U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

in cooperation with

MOJAVE WATER AGENCY

A product of the Southern California Areal Mapping Project:
A geologic mapping project sponsored jointly by
the U.S. Geological Survey and the
California Division of Mines and Geology

Geologic map database of the El Mirage Lake Area, San Bernardino and Los Angeles Counties, California

By David M. Miller[1] and David R. Bedford[1]

Digital preparation by D.R. Bedford[1]

Open-File Report OF 00-222
version 1.0
http://wrgis.wr.usgs.gov/open-file/of00-222

This report is preliminary and has not been reviewed for conformity with the U.S. Geological Survey (USGS) editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

This database, identified as "Geologic map database of the El Mirage Lake Area, San Bernardino and Los Angeles Counties, California" has been approved for release and publication by the Director of the USGS. Although this database has been reviewed and is substantially complete, the USGS reserves the right to revise the data pursuant to further analysis and review. This database is released on condition that neither the USGS nor the U.S. Government may be held liable for any damages resulting from its use.

[1] U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA

TABLE OF CONTENTS

INTRODUCTION

This geologic map database for the El Mirage Lake area describes geologic materials for the dry lake, parts of the adjacent Shadow Mountains and Adobe Mountain, and much of the piedmont extending south from the lake upward toward the San Gabriel Mountains. This area lies within the western Mojave Desert of San Bernardino and Los Angeles Counties, southeastern California (Fig. 1). The area is traversed by a few paved highways that service the community of El Mirage, and by numerous dirt roads that lead to outlying properties. An off-highway vehicle area established by the Bureau of Land Management encompasses the dry lake and much of the land north and east of the lake. The physiography of the area consists of the dry lake, flanking mud and sand flats and alluvial piedmonts, and a few sharp craggy mountains.

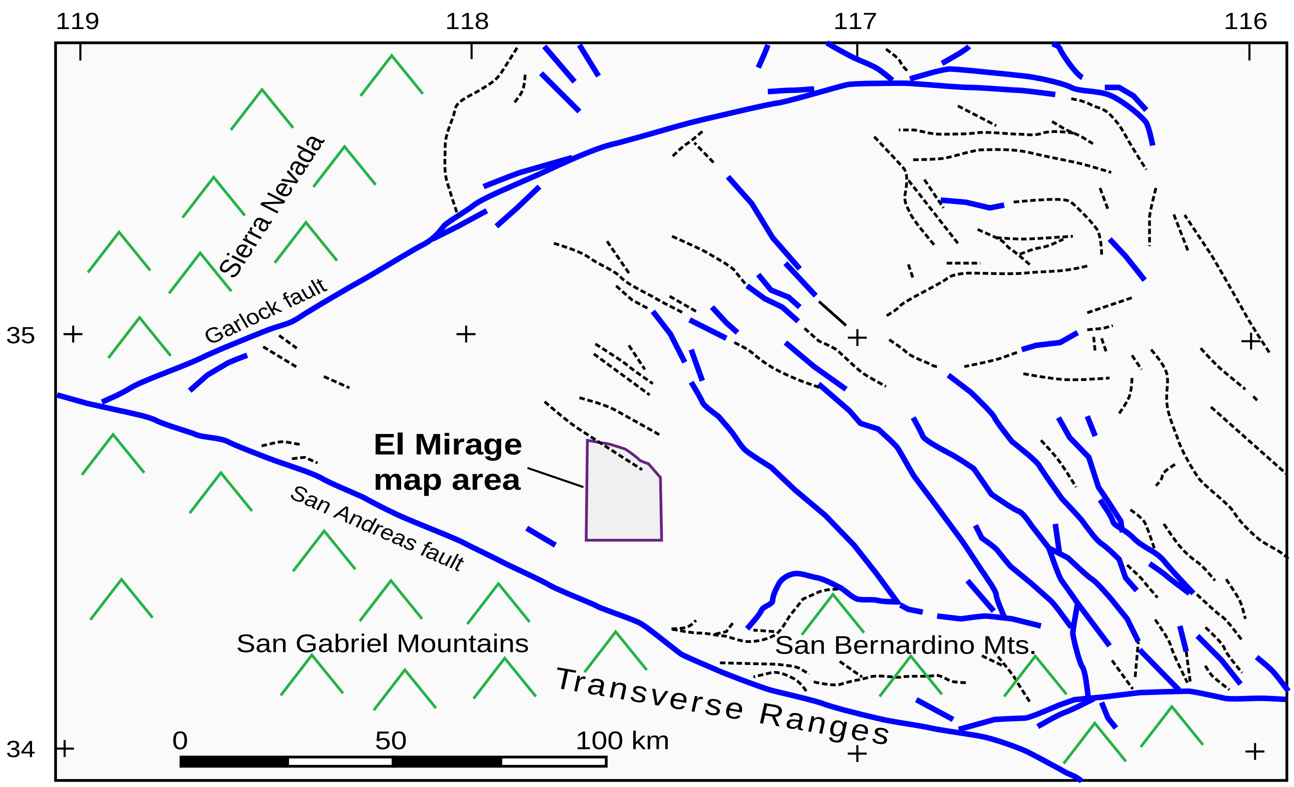


Figure 1. Map of active (Holocene - heavy lines) and inactive (Pleistocene - light dashed lines) young faults in the western Mojave Desert and Basin and Range Province to the north. El Mirage map area and major faults and mountain ranges are labelled.

This digital geologic map database, intended for use at 1:24,000-scale, describes and portrays the rock units and surficial deposits of the El Mirage Lake area. The map database was prepared to aid in a water-resource assessment of the area by providing surface geologic information with which deeper groundwater-bearing units may be understood. The area mapped covers the Shadow Mountains SE and parts of the Shadow Mountains, Adobe Mountain, and El Mirage 7.5-minute quadrangles (Fig. 2). The map includes detailed geology of surface and bedrock deposits, which represent a significant update from previous bedrock geologic maps by Dibblee (1960) and Troxel and Gunderson (1970), and the surficial geologic map of Ponti and Burke (1980); it incorporates a fringe of the detailed bedrock mapping in the Shadow Mountains by Martin (1992). The map data were assembled as a digital database using ARC/INFO to enable wider applications than traditional paper-product geologic maps and to provide for efficient meshing with other digital data bases prepared by the U.S. Geological Survey's Southern California Areal Mapping Project (http://geology.wr.usgs.gov/wgmt/scamp).

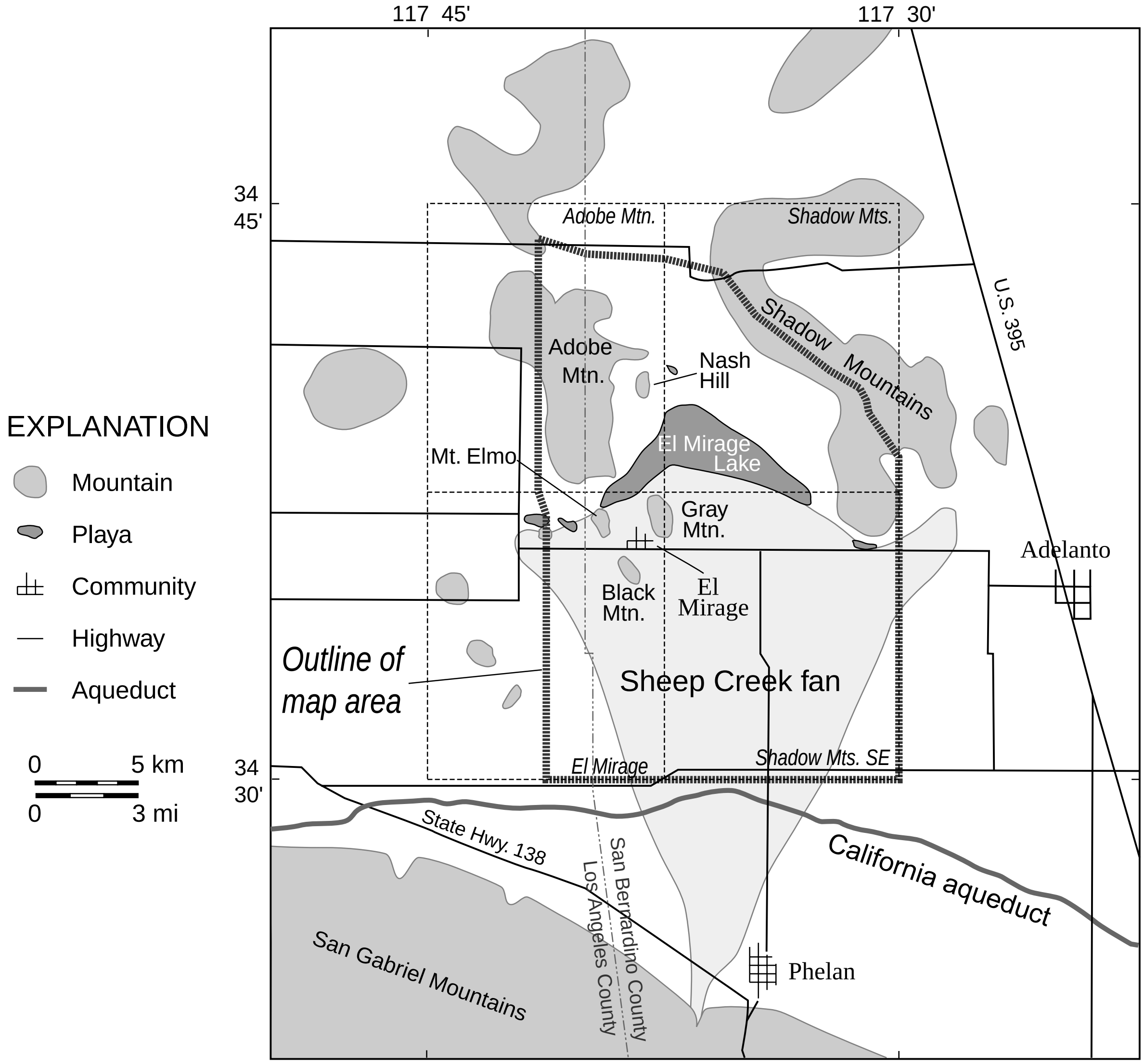


Figure 2. Location of mapped area, playas, mountains, and Sheep Creek fan. Topographic quadrangles shown by dashed black box outlines; names indicated on top and bottom margins.

INFORMATION ON THE DATABASE

The Geologic Map Database of the El Mirage Lake Area consists of three parts: 1) the geologic map and database explanation/discussion (this document), 2) the GIS dataset of the geology of the area, and 3) printable plotfiles of the database map. The GIS datasets consists of seven layers compiled in ARC/INFO (Environmental Systems Research Institute, Redlands, CA) version 7.2.1, and version 8.0.1, and distributed in ARC/INFO export format. Detailed descriptions of the parts of this publications can be found in appendix 1 of this report. The entire set of files is available on the internet at URL: http://wrgis.wr.usgs.gov/open-file/of00-222/.

SUMMARY OF GEOLOGY

Geologic Setting

The geologic history of the western Mojave Desert was most recently summarized by Glazner and others (1994). The El Mirage area lies near the San Andreas fault, and on the North American plate. The crust in this area formed during the early Proterozoic, and late Proterozoic and Paleozoic strata were laid on this crust as it gradually subsided (Stewart, 1970). Late Paleozoic and early Mesozoic continental-margin tectonics resulted in more complex sedimentation patterns of shallow marine and continental sediments (Stevens and Stone, 1988; Stone and Stevens, 1988; Martin and Walker, 1992). The area later lay within multiple Mesozoic magmatic arcs, which created a composite batholith of granitoids, most of which range in age from mid-Jurassic to latest Cretaceous. Pre-Jurassic rocks are now present as metamorphic rocks in pendants and screens between plutons in this batholith.

During the mid-Cenozoic, the area was fragmented along normal and strike-slip faults into sedimentary basins bounded by mountains, as the crust was sliced by the San Andreas fault system and related contractional and extensional basins (Glazner and Loomis, 1984). Several hundreds of kilometers of strike-slip separation occurred along the San Andreas fault and its precursors, ultimately placing the rocks of the San Gabriel Mountains against the bedrock of the El Mirage area (Powell, 1992). During the late Pliocene, uplift formed the San Gabriel Mountains (Meisling and Weldon, 1989), creating a rain shadow to the east and the beginnings of the topography and climate of today.

Rocks of the San Gabriel Mountains and the adjacent Mojave Desert differ significantly. Although both areas expose many granitoids from the Mesozoic batholith, the pre-batholithic rocks are distinct. The San Gabriel Mountains contain Proterozoic gneisses and the distinctive Pelona Schist, whereas the nearby desert contains Paleozoic continent-margin strata along with slightly older and younger strata.

Geomorphology

The El Mirage Lake map area lies in the Mojave Desert north of the San Gabriel Mountains, one of several massive, high-altitude mountain ranges in the Transverse Ranges. The interplay of these two geomorphic realms—the Transverse Ranges and the desert—controls the geomorphology of El Mirage Lake. The San Gabriel Mountains contain dozens of peaks higher than 2500 m, and some higher than 3000 m; steep slopes commonly are 25 to 65 percent. In contrast, the mountains to the north in the desert are much more subdued topographically; they rise 100 to 200 m above flatter lands that are about 850 to 1000 m in altitude, and steep slopes in mountains commonly are 12 to 30 percent. As a result, the San Gabriel Mountains have steeper slopes and capture more precipitation, and both of these factors cause greater production of alluvium from the Transverse Ranges than from the desert ranges.

El Mirage Lake lies at the junction of a desert semi-bolson to the north and a huge alluvial piedmont to the south (Fig. 2). The semi-bolson forms El Mirage Valley between the Adobe Mountain area and the Shadow Mountains; both mountains are fringed by broad pediments and gentle piedmonts. Valley-axis alluvial deposits are carried by intermittent streams southward toward El Mirage Lake. To the south of El Mirage Lake, an alluvial piedmont fringing the San Gabriel Mountains is rapidly aggrading over its ~25 km distance from head to toe. The greater depositional rates in this piedmont, and particularly in Sheep Creek fan, compared to piedmonts of the semi-bolson indicate that desert mountains and piedmonts are being buried, and desert valleys being dammed. One of these dammed valleys forms El Mirage Lake. El Mirage Lake receives sediments from the two lithologically distinct provinces—San Gabriel Mountains and Mojave Desert—and its sedimentary record therefore documents the interplay of sedimentation from these provinces.

Surficial deposits

Much of the map area was mapped in reconnaissance by Ponti and Burke (1980), who distinguished pediments, alluvium of Holocene and Pleistocene age, and eolian and playa deposits. Our more detailed mapping has subdivided these units and distinguished several ages of alluvial cover on the pediments.

El Mirage (dry) Lake lies in the center of the map area. The dry lake is covered by unvegetated sandy playa muds, as well as scattered eolian sand and sand-rich muds that support spotty vegetation. Playa muds are poorly sorted, ranging from minor fine sand to common clay and silt. Texture is punky with common voids. The playa muds grade outward to other map units by the increase of eolian and alluvial materials. The playa bed of El Mirage Lake is at 2833 feet altitude. A smaller playa lies to the east and slightly higher, at 2855 feet altitude. The outlet of the eastern playa leads eastward to Fremont Wash, which leads to the Mojave River. Both playas were dammed by Holocene alluvium from the Sheep Creek fan, as indicated by distinctive clasts in sediments crossing the east ends of the playas. Smaller playas east and west of Mt. Elmo and east of Nash Hill (Fig. 2) represent localized ponding of alluvial fines among sand sheets and dunes.

The lowest topographic threshold for El Mirage Lake lies at its east end, about 10 m (40 feet) above the playa bed, raising the possibility that one or more ancient lakes as deep as 10 m once existed. However, few signs of pluvial lakes, such as shoreline deposits or lacustrine deposits ringing the playa or at depth, are present. The alluvial deposits underlying the eastern threshold are loose and fine grained and likely would rapidly erode if overtopped by a lake outlet. These lines of evidence indicate a large lake probably never formed and that before the last progradational event of the Sheep Creek fan, external drainage to Fremont Wash probably existed. However, there are a few hints that a lake existed. A 2-m deep pit in the playa at a landfill site (~2845 ft altitude, border sec. 8 & 5, T. 6 N., R. 7 W.) exhibits a sequence of playa and alluvial sediments, including two thin laminated green clay beds. The well-sorted clay in the beds was probably deposited in a quiet-water lake or alluvial setting. However, the clay beds do not contain ostracodes or other lake fauna. In addition, along the northeast edge of Gray Mountain possible remnant shorelines and lake deposits may be present about 6 m (27 ft) above the playa bed (~2860 ft). Well sorted sand and dark mud lie below a subtle bench, possibly a shoreline. The dark brown mud contains abundant plant remains, apparently representing marshy deposits. Neither the sediment in the pit nor the possible lake deposits near Gray Mountain show significant soil development; they are therefore probably Holocene in age. Further support for a past lake lies in the linear pattern of active sand dunes south of the lake, at 2865 to 2875 feet altitude, 7 to 10 m above the playa. The dunes may represent eolian reworking of sands accumulated along a lake shoreline, a common feature in Great Basin pluvial lakes. However, no direct evidence for a shoreline exists. We conclude that only sparse evidence for a lake exists, and at most the playa may have undergone one or two brief lacustrine cycles during the Holocene.

Dockter (1980) reported the findings of a 81 m (265 ft) hole drilled near the center of the playa. The uppermost 7 m (22 ft) are described as greenish gray calcareous clay, below which are sands, gravels, and muds. The color and composition of the uppermost part are suitable for a parentage from Pelona Schist materials, whereas the remainder of the hole is described as yellow-brown in color and the few descriptions of pebble compositions indicate a granitic source with little mica. We consider that the sediments below 7 m represent alluvial fan and valley axis materials derived from El Mirage Valley, north of the playa, and probably do not represent any sediment from Sheep Creek fan. This inference is consistent with a model of northward progradation of the Sheep Creek fan causing playa sedimentation only recently.

Materials surrounding the lake vary greatly by position. North and northwest of the lake, alluvium grades to playa deposits at the edge of the lake by increase of mud content and decrease of grain size to medium and fine sand, largely in detritus derived from granitoids. Scattered eolian deposits generally complicate the transition, and areas that have significant eolian materials mixed with alluvium are mapped as hybrid units (Qyef and Qyfe). East of the lake, alluvial and eolian deposits flank the lake. In many places, the eolian component overwhelms the alluvial component, but eolian sands are generally reworked by alluvial processes, creating hybrid deposits. South of the lake, adjacent sands are green and gray color (in contrast with the tan or brown sand of the alluvial sections north of the lake) and composed of debris from the Pelona Schist in the San Gabriel Mountains. Most deposits here are alluvial, but a complex cover of wind-blown deposits, also green in color, exists.

The Sheep Creek fan, which lies south of El Mirage Lake, is distinctive because it is almost entirely composed of debris from Pelona Schist. Troxel and Gunderson (1970) noted the presence of Pelona Schist clasts in alluvial sediments south of El Mirage Lake and stated in their map description that the sediments were deposited by debris flows deriving from the San Gabriel Mountains, some 33 km distant near the vicinity of Wrightwood. Wrightwood area debris flows have been studied by Sharp and Nobles (1969) and by Morton and others (1979), who demonstrated that these sources of Pelona Schist material are periodically very active and send debris considerable distances down the alluvial fan. However, these workers did not document debris flow mechanisms operating to the toe of the fan, at El Mirage Lake. The debris fan (Sheep Creek fan) leading from Wrightwood to El Mirage Lake stretches 25 km horizontally and 1200 m vertically and currently is distinctive because of its green, nearly monolithologic sediment (Fig. 2). It is bordered to the east and west by alluvium with granitic parentage, typically a light brown or tan color.

Eroded alluvial deposits of the Sheep Creek fan are widespread beneath recently active eolian and alluvial deposits. These older alluvial materials characteristically form a sequence of gravelly sand with cobbles as large as 40 cm that lies on low-relief exposures of greenish-brown muddy fine sands. The gravelly sand forms lenticular channel deposits that are commonly poorly size-sorted; cobbles and pebbles lie in medium to coarse sand. Most pebbles and cobbles are well-rounded, but many are distinctively subangular to angular, supporting a debris-flow hypothesis. Clasts include Pelona Schist, gneisses, granitoids (some mylonitic), and marble; less common are granitoid dike rocks and thin-bedded quartzite. The clast assemblage is appropriate for derivation from the San Gabriel Mountains. Consistent lack of mud in the gravelly sand argues for a fluvial origin and against a debris-flow origin.

The muddy fine sand in the lower interval of the sequence represents deposits similar to modern deposits higher on the fan nearer Wrightwood. The overwhelmingly fine grain sizes probably are due to the unusual source of altered schist, which rapidly breaks down to mica, feldspar, quartz, and clay, forming a deposit of clay, silt, and fine sand. Bedding in the muddy sand deposit is laterally continuous over tens of meters, suggesting that these deposits formed on a very regular surface, probably during one or more periods of rapid aggradation. Individual fining-upward beds, less than one meter thick, are common. Parallel lamination and ripple lamination occur less commonly. Buried weakly developed soils, buried plants, and other evidence of subaerial exposure occur in some cases within the muddy section but generally are not conspicuous. Grain size increases up the fan in the muddy sand but appears to *decrease* up the fan in the overlying gravel and sand.

The interpretation and significance of a consistently muddy sand deposit, greater than 4 m thick and probably greater than 10 m thick, that covers the entire fan, but is lacking in gravel, is unclear at this time. This deposit has a volume of roughly 2.5 km^3, and is so large that it is a conspicuous feature from space. Likewise, the observation that the muddy sand is overlain in many places by gravel channel deposits is of uncertain interpretation. It appears that one or more voluminous depositional events took place over a short duration, perhaps a few years to a few hundred years. Either only the last event carried alluvial gravel across the fan, or each pulse of sediment efficiently removed lags of previously deposited gravel. A lack of voluminous gravel deposits near El Mirage Lake, at the surface or at depth, argues for the former interpretation. The event or events of deposition near El Mirage Lake may have relevance for understanding Holocene climate history and perhaps even earthquake-triggered landsliding and debris flows, since landslides trigger most debris flows (Morton and others, 1979). A weakly to moderately developed A_v horizon, weak B horizon, and incipient calcic horizon characterize soil development near the surface of the alluvial deposits. By analogy with soil development elsewhere in the Mojave Desert, and acknowledging a possible fast rate of development of A_v and B horizons due to the unusual clay and silt composition of the deposit, we infer a middle to early Holocene age for the deposit. Given the 140- to 200-year recurrence interval for San Andreas seismic events (Sieh, 1984; Weldon and Sieh, 1985), the poor resolution on the age of these deposits does not permit evaluation of the hypothesis that they are earthquake-generated deposits at this time.

Although most sediment south of the lake is alluvium of the Sheep Creek fan, eolian sand is widespread on the alluvium. Green-colored muscovite is ubiquitous in these deposits. Most active sediment deposits in this area are of eolian origin because many washes farther up the fan have been dammed during the last few decades, but a few active washes remain on the west side. These active washes carry muds of Pelona parentage to El Mirage Road, near El Mirage Lake, many times each winter.

Piedmonts north of the lake exhibit well-developed soils at shallow depths, including thick, bright-red, clay-rich B horizons and strongly developed calcic zones, both of which contrast with the immature soil development in piedmont deposits south of the lake. The soil development north of the lake closely matches changes in micro-topography of alluvial surfaces, both of which correspond to soils and micro-topography nearby (McFadden and Weldon, 1987), in the central Mojave Desert (Yount and others, 1994), and in the San Joaquin Valley (Ponti and Burke, 1980). This correlation indicates that much of the piedmont north of El Mirage Lake is composed of deposits tens of thousands to hundreds of thousands of years old. Young alluvial fan deposits flanking the Shadow Mountains are similar in age to the Sheep Creek fan deposits, but are generally 10 to 30 cm thick and at a maximum reach about 1 m thickness near the lake.

The piedmont deposits in general are shed from pediments that are covered by a thin veneer of alluvium. We mapped deposits as veneer on pediment where shallow bedrock was evident, such as (1) outcrops of dike rock protruding from an otherwise flat surface, (2) gruss and granite along walls of incised channels, and (3) presence of abundant sand derived from underlying granite that could not have eroded from farther upslope. In general, areas of pediment veneer have much flatter topography than do alluvial fans.

Bedrock deposits

All rock exposed around El Mirage Lake is granitoid or metamorphic. Dibblee (1960) first mapped the rocks and noted the Mirage fault. Troxel and Gunderson (1970) later mapped marble, schist, calc-silicate rock, and quartzite in the Shadow Mountains in much greater detail and distinguished felsic and mafic igneous rocks. Bowen (1954) reported brachiopods suggestive of a Pennsylvanian age for some strata in the Shadow Hills that are similar to strata in the map area and Brown (1983) made a strong case that some of the metamorphic rocks in the area are Paleozoic in age. Martin (1992) mapped the Shadow Mountains metamorphic rocks in detail and correlated them with Late Proterozoic and Paleozoic strata that were earlier extrapolated across the Mojave Desert (Stewart, 1970; Stewart and Poole, 1975), as well as early Mesozoic strata (Miller and Carr, 1978; Miller, 1981). We have largely adopted Martin's criteria for stratigraphic units and age assignments.

Granitoid rocks make up most of the bedrock. Two composite pluton complexes are identified, one in the Shadow Mountains and the other in the El Mirage Valley and Adobe Mountain area.

Granitoids in the Shadow Mountains form a complex ranging from (1) felsic granite, to (2) a wide range of intermediate-composition rock such as mafic granodiorite and biotite-hornblende quartz monzodiorite, and (3) mafic rocks such as gabbro, quartz diorite, and diorite. Martin (1992) described intrusive relations indicating that the several igneous rock types are closely related, but that in general the mafic rocks are oldest and felsic rocks youngest. The youngest rock he described is leucocratic tourmaline-garnet-muscovite pegmatite.

Much of the pediment northeast of El Mirage Lake is underlain by compositionally uniform medium- to coarse-grained biotite-hornblende granodiorite. This pluton probably intruded the complex of intermediate and mafic rocks, which displays considerable compositional and textural variability. In this latter complex, cone-shaped sheets of gabbro 70 to 200 m thick are prominent across an area 3 km wide, forming a ring-shaped outcrop pattern (Troxel and Gunderson, 1970). Pegmatite and aplite dikes cut all rocks.

Martin (1992) used U-Pb methods to date zircon and monazite from several samples from the complex. Quartz diorite from the mafic rocks group was dated at about 148 Ma. Felsic hornblende granite and biotite granite yielded ages of 143 to 148 Ma. The leucocratic pegmatite yielded a monazite age of 141.5 ± 1 Ma. Rocks of the complex other than the youngest dikes are therefore of latest Jurassic age, although as the age of the Jurassic-Cretaceous boundary becomes better defined, some rocks may be reclassified as earliest Cretaceous.

Felsic biotite granite along the west edge of the Shadow Mountains is widely exposed in the pediment in the northern part of the map area. It closely matches granite in plutons to the west in the Adobe Mountain area that appear to belong to a single intrusive suite on the basis of overlaps in composition (varying degrees of biotite and hornblende as the mafic minerals) and texture (distinctive shapes of biotite crystals). In addition, all plutons in this suite are riddled (up to 25% of the rock) with aplite dikes, some with pegmatitic segregations. Most dikes strike east or east-northeast.

The main intrusive phases in the Adobe Mountains suite are: Hornblende granodiorite, monzogranite of Adobe Mountain, and monzogranite of Nash Hill; microgranite is a minor phase. Hornblende granodiorite is medium- to coarse-grained with abundant hornblende, some as phenocrysts, and conspicuous sphene. Monzogranite of Adobe Mountain is medium-grained to sparsely porphyritic, containing mostly biotite with sparse hornblende and sphene. Monzogranite of Nash Hill is fine to medium grained but carries all grains in sizes characteristic of the Adobe Mountain unit distributed through the rock; as a result, texture is seriate. A notable characteristic of the Adobe Mountain and Nash Hill phases is presence of barrel-shaped biotite crystals. Although aplite is common as dikes in the Adobe Mountain intrusive suite, other very fine grained rocks occur, generally in accumulations too small to map. An exception south of Adobe Mountain is mapped as microgranite. It crops out over less than one km^2, forming brown-weathering outcrops with close-spaced jointing. The rock is pinkish and very fine- to fine-grained, and has gradational contacts to the surrounding Nash Hill granite.

Other than the observation that all of these phases predate the aplite dike swarm, intrusive relations among plutons in the Adobe Mountains suite are ambiguous. The Adobe Mountains, Nash Hill, and microgranite phases grade into one another over distances of a few meters and share many textures, so we consider them to be closely related. Hornblende granodiorite shows less similarity to the other plutons, and may possibly represent unrelated intrusions. All granitoids are highly jointed and commonly fractured. The hornblende granodiorite commonly is altered to silica, epidote, clay, and sericite, and hosts mineral deposits in a few places. The Nash Hill monzogranite is chloritized and silicified at Black Mountain but otherwise only rarely is altered; minor sericite was noted at a few locations at Adobe Mountain.

The Adobe Mountains granitoid suite is Cretaceous in age. K-Ar dates by Miller and Morton (1980) for samples collected at Gray Mountain and the west side of Adobe Mountain, of the Nash Hill and Adobe Mountain phases, respectively, indicate that the intrusive suite is approximately 76 to 84 Ma. Hornblende that was analyzed by Miller and Morton (1980) from the Nash Hill phase at Gray Mountain appears to conflict with the prevalence of biotite as its mafic phase, but the rock contains as much as 2% hornblende in places. The hornblende granodiorite unit has not been dated.

The Jurassic and Cretaceous granitoids intrude masses of metamorphosed rocks in several places. At Mt. Elmo, thin screens and wispy inclusion trails of quartzite, schist, and hornblende gneiss apparently represent a siliciclastic stratigraphic section with minor carbonate rocks; we correlate these rocks with the Late Proterozoic and Cambrian strata of the Mojave Desert. Similar metamorphic rocks lie on the east side of Black Mountain. The crest of Black Mountain is underlain by unusual metamorphic rocks that must represent considerable skarn replacement (metasomatism): hornblendite, Ca-amphibolite, and garnet-rich rock that are virtually monomineralic. These rocks probably are derived from a carbonate and siliciclastic source.

The southern Shadow Mountains exhibit relic stratigraphy of marble, quartzite, and calcsilicate rock in places, which Martin (1992) interpreted as a metamorphosed sandstone and carbonate sequence that most likely is late Paleozoic in age. The rocks range widely in composition, metamorphism, and structural overprint and can only be assigned ages based on general lithologic associations. The presence of carbonate breccia and siliciclastic rocks in the impure carbonate sequence are the best indicators that the sequence, if intact, is likely late Paleozoic in age. This sequence was metamorphosed at amphibolite facies and then folded on all scales. Metamorphism produced minerals such as tremolite, diopside, and garnet, and was interpreted by Martin (1992) as having occurred during the Middle to Late Jurassic. Retrograde metamorphism associated with Late Jurassic pluton emplacement produced hornfels with characteristic minerals such as chlorite, muscovite, wollastonite, tremolite, and diopside. In the southern Shadow Mountains, approximately northward plunging open folds deform the strata. Folds represent a syncline and two adjacent anticlines; vergence is not clearly defined. Cleavage associated with the major folds and associated minor folds is locally deformed by nearly coaxial folds that are also open and upright.

Farther north in the Shadow Mountains fine-grained quartz-rich mica schist and calcsilicate rock were interpreted by Martin (1992) as metamorphosed latest Paleozoic and Early Mesozoic strata. Schist is composed of biotite, quartz, and feldspar and is interlayered with minor quartzite and calcsilicate rock. The nearby calc-silicate map unit consists of fine-grained dark hornfels and lesser calcite marble. It is similar to some rocks in the southern Shadow Mountains, but was considered by Martin (1992) to lie higher in the structural and stratigraphic sequence.

Unlike the deformed rocks of the Shadow Mountains, which were intruded and metamorphosed by Jurassic plutons and therefore were deformed during the Jurassic or earlier, the mylonitic rocks at Mt. Elmo and Black Mountain affect plutons to which we assign Cretaceous ages. The mylonitic rocks at Mt. Elmo are the hornblende granodiorite phase of the Adobe Mountain intrusive suite. There, foliations dip steeply west and lineations plunge moderately south. At Black Mountain, mylonitic rocks are greenschist grade as indicated by extensive chlorite development in the zones, and are restricted to metamorphic rocks and the hornblende granodiorite. The Nash Hill phase of the intrusive suite cuts the mylonite zones. Foliation dips steeply west and lineation plunges steeply south.

YOUNG FAULTS

There is little information about the early Cenozoic evolution of this part of the Mojave Desert, but Mesozoic granites were deeply eroded before widespread early to middle Miocene volcanic and sedimentary rocks were deposited northeast of El Mirage Lake (Glazner and others, 1994) and younger faults developed. Strike-slip faults that cut the early to middle Miocene volcanic and sedimentary sequence are inferred by many workers to be late Miocene or Pliocene to Holocene in age. Dokka and Travis (1990) termed part of this strike-slip realm the Eastern California shear zone, and followed previous syntheses and models such as Dibblee (1961), Garfunkel (1974), and Dokka (1983) in describing several kilometers of dextral separation on most faults and proposing that some blocks bounded by the faults rotated as fault separation accumulated. The shear zone as defined by Dokka and Travis (1990) does not extend west to the El Mirage Lake area although the several faults in this area parallel those in the shear zone (Fig. 1).

Because the Eastern California shear zone accommodates part of the ongoing movement between North American and Pacific plates, understanding whether faults in the El Mirage Lake area belong to the shear zone has implications for seismic hazards. Much of the central part of the Eastern California shear zone is seismically active, and scattered seismicity extends to the western part of the zone, making careful assessment of recency of movement on faults necessary to assess seismic shaking and related hazards. For example, the Landers earthquake on June 28, 1993 ruptured faults across a large area east of El Mirage Lake, including several areas in which active faults were not known (Hauksson and others, 1993).

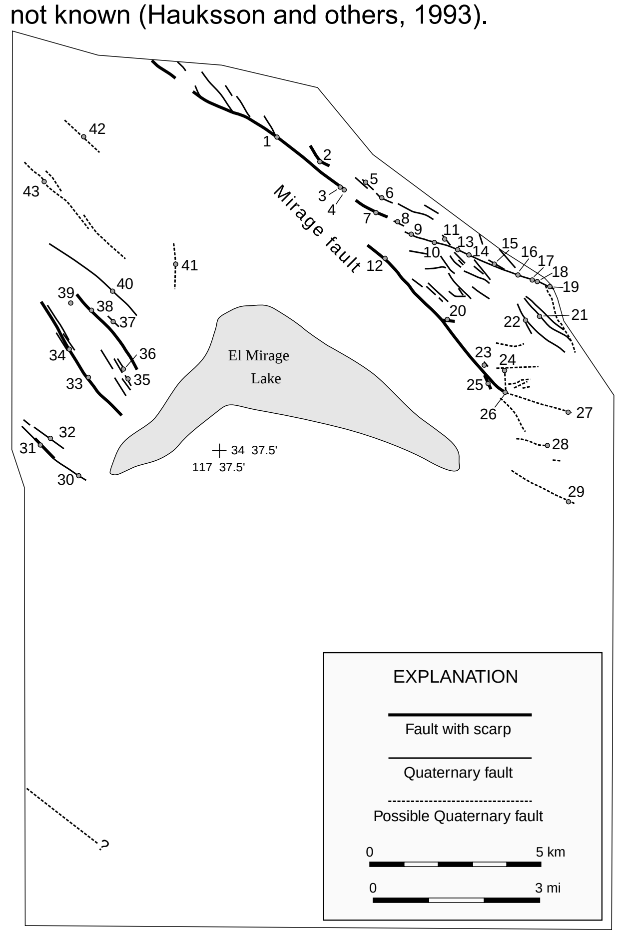


Figure 3. Index map of Quaternary faults and possible Quaternary faults, El Mirage Lake map area. Numbered dots keyed to locations described in Table 1. Queried fault in southwest described in text.

Quaternary faults were shown by Dibblee (1960) and Troxel and Gunderson (1970) along the southwest flank of the Shadow Mountains; the principal fault was named the Mirage fault by Dibblee (1960). The Mirage fault is a system composed of three segments about 6 to 10 km long that together are about 23 kilometers long (Ponti and Burke, 1980). Ward and others (1993) mapped more faults as the extension of the Mirage fault farther to the northwest where it crosses the Rogers Lake playa and continues northwest along the Bissell

Table 1. Quaternary and possible Quaternary faults near El Mirage Lake
[map numbers are plotted on Figure 3; field stations identfy notebook entries. Map numbers in bold indicate rupture at this location is known to be Quaternary]

Map No.	Field Station	Orientation	Offset	Geomorphic and Identifying Features	Age Constraints
1	M98EM-70	305	> 1 m down to W	rounded scarp, spring mounds	cuts Qof2; Qyf uncut
2	M98EM-82		2 m down to W	rounded scarp, spring mounds	cuts Qof1; Qyf uncut
3	M98EM-80	305	1.5 m down to W	rounded scarp	cuts Qof3; Qyf uncut
4	M98EM-81	305	1.5 m down to W	rounded scarp	cuts Qof1; Qyf uncut
5	M98EM-105	315		probable spring mounds, linear depression	Qof2 uncut
6	M98EM-104	315		line of spring mound remnants	Qof2 uncut
7	M97EM-17	320	down to W	bedrock limited to upslope side; 2.5 m rounded scarp	cuts Qvof; Qof2 uncut
8	M98EM-102	309, 64 NE		1-m-wide breccia zone	Qof1 uncut
9	M98EM-101	290		possible spring mound deposits	
10	M98EM-100	290		large spring mound	Qof2 uncut
11	M98EM-99	325	down to SW	line of degraded spring mounds	
12	M97EM-16	317	> 1 m down to W	bedrock limited to upslope side; 1.0 -1.5 m rounded scarp	cuts Qof2; Qyf2 uncut
13	M98EM-98	290		degraded spring mound	
14	M98EM-97	290		line of spring mounds, linear	
15	M98EM-96	309, 68 NE		breccia zone	
16	M98EM-95	290, 72 S		breccia zone	
17	M98EM-94	290		spring mound, little eroded	
18	M98EM-93	290		degraded spring mound	Qof2 uncut
19	M98EM-91	290		linear truncation of rocks	Qof2 uncut
20	M97EM-15	330, 70 SW	down to W	bedrock only on upslope side; gouge zones	cuts Qvof; Qyf2 uncut
21	M98EM-88	315			
22	M98EM-64	330, 74 NE	down to W	breccia zone	cuts stage III calcic zone; Qof2 uncut
23	M97EM-14	317	>1 m down to W	fault exposure in wash cut bank	cuts Qvof; Qof2 uncut
24	M97EM-13	360		vegetation lineament, breccia	possibly cuts stage IV calcic horizon
25	M97EM-12	350 - 340	down to W	1 m high linear rounded scarp, spring mounds	cuts Qvof; cuts or bends Qof; Qyf2 uncut
26	M98EM-65	320	1 m down to W	subtle scarp, spring mounds	cuts Qof2
27	M98EM-63	285, 80 N	~100 m sinistral		
28	M98EM-62	280, 83-55 N	~75 m sinistral	breccia zone	Qof2 uncut
29	M98EM-59	300, 70N	50 m sinistral	breccia zone	Qof2 uncut
30	M97EM-25	300	down to E	vegetation linear, vague scarp	pre-Holocene
31	M98EM-53	315	1-2 m down to E	prominent vegetation linear 10 m wide, rounded scarp	Qyfe uncut
32	M98EM-54	310		pale linear depression 10 m wide, 1 to 1.5 m deep	uncertain
33	M98EM-27	320	2-3 m sinistral; >1 m down to W	spring mound remnants, fractured rock, vegetation lineament	Qyf2 uncut
34	M98EM-33	320		eroded spring mounds	
35	M98EM-29	325	3-4 m sinistral	spring mound remnants, fractured rock, vegetation lineament	Qyf2 uncut
36	M98EM-30	325		eroded spring mounds	
37	M98EM-36	3342, 42 NW	down to W?	caliche in fault zone in granite	Qyf2 uncut
38	M98EM-35	315	>3-4 m down to E	3-4 m rounded scarp, spring mound remnants, vegetation lineament	Qyf2 uncut; Holocene fans not completely in equilibrium
39	M98EM-34	45	down to W	eroded spring mounds, vague scarp	
40	M98EM-37	315	down to E	spring mound remnants, rounded scarp 0.5	Qyf2 uncut
41	M97EM-21	006, 70W	3-15 m dextral	fractured granite	Qyf2 or Qyf3 uncut; Qof2 prob. uncut
42		138	500 m dextral	fractured granite, linear depression	Qof uncut
43		135		linear depression, sericitic breccia	Qyf uncut

Hills. During field studies, we have mapped many fault scarps in addition to the Mirage fault (Fig. 3) and determined that many cut Quaternary deposits. Table 1 presents data for the faults, including surface deposits cut by faults that have relative ages determined by qualitative soil and microtopography studies. Faults were identified by physical truncations of sediment, breccia and gouge in rock, and topographic, vegetation, and spring-mound lineaments. Many Quaternary faults strike northwest, but strikes vary as much as 30 degrees from this main orientation. Dips are steep. West- and west-northwest-striking faults in the southern Shadow Mountains dip steeply north (Martin, 1992) and do not provably cut Quaternary deposits in exposures examined by us; they may be early Quaternary or much older. Some of these faults displace steeply- to moderately-dipping markers in a sinistral and (or) normal sense. One northwest-striking fault southwest of Nash Hill cuts Quaternary materials and offsets east-striking, moderately south-dipping dikes in a sinistral sense. The fault may be sinistral, unlike most northwest-striking faults of the Eastern California Shear Zone, or it may be dextral with a large down-to-the-northeast component of dip slip (contrary to its scarp, which suggests down-to-the-west), or it may be polygenetic.

The Mirage fault appears to splay into many faults southeastward. North of the map area, one splay breaks from the main trace and passes immediately northeast of the area we mapped. Within the area we mapped, the main trace in the north part, as marked by scarps and spring mounds, ends in an area where the pediment is strongly dissected, exposing outcrop of bedrock farther into the valley floor than elsewhere. In this zone, the main trace appears to divide into two and possibly three splays, the southernmost of which is the most recently active and is defined by scarps. The latter splay appears to terminate next to the southern Shadow Mountains, because all faults crossing the mountains do not provably cut young Quaternary materials. We could find no evidence for a fault bordering the western front of the southern Shadow Mountains, as shown by Troxel and Gunderson (1970). The large-scale splaying pattern of the Mirage fault is consistent with an interpretation that the fault is terminating in a horse-tail splay. If this interpretation is correct, it provides partial explanation for the existence of the southern Shadow Mountains: the splay is a compressive feature, and fault movement may contribute to the topographic relief.

Dissected Pleistocene deposits present 10 km southwest of El Mirage depart from the typical less dissected Holocene deposits on the piedmont north of the San Gabriel Mountains. It is possible that an unexposed fault borders the northeast margin of the dissected deposits, much as the Llano fault mapped 10 km farther southwest (Dibblee, 1961) borders older uplifted deposits.

The approach used for determining ages of rupture on faults is that used by Yount and others (1994) and Miller and others (1994) at Fort Irwin. We define surface deposits cut by and overlapping the faults and assign ages to those units by correlating soils and microtopography as defined by Yount and others (1994), McFadden (1987), and Reheis and others (1989). Ages of these surface deposits are given in Table 2.

Table 2. Ages for chief alluvial fan deposits.

Map unit	Approximate age of deposit
Qf	<~200 yr
Qyf_1	~100 to 1,000 yr
Qyf_2	~1,000 to 15,000 yr
Qof_1	~15,000 to 50,000 yr
Qof_2	~20,000 to 180,000 yr
Qof_3	~180,000 to 500,000 yr
Qvof	>500,000 yr

By these age measures, many faults probably last ruptured during the middle to late Pleistocene, but a few deform latest Pleistocene deposits and may have experienced latest Pleistocene or early Holocene rupture. No unambiguous examples of faulted Holocene sediment were observed. Trenching is required for full investigation of the seismic potential for the faults.

The newly mapped faults that strike northwest in the Adobe Mountain area are similar to those of the Eastern California shear zone in orientation and age. If included in the shear zone, they would extend the zone westward to about 25 km from the San Andreas fault, raising questions about whether it is a discrete zone or simply a broad area of faulting northeast of the San Andreas, much as faults exist in a broad zone southwest of the San Andreas fault. The locations of seismically active faults within the broad zone over the last several million years and patterns of strain through time are more important for understanding the zone and its seismic implications than are arbitrary boun-daries defined for the zone.

GROUNDWATER

Groundwater in sufficient quantities for utilization is commonly found in unconsolidated sediment, and less commonly in fractured bedrock. In both cases the chief source of recharge for the El Mirage area probably has been from surface runoff from the San Gabriel Mountains. Young faults may influence the movement of groundwater by acting as impediments or conduits. Geologic evaluation of groundwater therefore involves extrapolating various kinds of bedrock and sediment to depth and inferring fracture distributions and locations of young faults (California Department of Water Resources, 1967).

Near-surface water near El Mirage Lake is reported by residents to be alkaline, and to lie at about 5 m (16 ft) depth. Deeper water at the south edge of the lake is potable; in one case at the north end of Gray Mountain, it is found at 92 m (280 ft) in fractured bedrock. Residents near the dry lake apparently have trouble predicting whether they will find potable water and at what depth. Near the center of the playa, Dockter (1980) reported finding the first aquifer (TDS=818 mg/l) at a depth of 53 m (175 ft). Groundwater in the Sheep Creek fan is relatively shallow near the toe of the fan and deepens southward, higher on the fan (Stamos and Predmore, 1995). Depth to groundwater 4 to 6 km south of the dry lake, near the village of El Mirage, is 12 to 31 m (38 to 102 ft), whereas it is 94 to 133 m (308 to 436 ft) up the fan near the south edge of the map area. Thus, the water table appears to progressively decline about 60 m in altitude northward in the Sheep Creek fan toward El Mirage, over a distance of about 10 km. It may connect with near-surface saline waters under El Mirage Lake, in which case it is partitioned from a deeper (50-90m) freshwater aquifer. Although uncertainties in interpretation exist, it appears that changes in depth to fresh water from El Mirage village to the dry lake (a distance of about 4 km over which surface altitude declines ~8 m) varies by 50 to 100 m and therefore lateral and/or vertical partitioning of groundwater is likely in this valley-bottom setting.

Geomorphology of desert mountains and presence of broad flanking pediments suggests that bedrock is shallow (2 to 20 m) under alluvial piedmonts flanking the Shadow Mountains and Adobe Mountain. In contrast, hills southwest of El Mirage Lake lack pediments and extensive alluvial aprons, suggesting that bedrock may be deeper under the flanking sediments, which are derived from the distant San Gabriel Mountains. Sediment shed from the San Gabriel Mountains apparently is burying any bedrock highs and their flanking piedmonts that once lay between the San Gabriel Mountains and El Mirage Lake. As a result, Quaternary groundwater-bearing sediment a few hundred meters thick probably is present in much of the area south of the lake, where it forms a generally southward-thickening wedge of alluvium. However, buried desert topography probably exists beneath this alluvial wedge, and detailed gravity surveys are necessary for completely describing its geometry.

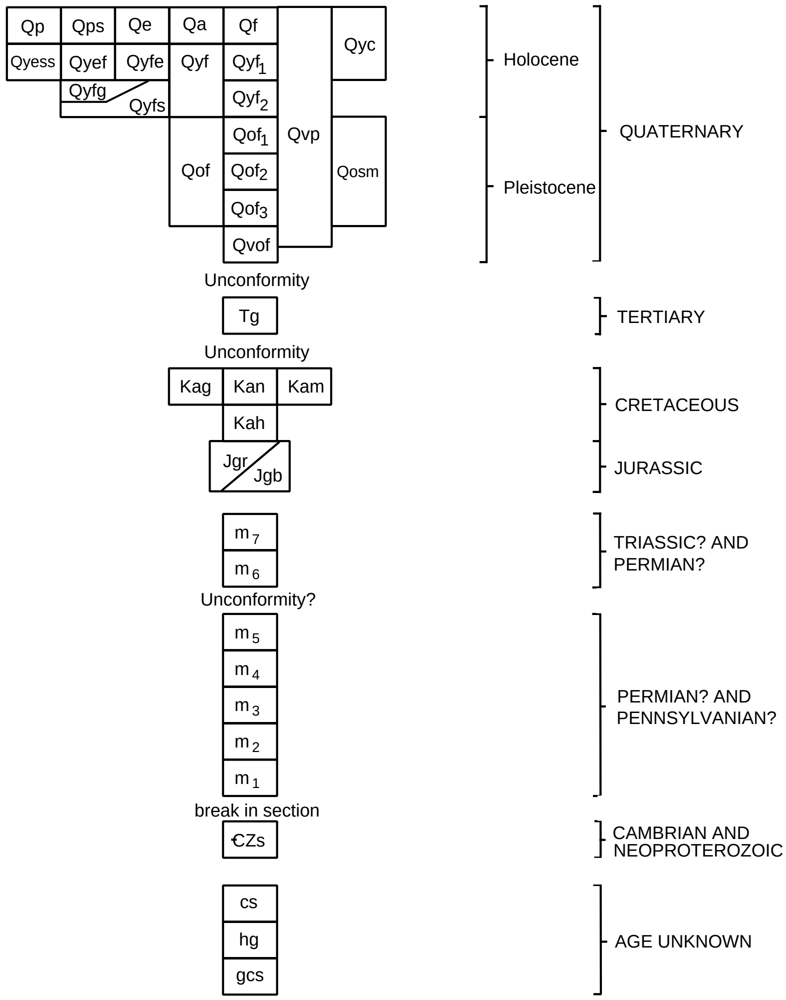
Deeper low-density sediment may exist beneath this alluvial wedge as a result of small basins formed by faults near the San Andreas fault. Biehler and others (1983) showed a northwest-trending shallow gravity trough in the southern part of our map area. Total gravity relief from the trough to bedrock of the southern Shadow Mountains is 15 mgal. A preliminary calculation of depth-to-bedrock using these gravity data predicts low-density material as thick as 1350 m (4500 ft) near the south edge of the map area. This deeper low-density material may be old sediment and characterized by lower water yield (California Department of Water Resources, 1967) than modern alluvium. A gentle gravity low in El Mirage Valley probably is not caused by significant thicknesses of alluvial materials, since it exists in areas where granite is exposed continuously across the valley. Gravity is essentially flat across El Mirage Lake between exposures of granite, suggesting that significant accumulation of sediment does not exist beneath the playa.

We could find no faults cutting sediment in the Sheep Creek fan, but buried older faults probably exist. To the west, a few northwest-striking faults splay northward from the San Andreas fault into the Mojave Desert, where they are marked by uplifts of early Quaternary and older materials (Dibblee, 1961). It is possible that the dissected terrane of Pleistocene gravels we mapped 10 km southwest of El Mirage has such an origin, although we did not find direct evidence for a fault there. In addition, the Mirage fault and faults in the Adobe Mountain area probably extend southeast from mapped exposures to the alluvial piedmont south of the lake. We consider it likely that buried Quaternary faults exist between the dry lake and the San Gabriel Mountains, and that they influence groundwater flow.

A more complete analysis of the geohydrology requires improved knowledge of the locations of buried faults, depths to basement (including subbasins partitioned by faults), and information on the water yield of buried materials. This information can be acquired by conducting detailed gravity studies and integrating drill-hole lithologic logs with surface geology.

Holocene muddy sands form a continuous sheet approximately 10 m thick across the entire distal part of the Sheep Creek fan extending from the San Gabriel Mountains. If similar deposits lie deeper in the buried fan, as they probably do, they could serve as aquitards that partition groundwater flow into gently north-dipping sheets of high transmissivity gravel deposits. As a result, recharging groundwater basins under the Sheep Creek fan may be best achieved by injection wells rather than by percolation ponds.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Mapping Conventions

Surficial geologic units in places exist as thin (<1 m) veneers over older units. In areas where this relationship is common the unit designators are shown on the map as being separated by a slash (/). The younger, or overlying, unit is indicated first. Thus, Qyf/Qof indicates an area where a veneer of young alluvial fan deposits overlies old alluvial deposits and Qyf/Kah indicates an area where a veneer of young alluvial fan deposits overlies Cretaceous hornblende granodiorite. The lateral extent of individual deposits is commonly so small that each deposit cannot be shown individually at the 1:24,000 map scale. Where areas are made up of deposits too small to show individually, the designators of deposits present are separated by a plus sign (+), with the most common deposit listed first. Thus, Qyf + Qof indicates an area with both Qyf and Qof deposits and associated surfaces, and that Qyf is more common than Qof. For the combined units, the color of the youngest unit is displayed on the map. For thin deposits over granite, a faint pattern is added that is keyed to the kind of granite beneath the deposit. The speckled pattern indicates deposits in which most clasts had a source of Pelona Schist (principally derived from the Sheep Creek fan in the San Gabriel Mountains).

Qp **Active playa deposits (Holocene)**--Dark brown and green micaceous clay and silt with minor fine to medium sand. Underlies El Mirage playa and smaller playas to east and north. White, reflective surface is characterized by mud-cracks. Little or no vegetation

Qps **Active playa deposits overlain by sand (Holocene)**--Micaceous muddy playa deposits interbedded with and/or overlain by complex of eolian and alluvial sands, generally less than 50 cm thick. White and pale brown on aerial photographs. More vegetated than playa deposits (unit Qp) but does not support dense cover

Qe **Active eolian sand deposits (Holocene)**--Active barchan dunes and sand ramps of fine- to coarse-grained sand; dunes as tall as 4 m. Unvegetated or sparsely vegetated. Most eolian sand south of El Mirage Lake is green in color due to large component of mica derived from Pelona Schist; transport is to the east

Qa **Active valley axis deposits (Holocene)**--Active sand and muds with subordinate gravel in braided washes within semi-bolson axes

Qf **Active alluvial fan deposits (Holocene)**--Poorly sorted gravel, sand, and silt in active alluvial systems. Deposited along braided channels on alluvial fans, as alluvial floodplains bordering streams, and as braided-stream sediment in incised stream channels

Qyc **Young colluvial deposits (Holocene)**--Active and inactive gravel and sand on steep slopes of Black Mountain

Qvp **Pediment veneer deposits (Holocene and Pleistocene)**--Poorly sorted gravel, sand, and silt in thin active and inactive alluvial systems. Overlie bedrock; less than 2 meters thick

Qyess **Young eolian sand sheets (Holocene)**--Largely inactive sheets of fine- and medium-grained green sand and minor silt; laminated to lenticular bedded with minor evidence of ripples. Surface is mounded, irregular. Thickness 2 to 8 m. Most eolian sand is derived from Pelona Schist

Qyef **Young eolian and alluvial fan deposits (Holocene)**--Eolian sand sheets and mounds with subordinate young alluvium. In southeast part of map area, largely represents granitic sediments carried north on Sheep Creek fan in gullies and then blown eastward into sand sheets. Thickness 1 to 4 m

Qyfe **Young alluvial fan and eolian deposits (Holocene)**--Young alluvium consisting of gravel, sand, and silt, along with subordinate eolian sand in mounds and small sheets. East of El Mirage Lake, consists of alluvium that reworks green eolian sand blown from playa. About 1 to 2 m thick

Qyf **Young alluvial fan deposits (Holocene)**--Poorly sorted gravel, sand, and silt. Primarily deposited as alluvial fans, which in many places are coalesced to form piedmonts flanking mountain ranges. Alluvial fan deposits emanating from Shadow and Adobe Mountains mostly consist of coarse sand and gravel derived from granitic rocks. In Shadow Mountains, generally 10-30 cm thick, resting on old alluvium. In Adobe Mountains, generally more than 1 m thick; base not exposed. Commonly covered by extensive biotic crusts. In places, subdivided into two units based on inset relationships and soil development:

Qyf_1 **Young alluvial fan deposits**--Inactive alluvial surfaces with bar and swale topography, no soil development

Qyf_2 **Young alluvial fan deposits**--Inactive alluvial surfaces with subdued bar and swale topography, incipient A_v horizon of sandy silt, incipient desert pavement

Qyfg **Young fan gravel (Holocene)**--Poorly sorted cobbles and pebbles in a matrix of medium- to coarse-grained sand. Lenses of cobbles. Many cobbles derived from Pelona Schist, granite, and gneiss. Generally less than 1 m thick; partly covered by thin eolian deposits in many places

Qyfs **Young fan sand (Holocene)**--Moderately to poorly sorted micaceous medium and fine sand, silt, and clay in a poorly bedded sequence greater than 4 m thick underlying young fan gravel (Qyfg). Unit colored medium to dark green due to abundant mica derived from Pelona Schist. Beds laterally continuous for greater than 50 m distance. Clay-rich beds typically parallel- and ripple-laminated. Lenticular bedding in sand and silt beds. Partly covered by thin eolian deposits in many places

Qof **Old fan deposits (Pleistocene)**--Moderately compact gravel, sand, and mud deposits; typically underlies inactive, partly dissected surfaces characterized by well-developed pavements and varnished clasts. Soil development generally includes moderate to strong A_v horizon, moderate to strong B horizon with white calcite stringers, and Stage **II** to **III** calcic horizon 10 to 150 cm thick. Deposits largely consist of sand near El Mirage Lake. In places, divided into subunits where inset relations exist and soils differ:

Qof_1 **Old fan deposits**--Alluvial fan deposits 1 to 2 m above active washes. Characterized by nearly flat surfaces with relic bar and swale topography visible, ~8 cm thick A_v horizon that contains a little sand with the silt; slightly to moderately developed argillic horizon, Stage **I+** calcic horizon, desert pavement, and moderate varnish

Qof_2 **Old fan deposits**--Alluvial fan deposits 2 to 3 m above active washes. Characterized by flat surfaces, ~10 cm thick silt A_v horizon; moderately developed argillic horizon ~1.5 m thick, Stage **II+** and **III** calcic horizon greater than 1 m thick, strong desert pavement and strong varnish

Qof_3 **Old fan deposits**--Alluvial fan deposits 3 to 5 m above active washes. Characterized by dissected surfaces, ~10 cm thick silt A_v horizon; strongly developed argillic horizon ~1.5 m thick, Stage **III+** calcic horizon 2.5 m thick, strong desert pavement and strong varnish

Qosm **Old spring mound deposits (Pleistocene)**--White, punky, calcium carbonate deposits with pelletal structure and abundant plant impressions. Form mounds and degraded remnants of mounds along piedmonts bounding Adobe Mountain and Shadow Mountains; commonly associated with young faults

Qvof **Very old fan deposits (Pleistocene)**-- Moderately compact gravel, sand, and mud deposits; typically underlie inactive, well-dissected ballenas with only fragments of original surfaces exposed. Soil development includes relic strong red B horizon and Stage IV calcic horizon greater than 2 m thick

Tg **Gravel (Tertiary)**--Moderately consolidated, crudely bedded, alluvial boulder- to pebble-gravel and sand underlying two hills north of El Mirage Lake. Sand is arkosic, derived from granitoids. Boulders consist of granitoid and metamorphic rock derived from Shadow Mountains. No obvious geomorphic connection to present topography remains

GRANITOID ROCKS OF ADOBE MOUNTAIN AND SOUTH AND EAST

Suite of granitoids underlying Adobe Mountain area. All are cut by numerous aplite and pegmatite dikes. Divided into:

Kag **Monzogranite of Adobe Mountain** (Cretaceous)--Medium-grained porphyritic biotite monzogranite containing minor hornblende. Ranges in a few places to coarse grained. Biotite 8-15%, hornblende 1-3%, quartz 30-35%. Potassium feldspar phenocrysts commonly 12 mm but as large as 17 mm. Quartz light gray to milky. Feldspars white to creamy. Minor sphene. Matrix to phenocrysts is subequigranular to seriate. Biotite partly as distinctive barrel-shaped crystals 4 mm x 10 mm. White to light gray, weathering to pale brown; commonly forms disintegrated granite on pediments. Dated by K-Ar at Adobe Mountain at 76.2 ± 2.3 Ma (biotite) by Miller and Morton (1980). Dike in granite near Shadow Mountains dated at 74.1 ± 2.2 Ma (biotite) by Miller and Morton (1980). Underlies much of low terrain south of Adobe Mountain and in Mirage Valley

Kan **Monzogranite of Nash Hill (Cretaceous)**--Fine- to medium-grained, seriate, leucocratic monzogranite containing minor biotite (CI=4 to 8). Biotite 2 to 8 mm diameter; partly as distinctive barrel-shaped crystals as large as 4 mm x 10 mm that commonly include plagioclase. Quartz light gray to milky, about 35%. Feldspars white to creamy; sparse potassium feldspar phenocrysts as large as 1.5 cm. Trace sphene. Forms craggy resistant hills with closely spaced jointing. Pale gray, weathering light tan. Crops out at Nash Hill, Gray Mountain, and nearby areas. Appears to grade to monzogranite of Adobe Mountain. Highly silicified at Black Mountain. Quartz veins and muscovite selvages along joints in Nash Hill. Dated by K-Ar at Gray Mountain at 82.2 ± 2.5 Ma (biotite) and 84.3 ± 2.5 Ma (hornblende) by Miller and Morton (1980)

Kam **Microgranite (Cretaceous)**--Very fine- to fine-grained, hypidiomorphic, leucocratic biotite monzogranite. Biotite 2-5 mm diameter, 2-5%. Quartz light gray to milky, about 35%. Feldspars white to creamy to pink. Light gray and pink on fresh surfaces, weathering to light brown to rust-brown. Forms low hills south of Adobe Mountain

Kah **Hornblende granodiorite (Cretaceous)**--Medium- and-coarse grained biotite-hornblende granodiorite, generally subequigranular to porphyritic with sparse hornblende phenocrysts. Hornblende predominates over biotite; together they compose 12 to 30 % of rock, and range in size from 6 to 10 mm. Quartz about 25% of rock. Sphene prominent: it is medium grained and 4-6% of rock. White to light tan or gray, weathering dark to medium gray. Locally mylonitic at Mt. Elmo. At Mt. Elmo and Black Mountain, contains common inclusions, screens, and wispy trails of metamorphic rocks: hornblendite, hornblende gneiss and schist, tremolite schist, and chlorite schist. Altered in many locations to combinations of epidote, chlorite, clay, sericite, and silica

GRANITOID ROCKS IN THE SHADOW MOUNTAINS

Jgr **Granodiorite, granite and related rocks (Jurassic**)--Biotite granite, hornblende granite, biotite-hornblende granodiorite and biotite-hornblende quartz monzodiorite. Medium to coarse grained, but compositionally and texturally variable. Granodiorite is most common and more mafic rocks such as quartz monzodiorite are relatively uncommon. Aplite and pegmatite dikes are common; one unusual composition contains tourmaline, muscovite, and garnet. Dated by Martin (1992) at 143 to 148 Ma

Jgb **Gabbro, diorite, and quartz diorite (Jurassic)**--Dark brown to black hornblende gabbro, hornblende diorite, hornblende-biotite quartz diorite, and mafic porphyritic hornblende-biotite quartz monzonite. Medium- and coarse-grained. Mafic minerals are biotite, hornblende, and augite. Age of quartz diorite is 148 Ma (Martin, 1992)

PRE-BATHOLITHIC METAMORPHIC ROCKS OF THE SHADOW MOUNTAINS — Assigned generic unit names because correlations uncertain

m_7 **Schist (Triassic? and Permian?)**--Quartz-feldspar-biotite schist with minor quartzite and calc-silicate rock, generally fine grained. Correlated by Martin (1992; map unit PM_4) to late Paleozoic and early Mesozoic strata of the central and western Mojave Desert

m_6 **Calc-silicate rocks (Triassic? and Permian?)**--Calc-silicate rock and calcite marble, generally fine-grained and dark in color. Correlated by Martin (1992; map unit PM_{cl}) to late Paleozoic and early Mesozoic strata of the central and western Mojave Desert

Marble (Permian? and Pennsylvanian?)--Calcite marble, siliceous marble, calcsilicate rock and minor quartzite. Divided by Martin (1992) into four stratigraphic units and units of uncertain position:

m_5 **Metamorphosed siliceous rocks**, including layered calcsilicate, feldspathic quartzite, and interlayers of marble. About 750 m thick (unit P_4 of Martin, 1992)

m_4 **Calcite and dolomite marble**. White to tan, massive. About 30 m thick (unit P_3 of Martin, 1992)

m_3 **Schistose feldspathic quartzite**. Dark gray to brown, fine- to medium-grained, and thin to medium layered; less commonly massive. About 30 to 100 m thick (unit P_2 of Martin, 1992)

m_2 **Calcite marble**, dark gray and thinly layered. Includes distinctive layers of metamorphosed carbonate pebbles and less common siliceous marble and white quartzite. About 500 m thick (unit P_1 of Martin, 1992)

m_1 **Siliceous marble**, thinly layered. Greater than 100 m thick (underlies unit P_1 of Martin, 1992)

PRE-BATHOLITHIC METAMORPHIC ROCKS OF BLACK MOUNTAIN AND MOUNT ELMO

CZs **Siliciclastic rocks (Cambrian and Late Proterozoic)**--Interlayered biotite schist, biotite-bearing quartzite, and quartzite, with minor tremolite schist and mafic gneiss. May represent the Zabriskie Quartzite, Wood Canyon Quartzite, Stirling Quartzite and Johnnie Formation. Present at Mt. Elmo and at Black Mountain

cs **Calc-silicate rocks (age uncertain)**--Undivided green and brown calc-silicate rocks at Black Mountain consisting of variably foliated rock with varying proportions of Ca-amphibole, pyroxene, quartz, chlorite, calcite, and plagioclase. Much rock is fine-grained green amphibole skarn, but some is coarse actinolite schist and gneiss with minerals as long as 6 cm. Fine-grained chlorite schist is distinctive component; it carries actinolite phenocrysts, as much as 1.5 cm long, in some cases. Locally mylonitic

hg **Hornblende gneiss (age uncertain)**--Black and dark brown, hornblende-rich gneiss and schist, hornblendite, and minor calc-silicate rock at Black Mountain. Hornblendite is finely laminated, fine-grained, and contains 75 to 95% hornblende. Locally mylonitic and retrograded to chlorite schist

gcs **Garnet calc-silicate rocks (age uncertain)**--Calc-silicate rocks at Black Mountain similar to the calc-silicate rock unit described above, but containing more muscovite and two distinctive subunits a few meters thick of brown rock composed nearly entirely of zoned euhedral garnet. Most rock is medium- to coarse-grained gneiss composed of Ca-amphibole and muscovite; hornblende schist, chlorite ± actinolite schist, and calc-silicate-bearing marble are distinctive minor components. Locally mylonitic

ACKNOWLEDGEMENTS

We are grateful for assistance and advice from Brett Cox, Doug Morton, Russ Campbell, and Les McFadden. Reviews by Fred Miller and Kevin Schmidt improved this report, as did a review of the database and metadata by Scott Graham.

REFERENCES CITED

Biehler, S., Tang, R.W., Ponce, D.A., and Oliver, H.W., 1983, Preliminary Bouguer gravity map of California, San Bernardino sheet: U.S. Geological Survey Open-File Report 83-96, scale 1:250,000.

Bowen, O.E., Jr., 1954, Geology and mineral deposits of the Barstow quadrangle, San Bernardino County, California: California Division of Mines and Geology Bulletin 165, 208 p.

Brown, H.J., 1983, Possible Cambrian miogeoclinal strata in the Shadow Mountains, western Mojave Desert, California: Geological Society of America Abstracts with Programs, v. 15, p. 413.

California Department of Water Resources, 1967, Mojave River ground water basin investigation: California Department of Water Resources Bulletin 84, 151 p.

Dibblee, T.W., Jr., 1960, Preliminary geologic map of the Shadow Mountains quadrangle, Los Angeles and San Bernardino Counties, California: U.S. Geological Survey Mineral Investigations Field Studies Map MF-227, scale 1:62,500.

Dibblee, T.W., Jr., 1961, Evidence of strike-slip movement on northwest-trending faults in the western Mojave Desert, California: U.S. Geological Survey Professional Paper 424-B, p. B197-199.

Dockter, R.D., 1980, Geophysical, lithologic, and water quality data from El Mirage Dry lake, San Bernardino County, California: U.S. Geological Survey Open-File Report OF 80-1200.

Dokka, R.K., 1983, Displacements on late Cenozoic strike-slip faults of the central Mojave Desert, California: Geology, v. 11, p. 305-308.

Dokka, R.K., and Travis, C.J., 1990, Role of the eastern California shear zone in accommodating Pacific—North American plate motion:

Geophysical Research Letters, v. 17, p. 1323-1326.
Fitzgibbon, T.T., 1991, ALACARTE installation and system manual (version 1.0): U.S. Geological Survey, Open-File Report 91-587B.
Fitzgibbon, T.T., and Wentworth, C.M., 1991, ALACARTE user interface - AML code and demonstration maps (version 1.0): U.S. Geological Survey, Open-File Report 91-587A.
Garfunkel, Z., 1974, Model for the late Cenozoic tectonic history of the Mojave Desert, California, and its relation to adjacent areas: Geological Society of America Bulletin, v. 85, p. 1931-1944.
Glazner, A.F., and Loomis, D. P., 1984, Effect of subduction of the Mendocino fracture zone on Tertiary sedimentation in southern California: Sedimentary Geology, v. 38, p. 287-303.
Glazner, A.F., Walker, J.D., Bartley, J.M., Fletcher, J.M., Martin, M.W., Schermer, E.R., Boettcher, S.S., Miller, J.S., Fillmore, R.P., and Linn, J.K., 1994, Reconstruction of the Mojave block, *in* McGill, S.F., and Ross, T.M., eds., Geological Investigations of an Ancient Margin: San Bernardino County Museum Association, Redlands, CA, p. 3-30.
Hart, E.W., 1988, Fault-rupture hazard zones in California; Alquist-Priolo Special Studies Zones Act of 1972 with index to special studies zones maps: California Division of Mines and Geology Special Publication 42.
Hauksson, E., Jones, L.M., Hutton, K., and Eberhart-Phillips, D., 1993, The 1992 Landers earthquake sequence: Seismological observations: Journal of Geophysical Research, v. 98, p. 19835-19858.
Martin, M.W., 1992, Stratigraphic and structural evolution of the Shadow Mountains, western Mojave Desert, California: Implications for the tectonic development of the central and western Mojave Desert: Unpubl. Ph.D. dissertation, University of Kansas, 196 p.
Martin, M.W., and Walker, J.D., 1992, Extending the western North American Proterozoic and Paleozoic continental crust through the Mojave Desert: Geology, v. 20, p. 753-756.
Martin, M.W., and Walker, J.D., 1995, Stratigraphy and paleogeographic significance of metamorphic rocks in the Shadow Mountains, western Mojave Desert, California: Geological Society of America Bulletin, v. 107, p. 354-366.
McFadden, L.D., and Weldon, R.J. II, 1987, Rates and processes of soil development on Quaternary terraces in Cajon Pass, California: Geological Society of America Bulletin, v. 98, p. 280-293.
Meisling, K.E., and Weldon, R.J. II, 1989, Late Cenozoic tectonics of the northwestern San Bernardino Mountains, southern California: Geological Society of America Bulletin, v. 101, p. 106-128.
Miller, D.M., Yount, J.C., Schermer, E.R., and Felger, T.J., 1994, Preliminary assessment of the recency of faulting at southwestern Fort Irwin, north-central Mojave Desert, California: San Bernardino County Museum Association Special Publication 94-1, p. 41-52.
Miller, E.L., 1981, Geology of the Victorville region, California, Part I and II: Geological Society of America Bulletin, v. 92, p. 160-163; 554-608.
Miller, E.L., and Carr, M.D., 1978, Recognition of possible Aztec-equivalent sandstones and associated Mesozoic meta-sedimentary deposits within the Mesozoic magmatic arc in south-western Mojave Desert, California, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western Untied States: Pacific Section, Society of Economic Paleon-tologists and Mineralogists, Pacific Coast Paleogeography Symposium v. 2, p 283-289.
Miller, F.K., and Morton D.M., 1980, Potassium-argon geochronology of the eastern Transverse Ranges and southern Mojave Desert, southern California: U.S. Geological Survey Professional Paper 1152, 30 p.
Morton, D.M., Campbell, R.H., Barrows, A.G., Jr., Kahle, J.E., and Yerkes, R.F., 1979, Wright Mountain mudflows: Spring 1969, *in* Landsliding and mudflows at Wrightwood, San Bernardino County, California: California Division of Mines and Geology Special Report 136, p. 7-21.
Ponti, D.J., and Burke, D.B., 1980, Map showing Quaternary geology of the eastern Antelope Valley and vicinity, California: U.S. Geological Survey Open File Report 80-1064, scale 1:62,500.
Powell, R.E., 1992, Balanced palinspastic reconstruction of pre-late Cenozoic paleogeology, southern California: Geologic and kinematic constraints on evolution of the San Andreas fault system, *in* Powell, R.E., Weldon, R.J. II, and Matti, J.C., The San Andreas fault system: Geological Society of America Memoir 178, p. 1-106.
Reheis, M.C., Harden, J.W., McFadden, L.D., and Shroba, R.R., 1989, Development rates of late Quaternary soils, Silver Lake Playa, California: Soil Science Society of America Journal, v. 53, p. 1127-1140.
Sharp, R.P. and Nobles, L.H., 1965, Mudflow of 1941 at Wrightwood, southern California: Geological Society of America Bulletin, v. 64, p. 547-560.
Stamos, C.L., and Predmore, S.K., 1995, Data and water-table map of the Mojave River ground-water basin, California, November 1992: U.S. Geological Survey Water-Resources Investigations Report 95-4148.
Sieh, K.E., 1984, Lateral offsets and revised dates of large pre-historic earthquakes at Pallet Creek, southern California: Journal of Geophysical Research, v. 9, p. 7641-7670.
Stevens, C.H., and Stone, P., 1988, Early Permian thrust faults in east-central California: Geological Society of America Bulletin, v. 100, p. 552-562.

Stewart, J.H., 1970, Upper Precambrian and Lower Cambrian strata in the southern Great Basin, California and Nevada: U.S. Geological Survey Professional Paper 620, 205 p.
Stewart, J.H., and Poole, F.G., 1975, Extension of the Cordilleran miogeosynclinal belt to the San Andreas fault, southern California: Geological Society of America Bulletin, v. 86, p. 205-212.
Stone, P., and Stevens, C.H., 1988, Pennsylvanian and Early Permian paleogeography of east-central California: Implications for the shape of the continental margin and the timing of continental truncation: Geology, v. 16, p. 330-333.
Troxel, B.W., and Gunderson, J.N., 1970, Geology of the Shadow Mountains and northern part of the Shadow Mountains SE quadrangles, western San Bernardino County, California: California Division of Mines and Geology Preliminary Report 12, scale 1:24,000.
Ward, A.W., Dixon, G.L., and Jachens, R.C., 1993, Geologic setting of the East Antelope Basin, with emphasis on fissuring on Rogers Lake, Edwards AFB, Mojave Desert, California: U.S. Geological Survey Open File Report 93-263, 9 p.
Weldon, R.J. II, and Sieh, K.E., 1985, Holocene rate of slip and tentative recurrence interval for large earthquakes on the San Andreas fault, Cajon Pass, southern California: Geological Society of America Bulletin, v. 96, p. 793-812.
Wentworth, C. M., and Fitzgibbon, T. T., 1991, ALACARTE user manual (version 1.0): U. S. Geological Survey Open-File Report 91-587C.
Yount, J.C., Schermer, E.R., Felger, T.J., Miller, D.M., and Stephens, K.A., 1994, Preliminary geologic map of Fort Irwin Basin, north-central Mojave Desert, California: U.S. Geological Survey Open File Report 94-173, 27 p., scale 1:24,000.

Appendix 1. Description of database

The geologic map database delineates map units that are identified by general age, lithology, and clast size following the stratigraphic nomenclature of the U.S. Geological Survey. For descriptions of the units, their stratigraphic relations, and sources of geologic mapping, consult the Description of Map Units section of this report, the combined geologic map and explanation (of00-222_5a.eps or of00-222_5a.pdf), or the explanation sheet (of00-222_5c.eps or of00-222_5c.pdf). The scale of the source map limits the spatial resolution (scale) of the database to 1:24,000 or smaller.

For those interested in the geology of El Mirage Lake Area and vicinity who do not use an ARC/INFO compatible Geographic Information System (GIS), but would like to obtain a paper map and explanation, PDF and PostScript plot files containing map images of the data in the digital database, as well as PostScript and PDF plot files of the explanation sheet and explanatory text, have been included in the database package (please see the section “Digital Plot Files", page 18). The PostScript plot files require a gzip utility to access them.

For those without computer capability, we can provide users with the PostScript or PDF files on tape that can be taken to a vendor for plotting. Paper plots can also be ordered directly from the USGS (please see the section "Obtaining Plots from USGS Open-File Services", page 18)

The content and character of the database, methods of obtaining it, and processes of extracting the map database from the tar (tape archive) file are described herein. The map database itself, consisting of six ARC/INFO coverages, can be obtained over the Internet or by magnetic tape copy as described below.

The database was compiled using ARC/INFO versions 7.2.1 and 8.0.1, a commercial Geographic Information System (Environmental Systems Research Institute, Redlands, California), with version 3.0 of the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991, Fitzgibbon, 1991, Wentworth and Fitzgibbon, 1991). The ARC/INFO coverages are stored in uncompressed ARC export format (ARC/INFO version 7.x). All data files have been compressed, and may be uncompressed with gzip, which is available free of charge over the Internet via links from the USGS Public Domain Software page (http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/public.html). ARC/INFO export files (files with the .e00 extension) can be converted into ARC/INFO coverages in ARC/INFO (see below) and can be read by some other Geographic Information Systems, such as MapInfo via ArcLink, and ESRI's ArcView.

DATABASE CONTENTS

The digital map database consists of digital files representing the 5 (a revisions list, the Open File Text, spatial data, metadata, and plot files) parts of the database. The names of the files are unique designators based on the report identifier, of00-222, followed by part numbers and an extension indicating file type. The larger files, which have been compressed with gzip, have .gz extensions as well.

1. Revision List
A list of the parts of the report and at what version number of the report each was last revised (if at all) followed by a chronologic list that describes any revisions:

a. of00-222revs1.txt	ASCII file

2. Open File Text
The text of the Open-Rile Report (this document), which discusses the geology of the area, and describes the database and how to obtain it:

a. of00-222_2a.txt	unformatted ASCII text
b. of00-222_2b.eps	PostScript file
c. of00-222_2c.pdf	PDF file

3. Geologic Map Database
The geologic map coverages, which are stored as uncompressed ARC/INFO export files compressed with gzip, are described below.

ARC/INFO export file	Size of gzip compressed export file (uncompressed)	Resultant Coverage (using import.aml)	Description of Coverage
of00-222_3a.e00	615 Kb (2.8 MB)	elm-geol	Depositional contacts, faults and unit labels
of00-222_3b.e00	11 kB (124 kB)	elm-str	Fold axes, strike and dip information
of00-222_3c.e00	2 kB (14 kB)	elm-spr	Locations of spring mound deposits
of00-222_3d.e00	3 kB (11 kB)	elm-kar	Locations of dated samples
of00-222_3e.e00	8 kB (44 kB)	elm-srcs	Areas of previous mapping
of00-222_3f.e00	3 kB (15 kB)	elm-strat	Areas depicting mapping strategies
of00-222_3g.e00	12.8 MB (68.6 MB)	elm-topo	Topographic base map
of00-222_3h.e00	14kB (122kB)	elm-obs	Locations of field observations
of00-222_3i.tar	13.3 MB (13.4 MB)		Tar file containing all 7 of the above files, and import.aml

ARC export files promote ease of data handling, and are usable by some other Geographic Information Systems in addition to ARC/INFO (see below for a discussion of working with export files).

4. Metadata
FGDC compliant metadata for the spatial data in this report was compiled using ARC/INFO version 8 ArcCatalog's built-in metadata editor. Metadata was checked for FGDC compliance using mp version 2.4.30 (http://geology.usgs.gov/tools/metadata/). Metadata is available in the following formats:

Filename	Description
of00-222_4a.txt	FGDC metadata in formatted text
of00-222_4b.html	FGDC metadata in MP formatted HTML
of00-222_4c.html	FGDC metadata in MP formatted FAQ HTML
of00-222_4d.sgml	FGDC metadata in MP formatted SGML
of00-222_4e.xml	FGDC metadata in MP formatted XML

5. PostScript and PDF plot files
The geologic map with explanation of the El Mirage Lake Area and smaller sized separate sheets of geologic map and accompanying explanation sheet (the PDF files are not compressed):

Plot file	Size of gzip compressed plot file	Description of plot file

	(uncompressed)	
---------------	-----------------	---
of00-222_5a.eps	3.2 MB (24 MB)	El Mirage geologic map with explanation (40 X 50 inch, PostScript)
of00-222_5b.eps	3 MB (23 MB)	El Mirage geologic map sheet (36 X 50 inch, PostScript)
of00-222_5c.eps	216 kB (3.4 MB)	El Mirage explanation sheet (20 X 32 inch, PostScript)
of00-222_5a.pdf	3.3 MB	El Mirage geologic map with explanation (40 X 50 inch, PDF)
of00-222_5b.pdf	3.2 MB	El Mirage geologic map sheet (36 X 50 inch, PDF)
of00-222_5c.pdf	300 kB	El Mirage explanation sheet (20 X 32 inch, PDF)

OBTAINING PAPER MAPS FROM THE USGS

The U.S. Geological Survey will make plots on demand from map files such as those described in this report.

Be sure to include with your request the Open-File Report number and the exact names, as listed in the Database Contents section above, of the plot file(s) you require. An Open-File Report number and its letter alone are not sufficient, unless you are requesting plots of all the plot files in this report. You may wish to determine the price before placing an order.

Order plots from:

USGS Information Services
Box 25286
Denver Federal Center
Denver, CO 80225-0046
(303) 202-4200
1-800-USA-MAPS
FAX: (303) 202-4695

e-mail: infoservices@usgs.gov

DIGITAL PLOT FILES

For those interested only in the map or explanation images, who don't use an ARC/INFO compatible GIS system, but would like to obtain paper maps, we have included separate PostScript and PDF plot files.

The plot files are available in any of the three ways described below, including the World Wide Web pages. The PostScript plot files have been compressed with gzip and they must be uncompressed before use. The gzip utility is available free of charge over the Internet via links from the USGS Public Domain Software page:

http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/public.html

The geologic map with explanation image is 40 inches wide by 50 inches long, and therefore will require a plotter capable of plotting files of this size. To provide for smaller format plotters, the map is also available as separate sheets of a 36 X 50 inch geologic map sheet, and a 20 X 32 inch explanation sheet. All of the map sheets require a large format plotter to produce paper copies at the intended scale.

OBTAINING THE GEOLOGIC MAP DATABASE OR DIGITAL PLOT FILES

The PostScript and PDF plot files can be obtained in any of three ways:

1. Send a tape with request

Geologic map data file(s) and/or plot file (s) can be obtained by sending a tape with request to:

El Mirage Lake Area Map Database and/or Plot File
c/o Database Coordinator
U.S. Geological Survey
345 Middlefield Road, MS 975
Menlo Park, CA 94025

The file (s) will be returned on the tape. The acceptable tape types are:

4.3 or 5.0 GB, 8 mm Exabyte tape.

In the request be sure to include with your request the Open-File Report number and the exact names, as listed in the Database Contents section above, of the file(s) you require. An Open-File Report number and its letter alone are not sufficient, unless you are requesting all of the files for this report.

If you are obtaining a plot file on tape to give to a vendor to plot, make sure your vendor is capable of reading these tape types and PostScript and/or PDF plot files.

2. Anonymous ftp over the Internet

To obtain files by ftp:

The files in these reports are stored on the U.S. Geological Survey Western Region FTP server. The Internet ftp address of this server is:

wrgis.wr.usgs.gov

Connect to this address directly using ftp or through a browser, log in with the user name `anonymous', and enter your e-mail address as the password. This will give you access to all the publications available from the server wrgis.

The files in this report are stored in the subdirectory:

pub/open-file/of00-222

3. From the Western Region Geologic Information Web Page

The U.S. Geological Survey supports a set of graphical pages on the World Wide Web from which digital publications such as this one can be obtained. The web server for digital publications from the Western Region is "http://wrgis.wr.usgs.gov". Once at the main page, click on **'Geologic Map Databases**' under the heading **'Data Online**'; next click on '**California**.' Scroll down to the link '**Open-File Report 00-222',** which will take you to the web page for this report. Set your web browser to save to a local disk and click on the link for each desired file to download it.

CONVERTING ARC EXPORT FILES

ARC export files are converted to ARC coverages using the ARC command IMPORT with the option COVER. Change directories to the database directory. An import routine written in ARC MACRO LANGUAGE (AML) has been included to aid in the extraction of the coverages from the ARC export files. From the ARC command line type:

Arc: &r import.aml

ARC export files can also be read by some other Geographic Information Systems. Please consult your GIS documentation to see if you can use ARC export files and the procedure to import them.

DIGITAL COMPILATION

Initial mapping by the authors of this report was conducted by tracing lines originally drawn on areal photographs onto USGS Orthophoto quadrangles, and then inked onto mylar. The mylar sheets were then scanned on an Altek monochrome scanner at a resolution of 600 dots per inch. The scanned images were vectorized and transformed from scanner coordinates to projected coordinates with digital tics placed by hand at quadrangle corners using ARC/INFO. The maps were then merged and attributed to create a single spatial database of geologic lines and polygons.

Further field mapping was conducted using Rockwell PLGR GPS units and 'palm-top' data gathering devices. Daily mapping using the GPS and data gatherers was incorporated into the original spatial database using ArcView GIS (Environmental Systems Research Institute, Redlands, California) version 3.1 by heads up digitizing of areal photograph linework on Digital Orthophoto Quadrangles (DOQ's). The revised geologic map was then brought into ARC/INFO for further topologic corrections and for map plotting.

The authors have compiled a spatial database of the general strategies used while collecting field data and preparing the map. This data is intended to inform the user of the level of detail of the studies. For instance, this information shows whether we were using aerial photograph reconnaissance or ground observations as the main interpretive tool. These general strategies provide information on how confidently we expect the geology as mapped (both location and content of information) to be correct. The information is summarized in Table 3 of the Geologic Description portion of this report, and is available as a spatial dataset in (of00-222_3f.e00, or elm-strat).

BASE MAP

The base map was created by scanning the four paper U.S. Geological Survey 7.5 minute quadrangle maps in the map area on an Altek monochrome scanner at a resolution of 600 dots per inch. The scanned images were vectorized and transformed from scanner coordinates to projection coordinates with digital tics placed by hand at quadrangle corners using ARC/INFO. Because the base map is for reference only, scanning artifacts have not been removed from this map.

SPATIAL RESOLUTION

Uses of this digital geologic map should not violate the spatial resolution of the data. Although the digital form of the data removes the constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. The fact that this database was edited at a scale of 1:24,000 means that higher resolution information is not present in the dataset. Plotting at scales larger than 1:24,000 will not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data.

FAULTS

This database is not sufficiently detailed or comprehensive to identify or characterize site-specific hazards represented by the faults shown; the faults shown do not distinguish active faults, nor do they take the place of fault-rupture hazard zones designated by the California Division of Mines and Geology (see, for example, Hart, 1988).

DATABASE SPECIFICS

The map databases consist of ARC coverages stored in UTM projection using the North American Datum of 1983 (Table 1).

Table 1 - Map Projection
The map is stored in State Plane projection

PROJECTION UTM	
UNITS METERS	-on the ground
ZONE 11	
DATUM NAD83	

PARAMETERS	-none

The content of the geologic database can be described in terms of the lines and areas that compose it. Descriptions of the database fields use the terms explained in Table 2.

Table 2 - Field Definition Terms

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B-binary integer, F-binary floating point number, I-ASCII integer, C-ASCII character string
N. DEC.	number of decimal places maintained for floating point numbers

LINES

The lines (arcs) are recorded as strings of vectors and are described in the arc attribute table (Table 3). They define the boundaries of the map units, the faults, and the map boundaries. These distinctions, including the geologic identities of the unit boundaries, are recorded in the LTYPE field according to the line types listed in Tables 4 and 5.

Table 3 - Content of the Arc Attribute Tables (ELM-GEOL.AAT, ELM-STR.AAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
FNODE#	4	5	B		starting node of arc (from node)
TNODE#	4	5	B		ending node of arc (to node)
LPOLY#	4	5	B		polygon to the left of the arc
RPOLY#	4	5	B		polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
LTYPE	35	35	C		line type (see Tables 4 and 5)

Table 4 - Line Types Recorded in the LTYPE Field in ELM-GEOL

contact, approx. located	fault, certain
contact, certain	fault, concealed
contact, gradational	fault, concealed, queried
fault, approx. located	map boundary, certain
fault, approx. located, queried	scratch boundary

Table 5 - Line Types Recorded in the LTYPE Field in ELM-STR

f.a., anticline, certain, n. plunge
f.a., syncline, certain, n. plunge
photo lineament

AREAS

Map units (polygons) and other areal features are described in the polygon attribute table (Table 6). The identities of the map units are recorded in the PTYPE field by map label (Tables 7 and 8). For a description of the map units, consult the “Description of Map Units” portion of this report, or the PostScript or PDF plot files with an explanation (of00-222_5a.eps, of00-222_5a.pdf, of00-222_5c.eps, of00-222_5c.pdf). Areal features in the geology layer (ELM-GEOL) that require attributes other than a map unit, are given unique identification numbers in the ITEMID field. ITEMID provides a common field to which other tabular data (ELM-GEOL.IDTAB) can be used in a relational database. ELM-GEOL.IDTAB is described in Table 8, and a listing of unique values in ELM-GEOL.IDTAB is given in Table 9. Mapping strategies of the authors of this report are represented as polygons depicting the strategies used in mapped area. The Polygon Attribute Table (ELM-STRAT.PAT) for this coverage is described in Table 10. Table 11 lists the unique records in ELM-STRAT.PAT

Table 6 - Content of the Polygon Attribute Tables (ELM-GEOL.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTYPE	35	35	C		unit label (see Tables 7 and 8)
ITEMID	10	10	I		attribute for individual features (relates to ELM-GEOL.PID)

Table 7 - Map Units in ELM-GEOL
(listed alphabetically)

CZs	Qf+Qyf	Qof1+Qyf/Kag	Qvof	Qyf1+Qyf2	hg
Jgb	Qf+Qyf+Qof	Qof2	Qvp	Qyf1+Qyf2+Qof	m1
Jgr	Qof	Qof2+Qof3	Qyc	Qyf2	m2
Kag	Qof+Qyf	Qof2/Jgr	Qyef	Qyf2+Qyf1	m2?
Kag?	Qof+Qyf+Qf	Qof3	Qyess	Qyfe	m3
Kah	Qof+Qyf/Kag	Qof3/Kag	Qyf	Qyfe+Qa	m4
Kam	Qof/Jgr	Qof3/m2	Qyf+Qf	Qyfg	m5
Kan	Qof/Kag	Qof3?	Qyf+Qof	Qyfs	m5?
Qa	Qof/m3+m5	Qosm	Qyf+Qof+Qf	Tg	m6
Qe	Qof1	Qp	Qyf+Qof/Kag	cs	m
Qf	Qof1+Qof2	Qps	Qyf/Kag	gcs	

Table 8 – Description of INFO Table ELM-GEOL.IDTAB
NOTE: only features with added attributes are given a non-blank SRC_ROCK attribute

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
ITEMID	10	10	I		used to link to ITEMID field in ELM-GEOL.PAT
SRC_ROCK	35	35	C		Description of the source material for certain alluvial deposits

Table 9 – Unique values in INFO Table ELM-GEOL.IDTAB
Pelona Schist

Table 10 - Content of the Polygon Attribute Table (ELM-STRAT.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters

<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
FIELDID	10	10	N	0	Identification number of area
GEOLOGIST	35	35	C		Last name(s) of geologist mapping in that area
METHODS	200	200	C		Description of the methods and tools used in mapping that area

Table 11 – Unique combinations of Mapping Strategies (ELM-STRAT.PAT)

FIELDID	1
GEOLOGIST	Miller
METHODS	Detailed reconnaissance of surficial materials by aerial photography and examination of key outcrops, supplemented by observations along roads.
FIELDID	2
GEOLOGIST	Miller
METHODS	Detailed study of surficial materials by aerial photography and field investigations supplemented by field verification of bedrock geology by Troxel and Gunderson(1970) and Martin(1992).
FIELDID	3
GEOLOGIST	Miller
METHODS	Detailed field studies of bedrock; reconnaissance of surficial materials by aerial photography and field studies
FIELDID	4
GEOLOGIST	Miller and Bedford
METHODS	Detailed field studies of bedrock and surficial materials
FIELDID	5
GEOLOGIST	Bedford
METHODS	Detailed field studies of bedrock supplemented with aerial photography

POINTS

Point information (strikes and dips, sample localities, etc) is recorded as coordinate pairs and related information is described in the Point Attribute Table (Table 12). The identities of point types recorded in the PTTYPE field of the ELM-STR.PAT table are listed in Table 13. Datasets not representing structural features (elm-spr, elm-kar, elm-obs) do not contain the DIP and STRIKE fields. Identities recorded in the PTTYPE of the ELM-SPR.PAT table are listed in Table 14, identities recorded in the PTTYPE field of the ELM-KAR.PAT table are listed in Table 15, and identities recorded in the PTTYPE field of the ELM-OBS.PAT table are listed in Table 16.

Table 12 - Content of the Point Attribute Tables in ELM-STRC.PAT

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	not used
PERIMETER	4	12	F	3	not used
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTTYPE	35	35	C		point type (see Table 10)

DIP	3	3	I	dip angle in degrees
STRIKE	3	3	I	strike angle in degrees

Table 13 - Point Types (ELM-STR.PAT)

bedding
foliation
vert bedding

Table 14 – Point Types (ELM-SPR.PAT)

Spring Mound

Table 15 – Point Types (ELM-KAR.PAT)

K-Ar Sample

Table 16 – Point Types (ELM-OBS.PAT)

Field Observation

REGIONS

Region information allows polygonal information to be stored in a way that areas, or regions, can be overlapping, or non-contiguous in nature. Attribute information for regions is stored in tables that have the name of the coverage Polygon Attribute Table (PAT), followed by the name of a region. Regions may have different table definitions (items) than the base Polygon Attribute Table, and regions within the same coverage may have different table definitions (items). The index of previous mapping (ELM-SRCS), consists of four regions: prevmap1, prevmap2, prevmap3, and prevmap4. Each region has identical table definitions, described in Table 17. The Polygon Attribute Table (ELM-SRCS.PAT) has no attributes with the exception of the default ARC/INFO attributes described in Table 6. A listing of the attributes in each region of ELM-SRCS is provided in Table 18. For complete bibliographic references, see the "REFERENCES CITED" section of this report.

Table 17 - Content of the Region Tables for ELM-SRCS.PATPREVMAPx)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
AUTHORS	200	200	C		Authors of previous mapping
YEAR	10	10	N	0	Year of publication or report
TITLE	200	200	C		Title of publication or report
PUBLICATION	200	200	C		Publication name and number, including agency of publication
SCALE	15	15	C		Scale of mapping

Table 18 – Listing of Attributes for ELM-SRCS

Table: ELM.SRC.PATPREVMAP1
AUTHORS: Dibblee, T.W., Jr.

YEAR: 1960
TITLE: Preliminary geologic map of the Shadow Mountains quadrangle, Los Angeles and San Bernardino Counties, California
PUBLICATION: U.S. Geological Survey Mineral Investigations Field Studies Map MF-227
SCALE:

Table: ELM.SRC.PATPREVMAP2
AUTHORS: Ponti, D.J, and Burke, D.B.
YEAR: 1980
TITLE: Map showing Quaternary geology of the eastern Antelope Valley and vicinity, California
PUBLICATION: U.S. Geological Survey Open File Report 80-1064
SCALE: 1:62,500

Table: ELM.SRC.PATPREVMAP3
AUTHORS: Troxel, B.W., and Gunderson, J.N.
YEAR: 1970
TITLE: Geology of the Shadow Mountains and northern part of the Shadow Mountains SE quadrangles, western San Bernardino County, California
PUBLICATION: California Division of Mines and Geology Preliminary Report 12
SCALE: 1:24,000

Table: ELM.SRC.PATPREVMAP4
AUTHORS: Martin, M.W.
YEAR: 1992
TITLE: Stratigraphic and structural evolution of the Shadow Mountains, western Mojave Desert, California: Implications for the tectonic development of the central and western Mojave Desert
PUBLICATION: Unpubl. Ph.D. dissertation, University of Kansas
SCALE: 1:12,000

Appendix 2. Quality Measures

Location Accuracy. Accuracy of line locations is carried in the database and displayed by different line symbols (solid vs. dashed lines) in the cartographic display. For the purpose of this database, solid lines represent contacts and faults located with an accuracy greater than 10 m and commonly greater than 5 m. Dashed lines represent two kinds of less certainly located features, each distinguished in the database: 1) contacts and faults located with an accuracy of 10 to 15 m, 2) contacts that represent gradational boundaries between adjacent units. Gradational contacts represent interleaving of sediments and smooth gradations in characteristics such as percentage of eolian sand. In general, these gradations take place over distances of 50 to 150 m. Lineaments and fold axes are lines whose positions do not affect location of polygons; they are located with an accuracy of 25 m.

Attribute accuracy and interpretation. Accuracy of polygon attributes depends on many factors. We provide three measures of quality and interpretation, each of which provides different kinds of information.

(1) Observation sites. [ELM-OBS] This data set shows locations that we visited while conducting field work, at many of which we made specific recorded observations. We observed many more points en route to these sites, so the data set is not a complete catalog of observations. Rather, it is an indication of the areas that we most comprehensively studied.

(2) Areas mapped by previous authors. [ELM-SRCS] These areas are shown in index map form on the map, and the information on previous mapping is provided in the database. The original sources can be consulted to evaluate agreements and disagreements about interpreting the geology in these areas. Previous mapping was not intended to be as comprehensive as the present product. Dibblee (1960) and Ponti and Burke (1980) conducted reconnaissance studies to identify the essential geologic features of the region. Bedrock mapping by Troxel and Gunderson (1970) and Martin (1992) focused primarily on exposures in mountains and provided less information on pediment and piedmont geology. This information is expanded in the following annotated bibliography, which is referenced in fields **AUTHORS, YEAR, TITLE, PUBLICATION, and SCALE** in the database and identified on the "index map for previous geologic mapping".

Dibblee (1960). *[Dibblee, T.W., Jr., 1960, Preliminary geologic map of the Shadow Mountains quadrangle, Los Angeles and San Bernardino Counties, California: U.S. Geological Survey Mineral Investigations Field Studies Map MF-227, scale 1:62,500.]* Distinguished a few surficial geologic units, four granitoid units, and several metamorphic rock units. Mapped the most evident faults, as well as folds in metamorphic rocks.

Troxel and Gunderson (1970). [*Troxel, B.W., and Gunderson, J.N., 1970, Geology of the Shadow Mountains and northern part of the Shadow Mountains SE quadrangles, western San Bernardino County, California: California Division of Mines and Geology Preliminary Report 12, scale 1:24,000.*] Distinguished a few surficial geologic units, a few granitoid units, and several metamorphic rock units. Mapped granitoid and metamorphic rock units in detail, as well as faults and folds in metamorphic rocks. Mapped lineaments and faults in pediments.

Ponti and Burke (1980). [*Ponti, D.J., and Burke, D.B., 1980, Map showing Quaternary geology of the eastern Antelope Valley and vicinity, California: U.S. Geological Survey Open File Report 80-1064, scale 1:62,500.*] Mapped a wide range of surficial geology with a focus on areas with active faulting. Mapped several previously unrecognized faults in the El Mirage Lake area but did not break out many surficial geology units in this area.

Martin (1992). [*Martin, M.W., 1992, Stratigraphic and structural evolution of the Shadow Mountains, western Mojave Desert, California: Implications for the tectonic development of the central and western Mojave Desert: Unpubl. Ph.D. dissertation, University of Kansas, 196 p.*] Conducted very detailed (1:12,000) mapping of bedrock in Shadow Mountains but none in pediments. Distinguished several map units in metamorphic rocks and deduced sedimentary, metamorphic, and structural history.

(3) General strategies. [ELM-STRAT] The general strategies we used while collecting field data and preparing the map are intended to inform the user of the level of detail of our studies. For instance, this information shows whether we were using aerial photograph reconnaissance or ground observations as the main interpretive tool. These general strategies provide information on how confidently we expect the geology as mapped (both location and content of information) to be correct. The information is summarized in Table 3.

Table 1. Field mapping strategies

Field ID	Geologist	Methods
1.	Miller	Detailed reconnaissance of surficial materials by aerial photography and examination of key outcrops, supplemented by observations along roads.
2.	Miller	Detailed study of surficial materials by aerial photography and field investigations supplemented by field reconnaissance verification of bedrock geology by Troxel and Gunderson (1970) and Martin (1992).
3.	Miller	Detailed field studies of bedrock; reconnaissance of surficial materials by aerial photography and field studies.
4.	Miller and Bedford	Detailed field studies of bedrock and surficial materials.
5.	Bedford	Detailed field studies of bedrock supplemented with aerial photography.