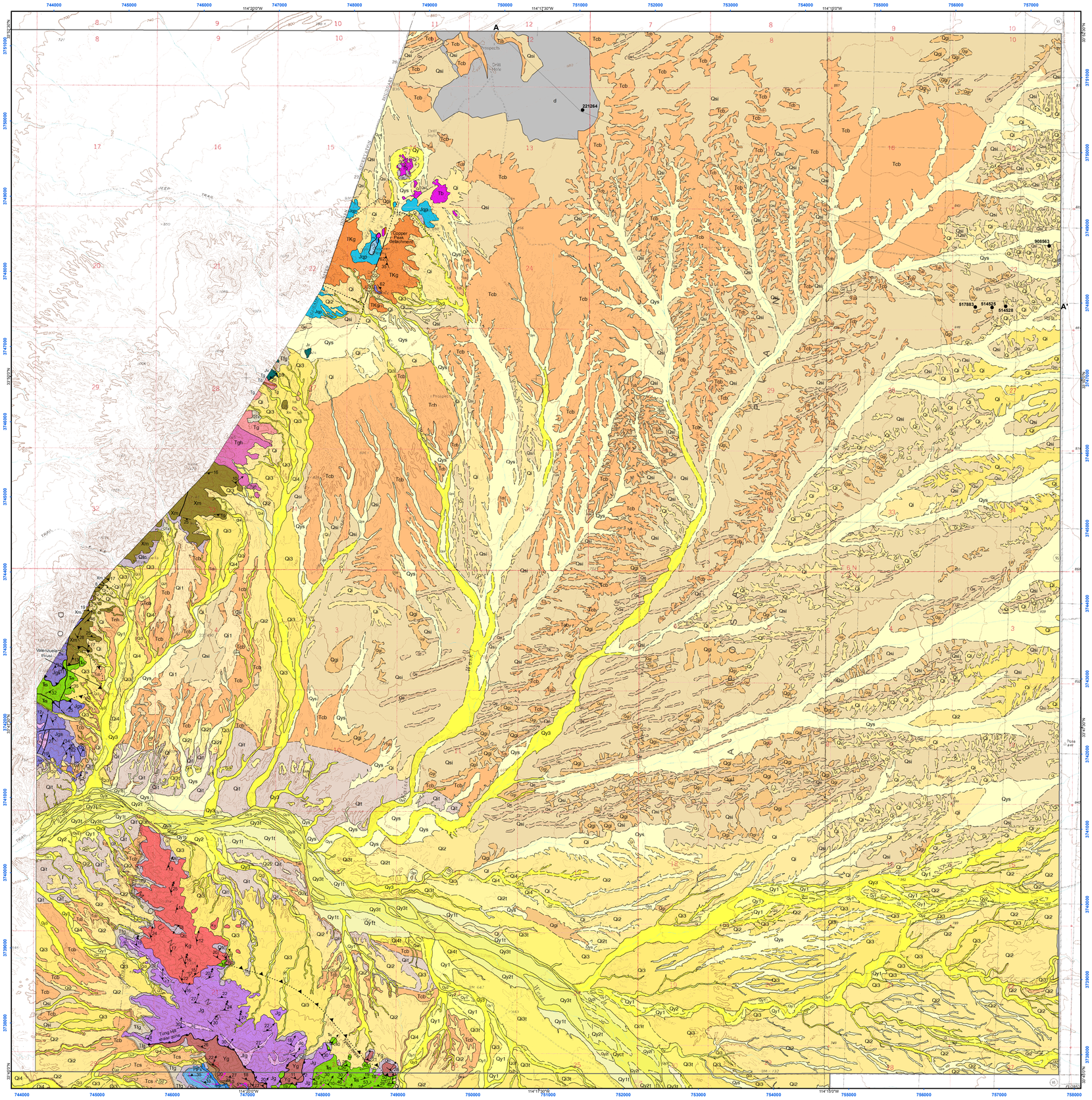


Geologic map of the Moon Mountain SE and western edge of the Bouse SW 7 ½' Quadrangles, La Paz County, Arizona

Brian F. Gootee, Philip A. Pearthree,

and Bradford J. Johnson

Arizona Geological Survey

Digital Geologic Map 122 (DGM-122)

December 2017

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under StateMap award number G15AC00519, 2015. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Introduction

The map area is located northwest of the town of Quartzsite, west of State Route 95 in La Paz County, western Arizona. This map covers all of the Moon Mountain SE 7 ½' Quadrangle except the westernmost edge, which is on the Colorado River Indian Tribes Reservation, and it covers the part of the South of Bouse 7 ½' Quadrangle west of SR 95. It encompasses the northernmost extent of Dome Rock Mountains, its flanking eastern piedmonts, a major regional wash, Tyson Wash, and a substantial portion of La Posa Plain. Thus, the geology in the map area is quite diverse and interesting. 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 #G15AC00519. Mapping was compiled digitally using ESRI ArcGIS software.

Late Cenozoic Geology

Surficial geologic units cover the eastern flanks of the northern Dome Rock Mountains, the valley axis, and western La Posa Plain. The oldest late Cenozoic deposits in the map area are nondeformed alluvial fan deposits composed primarily of metamorphic, plutonic and volcanic clasts, derived primarily from Dome Rock Mountains. These deposits are overlain by, and locally may interfinger with, well-rounded, lithologically diverse gravel and sand deposits that we correlate with the early Pliocene Bullhead Alluvium, unit Tcb. Evidence of this major river aggradation sequence is found all along the lower Colorado River corridor between the mouth of the Grand Canyon and the Gulf of California (Howard et al., 2015). Much more extensive areas are covered by poorly exposed fine-grained deposits (unit Tcs) whose upper, eroded surface is covered by Quaternary fan deposits, or minor sand and open gravel lag. These deposits may be a fine facies of the Bullhead Alluvium that filled the valley south of Tyson Wash – essentially a large back-water area, as topographic constraints farther south would have precluded the early Colorado River from continuing in that direction. Alternatively, they may be part of the siliciclastic Bouse Formation, but we have not found any deposits characteristic of the basal Bouse carbonate that would make this relationship clearer.

Excavation of the Copperstone Mine at the northern end of the Dome Rock Mountains exposed a thick sequence of cross-bedded fluvial sandstone and conglomerate over mineralized bedrock, which we observed from a safe distance. We interpret this siliciclastic sequence to be primarily early Pliocene Bullhead Alluvium. It is approximately 25-35 m thick, sub-horizontally bedded, is not obviously deformed, and unconformably overlies bedrock with up to 15-30 m of paleo-topographic relief. Paleo-current cross-bedding in the coarse sandstone indicates consistent flow to the south-southeast. A second, thinner, tan-colored sequence of sedimentary deposits is bound by unconformities between the Bullhead coarse sandstone and underlying bedrock. Locally, boulders of the same tan-colored sequence up to 2 meters in the long dimension are included in the overlying Bullhead deposits. The fine-grained unit underlying the Bullhead Alluvium probably represents an older basin-fill deposit or the Bouse Formation.

Poorly exposed but distinctive deposits of Bullhead Alluvium are very extensive on the east side of the Dome Rock Mountains from the Copperstone Mine to just south of Tyson Wash. The base of Bullhead Alluvium in the Copperstone Mine is estimated to be 230-240 m above sea level (asl). Further south along Tyson Wash, the base of unit Tcb rests unconformably on bedrock with buried paleo-topographic relief, and may lie unconformably on older pre-Bullhead fanglomerate near the piedmont. North of Tyson Wash the base of unit Tcb rests at 170-200 m asl. Thus, early Colorado River aggradation buried substantial paleotopography.

Quaternary deposits cover most of the eastern piedmont south of Tyson Wash and some of the piedmont adjacent to the Dome Rock Mountains north of Tyson Wash. These deposits range in estimated age from middle Pleistocene to late Holocene, and record periods of piedmont aggradation and incision. These alternating modes were probably primarily driven by climate change (Bull, 1991), although aggradation and incision of the Colorado River during the Quaternary may have impacted this area less directly. Deposits of the La Posa Plain in the northeastern part of the map area are a mix of eolian and alluvial deposits. Much of the substrate is likely alluvium derived from the Plomosa Mountains to the east, but most of the surface is covered by low-relief sandy deposits, sand dunes, and sand and fine gravel reworked by local drainages.

Bedrock Geology

The bedrock geology of this map was compiled from previous detailed maps by Yeats (1985), Knapp (1989), and Boettcher (1996). Rocks ranging in age from Proterozoic to Miocene crop out in the western part of the map area along the northernmost Dome Rock Mountains. Mesoproterozoic megacrystic augen gneiss exposed in the southwest corner of the map is unconformably overlain (stratigraphically) by Paleozoic metasedimentary rocks, which are overturned at the southern edge of the map. Triassic metasedimentary rocks intruded by Jurassic plutons are exposed in the footwall of the northeast-dipping Tyson thrust. Late Cretaceous granite intrudes the Jurassic rocks and the thrust. Paleoproterozoic crystalline rocks, Triassic metasedimentary rocks, Jurassic metavolcanic rocks, and Jurassic and Tertiary (Paleogene) granitic intrusions are exposed north of Tyson Wash along the west edge of the map area. Oligocene-Miocene basalt and conglomerate are exposed in the hanging wall of the Copper Peak detachment, at the north end of the Dome Rock Mountains.

The structure of the northern Dome Rock Mountains is dominated by folds, shear zones, and fabrics of the Maria fold-and-thrust belt, an east-west belt characterized by basement-involved Mesozoic deformation that extends from west-central Arizona into the eastern Mojave Desert of California (Reynolds et al., 1986; Laubach et al., 1989; Spencer and Reynolds, 1990). Jurassic and older rocks in the Moon Mountains SE quadrangle have been imbricated by thrust-sense shear zones. The Tyson thrust is a northeast-dipping shear zone exposed at the southern edge of the map area, along which Proterozoic augen gneiss has been juxtaposed over Triassic metasedimentary rocks (Yeats, 1985; Boettcher, 1996). The Valenzuela thrust, correlative with the Tyson thrust, has a nearly identical succession of recumbently folded Triassic rocks in its footwall and Jurassic plutonic rocks in the hanging wall (Knapp, 1989). The Tung Hill shear zone, another northeast-dipping zone along the south edge of the map area, has prograde upper greenschist- to lower amphibolite-facies mylonitic fabrics that indicate thrust-sense (southwest-verging) shear, overprinted by retrograde fabrics indicating northeast-verging reactivation (Boettcher and Mosher, 1998). Substantial extensional reactivation of the Tung Hill shear zone is evident in the southerly adjoining Middle Camp Mountain quadrangle, where younger Triassic rocks have been juxtaposed over older Proterozoic granitoid gneiss. Mylonite associated with the Valenzuela thrust also indicates northeast-verging reactivation (Knapp, 1989), which has been interpreted as reflecting Late Cretaceous gravity-driven extension of rocks thickened by thrusting (Boettcher and Mosher, 1998). The Tyson thrust is intruded by the Tyson Wash granite, which has locally been affected by late northeast-verging shear and has given a U-Pb sphene date of 86 +/- 1 Ma (Boettcher et al., 2002). Pegmatite emplaced in the hanging wall of the Valenzuela thrust during late stages of northeast-verging reactivation has yielded a U-Pb zircon lower-intercept age of 71 .1 +/- 6.7 Ma (Knapp, 1989).

At the northern end of the Dome Rock Mountains, a small remnant of Paleozoic sandstone and limestone, together with overlying Oligocene-Miocene basalt, are exposed in the hanging wall of the Moon Mountain - Copper Peak detachment. The detachment is a regional northeast-dipping low-angle normal fault that projects beneath the Whipple-Buckskin-Rawhide detachment system and is somewhat older (Spencer and Reynolds, 1990). In the footwall, mylonitic Copper Peak granite (unit TKg) exhibits S-C fabric indicating top-to-northeast shear sense, and west of the map area this granite is intruded by a younger granite that has given a lower-intercept U-Pb zircon date of 20.8 +/- 3.2 Ma (Knapp, 1989); ductile extensional shearing of the footwall therefore ceased by the earliest Miocene. $^{40}Ar/^{39}Ar$ data from the northern Dome Rock Mountains and nearby ranges indicate heating associated with crustal thickening in Late Cretaceous (approximately 80-90 Ma) and rapid cooling related to extensional denudation in Oligocene and Miocene time (Knapp and Heizler, 1990).

The Copperstone gold deposit, located at the edge of the map 1.5 km beyond the north end of the mountains, contains gold mineralization associated with quartz, hematite, and chrysocolla hosted in Miocene sedimentary breccias in the hanging wall of the Copper Peak detachment (Spencer et al., 1988). The Copperstone mine produced almost 500,000 ounces of gold between 1987 and 1993 through open-pit methods and has become a focus of renewed exploration (http://kerrmines.com/copperstone/).

References cited

Boettcher, S.S., 1996, Crustal shortening, extension, and unroofing in the Dome Rock Mountains, Arizona: Ph.D. dissertation, University of Texas at Austin.

Boettcher, S.S., and Mosher, S., 1998, Mid- to late Cretaceous ductile deformation and thermal evolution of the crust in the northern Dome Rock Mountains, Arizona: Journal of Structural Geology, v. 20, p. 745-764, doi:10.1016/S0191-8141(98)00005-4.

Boettcher, S.S., Mosher, S., and Tosdal, R.M., 2002, Structural and tectonic evolution of Mesozoic basement-involved fold nappes and thrust faults in the Dome Rock Mountains, Arizona, *in* Barth, A., ed., Contribution to the crustal evolution of the southwestern United States: Geological Society of America Special Paper 365, p. 73–97, doi:10.1130/0-8137-2365-5.73.

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

Howard, K.A., House, P.K., Dorsey, R.J., and Pearthree, P.A., 2015, River-evolution and tectonic implications of a major Pliocene aggradation on the lower Colorado River: The Bullhead Alluvium: Geosphere, v. 11, p. 1–30; doi:10.1130/GES01059.1

Knapp, J.H., 1989, Structural development, thermal evolution, and tectonic significance of a Cordilleran basement thrust terrane, Maria fold and thrust belt, west-central Arizona: Ph.D. thesis, Massachusetts Institute of Technology.

Knapp, J.H., and Heizler, M.T., 1990, Thermal history of crystalline nappes of the Maria fold and thrust belt, west central Arizona: Journal of Geophysical Research, v. 95, p. 20049-20073.

Laubach, S.E., Reynolds, S.J., Spencer, J.E., and Marshak, S., 1989, Progressive deformation and superposed fabrics related to Cretaceous crustal underthrusting in western Arizona, U.S.A.: Journal of Structural Geology, v. 11, p. 735-749.

Reynolds, S.J., Spencer, J.E., Richard, S.M., and Laubach, S.E., 1986, Mesozoic structures in west-central Arizona, *in* Beatty, B., and Wilkinson, P.A.K., eds., Frontiers in geology and ore deposits of Arizona and the Southwest: Arizona Geological Society Digest, v. 16, p. 35–51.

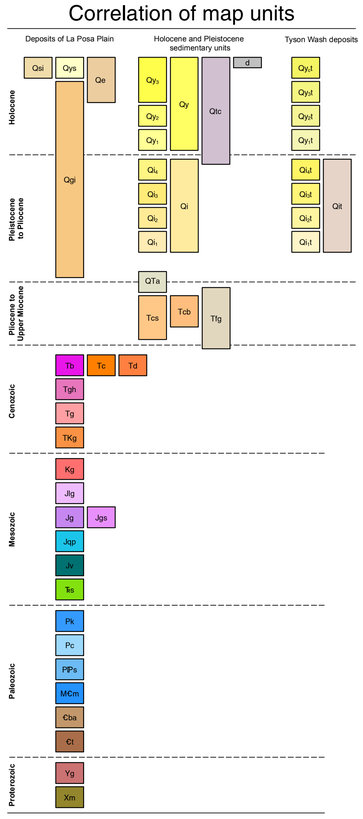
Reynolds, S.J., Spencer, J.E., and DeWitt, E., 1987, Stratigraphy and U-Th-Pb geochronology of Triassic and Jurassic rocks in west-central Arizona, *in* Dickinson, W.R., and Klute, M.A., eds., Mesozoic rocks of southern Arizona and adjacent areas: Arizona Geological Society Digest, v. 18, p. 65–80.

Spencer, J.E., and Reynolds, S.J., 1990, Relationship between Mesozoic and Cenozoic tectonic features in west central Arizona and adjacent southeastern California: Journal of Geophysical Research, v. 95, p. 539–555.

Spencer, J.E., Duncan, J.T., and Burton, W.D., 1988, The Copperstone mine: Arizona's new gold producer: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 18, no. 2, p. 1-3.

Tosdal, R.M., and Wooden, J.L., 2015, Construction of the Jurassic magmatic arc, southeast California and southwest Arizona, *in* Anderson, T.H., Didenko, A.N., Johnson, C.L., Khanchuk, A.I., and MacDonald, J.H., Jr., eds., Late Jurassic margin of Laurasia—A record of faulting accommodating plate rotation: Geological Society of America Special Paper 513, p. 189–221, doi:10.1130/2015.2513(04).

Correlation of map units



Map Unit Descriptions

Other Units

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

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

Tyson Wash deposits

Qyc – **Active channel deposits of Tyson Wash** - Deposits consist of unconsolidated gravel ranging from pebbles to small boulders, and sand with minor silt and clay. Topography is undulating between gravel bars and modestly incised channels. Minimal vegetation due to relatively frequent flow events, and no soil development.

Qyt – **Tyson Wash deposits in low terraces and small channels** - Deposits adjacent to larger active channels, includes gravel, sand and minor silt and clay deposits in smaller channels, bars, low terraces, or floodplain areas.Deposits are unconsolidated, relatively well-vegetated, and have minimal soil development.

Qyt – **Tyson Wash deposits in low terraces and overbank areas** - Low terrace and floodplain deposits located primarily along the flanks of larger channels. These deposits consist of unconsolidated sand, silt, and minor clay with sub-rounded to sub-angular pebble to cobble bars on the surface and beds and lenses in cross section. Vegetation is relatively dense and soil development is minimal.

Qyt – **Tyson Wash deposits in slightly higher terraces** - Gravel and sand deposits in slightly to moderately varnished terraces along Tyson Wash. Qyt1 deposits are sandy to pebbly in swales, with coarser lightly varnished pebble to cobble bars. Terrace surfaces typically are 2m or less above active washes. Soil development is weak, and vegetation in typically sparse.

Qit – **Youngest intermediate terrace deposits associated with Tyson Wash** - Poorly sorted cobble, pebble, sand deposits, with minor silt, clay, and boulders preserved in a few low-intermediate terraces. Clasts consist of a mixture of siliciclastic rock types, including intermediate to mafic volcanic rocks similar to assemblages in the modern Tyson Wash. Deposits are found along the margins of Tyson Wash, with moderately varnished terrace surface remnants about 3-5 m above adjacent Holocene terrace deposits.

Qit – **Younger intermediate terrace deposits associated with Tyson Wash** - Poorly sorted cobble, pebble, sand deposits, with minor silt, clay, and boulders preserved in intermediate remnant terraces. Clasts consist of a mixture of siliciclastic rock types, including intermediate to mafic volcanic rocks. Deposits are extensive along the margins of Tyson Wash, and are typically 5 to 10 m above active channels. Terrace surfaces are quite planar and darkly varnished.

Qit – **Old intermediate terrace deposits associated with Tyson Wash** - Poorly sorted cobble, pebble, sand deposits, with minor silt, clay, and boulders deposited by ancestral Tyson Wash. Clasts consist of a mixture of siliciclastic rock types, including intermediate to mafic volcanic rocks similar to assemblages in the modern Tyson Wash. Deposits are found along the margins of Tyson Wash, typically 5 to 8 m thick, and overlie older piedmont deposits and Bullhead alluvium unit Tcb. Rare planar remnants associated with these deposits are associated with older Qi2 piedmont deposits found at similar elevations and are thought to be similar in age. Qi2t deposits are 10 to 20 m above Tyson Wash. Scarps roughly colinear with the modern-day Tyson Wash are present near the elevation of these deposits and are interpreted to be associated with incision into older deposits during this time.

Qit – **Oldest intermediate terrace deposits associated with Tyson Wash** - Poorly sorted cobble, pebble, sand deposits, with minor silt, clay, and boulders deposited by ancestral Tyson Wash. Clasts consist of a mixture of siliciclastic rock types, including intermediate to mafic volcanic rocks similar to assemblages in the modern Tyson Wash. Deposits are found along the margins of Tyson Wash, are typically 5 to 8 m thick, and overlie older piedmont deposits and Bullhead alluvium unit Tcb. Rare planar remnants associated with these deposits are associated with older Qi1 piedmont deposits found at similar elevations and are thought to be similar in age. Qi1t deposits are 15 to 25 m above Tyson Wash. Scarps roughly colinear with the modern-day Tyson Wash are present near the elevation of these deposits and are interpreted to be associated with incision into older deposits during this time.

Qit – **Undivided deposits associated with Tyson Wash** - Undivided older deposits of Tyson Wash. Poorly sorted cobble, pebble, and sand deposits, with minor silt, clay, and boulders. Clasts consist of a mixture of siliciclastic rock types, including intermediate to mafic volcanic rocks similar to assemblages in the modern Tyson Wash, and less common gravel lithologies known to originate from Bullhead unit Tcb. Deposits of this unit are found along the margins of Tyson Wash and are up to 10 m thick, and overlie older piedmont deposits, Bullhead alluvium, and bedrock. Unit Qit may consist of multiple inset-fill terraces along Tyson Wash specifically in the bedrock pass across Dome Rock mountains. Planar remnants are mapped separately, where preserved, and appear to coincide with scarps roughly colinear to the modern-day Tyson Wash representing incision associated with downcutting by Tyson Wash into older deposits.

Piedmont alluvial units

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.

Qys – **Young sand and minor gravel 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.

Qsi – **Young sheet sand and minor gravel** - Interdune and laterally extensive sheet sand and small dunes. Areas covered primarily by sand, with absent to 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.

Qgl – **Fine-grained to gravel-mantled erosion surfaces** - Discontinuous gravel lag deposits on much finer substrate. Most erosion surfaces are formed on older fine-grained deposits in interdune areas. Gravel lithologies vary with location, and include locally derived crystalline and volcanic rocks, and rounded, far-traveled clasts from old Colorado River deposits.

Qy_0 – **Deposits in active channels, low terraces and bars** - Piedmont alluvial deposits located along active drainages including small channels, adjacent low terraces, or floodplain areas. Qy3 deposits are composed of unconsolidated, unvarnished sand, gravel, and silt deposits.

Qy_2 – **Young terrace deposits** - Low terrace deposits located primarily along the flanks of incised drainages and low-relief terraces inset into Pleistocene age fan deposits. These deposits consist of unconsolidated sand, silt, and minor clay with sub-rounded to sub-angular pebble to cobble bars on the surface and beds and lenses in cross section. Soil development is weak to absent, and very light rock varnish is found locally on gravel bars.

Qy_1 – **Slightly higher terrace and alluvial fan deposits** - Deposits form slightly to moderately varnished planar terraces along larger piedmont drainages and young relict alluvial fan deposits on lower piedmont areas. Qy1 deposits are composed of sandy to pebbly swales with coarser unvarnished to very lightly varnished pebble to cobble bars, and partially overlie Pleistocene deposits in some areas.

Qy – **Young alluvium, undifferentiated** - Poorly sorted deposits including pebbles, cobbles, sand, minor silt and clay, and locally boulders. Associated with active and recently active washes, and slightly higher terraces with modest rock varnish, minimal soil development.

Qi_4 – **Youngest intermediate alluvium** - Pebble, cobble, and sand deposits in low terraces and alluvial fans. Moderate varnish on clasts, moderate gravel lags to weak pavements, but pavements not as well developed as Qi3. Soil development is weak to moderate. Surfaces are moderately undulating, but may be smooth if deposits consist of fine gravel and sand.

Qi_3 – **Intermediate alluvial fan and terrace deposits** - Gravel and sand deposits with moderate to light desert pavements, 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.

Qi_2 – **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. Unit thicknesses up to 7 m were observed, but thicknesses of 2 to 3 m are typical.

Qi_1 – **Older intermediate alluvial deposits** - Poorly sorted cobble, pebble, sand deposits, with minor silt, clay, and boulders. Deposits are found capping moderately high ridges, and typically are 15 to 25 m above active washes. Planar surfaces are generally fairly narrow and margins are substantially rounded. Deposits typically are a few meters thick over underlying fan deposits or Bullhead alluvium. Soil development ranges from strong on well-preserved surfaces to weak to moderate on eroded slopes.

Qi – **Intermediate alluvial deposits** - Stream terrace and relict alluvial-fan deposits with weak to strong soil development

Colorado River deposits

Tcb – **Bullhead Alluvium** - Unconsolidated to moderately consolidated well-rounded to subangular cobbles and pebbles, including a substantial portion that are exotic, quartz-rich sand, and lesser amounts of silt and clay. Rounded pebbles and cobbles of primarily quartzite, chert, and other resistant rock types. Surfaces of these deposits are commonly mantled by gravel, and gravel beds are common, but sand may be dominant particle size. Deposits are exposed from about 170 m asl along Tyson Wash to 260 m asl in the Copperstone Mine. Areas in the northern part of the Moon Mountain SE quadrangle are mapped as Bullhead Alluvium if there is an obvious rounded, exotic gravel component in the surface lag.

Tcs – **Old silt, clay and sand** - Quartz-rich sand, silt and mud deposits capped by younger Pleistocene units mapped south of Tyson Wash. Unit Tcs exhibits thin to medium bedding and is occasionally massive. Quartz-rich sand beds thin, laminated, and occasionally massive. Sand grains are typically very well sorted and well-rounded to sub-rounded and commonly exhibit cross-laminations. Unit Tcs interfingers with locally-sourced tributary fan deposits. This unit is probably fine-grained Bullhead Alluvium or siliciclastic deposits of the Bouse Formation, but may be younger fine-grained deposits. In the southeastern part of the Middle Camp quadrangle this unit is capped by unit Tfg.

Pliocene alluvial fan deposits

QTa – **Old 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.

Tfg – **Fanglomerate** - Poorly sorted, light brown to medium gray conglomerate and conglomeratic sandstone with angular to subrounded clasts of local metamorphic rocks, granitoids, and other siliceous rocks. In the southeastern portion of the Middle Camp quadrangle, this unit is sand-supported with locally abundant subrounded pebble size grains of fine-grained carbonate. Locally this unit is moderately consolidated. Sand grains consist of medium to fine grained quartz and lithic sand grains, subangular to subrounded. This unit is interpreted as representing sandy and gravelly proximal to mid-alluvial fan deposits. This generalized unit is used for fanglomerate deposits where their relationship to Bouse and Bullhead deposits is uncertain, however, in the southeastern portion of the Middle Camp quadrangle unit Tfg is overlying unit Tcs unconformably with low relief. Unit Tfg in this area is generally nondeformed although fractures and minor faults and folding are evident.

Bedrock map units

Tb – **Basalt** - Dark brown- to black-weathering, mafic olivine-bearing volcanic rocks in association with coarse-grained sandstones north of Copper Peak. Contacts with sedimentary rocks are not well exposed, so the possibility that these are hypabyssal dike rocks cannot be ruled out. Mapped partially by Knapp, 1989. A sample from a volcanic plug or cinder cone collected 0.5 mile southwest of Copperstone Mine yield a K/Ar age of 11.4 +/- 0.3 Ma (Spencer and others, 1988).

Tc – **Monolithic conglomerate, Moon Mountain area** - Monolithic conglomerate consists exclusively of poorly-sorted, pebble- to boulder-size, angular to sub-angular, clasts of greenish gray-weathering, quartz porphyry in a clast-supported conglomerate. This unit rests in fault contact against crystalline gneisses of the Moon Mountain crystalline assemblage on the Moon Mountain detachment fault. From Knapp, 1989.

Td – **Basic dike rocks** - Basic to intermediate dike rocks in the Copper Peak and northern Dome Rock map area. Compositions range from diabase to biotite-porphyry dacite. In the Copper Peak area, a series of west-northwest-trending dikes intrudes the Copper Peak granite in the footwall of the Copper Peak detachment fault. These dikes are in turn cut by a high-angle fault which offsets the detachment, and may therefore place an upper age limit on movement of the Copper Peak/Moon Mountain detachment system (Knapp, 1989).

Tgh – **Hornblende-biotite granite** - Medium- to coarse-grained granite composed of 40-50% K-feldspar, 25-30% quartz, 10-15% plagioclase, 8-10% biotite, and 4-5% hornblende. Equigranular to porphyritic with up to 25% K-feldspar phenocrysts up to 1 cm. Medium gray, weathered dark brownish-gray.

Tg – **Biotite granite** - Medium-grained porphyritic granite, typically containing phenocrysts of feldspar (40%), quartz (30%), and biotite (~5%). Ranges to equigranular, weathered orange-brown.

TKg – **Copper Peak granite** - Biotite granite exhibiting weak to strong tectonite foliation characterized by flattened and elongate quartz and crushed K-feldspar grains, with biotite in part replaced by secondary muscovite and chlorite. Weathered orange-brown. Contacts with other rocks are faulted or not exposed.

Kg – **Tyson Wash granite** - Medium- to fine-grained equigranular monzogranite composed of 25-30% K-feldspar, 30-35% plagioclase, 30% quartz, and 5-8% aggregates of recrystallized biotite. Light gray to white, weathered tan to gray, variably foliated.

Jlg – **Leucogranite** - Medium- to fine-grained, equigranular to slightly porphyritic leucogranite, forms sheet-like intrusions that mostly dip northeast to north.

Jgs – **Megacrystic quartz syenite** - Quartz syenite containing 3-50% gray to purple K-feldspar megacrysts ranging from <1 cm to >15 cm in a medium- to fine-grained groundmass of quartz, K-feldspar, biotite, and plagioclase with secondary epidote, chlorite, and minor muscovite.

Jg – **Middle Camp quartz monzonite and monzogranite** - Medium-grained porphyritic quartz monzonite, monzogranite, granodiorite, and minor quartz monzodiorite, characterized by purple-gray K-feldspar that commonly forms phenocrysts 1-2 cm across, medium- to fine-grained plagioclase that commonly is a greenish color from partial replacement by sericite and epidote, and 15-35% fine-grained aggregates of mafic minerals. The mafic aggregates are typically <1 cm across, locally define a heterogeneous foliation, and consist of conspicuous biotite, subordinate hornblende, and traces of titanite. The rock is light green to green-gray and is weathered dark green-gray to dark brown. Despite the range in composition, this unit is texturally and compositionally homogeneous over large areas, with compositional variation mainly between different intrusions within the unit and near contacts between intrusions. U-Pb zircon ages for this suite range from 167-163 Ma regionally (Tosdal and Wooden, 2015), and samples from south of the map area indicate a preferred age of 164 +/- 1 Ma (Boettcher et al., 2002).

Jqp – **Quartz porphyry** - Gray-green rock containing phenocrysts of quartz, plagioclase, and K-feldspar, lithic fragments, and relict hornblende and biotite, in a very fine-grained groundmass of quartz and feldspar. Quartz grains are commonly embayed and many of the feldspar phenocrysts are angular or broken, suggesting a volcanic (pyroclastic) origin. The rock is weathered orange to dark brown and forms resistant outcrops.

Jv – **Mojave Paint Basin volcanic rocks** - Highly deformed, medium- to fine-grained, green- to gray-weathered metavolcanic rocks.

Ts – **Valenzuela - Tung Hill metasedimentary assemblage** - A succession of schist, marble, quartzite, and calcsilicate that are exposed along the west edge of the map area in the footwall of the Valenzuela thrust (Knapp, 1989) and along the southern edge of the map in the footwall of the Tyson thrust (Yeats, 1985). As noted by Knapp (1989), the rocks in both areas are nearly identical, and they are correlated with the Buckskin Formation (Reynolds et al., 1987) exposed in nearby ranges.

Knapp (1989) subdivided the Valenzuela rocks into four units that are repeated across a recumbent, southward-opening, isoclinal synform. From the structural base to the core of the fold they consist of (1) gray-green, fine- to medium-grained calcsilicate schist containing quartzite lenses interpreted as deformed pebbles and cobbles; (2) thin-bedded, medium- to fine-grained, light- to medium-gray micaceous quartzite; (3) quartz-muscovite schist with interlayered thin quartzite, weathered gray to brown and locally containing prograde sillimanite and relict kyanite; (4) orange- to brown-weathered, coarse-grained, micaceous marble.

Pk – **Kaibab Limestone** - Brecciated cherty limestone, exposed in a small outcrop in the hanging wall of the Copper Peak detachment fault. Within breccia blocks, the medium- to fine-grained limestone is laminated, is weathered gray-brown, and contains dark-brown resistant nodules of chert.

Pc – **Coconinо Sandstone** - Brecciated unit composed of red-brown-weathered angular pebbles and cobbles of white quartzite in a crushed matrix of subangular to subrounded fine-grained quartz. Some of the cobbles display primary sedimentary features, including silty laminations and well-rounded, medium- to fine-grained quartz sand grains in quartz cement.

PPs – **Supai Group** - Calcsilicate, calcareous quartzite, and marble. The basal part is light-green- to olive-brown-weathered calcareous schist and quartzite. This is overlain by dark-brown-weathered quartzite interlayered with light-brown-weathered marble composed almost entirely of wollastonite; marble becomes more abundant higher in the stratigraphic section. The upper part of the Supai Group is not exposed in the map area.

MCm – **Marble and calcsilicate** - Carbonate-dominated succession that includes equivalents of the Cambrian Muav Limestone, Devonian dolostone (Temple Butte), and Mississippian Redwall Limestone. The lower part of the Muav marble consists of coarse-grained, gray-weathered marble, interlayered with light-brown-weathered micaceous marble. The upper part of the Muav is fine- to medium-grained, foliated, tan-weathered marble with discontinuous layers of fine-grained, massive, white-weathered, calcitic and minor dolomitic marble. The Muav is capped by a heterogeneous succession of dark-green- to light-brown-weathered calcsilicate gneiss, quartzite, schist, and marble, and is stratigraphically overlain (structurally underlain) by massive, light-tan-weathered, dolomitic marble of probable Devonian age. This is stratigraphically overlain (structurally underlain) by white calcitic marble correlated with Redwall Limestone.

Cba – **Bright Angel schist** - Dark greenish-gray, medium-grained quartz-muscovite-biotite schist with minor thin layers of quartzite. Becomes calcareous up-section with discontinuous meter-thick epidote-bearing layers.

Ct – **Tapeats quartzite** - Medium- to fine-grained quartzite, micaceous quartzite, and muscovite-quartz schist. The lower part is thick- to medium-layered and exhibits heavy-mineral laminations and local crossbedding. The upper part is fine-grained laminated quartzite with interlayered quartz-muscovite schist. The rocks are gray and are weathered dark brown.

Yg – **Granitic augen gneiss** - Megacrystic granitic augen gneiss containing 10-40% K-feldspar porphyroclasts (relict megacrysts) 1-5 cm long in a medium- to fine-grained schistose matrix of plagioclase, quartz, 15-25% fine-grained biotite, and K-feldspar. Generally of monzogranite composition.

Xm – **Valen crystalline assemblage** - Megacrystic augen gneiss, banded gneiss, quartzofeldspathic schist, and amphibolite.

SCALE 1:24,000

1 0.5 0 1 Miles

1 0.5 0 1 Kilometers

0 1000 2000 3000 4000 5000 Feet

CONTOUR INTERVAL 20 FEET

TRUE NORTH

MAGNETIC NORTH

11°

Approximate mean declination, 2017

Topographic base map derived from Moon Mountain SE 7.5' USGS topographic quadrangle map originally with NAD27 datum. Reprojected to UTM NAD83 datum (zone 11) using iGage All Topo Maps V9. UTM NAD 83 grid and lat-lon markers produced using ESRI ArcMap v. 10.2.

Contacts and faults

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

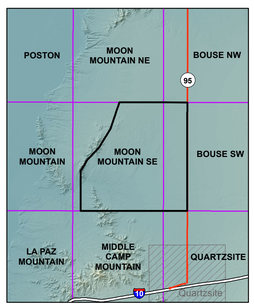
Structure symbols

- Strike and dip of main synmetamorphic tectonic foliation
- Strike and dip of post-peak-metamorphic cleavage
- Trend and plunge of elongation lineation
- Trend and plunge of elongation lineation, top-down-plunge shear sense
- Trend and plunge of intersection of bedding on schistosity
- Dip of contact

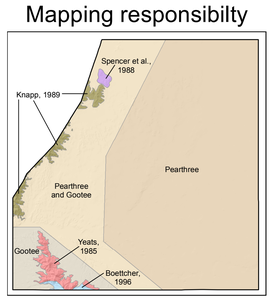
Other features

- Cross-section location
- Well used in geologic cross-section

Location of map area



Mapping responsibilty



Arizona Geological Survey
1955 East Sixth Street, PO Box 210184
Tucson, AZ 85721
(520) 621-2470
www.azgs.az.gov

THE UNIVERSITY OF ARIZONA