Geologic Map of the Southern Part of the Union Pass 7 ½' Quadrangle, Mohave County, Arizona

Charles A. Ferguson, Bradford J. Johnson, Philip A. Pearthree

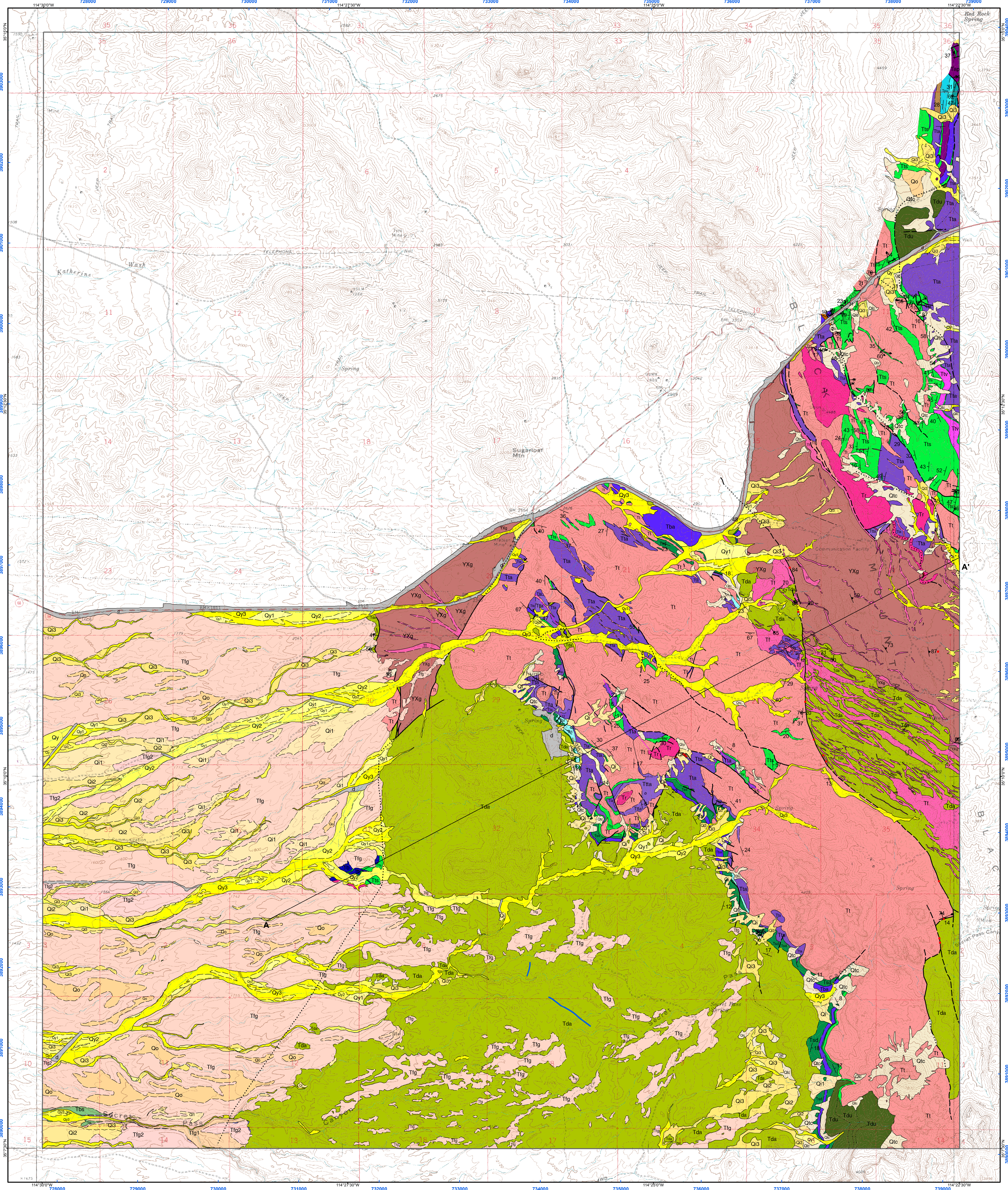
Arizona Geological Survey

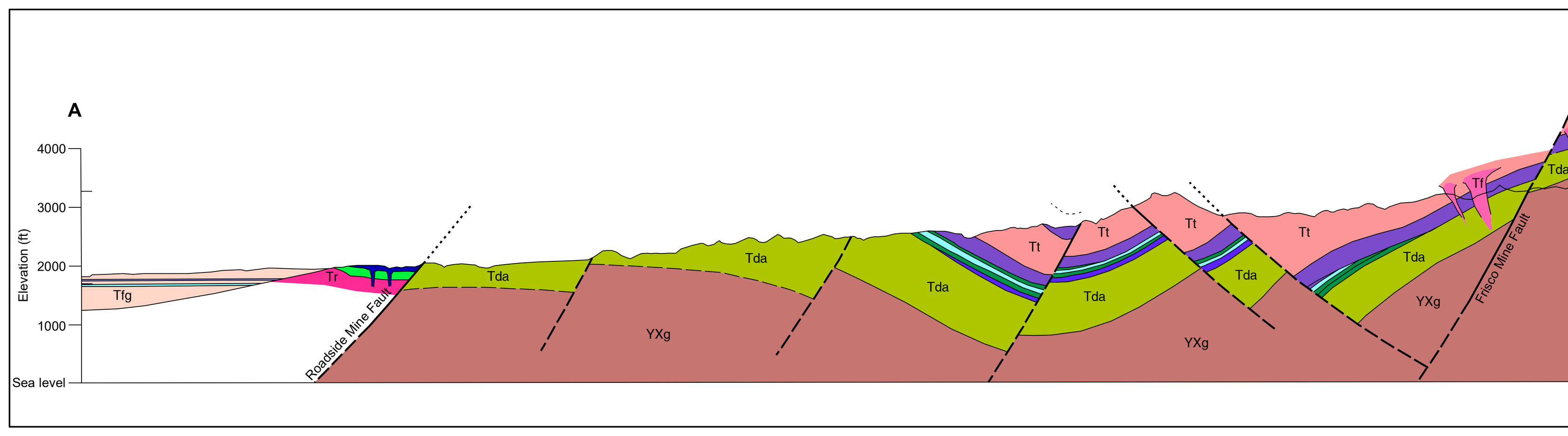
Digital Geologic Map 129 (DGM-129)

September 2018

1:24,000 scale

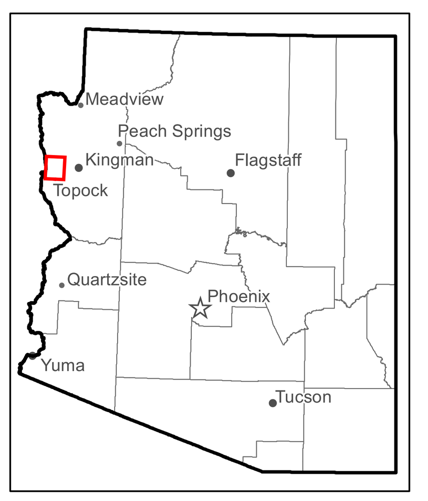
This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under StateMap award number G17AC00307, 2017. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.



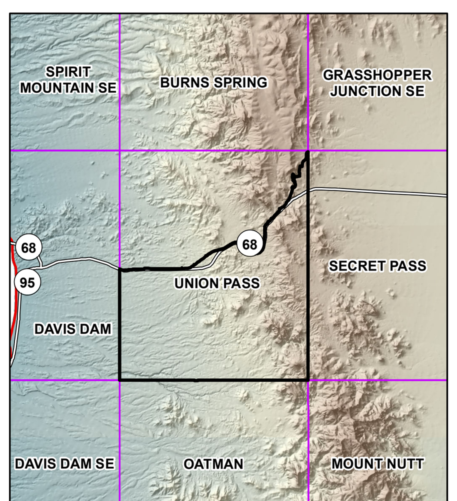


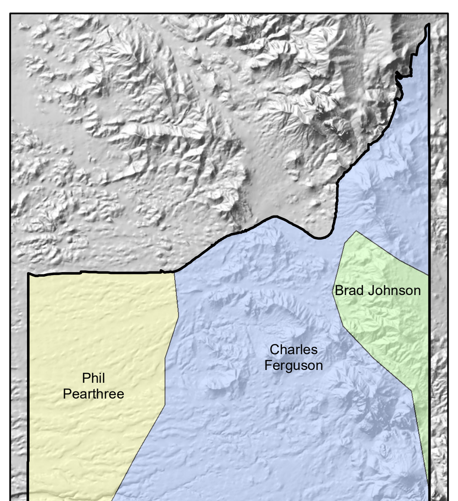
Symbols and Lines

- Contact, accurate
- Contact, approximate
- Contact, gradational
- Internal contact, approximate
- Key bed, concealed
- Fault, accurate
- Fault, approximate
- Fault, concealed
- Mafic dike
- Syncline
- Cross-section location
- Bedding
- Eutaxitic Foliation (in welded tuff)
- Flow-Foliation (in lava and hypabyssal rocks)
- Foliation (in granitic gneissic rocks)
- Slickenline lineation
- Dip of contact

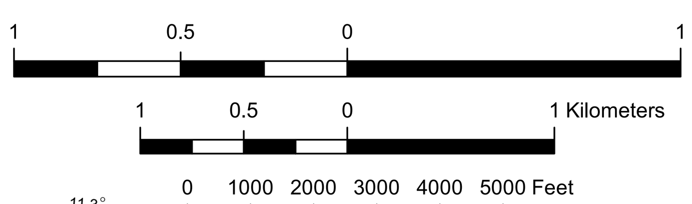


Location of map area

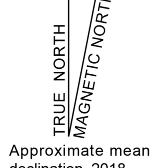




SCALE 1:24,000



CONTOUR INTERVAL 40 FEET



Approximate mean declination, 2018

Topographic base map derived from the Union Pass 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. 10.4.

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

Introduction

This map depicts the bedrock and surficial geology of much of the Union Pass quadrangle in the Black Mountains and the lower Colorado River Valley, Mohave County, northwestern Arizona. The geologic mapping is original but was informed by extensive previous mapping in the lower Colorado River Valley by AZGS geologists. This geologic map complements 11 previous Arizona Geological Survey 7 ½' quadrangle mapping projects in this area, and the geologic map of the Secret Pass quadrangle immediately to the east (Ferguson et al., in prep.).

Bedrock Geology

Miocene volcanic rocks ranging in age between ~19.5 and 16.5 Ma dominate the bedrock geology of the Union Pass map area which lies along a low, deeply incised, and especially rugged stretch of the 160 km-long Black Mountains, Arizona's longest Basin and Range uplift. The low stretch is the result of the intersection of a prominent, northwesterly striking structural horst with the north-south trending range. The core of the horst exposes recessive, Proterozoic granitic rocks. The volcanics, which nonconformably overlie the granitic rocks in the horst and on both sides of it, are overwhelmingly lava, and range in composition from basaltic andesite to high-silica rhyolite. Since a ~15 Ma sequence of basalts, which cap the volcanic sequence throughout the southern Black Mountains, are virtually absent from the map area, it can easily be said that the bulk of the volcanic series becomes strongly felsic up section. It is only in the hanging wall of the west-dipping, Mohave Basin-bounding Roadside Mine fault that any of these younger basalts (Tb) are preserved capping a section of quartz-phyric rhyolite lavas (Tr) and nonwelded tuffs (Tts), much like they do in the extreme northern part of this map area (Murphy and Faulds, 2004), and in the southerly adjacent Oatman and Mt Nutt Map areas (Ferguson and Cook, 2017; Ferguson et al., 2017). Three important regional ignimbrites occur within the section; the ~19 Ma Cook Canyon Tuff (Tct), the 18.78 Ma Peach Spring Tuff (Tpl, Tpu), and the 17.77 Ma Bonelli Tuff (Tbt). The two older tuffs are present only in the extreme north, in the hanging wall of the east-dipping Union Pass fault. The correlation is based on a good match between the exposures in this area with the distinctive vertical zonations of phenocryst assemblage and textures documented for both ignimbrite's type sections in the Kingman area, <20km to the east (Ferguson and Cook, 016; Cook and Ferguson, 2016). The Bonelli Tuff, dated near Thumb Butte (Lang et al., 2008), is present on both sides of the horst, but was not deposited, or is not preserved in at least 300m of volcanic section above the Peach Spring Tuff in the north. The Bonelli Tuff unconformably overlies a very thick (300-500m) sequence of ~19Ma trachydacite lavas (Tda), capped by less than 100m of dark volcaniclastic rocks with multiple flows of basaltic trachyandesite lava (Tba) which, farther south (Spencer et al., 2006), directly underlies the 18.8 Ma (Ferguson et al., 2013) Peach Spring Tuff. The upper part of the volcanic section is dominated by a pile of monotonous trachyte and high-silica rhyolite lavas (Tt, Tr) ranging in age from 17.6-16.2 Ma (Murphy and Faulds 2004; Lang et al., 2008).

Structurally, the range crest horst is a prominent tilt-domain boundary, with volcanic strata, regionally, tilted gently to moderately steeply (10-50 degrees) to the east in the hanging wall of the west-dipping, horst-bounding, Frisco Mine fault. In the immediate hanging wall of that fault however, at least two roughly coaxial synclines defined by ~17.5Ma and older strata are present, and there are some poorly defined stratigraphic indications that the synclines may be overlapped by younger (~16.2Ma) rhyolite lavas. Strata in the hanging wall of the east-dipping, horst-bounding, Union Pass fault are consistently, moderately to steeply, west-dipping in the northern part of this map area, but to the south, into the easterly adjacent Secret Pass map area, the dips decrease dramatically, as concomitantly, the Union Pass faults vertical component of displacement diminishes.

A note on lavas, porphyries, ignimbrites, non-welded tuffs, and volcaniclastic rocks

Lavas display all the typical ranges in flow facies from crystalline-matrix-coherent to vitric-autobreccia (McPhie et al., 1993). Massive, monolithic block and ash-flow deposits are generally included as part of their associated "lava" map unit. Shallow porphyries that in many areas are contiguously connected to lava flows of the same composition are mapped as part of their associated "lava" map unit. In instances where the rock is clearly an intrusion, especially if it isolated from its flow, an "I" suffix may be applied to lava map unit's symbol. Porphyries generally have massive to flow-foliated textures with fine-grained crystalline matrix. Lithic clasts in lavas and porphyries are rare, but are abundant in volcaniclastic and non-welded pyroclastic rocks where they can be used to help define map units. Ignimbrites are welded pyroclastic rocks that represent regionally correlative outflow sheets that can be identified based on distinctive phenocryst assemblages, and zonations (Smith, 1960).

Surficial Geology

Surficial deposits in the western portion of the map record the late Miocene and younger geologic history of this region. Most of the piedmont within the map area is covered by late Miocene to Pliocene alluvial fan deposits. Late Miocene alluvial fan deposits (unit Tfg1) interbedded with the 5.5-5.6 Ma Conant Creek or tuff of Wolverine Creek (House et al., 2008) are disconformably overlain locally by limestone, calcareous sandstone and fine siliciclastic deposits of the Bouse Formation. Bouse deposition represents a dramatic departure from alluvial fan sedimentation and hillslope erosion and deposition and records the relatively brief but deep inundation of Mohave Valley sometime after 5.24 Ma (House et al., 2008; Pearthree and House, 2014; Crow et al., 2018). A critical section of Bouse carbonate and siliciclastic deposits is well exposed along Secret Pass Wash; this section records the initial rise of the river-fed lake on the landscape, and its subsequent demise as sediment supplied by the Colorado River met the declining lake level (Pearthree and House, 2014. Small outcrops of basal carbonate deposits of the Bouse Formation, and altered alluvial fan deposits that commonly underlie the basal Bouse deposits, have been found at a few localities on the upper piedmont. Bouse deposits were deeply eroded and removed in most areas prior to deposition of more local fan deposits (unit Tfg2), which are the dominant deposits in middle piedmont areas. Where Bouse deposits are preserved, these younger fan deposits rest on an erosional contact. Farther downslope to the west of the quadrangle boundary, the younger fan deposits that interfinger with deposits of Bullhead Alluvium, a major phase of river aggradation in the early Pliocene (House et al., 2008). The 3.6-4.2 Ma Tuff of Artists Drive (Knott et al., 2018) has been found in these deposits at a number of localities, including in the map area. Multiple inset Quaternary alluvial fans and terraces record subsequent periods of piedmont aggradation and incision through the late Pliocene and Quaternary. Some of these processes were likely driven by changes in base level due to Colorado River aggradation and incision.

References cited

Cook, J. P., and Ferguson, C. A., 2016, Geologic map of the Kingman NW 7.5' quadrangle, Mohave County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-114, 1 sheet, 24,000 scale.

Crow, Ryan, Pearthree, P.A., House, P.K., Stelten, Mark, Heizler, Matthew, Schwing, J;.E., Champion, Dueane, Howard, K.A., and Hillhouse, J.W., 2018, Geochronologic study of pre-Colorado –River deposits in Cottonwood Valley, AZ: Implications for the timing of river integration : Geological Society of America Abstracts with Programs.

Ferguson C. A., McIntosh, W. C., and Miller, C. F., Silver Creek caldera, 2013, The tectonically dismembered source of the Peach Spring Tuff: Geology, v. 41, p. 3-6.

Ferguson, C. A., and Cook, J. P., 2016, Geologic map of the Kingman 7.5' quadrangle, Mohave County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-113, 1 sheet, 24,000 scale.

Ferguson, C. A., and Cook, J. P., 2016, Geologic map of the Mt Nutt 7.5' Quadrangle, Mohave County, Arizona: AZGS DGM-118, 2 sheets, 1:24,000 scale.

Ferguson, C. A., Pearthree, P. A, Johnson, B. J., Guynn, J., and McCosby, J. B., 2017, Geologic map of the Oatman 7.5' Quadrangle, Mohave County, Arizona: AZGS DGM-119, 2 sheets, 1:24,000 scale.

House, P.K., Pearthree, P.A., and Perkins, M.E., 2008, Stratigraphic evidence for the role of lake-spillover in the inception of the lower Colorado River in southern Nevada and western Arizona, in Reheis, M.C., Hershler, R., and Miller, D.M., eds., Late Cenozoic Drainage History of the Southwestern Great Basin and Lower Colorado River Region: Geologic and Biotic Perspectives: Geological Society of America Special Paper 439, p. 335-354, doi: 10.1130/2008.2439(15).

Knott, J.R., et al., 2018, Late Neogene–Quaternary tephrochronology, stratigraphy, and paleoclimate of Death Valley, California, USA: Geological Society of America Bulletin v. 130, no. 7/8, p. 1231–1255; https://doi.org/10.1130/B31690.1.

Lang, N.P., Walker, B.J., Claiborne, L.L., Miller, C.M., Hazlett, R.W., and Heizler, M.T., 2008, The Spirit Mountain batholith and Secret Pass Canyon volcanic center: A cross-sectional view of the magmatic architecture of the uppermost crust of an extensional terrain, Colorado River, Nevada– Arizona, in Duebendorfer, E.M., and Smith, E J., eds., Field guide to plutons, volcanoes, faults, reefs, dinosaurs, and possible glaciation in se- lected areas of Arizona, California, and Nevada: Geological Society of America Field Guide 11, p. 187–214, doi:10.1130/2008.fld011(09).

McPhie, J., Doyle, R., Allen, R., Volcanic textures: a guide to the interpretation of textures in volcanic rocks: Centre for Ore Deposits and Exploration Studies (CODES), University of Tasmania, 198 pp.

Morgan, L.A., and McIntosh, W.C., 2005, Timing and development of the Heise volcanic field, Snake River Plain, Idaho, western USA: Geological Society of America Bulletin; March/April 2005; v. 117; no. 3/4; p. 288–306; doi: 10.1130/B25519.1.

Murphy, R. T., and Faulds, J. E., 2004, Preliminary geologic map of the north half of the Union Pass Quadrangle, Mohave County, Arizona: Nevada Bureau of Mines and Geology, 1 sheet, 24,000 scale.

Pamuckcu,, A. S., Carley, T. L., Gualda, Guilherme A. R., Miller, C. F., and Ferguson, C. A. 2013, The evolution of the Peach Spring giant magma body: evidence from accessory mineral textures and compositions, bulk pumice and glass geochemistry and rhyolite- MELTS modeling: Journal of Petrology, v. 54, no. 6, p. 1109-1148.

Pearthree, P.A., and House, P.K., 2014, Paleogeomorphology and evolution of the early Colorado River inferred from relationships in Mohave and Cottonwood valleys, Arizona, California, and Nevada: Geosphere, v. 10; p. 1139–1160; doi:10.1130/GES00988.1.

Smith, R. L., 1960, Zones and zonal variations in welded ash flows: USGS Professional Paper 354, p. 149-159, 2 plates.

Spencer, J. E., Ferguson, C. A., Pearthree, P. A., and Richard, S. M., 2006, Gedogic map of the Boundary Cone 7.5' quadrangle, Mohave County, Arizona: Arizona Geological Survey Map DGM-54, 2 sheets, 24,000 scale, 10 p. text.

Map Unit Descriptions

Piedmont Alluvium

Qy_3 **Active channel deposits** - Very poorly sorted sand, pebbles, cobbles, boulders and minor silt deposits in active channels, bars, and low overbank areas along tributary washes. Gravel clasts consist of mixed, locally-derived volcanic rocks. Topography is smooth to undulating, with coarse gravel bars and sandy channels. Soil development is minimal.

Qy_2 **Deposits on bars, low terraces and active alluvial fans** - Very poorly sorted sand, pebble, cobble, boulder, and silt deposits in small stream channels, low terraces, and active or recently alluvial fans. Topography typically undulates between channels, terraces, and gravel bars. No desert pavement or soil development.

Qy_1 **Deposits on low terraces and inactive alluvial fans** - Very poorly sorted sand, pebble, cobble, boulder, and silt deposits in gravel bars, low terraces, and inactive alluvial fans. Surfaces are typically are undulating, with coarse gravel bars and relict channels. Channels are covered by open to moderately closely packed fine gravel lags, gravel bars are weakly to moderately varnished. Soil development is weak, with some carbonate accumulations.

Qy **Channel, low terrace, and alluvial fan deposits** - Sand and gravel deposits associated with active tributary wash systems, including channels, bars and low terraces. This unit is applied primarily to small tributaries where differentiating Holocene deposits by age is not practical.

Qi_3 **Young intermediate alluvial fan and terrace deposits** - Poorly sorted mixtures of silt, sand, pebbles, cobbles and boulders on relict alluvial fans and terraces. Surface topography varies from gently undulating relict bars and swales to quite smooth. Soil development is weak but desert pavement development is moderate to strong, with relatively smooth surfaces and brown to dark brown rock varnish.

Qi_2 **Intermediate alluvial fan and terrace deposits** - Relict alluvial fan and moderately high terrace deposits consisting of poorly sorted sand, pebbles, cobbles, and boulders, with minor silt and clay. Soil development is moderate, with some soil reddening and weak clay accumulation and obvious carbonate accumulation. Rock varnish is dark brown to black; desert pavement development is variable, with tight, darkly varnished patches on well-preserved, smooth surfaces.

Qi **Intermediate piedmont alluvium** - Undivided Pleistocene alluvial fan and terrace deposits, generally including Qi2, Qi3,

Qi_1 **Older intermediate alluvial fan deposits** - Moderately to deeply eroded relict alluvial fan deposits consisting of poorly sorted sand, pebbles, cobbles, and boulders, with minor silt and clay. Soil development and pavement development variable depending on local surface preservation, with stage III-IV calcic horizons associated with well-preserved surfaces.

Qo **Old alluvial fan deposits** - High, dissected relict alluvial fan deposits consisting of poorly sorted sand, pebbles, cobbles, and boulders, with minor silt. Soil development typically is variable, with moderately cemented petrocalcic horizon development (stage IV) on well-preserved surfaces.

QTa **Very old alluvial fan deposits** - High, deeply dissected relict alluvial fan deposits, consisting of poorly sorted cobbles, sand, pebbles, and boulders, with minor silt. Soil development is variable but can be very strong, consisting of indurated petrocalcic horizons at or near the surface. Cemented carbonate fragments reworked from underlying petrocalcic horizons are very common on QTa surfaces.

Basin-Fill Deposits

Tfg_2 **Fan gravel, post-Bouse Formation** - Poorly sorted, weakly to moderately lithified conglomerate and sandstone exposed in the middle and lower portions of high, eroded ridges. Clasts consist largely of subangular to angular locally derived Tertiary volcanic rocks. Deposits are locally interbedded with Bouse deposits in Secret Pass Canyon exposures, but generally rest unconformably on Bouse deposits in limited exposures. Tfb2 deposits are in part coeval with deposition of Bullhead Alluvium closer to the valley axis.

Tfg **Fan gravel, undivided** - Undivided locally derived fan gravel, relationship to Bouse deposition uncertain.

Tbs **Bouse Formation fine siliciclastic deposits** - Primarily tan, locally greenish gray, fine to medium bedded silt, sand, and clay deposits. Sand beds are pinkish to tan and quartz-rich, generally <1 m thick. Clay-rich greenish beds and thin and confined to the base of the section. Tbs beds conformably overlie thin basal carbonate beds, and locally grade up into overlying fan gravels (unit Tfb2), but more commonly the upper contact is erosional with overlying gravel.

Tbc **Bouse Formation basal carbonate** - Basal carbonate deposits of the Bouse Formation, including marl, calcareous sandstone, and minor travertine (tufa), Deposits unconformably overlie alluvial fan deposits (unit Tfb1), but locally are include local gravel lenses or are interbedded with local gravel beds. Commonly unconformably overlain by younger gravel (unit Tfb2).

Tbg **Bouse Formation basal gravels** - Greenish to orange, locally derived, subangular to locally well-rounded gravels with calcareous sand lenses at the base of the Bouse Formation. These sediments are altered and locally reworked underlying fan deposits (unit Tfb1). The deposits range from cobbles and pebbles to sand-dominated facies. Beds from this unit are overlain by, and locally interbedded with, Bouse limestone and calcareous sandstone.

Ttw **Wolverine Creek tephra** - White to tan ash-fall tuff within Tfb1 deposits. Correlated with geochemical analyses to the 5.6 Ma Wolverine Creek Tuff of the Heise Volcanic Field in Idaho (House et al., 2008)

Tfg_1 **Fan gravel, pre-Bouse Formation** - Poorly to very poorly sorted, moderately lithified, generally undeformed, locally-derived conglomerate and sandstone. Clasts consist largely of subangular to angular volcanic rocks and granite. Deposition pre-dates Bouse deposition, and in some areas Bouse inundation resulted in reworking of these deposits into the basal Bouse gravel.

Hillslope Deposits

Qyd **Young debris flow deposits** - Bouldery very poorly sorted, angular to subangular deposits associated with small, relatively steep watersheds. Deposits typically form lateral, curvilinear levees along active drainages, or more amorphous snouts. Rock varnish on gravel is weak to strong, indicative of a range of ages of deposition. Also includes some limited areas that are erosional scars associated with steep channels or chutes on bedrock hillslopes.

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

Ql **Landslide deposits** - Blocks of displaced indurated fan gravel that have slumped or slid downslope over underlying fine-grained siliciclastic Bouse deposits

d **Disturbed areas** - Profoundly disturbed areas; either earthen berms associated with drainage diversions or landscape alterations associated with mining activties

Bedrock Units

Tb **Basalt - Basalt**ic lava containing 2-5% <2mm olivine, iddingsite, and/or pyroxene phenocrysts.

Tc **Conglomerate** - Dark weathering, mostly clast-supported conglomerate containing sub-angular to sub-rounded, pebble-cobble-boulder clasts of intermediate (dacitic) volcanic clasts.

Tr **Rhyolitic rocks** - Phenocryst-poor to moderately phenocryst-rich (0.5% - 15%) rhyolitic lavas (Tr) and porphyries (Tri) containing feldspar (<8mm) and quartz (<5mm) phenocrysts in ratios ranging between 1:1 and 3:1, and sparse (<2mm) biotite. Feldspars are generally dominated by K-feldspar. Intrusive varieties (Tri) mapped separately where known.

Tf **Felsic intrusions** - Felsic dikes, mostly phenocryst-poor, containing trace to 5% feldspar phenocrysts (mostly 1-2 mm, up to 4 mm) in a white to pink aphanitic groundmass. Most of the phenocrysts are plagioclase (euhedral, elongate prisms, white to pink). Some dikes also contain phenocrysts of clear K-feldspar (probably sanidine), 2-3% quartz, and trace biotite. The rocks of this unit exhibit weak to intense quartz-sericite-pyrite alteration, are weathered yellow-brown to red-brown, and form resistant outcrops.

Tt **Trachytic rocks** - Glassy to fine-grained crystalline matrix lavas and related shallow porphyries containing 0. 5% – 12% phenocrysts of <2mm feldspar >> biotite (<1mm). Feldspar phenocrysts are dominantly plagioclase. Associated pyroclastic rocks, ranging from clast-supported block and ash-flows to thin-bedded fallout tephras are locally included within this map unit.

Ttv **Trachytic lava of "Window Peak"** - Moderately phenocryst-rich (7-12%) trachytic lava with a distinctive, fairly thick, vitric to spherulitic-lithophysal, strongly flow-foliated, coherent-facies core. Feldspars (plagioclase and sanidine) are up to 5mm and biotite up to 3mm. This lava is informally named for a distinctive peak in the easterly adjacent Secret Pass map area along the north-central edge of section 24, R 20 W, T 21N.

Tts **Non-welded tuff and volcaniclastic rocks:** - Sequences of non-welded felsic, pyroclastic rock (ash-fall, ash-flow, and surge), and volcaniclastic sedimentary rocks with variable amounts of volcanic, plutonic, metamorphic, and sedimentary clasts. Generally phenocryst-poor with feldsapar and minor biotite, +/ quartz, Bedding ranges from massive to thin-bedded. A tuff breccia containing abundant, dark, phenocryst-poor trachyandesitic lava clasts in the Thumb Butte area was mapped separately (Ttta).

Ttta **Trachyandesite tuff breccia** - A distinctive, massive trachyandesite, non-welded tuff breccia with clast-supported to matrix-supported texture, and containing 5-50% clasts of dark, phenocryst-poor, trachyandesite lava.

Tta **Trachyandesitic rocks** - Dark, very fine-grained to fine-grained crystalline matrix, aphyric to phenocryst-poor lavas/porphyries containing <5mm mafic phenocrysts (biotite, hornblende, and/or pyroxene) in equal or greater abundance than <2mm plagioclase. Phenocryst content generally <<2% and rarely up to 5%

Td **Dacitic rocks** - Moderately phenocryst-rich to phenocryst-rich (10-30%) dacitic lavas/porphyries containing <10mm plagioclase and 1-5% mafics of pyroxene and biotite in proportions ranging between 1:3 and 3:1. Hornblende may also be present. Dacitic lavas of this composition generally occur in the upper parts in volcanic sections (above the Peach Spring Tuff) in areas to the south where they are known referred to the dacitic rocks of Gold Road.

Tax **Phenocryst-rich andesitic rocks** - Andesitic lavas containing 10-20% plagioclase phenocrysts (euhedral, clear vitreous, 2-8 mm) and 2-4% green clinopyroxene phenocrysts (2-4 mm). Some flows contain up to 3% biotite 1-2 mm. Coherent facies are hard, platy, and weathered dark brown.

Tap **Phenocryst-poor andesitic rocks** - Phenocryst-poor to moderately phenocryst-rich (1-10%) andesitic lavas/porphyries containing <5mm plagioclase and pyroxene in proportions ranging between 1:3 and 3:1.

Tdu **upper trachydacitic rocks** - Phenocryst-rich (15-30%) dacitic to trachydacitic lava containing phenocrysts of <10mm plagioclase and 1-3% <4mm biotite with sparse pyroxene and/or hornblende. These rocks are very similar in composition to the Alcyone trachydacites, and are differentiated only because they overlie a prominent interval of dark volcaniclastic rocks (Tsd) with basaltic andesite lavas (Tba) which overlies the Tda unit in the southeast corner of the map area.

Tbt **Bonelli Tuff** - Tbt Phenocryst-poor rhyolite ignimbrite containing 1-5% <4mm feldspar (mostly or all sanidine) with sparse biotite and/or other mafics. Pumice lapilli (fiamme) range between 1 and 15%. Dark gray, finely crystalline matrix grades into semi-vitric near the base of the flow overlying a thin, poorly to non-welded base. The nonwelded base and the semi-vitric zone are not always present.

Tsa **Sandstone and argillite** - Gray to red weathering, fine- to medium-grained volcaniclastic, mostly clay-cemented, sandstone, siltstone, and argillite. The sedimentary rocks are commonly poorly indurated and recessive, but parts of the sequence are silica-cemented and resistant. Light green, fine-grained ash beds constitute up to 25% of the sequence. The map unit is only recognized in the northeast corner of the map area where it directly overlies the capping vitrophyre of the Peach Spring Tuff (Tpu).

Peach Spring Tuff

Tpu **Upper Peach Spring Tuff** - Red, phenocryst-rich ignimbrite containing 20-35% phenocrysts of sanidine (<6mm) > plagioclase (<3mm), and <0.5% mafics and opaque minerals, mostly <2mm biotite, with sparse to trace amounts of hornblende, pyroxene and sphene. The map unit has a distinctive black vitrophyre cap <5m that correlates with the Warm Springs zone of the Peach Spring Tuff. The base is a gradational change over a few meters into light colored moderately phenocryst-rich to phenocryst-poor ignimbrite of the lower Peach Spring Tuff map unit (Tpl).

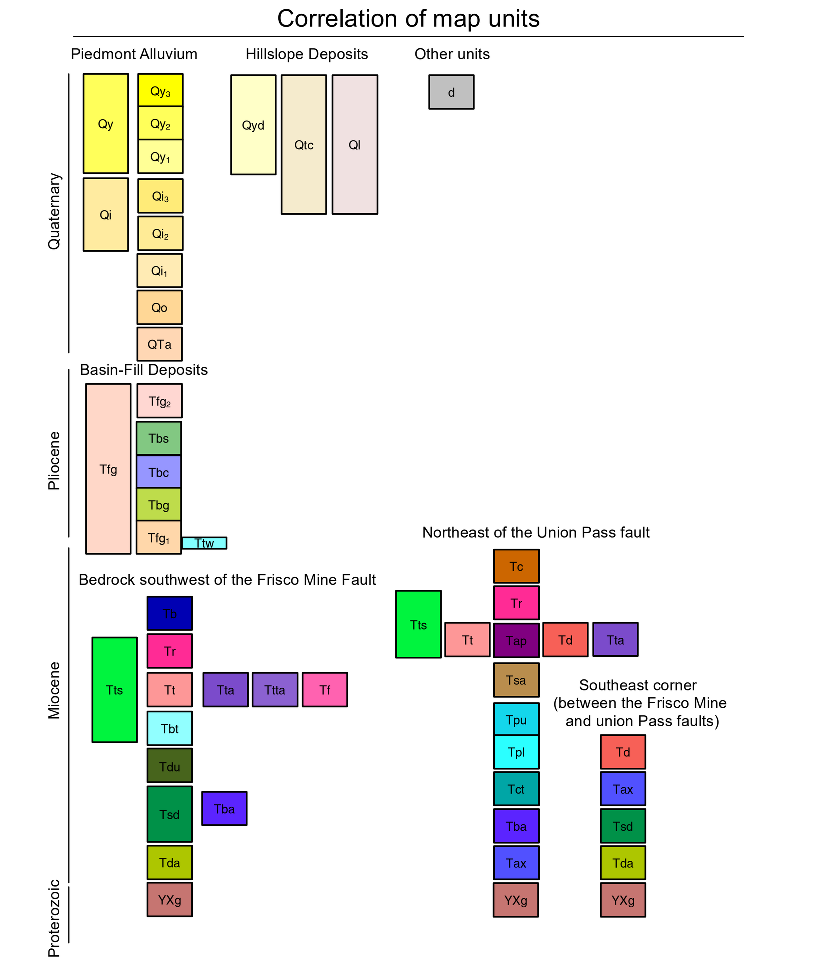
Tpl **Lower Peach Spring Tuff** - Light gray, phenocryst-poor to moderately phenocryst-rich ignimbrite containing 5-18% phenocrysts of sanidine (<6mm) > plagioclase (<3mm), and <0.5% mafics and opaque minerals, mostly <2mm biotite, with sparse to trace amounts of hornblende, pyroxene and sphene. The base is poorly exposed and nonwelded to poorly welded, and the top is a gradational, yet rapid (<5m interval), change upwards into red densely welded ignimbrite of the upper Peach Spring Tuff map unit (Tpu).

Tct **Cook Canyon Tuff** - Phenocryst-rich trachydacitic ignimbrite containing 15-25% phenocrysts of plagioclase (4mm) and 2-5% biotite (<4mm) in a dark reddish matrix. <5cm lithic lapilli are sparse, and pumice lapilli (<15cm) range between 5-15%.

Tsd **Dark volcaniclastic rocks** - Green, propylitically altered sandstone, argillite, conglomerate and breccia with clasts dominantly of mafic to intermediate volcanics. Sandstone ranges from arkosic to lithic-feldspathic (plagioclase). Sections of argillite are locally very thick and dominate the map unit, but always poorly exposed. Breccia and conglomerate are subordinate. Pebble-cobble conglomerates are commonly associated with sandstone dominated sections. Mafic to intermediate lavas (Ta, Tba, Td, Tda) are closely associated with this unit, which may include some unmapped flows of those compositions in some areas.

Tba **Basaltic andesitic rocks** - Phenocryst-poor to moderately phenocryst-rich (1-15%) basaltic andesitic lavas/porphyries containing pyroxene and/or iddingsite (after olivine or pyroxene) = or > plagioclase. Up to three distinct flows of basaltic andesite containing black and green pyroxene (ortho and clino) are present interbedded with the Tds map unit between Thumb Butte and the southern edge of the map area. These flows are similar to a distinctive suite of basaltic trachyandesite lava recognized immediately underlying the Peach Spring Tuff south of Oatman (Spencer et al., 2006). The mafic flows continue sparsely along the western base of the rugged spine of the Black Mountains between Oatman and this area but without any associated Peach Spring Tuff, and so are tentatively used as a stratigraphic marker, potentially of that age in this area.

Tda **Alcyone trachydacite** - Trachydacite lava flows, subordinate ignimbrite, and sedimentary rocks, chiefly at the base of the map unit. Dacite lava flows contain 20-30% 1-7-mm plagioclase phenocrysts and 5-10% 1-3-mm biotite phenocrysts in an aphanitic groundmass, typically purple or dark olive green. The contact between this unit and underlying Proterozoic rocks is a nonconformity. A discontinuous interval at the base of the unit consists of up to at least 5 m of conglomerate or breccia interbedded with pebbly sandstone. The basal unit is texturally variable. Breccia contains pebbles and cobbles of granitoid rocks, angular to subangular pebbles and granules of K-feldspar, and granules of plagioclase. Clast-supported conglomerate contains subrounded pebbles, cobbles, and a few boulders of crystalline rocks. Pebbly sandstone contains very coarse-grained, angular to subrounded, sand- and granule-sized grains of lithics and plagioclase, plutonic quartz granules, granitoid and other pebbles, in an unsorted (sand to clay) green matrix. Throughout most of the map area, a dacitic ignimbrite unit up to several tens of meters thick overlies either the basal conglomerate or lies directly on Proterozoic rocks. This unit contains 35-50% plagioclase phenocrysts (crystals and fragments, <1-2 mm), 10-20% biotite phenocrysts (chloritized in some intervals), 15% altered flattened pumice (purple to green or yellow with plagioclase and biotite phenocrysts), and 5-10% lithic lapilli (mostly <2 cm, up to 5 cm), in a light-colored matrix.

YXg **Granitic rocks and gneiss** - Proterozoic rocks form the core of an upthrown block bounded by high-angle extensional faults. The most abundant rock type in this unit is medium- to coarse-grained biotite monzogranite containing >20-25% K-feldspar megacrysts, at least 30% medium- to coarse-grained plagioclase, 20-25% medium-grained quartz, and at least 10% biotite. Most of the megacrysts are 2-3 cm (ranging up to 5 cm) and are Carlsbad-twinned. On the southwest slope of the ridge that extends from Secret Pass to west of Union Pass, megacrystic granite is nearly the only Proterozoic rock exposed. Some zones within the granite contain at least 10% 1-cm red garnet, probably reflecting alumina enrichment in zones of assimilated country rock. On the crest of the ridge, the granite contains xenoliths of country rock 5-20 cm long. Northeast of the ridge crest, granite encloses large xenoliths of gneiss several meters long. Sparse hummocky outcrops of granitoid and intervening low areas with sparse outcrops of gneiss are exposed on the northeast slope of the ridge. The granitoid on the northeast slope locally contains up to 10% 15-20-mm megacrysts, but typically most of the K-feldspar is 5 mm, with sparse megacrysts in the 10-15-mm size range. Much of the granitoid on the northeast slope is medium- to coarse-grained quartz monzonite to quartz monzodiorite containing 15-20% biotite and weathered dark gray. Locally it appears that domains of this more-mafic granitoid are engulfed by granitoid that contains less biotite and more megacrysts, more like the monzogranite on the southwest slope of the ridge.
The coarse-grained granitoid rocks intrude a suite of country rocks that includes biotite-quartz-feldspar and garnet-biotite-quartz-feldspar gneiss, fine- to medium-grained biotite granite (<10% biotite), and fine- to medium-grained garnet leucogranite with garnet up to 1 cm. The gneiss is composed of fine- to medium-grained quartz and feldspar, fine-grained biotite, and up to 15% garnet that is mostly 2-5 mm but up to >1 cm in some layers. Gneissic layering is on few-mm to few-cm scale, and some of the thinner layers are quartz-rich paragneiss.
The granitoid rocks and gneiss are intruded locally by fine-grained diabase that forms northwest-striking dike swarms.

Correlation of map units