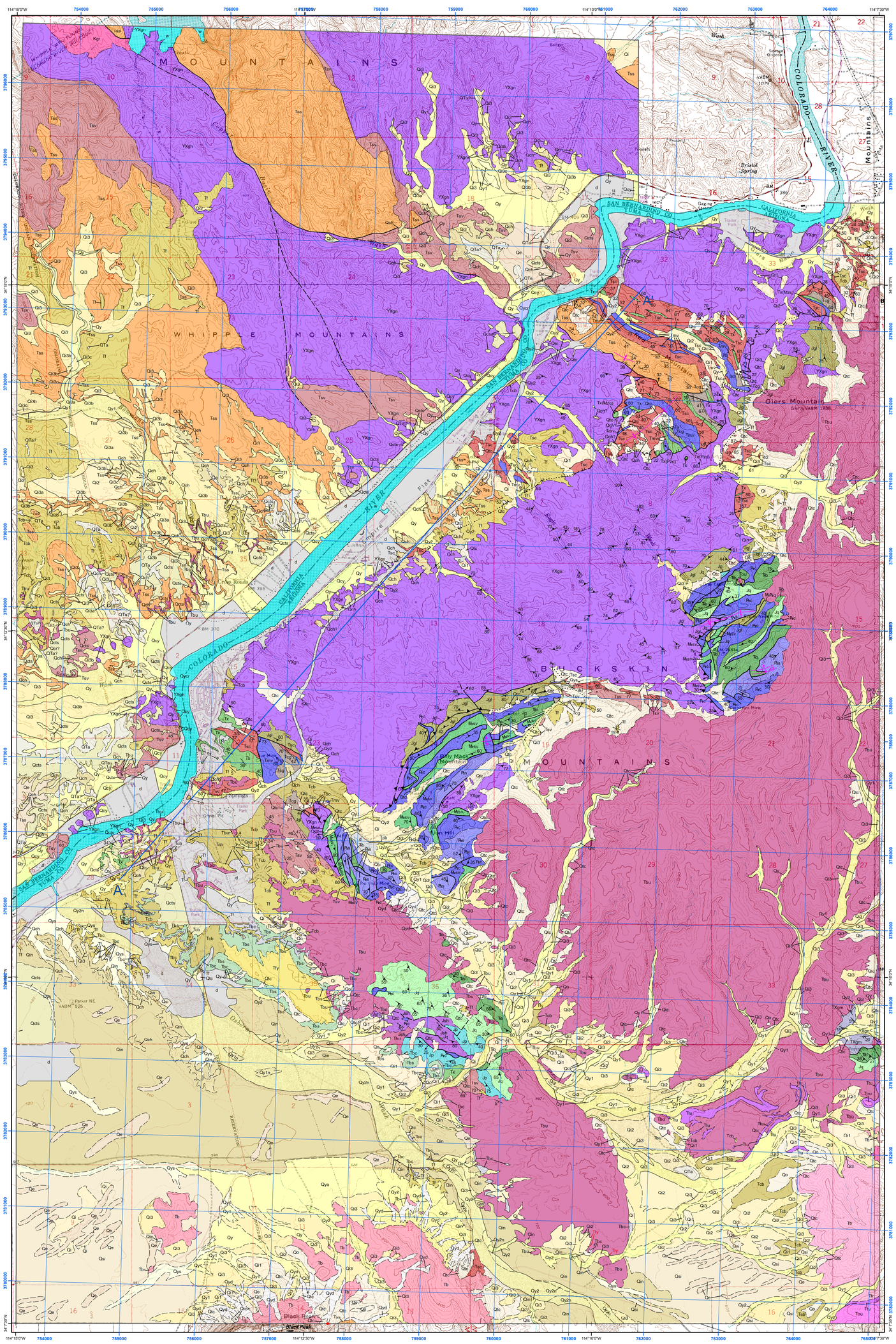

Geologic map of the Cross Roads 7 ½' Quadrangle and the southern part of the Gene Wash 7 ½' Quadrangle, La Paz County, Arizona, and San Bernardino County, California

Jon E. Spencer, Philip A. Pearthree, P. Kyle House, and Stephen J. Reynolds

Arizona Geological Survey
Digital Geologic Map 111 (DGM-111), version 1.0

November 2015

This map is dedicated to Jon E. Spencer, Chief Geologist, Arizona Geological Survey, in recognition and appreciation of his significant contributions to advancing the understanding and documentation of the geology of Arizona. Dr. Spencer's service ran from 1982 to 2015.

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Spencer, J.E., Pearthree, P.A., House, P.K., and Reynolds, S.J., 2015, Geologic map of the Cross Roads 7 ½' Quadrangle and the southern part of the Gene Wash 7 ½' Quadrangle, La Paz County, Arizona, and San Bernardino County, California: Arizona Geological Survey Digital Geologic Map DGM-111, scale 1:24,000.

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Introduction

The Cross Roads 7 ½' Quadrangle is located east and northeast of the town of Parker in La Paz County, western Arizona. The Quadrangle encompasses the westernmost Buckskin Mountains in Arizona, a segment of the lower Colorado River corridor, and part of the southeast flank of the Whipple Mountains in California. Geologic mapping in Arizona 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.

Surficial geology

Surficial geologic units were mapped using field observations, stereo aerial photographs, digital orthophotographs and/or georeferenced satellite imagery, and digital elevation models (DEMs). Relative ages of alluvial deposits were estimated using characteristics of clast weathering, soil development, carbonate accumulation, and position in the landscape (Gile and others, 1981; Machette, 1985; Bull, 1991; Birkland, 1999). Soil development and carbonate accumulation begin once a deposit is isolated from active alluvial processes. As a result, the degree of soil development and carbonate accumulation are one of the criteria used to identify 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 or red in color, with soil horizons reflecting clay and carbonate accumulations. Clasts in older alluvial deposits often exhibit darkened weathering rinds or some degree of oxidation (orange surface patina), and thus appear darker on the ground and in aerial photographs. Preserved alluvial surfaces may be smooth and flat (Qi3), becoming more rounded and coarser with age (Qi2). The oldest alluvial surfaces (Qi1) are often eroded, rounded ridges with no soils preserved and the carbonate horizon exposed.

Strata related to the Colorado River

The Pliocene Bouse Formation in the map area consists of several meters of limestone and marl overlain by siltstone. The deposits are thought to be lacustrine (deposited in lakes) based on strontium isotopes (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). Aggradation of Colorado River sediments following deposition of the Bouse Formation led to Pliocene aggradation of sandy and silty river sediments of the Bullhead alluvium.

Bedrock geology

Bedrock in the Cross Roads 7 ½' Quadrangle consists of upper Miocene basalt that overlies a sequence of (1) Proterozoic to Jurassic granitic and gneissic rocks, (2) metamorphosed and highly deformed Paleozoic metasedimentary rocks and Mesozoic metasedimentary and metavolcanic rocks, and (3) upper Oligocene to middle Miocene sandstone, conglomerate, rock avalanche breccia, and basalt lava flows. These bedrock units form two major fault blocks separated by the northeast striking, northwest dipping, Giers Mountain fault. This fault is a tear fault, also known as an accommodation zone (Faulds and Varga, 1998), that separates normal-fault tilt blocks in the Whipple Mountains from those in the western Buckskin Mountains (Davis et al., 1980; Spencer and Reynolds, 1989). Tilted Oligocene to middle Miocene sedimentary and volcanic rocks were deposited during normal faulting and related tilting above the regional Whipple-Buckskin-Rawhide extensional detachment fault (Davis et al., 1980; Spencer and Reynolds, 1991). Rock avalanche deposits are interpreted to have originated primarily from oversteepened normal-fault footwalls. Highly deformed Paleozoic and Mesozoic metasedimentary and metavolcanic rocks are juxtaposed with granitic and gneissic rocks along a fault that is inferred to be the structurally highest, generally south-vergent, thrust fault at the northern margin of the late Cretaceous Maria fold and thrust belt (Spencer and Reynolds, 1990).

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Description of map units

w — **Water** - Areas submerged by the Colorado River.

d — **Disturbed ground** - Heavily disturbed or altered ground associated with mine dumps, excavation, and municipal development. Original geologic features are concealed or obscured.

Hillslope Deposits

Qtc — **Colluvium and talus** - Very poorly sorted, angular to subangular, locally derived gravel, sand, silt and clay deposits on hillslopes. Deposits are derived from underlying or adjacent bedrock outcrops, or older alluvial deposits capping eroded ridges. Locally includes bouldery talus deposits with minimal fine matrix.

Qyd — **Debris-flow deposits and chutes** - Boulder and cobble levees lining channels and forming snouts; includes erosional scars caused by debris-flow activity high on hillslopes.

Piedmont Deposits

Qy$_2$ — **Youngest channel, low terrace, and alluvial fan deposits** - Deposits located along active drainages including small channels, adjacent low terraces, and floodplain areas. Deposits are composed of unconsolidated, unvarnished sand, pebbles, cobbles, and locally small boulders, with silt and minor clay.

Qys — **Young sandy deposits along active drainages** - Reworked sand and fine gravel in and along active drainages where source deposits are predominantly sand. Locally includes coarser gravel deposits in proximity to bedrock or older fan deposits.

Qya — **Young alluvial fan deposits** - **Young alluvial fan deposits** that are laterally extensive and composed of gravel, sand, and silt. These deposits are associated with distributary drainage systems and broad sheetflood areas on the lower piedmont around Black Peak near the southwestern corner of the map area.

Qy$_1$ — **Young terrace and alluvial deposits** - Deposits form planar terraces along piedmont drainages and young relict alluvial-fan deposits on lower piedmont areas. Deposits form sandy to pebbly swales with coarser unvarnished to lightly varnished pebble to cobble bars.

Qy — **Young deposits, undifferentiated** - Primarily alluvial deposits in small channels and forming terraces and small alluvial fans. Unit locally includes small eolian sand dunes.

Qi$_3$ — **Young intermediate alluvial-fan and terrace deposits** - Gravel and sand deposits with moderate to tight desert pavements and dark rock varnish, forming relict alluvial fans and intermediate terraces. Unit consists of weakly cohesive to loose silt, sand, pebbles, cobbles, locally small boulders. Soil development is weak to moderate, with slight reddening and minor clay accumulation; calcic horizon development II-III.

- **Qi$_3$c** — **Youngest division of map unit Qi3** -
- **Qi$_3$b** — **Intermediate divison of map unit Qi3** -
- **Qi$_3$a** — **Oldest division of map unit Qi3** -

Qi$_2$ — **Intermediate alluvial-fan and terrace deposits** - Gravel and sand deposits, with minor silt and clay, associated with moderately dissected relict alluvial fans and intermediate terraces. Rock varnish and pavement development is variable. Unit is quite dark with tight pavements on well-preserved surfaces and much lighter colored on more eroded surfaces. Incision of modern washes below Qi2 surfaces ranges from 1-3 m.

Qi$_1$ — **Older intermediate alluvial-fan deposits** - High dissected, gravelly, alluvial-fan deposits and dissected terrace deposits. Alluvial-fan remnants are deeply eroded, with limited preserved fan-surface remnants. Soil development ranges from strong on well-preserved surfaces to weak to moderate on eroded slopes. Qi1 surfaces range from a few meters to up to 15 m above active washes.

Qi — **Intermediate alluvial deposits, undivided** - Stream terrace and relict alluvial-fan deposits with weak to strong soil development.

Qo — **Very old alluvial-fan deposits** - Coarse, gravelly, high, remnant, alluvial fans with strong petrocalcic soil development. Cobbles and boulders commonly form surface lag and are commonly very darkly varnished. Surfaces are covered with abundant petrocalcic litter in some areas. Planar surfaces are typically supported by carbonate cementation and coarse grain size, but are also deeply eroded and high above active washes. Qo surfaces are commonly 10-20 m above active washes.

Colorado River Deposits

Qcy — **Young river deposits** - Sand, silt and clay deposits of the historical floodplain and low terraces of the Colorado River. Locally quite rich in salts.

Qy$_r$f — **Young river deposits in low-lying, vegetated riparian areas** - Colorado River marshes and side channels that area commonly associated with frequently inundated bars that host rich riparian vegetation.

Qcts — **Post-Chemehuevi terrace deposits** - Primarily fine to medium quartz-rich rounded sand grains, with exotic rounded gravel and subangular local gravel. Minor silt and clay may be part of this unit or eroded Chemehuevi Formation deposits underlying Qcts

Qch — **Chemehuevi Formation** - Sand, silt, clay and minor gravel deposits draped over bedrock and older deposits. These deposits record a period of major aggradation by the Colorado River in the late Pleistocene (Malmon et al., 2011, USGS PP 1786).

Tcb — **Bullhead Alluvium** - Unconsolidated to moderately consolidated well-rounded to subangular cobbles and pebbles, quartz-rich sand, and lesser amounts of silt and clay. Surfaces of these deposits are commonly mantled by gravel, and gravel beds are common, but sand may be dominant particle size. In paleovalley southeast of the modern river, deposits range from coarse gravel to mainly silt and clay. Rounded pebbles and cobbles of primarily quartzite, chert, and other resistant rock types. Tentatively correlated with the Bullhead Alluvium (Howard et al, 2015), but locally may include Quaternary Colorado River deposits.

Deposits of Osborne Wash

Qy$_y$n — **Deposits in active channels, flood channels, and low terraces along Osborne Wash** - Gravel, sand, and silt deposits in channels, bars and low terraces that are inundated commonly to rarely. Gravel clasts are primarily crystalline lithologies, but volcanic clasts are common. Gravel is primarily subangular pebbles and cobbles. Soil development is minimal to absent.

Qy$_y$n — **Young terrace deposits** - Gravel and sand deposits in low terraces that are 1-2 m above active channels, and generally are not subject to inundation. Gravel clasts are primarily crystalline lithologies, but volcanic clasts are common. Gravel is primarily subangular pebbles and cobbles. Weak rock varnish and minimal soil development are characteristic.

Qin — **Older deposits of Osborne Wash** - Thick gravel and sand deposits associated with high, prominent terraces along Osborne Wash. Lithologies are fairly diverse, but are primarily crystalline granitic and metamorphic rocks, with basalt and felsic volcanic clasts. Deposits include minor silt and clay, abundant sand and pebbles, common cobbles, and minor boulders. Poorly exposed sand and gravel deposits south of Osborne Wash, labeled "Qir?", are exposed on the margins of an extensive surface mostly covered by wind-blown sand. These deposits are interbedded with fine-grained deposits of Chemehuevi Formation and also erosionally overlie the Chemehuevi Formation. They evidently record alluvial fan deposition by Osborne Wash that was coeval with and slightly post-dates Chemehuevi deposition in the late Pleistocene.

Eolian Deposits

Qe — **Active dune sand** - Quartz-rich dune sand deposits, with lesser amounts of silt and clay associated with more stable parts of dunes. Predominantly curvilinear dunes that trend generally NE, but vary from ESE to NNE; dunes are up to 6 m high.

Qsi — **Young sand sheet** - Interdune and laterally extensive sheet sand and small dunes. Areas covered primarily by sand, with minor gravel, silt and clay; not spatially associated with drainages. Percent coverage of sand is variable, but typically is >50 percent. Includes small areas of gravel lag, and eroded fine-grained deposits.

Upper Miocene to lower Quaternary sedimentary units

QTa — **Very old alluvial-fan deposits** - Gravelly and sandy alluvial fan deposits, undivided. High-standing remnants present on older fanglomerate of map unit Tf are composed almost entirely of lower plate crystalline rocks.

Tfy — **Younger fanglomerate** - Poorly sorted, poorly consolidated, tan to light brown fanglomerate. Local lithologies, dominantly volcanic or crystalline rocks. Mostly coeval with Bullhead Alluvium, and younger than Bouse Formation

Tbs — **Bouse Formation - fine siliciclastic deposits** - Tan, gray, and greenish gray, finely bedded silt and clay deposits with pinkish to yellow quartz-rich sand beds <1 m thick. Fine pinkish quartz-rich sand bodies also fill substantial erosional topography cut into finer-grained deposits. All deposits appear to be subaqueous.

Tbc — **Bouse Formation - carbonate** - Calcium carbonate-dominated basal deposits of the Bouse Formation. Includes gray, thin-bedded limestone and calcareous sandstone that locally weathers to form thin plates, massive to thick-bedded, blocky to platy-weathering travertine or tufa, coarse, very poorly sorted carbonate-cemented paleohillslope deposits, white to cream-colored finely bedded micritic limestone, and soft white to gray, fine powdery marl.

Tfy — **Younger tuff(s)** - Small outcrops of white to gray, low-density volcanic tuff, typically reworked, in or closely associated with the basal carbonate unit of the Bouse Formation.

Tf — **Fanglomerate** - Poorly sorted, poorly consolidated, tan to light brown fanglomerate that underlies, and may locally be interbedded with, carbonate deposits of the Bouse Formation. Unit is not tilted by faulting except in a few exposures where it appears to be slightly tilted. Generally equivalent to the Osborne Wash Formation of Buising (1990).

Flat lying to gently tilted upper Miocene volcanic units

Tbu — **Basalt, upper unit** - Basaltic volcanic rocks that commonly contain fine plagioclase, clinopyroxene, and olivine. This unit forms "The Mesa" on the eastern side of the map area and many hills in the southern part of the map area. Near upper Osborne Wash this unit was interpreted by Grubensky (1989, AZGS Bulletin 198) to overlie trachytic volcanic rocks dated at 10.5 Ma, which in turn overlie basaltic volcanic rocks correlated with map unit Tb. Four K-Ar dates from this unit (Tbu) near the Colorado River in the western part of the map area are all between 8 and 17 Ma, but only one has uncertainty less than one million years (8.5 +/- 0.2 Ma, from Marvin and Dobson, 1979, Isochron/West no. 26; see review of K-Ar dates in Spencer et al., 1989, AZGS Bulletin 198, p. 184).

Ttru — **Trachyte lava flow, upper unit** - Upper trachyte lava flow with phenocrysts of coarse-grained anorthoclase and fine grained clinopyroxene and olivine in an intergranular-textured groundmass of sanidine microlites, apatite, zircon, and opaque minerals (description from Grubensky, 1989, for map unit Tf3).

Ttu — **Upper tuffs associated with trachyte lava** - Massive to bedded, fragmental volcanic-lithic tuff (map unit Tfl3 of Grubensky, 1989).

Ttr — **Trachyte lava flow** - Trachyte lava flow with 10-15% phenocrysts of andesine plagioclase (up to 5mm), clinopyroxene, and olivine (description from Grubensky, 1989, for map unit Tf2).

Ttrd — **Trachyte lava dome** - Grubensky (1989) described this trachyte as holocrystalline, with a trachytic texture that is defined by fine phenocrysts of sanidine and subordinate (<3%, <0.5 mm) clinopyroxene and olivine. The exogenous dome is characterized by a cryptic, subhorizontal layering on a scale of several meters.

Tb — **Basalt** - Basaltic volcanic rocks at Black Peak and along the north side of Cactus Plain. The basaltic volcanic rocks are generally flat-lying to gently dipping, and overlie tilted middle Miocene strata at Black Peak (Grubensky, 1989, AZGS Bulletin 198). Two K-Ar dates of this unit at Black Peak are 16.1 +/- 0.8 Ma (Shafiqullah et al., 1980, AGS Digest 12) and 14.1 +/- 0.7 Ma (reported by Spencer et al., 1989, AZGS Bulletin 198).

Tilted upper Oligocene to Middle Miocene rock units

Tf — **Tuff** - Ash-fall tuff bed <~1m thick.

Tss — **Sandstone** - Red to reddish tan, poorly to moderately bedded, poorly sorted, coarse-grained sandstone and conglomeratic sandstone.

Tsc — **Sandstone, conglomeratic sandstone, and conglomerate** - Unit varies from massive, unsorted, boulder conglomerate, with clasts up to 2 m, to weakly to moderately bedded cobble to pebble conglomerate, to tan to red sandstone. Clasts are typically subrounded to subangular, and dominated by granitic and gneissic rocks, but locally include a substantial component of metasedimentary rocks and Mesozoic metavolcanic rocks. Unit is typically reddish brown and thick bedded to massive, locally with channels interpreted to represent proximal to medial alluvial-fan depositional environments. Local pale gray conglomerate includes angular volcanic-lithic clasts. Unit is generally tilted 20-70 degrees.

Tcg — **Conglomerate** - Unit varies from massive, unsorted, boulder conglomerate, with clasts up to 2m, to weakly to moderately bedded pebble to cobble conglomerate. Unit is generally reddish brown to brown. Clasts are generally subrounded to subangular.

Tx — **Rock avalanche breccia** - Massive breccia composed of angular fragments derived from diverse rock types. Most breccias are monolithologic, and are derived from granitoids, quartzite, or carbonate. Map label with parenthetical term after "Tx" indicates protolith composition of breccia, as follows: Tx(gr) – granitic protolith; Tx(Mzv) – Mesozoic metavolcanic protolith; Tx(Pzc) – Paleozoic carbonate protolith; Tx(q) – quartzite protolith, undivided.

Tsv — **Sedimentary and volcanic rocks, undivided** - Conglomerate, sandstone, mafic lava flows, and rock avalanche breccia, undivided.

Tmv — **Mafic volcanic rocks** - Vesicular, phenocryst-poor to phenocryst-rich mafic lava flows and flow breccias. Pyroxene and olivine are typically oxidized, but black pyroxene phenocrysts, <1mm, locally comprise up to 3%of the unit.

Paleozoic metasedimentary and Mesozoic metasedimentary and metavolcanic rocks, undivided

Jsh — **Schist** - Silvery schist, purplish phyllite, quartz-feldspar-lithic sandstone, variably calcareous quartzose sandstone, and sparse, thin beds of carbonate.

Jp — **Planet Volcanics** - Weakly schistose rocks derived from felsic Planet Volcanics. Inlcudes quartz porphyry and quartzo-feldspathic low-grade schist.

Jq — **Quartzite of the Vampire Formation** - Slightly micaceous quartzite and slightly micaceous quartzose sandstone with calcareous cement.

Ꞧb — **Buckskin Formation** - Fine sandstone, phyllite and calc-silicate of the Triassic Buckskin Formation.

Mzsv — **Metasedimentary and metavolcanic rocks, undivided** - Calc-silicate, phyllite, quartzite, and metavolcanic rocks, undivided. These are metamorphic equivalents of the Triassic Buckskin Formation, Jurassic Vampire Quartzite, and Jurassic volcanic rocks.

MzPzq — **Quartzite, undivided** - Includes quartzite of the Cambrian Bolsa Quartzite, quartzite units within the Pennsylvanian to Permian Supai Group, quartzite derived from the Permian Coconino Sandstone, and Jurassic Vampire Quartzite.

Pzc — **Calcite and dolomite marble, undivided** - Calcite and dolomite marble, including siliceous and cherty varieties, derived from the Devonian Martin Formation, Mississippian Redwall Limestone, and Permian Kaibab Limestone.

Pzs — **Metasedimentary rocks, undivided** - Calcite and dolomite marble, siliceous and cherty marble, calc-silicate, metasiltstone, and fine, quartzose metasandstone. These rocks are metamorphosed equivalents of Bolsa Quartzite, Abrigo Shale, Martin Formation, Redwall Limestone, Supai Group, Coconino Sandstone, and Kaibab Limestone.

Intrusions and metamorphic rocks

Kgr — **Light-colored granitic rocks** - Leucocratic biotite and biotite-muscovite adamellite of Davis et al. (1980, GSA Memoir 153, p. 91).

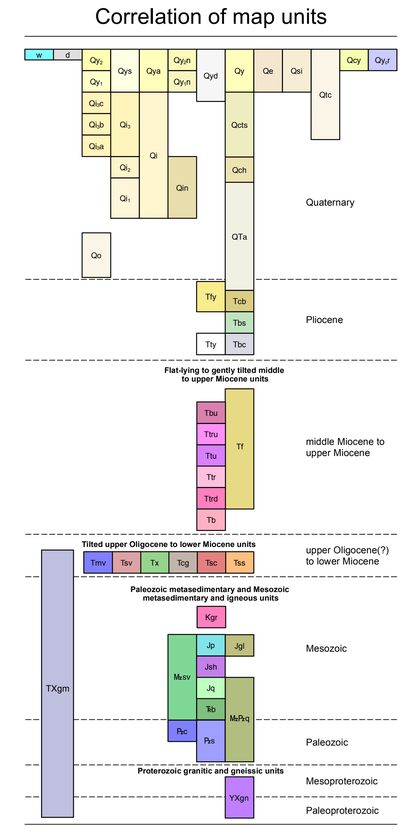
TXmd — **Mafic dike** - Fine-grained mafic dikes of basaltic to very fine-grained dioritic composition. Original mineralogy is obscured by chloritic and oxidative alteration and shattering.

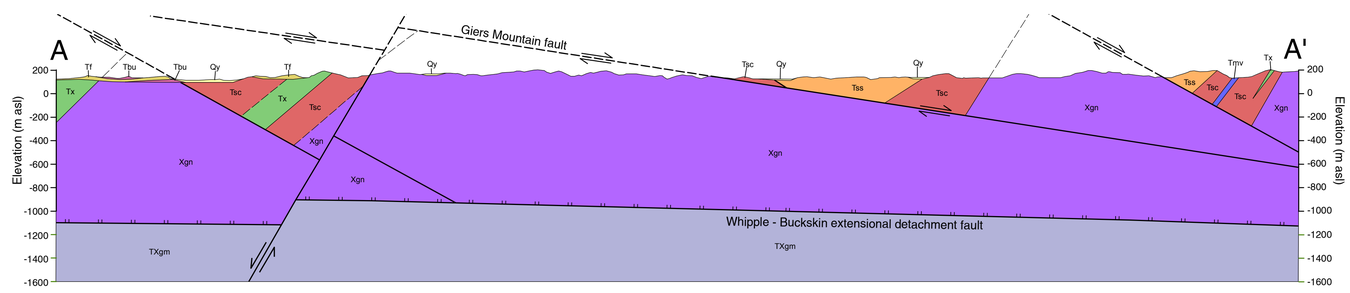
TXgm — **Mylonitic granitic and gneissic rocks, undivided** - Variably mylonitic gneissic and granitic rocks below the regional Buckskin detachment fault.

Jgl — **Leucogranite** - Medium to fine grained, light gray leucogranite with <3%, <1mm biotite, grading to weakly layered leucogneiss. Typically the rock unit is strongly shattered. A sample of this unit (760464 UTME, 3788171 UTMN, NAD83) yielded a Jurassic U-Pb zircon date (Mark Martin, U Kansas, written comm. to Jon Spencer, ~1997).

YXgn — **Gneiss and foliated metagranitoids** - Lithologically layered, pale gray to dark greenish gray to nearly black, fine-grained quartzo-feldspathic gneiss and foliated metagranitoids. Gneiss protolith may include partially melted metasedimentary rocks. Gneiss includes very fine grained, dark brown to dark greenish gray mafic intrusions. Rocks of this unit are typically affected by pervasive crushing and disruption of foliation and by pervasive chloritization. Oxidative alteration, represented by destruction of mafic minerals and iron staining, is locally pervasive. Original character of the rock unit is commonly obscure. Rocks northwest of the Giers Mountain fault (in the hanging-wall block) are mostly granitoids and foliated granitoids, with less common gneiss. It consists primarily of foliated, medium-grained, porphyritic granitoid, with 8-15% mafics and their oxidized, shattered, and flattened remains, with fracture-coating hematite, and with common mafic dikes and other fine grained intrusions that are also foliated and altered. Foliation is defined by microphyllosilicate preferred orientation and flattened K-feldspar augen.

Correlation of map units





Topographic base map derived from Cross Roads 7.5' USGS topographic quadrangle map originally with NAD27 datum. Reprojected to UTM NAD83 datum (zone 11) using iGage All Topo Maps V7. UTM NAD 83 grid and lat-lon markers produced using ESRI ArcMap v. 10.2.

Scale 1:24,000

Miles: 0 1 2 3 4

Kilometers: 0 1 2 3 4 5

TRUE NORTH / MAGNETIC NORTH — 11°

oximate mean
ation, 2013

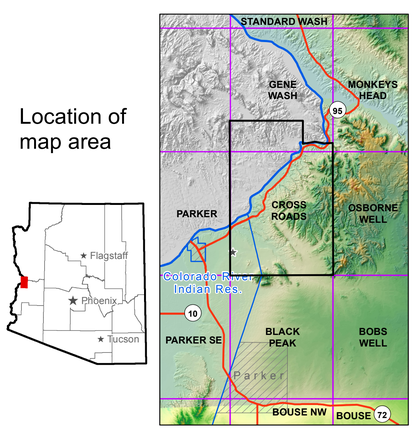
Structure symbols

- Bedding, inclined, accurate
- Bedding, inclined, approximate
- Foliation
- Foliation and parallel transposed bedding
- Mylonitic foliation and lineation
- Fault dip
- Anticline, upright
- Syncline, upright
- Syncline, overturned

Contacts and faults

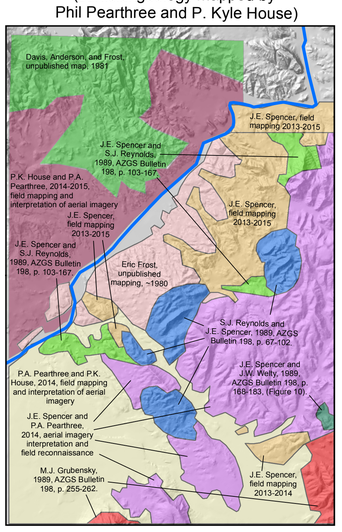
- Contact, accurate
- Contact, approximate
- Fault, high-angle, accurate
- Fault, high-angle, approximate
- Fault, high-angle, concealed
- Thrust fault, accurate
- Thrust fault, approximate
- Detachment fault, accurate
- Detachment fault, approximate
- Detachment fault, concealed
- Low-angle normal fault, accurate
- Low-angle normal fault, approximate

Location of map area



Sources of map data

(surficial geology mapped by Phil Pearthree and P. Kyle House)



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