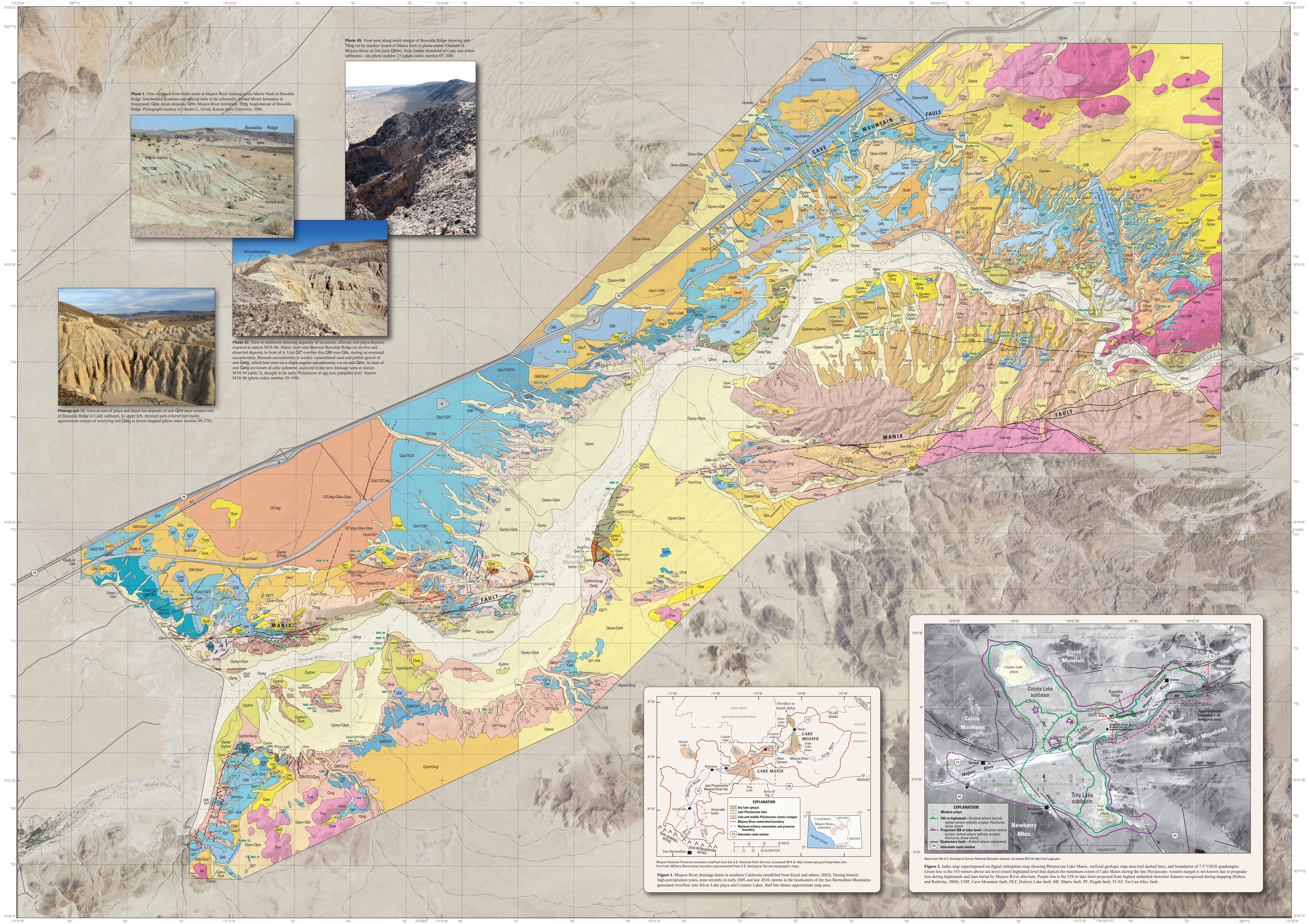
U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3312
Sheet 1 of 2
Pamphlet accompanies map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35°00'00"
34°57'30"
34°56'10"
7040000 FEET
7010000 FEET
2200000 FEET
2190000 FEET
ALVORD MOUNTAIN
POWERLINE ROAD
Midway
Dunn
New Dunn
CAVE MOUNTAIN FAULT
MANIX FAULT
Buwalda Ridge
Mojave River
Manix Wash
Midway Wash (informal)
Wilhelm Wash
Ninemile Waterhole
Field Siding (historic)
Canyon Campground
Afton Canyon
North Afton beach ridge
The Knob
Camp Cady
YERMO ROAD
CADY MOUNTAINS
15

Photo 1. View northeast from bluffs north of Mojave River looking across Manix Wash to Buwalda Ridge. Interbedded lacustrine and alluvial beds of the informally defined Manix formation in foreground. Qye, eolian deposits; Qmr, Mojave River formation; Tbrg, fanglomerate of Buwalda Ridge. Photograph courtesy of Charles G. Oviatt, Kansas State University, 2006.

Buwalda Ridge
Tbrg
Qye
Ql/Qalg
Qmr
Qyea
Manix tephra
Ql7 / Ql6
Qf5
Ql4
Ql3?
buried soils

Photo 49. View west along south margin of Buwalda Ridge showing unit Tbrg cut by inactive strand of Manix fault in photo center. Channel of Mojave River on left (unit Qfmr). Near former threshold of Cady and Afton subbasins—see photo number 25 (photo index number 07–204).

Photo 42. View to northwest showing sequence of lacustrine, alluvial, and playa deposits exposed at station M10–86. Manix fault runs between Buwalda Ridge on skyline and dissected deposits in front of it. Unit Ql7 overlies thin Ql6 over Qia, resting on erosional unconformity. Beneath unconformity is weakly consolidated sand and pebble gravel of unit Qalg, which here rests on a slight angular unconformity cut on unit Qmr. At base of unit Qalg are lenses of ashy sediment, analyzed in the next drainage west at station M10–94 (table 2), thought to be early Pleistocene in age (see pamphlet text). Station M10–86 (photo index number 10–198).

Unconformities
Ql7
Qye
Tbrg
Ql6/Qia
Qalg
Qmr

Photograph 55. View to east of playa and distal-fan deposits of unit Qmr near western end of Buwalda Ridge in Cady subbasin. In upper left, resistant pale-colored bed marks approximate contact of overlying unit Qalg as herein mapped (photo index number 09–278).

FORT IRWIN
MILITARY RESERVATION
Overflow to Death Valley
Silver Lake playa
Baker
Cronese Lakes
LAKE MOJAVE
Soda Lake playa
Harper Lake
Coyote Lake
Dunn
Map area
Afton Canyon
Mojave River fan
Kelso Wash
Barstow
Yermo
LAKE MANIX
late Pleistocene Mojave River fan
Troy Lake
Area of fig. 2
TO LAS VEGAS
TO NEEDLES
MOJAVE NATIONAL PRESERVE
NEVADA CALIFORNIA
Mojave River
Victorville
Victorville basin
West Fork
Deep Creek
SAN GABRIEL MTNS.
SAN BERNARDINO MTNS.
San Bernardino
EXPLANATION
Dry lake (playa)
Late Pleistocene lake
Late and middle Pleistocene clastic wedges
Mojave River watershed boundary
National military reservation and preserve boundary
Interstate route marker
CALIFORNIA
NEVADA
ARIZONA
MEXICO
Pacific Ocean
Mojave River watershed
0 10 20 30 MILES
0 10 20 30 KILOMETERS

Mojave National Preserve boundary modified from the U.S. National Park Service, accessed 2014 at *http://www.nps.gov/moja/index.htm*.
Fort Irwin Military Reservation boundary approximated from U.S. Geological Survey topographic maps.

Figure 1. Mojave River drainage basin in southern California (modified from Enzel and others, 2003). During historic high-precipitation years, most recently in early 2005 and late 2010, storms in the headwaters of the San Bernardino Mountains generated riverflow into Silver Lake playa and Cronese Lakes. Red line shows approximate map area.

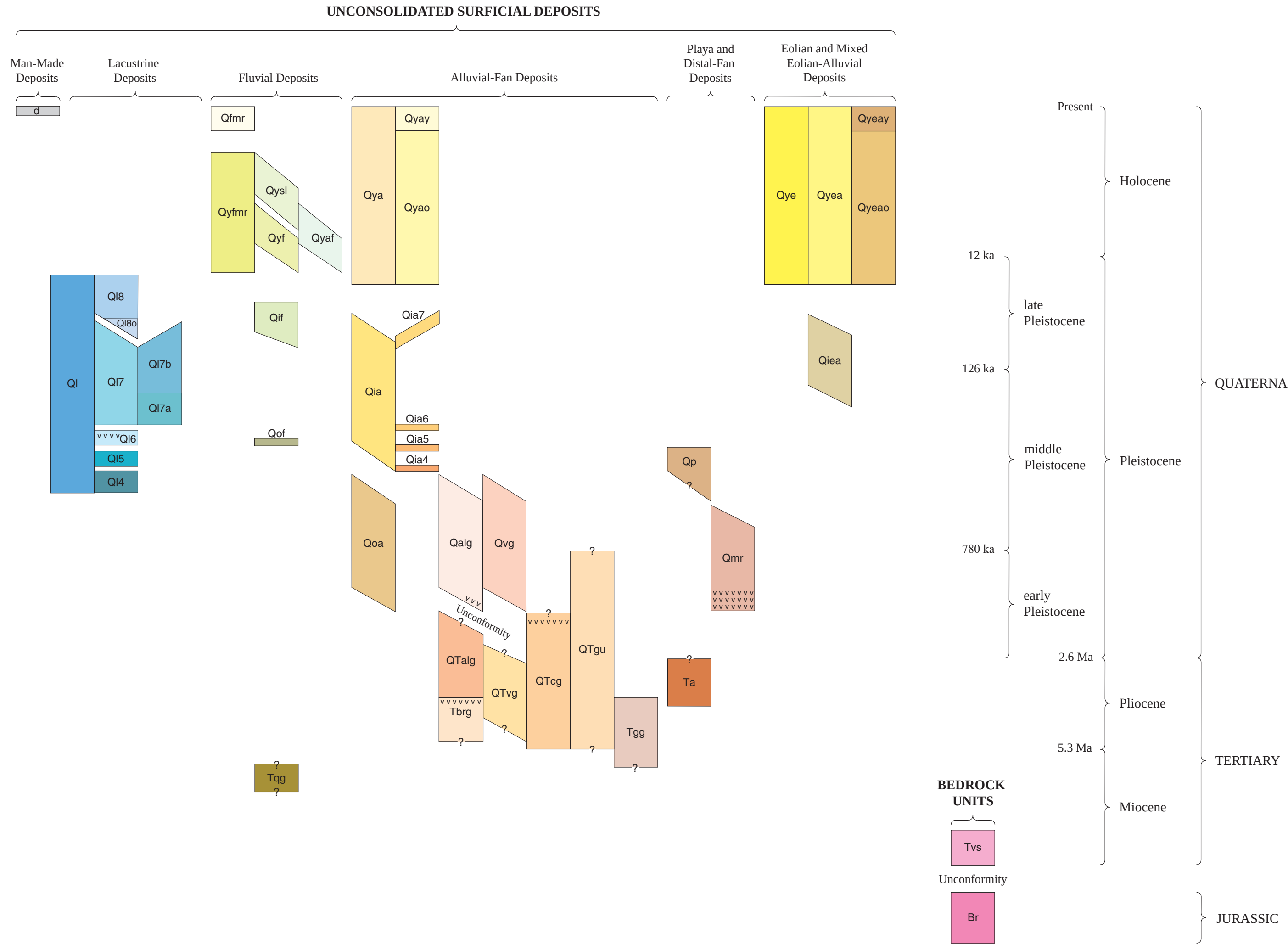
FORT IRWIN MILITARY RESERVATION
LANE MOUNTAIN
COYOTE LAKE
ALVORD MOUNTAIN WEST
ALVORD MOUNTAIN EAST
DUNN
CAVE MOUNTAIN
Alvord Mountain
Coyote Lake playa
Coyote Lake subbasin
543 m
557 m
558 m
HARVARD HILL
Harvard Hill
Buwalda Ridge
Manix Wash
MF
CMF
Dunn
Cave Mountain
Afton subbasin
Mojave River
Afton Canyon
Approximate boundary of mapped area
CORE (45-m core in thickest part of lacustrine deposits)
Cady subbasin
Cady Mountains
MANIX
HIDDEN VALLEY WEST
HIDDEN VALLEY EAST
NEBO
Calico Mountains
CALICO FAULT
YERMO
TCAF
DLF
Yermo
Mojave River
CADY FAULT
DAGGETT
MINNEOLA
NEWBERRY SPRINGS
TROY LAKE
HECTOR
SLEEPING BEAUTY
Newberry Springs
Newberry Mtns.
Troy Lake subbasin
Troy Lake playa
PF
EXPLANATION
Modern playa
543-m highstand—Dashed where buried; dotted where entirely eroded. Hachures show island
Projected 558-m lake level—Dashed where buried; dotted where entirely eroded. Hachures show island
Quaternary fault—Dotted where concealed
Interstate route marker
0 5 10 MILES
0 5 10 KILOMETERS

Base from the U.S. Geological Survey National Elevation dataset, accessed 2012 at *http://ned.usgs.gov*.

Figure 2. Index map superimposed on digital orthophoto map showing Pleistocene Lake Manix, surficial geologic map area (red dashed line), and boundaries of 7.5' USGS quadrangles. Green line is the 543-meters above sea level (masl) highstand level that depicts the minimum extent of Lake Manix during the late Pleistocene; western margin is not known due to progradation during highstands and later burial by Mojave River alluvium. Purple line is the 558-m lake limit projected from highest unfaulted shoreline features recognized during mapping (Reheis and Redwine, 2008). CMF, Cave Mountain fault; DLF, Dolores Lake fault; MF, Manix fault; PF, Pisgah fault; TCAF, Tin Can Alley fault.

CORRELATION OF MAP UNITS

[Angled boxes represent estimated range of age uncertainty; query indicates additional age uncertainty. This map report follows the currently accepted age of 2.6 million years (Ma) for the Pliocene-Pleistocene boundary (Geological Society of America, 2012); v symbol indicates stratigraphic position of the Manix tephra]


UNCONSOLIDATED SURFICIAL DEPOSITS
Man-Made Deposits
Lacustrine Deposits
Fluvial Deposits
Alluvial-Fan Deposits
Playa and Distal-Fan Deposits
Eolian and Mixed Eolian-Alluvial Deposits
d
Ql
Ql8
Ql8o
Ql7
Ql7b
Ql7a
Ql6
Ql5
Ql4
Qfmr
Qyfmr
Qysl
Qyf
Qyaf
Qif
Qof
Tqg
Qya
Qyay
Qyao
Qia7
Qia
Qia6
Qia5
Qia4
Qoa
Qalg
Qvg
Unconformity
QTalg
Tbrg
QTvg
QTcg
QTgu
Tgg
Qp
Qmr
Ta
Qye
Qyea
Qyeay
Qyeao
Qiea
BEDROCK UNITS
Tvs
Unconformity
Br
Present
12 ka
126 ka
780 ka
2.6 Ma
5.3 Ma
Holocene
late Pleistocene
middle Pleistocene
early Pleistocene
Pleistocene
Pliocene
Miocene
QUATERNARY
TERTIARY
JURASSIC

LIST OF MAP UNITS

[Unit names are locally queried where identification is uncertain. Ages of alluvial and eolian deposits are classified as young, intermediate, and old based on surface micro-topography, pattern and degree of channel dissection of alluvial-fan surfaces, degree of soil development, desert pavement development, and intensity of rock varnish developed on surface clasts (Miller and others, 2009). Units so classified based on field observations are extended into additional areas through interpretation of aerial photographs. Correlations with locally dated deposits provide age control for these deposits (Bedford, 2003; Miller and others, 2010). This map report follows the currently accepted age of 2.6 Ma for the Pliocene-Pleistocene boundary (Geological Society of America, 2012), and thus revises the age of some units such as the informal Mojave River formation.

Due to the addition of a shaded relief base, colors on the List of Map Units, the Correlation of Map Units, and the Combined Map Units may not exactly match unit colors on the map]

UNCONSOLIDATED SURFICIAL DEPOSITS

Man-Made Deposits

d	**Disturbed areas (modern)**

Lacustrine Deposits

Ql	**Lacustrine deposits, undivided (late and middle Pleistocene)**
Ql8	**Lacustrine deposits, unit 8 (late Pleistocene)**
Ql8o	**Lacustrine deposits, older unit 8 (late Pleistocene)**
Ql7	**Lacustrine deposits, unit 7 (early late Pleistocene and middle Pleistocene)**
Ql7b	**Lacustrine deposits, unit 7b (early late Pleistocene and late middle Pleistocene)**
Ql7a	**Lacustrine deposits, unit 7a (middle Pleistocene)**
Ql6	**Lacustrine deposits, unit 6 (middle Pleistocene)**
Ql5	**Lacustrine deposits, unit 5 (middle Pleistocene)**—Shown in sections on sheet 2 only
Ql4	**Lacustrine deposits, unit 4 (middle Pleistocene)**

Fluvial Deposits

Qfmr	**Active channel of the Mojave River (late Holocene)**
Qyfmr	**Mojave River fluvial deposits (Holocene and late Pleistocene)**
Qysl	**Young slackwater deposits (Holocene)**
Qyf	**Young fluvial deposits (Holocene and late Pleistocene)**
Qyaf	**Alluvial deposits of paleovalley fill (Holocene and late Pleistocene)**
Qif	**Intermediate fluvial deposits (late Pleistocene)**
Qof	**Older fluvial deposits (middle Pleistocene)**
Tqg	**Quartz-rich conglomerate (Miocene)**

Alluvial-Fan Deposits

Qya	**Young alluvial-fan deposits, undivided (Holocene and late Pleistocene)**
Qyay	**Young alluvial-fan deposits, younger subunit (late Holocene)**
Qyao	**Young alluvial-fan deposits, older subunit (Holocene and late Pleistocene)**
Qia	**Intermediate alluvial-fan deposits, undivided (early late Pleistocene and middle Pleistocene)**
Qia7	**Alluvial-fan deposits, unit 7 (late Pleistocene)**
Qia6	**Alluvial-fan deposits, unit 6 (middle Pleistocene)**
Qia5	**Alluvial-fan deposits, unit 5 (middle Pleistocene)**—Shown in sections on sheet 2 only
Qia4	**Alluvial-fan deposits, unit 4 (middle Pleistocene)**—Shown in sections on sheet 2 only
Qoa	**Older alluvial-fan deposits (middle and early Pleistocene)**
Qalg	**Arkosic-lithic fanglomerate (middle and early Pleistocene)**
Qvg	**Younger volcanic fanglomerate (middle and early Pleistocene)**
QTgu	**Fanglomerate, undifferentiated (early Pleistocene? and Pliocene?)**
QTalg	**Older arkosic-lithic fanglomerate (early Pleistocene? and Pliocene)**
QTcg	**Fanglomerate of Cave Mountain (early Pleistocene? and Pliocene)**
QTvg	**Older volcanic fanglomerate (early Pleistocene? and Pliocene?)**
Tbrg	**Fanglomerate of Buwalda Ridge (Pliocene)**
Tgg	**Granitic fanglomerate (Pliocene and late Miocene?)**

Playa and Distal-Fan Deposits

Qp	**Playa and distal-fan deposits (middle Pleistocene)**
Qmr	**Mojave River formation (informal) (middle and early Pleistocene)**
Ta	**Playa and distal alluvial-fan deposits (Pliocene)**

Eolian Deposits

Qye	**Young eolian deposits (Holocene and late Pleistocene)**
Qyea	**Young mixed eolian and alluvial-fan deposits, undivided (Holocene and late Pleistocene)**
Qyeay	**Young mixed eolian and alluvial-fan deposits, younger subunit (late Holocene)**
Qyeao	**Young mixed eolian and alluvial-fan deposits, older subunit (Holocene and late Pleistocene)**
Qiea	**Older mixed eolian and alluvial-fan deposits (late and middle Pleistocene)**

BEDROCK UNITS

Tvs	**Volcanic and sedimentary rocks, undivided (Miocene)**
Br	**Plutonic rocks (Jurassic?)**

COMBINED AND FRACTIONAL MAP UNIT SYMBOLS

[Combined map symbols (for example, Qyao+Qyay) are used where two Quaternary map units are interspersed at such a small scale that separating map units was impractical. The first unit listed is considered dominant in the area; the second unit must occur in at least 20 percent of the area to be listed. Fractional map symbols (for example, Qia7/Ql7) are used where a thin veneer of a younger unit (Qia7) overlies an older unit (Ql7), especially common for alluvial-fan deposits interbedded with lacustrine sediment and for eolian deposits. Unit names are locally queried where identification is uncertain. Dashes between units indicate all units stratigraphically between the two listed may be present; for example Ql7-Ql4 means that units Ql7, Ql6, Ql5, and Ql4 are all present.

Most combined map units are depicted using the dominant unit color and a label. However, some combined units are shown using a pattern in addition to the color of the dominant unit to enhance visual clarity. Some units have a combination of more than one unit for a veneer or fraction. In those instances, the pattern for the dominant veneer was used over the dominant or oldest fraction or combination. Please see unit labels on map sheet 1]

Combined Map Units with Patterns
[Not all combined units have patterns]

- Qyay+Qyao
- Qyay+Qye
- Qyao+Qyay
- Qia7+Ql7
- Qyao+Ql8
- Qia7+Ql8

Fractional Map Units

- **Thin veneer of Ql8 over older units**—Units include: Ql8/(Qiea+Ql7), Ql8/Qia7, Ql8/Qiea, Ql8/Ql7, Ql8/Ql7/Ql6, Ql8/Ql7/Qvg, and Ql8/Qvg
- **Thin veneer of Ql8o over Qai7**
- **Thin veneer of Ql7 over older units**—Units include: Ql7/QTalg, Ql7/Qalg, Ql7/Qia, Ql7/Ql5?/Ql4, Ql7/Ql6, Ql7/Ql6/Ql4, and Ql7/Qvg
- **Thin veneer of Ql6 over older units**—Units include: Ql6/Qia and Ql6/Qvg
- **Thin veneer of Ql over Qalg**
- **Thin veneer of Qyfmr over older units**—Units include: Qyfmr/QTcg, Qyfmr/Qof, Qyfmr/Qvg, Qyfmr/Qvg/Qalg, Qyfmr/Ta
- **Thin veneer of Qof exists over older units**—Units include: Qof/Ta and Qof?/Ta
- **Thin veneer of Qya exists over older units**—Units include: Qya/Ql6, Qya/Qvg, and Qya/ Qyfmr
- **Thin veneer of Qyay over Qyfmr**
- **Thin veneer of Qyao exists over older units**—Units include: Qyao/Talg, Qyao/Qia, Qyao, Qia7, Qyao/Ql7, Qyao/Ql8, Qyao/Ql8/Ql7, Qyao/Qvg, Qyao/Qye, Qyao/Qyfmr, Qyao/Qyfmr/Qmr, Qyao/Tgg, and Qyao/Tgg?
- **Thin veneer of Qia exists over older units**—Units include: Qia/QTalg, Qia/QTcg, Qia/Qoa, and Qia/Qvg
- **Thin veneer of Qia7 over older units**—Units include: Qia7/QTalg, Qia7/Ql7, Qia7/Ql7/Qalg, Qia7/Ql7/Ql6, and Qia7/Ql7b
- **Thin veneer of Qia6 exists over older units**—Units include: Qia6-5/Ql5/Ql4, Qia6-4/Ql4, Qia6-4/Ql4/Qalg, Qia6/Ql6, Qia6/Ql6/Qia, and Qia6/Qof
- **Thin veneer of Qalg exists over Tgg**
- **Thin veneer of Qvg exists over older units**—Units include: Qvg/Qmr and Qvg/Ta
- **Thin veneer of Qye over older units**—Units include: Qye/Qtvg, Qye/Qia/QTalg, Qye/Qia7, Qye/Ql7, Qye/Ql8, Qye/Qmr, Qye/Qvg, Qye/Qyao, Qye/Qyay, Qye/Qyfmr, Qye/Tgg, and Qye/Tgg?
- **Thin veneer of Qyea over older units**—Units include: Qyea/QTalg, Qyea/Ql7, Qyea/Ql8, and Qyea/Qvg
- **Thin veneer of Qyeao over older units**—Units include: Qyeao/Ql7 and Qyeao/Ql8
- **Thin veneer of Qiea exists over older units**—Units include: Qiea/QTalg and Qiea/QTcg

EXPLANATION

- **Contact**—Dashed where approximately located, dotted where concealed; queried where identity or existance questionable
- **Gradational contact**—Gradual or continuous lithologic change from one geologic unit to another
- **Fault**—Dashed where approximately located; dotted where concealed. Question mark where queried. Red arrows show strike and dip of beds adjacent to fault
- **Beach ridges**—Elongate ridges of beach deposits (sand and gravel) deposited by storm waves roughly parallel to the paleoshoreline
- **Scarp on fault**—Hachures on downthrown side
- **Inclined bedding**—Showing strike and dip
- ● M09–25 **Station point with number (when layer is turned on)**—See tables for detailed information

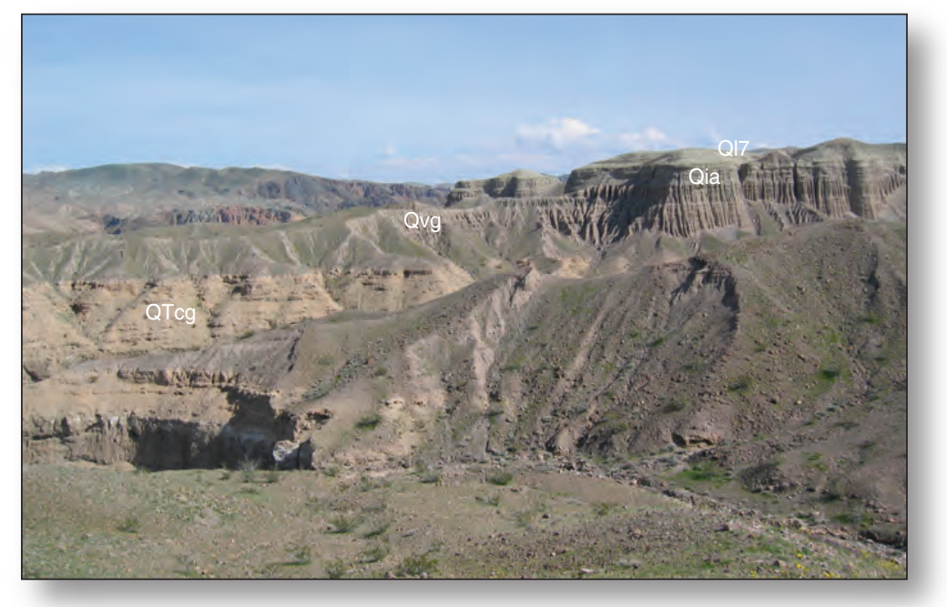

Ql7
Qia
Qvg
QTcg

Photo 43. View to east showing sequence of lacustrine and alluvial deposits south of Mojave River near Afton Canyon and eastern margin of Afton subbasin. Unit Ql7 (green mud) caps right skyline; overlies weakly consolidated alluvial-fan gravel of unit Qia, in turn conformably overlying unit Qvg (light brown, forming steep slopes in middle ground). Qvg rests unconformably on pinkish deposits of unit QTcg in left middle ground (photo index number 05–84).

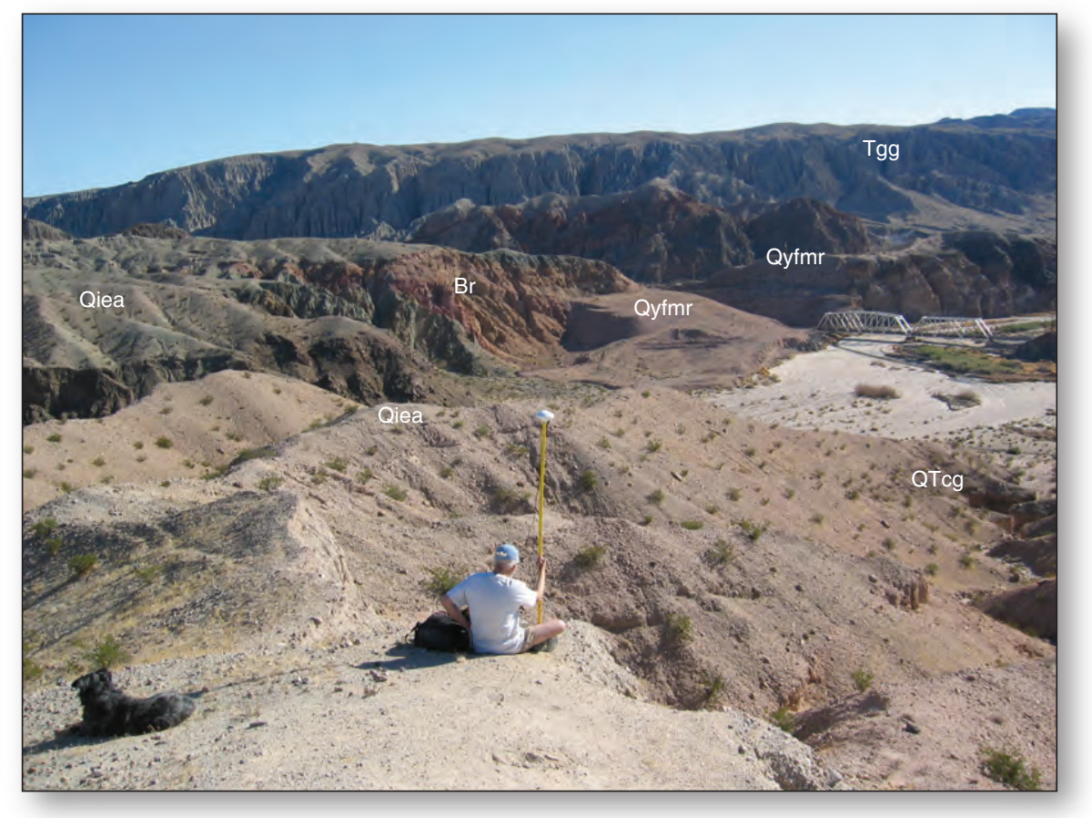
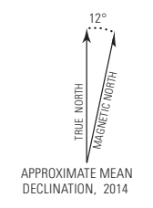

Tgg
Qyfmr
Qiea
Br
Qyfmr
Qiea
QTcg

Photo 24. View to southeast of strath terraces capped by Mojave River gravel (Qyfmr) near the head of Afton Canyon. Straths are inset into various units, including unit Tgg forming skyline and plutonic rocks (Br) in middle ground. Also inset below deposits of Lake Manix overlying units Qiea and QTcg. Mojave River (Qyfmr) and railroad bridge in right middle ground (photo index number 06–77).

Topographic base modified from U.S. Geological Survey US Topo 1:24,000 Alvord Mountain East, Dunn, Cave Mountain, Manix, Hidden Valley West, and Hidden Valley East, Calif., 2012
North American Datum of 1983 (NAD83), World Geodetic System of 1984 (WGS84)
Projection and 1 000-meter grid: Universal Transverse Mercator, zone 11S
10 000-foot ticks: California Coordinate System of 1983 (zone 5)
Orthographic image derived from National Agriculture Imagery Program, California, (NAIP, *https://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai*), accessed 2012
10-meter contours and shaded relief (used in mapped area only) from U.S. Geological Survey 10-meter National Elevation Dataset Digital Elevation Model (NED, *http://nationalmap.gov/elevation.html*), accessed 2012.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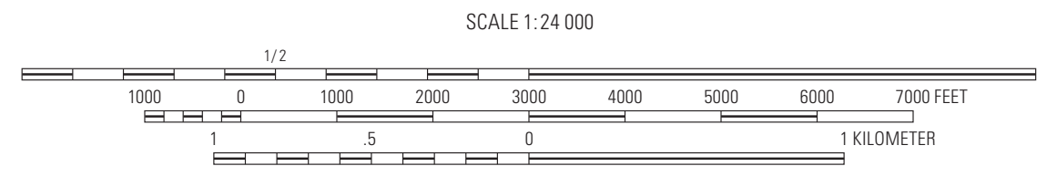
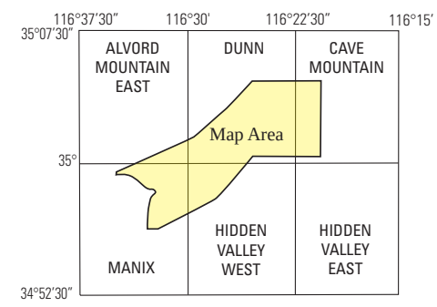
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2014


SCALE 1:24 000
1/2
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 50 METERS (MAPPED AREA ONLY)
NORTH AMERICAN VERTICAL DATUM OF 1988

LOCATION OF MAP AREA


116°37'30"
116°30'
116°22'30"
116°15'
35°07'30"
35°
34°52'30"
ALVORD MOUNTAIN EAST
DUNN
CAVE MOUNTAIN
Map Area
MANIX
HIDDEN VALLEY WEST
HIDDEN VALLEY EAST

LOCATION OF MAP AREA

Mapping in eastern one-third of area by J.R. Redwine; mapping in western two-thirds by M.C. Reheis.
Digital cartography and GIS database by D. Paco VanSistine.
Edit and cartographic layout by L.J. Binder
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Map of Surficial Geology and Stratigraphy of Pleistocene Lake Manix, San Bernardino County, California

By

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2014

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[2] U.S. Bureau of Reclamation

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