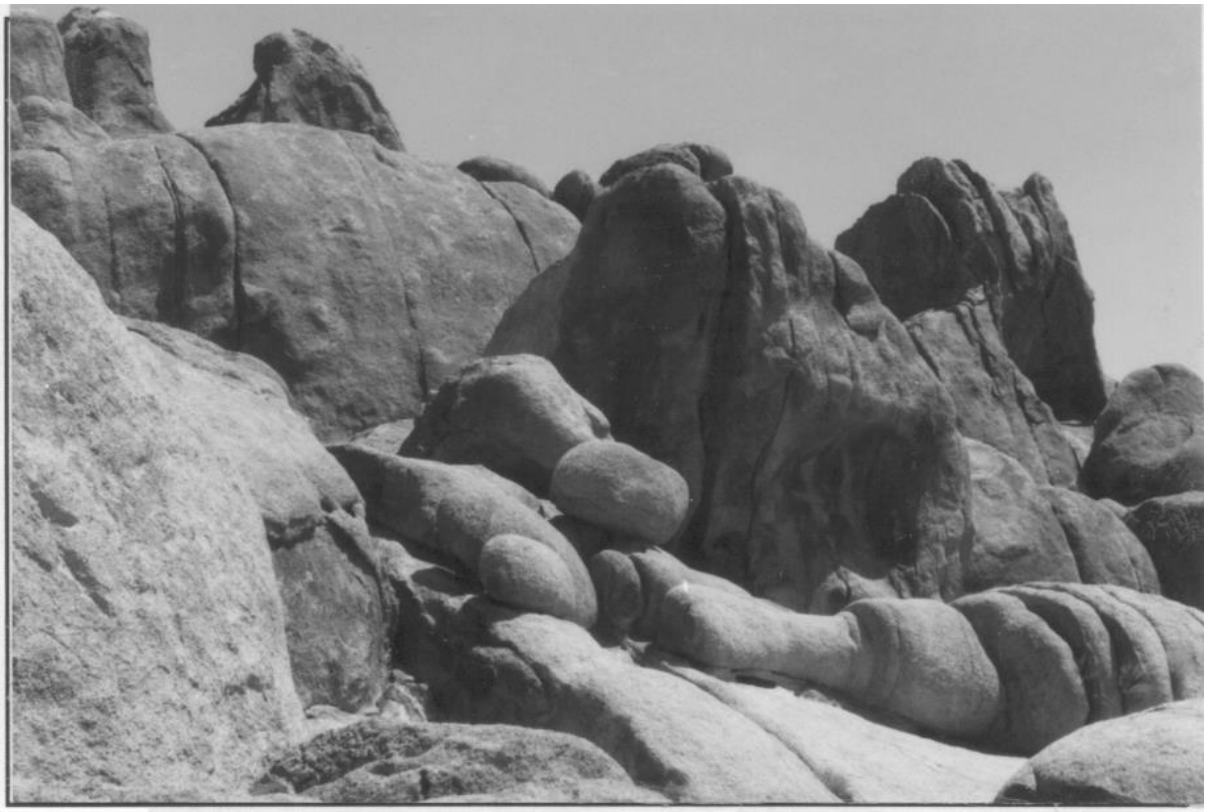
Von Huene, et al., 1963:86



Diagrammatic Cross Section Near Lone Pine. The Alabama Hills are the exposed portion of a block that has dropped midway between the crest of the Sierra and the bedrock low of Owens Valley. A subsurface fault zone on the east flank of the Alabama Hills has an escarpment that is higher than the visible Sierran escarpment to the west.

FIG. 4-20. Looking Southwest at Alabama Hills, With Sierra Nevada in Background. The west edge of Owens Lake is on the left margin.



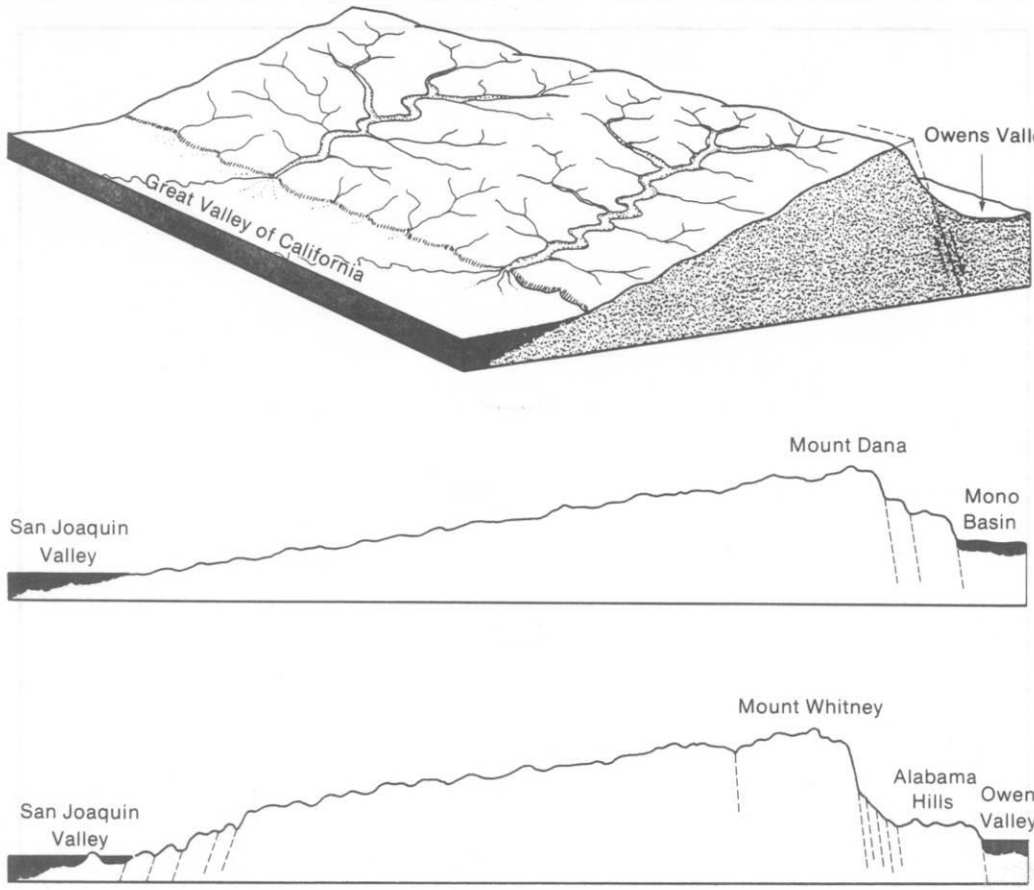
The deeply weathered granitic rocks of the Alabama Hills have made this area popular among western movie makers.

The first event in the formation of this sequence was the intrusion of a hypabyssal dike and sill complex of rhyolitic to andesitic composition into pre-existing volcanics. This stage was terminated by the emplacement of a basic dike swarm (lamprophyres). The volcanic and sedimentary (?) cover associated with these dikes and parts of the hypabyssal complex were then removed by erosion. A layer (approximately 300 ft.) of sediments (pelitic?) was deposited on this erosion surface. Then a (500-600ft.) tuff unit was deposited on top of the sediments. A thermal event raised most of these volcanics and sediments to the albite-epidote hornfels facies. The western margin of the metamorphic body was raised to the hornblende hornfels facies in response to the thermal aureole associated with the plutonic rocks to the west.

Deeply weathered granite at Alabama Hills. This ancient surface may have been "left behind" as the crest of the Sierra Nevadas rose to over 14,000 ft.

The plutonic rocks (granites, alaskites, nordmarkites) of the Alabama Hills are unusual compositions for the Sierra Nevada Batholith. These highly differentiated rocks were emplaced along the contact between the plutonic and metamorphic rocks. Their residual nature suggests that they are part of a plutonic province that formed from a more highly differentiated magma than that required to produce Sierran rocks. Indications are that the pressures and temperatures of formation of granitic rocks of the Alabama Hills were lower (Epizonal) than those reported for the Sierras.

The one age date available on the plutonic rocks (80 million years) is probably not representative of the entire spectrum of plutonic rocks in the Alabama Hills. Analysis of the petrographic, petrologic, and joint data indicates that the granitic rocks were emplaced as a series of intrusions. Structural relationships indicate that some of the plutonic rocks are younger than the dated rocks.



Generalized diagrams of the Sierra Nevada Range. The range is a westward-tilted block of granites and older metamorphic rocks as roof pendants. The Alabama Hills were, at one time, even with Mt. Whitney.

The Sierran Frontal Fault and the Central Owens Valley Fault form the eastern and western boundaries of the Alabama Hills. Detailed mapping of basement faults in the Alabama Hills has revealed east-west left lateral movement associated with these faults. The east-west left lateral faults have been interpreted as second order left lateral wrench faults formed in response to the first order right lateral wrench faulting along the Central Owens Valley Fault.

Final stages in the formation of the present day expression of the Alabama Hills includes exhuming of a preglacial pediment surface as normal faulting uplifted the Alabama Hills block relative to the Owens Valley. The Alabama Hills were then draped with glacial outwash debris of Sherwin, Tahoe, and Tiogan glacial ages. As recently as 1872 (1872 Owens Valley Earthquake) the expression of the Alabama Hills has been modified by tectonic forces.

Owens Valley Fault scarp with weathering on a boulder offset during the 1872 Lone Pine earthquake. The boulder was partially buried prior to uplift.

Owens Valley Fault Scarp (#094; T.15S, R.36E, Sec. 20)

In Lone Pine, turn west onto Whitney Portal Road. About a mile west of town the road crosses the LA aqueduct. Turn north onto a dirt road a few hundred feet west of the aqueduct. Follow the dirt road about 3 mile north to the 1872 fault scarp.

1872 fault scarp in an alluvial fan west of Lone Pine. The shape of the scarp face suggests at least three separate seismic events. Offset during the 1872 earthquake was 3-7 ft.

History of the Alabama Hills (from http://en.wikipedia.org/wiki/Alabama_Hills, April 7, 2007.)

The Alabama Hills were named for CSS *Alabama*. When news of the Confederate warship's exploits reached prospectors in California sympathetic to the Confederates, they named many mining claims after her, and the name came to be applied to the entire mountain range. Then, when *Alabama* was sunk off the coast of Normandy by USS *Kearsarge* in 1864, prospectors sympathetic to the North named a mining district, mountain pass, a peak, and a town after *Kearsarge*.

The Alabama Hills are a popular location for television and movie productions (especially Westerns) set in an archetypical "rugged" environment. Since the early 1920s 150 movies and about a dozen television shows have been filmed here including Tom Mix, *Hopalong Cassidy*, *The Gene Autry Show*, and *The Lone Ranger*. Classics such as *Gunga Din*, *Springfield Rifle*, and *How the West Was Won*, as well as more recent productions such as *Tremors* and *Joshua Tree* were filmed at sites known as *Movie Flats* and *Movie Flat Road*. In *Gladiator*, actor Russell Crowe rides a horse front of the Alabamas, Mount Whitney in the background, for a scene presumably set in Spain.

Movie Flat (#092) T.15S, R.35E, Sec. 25).

Continue west on Whitney Portal Road for 2.1 miles. Turn north onto Movie Flat Road. With Mt. Whitney as a backdrop, television and movie companies have used this area for filming over the past 50 years. The deeply weathered surface we are driving on may once have been equivalent with the surface represented by the Sierran crest prior to being left behind during faulting. These granitic rocks are Cretaceous in age. They are in contact with older metamorphosed volcanic rocks of Triassic/Jurassic age. The volcanic rocks are dark red and brown in color and have less spectacular outcroppings.

Return to Whitney Portal Road and continue west for about 2000 ft. Turn south onto Horseshoe Meadows Road. Continue for about 6.5 miles to the northern road cut exposure at Carroll Creek

The area of the Alabama Hills and Map 22 was mapped by Stone and others, 2000. The main units on this map are:

Qai **Inactive alluvium (Holocene)**—Fine to coarse gravels of inactive fan surfaces. Downslope from granitic bedrock, composed primarily of fine sand to pebble grus; downslope from sedimentary and metamorphic bedrock, composed of coarse, angular, poorly sorted gravel. Surface channels subdued or absent; dissected by channels that contain active alluvium (Qa). Overlies older lake deposits (Qlo) and younger alluvial and debris-flow gravels (Qgy)

Holocene Inactive Alluvium

Qlo **Older lake deposits (Holocene and Pleistocene)**—Mostly light-tan silt and sand; includes some gravel deposits near paleoshorelines. Massive to well bedded. Well exposed along channel of Owens River. Some deflation basins in upper surface of unit are filled by playa deposits (not mapped). Maximum elevation about 3,760 ft (1,146 m) except west of Lone Pine Fault, where deposits have been uplifted. Could be as much as 2,500 m thick in structural depression between Owens Valley Fault Zone and Inyo-White Mountains Fault Zone. Probably includes deposits of late Tertiary age at depth

Holocene and Pleistocene Lake Deposits

Qgy **Younger alluvial and debris-flow gravels (Pleistocene)**—Deposits of late Pleistocene age consisting of common to abundant, subangular to subrounded cobbles and boulders of plutonic rocks in a matrix of sand and fine gravel. Boulders 2 m or more in diameter are common; many clasts are porphyritic and contain mafic inclusions. Locally, deposits of two ages can be separated on basis of degree of weathering, decomposition, and iron-oxide staining of clasts. Dissected by Holocene streams

Pleistocene Younger Gravels

Qgo **Older alluvial and debris-flow gravels (Pleistocene)**—Deposits of early to middle Pleistocene age consisting of rare cobbles and boulders of felsic plutonic rocks in a matrix of coarse sand and fine gravel that locally contains subhedral feldspar crystals 2 to 6 cm long. Horizontal exposures characterized by 0 to 10 percent boulders; vertical exposures show few undecomposed clasts. Most beds stained by iron oxides to colors ranging from grayish orange or deep reddish brown to greenish gray. Locally contains veins of calcium carbonate. In some areas, unit acts as an aquitard that forces ground water nearly to the surface, which supports thick stands of vegetation where windblown silt and fine sand (not mapped) have accumulated

Pleistocene Older Gravels

30 d Kah **Alabama Hills Granite (Late Cretaceous)**—Hypidiomorphic seriate to faintly porphyritic, medium-grained biotite monzogranite that locally contains equant, pale-pink phenocrysts of potassium feldspar as large as 1 cm. Outcrop color very pale orange to pinkish gray. Stipple indicates local fine-grained, hypabyssal(?) facies. Areas of complexly mixed country rocks and granite present locally along pluton margin. Locally, contains abundant aplite and rare pegmatite dikes, most of which are gently dipping. A few prominent dikes are shown on map (d); the dip is shown where known. Biotite K-Ar age 82 Ma (Evernden and Kistler, 1970); preferred Pb-U age 85 Ma (Chen and Moore, 1982) (Locality G–4)

Cretaceous Granite of the Alabama Hills

Volcanic complex of the Alabama Hills (Middle Jurassic)—Divided into:

Javu **Upper part**—Consists chiefly of light- to medium-light-gray, massive, slightly welded tuff at least 450 m thick. Tuff contains 18 to 28 percent phenocrysts consisting of subequal amounts of quartz and potassium feldspar and sparse plagioclase and biotite. Flattened pumice lapilli generally rare but locally abundant near base of tuff. Medium- to dark-gray, aphanitic lithic lapilli typically compose less than 2 percent of tuff but locally form diffuse clusters composing as much as 20 percent. Top of tuff intruded by Alabama Hills Granite. Basal part of unit locally consists of muscovite schist, quartzite, and rare volcanogenic conglomerate having a maximum thickness of about 10 m. Lower contact of unit probably unconformable in southern exposure area but of uncertain character in northern exposure area. Minimum Pb-U age of tuff about 170 Ma (Dunne and Walker, 1993) (Locality G–1). Small part of northern outcrop area contains abundant dikes (KJd) as shown by pattern

Javl **Lower part**—Consists of an upper subunit of volcanogenic sedimentary and volcanic rocks and a lower subunit of rhyolite tuff. Unit characterized by intense hydrothermal alteration over much of its exposure area, which obscures many details of its stratigraphy. Upper subunit consists primarily of weakly bedded to massive, predominantly matrix supported pebble to cobble conglomerate, siltstone, sandstone, and pebbly sandstone. These rocks are interlayered with about 10 percent felsic tuff and, in southernmost outcrops, rare vesicular lava flows. Rhyolite tuff of lower subunit, present in northeasternmost exposures of unit, is grayish pink to yellowish gray, massive, and slightly welded. Tuff contains 15 to 35 percent phenocrysts consisting of subequal amounts of quartz and potassium feldspar and sparse plagioclase and biotite, and 1 to 2 percent volcanogenic lithic lapilli. Minimum Pb-U age of tuff about 167 Ma (Dunne and others, 1998) (Locality G–2). Unit cut by abundant dikes (KJd) as shown by pattern

Jurassic Volcanic Rocks of the Alabama Hills

Carroll Creek (#095A; T.16S, R.36E, Sec. 31).

Here in the road cut is a good exposure of the Sierran frontal fault. Although not apparent from this view, the fault is exposed on the surface (Milliken, 1979).

Very simply, this fault separates the Sierra Nevadas from Owens Valley. Prominent scarps are visible in talus and alluvial fans along the base of the Sierras past Whitney Portal to beyond Independence. North of Whitney Portal it is called the Independence Fault (there has been no known movement along the fault in historic times).

In a broader sense, the entire eastern Sierran escarpment between the Garlock fault in the south and Lake Tahoe in the north is a deeply eroded fault scarp with several thousand feet of displacement since late Tertiary. At this location, the fault displaces sheared and altered Sierran granitic rocks against down-dropped alluvial fan gravels.

Owens Lake Overlook (#096; T.17S, R.36, Sec. 4)

From the Alabama Hills, take the Horeshoe Meadows road 7.3 miles up the east flank of the Sierra Nevada for a spectacular view of Owen's Lake.

Walk a few feet to a granitic promontory overlooking Owens Valley. Owens Lake is about 5,000 feet directly below us. Prehistoric shorelines are visible at the north end of Owens Lake. At the time of these shorelines, the lake was about 90 feet deep. Note also the deformed lake sediments at Bartlett point.

Owens Valley is a graben, or downdropped block bounded by normal faults. Both the Sierran and Inyo Ranges are tilted westerly and continue to be uplifted.
Filling the graben are fan gravels, Owens Lake sediments, and a part of the Sierra Nevada Range that got left behind: the Alabama Hills. The east face of the Alabama Hills represents the top of a 10,000 foot high escarpment buried by 9,000 feet of sediment (Sharp, 1976. There is almost 20,000 feet of relief between the basement floor and the crest Mt. Whitney. This escarpment is represented on the surface by the 1872 fault scarp.

From the south end of Owens Lake rise the Coso Mountains. The Pleistocene high stand of Lake Owens is witnessed by the predominant 3880 ft elevation shoreline. The Coso Formation is a series of lake sediments and ash layers deposited in a large lake that extended as far east as the Argus Range. The lake sediments rest upon sediments derived from underlying granitic basement rocks. Numerous volcanic flows and cones of Pleistocene and Holocene ages characterize the Cosmos south to Indian Wells Valley.

At its maximum during the Pleistocene, Owens Lake was over 300 feet deep and extended northward to Independence. Now a playa that is flooded during occasional wet periods, Owens Lake was 30 feet deep in the late 1800s. Steamboats hauled Cerro Gordo ore from Keeler across the lake to Cartago. On return the boats hauled charcoal from the Cottonwood limestone kilns to be used in smelting ovens. The loss of recharge water through climate change, irrigation, and diversion resulted in a dry lake by 1926. Over 350,000 acre-feet of water are now exported to Los Angeles annually. During dry periods, the lake bed is often subjected to severe dust storms with health-threatening particulate traced 250 miles south (St. Amand, 1987).

Wells drilled on the playa have penetrated as much as 7,000 feet of sediment, primarily clays and silts. The lack of evaporite layers at depth suggests that Owens Lake was full for most of the Pleistocene. The thin layer of evaporite minerals on the surface probably represents a dry condition for the past 2,000 years (G.I. Smith, USGS, personal communication, 1991. Lake Minerals has been mining on the lake bed for many years. They are planning a 500,000 ton/year trona refinery to be constructed by 1994-95 near Cottonwood Creek.

Trona is a "double" salt, composed of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$). Sodium carbonate (soda ash) is extracted in the refining process, and is used primarily for glass manufacture and as a noncaustic base for detergents

West Side of Owens Lake

Lake Diaz (#097; T.16S, R.36E, Sec.31)

Lake Diaz. View is to the east from Owens Lake Overlook.

Diaz Lake was formed by the 1872 Lone Pine earthquake. The land dropped slightly here creating a depression that filled with water. US 395 is an expressway here with the southbound lanes comprising the original lanes of the highway. Until early 2000, the highway narrowed to two lanes at this point heading northbound.

The west margin of the lake is actually a west-facing segment of the 1872 fault. Lake Diaz appeared after the 1872 earthquake as groundwater filled a new depression formed between two faults.

Pittsburgh Glass Company (#097; T.17S, R.36E, Sec. 7)

The Pittsburgh Glass Company was the first to extract boron minerals from Owens Lake. The soda is used to make Pyrex glass. In the 1920's because of excessive melt waters being delivered to the aqueduct, Los Angeles Department of water and power diverted water into Owens Lake. This destroyed the soda mining project, leading to law suits. A judge approved the diversions of water into the lake and this put the company out of business.

While Owens Valley ranchers and farmers were suing LADWP for taking water out of Owens Lake, the miners were suing for putting water into it.

The remnants of the plant are at the Bartlett siding on the east side of the highway, and the west shore of Owens Lake, the ruins of the Pittsburgh Plate Glass Company's chemical plant are some of the few structures between Olancha and Lone Pine. The modernist lab building and the large sheds and silos have been largely unused since the 1960s, when the company ceased crystallizing and processing carbonate compounds mined from the exposed lake bed. After it was abandoned, the plant was bought by a Dr. McCabe, a medical valve inventor, who used it recreationally, along with some Hollywood friends. Though Dr. McCabe died some years ago, people who knew him still own the building. (http://www.clui.org/ludb/site/pittsburgh-glass-plant accessed June 16, 2019)

Pittsburgh Glass Plant, northwestern Owens Lake. Photo from http://www.clui.org/sites/default/files/ludb/ca/4629/5662814165_029696afef_o.jpg accessed June 16, 2019

Cottonwood Creek Charcoal Kilns (#098; T.17S, R.37E, Sec. 31)

Charcoal Kilns, Owens Lake.

In June 1873 Colonel Sherman Stevens built a sawmill and flume on Cottonwood Creek high in the Sierras directly west of this spot. The flume connected with the Los Angeles Bullion Road. The lumber from the flume was used for timbering in the mine and buildings, and the wood was turned into charcoal in these kilns, then hauled to Steven's Wharf east of here on Owens Lake. There it was put on the steamer the "Bessie Brady" or the "Mollie Stevens," hauled directly across the lake, and from there wagons took it up the "Yellow Grade" to Cerro Gordo Mine, high in the Inyo Mountains above Keeler. M.W. Belshaw's furnaces had used all available wood around the Cerro Gordo and this charcoal was necessary to continued production (California State Landmark #537)

The bullion which was then taken out by the reverse of this route was hauled to Los Angeles on Remi Nadeau's 14, 16, 18 animal freight wagons and played a major part in the building of that little pueblo into the city of today.

Map 24: South Owens Lake

U.S. Borax (formerly Cominco) Soda Mining Operation at Permanente

(#105; T.18S, R.37E).

Soda mining on Owen's lake has been idle since the 1950's. This new operation is in a program to make soda ash from the brines. As part of the operation, the old railroad spur to the mine site is being rebuilt.

U.S. Borax (Cominco) Operation on Owen's Lake. Photo from https://a.scpr.org/i/6cd39770f059203d4f463730db31c5c3/40040-full.jpg accessed June 16, 2019.

Crystal Geyser Bottling Plant **(#150; T.19S, R.36E, Sec. 1).**

Jessey and Reynolds give this description of the operation:

This plant began producing bottled water in 1990. Since then, two additional plants have been built to meet the growing demand. Their website proclaims "Our water really is from a spring. CRYSTALGEYSER ® ALPINE SPRING WATER ™ actually locates the perfect spring source first, and then builds our bottling plant there." A mystery surrounds the actual location of this "spring." Crystal Geyser publicity suggests the water is from a "protected source" below the summit of Olancha Peak. A visit to the bottling plant failed to resolve this issue as employees would not divulge the location. A report in the High Country News (Nov. 1996) states that Crystal Geyser has been involved in a dispute with Anheuser-Busch over the groundwater beneath their properties in the Owens Valley. They believed that increased pumping of groundwater by Anheuser-Busch immediately north might allow saline water into local aquifers. The Crystal Geyser water comes from a well inside the blue building - not exactly from the "pure mountain spring" their advertising suggests. Inyo Co. regulations only allow Busch to export water by truck-load. In 2009, most of the water was delivered to the Briggs Mine in Panamint Valley (Jessey and Reynolds, 2009:16-17).

Crystal Geyser Plant, Olancha, California

The plant is built on an alluvial fan that forms from outflow of Corrayo Creek canyon to the west. These alluvial materials came out on to ancestral Owens Lake. The lake beds are mostly impermeable clays. Fresh mountain spring waters flow down through the alluvial sediments, hit the underlying clays and come out as springs on the edge of the lake. This line of springs is clearly shown by a green line of vegetation east of the Crystal Geyser Plant.

Cartago Soda Evaporators (#110; T.18S, R.36E, Sec.36; T.18S, R.37E, Sec. 31).

This old mine site has a large pile of unprocessed calcium oxide. The calcium oxide is turning into calcium carbonate from the action of rain water

Map 21: North Owens Lake

East Side of Owens Lake

Federal White Aggregate (formerly Inyo Marble Company) (#101; T. 16 S., R. 37 E., Secs. 4,10,11,13, 14, 24, 25, and T. 16 S., R. 38 E., Secs. 19, 30, 31)

This unique limestone deposit is located along the southwestern flank of the Inyo Range from 2 to 8 miles northwest of Keeler. This operation dates from the 1870's when white marble was quarried for tombstones. Cemeteries from as far north as Reno, Nevada have tombstones made from Inyo Marble. This white marble is used in the stars of the Hollywood "Walk of Fame". It is the result of contact metamorphism. A dacite dike from the Independence Dike Swarm cuts through lower Paleozoic dolomites. This bleaches the rock and forms a coarsely crystalline, beautifully white marble. Southeast of the mine is the old mining townsite of ***Dolomite (#102).***

Federal White Aggregate Quarry. Photo from http://quarriesandbeyond.org/states/ca/images/inyo_dolomite_quarries/ca-lone_pine_fwagg_dolomite_bldg_2_3040.jpg accessed June 16, 2019

At this mine, Silurian and Devonian dolomite in a series of Paleozoic marine metasediments have been exploited along a belt half a mile wide and six miles long. The history of the deposit has been summarized by Logan (1947:244-245). Several colors of dolomite are available for terrazzo chips but the principal production in recent years has been white for roofing granules. Chemical analyses of the marble show the material to be nearly a pure dolomite. An analysis made by the State Mining Bureau in 1890 showed 54.25 percent $CaC0_3$, 44.45 percent $MgCO_3$, and 0.60 -percent iron and silica. The dolomite is mined in open cuts and hauled by truck to the crushing and screening plant at Dolomite Siding on the Keeler branch of the Southern Pacific railroad. The crude ore is crushed in a 9- by 12-inch jaw crusher. Crushed ore is passed through a trommel to a multitask vibrating screen. The normal roofing granule size is minus 4- plus 10-mesh. If terrazzo material is being made, the sizes are : Trade size No. 4 minus 4- plus 6-mesh Trade size No. *6* minus 6- plus 8-mesh Trade size No. 8 minus 8- plus 10-mesh.Some minus 32-mesh to pan-dolomite has been sold for use in rock wool manufacture. Other uses include plaster sand and chicken grit. The screened product is bagged in 100-pound bags and hauled by truck or railroad to the 110s Angeles area. Plant capacity is 300 to 400 tons per month. Between November 1948 and 1951, the property was operated under lease by the Dolomite Products, Inc. The company planed to enlarge the plant capacity to 300 tons per week. Ten men were employed in 1951 (Norman and Stewart, 1951:101-102).

Swansea Ovens (#103; T.16S, R.37E Sec.24)

The silver-lead furnaces at Swansea and the nearby mill at Keeler were built in 1869 and used until 1874 to refine ores from Cerro Gordo. In 1870 James Brady assumed operation and established the town of Swansea. Output from this furnace and another at Cerro Gordo reached 150 83-pound silver ingots every 24 hours.

Swansea smelter historical monument. Photo from http://quarriesandbeyond.org/states/ca/structures/images/ca-swansea_monument/ca-swansea_mon_at_a_distance_3168.jpg accessed June 16, 2019

Keeler Sodium Sulfate (#104; T.17S, R.38E, Sec. 5)

The piles of soda around the town of Keeler are sodium sulphate. It is not soluble and the piles stay for years.

Keeler Mill (#100B; T.17S, R.38E, Sec. 4.)

The Keeler mill processed ores from Cerro Gordo. Material was brought down on a tramway. Between Keeler and Cerro Gordo is another tramway, the Salt Tram. This brought salt over the Southern Inyo Mountains from Saline Valley. Steamboats used to take silver from Keeler to Olancha.

Keeler Townsite on Owens Lake, pre-1913

Keeler Smelter, post-1913

Keeler Smelter, 2009

Figure 3Keeler Smelter. Photo from https://i2.wp.com/strayngerranger.com/wp-content/uploads/2016/03/1620487_10152183937551484_344789228_n-1.jpg?resize=750%2C563 accessed June 16, 2019.

Dust Suppression Program on Owens Lake

The wind blows the clay and salts from Owens Lake and creates poor visibility. The soda minerals are linked to several health disorders. Because of the visibility, the China Lake

Naval Air Station has disruptions in their experiments and testing of airplanes and missiles.

The LADWP has initiated a multi-million dollar project to reduce dust emissions from Owens Lake. Some parts of the lake are being flooded. Others are being armored with gravel. There are four stratigies for controlling the dust: 1) submersion (a few inches of water), 2) armoring (with gravel), 3) vegetation (salt-resistant plants), and 4) trenching (burms on the up-wind side of trenches cause air velocity to decrease, causing dust and sand to drop into the trenches),

Map 23: Cerro Gordo

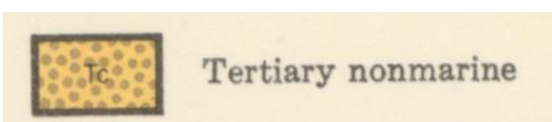
Swansee-Salt Tram-Cerro Gordo Loop

This four-wheel drive excursion can start at Swansee or at the Keeler Mill. The detailed maps to use are

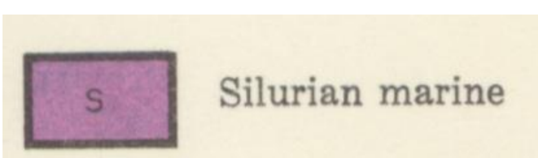
Map 23-1M (Cerro Gordo)
Map 23-2M (Boneham mine)
Map 23-3M (Salt Tram)
Map 23-4M (Swansee)
We describe the loop going counter-clockwise starting in Keeler.

Map 23-1M: Keeler to Cerro Gordo, lower road

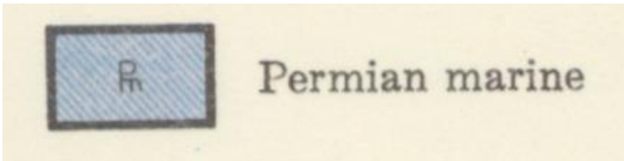
The following geologic information is depicted on the 250K Death Valley Sheet by Jennings 1958): At Keeler Mill we are on Tertiary non-marine alluvial materials with terraces representing older levels of ancestral Owen’s Lake.



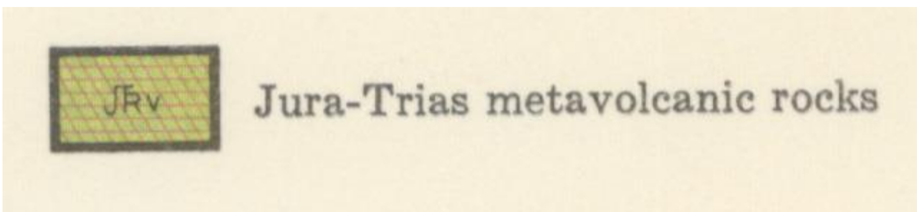
On Map 23-1 we drive over a fault that has Silurian rocks (S) (Sunday Canyon Formation and Vaugh Gulch Limesone of Ross and others, 1967).to the east.

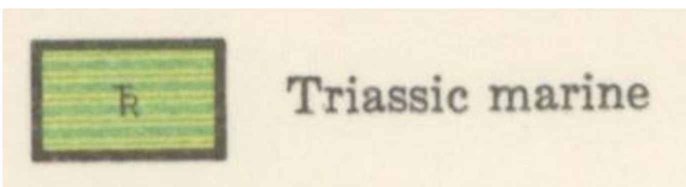


This fault block is 3,300 feet wide and terminates to the east at another fault. This fault that has Permian marine rocks (Pm)(Keeler Canyon Formation of Ross and others, 1967) to the east (point #217).

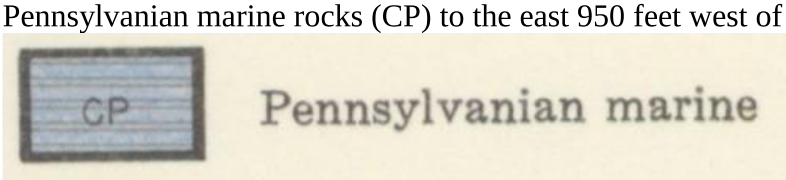


We cross a 6,000-foot wide block of Permian marine rocks and come to another fault. This fault has Jurassic-Triassic volcanic rocks (JTrv) and Triassic sediments (Tr) to the east. These rocks crop out in a belt 5,000 feet wide.

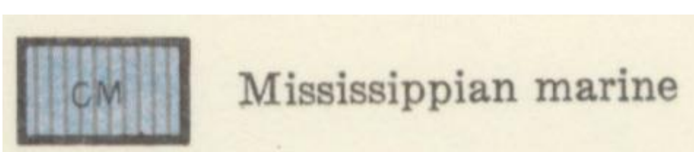


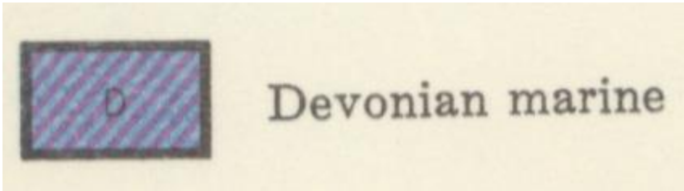


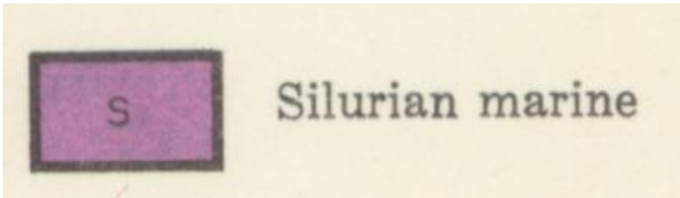
There is a geologic depositional contact between the Triassic rocks to the west and Pennsylvanian marine rocks (CP) to the east 950 feet west of the Ventura Mine.



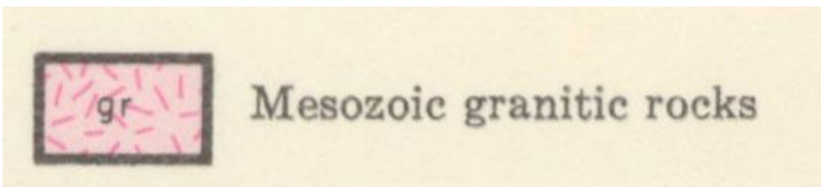
Entering the Cerro Gordo district we also encounter Mississippian,Resting Springs Shale and Tin Mountain Limestone Devonian Lost Burrow Formation and Silurian Hungry Valley Formation marine rocks.





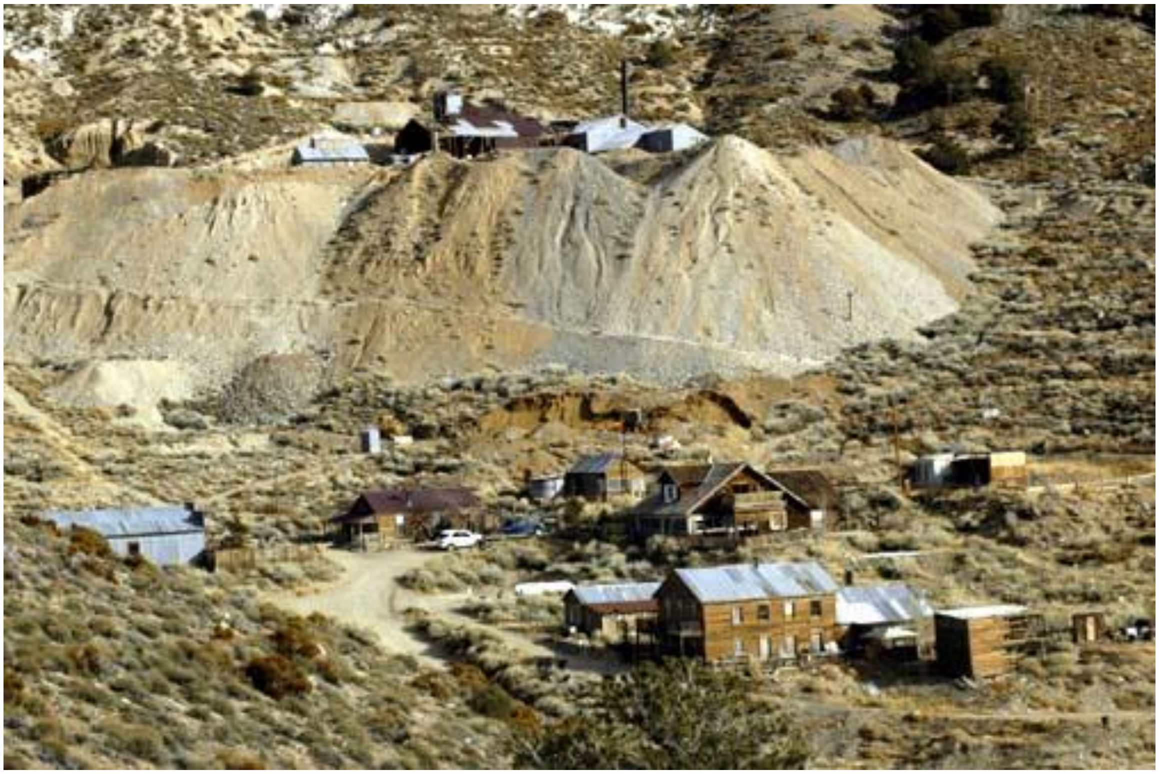


A mass of Mesozoic granite is exposed on the east side of the district



Cerro Gordo (#106; T. 16 S., R. 38 E., Secs. 12, 13, 23 and 24 and T.16 S., R.39 E, Secs 18 and 11)

The Cerro Gordo Mines are located in the Inyo Range near Cerro Gordo Peak at an altitude of 8500 feet, about 5 airline miles northeast of Keeler, California. The Cerro Gordo lead deposits include the Aries Consolidated Group, Armagh Mine, Bluff Group, Boushey Silver, Ignacio or Ygnacio, Mormon, New Enterprise, Omega Group, Pagan Group, Santa Maria, Summit No. 2, and Union Mines.



Cerro Gordo

Cerro Gordo, Spanish for "Fat Hill”, was a silver mining city high in the Inyo Mountains of Owens Valley. Cerro Gordon’s major development took place in the early 1870s primarily by Mortimer Belshaw’s and Victor Beau dry. By 1872, the town was producing 100 to 150 eighty-three pound bars of silver- lead each day. These bars, called "loaves" because of their resemblance to loaves of bread, were shipped in huge wagons to the nearest ocean port city, which happened to be Los Angeles. At the port, the silver was loaded on to ships that carried it to San Francisco and other destinations for final refining (http://www.geocities.com/Yosemite/1911/cerro2.htm, April 10, 2007).

The ores at Cerro Gordo are very rich with ores containing up to 12% lead. They are contact metamorphic replacement deposits formed when Mezozoic granites invaded the Paleozoic carbonates. The mines are near a north-south trending fault that connects the Bonham Talc Mine (#196) with the Cerro Gordo Mines (#158-161)

Cerro Gordo, on the western slope of the Inyo Mountains about seven road miles east of Keeler and thirty miles south of Independence, was the first major silver strike in the Owens Valley. Originally a small-scale operation worked by Mexicans between 1862 and 1866, the mine was included in the Lone Pine Mining District organized in April 1866. Three years later Americans took over the property and ultimately turned it into the largest producer of silver and lead in California, yielding ores that assayed at least as high as $300 per ton

In the early 1870s two smelters were erected at Cerro Gordo and one on Owens Lake near the rival town of *Swansea*. Contributing to Cerro Gordo's commercial success was the fact that this was an excellent area for smelting works: water and wood were abundant, good fire-clay was available, and because of the wide variety of ores in the district, necessary fluxes were obtainable. Productive mines of the area were the historic Union Mine, and the later Cerro Gordo, Cerro Gordo Extension, Estelle, Silver Reef, and Santa Rosa mines. Mule teams transported the ore to Los Angeles, 275 miles away, necessitating high-class ore and bullion in order to make a profit

In 1875 Cerro Gordo suffered a series of setbacks, necessitating the shutdown of its furnaces. These problems resulted from a scarcity of ore in the mine, which had lasted for several months, and the temporary drying up of its water supply; no small factor in the slowdown of production was the litigation that had been initiated in 1870 over ownership of the Union lode. This latter question was finally settled, and on 13 January 1876 the Union Consolidated Mining Company of Cerro Gordo was created and preparations made to return to full-scale production.

The revival was not destined to last, however, and by late 1876 and early 1877 the Union Mine appeared to be played out. A fire that raged through some of the mine buildings and the Union shaft was the final straw; the furnaces were closed the following February. A more lethal blow was dealt by falling lead and silver prices, effectively ending this era of activity at Cerro Gordo (http://mojavedesert.net/mining-history/cerro-gordo/, April 10, 2007).

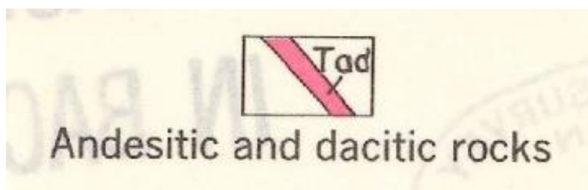
Today Mike Patterson privately owns Cerro Gordo. A number of buildings, from various periods in the town's history, remain standing. As funds would permit, Mike and his late wife, Jody were performing preservation and restoration work on the structures, including the landmark American Hotel, built in 1871. The rebuilding will continue.

You can call Robert Desmarais, manager for Cerro Gordo at 760-876-5030 or contact them by snail mail at PO Box 95, Keeler, CA 93530.

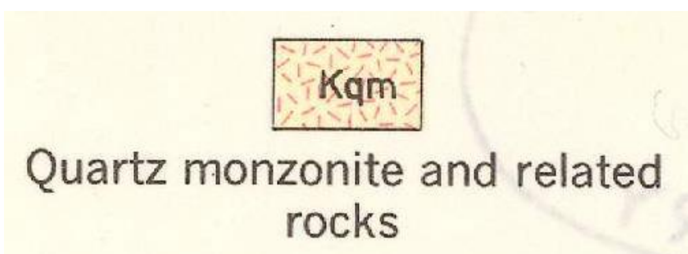
The Cerro Gordo deposits and mine workings have been described by Tucker and Samson (1938:431-433). Knopf (1918:106-116) has given a complete description of the geology of the district and mine. The lenticular ore bodies are mesothermal fissure deposits which have replaced Devonian marble. Geologic work indicates that ore deposition was controlled partly by bedding in Devonian quartzite. The ore bodies are composed of argentiferous galena, cerussite, anglesite, smithsonite, sphalerite, tetrahedrite and pyrite. The general trend of the orebodies is north or northwest, the dip about 70" W., and the plunge south. Two of the largest orebodies were the China Stope orebody, which was mined to a depth of about 550 feet, and the Jefferson orebody, which had a vertical dimension of more than 1000 feet. The Jefferson is 800 to 950 feet south of the China Stope. Most of the lead and silver was produced before 1877. During the period 1911 to 1915, a large amount of secondary zinc ore was mined, principally from orebodies on the footwall side of the China Stope. The principal opening is the 900-foot Belshaw shaft with levels at 85, 200, 400, 550, 700 and 900 feet. On the 900-foot level, 160 feet north of the shaft, a winze was sunk 200 feet with drifts on the 1000 and 1100 levels. About 470 feet south of the shaft, a 250-foot winze was sunk and drifts were extended from the bottom and the 1030-foot level. Underground workings total more than 15 miles.

In 1940 the Cerro Gordo group was acquired by the Silver Spear Mining Corporation. The property was operated from October 1943 to March 1945 by the Golden Queen Mining Company of Los Angeles. Their work consisted of diamond drilling and drifting to find a faulted segment of the Jefferson orebody. Ore was mined from the 900-foot level, and between 750 and 1000 tons of ore was shipped which assayed 17.50 percent lead and 13.2 ounces of silver. In 1946 the property was leased to W. R. Rigg and associates and was purchased by them in 1949. Exploration work in and around the China Stope area between the 200 and 550 levels, included several thousand feet of diamond drilling and several thousand feet of drifts, raises and winzes. Some diamond drilling was also done from the 900-foot level. A small amount of ore was shipped but the property is now idle. The value of ore produced from the Cerro Gordo District is estimated to be $17,000,000 (1951 dollars), of which the Cerro Gordo Mine produced ore worth $15,000,000 (Norman and Stewart, 1951:58-59).

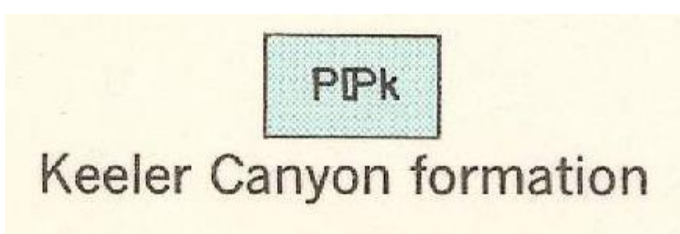
The Cerro Gordo district, shown on the ma, below, has the following geologic units:



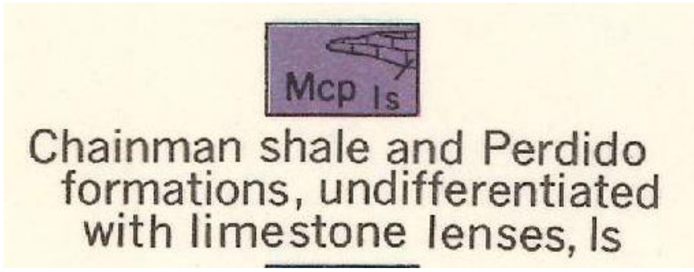
Tertiary



Cretaceous

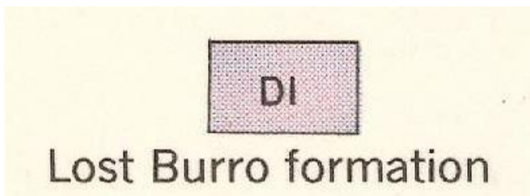


Permian-Pennsylvanian

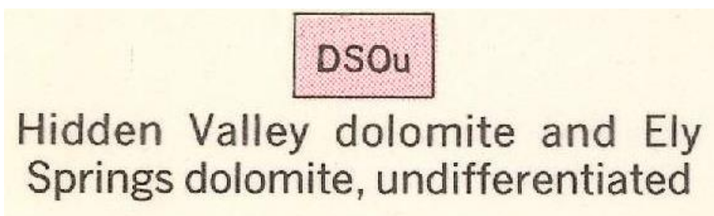


Mississippian

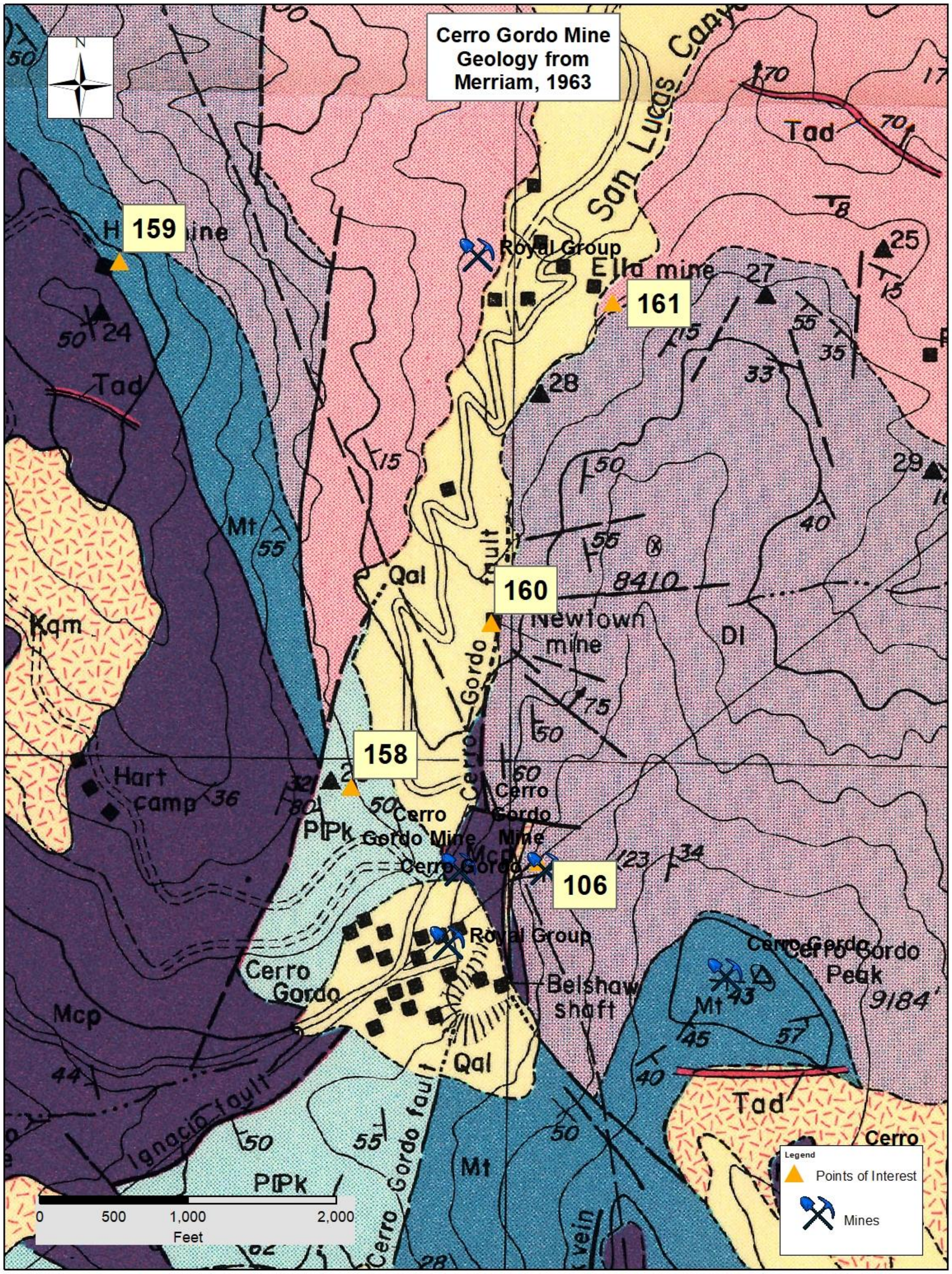
Devonian



Devonian



Devonian- Silurian and Ordovician



Geologic map of the Cerro Gordo mines and surrounding area. Geology from Merriam, 1963.

Map 23-2M: Side trip to Bonham Mine

The 8-mile drive from Cerro Gordo to the Bonham Mine takes us down to San Lucas Canyon. We start at 8,400 feet, go down to 4,700 feet at the canyon and then come back up to 7,400 feet. Driving down from Cerro Gordo to the east we pass through the Devonian and Silurian sections and through high-altitude alluvium all the way to San Lucan Canyon. Ascending back to the west, we climb up through the alluvium. Near the alluvium Paleozoic contact is the Florence Talk mine (#207) to the north.

Florence Talc Mine

The Bureau of Mines OFR 18-85 report for the Inyo Mountains Wilderness Study Area said the following about the Florence, Bonham and other talc mines in the area:

Most talc lenses mined in the WSA are in calcareous, dolomitic sedimentary rocks at the intersections between bedding plane fractures and crosscutting fault zones. The lenses are as thick as 40 ft, grade into the wall rock, contain pods of hard, siliceous, calcareous rock, and are near granitic intrusions. The four talc mines in the WSA are along two zones. One 8-mile-long zone trends southeasterly from the Willow Creek Camp talc mines (outside the study area) to the Doris Dee (fig. 2, no. 1} and Snowflake Mines (no. 41) (both in the WSA}. The second zone is 3 miles long and trends southeast .from the Bonham (no. 82) to the Florence Mines (no. 83) (both in the WSA), and then on south to the Holiday Mine (outside the WSA). The four talc mines in the WSA have marginal reserves of mixed steatite and non-steatite talc totaling about 640,000 tons (U.S. Bureau of Mines, 1985, Table 3).

The Bonham mine has 32,000 tons of reserves.

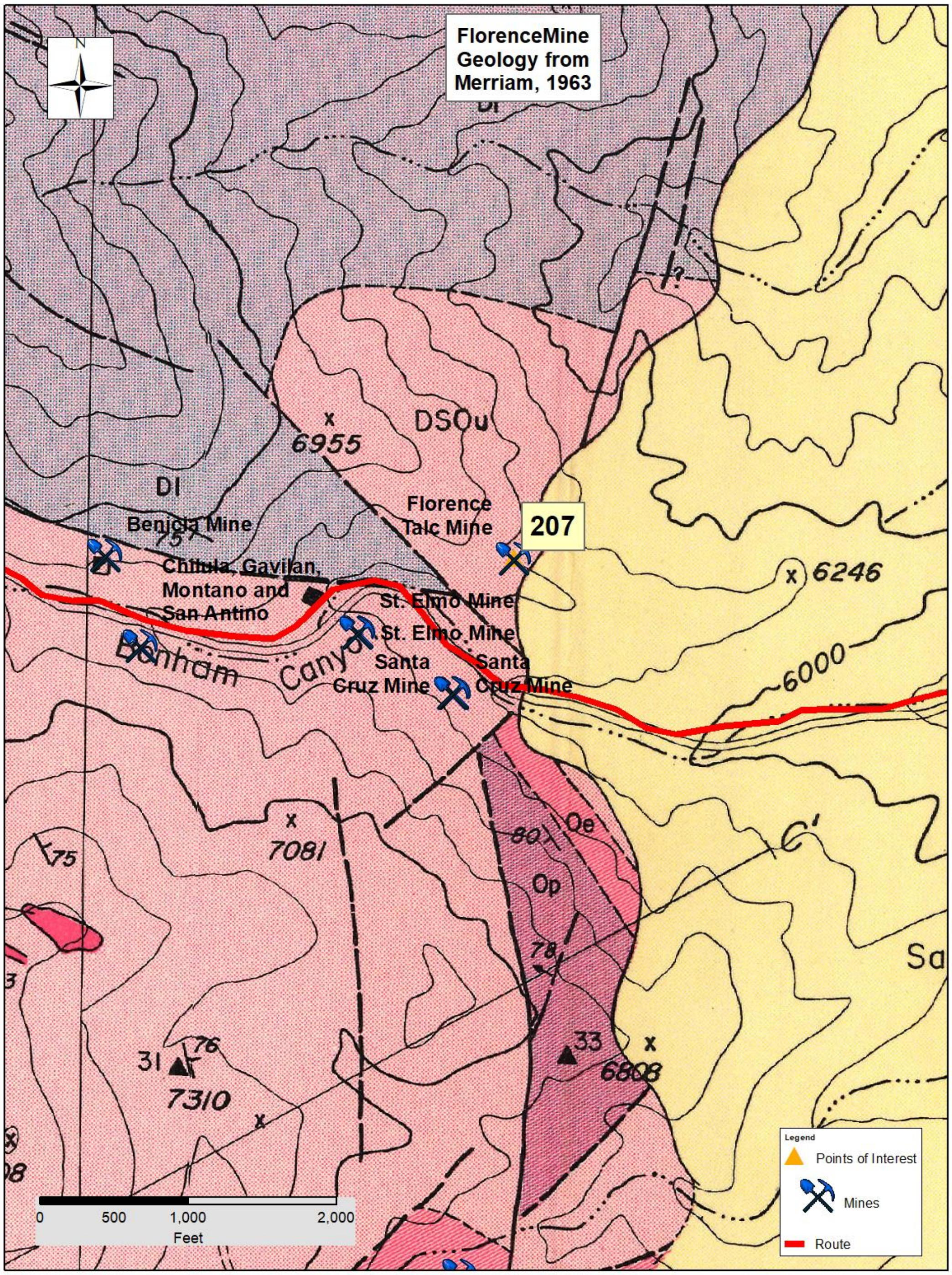
The Florence Talc Mine is at a fault that trends north-northeast to south-southwest and has Devonian-Silurinan Hungry Valley Formation to the west an Mississippian Tin Mountain and Quaternary Older Alluvium to the east

Here is the CDMG report for the Florence Mine from 1951:

White Mountain Claims (Florence Mine). Location : On the east flank of the Inyo Range near the southern end of Saline Valley about 8 airline miles northeast of Keeler, in T. 16 S., R. 38 E., M.D.M. (projected). Ownership: 6 claims are owned by Sierra Talc and Clay Company, 5509 Randolph Street, Los Angeles, California. Leased by Wilham Bonham, Lone Pine, California. . This property is one mile east of the White Mountain Mine and in the same canyon. The rock units, like those of the White Mountain Mine are principally limestone and dolomite with subordinate quartzite. Both the carbonate rocks and the quartzite have been altered to talc in numerous places. The talc is medium gray to light green and very blocky. It appears to_ have formed principally along fractures. In only a few places is the talc m deposits large enough to be of commercial interest. The surface exposure of the largest of the area's known talc deposits is about 200 feet long and from five to ten feet wide. The property is exploited by numerous open cuts, adits, and shallow shafts distributed through an area about one-half mile long and one tenth mile wide. One 80-foot adit driven southeastward from the canyon wall intersects the 200-foot talc zone described above, at a depth of about 55 feet. The total production from 1938 to 1948 was about 7000 to 8000 tons of talc. The property is was still in operation in 1951 (Norman and Stewart, 1951, p. 121-122)

The Burau of Mines report on the Inyo Mountains WSA had this to say about the Florence Mine (U.S. Bureau of Mines, 1985):

OWNERS: Benjamin J. Bonham, Los Angeles, CA; and Roy C. Troeger, Encino, CA
LOCATION: SE. 1/4, NE. 1/4 Sec. 1, T. 16 S., R. 38 E.; Lat. N. 360 34' 4811, Long. W. 1170 46' 54 11, on the south boundary of the WSA; in Bonham Canyon about 2 miles from San Lucas Canyon.
ELEVATION: 6,000 to 6,700 ft
ACCESS: East about 67 miles by the Saline Valley road from Lone Pine, CA
HISTORY: The mine was discovered in the 1930's and intermittently produced talc, in conjunction with the Bonham Mine, until the present (1984).
PRODUCTION: Norman and Stewart (1951, p. 122) report that about 8,000 tons of talc were produced from the mine between 1938 and 1948. The talc was shipped directly or processed in a mill located in Keeler, CA, prior to shipment. The mill closed in the 1960's.
GEOLOGY: The talc occurs as lenses in in flinty, dolomitic limestone at the intersections between bedding-plane fractures and fault zones (fig. 11). The four lenses are as thick as 4.1 ft and total about 2,200 ft in length. The limestone is overlain by quartzite. The fractures strike N. 60°-800 W. and dip 150-300 NE. The faults strike N. 100-200 W. and dip 500-100 SW. Typically the talc is blocky, white to green, grades into the wallrock, and contains pods of chert.
WORKINGS: Workings consist of seven open and seven caved adits, five benches, and several small pits. Most of the adits are short; total length is about 500 ft. The benches total 1,500 ft.
SAMPLING: Analyses of 47 samples indicate that four lenses (fig. 11, nos. 1-4) along two zones contain a mixture of steatite and non-steatite talc.
RESOURCE ESTIMATE: The four lenses average about 3.5 ft thick, total about 2,200 ft in length; they are estimated to contain about 250,000 tons of marginal talc reserves.
CONCLUSIONS: Additional talc resources would probably be deliniated by trenching and drilling. The large talc lenses may be minable, if markets are developed for this type talc; and prices on the order of $48/ton for unprocessed talc and $83/ton for processed talc, could be obtained.



Geologic map of the Florence Talc Mine and surrounding area. Geology from Merriam, 1963

Proceeding west we pass through the Silurian section again until we reach the fault that marks the location of the Bonham mine.

Bonham Talc Mine

(#196, T16S, R. 38E, Section 2)

The Bonham Talc mine is along a fault in Devonian-Silurian Hungry Valley Formation. On the east side of the fault, strata dip 70 degrees to the northeast. To the north of the Bohnam Mine is a west-northwest to east-southeast striking fault that joins the Bonham Fault 1,800 feet north of the mine. This fault places Devonian Lost Burrow Formation to the north against Devonian Hungry Valley Formation to the south.

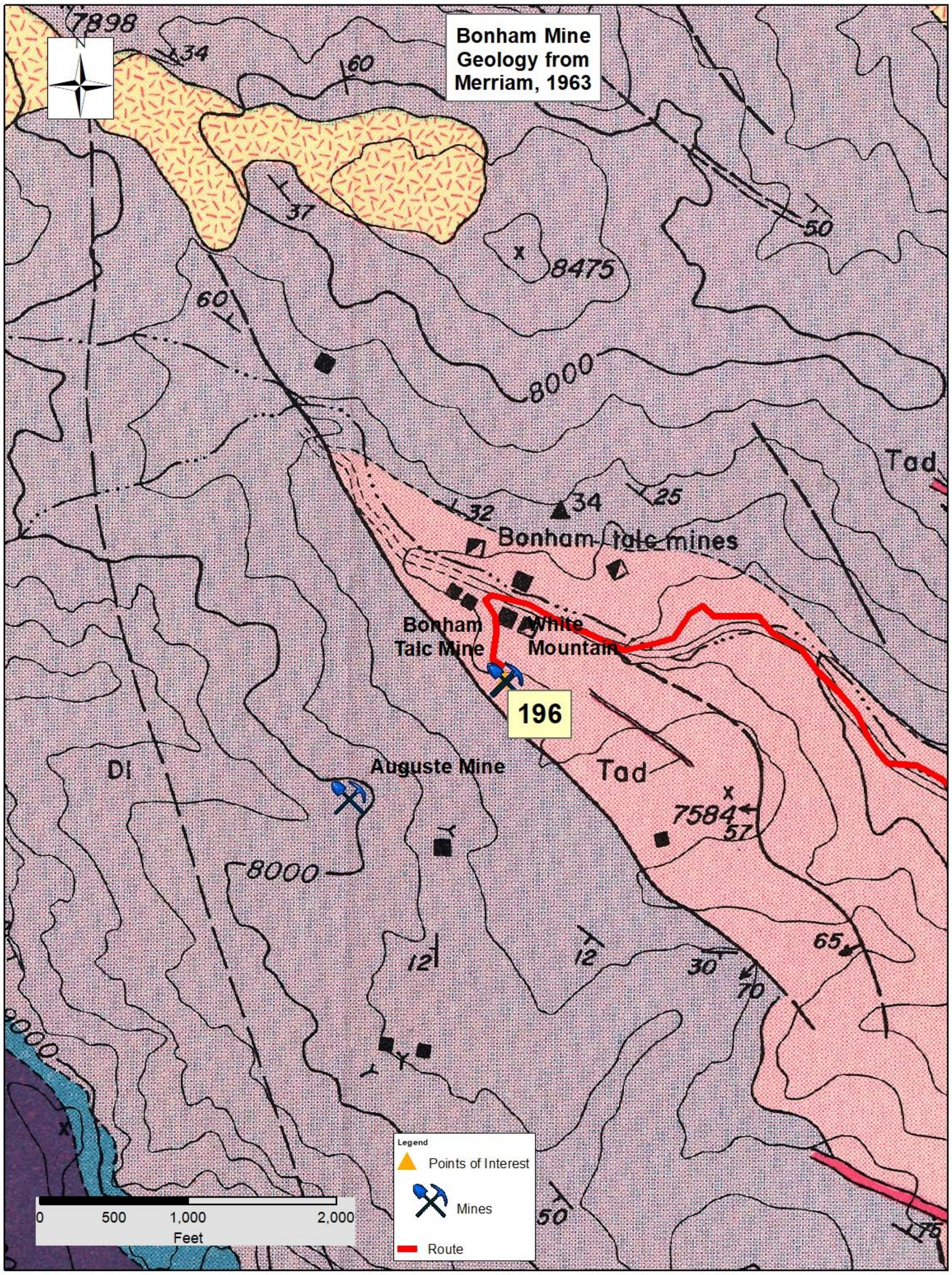
The Bonham Talc mine was owned by J Bonham and others. They also owned or operated several talc properties in the Inyo Mountains. The mine was patented after Mineral Survey M5857 for 52.171 acres

The Burau of Mines report on the Inyo Mountains WSA had this to say about the Florence Mine (U.S. Bureau of Mines, 1985, p. 52-53):

OWNERS: Virginia B. Troeger, Encino, CA; and Benjamin J. Bonham, Los Angeles, CA
LOCATION: SE. 1/4 Sec. 35, T. 15 S., R. 38 E.; and NW. 1/4 Sec. 1, and NE. 1/4 Sec. 2, T. 16 S., R. 38 E.; Lat. N. 36° 35' 02", Long. W. 1170 48 1 17 11 ; near the head of Bonham Canyon. The mine is beside the Bonnam Canyon road, about 2.5 miles from San Lucas Canyon. The part north of the road is inside the WSA; the Bureau's investigations concentrated there.
ELEVATION: 7,200 to 7,400 ft
ACCESS: East about 68 miles by tne Saline Valley road from Lone Pine, CA
HISTORY: Page (1951, p. 23) reported that the deposit was known to Indians wno sold talc to the Cerro Gordo Mine in the 1870's for use as a refractory in smelting. Tne deposit was claimed by Roy C. Troeger in 1914. It was leased and mined in conjunction with the Florence Talc Mine from the 1930 1s until time present {1984). The mine is covered by the Cerro Gordo Soapstone claims located in 1914, 1941, and 1943. Claims 1-3 are patented and claims 4-7 unpatented.
PRODUCTION: Prior to 1951, 20,000 to 25,000 tons of talc were snipped (Page, 1951, p. 23; Norman and Stewart, 1951, p. 121). An additional 13,000 tons are estimated to have been produced sporadically between the 1950 1s and tne present (1984). The talc was shipped directly or processed prior to shipment in a mill located in Keeler, CA. The mill closed in tne 1960's.
GEOLOGY: Three talc lenses are in flinty, dolomitic limestone at the intersections between northwest-trending, northeast-dipping, bedding-plane fractures and northwest-trending, steeply dipping fault zones (fig. 12). Lens No. 3 is mined-out. The talc lenses are as thick as 5.5 ft and total 700 ft in length. The talc is black to green, blocky, grades into the wallrock, and contains pods of hard, siliceous-calcareous rock. About 0.1 mile north are granitic intrusions.
WORKINGS: Two benches that total 400 ft; six adits, all but one caved, but estimated to total about 250 ft; and a number of small pits and cuts.

SAMPLING: The analyses of 25 samples indicate the presence of a mixture of steatite and non-steatite talc.
RESOURCE ESTIMATE: About 32,000 tons of marginal talc reserves remain in two lenses that total 750 ft in length and average about 2.4 ft thick.
CONCLUSIONS: Additional talc resources would probably be disclosed by trenching and drilling. The lenses identified are large, good grade, and may be minable, however, markets would need to be developed. Based on typical mining costs, a price on the order of $48/ton for unprocessed and $83/ton for processed talc would be required for profitable mining. 53

CALIF. DIV. MINES AND GEOL. SPECIAL REPORT 8, 1951, P. 23-
CALIF. JOUR. MINES AND GEOL., V. 47, 1951, P. 116.}
U. S. BUREAU OF MINES OPEN-FILE REPORT MLA 18-85, 1985, P. 52-53.}



Geologic map of the Bonham Talc Mine and surrounding area. Geology from Merriam, 1962.

After visiting Bonham, return to Cerro Gordo.

Map 23-3M: Cerro Gordo to Burgess Mine (Salt Tram)

It is 9 miles form Cerro Gordo to the Bonham Mine. The journey takes us through first Pennsylvanian marine rocks (CP), then Permian marine (Pm) ant then up-section to younger Triassic marine (Tr) and Triassic-Jurassic volcanic units (JTr) at the Burgess Mine. About half way between Cerro Gordo and the Burgess mine is the Salt Tram.

Saline Valley to Owens Lake Salt Tram

Piles of salt at Saline Valley Salt Works circa 1920

The Saline Valley cable tramway was constructed between 1910 and 1913 by the Saline Valley Salt Works to transport pure salt deposits from the salt lake in Saline Valley across the Inyo Mountains to Owens Valley. There it was milled and shipped via the Carson & Colorado narrow gauge railroad north to Nevada. Gondola cars carrying 800 pounds of salt traversed the series of tramways at a rate of 20 tons per hour over the Inyo Mountains. A total of 30,000 tons of high grade salt was carried over the tramway on and off through the early 1930's. The main salt tram summit control station straddles the crest of the Inyo Mountains. It once was totally enclosed with metal siding. A unique crossover system allowed the gondolas to go from one tramway to the other without stopping. Electricity was provided by the Edison Power Plant located in Cottonwood Canyon in the Sierra Nevada Mountains on the western side of Owens Valley. Salt tram towers are seen from the Swansea Grade on the west side of the Inyo Mountains. No two towers are exactly alike.

Before the salt could be transported on the tramway, it had to be harvested from the Saline Valley lake bed. Fresh water was pumped from a large spring into shallow ponds that were built on the lake bed. As the water evaporated, the salt crystals that remained were raked into piles. The salt was then shoveled into wooden railway cars that were pulled into a large storage hopper, where tramway gondolas automatically were loaded with salt. The unique system was capable of filling 56 gondolas per hour, or 20-24 tons per hour. As many as 40-60 men were employed at the salt tram, enduring summer temperatures which could reach as high as 120 degrees.

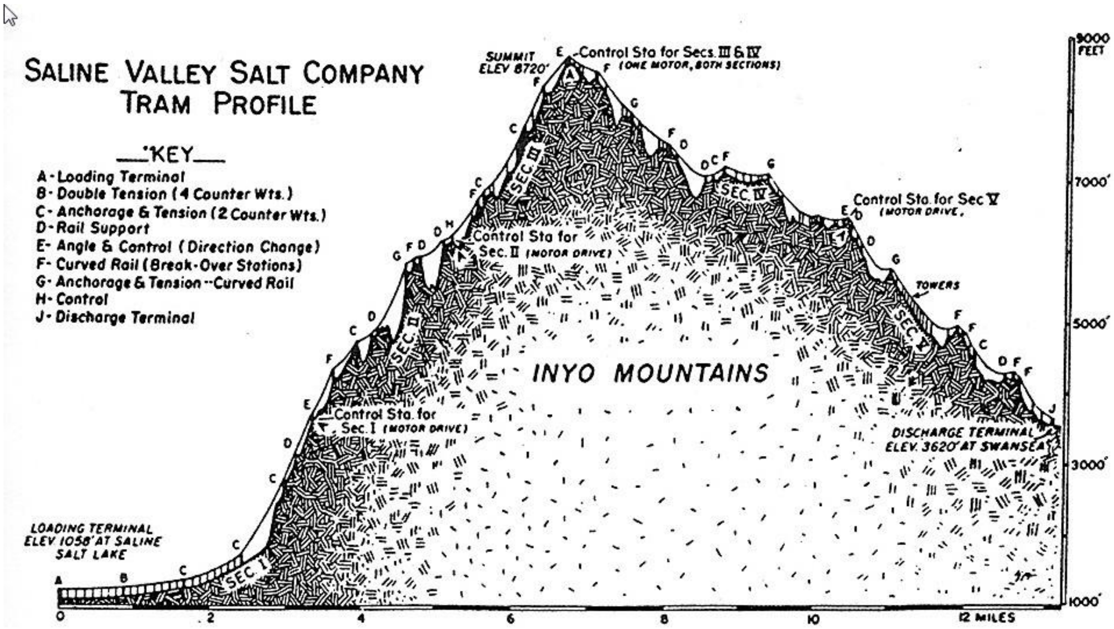
Processing Plant at Carson and Colorado siding.

After traversing the Inyo Mountains, the gondolas ended up at Owens Lake, northwest of Swansea adjacent to a Carson and Colorado Railroad siding. Here the salt was dried, screened, and prepped before railroad shipment. The first buckets of salt reached the Owens Lake railhead on July 2, 1913. “The World’s Purest Salt” was transported 24-hours a day over the tramway for seven years.


Main Tram Tower

The tram had a refrigerator gondola that was kept cool with ice. The refrigerated gondola provided fresh meat and vegetables twice a week to the men working at the Salt Works in Saline Valley. Dried beans, cereals, and other staples kept the men satiated in between time. The gondolas of the salt tram were comfortable for the men to ride in. Two men at a time could sit inside, facing each other. The bottom of the buckets had drain holes on them and a line of salt could be seen on the ground beneath the tram line. The ride on the tram must have been daunting. As they traversed over Daisy Canyon, the men could see cars lying on the canyon floor. They would look up ahead and wonder when the next bucket would break loose, and come back to smack them.

The high cost of the construction and maintenance of the great tramway over the Inyo Mountains prevented salt mining from being a profitable venture. Much of the equipment the salt company used had rawhide gears that failed often and needed to be replaced. The tramway operated from 1913 to 1918, again between 1920-21, and later in 1929 and 1936. Ownership changed hands on and off until the great depression hit and the gondolas stopped forever. The remains of the towers can be seen here and there as you travel the Swansea Grade today.



The tramway was a remarkable engineering feat perhaps rivaling even the Los Angeles Aqueduct which stretches from Mono Lake to Los Angeles. It was the steepest tramway in the United States, rising from 1100 feet in the Saline Valley floor to 8500 feet at the crest of the Inyo Mountains, then dropping to 3600 feet at Swansea in Owens Valley.
Materials for dozens of towers were packed in by mule and the towers were built by hand. Salt was the only food preservative in use at the time, and government price supports helped keep the operation afloat.

The Saline Valley Salt Tram is claimed to be "the most scenic, historic, best preserved, oldest, and largest of its kind remaining today." Although most the Saline Valley Salt Works in the floor of the Saline Valley have been carted off or burned for firewood by vandals, the summit structure on the crest of the Inyo Mountains is extremely difficult of access, and remains largely intact, together with the adjacent living quarters for the machinery operators. Many of the connecting tram towers located in the Inyos are also largely intact. The Summit Control Station and Power House can be seen at the top of Daisy Canyon northwest of Cerro Gordo ghost town. The control operator's house has been restored, and is a pleasant spot for modern backcountry travelers to pause for a picnic and ponder over the construction of the great salt tramway in the early 1900's.

Summit Control Station

Riding the gondola

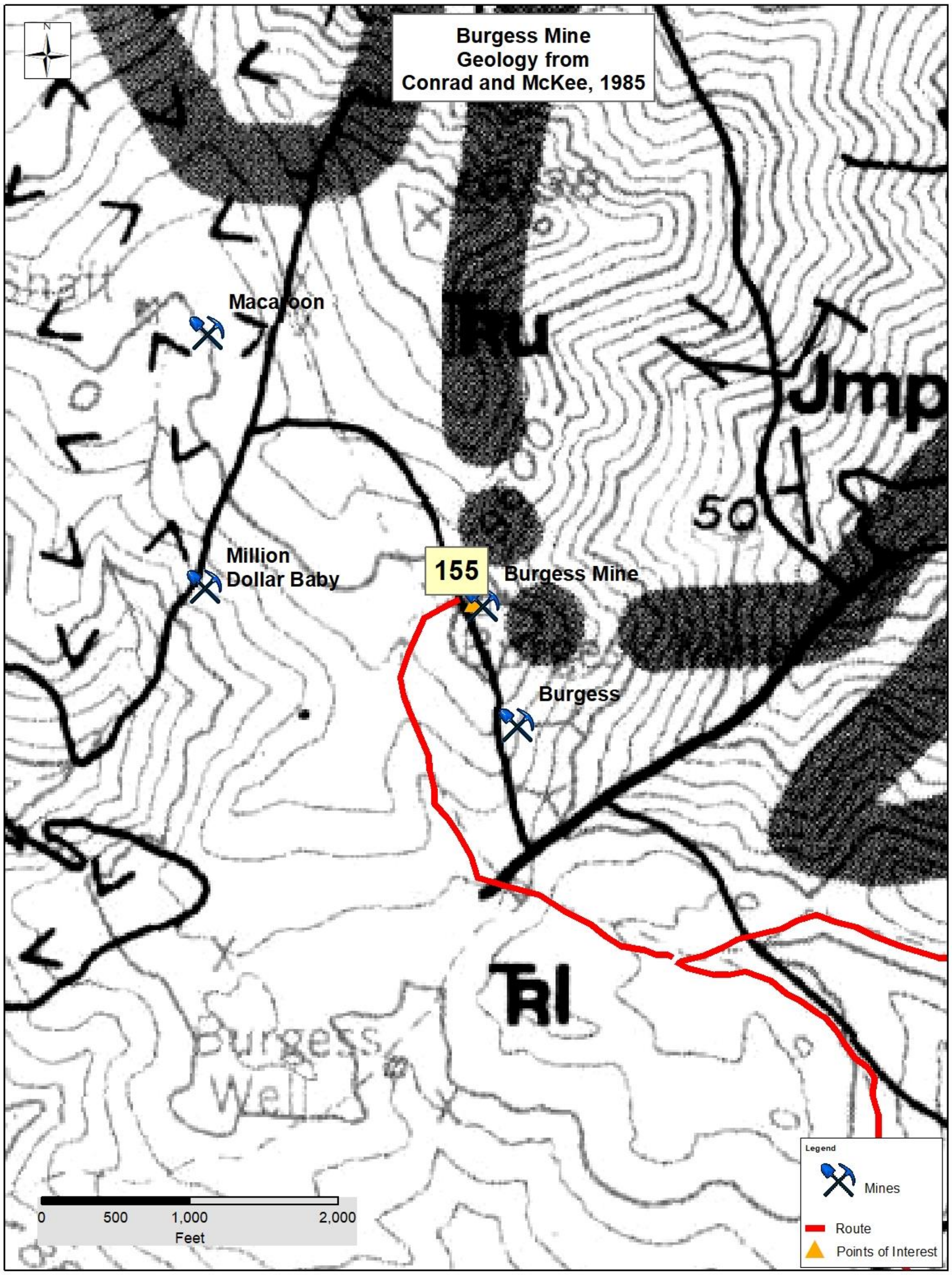
Eventually, in the 1920's, development of salt from the Dead Sea undercut the price for producers like the Saline Valley project, and the company was closed

Burgess Mine (T,15S, R.37E, Section 13)

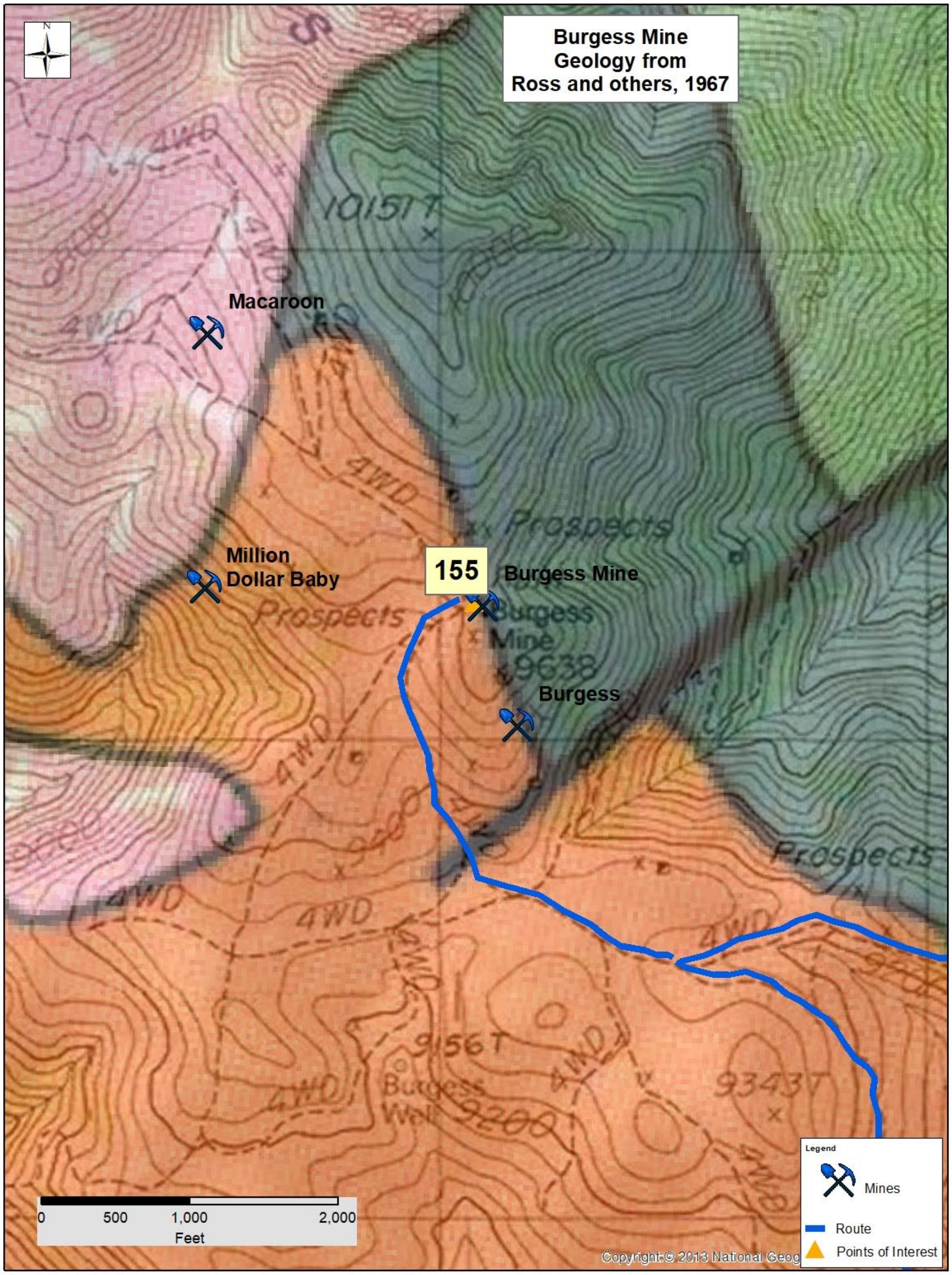
The Burgess Mine lies at a contact between Upper Triassic (Tru) rocks to the northeast and Lower Triassic rocks (Trl) to the southwest. The mine is 2,000 feet west of outrcrops of granite.

The mine was owned by Kate Wells of Big Pine in 1938.

The Burgess worked a gold-bearing quartz vein having a strike of N 30° W, 65°W in limestone. The mine has a 156-ft shaft, 700-ft. adit, and 2000 ft. of related drifts. Ore assyed $20-$40 per ton (Norman and Stewart, 1951, Gold Table, p. 147; Knopf, 1914, p. 119; Waring, 1919, p. 280.)



Geologic map of the Burgess Mine and surrounding area from Conrad and McKey, 1985.



Geologic map of the Burgess Mine and Surrounding Area. Geology from Ross and others, 1967.

Map 23-4M: Burgess Mine to Swansee

The 13-mile trip from Burgess Mine to Swansee starts at 9,600 feet ends at the Owens Lake shoreline (3,600 feet). The first half of this decent is in Jusassic Triassic metavolcanic rocks (JTrvc). 2,100 feet east of the Flagstaff mine (#153) is a contact between these volcanic rocks to the east and Permian Owens Valley Formation (Pov) marine rocks to the west. At the Pennsylvania Mine (#218) is a contact between Owens Valley Formation to the east and Mississippian Resting Springs Formation (Mrs) to the west.

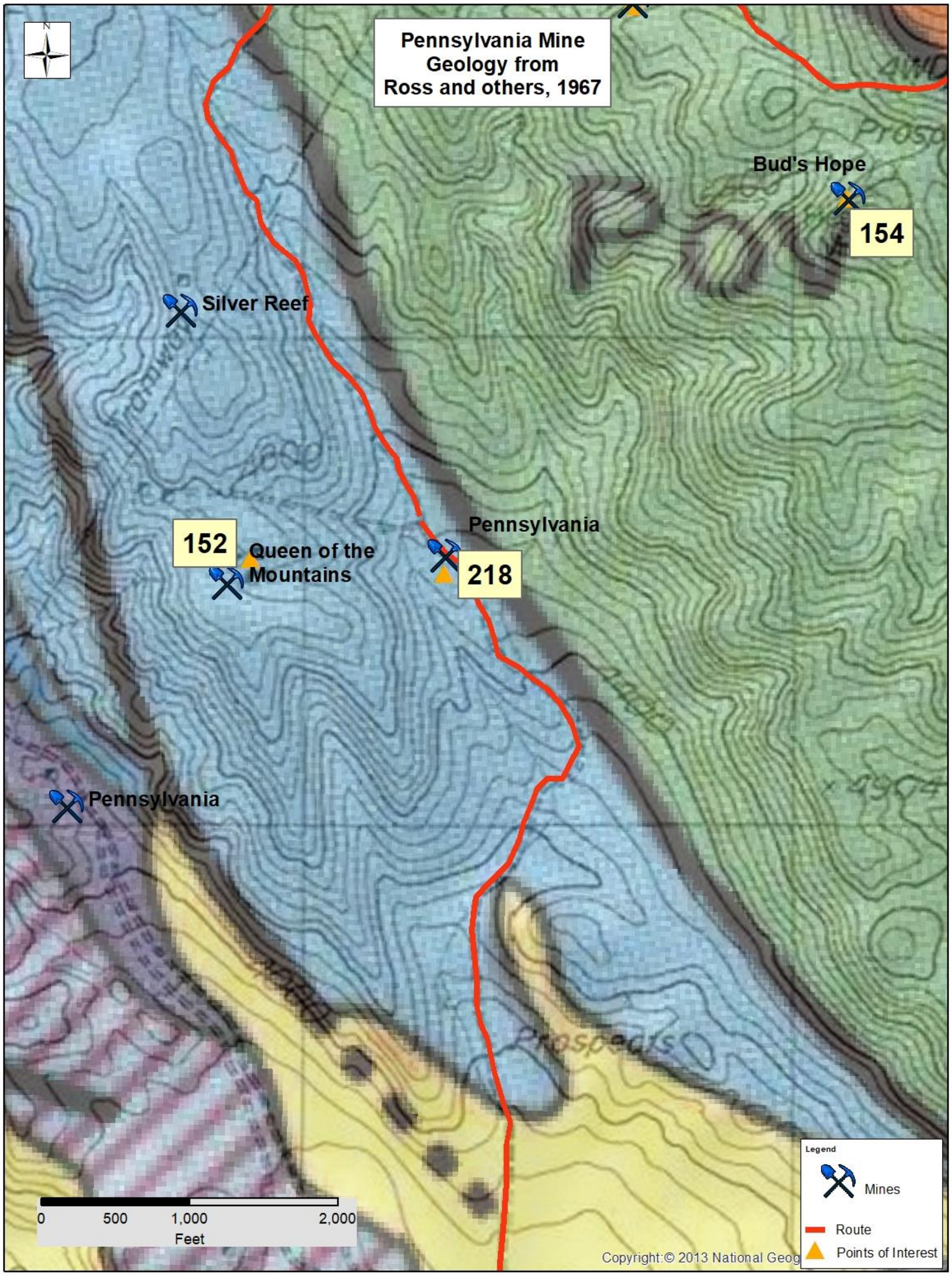
Pennsylvania Mine (#103, T16S, R 37E, Sec. 13 MDM)

The Pennsylvania Mine was owned by .J Carruthers (1942). Operators were:
C.E. Fashbaugh, Lone Pine (1942), and L. D. Foreman (1951)

Goodwin (1957, Inyo County Table, p. 500) described the Pennsylvania Mine as:

Class D. Type 1. Mine located in the Swansea district near Keeler. Galena and cerussite in fissure in limestone. Developed by 135-foot vertical shaft. Recorded production between 1918 and 1942 of high silver-bearing lead ore. In 1951 a carload of dump material was shipped; smelter recovery was 4.87% lead, 7.44% zinc, and 5.78 ounces of silver per ton. In 1952 some ore was milled and concentrates shipped to Tooele and Anaconda; smelter recovery was 6.67% lead, 8.34% zinc, and 12.1 ounces of silver per ton of bulk of ore. (Eric 1948: 249; Norman and Stewart 1951:183; Tucker 1921:293; 26:495; Tucker, 1938:451, 477, pl. 3)

Between the Pennsylvania and the Leary Mine (#103) we pass into Quaternary Alluvium.



Geologic map of the Pennsylvania Mine and surrounding areas. Geology from Ross and others, 1967.

Talc City (#107; T.18S, R.40E, Sec. 29)

Twenty kilometers (15 miles) southwest of the Keeler-Death Valley Junction is the mining camp of Talc City. These deposits are more contact-metamorphic deposits formed when the Mesozoic granites intruded the lower Paleozoic sequence. The Morning Star Shaft area of the Talc City mining district is shown on the next page, reproduced from Norman and Stewart, 1951, Plate 10.

Clay Pit Fossil Locality (#108; T.18S, R.38E, Sec. 22).

This mine produced talc from contact-metamorphic zones associated with dikes, similar to the mineralization at Inyo Marble. The lake beds that overly the talc deposits have yielded horse and camel fossils.

Dirty Socks Hot Springs (#109; T18S, R37E, Sec. 34)

This is a favorite spot for bathing and recreation, if you don't mind the smell of rotten eggs and lots of algae. A cement swimming pool was built in 1927. This is a good spot for bird watching

Dirty Socks Hot Spring. From https://www.ocf.berkeley.edu/~fricke/hotspring/dirtysock.jpg accessed June 13, 2019.

Olancha Sand Dunes and ORV Area (#110; T19S, R37E, Sec. 4, 9 and 16)

These dunes are not very extensive. There is one big dune. It is a good place to learn how to operate ATV's in the sand.

Olancha dunes. From https://i.ytimg.com/vi/YRYAG-Obh5M/maxresdefault.jpg accessed June 13, 2019

Owens Lake History

The history of Owens Lake is one of natural and man-made changes. It was one of the largest of the glacial ("pluvial") lakes of California during the Ice Age.

By the 1900, 500,000 acre feet of Owens River water was being used by farmers every year. After the aqueduct was completed, 350,000 acre feet per year were being used by LA. This was at a time when the river received 350,000 acre feet from snowfall. So there was overdraft, and he lake level dropped in 1913. There were wet years in 1912-13, and the lake began to rise again. The rain and snow melt stopped in 1920's. The lake dried up to its present configuration and has stayed that way ever since.

Waucoba Embayment

Several miles to the south east from Olancha can be seen the light colored gently westward dipping Waucoba Lakebeds. Pliocene/Pleistocene in age (less then 500,000 years old), these beds were deposited in a shallow lake that predated much uplift of the Inyo Range. They have no sedimentary material in them from rocks of the Inyo Mountains are in the Waucoba Lakebeds. These young beds are tilted, illustrating the rapid tectonic activity happening in this area.

The Inyo Range here is composed primarily of highly faulted and folded marine rocks of Cambrian age. To the SE are red and black cinder cones situated on the flanks of the Inyo Range. Whether cinders are red or black depends on the oxidation state of iron in the lava. When erupted, iron is in a ferrous (Fe^{++}) state in the form of black magnetite. Upon exposure to weathering over a period of time, the oxidation state changes to ferric (Fe^{+++}) in the form of red hematite (Roy Bailey, USGS, Personal Communication, 1991).

Map 25: Haiwee Reservoir to Fossil Falls

Haiwee Reservoir Uranium Deposits (#111, T.20S, R. 37 and 38E)

The volcanic rocks of the Coso Range contain uranium. As groundwater seeps through the rocks, the uranium is transported down-dip to form roll-front type uranium deposits. The up-dip solutions are oxidized, and the down-dip ones are reducing, especially where organic material is encountered in the lacustrian portions of the Coso lake beds. In the 1970's Gulf Western Corporation made many miles of exploration drilling roads east of Haiwee Reservoir.

These deposits would likely have been developed, had they not been so close to the aqueduct.

Haiwee Reservoir marks the southernmost "lake" in the LADWP system for the eastern Sierra. Two intakes, one constructed in 1913 and the second in 1970, draw water from the reservoir. From this point southward to Los Angeles, the Owens River flows only in aqueducts. The high peak on the Sierra crest at 10:00 is Olancha Peak (el. 12,122 ft; Jessey and Reynolds, 2009:16).

Haiwee Reservoir and Power House (#112; T.20S, R.37E, reservoir, #113 T.21S, R.37E, Sec.14, powerhouse).

This reservoir is part of the Los Angeles aqueduct system. It is an important area for wildlife habitat.

The Owens River has cut through the hard volcanic rocks at this location instead of taking an easier course through lake sediments and alluvial deposits to the west of Haiwee Powerhouse. As we drive by this site, observe the displaced erosional surfaces which are step-faulted downward toward the west.

The Haiwee Reservoir is actually two reservoirs - the North Haiwee and the South Haiwee - that are separated by an earthen dam called the Merritt Cut. At the Cut, a bypass channel can divert the water around the south reservoir through a channel. At the south end of the South Haiwee Reservoir is a dam with a hydroelectric power plant that can use the drop in elevation to generate electricity, one of five similar plants built by the DWP in the valley. At the north end of the North Haiwee Reservoir is another dam, next to the channel where the aqueduct water enters the reservoir. Swimming is not allowed in the Haiwee, though fishing with rubberized waders is permitted. The road north of the power house exposes a section of crushed pipe. This crushing occurred a few years ago when water was inadvertently shut off from the pipe. This caused suction in the pipe which collapsed it.

Map 26: Coso Junction and Coso Hot Springs

Coso Pumice Deposits (#114B; T.21S, R.27E, Sec. 13 and 24)

These are air fall deposits within the Coso lake beds. The pumice is mined for a variety of products including abrasives and posoline. The mines are northwest of **Coso Junction (#114A).**

The structural setting of the Coso volcanic field remains controversial. Monastero, et. al. (2005) conclude the Coso Range lies at a right step or releasingbend in a dextral shear system that extends from the Indian Wells Valley northward into the Owens Valley. This results in northwest-directed transtension, which is accommodated by normal and strike-slip faulting.
This necessitates that the Owens Valley fault must extend southward from Diaz Lake in the Alabama Hills, beneath the sediments of Owens Lake, to the eastern side of the Coso Range where it steps west to the Little Lake fault. If so, the tectonic setting would be analogous to southern Death Valley, where basalts have been emplaced along the Black Mountain detachment formed by a right step in the Furnace Creek-Southern Death Valley fault zone (Jessey and Reynolds, 2009:16).

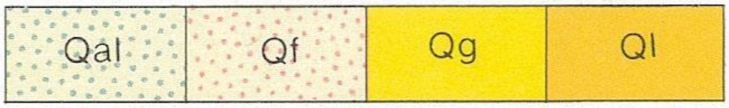
Coso Hot Springs and Geothermal Power Plants (#115; T.22S, R.39E, Sec. 3 and 4).

These power plants are on China Lake Weapon's Testing Reservation. When they were originally developed, in the 1950’s they were touted as able to produce “10,000 kilowatts for 10,000 years”. The plan has been injecting their produced water back into the reservoir. This has cooled the reservoir causing crystallization of minerals that would not crystallize at higher temperature. As a result, plant productivity had decreased. The photo above is from the Coso Geothermal Plant web site.

To visit the hot springs or geothermal power plant requires special permission from the Commander of the Naval Base. The hot spring mud pots are a sacred site to the Native Americans.

From the Roadside Rest area at Coso Junction, looking west you can see a line of vegetation that markes the Eastern California Shear Zone (ECSZ). Three lines to the west are: upper, old LADWP aqueduct (1913); center, Southern Pacific railroad to Lone Pine; lower, new LADWP aqueduct (1967; Jessey and Reynolds, 2009:16).

The area of Map 26 was mapped by Stinson, 1977b. The main geologic units are:



Surficial sediments

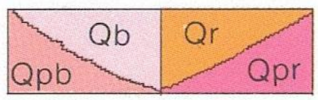
Qal - alluvium, windblown sand, stream wash.

Qf - fan deposits, Owens and Rose Valleys.

Qg - gravel deposits, Rose Valley.

Ql - lacustrine deposits.

Holocene Surficial Sediments



Volcanic rocks

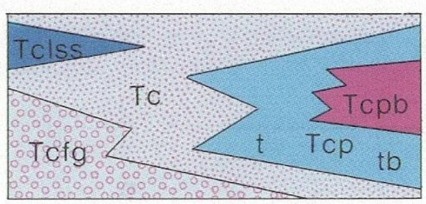
Qb - basalt and basaltic andesite flows.

Qpb - basalt cinder cones.

Qr - rhyolite flows, perlite domes, obsidian.

Qpr - rhyolite lapilli tuff.

Holocene and Pleistocene Volcanic Rocks



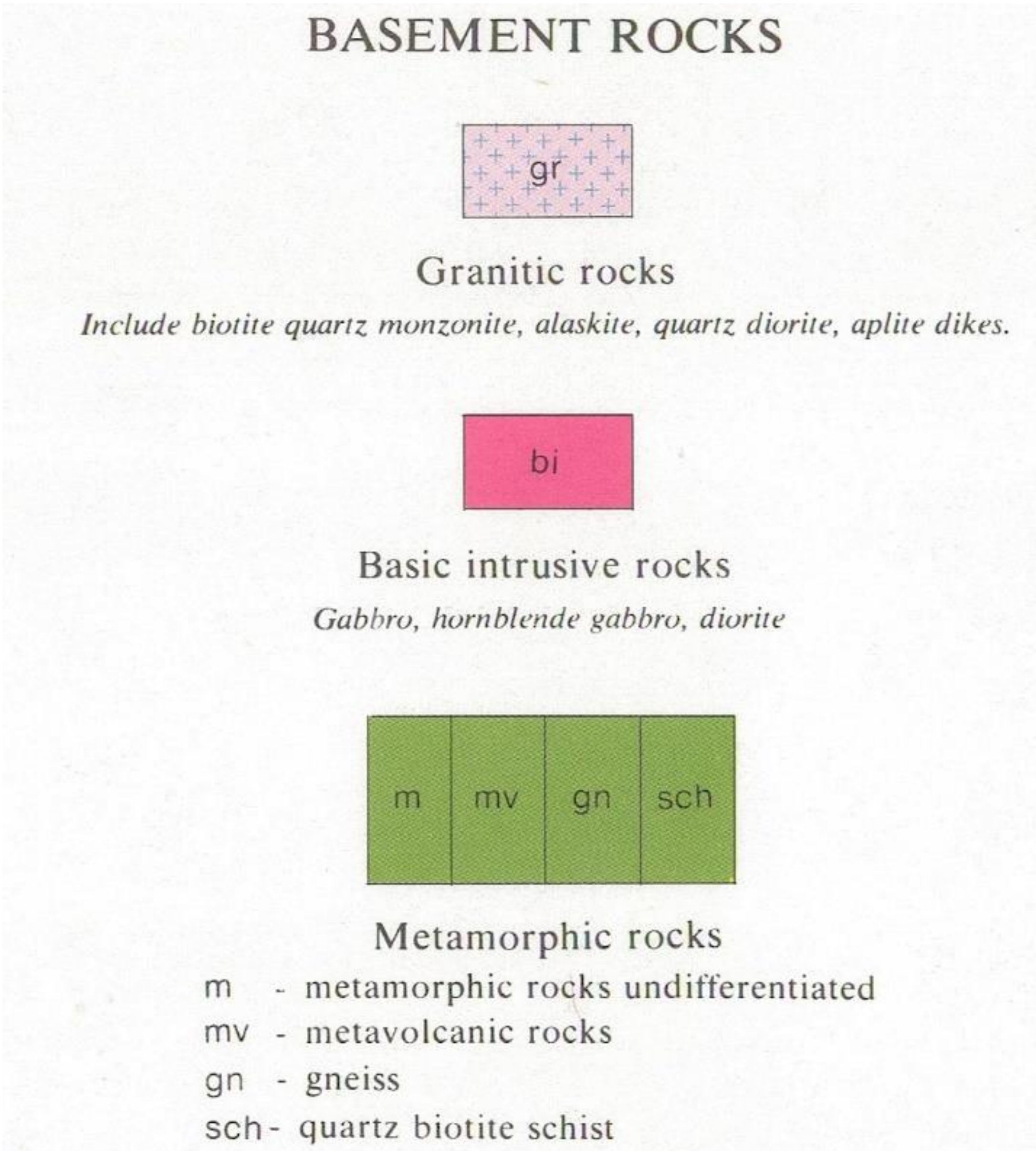
Coso Formation

Tc - undifferentiated sedimentary rocks, includes fanglomerate consisting of massive indurated arkosoic sandstone and conglomerate (Tcfg) and limy sandstone, often ferruginous (Tclss).

Tcp - undifferentiated rhyolitic pyroclastic rocks, includes tuff (t) and tuff breccia (tb).

Tcpb - silicified ferruginous rhyolite tuff and tuff-breccia

Pleistocene or Pliocene Coso Formation



Mesozoic Basement Complex

Step-Faulted Basalt Flows

Between Sugerloaf Mountain and Haiwee Powerhouse are a series of step-faulted lava flows.

Rhyolitic Perlite: Sugarloaf Mountain (#116; T.22S, R.38E, Sec. 12)

Petroglyph Canyon (#117; T.22S, R.40E, Sec. 19)


Sheep petrogplyphs, Little Petroglyph Canyon, photo by Janet Westbrook, 1999.

The Maturango Museum in Ridgecrest has an on-going program of field trips to Petroglyph Canyon, which is on China Lake Naval Weapons Center.

Map 27: Red Hill and Fossil Falls


Red Hill

Red Hill Cinder Mine (#118; T.22S, R.38E, Sec. 30)

This mine produces red and black cinders from a cinder cone.. There are many volcanic bombs in this deposit and a nice collection of them are around the mining company office buildings.

Red Hill is one of the youngest volcanic features in the Coso volcanic field. It is thought to be no older than 10,000 B.P. and may have last experienced a flank eruption within the last 1000 years. The flank eruption is marked by a small crater that lies on the northwest side of the cinder cone and is best seen traveling south on Hwy 395. CEMEX currently operates the Red Hill Quarry on the south flank of the cinder cone. They have a small crusher plant that produces a fine scoria aggregate used for road cinders and in the manufacture of cinder block, as well as larger-sized material utilized for landscaping. (Jessey and Reynolds, 2009).

The Red Hill Cinder mine applied for a mining patent in 1989 for the Cinderlite No. 1 Placer. That patent processing was delayed because of a dispute between the Bureau of Land Management, and the mining company about reserves. There are hundreds of years of reserves at Red Hill, based on current rates of production. BLM decided to award only a part of the lands applied for in the application because of "excess reserves", that is to say reserves that have no present value, because their development are so far in the future. The claimants appealed. Eventually, on February 28, 2007, six claimants received 118.22 acres in Sections 30 and 31 as Serial Patent CACA 26773 (Accession Number 04-2007-0002) under authority of the July 26, 1866: Mineral Patent-Placer (15 Stat. 251).

From Red Hill, a road goes east and then south along the power lines to an overlook of Little Lake (Site #120B).

Fossil Falls (#119; T.23S, R.38E, Sec. 6)

This fascinating geologic formation is an excellent place to see the combined effects of volcanism and water erosion. During the last ice age, the Owens River connected a series of lakes that stretched from the Eastern Sierra (Mono Lake) to the low-lying basins of the Mojave Desert and Death Valley. About 20,000 years ago, basaltic lava from the volcanoes in the Coso Range flowed into Owens River channel in the southern Owens Valley. The lave was subjected to powerful erosive action of the sediment-laden river and over time, the water cut a canyon through the lava bed, carving and polishing the rock as it cascaded south. Following the ice age, the area's climate became increasingly arid and about 4,000 years ago (Bates, 2009) the river ceased flowing through this channel, thus exposing a "fossilized waterfall". There are thousands of obsidian flakes at Fossil Falls. It is an important archaeology site.

The site has a very impressive display of fossil pot holes. They are created by high-velocity eddy currents in the falls.

Fossil Falls

Rocks in the bottom of the potholes act as cutting tools. As the water swirls around, the pot holes are excavated downwards. Sometimes they breech each other and interconnect.

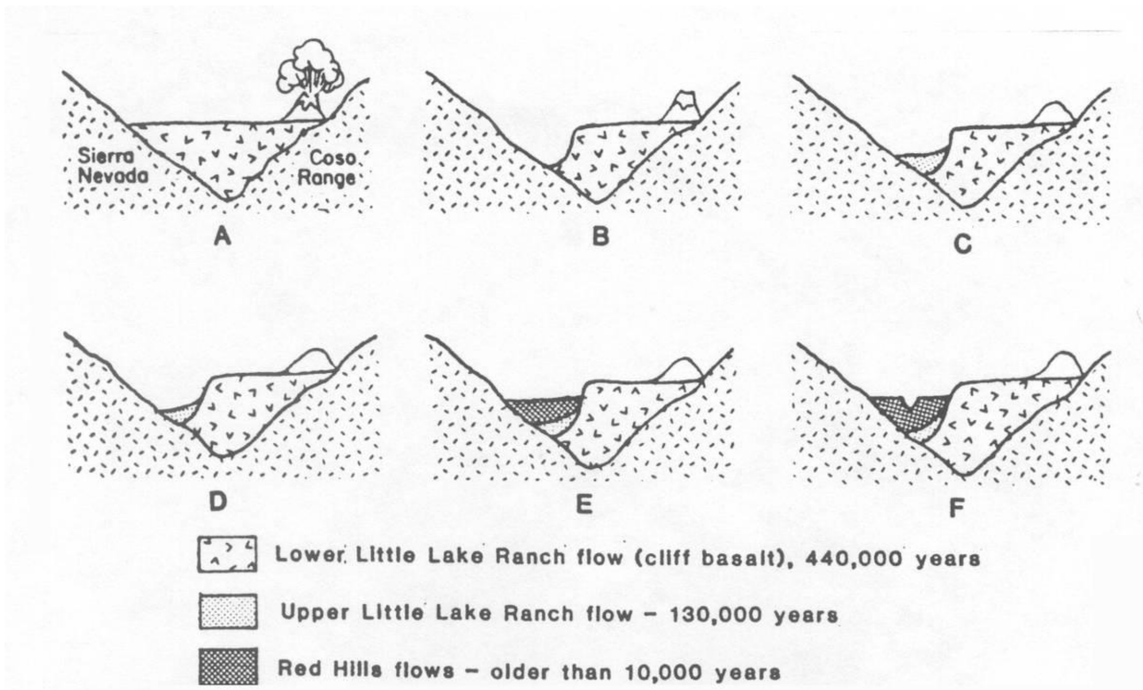
At Fossil Falls there is an on-going battle between the volcanoes and the river. As successive lava flows come west from the Coso mountains, the river is pushed to the west. Between volcanic eruption cycles, the river erodes the lava and underlying sedimentary materials to the east.

Hydrolacoliths

In the vicinity of Little Lake and Red Hill, and near Highway 395, are domed masses of lava. These are called hydrolacoliths. They form from steam eruptions as the lava flows make their way over material that is saturated with water. The heat causes steam explosions in the lava, and cause it to be domed-up in the form of laccoliths.

Little Lake (Atali Cliff) (#120A; T.23S, R.38E, Sec. 8)

This lake is in what used to be a stream channel for the ancestral Owens River. Indian house rings are common on the east side of Little Lake. The lake is a private and dedicated for wildlife habitat.



Alternating Basaltic Volcanism and Canyon Cutting at Little Lake.

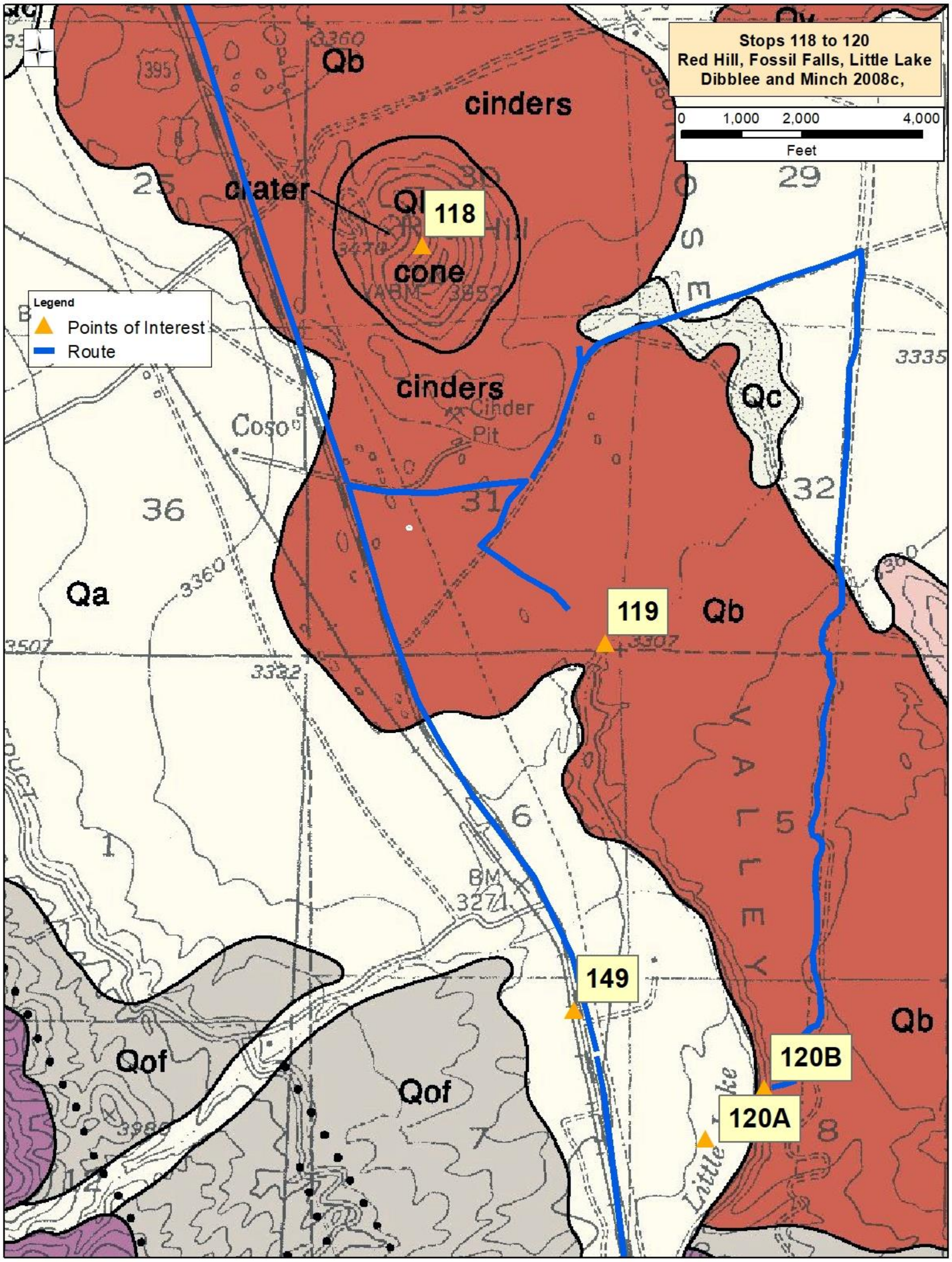
There are good examples of columnar jointing in the lava flows at Little Lake. The three flows at Little Lake and the interplay between volcanism and canyon cutting is shown the figure, above.

At and below Little Lake, the Owens River has cut a canyon between the Coso Range (east) and the Sierra Nevada (west). The oldest volcanic flows lie to the south. The Upper (prominent columnar jointing) and Lower Little Lake Basalt are 130,000 and 400,000 years old respectively. The Basalt of Red Hill, named for the prominent cinder cone just to the east of Hwy 395 at the Fossil Falls turnoff, overlies the Little Lake Basalts. It has not been dated, but is younger than 130,000 years and older than 10,000 years. The flow has followed the drainage of the Owens River and appears at first glance to lie below the older Little Lake Basalt. The most recent volcanic activity at Red Hill is dated at about 10,000 years although there is evidence for a more recent flank eruption from a small vent on the northwest flank of the cinder cone (Jessey and Reynolds, 2009:15).

Pictographs at Atlatl Cliff

This site is called Atlatl Cliff because of the many petroglyph depictions of atlatls found at this site, is located in the Little Lake, California, volcanic field. The site is approximately 100 meters wide and extends up a steep slope of basalt blocks that have dislodged from a shear two hundred foot tall near vertical wall that is the edge of a lava flow. The blocks are not stable and the outcrop is continuing to tumble. Evidence of movement can be seen in the repositioning of petroglyphs to the most unlikely orientations and on rocks that have split and moved apart. Many of the petroglyphs are representational: there are about a hundred atlatls depicted, also circles, circles attached to lines, concentric circles, dumbbells, lines of dots, lines of circles, occasional animal/ human tracks and various other elements.

This is a small rock art site, with only about two-three hundred petroglyphs spread out over the boulders. There is an archaic Pinto Culture site near Atlatl Cliff. There is no proof that they were the authors of this rock art, but the petroglyphs show repatinization and appear to be 4000 to 5000 years in age. There is occasional re-pecking of older images and Numic grid scratching over some of the petroglyphs (http://www.petroglyphs.us/photographs_atlatl_cliff_petroglyphs_AC.htm, April 10, 2007)



Red Hill, Fossil Falls and Little Lake. From Dibblee and Minch, 2008c.

Little Lake Hotel and Gas Station (Site) (#149, T.23S, R.38E, Sec. 7; N 35°56’00.2”; W 117°54’29.9”)

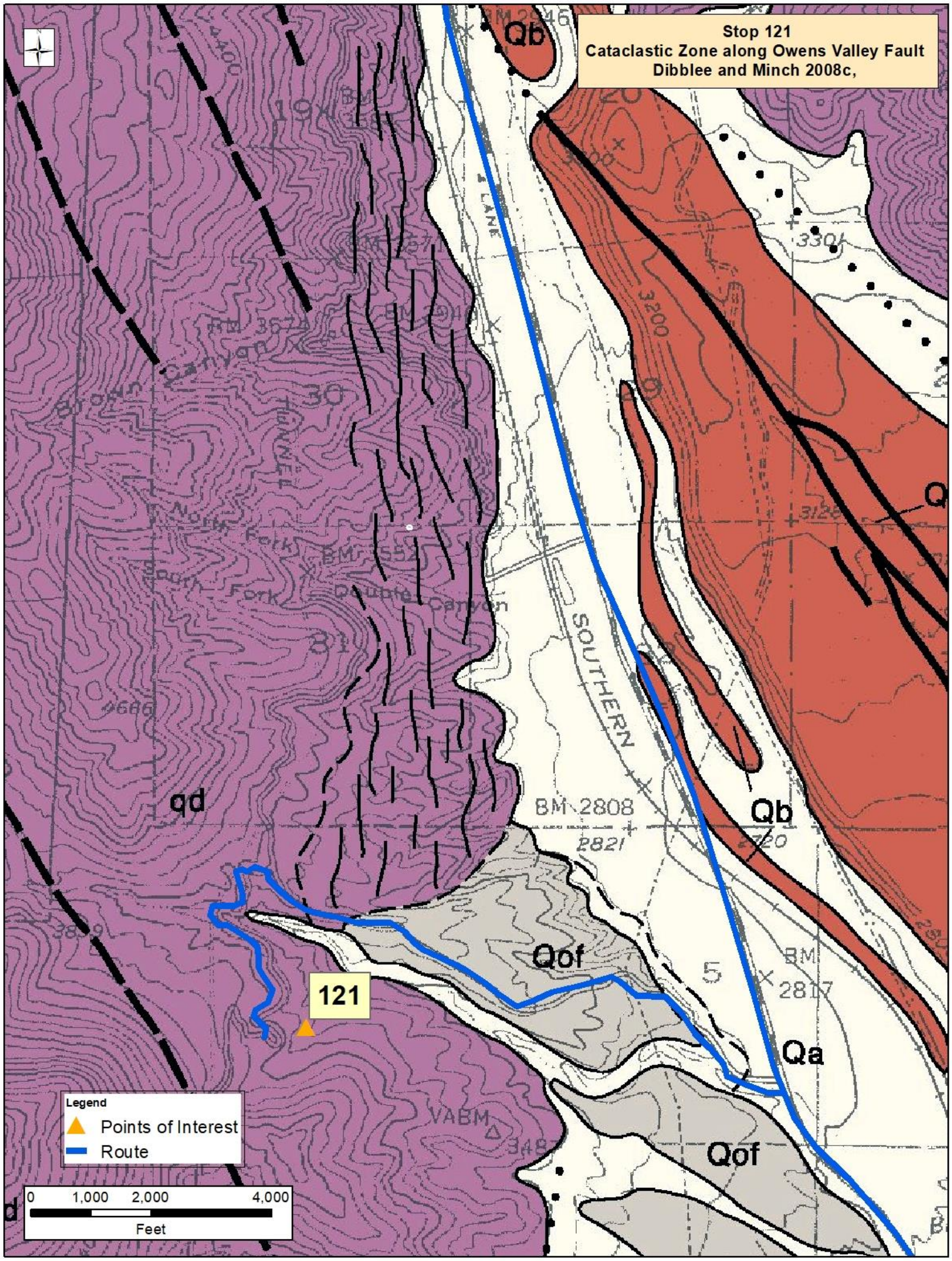
The Southern Pacific Railroad (SP) is on the west. The SP Lone Pine branch commenced in 1908 to facilitate building of the LA Aqueduct. This is the site of the Little Lake Hotel and gas station. The only building left is the green post office to the west. There are examples of columnar jointing in the flows at this site.

The Coso volcanic field lies to the east of the Sierra Nevada at the western edge of the Basin and Range province. It consists of Pliocene to Quaternary rhyolite domes and basaltic cinder cones covering 150 square miles. The youngest eruptions are bimodal, with basaltic lava flows intruded by 38 rhyolite lava flows and domes. The rocks exposed in this outcrop are columnar-jointed basalts of the Upper Little Lake Basalt. In general, the basalt flows and cones on the west side of the of Coso volcanic field are Pleistocene in age while those to the east are Pliocene. The volcanism occurred in two distinct pulses; one from 4.0-2.5 Ma, that resulted in 31 km3 of basalt, rhyodacite, dacite, andesite and rhyolite, and a second from 1.1 Ma to the Holocene with nearly equal amounts of basalt and rhyolite (Duffield, et. al., 1980, Jessey and Reynolds, 2009:15).

Map 28: Little Lake to Freeman Junction

Cataclastic Zone along Owens Valley Fault (#121; T.23S, R.38E, Sec. 6)

By turning off at the southern entrance to the business establishments at Little Lake, and going south and west on a dirt road, one can drive to an exposed portion of the Owens Valley Fault Zone. The Owens Valley Fault Zone is also called the East Sierra Fault Zone. Approximately 1 mile from Highway 395 the road branches. Here one cane see cataclastically granulated rock some of which has been reworked by water. A line of springs to the southeast marks the juncture of the Sierra fault zone and a northwest-trending fault. This tectonic interpretation was disputed by Pierre Amand, who believed the brecciation was due to a series of landslides.



Cataclastic zone along the Owns Valley Fault. From Dibblee and Minch 2008c,

Shore Lines of Ancestral China Lake

From the village of ***Pearsonville (#122)*** (T.24S, R.38E, Sec.33), the shorelines of pluvial China Lake can be seen to the northwest. Pearsonville was billed as the "hubcap capital of the world" since Lucy Pearson has a collection of hubcaps rumored to number in the tens of thousands. Cross the Inyo/Kern County Line at Pearsonville (Jessey and Reynolds, 2009:15)..

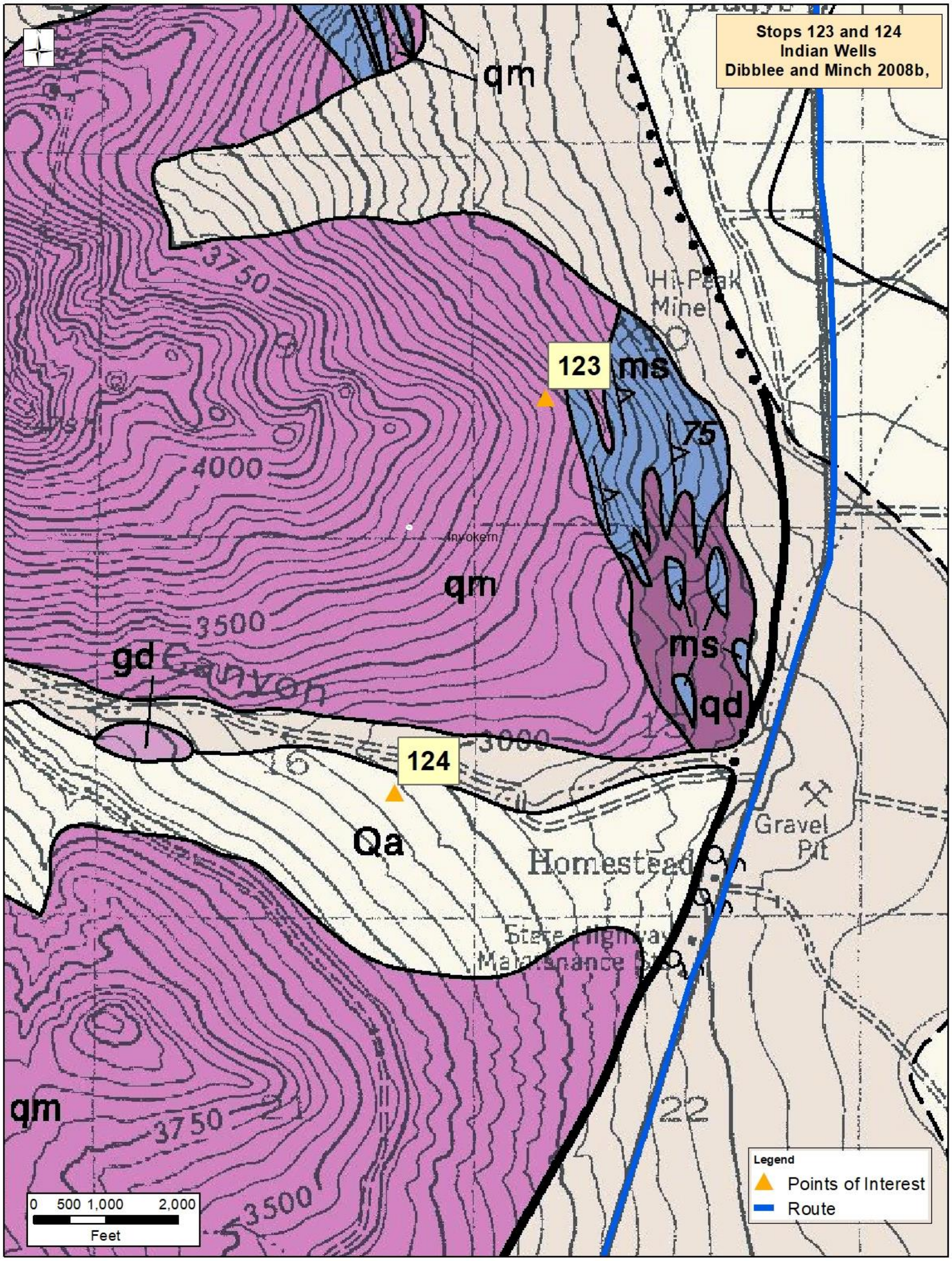
High Peak Mine (#123; T.26S, R.38E, Sec. 10).

The High Peak Mine is on the west side of Highway 14, near the junction with Highway 395. This is a wollastonite deposit, a calcium silicate.

Indian Wells (#124 T.26S, R.38E, Sec. 16)

This site is at a fault scarp of the East Sierra Nevada Fault zone. The fault is a conduit for groundwater and produces springs. These springs provide water for the Indian Wells Brewery and Lodge. Historically, rescuers of the Bennett/Arcane party stopped for water going to and coming from Death Valley. The wells serviced trade route travelers thereafter. Owens Peak (8453 ft.) to the northwest was named for Richard Owens, a member of Fremont's 3rd expedition (Jessey and Reynolds, 2009:14)

South of Indian Wells is a divide (el. 3300 ft.) that separates Fremont Valley drainage system from Indian Wells Valley, the latter draining east toward Searles Valley. The Scodie Mountains of the southern Sierra Nevada are to the west-northwest. Indian Wells Valley lies at an elevation of 2300+ feet, only 300 feet above Fremont Valley. Presumably the elevation difference results from movement along the El Paso fault, but it could also be related to transpression caused by a left step in the Garlock fault (Smith, 1998, from Jessey and Reynolds, 2009:14).

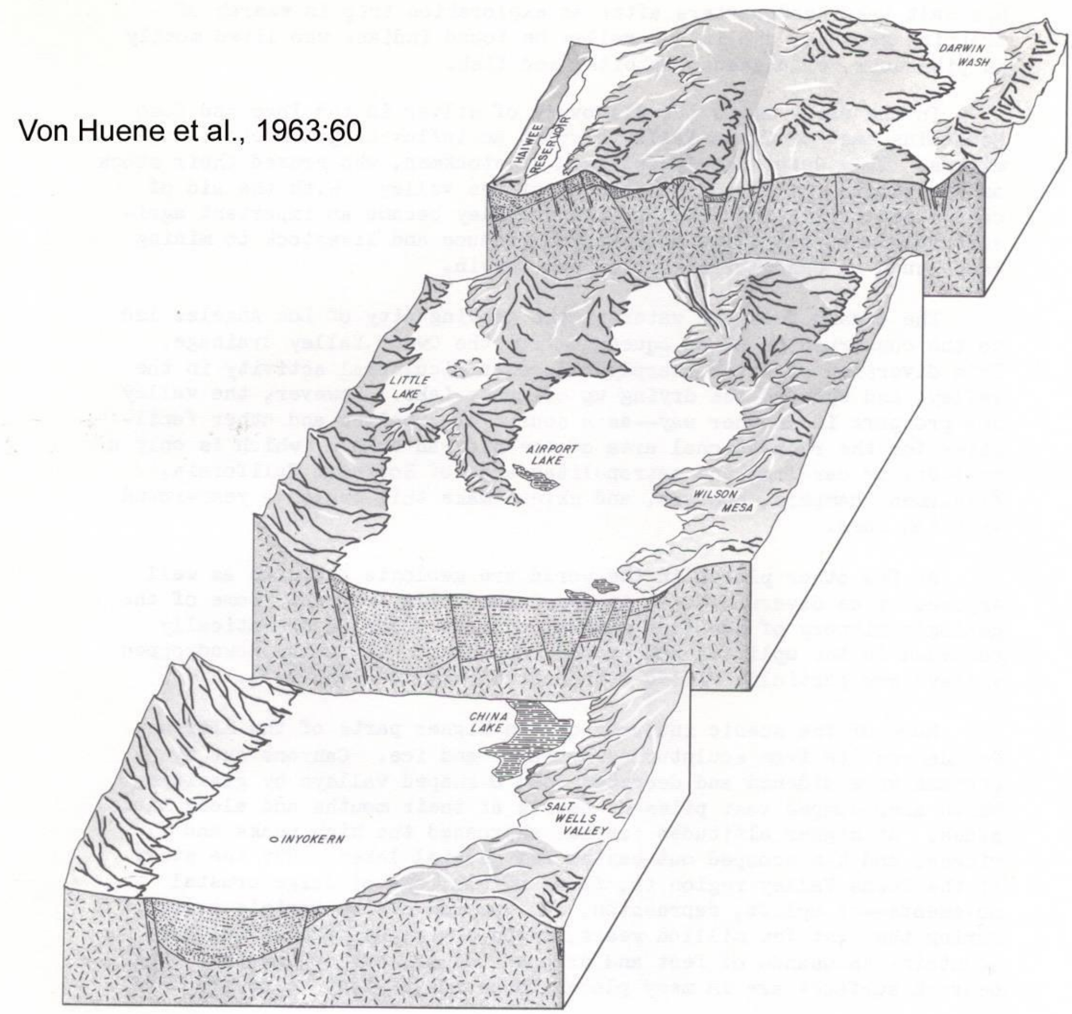


Indian Wells. From Dibblee and Minch, 2008b

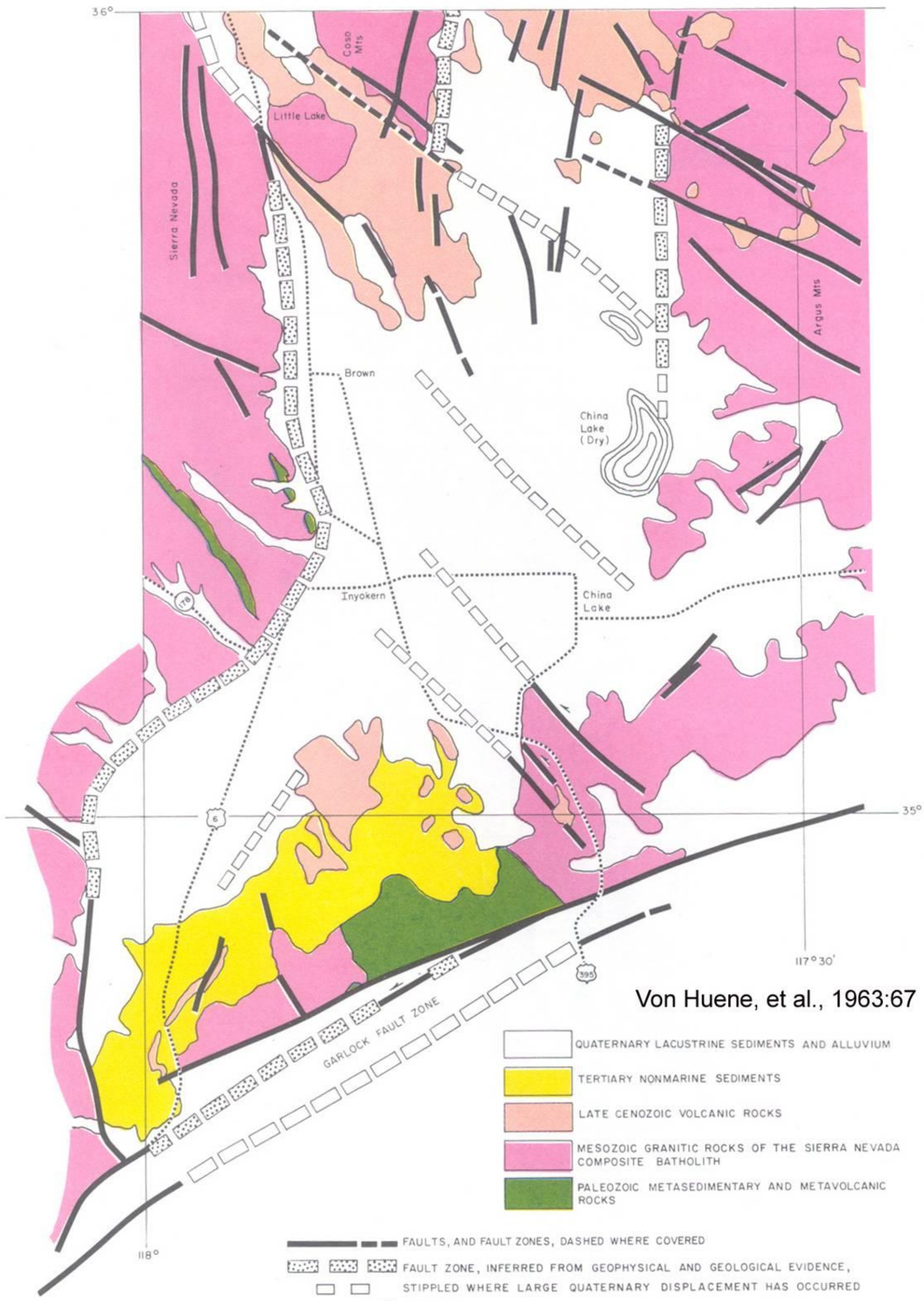
Map 29 Red Rock Canyon and Vicinity

Freman Junction (#231, T.27S, R.38E, Sec. 8)

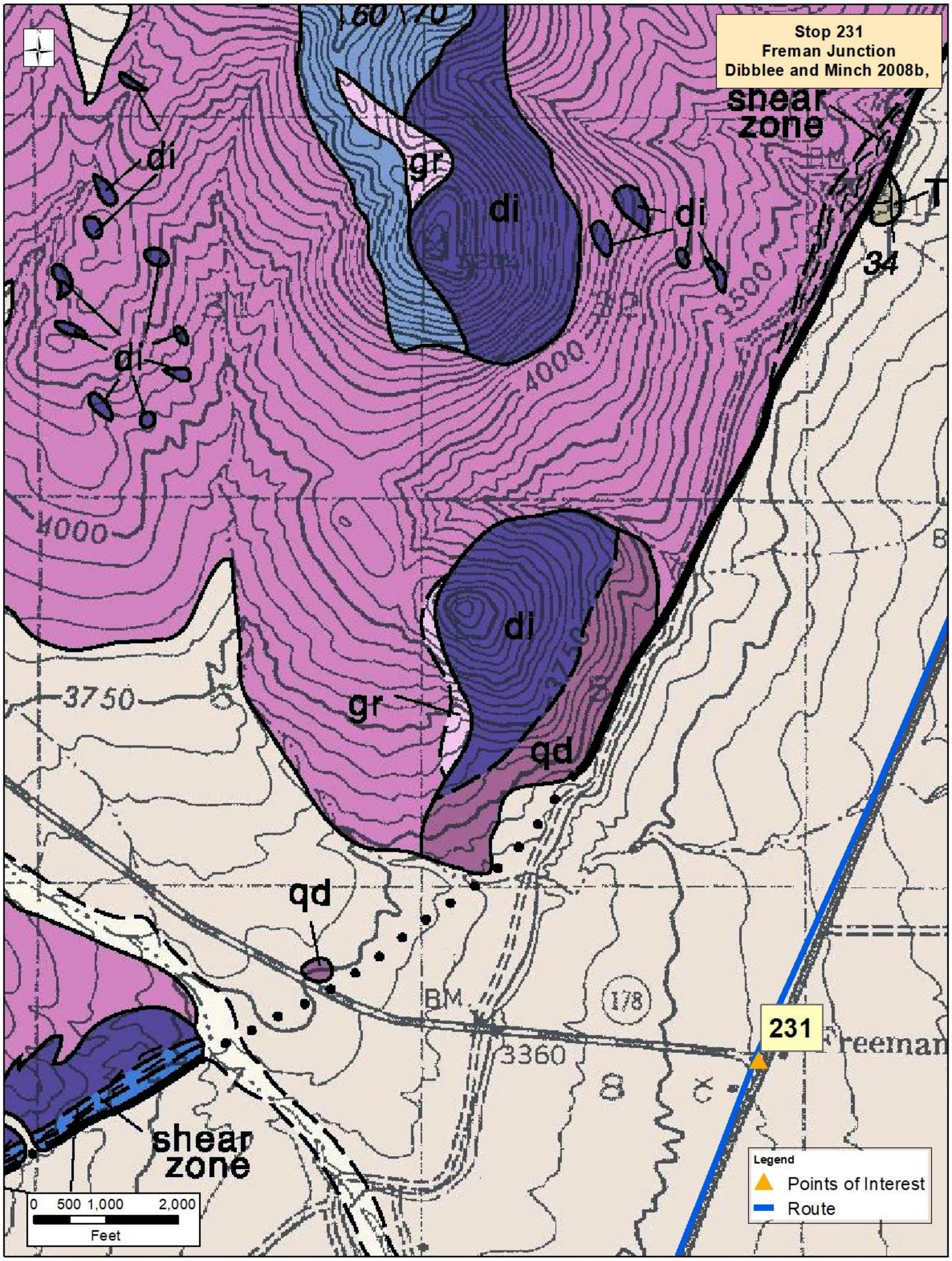
Roost granitic spires are to the southwest (Reynolds, 2002). Highway 178 leads from Freman Junction to Lake Isabella and Bakersfield. Walker Pass, at 5250 ft, is the obvious break in the Sierra. Joseph R Walker "discovered" this pass in 1834 leading the Bonneville expedition, the first wagon train to CA; it was later used by Frémont in 1845. The pass became a major route from gold fields at Keysville and Kernville to Mojave and north to Reno (Pracchia, 1994).



Generalized Block Diagram of Indian Wells Valley.



Generalized Geologic Map of Indian Wells Valley Region.



Freman Junction. From Dibblee and Minch, 2008b.

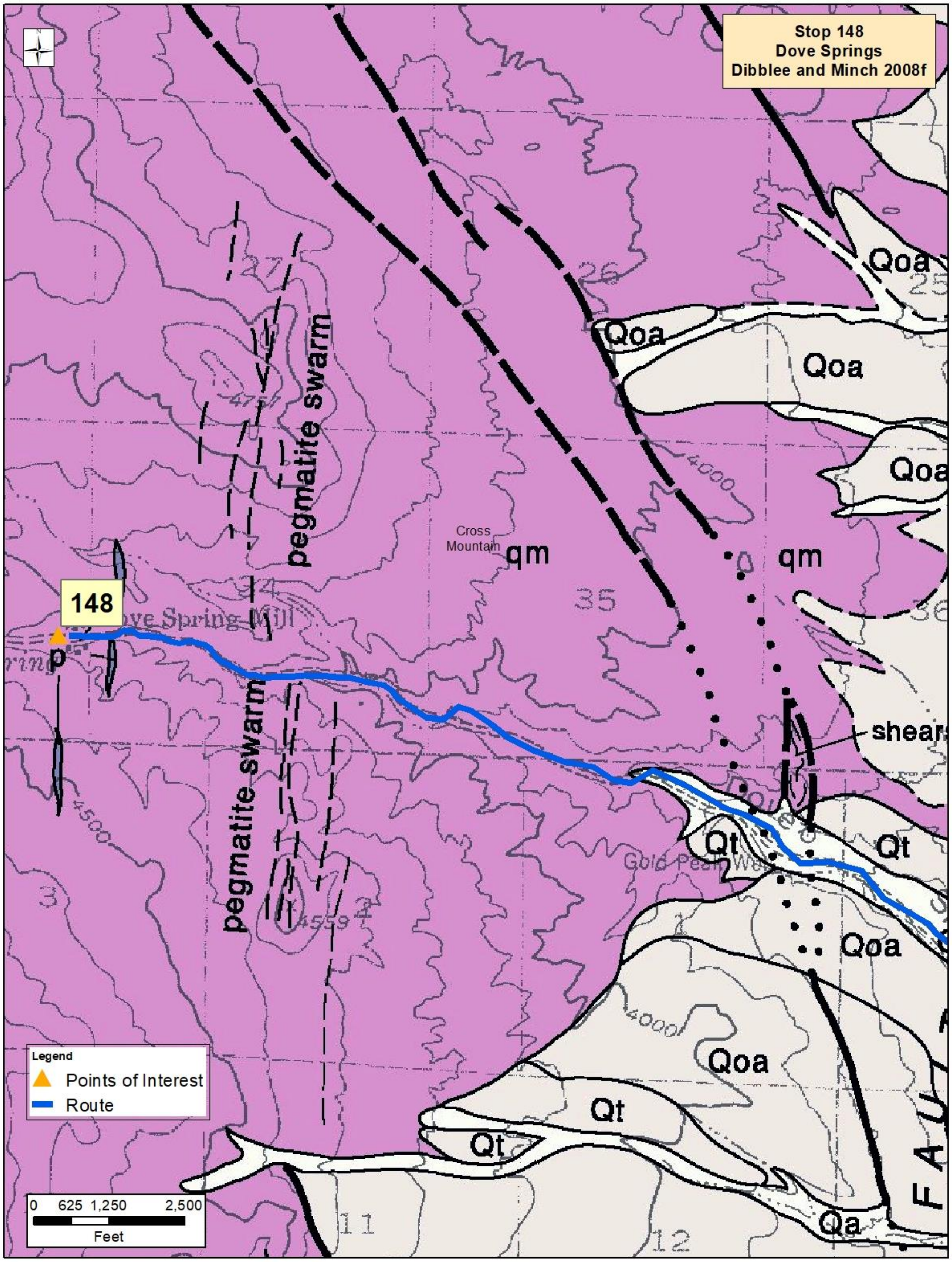
Red Rock Canyon Basalts and Dove Springs (#148. T.28S-29S, R.36E)

As you approach the entrance to Red Rock Canyon State Park, the Dove Springs Off Road Vehicle Recreational Area is to the west. It is an 8 mile journey from Highway 395 to Dove Springs and requires a high clearance 4x4 vehicle.

Pleistocene terrace deposits crop out along Dove Spring Wash. These sediments represent deposition of a bajada between the Sierra Nevada Range and the El Paso Mountains, and were dissected when erosion breached the fault complex along the south side of the El Paso Mountains. Sediments contain small and large mammal species including *Bison*, the Rancholabrean indicator mammal, and have produced C-14 dates between 19–10 ka (Whistler, 1990, 1991; Jessey and Reynolds, 2009:14)

There is a prominent outcrop of basalt along the road leading to the visitor's center at N 35°22'23.3"; W 117°59'18.3"**.** This outcrop (Fig. 1-5 in Jessey and Reynolds, 2009) lies within the west-dipping Dove Spring Formation of the Miocene Ricardo Group. Loomis (1984) divided the Dove Spring Formation into six units which range in age from 7 to 13 Ma. The Dove Spring formation lies unconformably on the Cudahy Camp Formation. The Cudahy Camp is thought to have been deposited from 15-19 Ma (Loomis and Burbank, 1988). The base of the Dove Spring is marked by conglomerate grading upward into arkose. Overlying layers are comprised of a variety of differing lithologies including lacustrine and fluvial sandstones, siltstones and conglomerates, felsic tuffs and basalt flows. The uppermost unit (Unit 6 of Loomis, 1984) is a nearly flat-lying sedimentary sequence that lies disconformably on the units 1-5 of the Dove Spring. Recent ages published by Frankel, et al., (2008) indicate the three lowermost basalts were extruded between 11.7 and 10.5 Ma. No age is available for the uppermost basalt flow, but Whistler (1987) quotes an age of 8.1 Ma for a rhyolite tuff above the basalt. This brackets basalt extrusion between about 8-12 Ma. Loomis and Burbank (1988) examined the evolution of the El Paso basin and concluded that extrusion of the basalts was coincident with the onset of left-slip motion along the Garlock fault and the east-west extension characteristic of Basin and Range topography. The subsequent emergence of the Sierra Nevada Mountains began at 8 Ma. Frankel (Frankel et al. 2008) argues that the Summit Mountains south of the Garlock fault are correlative with the Dove Spring Formation, but paradoxically they contain no basalt flows. This suggests a very local source for the basalts. Unfortunately, evidence for nearby faults of the proper age to provide a conduit for the basalt flows is absent. (Jessey and Reynolds, 2009:12).

The Cudahy Camp and the Dove Spring formations are biostratigraphically important because they contain North American Land Mammal Age (NALMA) transitions of middle and late Miocene faunas. The late early Miocene Cudahy Camp Formation is nonfossiliferous, while the Dove Spring faunas show the transition from the Clarendonian through Hemphillian land mammal age (13.4–7.3 Ma; Burbank and Whistler, 1987; Loomis and Burbank, 1988; Whistler, 1991). Research in the local stratigraphic sequence presents biostratigraphic, magnetostratigraphic and tephrochronologic age parameters (Whistler and Burbank, 1992) that can be compared to other sedimentary sections across the continent (Tedford and others, 2004). This stratigraphic section contains lithologic clasts that relate it to nearby tectonic events. Previous work suggested that clasts from the rising Sierra Nevada Mountains were present in an upper portion of the section that dates between 8.5–8.4 Ma (Whistler and Burbank, 1992). Current studies (D. P. Whistler, p. c. to Reynolds, 2008) suggest that *"Sierran-looking granitic clasts in place" have been found in a portion of the section above Ash 15 along the Powerline Road west of the campground that dates to 9.4 m.y. associated with the Dove Spring Local Fauna*. This suggests that granites of the Sierra Nevada geologic province were exposed by 9 Ma. (Jessey and Reynolds, 2009:14). To the east of Dove springs is a pegmatite dike swarm.



Dove Springs. From Dibblee and Minch, 2008f

Red Rock Canyon State Park (#125; T.29S, R.37E, Sec. 21)

In the southernmost foothills of the Sierra Nevada range, Red Rock Canyon State Park covers a small area of badlands and exposed, angled, mudstone strata which form cliffs and ravines, with the rocks eroded into many wonderful forms. Despite its proximity to the mountains, the surrounding region still presents a completely desert appearance and the approach from the south passes through wide, empty, desolate valleys with little or no vegetation, crossed by long straight roads such as the busy I- 14, between Mojave and US 395, which runs through the middle of the park. The road follows beside a seasonal wash along a shallow valley - the Red Rock Canyon - although not all is interesting as the colorful sedimentary formations are found only in certain places; other parts are bordered by dull scrubland.
(http://www.americansouthwest.net/california/red_rock_canyon/state_park.html, April 10, 2007)

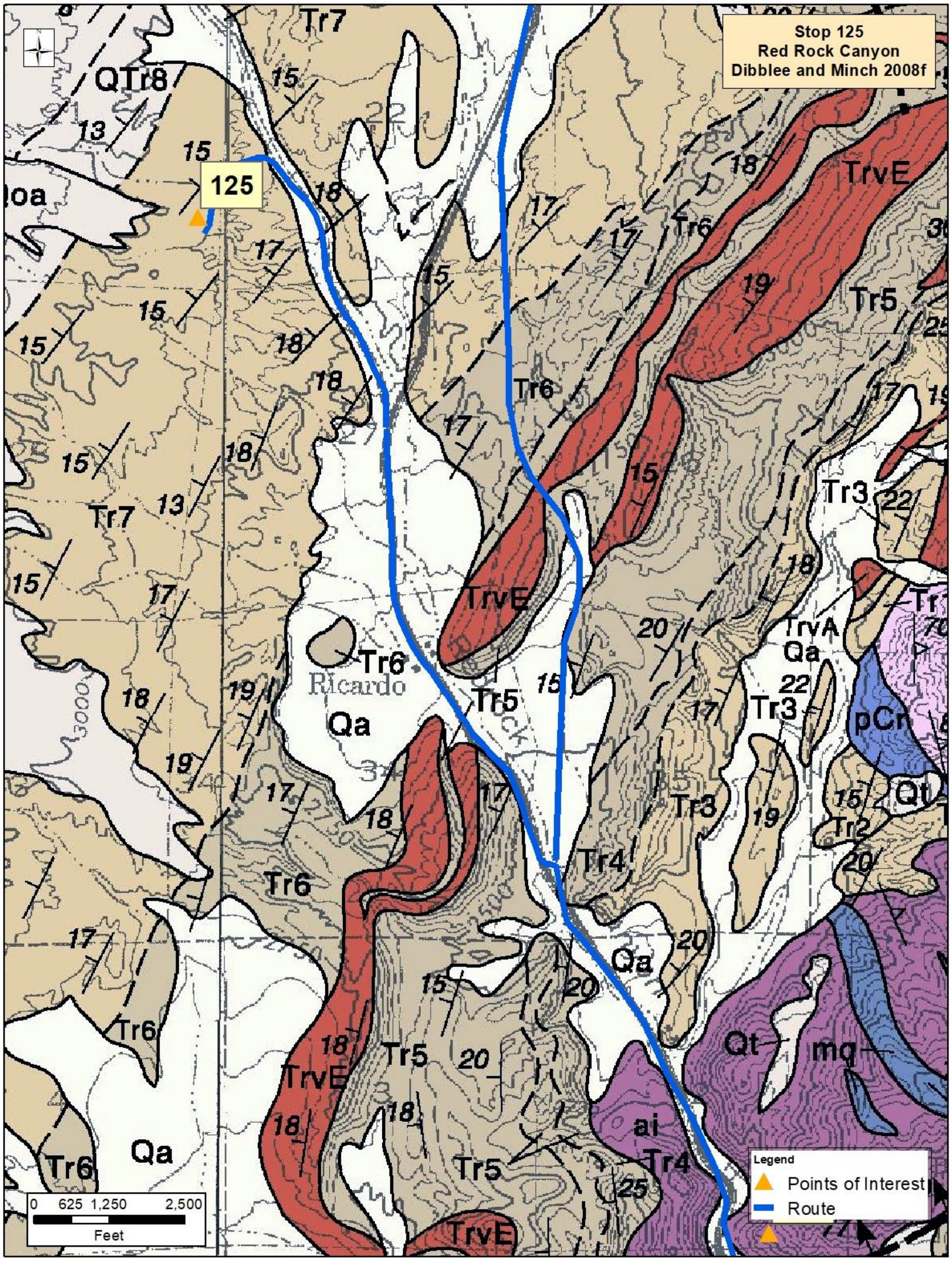
Each tributary canyon is unique, with vivid colors.

Red Rock Canyon State Park features scenic desert cliffs, buttes and spectacular rock formations. The park is located where the southernmost tip of the Sierra Nevada converges with the El Paso Range. Each tributary canyon is unique, with dramatic shapes and vivid colors. The photo on the upper right is from the State Park website (http://www.parks.ca.gov/?page_id=631, April 10, 2007). A photo from the Desert USA web site http://www.desertusa.com/rrsp/rrsp.html, May, 25, 2007 is also shown.

Historically, the area was once home to the Kuwaitis Indians, who left petroglyphs in the El Paso mountains and other evidence of their inhabitation. The spectacular gash situated at the western edge of the El Paso mountain range was on the Native American trade route for thousands of years. During the early 1870s, the colorful rock formations in the park served as landmarks for 20-mule team freight wagons that stopped for water. About 1850, it was used by the footsore survivors of the famous Death Valley trek including members of the Arcane and Bennett families along with some of the Illinois Jayhawkers. The park now protects significant paleontology sites and the remains of 1890s-era mining operations, and has been the site for a number of movies (http://www.parks.ca.gov/?page_id=631, April 10, 2007).

After wet winters, the park's floral displays are stunning. This winter was very dry so the wildflowers are more sparse this year, but the beauty of the desert, combined with the geologic features, makes this park a camper's favorite destination. Wildlife you may encounter includes roadrunners, hawks, lizards, mice and squirrels. (http://www.parks.ca.gov/?page_id=631, April 10, 2007).

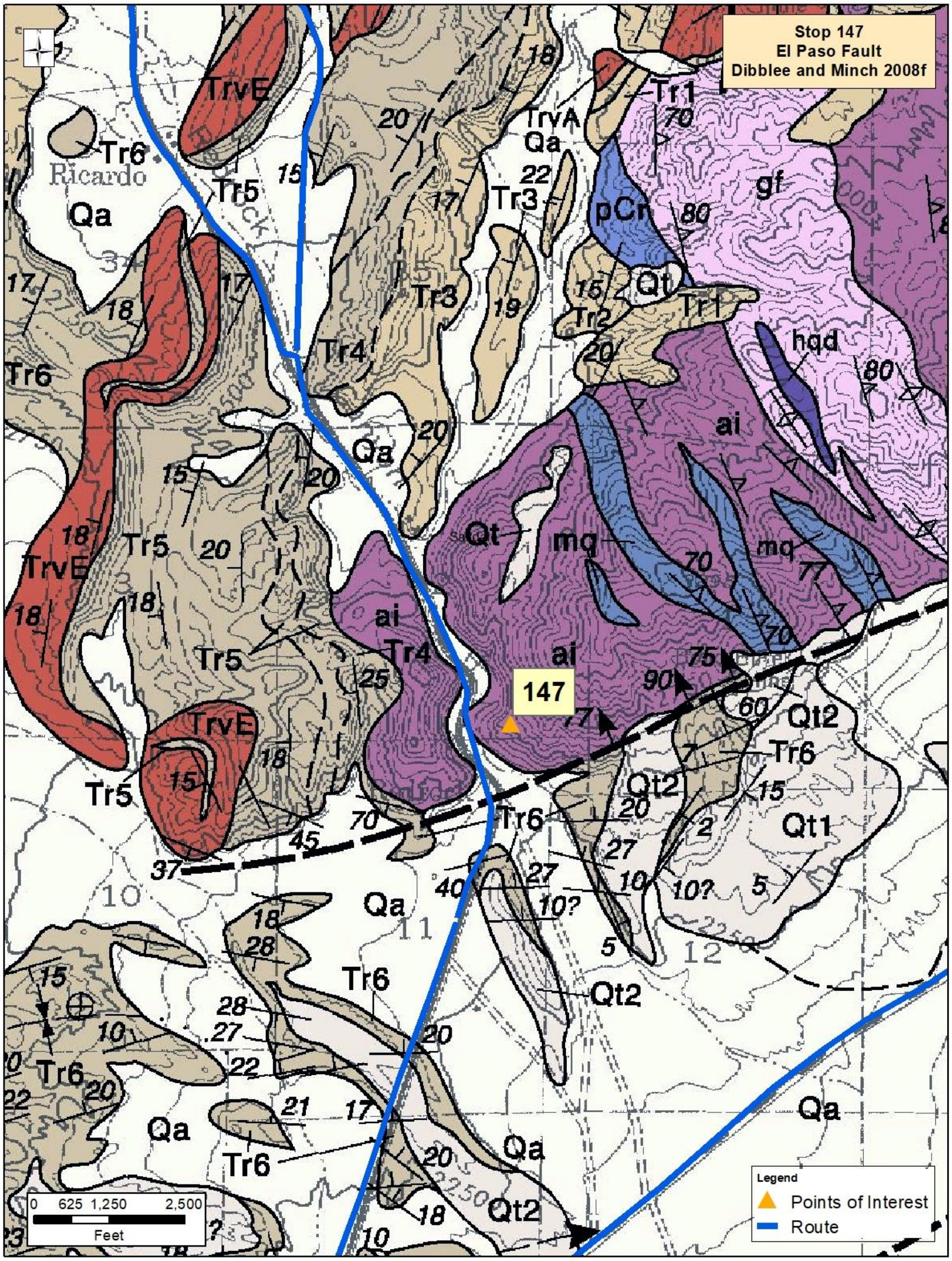
Red Rock Canyon is a popular place to teach geology and especially geologic mapping because the different rock units are easy to see. The area is an important paleontological site with Miocene-age mammals from the Ricardo formation. A very complete web site dedicated to the fossil resources at Red Rock Canyon is: http://members.aol.com/Waucoba7/redrock/redrockfossils.html (May 25, 2007).



Red Rock Canyon. From Dibblee and Minch, 2008f

El Paso Fault (#147; T.30S, R.37E, Sec. 11)

The trace of the El Paso fault is visible is at this site. The tan sediments to the west contain a fossil fauna that is significantly younger (late Hemphillian) than faunas in the Dove Spring formation. The sediments are bounded by the El Paso fault (north), the Sierra front fault (west) and the Garlock fault (southeast) and higher degree of clockwise rotation (35 degrees) than the Dove Spring Formation (15 degrees; Whistler, 1991, p. 111). This suggests that the block has a history independent from the Dove Spring Formation, and may have been left-laterally translated from the Bedrock Spring Formation in the Lava Mountains (east of Hwy 395); a distance of approximately 30 miles in the last 7–5 Ma. The El Paso fault, which here juxtaposes Mesozoic (Jurassic?) rocks and undifferentiated Ricardo Miocene Group on its down downthrown side (Whistler, 2005). Although motion along this fault has been characterized as predominantly dip-slip, its proximity to the Garlock fault suggests it may have a left-slip component. Despite paleoseismic studies on the nearby arlock fault (McGill, 1992), little is known about slip rates for the El Paso fault. The SCEDC website suggests last movement in the Late Quaternary, but this presents a structural conundrum. The Garlock fault near this location has moved within the past 500 years, suggesting it is quite active. As such, its close proximity to the south-dipping El Paso fault should result in the Garlock fault buttressing dip slip movement along the El Paso fault. Perhaps Quaternary movement along the El Paso fault has been largely left-slip? (Jessey and Reynolds, 2009:12).



El Paso Fault. From Dibblee and Minch, 2008f

Map 30: Saltdale

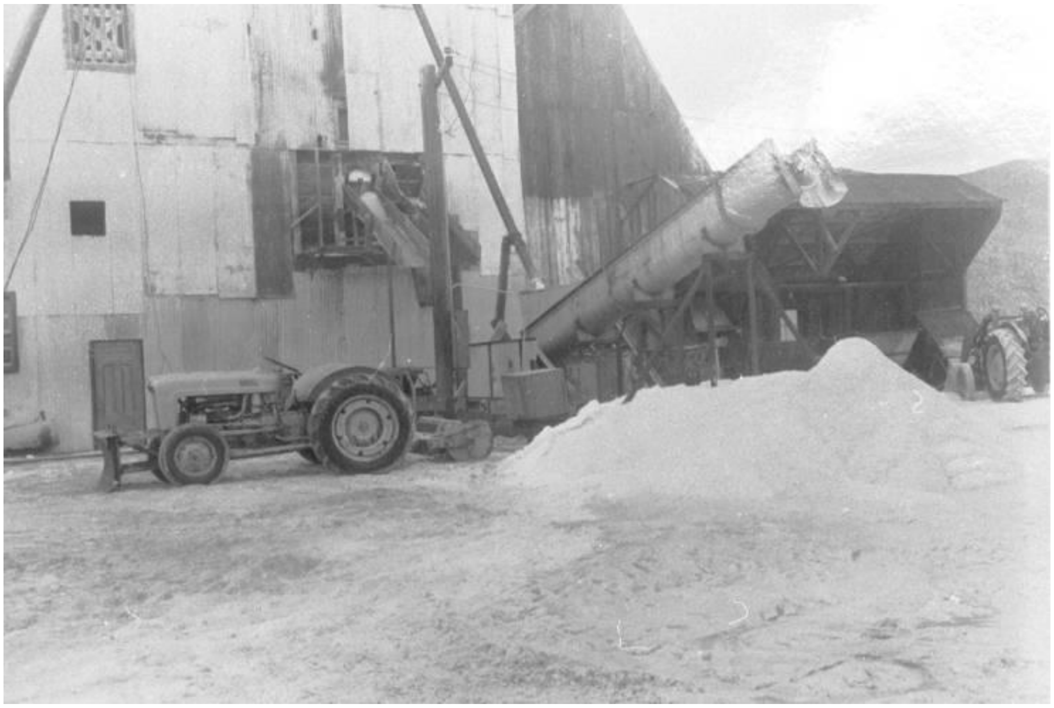
Gypsite and Saltdale (#126; T.30S, R.38E, Sec. 7 and 8 and #127, T.30S, R.38E, Sec. 3)

Saltdale is the site of the longest-running mining scam in the Mojave Desert. The following is from Larry Vredenburgh and Gregg Wilkerson:

Between 1909 and 1913, sixty saline placer mining claims were located on Kohen Dry Lake and subsequently leased to Thomas Thorkildsen and Thomas Rosenberger. The leases were transferred to the Consolidated Salt Company in March 1922, and in June 1933 they were transferred to the Long Beach Salt Company.

Saltdale Plant

Between 1916 and 1918 an additional one hundred-eleven claims were located for the Fremont Salt Company. Each 20 acre claim was located by a different individual, signed up by the Fremont Salt Company's hired promoters. The promoters found people willing to sign mining claim location notices for the company and then lease their claim to the company for a period of 40 years. In the return the "locators" were to receive stock with par value of $5,000 or 5,000 shares at $1 per share. The promoters received $2.50 for each person they succeeded getting. In November 1927 these claims were transferred to the Long Beach Salt Company. Around 1945 the General Land Office began investigating the fraudulent location of these claims but never proceeded to contest.



Saltdale Plant

Both the Fremont Salt Company and the Consolidated Salt Company recovered salt from Koehn Dry Lake. The Fremont Salt Company successful produced salt for about 3 years, with several carloads shipped to the Peacock Ice Cream Company of Bakersfield. About 1921 the Leslie Salt Company purchased the operation. As early as 1916 the Consolidated Salt Company had constructed a four-story mill, and had constructed a narrow-gauge railroad from the evaporation ponds to the mill. After the properties were acquired by the Long Beach Salt Company the Fremont plant was dismantled.

The Long Beach Salt Company had been actively recovering salt opposite Terminal Island between Wilmington and Long Beach from World War I until 1946, when oil field operations encroached on the evaporation ponds. At that time they moved their plant from Long Beach to Saltdale.

Finally, in July, 1933 the Long Beach Salt Company located an additional 36 placer mining claims, for potential gold values. Apparently the lakebed clays did contain some gold, and there was some prospecting for gold. However, in latter years the Long Beach Salt Company recovered salt from these claims. These 36 mining claims proved to be the downfall of the Long Beach Salt Company operations. For in 1920, Congress passed the Mineral Leasing Act, removing salt from the mining laws.

Saltdale Train

In 1971 the Bureau of Land Management began proceedings against the Long Beach Salt Company for producing salt, a leasable mineral, from mining claims. In 1975 the Interior Board of Land Appeals found in favor of the Bureau, and the operations ceased.

Honda Test Track (Site #146, T.30S, R.37E, Sec 35, 36**)**

Look to the south from Saltdale to see a curving line of vegetation. This marks the edge of a 3-mile-wide oval (clearly seen in Goggle Earth imagery) test facility owned by Honda Motor

Corporation. The facility is well guarded and off limits to travelers. At night, car headlights can often be seen as they circle the track. This has fueled conspiracy theories that the test track is the locus of "alien" activity from the nearby "vortex" in the El Paso Mountains. (Jerssay and Reynolds, 2009:7).


Honda test track. Photo from https://images.hgmsites.net/med/honda-proving-grounds-bakersfield-california-aerial-photo_100337386_m.jpg accessed June 13, 2019.

Jawbone Canyon Visitor's Center (#128; T.30S, R.37E, Sec. 22)

Great Siphon, LA aqueduct at Jawbone Canyon

The Jawbone canyon area is now a popular site for off-road vehicles. During the Owens Valley water wars, it was a site of several demolitions of the aqueduct siphon that crosses it.

Jawbone Canyon and surrounding area were mapped by Dibblee and Minch (2008f).

The Jawbone Canyon area, at Highway 395 is dominated by the Ricardo Formation……

RICARDO FORMATION

(of Merriam, 1914) continental and lacustrine sediments containing lava flows and tuff; separated from underlying Goler Formation by angular unconformity; age, Pliocene on basis of mammalian fauna of upper portion)

Tr *Undivided Ricardo of conglomerate, cobbles, gravel, and sand in sand matrix, with sandy clay beds*

QTr8 *Terrestrial gravel, light gray, granitic, interbedded with sand and micaceous light brown gritty clay*

Tr7 *Lacustrine beds, predominantly light gray nodular clay with interbedded gray-white calcareous sand, some layers of white tuffaceous siltstone, impure limestone, and opalized mud with local hard layers of opal chert*

Tr6 *Terrestrial sand and gravel; sand light pink-gray, fine- to coarse-grained, bedded, with some hard layers of calcareous sandstone; gravel brown to gray, pebbles and some sand of volcanic debris, grades laterally NW into* **Tr7**

Tr5 *Basalt, flows (***TrvC,D,E***), dense to fine-grained, black,weathers dark brown, with abundant vesicles and olivine phenocrysts; each flow separated by interbeds (***Tr5***) of light gray to pink pebbly sand with some calcareous and opal layers, and by one tuff-breccia layer of pumice, rhyolite, and andesite fragments in fine-grained tuff matrix*

Tr4 *Lake beds similar to those in* **Tr5***, with gray-white thin-bedded sandstone predominant, with 6 layers of fine, white, soft ash (seismotite)*

Tr3 *Conglomerate, pink-gray, cross-bedded, of rounded cobbles of pink to brown rhyolite, andesite, and basalt-andesite in soft pink to gray sandstone matrix; contains lens of white tuff breccia*

Tr2 *Andesite flows (***TrvA, TrvB***) interbedded with tuff-breccia and ash; andesite red-brown, brecciated, with feldspar phenocrysts in dense groundmass, locally vesicular and lenticular, and with phases of mottled gray and red rhyolite; tuff-breccia orange-pink to gray-white, with pumaceous and volcanic fragments in a hard tuff matrix; tuff and ash pure white, well bedded, fine-grained, partly altered to bentonite*

Tr1 *Basal conglomerate, light greenish-gray, cobbles, gravel, and sand of granitic rocks in soft sand matrix, with greenish sandy clay beds*

Ricardo Formation. From Dibblee and Minch, 2008f

…as well as Jurassic to Tertiary intrusive and extrusive rocks:

INTRUSIVE ROCKS

b	d	Tf	p	ap	ai	l

DIKE ROCKS

Numerous dikes intrusive into qm and qd; age, presumably Cretaceous, possibly Tertiary to late Jurassic

b *Basaltic to andesitic porphyry dikes, fine-grained to porphyritic, with scattered phenocrysts of plagioclase feldspar, hornblende, and some biotite in massive gray-black groundmass*

d *Dacite dikes, felsitic to porphyritic, light-gray, massive fine-grained groundmass and felsitic margins*

Tf *Felsic dikes, felsitic light-gray, massive groundmass*

p *Pegmatite dike swarms, white, up to 10 feet wide, generally parallel, very coarse, locally graphic textured with some gradation to aplite*

ap *Aplite dikes, massive, fine-textured, nearly white, fine-grained*

ai *Granophyre dikes, sills, and stocks, light gray, fine-textured, massive, quartzose, in places porphyritic with phenocrysts of white feldspar*

l *Lampophyre dikes, very fine-grained black, basic, weathers to dark brown, most too small to map, occur in shear or fault zones*

gr	gf	qm	hqd/hd/di	qd

PLUTONIC ROCKS

Intrusive rock, forms part of pre-Tertiary batholithic pluton; age, pre-Tertiary to Cretaceous, possibly late Jurassic

gr *Granite, massive, pink, medium-grained, equigranular, composed of quartz and feldspar in various proportions*

gf *Granite, foliated*

qm *Quartz monzonite, ranges to granodiorite, gray-white, massive, medium-grained, equigranular, in places hydrothermally altered to hard, coherent but cavernous-weathering masses or streaks*

hqd/hd/di *Hornblende-quartz diorite/hornblende diorite/diorite, dark-gray to black, massive to rarely gneissoid, medium to coarsely grained; composed of hornblende, plagioclase, chlorite, epidote, zircon, and iron oxides with local leucodiorite veinlets of plagioclase*

qd *Quartz diorite, nearly white, massive to rarely gneissoid, medium-grained, equigranular, about one-third quartz, two-thirds feldspar (mostly plagioclase, but including some potassic feldspar), biotite, sphene, and iron oxides*

Intrusive and Plutonic rocks of Jawbone Canyon. From Dibblee and Minch, 2008f

Cinco Quartz Crystal Mine (#129; T.30S, R.37E, Sec. 31)

The Cinco mine has dipyramidal quartz crystals and twinned orthoclase crystals (Troxel and Morton, 1961:91).

Map 31. Jawbone Canyon to Mojave

Mojave (#130; T.11N, R.12W, Sec. 8)

The city of Mojave began as an 1876 construction camp on the Southern Pacific Railroad. From 1884 to 1889, the town was also the end of the 165-mile, twenty-mule-team borax wagon route originating at Harmony Borax Works in Death Valley. It later served as headquarters for construction of the Los Angeles Aqueduct. The name Mojave comes from the name of the Indian nation occupying the area before the arrival of European settlers. (http://en.wikipedia.org/wiki/Mojave%2C_California; April 10, 2007).

POINTS OF INTEREST ON THE EAST SIDE OF OWENS VALLEY BETWEEN BISHOP AND OWENS LAKE

Poleta Mine (#143 : T. 7S, R.34E, Sec. 7 and 8)

The mineralogy of this mine gold mine has some free gold with pyrite and limonite in a narrow quartz vein in limestone. The mine was worked by a 400-foot long adit and a 600-foot decline (inclined winze). (Crawford, 1894:139; Crawford, 1896:183; Davidson, 1902:7, 11; Eric 1948:249; Tucker, 1938a:10; Tucker, 1938b:414-415; Tucker, 1940:24, 25; Norman and Stewart, 1951:160).

Black Canyon Group (#132; T.7S. R.34E, Secs. 13, 14, 23 and 24)

A 4x4 road leads up Black Canyon to prospects to the east. Mines are found in sections 13, 14, 23 and 24. This group of mines has been named the Black Canyon Group, Mineral Point, and Sanger mines. They are located on a ridge on the western slope of the White Mountains 2 miles south of Black Canyon Spring ,104 airline miles eastward from Limestone overlying quartzite and slate contains irregular replacement lenses of galena and cerussite in fissures. On the south slope of the -ridge, an open cut and a 60-foot inclined shaft have been sunk on a fissure which strikes north and dips 45^{o}'W. An adit 65 feet lower than the open cut has been driven N. 70' NW (??) intersecting this fissure at 75 feet and continuing to 115 feet. A drift was run north 60 feet on the fissure to the intersection of the fissure with a vertical, east-striking fissure. In this drift, 20 feet from the adit, S 40-degree inclined winze was sunk on the north-striking fissure. Beyond this another winze was sunk to a depth of 60 feet on the east-striking fissure. Ore bodies in these workings average two feet in width. The 600 tons of ore shipped assayed 60 percent lead, 150 ounces of silver and 0.10 ounce of gold per ton.

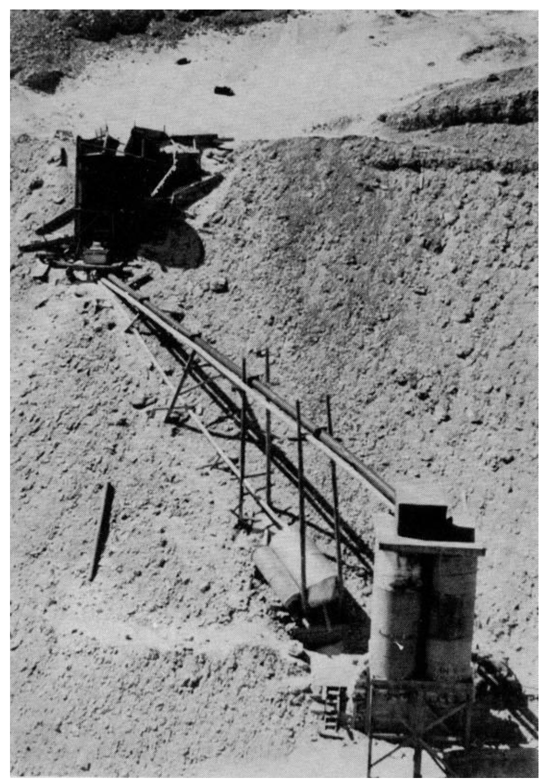
On the north slope of the ridge, an adit has been driven south 440 feet. A fissure, striking N. 60' W. and dipping 45' NE., was intersected 315 feet from the portal, and 170 feet of drifts were driven on the fissure. Lenses of ore were cut in these workings.

-

Before 1947, 900 tons of ore worth an average-of $60 per ton was shipped. Albertoli reported that five cars of ore were shipped during 1947. The property was idle in 1951
(Eric, 1948:247; Tucker, 1926:489-490; Tucker, 1938:426, 444-445, plate 3.; Norman and Stewart, 1951:57-58, 170).

In the eastern slops of Owen's Valley at the mouth of Black Canyon is a curious water tower.

Warm Springs-Jamieson (#133; T.8S, R.34E, Sec. 8)



The Jamieson deposit is about 7 miles north of Zurich on the east side of Owens Valley
at the base of Black Mountain.

The pumice bed, ranging from 6 to 10 feet in thickness, is interbedded with fanglomeratic materials which dip gently toward the west into Owens Valley. The pumice fragments are angular and range in size from 1/16 inch to 14 inches. The pumice is white, and contains grains of quartz and feldspar. Approximately 20 percent of the pumice bed is angular and sub-rounded grains of quartz and feldspar. The pumice was mined by open cut methods, which required that the fanglomeratic material making up the overburden be stripped before any pumice could be removed. Mine run pumice was hauled to a screening plant near the pit. The following screen sizes were produced: minus 13 inches, plus 8 inch, and minus Q inch. The property was idle in 1951 and has remained so ever since (Norman and

Stewart, 1951:.108109, Site #242, Plate 2, Screening plant, right, reproduced from plate 13, page, photo by C. Chesterman).

There is a delightful luke-warm spring and pond at Warm Springs (photo below) and neaby is a small adit.

Paul Pit and Mill (#134; T.9S, R.34E, Sec. 13)

Alvord Mine (#135; T.9S, R.35E, Sec. 30)

Montezuma Mine (#078; T.10S, R.35E, Sec. 7)

This mine produced limestone in the era 1910-1920 for the Owens Valley Aqueduct. The mine site has been converted to a bird sanctuary. The mine is accessible through the site of Monola (see below). Prior to use for limestone, the galena, gold and silver were mined here. These minerals occur in a quartz vein cutting limestone and calcareous slate. The width of the vein from 6 to 20 feet strikes N70^{o}E and dips 60^o to 65^o W. The mine has eight adits with total workings of 3000 feet (Davidson, 1902:8; Eric, 1948:239, 248, 252; Tucker, 1936:501-503; Tucker, 1934:311; Tucker, 1938:457, 469, 476, 479; Waring, 1919:84, Norman and Stewart, 1951:180.

Monola (#080; T.9S, R.34E, Sec. 22)

Access the Montezuma Mine through this townsite.

Gypsy Queen Mine (#136; T.11S, R.35E, Sec. 29)

Black Jack Mine North (#137, T.12S, R.35E, Sec. 5)

Black Jack Mine South (#138, T.12S, R.35E, Sec. 5)

Gypsy King (#139; T.12S, R.35E, Sec. 16)

Mazorka Canyon Placers (T. 12S, R.36E, Various Sections)

There are several placer workings in this general area (Crawford, 1894:139; Crawford, 1896:182; Davidson, 1902:9; Knopf, 1914:112; Knopf, 1918:118; Laizure, 1934:245; Tucker, 1938; 411, 476, pl. 3; Norman and Stewart, 1951:157).

Professor Mine (T.12S, R.36E, Sec. 30)

The Professor Mine and other mines of unknown name worked galena in veins. The Professor had 2 adits, one with 1000 feet of workings (Norman and Stewart, 1951:183).

Custer Mine (T.12S, R.36E, Sections 28 and 29)

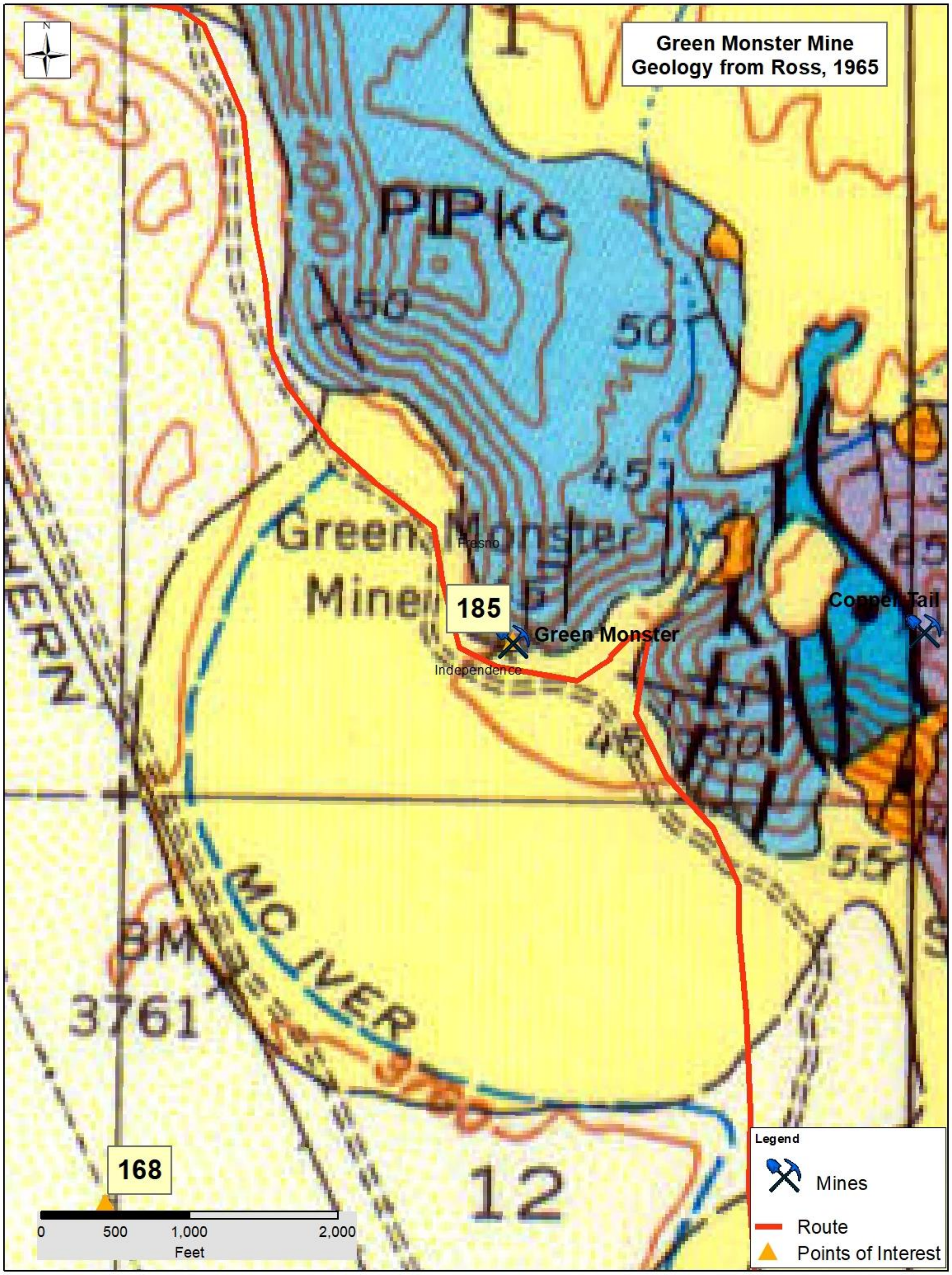
Galena and cerussite carrying silver and gold occur along a contact between limestone and granite in a zone 4 to 6 feet wide. There is also some copper. This prospect was worked by two adits (Eric, 1948:241; Tucker, 1938: 435, 470; Norman and Stewart, 1951:173.

Blue Stone Mine **(T.12S, R.36E)**

This mine is located 10 miles east-northeast of Independence on the west slope of the Inyo Range, reached by the Mazourka Canyon Road. The deposit is in a section of Paleozoic sedimentary rocks which dips steeply westward. Limestone predominates near the mine, but the talc has formed above a quartzite layer, 20 to 60 feet thick. The talc body, which is now largely worked out, was a lens which in plan was about 40 feet long and 10 feet in maximum width. It extended down-dip for about 40 feet. It has formed as a replacement of the quartzite. The talc is mottled gray, blocky, and is probably of- steatite-grade. (Norman and Steward, 1951:117)

Green Monster Mine (#185; T.13S, R.35E, Sec. 1)

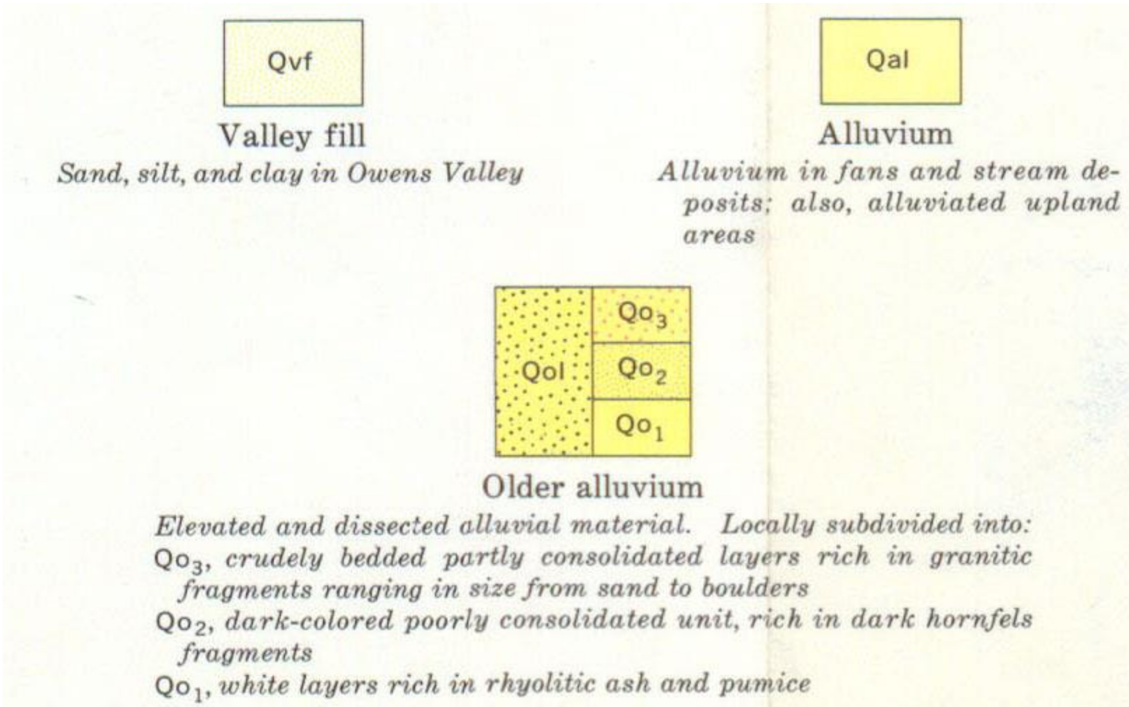
This mine has been a popular mineral collecting site since 1908. It is a copper mine in Keeler Canyon Formation.



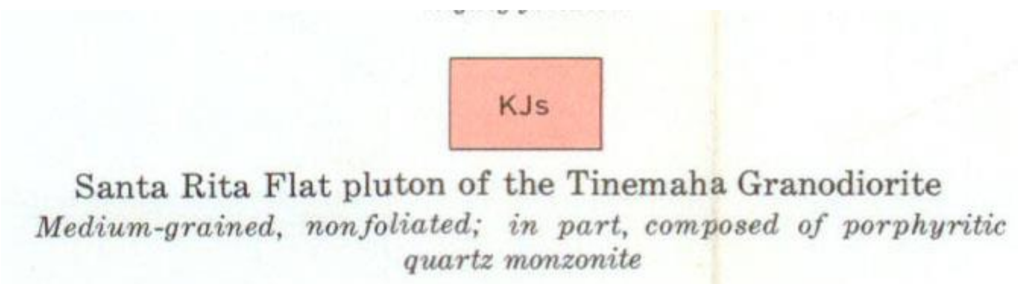
Geologic map of the Green Monster Mine and surrounding area. From Ross, 1965.

Map 19: Vaughn Gulch

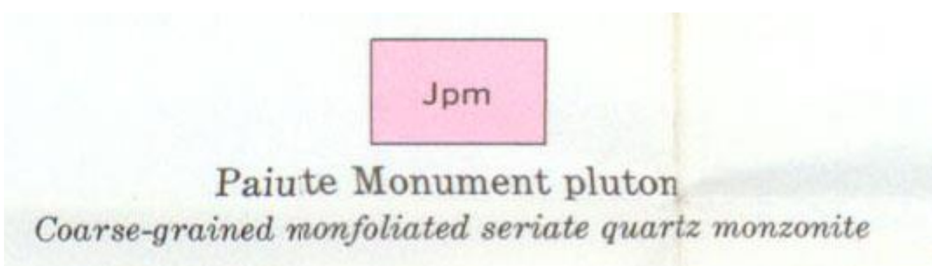
The area of Map 19 was mapped by Ross (1965). The major geologic units on this map are:



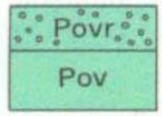
Quaternary alluvium units



Cretaceous-Jurassic Sata Rita Flat Pluton



Jurassic Paiute Monument Pluton

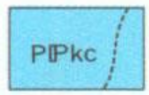


Owens Valley Formation

Povr, *Reward Conglomerate Member*

Pov, *varied gray; weathers reddish brown; composed of dense hornfels*

Permian Owens Valley Formation



Keeler Canyon Formation

Thinly bedded, varied gray limestone and dark-gray siltstone. Dashed line denotes zone of spheroidal black chert nodules ("golf ball" zone)

Permian-Pennsylvanian Keeler Canyon Formation

Rest Spring Shale

Dark-gray siltstone, shale, and mudstone; commonly metamorphosed to andalusite hornfels. Pattern shows locally mapped zone of carbon-rich beds that contains cravenocerid goniatites

Carboniferous Rest Spring Shale

Oes

Ely Springs Dolomite

Light- to dark-gray thin- to thick-bedded dolomite containing abundant black chert

Ojs

Johnson Spring Formation

Mixed sequence of quartzite, dolomite, limestone (in part coral-bearing), and lesser amounts of siltstone and shale

Obs | Obsu | Obsl

Barrel Spring Formation

Obs, *Barrel Spring Formation, undifferentiated. Mapped with Johnson Spring Formation on Badger Flat and to the northwest*

Obsu, *reddish-gray weathering shale, mudstone, and siltstone*

Obsl, *limestone, impure quartzite, and siltstone*

Obf

Badger Flat Limestone

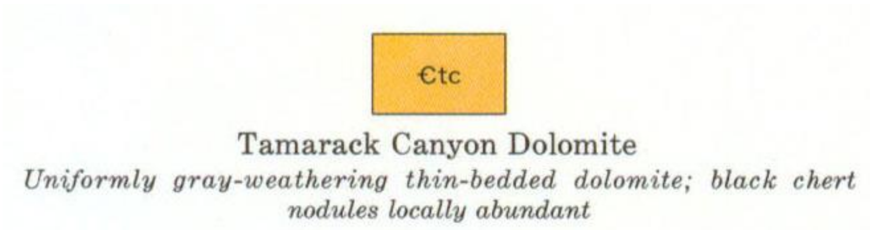
Blue-gray silty limestone and calcarenite and yellowish-gray siltstone; black chert abundant in lower part

Oa

Al Rose Formation

Brown-weathering siltstone, shale, and mudstone; limestone subordinate. Mapped with Badger Flat Limestone east of Bee Springs

Ordovician units.



€tc

Tamarack Canyon Dolomite

Uniformly gray-weathering thin-bedded dolomite; black chert nodules locally abundant

Cambia Tamarack Canyon Dolomite

San Carlos Mine (#140: T.13S, R.35E, Sec. 2)

Pierson Mining – Republic White-side Mine (T.13S, R.36E, Sec. 5)

This mine worked irregular lenses of galena and cerussite in limestone. It had a 3000 ft-long cross-cut adit and a 50-ft deep shaft (Tucker, 1926:496; Tucker, 1938:451, 477, pl. 3; Norman and Stewart, 1951:183, Site #158)

Snowcaps Mine (#104; T.13S, R.36E, Sec. 7)

Just before entering Independence, note the wide canyon to the east at the base of the Inyo Range. This is Mazourka Canyon, where intensive gold mining activity occurred during the late 1800s. Only the Snowcaps mine was active 1986-1993, and it is reclaimed. The ore at Snowcaps contains less than 0.25 ounces of gold per ton of ore, so creative extraction techniques (cyanide leaching) were required.

Vaughn Gulch Fossil Locality (#102;T.13S, R.36E, Sec. 9)

Mazourka Canyon at it's confluence with Vaughn Gulch contains spectacular sections of Paleozoic marine rocks (Lost Burro Formation, Vaughn Gulch Limestone). These limestones and shales often contain well preserved fossils of marine animal life. Crinoid stems and disks are shown in the photograph, below

Black Eagle Mine (T.13S, R.36E, Sec. 14 approx)

This mine has three parallel veins near a granite-limestone contact. One vein is worked by a shaft and adit (Eric, 1948: 239; Knopf, 1914:116; Knopf, 1918:120-121; Tucker, 1921:279; Tucker, 1926:466; Tucker, 1938:384-385, 469, pl. 3; Tucker, 1940:22-23; Warring, 1919:75; Norman and Stewart, 1951:146).

Jumbo Mine (T.13S, R.36E, Sec. 15)

This mine has tungsten and gold. It is located on the west slope of the Inyo Range, 4 miles east of Kearsarge, at an altitude of 7,000 to 7,500 feet.

The scheelite in this mine is typically disseminated in tactite along a contact between granite and lime shale. The tungsten content of the lenses of tactite along the contact ranges from 1.40 to 2.49 percent WO_3. Iron oxides and copper carbonates, carrying gold and silver, are in a quartz vein which trends northeast and dips 75°SE along the contact. The vein ranges from 1 foot to 3 feet wide.

A 120-foot adit has been driven southwest along the contact, which has also been intersected by a 60-foot crosscut adit. An inclined shaft has been sunk on the contact to a depth of 240 feet. The mine was idle in 1951 and has no reported production (Davidson, 1902:06; Jenkins, 1942:322; Tucker, 1926:469-470; Tucker, 1938:402, 474, pl. 3; Tucker, 1941:569; Norman and Tucker, 1951:89, 197, Site #193 on Plate 2.)

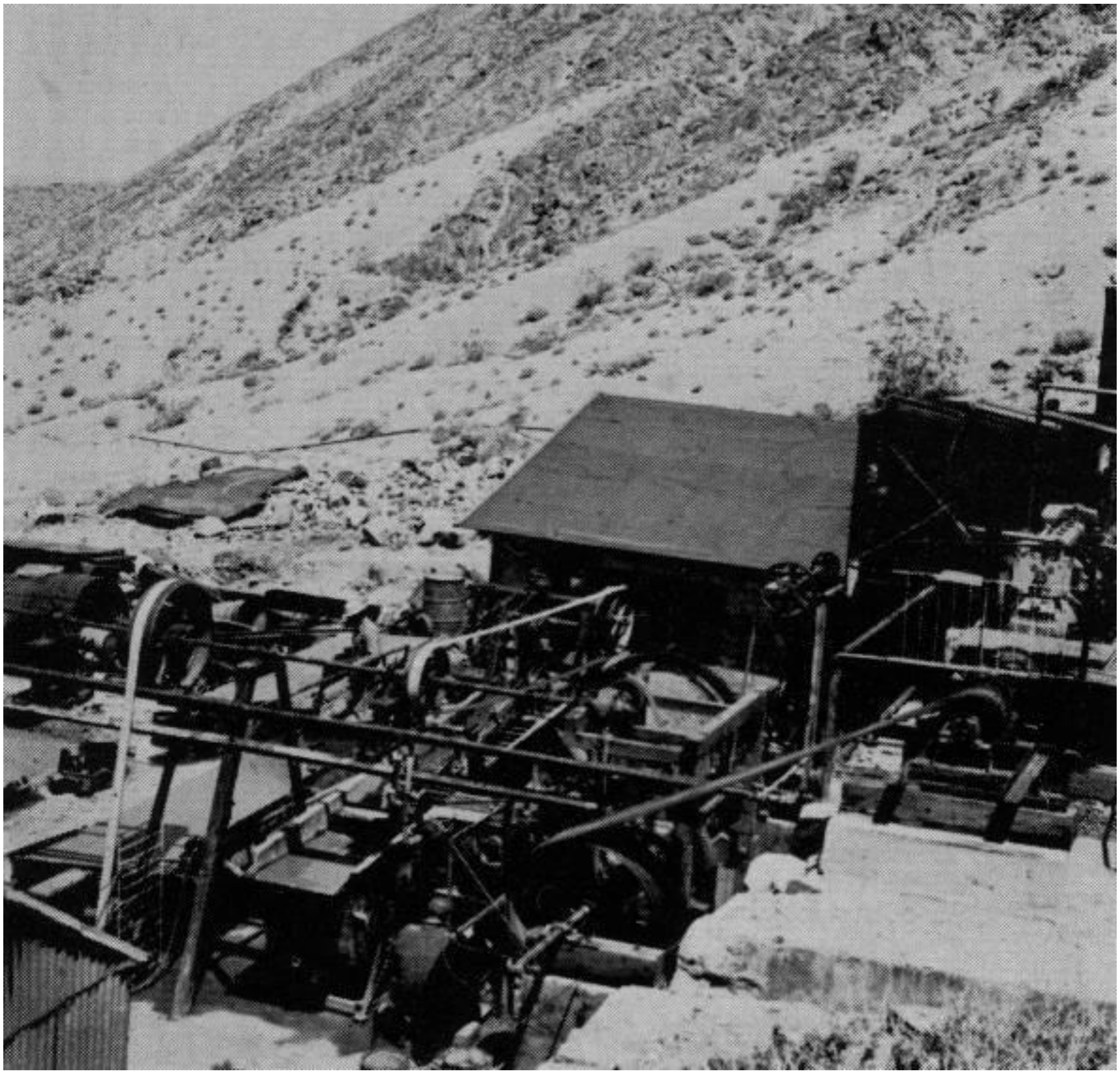
Roper (Mary Roper) Mine (T.13S, R.36E)

This mine has specular hematite with gold. It is worked with an adit and shaft (Tucker, 1921:282; Tucker, 1926:475; Tucker, 1938:425, pl. 3; Waring, 1919:87; Norman and Stewart, 1951:167, Site #95 on Plate 2).

Map 20: Reward Mine

Reward Mine (#141; T. 14S, R.36E, Sec. 3)

This mine is located on the west slope of the Inyo Range about 9 airline miles southeast of Independence. It has formerly been named the Brown Monster or Brown Monster-Reward Mine. It includes the Eclipse, Hidden Treasure Group, Hirsh and Telescope Group of mines.



The deposit and mine workings are fully described by Tucker and Sampson (1938:386-388) and a complete discussion of the geology of the property is given by Knopf (1918:121-122). The property was acquired under lease and option by the Golden Queen Mining Company, Los Angeles, and considerable exploration work
was done during the period from November 1940 to April 1942. Several hundred feet of drifts and crosscuts were driven, and diamond drilling was done on both the Reward and Brown Monster veins. The fault block between the two veins was also prospected. Some ore was mined and
shipped to the Golden Queen mill near Mojave, California, but the results were not favorable. Mr. T.L. Bright of Independence, California operated the property from 1936 thorough 1951, except for the period of the Golden Quail operation. Some gold ore has been mined along the footwall of the old stopes, and shipped to the Tropico mill at Rosamond. A vein carrying lead, silver and gold was discovered in the upper levels of the Reward workings. The vein was exploited in 1948. Bright reported a daily production of 10 tons which was shipped via truck to the American Smelting and Refining Company

plant at Selby, California. The ore is reported to assay from $100 to $150 per ton in those years. A small mill had been constructed to concentrate some of the lower grade ores and was still present in 1951. The crude ore was crushed to minus 1 inch in an 8 by 12-inch jaw crusher, carried by a belt conveyor to a small crushed-ore bin, and fed by a belt feeder to a 4 by 4-foot ball mill and rake classifier in closed circuit with a Denver Equipment Company jig between the ball mill discharge and the classifier. The overflow from the classifier was diverted to two 6 by
16-foot Wilfley concentrating tables. All the machinery was belt-driven with power furnished by a Gray 225 h.p. marine diesel engine. Mill capacity was 14 to 13 tons per hour. Three men were working in the mine and one was working in the mill in 1951 (Burchard, 1884: 160; Davidson, 1902:7, 11; Eric, 1948:250; Knopf, 1914:116-119; Knopf, 1918:121-122; Tucker, 1926:473; Tucker, 1938:386-388, 478, pl. 3; Tucker, 11940:23; Waring, 1919:83, Norman and Stewart, 1951:48-49, 161, Site #77 on Plate 2, photo above is reproduced from Plate 9.)

The area of the Reward (#141), Inyo Bee (#142) and Lucky Slim (#143) mines was mapped by Stone and others (2000). The major geologic units in this area are:

Qai **Inactive alluvium (Holocene)**—Fine to coarse gravels of inactive fan surfaces. Downslope from granitic bedrock, composed primarily of fine sand to pebble grus; downslope from sedimentary and metamorphic bedrock, composed of coarse, angular, poorly sorted gravel. Surface channels subdued or absent; dissected by channels that contain active alluvium (Qa). Overlies older lake deposits (Qlo) and younger alluvial and debris-flow gravels (Qgy)

Holocene inactive alluvium

Qlo **Older lake deposits (Holocene and Pleistocene)**—Mostly light-tan silt and sand; includes some gravel deposits near paleoshorelines. Massive to well bedded. Well exposed along channel of Owens River. Some deflation basins in upper surface of unit are filled by playa deposits (not mapped). Maximum elevation about 3,760 ft (1,146 m) except west of Lone Pine Fault, where deposits have been uplifted. Could be as much as 2,500 m thick in structural depression between Owens Valley Fault Zone and Inyo-White Mountains Fault Zone. Probably includes deposits of late Tertiary age at depth

Holocene and Pleistocene Lake Deposits

Jli **Intrusive rocks marginal to Pat Keyes Pluton (Middle Jurassic?)**—Primarily dark-gray, reddish-brown-weathering, fine-grained, altered and recrystallized diorite and tonalite that have been intensely sausseritized and sericitized. Composed principally of plagioclase, epidote, clinozoisite, calcite, and sericite; quartz is minor. Primary intrusive texture partly to completely destroyed by recrystallization. Includes minor light-colored intrusive rocks and small, irregular masses of metasedimentary rocks that are not mapped separately. Provisionally interpreted as cogenetic with mafic border facies of Pat Keyes pluton

Jurassic Pat Keyes Intrusive Margin

Jpk **Pat Keyes pluton (Middle Jurassic)**—Medium- to light-gray, medium-grained, hypidiomorphic granular to seriate plutonic rocks of variable composition. Main mass, exposed largely north and east of quadrangle, consists predominantly of ±clinopyroxene-biotite-hornblende monzogranite and quartz monzonite. These rocks grade irregularly into a relatively mafic border facies of clinopyroxene-biotite-hornblende quartz monzodiorite and less common quartz diorite, diorite, and monzodiorite (Ross, 1969; Dunne, 1970, 1971). Exposures in quadrangle are primarily of the mafic border facies. Hornblende K-Ar ages 178 and 163 Ma (Ross, 1969); Rb-Sr (whole-rock plus mineral separate) age 183 Ma (Dunne, 1970, 1971)

Jurassic Pat Keyes Pluton

PIPk **Keeler Canyon Formation (Early Permian and Pennsylvanian)**—Light- to medium-gray, medium- to thick-bedded limestone and silty to sandy limestone, generally metamorphosed to marble and calc-hornfels. Thickness about 500 m; base not exposed

Permian-Pennsylvanian Keeler Canyon Formation

Lone Pine Formation (Early Permian)—In descending order, consists of Reward Conglomerate Member and members C, B, and A of Lone Pine Formation as defined by Stone and Stevens (1987). Divided into:

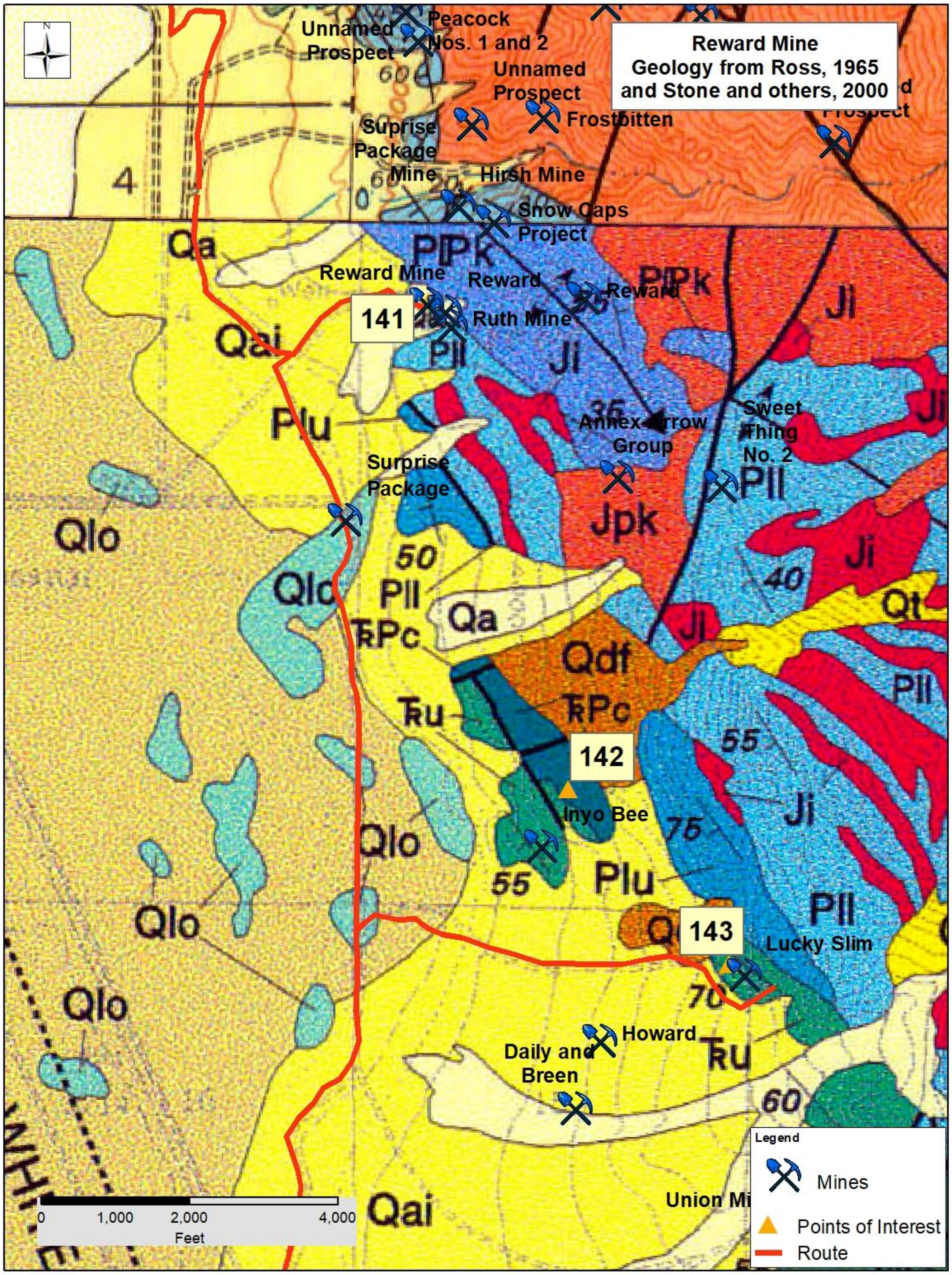
Plu

Upper part—Reward Conglomerate Member and member C, undivided. Reward Conglomerate Member, about 200 m thick, consists of dark-gray to brown, thick-bedded, medium- to coarse-grained quartzite and chert- and quartzite-pebble conglomerate; basal few meters consist of light-gray sandy limestone and marble. Member C, about 120 m thick, consists of dark-brown, massive quartzose siltstone and hornfels interbedded with minor fine- to coarse-grained quartzite and rare chert- and quartzite-pebble conglomerate. Unit is truncated southeastward by angular unconformity beneath Union Wash Formation

Pll

Lower part—Members B and A, undivided. Member B, about 180 m thick, consists of greenish-gray to reddish-brown, thin-bedded calcareous mudstone, siltstone, and calc-hornfels, and a few widely spaced beds of gray bioclastic limestone or marble 1 to 3 m thick. Member A, about 500 m thick, generally is metamorphosed and consists primarily of gray to reddish-brown, thin-bedded argillite, siltite, fine-grained quartzite, and calc-hornfels. Metamorphic grade decreases near east edge of quadrangle, where member A consists of light- to medium-gray, siliceous to calcareous mudstone, calcareous siltstone to very fine grained sandstone, and silty limestone

Permian Lone Pine Formation



Geologic map of the Reward Mine and surrounding area.

Fossil Hill (#142; T.14S, R.36E, Sec. 10)

Monte Carlo (Mount Whitney-Union) Mine (T.14S, R.36E, Sec. 14)

This mine has galena with gold and silver in a quartz vein cutting limestone and calcareous slate. The width of the vein is from 6 to 20 feet. The vein strikes N70°E, dips 60° to 65°W. The mine has 8 adits and a total of 3000 feet of workings (Davidson, 1902:8; Eric, 1948:239, 248, 252; Tucker, 1926:501-503; Tucker, 1934:311; Tucker, 1938:457, 469, 476, 479, pl.3; Waring, 1919:84, Norman and Stewart, 1951:180, Site #145 of Plate 2)

Lucky Slim Mine (#143; T.14S, R.36E, Sec. 15)

Cheri No. 20 Mine (#144; T.14S, R.36E, Sec. 13)

Owenyo Townsite (#145; T.14S, R.36E, Sec. 34)

Long John Mine (T.15S, R.37E, Secs. 16 and 21)

The minerals at this mine are galena and cerrusite. They are in a fissure vein in limestone. Reported production 1925-1926 was $60,000. The grade of ore shipped was 40% lead and 40 oz of silver per ton. The mine was worked with shafts and adits (Eric, 1948:247: Tucker, 1938:444, 475, p.3; Tucker, 1940:10, 26; Norman and Stewart, 1951:179, Site #137 on Plate 2).

APPENDIX A. EVA BELL MINE

APPENDIX B: RED HILL CINDER PATENT

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