GEOLOGIC MAP OF THE ARTILLERY PEAK AND RAWHIDE WASH 7 ½' QUADRANGLES, MOHAVE AND LA PAZ COUNTIES, ARIZONA

Arizona Geological Survey Digital Geologic Map DGM-100
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by
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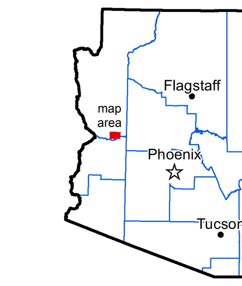


Introduction

The Artillery Peak and Rawhide Wash 7 ½' Quadrangles are located in southern Mohave County and northern La Paz County in western Arizona, and encompass Alamo Lake reservoir at the confluence of the Santa Maria and Big Sandy Rivers. New geologic mapping and map compilation for the two quadrangles, presented here, was done under the joint State-Federal STATEMAP program, as specified by 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 G11AC20455. This map was compiled digitally using ESRI ArcGIS software.

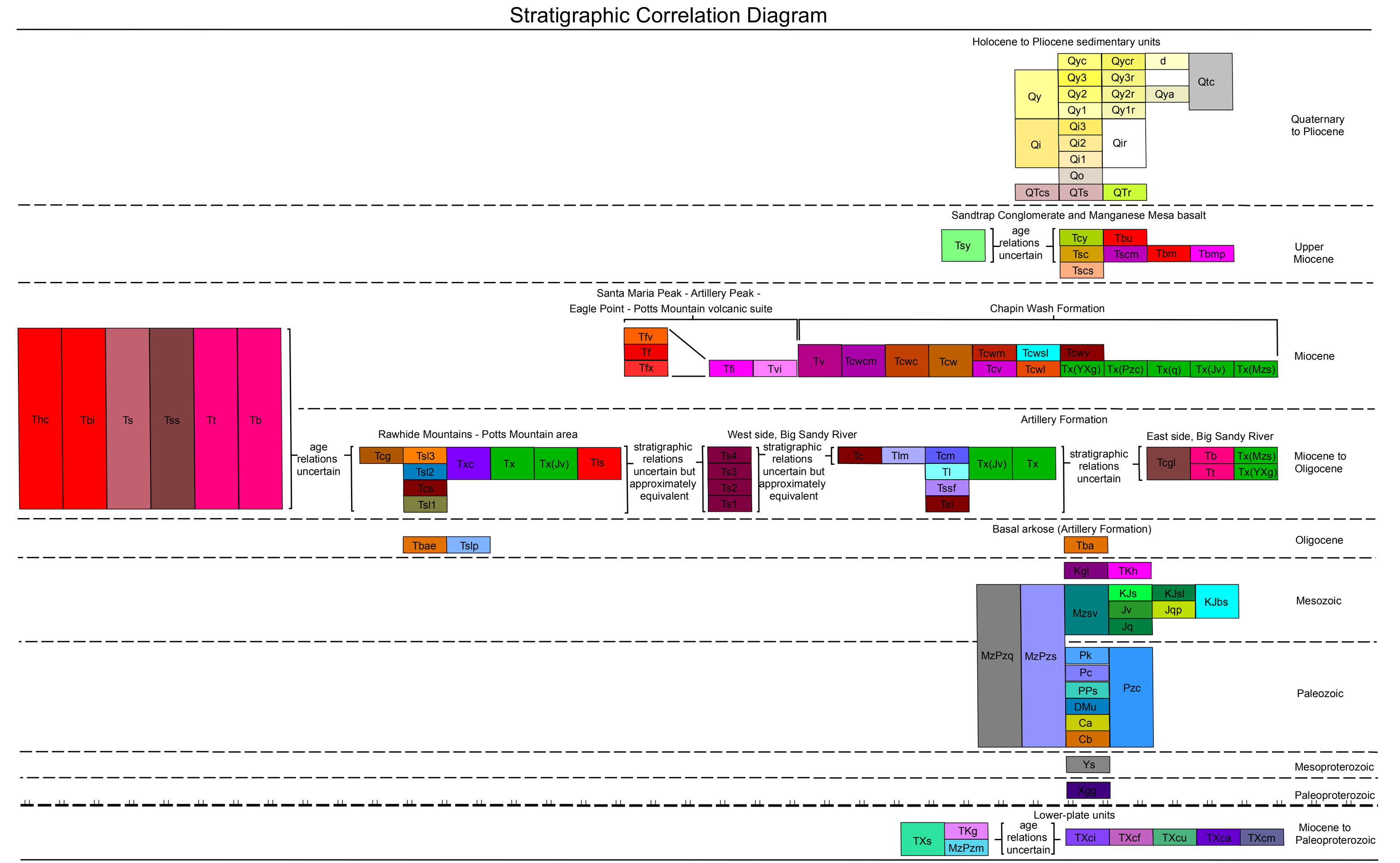
The Artillery Mountains and the northeastern flank of the Rawhide Mountains were partially mapped by Lasky and Webber (1949) and by Spencer et al. (1989). The northwestern part of the Rawhide Mountains was mapped by Yarnold and McDaniel (1992), and the entire range was mapped by Shackelford (1989). Two areas in the Rawhide Mountains were mapped in detail by Scott (2004). New mapping was done in unmapped areas, and to field check and improve mapping in previously mapped areas. Mapping by Lasky and Webber was not done on a modern topographic base, and their study area was almost entirely remapped. Previous mapping did not significantly differentiate Quaternary map units. For this mapping investigation, Quaternary units were differentiated in detail for entire map area. Georeferenced aerial-photograph imagery was used extensively for mapping Quaternary deposits.

The map area is located at the northeastern margin of the large Buckskin-Rawhide-Harcuvar metamorphic core complex, which was exhumed by tens of kilometers of displacement on the Buckskin-Rawhide extensional detachment fault (Spencer and Reynolds, 1991). The structural geology of the Rawhide Mountains is dominated by the Buckskin-Rawhide extensional detachment fault with top-to-the-northeast displacement. Rocks are divided into two suites. Those below the gently dipping to undulating fault (lower-plate rocks) consist almost entirely of variably mylonitic gneiss, granitoids, and hypabyssal intrusions. Those above the fault (upper-plate rocks) consist of highly deformed Paleozoic and Mesozoic metasedimentary and metavolcanic rocks and faulted and tilted Oligo-Miocene sedimentary and volcanic rocks. The lower-plate rocks were displaced from ~8-15 km deep in Earth's crust, and were uplifted and juxtaposed with the upper-plate rocks by 50-70 km of displacement on the Buckskin-Rawhide detachment fault (Spencer and Reynolds, 1991). Oligo-Miocene sedimentary and volcanic rocks were deposited during tectonic extension, half-graben basin genesis, and fault-block tilting (Yarnold, 1994). The Paleozoic and Mesozoic sedimentary and volcanic rocks were buried by late Cretaceous thrust faulting and metamorphosed within the Maria fold-and-thrust belt before further faulting during Oligo-Miocene tectonic extension (Spencer and Reynolds, 1990).

The Artillery Mountains consist largely of a gently to steeply southwest-dipping sequence of Oligo-Miocene sedimentary and volcanic rocks that rest depositionally on the ~1400 million-year-old Signal Granite (Lucchitta and Suneson, 1994; Bryant et al., 2001; Bryant, 1995). The sequence was deposited in a half-graben basin that was formed and tilted during tectonic extension (Spencer et al., 1989; Lucchitta and Suneson, 1993). The sequence has been divided into four assemblages, as follows (from Yarnold, 1994): (1) basal arkosic sandstone that contains a tuff dated at 26.3 Ma (Lucchitta and Suneson, 1993), (2) a complex mix of lacustrine limestone, siltstone, sandstone, conglomerate, and rock-avalanche breccias, (3) red arkosic sandstone and bedded manganese deposits of the Chapin Wash Formation, and (4) Sandtrap Conglomerate and Manganese Mesa basalt dated at 9.5 Ma (Shafiqullah et al., 1980). The lower two units make up the Artillery Formation of Lasky and Webber (1949). Clastic-sediment sources and paleocurrent directions were used to infer that units (1) and (3) were derived from northern, granitic sources, whereas assemblage (2) was derived from western areas of metamorphic rocks, including abundant, schistose, Jurassic metavolcanic rocks (Yarnold, 1994). Assemblage (4) was derived in part from the emerging mylonitic crystalline rocks of the metamorphic core complex (Spencer and Reynolds, 1989). In identifying map units for this mapping study, we noted that the upward transition from metamorphic clastic debris of assemblage (2) to arkosic debris of assemblage (3) occurred below the extensive, dominantly granitic, Artillery megabreccia, and accordingly placed the base of the Chapin Wash Formation below the megabreccia and lower in the stratigraphy than did Lasky and Webber (1949).

The large bedded sedimentary manganese deposit beneath Manganese Mesa has been the target of exploration activity for decades, including a major drilling program in 2011. The manganese deposits are hosted by the Chapin Wash Sandstone, and include vein deposits that extend upward into the Sandtrap Conglomerate (Lasky and Webber, 1949; Spencer et al., 1989). The Rawhide Mountains contain numerous small areas of specular hematite (Fe_3O_4) mineralization along and directly adjacent to the detachment fault (Spencer and Welty, 1989). Minor copper and gold deposits are associated with the iron mineralization, and have been the target of historic mining activity. All of the manganese and iron mineralization, and associated copper and gold, are thought to be related to ascent of basin brines along the detachment fault (Spencer and Welty, 1989).

Stratigraphic Correlation Diagram



Description of Map Units

Holocene to Pliocene alluvium

water — **Alamo Lake (2010 NAIP lake level)** - Lake water as indicated on NAIP 2010 imagery

d — **Disturbed ground (Recent)** - Areas where rock and soil have been buried or disturbed by mining activity, excavation, and other human activities, and geologic units, if exposed previously at the site, are concealed or obscure.

Qyc — **Active alluvium in channels (Holocene)** -

Qycr — **Active river channel deposits (Latest Holocene)** - Unconsolidated, very poorly sorted sandy to cobbly beds exhibiting bar and swale microtopography. Clasts are subangular to well-rounded. Clast lithologies include mixed latite and basalt, Paleozoic limestone and chert. Qycr deposits are typically unvegetated to lightly vegetated and exhibit no soil development. Qycr deposits are entrenched from 3 to 15 ft below adjacenthistorical floodplain deposits.

Qy3r — **Low terrace deposits (Latest Holocene)** - Very young terrace deposits that occupy elevations from 3 to 6 ft above active channels and are inset below the pre-incision historical floodplain. These surfaces are planar to rounded, and locally exhibit bar and swale microtopography. Deposits are poorly sorted silt, sand, pebbles and cobbles. Pebbles and cobbles are well-rounded to sub-angular.

Qy3 — **Deposits associated with active washes and drainageways (Late Holocene)** - Recently active piedmont alluvium located primarily along active drainages including floodplain, low-lying terrace, less active tributary drainages to Qyc channels, and distal reaches of active fan channels that have aggraded and transitioned to distributary flow and infiltration. Qy3 deposits are composed of unconsolidated to very weakly consolidated unvarnished sandy to pebbly deposits. Qy3 drainages are often wider, lower energy, and more heavily vegetated than the Qyc channels they drain into. These deposits may exhibit bar and swale microtopography and are susceptible to inundation during moderate to extreme flow conditions when channel flow exceeds capacity. Soil development is generally absent or incipient on Qy3 deposits which exhibit pale buff to light brown (10 YR) surface coloration.

Qy2r — **Historical floodplain deposits (Latest Holocene)** - Deposits associated with the floodplain that existed prior to recent entrenchment of the larger washes in the valley. Qy2r deposits are associated with broadly planar surfaces that locally retain the shape of historical river meanders. Qy2r surfaces are 3 to 15 ft above modern channels and are the most extensive river terraces in the valley. These deposits appear predominantly fine grained at the surface due in part to the input of organic matter and windblown dust deposition but are composed of interfingering coarse sandy to pebbly braided channel and fine sand to silty river 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.

Qy2 — **Low terrace deposits** - Unconsolidated sand, silt and gravel deposits with weak soil development associated with broad valley floors and low terrace. Channels included in this unit are very small and discontinuous. Deposits are predominantly sand and silt, but in upper piedmont areas include cobbles and small boulders. Topographic relief across Qy2 surfaces is generally very low.

Qya — **Active alluvial fan deposits (modern)** - Low relief splays and fine-grained distributary alluvial fan deposits comprising the active portion of alluvial fans where channel flow becomes unconfined. Qya deposits are typically found at the downstream outlet of discontinuous ephemeral channels and gullies. Qya deposits are extremely prone to flooding and channel migration. Sediments are unconsolidated and consist of very poorly sorted sand to small cobbles. Vegetation on Qya deposits consists of bunch grass, small shrubs, and weeds.

Qy1r — **Young river terrace deposits (Early to late Holocene)** - Sand, silt, and gravel deposits associated with slightly higher terraces that are remnants of older Holocene aggradation periods. Soil development is moderate and surface color ranges from 10 to 7.5 YR 4/4. A light dusting (incipient stage I) calcium carbonate accumulation is evident on the undersides of some buried clasts. Qy1r surfaces are commonly only slightly higher than adjacent Qy2r surfaces.

Qy1 — **Young alluvial fan and terrace deposits** - These deposits are unconsolidated and loose silt and gravel size clasts with a light to medium gray-brown soil.

Qy — **Undivided young deposits (Holocene)** - Undivided Holocene alluvial terrace or fan deposits, typically used where land surface is obscured by human activity

Qtc — **Talus and colluvium (Quaternary)** - Unconsolidated talus on steep slopes and coluvium on more gentle slopes.

Qa — **Alluvium, undivided (Quaternary)** -

Qi3 — **Intermediate alluvial fan and terrace deposits** - Moderately dissected alluvial fan and terrace deposits with moderate soil development. Deposits consist of poorly sorted pebbles, sand, and cobbles, with lesser amounts of silt, and clay. Qi3 surfaces typically are planar with rounded margins, but if sufficiently coarse, relict gravel bars are evident and stand slightly higher than surrounding surfaces. Surfaces commonly are covered with loose to moderately packed gravel lags with weak to moderate varnish. Soils are slightly reddened (7.5YR) but clay accumulation is minimal (cambic horizons); underlying calcic horizons include thin to moderately thick, discontinuous to continuous carbonate coatings on gravel and soft carbonate nodules (stage II to III). Qi3 surfaces are less than a few meters above active channels.

Qi2 — **Older intermediate alluvial fan and terrace deposits** - Moderately dissected alluvial fan and terrace deposits with moderate to strong soil development and variable desert pavement development. Deposits typically consist of poorly sorted cobbles, pebbles, and sand, with lesser amounts of silt, clay and small boulders. Well-preserved planar Qi2 surfaces typically have well-varnished, tight pebble and cobble pavements, although areas without desert pavements are common. Surface carbonate fragments from underlying soil horizons are uncommon. Soils are reddish brown to brown (5 to 7.5YR), with obvious clay accumulation in strong cambic or weak argillic horizons up to 0.5 m thick. Calcic horizon development ranges from carbonate nodules, thick gravel coatings (stage III), and weakly cemented petrocalcic horizons with incipient laminar horizons (stage IV). Qi2 surfaces are typically less than 3 m above active channels.

Qi — **Undivided older fan and terrace deposits (Pleistocene)** - Undifferientated alluvial fan or terrace deposits, likely of middle or late Pleistocene age

Qir — **Pleistocene river deposits (Pleistocene)** - Unlithified coarse conglomerate with subangular to rounded clasts, up to 1m diameter. Lithologic mix is diverse, including granite, gneiss, and mafic and felsic fine-grained volcanic rocks. Deposits form river terraces high above the modern channels.

Qi1 — **Eroded older fan deposits** - Moderately to deeply dissected relict alluvial fans with strong calcic horizon development. Deposits are poorly sorted, containing cobbles, pebbles, sand, silt and clay. Landforms are moderately eroded, and typically form gently rounded ridges with relatively limited planar remnants approximating the original fan surface. Carbonate fragments derived from underlying petrocalcic horizons are common on surfaces, giving them a light color on the ground and on aerial photographs. Active channels are incised up to 5 m below these surfaces. Soils are brown to yellowish red (7.5 to 5YR), with weakly to moderately cemented petrocalcic horizon development and some laminar carbonate (stage IV to V).

Qo — **Very high alluvial fan and terrace remnants (Early Pleistocene)** - This unit consists of relatively high-standing, moderately to deeply dissected relict alluvial fans with strong but variable calcic horizon development. Qo fan surfaces are preserved only near the mountains. Deposits are very poorly to poorly sorted gravel and sand. Some surface cobbles and boulders are darkly varnished, but varnish is variable due to rock weathering. Fragments from underlying petrocalcic horizons are common, giving the surface a very light color on the ground and on aerial photographs. Soils substantially eroded but are very calcareous with cemented petrocalcic horizons and laminar carbonate layers are exposed at the surface in some areas (stage IV to V).

Quaternary to upper Tertiary deposits

QTcs — **Carbonate-rich fine deposits (Quaternary to upper Tertiary)** - Fine-grained calcareous deposits, weakly to moderately indurated. Locally tufa-like morphology. Possibly related to spring discharge.

QTs — **Basin fill deposits (Quaternary to upper Tertiary)** - Weakly consolidated, poorly sorted conglomerate and sandy conglomerate. In the northeastern corner of the Artillery Peak Quadrangle, much of this unit may consist of disaggregated and reworked underlying conglomerate of map unit Tcg.

QTr — **River deposits (Quaternary to upper Tertiary)** - Unlithified coarse conglomerate with subangular to rounded clasts, up to 2m diameter. Lithologic mix is reasonably diverse, including granite, gneiss, and mafic and felsic fine-grained volcanic rocks. Deposits occupy high ridges east of Alamo Lake, and are the oldest evidence of the presence of the Santa Maria/Big Sandy Rivers in the map area.

Tertiary sedimentary and igneous rocks

Tcy — **Unconsolidated crystalline-clast conglomerate (Upper Miocene to Pliocene)** - Weakly consolidated conglomerate, pale gray, with subrounded cobbles of granitoids and sparse, high-grade quartzo-feldspathic gneiss. Most clasts are 2-20 cm, locally as large as 60 cm. Sparse to moderately abundant clasts of Tertiary volcanic rocks, generally intermediate to felsic, are also present. This unit contrasts with directly underlying Sandtrap Conglomerate because it is gray rather than tan, clasts are sub-rounded rather than subangular, and clast composition is dominated by granitoids rather than diverse lithologies that include mylonitic crystalline rocks, quartzite, and metasedimentary tectonites.

Tsy — **Basin-fill deposits (Upper Miocene to Pliocene)** - Poorly consolidated to unconsolidated, crudely stratified, tan to reddish brown sandstone, conglomerate, and conglomeratic sandstone in the southwestern corner of the Rawhide Wash 7.5' Quadrangle (description from Scott [1995, Ph.D. dissertation]). Clasts are predominantly subrounded to well rounded, sparse clasts area subangular to angular. Strata of this unit are similar in both clast content and apearance to the youngest tilted and faulted conglomerate (Sandtrap Conglomerate), but are unfaulted and flat lying.

Sandtrap Conglomerate and Manganese Mesa basalt

Tbu — **Basalt, upper (Miocene)** - Variably vesicular basalt that forms lava flows and, possibly, dikes along the Sandtrap Wash fault southeast of Potts Mountain. The unit outcrops as if it formed dikes in the fault, but is highly vesicular like lava flows. Associated felsite along the fault is brecciated, as if faulted, but breccia is highly indurated, as if brecciation occurred while the rock was semi-molten.

Sandtrap Conglomerate and Manganese Mesa basalt (cont...)

Tsc — **Sandtrap Conglomerate (Miocene)** - Tan to locally reddish-tan, moderately consolidated conglomerate, conglomeratic sandstone, and local sandstone and siltstone, named Sandtrap Conglomerate by Lasky and Webber (1949). Channels with coarse clasts in channel bottoms are locally common. This unit commonly forms massive, rounded outcrops and locally smooth, vertical canyon walls. It varies from matrix-supported conglomerate to stratified clast-supported gravel that resembles Quaternary fanglomerate. Clasts include a variety of Proterozoic crystalline rocks, Paleozoic carbonates, Jurassic metavolcanics, quartzite, Tertiary volcanics, Tertiary sandstone, and mylonitic crystalline rocks. Many mylonitic crystalline-rock fragments are variably overprinted by chloritic alteration and fracture-filling chlorite and epidote and were almost certainly derived from the footwall of the Buckskin-Rawhide detachment fault. The presence of these clasts is distinctive in the Sandtrap Conglomerate in most exposures, but such clasts are absent in northwestern exposures (upper Maggie Wash). This unit is interpreted as an alluvial-fan facies derived from western to southwestern sources where mylonitic crystalline rocks structurally below the Buckskin-Rawhide detachment fault were being exhumed by displacement on the active detachment fault (Spencer and Reynolds, 1989). Paleozoic and Mesozoic metasedimentary and metavolcanic rocks, also exposed only to the west and southwest, were a significant source of clasts. A siltstone facies south of Lake Mine is interpreted as having been deposited in a small playa between northeast-prograding alluvial fans that form the bulk of the Sandtrap Conglomerate and a southwest-tilted dip slope at the top of the underlying basalt.

Tscm — **Sandstrap Conglomerate, manganiferous (Miocene)** - Cobble conglomerate and sandy conglomerate withsecondary manganese oxides that impart black color.

Tscs — **Sandtrap Conglomerate, sandy facies (Miocene)** - Interbedded conglomerate, sandy conglomerate, and sandstone. Sandstone is commonly reddish. This unit is typically present at the upward transition from Chapin Wash Sandstone to Sandtrap Conglomerate. It is likely that Sandtrap Conglomerate prograded over Chapin Wash Sandstone, and that the transitional unit grades laterally, basinward, into Chapin Wash Sandstone. Because of structural disruption, however, this inferred lateral facies transition is not clearly present.

Tbm — **Manganese Mesa basalt (Miocene)** - Gently southwest-dipping basalt flows that form the top of Manganese Mesa (also known as Black Mesa). Includes Sandtrap basalt and Cobweb basalt of Lasky and Webber (1949), who described the basalt as a "hypersthene(?)-augite-olivine basalt" with labradorite (An55) phenocrysts and microlites.

Tbmp — **Manganese Mesa basalt, associated pyroclastic rocks (Miocene)** - Tan volcaniclastic sandstone in planar and planar cross-bedded beds greater than 1 m thick interpreted as a pyroclastic surge deposit. This unit is interbedded with the Manganese Mesa basalt, and is exposed in a single outcrop area near the northeastern corner of the Rawhide Wash 7.5' Quadrangle.

Tss — **Sandstone, undivided (Oligo-Miocene)** - Sandstone of uncertain affinity. Generally consists of small exposures within diverse lithologies of the Artillery Formation, and locally includes siltstone, limestone, conglomerate, and breccia.

Tbi — **Basalt intrusion (Miocene)** - Basalt dikes and irregular intrusions

Tb — **Basalt, lower (Oligo-Miocene)** - Basaltic lava flows in the Artillery and Chapin Wash Formations. Typically dark-gray, weakly resistant, lava flows of two-pyroxene olivine-phyric, plagioclase-microphyric basalt. Phenocrysts of olivine (up to 10% of the rock) are almost everywhere oxidized, whereas the less abundant pyroxene phenocrysts, whre present, are commonly only slightly altered.Thickness is as great as 80 m.

Tt — **Tuff, undivided (Oligo-Miocene)** - Undivided tuff that includes aphyric, variably indurated, thin ash-fall tuffs and possible aphyric to crystal poor ash-flow tuffs.

Thc — **Hydrothermal carbonate (Oligo-Miocene)** - Dark brown to gray hydrothermal carbonate developed immediately above the Rawhide detachment fault. Thickness is typically less than 1-2 m. Carbonate appears to replace various host-rock types.

Chapin Wash Formation

Tcw — **Chapin Wash Sandstone (Miocene)** - Tan, brown, red, and brick-red, well bedded sandstone, with less common siltstone and conglomerate. Some beds have basal pebbly zone or pebbly channel fill. Weakly normal-graded beds are common, some with silty upper zones. Beds are typically 5-50 cm thinck. Includes Arkose of Keenan Camp of Lucchitta and Suneson (1994). Common red color is attributed to secondary hematite growth during potassium metasomatism (e.g., Roddy et al., 1988) and is indicated by a single chemical analysis from west of Potts Mountain that reveals 9.25% K_2O and a K/Na ratio of 25.7 (unpublished analysis).

Tcwm — **Chapin Wash sandstone, manganiferous (Oligo-Miocene)** - Chapin Wash Sandstone that is dark red to black because of black manganese oxides within the sandstone matrix. Includes manganiferous siltstone interbedded with non-manganiferous siltstone or sandstone.

Tcwc — **Chapin Wash Sandstone, conglomerate member (Miocene)** - Pebbly sandstone, granule, pebble, cobble, and boulder conglomerate. Clasts are subrounded to rounded and consist of granitic and gneissic rocks in arkosic sandstone matrix. Commonly dark red to brick red to medium to dark brown. Black where manganiferous.

Tcwcm — **Chapin Wash Sandstone, conglomerate member, manganiferous (Miocene)** - Dark red to black, pebble to cobble conglomerate with subrounded to rounded clasts of granitic and gneissic rocks in an arkosic sandy matrix. Manganese oxides are pervasive in the matrix of the conglomerate and give the unit a black color.

Tcwsl — **Chapin Wash Sandstone, siltstone and limestone member (Miocene)** - Lenticular beds of thin-bedded, medium gray limestone interbedded with subordinate (0-40%) brown to orangish brown siltstone. Contact with adjacent units may be gradational over meters to tens of meters. This unit is exposed only in the area east of Alamo Lake and south of the Santa Maria River.

Tcwv — **Chapin Wash Sandstone, volcanic-clast conglomerate member (Miocene)** - Pebbly sandstone and granule to pebble conglomerate with clasts of mafic to intermediate volcanic rocks. This unit is exposed in one small area southeast of Alamo Lake, and is interbedded with rocks containing more typical (arkosic) Chapin Wash Sandstone and conglomerate.

Tcwl — **Chapin Wash Sandstone, lower member (Miocene)** - East of Santa Maria Peak in the Artillery Peak 7.5 Quadrangle, this unit consists of interbedded siltstone, sandstone, and conglomerate with well rounded clasts primarily of granitoids and gneiss up to 30 cm diameter, locally to 50 cm. In the northwest corner of the Rawhide Wash 7.5' Quadrangle, this unit consists of interbedded sandstone, less abundant maroon siltstone, and sparse limestone. Sandstone is commonly poorly lithified, poorly sorted, pale gray to tan, quartz-rich, medium to fine grained. In the southwestern corner of the Rawhide Wash 7.5' Quadrangle, this unit consist of medium to very thick bedded, brick red, yellow orange or gray conglomeratic sandstone and sandstone (Scott, 1995, Ph.D.). Most exposures of this unit, along with overlying conglomerate, are primarily located at the ends of the large Artillery megabreccia sheet. This spatial relationship suggests that the lower sandstone member of the Chapin Wash Sandstone, and associated conglomerate, filled low-elevation areas around the margins of the Artillery megabreccia sheet. This map unit is also present locally beneath the Artillery megabreccia sheet, where it consists of nonresistant, light-red or buff-colored, thick-bedded to massive, generally medium grained, well-sorted arkosic sandstone with subordinate lenses of pebbly sandstone.

Santa Maria Peak - Artillery Peak - Eagle Point - Potts Mountain felsic volcanic suite

Tfi — **Felsite intrusion (Miocene)** - Generally aphyric to crystal poor, light gray to tan felsite. Locally includes breccias derived from felsic volcanic or hypabyssal rocks.

Tvi — **Intermediate-composition volcanic rocks (Oligo-Miocene)** - This unit includes flow breccia(?) that caps a hill near the northeastern corner of the Artillery Peak 7 1/2' Quadrangle. It contains ~3-5%, <3mm, altered biotite, <4mm sanidine(?), and ~10%, <1mm plagioclase(?), in tan to gray groundmass. Unit also includes andesitic(?) flows and flow breccias south of Santa Maria Peak. A sample of this unit from west of Santa Maria Peak yielded a $^{40}Ar/^{39}Ar$ biotite date of 20.49 +/- 0.13 Ma (unpublished data from W.C. McIntosh).

Tv — **Volcanic rocks, undivided (Oligo-Miocene)** - Generally intermediate to felsic, pyroclastic rocks and lava flows. Southeast of Alamo Lake this unit consists of dacitic to rhyolitic tuff that is indurated possibly because it is welded, locally with biotite-bearing volcanic-lithic fragments. In this area this unit possibly includes lava flows.

Tcv — **Volcanic-lithic conglomerate (Oligo-Miocene)** - Conglomerate with subangular clasts, mostly less than 10 cm diameter, of tan volcanic or hypabyssal rock containing phenocrysts of biotite and hornblende.

Tfv — **Crystal-poor felsite, vitric (Miocene)** - Black, vitric top of flow-banded, brecciated, aphyric felsite of map unit Tfx. This unit formed an elevated area that was onlapped by sandstone and manganiferous sandstone of the Chapin Wash Formation.

Tf — **Crystal-poor felsite (Miocene)** - Massive aphyric felsite, locally weakly brecciated, pale pink.

Tfx — **Crystal-poor felsite, brecciated (Miocene)** - Pale gray to whitish gray breccia of flow-banded fragments of aphyric felsite, with <<1%, <1mm quartz. Flow bands are randomly oriented in breccia. Emplacement mechanism is uncertain but brecciation suggests abrupt emplacement and lithologic consistency of indurated matrix suggests volcanogenic emplacement. In northern exposures bedded tuff at base of unit contains 6-9% feldspar phenocrysts, including ~1% sanidine, all <1mm.

Rock avalanche breccia

Txc — **Rock-avalanche breccia, debris flows, and coarse conglomerate, undivided (Oligo-Miocene)** - Massive breccia with angular fragments, typically 1-100 cm, of Jurassic metavolcanic rocks typically consisting of sericitic schist and quartz porphyry with quartz phenocrysts up to 8mm. Breccia masses also consist of quartzite, megacrystic granite, and Paleozoic carbonates. Unit includes debris-flow deposits and massive conglomerate as well as breccia. Bedding is locally visible, primarily in crudely bedded conglomerate but also in rare sandstone beds.

Tx — **Rock-avalanche breccia, undivided (Oligo-Miocene)** - Brecciated rock masses derived from diverse rock types, consisting mostly of Proterozoic granite, Paleozoic carbonates, and Jurassic metavolcanic rocks.

Tx(YXg) — **Rock-avalanche breccia derived from megacrystic biotite granite (Oligo-Miocene)** - Clast-supported breccia consisting of angular fragments of megacrystic biotite granite of probable Proterozoic age, sparse mylonitic megacrystic biotite granite, and pink, fine-grained leucocratic granite. Grades from highly shattered, clast-supported megabreccia to slightly fractured, resistant, cliff-forming outcrops that are no more fractured than typical outcrops of structurally coherent bedrock crystalline rock. Basal contact is well exposed 3.7 km southwest of Artillery Peak (south edge of SE 1/4 sec. 28), where an approximately 50-m-thick ledge of massive, structurally coherent, fine-grained granite is juxtaposed with underlying conglomeratic sandstone along a cryptic, several-millimeter-thick planar contact. Pebbles directly below the thin contact zone are unbroken, and there are no lineations along the contact. Beds in the underlying unit are truncated at the contact.

Rock avalanche breccia (cont...)

Tx(Pzc) — **Rock-avalanche breccia derived from Paleozoic carbonate rocks (Oligo-Miocene)** - Brecciated masses of Paleozoic carbonate rocks, calc-silicates, phyllite, and quartzite, all derived largely or entirely from Paleozoic metasedimentary rocks. Carbonate breccia is the dominant lithology. Includes large blocks up to tens of meters across.

Tx(Jv) — **Rock-avalanche breccia derived from Jurassic metavolcanic rocks (Oligo-Miocene)** - Rock-avalanche breccia that consists of angular fragments, typically 1-100 cm, of sericitic schistose metavolcanic rocks and quartz porphyry with quartz phenocrysts up to 8 mm. Fragments are foliated to massive and gray to greenish-gray to brown. Rock masses vary from structurally coherent and unshattered (east edge of section 28) to highly shattered, clast-supported breccia. Metavolcanic rocks are virtually identical to the Jurassic Planet Volcanics in the Buckskin Mountains (Spencer et al., 1989, AZGS Bulletin 198, Appendix A).

Tx(Mzs) — **Rock-avalanche breccia derived from Mesozoic schist and calc-sliicate (Oligo-Miocene)** - Rock-avalanche breccia derived from quartz-sericite schist and calc-silicate rocks that are inferred to be Mesozoic metasedimentary and, possibly, metavolcanic rocks.

Tx(q) — **Rock-avalanche breccia derived from Mesozoic or Paleozoic quartzite (Oligo-Miocene)** - White, highly shattered quartzite with red, silicified matrix.

Artillery Formation

Tcg — **Conglomerate, undivided (Oligo-Miocene)** - Massive to bedded conglomerate and conglomeratic sandstone, generally medium to light brown to reddish brown, locally including rock avalanche breccia.

Sandstone and mudstone unit of the Artillery Formation

Ts4 — **Sandstone and mudstone, upper mudstone (Oligo-Miocene)** - Thinly bedded to medium-bedded, well-sorted siltstone and fine-grained sandstone.

Ts3 — **Sandstone and mudstone unit, upper sandstone (Oligo-Miocene)** - Thickly bedded to massive, well-sorted, coarse- to medium-grained sandstone with local pebble stringers. Plane beds are the dominant bedform. Rip-up clasts of underlying calcareous mudstone and other pebble-sized clasts are present in the basal bed of the member.

Ts2 — **Sanstone and mudstone unit, lower mudstone (Oligo-Miocene)** - Thinly bedded to medium-bedded, well-sorted, variably and locally calcareous siltstone and fine-grained sandstone. Ripple cross laminations are present near the top of the member. Micaceous sandstone is more abundant than in the underlying member.

Ts1 — **Sandstone and mudstone unit, lower sandstone (Oligo-Miocene)** - Thickly bedded to massive, poorly sorted to well sorted, coarse-grained sandstone, and matrix-supported sandy conglomerate. Locally clast-supported with a weakly developed imbrication. Bed thickness and grain size decrease up section.

Tsl3 — **Sandstone, siltstone, and limestone, upper unit (Oligo-Miocene)** - Well stratified, thin to medium bedded, light colored silty limestone, calcareous siltstone, sandstone, and pebbly sandstone. Unit is locally gypsiferous.

Tsl2 — **Sandstone, siltstone, and limestone, middle unit (Oligo-Miocene)** - Well stratified, thin to medium bedded, calcareous siltstone, silty limestone, and sandstone interpreted to represent marginal lacustrine deposits. Irregular chert beds and nodules are common in limestone. Lower part of unit is reddish brown and gradational with underlying conglomeratic sandstone of map unit Tcs. Middle and upper parts range from yellow to gray to pink. Fissile to platy character is common (Yarnold and McDaniel, 1992).

Tcs — **Conglomeratic sandstone (Oligo-Miocene)** - Moderately to well stratified, reddish brown to green, pebbly arkosic sandstone and rounded pebble conglomerate, with common cross-lamination and relict channels. Tuffaceous debris is common at higher stratigraphic levels. Clasts include metavolcanic and metasedimentary rocks, and quartzite (Yarnold and McDaniel, 1992).

Tsl1 — **Sandstone, siltstone, and limestone, lower unit (Oligo-Miocene)** - Reddish brown sandstone and yellow siltstone that contains an increasing amount of gray limestone up section. Limestone beds in this area locally contain silicified rootlets, chert nodules, and sandy turbiditic lithofacies. Pebbles in sparse pebbly beds consist of granitoids except near the top of the section where metavolcanic rocks are increasingly common (Yarnold and McDaniels, 1992).

Tc — **Conglomerate (Oligo-Miocene)** - Dark-brown, weakly resistant, interbedded pebbly sandstone and sparse sandstone and siltstone. The unit is typically poorly bedded, with individual beds defined by gradational variations in grain size. Most clasts are angular to subangular and consist of quartzite.

Ts — **Sedimentary rocks, undivided (Oligo-Miocene)** - Sandstone, conglomerate, debris-flow deposits, and rock avalanche breccia, with rare tuffs, lava flows, siltstone, and limestone.

Tcm — **Limestone, mudstone, sandstone, and pebbly sandstone (Oligo-Miocene)** - Weakly resistant, interbedded limestone, calcareous mudstone, siltstone, sandstone, and pebbly sandstone. Limestone beds are mesoscopically similar to those of map unit Tl and are typically 1 m or less thick, whereas sets of brown pebbly sandstone beds form 3-4 m thick subunits. Contacts between different types of beds are sharp.

Tlm — **Limestone and mudstone (Oligo-Miocene)** - Light- gray and green, weakly resistant, thinly bedded to laminated mudstone, calcareous mudstone, and siltstone. Unit is strongly folded. Some folds have wavelengths of as little as a few centimeters.

Tl — **Limestone and calcareous siltstone (Oligo-Miocene)** - South of Artillery Peak this unit consists of light-tan to gray, resistant, thickly bedded to massive limestone that is commonly folded, with fold wavelengths larger than 10 m. Translucent, lens-shaped, siliceous zones and nodules form replacements of calcareous algal mats and contain well-preserved gastropod fossils. The lower portion of this unit is silty and thin bedded. Large blocks or tongue-shaped bodies of brecciated Mesozoic schist and metavolcanic rock are present at several, widely separated locations. Stratigraphic thickness is estimated at approximately 180 m. Folding has resulted in structural thickening of the unit to more than 350 m in the northwest portion of the map area.

Tssf — **Fine-grained sandstone (Oligo-Miocene)** - Tan, fine-grained, thinly bedded to laminated sandstone and subordinate siltstone and calcareous siltstone. Rocks of this unit are interbedded with limestone within a few meters of the contact with unit Tl.

Tslp — **Sandstone, siltstone, and limestone at Potts Mountain (Oligo-Miocene)** - In the Potts Mountain area, this unit consists of well stratified, thin to medium bedded, light colored limestone, silty limestone, calcareous siltstone, and sandstone, locally interbedded with gypsum. This unit is interpreted to represent lacustrine and margnial lacustrine settings (Yarnold and McDaniel, 1992).

Tsl — **Sandstone, siltstone, and limestone (Oligo-Miocene)** - Green, thin-bedded to laminated, well-sorted sandstone, mudstone, and limestone. Mudstones are rhythmically interbedded with the fine-grained sandstones; each bedset is between 30 cm and 120 cm thick. Beds locally contain mudcracks. Unit contains two beds of pink, moderately resistant, biotite-feldspar-phyric tuff containing less than 3% phenocrysts. Both beds are interpreted as lithified and altered ash-fall tuffs based on thin-section examination that reveals devitrified, undeformed glass shards.

Tcgl — **Conglomerate, conglomeratic sandstone, and sandstone, lower unit (Oligo-Miocene)** - Dominantly poorly sorted, tan to pale brown conglomerate and sandy conglomerate. Includes cobble to boulder congomerate, sandy conglomerate with pebbles and cobbles, pebbly sandstone, and rare sandstone. Unit also contains rock-avalanche breccia deposits and sparse debris flow deposits. Conglomerate is generally weakly to moderately channelized. Clasts are typically subangular to subrounded, and consist primarily to almost entirely of granitic rocks and high-grade, quartzo-feldspathic gneiss, with sparse clasts of Tertiary volcanic rocks. At highest exposed stratigraphic levels, in areas where basalt is interbedded with conglomerate, unit contains a higher fraction of volcanic-rock clasts. Field examination suggests that sands are arkosic. Interpreted as proximal to medial alluvial fan deposits adjacent to an area with enough relief to yield debris flows and rock-avalanch breccias.

Basal Arkose

Tba — **Basal arkose (Oligocene)** - Conglomerate, conglomeratic sandstone, and sandstone. Unit consists of a lower subunit of medium-brown, weakly resistant, massive to poorly bedded arkose, conglomeratic arkose, conglomerate, and debris flows(?) derived from Proterozoic crystalline rocks, and an upper subunit of dark-brown, weakly resistant, bedded, moderately sorted, arkose and pebbly arkose containing clasts of Proterozoic crystalline rocks. Both upper and lower units thicken to the southeast where they reach maximum thicknesses of approximately 70 m and 180 m, respectively. This map unit forms a broadly fining-upward sequence that rests disconformably on the Proterozoic Signal Granite. An interbedded tuff was dated at 26.28 Ma ($^{40}Ar/^{39}Ar$ sanidine, sample AZ10-24-89, Lucchitta and Suneson, 1993, USGS Bulletin 2053).

Tbae — **Basal arkose in Ester Basin (Oligo-Miocene)** - Reddish orange to brown granular sandstone and conglomerate derived predominantly from Proterozoic crystalline rocks. Unit contains white to light green, lenticular reduction spots, and heavy-mineral-rich laminations. Granules and small pebbles are typically subangular to angular, while larger clasts are commonly subrounded. Beds are moderately to well stratified, and cross laminations are common. Deposits are dominantly fluvial with rare debris-flow interbeds. Cobble to boulder conglomerate facies locally crop out near the basal contact and contain clasts of Precambrian granite and gneiss, metarhyolite, and white to red quartzite. Clasts of Mesozoic metamorphic rocks increase in abundance toward the southeast. This map unit is finer up-section and grades into overlying fine-grain strata of the overlying unit (Yarnold and McDaniel, 1992).

Tertiary to Jurassic igneous and hydrothermal units

TKh — **Hydrothermal quartz and minor carbonate (Tertiary to Cretaceous)** - Massive hydrothermal quartz and areas of abundant quartz veinlets flooding host rocks. Locally this unit includes massive hydrothermal carbonate and open-space filling textures.

Kgl — **Heterogeneous leucocratic granitoids (Cretaceous)** - Fine to medium grain leucogranite, with up to 6% chlorite replacing biotite. Unit is foliated and suspected to have been intruded into Mesozoic rocks before metamorphism (pre-metamorphic), indicating likely Late Cretaceous age. This is "granitic gneiss" unit of Shackelford (1989).

Mesozoic metasedimentary and metaigneous rocks

KJs — **Metasandstone and metasiltstone (Jurassic to Cretaceous)** - Cleaved to schistose metasiltstone and metasandstone, with rare pebble to cobble conglomeratic sandstone. Unit is correlative with the McCoy Mountains Formation.

Mesozoic metasedimentary and metaigneous rocks (cont...)

KJsl — **Quartz-rich sandstone and maroon siltstone (Cretaceous to Jurassic)** - Medium to fine grained, quartzose sandstone and maroon siltstone. Flattened and foliated clasts up to 5 cm diameter are interpreted as metaconglomerate with originally subrounded clasts. This unit is interpreted as correlative with the basal unit of the McCoy Mountains Formation.

Mzsv — **Metasedimentary and metavolcanic rocks, undivided (Triassic to Cretaceous)** - Cleaved to schistose metasandstone, metasiltstone, and metavolcanic rocks. Metasedimentary rocks are thought to be part of the McCoy Mountains Formation. Metavolcanic rocks are thougth to be part of the middle Jurassic, dominantly felsic volcanic suite that generally underlies the McCoy Mountains Formation. This map unit possibly includes quartzite of the Jurassic Vampire Formation and calc-silicates of the Triassic Buckskin Formation, but these units were not specifically recognized. However, because of severe deformation, metamorphism, and alteration, these units could be present but unrecognized.

KJbs — **Biotite schist (Cretaceous to Jurassic)** - Fine grained, homogeneous biotite schist, with no phenocrysts or other porphyroblasts apparent in hand sample. Biotite(?) and quartz(?) are very fine grain. Sparse iron-oxide spots are possibly relicts of mafic phenocrysts. Schistosity is defined by preferred orientation of biotite. Major and trace elements analysis of a single sample (from station JES-12-116; SiO_2 = 55.6%) of this unit indicates that it is probably not part of the suite of basalts at the base of the McCoy Mountains Formation that reflect late Jurassic tectonic rifting (Spencer et al., 2011). La/Ta = 68, which is much higher than ~20, which is the threshold value for evidence of tectonic rifting unaffected by subduction-related magmatism or crustal contamination,

Jv — **Metavolcanic rocks (Jurassic)** - Metavolcanic rocks with up to 4%, <2mm quartz in otherwise aphanitic groundmass. Unit is generally schistose with fine secondary sericite. This rock unit is correlated with Jurassic quartz-porphyry and related volcanic rock units known elsewhere in western Arizona (Reynolds et al., 1987).

Jqp — **Quartz porphyry metavolcanic rocks (Jurassic)** - Metavolcanic rocks of inferred intermediate to silicic composition, with conspicuous quartz phenocrysts. Unit is commonly sericitic and schistose.

Jq — **Quartzite (Jurassic)** - This unit is exposed primarily in the Bonanza Mine area in the southeastern Rawhide Mountains where alteration and deformation obscure sedimentary structures. Association here with Jurassic quartz porphyry volcanics indicate correlation of the quartzite with the Jurassic Vampire Quartzite of Reynolds and Spencer (1989). The unit is also exposed at one location east of the Cleopatra Mine where it consists of pale gray, brown weathering, fine grained, thin bedded quartzite. Sericite content varies significantly so that the unit contains very little sericite in some areas and is schistose in other areas.

Paleozoic metasedimentary rocks, undivided

Pzc — **Paleozoic carbonate and calc-silicate rocks, undivided (Paleozoic)** - Gray to brown calcite and dolomite marble, commonly with dark brown siliceous stringers and nodules. Rocks are typically highly fractured and deformed so that bedding is transposed or obscure. Carbonates represent metamorphosed Devonian Martin Formation, Mississippian Redwall Limestone, and Permian Kaibab Limestone. This map unit also includes calc-silicates derived from the Cambrian Abrigo Formation (Bright Angle Shale) and Pennsylvanian-Permian Supai Group, and quartzite derived from the Cambrian Tapeats Sandstone and Permian Coconino Sandstone.

Pk — **Kaibab Limestone (Permian)** - Thick-bedded to massive, dark, variably cherty calcite marble. Deformation, metamorphism, and hydrothermal alteration have obscured original lithologies.

Pc — **Coconino Sandstone (Permian)** - Fine-grained gray orthoquartzite that, unlike stratigraphically underlying Supai Group, does not contain calc-silicate or sitlstone layers.

PPs — **Supai Group (Permian to Pennsylvanian)** - Fine-grained calc-silicate with associated fine quartzose sandstone, silty carbonate, and metasiltstone. Greenish epidote color is apparent in some outcrops. Deformation, metamorphism, and hydrothermal alteration have obscured original lithoigies.

DMu — **Martin Formation and Redwall Limestone, undivided (Missippian to Devonian)** - Massive calcite marble probably correlative with the Missippian Redwall Limestone and bedded dolomitic and siliceous limestone probably correlative with the Devonian Martin Formation. Deformation, metamorphism, and hydrothermal alteration have obscured original lithologies.

Ca — **Abrigo Formation (Cambrian)** - Metasiltstone and calc-silicate derived from calcareous siltstone.

Cb — **Bolsa (Tapeats) Quartzite (Cambrian)** - Fine to medium grained, pale to medium gray, generally massive metaquartzite. Bedding or transposed bedding is apparent in some outcrops, but generally is obscured by pervasive fracturing. At one location east of Miller Mountain (JES-12-200) a rounded-clast conglomerate is present at the depositional base of the quartzite.

Mesozoic to Paleozoic metasedimentary units, undivided

MzPzq — **Quartzite (Mesozoic to Paleozoic)** - Typically shattered quartzite that may be slightly sericitic and faintly bedded.

MzPzs — **Metasedimentary rocks, undivided (Mesozoic to Paleozoic)** - Predominantly Paleozoic carbonates with less abundant quartzite, phyllite, schist and metavolcanic rocks. Rocks of this unit are commonly strongly fractured and folded, and may locally include Oligo-Miocene rock-avalanche breccia (from Scott, 1995, Ph.D. dissertation).

Proterozoic granitic and metamorphic rocks

Ys — **Signal Granite (Middle Proterozoic)** - Medium grained, porphyritic biotite granite. K-feldspar phenocrysts are up to 4 cm diameter. Mafic minerals constitute 5-15% or rock unit but are too altered to determine, in hand sample, the relative significance of biotite, hornblende, and magnetite. In western exposures, the unit is typically highly altered and commonly shattered (especially in the Rawhide Wash 7.5' Quadrangle), with minor to abundant mafic dikes, pervasive iron-oxide staining, and sparse to common barite veins. This unit locally includes other intrusive phases, including fine to medium grain granitoids with less than 5% mafic phases. In the northeastern corner of the Artillery Peak 7.5' Quadrangle this unit contains up to 7 cm pink K-feldspar that may be blocky, tabular, or rounded. K-feldspar forms up to 40% to 60% of rock, in some cases where rock is megacryst supported (as with a conglomerate). Quartz is gray and <15 mm diameter. Plagioclase phenocrysts are <2 cm and white. Unit contains 4-6% biotite in clot-like aggregates. This granite was mapped as the Signal Granite by Bryant (1995) and dated at 1410 +/- 4 Ma by Bryant et al. (2001).

Xgg — **Granite and gneissic granite (Early Proterozoic)** - Granite and layered granitic rocks contain pale gray to pinkish gray K-feldspar up to 40mm, mostly <25 mm. Unit contains no tectonite fabric except that elongate minerals and segregation into layers with different ratios of light and dark minerals defines a gneissic fabric. Unit contains ~8-12%, <1mm biotite in aggregates and layers. Quartz is fine grained. This unit is part of the "Coarse-grained granitic rock" unit of Bryant (1995, Xcg) that makes up most of the Poachie Mountains, and was dated at 1706 +/- 3 Ma (Bryant et al., 2001).

Lower plate crystalline rocks

TKg — **Mylonitic leucogranite ((Tertiary - Cretaceous))** - Leucogranite mylonite forms more than half, and locally nearly all, of this unit. Locally, leucogranite and pegmatite are interfoliated with granitoid gneiss of unit TXcu or with biotite granitoids that resemble the quartz monzodiorite and granodiorite of unit TXci. Also locally contains layers of fine-grained diorite (TXcm?) that range from massive to mylonitic.

TXcm — **Mafic lower plate crystalline rocks. (Tertiary to Proterozoic)** - Fine-grained diorite (microdiorite) and medium grained dioritic granitoids, locally including mafic rocks that are so fine grain that they might be considered basalts. These rocks are probably correlative with the Swansea Plutonic Suite of Oligo-Miocene age. In many areas, especially near the Rawhide detachment fault, lower plate rocks are shattered and moderately to severely altered with secondary silica, chlorite, epidote, and iron oxides. Original protolith and contacts between units ara obscure in these areas. Mylonitic deformation is common where rock units are not severely affected by alteration and brittle deformation. However, mylonitic deformation is conspicuously absent in some areas, suggesting that intrusion post-dates mylonitization. Intrusion under post-mylonitic, near-surface conditions is consistent with the hypabyssal character of fine grained to basaltic rocks of this map unit.

TXci — **Intermediate lower-plate crystalline rocks (Tertiary to Paleoproterozoic)** - Medium-grained quartz monzodiorite to granodiorite, containing 5-15% chloritized mafic minerals, displaying heterogeneous mylonitic fabric, and typically affected by strong hematite alteration. Locally interlayered with mylonitic leucogranite and massive to foliated fine-grained diorite or diabase. Much of this unit reportedly belongs to the Swansea plutonic suite of Oligocene(?) to Early Miocene age (Bryant and Wooden, 1989; Scott, 1995; Bryant, 1995); a U-Pb zircon age of 21.86 +/- 0.60 Ma has been reported from the Swansea suite in the Buckskin Mountains (Bryant and Wooden, 2008). Lenses of K-feldspar-megacrystic (porphyroclastic) granodiorite are locally common in this unit and are probably sheared enclaves and xenoliths of Paleoproterozoic age; a U-Pb zircon upper-intercept age of 1408 +/- 1.5 Ma from an enclave was reported by Bryant and Wooden (2008).

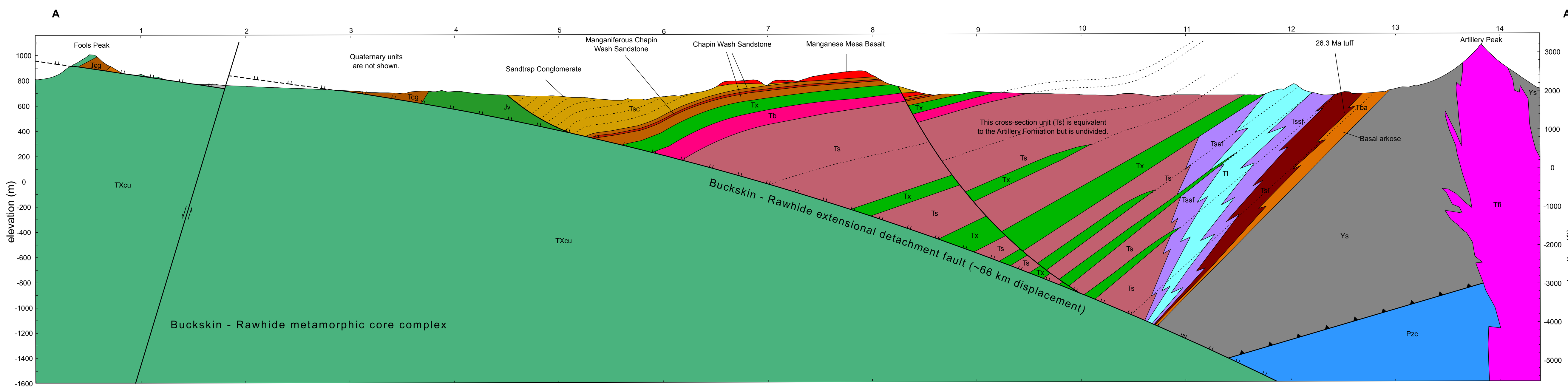
TXcf — **Felsic lower plate crystalline rocks (Tertiary to Proterozoic)** - This unit consists largely of fine-grained leucogranite, pegmatitic leucogranite, aplite, and aphyric felsite. Results of a single chemical analysis of a sample of aphyric felsite are as follows: 77.8% SiO_2, 12.8% Al_2O_3, 0.3% Fe_2O_3, 0.44% CaO, 0.05% MgO, 5.4% Na_2O, and 3.1% K_2O. In many areas, especially near the Rawhide detachment fault, the unit is shattered and moderately to severely altered with secondary iron oxides presumably introduced by hydrothermal solutions active along the detachment fualt. Mylonitic deformation is apparent in some leucogranite where rock units are not severely affected by alteration and brittle deformation. However, mylonitic deformation is conspicuously absent in some areas, suggesting that intrusion post-dates mylonitization. Intrusion under post-mylonitic, near surface conditions is consistent with the aphyric character of some rocks of this map unit. Some rocks of this map unit are correlated with the Swansea Plutonic Suite of Oligo-Miocene age, but coarser leucogranite and pegmatitic leucogranite are possibly Mesozoic or Proterozoic.

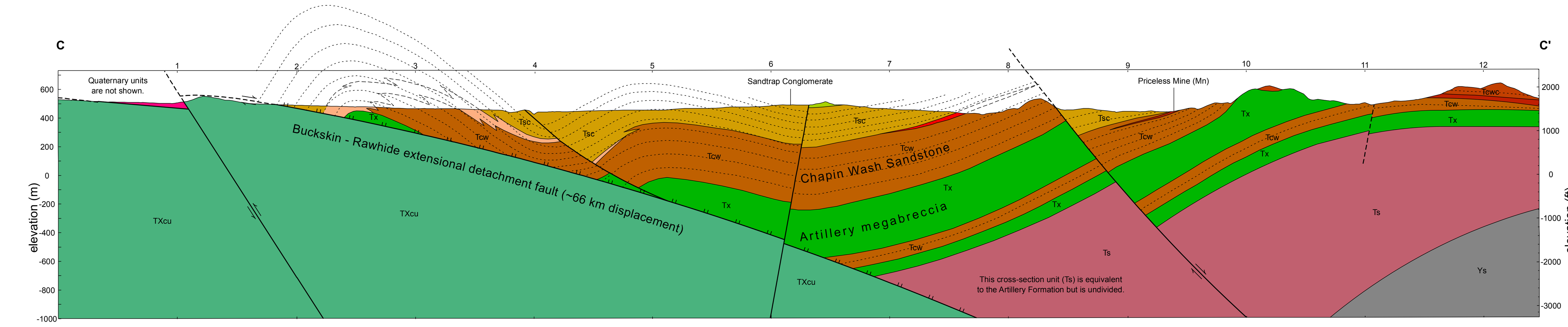
TXcu — **Lower plate crystalline rocks, undivided (Tertiary to ealry Proterozoic)** - This unit consists largely of three rock units, as follows: (1) fine-grained leucogranite and aplite to aphyric felsite, (2) basaltic intrusions, fine-grained diorite, and medium grained dioritic granitoids, and (3) banded gneiss including equigranular, porphyritic, and megacrystic granitic protoliths with rare carbonate and calc-silicate lenses and sheets. In many areas, especially near the Rawhide detachment fault, the unit is shattered and moderately to severely altered with secondary silica, chlorite, epidote, and iron oxides. Original protolith and contacts between units ara obscure in these areas. Mylonitic deformation is common where rock units are not severely affected by alteration and brittle deformation.

TXca — **Lower plate crystalline rocks, altered (Tertiary to Proterozoic)** - Lower plate crystalline rocks that are severely affected by hydrothermal alteration and/or brittle deformation. In extreme cases, rocks are converted to silicified cataclasite with no vestige of original rock type. Chloritic and hematitic alteration are common, as is brecciation.

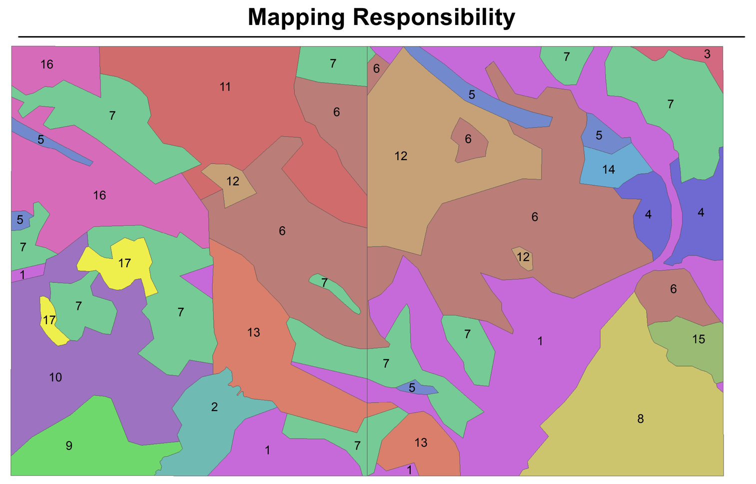
TXs — **Paragneiss assemblage (Tertiary to Paleoproterozoic)** - Heterogeneous assemblage of quartzofeldspathic paragneiss, quartzite, calcsilicate gneiss, and marble, interfoliated with leucogranite of unit TKg and mafic to felsic crystalline rocks resembling other lower-plate units. The quartzofeldspathic paragneiss includes quartz-biotite-feldspar and muscovite-quartz-feldspar mineral assemblages and contains quartzite and feldspathic quartzite layers.

MzPzm — **Marble tectonite (Mesozoic to Paleozoic)** - Fine-grained marble tectonite interfoliated with subordinate paragneiss, quartzite, and leucogranite. The marble is white to light gray, is weathered light to dark orange-brown, and locally contains chert nodules.





Mapping Responsibility



Surficial mapping by Phil Pearthree, 2011-2012

1. Aerial photograph interpretation
2. Brad Johnson, 2012
3. Bruce Bryant, USGS Map I-2489, and Spencer, aerial photo interpretation
4. Bruce Bryant, USGS, 1991, written communication, Jon Spencer, aerial photograph interpretation
5. Diane Love, 2011-2012
6. Jon Spencer, 1987-1994
7. Jon Spencer, 2011-2015
8. Phil Pearthree, 2012
9. Robb Scott, 2004, AZGS CM-04-D
10. Shackelford, 1989, AZGS Bulletin 198
11. Shackelford, 1989, and aerial photograph interpretation
12. Spencer et al., 1989, AZGS Bulletin 198
13. Steve Richard, 1994
14. Tom Weiskopf, 1990
15. Wyatt Gilbert, 1993
16. Yarnold and McDaniel, 1992, AZGS CM-92-B
17. Steve Reynolds, 1994 and 2012

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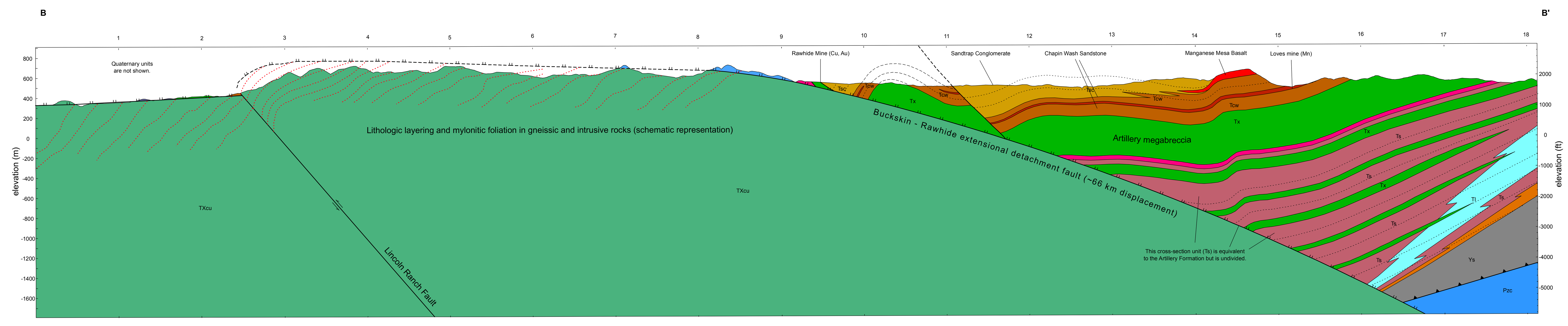
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