Geologic map of the western part of the Tucson 30’ x 60’ Quadrangle and the eastern part of the Silver Bell Mountains 30’ x 60’ Quadrangle, southeastern Arizona

by

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Introduction

The composite map of the Tucson metropolitan area straddles the western ~2/3 of the Tucson 30' x 60' quadrangle and the eastern ~2/3 of the Silver Bell Mountains 30' x 60' quadrangle in eastern Pima County and western most Cochise County. The geomorphology is dominated by the watershed of the Santa Cruz River flowing northward through the center of the map area, with its tributaries of Cienega Creek and the Rillito River in the Tucson Valley and Brawley Wash in Avra Valley. The San Pedro River, east of the Rincon and Santa Catalina Mountains, constitutes a separate watershed along the eastern edge of the map area. Incision by axial streams and related basin dissection vary dramatically across the map area. In the east, the San Pedro River and tributaries have eroded deeply into basin deposits during the Quaternary. The swath of axial valley alluvium is relatively narrow and piedmonts are covered with tributary deposits ranging in age from Holocene to middle and early Pleistocene. The Santa Cruz River and its large tributaries of the Tucson basin are less incised, although piedmonts on the basin margins are moderately to deeply dissected. The broad valley floor is covered by deposits ranging in age from Holocene to early Pleistocene, with early to middle Pleistocene deposits being most extensive. Valley axes in the western part of the map drained by Brawley and Aguirre Washes are broad and minimally incised. These areas are covered by generally fine-grained Holocene floodplain deposits and low late to middle Pleistocene terraces. Holocene and late Pleistocene deposits cover most piedmont areas, with older Pleistocene remnants confined to upper piedmont areas.

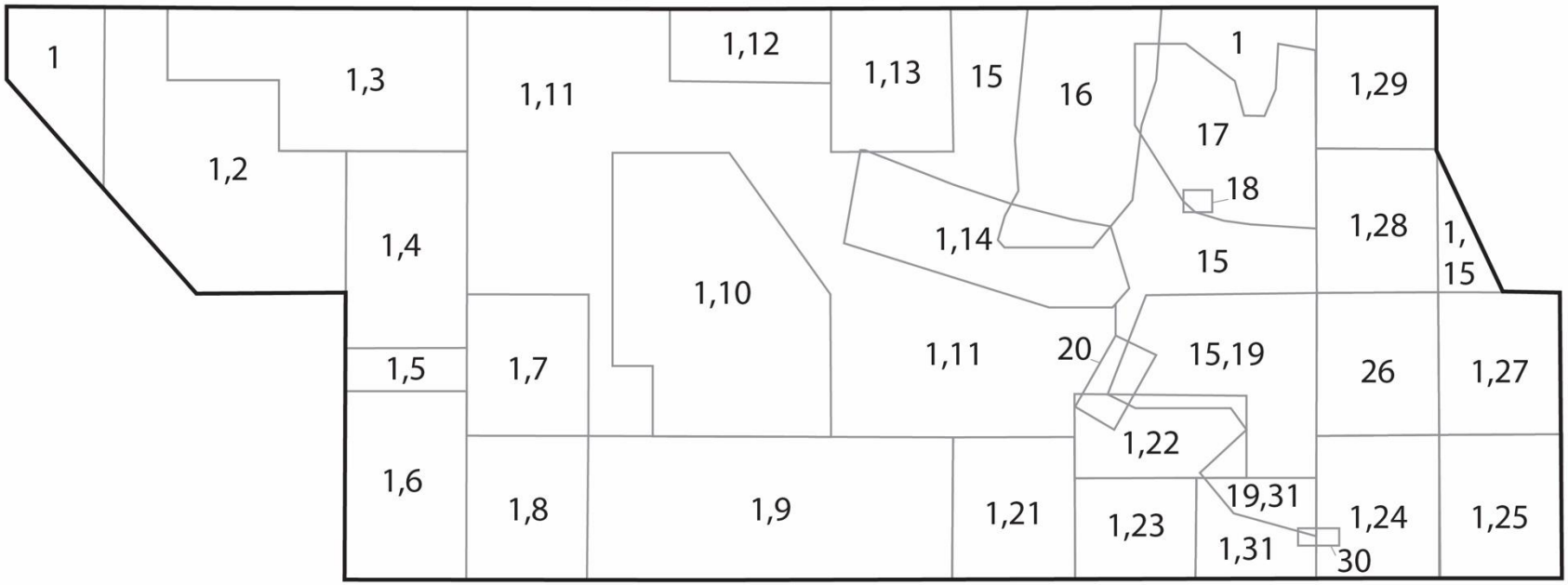
The oldest rocks in the Rincon, Santa Catalina, and Tortolita Mountains in the eastern third to half of the map area consist of Paleoproterozoic Pinal Schist and plutonic rocks intruded by Mesoproterozoic plutonic rocks and overlain rocks of the Apache Group. These basement rocks are overlain by Paleozoic sedimentary rocks and thin Jurassic-Triassic sedimentary rocks that underly the latest Jurassic to early Cretaceous Bisbee Group. Cretaceous and Cenozoic plutons intrude this stratigraphic framework. These rocks were exhumed along the Catalina detachment between ~26-17 Ma producing a well-developed mylonitic fabric with S/C fabrics with top-to-the-southwest sense of shear and sedimentary rocks filling hanging-wall half-grabens. The Tucson Mountains in the center of the map area represent a Cretaceous caldera that erupted the Cat Mountain Tuff, with the Amole pluton potentially constituting a resurgent ring intrusion. The Roskruge and Waterman Mountains are dominated by the Tuff of Sharp Peak (which may be correlative with the Cat Mountain Tuff) but also host several Cretaceous and Cenozoic intrusions and late Cenozoic basalt flows. The Silver Bell Mountains, in the northwestern part of the map, represent another Cretaceous caldera which erupted the Confidence Peak Tuff and were in turn intruded by a suite of late Cretaceous to early Cenozoic ("Laramide") intrusive rocks that formed the Silver Bell porphyry copper deposit. Mid- to late Cenozoic volcanic rocks overlie the Cretaceous rocks.

Sources of Data

The map was compiled from previously published 1:24,000- to 1:62,500-scale geologic maps, some unpublished mapping, and some new aerial photogeologic mapping, as shown in Figure 1. Some editing was done, especially of surficial geologic map units and of bedrock units within

parts of the Santa Catalina and Rincon Mountains where detailed mapping was lacking, in order to correct mismatches along shared edits of source maps and to refine contacts based on modern satellite imagery.

Compilation Map Sources



1. Philip A. Pearthree, new geologic mapping and photogeologic interpretation, 2021-2022
2. Banks and Dockter (1976)
3. Sawyer (1996)
4. Richard et al. (2000)
5. Charles A. Ferguson, photogeologic interpretation, 2022
6. Ferguson et al. (2000)
7. Skotnicki and Pearthree (2000)
8. Pearthree et al. (2000)
9. Jackson (1989)
10. Lipman (1993)
11. McKittrick (1988)
12. Ferguson et al. (2003)
13. Spencer and Pearthree (2004)
14. Dickinson (1999)
15. Dickinson (1987)
16. Force (1997)
17. Bykerk-Kauffman (2008)
18. Spencer and Constenius (2020)
19. Drewes (1977)
20. Davis et al. (2023, Figure 3-2)
21. Shipman (2004)
22. Richard et al. (2005)
23. Richard et al. (2001)
24. Skotnicki and Siddoway (2001)
25. Youberg et al. (2009)
26. Spencer et al. (2011)
27. Spencer et al. (2008a)
28. Spencer et al. (2008b)
29. Cook and Spencer (2007)
30. Davis et al. (2011)
31. Spencer et al. (2001)

Unit Descriptions

Piedmont Deposits

Qy – Young alluvium (Holocene) – Channels, floodplains, low terraces, and alluvial fans. Composed of weakly to well-bedded sand, pebbles, cobbles, silt, boulders, and minor clay. Surfaces are brown to gray in color color, scattered gravel lags are common, no to light surface rock varnish. Oldest alluvial surfaces in this group are less than 3 m above active channels.

Qye – Young and intermediate alluvium and eolian deposits (Holocene to late Pleistocene) – Mixed young alluvial deposits (unit Qy) and eolian silt, sand, and clay. Eolian landforms consist of low linear or hummocky dunes, and coppice dunes around bushes. Areas between eolian deposits typically are covered by open gravel lags, but also include some Pleistocene (Qi) deposits with moderately to darkly varnished desert pavements.

Qi3 – Young intermediate alluvium (Late Pleistocene) – Minimally dissected alluvial fan and terrace deposits. Composed of cobbles, pebbles, sand, silt, and clay, with some boulders in middle and upper piedmont areas. Poorly sorted, moderately bedded, subrounded to angular clasts. Soil development typically is moderate, with clay accumulation and soil reddening and carbonate accumulation deeper in soil profiles; surface soil is commonly orange in color. In drier parts of the map area surfaces typically have gray to black varnished desert pavements. Orange varnished surface clasts dominate in higher, moister parts of the map area.

Qi2 – Intermediate piedmont alluvium (Middle to late Pleistocene) – Minimally to moderately dissected alluvial fan and terrace deposits. Composed of cobbles, pebbles, sand, silt, and clay; deposits typically include boulders in middle and upper piedmont areas. Poorly sorted, moderately bedded, subrounded to angular clasts. Soil development typically is quite strong, with substantial clay and carbonate accumulation, and surfaces commonly are obviously reddened. Gravel pavements are typical on well-preserved planar surfaces. In drier parts of the map area surfaces commonly have darkly varnished, moderate to tight desert pavements. Reddish varnished surface clasts dominate surfaces in higher, moister parts of the map area.

Qi – Intermediate alluvium, undifferentiated (Middle to late Pleistocene) – Intermediate age terrace and alluvial fan deposits, undivided.

Qi1 – Older intermediate piedmont alluvium (Middle Pleistocene) – Dissected alluvial fan and high terrace deposits. Composed of cobbles, pebbles, boulders in middle and upper piedmont areas, sand, silt, and clay. Poorly sorted, moderately bedded, subrounded to angular clasts. Soil development is variable, but strong carbonate accumulations are common. Surfaces typically are light gray, pale orange, or white in color due to abundant carbonate; gravel lags are very common, but tight desert pavements are rare.

Qo – Old piedmont alluvium (Early Pleistocene) – Highest and oldest alluvial fan deposits associated with preserved, planar relict fan surfaces. Preserved fan surfaces may be remarkably planar, but landforms in generally are highly eroded. Deposits typically are quite coarse,

dominated by cobbles, pebbles, common boulders, sand, silt and clay. Very poorly sorted and crudely bedded.

Axial Valley Deposits

Qyr – Young fine-grained alluvium (Holocene) – Deposits in active channels, low terraces, and overbank / floodplain areas in valley axes consisting primarily of silt, sand, clay, and fine gravel. Channels are typically sandy with some gravel; channels are discontinuous and small in many areas. Overbank / floodplain areas are characterized by bar-and-swale topography or are relatively smooth and planar. Fine gravel forms surface lags in areas that have not been inundated recently. Variable surface color depends mainly on vegetation density, dark brown color along channels and where vegetated, brown or light gray where more sparsely vegetated. Older surfaces within this unit typically are up to 1 m higher, are brown to light gray in color, and have fine gravel lags with light rock varnish.

Qyre – Young valley alluvium and eolian deposits (Holocene) – Mixed young fine-grained alluvial deposits and eolian deposits in valley axes. Landforms consist of low coppice dunes and intervening flat surfaces with minimal gravel lags and no pavement development, less than 1 m above adjacent floodplains. Drainage networks are discontinuous because they are broken up by or work around low eolian landforms. Low coppice dunes are abundant and vegetation is sparse. Surfaces appear broadly striped or mottled on aerial imagery due to the eolian landforms.

Qir – Older valley axis deposits (Middle to late Pleistocene) – Deposits associated with low terraces and elevated floodplain remnants along axial washes; they also form broad alluvial fans near the confluence of these washes. Surfaces are commonly ~1-5 m above adjacent floodplains. They are smooth and flat to broadly rounded, with moderate pebble to cobble lags composed of mixed lithologies that have weak to moderate rock varnish. This unit includes minor amounts of low coppice dunes around bushes. Surface color is light gray on aerial photos due to weakly varnished gravel pavements.

River Deposits

Qyrs – Young river deposits (Holocene) – Deposits in active channels, bars, low terraces, abandoned floodplains associated with Santa Cruz, Rillito, and San Pedro Rivers, Tanque Verde and Cienega Creeks, and Pantano and Canada del Oro Washes. Channels commonly contain pebbles, sand, and cobbles with diverse lithologies; bar-and-swale topography is common. The unit includes a complex of low terraces, and higher terraces that formed floodplains prior to historical channel incision. Exposures beneath these higher deposits reveal complex stratigraphy, buried soils, and primarily sand and finer deposits.

Qirs – Intermediate river deposits (Middle to late Pleistocene) – Moderately dissected terrace deposits associated with large fluvial systems, including the Santa Cruz and Rillito Rivers, Tanque Verde and Cienega Creeks, and Pantano Wash. Composed of sand, silt, clay, pebbles and cobbles, moderately sorted and well-bedded. Soil development is moderate to strong, with clay accumulation and soil and surface reddening; carbonate accumulation is variable, but is quite strong in older deposits included in this unit.

Qors – Old river deposits (Early Pleistocene) – Moderately to deeply dissected terrace deposits associated with the Santa Cruz and Rillito Rivers, Tanque Verde and Cienega Creeks, and Pantano Wash. Composed of cobbles and pebbles of diverse lithologies, sand, silt, and clay; deposits are moderately sorted and well-bedded. Soil development is variable, but calcium carbonate cemented (petrocalcic) horizons are common.

Other Deposits

Qtc – Colluvium, talus, regolith (Quaternary) – Hillslope deposits and thin mantles of weathered material over bedrock. Composed of locally-sourced material ranging in size from clay to boulders. Very poorly sorted, weakly bedded deposits with angular to subangular gravel clasts. Soil development is variable, generally weak to moderate clay and carbonate accumulation but strongly developed with cemented petrocalcic horizons on the oldest hillslope remnants.

Qls – Landslide deposits (Quaternary) – Disrupted deposits associated with a moderate-sized landslide on the northwest side of Martina Mountain. The age of this landslide is unknown, but its geomorphic expression is fresh enough to make the landslide obvious on aerial photographs.

d – Disturbed areas (Holocene) – Surface areas that have been substantially modified by human activities. Includes mines and mine tailings, aggregate pits and related operations, landfills, Central Arizona Project canal, recharge ponds, large retention basins, and part of the I-10 highway corridor outside of the Tucson urban area.

BASIN FILL DEPOSITS

Tsy – Basin-fill deposits (Late Neogene) – Gravel, sand, silt, and clay deposits dominated by clasts from currently exposed bedrock in adjacent mountain ranges. May be faulted but typically are not tilted except adjacent to faults. Includes deposits of the Quiburis and San David Formations in San Pedro Valley, the Ventana Benchlands and Campbell Avenue fan complexes of the Santa Catalina foothills, and many unnamed outcrops around the margins of all valleys in the map area.

Tsm – Tilted basin-fill sedimentary rocks (Miocene) – Gently to moderately tilted sandstone, conglomerate, siltstone and lesser mudstone in Cienega Gap. These strata, mapped as the unit of Wakefield Canyon, and the conglomerate of Agua Verde Creek (Spencer et al., 2001) overlie an extensive sheet of avalanche breccias (Tsx).

Tsx – Avalanche Breccia (Pantano Formation) (Miocene) – Extensive sheets of avalanche breccia in Cienega Gap containing clasts of Phanerozoic rocks, and mylonitic granitoids of the Rincon Mountains (Spencer et al., 2001). The breccias overlap moderately to steeply tilted conglomeratic strata of the Pantano Formation and are overlain by gently to moderately tilted strata of the Tsm unit.

Ts – Older basin deposits (Oligocene to Miocene) – Deformed basin deposits exposed around the margins of modern basins. Deposits are faulted and tilted moderately to steeply. Older deposits in this group contain volcanic clasts not exposed in adjacent mountains. Includes the Pantano Formation and Swan-Craycroft beds of the Santa Catalina foothills, and the San Manuel and Mineta Formations in San Pedro Valley.

CENOZOIC FAULT ROCKS

Tcb – Chloritic breccia (Miocene) – Black to very dark maroon-gray, flinty, silicified, ultracataclasite to greenish-gray protocataclasite rock typically, but not always, occurring in Rincon Vallehy immediately below the detachment fault at Tanque Verde Ridge (Richard et al., 2005). The original (Richard et al. 2005) description indicates that the ultracataclasite contains 2-10% fragments of granitic(?) protolith. Cataclasite and protocataclasite consists of broken, variably mylonitic granitoid or metamorphic rock from the footwall. Mafic minerals in cataclasitic rocks are intensely chloritized, giving the rock a characteristic greenish- gray color. The base of this chloritic breccia is gradational over about 10 m. Black ultracataclasite forms a thin lens along detachment fault contact where present. Based on the observation that the ultracataclasite matrix is actually pseudotachylite (Paul Kapp, personal communication), Ferguson (2018) interpreted this unit as a pseudotachylite breccia which entrained the angular (broken) clasts of footwall granite after they had been mylonititized. A pervasive preferred northwesterly orientation (312, n=15) of the entrained, rod-shaped mylonitic clasts in several locations along the outcrop belt of this map unit was interpreted as further evidence of a phase of post-mylonitic, northwesterly extension previously recognized by (Perry, 2005).

TXmy – Heterogeneous gneiss and mylonite (Miocene) – Interlayered marble, siliceous hornfels, mylonitic granitoid, mica schist, and pegmatite mapped by Richard et al. (2005) in Rincon Valley. The rocks are extensively weakly silicified, but locally can be strongly silicified. The heterogeneous mylonitic gneiss complex is dominated by rocks derived from pegmatite, leucogranite, biotite-feldspar-quartz gneiss, and granodioritic rocks typical in the footwall gneiss complex. Marble, calcsilicate, and quartzose rocks of probably Paleozoic or Mesozoic sedimentary protoliths are sparse to common. Marble may be hydrothermal carbonate or Paleozoic limestone and is typically a gray, fine- to medium-grained calcite(?) marble, locally with siliceous stringers. Buff dolomitic marble is also present. Associated epidote-rich siliceous hornfels may be derived from calcareous sliciclastic protolith. Silicified mylonitic rocks do not fracture along the mylonitic foliation, which is only apparent on close inspection. White to light tannish gray siliceous hornfels in some areas has relict granular texture suggesting derivation from quartzose sandstone (Bisbee Group or upper Paleozoic protoliths), and in other areas contains sparse relict <1mm grains of quartz or feldspar, suggesting a felsic porphyritc igneous protolith. Muscovite-biotite mylonitic schist with 1-3 mm muscovite flakes is similar to some of the micaceous schistose rock in the footwall, but contains more muscovite than is typically observed in those rocks. Foliation in schist is wildly crenulated in the superimposed mylonitic foliation; new schistosity is developed in mylonite foliation orientation. Some thin quartz veinlets parallel to older foliation in schist are folded. Limonite staining is common, and 3-5 cm globs of massive specular hematite are observed locally in float. Lenses of dark gray, aphanitic, mafic rock appear to be dismembered dikes. Base of mixed-rock zone is more abrupt on the north side of Rincon Valley where more massive leucogranite forms the footwall beneath the

zone. The boundary on the south side of Rincon Valley is much more gradational into the more heterogeneous footwall complex. The TXmy unit is closely associated with the chloritic breccia (Tcb) map unit which, when they occur together occurs between the heterogeneous mylonitic gneiss complex and the footwall.

CENOZOIC SEDIMENTARY AND VOLCANIC ROCKS

Ttmt – Tuff of Tumamoc Hill (Oligocene) – A sanidine, plagioclase, biotite-phyric welded ash-flow tuff present in the southeastern Tucson Mountains (Phillips, 1976).

Txx – Porphyritic andesite (Oligocene) – A distinctive suite of coarsely plagioclase porphyritic (10-30% plagioclase phenocrysts up to 3 cm) andesitic lava flows present in the southern Tucson Mountains (Phillips, 1976), Del Bac Hills (Percious, 1968), and Cienega Gap. The andesite occurs primarily as lava flows, except in the Del Bac Hills where thick dikes of the unit are interpreted to underlie younger Tertiary mafic lavas (Tm).

Tvi – Intermediate volcanic rocks (Cenozoic)– Medium to dark gray to dark brown, generally massive lava flows with conspicuous, 10-50%, 3-30 mm, tabular, plagioclase phenocrysts (Spencer et al., 2008).

Tv – Volcanic rocks, undivided (Cenozoic)– Gray to light-brown dacitic and rhyolitic lava flows containing 10-20 percent phenocrysts of plagioclase, biotite, and augite. Individual flows are 25-100 m thick (Lipman, 1993).

TKt – Tuff of Beehive Peak (Cenozoic to Cretaceous) – Light-gray to tan, massive dacite ash-flow tuff (69-70% silica) containing 35-45% phenocrysts of plagioclase, sanidine, embayed quartz, and biotite. The ash-flow tuff is nonwelded to poorly welded. The tuff was renamed by Lipman (1993) for rocks previously thought to be intrusive.

TKvs – Post-collapse volcanic and sedimentary rocks (Late Cenozoic to Cretaceous) – Intermediate volcanic and hypabyssal rocks and volcaniclastic sedimentary rocks. Includes a phenocryst-poor tuff in the southern Roskruge Mountains.

Tb – Basalt (Upper to Middle Miocene) – Basaltic lava containing phenocrysts of olivine and/or pyroxene (0-20% <4mm) with lesser (0-5%, <4mm) plagioclase.

Tert – Tuff of El Recortado (Neogene) – Moderately phenocryst-rich, ash-flow tuff containing 5-10% sanidine (1-5 mm), <1% pyroxene up to 2mm, sparse biotite, up to 15% angular lithic lapilli of phenocryst-poor, flow-foliated rhyolitic lava, and 15-30% brown to black fiamme. The tuff was erupted from a vent in the vicinity of a breccia unit (Tex) in the Cocoraque Butte area of the southeastern Roskruge Mountains. The tuff has a strongly welded, main, upper unit with a distinctive tripartite yellow-orange-black (vitric) coloration, and an equally extensive non-welded basal unit (Ttn of Skotnicki and Pearthree, 2000). K-Ar sanidine dates of 12.93 ± 0.60, 12.96 ± 0.40, and 14.25 ±0.50 Ma were obtained by Bikerman (1967).

Tex Breccia (Miocene) – Cryptic breccia containing angular clasts of Jurassic rhyolitic lava (Jfv), Jurassic quartzite (JTrs), and andesite (Ka). Sparse description (no size ranges given, or description of the matrix) in Skotnicki and Pearthree (2000) suggests that the unit, as shown on this map, is either a megabreccia related to the vent for the tuff of El Recortado (Tert) or a megabreccia (Kspx) within the tuff of Sharp Peak (Ksp), or both.

Tvf – Felsic volcanic rocks (Miocene) – Rhyolitic, dacitic, and trachytic lavas and associated pyroclastic rocks. Phenocryst phases consist of quartz, sanidine, plagioclase, biotite, hornblende, and pyroxene.

Tmo – Older mafic volcanic rocks (Miocene) – Older mafic volcanic rocks in the Pan Quemado area east of the Silverbell Mountains.

Tm – Basaltic andesite, basaltic trachyandesite, and trachyandesite (Miocene) – Various mafic lavas containing plagioclase phenocrysts (0-25%) with lesser amounts (0-10%) of pyroxene, and rare olivine. A sequence of trachyandesite in the southern Roskruge Mountains contains practically no plagioclase phenocrysts and up to 7% pyroxene.

Trt – Ragged Top Rhyolite (Oligocene) – Rhyolite dome and related dikes in the Silverbell Mountains. Dome makes up Ragged Top and Wolcott Peaks and is strongly flow-foliated. Rhyolite dome intrudes the Ragged Top fault and provides an upper limit on the age of fault movement. Rhyolite is typically grayish-pink and phenocryst-poor, containing 5-10% phenocrysts of sanidine, plagioclase, and biotite. Dikes trend NNW in several swarms that cut the porphyry copper mineralization in the Silverbell caldera. Biotite K-Ar age of 25.7 Ma by K-Ar (Mauger et al., 1965).

Tgv – Galiuro volcanic rocks (Oligocene to earliest Miocene) – Andesitic to latittic lavas, rhyodacitic to rhyolitic ignimbrites, and rhyolitic domes, with intercalated volcaniclastic strata.

Tms – Quartz-muscovite schist (Tertiary) – Contains large quartz ""yes" within a micaceous matrix. Interpreted to be derived from coarse-grained granite (Yg).

CENOZOIC INTRUSIVE ROCKS

Tp – Plagioclase porphyry of Ajo Road detachment fault (Miocene) – Pervasively altered intermediate composition porphyry with limonite-stained fractures and white, chalky plagioclase phenocrysts (1-3 mm, 25-40%) in a bleached, light brown, crumbly, fine- grained matrix. The porphyry intrudes the footwall of the Ajo Road detachment fault in the Coyote Mountains in southwestern corner of this map area, and contrary to the description of this unit in Ferguson et al. (2000), the porphyry appears to clearly also intrude the detachment fault parts of the hanging wall.

Tmz – Trachyte porphyry of Martina Mountain (Tertiary) – Intrusive complex of dark-colored porphyritic trachyte porphyry containing 5%, 0.5-2.0 mm phenocrysts of strongly zoned plagioclase (An_{55} cores), euhedral hornblende (1-3%, 0.5-2.0 mm), biotite (1-3%, < 0.5 mm), and clinopyroxene (< 0.5%, < 0.5 mm). The unit forms the top of Martina Mountain in the

southern Roskruge Mountains, and its map pattern suggests that the body may be the flat-bottomed remnant of a laccolith. The rock is remarkably devoid of fractures, veins, or alteration that weathers/erodes into distinctive, rounded. non-equant, orthogonal blocks. The slightly porphyritic texture is consistent throughout, although in some areas sharp boundaries are present between slightly different textural variations of the same rock. The porphyry is also characterized by up to 1% xenoliths of medium-grained, equigranular leucogranite ranging in size from 2 cm to 30 cm. Shafiqullah et al. (1978) interpreted this rock as a dacite tuff and obtained a K-Ar whole rock age of 25.65 ± 0.54 Ma.

Ttz – Porphyry of La Tortuga Butte (Paleogene)– A mafic to intermediate composition intrusive complex that occurs as east-west striking dikes invading the Mesozoic country rock, and at least two elongate, east-west striking stocks in La Tortuga Butte ΓÇô Aguirre Wash area of the Roskruge Mountains. Textures vary from medium-grained equigranular with very sparse plagioclase phenocrysts, to fine-grained plagioclase porphyritic. The average compostion of the rock is probably quartz monzodiorite. The rocks are propylitically altered, veined, and highly fractured, much like the Mesozoic country rock. Euhedral to subhedral plagioclase (An < 35) is typically strongly zoned and badly altered. Interstitial quartz (< 5 %, < 0.5 mm) is present in the more equigranular varieties, along with a few percent K-feldspar. Mafic minerals, commonly altered to felted masses of calcite, chlorite, and opaques (5-20%, 0.5-5.0 mm) are ubiquitous, and locally reveal themselves to be hornblende, opaques, and/or clinopyroxene. Bikerman (1967) reports a K/Ar plagioclase age of 34.90 ± 0.30 Ma age for this rock.

Tpg – Pegmatitic granite (Paleogene) – Coarse-grained pegmatitic leucogranite displaying a wide range of textural variation including fine-grained aplite. The unit is part of the Pan Tak Granite of the Coyote Mountains, dated at 58.00 ± 2.00 Ma (U-Pb zircon, Wright and Haxel, 1982). The unit forms, tabular, sill-like, northeast-dipping bodies that invade older dioritic rocks. The pegmatite is locally foliated parallel to these intrusive contacts, but it is typically non-foliated. The unit is finer grained along intrusive contacts and in narrow dikes that infiltrate the dioritic (Mzd) country rock. Just to the west, the pegmatite also intrudes northeast-dipping tabular masses of quartzite and limestone interpreted to be Paleozoic in age by Gardulski (1990) who also reports that intense mylonitic foliation occurs in the granite directly adjacent to the strongly deformed quartzite bodies.

Ttmg – Tortolita Mountains granite (Miocene) – Medium-grained, equigranular granite containing 5-12% biotite in the southern Tortolita Mountains. In the south, the pluton is pervasively deformed displaying weak to moderate protomylonitic foliation and stretching lineation, but to the north this deformation is minor to absent. The dike swarm which intrudes the pluton of Wild Burro Canyon is characterized by fairly intense ductile deformation with strong protomylonitic to ultramylonitic fabrics confined to the dikes, particularly to the south. This unit was previously referred to as the quartz monzonite of Tortolita Mountains by Banks (1980), and it correlates with the Tgf unit of Skotnicki (2000). A K/Ar biotite cooling age of 22.7 + 0.7 Ma was obtained from this unit near the center of its pluton in the southeastern Tortolita Mountains (Creasy et al., 1977). A $^{40}Ar/^{39}Ar$ biotite cooling age of 23.69 ± 0.15 Ma (Spell et al., 2003) was obtained from this unit.

Tgb – Barney Ranch quartz monzonite (upper Oligocene to Eocene) – Leucocratic biotite quartz monzonite of Lingrey (1982) forms a ~1 km ^{2} stock in the central part of the map area, east of Barney Ranch. Biotite content is ~5%; garnet and muscovite were not observed by Lingrey (1982); texture is medium grained, hypidiomorphic-granular with sparse feldspar phenocrysts (Spencer et al., 2011).

Tgh – Granodiorite of Happy Valley (Oligocene)– Medium-grained, equigranular biotite granodiorite (Drewes, 1974). Local border phase consists of fine grain, two-mica granite (all phenocrysts <2mm, with ~4-6%, <2mm biotite, 0-2%, <2mm muscovite, and locally, <<1% garnet, <3mm). Border phase may include locally abundant dikes with highly variable muscovite content (Spencer et al., 2011).

Tfg – Dierro Canyon Granite (Miocene) – A mixed body of medium- to coarse-grained leucogranite with abundant (>5%) pegmatite in the Tortolita Mountains. The leucogranite ranges from muscovite-garnet bearing to muscovite-biotite and magnetite, + garnet bearing. Pegmatite, which is typically an alkali feldspar granite with minor muscovite, garnet and rare biotite, occurs as irregular dikes and pods with overlapping cross-cutting relationships with the leucogranite. The unit occurs as discrete plutonic bodies in the northwestern part of the range and as an extensive dike swarm that extends into the central and eastern parts of the range where it intrudes two units; the Pinal Schist, and the pluton of Chirreon Wash. The dikes are almost always composite, typically consisting of a core of coarse-grained pegmatite with walls of fine- to medium-grained leucogranite. The unit was previously known as the quartz monzonite of Samaniego Ridge (Banks et al., 1977), the pluton of Cottonwood Canyon (Banks, 1980), and the Granite of Fresnal Canyon (Ferguson et al., 2003).

Twb – Wild Burro Quartz monzonite (Miocene) – A northeast-southwest elongate composite pluton with three main phases. The main and oldest phase (Tw) consists of medium- to coarse-grained, potassium feldspar porphyritic quartz monzonite to quartz syenite with 15-30% biotite and hornblende. The main phase is pervasively foliated with a steep regional southeasterly dip, parallel to a swarm of metasedimentary enclaves located in the northwestern part of the pluton. The foliation is weak shape fabric described as weak foliation or weak to moderate protomylonitic foliation in most areas. The pluton contains up to 10% schlieren oriented parallel to the foliation, and these are most abundant near bodies of the mafic phase (Twm). Correlates with the Tgc map unit of Skotnicki (2000). A K-Ar biotite cooling age of 28.0 ± 0.9Ma was obtained from this unit near the mouth of Wild Burro Canyon (Mauger et al., 1968). A $^{40}Ar/^{39}Ar$ biotite cooling age of 22.36 ± 0.15 Ma (Spell et al., 2003) was obtained from this unit along the southwestern edge of the range.

Tcg – Catalina Granite (Oligocene) – Porphyritic biotite ± hornblende granite with pink orthoclase phenocrysts as long as 4-7 cm (Budden, 1975). Texture is hypidiomorphic granular, with plagioclase compositions of An_{26-32} (Suemnicht, 1977). Fornash et al. (2013) reported a U-Pb zircon age of 25.8 +0.4/-0.5 Ma.

Tw – Wilderness Suite Leucogranites, undivided (Eocene)– Peraluminous two-mica granites of the Catalina-Rincon metamorphic core complex. This encompasses numerous local names for lithologicaly similar rock types, including the Derrio Canyon granite of the Tortolita Mountains,

Wilderness granite and Lemmon Rock leucogranite, Youtcy granite in Redington Pass, Espiritu Canyon granite and Wrong Mountain granite of the Rincon Mountains, and Happy Valley grnaite of the Little Rincon Mountains, as well as the "gneiss of Windy Point" and Quartz Monzonite of Samaniego Ridge (Keith et al., 1980).

Trs – Ruby Star Granodiorite (Paleogene) – The Ruby Star Granodiorite (Cooper, 1973) forms a large composite pluton that is exposed throughout the northern and eastern parts of the Sierrita Mountains. The most abundant rock type in the pluton is medium-grained, equigranular granodiorite. Potassium feldspar megacrystic monzogranite to granodiorite forms a northerly elongate zone 1-3 km wide in the core of the pluton. A transitional medium- to coarse-grained phase with up to 2% megacrysts occurs within both the equigranular granodiorite and the megacrystic monzogranite, and forms a transition zone 0-100 m wide along the contact between them. Biotite is the dominant mafic phase ranging in abundance from 10-25% with up to 5% hornblende and 2% sphene. Herrmann (2001) obtained a concordant U-Pb zircon date of 64.3 ± 0.4 Ma from the equigranular granodiorite, and a concordant U-Pb zircon age of 63.4 ± 0.3 Ma from the megacrystic phase.

CRETACEOUS INTRUSIVE ROCKS

TKf – Felsic intrusions (Cretaceous - Paleogene) – Dacitic to rhyolitic intrusions.

TJm – Hornblende meladiorite (Tertiary to Jurassic) – The rock is composed of hornblende, fine-grained plagioclase, and locally biotite. Hornblende typically is fine- to medium-grained and forms aggregates 5-10 mm long, although crystals up to 1 x 12 cm are locally present in dikes. The mafic-mineral content is typically 60% or more, and some dikes range to hornblendite in composition (with >90% hornblende). Thin sections from Paige Creek east of Driscoll Mountain contain 45-60% hornblende, 0-10% biotite, 30-40% plagioclase, 3-5% opaque minerals (ilmenite?), and trace apatite.

Kmp – Quartz monzodiorite porphyry suite (Cretaceous) – Post-caldera porphyry dikes and small stocks in the Silverbell Mountains consist of quartz monzodiorite, monzodiorite, and orthoclase quartz monzodiorite (Sawyer, 1996). Crystal content ranges from 25-40% phenocrysts of plagioclase and biotite; sparse orthoclase, hornblende, and clinopyroxene set in a groundmass of aligned plagioclase microlites with high magnetite content. Usually strongly altered in vicinity of mineralized areas to epidote, chlorite, and calcite propylitic assemblage.

Kga – Granite of Alamo Canyon (Late Cretaceous) – Dark, foliated, equigranular, fine to medium grained, biotite (4-8%) granite, intruded by abundant leucogranite and pegmatite dikes and sills. Granite is weakly segregated into layered and/or lineated fabric as defined by color variations that reflect light/dark mineral content. Foliation is somewhat defined by lithologic layering, somewhat by preferred orientation of biotite, generally with little or no evidence of grain-size reduction as is so characteristic of forerange mylonitic fabrics. Granite is not consistently foliated and in many areas is an L-tectonite where only lineation could be measured. Biotite granite is extensively intruded by 20-200 cm thick pegmatite and fine-grained leucogranite dikes and sills. Pegmatites, as in heterogeneous pegmatitic muscovite leucogranite,

are dominated by K-feldspar and contain 0 to 1%, 2 to 20 mm biotite, no muscovite and, commonly, little or no quartz.

Kgl – Leatherwood Granodiorite (Late Cretaceous) – Mesocratic equigranular granodiorite forming sub-parallel sills of dark gray aphanitic groundmass and 3-4 mm plagioclase, biotite, and quartz phenocrysts (Force, 1997).

Kdt – Felsite of Dos Titos (Cretaceous) – Light-gray colored, hypabyssal intrusive rocks of intermediate to felsic character, with cryptic intrusive and faulted intrusive contacts against Cretaceous or Jurassic sedimentary rocks and tuff of Sharp Peak in northern Roskruge Mountains. Mixed, gradational contacts with intracaldera mesobreccia of the tuff of Sharp Peak suggest that the felsite of Dos Titos intruded before complete solidification of the mesobreccia or that the two were emplaced simultaneously. The felsite of Dos Titos is interpreted as a hypabyssal intrusion associated with the tuff of Sharp Peak, which intruded along the vent zone represented by the mesobreccia late in the eruption of the tuff. The porphyry consists of three subunits (Richard et al., 2000), a main phase felsite, a fine-grained felsite and a mixed felsite and mesobreccia of the tuff of Sharp Peak.

Krgp – Rice Peak Granodiorite Porphyry (Late Cretaceous) – Typically green-gray porphyritic rocks with ≤2 mm pheonocrysts of plagioclase, biotite, hornblende, and local orthoclase and quartz, in a microlitic to aplitic groundmass (Suemnicht, 1977). Two varieties are present, often visible in the same outcrop demonstrating age relations, with a darker porphyry with abundant plagioclase and few hornblende phenocrysts that occurs as inclusions within a trachytic-textured porphyry with biotite, amphibole, and plagioclase phenocrysts (Force, 1977).

Kd – Diorite (Cretaceous) – Medium- to coarse-grained, locally plagioclase porphyritic, and moderately foliated. Plagioclase phenocrysts are commonly 2-5 mm across and rarely up to 2 cm across. The dark matrix of quartz and biotite are in marked contrast to the lighter plagioclase phenocrysts. From a distance this rock commonly appears both darker and lighter than the coarse-grained granite (map unit Yg) it intrudes. The quartz diorite has not been dated in this area. Smith (1989) tentatively correlated these intrusions to the Late Cretaceous Leatherwood Suite (Keith et al., 1980; Force, 1997).

Kg1 – Amole pluton (Cretaceous) – The Amole composite pluton consists of an early border phase of hornblende-biotite diorite to granodiorite, a central phase of biotite granite with large bodies of aplite (Lipman, 1993). Greig (2021) reports a U-Pb zircon age of 72.6 ± 0.7 Ma for the early hornblende-biotite diorite to granodiorite and a U-Pb zircon age of 72.3 ± 0.7 Ma for the biotite granite.

Kgds – Granodiorite porphyry (Cretaceous) – Granodiorite porphyry in the Silverbell Mountains that intrudes the Confidence Peak Tuff and predates the Cat Mountain Tuff. Phenocrysts comprise 50-80 percent of the rock, and plagioclase is dominant, with subordinate biotite greater than quartz, hornblende, and orthoclase. Typically affected by chlorite-calcite-smectite propylitic alteration (Sawyer, 1996).

Kcbg – Cocoraque Butte Granodiorite (Cretaceous) – Mostly fine-grained to medium-grained granodiorite. Contains phenocrysts of subhedral to euhedral light gray feldspar, clear-gray quartz, about 5-10% anhedral biotite, and locally minor black hornblende. Feldspars are easier to see on weathered surfaces. All crystals are typically 1-2 mm across. Locally, K-feldspar crystals are as large as 8 mm wide, but that size is rare. Bikerman (1967) reports a K-Ar biotite age of 70.3 ± 1.4 Ma.

Keg – El Tiro Granite (Cretaceous) – Fine-grained to medium-grained granodiorite with 5-10% biotite, and minor hornblende. Bikerman (1967) reports a K-Ar biotite age of 70.30 ± 1.40 Ma.

LATE CRETACEOUS SEDIMENTARY AND VOLCANIC ROCKS

Kru – Volcanic rocks, undifferentiated (Cretaceous) – Undifferentiated late Cretaceous volcanic rocks.

Kr – Younger intermediate to felsic extrusive rocks (Cretaceous) – aphanitic rhyolite lava, some volcanic lithic sedimentary rocks, tuff, minor welded tuff; younger than Cat Mountain Rhyoltie in Tucson Mountains and Silverbell Mountains.

Ka – Andesite (Cretaceous) – Andesitic lavas of the Salero Group. Lavas contain 0-35% 1-12mm plagioclase phenocrysts with lesser amounts (0-5%) of generally <3mm pyroxene, hornblende, and rarely biotite.

Kft – Felsic volcanic rocks (Cretaceous) – Salero Group rhyolitic, dacitic, and trachytic lavas and associated nonwelded pyroclastic rocks.

Kspu – Upper flow unit of the tuff of Sharp Peak (Cretaceous) – Moderately phenocryst-poor (5%) welded to nonwelded ash-flow tuff containing phenocrysts of feldspar and quartz <2mm.

Kspx – Tuff of Sharp Peak, megabreccia (Cretaceous) – Swarms of lithic-rich (>25%) poorly to non-welded tuff of Sharp Peak, typically found near the base of the unit. Clasts of older Mesozoic volcanics are generally less than 1 meter, but abundant clasts >> 1 meter are also present.

Ksp – Tuff of Sharp Peak (Cretaceous) – Moderately crystal-rich (18-30%) welded ash-flow tuff, containing phenocrysts of plagioclase (5-15%, 0.5-4.5 mm), quartz (4-8%, 0.7- 8.0 mm), sanidine or perthitic K-feldspar (3-9%, 1.0-4.0 mm), and biotite (0.2-1.5%, 0.5- 1.5 mm). At its type section in the southern Roskruge Mountains (Ferguson et al., 2000) the tuff is compositionally zoned with an abrupt upward increase in plagioclase and biotite content corresponding to a gradual upward change from non-welded to welded (map units Kspl and Ksp of Ferguson et al., 2000). In the basal nonwelded to poorly welded zone, plagioclase is subordinate to equal in proportion to quartz and K-feldspar, but in the welded zone, plagioclase represents at least half of the total phenocrysts. K-feldspar typically displays perthitic texture throughout, but at the type section, sanidine is preserved in the middle portion of the non-welded zone. Elsewhere, sanidine has also been observed in the welded zone. The welded zone of the

tuff of Sharp Peak is pinkish gray or peach colored and very resistant, forming nearly all of the high-standing peaks in the southern Roskruge Mountains. The paleomagnetic polarity of the tuff of Sharp Peak is reversed (Vugteveen et al., 1981). The unit was formerly known as the Roskruge rhyolite of Heindl (1965) and the middle member of the Roskruge volcanics of Bikerman (1965, 1967, 1968).

Kcwu – Upper flow unit of the Cat Mountain Tuff (Cretaceous) – An upper flow unit of the Cat Mountain Tuff mapped by Sawyer (1996) in the Silverbell Mountains.

Kcx – Cat Mountain Tuff, megabreccia (Cretaceous) – Zones of lithic megabreccia within the Cat Mountain Tuff of the Tucson Mountains, including map units defined by different types of lithic blocks Kcm, Kcmt, Kcma, Kcms, Kcmg, Kcmr, Kcmb, and Kcmp of Lipman (1993).

Kct – Cat Mountain Tuff (Cretaceous) – Phenocryst-rich (25-30%) low-silica rhyolite ash-flow tuff containing 10-15% phenocrysts of sanidine, 10% quartz, and 5-10% plagioclase with minor biotite. Includes map units Kcw, Kcp, and Kcn of the Cat Mountain tuff of Lipman (1993).

Kcwl – Lower Cat Mountain Tuff (Cretaceous) – A lower flow unit of the Cat Mountain Tuff mapped by Sawyer (1996) in the Silverbell Mountains. The tuff is separated from the main unit by variable thicknesses of andesite (Ka).

Kvt – Viopuli Tuff (Cretaceous) – Moderately phenocryst-poor (5-15%) densely welded ash-flow tuff with phenocrysts of plagioclase>biotite found throughout the Roskruge Mountains. This unit is characterized by abundant, extremely flattened, light pink to light gray fiamme in a darker colored, pink to lavender, densely welded matrix. Plagioclase phenocrysts (5-7%, I-5 mm) tend to be equant, euhedral, and unbroken. Biotite is fairly abundant (1-2%, 1-4 mm). The scarcity of lithic clasts in the main body of the flow, the extreme eutaxitic foliation, and the euhedral character of the plagioclase phenocrysts gives the appearance of a lava flow in some areas. Near the base, lapilli-sized, mafic lava lithic clasts are abundant (up to 10%), and pumice fragments are less compacted giving the unit a distinctive pyroclastic texture. The unit consists of two flow units (compound cooling unit) in the south, and the contact between the two is defined by a thin interval of poorly to moderately welded, light gray, faintly thin-bedded, fine-grained tuff. The tuff is zoned from a high-silica trachyte near the base to a low-silica rhyolite higher in the unit (Hagstrum et al. 1994), and its paleomagnetic polarity is normal (Vugteveen et al., 1981; Hagstrum et al. 1994).

Kcpx – Confidence Peak Tuff, megabreccia (Cretaceous) – Phenocryst-rich ash-flow tuff containing 5-50% lithics up to 5m.

Kcp – Confidence Peak Tuff (Cretacous) – Phenocryst-rich (20-30%) welded ash-flow tuff containing phenocrysts of quartz (10-15%, 0.5-10.0 mm), plagioclase (10-15%, 0.6-4.0 mm), K-feldspar (2-5%, 0.5- 3.0 mm), biotite (1-3%, 0.5-2.0 mm). K-feldspar phenocrysts are typically perthitic, but where fresh consist of sanidine. The Confidence Peak Tuff can be differentiated from other feldspar-quartz phyric ash-flow tuffs in the Salero Group because its quartz phenocrysts are much larger (up to 1 cm), and because it contains very abundant biotite

phenocrysts. Biotite K/Ar ages of approximately 57 and 59 Ma (Mauger et al.., 1965) are too young based on stratigraphic constraints in the Silver Bell Mountains (Sawyer, 1996) who indicates a probable age range between 72.7 and 68.6 Ma based on bracketing between "well dated" units. In the Silver Bell Mountains the unit's paleomagnetic polarity is normal (Hagstrum and Saywer, 1989).

Ktp – Phenocryst-poor tuff (Cretaceous) – Pink or light gray, pumice-poor, ash-flow tuff containing 3-7% phenocrysts of quartz (1-2%, 0.5-3.0 mm), plagioclase (1-5%, 0.5-6.0 mm), K-feldspar (1-2%, 0.5- 3.0 mm), and sparse biotite (< 1.0 mm). The tuff is preserved in two areas of the Roskruge Mountains; in the southwest, near Bell Mountain and Sharp Peak, a pink tuff with this phenocryst assemblage occurs near the top of the volcaniclastic/mafic lava map unit (Kss), and in the northeast, near Pescadero Mountain, a thin sequence of gray tuff with this phenocryst assemblage occurs either at the base of the same sedimentary rock unit (Kss), or below an angular unconformity within rocks of older Cretaceous and/or Jurassic age (KJvs, or KJb) indicating that at this locality, the tuff might correlate with a phenocryst-poor Jurassic tuff (Jt) known in the Tucson and Silverbell Mountains (Lipman, 1993; Sawyer, 1996).

Kspt – Tuff of San Pedro (Cretaceous) – Ash-flow tuff in the Roskruge Mountains containing up to 30% phenocrysts of plagioclase phenocrysts (1-8 mm), and 1-3% biotite (<2mm), but no quartz or K-feldspar. The tuff is typically dark red, but locally is gray.

Kss – Volcaniclastic rocks and mafic lava (Cretaceous) – A monotonous sequence of dark-colored, typically argillaceous, volcaniclastic sandstone, siltstone, conglomerate interbedded with somber-hued, generally friable, plagioclase porphyritc mafic lavas that erode easily into subdued hills and pediment surfaces throughout the Roskruge, Silverbell, and Tucson Mountains. Plagioclase phenocrysts are typically small (0.5-2.5 mm) and constitute <15% of the rock. Felted mafic phenocrysts <2mm and <5% of the rock are typically strongly altered with abundant calcite and chlorite. Equivalent to the Roadside Formation of Heindl (1965) in the Roskruge Mountains whose mafic lavas which were dated at 66.70 + 2.00 Ma (K-Ar whole rock, Bikerman, 1967).

Kcs – Cascabel Formation (Cretaceous) – Volcaniclastic to polymictic conglomerate, pebbly sandstone, and finer-grained red-beds

Kfc – Fort Crittenden Formation (Cretaceous) – Clast-supported quartzite boulder cobble conglomerate in the Cocoraque Butte area of the Roskruge Mountains. The conglomerate overlies Jurassic strata along buttressed, angular unconformity. Clasts are probably derived from a local Jurassic eolian sandstone (JTrs).

Mzu – Undifferentiated Mesozoic supracrustal rocks (Mesozoic) – Sandstone, mudstone, conglomerate, and various volcanic rocks in the northwestern Roskruge Mountains.

LOWER CRETACEOUS BISBEE GROUP

KJb – Bisbee Group (Upper Jurassic to Middle Cretaceous) – A sequence of dominantly siliciclastic, dominantly argillaceous sedimentary rocks; sandstone, shale, siltstone, conglomerate and limestone. Includes Willow Canyon, Apache Canyon, Shellenburger Formations.

KJbg – Glance Conglomerate, Bisbee Group (Cretaceous - Jurassic) – The basal unit of the Bisbee Group, a conglomerate containing clasts of granitoid, and Phanerozoic carbonated and quartzite units.

JURASSIC-TRIASSIC ROCKS

KJsv – arkosic, argillaceous, conglomeratic, and mafic volcanic rocks undifferentiated (Cretaceous - Jurassic) – Bisbee or Salero or Jurassic supracrustal rocks undivided. Can't see angular relationships with other rocks and it has components of all three units. Salero and Jurassic have strong volcanic components and the Bisbee does not. Includes locally some fossiliferous limestone.

Mzd – Diorite (Mesozoic) – Medium- to fine-grained biotite- and/or hornblende-rich (>25%) diorite, quartz diorite, and/or quartz monzodiorite in the northern Coyote Mountains intruded by the pegmatitic granite (Tpg). According to Gardulski (1990), this map unit (which is divided into three map units: biotite quartz diorite, hornblende diorite, and hornblendite) also intrudes tabular bodies of middle and early Paleozoic quartzite and limestone just to the west of the map area. Near the Ajo Road detachment fault the diorite is locally pervasively foliated with a well-developed mylonitic fabric, but in most areas, the rock is non to weakly foliated.

JTu – Undivided mudstone, sandstone, and sparse conglomerate (Early Mesozoic) – Undivided mudstone, sandstone, and sparse conglomerate.

Jfv – Felsic volcanic rocks, chiefly rhyolite lava (Jurassic) – Rhyolite lava in the Cocoraque Butte area of the Roskruge Mountains.

Jt – Rhyolitic ash-flow tuff (Jurassic(?)) – Phenocryst-poor rhyolite ash-flow tuff at Brown Mountain in the western Tucson Mountains (Lipman, 1993). The tuff contains a few % quartz and altered feldspar phenocrysts <2mm, small sparse pumice lapilli and sparse lithic lapilli.

JTrs – Siliciclastic sedimentary rocks (Jurassic to Triassic) – Sandstone, locally thick-bedded and of probable eolian origin, and volcanic-lithic sandstone and conglomerate.

Jmv – Andesitic volcanic rocks (Jurassic) – Andesite lavas in the Cocoraque Butte area of the Roskruge Mountains, and southeastern Waterman Mountains.

JTrb – Recreation Red Beds (Jurassic toTriassic) – Thin- to medium-bedded deep red sandstone, shale and siltstone in the western Tucson Mountains.

PALEOZOIC ROCKS

Pzc – Paleozoic carbonate rocks, undifferentiated (Cambrian-Permian) – Undifferentiated Paleozoic carbonate rocks.

Pu – Permian sedimentary rocks (Permian) – Undifferentiated Concha Limestone, Sherrer Formation, Epitaph Formation, and Colina Limestone.

PPeh – Earp Formation and Horquilla Limestone, undivided (Permian to Carboniferous) – Upper Carboniferous and lowermost Permian limeston and calcareous siltstone.

Cu – Carboniferous undifferentiated (Carboniferous) – Undifferentiated Horquilla, Escabrosa, and locally Earp Formations.

PhMe – Horquilla Limestone and Escabrosa Limestone, undivided (Carboniferous) – Medium- to thick-bedded to massive, medium-gray to locally dark-gray limestone, commonly with chert and siliceous stringers. Bedding is generally defined by variable resistance to weathering and sparse stringers of silica. Limestone is recrystallized; some pale gray limestone consists of 1-3 mm calcite crystals. Elsewhere recrystallization is cryptic and carbonate is inferred to be less pure. Locally includes terra rosa breccia zones that are not clearly laterally continuous. Locally this unit includes laminated to thin bedded silty limestone to siltstone.

DMc – Martin, Escabrosa, and Horquilla Formations, undivided (Devonian-Mississippian) – Undifferentiated Martin, Escabrosa, and Horquilla Formations.

DmCa – Martin Formation and Abrigo Formation, undivided (Devonian and Cambrian) – Undifferentiated Martin Formation and Abrigo Formation.

Du – Devonian sedimentary rocks (Devonian) – Light-brown to tan, silty to sandy, thin- to medium-bedded dolostone and limestone; fine- to medium-grained, calcareous, quartzose sandstone; calcareous siltstone; and locally thick beds of massive gray limestone. Sand grains are fine- to medium-grained, well rounded, and almost all quartz. In general, the lower Martin Formation consists of thin-bedded to laminated, very fine-grained, quartzose sandstone and medium-gray to light-brownish-gray bioclastic limestone. The limestone is commonly mottled as if bioturbated, and limestone locally grades abruptly along strike to tan- or orange-brown-weathered dolostone. Overlying middle Martin Formation (~30-50 m thick) consists of thin- to medium- bedded (10-100 cm), very-fine- to medium-grained quartzose sandstone, siltstone, calcareous siltstone, and silty tan carbonate. Upper Martin Formation is similar, with very fine-grained quartzose sandstone forming the top of the formation. Sandstone and sandy carbonate units are locally cross-bedded (including herringbone cross-bedding), and some contain glauconite.

Cs – Cambrian sedimentary rocks (Cambrian) – Bolsa and Abrigo Formations, undivided. Abrigo Formation consists of tan to light-brown to gray limestone and dolostone, thinly interbedded with fine-grained, light-brown, shaley, commonly calcareous quartz sandstone and yellow to olive-green shale containing flakes of white mica. Bolsa Quartzite consists of generally medium- to fine-grained, thin- to thick-bedded, locally cross-bedded, quartz-rich sandstone.

CYq – Bolsa Quartzite and Dripping Springs Quartzite, undivided (Cambrian and Mesoproterozoic) – White, light- to medium-gray, or pale reddish-gray quartzite, commonly with transposed thin beds and laminations. The unit locally contains conglomerate beds and pelitic schist. Several conglomerate beds, 0.5 to 3 m thick, contain quartzite clasts that are flattened parallel to compositional layering and that rarely exceed 15 cm in longest direction.

PROTEROZOIC ROCKS

ZYs – Proterozoic sedimentary (Neo- Mesoproterozoic) – Rocks reminiscent of the Apache Group, but a fossil of likely Ediacaran age has been found in float near outcrops (but not yet observed in place).

Ya – Apache Group (Mesoproterozoic) – Apache Group sedimentary rocks including Dripping Spring Quartzite and Pioneer Shale. Locally includes diabase dikes and sills.

Yd – Diabase (Mesoproterozoic) – Diabase dikes and sills

Yg – Granitic rocks (Middle Proterozoic) – Coarse-grained granite with 3-10% biotite, locally K-feldspar porphyritc.

YXgj – Mixed border phase of Johnny Lyon granodiorite (Mesoproterozoic to Paleoproterozoic) –Gradational contacts with adjacent equigranular biotite granite indicate that the margin of the Paleoproterozoic Johnny Lyon granodiorite underwent melting and mixing when intruded by two Mesoproterozoic granites. Variation in the fraction of K-feldspar megacrysts characterizes the margin of the porphyritic main phase, and K-feldspar megacrysts may locally form xenocrysts in adjacent phases.

Xp – Pinal Schist (Paleoproterozoic) – Fine-grained quartz-feldspar-muscovite schist, commonly with fine magnetite, and fine-grained quartzite. Includes slightly to moderately micaceous quartzose metasandstone and schist intruded by locally abundant pegmatites, leucogranite dikes or sills, and quartz veins.

Xg – Proterozoic plutonic (Paleoproterozoic) – Equigranular, medium- to fine-grained granite or granodiorite with biotite, hornblende(?), and secondary chlorite. Probably equivalent to Rincon Valley Granodiorite of Drewes (1977) but suspected to be Early Proterozoic based on lithologic dissimilarity to 1.4 Ga granites in southeastern Arizona. This unit is mapped in Rincon Valley where in detail (Richard et al., 2005) the unit consists of several phases (Xg, Xgd, Xgt, Xgf) of which Xgd is the only one described in that report.

Xgr – Rincon Valley granodiorite (Paleoproterozic) – Medium-grained (2-4 mm), generally homogranular hornblende-biotite granodiorite. Rock consists of 15-30% 1-4 mm quartz, 50-60% 2-3 mm subhedral white plagioclase, 5-15% anhedral pink potassium feldspar, 7-15% biotite in 2-3 mm diameter books and hornblende in prisms up to about 5 mm long. Biotite is the predominant mafic mineral. Biotite and hornblende are typically altered to chlorite, epidote and catenulate. Euhedral plagioclase crystals up to 8 mm long are locally present. Quartz is typically more anhedral and interstitial to plagioclase than in coarse-grained granitoid. Accessory sphene

in 1 mm honey-colored crystals is present. Zones of reddish iron oxide staining are common. Outcrop is rubbly and fractured on 5-15 cm scale. Enclaves composed of non-foliated, fine-grained plagioclase-mafic mineral granofels, with 2-5 mm plagioclase crystals are 5-15 cm long and ellipsoidal in section. Rock is weakly to moderately mylonitic in a thin, rarely preserved zone along the fault contact on Bisbee Group.

Xgj – Johnny Lyon granodiorite (Paleoproterozoic) – Johnny Lyon granodiorite, consisting of medium- to coarse-grained biotite granite and granodiorite with up to 20% K-feldspar megacrysts that are up to 5 cm long, white to pale-pinkish to pale-gray, and generally blocky or tabular. Prominent gray quartz is up to 10 mm, but mostly 2-8 mm. Fresh biotite is preserved locally, but mafic minerals are typically altered; felted aggregates typically form 4-7% of the rock. The rock is generally not foliated. A sample of this unit was dated at 1651 ± 17 Ma (Spencer et al., 2011).

REFERENCES

Banks, N. G., 1980, Geology of a zone of metamorphic core complexes in southeastern Arizona, in Crittenden, M. D., Jr., Coney, P. J., and Davis, G. H., eds., Cordilleran metamorphic core complexes, Geological Society of America Memoir 153, p. 177-215.

Banks, N. G. and Dockter, R. D., 1976, Reconnaissance geologic map of the Vaca Hills quadrangle, Arizona, U.S. Geological Survey, Miscellaneous Field Studies Map MF-793, scale 1:62,500.

Banks, N. G., Dockter, R. D., Briskey, J. A., Davis, G. H., Keith, S. B., Budden, R. T., Kiven, C. W., and Anderson, P., 1977, Reconnaissance geologic map of the Tortolita Mountains quadrangle, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-864, scale 1:62,500.

Bikerman, M., 1962, Geologic-geochemical study of the Cat Mountain Rhyolite: Unpublished M.S. thesis, University of Arizona, Tucson, 43 p.

Bikerman, M., 1965, Geological and geochemical studies of the Roskruge Range, Pima County, Arizona: Unpublished Ph.D. dissertation, University of Arizona, Tucson, 112 p.

Bikerman, M., 1967, Isotopic studies in the Roskruge Mountains, Pima County, Arizona: Geological Society of America Bulletin, v. 78, p. 1029-1036.

Budden, R. T., 1975, The Tortolia-Santa Catalina Mountain complex: Unpublished M.S. thesis, University of Arizona, Tucson, 133 p.

Bykerk-Kauffman, A., 2008, Geologic map of the southeastern Santa Catalina Mountains, Pima County, Arizona: Arizona Geological Survey Contributed Map Series CM-08-A, 2 sheets, scale 1:24,000.

Cook, J. P., and Spencer, J. E., 2007, Geologic map of the Redington 7 ½' quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-60, scale 1:24,000.

Cooper, J. R., 1973, Geologic map of the Twin Buttes quadrangle, southwest of Tucson, Pima County, Arizona: U.S. Geological Survey Miscellaneous Geological Investigations Map I-745, scale 1:48,000.

Creasey, S. C., Banks, N. G., Ashley, R. P., and Theodore, T. G., 1977, Middle Tertiary plutonism in the Santa Catalina and Tortolita Mountains, Arizona: U.S. Geological Survey Journal of Research, v. 5, no. 6, p. 705-717.

Davis, G. H., Constenius, K. N., Ornelas, E. P. R., and Cox, L. J., 2011, Structural-geologic map relationships in the Salcito Ranch area, Rincon Mountains, southern Arizona: Arizona Geological Survey Contributed Report CR-11-C, scale 1:10,000, and 20 p. text.

Davis, G. H., Bos Orent, E., Clinkscales, C. A., Ferroni, F. R., Gehrels, G. E., George, S. W. M., Guns, K. A., Hanagan, C. E., Hughes, A. N., Iriondo, A., Jepson, G., Kelty, C., Krantz, R. W., Levenstein, B. M., Lingrey, S. H., Miggins, D. P., Moore, T., Portnoy, S. E., Reeher, L. J., and Wang, J. W., 2023, Structural analysis and chronologic constraints on progressive deformation within the Rincon Mountains, Arizona: Implications for development of metamorphic core complexes: Geological Society of America Memoir 222, 125 p.

Drewes, H., 1974, Geologic map and sections of the Happy Valley quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-832, scale 1:48,000.

Dickinson, W. R., 1987, General geologic map of Catalina Core Complex and San Pedro Trough, Arizona: Arizona Bureau of Geology and Mineral Technology Miscellaneous Map MM-87-A, 18 p., 15 sheets, scale 1:62,500.

Dickinson, W. R., 1999, Geologic framework of the Catalina Foothills, outskirts of Tucson (Pima County, Arizona): Arizona Geological Survey Contributed Map CM-99-B, scale 1:24,000, and 31 p. text.

Ferguson, C. A., 2018, Evidence for northwesterly extension in the Tucson basin, Arizona, USA, from pseudotachylite breccia along the main detachment fault of the Santa Catalina-Rincon Mountains core complex: Geological Society of America Abstracts with Programs, v. 50, no. 5, doi: 10.1130/abs/2018RM-314363.

Ferguson, C. A., Gilbert, W. G., Pearthree, P. A., and Biggs, T. H., 2000, Geologic map of the southern Roskruge Mountains (the San Pedro and southern half of the La Tortuga Butte 7.5' quadrangles), Pima County, Arizona: Arizona Geological Survey Open-File Report OFR-00-06, scale 1:24,000, 2 plates, and 40 p. text.

Ferguson, C. A., Johnson, B. J., Skotnicki, S. J., Maher, D. J., Spencer, J. E., Gilbert, W. G., Richard, S. M., Youberg, A., Demsey, K. A., and House, P. K., 2003, Geologic map of the Tortolita Mountains, Pinal and Pima Counties, Arizona [updated to v. 2.0 in 2021]: Arizona Geological Survey Digital Geologic Map Series DGM-26, scale 1:24,000, and 46 p. text.

Force, E. R., 1997, Geology and mineral resources of the Santa Catalina Mountains, southeastern Arizona: A cross-sectional approach, with sections by Danie M. Unruh and Robert J. Kamilli: University of Arizona, Center for Mineral Resources, Monograph in Mineral Resource Science No. 1, 145 p. text, two plates, scale 1:48,000.

Fornash, K. F., Patchett, P. J., Gehrels, G. E., and Spencer, J. E., 2013, Evolution of granitoids in the Catalina metamorphic core complex, southeastern Arizona: U–Pb, Nd, and Hf isotopic constraints: Contributions to Mineralogy and Petrology, v. 165, p. 1295-1310.

Gardulski, A. F., 1980, A structural and petrologic analysis of a quartzite-pegmatite tectonite, Coyote Mountains, southern Arizona: Unpublished M.S. thesis, University of Arizona, Tucson, 69 p. and 2 plates.

Greig, R. E., 2021, Superposed magmatic and hydrothermal systems, and the evolution of the Laramide arc and porphyry copper province, southwestern North America: Unpublished Ph.D. dissertation, University of Arizona, Tucson, 346 p.

Hagstrum, J. T., and Sawyer, D. A., 1989, Late Cretaceous paleomagnetism and clockwise rotation of the Silver Bell Mountains, south central Arizona: Journal of Geophysical Research: Solid Earth, v. 94, no. B12, p. 17847-17860.

Hagstrum, J., Lipman, P., and Sawyer, D., 1994, Paleomagnetism, stratigraphy, and petrology of the Upper Cretaceous Roskruge volcanics at Bell Mountain, southeast Arizona: Journal of Geophysical Research: Solid Earth, v. 99, no. B8, p. 15097-15102.

Heindl, L. A., 1965, Mesozoic formations in the Comobabi and Roskruge Mountains, Papago Indian Reservation, Arizona: U.S. Geological Survey Bulletin 1194-H, p. H1-H15.

Hermann, M. A., 2001, Episodic magmatism and hydrothermal activity, Pima mining district, Arizona: Unpublished M.S. thesis, University of Arizona, Tucson, 44 p.

Jackson, G. W., 1989, Surficial geologic maps of the northeastern, southeastern, and southwestern portions of the Tucson metropolitan area: Arizona Geological Survey Open-File Report OFR-89-02, 7 sheets, scale 1:24,000.

Keith, S. B., Reynolds, S. J., Damon, P. E., Shafiqullah, M., Livingston, D. E., and Pushkar, P. D., 1980, Evidence for multiple intrusion and deformation within the Santa Catalina-Rincon-Tortolita crystalline complex, southeastern Arizona, in Crittenden, M. D., Jr., Coney, P. J., and Davis, G. H., eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153, p. 217-267.

Lindgrey, S. H., 1982, Structural geology and tectonic evolution of the northeastern Rincon Mountains, Cochise and Pima Counties, Arizona: Unpublished Ph.D. dissertation, University of Arizona, Tucson, 202 p., and 6 plates.

Lipman, P. W., 1993, Geologic map of the Tucson Mountains caldera, southern Arizona: Arizona Geologic Survey, 2 sheets, scale 1:24,000.

McKittrick, M. A., 1988, Surficial geologic maps of the Tucson metropolitan area: Arizona Geological Survey Open-File Report OFR-88-18, 12 sheets, scale 1:24,000.

Muager, R. L., Damon, P. E., and Giletti, B. J., 1965, Isotopic dating of Arizona ore deposits: Society of Mining Engineers Transactions, v. 232, p. 81-87.

Pearthree, P. A., Ferguson, C. A., Gilbert, W. G., and Skotnicki, S. J., 2000, Geologic map and geologic hazards of the Three Points 7.5' quadrangle, Pima County, Arizona [updated to v. 2.0 in 2019]: Arizona Geological Survey Digital Geologic Map Series DGM-04, scale 1:24,000, and 19 p. text.

Percious, J. K., 1968, Geology and geochronology of the Del Bac Hills, Pima County, Arizona, in Titley, S. R., ed., Southern Arizona guidebook III: Geological Society of America Cordilleran Section 64th Annual Meeting, April 11-13, 1968, Arizona Geological Society Guidebook III, Part B, p. 199-207.

Perry, E. R., 2005, Field and petrographic analysis of mylonitic fabrics: Implications for tectonic corrugation development, Tanque Verde Ridge, Arizona, USA: Unpublished Ph.D. dissertation, University of Texas, Austin, 206 p.

Phillips, M. P., 1976, Geology of Tumamoc Hill, Sentinel Peak and vicinity, Pima County, Arizona: Unpublished M.S. thesis, University of Arizona, Tucson, 83 p. and 1 plate.

Richard, S. M., Ferguson, C. A., Spencer, J. E., and Youberg, A., Orr, T. R., 2000, Geologic map of the Waterman Peak 7.5' quadrangle and northern La Tortuga Butte 7.5' quadrangle, Pima County, Arizona [updated to v. 2.0 in 2019]: Arizona Geological Survey, Digital Geologic Map Series DGM-02, scale 1:24,000, and 30 p. text.

Richard, S. M., Spencer, J. E., Ferguson, C. A., and Youberg, A., 2001, Geologic map of the southern part of the Vail 7.5' Quadrangle, eastern Pima County, Arizona [updated to v.

2.0 in 2020]: Arizona Geological Survey Digital Geologic Map Series DGM-12, scale 1:24,000, and 29 p. text.
Richard, S. M., Spencer, J. E., Youberg, A., and Ferguson, C. A., 2005, Geologic map of the Rincon Valley area, Pima County, Arizona [updated to v. 2.0 in 2020]: Arizona Geological Survey Digital Geologic Map Series DGM-44, scale 1:24,000, and 11 p. text
Sawyer, D. A., 1996, Geologic map of the Silver Bell and West Silver Bell Mountains, southern Arizona: U.S. Geological Survey Open-File Report 96-6, scale 1:24,000, and 21 p. text.
Shafiqullah, M., Damon, P. E., Lynch, D. J., Kuck, P. H., and Rehrig, W. A., 1978, Mid-Tertiary magmatism in southeastern Arizona, in Callender, J. F., Wilt, J. C., Clemons, R. E., and James, H. L., eds., Land of Cochise, southeastern Arizona, New Mexico Geological Society 29th Field Conference Guidebook, p. 231-241.
Shipman, T. C., 2004, Geologic map of the Tucson SE 7.5' quadrangle, Pima County, Arizona: Arizona Geological Survey Digital Geologic Map Series DGM-43, scale 1:24,000.
Skotnicki, S. J., 2000, Geologic map of the Oracle Junction 7.5 quadrangle and the eastern third of the Tortolita Mountains 7.5’ quadrangle, Pima and Pinal Counties, Arizona: Arizona Geological Survey Open-File Report OFR-00-04, scale 1:24,000, and 19 p. text.
Skotnicki, S. J., and Pearthree, P. A., 2000, Geologic map of the Cocoraque Butte 7.5' quadrangle, Pima County, Arizona [updated to v. 2.0 in 2020]: Arizona Geological Survey Digital Geologic Map Series DGM-06, scale 1:24,000, and 27 p. text
Skotnicki, S. J., and Siddoway, C. H., 2001, Combination geologic map of the Galleta Flat West 7.5' quadrangle, Pima and Cochise Counties, Arizona [updated to v. 2.0 in 2021]: Arizona Geological Survey Digital Geologic Map Series DGM-08, scale 1:24,000, and 18 p. text.
Smith, C.H., 1989, Compressional deformation and peraluminous plutonism in the Little Rincon Mountains, southeastern Arizona; a component of the fabric of the Rincon metamorphic core complex: Unpublished M.S. thesis, University of Arizona, Tucson, 54 p.
Spell, T. L., Zanetti, K. A., Spencer, J. E., Richard, S. M., Ferguson, C. A., Skotnicki, S. J., and Orr, T. R., 2003, Eighteen new 40Ar/39Ar thermochronologic analyses from southern and central Arizona: Arizona Geological Survey Open-File Report 03-03, 63 p.
Spencer, J. E., and Pearthree, P. A., 2004, Geologic map of the Oro Valley 7.5' quadrangle and the Pusch Peak area, northeastern Pima County, Arizona [updated to v. 3.0 in 2019]: Arizona Geological Survey Digital Geologic Map Series DGM-21, scale 1:24,000.
Spencer, J. E., and Constenius, K. N., 2020, Reconnaissance study of mylonitic fabrics in the Bellota Ranch area, eastern Santa Catalina Mountains, Arizona: Arizona Geological Survey Contributed Report CR-20-C, 12 p. and 1 appendix.
Spencer, J. E., Ferguson, C. A., Richard, S. M., Orr, T. R., Pearthree, P. A., Gilbert, W. G., and Krantz, R. W., 2001, Geologic map of The Narrows 7 1/2' quadrangle and the southern part of the Rincon Peak 7 1/2' Quadrangle, eastern Pima County, Arizona (updated to v. 2.0 in 2020]: Arizona Geological Survey Digital Geologic Map Series DGM-10, scale 1:24,000, and 33 p. text.
Spencer, J. E., Cook, J. P., Lindgrey, S. H., Richard, S. M., and Guynn, J. H., 2008, Geologic map of the Wildhorse Mountain 7.5’ quadrangle, Cochise County, Arizona [updated to v. 2.0 in 2018]: Arizona Geological Survey Digital Geologic Map Series DGM-62, scale 1:24,000.
Spencer, J. E., Richard, S. M., Cook, J. P., Dickinson, W. R., Lingrey, S. H., and Guynn, J. H., 2008b, Geologic map of the Soza Canyon 7.5’ quadrangle, Cochise and Pima Counties,

Arizona [updated to v. 2.0 in 2018]: Arizona Geological Survey Digital Geologic Map Series DGM-61, scale 1:24,000.

Spencer, J. E., Lindgrey, S. H., Johnson, B. J., Cook, J. P, and Richard, S. M., 2011, Geologic map of the Happy Valley 7.5' quadrangle, Cochise and Pima Counties, Arizona [updated to v. 2.0 in 2019]: Arizona Geological Survey Digital Geologic Map Series DGM-89, scale 1:24,000.

Suemnicht, G. A., 1977, The geology of the Canada del Oro headwaters, Santa Catalina Mountains, Arizona: Unpublished M.S thesis, University of Arizona, Tucson, 108 p. text, and 1 plate.

Vugteveen, R. W., Barnes, A. E., and Butler, R. F., 1981, Paleomagnetism of the Roskruge and Gringo Gulch volcanics, southeast Arizona: Journal of Geophysical Research, v. 86, p. 4021-4028.

Wright, J. E., and Haxel, G., 1982, A garnet-two-mica granite, Coyote Mountains, southern Arizona: Geologic setting, uranium-lead isotopic systematics of zircon, and nature of the granite source region: Geological Society of America Bulletin, v. 93, no. 11, p. 1176-1188.

Youberg, A., Spencer, J. E., Richard, S. M., 2007, Geologic map of the Galleta Flat East 7.5 quadrangle, Cochise County, Arizona [updated to v. 3.0 in 2019]: Arizona Geological Survey Digital Geologic Map Series DGM-56, scale 1:24,000.