OLD ROUTES TO THE COLORADO

compiled by

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Cover photograph: Parker Dam at the Colorado River. *R.E. Reynolds photograph*

Back cover map: from Map of the Saline Deposits of the Southern Portion of California. *G.E. Bailey, California Division of Mines Bulletin No. 24, 1902.*

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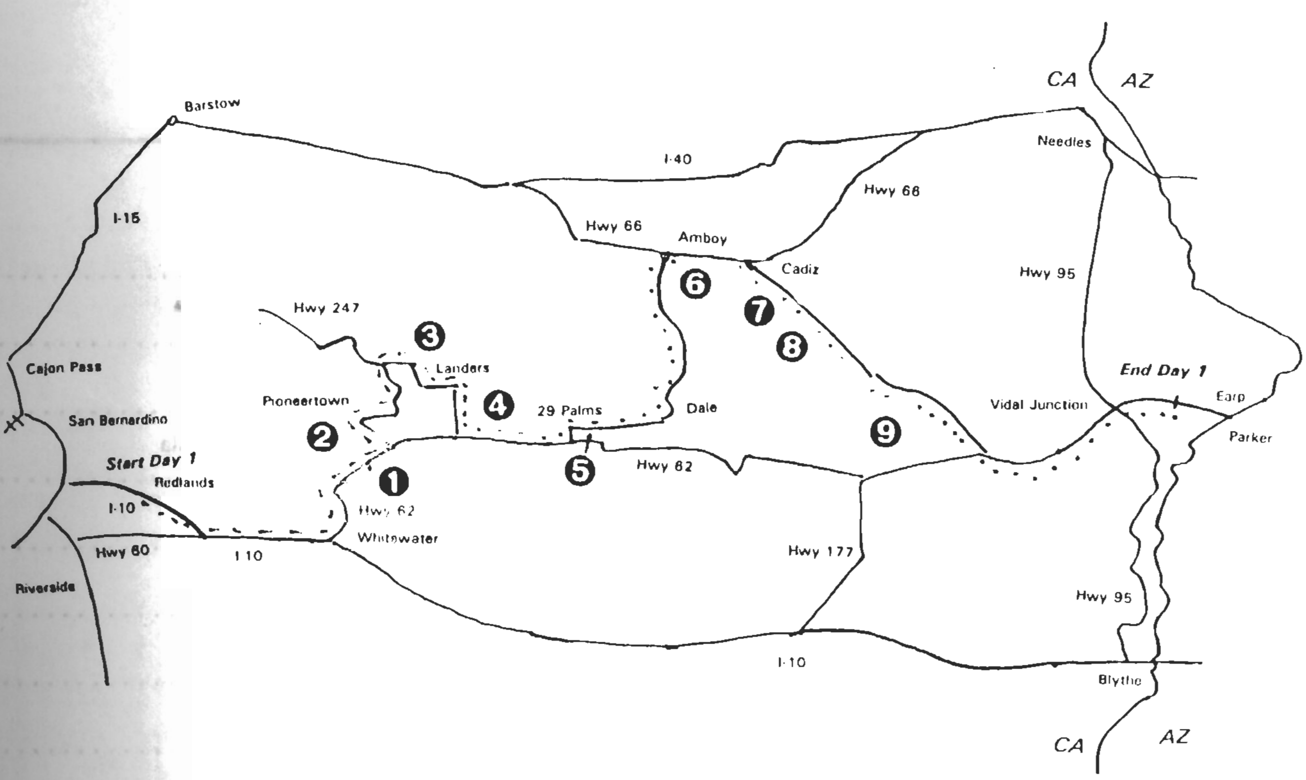

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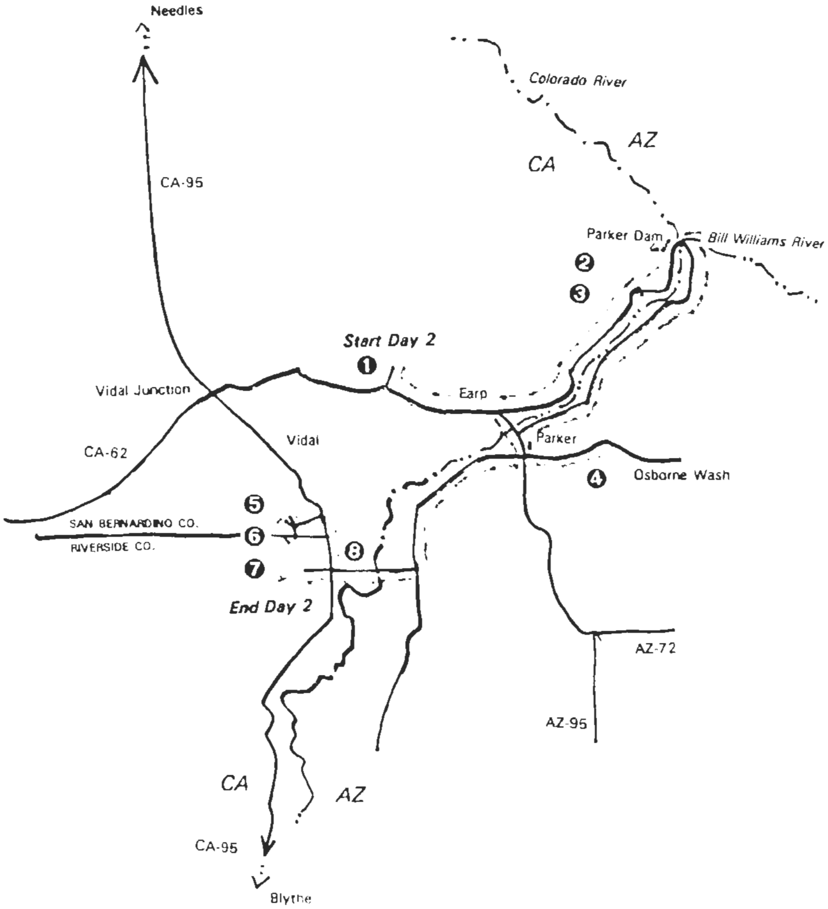

Day 2. The Colorado River Extensional Corridor

Old Routes to the Colorado

The 1992 Mojave Desert Quaternary Research Center Field Trip

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DAY 1

0.0 (0.0) START at the San Bernardino County Museum, 2024 Orange Tree Lane, Redlands. TURN RIGHT from parking lot entrance onto Orange Tree Lane, proceed to California Street.

0.2 (0.2) TURN LEFT at the stop sign onto California Street.

San Andreas Fault Segment

The San Andreas Fault system marks the boundary between the Transverse Range Province and the Penninsular Range Province. The right lateral San Andreas fault system, which includes the San Jacinto Fault to our south, controls the local geography and topography. We will be driving parallel to various components of the San Andreas system as we go southeast toward Palm Springs and Indio (Crowell, 1992).

0.4 (0.2) TURN LEFT onto Interstate 10 East, heading east toward Yucaipa and Palm Springs. Ahead you can see Yucaipa Ridge and San Bernardino Peak (elevation 10,525'). Yucaipa Ridge sits between the north branch (Mill Creek strand) and south branch (San Bernardino strand) of the San Andreas Fault.

Basement rocks similar to those found in the San Gabriel Mountains are overlain by the Mill Creek Formation where it is exposed on Yucaipa Ridge south of the mountain front. The Mill Creek Formation is a series of nonmarine Tertiary sediments deposited in a pull-apart basin (Demirer, 1985; Sadler and Demirer, 1986). The formation contains fossils which suggest an early Pliocene age (Axelrod, p.c. to Reynolds, 1985) but which may be as old as late Miocene or as young as middle Pliocene (Gibson, 1971). The Wilson Creek Fault (Matti and others, 1983 and 1985) crosses Yucaipa Ridge and separates the San Gabriel basement from basement rocks typical of the San Bernardino Mountains.

San Bernardino Peak and Mt. San Gorgonio are part of a complex of Precambrian biotite gneiss and schist, and granitoid gneiss intruded by Mesozoic quartz monzonite and granodiorite (Morton and others, 1980b). The massif was glaciated during the Pleistocene (Sharp and others, 1959; Dibblee, 1964).

2.3 (1.9) Holocene alluvium is on both sides of the freeway; to the right at about 2:00, Smiley Heights is on a Pleistocene alluvial surface with a Pleistocene soil (Reynolds and Reeder, 1986). This Pleistocene surface will be encountered repeatedly throughout the Yucaipa/Banning area.

2.6 (0.3) We are driving over terraced Pleistocene sediments near the Orange Street overpass.

3.8 (1.2) At University Street, the freeway crosses the zanja, California State Historical Landmark 43. The first irrigation project in the county, the zanja was constructed in 1819 and 1820 by Serrano and Cahuilla Indians under the guidance of Franciscan fathers from the Mission San Gabriel to develop agriculture at Guachama, the Indian rancheria near the site of the Asistencia mission branch in Old San Bernardino (Redlands) (Quinn, 1980).

4.2 (0.4) Cypress overpass. We are now driving on Pleistocene alluvium (Qoa of Morton, 1978).

4.8 (0.6) Cross the Redlands Fault, a normal fault which elevated Pleistocene alluvium on its southeast side. The trace runs southwest along Crescent Avenue across San Timoteo Canyon to join the San Jacinto fault zone.

5.1 (0.3) Ford Street off ramp. Houses at 10:00 are built on the Pleistocene erosional surface. The degree of soil development suggests the surface is of late but not terminal Pleistocene age.

6.1 (1.0) Reservoir Canyon. Cross the trace of the Crafton Fault (Reservoir Canyon Fault) offsetting Quaternary alluvium and uplifting Precambrian metamorphic and igneous basement rocks (Rogers, 1967). The Crafton Hills are a faulted complex of upper and lower plate rocks divided by the Vincent Thrust. Octavius Decatur Gass located gold-bearing quartz veins on the Yucaipa side of these hills in 1884. By 1889 the "Gold Bar Company" had developed a 60-foot tunnel and in 1890 the water-powered Yucaipa Quartz Mill had been constructed to process gold ore. The mine property was located in the canyon north of Crafton Hills College water tank; the mill site was in Dunlap Acres near 10th Street (Archer, 1976).

6.4 (0.3) Upper plate gneissic quartz diorite exposed in these road cuts, is separated from lower plate Pelona Schist by the Vincent Thrust. On the left, these exposures of the upper plate gneisses include Permo-Triassic Lowe Granodiorite and cataclasites. Pelona Schist is exposed in the road cuts to the left near the top of Reservoir Canyon.

6.8 (0.4) Marked by trees and bushes to the right, Crystal Springs comes to the surface at the fault trace. These springs supported a small bottled water industry in the past. Reservoir Canyon was named from the municipal water reservoir constructed for the Redlands Colony in 1881 (Archer, 1976).

Much of the Yucaipa area was drained through Reservoir Canyon in late Pleistocene times; the drainage was later captured through Live Oak Canyon (Dutcher and Burnham, 1960). Reservoir Canyon was the site of Maria Armenta Bermudez' pioneering farming activities in the area in 1836, when she raised vegetables for the Los Angeles market. Her crops were irrigated by a ditch dug from the zanja near present-day Crafton (Beattie and Beattie, 1951).

7.4 (0.6) Continue on Interstate 10 past the Yucaipa Boulevard exit. We are crossing from the upper plate rocks of gneissic quartz diorite into Pleistocene alluvium.

8.1 (0.7) Cross the Western Heights Fault, cutting Pleistocene alluvium. This fault, which bounds the Crafton Hills on the southeast, is subparallel to the Redlands Fault.

8.6 (0.5) Mount San Jacinto is seen ahead at 12:00; Pisgah Peak (elevation 5,480') is at 10:30. Pisgah Peak is south of the south branch of the San Andreas Fault and consists of upper plate granitic and granitoid gneissic rocks overlying the Vincent Thrust.

9.2 (0.6) Cross Live Oak Canyon Holocene alluvium.

9.8 (0.6) To the right is deep dissection in the Holocene alluvium overlying eroded Quaternary old alluvium of Live Oak Canyon. The dissection of these recent sediments has occurred since the start of agricultural development in the area, no more than 130 years ago (D. Morton, pers. comm. 1986).

11.2 (1.4) At County Line Road off ramp, we have returned to the Pleistocene surface. Fossiliferous Pleistocene sediments of the San Timoteo Formation beneath the Pleistocene surface are located between this off ramp and Calimesa Blvd. off ramp (Dibblee, 1981; Reynolds and Reeder, 1986 and 1991).

12.0 (0.8) Calimesa Boulevard off ramp. Continue on I-10.

12.5 (0.5) Cross tributary canyon of San Timoteo drainage on flat surface of Holocene alluvium. Here and in the next 0.6 mile, note again the depth of incision that has taken place in little more than 100 years.

14.2 (1.7) Terraces to the right are developed on Pleistocene and Holocene alluvium. The badlands topography is developed in the Plio-Pleistocene San Timoteo Formation (Reynolds and Kooser, 1986; Reynolds and Reeder, 1986, 1991). At 10:00 the terraces have been developed at a lower elevation than the badlands topography, and are truncated at their contact with the San Timoteo Formation. The northeast-striking valleys toward the skyline on the left are controlled by a branch of the Mission Creek Fault and the Vincent Thrust. These faults run northeasterly between the south branch of the San Andreas Fault (San Bernardino strand) and the Raywood Flat area on the skyline to the left (Matti and others, 1983).

14.3 (0.1) Cherry Valley offramp.

15.0 (0.8) Return to the Pleistocene surface. At 9:00, notice again how the Pleistocene terraces are truncated at the dissected San Timoteo Formation.

16.8 (1.8) The San Timoteo Canyon Road offramp enters San Timoteo Canyon. The freeway leaves the Pleistocene surface and crosses badlands topography and valley fill, regaining the Pleistocene surface near the junction of Highway 60. A terrace inset along San Timoteo Creek is about 200 years old (Reynolds and Kooser, 1986).

17.8 (1.0) CONTINUE on Interstate 10. Offramp to I-60 West is on the right.

18.9 (1.1) Beaumont Avenue/Highway 79 exit. Continue on I-10 East.

19.7 (0.8) San Gorgonio Pass is the lowest topographic break in southern California through the mountains to the inland deserts, separating Mt. San Gorgonio (11,502') and Mr. San Jacinto (10,786'), the two highest mountains in southern California. The crest of the pass, although broad and ill-defined, is the complicated junction of three major drainage basins: the interior-draining Whitewater River-Salton Trough to the east via Smith Creek; the generally interior-draining San Jacinto basin to the south via Potrero Creek; and the Santa Ana basin to the west via San Timoteo Canyon. The junction of these three basins is on the crest of an alluvial fan complex 2.5 miles north of I-10 between Noble Creek on the west and Smith Creek on the east.

We leave the Santa Ana basin and cross eastward to the San Jacinto basin. Through rapid headward erosion, Potrero Creek (to the right at 3:00) has progressed northward, extending the northward limit of the San Jacinto basin along the crest of the alluvial fan complex essentially to Highland Springs, 2.5 miles north of Interstate 10.

20.5 (0.8) At Highland Springs Avenue we leave the San Jacinto basin and cross eastward into the Whitewater River drainage, to the right.

21.0 (0.5) At 10:00, the Banning Bench is bounded on the south by an unnamed thrust fault, and capped by the Heights Fanglomerate of Allen (1957). The deposit is dominated by deeply weathered clasts of gray migmatitic gneiss and greenschist (Pelona Schist) which is probably derived from the upper San Gorgonio River area near the juncture of the Mission Creek and San Bernardino strands of the San Andreas Fault. *Bison* remains have been recovered from the Heights Fanglomerate (Jefferson, 1986) indicating that it is less than 500,000 ybp (Savage and Russell, 1983). The Heights Fanglomerate unconformably overlies sediments similar in appearance to the San Timoteo Formation, which coarsens north of the Banning Fault.

From this point eastward to Whitewater, we enter an area dominated by compressional features.

24.1 (3.1) Pass the exit for Highway 243 to 8th Street and Idyllwild.

26.4 (2.3) The houses straight ahead are built on a surface cut by dissected thrust fault scarps (Bortugno and Spittler, 1986; Dibblee, 1982). In the hills to the left, the Banning Fault has thrust basement rocks over non-marine sandstones, siltstones, and conglomerates of the Hathaway Formation. In Lion Canyon, the Hathaway Formation is conformably overlain by the marine Imperial Formation which is in turn conformably overlain by the nonmarine Painted Hill Formation. Elsewhere, the Hathaway Formation is directly overlain by the Painted Hill Formation (Allen, 1957). These three formations, Pliocene in age, are caught up between thrust faults along the base of the mountain front from this point to Stubbe Canyon (Allen, 1957; Dibblee, 1982). Allen (1957) divided the Hathaway Formation into two members, a sandstone-dominated lower member and a conglomerate-dominated upper member distinguished by clasts of laser gneiss derived from an area north of the Banning Fault between Cottonwood and San Gorgonio canyons. He also mentioned rare clasts of silicified limestone without speculating upon their possible source.

The San Gorgonio igneous-metamorphic complex in this area is predominantly migmatitic gneiss with intrusions of quartz monzonite (Morton and others, 1980b).

27.0 (0.6) The Cabezon Fanglomerate (lower hills straight ahead) has been anticlinally folded and cut by thrust faults. The Quaternary Cabezon Fanglomerate includes gravels from a variety of sources.

27.6 (0.6) To the left, beneath the water tank, is the most youthful thrust fault scarp in this area related to compression associated with activity along the Banning Fault. At this point, the scarp changes orientation from a northwest strike to a northeast strike.

28.3 (0.7) To the right at 1:00 is the north portal of the San Jacinto Tunnel, a part of the Colorado River Aqueduct system. It cuts through the Paleozoic? metasediments (quartzofeldspathic gneiss and schist, phyllite, quartzite, and marble) intruded by quartz diorite of Mt. San Jacinto (Morton and others, 1980a).

To the left is Millard Canyon; a fault scarp crosses the alluvial fan near the canyon mouth. The debris of the Millard Canyon fan overwhelms debris from Mt. San Jacinto. Drainage to the base of Mt. San Jacinto is thus forced eastward from this point to the Whitewater River.

28.9 (0.6) Cabezon exit. Continue along freeway. To the right, the steep escarpment of the San Jacinto Mountains is interpreted to be the result of uplift on the postulated South Pass Fault (Allen, 1957).

31.2 (2.3) Dinosaurs to the north!!

31.5 (0.3) Good exposures of the Cabezon Fanglomerate are to the left. Hathaway, Imperial and Painted Hill sediments are thrust over the Cabezon Fanglomerate and are in turn overthrust by the San Gabriel igneous-metamorphic complex. Landslides are common at the noses of the ridges. To the left at 11:00, Lion Canyon is bounded on the east by a large landslide. The upper "boundary" of this landslide is in the Cabezon Fanglomerate and, as shown by Allen (1957), is convex and points to the south. This is contrary to a landslide headscarp and, because pressure ridges are also apparent within the landslide, suggests that the feature is the result of "bulldozing" by a larger mass to the north and not simply a slope failure.

32.4 (0.9) A thrust in the basement rocks to the left at 10:00 at Stubbe Canyon is seen where pink piemontite-bearing rocks are thrust over green epidote-bearing rocks. The distinctive piemontite-bearing gneisses are found as clasts in sediments north and south of the Banning Fault. Since the source area is of limited extent, this has proven useful in estimating fault offset as well as identifying source areas and transport directions (Allen, 1957).

33.2 (0.8) The Banning Fault changes from a low angle fault to a steep angle fault (Reynolds and Kooser, 1986).

34.3 (1.1) Based on geophysical evidence, the ridge of metamorphic rocks (ahead at 12:00 extending from Mt. San Jacinto) continues beneath the alluvium to a point north of the freeway and northward of the southernmost thrusts characteristic of the San Bernardino Mountains' side of the pass. This ridge reduces the energy of the strong winds which are regularly funneled through San Gorgonio Pass, and dune sands are deposited against it.

35.2 (0.9) Whitewater Gravels of the Cabezon Fanglomerate are to the left at 11:00 (Whitewater Hill). The gravels are capped by a Pleistocene soil.

36.0 (0.8) Verbenia exit; continue on Interstate 10.

36.7 (0.7) Highway 111 to Palm Springs passes through the old Whitewater Ranch property. Do not exit. Landslide deposits are to the left.

37.0 (0.3) To the left, the Garnet Hill Fault disrupts alluvium 2/3 of the way from the freeway to the base of the hills. The fault runs across the mouth of Whitewater Canyon where it is visible at 9:00. The fault trace is exposed only west of Whitewater River. Based on trenching between Cottonwood and Whitewater Canyons, there is no evidence for Holocene activity on the Garnet Hill Fault (Reeder, p.c. 1986, cited in Reynolds and Kooser, 1986). The Garnet Hill Fault displaces Pleistocene-age Whitewater gravels of Windmill Hill (Allen, 1957). To the east, its trace is covered by alluvium and the main evidence for its existence within the Coachella Valley is a strong gravity anomaly. Gravity low contours define a trough which is almost as well delineated as the gravity troughs associated with the Banning and Mission Creek faults (Proctor, 1968). Proctor suggests that the Garnet Hill Fault may be an ancestral branch of the San Andreas Fault.

37.6 (0.6) South of the Interstate, large cottonwood trees and scant building ruins mark the site of the Whitewater Ranch headquarters. Pauline Weaver and Isaac Williams were the first Anglos to own land in the San Gorgonio Pass; their San Gorgonio Rancho was granted in 1845 and encompassed the entire pass area. Weaver sold a portion of the rancho to Isaac Smith in 1853; this purchase, which included the land from Beaumont to Palm Springs, was to develop into the Whitewater Ranch. The riparian water rights from the Whitewater River granted in 1850 passed with the ranch to successive owners and allowed ranching to continue. The site was also a regular freight and stage stop along the Butterfield route (Stocker, 1973).

37.8 **(0.2)** Rest area at Whitewater Ranch site.

38.5 **(0.7)** Whitewater Road exit; continue on I-10.

39.0 **(0.5)** Beneath the three buildings at 11:00 (left) is the reverse fault scarp of the Garnet Hill Fault.

39.3 **(0.3)** Cross the Whitewater River.

39.8 **(0.5)** The north side of the freeway runs along the trace of the Garnet Hill Fault next to Whitewater Hill. To the left are Pleistocene fan sediments of the Cabezon Fanglomerate separated from the Imperial and Painted Hill formations (Murphy, 1986) by the Banning Fault. The Cabezon Fanglomerate of Whitewater Hill includes a lens of limestone breccia believed to have been derived from the San Jacinto block (Allen, 1957). Proctor (1968) notes that Whitewater Hill has been uplifted so recently that relict drainages exposed on its surface do not conform to its current topography.

Move to the right lane and prepare to exit.

40.7 **(0.9)** EXIT RIGHT on the Yucca Valley—29 Palms offramp, following Highway 62 northward over the freeway.

41.1 **(0.4)** View southeast down the axis of the Salton Trough. The Garnet Hill Fault trace is on the south side of the low hills (Garnet Hill).

42.2 **(1.1)** Dillon Road. Red exposures at the Whitewater Rock Quarry are visible to the left at 9:00.

42.6 **(0.8)** To the right at 1:00, the trace of the Banning Fault is expressed as shutter ridges between the powerline and windmills. Devers Hill protrudes through the alluvium to the right.

42.9 **(0.3)** Cross the Banning Fault over the next 0.1 mile.

44.8 **(1.9)** Pierson Blvd. Mt. San Gorgonio is viewed to the left at 10:00; to the right at 2:00 are the Little San Bernardino Mountains.

46.4 **(1.6)** Mission Creek Road crosses Highway 62. To the left are dissected Mission Creek alluvial deposits cut by northeast-striking faults with the east side down. To the right at 2:00 is a fault-bounded prism of pinkish sediments against the mountain front which is bounded by the Mission Creek strand of the San Andreas fault system.

47.1 **(0.7)** Cross Mission Creek Wash for the next 0.3 miles.

47.9 **(0.8)** Indian Avenue; continue on Highway 62.

48.1 **(0.2)** Cross the Mission Creek Fault of the San Andreas fault system as you head up Dry Morongo Canyon, entering Mesozoic deformed pluton and Precambrian gneiss. We are leaving the segment of the field trip that is controlled by the right lateral San Andreas fault system and entering the segment of the trip that is influenced by the left lateral Pinto Mountain fault system.

Pinto Mountain Fault Segment

A portion of the Transverse Range Province lies north of the San Andreas fault system and south of the left lateral Pinto Mountain Fault. The Pinto Mountain Fault is a major left-lateral fault which represents the southern structural boundary of the Mojave block (Dibblee, 1992). The Mojave Desert is characterized by a series of active northwest-trending right lateral faults. These faults apparently terminate at or are truncated by the Pinto Mountain Fault. We will be traveling parallel to the left lateral Pinto Mountain Fault until we reach Twentynine Palms.

50.4 **(2.3)** Cross the trace of the Morongo Valley Fault, trending northeast towards Morongo Summit, where it intersects with the Pinto Mountain Fault.

50.7 **(0.3)** To the left is perched alluvium.

51.0 **(0.3)** The highway enters fault-bounded Morongo Valley, with the Pinto Mountain Fault on the north side of the valley and the Morongo Valley Fault on the south side. Morongo Valley drains southward into the Whitewater drainage, which runs through the Coachella Valley and into the Salton Sea.

52.2 **(1.2)** Covington Park and the Big Morongo Wildlife Refuge are to the right via East Drive. The nature reserve is a habitat for more than 240 species of resident and migrant birds as well as a sanctuary for mammals including big horn sheep. Permanent water, brought to the surface at springs along the Morongo Valley Fault, supports a lush riparian community. Continue on Highway 62.

52.7 **(0.4)** A landfill is to the right at 2:00. Note that ridges are terminated by the *en echelon* Morongo Valley Fault east of Big Morongo Canyon. The terrace at the east end of the landfill is capped by a well-developed red soil horizon.

54.0 **(1.3)** The Pinto Mountain Fault runs on the north side of the valley north of the highway. As you look ahead toward the pass, you see the intersection of the Pinto Mountain Fault and the Morongo Valley Fault.
56.3 **(2.3)** Pass Ole Street.

56.5 **(0.2)** Light gray granitic bedrock to the left is separated from overlying brownish granitic bedrock by low angle faults and shears. Note the vegetation growth along the fault contacts. North, at 9:00, the Pinto Mountain Fault crosses near the house (at 11:00) and water tank.

57.0 **(0.5)** Pass Highland Street.

57.7 (0.7) Pass Hoopa Road.

58.0 (0.3) Morongo Valley Park. The contact above the shooting range exhibits gray granitic bedrock below overlying reddish bedrock.

58.4 (0.4) The leveled pad at 2:00 on right exposes vertically dipping braided stream deposits.

59.0 (0.6) We are entering the Yucca Valley drainage, which runs eastward along the Pinto Mountain Fault to Copper Basin, and then eastward to Mesquite Lake at Twentynine Palms.

59.5 (0.4) TURN RIGHT off Highway 62 onto Piñon Drive; proceed up hill.

59.7 (0.2) TURN RIGHT on Navajo; proceed to end.

Figure 1. Stop 2. White arkosic sediments capped by basalt north of Pioneertown. *R.E. Reynolds photo.*

60.0 (0.3) STOP 1. PINTO MOUNTAIN FAULT SEDIMENTS. (see Grimes, this volume). Park at end of cul de sac; do not enter private property. We are near the intersection of the Pinto Mountain Fault and the Morongo Valley Fault. From this vantage point, note the sediments to the north, which contain clasts of basalts with ultramafic inclusions (kaersutite). This fanglomerate overlies and is in fault contact with the quartzite fanglomerate which composes the relatively flat surfaces to the south. The basin between us and these surfaces contains finer-grained arkosic sediments which dip steeply to the north. The arkose is a fault-bounded wedge unconformably overlain by the capping quartzite fanglomerate (Grimes, 1986).

Return to Highway 62, preparing to turn east (right). The Sawtooths are visible against the horizon at 1:00.

60.5 (0.5) TURN RIGHT onto Highway 62 and continue easterly. Look ahead for the flashing yellow traffic lights, where we will be turning left.

62.1 (1.6) TURN LEFT on Pioneertown Road, just past flashing yellow pedestrian crossing lights. To the right, this road is called "Deer Trail". The drainage here runs to Copper Basin.

62.2 (<0.1) Stop sign at Yucca Trail. Proceed ahead on Pioneertown Road.

62.7 (0.5) Cross the most northern suspected trace of the Pinto Mountain Fault as mapped by Dibblee (1967a).

64.5 (1.8) Water Canyon Fault. Notice that the fluviatile sediments past Water Canyon, exposed below the terrace on the left, are undisturbed by the Water Canyon Fault.

65.0 (0.5) During the Tertiary, granitic basement rocks were deeply weathered along joint sets (Oberlander, 1972). Recent weathering has exposed this boulder terrain in the Sawtooths.

65.9 (0.9) Ahead and to the right are the dark Pioneertown Basalts and white patches of Tertiary sediments. The Pioneertown Basalts cover an area of approximately 22 km^2 and may reach a thickness of 60 m. The pile is made up of individual flow units three to seven m thick, each capped by a terminal vesiculated or amygdoloidal top. Eight or nine individual flow units have been observed in the thickest portion of the pile. These basalts are alkali olivine in composition (Neville, 1983); potassium/argon dates for similar flows range from 6.9 to 9.3 Ma (Morton, p.c. 1985, cited in Reynolds and Kooser, 1986; Peterson, 1976; Oberlander, 1972). The basalts overlie and are interbedded with Tertiary arkose deposits and overlie granitic basement. In some places, Tertiary granitic soil horizons are preserved beneath the flows (Oberlander, 1972). The basalts are correlative, in terms of time and petrogenesis, with other alkaline volcanics found throughout the Mojave Desert, such as Cima Dome, Amboy Crater, Dish Hill, and Pisgah Crater (Neville, 1983; Neville and others, 1985, and see Reynolds, this volume; Lawton, this volume; and Hazlett, this volume).

66.3 (0.4) Pioneertown was built as a set for western movies. It was named by Dick Curtis, an actor, on Labor Day 1947 (Gudde, 1974).

66.7 (0.4) Pavement turns right 90 degrees to the northeast; continue along Pioneertown Road. Chaparrosa Springs is in bedrock to the left.

67.0 (0.3) Cross Chaparossa Wash.

67.5 (0.5) Leaving wash, proceed along road to top of terrace; prepare to turn right.

67.8 (0.3) TURN RIGHT onto dirt road marked with rock gate structure and wooden post. Take roads to left, watching for vehicle-size ruts.

68.1 (0.3) STOP 2. TERTIARY PIONEERTOWN SEQUENCE. Park within view of Pioneertown Basalts overlying and interfingered with Tertiary arkose. Tertiary sediments are rare in the eastern San Bernardino Mountains. This section has been referred to as the Old Woman Sandstone by Dibblee (1967b), but the difference in clast lithologies and the age of the overlying basalts indicate that their age and source differ significantly from the Old Woman Sandstone. Similarly, lithology and stratigraphy distinguish this arkose from the Santa Ana Sandstone Fragmentary vertebrate fossils appear to corroborate an age greater than 7 Ma but less than 15 Ma for the lower silty sediments, which suggests they are time correlative with the upper portion of the Crowder Formation in Cajon Pass (Reynolds, this volume).

Walk ahead about 0.2 mi to road cuts exposed faulted sediments. In the cut you can see, from lowest: (1) low energy deposition of brown silty sands and paleosols; (2) higher energy deposition of arkosic sands; (3) vertical faults offsetting the sedimentary section downward, to the east; (4) a possible erosional surface and soil which may have formed prior to basalt flows; and (5) 6.9—9.3 Ma basalts laid down on undulating topography and interfingering with arkose.

Piñon, juniper, joshua tree, scrub oak, manzanita, Mojave yucca, and nolina are members of this handsome plant community (Fig. 1).

RETRACE ROUTE along ruts to pavement.

Figure 2. Stop 3. Pleistocene sediments capped by a dense layer of calcium carbonate along Linn Road. *R.E. Reynolds photo.*

68.4 (0.3) TURN RIGHT onto Pioneertown Road and resume route northwest. The basalts appear to have flowed over a gently undulating surface and are thickest to the southeast. The apparent flow direction was roughly northeast to east. The location of the source vent of these volcanics is unknown (Vaughan, 1922).

70.2 (1.8) TURN RIGHT onto Pipes Canyon Road; proceed northwest.

70.5 (0.3) View ahead of mesas of the Pioneertown basalt flow including Flat Top Mountain to the northeast and Black Hill to its south.

70.8 (0.3) Cross Pipes Wash. Water rises to the surface in Pipes Wash as a result of the shallow bedrock between the volcanic tablelands.

73.3 (2.5) To the right at 1:30, note the crude columnar jointing in basalts overlying a middle Tertiary erosional surface that developed on granitic rocks.

74.3 (1.0) Approximately 8 individual flow units make up the basalt pile to the left.

74.8 (0.5) Coarse Pleistocene gravels are deposited against Tertiary arkose to the south at 2:00 in the bank of Pipes Wash. The dark varnish on the basalt scree at 10:00 indicates that this debris may have been stable since middle Pleistocene times.

76.3 (1.5) Quaternary stream deposits of Pipes Wash are exposed to the left and in road cuts. Pipes Wash and Chaparossa Wash drain northerly and empty into Emerson Lake basin.

76.9 (0.6) Reach Old Woman Springs Road, Highway 247, GO NORTH (LEFT) towards Flamingo Heights.

78.8 (1.9) Pass Chaparral Road to the left in downtown Flamingo Heights.

80.6 (1.4) Hondo Street. Continue on Highway 247.

81.7 (1.1) A deep wash from Bolo Springs cuts through Pleistocene sediments.

82.2 (0.5) Reche Road. Continue north on Highway 247.

82.9 (0.7) New Dixie Mine Road. To the west are mantle xenoliths discussed by Neville (1986).

84.0 (1.9) Lum Lane. Prepare to turn right at Linn Road.

84.5 (0.5) TURN RIGHT (east) onto Linn Road.

84.6 **(0.1)** Cross the trace of the Johnston Valley Fault. We are between the left lateral Pinto Mountain Fault (the southern margin of the Mojave Desert Province); the northern margin of the province is the left lateral Garlock Fault, 90 miles north. The right lateral San Andreas Fault forms the southwest margin of the Mojave Desert Province.

87.7 **(3.1)** **STOP 3. HOMESTEAD VALLEY FAULT.** Park off pavement. Linn Road cuts through Pleistocene sediments: red-brown gravel, gray-brown sands, capped with a 2-foot layer of dense calcium carbonate (Fig. 2). The sharp contact between the sediments and the carbonate layer suggest that the layer is not of pedogenic origin, but may be the result of a groundwater barrier and associated springs. The Homestead Valley Fault is immediately east (see Umbarger, this volume) and Pipe's Wash drainage follows the fault for a short distance.

The Mojave Desert Province is cut by a series of northwest-trending right lateral faults that parallel the San Andreas Fault. The Johnston Valley Fault is the first of these northwest-trending faults that we will cross. We will also cross, in order, the Homestead Valley Fault, the Copper Mountain Fault, the Hidalgo Mountain Fault, the Emerson Fault, and the Mesquite Lake Fault.

Continue east on Linn Road. Goat Mountain is west; Giant Rock is 2 miles east.

87.8 **(0.1)** TURN RIGHT onto Belfield Blvd, proceed 2 miles south to Reche Road. We are paralleling the projected trace of the northwest-trending Homestead Valley Fault (Hill and others, 1980).

89.9 **(2.1)** Stop sign. Go east (left) on Reche Road. Cross Pipes Wash drainage which runs north into Emerson Lake basin.

90.5 **(0.6)** Pass Landers Road.

92.4 **(1.9)** Hidalgo Mountain, north, is bounded on the north by the West Calico Fault and on the south by the Hidalgo Mountain Fault. Gypsum Ridge, the low ridge at 9:30 southeast of Hidalgo Mountain, consists of Pleistocene lacustrine sediments deformed along the West Calico Fault (Dibblee, 1967; Knauer, 1982).

96.0 **(3.6)** TURN RIGHT (south) on Border Avenue. Cross the trace of the Emerson Fault near its intersection with Copper Mountain Fault, which runs southeast at 10:30. We are driving over calichified Pleistocene fans, and we have left the Emerson Lake drainage system and have entered the drainage which runs northeast to Deadman Lake and Bouillon Wash. Surprise Spring, which is the locality of a Pleistocene fauna discussed by Jefferson (this volume) is to the east-northeast at 8:00.

100.0 **(4.0)** TURN LEFT onto La Brisa Drive, a graded dirt road. We have left the Deadman Lake drainage and have entered the drainage that runs parallel to the Pinto Mountain Fault and then to Copper Basin and Mesquite Lake.

102.2 **(2.2)** VIEWPOINT. Copper Playa is at 2:00, in front of Copper Mountain (Reynolds and Jenkins, 1986), visible at 12:00 and extending to the southeast. The Copper Mountain Fault is on the west side of Copper Mountain and cuts southeasterly through the mountain. The view also includes eroded granitic rocks of the Little San Bernardino Mountains on the distant skyline, part of Joshua Tree National Monument.

103.1 **(1.1)** TURN RIGHT onto Sunfair, a paved street (except not at the intersection).

104.5 **(1.4)** Playa sediments (elevation 2380') of Copper Basin are at an elevation 20' higher than the present-day playa surface (which contained water in February 1992).

106.8 **(2.3)** Pass the High Desert Airport on the outskirts of Sunfair.

107.4 **(0.6)** TURN LEFT onto Pole Line Road. We are traveling parallel to the trace of the Pinto Mountain Fault. Copper Basin playa, to the north (left), receives water from Yucca Valley and, during the Pleistocene, may have overflowed eastward into Mesquite Lake.

108.4 **(1.0)** Intersection of Cascade Road. Continue on pole line road.

108.9 **(0.5)** **STOP 4. COPPER BASIN LACUSTRINE SECTION.** Green lacustrine sediments capped by caliche on the south side of the Pinto Mountain Fault contain Pleistocene vertebrate fossils (Fig. 3).

109.4 **(0.5)** Arkosic sediments dip steeply to the southwest on the south side of the Pinto Mountain Fault (Fig. 4). The intersection of the left lateral Pinto Mountain Fault and the right lateral Copper Mountain Fault is approximately 3 miles ahead (east) on the east side of Copper Mountain.

109.6 **(0.2)** Saddle at elevation 2410+'. If Copper Basin filled during the Pleistocene, it would have drained here. Lacustrine sediments seen at Stop 4 are at the elevation of this saddle. Notice the dissected terraces with well-developed soil on the south side of Copper Mountain.

109.8 **(0.2)** TURN RIGHT (south).

110.0 **(0.2)** TURN RIGHT (west).

110.3 **(0.3)** TURN LEFT (south) at intersection of dirt road and Rotary Way.

111.0 **(0.7)** TURN LEFT (east) at stop sign at intersection of Rotary Way and Highway 62.

111.9 **(0.9)** Twenty-nine Palms city limits. *Make certain your vehicle gets fueled in Twentynine Palms; the next reliable gas stop is not until Parker.*

114.3 **(3.4)** Indian Cove Road. Continue on Highway 62.

Figure 3. Stop 4. Green lacustrine sediments at Copper Basin. *R.E. Reynolds photo.*

114.6 (0.3) To the north at 10:00 is a thick section of Pleistocene sediments between the Hidalgo Mountain Fault, on the east side of Copper Mountain, and the Mesquite Lake Fault. These sediments are cut by the drainage from Copper Basin into Mesquite Lake. The bend in the drainage is on the east side of the Hidalgo Mountain Fault.

118.1 (3.5) Larrea/Manzanita Avenue. Continue on Highway 62. We are driving easterly along the trace of the Pinto Mountain Fault. The southeast branch of the Pinto Mountain Fault runs to the south side of Donnell Hill, south of Hwy 62.

119.1 (1.0) Mesquite Springs Road. We are on the trace of the Pinto Mountain Fault as Highway 62 goes up the mid-Pleistocene alluvium of Donnell Hill.

119.6 (0.5) TURN RIGHT on Boullion Avenue; proceed south.

119.7 (0.1) Stop sign at Cactus Drive.

119.8 (0.1) Stop sign at Old Dale Drive.

119.9 (0.1) Cross the trace of the southeast branch of the Pinto Mountain Fault. Notice scarp on the south side of Donnell Hill.

120.1 (0.2) TURN LEFT (east) at stop sign at intersection with Sullivan Road.

120.6 (0.5) TURN LEFT (north) at stop sign onto Adobe Road.

120.7(>0.1) TURN RIGHT (east) onto Cottonwood Drive; the pavement turns to dirt. Pass the 29 Palms Inn. Groves of native palm trees grow along the trace of the Pinto Mountain Fault (Cornett, 1991).

121.2(<0.4) Stop sign. TURN RIGHT onto National Monument Drive. Go south, then east along the trace of the Pinto Mountain Fault. The palms on the right are on the trace of the Pinto Mountain Fault.

121.8 (0.6) Stop sign at Utah Trail and the Joshua Tree National Monument Visitor Center. TURN LEFT (north) and proceed along Utah Trail.

122.2 (0.4) Stop sign at Twenty-nine Palms Highway. Continue north on Utah Trail.

122.5 (0.3) Utah Trail cuts through calichified sediments below desert pavement. Campbell Hill is to the northeast at 2:00.

123.3 (0.8) Stop sign at Two Mile Road.

124.0 (0.7) TURN RIGHT (east) onto Michaels Road.

Figure 4. Arkosic sediments dip steeply near the pass at Copper Mountain. *R.E. Reynolds photo.*

124.2 (0.2) Cross the flood control drainage. The pink house (ahead) belonged to Elizabeth W.C. and William H. Campbell, famous for their investigative archaeologic work in this area (Campbell and Campbell, 1935).

124.4 (0.2) At the first pole line, cross the trace of the Mesquite Lake Fault.

124.5 (0.1) TURN SHARP RIGHT (south) on dirt track; do not take the road to the Campbell home.

124.7 (0.2) Drive through limonite-stained sediments along the trace of the Mesquite Lake Fault.

124.8 (0.1) STOP 5. CAMPBELL HILL. Late Pleistocene sediments at Campbell Hill (Fig. 5) have been uplifted along the northeast side of the Mesquite Lake Fault (Dibblee, 1968; Jagiello and others, 1992; and see Foster, this volume). Vertebrate remains are typical of the Rancholabrean Land Mammal Age and include ground sloths, dwarf pronghorn, sabertooth, mammoth, horse, and camel (Jefferson, this volume). Bachellor (1978) tentatively identified the Bishop Tuff in the section, which is dated at 0.73 Ma.

The Bullion Mountains are due north; Hidalgo Mountain is N30°W, and Gypsum Ridge the low ridge to the right. The Rodman Mountains are left of Hidalgo Mountain. Copper Mountain is due west and Goat Mountain is N55°W, just to the left of a rise in the Pleistocene sediments which lie between the Emerson/Copper Mountain Fault and the Hidalgo Mountain Fault.

USE CAUTION WHEN TURNING AROUND; it is very sandy. RETRACE route to Utah Trail.

125.7 (1.9) Stop sign. TURN RIGHT (north) on Utah Trail.

125.9 (0.2) Stop; TURN RIGHT on Amboy Road. Shortz Lake (elevation 1795′) is one-half mile northwest, and Mesquite Lake is about 2.5 miles further north-northwest. If Dale Lake received water from the Mesquite Lake basin, the basin would have been filled to an elevation of 1800′.

127.0 (1.1) We are between the Mesquite Lake Fault and the north branch of the Mesquite Lake Fault. The drainage one mile north of the road leads to Dale Lake.

130.4 (3.4) Enter calichified Pleistocene sediments. We are going north into Wonder Valley from the Pinto Mountains. Note the thick sequence of sediments uplifted at the base of the Pinto Mountains near the junction of the Bullion Mountain Fault and the combined trace of the Mesquite Lake Fault.

130.6 (0.2) An energy-efficient jojoba farm is on the right.

132.0 (1.4) Cross the approximate trace of the northwest-trending Bullion Mountain Fault.

133.6 (1.6) Wonder Valley Fire Station. We are beginning to enter the sand dunes of the Dale Lake system, visible to the south against the Little San Bernardino Mountains.

136.9 (0.3) "The Palms" watering hole is to the right.

142.7 (5.8) Barnett's Trading Post (no gas). Look right to Dale Lake. The Dale Lake salt works are in the playa surface at 1:00, below Clarks Pass (see Gundry, this volume, for a summary of salt production in the playas we will cross). Dale Lake (elevation 1200′) is an internally drained basin that may have received overflow waters from Yucca Valley (3400′), Copper Basin (2400′), and Mesquite Lake (1750′) during Pleistocene times. Schroth (this volume) reviews the prehistory of this area; Tchakerian (this volume) discusses the dune field at Clarks Pass.

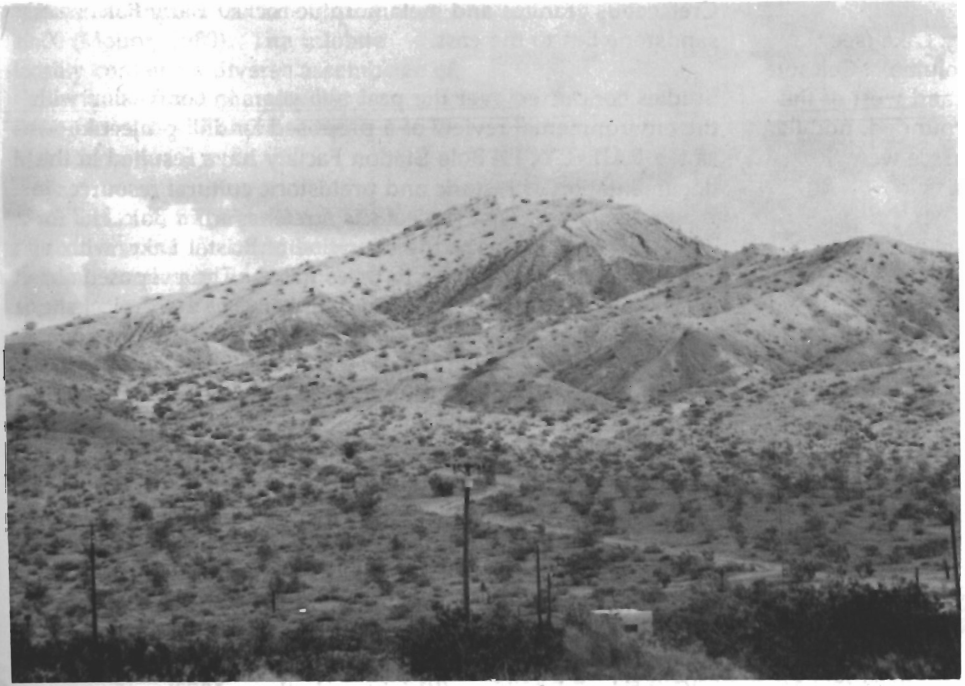

Figure 5. Stop 5, Campbell Hill. *R.E. Reynolds photo.*

143.1 (0.4) Road bends northeast. The Sheep Hole Mountains are at 2:00.

144.1 (1.0) We are crossing the trace of a northwest-trending fault that runs through the eastern Bullion Mountains and projects toward the trace of the Ludlow fault zone.

145.8 (1.7) A northwest-trending fault is mapped as separating the steep granitic escarpment of the Sheephole Mountains from dissected, calichified alluvial fans or debris flows. When we reach Sheep Hole Pass, we will cross a pediment where no alluvial fans are preserved.

Bristol/Danby Trough Segment

148.6 (2.8) Sheep Hole Summit, elevation 2368′. Microwave relay tower

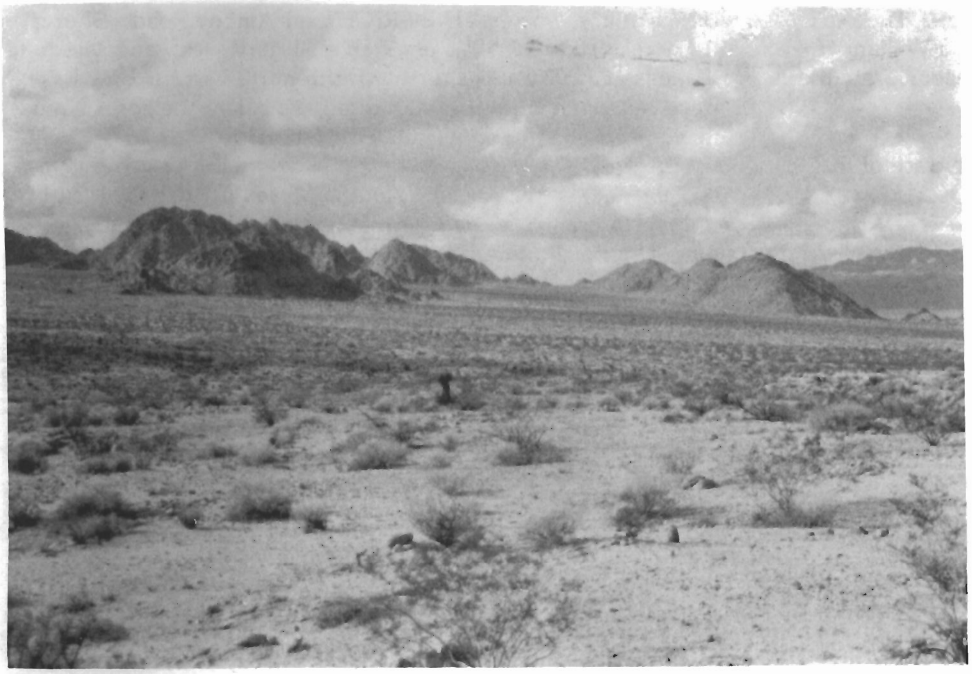

Figure 6. Sheep Hole Mountains Pass, where no fanglomerates are preserved at the base of the peaks on the granitic pediment. *R.E. Reynolds photo.*

is on the right. Look to the west at the eroded granitic pediment; there are no fanglomerates preserved at the base of the peaks, which rise steeply from the pediment (Fig. 6). Further north along the highway we can see the Granite Mountain pediment at the base of the light-colored Granite Mountains (Edinger, 1990).

We are driving downhill into the Bristol Basin (Gardner, 1980; Howard and Miller, 1992; and see Brown and Rosen, this volume). Jachens and Howard describe the structure of the Bristol/Cadiz trough (this volume).

165.2 (16.6) The south margin of Bristol Dry Lake (see Rosen, this volume; Brown and Rosen, this volume). Celestite (strontium sulphate) is found for 3 miles east and west of the highway at the south end of the playa. The rounded, nodular, potato-like masses in muds on or near the surface were exposed by dozing (Gale, 1951; Durrell, 1953).

166.2 (1.0) Salt growth on playa has caused heaving of crust on west side of road (left)

167.0 (0.8) The National Chloride salt plant (Wright and others, 1953; and see Gundry, this volume).

167.4 (0.4) The very rare mineral Antarcticite has been recovered from a trench on the west side of road (Muehle, 1970). This mineral is stable only under very restricted environmental conditions; it is difficult to find, complicated to collect, and nearly impossible to store.

169.4 (2.0) View at 10:00 of Amboy Crater and Amboy basalt flows (see Hazlett, this volume).

170.3 (0.9) View of weathered flows near the road. Brown and Rosen (this volume) note that flows occur 30′ below the elevation of the playa surface.

172.4 (2.1) Slow down; sharp bend to the west is 30 mph

173.2 (0.8) STOP at intersection with National Trails Highway. TURN RIGHT onto National Trails Highway, cross over railroad tracks. The western section of the National Old Trails Highway opened between 1911 and 1914; it was the last portion of the highway that crossed the continental United States to open. The general route was originally a Mojave travel and trade trail from the Colorado River to the California coast (Smith and others, 1969).

174.0 (0.8) Amboy. In February, 1992, you could buy gas here during daylight hours.

176.5 (2.5) Pass a road on right that leads to Saltus; continue on National Trails Highway.

179.9 (3.4) STOP 6. BRISTOL BASIN. Kelbaker Road, on left, leads to Interstate 40 (no gas available). Bolo Hill, reached by a gravel road 0.3 miles east of the Kelbaker Road junction with National Old Trails Highway, marks the trace of lineaments discussed by R.E. Reynolds (this volume). The historic route that led to Needles runs to the south of Bolo Hill, to the southerly tip of the Marble Mountains, and then northeasterly to avoid this rugged range. Note volcanic tuff and flows of the Marble Mountains (north) overlying Cretaceous granites and metamorphic rocks. Early Paleozoic sandstone lies to the east.

Studies conducted over the past two years in connection with the environmental review of a proposed landfill project known as the RAIL•CYCLE Bolo Station Facility have resulted in the documentation of historic and prehistoric cultural resources in the project area. That project site stretches from Bolo Hill for a distance of four miles to the shoreline of Bristol Lake, with a width that varies from one to three miles. The proposed landfill will be located on the southern half of the project site, on the opposite side of the railroad. The area between your location and the railroad is to be maintained as a desert preserve. Based on the cultural resources studies conducted for the RAIL•CYCLE project, a brief review of the historic, ethnographic, and prehistoric background of the area is presented by Lerch (this volume).

The Hope-New Method mine is approximately 1 mile north along Kelbaker Road. Collectors have recovered a variety of uranium minerals, including rare fluoborite, at this prospect. The Iron Hat mine, at 10:0, was mined in the 1940s; the iron ore (hematite and magnetite) occurred in small, shallow lenses in Cambrian? limestone (Wright and others, 1953).

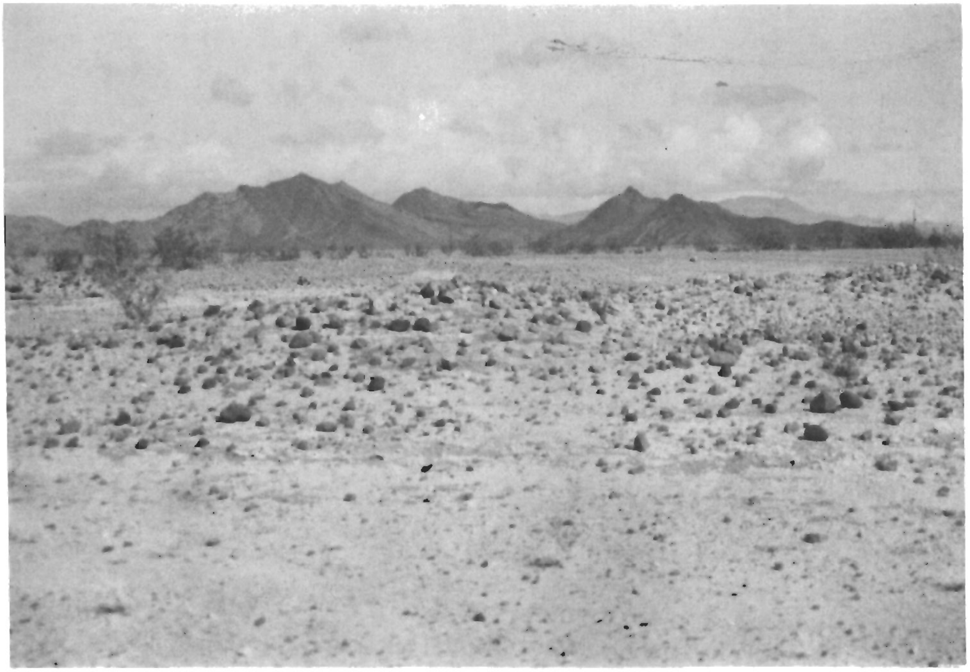

Figure 7. Pleistocene sediments near Stop 7 at Cadiz; Marble Mountains distant. *R.E. Reynolds photo.*

Proceed east to Chambless on National Old Trails Highway.

185.6 (5.5) Chambless. TURN RIGHT ON CADIZ ROAD and proceed to Cadiz.

186.3 (0.7) View to the east of Pre-Cambrian sequence in contact with granitic rocks that date to 165 m.y.a. (Bishop, 1963).

188.9 (2.6) Cadiz railroad siding. Go east 1 mile on pavement. The Marble Mountains trilobite quarry is at 10:00 (Mount, 1980). The trilobite locality contains a diverse assemblage of California's oldest complex life froms, dating to earliest Cambrian times (~570 Ma). Slow to 20 mph.

190.1 (1.2) STOP at the AT&SF railroad tracks. Go over the tracks, heading southeast, and proceed southeast on dirt road to sharp bend.

192.1 (2.0) Sharp bend warns, "Caution 10 MPH".

192.3 (0.2) Cross the tracks again, to the southwest side.

192.5 (0.2) The All-American Pipeline right of way runs northwesterly (right). Proceed northwest on pipeline road to pipeline mile marker 215

193.0 (0.5) STOP 7. CADIZ PLEISTOCENE SEDIMENTS at Mile Marker 215 (Fig. 7). The pipeline right of way cuts through white and tan calcium carbonate about 200′ above the elevation of Bristol playa (Reynolds, 1991; and see Reynolds and others, this volume). These middle Pleistocene sediments contain pedogenic carbonates that may have been deposited as part of a distal drainage system from Lanfair and Fenner valleys. The sediments become finer as they extend westward for about 4 miles, where they end in dissected bluffs. Look northward toward sediments at Bolo Hill on east side of a lineation in eastern Cadiz Valley.

193.6 (0.6) Return to Cadiz Road.

193.8 (0.2) Continue along the south side of the AT&SF railroad tracks, past heat station. This dirt road is not maintained by the county; watch for dips and washouts.

194.4 (0.6) Steep-dipping Paleozoic sediments at 9:00 are on the west side of the Ship Mountains, which contain granitic rocks dating to 150 m.y.a. (Bishop, 1963).

198.3 (3.9) STOP 8. ARCHER TUFA LOCALITY. Park at the bend in Cadiz Road. The Archer tufa locality, on the south side of road, consists of clastic fluviatile sediments and root casts with an abrupt transition to massive carbonates (Fig.

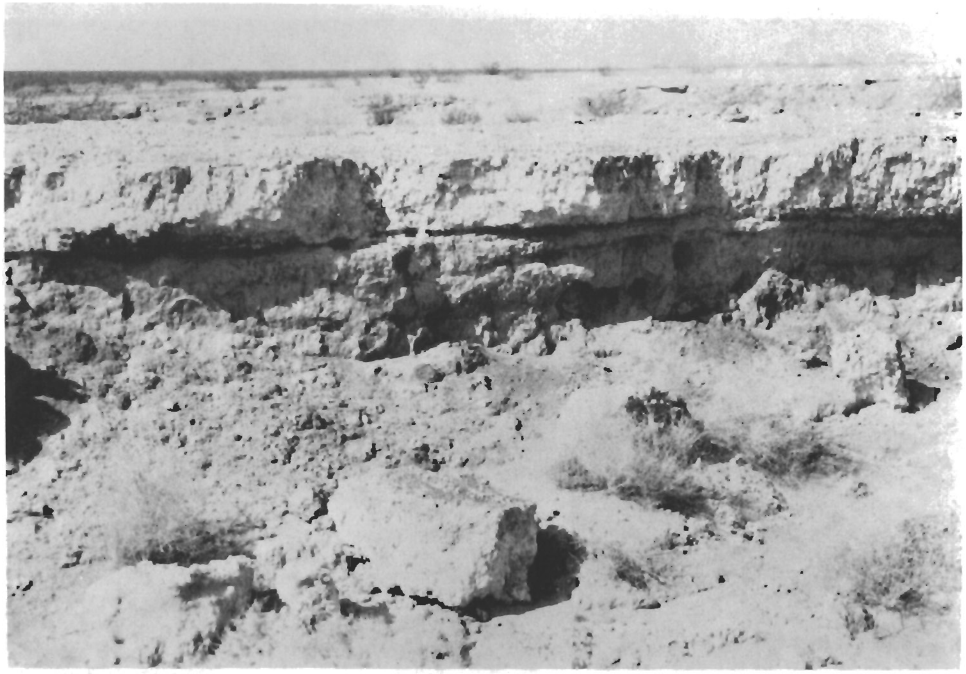

Figure 8. Fluvial sediments containing root casts in sharp contact with columnar to massive pedogenic carbonate at Archer, Stop 8. *R.E. Reynolds photo.*

8). This suggests that the carbonate layer is not pedogenic in origin. The locality is at elevation 750′, more than 100′ above Cadiz Lake (due south) and 150′ above Bristol Lake (west). The Pleistocene fauna recovered here is described by Reynolds and others (this volume). The Cadiz dune field on the east margin of Cadiz Lake is visible to the south at 2:00.

200.8 (2.5) Site of Archer. Watch for dips; do not take the road heading south. The Old Woman Mountains are visible on the skyline (Howard and others, 1987; Knoll, 1985; Miller and others, 1982).

206.8 (6.0) Do not take the road south to New Frontier mine. Formerly known as the Desert Butte Group, this mine shipped a complex ore from a zone of copper, gold, silver, lead, and zinc in 1914 (Wright and others, 1953).

208.6 (1.8) The road north (do not take) goes to Skeleton Pass and Danby.

209.3 (0.7) Chubbuck. Limestone mines to the south, operated by the Chubbuck Lime Company from 1925-1948 and intermittently since (Fig. 9), explored bodies of metamorphosed limestone in the Kilbeck Hills (Wright and others, 1953).

212.8 (3.5) Fishel. The Little Piute Mountains, at the northeast end of the Old Woman Mountains, contain fossiliferous Tertiary sediments (see Reynolds and Knoll, this volume).

Figure 9. Lime mill at Chubbuck. *R.E. Reynolds photo.*

216.8 (4.0) At the south tip of the Old Woman Mountains, we are entering the Danby basin. The Danby and Bristol basins are at similar elevations, ~610′; Cadiz basin, due south, is ~70′ lower (see Reynolds and Reynolds, this volume). Ward Valley is to the north, the Turtle Mountains are at 11:00, and the West Riverside Mountains at 12:00. The Arica Mountains lie at 1:00, the Iron Mountains at 3:00. The turnoff south goes to the Standard Salt Company (do not take).

218.3 (1.5) Site of Milligan.

219.6 (1.3) Standard Salt processing plant (Fig. 10)(see Calzia, this volume). Three roads go east; take the middle route, not northeast or southeast routes.

221.8 (2.2) Tan silts capped with basalt gravels from the Turtle Mountains are 40 feet above the Danby playa surface, at elevation 670′.

222.6 (0.8) Power line road in Ward Valley. The road south to Iron Mountain is closed. I-40 can be reached to the north. Proceed easterly, towards Rice.

224.6 (2.0) Playa sediments here are at elevation 650′.

226.2 (1.6) The Salt Marsh railroad siding is marked by salt cedar trees.

Figure 10. Standard Salt processing plant near Milligan. *R.E. Reynolds photo.*

Figure 11. Saltmarsh paleosol, Stop 9. *R.E. Reynolds photo.*

227.4 (1.2) Mile Post 248 on gas line.

227.5 (0.1) STOP 9. SALT MARSH. The Salt Marsh site, at elevation 630′, is within 20′ of the current playa surface of Danby Lake. Stabilized dunes have been deposited within dissected pedogenic carbonate horizons developed on silts which contain Pleistocene vertebrate fossils (figs. 11, 12)(see Reynolds and others, this volume).

231.0 (3.5) Sablon Siding.

236.6 (5.6) TURN SOUTH, away from railroad.

237.1 (0.5) Stop at Highway 62. Note that stabilized Pleistocene dunes surround mountains at this point. The Arica Mountains, due south, have yielded gold ore since the late 1800s (Baltz, 1982); the Lum Grey and the Old Priest mines are visible south. Patton's Camp is to the west. Note the carbonate-cemented red soils on the south side of the highway. The surfaces of these deposits appear to dip into Danby basin and are covered by stabilized dunes. We are at the 850′ elevation divide between Danby basin to the northwest and Rice Valley, which drains into the Colorado River, to the southeast. TURN LEFT (east) onto Highway 62. The Granite Mountains at 11:00, the Iron Mountains at 3:00.

239.1 (2.0) Danby Basin now drains internally, but subsurface cores in Danby and Cadiz lakes indicate the presence of brackish-water deposits correlated with the Bouse Formation, suggesting a trough during early Pliocene times (see Brown and Rosen, this volume).

242.1 (5.0) Rice. Emergency gas available. Do not take the Rice/Blythe Road heading south. The Turtle Mountains are at 9:00 to the north (see Hazlett, this volume).

243.3 (1.2) A historic marker is placed at the site of Rice Army Air Field. The Camp Rice Desert Training Center was established in 1942. Other camps were Young, Coxcomb, Granite, Iron Mountain, Ibis, Clipper, Pilot Knob, Laguna, Horn, Hyder, and Bouse. The operations involved 13 infantry divisions and 7 armored divisions. Training ended in the spring of 1944. The 5th Armored Division was the first unit trained at Camp Rice, and later spearheaded victories in Europe during World War II.

246.2 (2.9) Note west-dipping Tertiary volcanics to the north at 3:00.

247.7 (1.5) Pass the site of Grommet. We are at the divide between Rice Valley (to the west) and Vidal Valley, at elevation 950′ (Carr, 1981).

248.1 (0.4) Cross the railroad tracks. Castle Rock is at 10:00, between the Turtles and the Mopah Range.

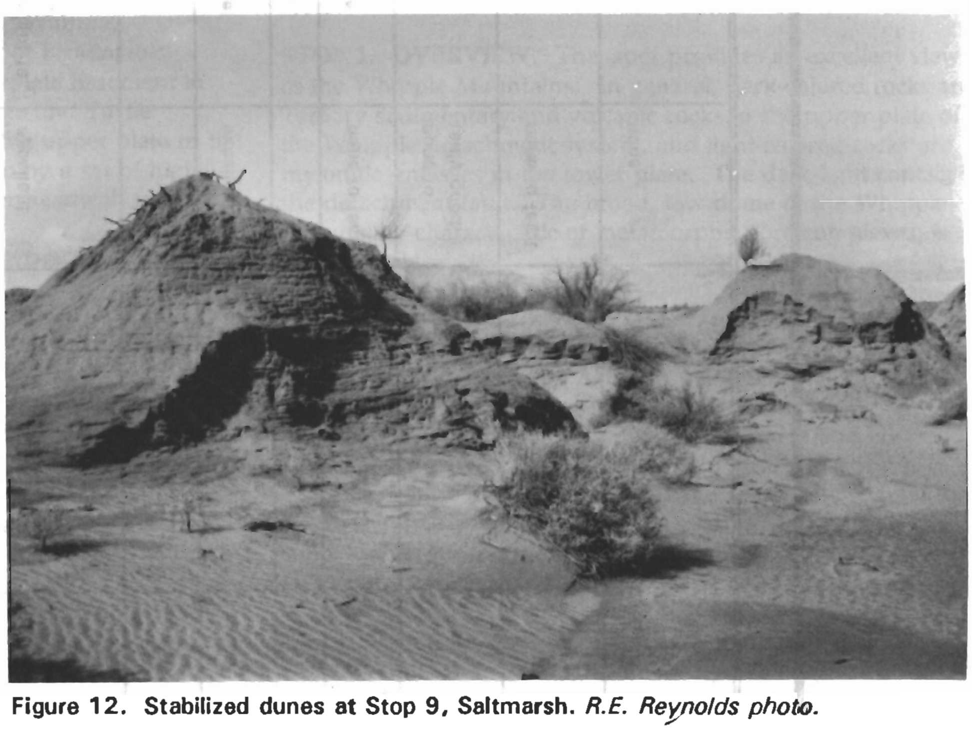

Figure 12. Stabilized dunes at Stop 9, Saltmarsh. *R.E. Reynolds photo.*

Table I. Summary of features of alluvial surfaces and desert varnish in the lower Colorado Region (summarized from Tables 2.4 and 2.13, Bull 1991).

AGES OF ALLUVIAL SURFACES LOWER COLORADO RIVER REGION					DESERT PAVEMENT CHARACTERISTICS SOUTH OF WHIPPLE MOUNTAINS							
Surface	Epoch		Age Range (ka)	Basis for Age Estimate	% Surface in Pavement	% Bare Ground	Varnish	Stream channel preservation	Gravel bar preservation	Median particle size (mm)	Sorting	% >32 mm
Q4b		HOLOCENE	0	Loci of present streamflows								
Q4a	late		0.1-2	No trees in unvarnished abandoned channels	0	n/a	none	excellent to good	excellent	16	poor	22
Q3c			2-4	light brown varnish								
Q3b	middle		4-8	brown varnish; C-14 date	>90	<5	7/5YR 3/4	·none	excellent	14, 15	poor	18-20
Q3a	early		8-12	C-14 dates								
Q2c	late	PLEISTOCENE	12-70	C-14 & Th-230/U-234	>80	<2	7/5YR 2/3	none	none to faint	11-15	good	10-16
Q2b			70-200	Th-230/U-234; carbonate in Bk horizon	60-80	4	7/5YR 2/3	none	none to fairly good	13, 14	poor to good	6-18
Q2a	middle		400-730	Bishop Tuff, basalt K/A date; normal polarity	~30-40	4-20	7/5YR 2.5/2	none	none to faint	12-25	poor	8-12
Q1	early		>1200	Rare basalt; normal & reversed polarity	<1	>20-30	7/5YR 2/2	none	none	18	poor	15

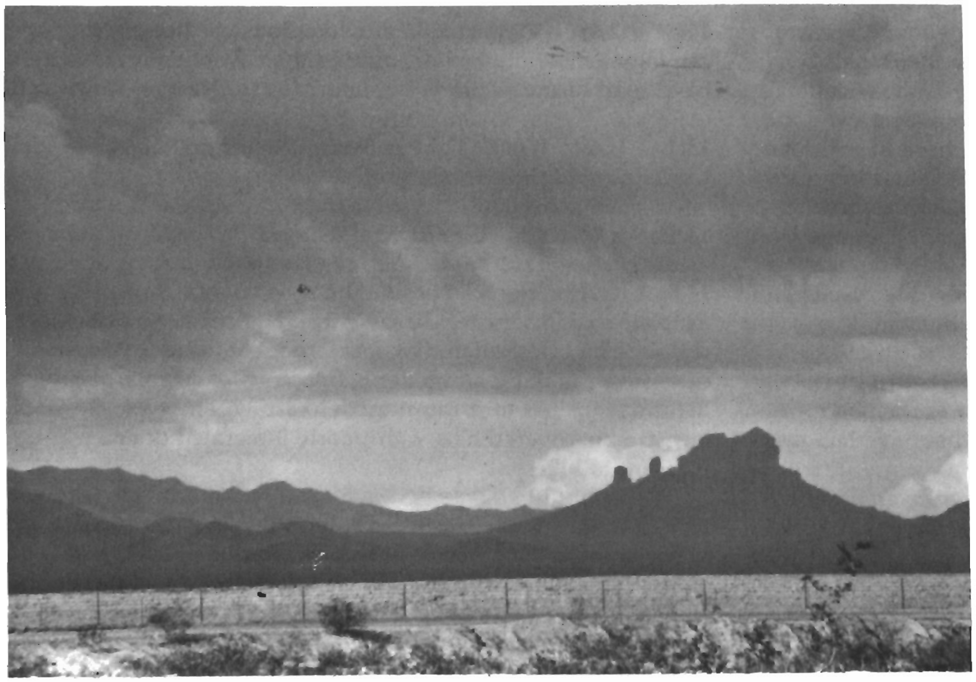

Figure 13. Volcanic buttes of the Mopah Range. *R.E. Reynolds photo.*

255.2 (7.1) Road cuts dissect calichified Pleistocene fanglomerate. Pyramid Butte is at 10:00.

256.9 (1.7) Junction of CA 62 and CA 95 at Vidal Junction. DRIVE EAST on CA 62, towards Parker, AZ. The mountain range to the northwest of the junction is the Mopah Range (Fig. 13), an eastward spur of the Turtle Mountains. The Mopah Range consists of Tertiary volcanic rocks, including the remains of volcanic vents. The neck of one such vent forms the prominent thumb-shaped peak in the middle of the range. These volcanoes mark one of the major volcanic centers active during Miocene extension, and probably was the source of volcanic flows in the western and southern Whipple Mountains. The Turtle Mountains consist of Proterozoic granite and gneiss that is similar to upper-plate basement in the Whipple Mountains. The Mopah Range and Turtle Mountains, both considered to be within the upper plate of the Whipple detachment system, are separated by a set of high-angle normal faults which may be a former headwall splay.

259.9 (1.0) The tan sediments are Quaternary Colorado River sediments.

260.9 (3.0) Savahia Peak is to the north at 8:00. Pass Chambers Well Road.

261.2 (0.3) Mile post 130

261.8 (0.6) A microwave relay station is on the south side of the road. A good overview of the Whipple Mountains can be seen to the north as you drive along this stretch of highway.

266.4 (4.6) Mile post 133

267.4 (1.0) Mile post 134. Check your odometer here; proceed 0.9 miles, just prior to Marker 135. Slow down and prepare to turn left.

268.3 (0.9) Turn left (north) off pavement onto dirt road (the turn is just past a large palo verde tree). Proceed north. This road eventually crosses the Colorado River Aqueduct and then leads to Turk Mine and Chambers Well. PLEASE DO NOT DISTURB THE DESERT PAVEMENT.

Climatic changes during the Quaternary caused profound changes in the mountains, alluvial fans, and soils of the Mojave Desert along the Colorado River (Bull, 1991). The Whipple Mountains piedmont (see Fig. 16) demonstrates many of the general characteristics of alluvial fan morphology, soil development, and chronology (Table I).

– END OF DAY 1 –

DAY 2

Colorado River Extensional Zone Segment

If you camped out at the end of Day 1, return to the large tree immediately north of Highway 62 for start of Day 2. For people joining the field trip on Day 2, go to Vidal Junction, proceed east on Highway 62. DO NOT PARK ON HIGHWAY; PARK NORTH OF HIGHWAY AT THE LARGE TREE on the side of "East Chambers Well Road" (the dirt road).

STOP 1. OVERVIEW. This spot provides an excellent view of the Whipple Mountains. In general, dark-colored rocks are Tertiary sedimentary and volcanic rocks in the upper plate of the Whipple detachment system, and light-colored rocks are mylonitic gneisses in the lower plate. The dark-light contact is the detachment fault. The broad, low dome of the Whipple Mountains, characteristic of metamorphic core complexes, is readily visible.

0.0 (0.0) Cautiously get onto Highway 62 and proceed east (left), towards Parker AZ.

0.9 (0.9) Road cut with pinkish tan sands and brown silts of the Colorado River sediments to the right (south).

3.0 (2.12) Deep gully with dark Tertiary volcanics and red sandstone of the Turk Mine and Twin Lode Mine (?) formations, which predate the Peack Springs Tuff.

3.4 (0.4) Rio Mesa Road. This is the entrance to Big River. Win cash prizes and cadillacs by listening to condo salespeople.

The low, dark hills north of the road are made up of Tertiary andesites. The volcanic flows in the Whipple Mountains, particularly on the southern flank of the range, have been subjected to a type of alteration known as potassium metasomatism. Large volumes of potassium have been added to these rocks, with removal of sodium. K_2O values in typical andesites are commonly less than 1%; K_2O values as high as 16% have been measured from these andesites. Silica and iron were also dumped into both volcanic and sedimentary rocks during this event. The resistant red sandstone ridges seen at mile 21.5 probably reflect this alteration (see Beratan, this volume).

6.5 **(3.1)** Green sediments of the Bouse Formation (Metzger, 1968) on the north side of the road are overlain by pinkish Colorado River sediments.

7.3 **(0.8)** Turn right onto Highway 72 at Earp, CA. This little town (one restaurant/gas station/store, and a post office)is named after Wyatt Earp. He hired out as a guard for stage coaches transporting gold, and eventually stayed on in this area. Turn right (east) to Parker. The white bed in the roadcut on the south side of the road before reaching the bridge is the basal marl of the Bouse Formation (more about this later on). Note the excellent large-scale cross-beds in the gravels below the Bouse. Dugout cabins on right (west) were excavated below marl of the Bouse Formation at intersection with Rio Vista, in 0.3 miles (Fig. 14).

7.7 **(0.4)** Cross Colorado River into Arizona and the metropolis of Parker. Gas up and get foodstuffs for a picnic lunch.

8.6 **(0.9)** Stop, TURN NORTH (left) onto AZ Highway 95.

Figure 14. Shelters dug out under the basal marl of the Bouse Formation. ***R.E. Reynolds photo.***

11.5 **(2.9)** View at 2:00 of white Bouse sediments ringing canyon. The white bed exposed to the east of the road is the basal marl of the Bouse Formation. Cross Osborne Wash.

13.1 **(1.6)** Traffic light at Beacon/Riverside Roads. Continue straight across.

14.1 **(1.0)** Rio Vista Road, Cienega Springs.

14.3 **(0.2)** The hills beside the road contain typical exposures of Proterozoic basement. The basement in this region is highly shattered and sheared, both due to Miocene extensional faulting and older (Cretaceous and Proterozoic) deformation. As a result, it erodes readily, and typically forms low, rubble-covered hills with poorly integrated drainages—not pleasant to hike on.

15.7 **(1.4)** The red-colored ridge straight ahead consists of Miocene sedimentary rocks, predominantly hematite- and quartz-cemented sandstone and conglomerate deposited in alluvial fan-fluvial settings. These redbeds are part of the Copper Basin Formation (Teel and Frost, 1982), which we will drive through.

16.3 **(0.6)** La Paz County Park

18.8 **(2.5)** Another view of the coarse, red Tertiary sediments of the Copper Basin Formation.

19.3 **(0.5)** The light-colored rock exposed in the roadcut is the 18.5 Ma Peach Springs Tuff. This distinctive ignimbrite unit is found throughout the eastern Mojave Desert, and forms an important marker bed. The Whipple Mountains lie at the distal margin of the unit. Exposures are lens-shaped; the hot ash followed topographic lows, and accumulated in valleys. In the Parker Dam area, these lenses are located just below the Gene Canyon-Copper Basin unconformity.

19.7 **(0.4)** Entrance to Buckskin Mountain State Park on left. This is a very nice little campground, with tent spaces along the river (away from RV's) and very friendly rangers. Recommended to those who prefer camp sites with showers.

21.1 **(1.4)** River Island Park. The distinct strata in the high skyline to the east (right) are discussed below (MP 23.2).

22.4 **(1.3)** Volcanic breccias are exposed to the right in road cut.

22.9 **(0.5)** The road goes by a cliff which forms a dramatic exposure of brick-red conglomerates and sandstones of the Copper Basin Formation. These rocks are correlative with those at Stop 3, but are significantly coarser-grained, consistent with a source area to the east-southeast. Clast types include Mesozoic(?) metasedimentary and metavolcanic rocks; such rocks are found in the Buckskin Mountains but are absent from the Whipple Mountains.

23.2 (0.3) The strata underlying the cliff-forming redbeds, part of the Gene Canyon Formation, are dominated by monolithologic breccia beds. Boulder-size material is common. The beds generally are clast-supported, and the matrix consists of the same material as the clasts. The beds are unsorted and disorganized. These breccia beds are interpreted as rock avalanche deposits. The breccia beds on this side of the river are much coarser, thicker, and more abundant than those on the California site, consistent with a source to the east-southeast.

The flat-lying strata that form the high skyline to the east (right) of the road are discussed below (MP 23.2) are dominantly olivine basalts of Late Miocene age that unconformably overlie the Gene Canyon and Copper Basin formations. These volcanic rocks have not experienced the intense alteration that affected the older andesites.

23.8 (0.8) DO NOT TAKE the viewpoint exit. TURN LEFT off Highway 95 onto the road to Parker Dam.

24.6 (0.8) Cross over Parker Dam. (Be careful—the road across the dam is very narrow). Arizona Highway 95 turns into California Highway 62 at the California state line.

24.8 (0.2) STOP 2. GRANITE PORPHYRY OF PARKER DAM. PARK at lot on west side of dam. The roadcut bordering the parking lot on the west side of the dam is the type area for the Granite Porphyry of Parker Dam (better known as "Fred" to geologists working in the Colorado River extensional corridor.) This badly-sheared granite porphyry is part of a distinctive suite of ~1.4 billion year old anorogenic granites. Varieties of this rock are one of the most common rock types within the basement throughout the region.

25.2 (0.4) TURN WEST (right) just before the small community of Parker Dam, before Gene Wash Reservoir Road, onto a road leading to the Metropolitan Water District's Gene Pumping Plant. There is a sign for "Black Meadow Landing Resort" at the turnoff.

25.7 (0.5) STOP 3: PARKER DAM SECTION. Park in the large turnout on the south (left) side of the road. **Watch out for oncoming traffic** — cars travel much too fast on this road. This property belongs to the Metropolitan Water District; permission to visit the exposure can be obtained at the Gene Pumping Plant, about a mile further up this road. The base of the Parker Dam section is just across the road from the turnout. This is one of the most complete and least structurally disrupted Miocene sections anywhere within the Colorado River extensional corridor. Walk upsection along the road.

A basement assemblage dominated by the Granite Porphyry of Parker dam is nonconformably overlain by sandstones, conglomerates, monolithologic breccias, and rare limestones of the Gene Canyon Formation. Note the textural variability of the unit, and the lack of volcanic rocks as clasts. Stratal dips within the Gene Canyon Formation range from approximately 75 degrees near the base to about 40 degrees at the top. A volcanic flow is exposed in the roadcut at the turnoff in the center of the hairpin curve near the top of the hill. The upper member of the Gene Canyon Formation contains some thin andesite flows. This unit is capped by a lens of the 18.5 Ma Peach Springs Tuff, and is unconformably overlain by the Copper Basin Formation.

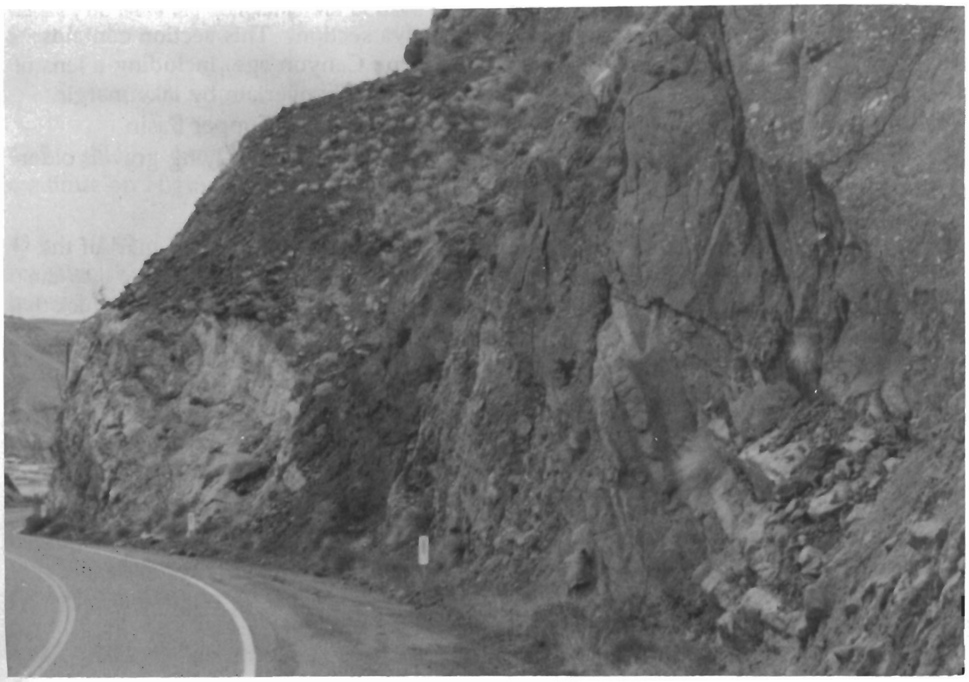

Figure 15. Unconformity between the Gene Canyon and Copper Basin formations. *R.E. Reynolds photo.*

The Gene Canyon—Copper Basin unconformity lies at the top of the hill, just past the hairpin curve. The power line at the top of the ridge sits on a pale pink exposure of the Peach Springs Tuff. The unconformity is well-exposed to the east (left), across the stream. The unconformity where it crosses the road is marked by a complex lens of deformed sedimentary and volcanic rocks. Just beyond the ridge, a pull-off leading to the Gene Reservoir Dam contains a good exposure of typical Copper Basin Formation redbeds.

Return to the vehicles, and proceed to the east on Gene Wash Reservoir Road, back to Highway 62 and the town of Parker Dam.

26.2 (0.5) Stop, TURN SOUTH (right) on CA Hwy 62/AZ 95 and go south.

26.8 (0.6) The coarse-grained deposits viewed at mile 23.3 can be seen eastward across the river. Those rocks are part of the same fault block as the Parker Dam section.

27.3 (0.5) The Gene Canyon—Copper Basin unconformity is well exposed in the cliff on the right (Fig. 15). **Be careful driving along this stretch of road.** People drive stupidly through these curves; head-on collisions and cars in the river are fairly common.

27.5 (0.2) The unconformable relationship between the tilted Gene Canyon and Copper Basin formations with the overlying, flat-lying olivine basalts can be seen eastward (to the left) across the river.

28.9 (1.4) Cable Car day use area.

29.4 (0.5) Quail Hollow day use area.

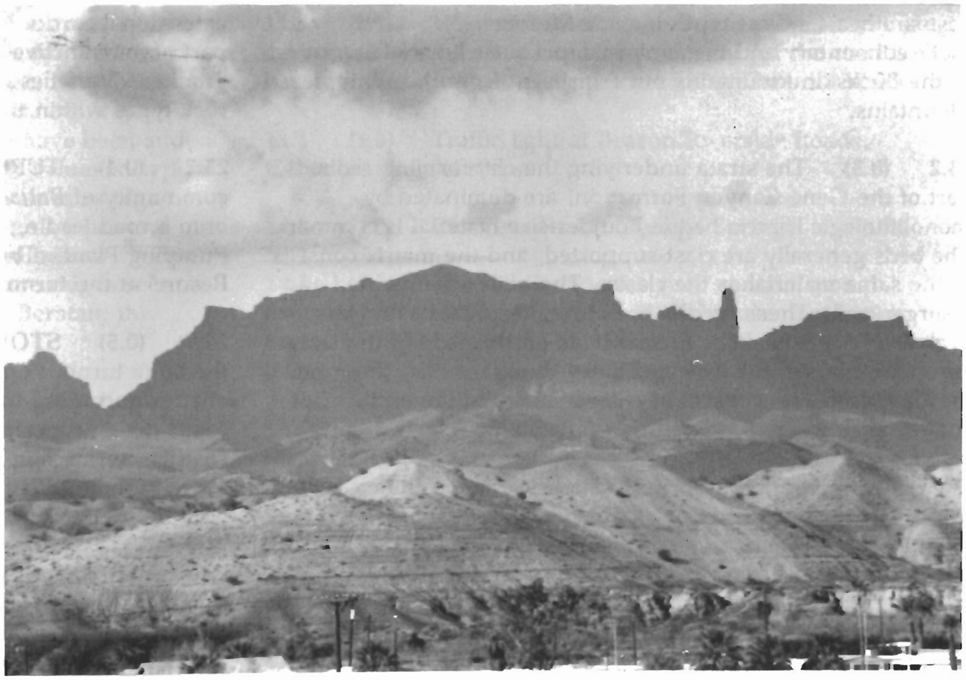

Figure 16. View north of Whipple Mountains. *R.E. Reynolds photo.*

30.7 (1.3) The sand dunes on the right are eolian dunes derived from reworking of underlying sediment. The sediment is probably part of the Bouse Formation, but may also in part be derived from Quaternary sediment deposited by the Colorado River.

30.9 (0.2) Echo Lodge Resort. The exposure on the left, between the road and the river, contains Gene Canyon Formation sedimentary and volcanic rocks unconformably overlain by Copper Basin Formation redbeds. The Whipple Mountains (Fig. 16) are north.

31.3 (0.4) Transition from red volcaniclastic sediments to mostly Proterozoic granite and gneiss; both the sediments and the crystalline rocks are within the upper plate of the Whipple Detachment, and are separated by a high-angle normal fault which presumably soles into the Whipple Detachment Fault.

32.9 (0.7) Bullfrog Day Use Area.

33.2 (1.2) The hills to the north (right) consist of Quaternary gravels deposited by the Colorado River on metamorphic rocks.

34.9 (2.7) Cross Roads Day Use Area and historic monument. The jeep trail that begins here heads up Bowman's Wash to the feather edge of the upper plate. The detachment fault can be easily reached from Bennett Wash, a left fork off of the Bowman's Wash Road. Exposures near the bulldozed rubble pile at the bend in the Bennett's Wash road include limestone and mudstone that were deposited in the lake that formed during the tilting episode that created the Gene Canyon—Copper Basin unconformity.

35.9 (1.0) Bass Point day use area. Metamorphics in the upper plate are visible at 12:00. More Quaternary gravels are to the west (right) at 3:00. **Be careful going around this curve.**

36.7 (0.8) The cliff to the north (right) exposes the unconformity between the tilted mid-Miocene Copper Basin Formation strata and flat-lying strata assigned to the late Miocene Osborne Wash Formation along the next 0.4 miles.

37.3 (1.1) The Bouse Formation can be seen on the north side of road for the next 0.4 miles.

39.0 (1.7) Lake Moovalya section. This section contains strata of middle Miocene Gene Canyon age, including a lens of Peach Springs Tuff, unconformably overlain by lake margin deposits belonging to the mid Miocene Copper Basin Formation. These rocks are overlain by flat-lying gravels older than the Bouse Formation.

40.5 (1.3) Note the distinctive white band of marl of the basal Bouse Formation. The marl is visible from here into the town of Earp. In this area, the marl is underlain by a thick section of flat-bedded gravels.

41.6 (1.1) Earp again. Turn south on Highway 72 and cross the Colorado River into Parker, Arizona.

41.7 (0.1) The road cuts through strata belonging to the Osborne Wash Formation, and the overlying yellow sandstone and the basal marl of the Bouse Formation. The marl is particularly distinctive here, forming a readily recognizable thin white band.

41.8 (0.1) Rio Vista.

42.0 (0.2) We are crossing the Colorado River.