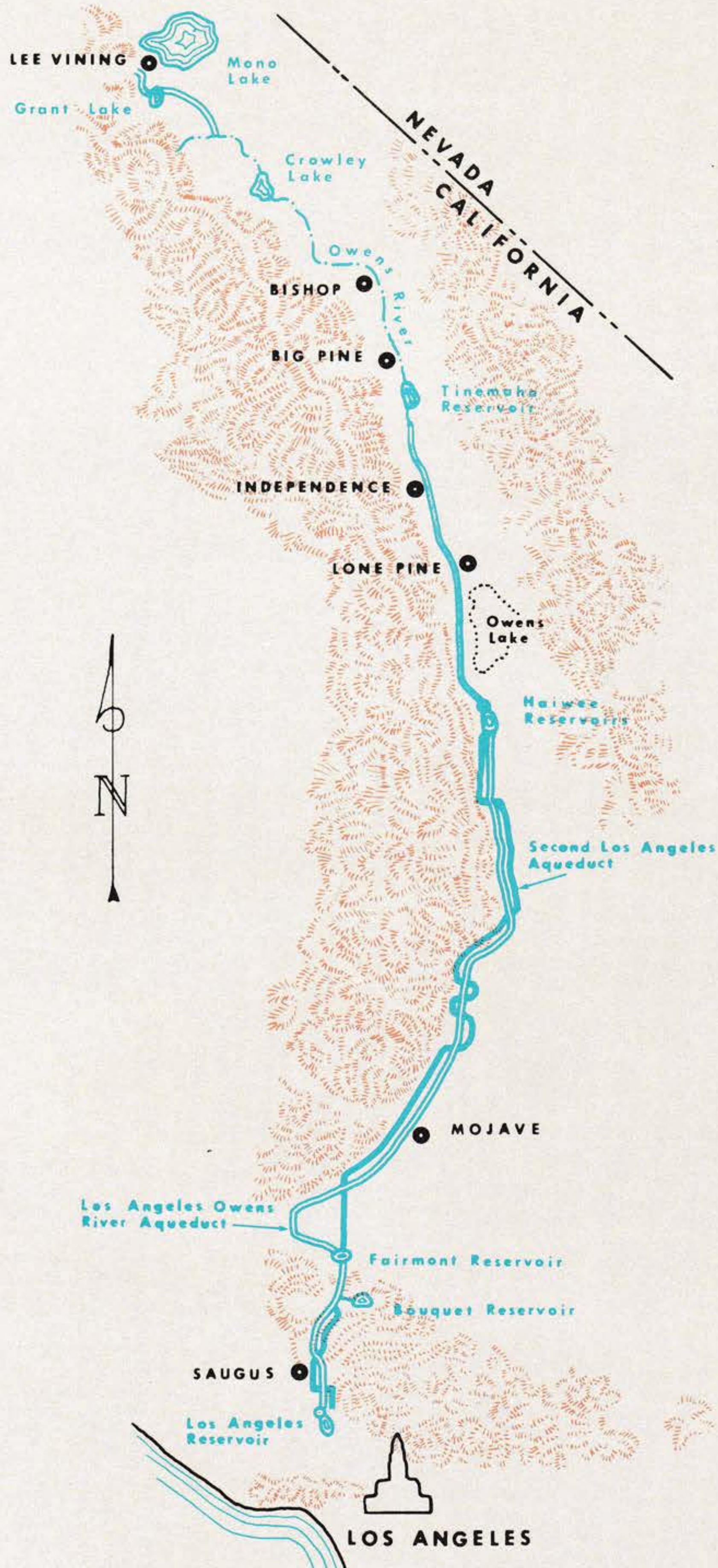
Los Angeles Department of Water and Power

GEOLOGIC GUIDEBOOK

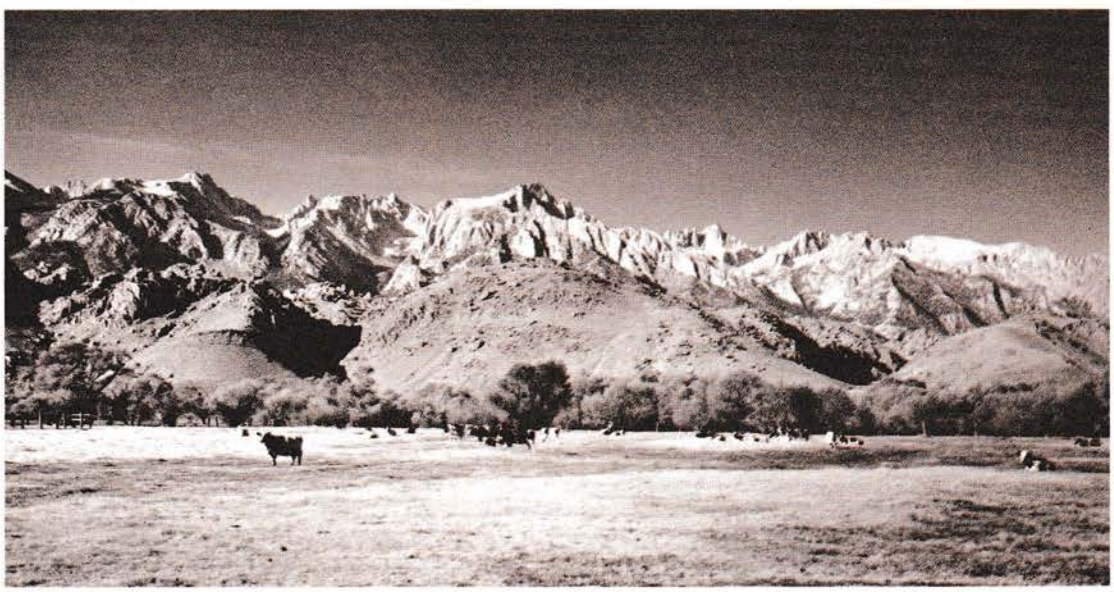
LOS ANGELES AQUEDUCT SYSTEM



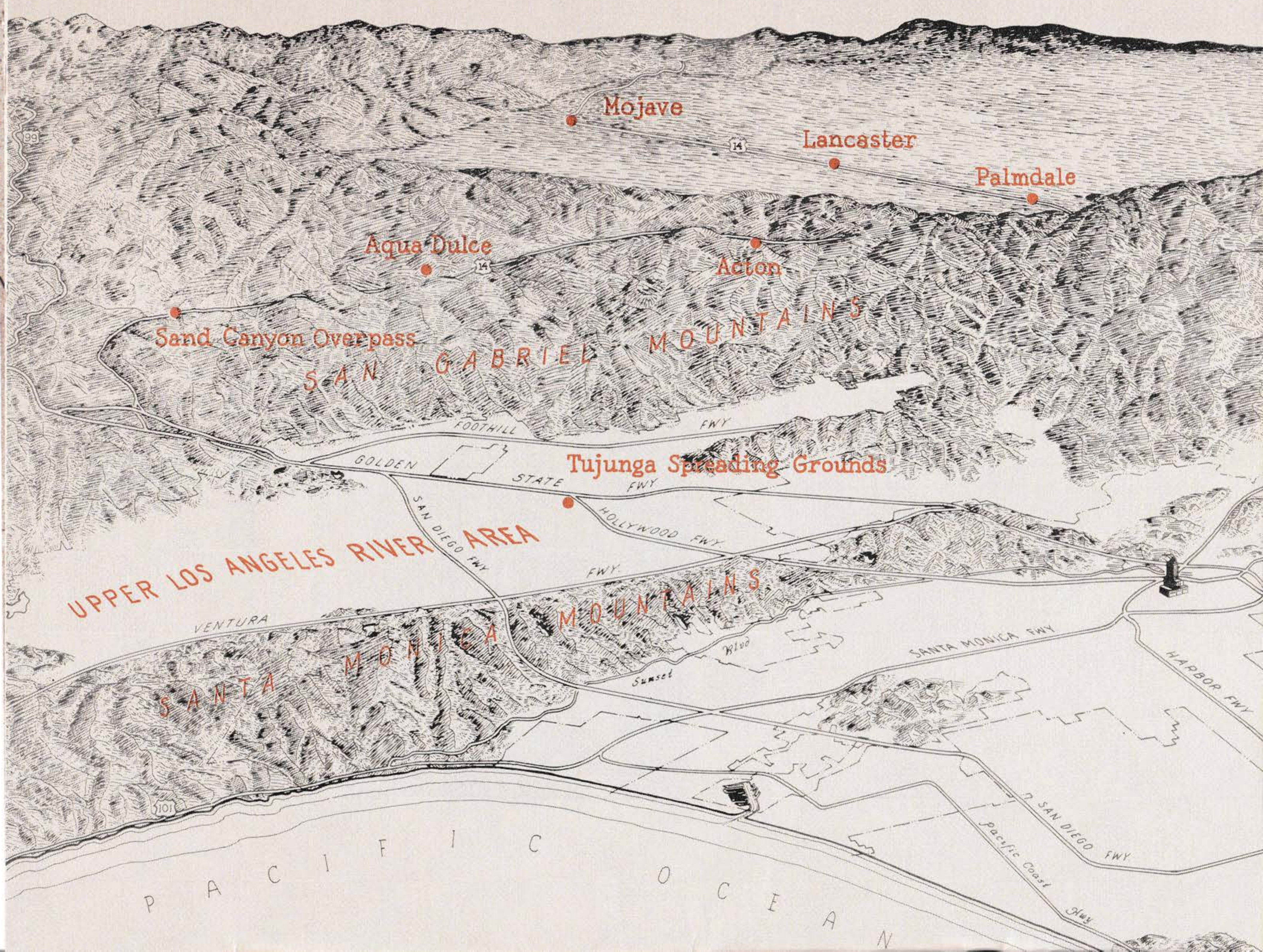
LEE VINING
Mono Lake
Grant Lake
NEVADA
CALIFORNIA
Crowley Lake
Owens River
BISHOP
BIG PINE
Tinemaha Reservoir
INDEPENDENCE
LONE PINE
Owens Lake
Haiwee Reservoirs
N
Second Los Angeles Aqueduct
MOJAVE
Los Angeles Owens River Aqueduct
Fairmont Reservoir
Bouquet Reservoir
SAUGUS
Los Angeles Reservoir
LOS ANGELES

THE GEOLOGIC GUIDEBOOK
Los Angeles Aqueduct System

This guidebook is designed to aid in understanding the basic geologic features along the Los Angeles Aqueduct System. The guidebook is designed to be compatible with the Points of Interest — Los Angeles Aqueduct System guidebook available through the Public Affairs Division of the Los Angeles Department of Water and Power. The format of this guidebook is a series of map sheets with the aqueduct system indicated in blue and the geologic interest points indicated in brown with corresponding descriptions on the facing pages.



Cover photo shows crumpled beds of pliocene anaverde formation in fault-slice ridge within San Andreas Fault zone.


Mojave
Lancaster
Palmdale
Aqua Dulce
Acton
Sand Canyon Overpass
SAN GABRIEL MOUNTAINS
FOOTHILL FWY
GOLDEN STATE FWY
Tujunga Spreading Grounds
HOLLYWOOD FWY
SAN DIEGO FWY
UPPER LOS ANGELES RIVER AREA
VENTURA FWY
SANTA MONICA MOUNTAINS
Sunset Blvd
SANTA MONICA FWY
HARBOR FWY
SAN DIEGO FWY
Pacific Coast Hwy
PACIFIC OCEAN
14
99
101

The Upper Los Angeles River Area A little over 200 years ago (1769), the Los Angeles River was discovered by Gaspar de Portola who named it Rio Porciuncula. Twelve years later, a small settlement began on the banks of this river. The settlement relied heavily on the Los Angeles River for irrigation as well as domestic water. The main source of the Los Angeles River was runoff from the San Gabriel, Santa Susana, and Santa Monica Mountains. During rainfall the water ran off these mountains and flowed across the porous alluvium. Some of this water percolated underground into the alluvium while the rest flowed into the Los Angeles River and eventually reached the Pacific Ocean. During the summer months, which have historically been dry months, lack of rainfall resulted in diminished flows to the river and the river's flow was maintained by ground water discharge.

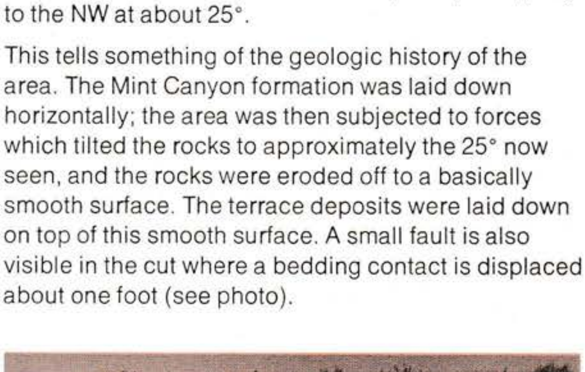
Presently, the river does not flow all year because the ground water is used by several municipal agencies. Most of the water is currently used before it reaches the river bed which diminishes the annual flow. Housing developments and industrial growth in the San Fernando Valley have reduced ground water recharge from rainfall. However, the recharge from imported sources has doubled the average yield of the basin. There are several areas which have been set aside for the sole purpose of recharging the underground basin. One such area, the Tujunga Spreading Grounds, can be seen near the Roscoe Boulevard offramp.

San Gabriel Mountains The San Gabriel Mountains are mainly composed of granitic type rocks. The area is complicated by NW-SE trending faults, one of which is the San Gabriel Fault crossing just east of Saugus. The February 9, 1971 earthquake, which did extensive damage in the San Fernando Valley and Newhall areas, was the result of movement along a thrust fault in this area called the Santa Susana thrust, which raised the San Gabriel-Saugus Mountains approximately three feet in relation to the San Fernando Valley.

The light buff-colored formations seen in the road cuts between the Cascades and the Solemint Junction area are typical exposures of the non-marine Saugus formation. This formation is principally alluvial. Other fine grained marine deposits are referred to as the Pico formation. Two zones of the Pico formation are oil bearing, and the oil wells in the area between Van Norman Reservoir complex and the Saugus-Newhall area (Placerita oil field) produce oil from these zones.

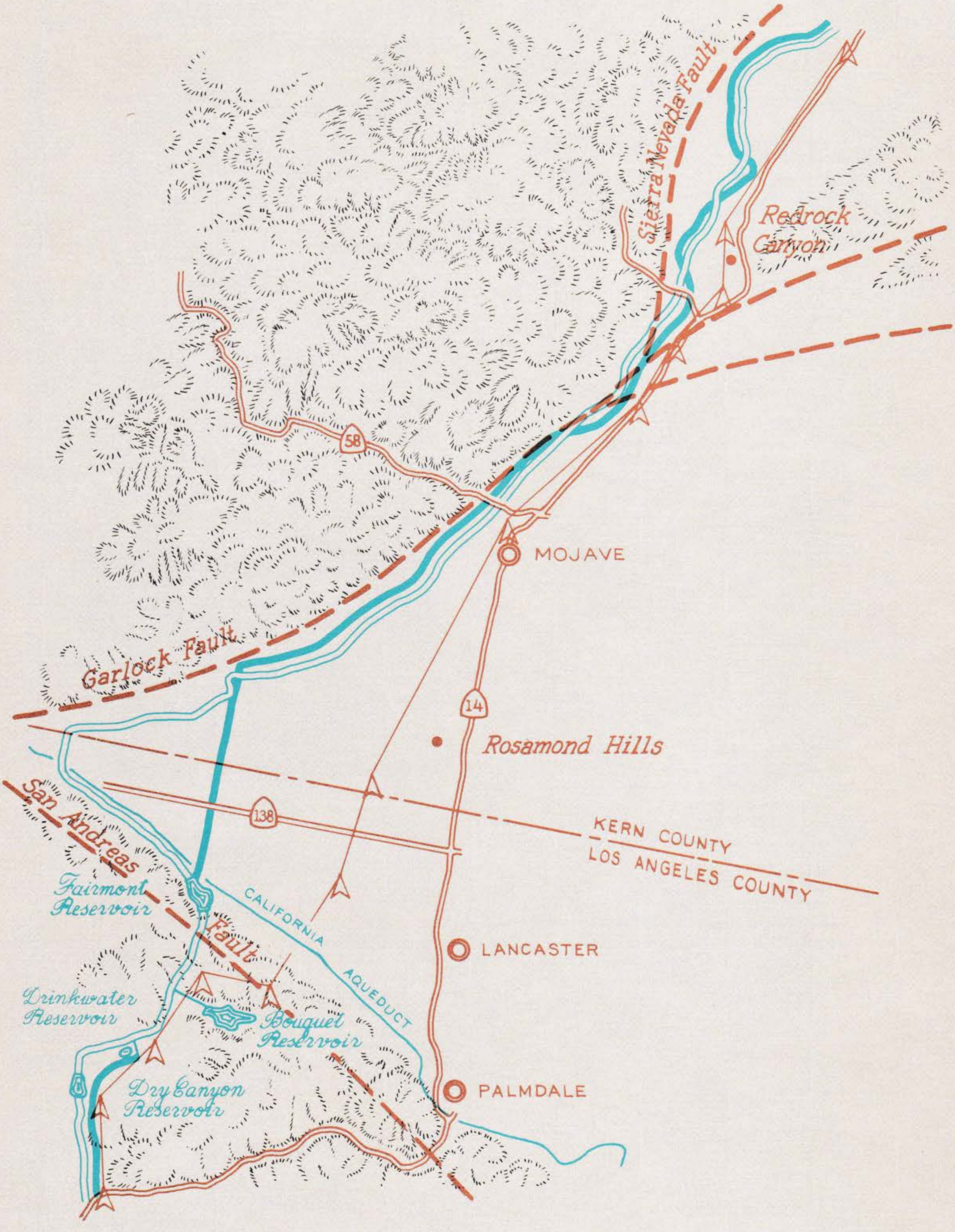
Sand Canyon The sedimentary rocks visible from the road between Solemint Junction and Spring Canyon were deposited in fresh water. These rocks compose what is called the Mint Canyon formation. The general character of these beds can be seen in the north road cut just before the Sand Canyon overpass. The road cut also illustrates a geologic feature called an angular unconformity. The materials which make up sedimentary rocks are normally laid down in a horizontal position with the oldest rocks on the bottom. As seen here, the boulder and gravel-bearing terrace deposits (upper beds) are essentially horizontal while the Mint Canyon formation (lower) is dipping to the NW at about 25°.

This tells something of the geologic history of the area. The Mint Canyon formation was laid down horizontally; the area was then subjected to forces which tilted the rocks to approximately the 25° now seen, and the rocks were eroded off to a basically smooth surface. The terrace deposits were laid down on top of this smooth surface. A small fault is also visible in the cut where a bedding contact is displaced about one foot (see photo).



Sand Canyon

The age of activity of this fault can be estimated from the geometry. That is, the fault offsets the buff-colored beds and so must have occurred after they were deposited. The Mint Canyon formation was eroded to a smooth surface after the faulting otherwise the erosional surface would be displaced, as are the tilted beds. Likewise, no additional faulting has taken place after the terrace deposits were laid down. This technique is useful in judging whether a particular fault has been active in recent time.



Sierra Nevada Fault
Redrock Canyon
58
MOJAVE
Garlock Fault
14
Rosamond Hills
138
KERN COUNTY
LOS ANGELES COUNTY
San Andreas Fault
Fairmont Reservoir
CALIFORNIA AQUEDUCT
LANCASTER
Drinkwater Reservoir
Bouquet Reservoir
Dry Canyon Reservoir
PALMDALE

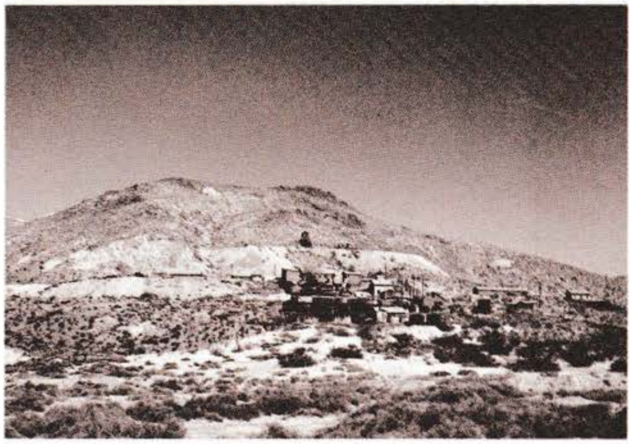
Vasquez Rocks County Park The rocks of the Vasquez and Tick Canyon formations can be seen in this area. These formations, although similar in appearance (light grey to reddish brown sandstones and conglomerates), are separated by an unconformity. That is, between the deposition of the Vasquez and the younger Tick Canyon formations there was a period of vigorous faulting and folding after which much of the Vasquez formation was eroded away.

In the area of the county parks, the rocks are weathered to a rugged topography because of their tilted nature. If the erosional processes had been effective over a longer period of time, then the surface would be flat, similar to the Sand Canyon road cut if all of the terrace material was removed (see photo).

Vasquez Rocks

San Andreas Fault The road cut just north of Lake Palmdale exposes an area of twisted and broken rocks (see cover). This area is part of the San Andreas Fault zone (over a mile wide in some places). The twisting and breaking are results of movement along the fault. The San Andreas is one of the more famous of the major fault zones in California, extending from the California-Mexico border to an area north of San Francisco where it extends into the ocean. The fault is responsible for several great earthquakes (1857-Tejon Pass and 1906-San Francisco).

Rosamond Hills Tropico Hill west of Rosamond, is the site of famous gold and silver mines. The Tropico Mine off of Rosamond Blvd., is now a historical museum. Just north of Rosamond is Soledad Mountain, site of the Golden Queen, Bobtail, and Elephant Mines. The mines in this area have produced 23 million dollars worth of gold and silver since the area's discovery in 1894.



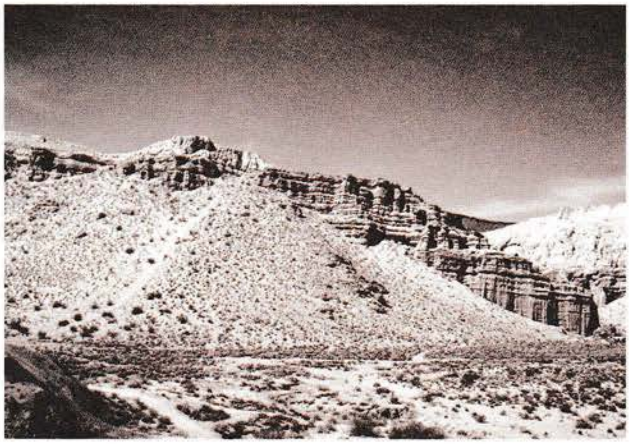
Tropico Mine

Garlock Fault The Garlock fault is one of the major fault systems in Southern California. The fault forms the Mountain front of the Tehachapi, Sierra Nevada, and El Paso mountains.

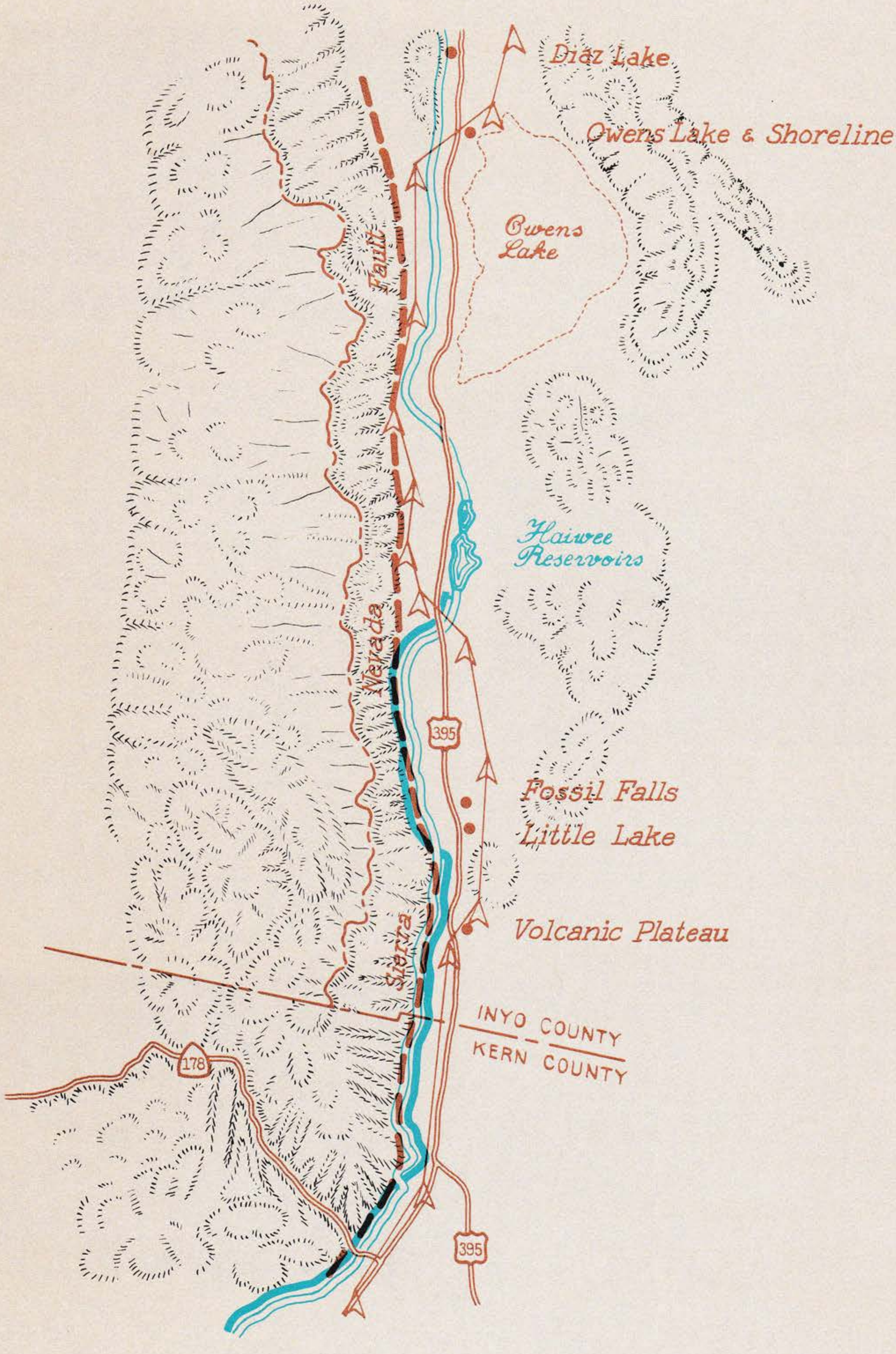
Garlock, San Andreas, and Sierra Nevada Faults
The Garlock and San Andreas faults join west of Rosamond. The triangular shape of the valley is a result of the topographic control of these faults (see map). These faults are classified as active and there are sections of the San Andreas along which movements of from 0.1 to 1 inch per year have been reported. Similarly, movements have been recorded along the Sierra Nevada fault. These faults were and are of great concern to Department of Water and Power engineers who built and operate an aqueduct system which crosses in the area.

Redrock Canyon This canyon with its unusual weathered surface and colorful rocks, has long been a location used by the motion picture industry.

The badlands topography is the result of wind and water erosion of the various formations. The red-colored, easily eroded sandstones (Ricardo formation) are capped by recent dark-colored basaltic lavas. The basalt forms a resistant cap which protects the Ricardo formation from erosion, resulting in very steep sided mesas with deep gullies (see photo).



Redrock Canyon



Diaz Lake
Owens Lake & Shoreline
Owens Lake
Fault
Haiwee Reservoirs
Nevada
395
Fossil Falls
Little Lake
Volcanic Plateau
Sierra
INYO COUNTY
KERN COUNTY
178
395

Volcanic cliff

Volcanic Cliff Area The steep cliff east of the road is the edge of a basalt plateau. The cliff was formed during the Pleistocene ice ages when excessive runoff caused Owens Lake to spill cutting through the basalt (see photo). Just south of Little Lake, columnar jointing, resulting from cooling cracks, can be seen in the basalt.

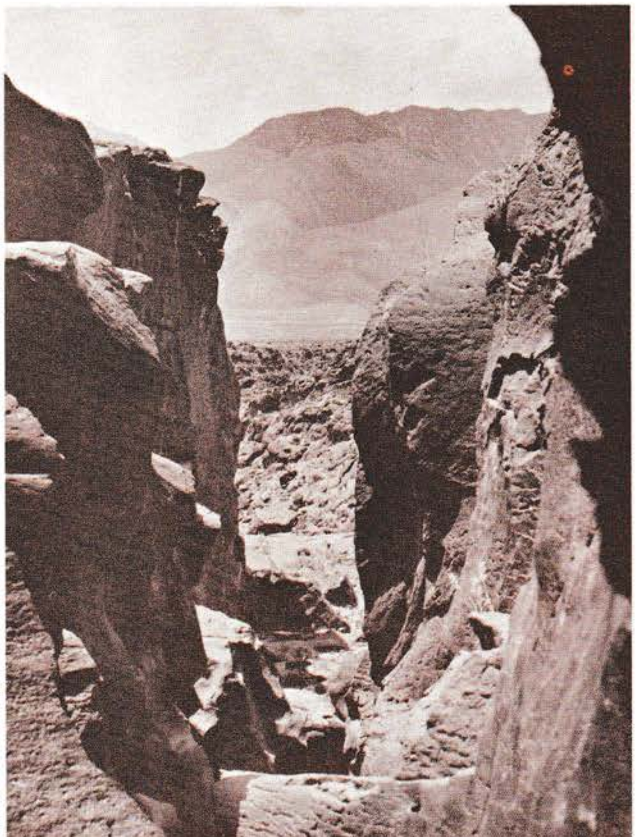
Little Lake This small lake bordered by lava flows is an excellent example of a lake formed by ground water. The lake is just east of the Sierra Nevada frontal fault system. The fault and lava come together forcing ground water to the surface.

Fossil Falls This area is covered by basalts and other volcanic debris. During the Pleistocene there were many large lakes, in fact the lower Owens Valley was covered by water. When the depth of water in the lake exceeded about 100 feet, it started to spill at the southern end. Over a period of time, the water eroded a steep walled notch through the basalts (see photo).

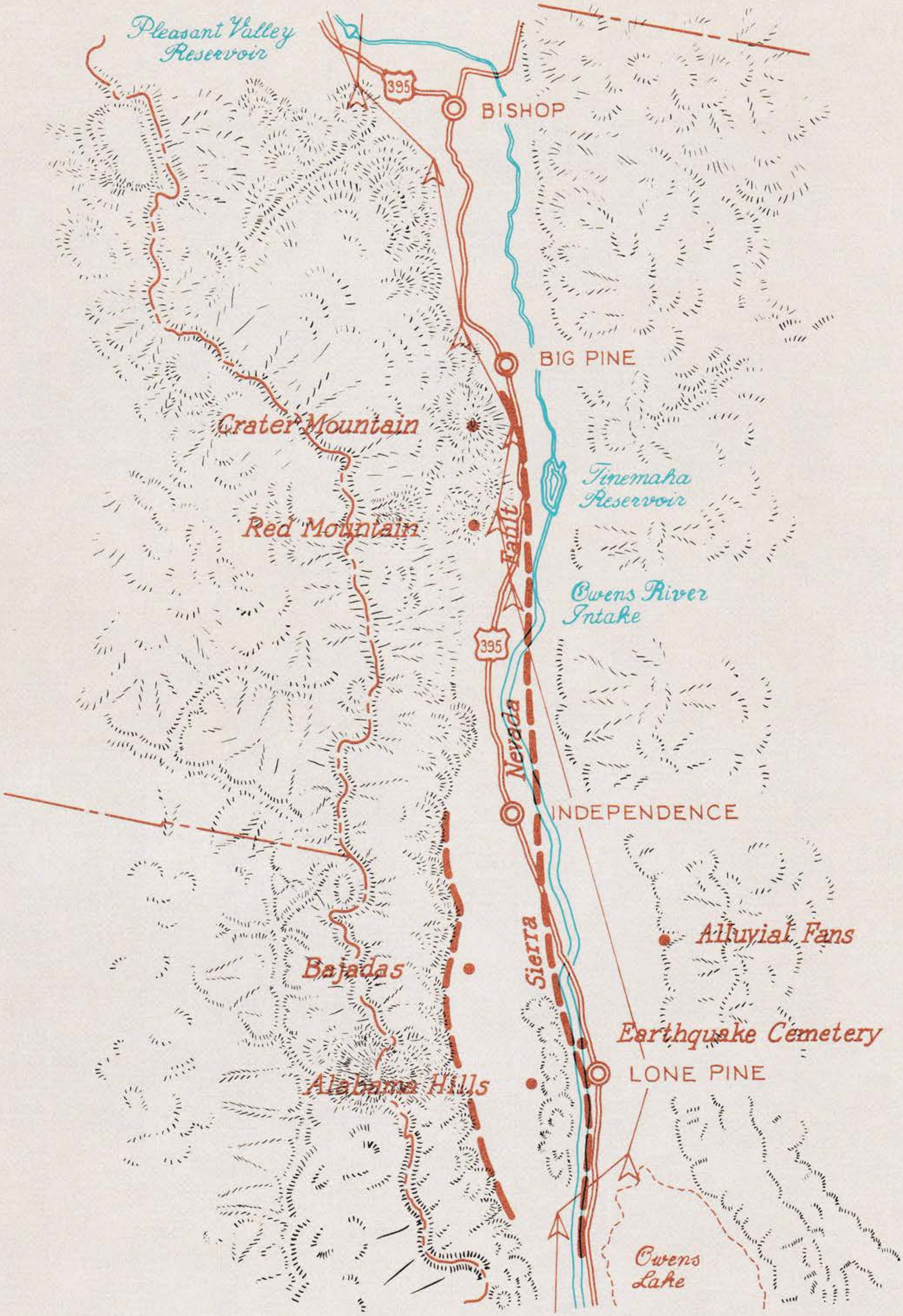
Owens Lake The curved features at the northern end of the lake are remnants of ancient Owens Lake shorelines. This lake occupied a fairly large portion of Owens Valley during the wet periods of the ice ages.

The last time that the lake elevation was high enough to spill was about 6,000 years ago. Since that time, the lake has continued to dry up. The lake has essentially been a dry lake for many years. The salts left by the prehistoric lake have been mined since 1885.

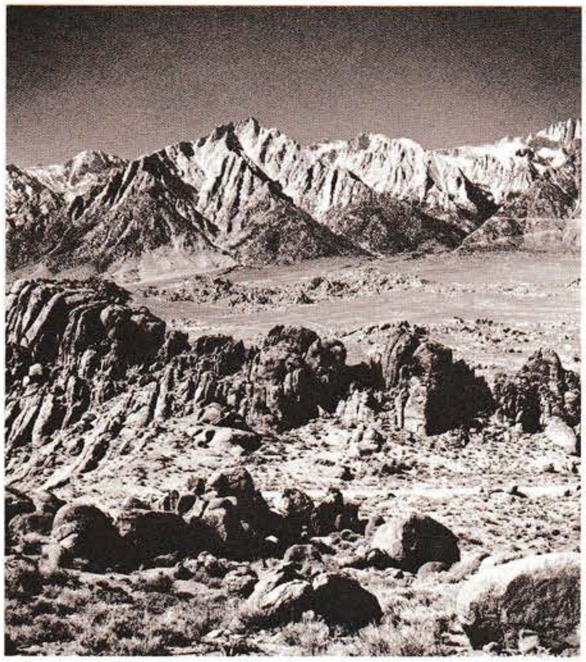
Diaz Lake A natural lake not a part of the aqueduct system. The site is a fault sink formed by the 1872 earthquake. Diaz Lake is a popular recreation center on city land leased and operated by Inyo County.



Fossil Falls


Pleasant Valley Reservoir
395
BISHOP
BIG PINE
Crater Mountain
Tinemaha Reservoir
Red Mountain
Fault
Owens River Intake
395
Nevada
INDEPENDENCE
Alluvial Fans
Sierra
Bajadas
Earthquake Cemetery
LONE PINE
Alabama Hills
Owens Lake

Alabama Hills and Movie Flat This area of grotesque-shaped rocks is composed mainly of granite. The unusual shapes are a result of exfoliation (a type of weathering) along joint patterns in the granite. Wind erosion played a major role in sculpturing the present landscape. The unusual erosional shapes are illustrated in the picture below.



Alabama Hills

1872 Earthquake Fault The small bluff to the west of the road marks the spot where a major earthquake (one of the largest in California's history ranking along with the 1906 San Francisco and the 1857 Tejon Pass earthquakes) occurred in 1872. The earthquake was a result of movement along major fault blocks in the Owens Valley. In places, fault scarps as high as 23 feet can be seen in the alluvial material.

The horizontal displacement of this fault has been described by investigators on the basis of a row of trees north of Lone Pine. The displacement described in 1907 was about 9 feet and is now 10 to 13 feet, which may indicate creep since the 1872 earthquake.

Bajadas and Alluvial Fans The eastern flank of the Sierra Nevada is flanked by a series of alluvial fan deposits which have merged, forming a broad sloping plain. This plain is known as a bajada. The bajadas are large and different from the well defined smaller alluvial fans seen across the valley at the base of the White and Inyo Mountains because storms originating from the west lose most of their precipitation on the Sierras leaving relatively little water to erode the White and Inyo Mountains.

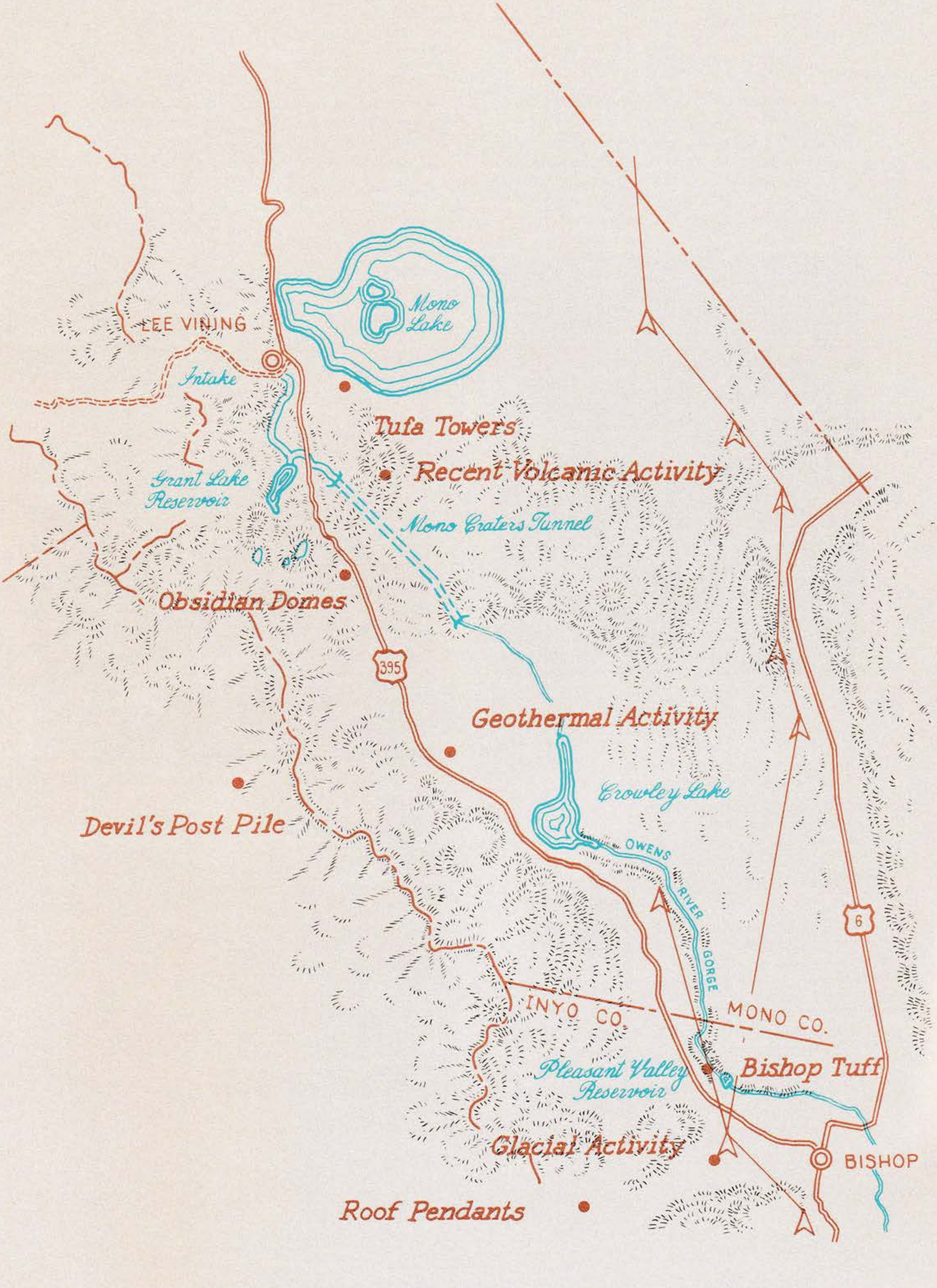
Continuous percolation of water from melting snow fields into the bajadas has built up large underground reservoirs which are presently being used to supplement the surface water supply to the aqueducts.

Red Mountain, Crater Mountain and Poverty Hills The prominent hills and cones in this area are old volcanoes. Lava from the more prominent volcanoes (Red Mountain and Crater Mountain) flowed down the slopes into the valley floor. Frothy, broken basalts can be seen next to the road by Charlie's Butte, about three miles south of Tinemaha Reservoir (see photo).

Red Mountain

Other hills in the area are composed of much older igneous and metamorphic rocks. Contact zones between igneous rocks of other types are potential zones of mineralization. The New Era Mine (also known as the Buckeye or Never Rest Mine) is located in the Poverty Hills along one of the contact zones. The Cleveland Mine is in a similar geologic location near the Fish Springs Hill. Mines in this area have produced gold, lead, silver, and zinc.

White Mountain White Mountain Peak, seen on the skyline northeast of Laws, is at an elevation very close to that of Mt. Whitney. This peak is the site of the White Mountain Research Laboratory which specializes in high altitude research on plant and animal organisms.



LEE VINING
Intake
Mono Lake
Tufa Towers
Recent Volcanic Activity
Grant Lake Reservoir
Mono Craters Tunnel
Obsidian Domes
395
Geothermal Activity
Devil's Post Pile
Crowley Lake
OWENS RIVER GORGE
6
INYO CO.
MONO CO.
Pleasant Valley Reservoir
Bishop Tuff
Glacial Activity
BISHOP
Roof Pendants

Glacial Activity The mouth of Pine Creek Canyon shows excellent examples of lateral moraines which occurred during the ice ages. These lateral moraines formed when the glacier flowed down the valley depositing debris at the sides. The "U" shaped cross-section seen looking up the canyon is typical of glaciated valleys. Typical stream cut canyons are "V" shaped as seen in the smaller canyon just south of Pine Creek (see photo).

Pine Creek Canyon

Granites and Roof Pendants Also in the vicinity of Pine Creek Canyon, several different colors can be seen in the cliff which forms the mountain front. The different colors are the result of mineral separation as the molten mass of granite cooled. Darker colored rocks, called roof pendants, can be seen in the Sierra near the Pine Creek Mine operated by Union Carbide. These roof pendants are altered remains of sedimentary rocks which were intruded by molted magma. Most of the sedimentary rocks were assimilated by the magma to become part of the granites. However, some of the sedimentary rocks remained intact and can now be seen on top of the granites as roof pendants (see photo).

Bishop Tuff The light pink colored formation containing fragments of smaller rocks is called the Bishop Tuff. This formation originated about 700,000 years ago as the result of volcanic activity. Hot viscous material containing glassy fragments flowed down from various vents in Long Valley and encompassed the entire Bishop, Round Valley, and Mono areas. The heat contained within the viscous mass caused the fragments to become welded after the mass came to rest. Interbedded with the welded tuff are some unconsolidated deposits (mainly pumice sands). The tuff was later buried by recent glacial deposits in the Bishop and Round Valley area.

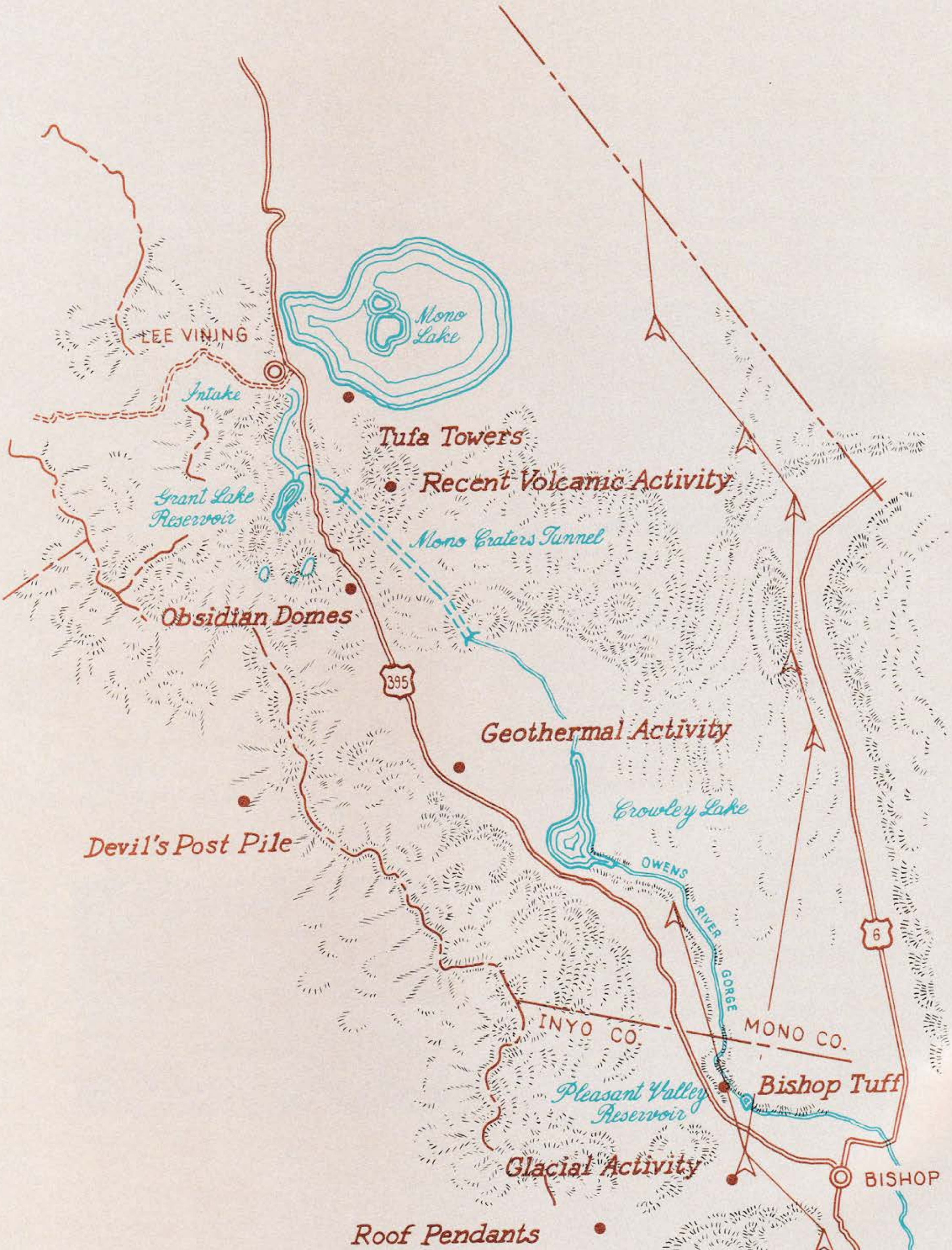
Granitics To the east of the road near Tom's Place, Bishop tuff can be seen, weathered in an etched fashion. To the west of the road typical Sierra granitics can be contrasted. Notice the different features that occur as the result of weathering. The tuff is irregular and pock marked while the granites are smooth and rounded. This weathering difference is due primarily to the different nature of the rock types — the granite being uniformly hard and the tuff having hard and soft areas.

Matterhorn Peaks The skyline to the south of the road contains many Matterhorn type peaks. Where a glacier begins, the freezing action plucks the rocks away from the mountain face leaving a semi-circular bowl. Where three glaciers start on one peak these semi-circular areas facet the peak into the classic Matterhorn style.

Geothermal Activity Steam vents can be seen discharging into the air about ¼ mile east of the Mammoth Road turnoff on the old highway. The steam reflects what was once a very active volcanic area. Heat from cooling rocks and gases heat the underlying ground water and pressure builds up until the steam is forced to the surface through cracks and fissures. Wells have been drilled in this area in an attempt to harness this geothermal power. This technique is used in many countries including the United States (at the Geysers in northern California) and Mexico (at Cerro Prieto in Baja California).

Devil's Post Pile When molten rocks cool, the shrinkage will often cause distinct cracks called jointing. The jointing character of basaltic lava is in the form of hexagonal columns. Devil's Post Pile is an excellent example of hexagonal jointing in basalt. The hexagonal shape is seen in the massive columns at the foot of the cliff (see photo).

Devil's Post Pile


Mono Lake
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INYO CO.
MONO CO.
Bishop Tuff
Pleasant Valley Reservoir
Glacial Activity
BISHOP
Roof Pendants

Obsidian Domes When molten rock is chilled very quickly the material becomes glassy, while if it is cooled slowly, the individual crystal structure is more evident and it appears grainy. South of the road is a good example of a lava flow which has cooled rapidly, and many volcanoes in this area show evidences of lava which cooled very rapidly forming a glass called obsidian.

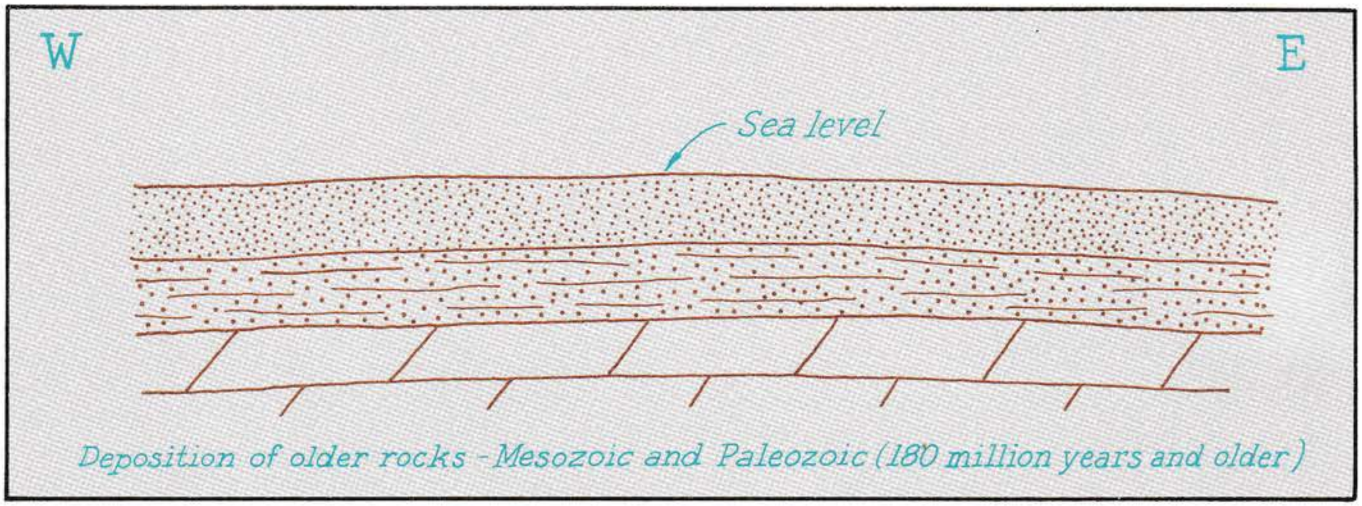
Volcanic Activity The area from Bishop north to Mono Lake is one of complex volcanic and tectonic activity. The area from Bishop to Mono Lake was fairly well covered by lava flows similar to those seen in the Owens Valley. These flows and other later flows were displaced by faults. Additional flows from volcanoes such as Glass Mountain covered part of the area. Volcanic activity continued from that time with the Bishop Tuff being scattered from various vents in Long Valley over an area from Bishop north to the Mono Craters area (estimated 400-450 square miles). The Bishop Tuff was formed as a result of hot viscous flows of ash which was welded together by heat. After the Bishop Tuff was deposited, lava flows from the Sierra Nevada extended into the western portions of Long Valley and Mono Craters areas. The northern portion of the area was then covered by pumice from the Mono Craters (see photo). The entire complex of volcanic materials form a geographic high area referred to as a volcanic tableland.

Mono Craters

Tufa Towers White deposits on the periphery of Mono Lake are called tufa. Tufa is composed of calcium carbonate deposited when minerals from the water precipitate where fresh water is entering the lake through springs. Throughout the years, these deposits have built up fairly large structures. Studies indicate that algae contributes to the formation of tufa. (see photo)

Tufa towers

GENERALIZED SEQUENCE OF EVENTS



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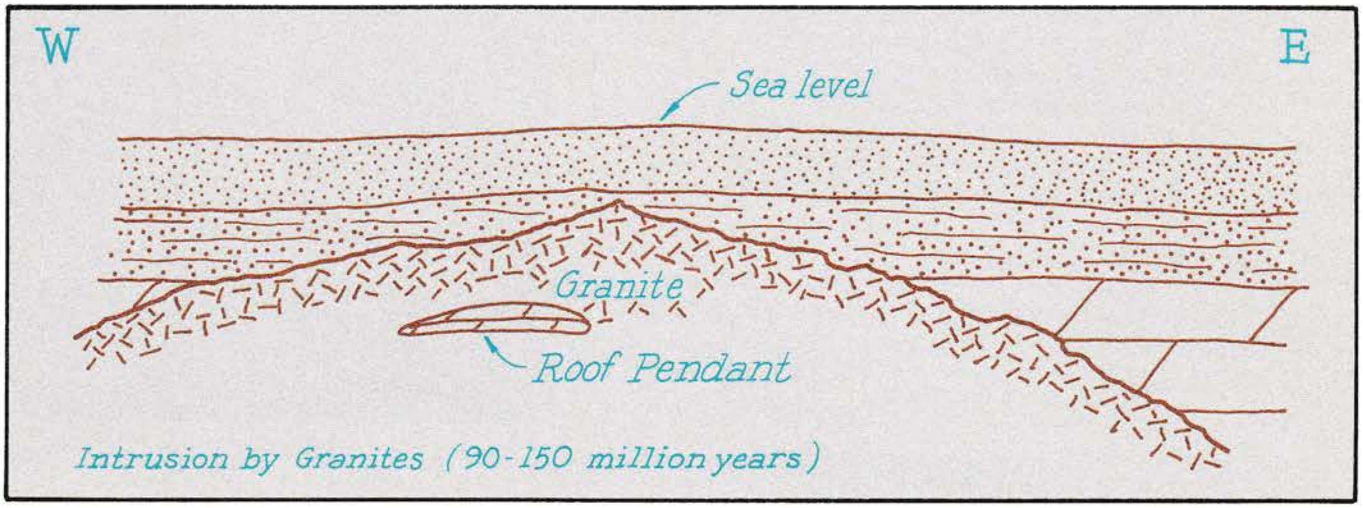

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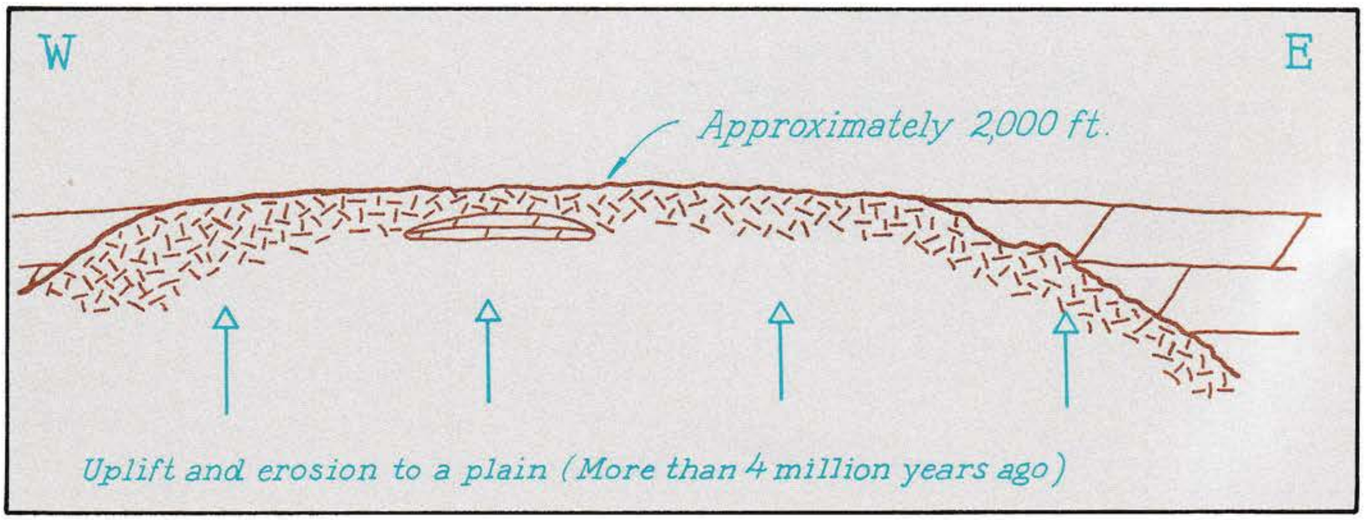
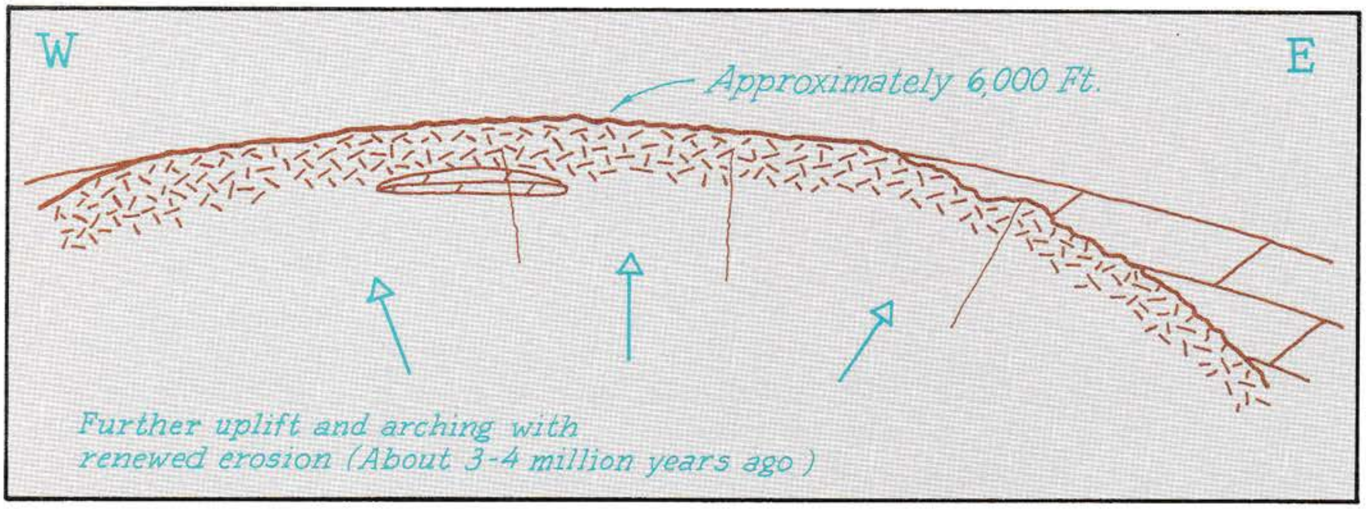


3

IN FORMING THE OWENS VALLEY



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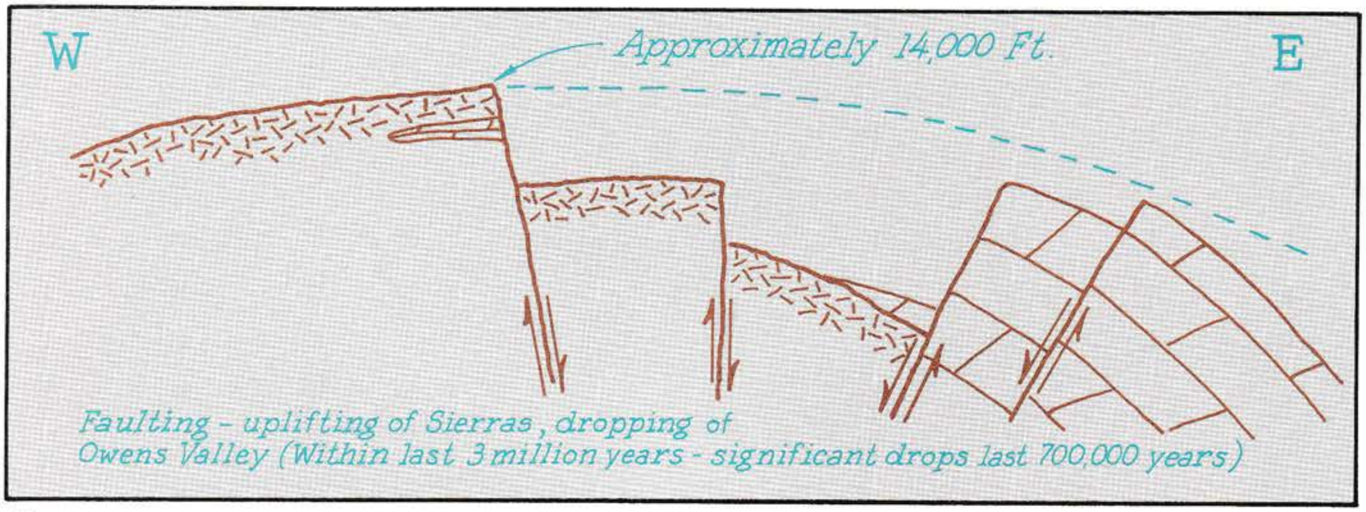

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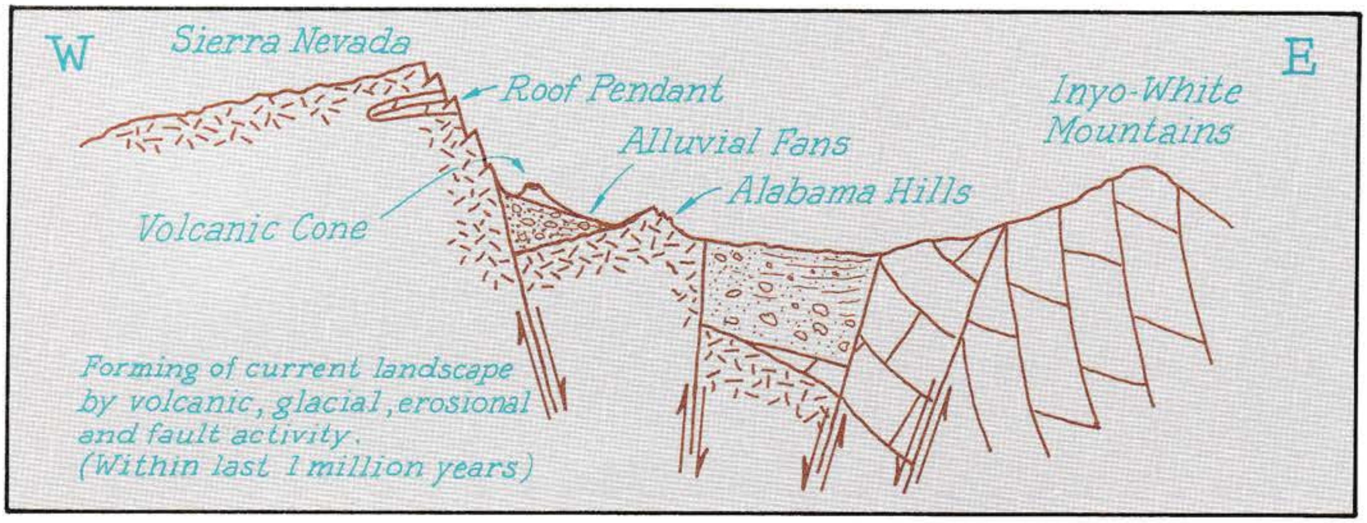

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GEOLOGIC SEQUENCE — OWENS VALLEY

ERA	PERIOD	EPOCH	APPROXIMATE TIME	OCCURRENCE
CENOZOIC (AGE OF MAMMALS)	QUATERNARY	HOLOCENE	6,000 years	Last spilling of Owens Lake
			10,000 years	Last of canyon glaciers
			11,000 years	
		PLEISTOCENE	6,000-65,000 years	Formation of Mono Craters
			700,000 years	Significant faulting—dropping of Valley floor
			1,000,000 years	Deposition of Bishop Tuff
				Formation of first canyon glaciers
			2,000,000 years	
	TERTIARY	PLIOCENE	3,000,000 years	Beginning of faulting
			4,000,000 years	First indications of regional warping and uplift
			12,000,000 years	
		MIOCENE		Continued intrusion of older rocks by granites with accompanying regional uplift (Alabama Hills granites intruded)
			26,000,000 years	
		OLIGOCENE		
			37,000,000 years	
		EOCENE		
			53,000,000 years	
		PALEOCENE		
			70,000,000 years	
MESOZOIC (AGE OF REPTILES)	CRETACEOUS			
			135,000,000 years	
	JURASSIC		150,000,000 years	Beginning of intrusion by granites
			190,000,000 years	
	TRIASSIC			Deposition of older rocks
			230,000,000 years	
PALEOZOIC (AGE OF INVERTEBRATES)	PERMIAN			Deposition of older rock sequence as seen in the Inyo-White Mountains
			280,000,000 years	
	PENNSYLVANIAN			
			(not well defined)	
	MISSISSIPPIAN			
			350,000,000 years	
	DEVONIAN			
			400,000,000 years	
	SILURIAN			
			430,000,000 years	
	ORDOVICIAN			
			500,000,000 years	
	CAMBRIAN			
			600,000,000 years	
PRE-CAMBRIAN				

IGNEOUS ROCK CLASSIFICATION CHART

GRAIN SIZE OR TEXTURE	ROCK NAME / COLOR OF ROCK: LIGHT	MEDIUM	DARK	ORIGIN Where and How Cooled
Glassy . . . no visible grains			OBSIDIAN	Chilled rapidly on surface or in water
Semi-glassy (frothy)	PUMICE			Chilled rapidly . . . contained gas to form bubbles . . . probably blown into the air
Ash-like, sometimes with fragments	TUFF AND TUFF BRECCIA	TUFF AND TUFF BRECCIA		Cooled on surface or air. Fragments ejected into air.
Grains invisible	RHYOLITE	ANDESITE	BASALT	Cooled at or near ground surface
Large grains can be seen	GRANITE	DIORITE	GABBRO	Cooled deep in earth so that grains could grow to large sizes