Preliminary Surficial Geologic Map of a Calico Mountains Piedmont and Part of Coyote Lake, Mojave Desert, San Bernardino County, California

By Stephanie L. Dudash

2006

Open-File Report 2006–1090

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Lynn Scarlett, Acting Secretary

U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia 2006

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Introduction

This 1:24,000 scale detailed surficial geologic map and digital database of a Calico Mountains piedmont and part of Coyote Lake in south-central California depicts surficial deposits and generalized bedrock units. The mapping is part of a USGS project to investigate the spatial distribution of deposits linked to changes in climate, to provide framework geology for land use management (*http://deserts.wr.usgs.gov*), to understand the Quaternary tectonic history of the Mojave Desert, and to provide additional information on the history of Lake Manix, of which Coyote Lake is a sub-basin. Mapping is displayed on parts of four USGS 7.5 minute series topographic maps (Figure 1). The map area lies in the central Mojave Desert of California, northeast of Barstow, CA and south of Fort Irwin, CA and covers 258 km^2 (99.5 mi^2). Geologic deposits in the area consist of Paleozoic metamorphic rocks, Mesozoic plutonic rocks, Miocene volcanic rocks, Pliocene-Pleistocene basin fill, and Quaternary surficial deposits. McCulloh (1960, 1965) conducted bedrock mapping and a generalized version of his maps are compiled into this map. McCulloh's maps contain many bedrock structures within the Calico Mountains that are not shown on the present map.

This study resulted in several new findings, including the discovery of previously unrecognized faults, one of which is the Tin Can Alley fault. The north-striking Tin Can Alley fault is part of the Paradise fault zone (Miller et al., 2005), a potentially important feature for studying neo-tectonic strain in the Mojave Desert. Additionally, many *Anodonta* shells were collected in Coyote Lake lacustrine sediments for radiocarbon dating. Preliminary results support some of Meek's (1999) conclusions on the timing of Mojave River inflow into the Coyote Basin.

The database includes information on geologic deposits, samples, and geochronology. The database is distributed in three parts: spatial map-based data, documentation, and printable map graphics of the database. Spatial data are distributed as an ArcInfo personal geodatabase, or as tabular data in the form of Microsoft Access Database (MDB) or dBase Format (DBF) file formats. Documentation includes this file, which provides a discussion of the surficial geology and describes the format and content of the map data, and Federal Geographic Data Committee (FGDC) metadata for the spatial map information. Map graphics files are distributed as Postscript and Adobe Portable Document Format (PDF) files, and are appropriate for representing a view of the spatial database at the mapped scale.

Methods

The map and database were produced at 1:24,000 scale (coordinate system NAD 1983, UTM zone 11N) using traditional field methods, interpretation of remote sensing images, and previous mapping. Field methods include description of landforms, deposit characteristics, and soil morphology. Stereoscopic analysis was conducted using 1:24,000 and 1:30,000 scale aerial photographs. Remote sensing images were used to evaluate topography and landforms. Process of deposition, geomorphic position, surface roughness, desert pavement maturity, soil morphology, and inset relations were used to classify Quaternary surficial deposits. All line work was compiled in ESRI's ArcMap® using referenced digital orthoquarter quadrangles (DOQQs) and topographic maps. The digitizing scale was approximately 1:3000.

New geochronology was conducted to provide supplemental data to existing geochronology and to understand the ages of collected material in stratigraphic context. Material collected for accelerator mass spectrometry (AMS) radiocarbon dating consisted of *Anodonta* shells. Genus *Anodonta* are thin-shelled freshwater mussels found in both lacustrine and fluvial environments (http://www.pacificbio.org/ESIN/OtherInvertebrates/CaliforniaFloater/CaliforniaFloater_pg.html). *Anodonta* shells were mainly found in muddy sand or sand layers by digging pits or cleaning off exposures. Shells were submitted to John McGeehin at the U.S. Geological Survey for AMS radiocarbon dating (Table 1).

Previous Work

Coyote Basin was first studied as a part of Pleistocene Lake Manix. Studies in the area include many aspects of geology, including paleontology, geomorphology, and tectonics. Investigations aimed to decipher the paleoclimatic history of the Mojave Desert in addition to the region's active tectonic and geologic record. Buwalda (1914) first described lacustrine and deltaic sediments in the Afton basin and named the Lake Manix basin. Thompson (1929) conducted a reconnaissance study of the Mojave River valley. Soon thereafter, Lake Manix became the focus of two other studies by Ellsworth (1933), and Blackwelder and Ellsworth (1936). Ellsworth demonstrated that there were at least three major lake highstands in the basin and provided evidence that Afton Canyon was cut in the late Pleistocene. It was not until 1966 that a detailed study of the Coyote Basin was conducted. Hagar (1966) studied the geomorphology of the basin, which included classification of the surface morphology and the marginal zones of the playa, the fluvial plain south of the playa, and the alluvial fans that surround the playa. Hagar also conducted a subsurface reconnaissance study in the basin. Jefferson (1965, 1985, 2001, and 2003) investigated the paleontology and stratigraphy of the Manix basin. Meek began studying the Afton and Coyote Basins in the 1980's (Meek, 1987, 1989a and b, 1990, 1994, 1999, and 2000). Meek focused on the geochronology of lake highstands and the geomorphology of Manix basin. Based on radiocarbon ages of shoreline deposits and relations downstream, Meek (1989a) concluded that Afton Canyon was incised at about 18,000 ^{14}C yr B.P. Meek (1989a) also concluded that Afton Canyon failed catastrophically based on the lack of recessional shorelines and terraces within Afton Canyon, and the presence of deeply incised tributary channels into the canyon. Meek (1999) also suggested that the Mojave River episodically drained into Coyote Lake between 17,000 and 11,000 ^{14}C yr B.P. based on shoreline data and *Anodonta* shell radiocarbon dating.

Mojave Desert regional tectonics has been studied since the recognition that strike-slip faults accommodate North American-Pacific plate motion not accounted for by motion on the San Andreas fault (Atwater, 1970; Dokka and Travis, 1990b). Studies in the region include Schermer et al. (1996) who conducted a study of late Cenozoic structures and tectonics in the northern Mojave, an area dominated by northwest-striking faults, with emphasis on the northern of two east-striking fault domains, which contains Coyote Basin (Figure 2). Investigations dealing with active tectonics near the map area include Nagy and Murray (1996), Miller and Yount (2002), Dudash (2004), and Miller et al. (2005). Other work on Quaternary faults within the Coyote Basin (Figure 3) includes Meek (1994), who first noted that the Southwest Coyote Basin fault cuts Pleistocene alluvial sediments; Dibblee and Bassett (1966) who observed that the Lake Dolores fault on the west side of Agate Hill had right-lateral offset; and Hamilton (1976) who examined the area near the Dolores Lake fault with gravity measurements. The Manix fault is a major east-striking fault that last ruptured in 1947 during a magnitude 6.2 earthquake centered on Buwalda Ridge (Richter and Norquist, 1951). Field evidence suggests that the fault is left-lateral with approximately 5.2 km of separation; displacement caused by the 1947 earthquake was only a few centimeters. Doser (1990), Meek and Battles (1991), and Nagy and Murray (1996) have more recently studied the Manix fault.

Physiography

Coyote Lake playa lies in an internally drained basin bounded by mountains that include the Calico Mountains to the southwest, Lane Mountain to the west, the Paradise Range to the northwest, Noble Dome to the north, and Alvord Mountain to the east (Figure 3). To the south and southeast of Coyote Lake lies a broad plain that is incised by the east-flowing Mojave River. Alluvial fans from all mountains grade down into the basin (Figure 3).

The area covered by the Coyote Lake, Yermo, Alvord Mountain and Harvard Hill 7.5 minute quadrangles lie at the boundary between the northwest- and east-striking fault domains (Figure 2). Faults located in the northwest-striking fault domain tend to dip steeply to the southwest or northeast. Many mountain fronts in the Mojave Desert are aligned along these faults; the faults may control topography (Miller and Yount, 2002). However, within the Fort Irwin area, northwest-striking faults show little dip-slip component and have a modest influence on topography. Faults in the east-striking fault domain dip south, tend to display a reverse component, and they lie at topographic steps (Miller and Yount, 2002). Major east-striking faults in the region are the Coyote Lake and Manix faults; major northwest-striking faults include the Calico fault and Paradise fault zone (Miller et al., 2005) (Figure 3). Tectonic domain boundaries are complicated and normal faults, thrust faults, and folds may accommodate strain.

Landforms within the map area include the Calico Mountains in the southwest, with Calico Peak at an elevation of 1384 m, flanking piedmonts leading to Coyote Lake, and the Coyote Lake fluvial plain. Alluvial fans originating from the Calico Mountains display two styles of piedmonts separated by low hills composed of Mesozoic plutonic rocks (Figure 3) (UTM: 519319, 3875370; all UTM coordinates given in NAD 83 and are for field reference, they are not intended for locating the sites on the map). North of the low hills, alluvial fans are long (as much as 6 km in length) and slope gently, whereas to the south, the fans are short (as much as 2.5 km in length) and steeper. East of the Calico Mountain piedmont lies Coyote Lake and its associated fluvial plain, which occupy approximately half of the map area. The fluvial plain south of the playa has a gentle gradient northward to the playa and displays subtle topography. Abundant groundwater has afforded the opportunity for agriculture and homesteads. Coyote Wash, sourced from the Calico

Mountains, lies at the boundary between the eastern Calico piedmont and the fluvial plain and drains north to Coyote Lake (Figure 3). Two large constructional beaches lie south of the playa. To the southeast lies the largest beach, which Hagar (1966) called the bay bar, it may be late Pleistocene in age. The second beach lies 1.5 km south and west of the playa and represents construction during lower lake stands of the latest Pleistocene at ~13 ka ^{14}C yr B.P. Lake regression has possibly modified the sand beach (see geologic map).

Climate and Biology

Coyote Basin is roughly at the boundary between two precipitation regimes at the 117 º meridian, near Barstow, CA (Figure 2) (Hereford, et al., 2004). West of the 117º meridian, precipitation occurs mainly in the winter, whereas east of the meridian, a biseasonal pattern occurs with precipitation falling in the winter and in late summer (Hereford, et al., 2004). Coyote Basin, as extrapolated from the Daggett weather station (Figure 1) shows a biseasonal pattern of precipitation (Figure 4). Average annual precipitation ranges from 34 to 310 mm/yr (recorded from 1945-1996). Temperatures fluctuate greatly from season to season; a maximum annual temperature of 105ºF occurs in August while a minimum annual temperature of 30 º F occurs in December and January (recorded from 1948-1996) (Hereford and Longpré, 1998).

The map area is rich in both flora and fauna. The area is shrub-dominated although cover varies with age and type of deposit throughout the map area on almost all types and ages of deposits. Creosote bush (*Larrea tridentata*) is the dominant shrub. Holocene alluvial deposits support creosote bush and white bursage (*Ambrosia dumosa*), less common Mormon tea (*Ephedra* sp.) and several members of the cactus family such as beavertail (*Opuntia basilaris*), cholla (*Opuntia* sp.) and cotton top (*Echinocactus polycephalus*). Annual grasses and forbs are abundant in the spring. Typically, in the Mojave Desert Pleistocene deposits are more poorly vegetated, but in the map area, the surfaces of these deposits are generally disturbed by bioturbation and lack well-developed pavements, which allows a variety of vegetation to grow. Hence, creosote bush and cacti are common on Pleistocene deposits, although in lower density than on the Holocene deposits. Vegetation on hillslopes typically includes creosote bush, ambrosia, and annual grasses. Vegetation on Coyote Lake is sparse, but saltbush (*Atriplex* sp.) is found throughout the playa. Directly south of Coyote Lake, creosote bush, Mormon tea, and saltbush dominate the surfaces, whereas white bursage is uncommon. Approximately 1 km south of the playa, saltbush and Mormon tea become less common. Also found south of the playa is the desert lily (*Hesperocallis undulate)* that produces a beautiful cream-colored flower when in bloom. Biologic soil crusts, such as lichen and cyanobacteria that stabilize soil and fix nitrogen and carbon (Belnap et al., 2001) are common south of the playa on the fluvial plain and are uncommon on all other alluvial surfaces.

In addition to many of the common reptiles that live in the Mojave Desert, desert tortoise, horned lizards and the common king snake are plentiful. Birds include ravens, owls, roadrunners, and many other common birds. Mammals include cottontail rabbit, jack rabbit, bobcat, kit fox, coyote, and various rodents.

Geologic Setting

The map area lies in the Mojave block, which is bounded by the San Andreas and Garlock faults (Garfunkle, 1974). Mojave Desert basement rocks are widely distributed and comprise ca. 1.7 Ga and ca. 1.4 Ga Precambrian metamorphic and igneous rocks (Anderson et al., 1993). The

Precambrian rocks are overlain by an Upper Precambrian-Lower Permian miogeoclinal-cratonal section (Walker et al., 2002). Eugeoclinal rocks of Paleozoic age are found in the northern Mojave, but are not exposed in the southern Mojave. The eugeoclinal strata are overlain by Late Permian volcanic rocks (Walker et al., 2002). Permian-Triassic plutonic rocks intrude both the miogeoclinal and eugeoclinal sections (Miller and Sutter, 1982; Carr et al., 1984; Miller et al., 1995). Mesozoic rocks consist of Jurassic volcanic rocks, Cretaceous plutons, and marine sedimentary rocks (Walker et al., 2002). During the early Miocene, volcanism was voluminous and persisted intermittently through the Quaternary. Volcanic rocks are primarily basalt and andesite lava flows, and rhyolite tuff and lava (Walker et al., 2002). By the late Cenozoic, large lake basins existed, evidenced by the 1000 m thick ~16 Ma Barstow Formation composed of fluviatile and lacustrine sediments and water-laid air-fall tuff (Woodburn et al., 1990). Pluvial lakes formed during glacial cycles of the late Quaternary in the Mojave, and desiccated during more arid interglacial periods. In the Manix Basin, at least six transgressive/regressive lacustrine depositional events over the past ca. 500 ka are recorded in the Manix Formation (Jefferson, 1985).

The current tectonic regime was established approximately 11-7 m.y. ago and influences the modern topography. The Mojave block is a region of largely strike-slip faults, known as the Eastern California shear zone (Dokka and Travis, 1990a, b) that extends across the Mojave Desert and northward to Owens Valley. Active faults in this region accommodate strain east the San Andreas fault (Atwater, 1970). Studies of earthquake focal mechanisms by Hardebeck and Hauksson (1999) determined that the maximum principal stress in the Eastern California shear zone is oriented ~N20°E. Sauber et al. (1986) have used geodetic data to determine that there is 8-10 mm of dextral shear across the province annually. Strain in the region is manifested as strike-slip faults, normal faults, thrust faults, and folds (Miller and Yount, 2002). The central Mojave Desert geomorphology is to some extent controlled by fault orientation. Many mountain ranges trend either northwest or east; basin fill is generally thin reflecting an overall youthful landscape (Jachens et al., 2002).

Jachens et al., (2002) used magnetic and gravity geophysical data within the Mojave Desert to identify magnetic anomalies, offset along strike-slip faults, and basin configurations. Jachens et al. (2002) concluded that northwest-striking faults in the western Eastern California shear zone have small offsets (≤ 5 km) compared to offsets of 12-20 km in the eastern Eastern California shear zone. Either northwest-striking faults in the eastern Eastern California shear zone may be older and thus more evolved than those in the west, or there maybe an asymmetrical spatial distribution of slip within the Eastern California shear zone. Displacements on east-striking faults range from zero on the Coyote Lake fault (Jachens et al., 2002) to more than 6 km on the Bicycle Lake fault, but generally are less than 5 km (Schermer et al., 1996). Gravity data have revealed that many of the basins in the Eastern California shear zone are shallow, in contrast to models that predict deep basins.

Surficial Deposits

Surficial deposits in the map area are diverse and part of the classic elements of desert landscapes: flat-floored valley bottoms occupied by a dry lake or playa, which are fed by drainages that stem from mountain ranges and flow onto and through alluvial fan piedmonts. The Coyote Basin floor is the locus for Lake Manix and Coyote Lake lacustrine deposits. The hills and mountains surrounding the basin include areas representing ephemeral erosion and deposition such as piedmonts and hill-slope colluvial deposits. Both the basin floor and the Alvord Mountain piedmont contain eolian deposits derived from erosion of Coyote Lake sediments.

Mapped surficial deposits are classified by depositional or erosional processes, whereas soil development, geomorphic relationships, and surface characteristics are used to define the relative age classifications. Relative age criteria in desert environments are largely based on the work of Bull (1991). In addition, Yount et al. (1994) have developed relative age criteria for surficial deposits in Fort Irwin, near the map area. The criteria, based on the work of Ritter (1987), McFadden et al. (1989), and Reheis et al. (1989), include microtopography development, degree and pattern of incision, degree of flatness or rounding of interfluves between channels, grain size of surface clasts, degree of soil development, degree of desert pavement development, and desert varnish development. Old (Qox), intermediate (Qix), and young (Qyx) are the terms used to classify the relative age of mapped surficial deposits. This simple evolutionary progression of relative ages is distinguishable in the field and from remote sensing techniques in the absence of tectonic or base-level changes. Subdivisions within the three main age classifications are based on degree of soil development, desert pavement development, inset relations, amount of degradation of original landform or burial of surfaces (Figure 5) (Dave Miller, U.S. Geological Survey, written commun., 2004); such subdivisions generally require field observations. Factors affecting pedogenesis of surficial deposits such as lithology, bioturbation, climate or tectonics complicate the estimate of ages of some deposits. For example, one of the differences between the subdivisions Qya4 and Qya3 (Quaternary young alluvium) is the amount of flattening or smoothing of meso- to microtopography. Qya4 surfaces typically show less relief compared to Qya3. However, the weathering characteristics of some of the volcanic units in the map area combined with the breakdown of plutonic rocks to grus (see description of map units) create surficial deposits that have very little microtopography, regardless of deposit age. In addition, precipitation infiltration into these deposits is excellent due to the equant grain size, hence, soil morphologic differences may be subtle. Therefore, the differences between Qya3 and Qya4 are not always easily recognized, which can create ambiguity when interpreting the relative age of these surficial deposits. In addition, young deposits may overlie older deposits with eroded surfaces (Figure 6) creating misleading microtopography. Where the relative age of the alluvial fan deposits is uncertain, the unit is mapped as Qya3+Qya4 or Qya4+Qya3, with the most abundant deposit listed first.

In the past, numeric ages for Quaternary surficial deposits and processes were difficult to obtain. With the advancement of techniques for radiocarbon and cosmogenic dating, thermoluminescence, optically stimulated luminescence (OSL), and other methods of dating surficial materials, numeric ages have become more available. In the eastern Mojave, studies in the Providence Mountains, Soda Mountains, and Silver Lake have yielded numeric ages for groups of soil units or soil chronosequences (Wells et al., 1985; Reheis et al., 1989; McDonald, 1994; Yount et al., 1994). Age control for older Quaternary deposits (Qox) comes mainly from the diagnostic ~758 ka Bishop Ash (Sarna-Wojcicki et al., 2000) found rarely in this deposit. Many surfaces within the Mojave Desert, in general, that have desert pavements have been dated as middle to late Pleistocene in age (Bull, 1991; McDonald et al., 1995). Direct dating methods suggest that two pulses of aggradation occurred between about 22,000 and 130,000 yrs B.P. (McDonald, 1994). These two pulses may roughly correlate with intermediate age units of intermediate subdivisions one and two, respectively (e.g. Qia1 and Qia2).

There are four subdivisions of the young (Qyx) deposits. Eolian sand lenses within an alluvial deposit with Qya4 surface characteristics in the Providence Mountains yielded an infrared-stimulated luminescence (IRSL) age of ~10 ka and groundwater deposits that are overlapped by Qya4 deposits in Kelso Wash yielded an OSL age of ~13 ka (McDonald, 1994; McDonald et al., 2003). Quaternary young alluvium (Qya3) deposits in the Providence Mountains yielded ages from 4 to 5.5 ka (McDonald, 1994), and in the Silver Lake area ages range from 3 to 6 ka (Wells et al., 1990). There are no numeric ages on Qyx2 or Qyx1 deposits; however, the general interpretations that Qyx2 surfaces are still active on centennial scales and Qyx1 deposits are presently active are accepted.

There are no described soil chronosequences in the immediate map area, but the geomorphic surface and soil properties in the study are similar to those of authors working in the eastern Mojave Desert and in Fort Irwin. West of Coyote Wash, deposits with characteristics of Qya4 units overlie a lacustrine deposit. Radiocarbon dating on *Anodonta* shells collected in the lacustrine deposit yielded an age of 13,145±45 ^{14}C yr B.P. (Table 1, sample M03SM-1686) (UTM: 522298, 3875015).

Landscape History

Quaternary Faulting and Tectonic Geomorphology

Results from this study and ongoing surficial geologic mapping elsewhere in the Mojave Desert have increased our knowledge of Cenozoic faults and improved our conceptual models for the kinematics for the region. Mapping in the Calico piedmont has identified the north-striking Tin Can Alley fault (Dudash, 2004), which connects to the previously mapped Southwest Coyote Basin fault (Meek, 1994) (Figure 3). These two faults in combination with faults to the north comprise the Paradise fault zone, which extends to the Goldstone Lake area (Figure 1) where Holocene slip on the fault has been observed (Miller et al., 2005). Other north-striking faults mapped by Miller and Yount (2002), and in ongoing USGS studies within the Mojave Desert, generally lie at domain boundaries and cut middle to late Pleistocene deposits.

Southwest Coyote Basin fault

The Southwest Coyote Basin fault lies ~2 km southwest of Coyote Lake (Figure 3). Meek (1994) first reported this fault, although McCulloh (1960) and Hagar (1966) show truncated alluvial fan deposits in their mapping. The observed fault length is 2 km and the projected length is at least 4 km. The southern portion of the exposed fault trace strikes ~330˚; midway it strikes 340˚ (Table 2). Fractures in pedogenic carbonate have similar orientations. Evidence for faulting includes: 1) displaced Pleistocene alluvial deposits and Mesozoic plutonic rocks, 2) numerous fractures, and 3) linearly truncated alluvial deposits along rounded fault scarps (Figure 7). In places, a degraded ~ 2 m high scarp marks the Southwest Coyote Basin fault. Scarps in Pleistocene alluvial fan deposits and Mesozoic plutonic rocks represent the northwestern half of the fault and indicate east side up. Slip-sense is ambiguous due to the nature of the material cut by the fault; however, the uplift on the northeast side of the fault may be a contractional feature caused by a left step in a dextral strike-slip fault. The youngest units offset by the Southwest Coyote Basin fault are middle Pleistocene (Qia3) deposits, and the oldest units not cut are early Holocene to latest Pleistocene in age (Qya4). However, there is an alluvial deposit remnant of possible late Pleistocene age that may be cut by the fault (UTM: 517146, 3879289). The surface is not obviously offset or truncated by the fault, but the surface pavement is somewhat disaggregated along the trace of the fault.

The middle Pleistocene alluvial deposits overlie plutonic bedrock. Near the southern exposure of the fault trace, the plutonic bedrock is exposed at the surface and overlain by a thin veneer of alluvium. Elsewhere, bedrock is exposed underneath the alluvium in cut banks. Adjacent Mesozoic plutonic rocks are highly weathered and may represent an underlying pediment. Holocene alluvium buries the fault to the north, which makes tracing the fault difficult. Gravity and magnetic measurements taken across the fault revealed no consistent signature of a buried fault that could be followed to the northwest. These findings are not surprising if the subsurface is composed of older alluvium or a pediment; offset in these substrates would be difficult to detect. To the south, Holocene alluvium buries the fault, but remnants of truncated Pleistocene fans observed from aerial photographs and DOQQs are suggestive of a fault trace (Figure 8). Ground observations in the area include displaced Pleistocene alluvium and soil carbonate exposed laterally along the fault trace.

The Southwest Coyote Basin fault includes at least three fault strands; the main strand described above, and parallel strands on the east and west side of the Southwest Coyote Basin fault. The eastern strand is best exposed for ~0.5 km in the Mesozoic plutonic rocks. The scarp is ~2 m high and groundwater deposits are voluminous along the strand. About 0.5 km upfan to the southwest of the Southwest Coyote Basin fault, Pleistocene alluvial deposits appear truncated and there is a slight warp in the fan interpreted as a possible fold or blind fault. The trace of this feature aligns with a fault to the southeast (Bonham and Danehy, 1959) that cuts Mesozoic plutonic rocks (UTM: 518845, 3875625).

Spring mound deposits (Qigsm) are located along the trace of the Southwest Coyote Basin fault. The largest mound is at the bend in the middle of the fault; preliminary sample results of the deposit revealed an ostracode assemblage (Richard Forester, U.S. Geological Survey, written commun., 2005) (Figure 9) (UTM: 517378, 3878711). Additionally, preliminary results of U-series dating of silica from the fault plane within the spring mound yields an age of 350 ka (Kate Maher, U.S. Geological Survey, written commun., 2005).

It appears that groundwater from the spring mounds has contributed to the pedogenic carbonate horizon in soils formed on the middle Pleistocene surfaces. In cut banks, thick horizontal beds of layered and cemented carbonate are exposed as deep as2 m; unlike a normal petrocalcic stage IV horizon where the laminar carbonate horizon forms on top of a generally decreasing-downward accumulation of calcium carbonate (Marith Reheis, U.S. Geological Survey, written commun., 2005). Carbonate within the horizontal layers appears nodular and irregularly shaped similar to groundwater carbonate concretions. Additionally, vertical fractures are filled with carbonate.

Tin Can Alley fault

South of the Southwest Coyote Basin fault lies the north-striking Tin Can Alley fault, which separates the Calico Mountains from a swath of Mesozoic plutonic hills (Figure 3 and 10). The fault extends for 9 km and projects to >11 km, from an outcrop of faulted Mesozoic plutonic rocks (McCulloh, 1960) in the middle of the map area (UTM: 519032, 3876233) to south of the map area where it is inferred to intersect the Manix and Calico Faults. Along the Tin Can Alley fault, fractures in soil carbonate strike 349° with near vertical dips. Outside of the map area, the fault apparently cuts volcanic rocks of the Calico Mountains with an orientation of 349°, 56° northeast. Farther south, a fault plane strikes 320° and dips 70° northeast and slicken-lines indicate oblique dip-slip. Evidence for the Tin Can Alley fault includes high, dissected middle Pleistocene and Pliocene-Pleistocene alluvium and faulted volcanic rocks in the southern Calico Mountains. All features are co-linear. Rounded scarps are usually no higher than 1 m in the middle Pleistocene alluvium. Slip-sense or amount of slip is not obvious for the Tin Can Alley fault, but extensional right- steps and contractional left-steps suggest dextral motion along the fault. The youngest units displaced by the Tin Can Alley fault are middle Pleistocene (Qia3) deposits, whereas the oldest units not cut are late Pleistocene (Qia2) deposits. The Tin Can Alley fault is a complex set of two north-striking faults that run the length of the piedmont. Along the length of the fault, the topographically high side changes across the fault, suggesting strike-slip behavior. At the midway point of the fault, the two strands of the Tin Can Alley fault form a graben where young alluvium has been deposited and is inset against the fault scarp.

An intersecting (UTM: 5519769, 3870485) northwest-striking fault (Figure 10a) may be part of the Tin Can Alley fault system. The fault may extend for 3 km to displace Pliocene-Pleistocene gravels overlying the Barstow Formation, or extend as much as 7 km to intersect the Manix fault. Evidence for the northwest-striking strand includes faulted Mesozoic plutonic rocks and Pliocene-Pleistocene gravels, and linear valleys aligned with the trace of the fault. The fault plane orientation in the Mesozoic plutonic rocks is 306°, 50° northeast.

It is not clear if the northwest-striking segment is kinematically related to the Tin Can Alley fault. If it is, one would suspect dextral motion on the fault if it behaved as a splay of the Tin Can Alley fault or as an escape feature. As of yet, there are no clear observations to indicate whether the segment is related.

Features of the Southwest Coyote Basin fault that align with the Tin Can Alley fault at a faulted promontory of Mesozoic plutonic rocks near the center of the map (UTM: 519030, 3876263) indicate that the Southwest Coyote Basin fault and the Tin Can Alley fault may be a complex set of faults ~15 km in length. Additionally, the Southwest Coyote Basin fault trace aligns with the Paradise fault in the Paradise Mountains (Figure 3). These faults, in combination with faults to the north, represent the Paradise fault zone (Miller et al., 2005). The Paradise fault zone is a complex set of dextral faults that interact with the Manix fault to the south and includes the West Goldstone Lake fault to the north. Faulted early Holocene deposits lie just north the Paradise Range. The Paradise fault zone bounds east-striking and northwest-striking fault domains and may be an important feature because it may accommodate significant inter-plate strain in the Mojave Desert.

Dolores Lake fault

The Dolores Lake fault, first recognized by Dibblee and Bassett (1966) is a northwest-striking fault found on the fluvial plain, south of Coyote Lake (Figure 11). Dibblee and Bassett (1966) mapped the fault extending for 1.5 km, adjacent to Agate Hill (UTM: 5268779, 3872451), cutting the Pliocene-Pleistocene gravels. However, Meek (1994) documented uplifted Mojave River gravels that are apparently earliest Holocene or latest Pleistocene south of Agate Hill. Uplifted gravels are found along the trace of the fault for about 9 km from Agate Hill southeast to Harvard Hill.

Coyote Lake/Playa History

The Mojave Desert contains numerous playas, which in most cases represent internally drained valley bottoms. Coyote Lake typically is a dry, relatively vegetation-free playa in the center of Coyote Basin. The playa is prone to flooding and receives stream flow from Coyote Wash and other tributaries from the bounding alluvial fans. Abundant rain in the winter and spring of 2005 filled the valley floor through April 2005 (Figure 12).

The formation of Coyote Basin probably began during the latest Pliocene to early Pleistocene when tectonic activity caused subsidence of the basin and uplift of Alvord Mountain

(Miller and Yount, 2002). The Manix basin apparently formed at the same time and has been extant since at least ~2.5 Ma (Nagy and Murray, 1996). The Coyote Basin was separated from the Manix Basin by a threshold that is of uncertain altitude, but probably only a few meters below the level of full Lake Manix (543 m).

The filling of Lakes Manix and Coyote by the ancestral Mojave River are a consequence of past pluvial climates and tectonic activity along the San Andreas fault system. The Mojave River began its northward journey to the Mojave Desert in response to tectonic uplift of the central Transverse Ranges via the San Gabriel and San Andreas fault systems. Pre-existing geomorphology of the Mojave Desert and contemporaneous tectonism influenced the river's development. The northward flow of the ancestral Mojave River between 3.8 and 2.5 Ma was initiated in a drainage reversal caused by uplift of the Transverse Ranges (Cox et al., 2003). By 475-575 ka, the ancestral Mojave River had probably advanced to Harper Lake west of Barstow and then to the Lake Manix Basin, both of which held perennial lakes during high fluvial discharge (pluvial) intervals. Eventually, by 60-70 ka the upper Mojave River basin acquired its modern configuration and deposited voluminous sediment into Lake Manix and its delta east of Barstow (Cox et al., 2003). Eventually, Lake Manix overflowed and became integrated with downstream basins of Soda Lake and Silver Lake. According to Meek (1999), the integration was achieved by the incision of Afton Canyon at ~18 ka ^{14}Cyr B.P., which triggered upstream incision of the Manix basin and separation of Coyote Basin from the Manix Basin. Preliminary data from this study suggest that this separation had occurred about by 19.6 ka ^{14}Cyr B.P. (Table 1). We conclude that either incision of Afton Canyon occurred before 19.6 ka ^{14}Cyr B.P. or Lake Manix was not at a highstand when incision occurred.

During the middle to late Pleistocene, Coyote Lake was the northern arm of Lake Manix and after the cutting of Afton Canyon was at times a terminus for the Mojave River. Coyote Lake may have persisted until entrenchment of the modern Mojave River prevented inflow into Coyote Basin at approximately 11 ka ^{14}Cyr B.P. (Meek, 1994).

Meek (1994) found direct evidence for Mojave River discharge into the Coyote Basin during a study of trenches excavated for a construction project. Meek found abundant *Anodonta* shells in beach sands overlain by Mojave River deltaic sediments. Radiocarbon analysis of the *Anodonta* yielded an age of 17,590 ±1500 ^{14}Cyr B.P. *Anodonta* shells found in other sediments yielded ages of 13,110±290 and 15,125±230 ^{14}Cyr B.P. interpreted as representing Mojave River inflow into the Coyote Basin (Meek, 1994). In Coyote Wash, *Anodonta* shells buried by Mojave River deltaic sediments yielded an age of 12,450±340 ^{14}Cyr B.P. Preliminary analysis of *Anodonta* shells collected throughout the fluvial plain from this study (Table 1) supports Meek's (1994) conclusion that the Mojave River flowed periodically into the Coyote Basin during the latest Pleistocene.

Notes on Map Units

Surficial deposits in the study area represent a diverse spectrum of geologic and surficial processes. The deposits are briefly described in the unit descriptions, and the following discussion focuses on deposits that are unusual or unique to the study area.

Drainages that carry a combination of certain types of volcanic rocks from the Calico Mountains and Mesozoic plutonic rocks in the Calico foothills deposit a special type of alluvial fan deposit (Qyasg, semi-grussy). This unit is mapped separately from the rocky alluvial fan (Qya) deposit and grussy alluvial fan (Qyag) deposit (Figure 13). Rocky alluvial fan deposits are poorly sorted and typically consist of sand and gravel with well to moderately developed bar and swale microtopography. The coarsest clasts may include boulders the size of small vehicles. Alluvial fan deposits composed of weathered Mesozoic plutonic rocks (Qyag) produce surfaces with very little microtopography or incision. The clasts are commonly no larger than pebbles. Alluvial deposits that are termed semi-grussy (Qyasg) have characteristics similar to both rocky and grussy fans. Although the deposits can contain boulder size clasts, relief is subtle on the deposits and differs little among the age subdivisions. Grain-by-grain disintegration of the plutonic rocks and a similar equant breakdown of several types of volcanic rocks evidently produce the subtle relief. Clast size plays a large role in the hydrology, cohesive strength of the deposit, and possibly surface stabilization and depth of soil formation. Because the semi-grussy deposits have characteristics of both rock- and grus- dominated fans, they form unique alluvial fan environments that may be important in studies for land use, weathering, soils, and ecology.

Another unusual deposit within the study area is latest Pleistocene Mojave River channels (Qyw4-r) that form positive relief features that suggest topographic inversion has occurred (Figure 14). The channels originate from the Mojave River fluvial plain extend to the north and northwest towards Coyote Lake. Hagar (1966) first recognized the northward trending features as fluvial channels. These deposits are found in the southeast section of the map area and because of the subtle relief of the fluvial plain, are best recognized using remote sensing techniques. On aerial photographs, branching and sinuous distributary channel forms are distinct.   They appear darker than the surrounding plain due to a veneer of coarse gravel with light desert varnish.

There are two main channel systems; western and eastern (Figure 14). The western channel morphology suggests a fluvial origin. The western channel starts just west and south of Agate Hill (UTM: 525746, 3871002) and ends in a distributary pattern branching into a ~13 ka arcuate barrier beach at an altitude of ~541 m. Coyote Wash has incised some of the distributary branches. The eastern channel also begins west of Agate Hill (UTM: 526196, 3872019), but its channel form is less distinct than the western channel. The eastern channel appears to end at the 543 m highstand elevation, suggesting that it may have flowed into a full Lake Manix.

Hagar (1966) confirmed the fluviatile origin of the features by digging a lateral trench partially across one of the deposits. The trench revealed typical channel-fill deposits of coarse sand and gravel near the center of the ridge and the deposits increased in depth toward the center. Grain size decreased laterally and the gravel interfingered with sandy silt near the margins of the channels. Similar observations were made in this study by digging a series of pits and trenches across part of one of the channel deposits. The lateral decrease in grain size combined with the equant subrounded gravel lag only on the surface, and the channel form is suggestive of a fluvial origin for the deposits.

Hagar (1966) also interpreted the subsurface sediments at the channel terminations and in the area between the playa and arcuate beach barrier to represent fluvial deposits interfingering with lacustrine clays. There, he found foreset beds indicative of a delta deposited by northward flowing streams into a lake. Gravel decreases toward the playa, sand and gravel thin, and silt and clay increase.

Between the topographically high channel forms are linear low areas and a few enclosed basins or depressions; some appear to grade toward Coyote Wash and others appear to be closed basins. Along the edges or at the bottom of the closed basins lie intercalated and rippled sand, muddy sand and mud capped by alluvial coarse-grained sand and gravel. The largest basin (Figure 14) contains fragments of *Anodonta* shells and sediments that suggest deposition in a marsh or fluvial mud flat environment such as groundwater carbonate mottles, mud lenses, and bioturbation. In the open basins, the fine-grained sediments are not apparent. It is highly likely that in the areas where fine-grained sediment was not armored by coarse sand and gravel, fluvial and eolian processes have eroded the fine sediment.

Are these topographically high channel deposits original constructional features or are they formed from deflation of the surrounding surface? Relict channels can form topographic highs in three ways: 1) deflation or erosion of surrounding surface, leaving channel deposits differentially exposed (Maizels, 1990); 2) construction as a positive feature, deposited in a low gradient aggrading system (Lang et al., 2001) or 3) a combination of the above.

Several observations suggest that the channel forms are not original and they have formed from deflation of the surrounding surface and there are also indications that these surfaces are original constructional features. In many locations throughout the fluvial plain, there are mounds of soft fine-grained sediment armored by coarse sand and gravel (Figure 15). Outcrops such as these lie within the depressions and at the surface of the fluvial plain. The coarse sediment had apparently armored parts of the fine-grained sediment from erosion. However, northern distributions of the western inverted channel appear to lie stratigraphically beneath an arcuate barrier beach. It appears that as the western channels flowed into a lake, lake currents distributed the fluvial sediments along the shore to create the barrier. If the channels provided the barrier sediment, the relation between the channels and the barrier beach is most simply interpreted as resulting from constructional channels feeding the lake edge. It is possible that the channels are constructional features and that the deflation of the surrounding surface has accentuated the amount of relief on the fluvial plain.

Composite symbols

Surficial geologic deposits commonly exist as thin (<2 m) veneers over older units. Where this relation is common, the unit designators are shown separated by a slash (/). Indicated first is the younger or overlying deposit. Qya/Qoa, for example, indicates an area where a veneer of young alluvial fan deposits overlies old alluvial fan deposits and Qya/Mzp indicates an area where a veneer of young alluvial fan deposits overlies Mesozoic plutonic rocks.

The lateral extent of individual deposits is commonly so small that each deposit cannot be shown individually at the map scale. Such areas are indicated by deposits (representing more than 20% of the area) separated by a plus sign (+), with the most common deposit listed first. Thus, Qya + Qia indicates an area with both Qya and Qia deposits and that Qya is more common than Qia; other deposits in the area comprise less than 20%.

Surficial Deposits

Man Made Deposits

dl **Disturbed land (Recent)** – Material moved for construction purposes and agricultural disturbances sufficiently extensive to make landforms and deposits difficult to identify.

Wash Deposits

Qyw **Young wash deposits, undifferentiated (Holocene to latest Pleistocene)** – Alluvial wash deposits characterized by surfaces and channels that received sediments from the present through the latest Pleistocene. Although wash deposits are similar to alluvial fan deposits, they are mapped separately because they typically have longer flow distances relative to alluvial fans, they are generally confined to channels, and they may integrate more sediment sources. In the study area, wash deposits are mapped only along Coyote Wash, which is about 15.5 km long and drains from the southeast Calico Mountains into Coyote Lake. The upper and lower sections of Coyote Wash behave differently. The upper section of Coyote Wash is a large braided drainage that flows to the northeast. Midway (UTM: 523265, 3873268) it changes direction and becomes a confined channel system incised into lacustrine sediments. In the braided system, clasts are moderately to poorly sorted and moderately bedded. Clasts comprise volcanic rocks derived from the Calico Mountains and siliceous and calcareous sediments from the Barstow Formation. Grains are generally subangular to subrounded. Biologic crusts are rare. The large integrated drainages in the braided section are prone to flooding during heavy rain. The lower section of the wash is confined to a channel incised into lacustrine sediments, which erode to create gentle slopes along wash edges. The surface of the wash has a veneer of moderately sorted and moderately rounded clasts. Clasts within the wash are composed of Mojave River gravels and Calico Mountain clasts. Typically, Mojave River gravels are moderately rounded and sorted and are composed primarily of granitic grus with minor volcanic and metasedimentary rocks. Unit Qyw is mapped in the lower part of the upper braided system where subunits were too small to map separately, and in the lower section where low relief hampered differentiation of subunits. Elsewhere, subdivided into four units:

Qyw1 **Young wash deposits, unit 1 (latest Holocene)** – Active wash deposits in channels receiving sediments on decadal time scales. Sand and gravel occupies major ephemeral stream channels and sediments are loose. Lacks soil development. Surface is prone to flooding during heavy rain. Vegetation is absent to sparse.

Qyw2 **Young wash deposits, unit 2 (late Holocene)** – Semi-active wash deposits in channels receiving sediments on centennial time scales. Sediments are loose to minimally indurated. Bar and swale topography is well developed. Soil development is very weak with a locally sandy Av horizon about ~0.5 cm thick. Surface is prone to flooding or receiving overbank deposits during heavy rain. Vegetation is commonly more dense than found on active channels or older wash surfaces and consists of creosote bush, white bursage, Mormon tea, desert holly (*Atriplex hymenelytra*), and burrobush (*Hymenoclea?).*

Qyw3 **Young wash deposits, unit 3 (late to middle Holocene)** – Surfaces are stable. Sediments are weakly indurated. Surfaces commonly have slightly subdued bar and swale topography. Soil consists of a weak to incipient 0.5 to 1 cm thick sandy Av horizon and a Bw horizon. Vegetation consists of annual grasses, creosote bush, white bursage, and desert senna (*Cassia armata).* Cactus species include cotton top (*Echinocactus polycephalus*) and several species of cholla (*Opuntia* sp.*).*

Qyw4 **Young wash deposits, unit 4 (early Holocene to latest Pleistocene)** – Surfaces are stable. Sediments are moderately indurated. Surfaces have subdued bar and swale topography. Weakly developed desert varnish on clasts is a distinctive characteristic for unit Qyw4. Soil development consists of a weak to incipient Av horizon, Bw or Bt horizons, and stage I carbonate development. Vegetation dominantly consists of creosote bush and white bursage.

Alluvial Fan Deposits, Rocky

Qya **Young alluvial fan deposits, undifferentiated (Holocene to latest Pleistocene)** – Alluvial fan deposits characterized by surfaces and channels that received sediments from the present through the latest Pleistocene. Alluvial fan deposits typically consist of sand and gravel. Clasts are moderately to poorly sorted and moderately bedded. Grains are generally subangular to subrounded. Bar deposits tend to be coarser grained than swale deposits. Deposits grade from active channels incised into older alluvial fan surfaces near the mountain fronts, to undulating depositional expanses where flow is not confined. Biologic crusts are rare on all surfaces. **Qyas,** alluvial deposits undifferentiated with a sandy matrix. Unit is found in the north central section of the map just below the Lake Manix highstand elevation of 543 m. Sand is thought to be derived from the lake's nearshore facies and reworked into the Holocene deposits.

Qya1 **Young alluvial fan deposits, unit 1 (latest Holocene)** – Active deposits in discrete channels receiving sediments on annual to decadal time scales. Unit Qya1 cover a small area. Sediments occupy ephemeral stream channels and are loose. Unit displays abundant bar and swale topography. Vertical cutbanks are found along channel margins near mountain fronts, and rounded transitions to older deposits toward toe of fans. During and following heavy rains, deposits are prone to channelized floods near the mountain fronts and shallow but possibly wide sheet floods away from the mountain fronts. Soil evidence of development, varnished clasts, and desert pavement are absent. Annual grasses are sparse and perennial vegetation is absent. **Qyas1**, similar deposit but with a sandier matrix derived from Lake Manix nearshore facies.

Qya2 **Young alluvial fan deposits, unit 2 (late Holocene)** – Semi-active deposits in channels receiving sediments on centennial time scales. Sediments are loose to minimally indurated. Bar and swale topography is well developed and a typical characteristic for the surface. Surfaces are prone to flooding and sheet flow during and after heavy rains. Minor soil development expressed as very incipient Av horizons and accumulations of very fine sand and silt in upper portions of the soil profile. Unit tends to be moderately to well vegetated with perennial shrubs such as creosote and white bursage. **Qyas2**, similar deposit characteristics as Qya2 but with a sandier matrix derived from Lake Manix nearshore facies.

Qya3 **Young alluvial fan deposits, unit 3 (late to middle Holocene)** – Deposits are channelized and abandoned by active flow systems. Surfaces are stable and sediments are weakly indurated. Surfaces commonly have slightly subdued bar and swale topography. Desert varnish is weak and desert pavement is absent. Alluvial deposits on the short and steep fans in the southern section of the study area have a bimodal size distribution of clasts. Bars are composed of poorly sorted boulders up to 1 m in diameter. Swales are composed of well sorted and moderately rounded grus from volcanic rocks as much as ~4 cm in diameter. Proximal fans have debris flow characteristics that include levees. Soil development includes 1 to 3 cm thick fine Av of loose sand and silt, a Bw horizon, and minor stage I carbonate development. Units are moderately vegetated with perennial shrubs such as creosote bush and white bursage. As mapped, unit includes small areas of younger alluvium (Qya1, Qya2) that are generally located in narrow channels cut into Qya3 deposits. Also includes irregular small patches of unit Qya4 with indistinct boundaries. In the northern section of the map area, grus derived from granite is generally present in all deposits. The presence of grus leads to an overall flattening of the surface and a soil that is less developed and deeper than would be expected. **Qyas3**, similar deposit as unit Qya3 but with a sandier matrix derived from Lake Manix nearshore facies.

Qya4 **Young alluvial fan deposits, unit 4 (early Holocene to latest Pleistocene)** – Surfaces are stable. Sediments are moderately indurated. Surfaces have subdued bar and swale topography with 1 to 5 m diameter patches of incipient desert pavement and varnish. Weakly developed desert varnish on clasts is a distinctive characteristic for unit Qya4. Soil development consists of 1 to 4 cm thick Av horizon, weak Bt horizon, and stage I to II carbonate horizon. Surfaces are moderately vegetated with creosote bush and white bursage. Mapped unit includes small areas of younger alluvium (Qya1, Qya2) that are generally located in narrow channels cut into unit Qya4 surfaces and irregular patches of unit Qya3 with indistinct boundaries. **Qyas4**, similar deposit as Qya4 but with a sandier matrix derived from Lake Manix nearshore facies. Deposits of this age emanating from Mesozoic plutonic rocks on the southwest side of the playa appear to grade to two separate base levels, suggesting at least two pulses of deposition. At about mid-fan, Qya4 deposits overlie older Pleistocene alluvial deposits. Farther down fan and inset into the above deposits is another set of Qya4 deposits. Both sets of Qya4 deposits display similar soils, surface characteristics and vegetation. Along the west and east margins of Coyote Lake are thin unit Qya4 deposits lying over lake muds. Clasts are subangular and are composed mainly of varnished volcanic rocks. Unit Qya4/Qilf commonly forms a dendritic pattern due to armoring of underlying muds by gravel deposited in former channels, between which thin alluvium and muds have been eroded.

Qia **Intermediate alluvial fan deposits, undifferentiated (late to middle Pleistocene)** – Alluvial fan deposits characterized by surfaces that have been abandoned for tens of thousands of years. Clasts are moderately to poorly sorted and moderately bedded. Grains are subangular and coarsen toward mountain fronts. Surfaces are generally slightly rounded at edges of incised channels. Moderate to well developed interlocking desert pavement with a moderate to strong varnish on clasts. Clast bottoms are moderately to well rubified. Pavement covers entire surface or occurs as patches. Patchy desert pavement may be due to either degradation of surface to partial burial by younger deposits. Unvarnished, thin ripple-like stripes of sand and fine gravel spaced approximately 2 m apart, roughly parallel to contour is typical; apparently formed by sheetwash on pavement (Wells and Dohrenwend, 1985) Surfaces either lie 1 to 2 meters above young alluvial fan surfaces (Qya) or are directly adjacent to younger surfaces suggesting aggradation of young deposits. Soil profile is characterized by well developed Av horizon as much as 8 cm thick, distinct argillic Bt horizons as much as 30 cm thick, and stage II to III carbonate horizons. Carbonate stringers and nodules occur within Btk horizons and color lightening is common. Sparse and stunted vegetation typically occurs along shoulders of incised channels or as isolated clumps on the surface. Vegetation consists of creosote bush and *Opuntia* sp.

Qia2 **Intermediate alluvial fan deposits, unit 2 (late Pleistocene)** – Alluvial fan deposits characterized by surfaces that have been abandoned for tens of thousands of years.

Pavement surfaces are compact and flat with well-varnished interlocking clasts and strong rubification on the bottom of clasts. Incision is generally about 1 m. Soil development consists of 2 to 8 cm thick platy Av horizon, an argillic Bt horizon, and with stage II to III carbonate development.

Qia3 **Intermediate alluvial fan deposits, unit 3 (middle Pleistocene)** – Alluvial fan deposits characterized by crowned surfaces that have been abandoned for hundreds of thousands of years. Deposits are generally 2 – 3 m thick, substantially incised and commonly overlie bedrock. Desert pavement is typically degraded, occasionally found as patches of moderately interlocking, poorly leveled pavement that exhibits moderate to strong desert varnish and rubification. Commonly, clasts on surface comprise disaggregated pieces of pedogenic carbonate brought to the surface via bioturbation. Av horizons are platy, and are commonly 4 cm thick, and very silty. Strong Bt and Btk horizons exist with stage III and IV carbonate development.

Qoa **Old alluvial fan deposits (middle to early Pleistocene)** – Alluvial fan deposits characterized by degraded remnants of deeply dissected surfaces. Deposit is compact to cemented. Commonly forms pale-colored ballenas several meters above active washes and other nearby surfaces in upper parts of alluvial fans near mountain fronts on Calico Mountains piedmont. Widespread presence of bedrock under deposits may suggest unit was deposited on an older pediment. In places, remnant varnished pavement clasts occur at the surface. Surface clasts commonly made up of disaggregated pieces of cemented pedogenic carbonate. Most of the upper soil horizons are stripped off by erosion but unit commonly shows weak soils superimposed on much older carbonate horizon. Rarely, very thin Bt horizons remain. Stage IV and greater carbonate horizons are 2 to 7 m thick. Surface is moderately vegetated with creosote bush and white bursage.

QTg **Gravel (early Pleistocene to Pliocene)** – Semi-consolidated gravel of primarily volcanic composition. Outcrops have strong desert varnish on clasts. Chips of cemented pedogenic carbonate litter the surface due to bioturbation. Deposits exhibit well developed dendritic drainage patterns in map view. Near-surface soil horizons have been stripped and replaced a silty Av, Bw, and stage IV carbonate horizons. Unit generally lacks original geomorphic surface. The large exposure in the southern study area overlies the Barstow Formation.

Alluvial Fan Deposits, Grussy

Qyag **Young alluvial fan deposits composed of grus, undifferentiated (Holocene to latest Pleistocene)** – Alluvial fan deposits primarily composed of clasts from Mesozoic plutonic sources that weather to grus. Surfaces are undulating with smooth microtopography and little channel incision. Inset surface relations are subdued to absent. Coarsest grain size fraction is commonly no larger than pebble. Grains tend to be moderately well sorted and subangular to subrounded. Sandy 1–2 cm thick Av horizons are uncommon. The Bk horizon typically is found at approximately 11cm depth in Pleistocene deposits. Unit is not subdivided based on lack of inset relations and inconsistent soil development. Moderately vegetated with creosote bush, pencil cholla (*Opuntia arbuscula*), white bursage and annual grasses on older surface; younger surfaces lack perennial vegetation. Biologic crusts are infrequent.

Qiag **Intermediate alluvial fan deposits composed of grus, undifferentiated (late to middle Pleistocene)** – Alluvial fan deposit composed of clasts from Mesozoic plutonic sources that weather to grus. Unit Qiag is a spatially minor unit. Surfaces are low and rounded with no desert pavement. Av is patchy and thin, composed mainly of sand and silt. Unit displays a strong Bt horizon.

Alluvial Fan Deposits, Semi-Grussy

Qyasg **Young alluvial fan deposits composed of semi-grus, undifferentiated (Holocene to latest Pleistocene)** – Alluvial fan deposits characterized by surfaces and channels that received sediments from the present through the latest Pleistocene. Deposits are composed of a mixture of sediments from deeply weathered Mesozoic plutonic rocks and other types of rocks in the Calico Mountains. The coarsest grain size fraction is fine boulder and generally consists of sand with fine gravel. Clasts are moderately sorted and moderately bedded. Grains are generally subrounded to rounded. The mixture of rock types creates deposits with surfaces that form moderate to subtle bar and swale topography. The surface is smooth with subdued topography in medial to distal fan positions and with moderately developed bar and swale topography in proximal fan positions. Deposits display inset relations near mountain fronts and in distal fans deposits lack inset relations. Biologic crusts are rare on all surfaces. Semi-grussy deposits are mainly found on the east side of the Calico Mountains and in fans that emanate from Lane Mountain. **Qyassg**, alluvial deposits undifferentiated with a sandy matrix. Unit is found in the north central section of the map just below Lake Manix highstand elevation of 543 m. Sand is thought to be reworked from the lake's nearshore facies.

Qyasg1 **Young alluvial fan deposits composed of semi-grus, unit 1 (latest Holocene)** – Active deposits in discrete channels receiving sediments on annual to decadal time scales. Unit Qyasg1 covers a small area. Sediments occupy ephemeral stream channels and are loose. Bar and swale topography is subdued to absent. Unit displays no evidence of soil development, varnished clasts, or desert pavement. Units are rarely occupied by annual grasses and lack perennial vegetation.

Qyasg2 **Young alluvial fan deposits composed of semi-grus, unit 2 (late Holocene)** – Semi-active deposits in channels receiving sediments on centennial time scales. Sediments are loose to minimally indurated. Bar and swale topography is prevalent but subdued. Surface is prone to flooding and sheet flow during and after heavy rains. Little or no soil development expressed as a very incipient Av horizon or accumulation of very fine sand and silt in upper part of the soil profile. Unit tends to be moderately to well vegetated with perennial shrubs such as creosote bush.

Qyasg3 **Young alluvial fan deposits composed of semi-grus, unit 3 (late to middle Holocene)** – Deposits channelized and abandoned by active flow systems. Surfaces are stable and sediments are weakly indurated. Surfaces commonly have smooth bar and swale topography. Desert varnish is weak and desert pavement is absent. Soil development consists of 1 to 3 cm thick Av horizon composed of loose fine sand and silt, a weak Bw horizon, and minor stage I carbonate. Unit is moderately vegetated with creosote bush and minor white bursage. Where mapped, unit includes small areas of younger alluvium (Qyasg1, Qyasg2) generally located in narrow channels cut into unit Qyasg3 surfaces and includes small irregular patches of unit Qyasg4 with indistinct boundaries.

Qyasg4 **Young alluvial fan deposits composed of semi-grus, unit 4 (early Holocene to latest Pleistocene)** – Surfaces are stable. Sediments are moderately indurated. Bar and swale topography typically very subdued with 1 to 5 m wide patches of incipient desert pavement and varnish. Soil development consists of 1 to 3 cm thick sandy Av horizon, weak to moderate Bt horizon, and stage I to II carbonate horizon. Unit is moderately vegetated with perennial shrubs, creosote bush, and white bursage. Where mapped, unit includes small areas younger alluvium (Qyasg1, Qyasg2) that is generally located in narrow channels cut into unit Qyasg4 surfaces and includes small irregular patches of unit Qyasg3 with indistinct boundaries.

Fluvial Plain Deposits

Qyfp **Young fluvial plain deposits (Holocene to latest Pleistocene)** – Deposit lies south of Coyote Lake and continues south to the Mojave River. Hagar (1966) first called the deposit a desert fluvial plain; Meek (1990) mapped the area as a delta or deltaic plain. It is composed of granitic grus with minor amounts of metasedimentary and volcanic clasts; deposit is identical in composition and grain size to deposits of the modern Mojave River. Surface is broadly undulating with very muted microtopography. Other features within the fluvial plain consist of active and remnant stream channels (Qyw4-r), sand dunes (Qyed), and a prominent barrier beach to the southeast of Coyote Lake (Qilg). Hagar (1966) confirmed a fluvial origin for the plain (see section Notes on Map Units). Modern agriculture has destroyed much of the surface characteristics of the fluvial plain, however locally the surface has a veneer of coarse pebbles composed of plutonic, volcanic and metasedimentary rocks. The coarse pebbles overlie medium to coarse sand. Fluvial structures such as cross-bedding are uncommon. Soil development is weak to absent. Vegetation uniformly covers the fluvial plain and consists mainly of creosote bush, with minor Mormon tea and *Atriplex* spp. Unit is locally subdivided by topography and deposit characteristics into unit Qyw4-r and unit Qyed.

Qyw4-r **Young relict wash deposits, unit 4 (early Holocene to latest Pleistocene)** – Deposits are confined to the fluvial plain south of Coyote Lake playa. Deposits are composed of fine to coarse sand and sparse pebble layers, similar to the modern Mojave River channels, which leads to the interpretation that these deposits are relict Mojave River channels. Clasts are well sorted and rounded. Bedding is not apparent. The relict channels are straight to slightly curved, and where channels end at an elevation of ~541 m, they have bulbous snouts. Channel deposits slope to the northwest gently at 0.13˚. Relict channel crests are flat with gently sloping margins. In transverse cross-section, deposits underlie ridges whose crests lie 1 to 3 m above the surrounding plain, indicating that they are topographically inverted. The surfaces of the deposits are covered by pavement consisting of patches of well-sorted, subrounded pebbles composed mainly of Mojave River gravel (plutonic rocks, metasedimentary rocks, quartz). Farther south, the surfaces also contain subangular, locally derived volcanic gravel mixed with Mojave River gravel. On aerial photographs, the paved patches are generally darker and moderately indurated, which is due to the development of desert varnish and soil. Soil development varies. Under patches of pavement, the Av horizon ranges from 0.5 to 5 cm and is composed of silt and sand. Where the Av is 5 cm thick, it is commonly highly indurated by carbonate cement and platy. Bw and/or Bt horizons are present and range from 3 cm to 30 cm thick. Indurated carbonate horizons are sparse, but individual sand grains may be encrusted by stage I carbonate. Soil development is considerably weaker under areas that are not covered by desert pavement. Vegetation is generally evenly spaced and consists of creosote bush and white bursage. Desert Lily comprises a small component of the vegetation. Biologic crusts are present, but not ubiquitous.

Eolian Deposits

Qye **Young eolian sand deposits (Holocene) –** Deposits are composed of tan, moderately to well sorted, fine- to medium-grained, loose sand that form sand sheets. Unit Qye is mapped on the fluvial plain, south of the playa and commonly overlie lacustrine fines (Qylf) or gravel (Qylg). On air photos, sand deposits have a moderate albedo. Deposits are moderately vegetated with *Atriplex* spp. Coppice dunes around perennial plants are common. Weak to no soil development.

Qyed **Young eolian sand dune deposits (Holocene to latest Pleistocene)** – Deposits are composed of well sorted tan, very fine-grained sand and silt that form dunes. Deposits are massive to weakly cross-bedded. Little or no soil development. Vegetation varies from none to dense. Sand dunes are found around the north, west, and south perimeter of Coyote Lake, with the largest concentrations to the south and southeast of the playa. Dunes to the west of the playa may have formed by wind erosion from littoral sands and could be late Pleistocene in age (Meek, 1994). Near the large beach southeast of Coyote Lake, large dunes overlie lacustrine sediments. *Anodonta* shells (sample SD04CL-1380) collected from the uppermost lacustrine sediments that underlie a dune yielded a radiocarbon age of 15,805 ± 45 ^{14}Cyr B.P., which provides a maximum age for deposition of eolian sand (UTM: 528440, 38777482).

Mixed Alluvial Fan and Eolian Deposits

Qyae **Young mixed alluvial and eolian deposits, undifferentiated (Holocene to latest Pleistocene)** – Deposit consists of alluvial and eolian sediments that are thoroughly mixed, with alluvial sediments dominant. These units are found mainly in the eastern part of the map area, where significant eolian contribution stems from the playa. Deposits are moderately to well sorted sand and gravel. Sediments are typically loose. Soil development is similar to or less pronounced than that exhibited by correlative alluvial unit. Generally, desert pavement is less developed and A_v horizons are subdued compared to correlative alluvial unit. Deposits form more muted topographic surfaces than alluvial surfaces lacking significant eolian sand. Surfaces are sparsely vegetated, generally supporting creosote bush, white bursage, and annual grasses. Deposits grade complexly toward eolian sand sources by increase of sand component and decrease of discrete alluvial beds. Where correlative with nearby alluvial fan deposits, units are subdivided with numeral subscripts corresponding to age units of Qya: **Qyae1, Qyae2,** and **Qyae4**.

Qyea **Young mixed eolian and alluvial deposits, undifferentiated (Holocene to latest Pleistocene)** – Deposit consists of eolian and alluvial sediments that are thoroughly mixed, with eolian sediments dominant. Deposits are found in the north-central map area, west of the playa, at the intersection of eolian dunes and distal alluvial fans. Deposits are moderately to well sorted sand and gravel, with less gravel than in unit Qyae deposits. Topography is muted and flat. Sediments are typically loose. Deposits may exhibit a 2cm thick sandy silty Av and lack desert pavement or varnish. Sparsely vegetated, generally supporting *Atriplex* spp. and sparse creosote bush. **Qyeag**, eolian and grussy alluvial sediments that are thoroughly mixed, with eolian processes dominating.

Qiae **Intermediate mixed alluvial and eolian deposits (late to middle Pleistocene)** – Deposit consists of alluvial and eolian sediments that are thoroughly mixed, with alluvial sediments dominant. Soil development is similar to or less pronounced than that exhibited by unit Qia. Sparsely vegetated, generally supporting creosote bush and white bursage. Qiae mapped in the northeast corner of the map area where alluvial deposits are composed mostly of grussy granite from Alvord Mountain and contain an eolian admixture. The surface of these deposits is littered with volcanic rocks, also from Alvord Mountain. The gradient of these deposits is less steep than that for the Holocene deposits, either which suggests the Qiae deposit graded to a higher base level controlled by a higher lake level or that the gradient has been affected by tectonics. Scarps found on the toes of these deposits could either be lacustrine erosional scarps or fault scarps.

Playa, Groundwater, and Lacustrine Deposits

Qap **Active playa deposits (latest Holocene)** – Playa sediments that are seasonally inundated, composed of weakly bedded, poorly sorted clay, silt, and sand, and rare salt. Surface of playa is flat and compact, in some places has a soft-puffy texture underlain by compact material. Mud-cracks are ubiquitous and in places cut by linear fissures that support vegetation. The playa is prone to flooding and receives run off from Coyote Wash and other streams, as well as active groundwater seepage in the north, west, and south (Hagar, 1966). Vegetation is sparse, composed of salt-tolerant species such as saltbush that grows on the borders of the playa and locally on the interior of the playa. The southern playa was cored to a depth of 5.16 m (UTM: 523616, 3879080). At a depth of ~3.5 m, *Anodonta* shells yielded an apparently finite age of 46,240 ±1580 ^{14}Cyr B.P. Based on the shallow depth of the *Anodonta* shells, either deposition during the last 46 ka has been virtually nil or deflation of the playa surface has been extensive.

Qapf **Active playa fringe deposits (latest Holocene)** – Playa fringe deposits are composed of complexly mixed eolian, lacustrine, playa, alluvial, and groundwater discharge deposits. Displays little or no soil development. Vegetation is composed of creosote bush and salt-tolerant species such as saltbush.

Qigsm **Intermediate groundwater-discharge spring mound deposits (middle Pleistocene)** – Carbonate-rich silt and fine sand with a hard carbonate cap formed in former zones of groundwater discharge. Deposits are generally white to light brown; compact to soft except for hard carbonate cap. Sand and pebbles are ubiquitous throughout the carbonate cap. These deposits occur along Southwest Coyote Basin fault and form low mounds. The Southwest Coyote Basin fault bends at a large mound that contains a silica-rich fault plane. U-series dating on the silica within the fault plane has yielded a preliminary age of 350 ka, providing a minimum age for the deposit. The deposits are interpreted as groundwater deposits based on fine grain size, carbonate and silica content, location along the fault, and texture of hard carbonate cap.

Qylf **Young lacustrine fines (early Holocene to latest Pleistocene)** – Deposits consist of well rounded and well sorted fine-sand, silt and clay. Muddy sand and mud are massive or interbedded with wavy to flat laminae. Grains are commonly quartz, feldspar, and olivine; layers of biotite-rich sediment are common. Unit is capped by pea sized gravel that is typically composed of plutonic grus. Iron staining and other ground water alteration such as carbonate nodules are commonly found. There is little soil development. Vegetation consists of creosote bush. *Anodonta* shells are locally present in this unit. Dated samples M03SM-1686, M05SM-2418(2 samples), M05SM-2464 and SD04CL-1337 gave radiocarbon ages of 15,100±45, 15,825±45, 16,175±45, 13,810±34, and 13,145±45 ^{14}Cyr B.P. respectively (Table 1). Sediment is commonly barren of ostracode valves.

Qyls **Young lacustrine sand (early Holocene to latest Pleistocene)** – Deposits typically consist of massive or thin to medium bedded fine to coarse sand and lie offshore from beach gravels. Grains are commonly well sorted quartz, feldspar and olivine. Deposits are interpreted to represent the nearshore (littoral) lacustrine environment. In some places, this unit contains delta foreset beds and fluvial sands that interfinger with lacustrine clay (Hagar, 1966). Typical vegetation is evenly distributed and consists of creosote bush and white bursage. Close to the playa *Atriplex* spp. is more common.

Qylg **Young lacustrine gravel (early Holocene to latest Pleistocene)** – Deposits consist of moderately well sorted, subangular to subrounded gravel at the surface and massive sand in subsurface. Gravel is composed of plutonic, volcanic and metasedimentary clasts as much as 3 cm in diameter. Gravel deposits west of Coyote Wash are composed primarily of Calico Mountain volcanic clasts at the surface, but in the subsurface consist of Mojave River sediment. Deposits occur as bars and barrier beaches in the western section of the fluvial plain. The typical altitude for gravel is between 542 m and 540 m. Sediments in subsurface are moderately rounded sands with sparse gravel lenses. Surfaces are generally flat with crowned edges and are 1 to 3 m higher than surrounding plain. Desert pavement and varnish are weak and occur in gravel-rich patches. Soil development consists of a 1 to 5 cm thick Av horizon that is generally sandy silt. A well-indurated layer of carbonate-cemented sands 5 to 10 cm thick commonly occurs under the Av horizon. Bw horizons are generally about 20 cm thick. Stage I carbonate generally does not occur as a distinct horizon, but carbonate coats individual grains. Vegetation is sparse and consists of creosote bush and uncommon white bursage.

Qilf **Intermediate lacustrine fines (latest to late Pleistocene)** – Well rounded, well sorted lake sediments. Sediments consist of finely laminated sand and mud. Soil development commonly consists of 0.5-1.0 cm thick Av and Bw and/or Bt of varying thickness. Groundwater alteration is common. Vegetation is sparse to absent. *Anodonta* shells collected from this unit (UTM: 528449, 3878975) near large barrier beach east of Coyote Lake yielded an age of 19,660 ± 70 ^{14}Cyr B.P.

Qilg **Intermediate lacustrine gravel (latest to late Pleistocene)** – Lake sediments with moderately well sorted, subangular to subrounded gravel clasts at surface. Units form bars and spits. These deposits are very similar to unit Qylg, but gravel of shorezone is at or near Lake Manix highstand of 543 m. The relation between Lake Manix highstand and unit Qilg suggests that the gravels are older than 18 ka (Meek, 1990). The largest deposit lies southeast of the playa and extends from the Alvord Mountain piedmont nearly to Agate Hill; Hagar (1966) termed this deposit the bay bar. The bay bar is ~0.5 km wide and is composed of moderately well sorted and rounded sand with gravel clasts at the surface that originated from Alvord Mountain. Playa or lagoonal deposits lie shoreward of the bay bar. The bay bar has several wave cut notches along the western lakeward side. Much of the bay bar is covered or surrounded by eolian dunes. Vegetation on unit Qilg consists of evenly spaced creosote bush and sparse white bursage.

Mass Wasting Deposits

Qymc **Young colluvial deposits (Holocene) –** Poorly sorted angular to subangular boulders, cobbles and sand. Unit consists of talus below steep bedrock areas that obscures underlying bedrock.

Qimc **Intermediate colluvial deposits (latest to middle Pleistocene) –** Poorly sorted angular to subangular boulders, cobbles and sand. Unit consists of talus below steep bedrock areas that obscures underlying bedrock. Moderate to well developed, interlocking desert pavement containing clasts with moderate to strong varnish.

Substrate Units

Tcm **Rocks of the Calico Mountains, undivided (Tertiary)** – Includes rocks of the Lane Mountain Formation, Newberry Formation, Pickhandle Formation, and the Barstow Formation (Bohnam and Danehy, 1959). The Lane Mountain Formation consists of biotite dacite, calcic andesite, granitic breccia and dacite mudflow breccia. The Newberry Formation consists of dacite, latite, and andesite. The Pickhandle Formation consists of dacite tuff breccia and welded tuff, landslide breccia, olivine basalt, and arkosic conglomerate with limestone. Rocks of the Barstow Formation consist of fluviatile and lacustrine sediments. Intrusive rocks consist of quartz latite porphyry, dacite, latite, and andesite. $^{40}Ar/^{39}Ar$ dating yielded ages of ~19.4 – 19.0 Ma on volcaniclastic sediments and dacitic volcanics associated with the Pickhandle Formation (Singleton, 2005). Tuffs in fine-grained lacustrine deposits within the Barstow Formation yielded ages between ~19 and 17 Ma (Singleton, 2005).

Mzp **Plutonic rocks (Mesozoic)** – Includes quartz monzonite, biotite granite, and undifferentiated gabbro-to-quartz diorite mafic rocks and silicic felsite dikes (McCulloh, 1960). Coarse-grained rocks weather to grus, or where rocks are altered, weather to fine boulder-sized blocks.

Pzms **Metamorphosed sedimentary rocks (Paleozoic)** – Rocks include metaconglomerate, quartzite, hornfelsed shale and siltstone, metachert, hornfelsed marl and impure dolomite, marble and metavolcanic rocks (McCulloh, 1960).

Acknowledgements

I would like to thank David Miller for his invaluable help in understanding Quaternary geology and for participating in many thoughtful discussions. Norman Meek also significantly contributed his knowledge, experience and resources from his years of working in the Coyote basin. Joanna Redwine and Marith Reheis helped significantly in understanding soils and soil development. Heather Lackey provided much needed help and comic relief in digging numerous soil pits. Lee Amoroso and Marith Rehies reviewed the map and manuscript whose reviews considerably improved earlier versions. Sue Priest provided a technical review of the digital data and documentation. John McGeehin provided his time and lab conducting the radiocarbon analyses.

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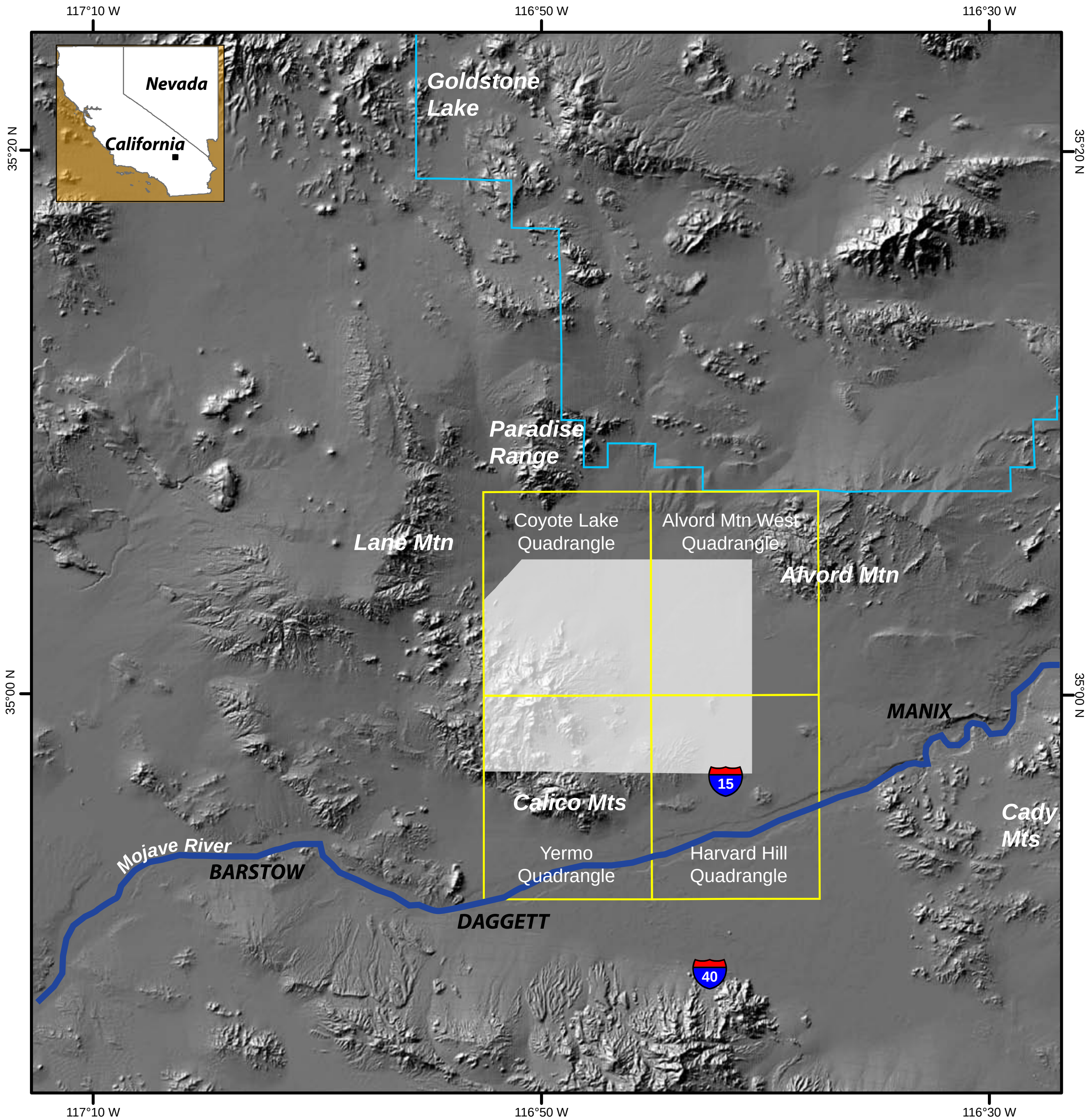


Figure 1. Location for study area and mapped portions of USGS 7.5-minute quadrangles Coyote Lake, Yermo, Alvord Mountain West, and Harvard Hill. The map area lies in the central Mojave Desert, CA. Yellow boxes indicate quadrangle extent and blue line indicates boundary of Fort Irwin.

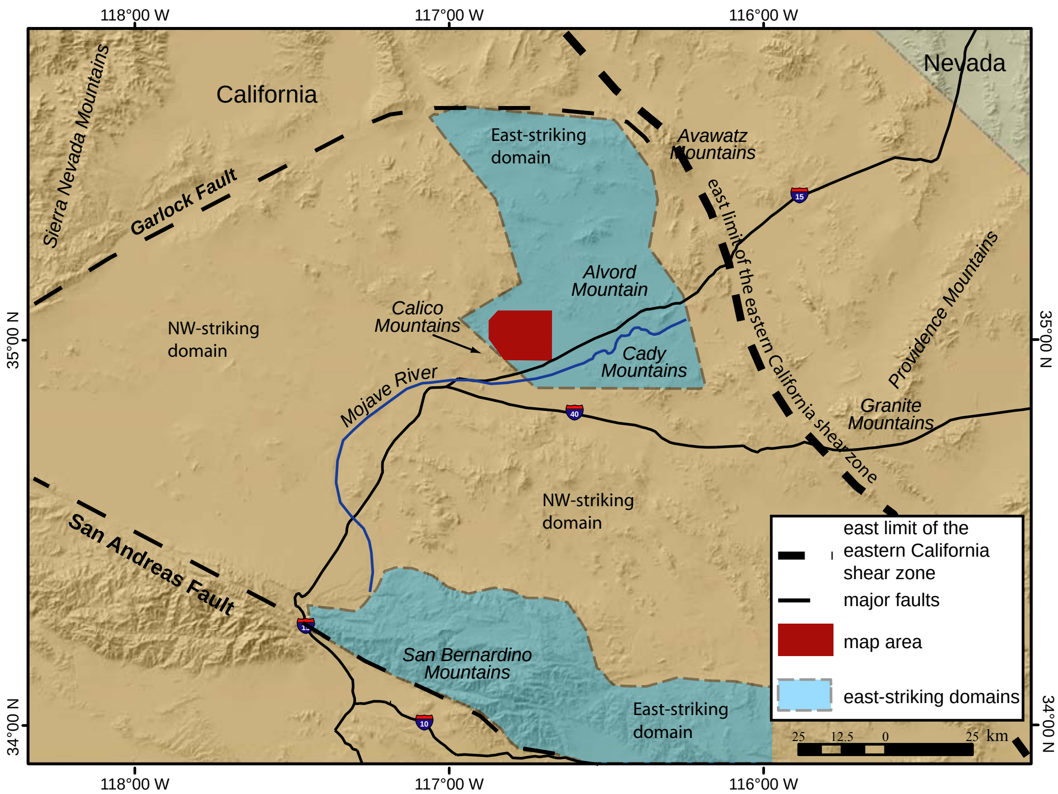


Figure 2. Location of east-striking fault domains within the Mojave Desert. Outside of east-striking domains, faults generally strike northwest. The study area lies at the boundary between the two domains and contains faults that strike both east and northwest.

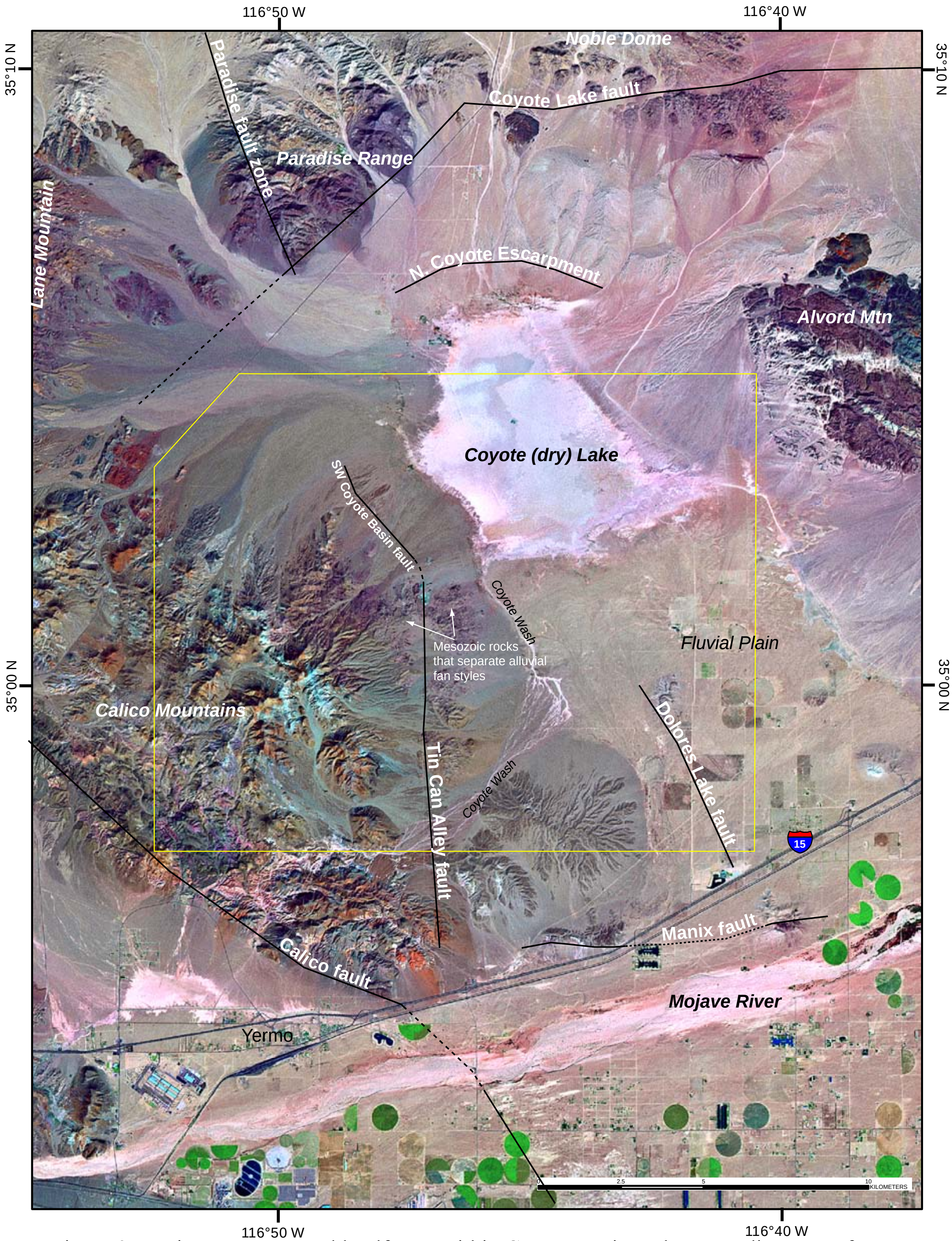


Figure 3. Major structures and landforms within Coyote Basin and surrounding area after Meek (1990 and 1994); Jennings (1994); Albert (1999); and Miller and Yount (2002). Mapping from this study revealed the Tin Can Alley fault and its connection to Meek's (1994) Southwest Coyote Basin fault. Yellow box indicates study area.

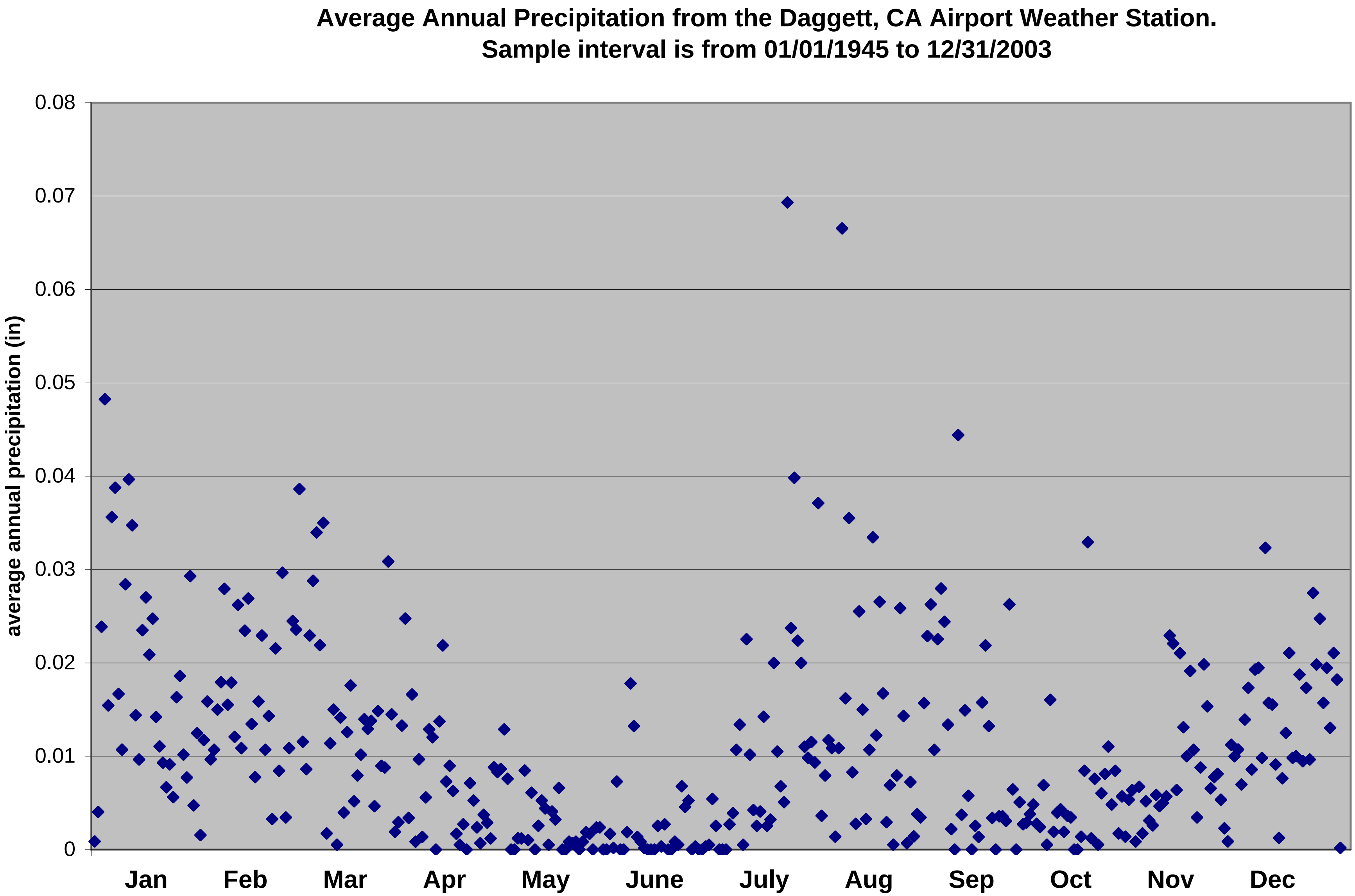


Figure 4. Average annual rainfall at the Dagget, CA airport weather station. Sample interval is from January 1, 1945 to December 31, 2003. Data from Hereford, R. and Longpre', Claire, 1998, Climate History of the Mojave Desert Region, 1892-1996. http://mojave.usgs.gov/climate-history.

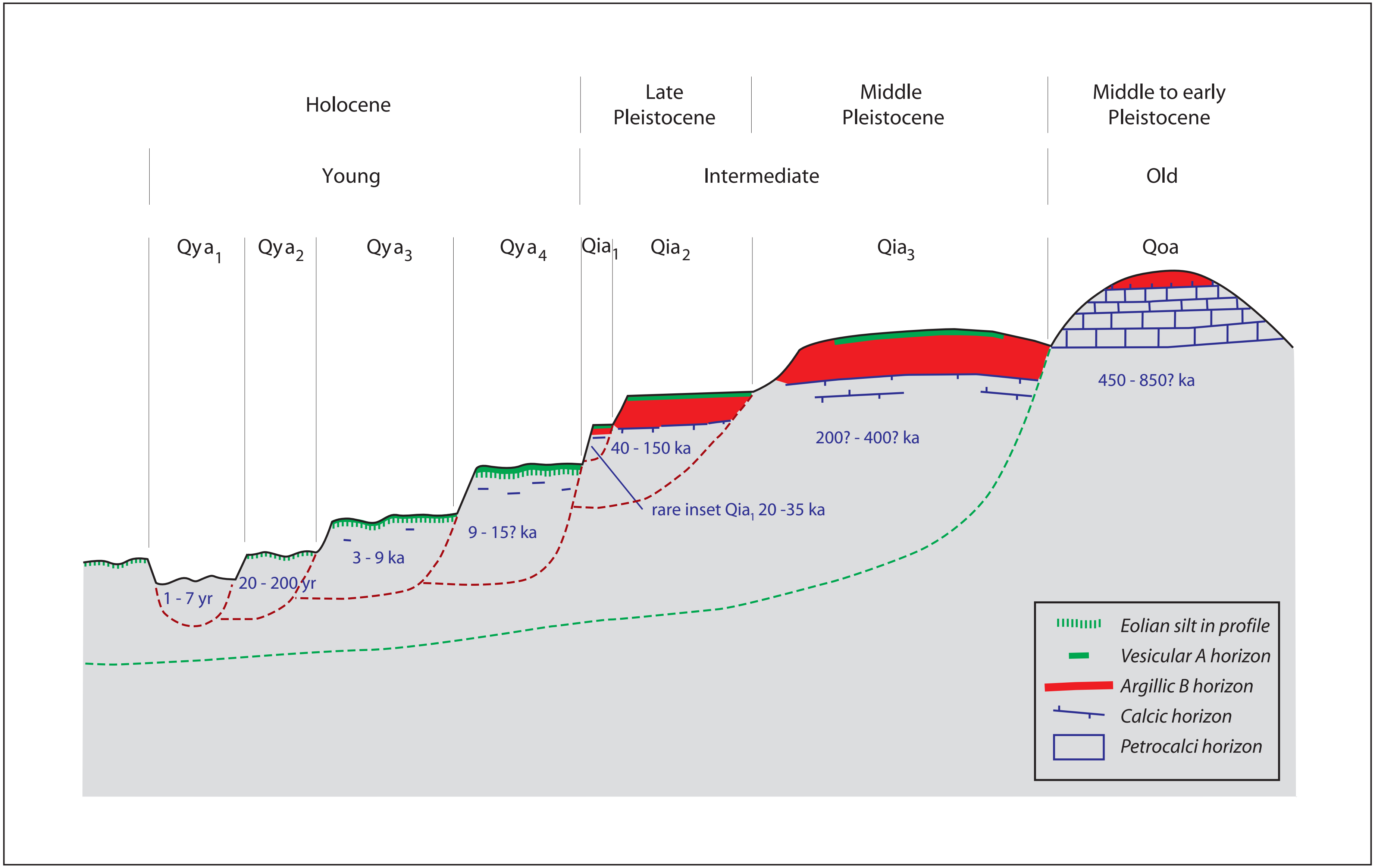


Figure 5. Schematic cross-section showing alluvial fan deposit inset relations, soil geomorphic characteristics, and approximate age ranges determined from geochronologic studies in the Mojave Desert (courtesy of D.M. Miller).

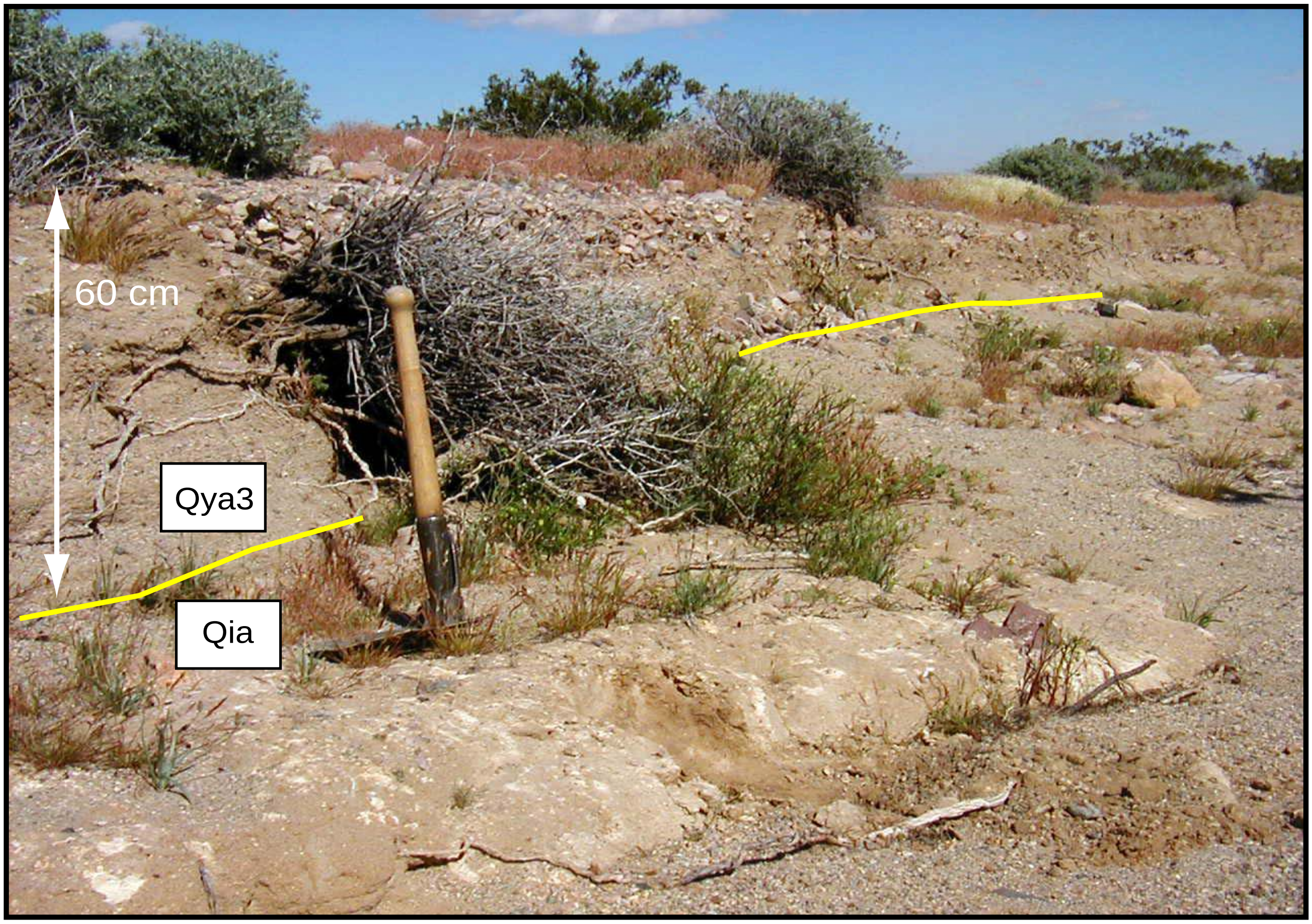


Figure 6. Photo showing Holocene alluvium (Qya3) that formed on a stripped Pleistocene alluvial deposit (Qia). Red soil horizon Btk is speckled with carbonate nodules. The smooth microtopography of the Qya3 deposit (not visible here) may be a result of the underlying Qia surface.

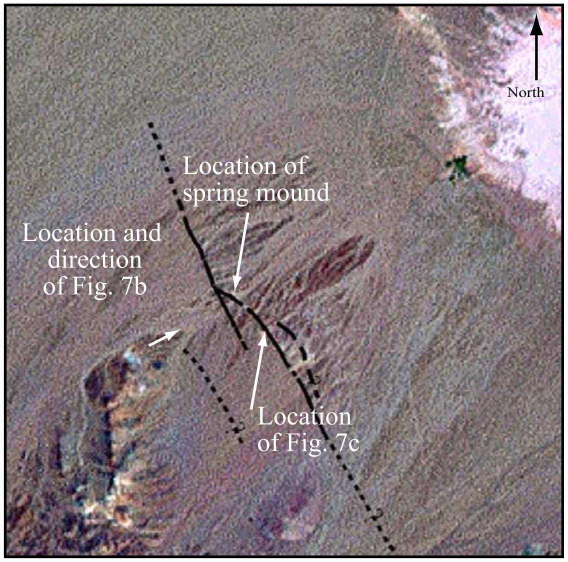


Figure 7a. Landsat image of Southwest Coyote Basin fault in the Calico Mountains piedmont. The Southwest Coyote Basin fault truncates Pleistocene age alluvial deposits and degraded Mesozoic plutonic rocks.

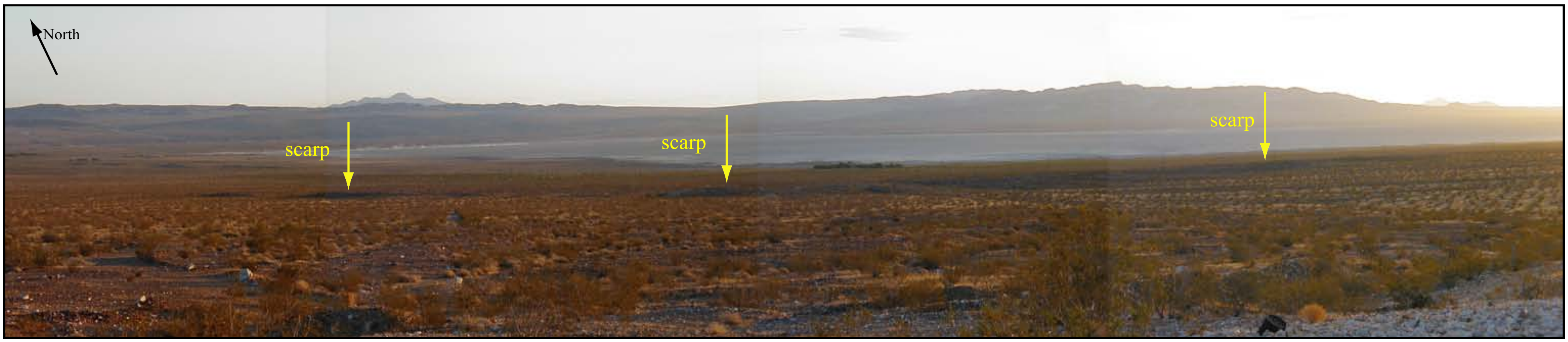


Figure 7b. Low sun-angle photomosaic of Southwest Coyote Basin fault. View to northeast. Alvord Mountain is in the background. Fault scarp is shadowed in central part of the photo. Distance to fault scarp is ~ 800 m.

Figure 7c. Photomosaic of the central part of the Southwest Coyote Basin fault showing rounded fault scarp in Pleistocene alluvium and Mesozoic plutonic rocks. Dark area at photo-right is highly weathered Mesozoic plutonic rocks. Scarp is ~2 m high. Early to middle Holocene deposits in foreground. View to north.

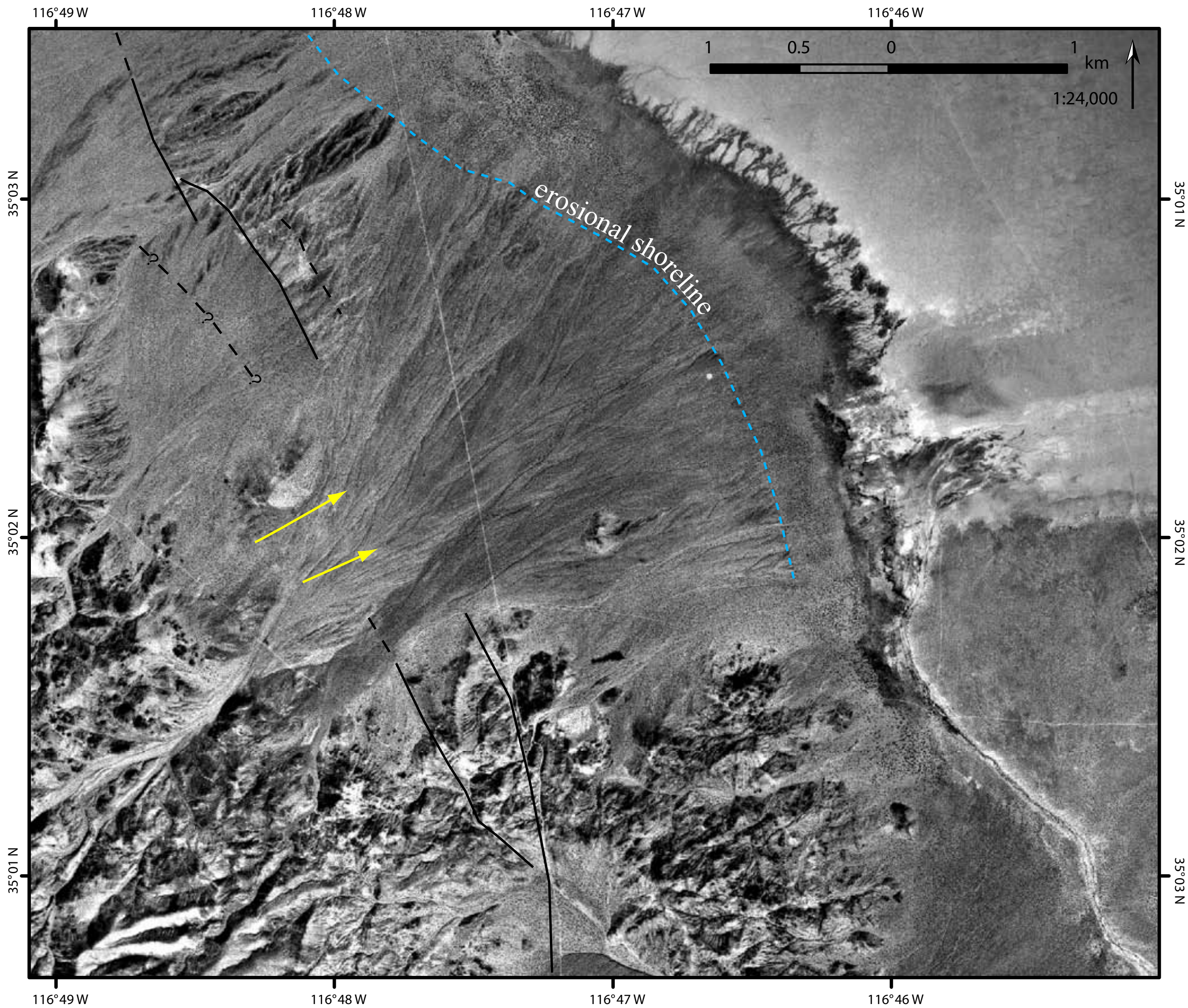


Figure 8. DOQQ showing parts of the Southwest Coyote Basin fault to the north and the Tin Can Alley fault to the south. Yellow arrows point to truncated intermediate age alluvial fans under Holocene alluvium. Blue line indicates a Lake Manix erosional shoreline.

Figure 9a. Spring mound deposit composed of fine-grained sand and silt and has a hard cap of carbonate-encrusted granules. The loose carbonate on the surface has a popcorn texture.

Figure 9b. Fault plane (strikes 295° and dips 72°NE) in Pleistocene spring mound deposit. Spring mound deposits are found in several places along the trace of the fault. View to southeast.

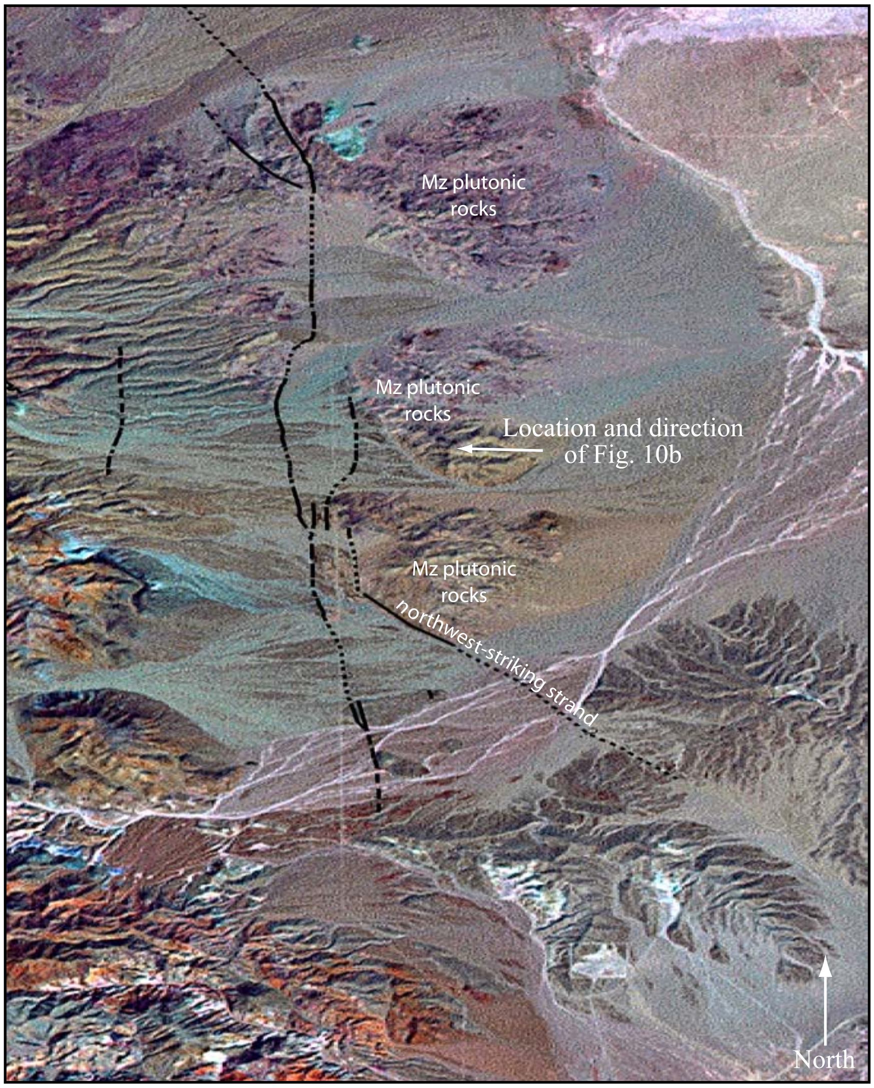


Figure 10a. Landsat image of Calico Mountains and piedmont showing location of Tin Can Alley fault traces. Fault continues south, but is only shown within the map area of this report.

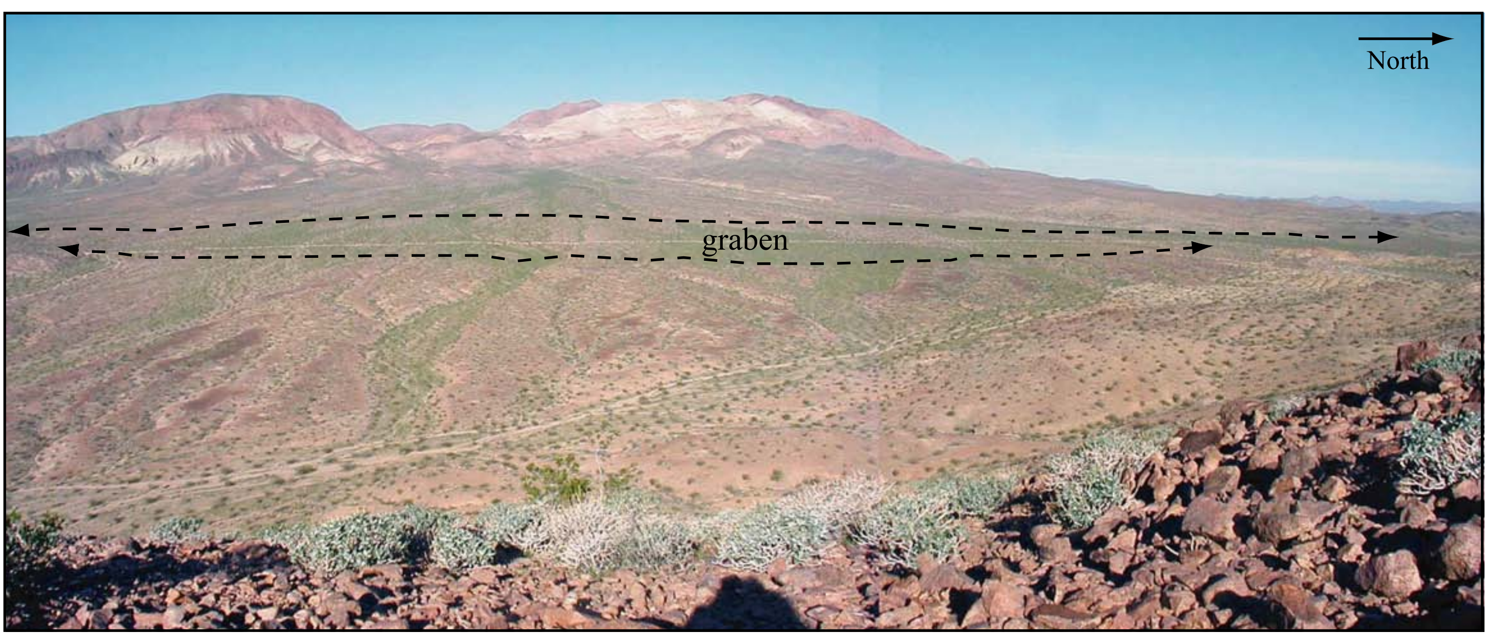


Figure 10b. Photomosaic of the central part of the Tin Can Alley fault showing approximate location of fault strands (dashed lines) and graben. View to west. Holocene deposits are covered in green annual plants. Pleistocene deposits are red-tan. The Calico Mountains are in the background.

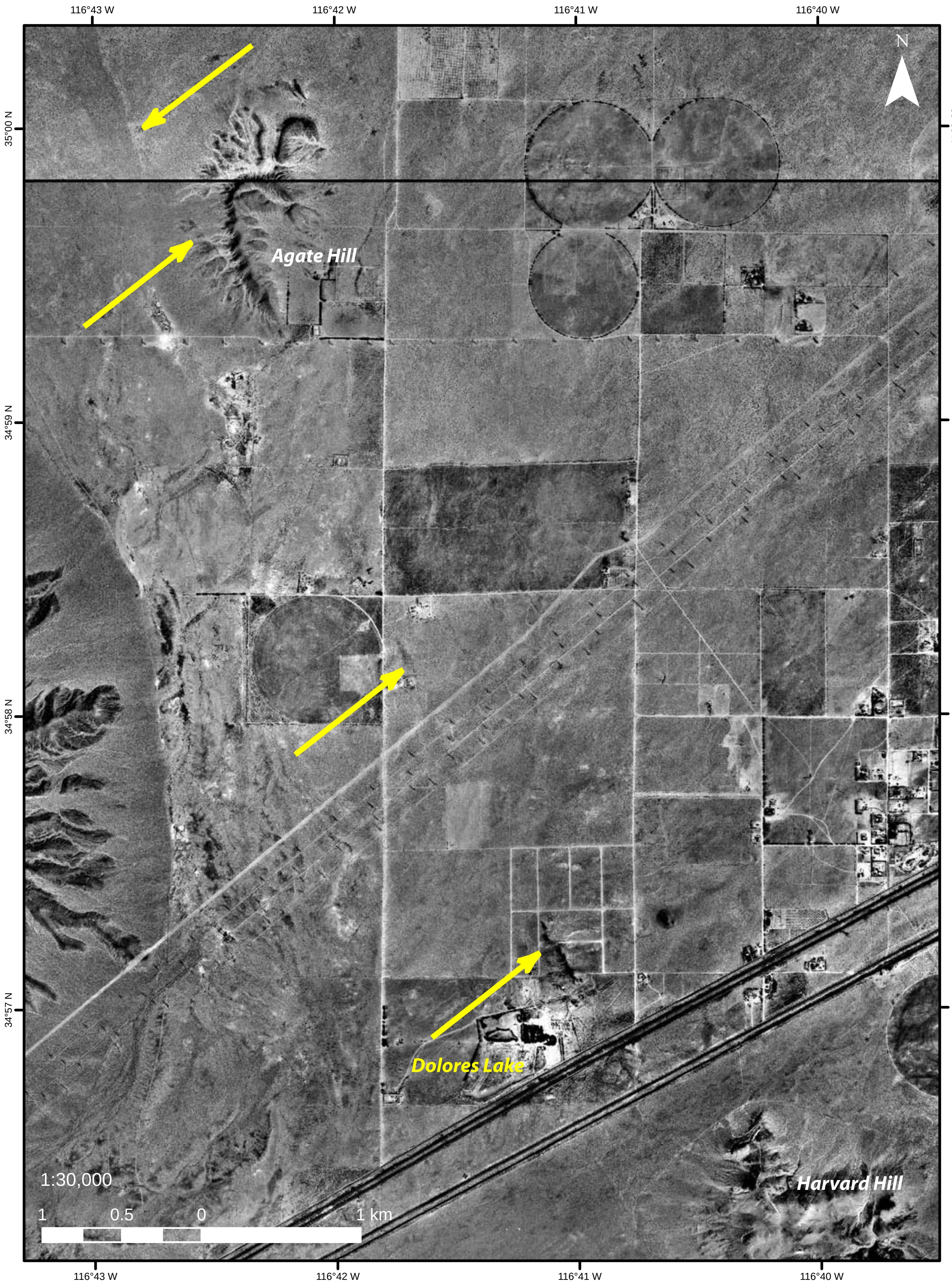


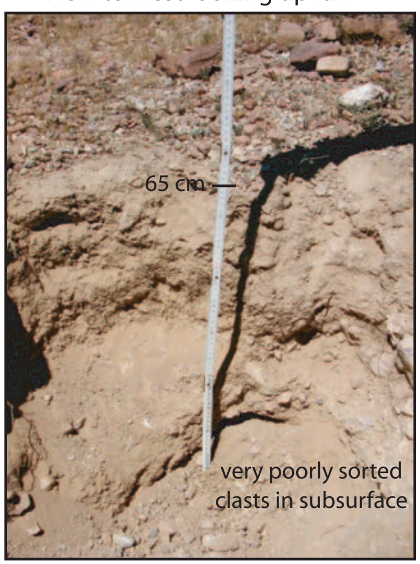
Figure 11. DOQQ showing the Dolores Lake fault trace indicated by yellow arrows. Trace of fault may continue through Harvard Hill.

Figure 12. Coyote Lake 3/17/05. Alvord Mountain is to the left of the photo, view to southeast. *Atriplex* sp. are above the surface of the water at this location (UTM: 520582, 388319) and the estimated depth of water is ~30 cm. The deepest part of the basin is to the southeast where the surface elevation is ~4 m lower.

Figure 13. Photographs showing examples of three types of mapped alluvial fan deposits-rocky (Qya4), grussy (Qyag3/4) and semi-grussy (Qyasg4). Upper photo shows the surface of the deposit; lower photo shows subsurface about a meter deep. Qya deposits are generally poorly sorted, Qyasg deposits are moderately sorted, and Qyag deposits are well sorted. Clast size plays a large role in the hydrology, cohesive strength of the deposit, and possibly surface stabilization and depth of soil formation.

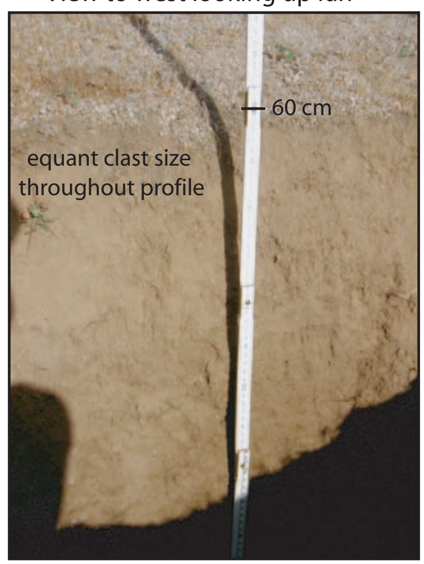
Rocky alluvial fan (Qya4)

View to west looking up fan



Grussy alluvial fan (Qyag3/4)

View to west looking up fan



Semi-grussy alluvial fan (Qyasg4)

View to north looking across fan

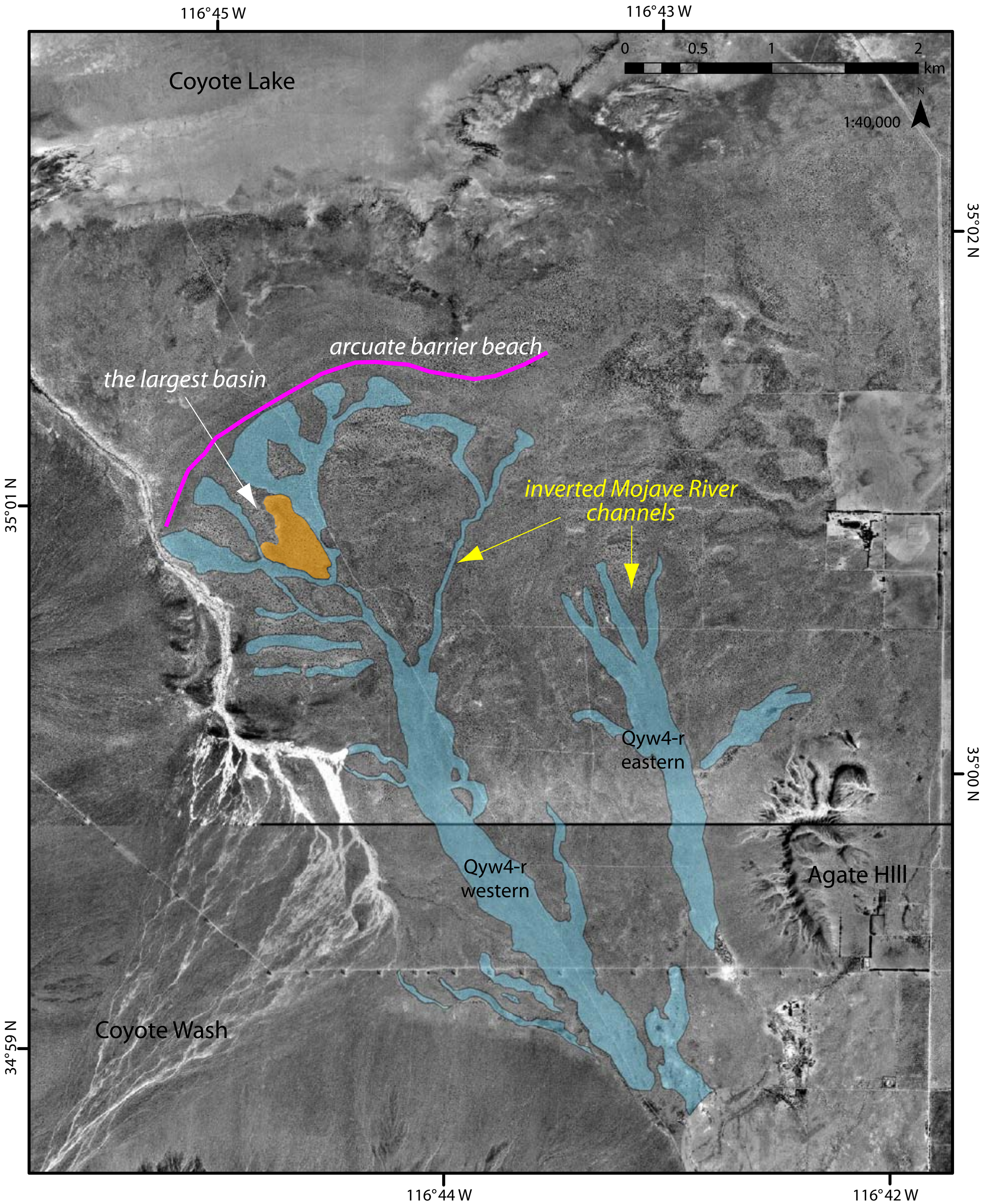


Figure 14. Inverted Mojave River channels sit in positive relief above the surrounding fluvial plain. Highlighted in pink is the ~13 ka barrier beach that overlies the channels. Colored orange is the largest depression or basin on the fluvial plain. The basins may be deflationary features.

Figure 15. Topographically high mound with an 8 cm thick layer of coarse pebbles and sand overlying mud and sandy mud. Evidence of groundwater alteration and carbonate stringers are seen in the mud. The deposit coarsens downward to clean well sorted and rounded sand. If this package of fines had been laterally continuous, fines were likely eroded or deflated where they were not armored by coarser sediment. Small patches of fine-grained sediment exist nearby. View to west, UTM: 525304, 3874320.

Table1. Uncalibrated radiocarbon ages from samples of Anodonta shells collected by D. Miller and S. Dudash.

FIELD SAMPLE NO.	LAB SAMPLE NO.	UTM COORDINATES	DEPOSITIONAL ENVIRONMENT	^{14}C AGE
SD04CL-1381a	WW5146	528542, 3877714	lacustrine sand	15707±45
SD04CL-1381b	WW5147	528542, 3877714	lacustrine sand	15910±45
SD04CL-1381c	WW5519	528542, 3877714	lacustrine sand	19680±70
SD04CL-1380a	WW5145	528440, 3877482	lacustrine sand	15805±45
SD04CL-1337a	WW5144	522748, 3874088	lacustrine sand	15100±45
M03SM-1664	WW4562	528449, 3878975	sandy mud	19660±70
M055M-2474	WW5355	528459, 3878999	sand and gravel	15590±45
M055M-2464	WW5354	522443, 3874733	lacustrine sand	13810±35
M055M-2462	WW5353	522475, 3874610	lacustrine sand	14335±40
M055M-2418A	WW5351	522748, 3874088	lacustrine sand	15825±45
M055M-2418B	WW5352	522748, 3874088	lacustrine sand	16175±45
M03SM-1686	WW4564	522298, 3875015	sandy mud	13145±45

Table 2. Fault characteristics for the Southwest Coyote Basin fault, Tin Can Alley fault and the Dolores Lake fault.

Fault	**Strike**	**Observed Length (km)**	**Projected Length (km)**	**Up-thrown Block**	**Youngest Unit Cut**	**Oldest Unit Not Cut**
Southwest Coyote Basin fault	330°-340°	2	4	East	Qia2	Qya4
Tin Can Alley fault	350°	9	11	Variable	Qia3	Qia2
Dolores Lake fault	340°-350°	1.5	9	Uncertain	Early Holocene to latest Pleistocene?	Early Holocene to latest Pleistocene?