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

Prepared in cooperation with the
MOJAVE WATER AGENCY
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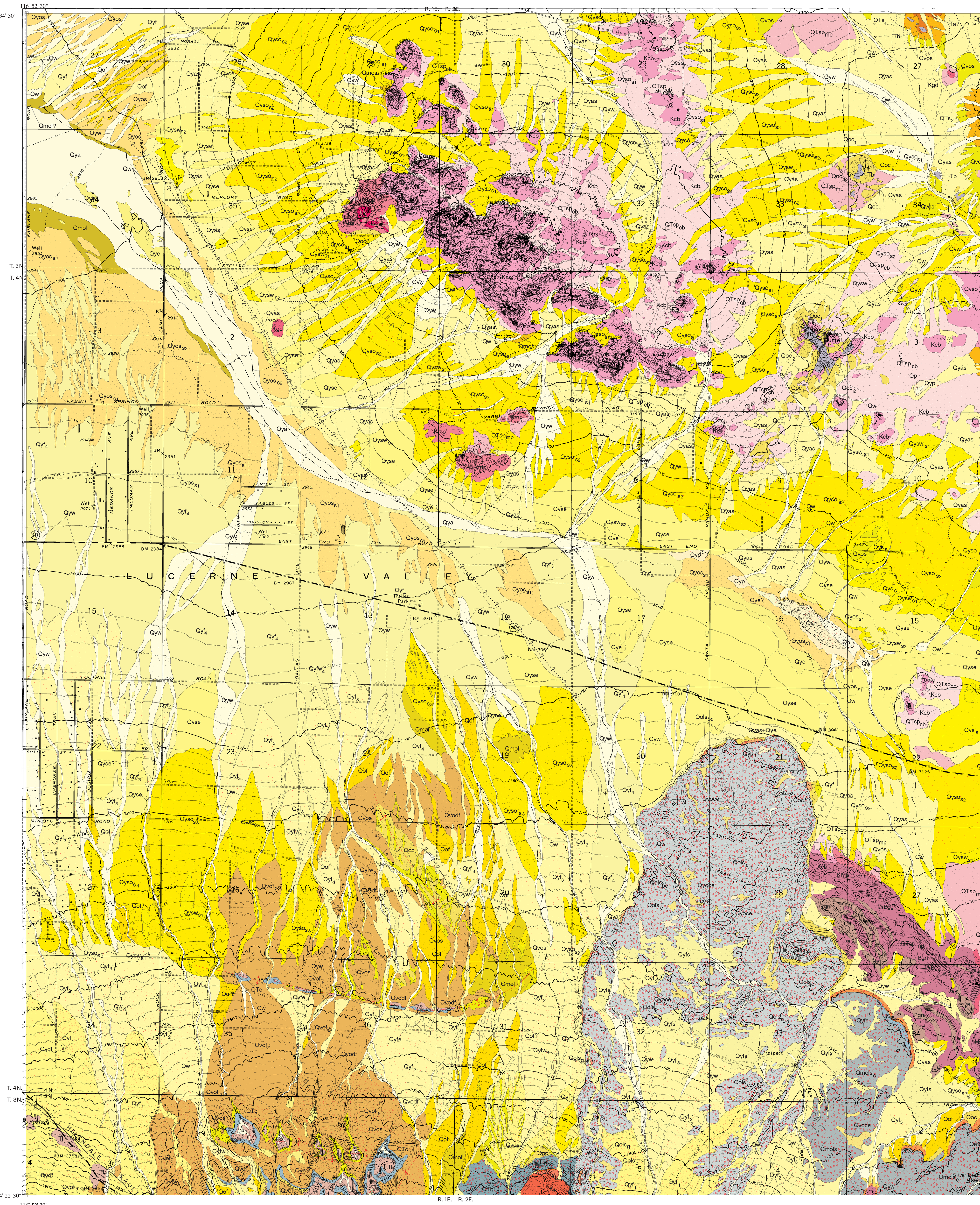
CALIFORNIA DIVISION OF MINES AND GEOLOGY

OPEN-FILE REPORT
00-175, Version 1.0
Pamphlet accompanies map



Base from U.S. Geological Survey 7.5' Cougar Buttes quadrangle, 1971
Polyconic projection

Geology mapped by R.E. Powell, 1995-98; J.C. Matti, 1995-98

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET

GEOLOGIC MAP AND DIGITAL DATABASE OF THE COUGAR BUTTES 7.5' QUADRANGLE, SAN BERNARDINO COUNTY, CALIFORNIA

Version 1.0

By

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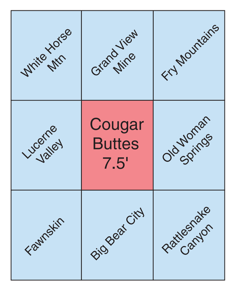
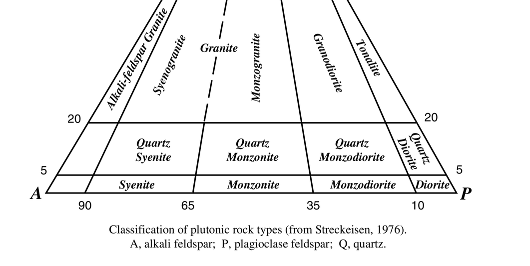


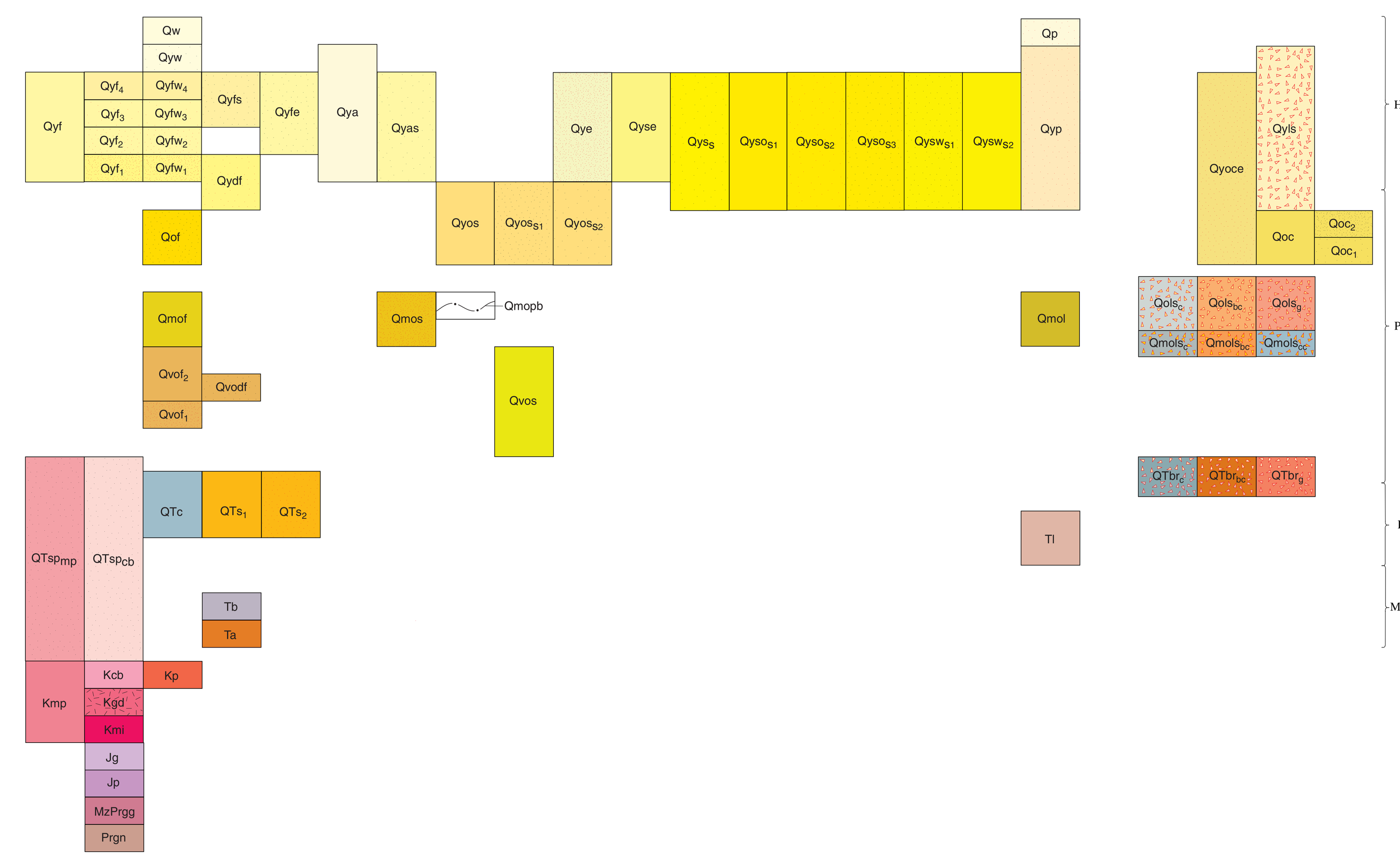
SURROUNDING 7.5' QUADRANGLES



Classification of plutonic rock types (from Streckeisen, 1976). A, alkali feldspar; P, plagioclase feldspar; Q, quartz.

The matrix color of surficial materials and their pedogenic soils is classified according to the Munsell soil-color charts (Munsell, 1975).

CORRELATION OF MAP UNITS



Contact—Solid where location meets map accuracy standard (±15 m); dashed where approximately located, may not meet map accuracy standard; dotted where concealed by mapped or unmapped covering unit

Contact—Internal. Approximately located, may not meet map accuracy standard. On bajadas, separates alluvial deposits derived from different drainages or gravelly proximal fan facies from sandy distal fan facies. In carbonate landslide breccia deposits, separates upper, more cemented breccia from lower, less cemented breccia

Contact—Geomorphically defined boundary between young alluvial fan deposits and their feeder wash deposits. Approximately located, may not meet map accuracy standard

Contact—Questionable. Dashed where approximately located, may not meet map accuracy standard; dotted where concealed. Inferred zone of differential movement within landslide breccia deposits

Fault—High angle, observed. Approximately located, may not meet map accuracy standard; dotted where concealed

Fault—High angle, inferred. Dashed where approximately located, may not meet map accuracy standard; dotted where concealed; queried where existence questionable

Thrust fault—Low angle, older-over-younger. Approximately located, may not meet map accuracy standard. Contained within landslide breccia deposits

Fault—Low angle, younger-over-older. Approximately located, may not meet map accuracy standard. In Tertiary and (or) Quaternary breccia deposits

Marker bed—Buried soil B-horizon (Qmopb). Location meets map accuracy standard (±15 m)

Anticline

Syncline

Strike and dip of bedding in sedimentary strata

10 **Inclined**

Strike and dip of foliation and layering in metamorphic rocks

40 **Inclined**

37 **Bearing and plunge of minor fold axis and parallel lineation**

DESCRIPTION OF MAP UNITS

YOUNGEST DEPOSITS—Deposits in washes incised into all older units and graded to base level playa deposits in Lucerne Valley and Fry and Johnson valleys. Geomorphic surfaces characterized by active and recently active sediment accumulation; little or no soil-profile development

Qw **Active wash deposits (late Holocene)**—Unconsolidated medium- to coarse-grained sand and sandy gravel with subordinate fine sand and silt; white; bar and swale morphology. No soil profile development. Unvegetated. Transported and deposited in most recently active channels incised into young wash (Qyw) and older deposits. Mostly sand in washes on slopes flanking granite inselbergs. As mapped, unit contains young wash deposits (Qyw) where they are not mapped separately in terraces along wash margins and as islands within active channels

Qp **Active playa deposits (late Holocene)**—Micaceous silt and clay with minor sand. Occupy most recently flooded areas of playas. Surface is white and exhibits mudcracks. Surface of playa near east margin of map and just north of State Highway 247 is characterized by abundant pebble-sized angular fragments of calcrete. No soil profile development. Unvegetated

Qyw **Young wash deposits (late Holocene)**—Unconsolidated to slightly consolidated medium- to coarse-grained sand and sandy gravel with subordinate fine sand and silt; light gray (2.5YR 7/2) to pale yellow. Little or no soil profile development. Sparsely to moderately vegetated. Transported and deposited in channels incised into young fan (Qyf) and older deposits. Incised by active wash channels. As mapped, unit includes small fans at base of Cougar Buttes inselberg and active wash deposits where they are not mapped separately

YOUNG DEPOSITS—Deposits in washes incised into Pleistocene and older units, in alluvial fans and sheet wash on piedmont slopes, and in base-level playas. Units exhibit slightly dissected geomorphic surfaces and include latest Pleistocene through late Holocene deposits. These deposits form a thin mantle of unconsolidated sand and gravel draped over an inherited Pleistocene landscape. Rarely thicker than about 3 m; typically less than 2 m thick

Qya **Young axial valley deposits (late and (or) middle Holocene)**—Unconsolidated silt and fine sand; some interbedded sand and fine gravel. White to pale brown. Sparsely to moderately vegetated. Deposited in broad wash that occupies Lucerne Valley between Cougar Buttes and the San Bernardino Mts. piedmont

Qyp **Young playa deposits (Holocene and (or) latest Pleistocene)**—Micaceous silt and clay with minor sand; scattered granules and pebbles; very pale to pale brown. Light-colored surface. Little or no soil profile development. Sparsely to moderately vegetated. As mapped, unit contains active playa deposits (Qp) where these deposits are not mapped separately; as mapped in small playas on Blackhawk landslide, may include old playa deposits. Older parts of this unit overlain locally by windblown sand, distal fan, and slope wash deposits

Qyls **Young landslide deposits (Holocene and (or) latest Pleistocene)**—Slope failure deposits on clay-rich fluvio-lacustrine strata (Tl)

Qyf **Young alluvial fan deposits (late and (or) middle Holocene)**—Nested complex of alluvial fans deposited as a thin veneer on the north piedmont of San Bernardino Mts. Fans grew progressively northward down the piedmont across a landscape inherited from the Pleistocene. Abandoned, slightly dissected geomorphic surfaces characterized by Av/Cox and Av/Bw/C soil profiles typical of middle to early late Holocene surfaces (Bull, 1991, p. 54, 68, 75, 86; Eppes and others, 1998). Av horizons consist of loess-like, vesicular light brown (10YR 6/4) calcareous silt. Buried early Holocene and latest Pleistocene deposits may be present. Includes:

Qyf_4 **Young alluvial fan deposits, unit 4 (late and (or) middle Holocene)**—Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted; very pale brown (10YR 7/3). Sand is medium- to coarse-grained; gravel clasts are mostly pebbles with scattered cobbles. Debouched low on piedmont from feeder channels incised into unit 2 fan deposits. Surface morphology is smoother than that of older young fan units

Qyf_3 **Young alluvial fan deposits, unit 3 (late and (or) middle Holocene)**—Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted; pale brown (10YR 6/3). Sand is medium- to coarse-grained; gravel includes mostly pebbles and cobbles. Debouched mid-piedmont from feeder channels incised into unit 2 fan deposits. Surface exhibits prominent bar and swale morphology. Surfaces have slightly to moderately varnished pebbly pavements underlain by Av horizon

Qyf_2 **Young alluvial fan deposits, unit 2 (late and (or) middle Holocene)**—Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted. Sand is medium- to coarse-grained; gravel includes pebbles, cobbles, and boulders. Debouched high on piedmont from feeder channels incised into unit 1 fan deposits. Surface exhibits prominent bar and swale morphology; swales and distal surfaces have slightly to moderately varnished pebbly pavements underlain by Av horizon

Qyf_1 **Young alluvial fan deposits, unit 1 (late and (or) middle Holocene)**—Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted. Sand is medium- to coarse-grained; gravel includes pebbles, cobbles, and boulders. Debouched high on piedmont proximal to canyon mouths. Surface exhibits prominent bar and swale morphology. Moderate varnish on surface clasts gives these deposits a relatively dark color compared to younger units. As mapped, unit may include early Holocene deposits

Young alluvial fan feeder wash deposits (late and (or) middle Holocene)—Sand and gravel deposited in feeder channels to alluvial fans. The distinction between feeder wash deposits and alluvial fan deposits is one of geomorphic position rather than a lithologic difference. Bounding contacts are placed approximately at the mouth of the feeder wash and the apex of the fan deposits. Includes:

$Qyfw_4$ **Young alluvial fan feeder wash deposits, unit 4 (late and (or) middle Holocene)**—Sand and gravel deposited in feeder channels to young alluvial fans of unit 4

$Qyfw_3$ **Young alluvial fan feeder wash deposits, unit 3 (late and (or) middle Holocene)**—Sand and gravel deposited in feeder channels to young alluvial fans of unit 3

$Qyfw_2$ **Young alluvial fan feeder wash deposits, unit 2 (late and (or) middle Holocene)**—Sand and gravel deposited in feeder channels to young alluvial fans of unit 2

$Qyfw_1$ **Young alluvial fan feeder wash deposits, unit 1 (late and (or) middle Holocene)**—Sand and gravel deposited in feeder channels to young alluvial fans of unit 1. As mapped, unit may include early Holocene deposits

Qyfs **Young alluvial fan sand deposits (late and (or) middle Holocene)**—Distal sand skirts that accumulated at toes of alluvial fans where they have buttressed against local high-ground on the piedmont. Deposits include sheet wash and eolian sand

Qyfe **Young alluvial fan and eolian deposits (Holocene)**—Abandoned alluvial fan surface with windblown sand

Qyas **Young alluvial and slope wash deposits (Holocene)**—Alluvial and slope wash apron on flanks of inselbergs. Unit includes sand and pebbly sand deposited by channelized flow on small alluvial fans and in small washes, and by unconfined overland flow across older surfaces. As mapped, includes some younger late Holocene slope wash deposits

Qye **Young eolian deposits (Holocene)**—Windblown sand in relict dunes, ramps, and coppices. Unconsolidated and pale yellow on natural surfaces; firm to indurated and slightly reddened where exposed in roadcuts. Deposited on moderately old lacustrine deposits (Qmol), on pavemented surface of old alluvial fan deposits (Qof), and on pavemented surface of young(?) and old slope wash and alluvial deposits (Qyos). Includes sand ramps on toe of Blackhawk landslide. As mapped, unit may include late Pleistocene eolian deposits, especially if the surface of Qyos is entirely Pleistocene in age

Young slope wash and alluvial deposits (Holocene and latest Pleistocene?)—Veneers of unconsolidated sand and pebbly sand that mantle piedmont slopes flanking the San Bernardino Mts. and Mojave Desert inselbergs. Slope wash units exhibit slightly dissected geomorphic surfaces characterized by Av/Cox and Av/Bw/C soil profiles typical of middle to early late Holocene surfaces (Bull, 1991, p. 54, 68, 75, 86; Eppes and others, 1998). Buried early Holocene and latest Pleistocene deposits are probably present. Units are distinguished by lithology and by the character of their substrate. Deposited on surfaces that predate young fan deposits (Qyf), but surficial processes continued on these surfaces during deposition of fan deposits and on some slopes continued into the late Holocene as well. Includes:

Qyse **Young slope wash, alluvial, and eolian deposits (Holocene)**—Sand and pebbly sand with reworked and admixed windblown sand. No bar and swale morphology is evident. Surface darker than adjacent young fan deposits (Qyf_4) and characterized by a mottled appearance on aerial photographs, presumably due to the presence of mounded windblown sand. Substrate of this unit is cryptic: may be young alluvial or colluvial deposits modified by younger surficial reworking or may mask Pleistocene deposits

Qys_S **Young slope wash and alluvial deposits, sandstone substrate (Holocene and latest Pleistocene?)**—Sand and pebbly sand. Continuous with surficial deposits that overlie Quaternary and (or) Tertiary sandstone (QTs_1) just east of the quadrangle boundary

Young slope wash and alluvial deposits, oxidized (Holocene and latest Pleistocene?)—Sand and pebbly to cobbly sand that occur as aprons on mountain-front and inselberg piedmonts. Thickest where buttress against inselbergs or range-front, tapering down-piedmont into thin veneers on older Pleistocene deposits. These aprons appear to have been active from the latest Pleistocene through the middle Holocene. Surface characterized by oxidized grains of potassium feldspar that range in color from reddish yellow (5YR 6/6 to 7/6) to yellowish red (5YR 5/6) to pink (5YR 7/4); appears orange on color aerial photographs. These grains occur as veneer underlain by a pedogenic Av horizon of loess-like, vesicular very pale brown (10YR 7/3) calcareous silt, typically 1 to 4 cm thick. Av horizon underlain by pale brown (10YR 6/3 to 6.5/3) to light yellowish brown (10YR 6/4) sand. Although these slope wash deposits are incised by channels in which young wash (Qyw) and alluvial fan (Qyf) deposits have accumulated, slope processes continued on surviving surfaces. As mapped, the surface of this unit at least locally has accumulated late Holocene sheet flood and channelized flow deposits. Unit occurs as a veneer on older surficial deposits and is subdivided by the character of its substrate. Includes:

$Qyso_{S1}$ **Young slope wash and alluvial deposits, oxidized, substrate 1 (Holocene and latest Pleistocene?)**—Loose surficial sediment passes down firmer alluvial and slope wash and alluvial deposits high on the slopes flanking inselbergs. These deposits redden with depth and contain one or more buried soil horizons. In places reddened soil contains scattered equant blebs of filamentous calcite, indicating an incipient (Stage I) calcic soil. Unit overlies a substrate of moderately old slope wash and alluvial deposits (Qmos) with a strongly reddened, argillic pedogenic B-horizon (Qmopb) which grades down into strongly (Stage III-IV) calcic soil. Oxidized slope wash deposits overlap older deposits onto pediments underlain by saprolitic granite

$Qyso_{S2}$ **Young slope wash and alluvial deposits, oxidized, substrate 2 (Holocene and latest Pleistocene?)**—On middle reaches of slopes flanking inselbergs, underlain by a substrate of strongly reddened, argillaceous B-horizon (Qmopb) 10 to 40 cm thick. This buried soil overlies firm to hard, pervasively cemented (Stage V-VI) slope wash deposits (Qvos). On surface veneer, orange feldspar grains accompanied by scattered angular fragments of white to tan calcrete

$Qyso_{S3}$ **Young slope wash and alluvial deposits, oxidized, substrate 3 (Holocene and latest Pleistocene?)**—Oxidized slope wash and alluvium deposited on a substrate of moderately old and (or) very old fan deposits on the middle to upper piedmont of the San Bernardino Mts.

Young slope wash and alluvial deposits, white (Holocene and latest Pleistocene?)—Sandy slope wash and alluvium with abundant fragments of calcrete. Includes:

$Qysw_{S1}$ **Young slope wash and alluvial deposits, white, substrate 1 (Holocene and latest Pleistocene?)**—Sandy slope wash and alluvium with abundant fragments of calcrete, interpreted as reworked from underlying cemented Pleistocene very old slope wash or alluvial fan deposits (Qvos)

$Qysw_{S2}$ **Young slope wash and alluvial deposits, white, substrate 2 (Holocene and latest Pleistocene?)**—Sandy slope wash and alluvium with abundant fragments of calcrete, interpreted as reworked from underlying cemented Pleistocene slope wash or alluvial fan deposits

Qyoce **Young and old colluvial and eolian deposits (Holocene and late Pleistocene)**—Old colluvium in depressions on Blackhawk landslide breccia mantled by old and young windblown sand and silt

Qydf **Young debris flow fan deposits (early Holocene or latest Pleistocene)**—Unsorted bouldery debris flows with boulders of biotite monzogranite as large as 2 m in diameter. Surface morphology is hummocky and exhibits debris flow levees

Qyos **Young(?) and old slope wash and alluvial deposits (Holocene? and Pleistocene)**—Weakly to moderately pavemented slope wash and alluvium. Pavement consists of scattered, moderately varnished pebbles and small cobbles underlain by Av horizon of vesicular calcareous silt. On Cushenbury fan, pavement and Av horizon overlie chalky-cemented, unsorted sand and pebbly sand; firm to hard; cemented to moderately well cemented. Bedding features absent or obscured by cementation process. Cemented deposits exposed in trenches, roadcuts, and roadbeds. Around small playa in east-central part of quadrangle, pavement and Av horizon overlie strongly reddened argillic B-horizon mottled with abundant coarse, white calcite nodules 1 to 4 cm in diameter. This texture indicates carbonate illuviation subsequent to formation of the argillic B-horizon and is consistent with a polygenetic origin for the soil profile (Bull, 1991, p. 73, 107-112). As mapped, unit is partially covered by windblown sand and incised by shallow channels containing young wash deposits. Logs from commercially drilled water wells indicate that this unit is a thin cap above interbedded lacustrine clay and fluvio-lacustrine silt, sand, and fine gravel. In wells spudded below about 2,900 ft, the unit overlies deposits described as clay, interpreted herein as lake deposits. In wells spudded above 2,900 ft, the unit overlies deposits described as sand and gravel, interpreted herein as distal fan-delta deposits. Unit is subdivided by the character of its observed and inferred substrate. Includes:

$Qyos_{S1}$ **Young(?) and old slope wash and alluvial deposits, substrate 1 (Holocene? and Pleistocene)**—Deposits as described for Qyos; interpreted from mapped distribution and from water well logs to overlie lacustrine deposits

$Qyos_{S2}$ **Young(?) and old slope wash and alluvial deposits, substrate 2 (Holocene? and Pleistocene)**—Deposits as described for Qyos; interpreted from water well logs to overlie fan-delta fluvio-lacustrine deposits

OLD SURFICIAL DEPOSITS—Deposits in alluvial fans, on piedmont slopes, and in colluvial debris aprons. Old deposits exhibit slightly to moderately dissected geomorphic surfaces; granitic debris characterized by Av/Bt/Bk/Cox soil profiles. These deposits form a thin mantle of consolidated sand and gravel draped over an inherited older Pleistocene landscape; rarely observed to be thicker than about 2 m

Qof **Old alluvial fan deposits (late Pleistocene)**—Sand and pebbly to cobbly gravel. Well developed pavement with moderately to strongly varnished pebbles. Pavement underlain by pedogenic Av horizon of very pale brown (10YR 7/3) loess-like, vesicular silt. Graded to base-level lakes with prominent shoreline gravel beach and bar deposits in Lucerne Valley west of the Cougar Buttes quadrangle and in Fry and Johnson valleys to the east

Qoc **Old colluvial deposits (late Pleistocene)**—Varnished debris aprons on recessive slopes below resistant cap rocks; varnished lag gravels. Around basalt-capped buttes on Cougar Buttes, colluvial aprons of basalt debris blanket slopes on more readily eroded granite, saprolite, and sedimentary rocks that underlie the basalt. On hogbacks developed in tilted strata on the San Bernardino Mts. piedmont, colluvial aprons of limestone debris from resistant conglomerate beds blanket slopes on underlying clay beds. On very old slope debris deposits (Qvos) and on conglomeratic sandstone deposits (QTs_1), colluvial deposits consist of lag gravels with varnished pebbles and cobbles. Debris aprons typically are dissected and partially eroded, leaving resistant flatirons of relict colluvium on slopes eroded into less resistant substrate. Includes:

Qoc_2 **Old colluvial deposits, unit 2 (late Pleistocene)**—Colluvial debris aprons preserved in flatirons on steeper slopes adjacent to cap rock

Qoc_1 **Old colluvial deposits, unit 1 (late Pleistocene)**—Colluvial debris aprons in flatirons on gentler slopes more distant from present exposures of cap rock

Old landslide breccia (middle or early Pleistocene)—Rock avalanche breccia that constitutes the Blackhawk landslide. Breccia is derived chiefly from metamorphosed Paleozoic carbonate strata and subordinately from Pliocene conglomeratic sandstone and granitic rocks. Cemented carbonate breccia is overlain in swales on landslide surface by pedogenic Av horizon of loess-like, vesicular calcareous silt as thick as 6 cm. Includes:

$Qols_c$ **Old landslide breccia, carbonate-rock (middle or early Pleistocene)**—Rock avalanche breccia derived from metamorphosed Paleozoic carbonate strata

$Qols_{bc}$ **Old landslide breccia, strata of Blackhawk Canyon (middle or early Pleistocene)**—Rock avalanche breccia derived from Pliocene conglomeratic sandstone that constitute the strata of Blackhawk Canyon and lacustrine brown clay and silt (Tl)

$Qols_g$ **Old landslide breccia, granitic rocks (middle or early Pleistocene)**—Rock avalanche breccia derived from granitic rocks

MODERATELY OLD SURFICIAL DEPOSITS—Deposits in alluvial fans and on pediments. Older deposits exhibit moderately to strongly dissected geomorphic surfaces; granitic debris characterized by Av/Bt/Bk/Cox soil profiles. On deposits rich in granitic debris, argillic B-horizons are reddened to 7.5 YR to 5 YR hues; Stage III-IV carbonate morphology

Moderately old landslide breccia (middle or early Pleistocene)—Rock avalanche breccia that constitutes the Silver Reef breccia of Shreve (1968). Pedogenic Av horizon of loess-like, vesicular calcareous silt as thick as 6 cm developed in swales on surface of landslide. Breccia is derived chiefly from metamorphosed Paleozoic carbonate strata and subordinately from Pliocene conglomeratic sandstone and Mesozoic granitic rocks. Includes:

$Qmols_c$ **Moderately old landslide breccia, carbonate rocks (middle or early Pleistocene)**—Rock avalanche breccia derived from metamorphosed Paleozoic carbonate strata

$Qmols_{bc}$ **Moderately old landslide breccia, strata of Blackhawk Canyon (middle or early Pleistocene)**—Rock avalanche breccia derived from Pliocene conglomeratic sandstone that constitute the strata of Blackhawk Canyon and lacustrine brown clay and silt (Tl)

$Qmols_{cc}$ **Moderately old landslide breccia, conglomerate of Cushenbury Springs (middle or early Pleistocene)**—Rock avalanche breccia derived from carbonate clast conglomerate

Qmopb **Moderately old pedogenic B-horizon (middle? Pleistocene)**—Reddened (7.5YR 5.5/6) to strongly reddened (5YR 5.5/6) arkosic sand with clay coatings on grains, interpreted as an argillic B-horizon. Soil profile developed on moderately old alluvial and slope wash deposits (Qmof, Qmos). Where it overlies chalky-cemented very old debris mantle deposits (Qvos), the abrupt contact with the underlying K-horizon suggests that B-horizon is actually developed on a very thin veneer of arkosic sand that overlies a pre-existing K-horizon developed on Qvos. Ranges in thickness between about 10 cm and 1 m; as mapped, may represent more than one B-horizon occupying the same broad stratigraphic position

Qmof **Moderately old alluvial fan deposits (middle Pleistocene)**—Cemented sandstone and conglomerate. Fans that occupy the mid-piedmont slope in the center of the quadrangle were derived from the range front between Cushenbury Canyon on the east and Blackhawk Canyon on the west and are composed of pebbles and cobbles of predominately carbonate rock. The fan that debouched from Cushenbury Canyon contains a mixed clast assemblage of carbonate rocks, granitic rocks, quartzite, and gneiss. Where these fans coalesce along about Camp Rock Road, deposits consist of interbedded carbonate clast conglomerate and arkosic sandstone. Similarly, the carbonate-dominated fans coalesce eastward with mixed-clast fan deposits. Where arkosic sands are present, the fan surfaces appear to have had a reddened soil. From lithologic descriptions of subsurface units in water well logs, we infer that the fan system passed basinward into fluvio-lacustrine deltas and lake-bottom deposits. Somewhat deformed in upper piedmont folds

Qmos **Moderately old slope wash and alluvial deposits (middle? Pleistocene)**—Slope wash and alluvium deposited in an apron buttressed against base of inselbergs. Rarely exposed beneath young slope wash and alluvial deposits ($Qyso_{S1}$). Qmos deposits buried the erosional landscape on which pediment flatirons had developed in well cemented very old slope wash debris aprons (Qvos); where they overlie basement, Qmos deposits filled weathered joints in saprolitic granitic rocks. Soil profile includes reddened (7.5YR 5.5/6) argillic B-horizon (Qmopb) passing down into Stage III Bk/K horizon

Qmol **Moderately old lacustrine deposits (middle Pleistocene)**—Brown clay, silty clay, and clayey silt with irregular domains of grayish calcareous clay

VERY OLD SURFICIAL DEPOSITS—Deposits in alluvial fans and on piedmont slopes. Very old deposits exhibit strongly dissected geomorphic surfaces characterized by truncated Av/K soil profiles; carbonate morphology in K horizon is consistent with pedogenesis in the range of Stage IV-VI; pervasive hard to very hard chalky cementation is typically accompanied by abundant veins of laminar calcrete

Very old alluvial fan deposits (middle and early Pleistocene)—Moderately to very well cemented fanglomerate, including fluvial and debris flow deposits. Deposits high on San Bernardino Mts. piedmont in south-central part of quadrangle are predominately limestone clasts that debouched from range-front canyons in carbonate rocks east of Cushenbury Canyon. From lithologic descriptions of subsurface units in water well logs, we infer that the fan system passed basinward into fluvio-lacustrine deltas and lake-bottom deposits. Includes:

$Qvof_2$ **Very old alluvial fan deposits, unit 2 (middle and early Pleistocene)**—Well cemented pebbly to cobbly fluvial fanglomerate; subrounded to well rounded clasts. Unit crops out in hard, resistant ledges. Moderately deformed in upper piedmont folds; deposited in channels incised into more deformed deposits of unit 1

Qvodf **Very old debris flow fan deposits (middle or early Pleistocene)**—Unsorted; massive. Angular, matrix-supported pebble- to cobble-sized clasts in sand matrix; angular to subrounded clasts. Very well cemented. Clasts are predominantly light and dark gray metamorphosed limestone. Moderately deformed in upper piedmont folds; deposited in channels incised into more deformed deposits of unit 1

$Qvof_1$ **Very old alluvial fan deposits, unit 1 (middle and early Pleistocene)**—Very well cemented fanglomerate; interbedded fluvial and debris flow deposits. Fluvial deposits are thin- to thick-bedded, poorly sorted pebbly to cobbly conglomerate that exhibit channels and cross-bedding; subrounded to well rounded clasts. Debris flow deposits are massive and unsorted with angular pebble- to cobble-sized angular to subangular clasts. Clasts are predominately light and dark gray metamorphosed limestone set in a very well cemented sandy matrix with grains of quartz, feldspar and limestone. Scattered clasts of granitic rocks and massive and vesicular basalt also occur. Unit crops out in hard, resistant ledges with hackly weathering surfaces characterized by strongly etched and pitted limestone clasts; where granitic clasts are more abundant near State Highway 18, erosional ridges are rounded and surface is littered with calcrete fragments. Strongly deformed in upper piedmont folds

Qvos **Very old slope wash and alluvial deposits (middle or early Pleistocene)**—Pervasively chalky-cemented sand and pebbly sandstone; firm to hard; poorly sorted; cemented to well cemented. Unit exhibits a disorganized texture and bedding features, rarely observed, are typically absent or obscured by cementation process. Calcification is at least in part pedogenic. Veins of hard white laminar calcite 0.5 to 2 cm thick are abundant in these deposits. The pervasiveness and morphology of petrocalcic precipitation is consistent with a Stage IV to VI calcic soil. Exposures just east of the Cougar Buttes quadrangle and just north of Highway 247 exhibit brecciated, pisolitic texture. Unit formed as thin debris aprons mantling erosion surfaces beveled onto tilted Pliocene and early Pleistocene lacustrine and fluvio-lacustrine strata. These debris aprons were subsequently cemented and eroded to form flatirons on piedmont slopes flanking the San Bernardino Mts. and the Mojave Desert inselbergs. Where stratigraphic relations are exposed, very old and moderately old alluvial fan deposits ($Qvof_1$, $Qvof_2$, Qmof) overlie these pediment-mantling slope wash deposits. Parts of unit as mapped, however, may be coeval with these cemented fan deposits

Saprolite (Quaternary? and Tertiary)—Weathered in situ regolith on granitic rocks beneath pediments. Exhumed rock pediments; discontinuous veneer of gruss, not mapped separately. Saprolitic granitic rocks clearly underlie Tertiary strata (Tb, QTs_1, QTs_2), but some of unit may have developed during Quaternary pediment formation. Includes:

$QTsp_{mp}$ **Saprolite, mixed plutonic rocks (Quaternary? and Tertiary)**—In situ regolith developed on mixed plutonic rocks (Kmp); grussy

$QTsp_{cb}$ **Saprolite, monzogranite of Cougar Buttes (Quaternary? and Tertiary)**—In situ regolith developed on monzogranite of Cougar Buttes (Kcb); light-colored; grussy

Breccia (Quaternary and (or) Tertiary)—Rock avalanche(?) breccia. Breccia is derived chiefly from metamorphosed Paleozoic carbonate strata and subordinately from Pliocene conglomeratic sandstone and granitic rocks. Includes:

$QTbr_c$ **Breccia, carbonate rock (Quaternary and (or) Tertiary)**—Rock avalanche(?) breccia derived from metamorphosed Paleozoic carbonate strata

$QTbr_{bc}$ **Breccia, strata of Blackhawk Canyon (Quaternary and (or) Tertiary)**—Rock avalanche(?) breccia derived from Pliocene strata of Blackhawk Canyon (see summary pamphlet). Disorganized domains of medium- to coarse-grained, reddish, buff, or gray sandstone and conglomeratic sandstone with pebbles to boulders of quartzite, lineated granitic gneiss, amphibolite, granite, basalt, and rare limestone. Where undisturbed strata crop out just south of the quadrangle boundary, they are thin-bedded to massive with well-developed cross-bedding. Previously mapped as the Old Woman Sandstone of Shreve (1968; see also, Dibblee, 1964; Sadler, 1982)

$QTbr_g$ **Breccia, granitic rocks (Quaternary and (or) Tertiary)**—Rock avalanche? breccia derived from granitic rocks

QTc **Conglomerate of Cushenbury Springs (Quaternary and (or) Tertiary)**—Fluvial conglomerate and sandstone. Conglomerate consists of pebbles, cobbles, and scattered small boulders; commonly clast-supported and cobble-rich; well-cemented. Typically thick-bedded to massive, with scattered thin sandstone beds near source, the unit grades basinward into pebbly to cobbly conglomeratic sandstone and sandstone. Clasts predominantly gray metamorphosed limestone; scattered clasts of biotite monzogranite, quartzite, and basalt. Interfingers with and overlies Pliocene lacustrine strata (Tl). Equivalent to member 1 of the Cushenbury Springs Formation of Shreve (1968). As mapped, locally includes very old slope debris deposits (Qvos)

Sandstone and conglomerate (Quaternary and (or) Tertiary)—Sandstone, conglomeratic sandstone, and conglomerate deposited on saprolitic granitic rocks and overlain by cemented debris mantle and K-horizon (Qvos). Includes:

QTs_1 **Sandstone and conglomerate, member 1 (Quaternary and (or) Tertiary)**—Sandstone, conglomeratic sandstone, and conglomerate; poorly sorted. Clasts include vesicular and massive basalt, leucogranitic rocks, porphyritic quartz monzonite with lavendar-tinted phenocrysts of alkali feldspar, mafic plutonic rocks, fine-grained light gray quartzite, vein quartz, and epidote derived from Mojave Desert source terrane such as that exposed in Fry Mts.; interfingers with member 2. Abundant varnished clasts in colluvial lag (Qoc?) on surface give this member a darker color than member 2

QTs_2 **Sandstone and conglomerate, member 2 (Quaternary and (or) Tertiary)**—Sandstone and conglomeratic sandstone; yellowish brown (10YR 5.5/5). Arkosic sand with granules and pebbles of basalt. Derived from source terrane such as that exposed on Cougar Buttes; interfingers with member 1

Tl **Lacustrine strata (late Pliocene)**—Brown lacustrine clay and silty clay and fluvio-lacustrine greenish gray and brown silt and fine sand; interbedded. Overlie the strata of Blackhawk Canyon (see summary pamphlet) with angular unconformity just south of quadrangle boundary. Interfinger with and overlain by limestone-clast conglomerate sandstone and cobble-boulder conglomerate of Cushenbury Springs. Has yielded late Pliocene vertebrate fossils along the south boundary of the quadrangle just east of State Highway 18 (see summary pamphlet). Previously mapped as the Old Woman Sandstone of Shreve (1968; see also, Dibblee, 1964; Sadler, 1982). As mapped, unit may include early Pleistocene strata

Tb **Basalt (late Miocene)**—Basalt; olivine-bearing; massive; black. Crops out on Negro Butte and elsewhere on eastern Cougar Buttes where near-vent basalt flows overlap a thin reddish arkose onto saprolitic granitic basement rock. Similar basalt flows are widely distributed in the western Mojave Desert and San Bernardino Mts. and range in age roughly from 6 to 23 Ma (see references in summary pamphlet)

Ta **Arkosic sandstone (Miocene)**—Thin reddish arkose; some pebbles and cobbles. Poorly exposed on the east flank of Cougar Buttes beneath Miocene basalt. This basal arkose is deposited on saprolitic granitic rock, lacks basalt clasts, and is unconformably overlapped by basalt

Kmp **Mixed plutonic rocks (Cretaceous?)**—Heterogeneous mixture of granitic and intermediate plutonic rocks. From youngest to oldest, includes: aplitic to pegmatitic dikes; monzogranite of Cougar Buttes (Kcb); equigranular, medium-grained sphene-biotite-hornblende granodiorite (Kgd); seriate porphyritic sphene-biotite-hornblende quartz monzonite with phenocrysts of alkali feldspar as large as 3 cm; sphene-biotite-hornblende diorite, quartz diorite, and mafic granodiorite (Kmi). As mapped, may include some Jurassic plutonic rocks in northeasternmost corner of quadrangle

Kcb **Monzogranite of Cougar Buttes (Cretaceous)**—Medium- to coarse-grained biotite monzogranite. Typically equigranular; locally seriate-textured with scattered small phenocrysts of alkali feldspar. Color index 5 to 10. Quartz-rich; allanite-bearing

Kp **Porphyritic monzogranite (Cretaceous?)**—Biotite monzogranite. Medium-grained groundmass with abundant to sparse phenocrysts of alkali feldspar, typically 1 to 4 cm long. Color index of about 10; weathered outcrops are typically oxidized to light orangish brown. Exposures in Cougar Buttes quadrangle contain abundant inclusions of dioritic rock

Kgd **Granodiorite (Cretaceous)**—Sphene-biotite-hornblende granodiorite; medium- to coarse-grained

Kmi **Mafic-rich intermediate rocks (Cretaceous?)**—Sphene-biotite-hornblende diorite, quartz diorite, and mafic-rich granodiorite. Variably dark-colored; color index ranges from 40 to 60. Varying amounts of quartz and alkali feldspar. Occurs as inclusions in sphene-biotite-hornblende granodiorite

Jg **Granite (Jurassic?)**—Coarse-grained leucocratic granite. Intrusive into Jurassic porphyritic plutonic rocks (Jp)

Jp **Porphyritic quartz monzonite, monzogranite, and granodiorite (Jurassic)**—Medium- to coarse-grained porphyritic plutonic rocks; vary in composition from quartz monzonite to monzogranite and granodiorite. Unfoliated to foliated. Hornblende-biotite to biotite-hornblende; phenocrysts of lavendar-tinted to pinkish alkali feldspar. Some propylitic alteration. As mapped, unit may contain inclusions of Mesozoic metavolcanic and metasedimentary rocks as observed just north of quadrangle boundary, where unit also is intruded by dike swarm of Jurassic hypabyssal porphyry

MzPrgg **Granitic orthogneiss (Mesozoic or Proterozoic)**—Foliated, lineated leucocratic biotite granite gneiss

Prgn **Gneiss (Proterozoic)**—Biotite-quartz-feldspar layered gneiss with interlayered muscovite-biotite±sillimanite±garnet pelitic gneiss, quartzite, and amphibolite; dark-colored; chiefly metasedimentary

REFERENCES CITED

Bull, W.B., 1991, Geomorphic responses to climatic change: New York, Oxford University Press, 326 p.

Dibblee, T.W., Jr., 1964, Geologic map of the Lucerne Valley quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-426, scale 1:62,500.

Eppes, M., Matti, J., Powell, R., and McFadden, L., 1998, Soil landscapes of the northern flank of the San Bernardino Mountains in the Transverse Ranges of southern California: Geological Society of America Abstracts with Programs, v. 30, no. 1, p. A-330.

Munsell Color, 1975, Munsell soil color charts, 1975 edition: Baltimore, Maryland, Macbeth Division of Kollmorgen Corporation.

Sadler, P.M., 1982, Geologic map of the Cougar Buttes 7.5' quadrangle: California Division of Mines and Geology Open File Report OFR 82-18 S.F., Plate E, scale 1:24,000.

Shreve, R.L., 1968, The Blackhawk landslide: Geological Society of America Special Paper 108, 47 p.

Streckeisen A., 1976, To each plutonic rock its proper name: Earth Science Reviews, v. 12, p. 1-33.

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