GEOLOGIC MAP OF THE GRASSHOPPER JUNCTION 7 ½' QUADRANGLE, MOHAVE COUNTY, ARIZONA

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Arizona Geological Survey Digital Geologic Map 70 (DGM-70), version 1.0

Sheet 1 of 2

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Geologic map of the Grasshopper Junction 7 ½' Quadrangle, Mohave County, Arizona
Arizona Geological Survey Digital Geologic Map DGM-70, version 1.0, scale 1:24,000, 2 sheets.

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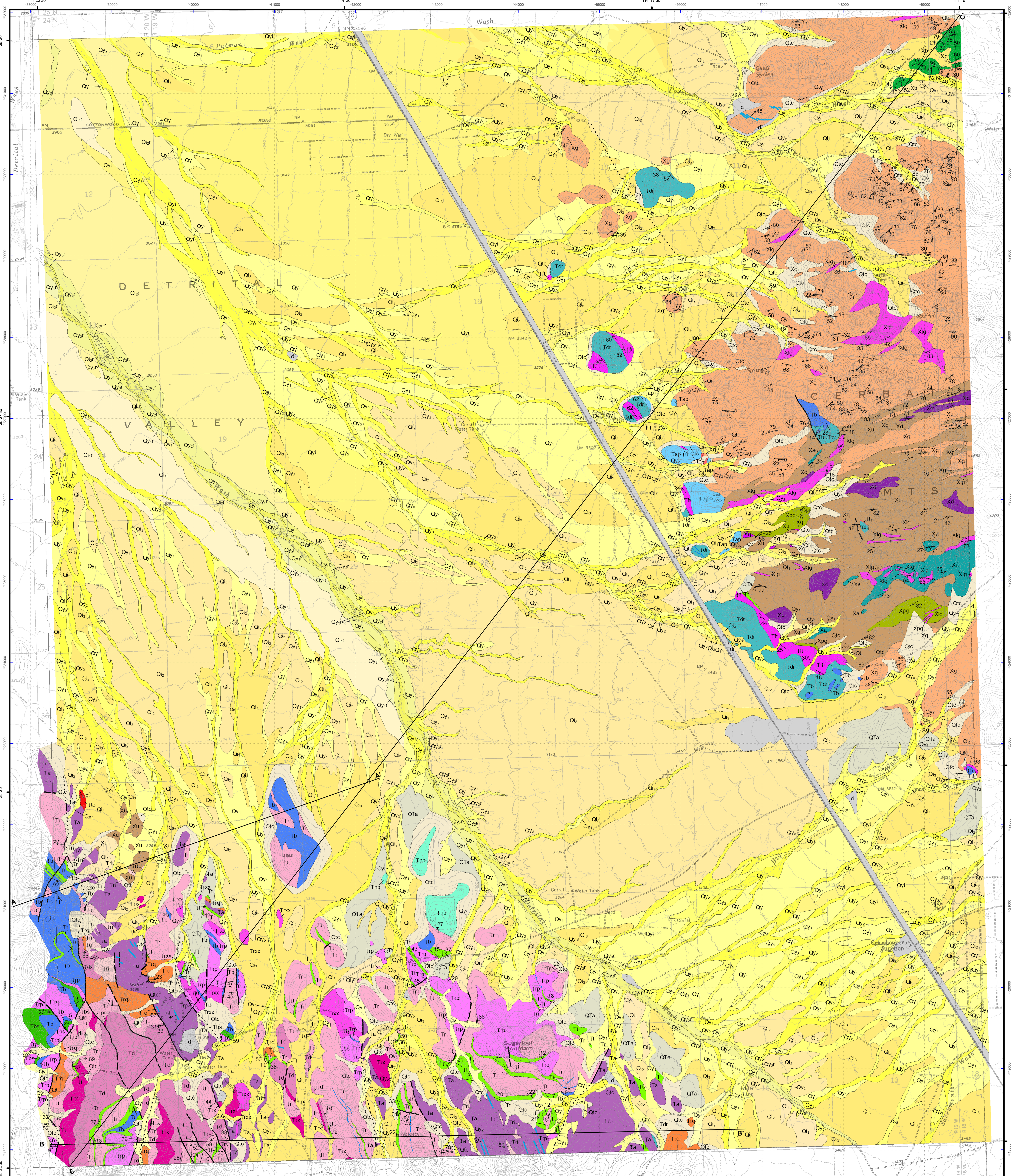


Topographic base from USGS 1:24,000 Quadrangle Series.
Seamless basemap generated using iGage All Topo Pro software.

Projection Information:
North American Datum of 1983.
1000-meter Universal Transverse Mercator grid tics, zone 11, shown in blue.

Cartography and Map Layout by Ryan J. Clark and Helen Ireland

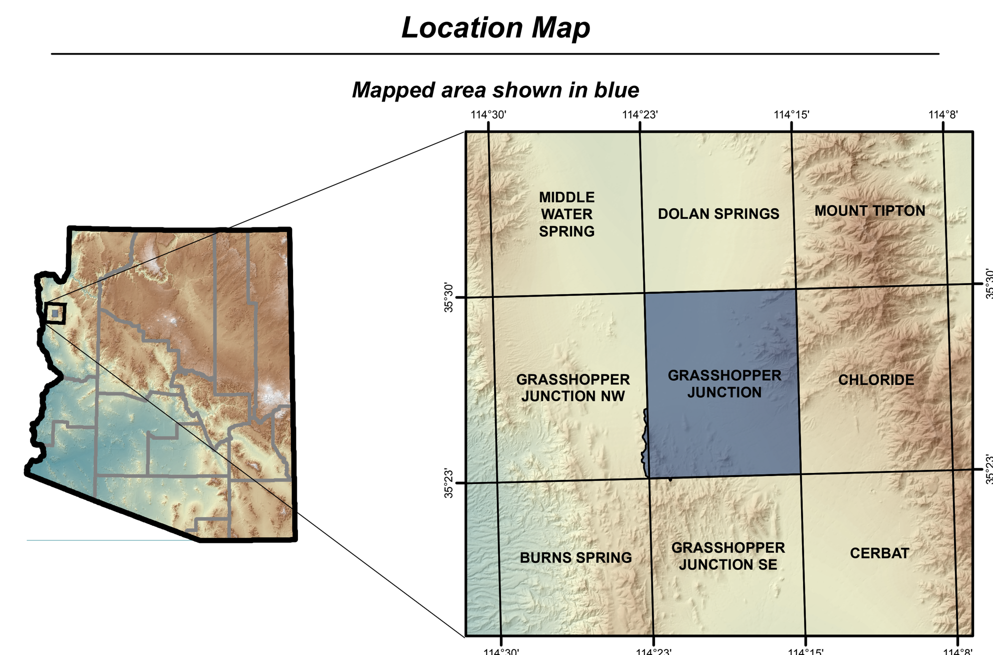
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

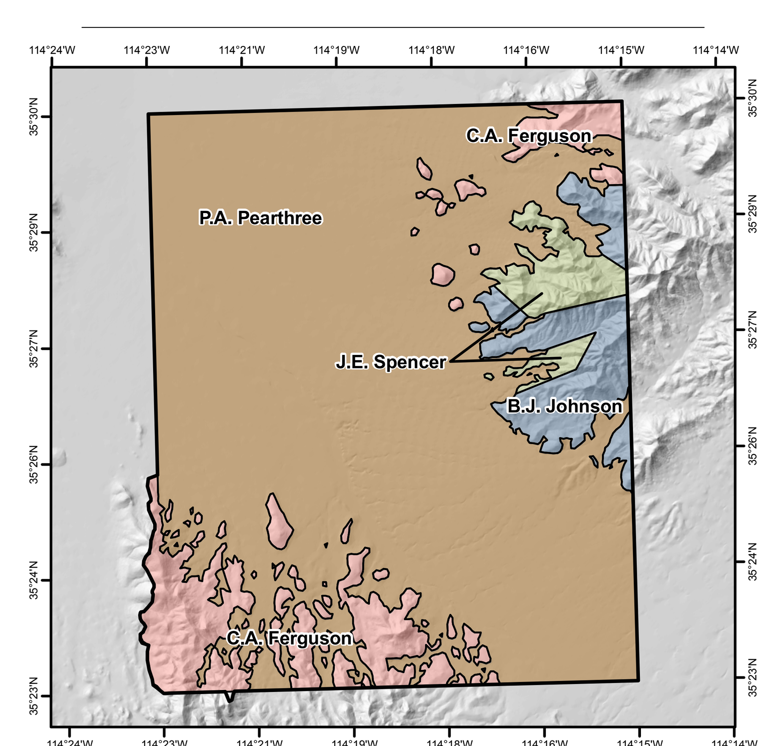
2007 MAGNETIC NORTH DECLINATION

Location Map

Mapped area shown in blue



Mapping Responsibility



Map Symbol Descriptions

- Mine adit
- 10 Bedding
- 24 Gneissic foliation or compositional layering in metamorphic rocks
- 61 Tectonic foliation - Most commonly mylonitic foliation and/or annealed mylonitic foliation in plutonic rocks, and schistosity in metamorphic rocks. Also includes rare instances of generic foliation.
- 22 Mylonitic foliation
- 52 Flow-foliation
- 37 Eutaxitic foliation
- 13 Directed stretching lineation - Sense of shear (direction of movement of upper members of shear couple) indicated by normal (positive) and reverse (negative) plunge values.
- 48 Tectonic lineation - Most commonly stretching lineation, but also mineral-aggregate lineation. Also includes rare instances of generic lineation
- 62 Dip of contact or dike
- 21 Strike and dip of minor fault or dike not corresponding to a mapped trace.
- 81 Slickenline lineation

- Accurately located contact
- Approximately contact
- Contact concealed beneath surficial units
- Accurately located fault
- Approximately located fault
- Fault concealed beneath surficial units
- Mafic dike

Map Unit Descriptions

Piedmont Deposits

Qyc **Modern channel alluvium** - Unconsolidated, very poorly sorted sand, pebbles, cobbles and locally boulders in larger channels of piedmont washes. Channels may exhibit bar and swale microtopography with bars composed of coarser sediments. Qyc deposits are typically unvegetated and exhibit no soil development although small shrubs and grasses can be found on slightly elevated bars and trees line some channel reaches.

Qy3 **Latest Holocene alluvium** - Poorly sorted, unconsolidated sand, pebbles, cobbles, silt and boulders located in small channels, on floodplains and on low-lying terraces. Vegetation size and density is relatively large. Alluvial surfaces commonly exhibit bar and swale microtopography, but may be quite planar where deposits are fine. Soil development is generally absent on Qy3 deposits. Qy3 areas are active portions of the fluvial systems, and are susceptible to inundation during moderate to extreme flow conditions when flow exceeds channel capacity.

Qy2 **Late Holocene alluvium** - Poorly sorted, unconsolidated sand, pebbles, cobbles, silt and boulders low terraces, active floodplains, and sheetflood areas. Fan and terrace surfaces typically are gently undulating, with gravel bars and finer-grained swales. Desert pavement development is minimal and rock varnish is very light or nonexistent. Soil development is weak. Surfaces are minimally eroded with channel incision of less than 1.5 m. Channel patterns are variable, including linked anastamosing or distributary channels, discontinuous channels, and separate small tributary channels feeding into larger channels.

Qy1 **Early to late Holocene alluvium** - Poorly to very poorly sorted, weakly consolidated sand, silt, pebble, cobble and boulder deposits associated with low to intermediate terraces, abandoned drainageways, and inactive or rarely active alluvial fans. Bar and swale topography is common where deposits are gravelly. Soil development is weak, with minimal soil structure and visible carbonate accumulation, but gravelly surfaces appear darker brown than younger Qy2 surfaces due to moderate rock varnish accumulation.

Qy **Holocene alluvium, undivided** - Holocene alluvium, undivided

Qyi **Holocene to latest Pleistocene alluvium** - Sand, silt, and clay with some pebble and cobble concentrations in low-relief alluvial fan / sheetflood areas. Rock varnish on surface gravel is weak to moderate. Surface soil color typically is slightly orange to reddish brown, and soil development is weak to moderate, with some clay accumulation and stage I to II calcic horizon development. Washes typically are incised ~1 m below Qyi surfaces.

Qi3 **Late Pleistocene alluvium** - Very poorly sorted, weakly consolidated sand, pebbles cobbles, silt and some small boulders associated with inactive alluvial fans and higher terraces along washes. Surfaces are slightly to moderately dissected by tributary drainages that head on the surfaces and through-going distributary channels. Local surface topographic relief varies from about 1 to 5 m. Soil development is moderate, with some clay accumulation and soil reddening, and stage II calcic horizon development discontinuous and continuous clast coatings. Rock varnish on surface gravel is orange to dark brown.

Qi2 **Middle to late Pleistocene alluvium** - Very poorly sorted, weakly to moderately consolidated cobble, pebble, sand, boulder, silt and clay deposits associated with dissected relict alluvial fans. Surfaces are drained by extensive, incised tributary drainage networks. Surfaces are moderately to deeply dissected, with local topographic relief varying from about 1 to 10 m. Original depositional topography is typically is modified by erosion along incised valleys, but surfaces commonly are quite smooth between valleys. Deposits are typically coarser than younger deposits, with relict boulder trains evident on the surface far out from mountain source areas. Well-preserved surfaces are typically reddish brown, with some orange to black varnish on cobblesand boulders. Soils have moderate clay accumulation and calcic horizons typically are stage II to III with continuous coatings on gravel clasts and some whitening of the soil matrix.

Qi1 **Early to middle Pleistocene alluvium** - Very poorly sorted, weakly to moderately consolidated sand, pebbles, cobbles and boulders associated with deeply dissected relict alluvial fans. Locally surfaces are reddened, but more commonly they are light gray due to common calcic fragments. Soil development is variable, but weakly cemented petrocalcic horizons (stage IV) are common. Surfaces are moderately to deeply dissected, with local topographic relief varying from about 2 to 10 m. Original depositional topography has been extensively modified by erosion, and surfaces are rounded and seldom planar. Surfaces are higher and are much more eroded than adjacent Qi2 surfaces.

Qi **Middle to late Pleistocene alluvial deposits, undivided** - Middle to late Pleistocene alluvial deposits, undivided

QTa **Late Pliocene to early Pleistocene alluvium** - Very poorly sorted, moderately consolidated cobbles, pebbles, boulders and sand associated with alluvial fan deposits underlying the highest alluvial ridges in the valley. Ridgelines typically are 5 to 10 m above active washes. Soil development is moderate and variable, and dominated by calcium carbonate accumulation. Surfaces typically are light in color because they are covered with debris churned up from indurated petrocalcic horizons and unvarnished to lightly varnished gravel.

Axial Valley Deposits

Qycr **Modern channel deposits** - Unconsolidated, very poorly sorted sandy to cobbly beds exhibiting bar and channel microtopography. Clasts are typically subangular to subrounded, with mixed lithologies including fine-grained volcanics, granite and metamorphic rocks. Deposits are typically unvegetated to lightly vegetated and exhibit no soil development. These deposits are the first to become submerged during moderate to extreme flow events and can be subject to deep, high velocity flow and lateral bank erosion.

Qy3r **Modern flood channel and low terrace deposits** - sand, pebble, cobble and silt deposits in recently active flood channels and lightly vegetated in-channel bars and small planar fluvial terraces less than 1 m above active channel. These deposits do not exhibit soil development but commonly have a light vegetation cover of small trees and bushes and grasses due to their relatively frequent inundation. These surfaces are commonly inundated under moderate to extreme flow events and can be subject to deep, high velocity flow and lateral bank erosion.

Qy2r **Latest Holocene to historical river deposits** - Sand, silt, clay, pebbles and cobbles associated with low river terraces. In roughly the southern 1/2 of the quadrangle, these terraces were probably the floodplain prior to historical channel entrenchment. Qy2r deposits are associated with broadly planar surfaces that locally retain the shape of the historical valley bottom. Qy2r surfaces are up to 2 m above modern Qycr deposits and are the most extensive river terraces in the valley. Qy2r sediments were deposited when the Detrital Wash was a widespread, shallowly-flowing river system and are dominated by fine grained floodplain deposits. These surfaces appear predominantly fine grained at the surface due in part to shallow flood inundation, but are composed of interfingering coarse sandy to pebbly braided channel and fine sand to silty floodplain deposits. Where Qy2r deposits are moderately to deeply incised they not subject to inundation by river floods, but they may be flood-prone in areas with less channel incision. Qy2r deposits are subject to catastrophic bank failure due to undercutting and lateral erosion during flow events.

Qy1r **Late to early Holocene terrace deposits** - Sand, silt, pebble, clay and cobble deposits associated with slightly higher terraces that represent remnants of older Holocene aggradation periods. Soil development is moderate and surface color typically is gray. Incipient stage I calcium carbonate accumulation is evident on the undersides of some buried clasts. Qy1r surfaces are up to 3 meters above the active channel in highly incised locales and typically are less than 1.5 m higher than adjacent Qy2r surfaces.

Qi3r **Late Pleistocene terrace deposits** - Sand, silt, clay, pebble and minor cobble deposits associated with the late Pleistocene axial valley floor. Surfaces are slightly dissected by tributary drainages that head on the surfaces and through-going channels. Local washes are incised by about 1 to 5 m, and Detrital Wash in incised 2-5 m below Qi3r surfaces. Soil development is moderate, with some clay accumulation and soil reddening and stage II calcic horizon development with soft nodule development.

Qi1r **Middle to late Pleistocene river terrace deposits** - Sand, silt, clay, pebbles and cobbles associated with an older relict basin floor. Deposits are compositionally similar to Qi3r deposits, but relict alluvial surfaces occupy higher positions in the landscape. Terrace surfaces are slightly to moderately rounded. Vegetation is sparse, consisting of small shrubs and grasses. Soil development is moderate, with weak soil reddening and stage II to III calcic horizon development. Qi2r surfaces are typically preserved as high-standing surfaces abutted by distal fan alluvium or as small remnants surrounded by younger axial valley deposits.

Other Units

Qtc **Quaternary talus and colluvium** - Angular to subangular, locally derived, weakly bedded to unbedded, moderately to steeply dipping slope deposits associated with bedrock hills and mountains. Most deposits are colluvium, consisting of very poorly sorted cobbles, boulders, sand and clay. Local coarse framework deposits (talus) have little or no fine material at the surface.

d **Modern disturbed areas** - Areas profoundly disturbed by human activity. Road embankments, stockponds, and mining disturbance.

Bedrock Units, Cerbat Mountains

Tft **Felsic tuff(s) (Miocene)** - At least two felsic ash-flow tuffs interbedded with mafic to intermediate lavas along the western slope of the Cerbat Mountains. The tuffs contain 7-25% phenocrysts of euhedral to subhedral plagioclase > sanidine (1-3mm) in ratios ranging from 1:1 to 2:1. The tuffs are typically strongly welded with abundant vitric pumice lapilli up to 30cm and dark red, brown, or black vitric matrix. Poorly to nonwelded, light gray intervals are locally present near contacts with interbedded lavas, but also within flow sequences. The basal part (<15m thick) is nonwelded tuff with at least one interval <2m thick of lithic-rich and lithic-poor layers defining crude bedding that may be ash-fall tuff.

Tap **Phenocryst-poor intermediate lava (Miocene)** - Andesite or dacite lava containing >10% 1-4mm plagioclase phenocrysts and >1% green mafic phenocrysts (altered pyroxene or amphibole) up to 1mm. The groundmass is dark to light gray, typically glassy, and locally vesicular.

Tlt **Lower felsic tuff (Miocene)** - Phenocryst-poor rhyolite tuff containing <5%, <1mm quartz and feldspar phenocrysts.

Xlg **Leucogranite (Paleoproterozoic)** - Fine-grained to aplitic leucogranite and pegmatite dikes, commonly forming dike complexes with screens of metamorphic and older plutonic rocks. Leucogranite and pegmatite dikes intrude all older units extensively; only a few of the larger dikes have been mapped separately.

Xg **Granite (Paleoproterozoic)** - Exposed over large areas of the western Cerbat Mountains, this granite also forms dikes and extensive sheet-like intrusions within the metamorphic complex (unit Xu). North of Putman Wash, the granite is medium- to coarse-grained, and mostly equigranular, typically containing 10-20% biotite. To the south, the granite is mostly fine-grained but is recrystallized, apparently an annealed protomylonitic texture that overprints a probable medium- to coarse-grained equigranular igneous texture similar to that in the northern area. In some smaller intrusions within the metamorphic complex (Xu), the granite locally contains >30% biotite. 38 zircon crystals separated from sample JES-11-16-07-1 of this granite yielded a U-Pb age of 1760 +/- 33.6 MS (LA-ICP-MS single crystal analysis, data provided by Victor Valencia, University of Arizona, 2009).

Xa **Amphibolite (Paleoproterozoic)** - Fine-grained amphibolite, commonly characterized by alternate black hornblende-rich and brown-weathered diopside-plagioclase layers. Where present, the diopsidic layers are typically 5cm thick. The unit contains other rocks of the metamorphic-plutonic complex (Xu) in subordinate amounts and these weather recessively relative to the resistant amphibolite outcrops.

Xpg **Paragneiss (Paleoproterozoic)** - Fine-grained garnet-biotite-quartz-feldspar gneiss.

Xq **Quartzite (Paleoproterozoic)** - Lenses and pods of quartzite

Xb **Mafic lava (Paleoproterozoic)** - Weakly foliated mafic lava and pillow lava containing abundant pyroxene porphyroblasts and/or phenocrysts. Within contact aureoles adjacent to the biotite granite (Xg), this unit contains abundant matrix biotite and garnet porphyroblasts up to 1cm.

Xd **Diorite (Paleoproterozoic)** - Fine to medium-grained hornblende diorite, including leucocratic and melanocratic phases. Fine-grained recrystallized leucodiorite commonly contains 5mm lenticular aggregates of hornblende (+/- biotite). Hornblende melanodiorite grades to medium-grained hornblendite.

Bedrock Units, Black Mountains

Thp **Hornblende-pyroxene andesite (Miocene)** - Andesitic lava containing 5-10% plagioclase (1-4mm), 1-2% hornblende (<1mm) and ~1% pyroxene (<1mm). Vesicular and typically with crystalline matrix.

Tbs **Tuff of Bridge Spring (Miocene)** - Felsic ash-flow tuff containing 5-12% phenocrysts of sanidine (anhedral to subhedral 1-5mm) >> biotite (<1.5mm) + plagioclase (subhedral to euhedral <2mm). Sparse quartz and pyroxene phenocrysts are also present. The tuff has a light gray matrix and sparse mafic and felsic volcanic lithic lapilli. Varga et al. (2004) report a sanidine Ar/Ar age of 15.2 +/- 0.1 Ma.

Trp **Phenocryst-poor to aphyric andesitic lava (Miocene)** - Felsic appearing andesitic lavas containing <3% and typically <1%, <2mm phenocrysts of feldspar (mostly plagioclase, but also sanidine), biotite, and pyroxene.

Tr **Moderately phenocryst-poor rhyolitic lava (Miocene)** - Rhyolitic lava containing 4-10% phenocrysts of plagioclase (<1-3mm), 1% biotite (<1mm), <1% pyroxene (<<1mm), +/- sparse quartz and sanidine. Some flows contain subequal amounts of plagioclase and sanidine, but this is not discernible in the field. Flows are typically very fresh and unaltered with well-developed coherent vitric, and autobreccia zones. Thicker flows have crystalline cores with ubiquitous lithophysal-spherulitic transition zones between the core and vitric zones.

Td **Moderately phenocryst-rich felsic lava (Miocene)** - Rhyolitic lavas containing 10-25% phenocrysts of euhedral to subhedral plagioclase (1-15mm but mostly <3mm), <2% biotite (1-2mm), and <1% pyroxene (<<1 to 1mm). The unit is characterized by sparse plagioclase megacrysts.

Tdx **Vent facies, phenocryst-rich felsic lava (Miocene)** - Coarse-grained pyroclastic and autoclastic lava breccia consisting of clasts of the phenocryst-rich dacitic lava (Td) in mostly clast-supported, very thick-bedded to massive sequences.

Trx **Sparsely megacrystic andesitic lava (Miocene)** - Andesitic lava containing 2-10% plagioclase (1-10mm), <1% biotite (<1mm), and <1% pyroxene (<1mm). Most of the plagioclase is less than 2mm, but sparse megacrysts are ubiquitous. The matrix is typically crystalline and very dark-colored (gray to purple). Vitric zones and autobreccia are characteristically poorly represented.

Trxx **Phenocryst-rich felsic lava (Miocene)** - Rhyolitic lava and hypabyssal bodies containing 12-25% euhedral to subhedral feldspar (1-4mm), 1-3% biotite (1-2mm), and sparse pyroxene (<1mm). This unit is distinguished from the dacitic lava (Td) by its lack of megacrystic feldspar. It is also characteristically fresh and unaltered.

Tri **Hypabyssal rhyolite (Miocene)** - Dikes and hypabyssal bodies of rhyolite containing 0-15% phenocrysts of plagioclase and/or sanidine (<1-4mm), <1% biotite (<1mm), sparse pyroxene (<<1mm) +/- quartz, and hornblende. Probably the intrusive equivalent of the Tr and Trp map units.

Trq **Quartz-phyric rhyolitic lava (Miocene)** - Quartz-phyric rhyolitic lavas. The lavas contain 5-15% phenocrysts of subhedral to euhedral plagioclase (<1-4mm), 1-7% subhedral to anhedral quartz (<1-4mm) +/- biotite (<1mm) pyroxene (<<1mm) and sanidine (<1-4mm). The unit iincludes all lavas containing obvious quartz phenocrysts and as such varies considerably in content, size, and ratios of phenocrysts.

Ta **Andesitic lava (Miocene)** - Moderately phenocryst-poor to phenocryst-rich andesitic lava containing 5-30% phenocrysts of plagioclase (<1-6mm), <5% pyroxene (<1-3mm), and sparse olivine (<1mm).

Tto **Older felsic tuff (Miocene)** - Light gray, welded rhyolitic ash-flow tuff containing about 10%, euhedral to subhedral, strongly altered feldspar phenocrysts. Other phenocryst phases, if present, are too altered to identify. The feldspar is so strongly altered that it can not be identified.

Bedrock Units Common to Both Areas

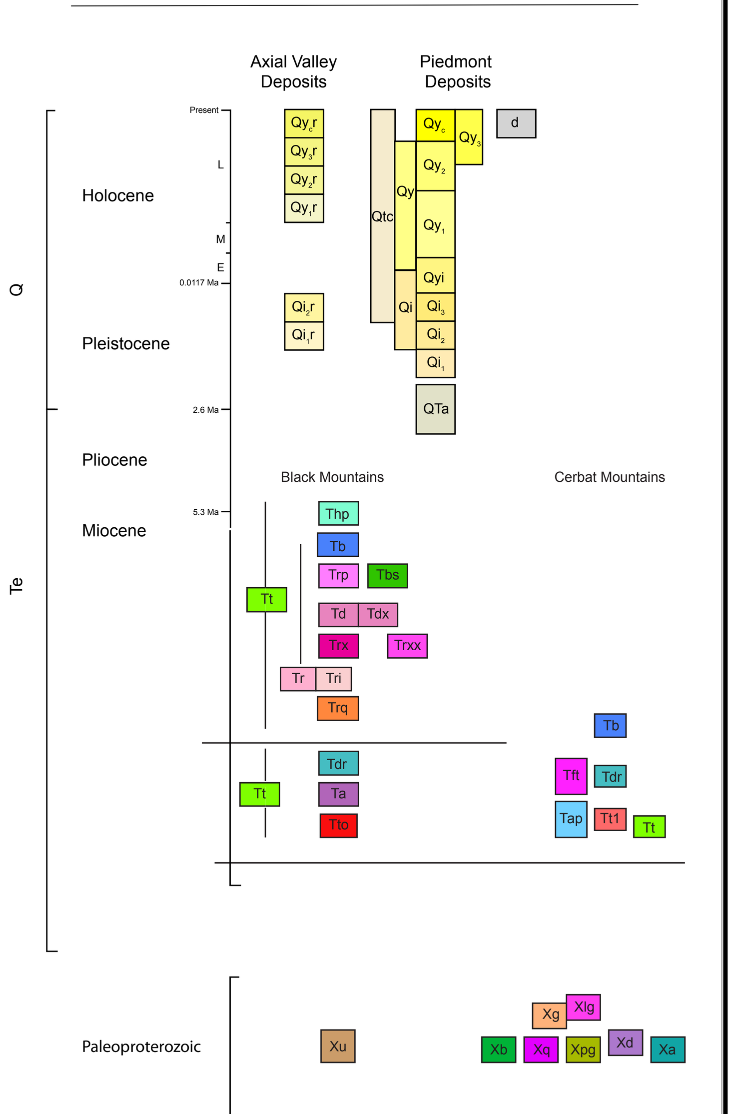
Tb **Basaltic lava (Miocene)** - Moderately phenocryst-poor basaltic lava containing 3-10% phenocrysts of plagioclase (<1-5mm) and pyroxene (<1-3mm) in roughly equal proportions, and 1-3% olivine (<1mm). Basaltic lava in the Cerbat Mts., where plagioclase is generally subordinate to pyroxene, is probably not correlative with the lavas in the Black Mts.

Tt **Pyroclastic and volcaniclastic rocks (Miocene)** - Nonwelded ash-flow tuff, and ash-fall tuff in thin- to thick-bedded sets, interbedded locally with thin- to thick-bedded volcaniclastic rocks. Tuffs and volcaniclastic rocks are mostly felsic, but locally the unit includes scoriaceous units and volcaniclastic rocks with abundant mafic lithic clasts. Volcaniclastic rocks consist mostly of thin- to medium-bedded, cross-stratified, clast-supported sandstone, pebbly sandstone, and pebble-cobble, rarely boulder conglomerate. Medium- to thick-bedded intervals of matrix-supported pebbly sandstone interpreted as debris flows are also present. In the vicinity of Sugarloaf Mountain, this unit contains locally abundant granite and granitic gneiss cobbles.

Tdr **Phenocryst-rich dacitic to andesitic lava (Miocene)** - A phenocryst-rich lava unit applied to two principal outcrop belts with slightly different compositions. The main belt, which occurs at the base of the Cerbat Mts along highway 93, consists of lavas locally intercalated with pyroclastic units. The lavas contain 30-40% euhedral to subhedral plagioclase (1-8mm), 2-5% green mafic minerals (up to 1mm), and trace to 3% euhedral biotite (<1 to 2mm) in a glassy to aphanitic, light gray to light purple groundmass. Glomerocrysts of plagioclase and mafic minerals are common. Another belt occurs in a parallel band higher in the range and consists of lava containing 30-35% euhedral to subhedral plagioclase (3-5mm), 5-10% hornblende and/or pyroxene (1-3mm), and trace to 1% euhedral biotite (1-2mm) in a light gray aphanitic groundmass. A small area of this unit is also recognized in the easternmost Black Mountains.

Xu **Metamorphic complex (Paleoproterozoic)** - A complex assemblage of fine-grained mafic and quartzofeldspathic gneiss and schist interfoliated with dioritic and granitic intrusions. Amphibolite, characterized by alternate black hornblende-rich and brown-weathered diopside-plagioclase layers, forms resistant outcrops throughout the complex. Fine-grained gneiss and schist with quartz-biotite-hornblende-feldspar and garnet-quartz-biotite-feldspar mineral assemblages also are common and tend to weather more recessively. Siliceous hornblende-biotite-feldspar-quartz paragneiss and thin (1cm to 1m) quartzite layers are relatively uncommon. Amphibolite and garnet-quartz-biotite-feldspar gneiss are mapped separately as units Xa and Xs, respectively, where they are the only metamorphic rocks exposed. Diorite of unit Xd is interfoliated with the metamorphic rocks, and some of the biotite-hornblende-plagioclase gneiss and schist appears to have been derived from shearing and recrystallization of diorite and host rocks. Intrusive contacts between diorite and host amphibolite are rarely preserved. Only large continuous bodies of diorite were differentiated as unit Xd. The complex is intruded by abundant leucogranite and pegmatite dikes of unit Xlg, but only the larger dikes are shown separately.

Correlation of Map Units



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