# SECOND ANNUAL SPRING FIELD TRIP

# CSUN GEOLOGY DEPARTMENT AND GEOLOGY CLUB

# A FIELD GUIDE TO THE SALTON SEA AREA, SOUTHERN CALIFORNIA

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January, 1985

# PREFACE

The intent of this field-trip guide is to provide a general background to the geology of the Salton Sea area and, also, to provide a commentary on the specifics from stop to stop.

I have tried to be comprehensive in my coverage of the geology. The guide is by no means an exhaustive treatment. It is hoped that this trip will not only inform but will spark discussions and result in some of you returning here to work on Senior Thesis or Master Thesis problems.

The guide consists mostly of excerpts taken from published works by other geologists. The sources of data are noted in the text.

I anticipate an enjoyable trip. The pace is different from day-to-day, and overall the trip will be a leisurely one. Above all else, please consider yourself a participant in this trip and not just a spectator. Participation will be achieved by your asking questions. Do not hesitate in asking questions, as this trip is for you.

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## BACKGROUND INFORMATION

One of the most striking topographic and tectonic features of southern California is the Salton trough. This structural depression is the northern segment of the Gulf of California structural province. The trough extends for 225 km from the tidelands at the head of the Gulf to San Gorgonio Pass west of Palm Springs (Sharp, R.P., 1972).

The Salton trough is only a few kilometers wide at the northwest end but attains a maximum width of roughly 112 km at the Mexican border (Sharp, R.P., 1972). The trough is marked by a broad flat alluviated valley with an area of 10,000 square miles, of which 2,000 square miles lie below sea level. The Colorado river delta south ot the international border rises to a height of 12 to 16 m above sea level, forming a natural dam which prevents this sink from being inundated by sea water from the Gulf of California (Biehler and Rex, 1971).

Geophysically and physiographically the Salton trough can be divided into four units: the Coachella Valley, Salton Sea, Imperial Valley and the Colorado River delta proper. The Coachella Valley extends southeast from San Gorgonio Pass to the north end of the Salton Sea (Biehler and Rex, 1971).

The Salton Sea is located in the transition zone between the narrow Coachella Valley in the north and the broad Imperial Valley in the south (Fig. 1). This topographic center of the Salton trough is

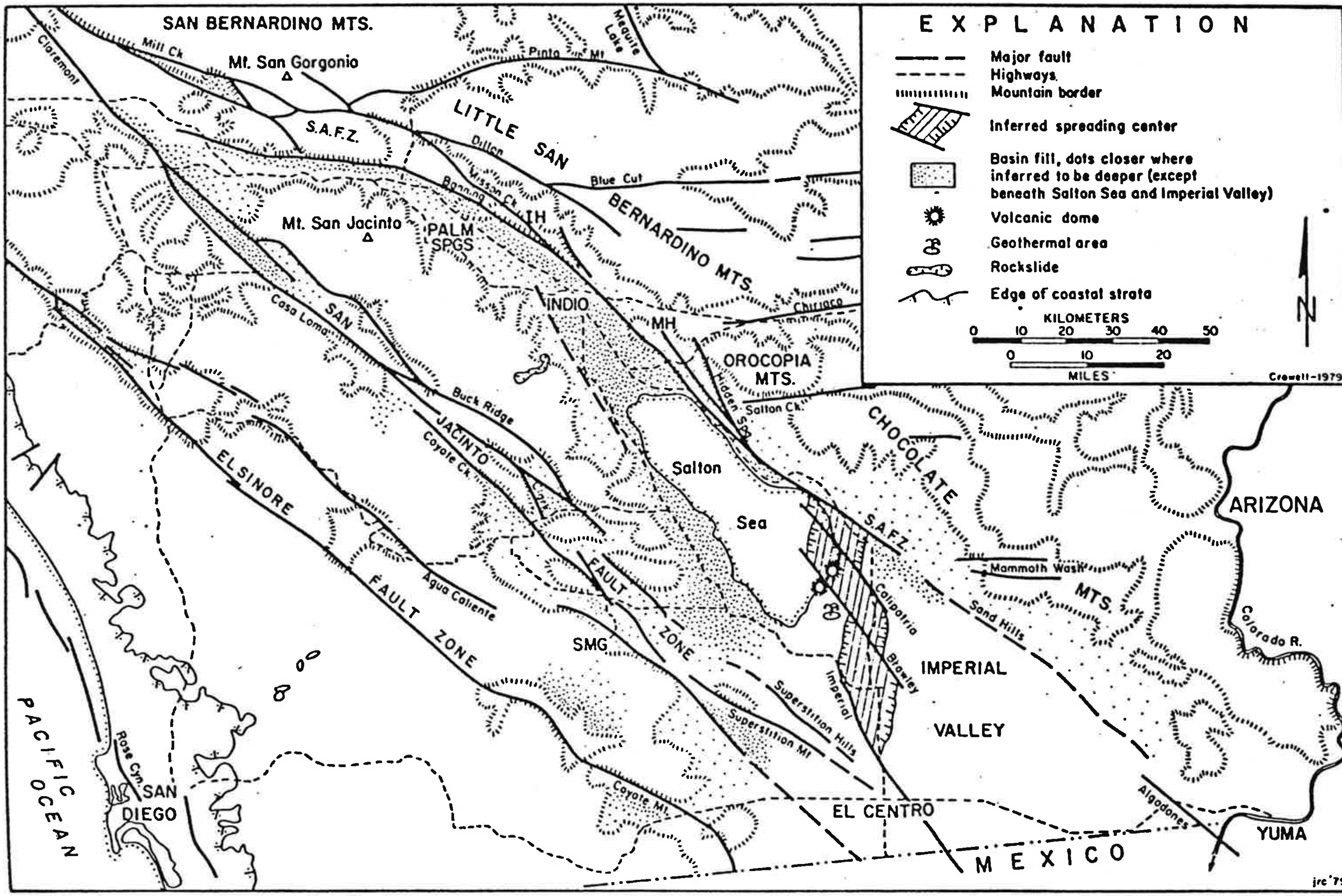


Fig. 1. Diagrammatic fault map of central Peninsular Ranges and Salton Trough region. The map shows the major faults of the San Andreas system near their juncture with the divergent plate boundary in the Salton Trough. Basin fill is indicated by stippling, and inferred active spreading centers by the line pattern SE of the Salton Sea. Abbreviations: IH, Indio Hills; MH, Mecca Hills; SMG, Split Mountain Gorge (From Crowell and Sylvester, 1979a).

covered by a large man-made lake approximately 56 km long and 16 to 24 km wide, which forms a sink for all of the drainage in the area. The surface of the sea is presently 71 m below sea level with a maximum measured depth of 14 m. Prior to the flooding of the sink, this area was a broad flat sandy playa which at one time formed the bottom of an ancient fresh-water lake. Before the disastrous inundation of the area in 1905-1907 by the accidental diversion of the Colorado River, the lowest exposed land area of the Salton trough was only 1.2 m higher than Death Valley. The Salton trough is still the second lowest land area in the United States (Biehler and Rex, 1971).

Four volcanic cones protrude over 30 m above the valley floor at the south end of the Salton Sea. The northeast dome, Mullet Island, is now partially submerged in the Salton Sea. Associated with these domes are extensive hot springs activity and potential geothermal reservoirs (Biehler and Rex, 1971).

South of the Salton Sea lies the broad Imperial Valley, which is a site of intense agricultural use. The valley is not as clearly defined as the Coachella Valley. In the northeast part of the Imperial Valley there is a narrow northwest-trending band of low ridges called the Sand Hills or Algodones Dunes. They are an almost unbroken mass of sand 73 km long and 6 to 13 km wide (Biehler and Rex, 1971).

The Colorado River delta proper designates that area in Mexico between the Imperial Valley on the north and the head of the Gulf in the south. This area is daily receiving large quantities of sediments from the Colorado River. The Colorado River has digressed many times across this cone, at times emptying into the Salton sink and then returning to the Gulf of California. This area is also referred to as the Mexicali Valley (Biehler and Rex, 1971).

The Salton trough is bounded and cut internally by active northwest-striking faults. The faults of the San Andreas fault zone form the northeastern margin of the trough and extend southward into the gulf (Fig. 1) (Oakeshott, 1971).

The southwestern fault margin is not quite so simply and clearly marked. Interrupted faults extend along the steep eastern scarps of the San Jacinto and Santa Rosa Mountains, however, and the great active San Jacinto and Elsinore fault zones slice southeasterly across the Peninsular Ranges and across the southwestern Salton trough into the gulf (Oakeshott, 1971).

Fault traces are generally straight and fault planes nearly vertical. Historic displacements have been largely right-lateral, but the steepness of bounding scarps on both sides of the Salton trough and the tremendous thicknesses of upper Tertiary and Quaternary sediments which fill the trough give evidence of great vertical displacements in late geologic history. Folding of the sedimentary strata within the basin, along with both strike-slip and vertical fault movements, suggests the complexity of the geologic forces that have been operating. Displacement within the Salton trough is going on very rapidly, with an average of about 2.5 cm per year in historical times (Oakeshott, 1971).

The Salton trough is one of the most seismically active parts of California. Notable earthquake activity since the turn of the century includes the 1940 Imperial Valley earthquake (M 7.1 with up to 6.3 m of right-lateral offset at the International Boundary), the 1948 Desert Hot Springs earthquake (M 6.5), and the 1968 Borrego Mountain earthquake (M 6.4) (Rockwell and Sylvester, 1979).

Imperial Valley faults are currently experiencing slow continuous slippage (Sharp, R.P., 1972).

Folds are displayed along the margins of Salton trough where the young (Cenozoic) sedimentary fill has been uplifted. In Painted Canyon east of Mecca, there are severely deformed beds. One or two of the anticlines have Precambrian crystalline rocks squeezed into their cores (Sharp, R.P., 1972).

Gravity and seismic-wave studies show that the continental crust of the earth is lacking below the southern part of the Gulf of California. The crust thickens gradually northward, but is still only 19 to 24 km thick beneath the Salton Sea -- 10 to 16 km less thick than the crust beneath the bordering Peninsular and Transverse Ranges. High heat flow through the thin crust, hot springs, and volcanism are characteristic of the Salton Basin (Oakeshott, 1971).

The Gulf of California probably developed as a great rift trough as the Peninsula of Baja California pulled obliquely northwestly away from the mainland of Mexico. The earth's crust was thinned as it was stretched and split across the trough (Oakeshott, 1971). The opening of the Gulf of California resulted in a sharp cleft within continental rocks, one that is now functioning as a divergent plate boundary. En echelon spreading centers arranged with transform faults characterize its floor. Some of these transforms are confined to new oceanic crust believed to be forming as floor beneath sediments of the Gulf and part of the Salton trough (Crowell and Sylvester, 1979a).

The splitting and rifting which formed the Salton trough, began during middle Miocene time. The oldest sediments in the trough are nonmarine and lie on the eroded surfaces of Mesozoic crystalline rocks. These oldest sediments are assigned to the Anza Formation (middle Miocene), Coachella Fanglomerate (late Miocene), and Split Mountain Formation (Miocene or Pliocene) (Fig. 2) (Crowell and Baca, 1979). As the rifting processes opened a trough, coarse continental sediments were deposited. Then, as rifting extended further, the sea entered in latest Miocene-early Pliocene time and coarse, oyster-bearing shallow-marine sediments of the Pliocene Imperial Formation were laid down (Oakeshott, 1971). The marine fossils of the Imperial formation are not the same species that are typically found in the coastal regions of southern California. They are more tropical and apparently migrated into the Salton trough region (Sharp, R.P., 1972). The seas in which the Imperial sediments were deposited probably advanced northward from the Gulf of California. In places

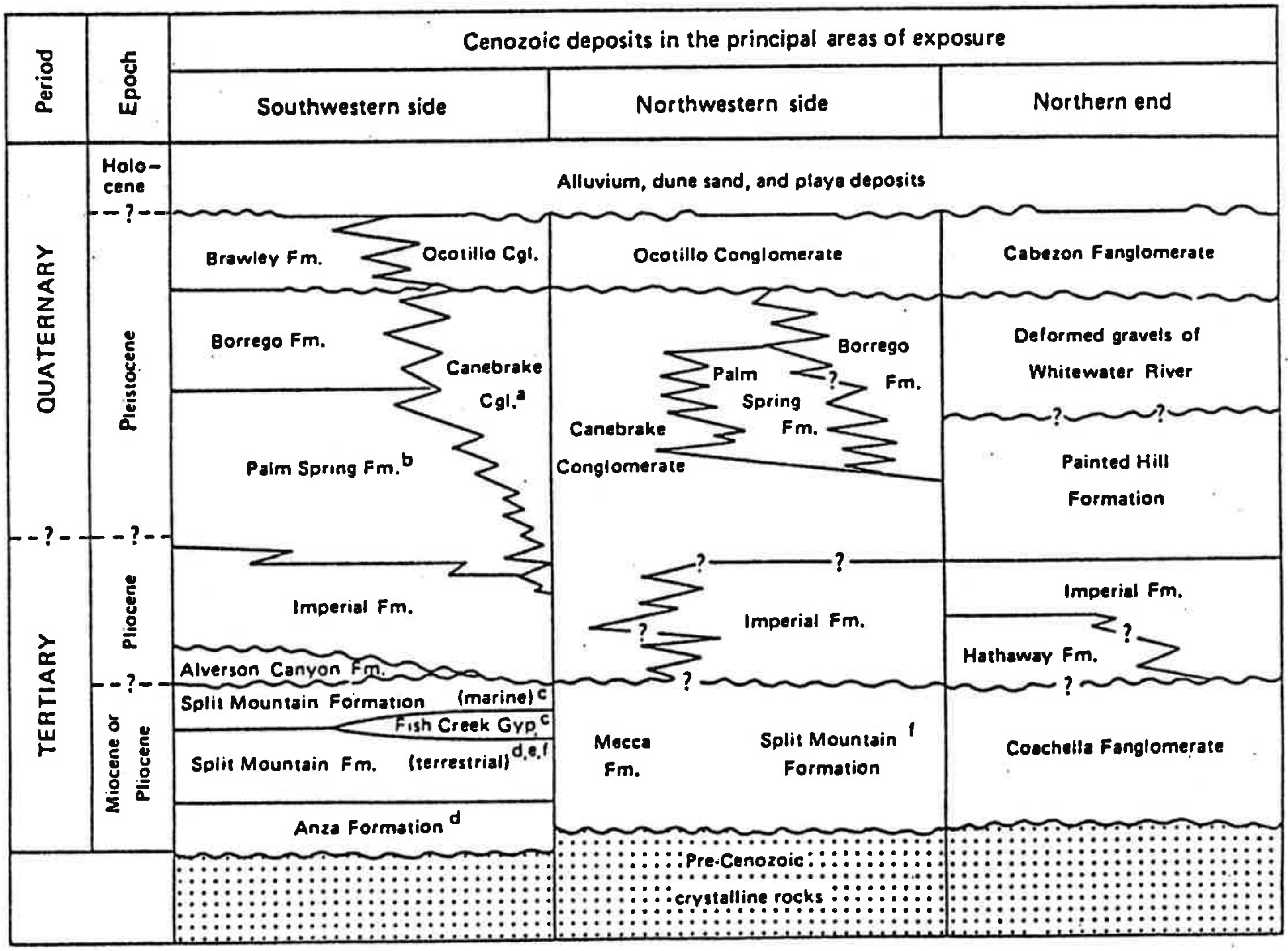


FIGURE 2.—Composite stratigraphic columns along the flanks of the northern part of the Salton Trough. Wavy lines indicate unconformable contacts, smooth lines indicate conformable contacts, queried lines indicate contacts not exposed. (From R. V. Sharp, 1972).

this formation is over 900 m thick, and it is thought to contain petroleum reserves (Oakeshott, 1971).

By the close of Pliocene time, deposition had caught up with rifting and subsidence, and the sediments again became land-laid. Many hundreds of meters of coarse, nonmarine sediments, with minor thicknesses of lake beds and volcanics, make up the upper Tertiary and Quaternary section of the Salton trough (Oakeshott, 1971). Sediments as thick as 6 km apparently underlie deeper parts of the trough and are largely Plio-Pleistocene in age. The main exposures of Neogene strata are in hills and mountains along the west side of Imperial Valley and the San Gorgonio Pass region, and in the Indio, Mecca, and Durmid Hills (Crowell and Baca, 1979).

At about the mid point of the Gulf of California south of Tiburon Island, seismic evidence indicates a transition from continental to oceanic structures. It is in this area also that the gravity anomalies become positive. This suggests that sea floor spreading is active in the Gulf and that the Gulf floor is undergoing a gradual transition from continental to oceanic type crust by rifting and northwest movement of Baja relative to the Mexican mainland. The emplacement of more basic material into the upper portion of the crust is occurring along zones of weakness (Biehler and Rex, 1971). The Salton trough is one of the few places upon the continents today where we can observe directly the joining of a divergent plate boundary with a system of transform faults (Crowell and Sylvester,1979a).

ROAD LOG (Note: Copies of road maps are provided for you in the last four pages of the guide).

Start (San Gorgonio Pass) to Stop 1 (Painted Canyon)

The two highest peaks of southern California flank the Pass-Mount San Gorgonio 3505 m (11,499 ft) on the north and San Jacinto Peak 3304 m (10,804 ft) on the south. The San Gorgonio Pass marks the northern limit of the Salton trough as well as the rift of the Gulf of California. The high peaks on both sides of the pass are mid-Cretaceous granitic rocks of the Southern California batholith, and they are located in the eastern part of the Peninsular Ranges (Biehler and Rex, 1971).

At the town of Cabazon, note the models of _Apatosaurus_ (formerly referred to as _Brontosaurus_) and _Tyrannosaurus_. These are _not_ life size.

The information given below is all from Crowell and Sylvester (1979b).

Interstate-10 parallels the Little San Bernardino Mountains on the north. These mountains are composed largely of Mesozoic plutons that intrude older gneisses, some of which are probably of Precambrian age.

North of Thousand Palms are the Indio Hills. They are comprised of folded and faulted strata belonging to the Palm Spring and Imperial Formations. A few isolated outcrops of granitic basement rocks are exposed at the SE end of the hills, but their relation to the overlying sedimentary rocks is not clear. Two faults bound the uplifted part of the Indio Hills: the Banning fault on the SW side and the Mission Creek fault on the NE side. These faults constitute the N and S branches of the San Andreas fault. The two faults merge together at the SE end of the Indio Hills where they continue SE as the San Andreas fault. The San Andreas fault crosses Dillon Rd. 0.6 mi N of Interstate-10 and is marked by a prominent growth of vegetation due to impounding of southward-flowing groundwater.

Groundwater barriers are especially prominent in the Indio Hills. They are marked by lush growth of vegetation, especially palm trees. The moisture-loving native California fan palm [Washingtonia filifera] is a "trademark" of these oases. Thousand Palms is one such oasis along the NE-facing scarp of the Mission Creek fault.

Leaving Interstate 10 just west of Indio, travel southeast on Hwy 111. Southeast of Indio are the Mecca Hills. Together with the Indio and Durmid Hills, they are one of three tectonic culminations along the San Andreas fault in the Salton trough. The Mecca Hills are warped and uplifted between the San Andreas fault on the SW and the Painted Canyon and Hidden Spring faults on the NE.

The high, ruggedly sculptured part of the Mecca Hills is underlain by the Plio-Pleistocene Palm Spring Formation, consisting of sandstone and conglomerate with interbeds of greenish-gray siltstone. In the core of the Mecca Hills, the lower part of the Palm Spring Formation is interbedded with and underlain by the Mecca Formation, a coarse, dark reddish-brown unit of torrentially deposited breccia and conglomerate. The Mecca Formation, in turn, lies nonconformably on a heterogeneous basement terrain of Precambrian gneiss, Mesozoic granitoids and greenschist, and Tertiary hypabyssal intrusive rocks. The hills have formed since mid-Pleistocene time by folding, faulting, and broad arching and uplift.

Geophysical studies have shown that there is a steep gravity gradient across the San Andreas fault in the Mecca Hills area. This gradient indicates a near vertical step of the basement-sediment interface of at least 4000 m. Thus, the San Andreas fault is the principal structural boundary between the Salton trough and the high standing terrane to the northeast in the Mecca Hills.

Continue NW along Hwy 111 about 17 mi to the intersection with Hwy 195 at Mecca. Turn NE onto Hwy 195, follow it through Mecca and eastward toward the Mecca Hills. After crossing the Coachella Canal, drive NW along the gravel road that is parallel to the power lines about 3 mi from the paved road to the mouth of Painted Canyon. Vehicles can proceed a few more miles up the canyon where there are picnic tables and pit toilet facilities, but no water.

The San Andreas fault strikes parallel to the course of the gravel road leading to Painted Canyon. Its course is marked by streaks and talus-strewn slopes of dark red-brown clay-gouge. Dark brown, gravel-strewn slopes and hillocks in the foreground are underlain by

Pleistocene Ocotillo Conglomerate which contains schist debris derived from the Orocopia Mountains to the E and subsequently offset 24 km NE along the San Andreas fault.

Stop 1 (Painted Canyon)

The information given below is all from Crowell and Sylvester (1979b).

The main trace of the San Andreas fault strikes across the mouth of Painted Canyon (Fig. 3). As you drive up into Painted Canyon, the general structure traversed by the road is as an asymmetric anticline with basement and a complex zone of faulting in its core. However, because of strike slip on that fault, the structure is much more complex. From the San Andres fault zone at the mouth of Painted Canyon, the road up Painted Canyon crosses the Skeleton syncline which, because of a local structural depression, is not well expressed in the canyon walls except for a few gentle reversals of dip. About 1/4 mi up the canyon, however, the dip of the beds is consistently down-canyon (SW) on the SW flank of the main anticline. The generally thin-bedded, gently dipping, tan-colored sandy and conglomeratic beds constitute the upper part of the Palm Spring Formation. About 1/2 mi up the canyon, in the vicinity of the picnic tables and pit toilets, the sandstone and conglomeratic strata have interbeds of greenish-gray siltstone. These strata, which are overturned locally, constitute the lower member of the Palm Spring Formation. All of the Palm Spring Formation in the Mecca Hills represents coalescing alluvial fan deposits, derived from mountains NE

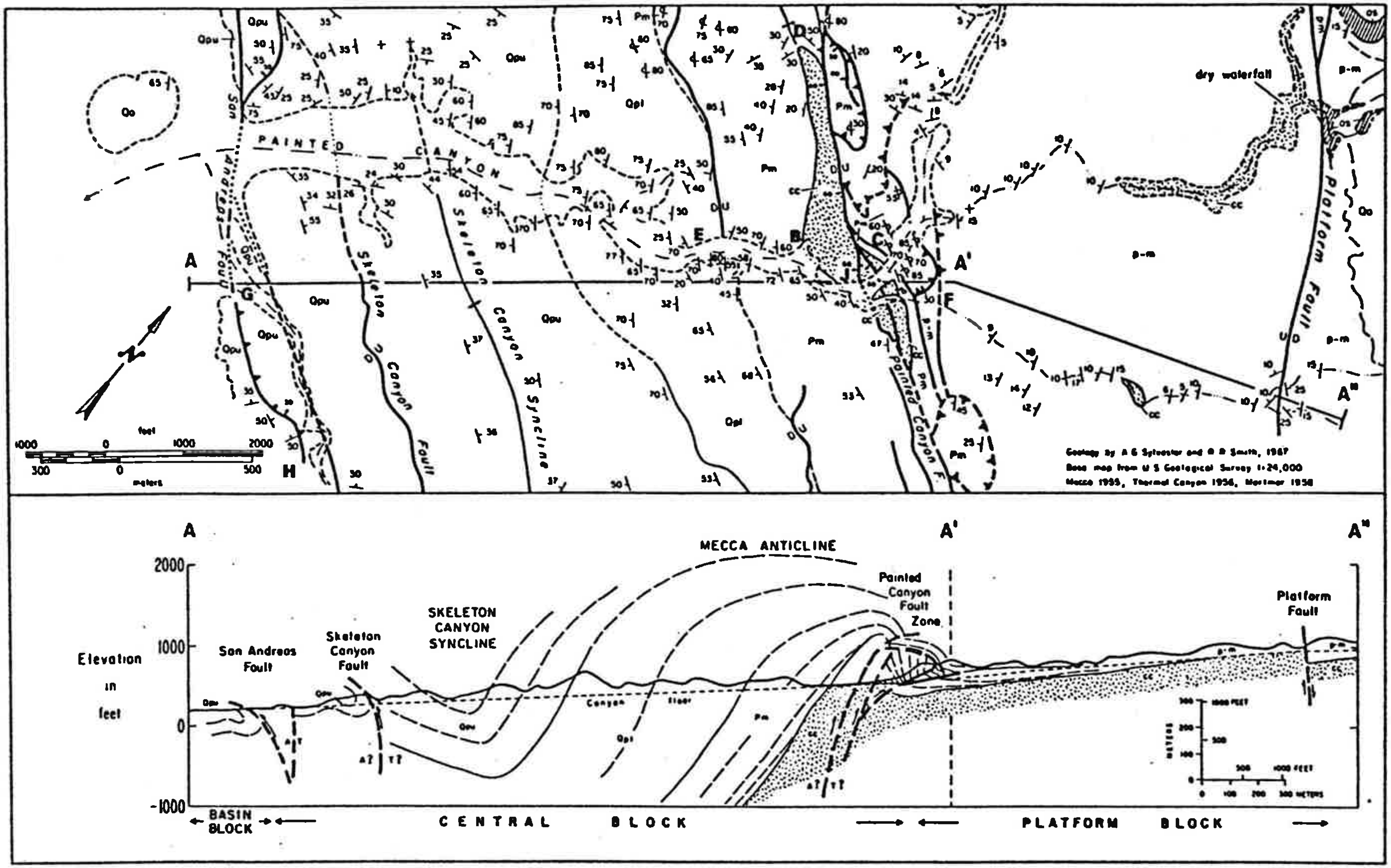


Figure 3.
Geologic map and structural profile of Painted Canyon, Mecca Hills. Symbols (oldest to youngest): Chuckawalla Complex (cc); Orocopia Schist (os); Mecca Formation (Pm); Palm Spring Formation (Qpl, lower member;Qpu,upper member); Palm Spring and Mecca Formations, undifferentiated (p-m); Canebrake-Ocotillo Conglomerate, undifferentiated (Qo) (From Sylvester and Smith, 1976).

of the Mecca Hills. On the SW limb of the anticline, the Palm Spring Formation is more than 1200 m thick, whereas it is less than 60 m thick NE of the Painted Canyon fault in the core of the anticline.

Up-canyon, around the corner from the picnic facilities, the Palm Spring Formation is underlain by the dark red-brown Mecca Formation, torrentially deposited breccia and conglomerate of locally derived gneiss, schist, and granitoids. The contact between the Mecca and Palm Spring Formations on the NW canyon wall is a minor fault. On the SE canyon wall it is a gradational contact. About 1/4 mi up-canyon from the Mecca Formation are vari-colored outcrops of highly fractured basement, including black gneiss, white granitoids, and orange felsic hypabyssal intrusive rocks. The contact of the Mecca Formation with the basement is a buttress unconformity which has been folded and faulted. The Painted Canyon fault cuts through the central part of the basement outcrops in this area. The fault is a major high-angle reverse fault that dips steeply where observed except where it flattens locally upward into thin nappe-like structures. The fault is part of a wrench-fault system along the San Andreas fault zone. The wrenching has taken place where the slip of two crustal blocks is simultaneously lateral and convergent (= "transpression") Sylvester and Smith (1976).

Continue up-canyon to a sign that reads "End of County Maintained Road". Proceed 0.8 mi up the extreme right fork of the main canyon to a dry waterfall. As you travel up the increasingly steep-walled, narrow canyon, note the exposures of Precambrian gneiss along the lower sides of the canyon. The gneiss, which is considered as part of the Chuckawalla Complex, consists of interlayered mafic gneiss, leucogneiss, and amphibolite. The gneiss is overlain nonconformably by beds of the Mecca and Palm Spring Formations. Eventually you will reach the dry waterfall cut into the gneiss. Scramble up the dry waterfall with care. About 200 m up-canyon from the waterfall are exposures of Precambrian anorthosite associated with gabbro, diorite, and related veinlike mafic bodies. The anorthosite and related rocks intruded the Chuckawalla Complex. According to Crowell and Walker (1962), the anorthosite and related rocks may correlate with similar ones in the San Gabriel Mountains 280 km NW of the Mecca Hills on the other side of the San Andreas fault.

Painted Canyon to Stop 2 (Box Canyon)

Drive down Painted Canyon and back to the paved Hwy 195. Turn left and drive NE up Box Canyon.

In driving up Box Canyon note in turn: the nondescript crossing of the San Andreas fault zone about 1/2 mi from the intersection with the Painted Canyon turnoff; a zone of 1/3-mi-wide steep and irregularly-dipping strata between the San Andres and Skeleton Canyon faults; a local unconformity in the Palm Spring Formation that has been folded in a gentle syncline; and numerous folds and faults along the canyon over the next few miles. The road trends generally obliuely to structure in this badlands terrain, so that structural correlation and continuity from one side of the road to the other are not readily apparent. Note the coarsening of strata up-canyon from distal to proximal parts of the alluvial-fan sequence. The upper part of the canyon is underlain by relatively flat-lying beds of coarse conglomerate that lap onto dark-colored basement rocks in an irregular buttress unconformity such as that in Painted Canyon (Crowell and Sylvester, 1979b). Proceed on Hwy 195 to Shaver's Well, Box Canyon.

Stop 2 (Shaver's Well, Box Canyon)

In the vicinity of Shaver's Well are outcrops of the Orocopia Schist, a glaucophanic greenschist. This rock unit, is confined to the footwall of the great Chocolate Mountain-Orocopia-Vincent thrust system of probable latest Mesozoic age. The volcanic rocks, graywackes and mudstones that have since been metamorphosed may have been deposited in an ancient backarc basin associated with Mesozoic subduction, or within an elongated rhomochasm associated with movements between the Kula and North American lithospheric plates. The thrust sheet was folded in mid-Tertiary time (Crowell and Sylvester, 1979b).

Glaucophanic greenschists similar to the Orocopia Schist are present in the Pelona Schist of the San Gabriel Mountains and the Rand Schist of the northern Mojave Desert. All these widely scattered bodies appear to be tectonically dispersed parts of a previously more coherent Late Mesozoic metamorphic complex (Ernst, 1984).

We are near outcrops of lower through lower middle marine Eocene strata (Maniobra Formation) in the Orocopia Mountains east of Shaver's Well. These strata are the only marine Eocene rocks east of the San Andreas fault. There are some geologists who believe that their offset counterparts can be found 300 km to the NW on the other side of the San Andreas fault in the north-central Transverse Ranges.

The Maniobra Formation consists of 1460 m of cobble-boulder conglomerate, mudstone, and sandstone. Most of the Maniobra consists of deep-sea submarine-fan deposits (Advocate, 1983). These beds lie unconformably above Cretaceous granite and unconformably below nonmarine beds of the lower Miocene nonmarine Diligencia Formation. For a discussion of the depositional environments of the Diligencia Formation, see Squires and Advocate (1982).

NOTE: In 1983, Dave Advocate of C.S.U.N. wrote a Master's thesis on the Maniobra Formation, and I presently have a paper in review that describes new species of early Eocene gastropods and bivalves. Roads into the area are in poor condition, and they are impassable to our vehicles.

Return back down Hwy 195 to Painted Canyon (campsite for second night). Next morning return to Hwy 111 and proceed to Stop 3 (Salton Sea, Visitor Center Headquarters).

Stop 3 (Salton Sea and Barnacles, Visitor Center Headquarters)

The Salton trough is a land-locked basin that represents the direct northward extension of the Gulf of California, separated from the Gulf only by a low divide consisting of sediments of the Colordo River delta. Wave-cut shorelines, freshwater mollusk shells, and local deposits of travertine show that the basin was occupied intermittently in the late Pleistocene, and up to a few hundred years ago, by freshwater lakes. The largest of these Ice-Age lakes, whose level rose about 12 m above present sea level, has been called Lake Coahuila. It had a maximum depth of 91 m. Shorelines of ancient Lake Coahuila are readily seen from State Highway 111--along the eastern side of the sea--and, on the west, from State 86 which follows the western shore (Oakeshott, 1971).

In the Salton trough, the lowest elevation today is -84 m (-276.7 ft), only 1.2 m higher than the lowest point in the western hemisphere, in Death Valley, California. Between 1900 and 1905 the floor of Salton Trough was dry, although in the 1880's and again in 1891 overflows from the Colorado River had created lakes a few meters deep in its lowest part. Starting in 1905, the main flow of the Colorado River was accidentally diverted by way of irrigation canals into the Salton trough. This was the beginning of the present Salton Sea. Only the herculean efforts of the Imperial Irrigation District and the Southern Pacific Company restored the river to its normal channel by 1907. By then, flood waters flowing down the channels of the Alamo and New rivers had created a lake nearly 24 m deep, with a water level and shoreline at -60 m, covering over 400 squares miles. Once inflow was shut off the lake began to shrink owing to intense evaporation, and by 1925 it had become stabilized at -76 m. The lake fluctuated around that level until 1935 when it began to rise again. It has risen steadily ever since to the 1970 level of -70 m. Completion of the All American Canal, thereby introducing more water into Imperial and Coachella valleys, was the cause of this last rise (Oakeshott, 1971).

About 2 m of water are evaporated from the surface of Salton Sea each year. As its size increases so does the area from which evaporation occurs. Eventually a balance will be struck between inflowing water and evaporation loss. Calculations suggest that this will happen before 1980 and at some level below -67 m. Accordingly all lands bordering Salton Sea below -67 m have been withdrawn from public occupation in order to prevent economic loss. The rising level has already made islands out of some of the volcanic knobs at the southeast end of Salton Sea and has submerged the former hot springs, steam jets, mud pots, and mud volcanoes of the Niland area (Oakeshott, 1971).

In addition to the Colorado River source, sediment is derived from the mountains that flank the Salton trough. These sediments are deposited in alluvial fans, braided stream, deltas, barrier beaches, and lacustrine beds. Sands brom both sources have been reworked into extensive aeolian deposits (Van de Kamp, 1973).

Faunal variations in the lacustrine sediments are related to salinity changes with changes in lake volume. The saline lacustrine fauna is a restricted type and is unlike the marine fauna of the nearby northern Gulf of California (Van de Kamp, 1973).

Arenaceous and miliolid foraminifera are the most abundant micro-organisms in the lake. This is interesting because records of foraminifera living in inland seas are very rare. The living foraminiferal assemblage is due to accidental introduction, but the natural effect of environmental conditions has resulted in a dwarf fauna and many malformed individuals. In contrast to conditions in the ocean, abundance of species decreases offshore. The average productivity of the Salton Sea is greater than that of the oceans. Other micro-organisms include diatoms, dinoflagellates, radiolaria, and ostracodes (Arnal, 1961).

Along the shores of the Salton Sea, there is another interesting biologic phenomenon; namely, the presence of a great number of shells of Balanus amphitrite saltonensis, the subspecies of barnacle now thriving in the lake (Arnal, 1961). At places, like the Visitor Center Headquarters, the remains are abundant enough to form "barnacles beaches". The barnacles were introduced accidentally during World War II. Navy seaplanes anchored in Mission Bay, San Diego would be flown routinely to Salton Sea for maneuvers. While anchored in the Salton Sea, barnacle larvae were expelled from barnacles encrusting the plontoons of the seaplanes.

In 1950, the California Department of Fish and Game introduced three species of Gulf of California fish; namely, corvina, sargo, and Gulf croaker. These species, which have done well in the lake, are major attractions for sport fishermen. The record corvina from the Salton Sea is 32 pounds (45 inches). Around 1965, tropical fishes called mollies were accidently introduced into Salton Sea. They are probably the most numerous fish in the Salton Sea, numbering in the millions. Tilapia/ commonly called African perch, was introduced in 1975 by the Coachella Valley Country Water District in order to control aquatic plant growth.

The variety of number of water foul makes the Salton Sea the largest wintering area on the SW coast of the U.S.

Salton Sea, Visitor Center Headquarters to Stop 4 (Red Hill)

Return to Hwy 111. From the visitor center headquarters to Bombay Beach, Hwy 111 parallels the trace of the Mission Creek fault which is just east of the highway.

Starting from the vicinity of Salt Creek Campground, Hwy 111 is parallel to the front of the Chocolate Mountains NE of the highway. The entire mountain area is an active bombing range which makes detailed studies of the geology somewhat difficult. In general, the rocks comprise Mesozoic(?) Orocopia Schist overthrust by Pre-Cambrian gneiss which is intruded by Mesozoic granitoids, and all intruded by and overlain by dikes and flows, respectively, of Tertiary volcanic rocks (Crowell and Sylvester, 1979b).

The most southerly surface evidence of the San Andreas fault can be observed just off the highway in Salt Creek (also called Salton Creek). At least 550 m of Recent horizontal separation across the San Andreas is indicated by the offset of Salton Creek and at least 1120 m of vertical separation is indicated by stratigraphic offset (Biehler and Rex, 1971).

Several Hot Springs and a few? mud volcanoes are aligned along the trace of the San Andreas fault on the eastern side of the Valley. These extend from Desert Hot Springs in the north into Mexico. They are considered by many to have therapeutic value. They are considered an indication of the potential geothermal reservoirs in the valley (Biehler and Rex 1971) and are associated with the rifting process that formed the Salton trough and the Gulf of California (Oakeshott, 1971).

As you proceed southeastwardly along Hwy 111 between Salt Creek and just north of Bombay, the exposures to the east of the highway are of the nonmarine Shavers Well Formation (late Pliocene or early Pleistocene) and lacustrine Borrego Formation (Pleistocene). These formations are tightly folded and cut by numerous closely spaced faults of the San Andreas system. The San Andreas fault is the major structure in the area. Right-lateral separation of drainage and vertical separation (northeast side relatively upthrown) of approximately 1000 m are observable along the fault. The major fold in the area is the Durmid anticline. Gravity and aeromagnetic data suggest that it is probably a drape fold caused by passive folding of the sedimentary cover over an upfaulted basement block or possibly a near-surface intrusive body (Babcock, 1974).

Proceed from Bombay Beach to Niland. Continue on Hwy 111 from Niland to Sinclair Road. Head west to Garst Road and turn north. Proceed to Red Hill Marina Campground. Note the presence of barnacles along the shoreline of Salton Sea.

Stop 4 (Red Hill)

Surface volcanic rocks within the Salton Sea Geothermal Field consist of five small rhyolitic domes, collectively called the Salton Buttes, which were extruded onto Quaternary sediments of the Colorado River delta. These domes lie along a northeast lineament over a distance of approximately 7 km and are spaced 2 to 3 km apart. A K-Ar age on obsidian from Obsidian Butte is approximately 16,000 years (with a maximum of 55,000 years). Steam is still being discharged from cracks in three volcanoes (Korsch, 1979).

Red Hill (or Red Island) consists of two of the five rhyolitic plugs or domes that intrude Quaternary sediments near the SE shoreline of the Salton Sea. They are composed of low-calcium, alkali rhyolite, pumice, and obsidian with from 1 to 2% crystals. Xenoliths are present and consist of low-potassium tholeite basalt and partly melted granite, with many showing strong hydrothermal alteration. The bimodal basalt-rhyolite assemblage probably formed by partial fusion of mantle peridotite in two stages, forming successive rhyolitic and basaltic melts. Compositions and textures suggest that the granite xenoliths are fragments of basement rather than the crystallized equivalents of the rhyolitic magma. The domes are interpreted to lie above a hot-spreading center underlain at great depth primarily by a mantle diapir that has broken and fragmented the attenuated basement of older continental rocks as the Pacific and North American plates diverged. The Salton Buttes are chemically similar to rocks of the East Pacific Rise and suggest an origin related to crustal spreading (Crowell and Sylvester, 1979b).

The domes at Red Island are linked by subaqueous pyroclastic deposits, whereas the others are single extrusions with or without marginal lava flows. The domes are mushroom-shaped, and the areally large extent of magnetic anomalies around the entire volcanic field suggests that they are underlain by a relatively large pluton at depth (Korsch, 1979). The area is associated with both a large gravity positive anomaly and a broad magnetic positive. The geophysics indicates that the anomalous mass extends at least 6 km in depth--which coincides in this area with the thickness of alluvium (Biehler and Rex, 1971).

NE of Red Hill lies an abandoned $CO_2$ field that produced this gas from 1934 to 1954 from 54 wells with depths ranging from 152 to 214 m at pressures exceeding the hydrostatic. The gas was used mainly for manufacturing "dry ice." Abundant $CO_2$ is thought to have been released by decarbonation accompanying metamorphism of the young sediments, then the $CO_2$ migrated upward into the field. The initial source of the carbonate was probably detrital carbonate grains eroded from older sedimentary formations of the Colorado Plateau region and brought to the Salton trough by ancestral Colorado Rivers (Crowell and Sylvester, 1979b).

Red Hill to Stop 5 (Geothermal Wells)

Return to Sinclair Road and head west to Gentry Road. Turn south on Gentry Road. West of Gentry Road, there are geothermal wells which reach depths up to 4500 m.

Stop 5 (Geothermal Wells)

Samples from these geothermal wells show increasing induration with depth along with increasing metamorphism that reaches the greenschist facies. Temperatures range up to 360°C at 7100 ft, and some wells produce brines containing over 250,000 ppm dissolved solids, primarily Cl, Na, Ca, K and Fe. Corrosion problems involved in bringing the geothermal field into heat production are therefore considerable. During 1978, 13 geothermal wells were drilled in the Imperial Valley and a new field (South Brawley) was discovered. Within it, bottom-hole temperatures of 475° to 500°F prevail at 4,078 m, with an initial one-hour flow test at a rate of 60,000 bbl/day from deep-fracture production (Crowell and Sylvester, 1979b).

The Imperial Valley geothermal region is inferred to lie above spreading centers at the divergent boundary between the North American and Pacific lithospheric plates (Crowell and Sylvester, 1979b). The

Salton Sea geothermal region is entirely within Pliocene and Quaternary sediments of the Colorado River delta at the south end of the Salton Sea. At the time of deposition these sediments consisted of sand, silt and clay of uniform original mineralogical composition, but under the elevated temperatures and pressures of the geothermal system they are being transformed to low-grade metamorphic rocks of greenschist facies (Crowell and Sylvester, 1979a).

Concentrated brine tapped by a deep well drilled for geothermal power near the Salton Sea in California deposited metal-rich siliceous scale at the rate of 2/3 tons/month. This iron-rich opaline scale contains an average of 20% copper and up to 6% silver present in bornite, digenite, chalcopyrite, chalcocite, stromeyerite, and native silver. The heavy metals in solution greatly exceed the sulfur content, on a modal basis. They are apparently derived from the sediments of the brine reservoir, being released from the silicate minerals in which they occur in trace amounts as metamorphism of the sediment proceeds (Crowell and Sylvester, 1979a).

Note the steam coming from the plant on the western horizon. This is a geothermal plant co-owned by Southern California Electric and Union Oil.

Geothermal Wells to Stop 6 (Painted Gorge)

Continue South on Gentry Road to County Hwy S30. Take S30 to Westmorland and then take Hwy 78 from westmorland to Brawley. Then take Hwy 86 south to El Centro.

At the SE corner of Hwy 86 and Keystone Rd., note that the ground surface is about 30 m below sea level as indicated by the sea level mark on the Holly Sugar silos.

Southeast of Brawley is Mesquite Lake which is believed to be a tectonic sag centered over a small pull-apart in the floor of the Salton trough. Seismic refraction and gravity data show that about 6 km of sediments fill the pull-apart in this part of the Salton trough (Crowell and Sylvester, 1979b).

In 1940, the Imperial Valley (or El Centro) earthquake, magnitude 7.1, which originated on the Imperial fault southeast of El Centro (Fig. 4), resulted in deaths of nine people and caused $6 million in damages to irrigation works. Surface fault displacement reached a maximum of 6.3 m in a right-lateral sense. The All-American Canal at the Mexican border was offset 4.3 m. It is interesting that even very small earthquakes can be accompanied by surface displacement on the Imperial fault (Oakeshott, 1971).

Imperial Valley, presumably the deepest part of the Salton trough, is characterized geophysically by a gravity high, which is the opposite of what one would expect for a deep sediment-filled basin. The Coachella Valley, on the other hand, is characterized by a gravity low. In the Imperial Valley, the Salton trough Bougher gravity values are from 20 to 40 mgal higher than the regional average values, and

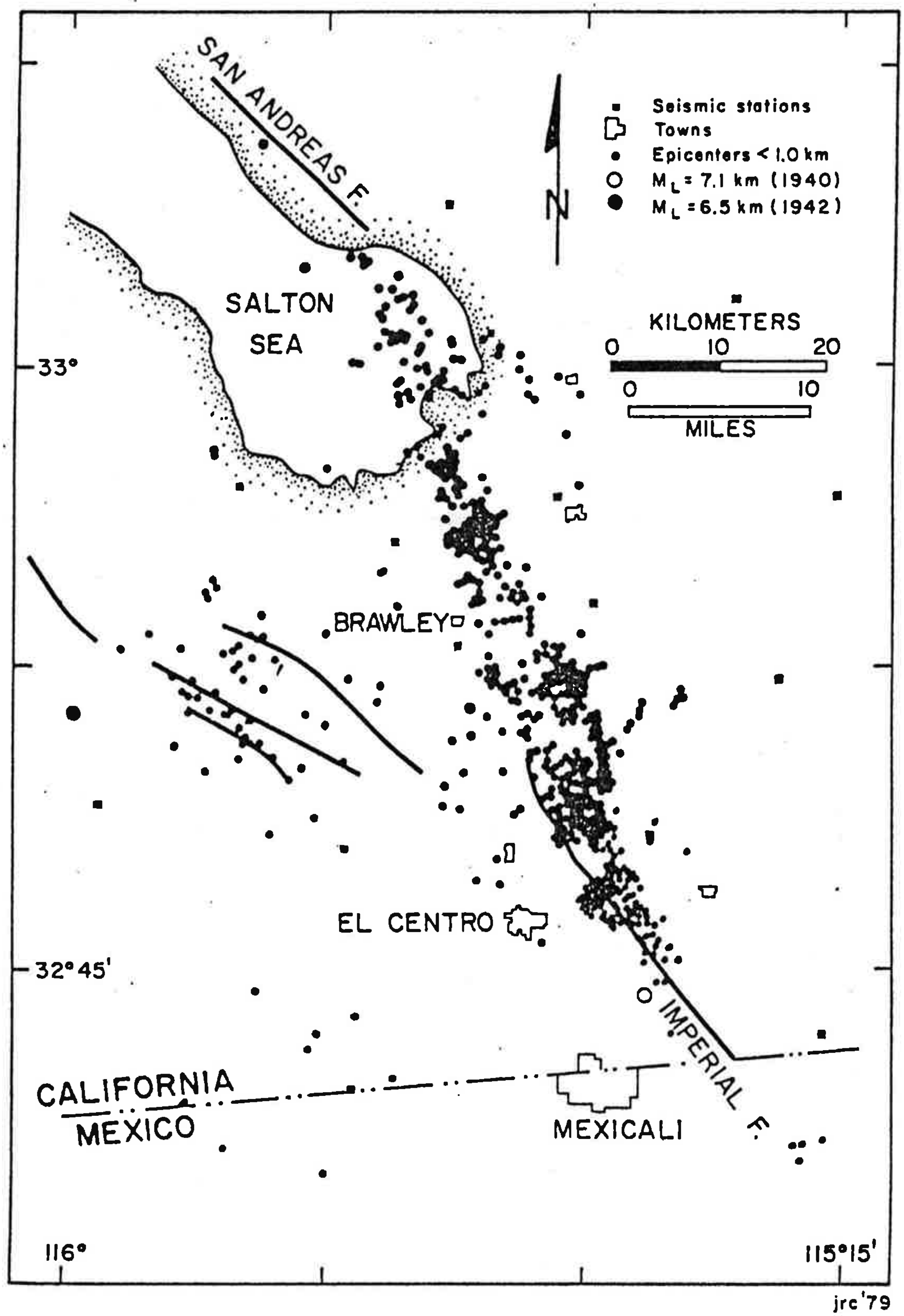


Fig. 4. Seismicity of Imperial Valley, 1973-78, showing earthquake epicenters located with a precision of 1 km or less (From Rockwell and Sylvester, 1979).

form a welt of high gravity values trending northwest to the middle of the Salton Sea (Fig. 5) (Keller, 1979).

Take Hwy 86 south through El Centro to Interstate 8. Proceed 25 miles west on Interstate 8 to Ocotillo.

At Ocotillo, take County Hwy S80 east 4.2 miles to Painted Gorge Road. Proceed north along this improved dirt road for about 5 miles to the vicinity of Painted Gorge.

Stop 8 (Painted Gorge)

Painted Gorge is in the general vicinity of where Woodring originally described the Imperial Formation in 1932 (Quinn and Cronin, 1984). Painted Gorge is in the southeast Coyote Mountains whose structure is dominated by the Elsinore fault, which uplifted and tilted the Coyote Mountains northward. The southeast Coyote Mountains contain a complete but discontinuous section of the Imperial Formation. In Painted Gorge, the Alverson Andesite (16 my) constitutes the basement rocks (Bell-Countryman, 1984).

The Imperial Formation is a lower Pliocene marginal marine to marine deposit which is found in an almost continuous band from the Yuha Buttes through the Fish Creek Mountains and northwest to the Vallecito Mountains. It also occurs as far north as Whitewater just east of San Gorgonio Pass. The formation is not known to crop out on the east side of the Salton trough (Bell-Countryman, 1984).

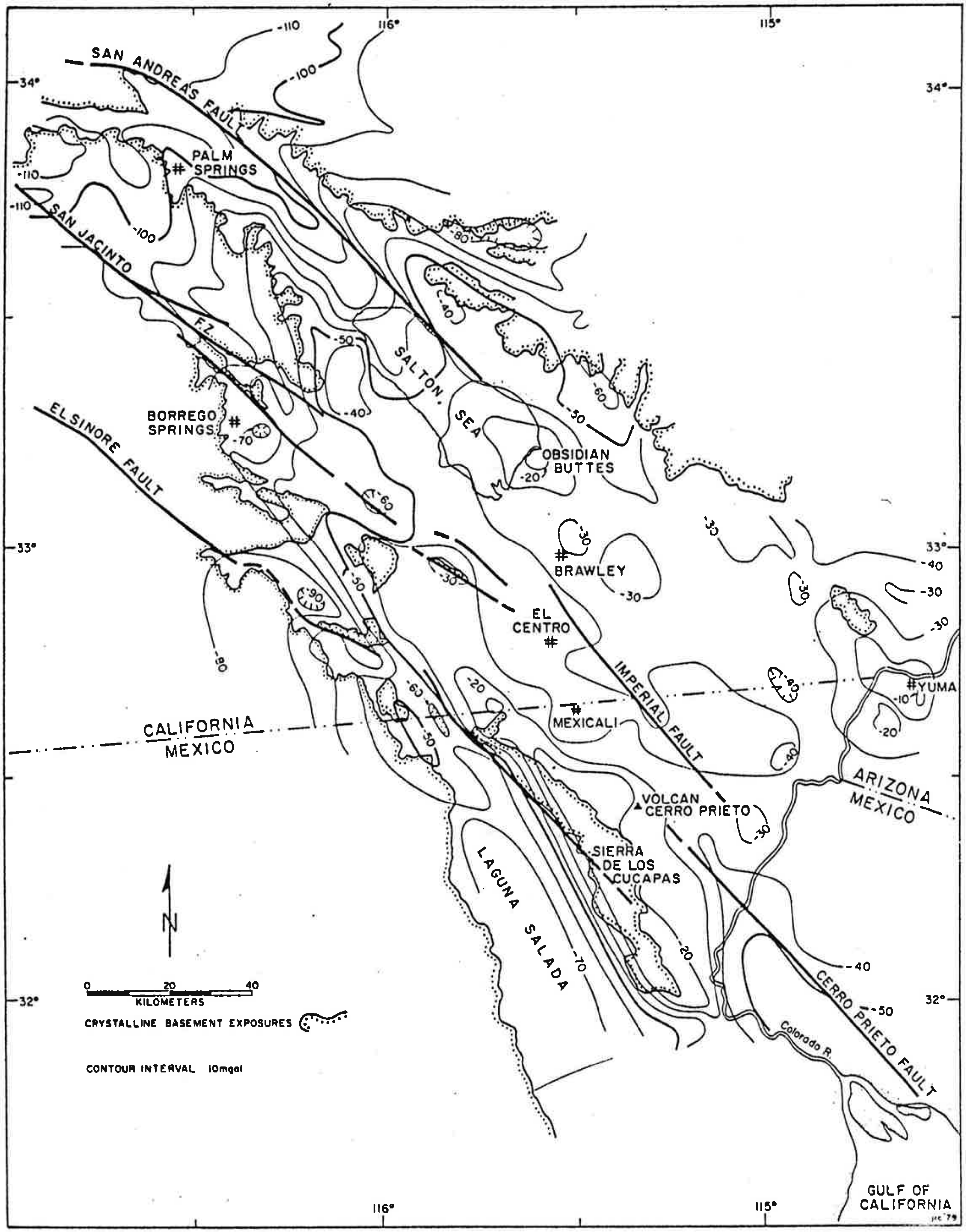


Fig. 5. Simple Bouguer anomaly map of Salton Trough (From Keller, 1979).

Most of the Imperial Formation consists of deltaic sand, silt, and clay from a Colorado River source. Diverse invertebrate fossils indicate warm-water marine to brackish-water conditions. The uppermost beds contain terrestrial and mammals. Thus, during Imperial time (4.3-4.0 m.y. ago, based on magnetic polarity studies) progressive shoaling occurred, with sedimentation eventually reaching sea level (Johnson and others, 1983).

The information given below is mostly from Bell-Countryman, 1984:

> The Imperial Formation as exposed in the southeast Coyote Mountains consists of three major facies (Fig. 6).
>
> Facies A consists of shoreline deposits associated with alluvial fans. This facies is almost entirely non-fossiliferous. Fossils, when found, are of Clypeaster sand dollar type. Facies A records the initial flooding of the Salton trough in earliest Pliocene times. The Salton trough was a low-lying area with rugged topography. When inundated, this resulted in a highly irregular shoreline of high relief characterized by headlands, bays, islands, and submerged hills.
>
> Facies B (also called the upper Latrania Sands) consists of shallow-marine, golden-colored sandstone and silstone with scattered sand dollar and coral fossils.

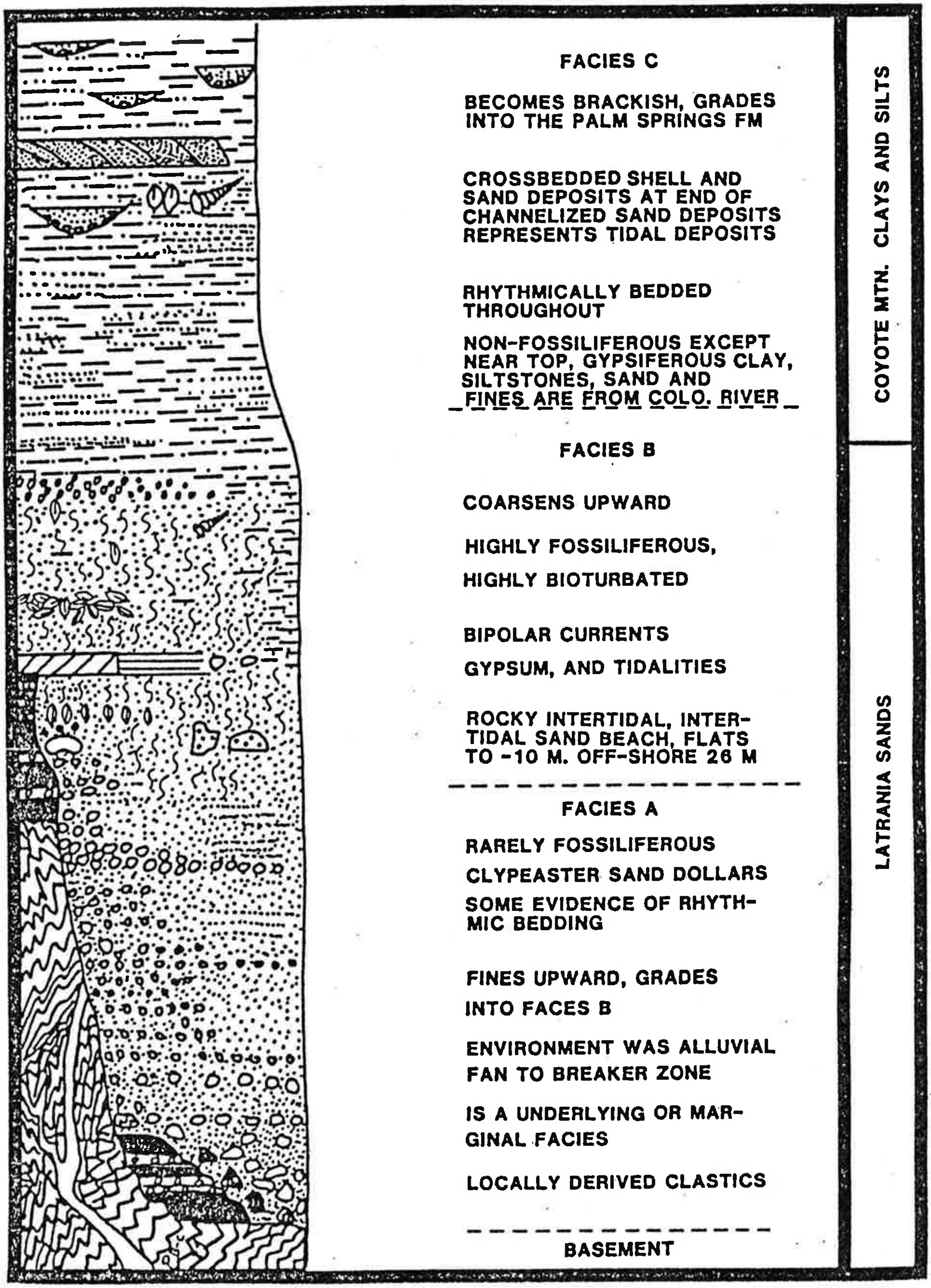


FIG 6. *SUMMARY OF FACIES, IMPERIAL FORMATION*
(From Bell-Countryman, 1984).

Locally, there are gypsum deposits.

Facies C (also called the Coyote Mountain Clays) consists of golden-colored siltstone and claystone indicating a filling of the Salton trough by fine clastic material from the Colorado River. In places there are ostreid limestone beds. These resistant limestone beds are richly fossiliferous in the Painted Gorge area. The macrofauna consists predominantly of small specimens of the plicate oyster *Ostrea vespertina* and normal-sized specimens of the jingle shell *Anomia subcostata*. Bryozoans and small specimens of colonial coral are fairly rare. Many of these bivalves are articulated and apparently they helped to form reefs adjacent to coastal mud flats. The macrofauna has a warm-water aspect to it - warmer than similar-age faunas in formations found along the coastal regions of southern California. The Imperial Formation macrofauna has several species closely allied to those of the modern Gulf of California tropical macrofauna. For a description of the Imperial Formation macrofauna, see Kew (1914) and Hanna (1926).

The lowermost rocks of Facies C are locally gypsiferous. The major portion of Facies C is non-fossiliferous and may indicate rapid sedimentation and high evaporating conditions on tidal flats.

Painted Gorge to Stop 7 (Split Mountain Gorge)

Return to S80 and take it east to Huff Road. Turn north on Huff Road which eventually turns into Imler Road. Then turn north on Courty Hwy S30, which goes to Westmorland. Then, continue west of Hwy 86 to the junction with Hwy 78 near the southern portion of Salton Sea.

As you travel from Westmorland to the junction with Hwy 78, note the Superstition Hills to the west. Shorelines of ancient Lake Coahuila (1600 to 300 years ago) are conspicuous along the flanks of the Superstition Hills.

The Superstition Hills is an anticlinal uplift on the northeast side of the Superstition Hills fault. The northern part of this uplift is a series of many small, east-trending folds in the nonmarine Brawley Formation (early Pleistocene age) (Dibblee, 1954, 1984).

Head west on Hwy 78 to Ocotillo Wells. Then, take Split Mountain Road south to a junction with a dirt road just north of the U.S. Gypsum Company's processing plant in the Fish Creek Mountains. The Fish Creek gypsum (Pliocene age) crops out extensively in the hills around the processing plant. The formation is at least 30 m of nearly pure, massive gypsum. The Fish Creek Gypsum lies unconformably on the Split Mountain Formation (Fig. 7) (ver Planck, 1952).

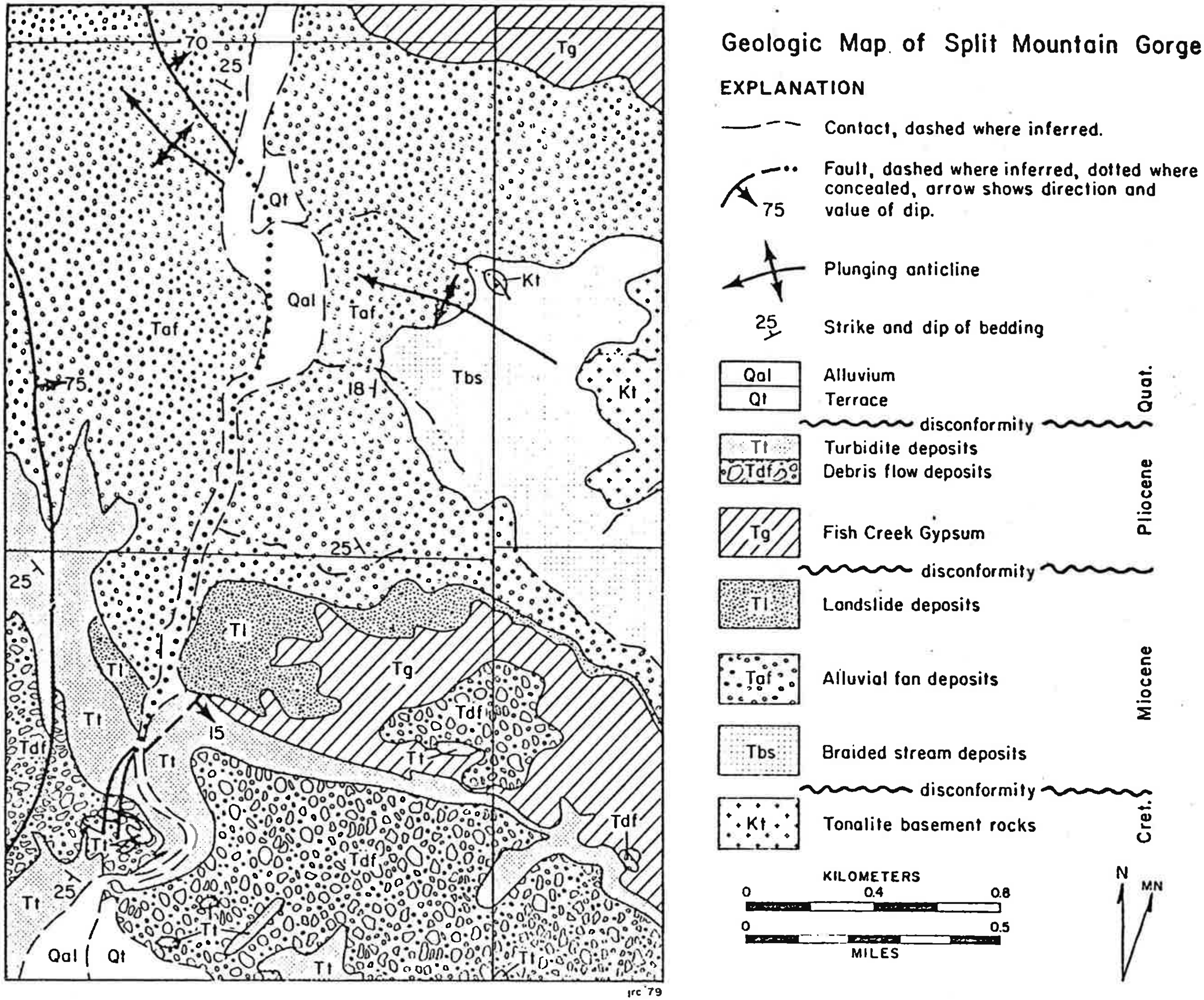


Fig. 7. Geologic map of the Split Mountain Gorge area, eastern San Diego County, California (From Kerr, Pappajohn, and Peterson, 1979).

Proceed southwest on the dirt road about 2 1/2 mi to the near vertical walls (400-feet-high cliffs) Split Mountain Gorge, which has been cut by Fish Creek.

Stop 7 (Split Mountain Gorge)

The information given below is all from Kerr, Pappajohn, and Peterson (1979).

A spectacular section of Mio-Pliocene rocks is exposed at Split Mountain Gorge. The section consists of six distinctive rock units (Fig. 8). The lower three rock units (Miocene) are nonmarine and include (in ascending order) braided-stream deposits, alluvial-fan deposits, and a landslide deposit. The upper three rock units (Pliocene) are paralic or marine and include the Fish Creek Gypsum, turbidite deposits, and a second landslide-debris flow deposit. Together, these rock units record the initial tectonic subsidence within the Salton trough region probably both before and during the origin of the proto-Gulf of California. They include the first indication of marine sedimentation associated with the Gulf.

Stratigraphic nomenclature for these six rock units is complicated and controversial. The most recent workers, Ken Pappajohn, and Peterson (1979) tentatively assigned the lower three rock units to the Split Mountin Formation and the upper three rock units to the Imperial Formation.

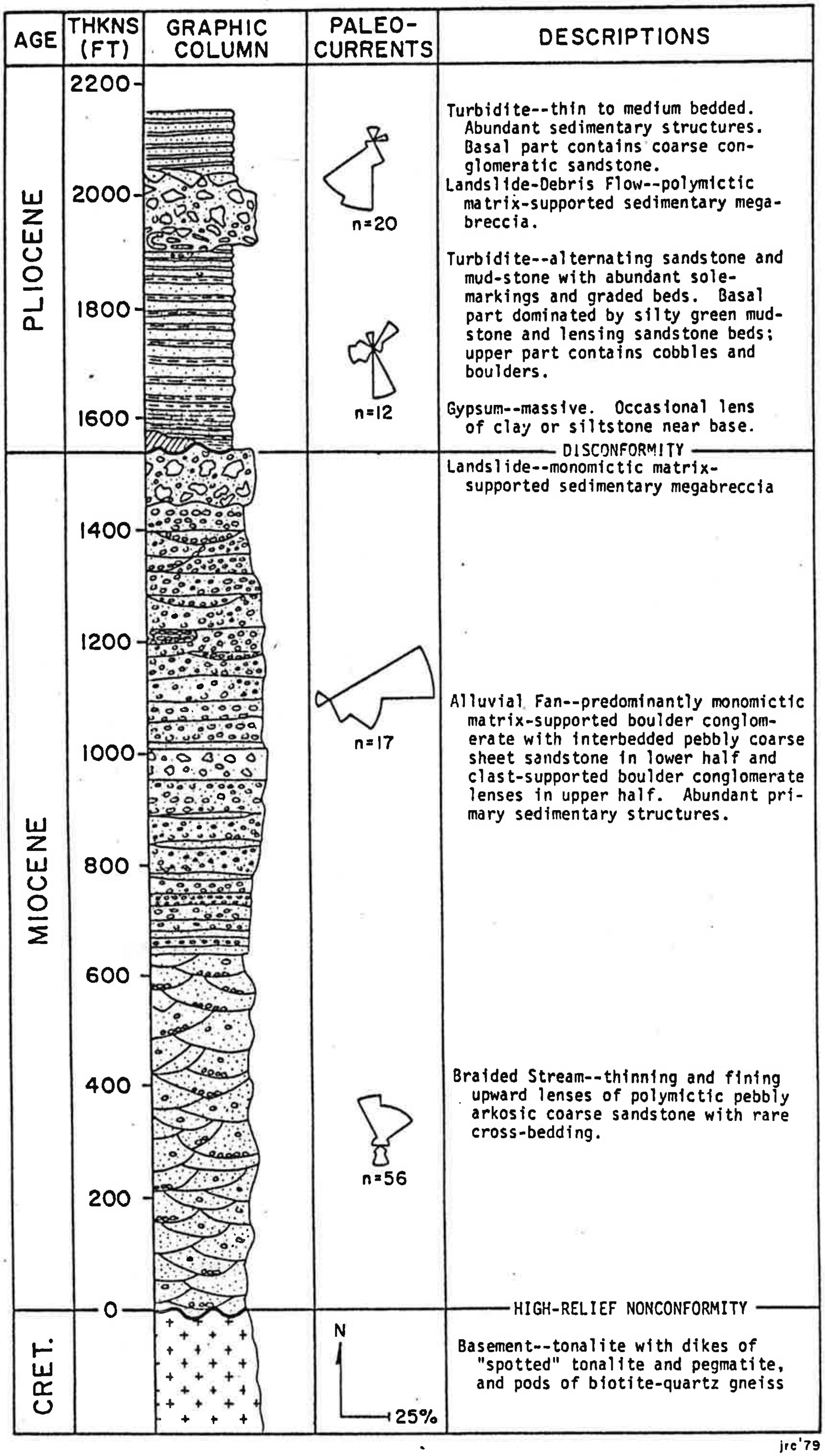


Fig. 8. Columnar section for Split Mountain Gorge. (From Kerr, Pappajohn, and Peterson, 1979).

The basement complex is not exposed in the gorge proper but crops out within the core of the Fish Creek anticline to the east. The basement complex consists of tonalite (30% quartz, 50% plagioclase, 10% K-feldspar, and 10% biotite).

The lowest Miocene rock unit (braided-stream deposits) is not exposed in the gorge proper. Over half of the section exposed in Split Mountain Gorge is dominated by conglomerate of the alluvial-fan deposits. Three types of sedimentologic processes are inferred to have deposited the conglomerate: debris-flow, sheetflood, and fluvial-channel fill. Debris-flow deposits dominate the section and are characterized by matrix-supported conglomerate. Sheetflood deposits are less common and consist of graded beds. Fluvial channel-fill deposits are characterized by lenticular-shaped, poorly stratified clast-supported conglomerate.

Overlying the alluvial-fan deposits is a landslide deposit. This unusual cliff-forming deposit has a uniform thickness of about 46 m over about 5.5 km of outcrop. It abruptly pinches out in the west wall of the gorge. The lower contact is undulatory and is concordant with the underlying alluvial-fan deposits. The deposit is a sedimentary megabreccia with tonalite boulders (up to 5 m in diameter) suspended in a greenish gray, sandy mud matrix. The megabreccia probably was catastrophically deposited in mass as a rockslide that traveled on a cushion of air. When the entrapped air layer escapes from beneath, the mass comes to a sudden and dramatic halt which causes intense internal deformation (i.e., brecciation).

The Fish Creek Gypsum forms white, smooth, rounded slopes high atop the eastern wall of Split Mountain Gorge. The deposit consists of thin beds of gypsum with local beds of selenite. Anhydrite occurs near the base. The Fish Creek Gypsum is not present in the canyon area proper.

As you proceed south through Split Mountains Gorge, exposures reveal a vertical gradation from green mudstone, constituting the lateral equivalents of the Fish Creek Gypsum, to rhythmically bedded turbidite sandstone of Pliocene age. Sedimentary structures in the turbidite sandstone include sole marks (some nearly 10 m in length), flute casts, sand injections, flames, rip-up clasts, and trace fossils. About 2.5 km to the northwest, the turbidites grade laterally into paralic deposits and distal alluvial-fan deposits.

Within the turbidites, thre is a second megabreccia deposit, exposed at the south end of Split Mountain Gorge. It contains clasts of tonalite, pegmatite, schist, gneiss, and marble of cobble to large boulder sizes (some in excess of 10 m in diameter) suspended in a green-gray to reddish brown matrix. The megabreccia deposit has a maximum thickness of 36 m and extends for about 3 km both east and west of Split Mountain Gorge. The origin of the megabreccia is probably similar to the landslide deposits in the lower part of the section.

In summary, the stratigraphic sequence at Split Mountain Gorge reveals that a debris-flow dominated alluvial fan accumulated along a tectonically active western margin of an alluviated valley. A catastrophic landslide subsequently covered a part of alluvial-fan surface and probably denoted the beginning of major tectonic adjustments (i.e., possibly the beginning of the opening of the Gulf of California). With the incursion of the Gulf of California in early Pliocene time, deposition of a paralic-to-marine units succeeded the nonmarine deposits and accumulated in a southeastward-deepening basin. A lagoonal environment to the northeast was the site of evaporite precipitation. While alluvial fans built into the basin from the north and west, turbidites accumulated around their submarine fringe. Employment of the upper landslide-debris flow temporarily interrupted the turbidite deposition.

Split Mountain Gorge to Stop 8 (Borrego Badlands Area)

Return north down Split Mountain Road to Ocotillo Wells. Turn west on Hwy 78. To the north is Borrego Mountain, site of the 1968 Borrego Mountain earthquake (M6.4)(see Sharp, R.V., and many others, 1972, for details). The earthquake caused a maximum right-lateral displacement of 38 cm at the town of Ocotillo Wells. The temblor was felt over 60,000 square miles. It triggered surface movements up to 0.5 cm on the Superstition Hills, Imperial, and Mission Creek faults, (Oakeshott, 1971). To the south are the Vallecito Mountains.

Continue west on Hwy 78 through Borrego Valley to Borrego Springs

Road. Displacements along braided strands of the San Jacinto fault zone are largely responsible for the topography within Borrego Valley and at its northwest and southeast margins (Crowell and Sylvester, 1979b).

Head northwest on Borrego Springs Road to the town of Borrego Springs. From Borrego Springs, take County Hwy S22 eastward to where it makes a sharp turn north (i.e. Pegleg Road).

Stop 8 (Borrego Badlands Area)

From anywhere on Pegleg Road, there is an excellent view eastward of dissected and deformed Plio-Pleistocene strata of the Borrego Badlands, assigned to the Palm Spring and Borrego Formations.

The Palm Spring Formation, from 2000 to 3000 m thick, grades laterally into and overlies the Imperial Formation. It consists predominantly of nonmarine sandstone, siltstone, mudstone, conglomerate, and some beds of fresh-water limestone (Crowell and Baca, 1979). Locally, there are abundant land-mammal fossils (Johnson and others, 1983). A limited marine invertebrate fauna collected from the upper part of the formation indicates intermittent nearshore marine conditions existed in the Salton trough as late as middle Pleistocene time. The Palm Spring Formation is mostly Pleistocene in age, but parts may have been deposited during late Pleistocene time (Crowell and Baca, 1979).

The upper part of the Palm Spring Formation grades eastward into lacustrine silt and clay of the Pleistocene Borrego Formation. The Borrego Formation, in turn, is overlain both gradationally and unformably by the Ocotillo Conglomerate and its eastern lacustrine facies, the Brawley Formation. The Ocotillo Conglomerate is up to 300 m thick and consists of gray granitic-pebble detritus and the Brawley Formation, 600 m of silt, sand, and mud. Both the Brawley and Borrego Formations contain a lacustrine fauna of mollusks, ostracodes and foraminifera, and are interpreted as deposited in a nearshore lacustrine environment (Crowell and Baca, 1979).

Borrego Badlands Area to Stop 9 (Travertine Rock)

Stay on County Hwy S22. In traveling eastward near the southeast end of Coyote Mountain, note the depression occupied by Clark Dry Lake and the gentle swell of the Borrego Badlands consisting of upper Cenozoic sediments deformed and arched along the trend of the San Jacinto fault zone. Clark Valley lies between two major strands of this system, as shown topographically by the faceted spurs and linear trends of the ranges (Crowell and Sylvester, 1979b).

Rocks in Coyote Mountain-Borrego Springs region include the Santa Rosa mylonite which is a tectonic-movement zone of Late Cretaceous age that has been displaced by late Cenozoic faults (Simpson, 1984). The Santa Rosa mylonite belt extends from Palm Springs southeastward through the Santa Rosa Mountains to the area of Borrego Springs (Fig.

9). The zone, which reaches a thickness of 8 km south of Indio, consists of sheared cataclastic rocks of mid-Cretaceous and older basement rocks, deformed under ductile conditions at depths estimated between 11-23 km and temperatures approaching the minimum melting temperature of granite (650°-700°C). The movement zone, now deeply eroded, is probably a result of events when a convergent plate boundary existed in western Northern America (Crowell and Sylvester, 1979b). Unfortunately the mylonite zone is not exposed along the highway.

As you drive toward Salton Sea, the exposures are of the Palm Spring Formation (terrestrial sandstone and red clay). This formation is exposed extensively in the Borrego Badlands area. It attains a maximum thickness of about 2500 m. Many of the finer sandstone strata contain calcareous concretions of various shapes. The Palm Spring formation accumulated in the Imperial basin as deltaic deposits by streams that drained eastward from the rising southern California Peninsular Range terrane. These sediments filled the Imperial basin as the Gulf of California waters receded southward in late Cenozoic time. During that time, fine sediment brought in by the Colorado River accumulated as a large delta fan across the Gulf of California to bar the marine waters of the Gulf from what is now the Imperial basin. This condition probably persisted to the present (Dibblee, 1984).

Head east on S22 to Salton City. Take 86 north at Salton City. Continue along the west side of Salton Sea to Travertine Rock just

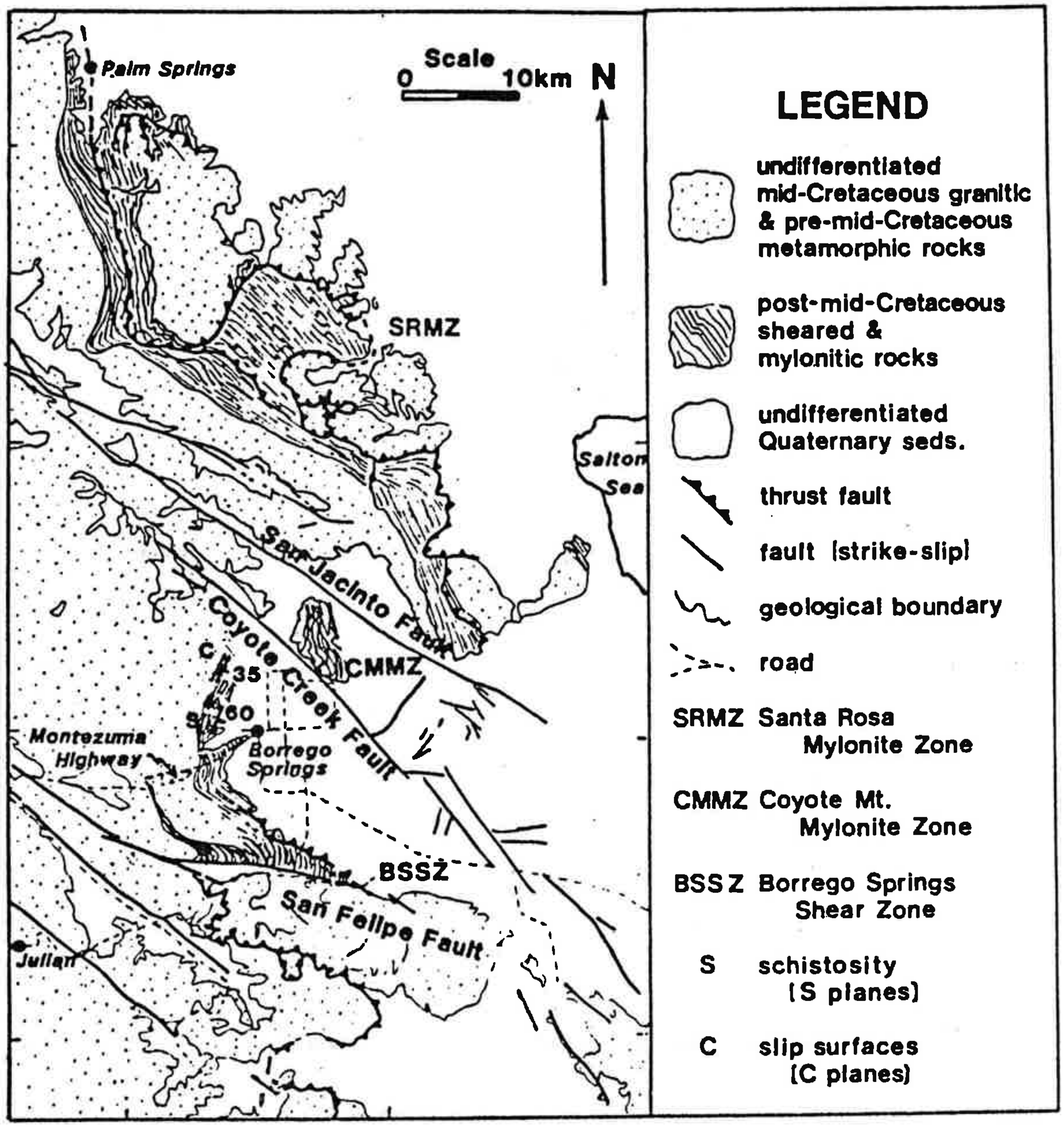


Figure 9. Generalized geologic map of Borrego Springs-Santa Rosa mylonite zone, Riverside and San Diego Counties, California (From Simpson, 1984).

north of Desert Shores. The Santa Rosa Mountains flank the Salton Sea to the west.

Stop 9 (Travertine Rock)

A superb Lake Cahuilla (900A.D.-1500A.D.) shoreline was cut into the mountain front in the vicinity of Travertine Rock. Rocks above the shoreline appear light because of wave cutting which produced a cliff and destroyed the desert varnish still preserved at higher levels. Rocks below the shoreline are coated with dark travertine. The travertine (a porous, irregular deposit of calcium carbonate on rock surfaces) of Travertine Rock alongside the highway was deposited below the surace level of Lake Cahuilla. The encrustation is as much as 30 inches thick (Sharp, R.P., 1972).

Travertine Rock to Indio

Continue north on Hwy 86 to the junction with Hwy 111 just south of Indio. Hwy 86 parallels outcrops of pre-Cenozoic metamorphics and portions of Mesozoic granitic rocks. Just west of Indio, a high shoreline of ancient Lake Cahuilla is crossed. Indio lies about in the center of the Coachella Valley on Quaternary alluvium and lake deposits. The Santa Rosa Mountains on the west and the Mecca Hills on the east mark the boundaries of the valley (Biehler and Rex, 1971).

This concludes CSUN Geology Department Second Annual Spring Field Trip. I hope that you have enjoyed it. Head back to Los Angeles via Interstate 10.

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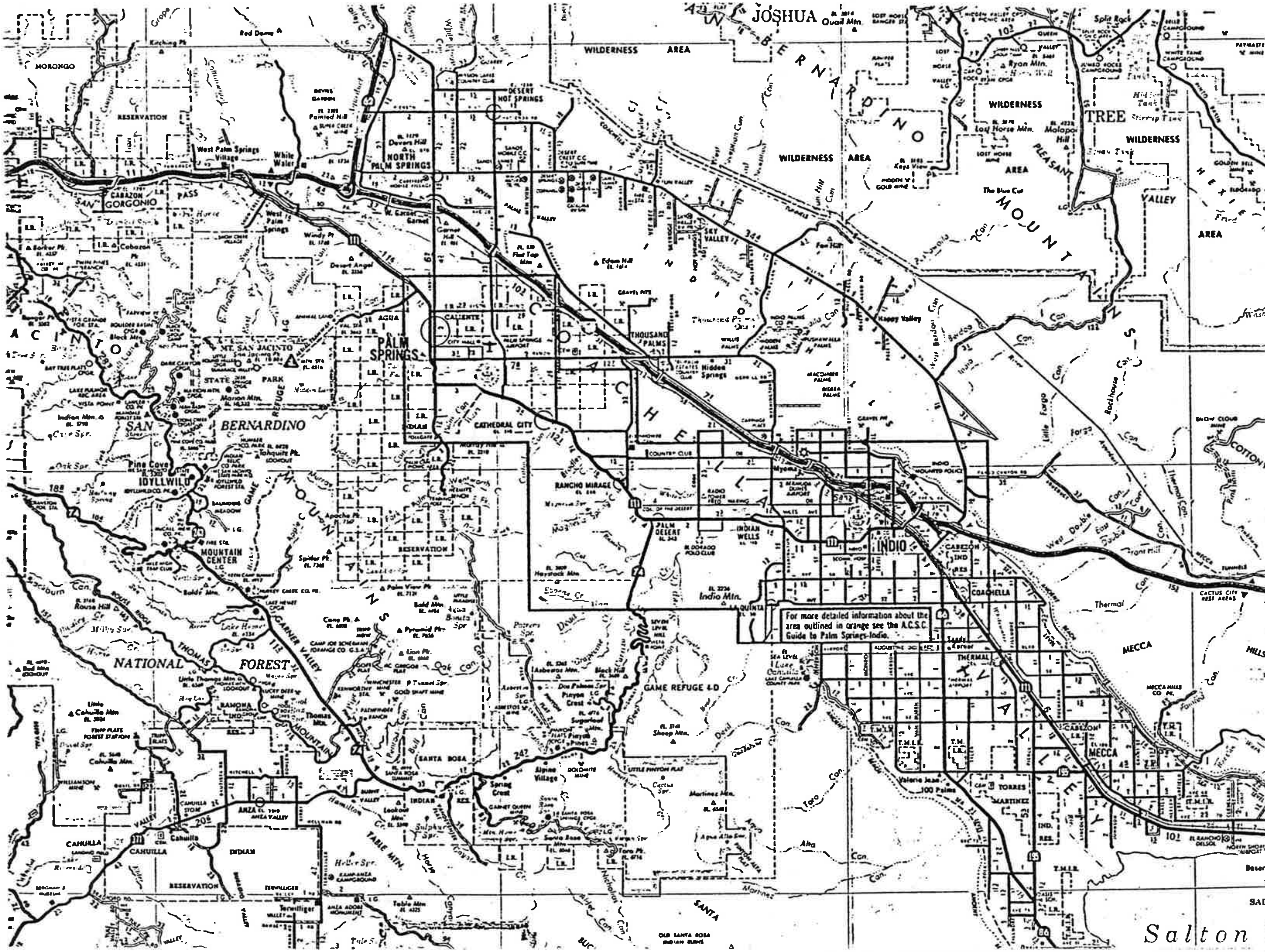
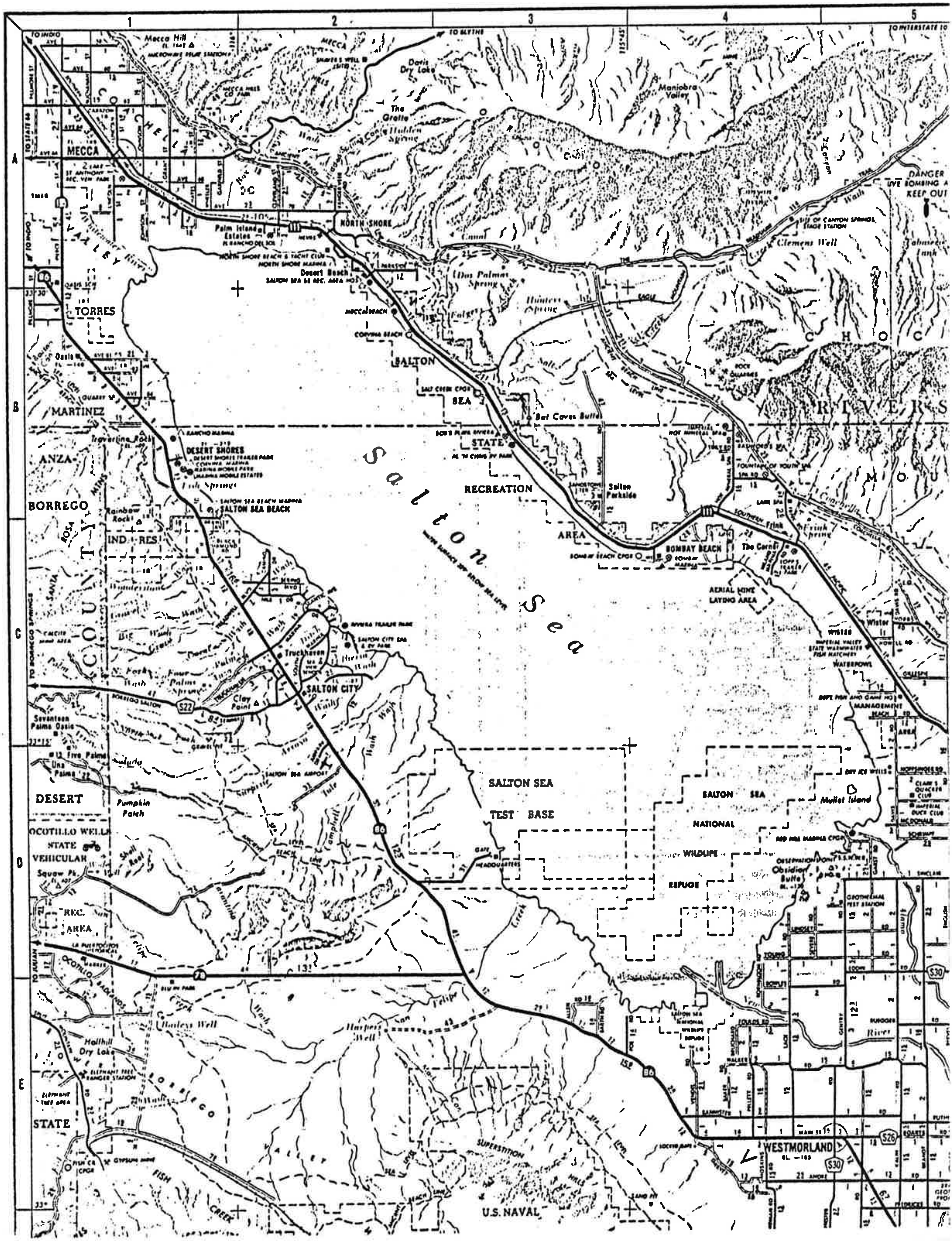


JOSHUA
TREE
WILDERNESS AREA
SAN BERNARDINO MOUNTAINS
PLEASANT VALLEY
HEXIE
MORONGO
RESERVATION
West Palm Springs Village
White Water
CABAZON
SAN GORGONIO PASS
NORTH PALM SPRINGS
DESERT HOT SPRINGS
SKY VALLEY
Edom Hill
THOUSAND PALMS
Hidden Springs
PALM SPRINGS
CALIENTE
AGUA
CATHEDRAL CITY
RANCHO MIRAGE
PALM DESERT
INDIAN WELLS
INDIO
COACHELLA
THERMAL
MECCA
Indio Mtn.
QUINTA
COACHELLA VALLEY
MT. SAN JACINTO STATE PARK
SAN BERNARDINO NATIONAL FOREST
GAME REFUGE
Pine Cove
IDYLLWILD
MOUNTAIN CENTER
GARNER VALLEY
THOMAS MOUNTAIN
RAMONA
SANTA ROSA
SAN JACINTO MOUNTAINS
GAME REFUGE 4-D
Spring Crest
Alpine Village
ANZA
CAHUILLA
TABLE MTN.
Salton
For more detailed information about the area outlined in orange see the A.C.S.C. Guide to Palm Springs-Indio.


1
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A
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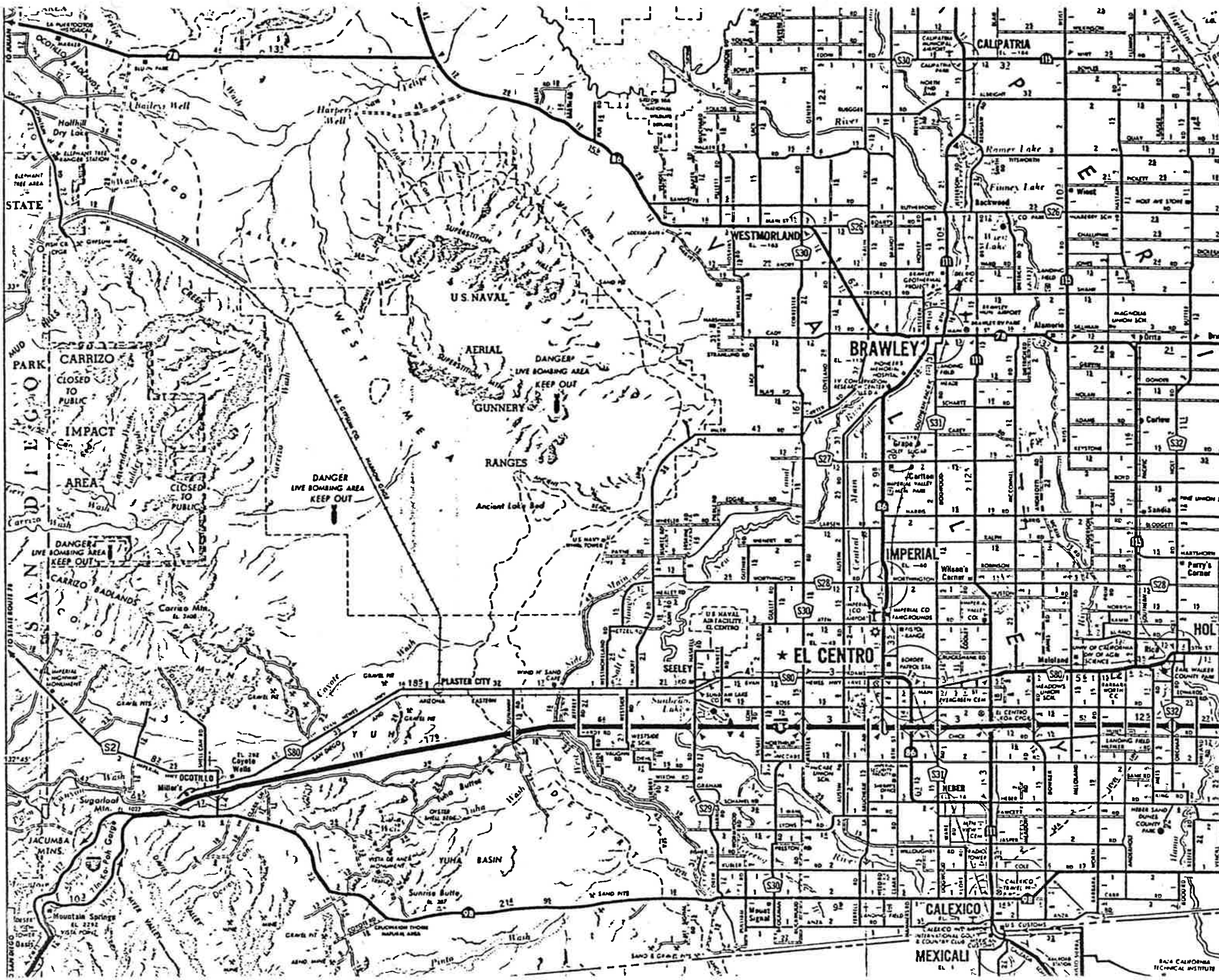
E
TO INDIO
TO BLYTHE
TO INTERSTATE 10
Mecca Hill
MECCA
Davis Dry Lake
Maniobra Valley
The Grotto
NORTH SHORE
Palm Island Estates
Desert Beach
MECCA BEACH
CORVINA BEACH
SALTON
SEA
STATE
RECREATION
AREA
Bat Caves Butte
Salton Parkside
BOMBAY BEACH
The Corner
AERIAL MINE LAYING AREA
Clemens Well
DANGER
KEEP OUT
TORRES
Oasis
MARTINEZ
ANZA-
BORREGO
DESERT SHORES
SALTON SEA BEACH
Truckhaven
SALTON CITY
Clay Point
Salton Sea
Seventeen Palms Oasis
Una Palma
DESERT
Pumpkin Patch
OCOTILLO WELLS
STATE
VEHICULAR
Squaw Pk.
REC.
AREA
STATE
SALTON SEA
TEST BASE
SALTON SEA
NATIONAL
WILDLIFE
REFUGE
Mullet Island
Obsidian Butte
Niland
Wister
Harpers Well
Hallhill Dry Lake
SUPERSTITION
U.S.NAVAL
WESTMORLAND
S22
S26
S30
78
86



IMPERIAL VALLEY
CALIPATRIA
WESTMORLAND
BRAWLEY
IMPERIAL
EL CENTRO
HOLTVILLE
SEELEY
HEBER
CALEXICO
MEXICALI
PLASTER CITY
OCOTILLO
Coyote Wells
Wilson's Corner
Perry's Corner
U.S. NAVAL AERIAL GUNNERY RANGES
DANGER LIVE BOMBING AREA KEEP OUT
SUPERSTITION MTN
SUPERSTITION HILLS
WEST MESA
Ancient Lake Bed
U.S. NAVAL AIR FACILITY EL CENTRO
CARRIZO IMPACT AREA CLOSED TO PUBLIC
CARRIZO BADLANDS
COYOTE MTNS.
Carrizo Mtn.
FISH CREEK MTNS
ANZA BORREGO DESERT STATE PARK
SAN DIEGO
YUHA DESERT
YUHA BASIN
Sunrise Butte
Yuha Buttes
JACUMBA MTNS.
Mountain Springs
Sugarloaf Mtn.
In-Ko-Pah Gorge
Harpers Well
Baileys Well
Hollhill Dry Lake
Ramer Lake
Finney Lake
Sunbeam Lake
Mount Signal


11
12
13
14
15
A
B
C
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F
G
SAN BERNARDINO NAT'L FOR.
SANTA ROSA COUNTY
BUCK RIDGE
Cottonwood Spring
Rabbit Pk.
TO COACHELLA
TO MECCA
TORRES
MARTINEZ
Salton Sea
OASIS
FIG TREE VALLEY
Table Mtn.
ANZA - BORREGO
MOUNTAINS
COLLINS VALLEY
Villager Pk.
Combs Pk.
Desert Gardens
OCOTILLO FLAT
COYOTE MTN.
Coyote Pk.
Clark Well
Clark Dry Lake
Little Clark Dry Lake
Rattlesnake Spring
Wonderstone
Palo Verde Spring
LOS COYOTES
Hot Springs Mtn.
INDIAN
RESERVATION
Rainbow Spring
Los Tules
PALM MESA
Henderson
Palm
MTNS.
BORREGO
S22
BORREGO SPRINGS
SAN YSIDRO
Borrego Sink
SAN GORGONIO HIST MARKER
SLEEPY HOLLOW
BORREGO BADLANDS
Fonts Point
Seventeen Palms Oasis
Five Palms
PUMPKIN PATCH
OCOTILLO WELLS STATE VEHICULAR REC. AREA
SHELL REEF
Squaw Pk.
Wolfe Well
COUNTY
TO SALTON CITY
RANCHITA
San Felipe
SAN FELIPE HILLS
PINYON RIDGE
GRAPEVINE HILLS
YAQUI MEADOWS
YAQUI RIDGE
YAQUI FLAT
S3
Grapevine Mtn.
LOWER BORREGO VALLEY
OCOTILLO WELLS
OCOTILLO BADLANDS
TO BRAWLEY
S2
DESERT
Round Granite Hill
Sunset Mtn.
VALLECITO
Whispering Pines
Banner
JULIAN
Kentwood in the Pines
Granite Mtn.
EARTHQUAKE VALLEY
PINYON MTNS.
PINYON MOUNTAINS
HARPER FLAT
Split Rock
Harper
Hollhill Dry Lake
ELEPHANT TREE RANGER STA.
Whale Pk.
HAPAHA FLAT
Matthew Can.
FISH CREEK MTNS.
SPLIT MOUNTAIN
HILLS
Chariot Mtn.
LITTLE BLAIR VALLEY
BLAIR VALLEY
Harrison Park
North Pk.
Cuyamaca
Lake Cuyamaca
Oriflamme Mtn.
MASON VALLEY
MUD
CARRIZO
CLOSED TO PUBLIC
EAST MESA
Stonewall Pk.
YAMACA
RANCHO
Troutman Mtn.
VALLECITO VALLEY
SAWTOOTH RANGE
Agua Caliente Springs
STATE
Garnet Mtn.
Japacha Pk.
STATE
PARK
CUYAMACA
LAGUNA
Monument Pk.
SAWTOOTH MTNS.
INNER PASTURE
SIERRA BLANCA MTNS.
Canebrake
Well of Eight Echoes
Indian Gorge
CARRIZO
SOUTH MESA
IMPACT
AREA
DANGER KEEP OUT
LIVE BOMBING AREA
Red Top
Oakzanita Pk.
SAMAGATUMA VAL.
MT. LAGUNA
33°30'
33°15'
33°
116°15'