Geologic map of the Cibola area, La Paz County, Arizona, and Imperial County, California: Arizona Geological Survey Digital Map DGM-112, 1:24,000 scale, with text

Mapping area includes the Cibola and portions of the Cibola SE 7½' quadrangles

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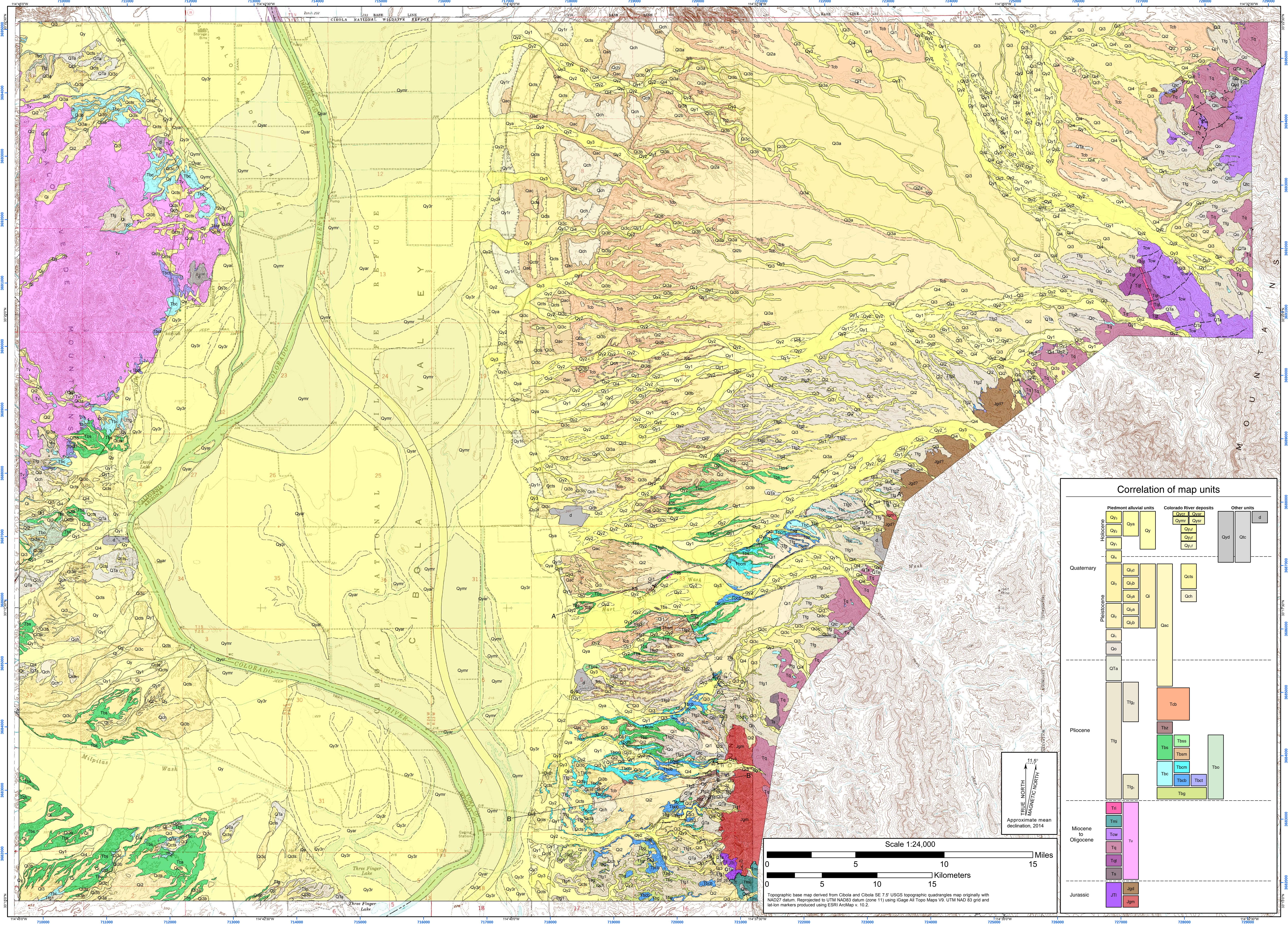
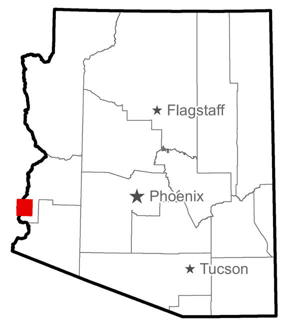
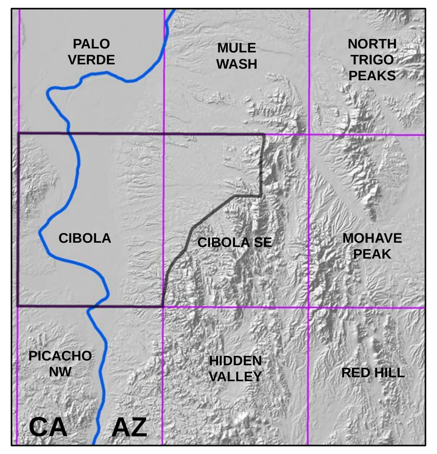
Arizona Geological Survey Digital Geologic Map 112 (DGM-112), version 1.0

March 2016

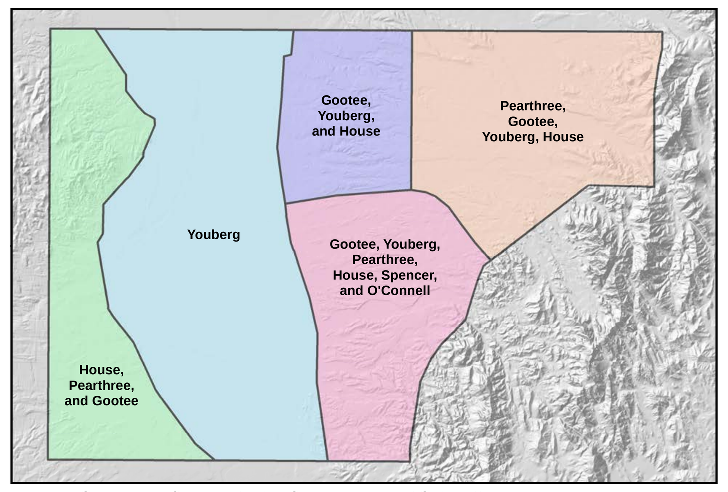


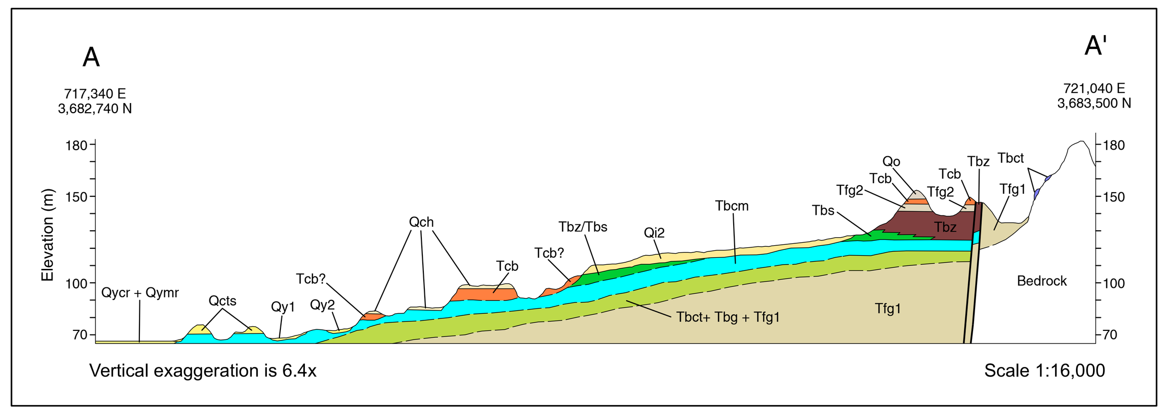


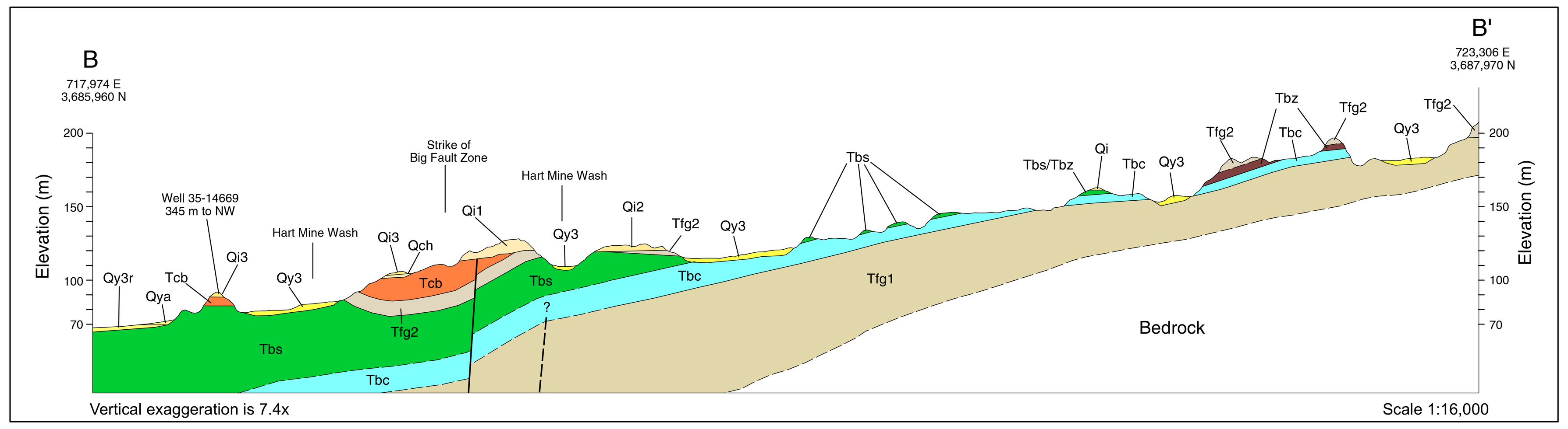


Location of map area

Mapping Responsibility







Contacts and faults

- Contact, accurate
- Contact, approximate
- Contact, concealed
- Contact, gradational
- Fault, accurate
- Fault, approximate
- Fault, concealed
- Low angle normal fault, accurate
- Low-angle normal fault, approximate
- Normal fault, accurate
- Normal fault, approximate
- River incision scarp, accurate
- River incision scarp, approximate
- River incision scarp, queried

Structure symbols

- Bedding, inclined
- Bedding, approximate
- Apparent dip (dip and dip direction, generally visible on slope or cliff, strike uncertain)
- Dip of fault
- Lithologic layering
- Trace of anticline axial plane

Citation for this map:

Gootee, B.F., Pearthree, P.A., House, P.K., Youberg, A., Spencer, J.E., and O'Connell, B., 2015, Geologic map of the Cibola 7 ½' Quadrangle and the northwestern part of Cibola SE 7 ½' Quadrangle, La Paz County, Arizona, and Imperial County, California: Arizona Geological Survey Digital Map DGM-112, scale 1:24,000, with text.

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Introduction

The Cibola and Cibola SE 7 ½' Quadrangles are located south of Blythe, California, in La Paz County, Arizona, and Imperial County, California. Geologic mapping was done on the Arizona part of the map area primarily by Arizona Geological Survey (AZGS) personnel, and mapping in California was done primarily by our cooperator with USGS. Geologic mapping was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992, and was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP assistance award # G13AC00374. Mapping was compiled digitally using ESRI ArcGIS software.

Piedmont Geology

Surficial geologic units were mapped using field observations, stereo aerial photographs, digital orthophotographs, topographic maps, and digital elevation models (DEMs). Relative ages of alluvial deposits were estimated using position in the landscape, characteristics of surface clast rock varnish and weathering, surface morphology, and soil color and carbonate accumulation (Machette, 1985; Bull, 1991; Birkland, 1999). Soil development, rock varnish accumulation, and changes in surface morphology begin once a deposit is isolated from active alluvial processes. Thus, we use these criteria to correlate surficial deposits throughout the map area, and to estimate the approximate ages of surficial units.

Younger alluvial deposits have little to no soil development, retaining the original grey or brown color of the alluvial sediments, and no carbonate accumulation. Clasts in these deposits have no weathering rinds or surface patinas and thus appear brighter and fresher than older clasts. Young alluvial surfaces often retain original depositional characteristics such as bars and swales. Conversely, older alluvial deposits have better developed soils that appear orange in color, with soil horizons reflecting carbonate accumulation. Clasts in older alluvial deposits often exhibit darkened rock varnish on surface clasts, with some degree of oxidation (orange surface patina) on the undersides of clasts; thus, these surfaces appear darker on the ground and in aerial photographs. Preserved alluvial surfaces may be gently undulating (Qi3) to smooth and flat (Qi2), becoming more rounded and coarser with age (Qi1, Qo).

Strata Related to the Colorado River

The Latest Miocene or earliest Pliocene Bouse Formation in the map area consists of several meters of limestone and marl overlain by siltstone (Metzger et al., 1973; Homan, 2014). Analyses of strontium isotope ratios (Spencer and Patchett, 1997; Roskowski et al., 2010) and on the relationship between Bouse strata and first arriving Colorado River deposits in the Bullhead City area in northwestern Arizona (House et al., 2008; Pearthree and House, 2014) are consistent with deposition of the Bouse Formation in a series of downstream-spilling lakes fed by the developing Colorado River. Aggradation of Colorado River sediments following deposition of the Bouse Formation led to deposition of the sand, rounded exotic gravel, and lesser amounts of silt and clay of the Bullhead Alluvium (Howard et al., 2015).

Bedrock Geology

Bedrock in the eastern Cibola and northwestern Cibola SE 7 ½' Quadrangles consists of compositionally variable mafic and leucocratic granitic rocks that are probably part of the regional Jurassic Kitt Peak – Trigo Peaks superunit of Tosdal et al. (1989). Bedrock mapping, where not mapped by Spencer, is extracted from Sherrod and Tosdal (unpublished mapping).

References cited are listed in the accompanying text document.

Description of map units

Bedrock map units

Unit descriptions are primarily from Sherrod and Tosdal, unpublished data

Tri — **Rhyolite dikes** - felsic dikes intruding Miocene tuffs.

Tmi — **Mafic intrusion** - Mafic intrusion with 5-7% green pyroxene(?) in aphanitic groundmass.

Tcw — **Tuff of Crazy Woman Wash** - Partially to moderately welded rhyolitic ash-flow tuff. Forms compound emplacement and cooling unit in east part of map area. Thickness and degree of welding increase towards north of outcrop band.

Tq — **Quechan Formation** - Chiefly thick flows and domes of olive-brown to reddish-brown slightly porphyritic andesite, dacite, and rhyodacite. Includes minor interbedded tuff, lapilli tuff, tuff breccia and breccia, and intrusions.

Tqt — **Quechan Formation Tuff** - Pyroclastic-flow and debris-flow deposits (lithic lapilli tuff), breccia, and volcaniclastic sandstone. Lapilli tuff is bedded 2-5 m thick, with partings defined by 5-10 cm-thick sandstone layers, and contains 10-20 percent fragments 1-2 cm across of aphanitic volcanic and, locally, crystalline clasts. Generally unwelded to only partially welded, but densely welded tuff is exposed locally.

Tv — **Volcanic rocks, undifferientated** - Undifferentiated felsic to mafic extrusive rocks with volcaniclastic layers.

Ts — **Breccia and tuffaceous sandstone** - Locally derived breccia and thin-bedded, well-bedded, flaggy white tuff and sandstone, some of which is arkosic. Devitrification and zeolitization have destroyed most sedimentary structure within beds. Forms nonconformable but slightly faulted cover above Jurassic granodiorite.

JTl — **Leucogranite** - Fine grained leucogranite with 2-4% mafics that include biotite. This unit intrudes mafic granitoids of map unit Jgm.

Jgd — **Granodiorite**

Jgm — **Mafic granitic rocks** - Compositionally variable mafic diorite to granodiorite. Unit varies from (1) porphyritic medium grained granodiorite with up to 10%, <2cm, pale reddish gray K-feldspar, with ~10-15% mafics, including biotite, in aggregates that are deformed and locally felted (intergrown and fine grained, possibly because of secondary processes). Mafics probably include hornblende and magnetite, but these are obscure. Unit includes locally abundant, fine grained, flattened mafic inclusions, 1-10cm thick, 10-30 cm long. (2) Dark hornblende diorite with 40-60% (locally up to 90%), ~5mm hornblende(?). (3) Medium-grained hornblende diorite with ~5mm, ~30-40% hornblende with very sparse, pale gray k-feldspar up to 15 mm. Weak lithologic layering that affects mafic granitoids does not affect leucogranite that forms dikes in the mafic granitoids. Mafic granitoids are part of the Jurassic Kitt Peak – Trigo Peaks superunit of Tosdal et al. (1989).

Description of map units continued

Other units

d — **Disturbed ground** - Mine dumps, highways, and other areas of excavation and burial where original geologic characteristics are obscure or invisible.

Qtc — **Colluvium and talus** - Poorly sorted, angular to subangular, weakly to massively bedded, locally derived hillslope deposits.

Qyd — **Debris flow channels and deposits** - Young scoured debris flow channels and adjacent deposits are mapped on steep mountain drainages. Deposits are very coarse, extremely poorly sorted, and form lateral levees paralleling drainages, and more amorphous snouts near their termini. Channels associated with these deposits are commonly scoured to bedrock.

Piedmont alluvial units

Qy3 — **Deposits in active channels, low terraces and bars** - Piedmont alluvial deposits located along active drainages including small channels, adjacent low terraces, or floodplain areas. These deposits are composed of unconsolidated sand, gravel, and silt deposits. Soil development is minimal to none, and no rock varnish is found on surface clasts unless they are partially buried or reworked from older alluvial surfaces.

Qy2 — **Deposits associated with broad valley floors, low terraces, and gravel bars and swales adjacent to active channels** - Alluvial deposits forming terraces and bars located primarily along the flanks of the most active parts of piedmont fluvial systems drainages, and low-relief terraces inset into Pleistocene age fan deposits. Some Qy2 deposits comprise extensive low relief alluvial fans where young deposits are less confined by older piedmont alluvium. Qy2 deposits consist of predominantly sand and silt, with common to dominant sub-rounded to sub-angular pebbles and cobbles, and are unconsolidated to weakly consolidated sediments with pebble and cobbles. These deposits exhibit bar and swale micro-topography, with beds and lenses in cross section. Soil development is weak to none, and very light rock varnish is found locally on gravel bars.

Qy1 — **Piedmont terraces and isolated alluvial fan deposits adjacent to active fluvial systems** - Qy1 deposits typically form undulating terraces and broad channel fans along larger piedmont drainages, and remnant alluvial fan deposits on lower piedmont areas. Qy1 surfaces are composed of sandy to pebbly swales with weak to moderate desert pavement formation, and coarser lightly to moderately varnished pebble to cobble bars. Soil development consists of stage I to weak stage II calcic horizons. Locally, Qy1 sediment partially buries or is deposited around remnant late Pleistocene deposits.

Qya — **Young alluvial fan deposits** - Deposits forming laterally extensive active alluvial fans near the interface of piedmont tributary drainages and the margin of the Colorado River floodplain. Deposits are composed of pebbles, cobbles, sand, and silt. The channel pattern is distributary, with broad sheetflood areas between channels. Rock varnish is minimal to none, with no significant desert pavement development. Gravel bars and finer-grained swales are common, but where deposits are generally fine-grained surfaces may be fairly planar.

Qy — **Young tributary deposits, undifferentiated** - Young tributary channel, terrace and alluvial fan deposits, undifferentiated. Includes poorly to very poorly sorted, predominantly locally-sources pebbles, cobbles, and boulders, sand, silt and clay. Soil development ranges from weak to minimal. Rock varnish is light to moderate, desert pavement formation is weak, and original depositional topography is well preserved.

Qi4 — **Youngest intermediate alluvial fan and terrace deposits** - Pebble, cobble, and sand deposits in low terraces and alluvial fans. Moderate to dark varnish on surface gravel clasts, weak to moderate desert pavements, but generally not as strongly developed as Qi3. Surfaces commonly are moderately undulating, but may be quite smooth if deposits consist of fine gravel. Soil development is weak to moderate, commonly with stage II calcic horizons and slight reddening. Qi4 deposits and surfaces may be partially correlative in age with Qi3c deposits mapped closer to the Colorado River.

Qi3 — **Intermediate alluvial fan and terrace deposits** - Gravel and sand deposits with moderate to light desert pavements, and dark rock varnish, forming relict alluvial fans and intermediate terraces. Unit thickness is less than 5 m. Soil development is moderate with slight reddening, minor clay accumulation, and calcic horizon development stage II-III. In the northern part of the quadrangle, Qi3 surfaces can be divided into three levels based on their relationships to the fluvial scarps associated with deposition of the Chemehuevi Formation by the Colorado River. Elsewhere on the map Qi3 is undivided.

Qi3a — **Intermediate deposits, highest level** - Highest Qi3 surfaces in the northern part of the quadrangle, which are graded close to the highest level of Chemehuevi deposits. Well-developed, darkly varnished pavements are inset approximately 5 to10 m below Qi2 surfaces. The surfaces of Qi3a are smoother with slightly more rounded margines than the younger Qi3 surfaces, with more carbonate development on clasts with mm-thick rinds.

Qi3b — **Intermediate deposits, middle level** - Qi3b deposits form the middle level of the Qi3 fans and terraces. They are graded to a river level below the maximum level of Chemehuevi deposition; thus slightly post-dating the Chemehuevi Formation. Qi3b surfaces are broad and flat, strongly varnished with well-developed pavements, and exhibit subtle bar and swale micro-topography. The vesicular (Av) horizon is up to 10 cm thick on this surface. Qi3b surfaces are typically 2 to 3 m below Qi3a.

Qi3c — **Intermediate deposits, lowest level** - Qi3c surfaces are the lowest and youngest of the Qi3 fans. Qi3c surfaces grade a river level at or below the lowest preserved fluvial scarps associated with post-Chemehuevi river incision. Qi3c have well-developed pavements with moderately to strongly varnished clasts. Bar and swale micro-topography is more pronounced on these surfaces than on the older Qi3 surfaces.

Qi2 — **Older intermediate alluvial fan and terrace deposits** - Gravel and sand deposits, with minor silt and clay, associated with moderately eroded relict alluvial fans and intermediate terraces. Rock varnish is typically dark, with orange varnish on the undersides of surface clasts. Desert pavement development is variable, quite strong on well-preserved surfaces and moderate to weak on more eroded surfaces. Near-surface soil horizons are distinctly reddened. Incision of modern washes below Qi2 surfaces ranges from 1 to 10 m, and Qi2 surfaces are typically 1-10 m higher in the landscape than adjacent Qi3 surfaces. Qi2 surfaces are truncated by the highest fluvial scarps associated with deposition of the Chemehuevi Formation by the Colorado River, and thus are older than the Chemehuevi Formation. Unit thicknesses up to 5 m were observed, but thicknesses of 2 to 3 m are typical. Qi2 surfaces are subdivided only on Crazy Woman Wash alluvial fan in the northern part of the map area.

Qi2a — **Older intermediate fan and terrace deposits - higher level** - Highest level of unit Qi2.

Qi2b — **Older intermediate fan and terrace deposits - lower level** - Lowest level of unit Qi2.

Qi — **Intermediate alluvial deposits, undivided** - Middle and late Pleistocene terrace and alluvial fan deposits, generally correlative with Qi2 and/or Qi3 deposits.

Qi1 — **Oldest intermediate alluvial fan and terrace deposits** - High-standing, dissected, thin (less than 4 m) gravelly alluvial fan and terrace deposits consisting of pebbles, cobbles, small boulders, sand, silt and minor clay. Qi1 deposits form fairly thin caps over underlying fan or river deposits and are deeply eroded, with limited preserved planar surface remnants. Soil development is strong on well-preserved surfaces, with stage III calcic horizons and obvious soil reddening, but more commonly is weak to moderate on more eroded remnants. Rock varnish on surface gravel is variable, but typically is very dark on well-preserved surface remnants.

Qo — **Old alluvial fan deposits** - Coarse gravelly very high alluvial fan remnants. Exposures are poor, but deposits are probably less than 3 m thick in most areas, and erosionally overlie older fan deposits or bedrock. Cobbles and boulders are common, but deposits include pebbles, sand, silt, and clay. Planar, reasonably well-preserved surfaces are supported by stage III, and locally, stage IV carbonate cementation and coarse grain size, but in many areas surface preservation is poor and soil development is quite variable.

Colorado River deposits

The historical Colorado River floodplain has been significantly altered and modified, mainly through agricultural practices, so Holocene River deposits outside the active channels were mapped using 1938 and 1979 aerial photographs, Google Earth imagery, and NAIP imagery from 2010 and 2013.

Qycr — **Active Colorado River channel deposits** - Sand, gravel, silt and clay deposits under or immediately adjacent to active or recently active Colorado River channel(s). The locations and extents of these channels are now mostly confined by rip-rap and artificial levee.

Qyar — **Historical (pre-regulation) Colorado River channel deposits** - Recently abandoned Colorado River channel deposits composed mainly of sand, silt and clay, with minor gravel. Includes oxbow channels and small, isolated lakes. These areas were mapped using 1938 and 1979 aerial photographs, Google Earth and National Agricultural Imagery Program (NAIP) imagery from 2010 and 2013.

Qymr — **Colorado River meander-belt deposits** - Meander deposits consisting of mixtures of fine sand, silt and clay with coarser sands and gravels. The river floodplain has been substantially altered and modified, mainly through agricultural practices, but in some areas conspicuous meander-scroll patterns are discernible in aerial and satellite imagery. Mapped using 1938 and 1979 aerial photographs, Google Earth and NAIP imagery from 2010 and 2013.

Qysr — **Colorado River splay deposits** - Splay deposits consisting of clay, silt and sand from overbank flooding.

Qy3r — **Youngest Colorado River terrace deposits** - Low terrace deposits are composed of a mixture of sediment sizes ranging from cobbles to clay, but sand and finer deposits dominate. Qy3r terraces are typically found near the edges of the floodplain, and these deposits are a combination of Colorado River deposits interfingered with locally derived young alluvial fan deposits.

Qy2r — **Younger Colorado River terrace deposits** - Slightly higher terrace deposits typically about 1 to 2 m above the historical floodplain. Most are disturbed by agricultural practices or development. Includes sand, silt and clay with rounded gravels and pebbles. These deposits are a combination of Colorado River deposits interfingered with locally derived fan deposits.

Qy1r — **Young Colorado River terraces** - Highest young terrace deposits approximately 2 to 4 m above the historical floodplain. Deposits consist mainly of sand with well-rounded gravel, pebbles and cobbles interfingered with locally derived fan deposits. Clasts have little to no varnish. Soil development is weak.

Qcts — **Intermediate Colorado River terraces** - Intermediate river terraces and associated thin deposits composed of sand, silt and clay with well-rounded clasts of pea gravel, pebbles, and cobbles. Where coarser clasts are present, they are moderately varnished. In most areas these deposits are probably quite thin, and are in erosional contact with underlying Chemehuevi deposits. Individual map polygons may contain several levels of terraces and minor to moderate amounts of mixed, locally derived alluvium from piedmont channels. Because these deposits are inset below the level of maximum Chemehuevi vintage aggradation, they are less than about 70-100 ka (Malmon et al., 2011).

Qch — **Chemehuevi Formation** - Colorado River sand, silt, clay and minor gravel deposits associated with a major late Pleistocene period of river aggradation. Deposits consist primarily of beds of sand, clay and silt, but locally include beds of rounded exotic river gravel and interbeds of locally-derived tributary gravel. OSL data farther upstream along the Colorado River indicate that they were deposited approximately 70 to 100 ka (Malmon et al., 2011).

Qac — **Intermixed alluvial fans and river sediments** - Poorly exposed sediments composed of interbedded locally derived alluvial fans and Colorado River deposits. Few to no exposures; most slopes are covered with colluvium. Colorado River deposits may include Bullhead Alluvium (Tcb), Chemehuevi Formation (Qch) and younger terrace deposits.

Tcb — **Bullhead Alluvium** - Deposits of quartz-rich sand, minor silt and clay, and subangular to well-rounded pebbles and cobbles, a substantial portion of which are exotic. Interbedded with locally-derived fanglomerate (unit Tfg2) in places away from the valley axis; found as distinct beds of quartz-rich sand and rounded gravel interbedded with tributary fan gravel as high as ~255-260 m in the northeastern part of the map area. In a few outcrops, Tcb deposits rest over an erosional unconformity on Bouse deposits. We correlate these deposits with the Bullhead Alluvium, which has been found all along the lower Colorado River and represents a period of major early Pliocene river aggradation (Howard et al., 2015).

Bouse Formation

Tbo — **Bouse Formation, undivided unit** - Fine siliciclastic and carbonate deposits. This generalized unit is used for a few areas in the California part of the map area that have not been visited in the field.

Tbz — **Bouse Formation, upper bioclastic unit** - Gravel-rich, matrix- and clast-supported sand and conglomerate with a wide range of bioclastic content in matrix. Bioclastic material includes barnacles, bivalves, Halimeda green algae, and mollusks. Interbedded reddish brown mud, sand, and gravel beds with abundant shell hash and some reworked tufa are common near the base in some exposures. Typically, the upper boundary is erosional with Quaternary piedmont deposits above. Where thick sections of Tbz are preserved, deposits grade upward from pebbly carbonate sand to a calcarenite matrix conglomerate, to a weakly calcareous, poorly indurated, Colorado River supplied mudstone-silty sandstone with calcarenite matrix conglomerate channels, to a locally-derived conglomerate with minor bioclastic component, decreasing up-section. Locally bioclastic-rich beds are interbedded with, and grade upward from, reddish brown mud deposits with well-developed mud cracks on their upper surfaces. More commonly, the contact with underlying Bouse carbonate or siliciclastic deposits is erosional.

Tbs — **Bouse Formation, undivided siliciclastic deposits** - Generally pale reddish tan to pale grayish green, friable siltstone and mudstone and fine-grained sand. Unit Tbs locally is divided into two siliciclastic units, sand-dominated (Tbss) and mud-dominated (Tbsm) facies.

Tbss — **Bouse Formation, sand facies** - Sand-rich facies interbedded with and grading laterally into reddish brown silt and clay. Sand is overall light yellow-brown to pale reddish tan, fine to medium-grained, very well-sorted, quartz-rich, thinly laminated to massive-bedded, and typically these deposits contain little silt and clay. Sand grains are generally subrounded and sourced from Colorado River and local tributaries. U-Pb geochronologic analysis of 94 zircon sand grains (Arizona Laserchron Center, University of Arizona) indicates that these sands resemble other Colorado River sands (Kimbrough et al., 2015). Sands are locally Interbedded with thin bioclastic calcarenite beds and overlain by thicker bioclastic limestone beds. Slumping and mass-wasting structures are common, and include components of underlying green and brown clay beds.

Tbsm — **Bouse Formation, mud facies** - Clay- and silt-rich deposits, varying in color from green to yellow to red-brown. Typically, the lowest deposits are a pale green claystone, and these are sharply overlain by reddish brown mudstone (Homan, 2014). In the California portion of this map, mud colors are more complex and less predictable, and intense internal deformation is common. These deposits are conformable and gradational with underlying marl, and locally grade upward into brown mudstone interbedded with bioclastic-rich deposits of the upper bioclastic unit.

Tbc — **Bouse Formation, undivided carbonate deposits** - Bouse Formation, undivided tufa, bioclastic limestone, marl, and limestone.

Tbcm — **Bouse Formation, marl and calcareous siltstone** - White to pale yellowish tan, friable calcareous siltstone and resistant white marl (silty limestone) that forms protruding beds generally 5 to 30 cm thick. In detail, there are at least 3 marl subunits. (1) White, tan/pink silty clay marl is dominated by alterations of silty resistant marl with clay recessive marl. Typically the more silty beds are 1-3 cm thick, with interbedded more clay rich 1 mm - 3 cm thick. Bedding surfaces are often wavy and irregular, with some pinch and swell. (2) White clay to silty-clay chalky marl contains both paper shale thin beds (3-10 cm) of very thinly laminated (1-3 mm) clay, to thick massive beds of white marl with no internal structure or lamination. (3) Light green - yellow marl with interbeds of recessive ~20-50 cm thick fissile marl beds coupled with 3-30 cm beds of more massive resistant marl. This unit is interbedded upward into green claystone (Tbsm). Calcareous siltstone locally contains gypsum beds up to 5 cm thick with crystals oriented perpendicular to bed margins, and rare gypsum forms veins that cut across bedding, but most are parallel to bedding and are possibly primary. Deformation is fairly common within this unit, presumably before sediments were consolidated.

Tbcb — **Bouse Formation, bioclastic limestone** - Pale gray to tan, generally thin-bedded, moderately to well-sorted bioclastic limestone, typically containing abundant skeletal-barnacle fragments and, locally, subrounded pebbles and cobbles primarily of Tertiary volcanic rocks and leucogranite. Internal sedimentary structures are often well-preserved and include parallel lamination, both wave ripple and unidirectional cross-lamination, and trough and tabular crossbed sets. Bioclastic limestone beds are generally interbedded within more abundant marl and calcareous siltstone. Tbg pebble beds and lenses are common within bioclastic limestone facies. This unit is generally 1-5 m thick and is typically present at one or two stratigraphic zones within the ~10-30 m thick Bouse carbonate sequence. Locally includes up to ~5-m high, west-facing, planar cross beds that are interpreted as beach and nearshore deposits, and ripple cross beds in sets 3 to 8 cm thick. Limestone is typically much more resistant than associated white marl (silty limestone) and calcareous siltstone and forms flat, resistant surfaces that disaggregate to form limestone plates that mantle downslope areas. At two localities upper bioclastic limestone beds overlie sandstone that contains branching, cylindrical limestone structures 5- to 10 mm across, some of which are hollow. These may be Thalassinoides burrows (written comm., Steve Hasiotis, University of Kansas) or tufa structures where groundwater seeped into bottom-water and carbonate precipitation occurred in the zone of water mixing.

Tbct — **Bouse Formation, tufa** - Massive tufa deposits and scabrous encrustations, typically fossiliferous, algal forms, hemispherical shapes, commonly draped on moderately-sloping paleo-hillslopes formed on bedrock and older, eroded fanglomerate. Also found as aggregations in marl and bioclastic limestone deposits. Color of tufa ranges from light to dark gray. This unit ranges from a few cm thick up to 1-2 m thick.

Tbg — **Bouse Formation, basal gravels** - Greenish to olive yellow to orange, locally derived, subangular to well-rounded, well-sorted gravels and cobbles with calcareous sand lenses at the base of the Bouse Formation. Includes coarse gravel beds with 1- 5 cm clasts forming cross-beds up to 2 m thick. This unit is exposed primarily in the southeastern corner of the map area, and locally farther north. These sediments are primarily reworked from underlying fan deposits. The deposits range from coarse fanglomerate cobbles and pebbles to sand-dominated facies and include moderate to well-sorted, well-rounded beach and nearshore gravel deposits. Beds from this unit are overlain by, and locally interbedded with, Bouse marl and calcareous siltstone (unit Tbcm) and bioclastic limestone (unit Tbcb).

Miocene and Pliocene alluvial fan deposits

QTa — **Deeply dissected alluvial fan deposits** - Locally derived alluvial fan deposits forming deeply eroded ridges. Original fan surfaces are eroded, leaving rounded ridge crests. Clasts on the surface are coarse, often cobbles and small boulders, which are strongly varnished. These deposits are difficult to distinguish from Tfg2 deposits described below.

Tfg — **Fanglomerate undivided** - Poorly sorted, light brown conglomerate and conglomeratic sandstone with angular to rounded clasts of local volcanic rocks, granitoids including locally derived leucogranite, and siliceous rocks of uncertain origin. Locally this unit is poorly consolidated medium to fine grained sand with subrounded to rounded sand grains, with some local gravel beds. This unit is interpreted as representing sandy alluvial fan deposits. This generalized unit is used for fanglomerate deposits where their relationship to Bouse deposits is uncertain. Where queried, Tfg is suspected of underlying hillslope colluvium in old fan deposits either above (Tfg2) or below (Tfg1) the Bouse Formation.

Tfg2 — **Younger fanglomerate** - Poorly sorted, weakly to moderately lithified sandstone, conglomeratic sandstone, and conglomerate. Clasts consist largely of subangular to angular locally derived Tertiary volcanic rocks and granitoids, but includes trace to several percent clasts of bioclastic calcarenite, rounded local clasts reworked from Tbg deposits, and rounded black chert and quartzite presumably supplied by the Colorado River. This unit thus represents mostly locally derived fan material interfingered with minor amounts of Colorado River derived sediments. Unit Tfg2 grades laterally into unit Tcb towards the basin, and locally is unconformably overlain by unit Tcb. Unit Tfg2 is gradational to unconformable with underlying Tbz deposits, and erosionally overlies bedrock and lower Bouse strata.

Tfg1 — **Older fanglomerate** - Poorly sorted, light brown conglomerate and conglomeratic sandstone with angular to rounded clasts of local volcanic rocks, granitoids including locally derived leucogranite, and siliceous rocks of uncertain origin. Locally this unit is represented by poorly consolidated medium to fine grained sand with subrounded to rounded sand grains. This unit is interpreted as representing sandy alluvial fan deposits. Just off the southwest corner of the quadrangle, this unit was found to interfinger with 8 Bouse tufa beds (unit Tbct) thus the uppermost part of this unit is coeval with Bouse deposition. The top of this unit typically grades conformably into Bouse unit (Tbg) but may be locally erosionally unconformable.

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