Geologic map of the Middle Camp Mountain 7 ½' Quadrangle, La Paz County, Arizona

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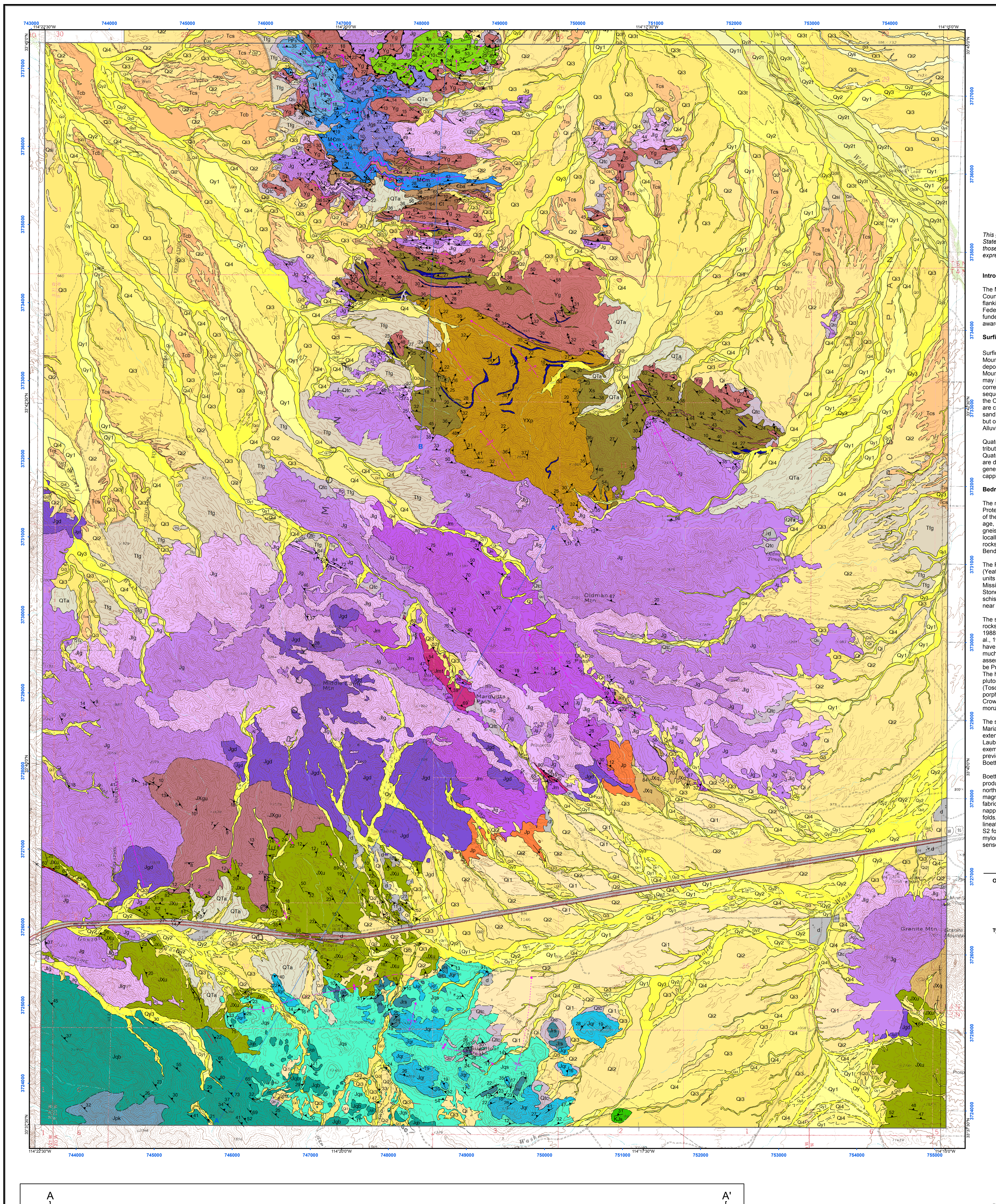
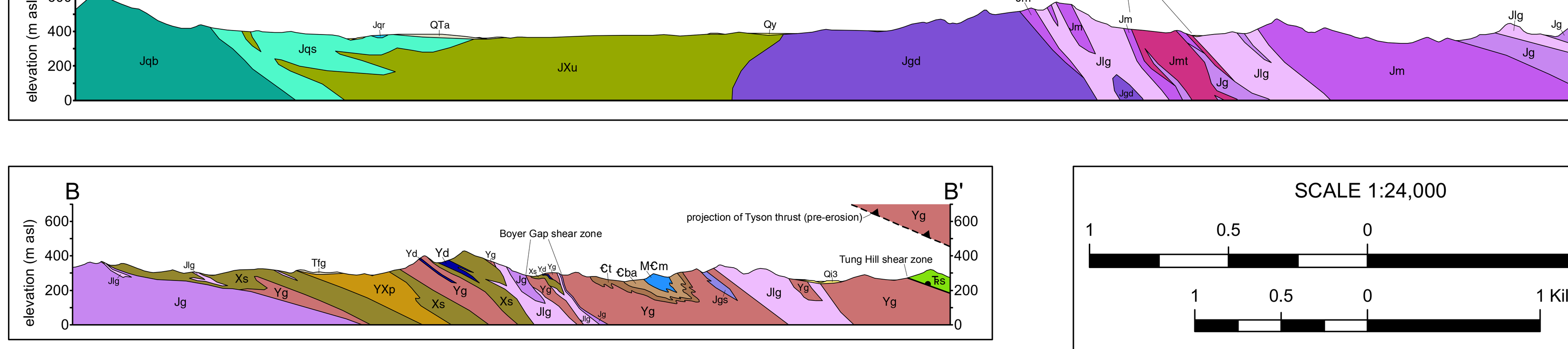
Arizona Geological Survey

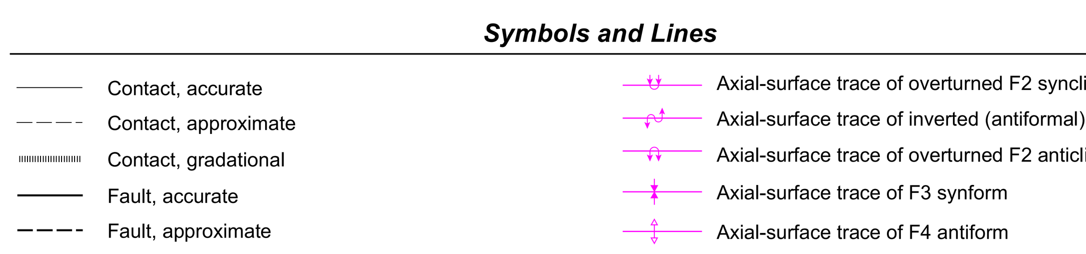
Digital Geologic Map 121 (DGM-121)

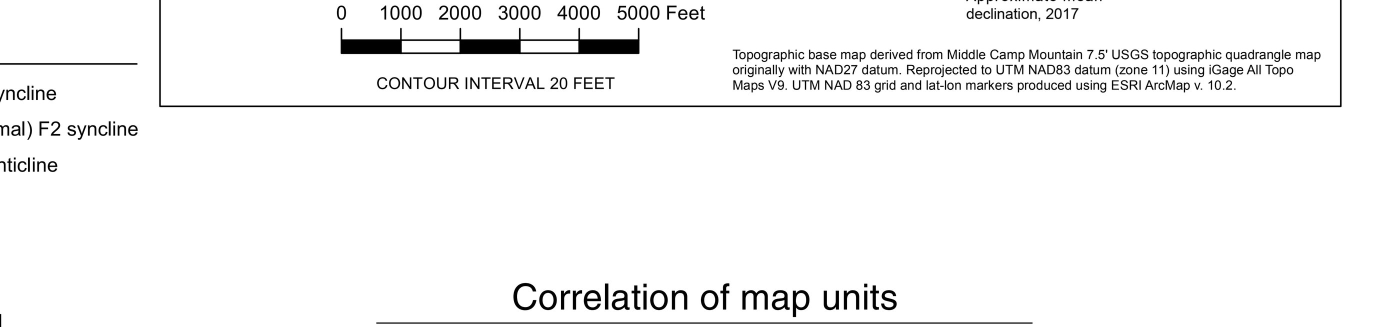
December 2017

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.









Topographic base map derived from Middle Camp Mountain 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.

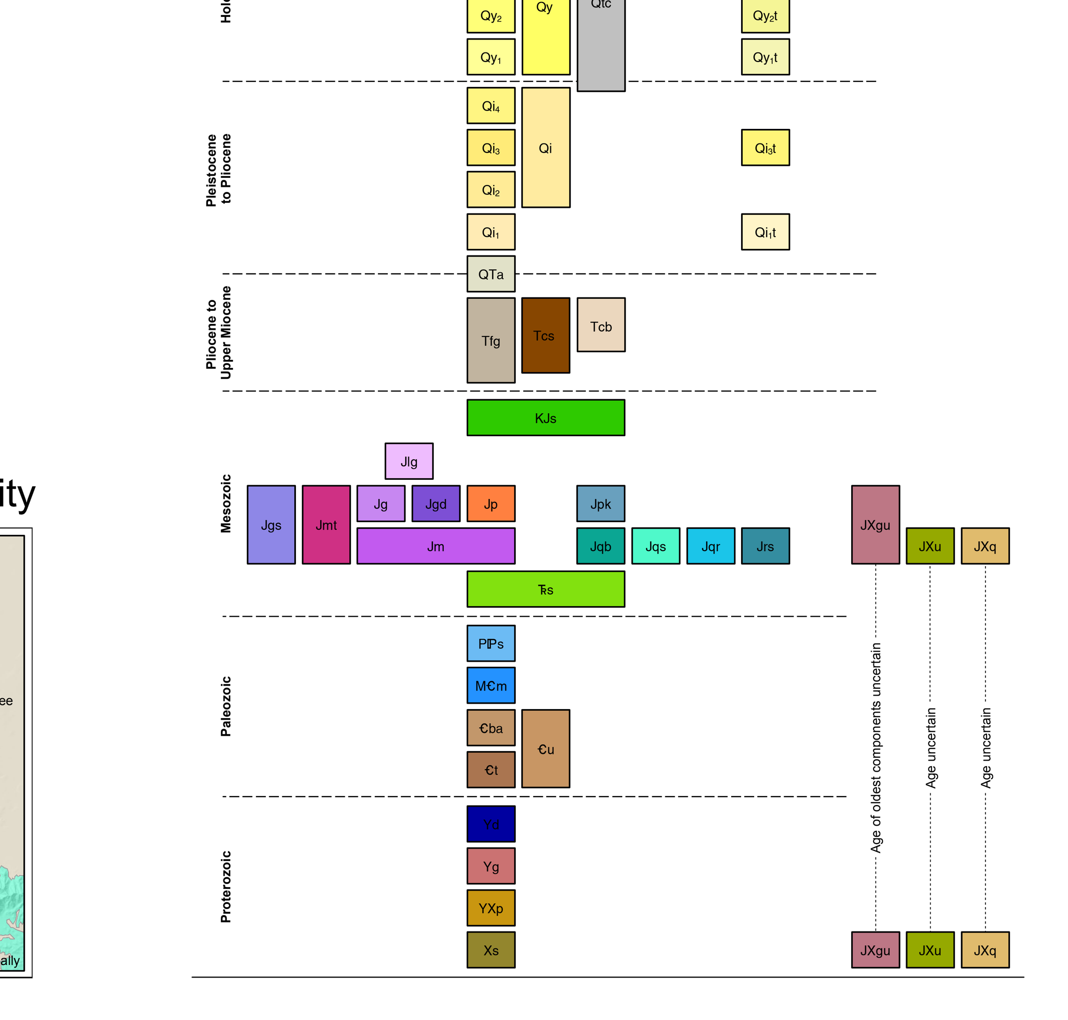
Symbols and Lines

- Contact, accurate
- Contact, approximate
- Contact, gradational
- Fault, accurate
- Fault, approximate
- High-angle normal fault, ornament on hanging wall
- Low-angle normal fault, ornament on hanging wall
- Thrust fault, ornament on hanging wall
- Dip of fault
- Quartz vein, showing dip
- Strike and dip of inclined bedding
- Strike of vertical bedding
- Strike and dip of overtuned bedding
- Strike and dip of main synmetamorphic tectonic foliation (S2; locally S1, S1-S2, or S2-S3; see text)
- Strike and dip of post-peak-metamorphic cleavage (S3)
- Trend and plunge of mineral elongation lineation (L2)
- Trend and plunge of elongation lineation, top-down-plunge (normal) shear sense
- Trend and plunge of elongation lineation, top-up-plunge (reverse) shear sense
- Trend and plunge of intersection of layering (S0-S1) on schistosity (S2)
- Trend and plunge of F1/F2 minor-fold axis
- Trend and plunge of F3 minor-fold axis
- Axial-surface trace of overturned F2 syncline
- Axial-surface trace of inverted (antiformal) F2 syncline
- Axial-surface trace of overturned F2 anticline
- Axial-surface trace of F3 synform
- Axial-surface trace of F4 antiform
- Axial-surface trace of F4 synform
- Approximate axial-surface trace of fold
- Concealed axial-surface trace of fold
- Axial-surface trace of fold showing plunge

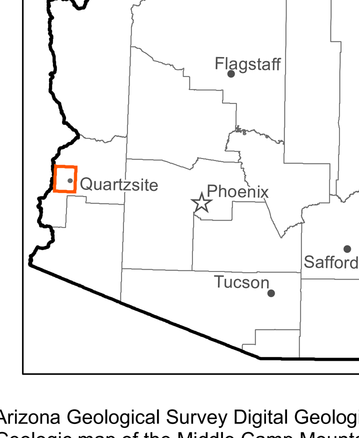
For simplicity, traces of F1 folds are not shown on the map

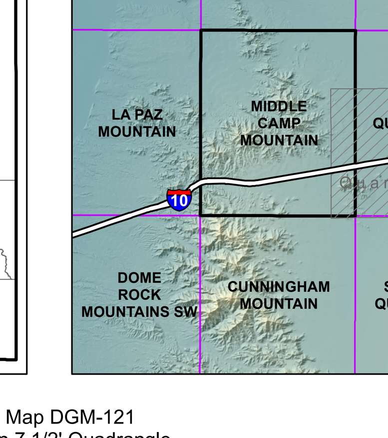
A —— A' Location of cross section

Correlation of map units

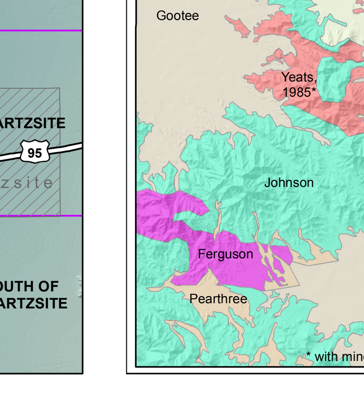


Location of map area





Mapping responsibility



Introduction

The Middle Camp Mountain 7 ½' Quadrangle is located just to the west of the town of Quartzsite in La Paz County, western Arizona. The Quadrangle encompasses part of the northern Dome Rock Mountains and flanking piedmonts, as well as part of La Posa Plain. 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.

Surficial geology

Surficial geologic units in the map area are mainly found around the flanks of the northern Dome Rock Mountains and on La Posa Plain. The oldest late Cenozoic deposits in the map area are nondeformed fan deposits composed primarily of metamorphic and plutonic clasts, derived primarily from the Dome Rock Mountains and to a lesser extent from the Plomosa Mountains. These deposits are overlain by, and locally may interfinger with, well-rounded, lithologically diverse gravel and sand deposits that we tentatively correlate with the early Pliocene Bullhead Alluvium (Howard et al, 2015). This major river aggradation sequence is found all along the lower Colorado River corridor between the mouth of the Grand Canyon and the Cibola Area (House et al., 2008; Howard et al., 2015; Gootee et al., 2016). Much more extensive areas are covered by poorly exposed fine-grained deposits whose upper, eroded surfaces are covered by minor sand and open gravel lag. Many of these deposits may be part of the siliciclastic Bouse Formation as well, but others are almost certainly younger and are associated with sandy and muddy facies of the Bullhead Alluvium.

Quaternary sedimentary deposits are limited to an extensive area associated with Tyson Wash and tributaries from the southern, eastern, northern and western flanks of the Dome Rock Mountains. Quaternary and possibly Pliocene deposits in La Posa Plain in the northeastern portion of the quadrangle are derived from the Plomosa Mountains. The oldest Quaternary deposits of early to middle Pleistocene are generally not well preserved. Middle to late Pleistocene alluvial fan terrace deposits are the most extensive, capping older fine-grained sedimentary deposits.

Bedrock geology

The northern Dome Rock Mountains are underlain by plutonic and metamorphic rocks ranging in age from Proterozoic to Jurassic. Paleoproterozoic schist and micaceous quartzite are exposed in the northern part of the Middle Camp Mountain quadrangle. Sr and Nd isotopic data from the schist indicate a Proterozoic age, including a calculated Nd model age (T_{DM}) of >2.0 Ga (Lerch et al., 1991). Granitic megacrystic augen gneiss is generally in tectonic contact with the schist, although interfoliated sill-like layers a few meters thick locally appear intrusive (Yeats, 1985). The granitic gneiss resembles Mesoproterozoic (1.4 Ga) granitic rocks elsewhere in western Arizona and southeastern California (e.g., Silver et al., 1977; Anderson and Bender, 1989).

The Proterozoic rocks are overlain unconformably by a succession of Paleozoic metasedimentary rocks (Yeats, 1985; Boettcher, 1996). These include a basal Cambrian quartzite and overlying schist and marble units that here and in nearby mountain ranges have been correlated with Cambrian, Devonian, and Mississippian strata in the western Grand Canyon and southeastern Arizona (Miller, 1970; Hamilton, 1982; Stone et al., 1983). Pennsylvanian-Permian schist and calcsilicate cap the Paleozoic succession. Triassic schist, quartzite, and calcsilicate are exposed in the hanging wall of the Tung Hill extensional shear zone near the north edge of the map area.

The southern part of the map area is underlain by Jurassic silicic metavolcanic and hypabyssal intrusive rocks, which are part of a thick volcanic pile that extends into the central Dome Rock Mountains (Tosdal, 1988). Related rocks are widespread in southwestern Arizona and adjacent parts of California (Tosdal et al., 1989). The Jurassic volcanic rocks along the southern edge of the Middle Camp Mountain quadrangle have undergone extensive hydrothermal alteration, low-grade metamorphism, and deformation such that much of the rock is now schist. These rocks are juxtaposed, and in part interfoliated, with heterogeneous assemblages of schist and quartzite of uncertain age (units JXu and JXq). Protoliths of unit JXu may in part be Proterozoic or Paleozoic, interfoliated with schist derived from Jurassic rocks.
The higher mountains in the west-central part of the map area are underlain by Middle to early Late Jurassic plutonic rocks that are part of a regional calc-alkaline suite that ranges in age from about 173 to 158 Ma (Tosdal and Wooden, 2015). The most abundant rocks of the suite in this area are medium-grained porphyritic biotite quartz monzonite, monzogranite, and granodiorite (Middle Camp quartz monzonite of Crowl, 1979). Tabular intrusions of medium- to fine-grained biotite leucogranite have intruded the quartz monzonite and older rocks.

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). In the Dome Rock Mountains, this deformation is best exemplified in the Boyer Gap area near the northern edge of the Middle Camp Mountain quadrangle, where previous detailed mapping studies have documented multiple phases of deformation (Yeats, 1985; Boettcher, 1996).

Boettcher and Mosher (1998) described three phases of deformation at Boyer Gap. The first phase (D1) produced a recumbent isoclinal syncline (F1) with amplitude of at least 2 km, opening to the north or northwest and cored by Pennsylvanian and Permian rocks of the Supai Group, during late Middle Jurassic magmatism. Bedding (S0) was transposed into parallelism with the S1 foliation, forming a composite S0-S1 fabric. The F1 fold was refolded during D2 by tight to isoclinal, recumbent, south- to southwest-verging fold nappes and sheath folds (F2) that produced elliptical interference patterns within the Paleozoic rocks. F2 folds, gently to moderately northeast-dipping axial-planar S2 foliation, and northeast-plunging elongation lineation (L2) formed during mid- to Late Cretaceous greenschist- to amphibolite-facies metamorphism. The S2 foliation is generally expressed as schistosity in metasedimentary rocks and as protomylonitic to mylonitic fabric in plutonic rocks. D2 led to development of a broad zone of distributed shear and thrust-sense shear zones, including the Tyson thrust at the northern edge of the map area which juxtaposed Proterozoic augen gneiss over Triassic metasedimentary rocks. Yeats (1985) documented a steeply to moderately north-dipping mylonite zone in granitoid rocks on the south side of Boyer Gap in which D2 fabrics have been overprinted locally by mylonite and ultramylonite with a gently west-northwest-plunging lineation, in which S-C fabrics indicate sinistral sense of shear attributed to late-D2 transpression. The third phase of deformation (D3) formed small northeast-verging folds, northeast-dipping non-penetrative S3 cleavage, and mylonite with top-to-northeast shear sense. The Tung Hill shear zone, which shows evidence of both D2 and D3 shearing, was reactivated as a normal-sense shear zone during D3. D3 postdated the metamorphic peak and is interpreted as reflecting Late Cretaceous gravity-driven extension of rocks thickened by D1 and D2 contraction and weakened by metamorphic fluids generated during and after D2 (Boettcher and Mosher, 1998; Boettcher et al., 2002).

South of the Boyer Gap area, northeast-dipping foliation is well-developed in Proterozoic rocks and sporadically in Jurassic plutonic rocks, generally as a weak protomylonitic foliation punctuated by discrete mylonite zones a few meters to tens of meters thick. The oldest component of the Jurassic plutonic complex (unit Jm) is ubiquitously foliated, while the youngest intrusions (unit Jlg) are rarely foliated and typically only near contacts with other units. This suggests that the foliation in these rocks is Jurassic (S1) or a composite S1-S2 fabric, although the abundance of biotite in the older rocks may have led to preferential foliation development in them. In the Marquitta Pass area, a shear zone along the contact between unit Jm and other rocks is up to 300 m thick (mapped as unit Jmt where tectonite has been derived from mixed protoliths). Along strike to the northwest, mylonitic fabric is distributed in narrow zones within unit Jg and Jlg, the thickest being 50 m. Rocks in the Marquitta shear zone locally display a gently plunging elongation lineation. Field observations suggest the presence of dextral S-C fabric (not yet confirmed petrographically), implying that this zone may be antithetic to the Boyer Gap shear zone in the context of late-D2 sinistral transpression proposed by Yeats (1985).

Supracrustal rocks in the southern part of the quadrangle display steeply dipping bedding (in units JXu and JXq) and gently dipping synmetamorphic foliation. The foliation ranges from a spaced schistosity in the more siliceous rocks to a well-developed phyllonitic foliation in porphyroclastic schist. Most of the rocks south of Interstate 10 exhibit northeast-dipping foliation, whereas gently southwest dipping foliation is predominant north of the highway. The synformal fold of the foliation has no associated cleavage and postdates the metamorphic peak; it is interpreted as an F3 structure, although its age relative to D3 in Boyer Gap is uncertain. The trend and plunge of the F3 synform vary along its trace such that the pattern of folded schistosity exhibits basinal and domal warps, notably near Sugarloaf Peak. This effect appears to be an interference pattern resulting from refolding of the F3 synform by north- to northwest-plunging open folds, here interpreted as F4.

Mineral deposits in the Middle Camp Mountain quadrangle are of several types. Late Cretaceous tungsten skarns (Keith et al., 1983) hosted in Paleozoic calcsilicate rocks north of Boyer Gap were mined during the 1940s and 1950s (http://www.mindat.org/loc-33552.html). Gold, associated with extensive hydrothermal alteration of Jurassic metavolcanic rocks in the Sugarloaf Peak area, has been targeted in recent exploration (Smith, 2016). Gold mineralization there occurs in quartz veins and stockworks and is disseminated in altered wallrocks. Peripheral zones of argillic alteration have been prospected for pyrophyllite and alunite. Gold-bearing quartz veins in schist and tectonized Jurassic plutonic rocks near Marquitta Pass and near the west edge of the map area north of Interstate 10 (the Goodman vein) have intermittently supported small mining operations, dating to the late 1800s (Jones, 1915). And gold placer deposits in the alluvium of the Middle Camp area, discovered in the 1860s, are a continuing focus of enthusiastic prospecting and mining activity.

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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

Qyct — **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.

Qy3t — **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.

Qy2t — **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.

Qy1t — **Tyson Wash deposits in slightly higher terraces** - Gravel and sand deposits in slightly to moderately varnished terraces along Tyson Wash. Qy1t 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.

Qi3t — **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.

Qi2t — **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, 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 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.

Qi1t — **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.

Piedmont alluvial units

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.

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. Qy3 deposits are composed of unconsolidated, unvarnished sand, gravel, and silt deposits.

Qy2 — **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.

Qy1 — **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.

Qi4 — **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.

Qi3 — **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.

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

Qi1 — **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

KJs — **McCoy Mountains Formation ?** - Schist and slate derived from siltstone, interlayered with fine-grained semipelitic sandstone and quartzite. The unit crops out in a small, isolated bedrock inlier near the south edge of the quadrangle.

Jlg — **Leucogranite** - Medium- to fine-grained, equigranular to slightly porphyritic leucogranite, forms sheet-like intrusions that mostly dip northeast to north. White on fresh surfaces, the rock is weathered white, although joint surfaces exposed over large areas on northeast-facing slopes are weathered rusty yellow-brown and are commonly coated with dark-brown desert varnish. Some intrusions are compositionally zoned, with medium-grained syenogranite predominant in the basal parts and medium- to fine-grained alkali granite in the upper parts. The syenogranite contains up to 20% pale-green altered plagioclase and 5% biotite, and K-feldspar locally forms sparse phenocrysts up to 1 cm. The alkali phase is composed of 2-5-mm K-feldspar and 30-35% 2-3-mm quartz, and contains only trace-2% fine-grained aggregates of mafic minerals including biotite and magnetite. Contacts between the two phases range from gradational to sharp, with the alkali phase clearly younger. South of Gonzalez Wash near the southwest corner of the quadrangle and along the floor of the canyon near Marquitta Mine the granite has been hydrothermally altered, exhibiting silicification, quartz-sericite-pyrite alteration, and quartz-muscovite greisen. The leucogranite has been interpreted as part of a regional suite that ranges in age from 163-158 Ma (Tosdal and Wooden, 2015). A sample dated by Boettcher et al. (2002) from near Diablo Pass revealed complex, discordant U-Pb data, that they interpreted as indicating an age between 161 and 158 Ma.

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 within the map area indicate a preferred age of 164 +/- 1 Ma (Boettcher et al., 2002).

Jgd — **Middle Camp monzogranite with diorite inclusions** - Medium-grained monzogranite and granodiorite like unit Jg with 25-50% inclusions of fine-grained to aphanitic diorite or quartz diorite. The inclusions range from several cm to tens or hundreds of meters across, commonly have rounded perimeters, and display uniform fine-grained texture; they are interpreted as xenoliths.

Jp — **Quartz porphyry** - Pink to white, aphanitic, quartzofeldspathic rock containing 5-7% phenocrysts of polycrystalline quartz that range from spherical (2-5 mm in diameter) to elongate (up to 10 mm long), locally defining a pronounced lineation. Feldspar crystal faces 3-4 mm across are rarely visible, and 1-2% tourmaline is seen in thin section. Fractures and weathered surfaces are stained dark red-brown from hematite. Contacts with the Middle Camp granite of unit Jgd range from abrupt to cryptic; toward the contact the monzogranite becomes fine-grained, exhibits a decrease in biotite content, and quartz takes the form of round phenocrysts 3-5 mm in diameter, similar to those in the porphyry. Unit Jp is tentatively interpreted as a border phase of unit Jgd granite.

Jm — **Fine-grained quartz monzonite and derived schist** - Fine- to medium-grained biotite quartz monzonite, typically dark green to green-gray and exhibiting foliation defined by preferred orientation of biotite and greenish-yellow streaks of epidotized plagioclase. The rock is composed of 35-45% K-feldspar, 25-40% plagioclase (almost completely replaced by epidote), 10-15% quartz, and 20-30% biotite. About half of the quartz forms partial pseudomorphs of feldspar and the remainder forms interstitial polycrystalline aggregates. In zones of high strain and near contacts with schistose units (especially Jmt and JXu), this rock grades to quartz-feldspar-epidote-biotite schist, and those contacts tend to be cryptic and transposed.

Jmt — **Quartz monzonitic tectonite** - Fine-grained quartz-biotite-feldspar schist, green-gray, weathered brown to gray-green, locally containing feldspar porphyroclasts 1-3 mm. This is a tectonite derived in part from fine-grained quartz monzonite (unit Jm) and in part from other rocks, including a fine-grained granitoid containing sparse 5-10-mm K-feldspar phenocrysts and ~15% biotite that is interpreted as a border phase of the Middle Camp quartz monzonite.

Dome Rock volcanic assemblage - These rocks are altered and metamorphosed correlatives of the Dome Rock sequence of Tosdal et al. (1989), and include rhyodacitic to rhyolitic volcanic rocks (predominantly ignimbrite) and related shallow-level intrusions. The assemblage is here subdivided based on present mineralogy and texture, which are largely a function of hydrothermal alteration and deformation but may reflect protolith mineralogy. A unifying characteristic is the presence of embayed monocrystalline quartz phenocrysts in all of these rocks. Feldspar phenocrysts are also present in most of the rocks, but extensive alteration makes identification of their original composition, and that of other constituents, problematic both in the field and in thin section.

Jpk — **K-feldspar porphyry and derived schist** - Fine-grained quartz-feldspar porphyry containing 1-3% 1-3-mm quartz phenocrysts, 10-20% variably altered K-feldspar phenocrysts >2 mm (including 2-8% that are 5-20 mm), 15-20% green altered plagioclase 1-5 mm, and 10-15% fine-grained mafic aggregates, in a light-green, recrystallized, variably schistose groundmass composed of microcrystalline quartz, feldspar, sericite, and chlorite. The mafic aggregates are composed of chlorite, sericite, epidote, and opaque oxide minerals with relict biotite and minor hornblende. This rock is interpreted as having been emplaced as a hypabyssal or epizonal intrusive.

Jqb — **Biotite-quartz-feldspar metarhyodacite and derived schist** - Light green to green-gray porphyritic rocks containing up to 40% phenocrysts, including 5-10% quartz (2-5-mm), trace-3% K-feldspar (1-3 mm), up to 35% highly altered plagioclase up to 1 mm, and 3-5% biotite (in part altered to hematite and chlorite), in a light-green-gray groundmass of microcrystalline quartz, sericite, and epidote. Much of the plagioclase has been completely replaced by microcrystalline sericite, epidote, and quartz. Some altered grains are elongate and angular and may have originally been fragmented plagioclase, lithic grains, or glass shards. Protoliths of these rocks probably included ignimbrite and related hypabyssal intrusions. The mineralogy is in part a product of propylitic alteration and subsequent metamorphism. Near contacts with unit Jqs the rock grades to porphyroclastic biotite-epidote-sericite schist.

Jqs — **Porphyroclastic quartz-sericite schist** - Quartz-sericite and quartz-feldspar-sericite schist with sparse 2-3-mm quartz porphyroclasts (relict phenocrysts) and locally containing >10% plagioclase and K-feldspar porphyroclasts (1-2-mm) in a matrix of microcrystalline quartz and sericite. The rock is white to pink to light green-gray and forms white-weathered slopes with thin resistant ledges weathered dark brown. This unit is interpreted as the phyllic-altered and sheared equivalent of unit Jqr, which internally grades into intervals of identical schist. Southeast of Sugarloaf Peak, this unit locally contains abundant pyrophyllite and some kyanite. Several old mine workings targeted the pyrophyllite and also alunite veins (Smith, 2016).

Jqr — **Quartz-feldspar metarhyolite and derived schist** - Platy metarhyolite and sericite-quartz-feldspar schist containing phenocrysts of quartz (1% to >5%, 1-5 mm) and feldspar (<1% to >10%, <1 to 2 mm) in a microcrystalline groundmass of quartz and sericite that ranges from light pinkish-gray to pink to light green. Feldspar phenocrysts include white to pink K-feldspar and subordinate altered plagioclase. In some places up to 40% feldspar phenocrysts are present, although they are highly altered to sericite and are mantled by microcrystalline quartz and sericite that grade into the enveloping matrix. The unit forms dark-brown-weathered resistant cliffs and platy ledges that contain sericitic partings and that grade to slope-forming intervals of white to light green-gray quartz-feldspar-sericite schist identical to unit Jqs. The alteration assemblage in the resistant intervals is quartz-sericite-pyrite. The protolith of unit Jqr was rhyolite or rhyodacite ignimbrite.

Jrs — **Silicified metarhyolite porphyry** - Metarhyolite like Jqr with intense silicic alteration, this unit forms massive outcrops and cliffs. Quartz phenocrysts are locally preserved, remnants of altered feldspar phenocrysts are rare, and the groundmass has typically been replaced by massive microcrystalline quartz. Quartz stringer veinlets and disseminated pyrite are common.

JXgu — **Granitic rocks and schist** - Middle Camp granite (units Jg, Jgd) and schistose country rocks (JXu) undifferentiated.

JXq — **Quartzite** - Fine-grained siliceous metasedimentary rocks, mainly fine-grained to very-fine-grained quartzite with a few thin micaceous layers. Green dioritoid intrusions are common.

JXu — **Heterogeneous schist** - Includes a variety of metasedimentary and metaigneous rocks that generally exhibit cryptic, transposed contact relationships, both between various components of this unit and with adjacent schist units.

Metasedimentary components include fine- to medium-grained quartzofeldspathic metasandstone, biotite-quartz-feldspar semipelite, and pelitic biotite-quartz-sericite schist. Metasandstone is very fine- to medium-grained, thin- to medium-bedded, in part micaceous, locally contains epidote, is light tan to light green, and some layers contain small pebbles. Pelitic and semipelitic schists are fine-grained and weathered light brown to light gray.

Metaigneous components include olive-green to dark-gray quartz-feldspar-epidote-biotite schist that contains variable amounts of sericite and locally contains quartz and feldspar porphyroclasts up to 1 mm. South of Gonzalez Wash this schist locally grades into a small remnant of fine-grained quartz monzonite resembling unit Jm. Another type of schist, derived from a biotite granitoid(?) rock (possibly Middle Camp granite), is light gray quartz-biotite-sericite schist with 1-cm sericite aggregates that appear to be pseudomorphs after flattened and transposed feldspar phenocrysts. Aplitic leucogranite is locally abundant, and ranges from massive with sharp contacts to fine-grained, white, quartz-sericite schist with transposed contacts.

T̄s — **Tung Hill metasedimentary rocks** - Succession of quartzofeldspathic mica schist and micaceous marble with layers of quartzite and quartz-pebble metaconglomerate. The schist is fine- to medium-grained, thin-layered, green-gray to green, and weathers olive brown. Quartz-muscovite-kyanite schist is locally present (Boettcher, 1996). Micaceous calcitic marble is medium- to coarse-grained and weathered yellow-brown. This assemblage is assigned a Triassic age (Yeats, 1985; Boettcher, 1996) based on correlation with the Buckskin Formation (Reynolds et al., 1987) exposed in nearby ranges.

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.

MꞒm — **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. North of Boyer Gap the Muav is capped by a heterogeneous succession of dark-green- to light-brown-weathered calcsilicate gneiss, quartzite, schist, and marble. North of Dome Basin mine, the Muav marble is stratigraphically overlain (structurally underlain there) 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.

Ꞓba — **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.

Ꞓt — **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.

Ꞓu — **Metasedimentary rocks** - Coarse-grained feldspathic quartzite, quartz-mica schist, micaceous marble.

Yd — **Metadiorite and mafic schist** - Fine- to coarse-grained amphibole schist composed of 30-50% hornblende, 10-40% actinolite, 35-40% recrystallized plagioclase.

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.

YXp — **Feldspar-porphyroclastic schist** - Fine-grained, foliated, quartzofeldspathic rock with up to 10% relict feldspar phenocrysts that typically are 2-4 mm. In thin section, the feldspar is broken and recrystallized and includes both plagioclase and K-feldspar in lenticular domains. There are also lenticular domains of fine-grained polycrystalline quartz and quartz-feldspar aggregates. These and the feldspar domains are enclosed in a foliated matrix of microcrystalline quartz, feldspar, and sericite. Yeats (1985) reported that this unit locally contains up to 60% stretched and recrystallized aggregates of quartz and feldspar 1-20 mm long. The rock is interpreted as a sheared and recrystallized intrusive rock. Sr and Nd isotopic data from a single sample of the unit, which include a calculated Nd model age of 2.1 Ga, clearly indicate a Proterozoic age (Lerch et al., 1991).

Xs — **Schist** - Fine-grained feldspathic and micaceous quartzite, psammitic to semipelitic biotite-feldspar-quartz schist, and quartz-biotite-actinolite schist. The quartzite is light tan, weathered tan to brown, and exhibits metamorphic layering defined mainly by seams of sericite and fine-grained muscovite and to some extent by grain-size variation. Dark-brown desert varnish is common throughout the unit. Sr and Nd isotopic data from several samples of this unit include calculated Nd model ages of 1.9-2.3 Ga and clearly indicate a Proterozoic age (Lerch et al., 1991).

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