# Geologic Map of the Casa Grande 30’ x 60’ Quadrangle, west-central Arizona

Compiled by

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# INTRODUCTION

The Casa Grande 30' x 60' quadrangle is located between Tucson and Phoenix in Pinal County and northernmost Pima County, southern Arizona. The geomorphology of the area is dominated by the Santa Cruz River and several large tributaries whose courses traverse broad, low-relief valley floors, adjacent broad, gently sloping piedmonts, and generally narrow, northerly elongate mountain ranges. All or parts of at least 10 mountain ranges with diverse geology are covered by this map, but surficial deposits of various types cover about 3/4 of the map area. The Santa Cruz River crosses from the south-central edge to the northwest corner of the map area, passing between the Samaniego Hills and Picacho Peak in the south and exiting west of the Sacaton Mountains. Santa Rosa Wash and its tributaries in the southwest part of the map flow northward to the river. The eastern 1/3 of the map is primarily bedrock of the Tortolita Mountains and Ninetysix Hills and broad, westward-sloping piedmonts covered primarily with variably dissected Pleistocene alluvial fan deposits and lesser amounts of Holocene deposits along or near modern washes. Valley floor deposits associated with regional drainages dominate the western 2/3 of the map. Bedrock mountains have relatively small footprints; their adjacent alluvial piedmonts are covered primarily by late Pleistocene and Holocene tributary deposits and are only locally dissected, typically near the mountain ranges. Generally fine-grained Holocene deposits are widespread on the broad valley floors, but slightly higher late to middle Pleistocene relict basin floor deposits are also laterally extensive.

Surficial geologic units range from Holocene stream channel and floodplain deposits along the Santa Cruz River and its larger tributaries and channel, floodplain, and alluvial fan deposits throughout the piedmonts, to remnant early Pleistocene alluvial fan deposits capping very well-rounded Neogene basin fill in a few locations near mountain fronts. Channel deposits and terraces are relatively narrow in the proximal piedmont where incised into higher-standing older alluvium. These deposits are much more laterally extensive in the lower relief mid- and distal-piedmont. Carbonate and clay accumulation in Holocene piedmont deposits is modest to minimal. Late and middle Pleistocene alluvial fan and terrace deposits typically have desert pavement, rock varnish, argillic horizons, and soil carbonate accumulation. Some relict early Pleistocene deposits are littered with carbonate fragments from an eroding petrocalcic horizon. Basin fill alluvium is exposed in deeply dissected, very well-rounded hills in the proximal piedmont. Some of these deposits are capped by early to middle Pleistocene alluvium along the ridge crest.

Bedrock geology includes rocks ranging in age from Paleoproterozoic to early Miocene. The Paleoproterozoic Pinal Schist, along with Mesoproterozoic plutonic rocks that intrude it, are exposed in ranges throughout the area. Sedimentary rocks of Mesoproterozoic and Paleozoic age overlie these crystalline basement rocks in the Slate Mountains, Tat Momoli Mountains, and Vaiva Hills. Cretaceous to mid-Cenozoic intrusive rocks crop out in the Tortolita Mountains, Suizo Mountains, Durham Hills, Desert Peak, Picacho Mountains, and Sacaton Mountains. Late Oligocene to early Miocene basaltic to trachtic lava flows and clastic sedimentary rocks are exposed north of the Tortolita Mountains and in the Samaniego Hills, Picacho Peak, Sawtooth Mountains, Tat Momoli Mountains, and Vaiva Hills.

Late Cretaceous to Oligocene plutons and their country rocks in the eastern part of the map occupy the northwestern part of the Catalina-Rincon metamorphic core complex (Davis, 1980; Dickinson, 1991). They form culminations that are small in comparison with the major exposures of the core complex in the Santa Catalina and Rincon Mountains, southeast of the map area. These crystalline rocks are variably foliated and lineated, ranging from massive to gneissic to mylonitic. Mylonitic foliation and lineation are developed in the structurally highest rocks, and asymmetric shear fabrics are predominantly indicative of top-to-WSW shearing (Spencer et al., 2002; Ferguson et al., 2002; Richard et al., 1999, 2002). The crystalline rocks of the metamorphic core complex lie in the footwalls of detachment faults that are associated with the Catalina detachment (e.g., Dickinson, 1991) and along which they were exhumed in the late Oligocene to early Miocene (Spencer et al., 2022). In this map area the detachment system is represented by the Guild Wash, Suizo, and Picacho Peak detachments and subsidiary low-angle normal faults. Late Oligocene to early Miocene volcanic and sedimentary rocks are in the hanging wall of the detachment system. Proterozoic rocks occupy structural positions in both the footwall and the hanging wall.

# SOURCES OF DATA

This map was compiled from previously published 1:24,000-scale geologic maps and some unpublished maps, as shown in Figure 1. Some editing was done, especially of surficial map units, in order to correct mismatches along shared edges of some of the source maps and to refine contacts based on modern satellite imagery. Descriptions of bedrock units include results of geochronology that have become available since the publication of the original sources.

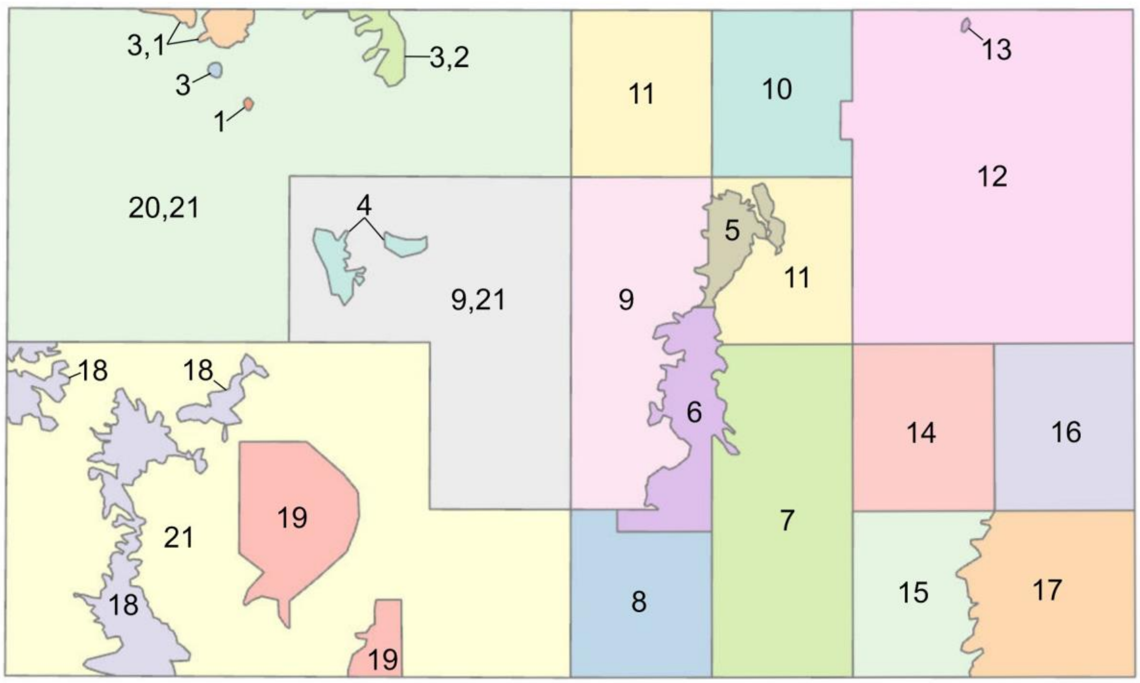


Figure 1. Sources of data used in this compilation.

1. Bergquist and Blacet, 1979a, OF-79-390
2. Bergquist and Blacet, 1979b, OF-79-391
3. Skotnicki and Ferguson, 1996, OFR 96-10
4. Bergquist and Blacet, 1978, OF-78-547
5. Johnson, 1981, MM-81-A
6. Richard et al., 1999, OFR-99-18
7. Field and Pearthree, 1993, OFR-93-13
8. Ferguson et al., 1999b, OFR-99-17
9. Jackson, 1990, OFR-90-02
10. Pearthree, 2012, DGM-95
11. Pearthree, 2002, reconnaissance
12. Skotnicki, 1999, OFR-99-20
13. Spencer et al., 2022, Geosphere
14. Richard et al., 2002, DGM-19
15. Youberg et al., 2002, DGM-20
16. Spencer et al., 2002, DGM-22
17. Ferguson et al., 2002, DGM-26
18. Blacet et al., 1978, MF-934
19. Ferguson et al., 1999a, OFR-99-16
20. Klawon et al., 1998, OFR 98-23
21. Pearthree, 2023 new mapping

# DESCRIPTION of MAP UNITS

## Piedmont deposits

**Qy – Young alluvium (Holocene)**
Sand, silt, pebbles, cobbles, boulders, and clay associated with channels, low terraces, overbank areas, and alluvial fans. Caliber of gravel varies greatly with position in the landscape; cobbles, pebbles, and boulders dominate in upper piedmont areas, and pebbles and granules with some cobbles in middle and lower piedmont areas. Deposits are poorly sorted and moderately bedded. Surfaces on coarser deposits are characterized by obvious bar-and-swale topography; gravel clasts are unvarnished to lightly varnished. Surfaces on finer-grained deposits are relatively smooth and planar. Older surfaces in this group may be incised up to 2 m. Surfaces and soils typically have hues of 7.5 YR.

**Qye – Mixed young eolian and alluvial deposits (Holocene)**
Medium to very fine-grained sand deposited by eolian processes interspersed with typically fine-grained young alluvium. Low-relief dunes and vegetation mounds are present in some areas.

**Qi – Intermediate alluvium, undifferentiated (middle or late Pleistocene)**
Used in areas where different ages of intermediate deposits exist but cannot be reasonably subdivided at the map scale, and in areas where deposits likely belong to more than one of the three Qi subdivisions. In most areas where this unit is used deposits are either Qi3 and Qi2, or a mix of the two.

**Qi3 – Young intermediate alluvium (late to latest Pleistocene)**
Alluvial fan surfaces and terrace deposits consisting of poorly to moderately sorted, clast-supported sandstone and pebble to cobble conglomerate with a sandy to silty matrix. Qi3 terraces are typically less than 5 m thick and commonly overlie older Tsy alluvium. Surfaces are moderately incised (up to 3-4 m) by stream channels, but are planar with rounded edges where well-preserved. Subdued bar and swale topography is common. Desert pavement and rock varnish development ranges from nonexistent to moderate. Surface colors are slightly reddened (light brown to reddish yellow, 7.5 YR 6/6) relative to Holocene surfaces. This color difference is due to mild to moderate soil development and tan to reddish-brown argillic horizons found on Qi3 deposits. Soils on Qi3 deposits exhibit Stage II-III calcium carbonate development and are classified as Haplargids, Camborthids, and Calciorthids. Qi3 surfaces appear whitish tan on aerial photos. The low infiltration rates of these surfaces favor plants that draw moisture from near the surface. Vegetation on Qi3 deposits is dominated by creosote, saguaro, palo verde, and ocotillo. Qi3 surfaces are not typically prone to flooding except possibly in very large floods and areas adjacent to active washes or in low-relief environments in the distal fan.

**Qi2 – Middle intermediate alluvium (Middle to late Pleistocene)**
Pebbles, cobbles, sand, silt, boulders, and clay associated with moderately dissected relict alluvial fans and terraces. Deposits are poorly sorted and moderately bedded. Desert pavement is variable, but well-preserved planar surfaces have tight pebble-cobble pavements with dark rock varnish. Soil development is moderate to strong; maximum redness in soils typically is 5YR,

with obvious clay accumulation in strong cambic or argillic horizons up to 0.5 m thick. Calcic horizon development ranges from carbonate nodules to thick gravel coatings. Near the mountains Qi2 deposits are dominated by cobbles and boulders, and surfaces may be up to 5 m above active channels. On the lower piedmont, deposits are sandy with pebbles and cobbles.

**Qo – Old alluvial fan deposits (early Pleistocene)**
Alluvial fan surfaces and deposits composed of very poorly sorted angular to subangular cobbles and pebbles with sand and minor silt and clay. These deposits are moderately consolidated and commonly indurated with soil carbonate. Surfaces are moderately to deeply dissected, with 2 to 10 m of relief between channels and ridge crests. These deposits occupy the highest topographic positions in the piedmont and are only preserved in the proximal piedmont. Original fan surfaces have been eroded away so the characteristic topographic expressions of these deposits are alternating ridges and valleys. Soil development is moderate to strong depending on local preservation. Reddish-brown argillic horizons are moderately- to well-developed on planar, relatively well-preserved alluvial surface remnants in some areas. All soils are dominated by carbonate accumulation. Surfaces are typically littered with carbonate fragments derived from eroded petrocalcic horizons which cause some Qo surfaces to have a light-colored to whitish appearance on aerial photographs. Well-cemented, intact petrocalcic horizons are commonly exposed on the upper slopes of Qo deposits below ridge crests.

**Nsy – Very old alluvial fan deposits (late Neogene)**
Very old alluvial fan deposits underlying Pleistocene fan caps and terraces. Tsy deposits are composed of moderately to well-consolidated sand to conglomerate exposed in deeply dissected hills. Relict pedogenic carbonate may armor ridge tops but soil formed on the depositional surface has been stripped away. Includes unit Tc of Skotnicki, 1999 and QTs of Spencer et al., 2002 and Ferguson et al., 2003.

## Axial valley deposits

**Qyr – Holocene river terrace alluvium, undivided (Holocene)**
Young river terrace deposits that stand 0.5 – 3 m above the active river channels but are subject to inundation and fine-grained deposition during large flood events. These deposits include sand and gravel lithologies equivalent to those found in channel (Qycr) deposits, as well as overbank silts and clays deposited during floods. Terrace surfaces are typically smooth but may exhibit local bar and swale topography. Bars are typically more heavily vegetated than swales. Vegetation on Qyr surfaces is dominated by grasses and small shrubs or young mesquite trees. These deposits are unconsolidated and exhibit little to no soil development.

**Qyrs – Young sand, silt, and gravel deposits of the Santa Cruz River (Holocene)**
Primarily sand, silt, and and clay, with local concentrations of well-rounded, lithologically diverse gravel deposits.

**Qir – Old river terrace alluvium (middle to late Pleistocene)**
Older river deposits composed of poorly sorted, subrounded to subangular cobbles, gravel, pebbles, and coarse sand. Soil development on Qir deposits is moderate to mature with some

clay accumulation where terrace surfaces are well-preserved. Terrace elevation ranges from 10 to 25 m above the active river channel (Pearthree et al., 2004). Terraces are generally planar but beveled along edges and internally incised to the modern regional drainage. Surface flow on Qir deposits is confined to within incised channels with some sheet flow on more extensively preserved deposits. Soil color is reddish-yellow (7.5 YR 6/6) and appears as light tan on aerial photos. Vegetation on Qir surfaces is dominated by cholla and creosote.

Qirs – **Older Santa Cruz River deposits (middle to late Pleistocene)**
Qirs surfaces are 1 to 4 m higher than adjacent Qyrs surfaces and are typically moderately rounded. Relatively stable planar surface remnants with pebble or cobble lags have moderately dark to dark rock varnish.

## Other surficial units

d – **Profoundly disturbed areas (modern)**
Areas that are substantially disturbed by human activities that impact surface water flow; includes Interstate Highways and the Central Arizona Project canals.

da – **Areas altered by mining (modern)**
Aggregate pits, mines, and related facilities.

Qtc – **Colluvium, talus, regolith (Quaternary)**
Regolith derived from underlying bedrock, with minor amounts of alluvium of various ages, and colluvium. Deposits are angular to subangular sand, gravel, and cobbles composed of underlying bedrock. Soil development varies but in general deposits are very thin (< 1 m) with scattered outcrops of underlying rock. From Spencer et al. (2002).

## Late Paleogene – Neogene volcanic and sedimentary rocks

***Vaiva Hills, Tat Momoli Mountains, and Silver Reef Mountains***

Tbv – **Basalt of Vaiva Hills (Miocene)**
Dark-gray to black olivine basalt flows.

Tmf – **Mudflow deposits (Miocene)**
Tuffaceous mudflow deposits associated with basalt flows in the Tat Momoli Mountains.

Tl – **Latite (Miocene)**
Light-gray, flow-banded, biotite-hornblende latite lava flows in the Tat Momoli Mountains (Blacet et al., 1978). May correlate with trachyte lava flows in the Sawtooth Mountains (unit Ttl).

Ta – **Andesite (Oligocene–Miocene)**
Vesicular andesite lava flows in the Silver Reef Mountains.

**Tap** – **Andesite porphyry (Oligocene–Miocene)**
Dark-gray, porphyritic, hornblende-biotite andesite in the northern part of the Slate Mountains.

***Sawtooth Mountains and Silver Reef Valley***

**Tr** – **Rhyolite (Miocene)**
Flows and plugs of light-pinkish-gray flow-banded rhyolite, locally autobrecciated. On the west-central flank of the Sawtooth Mountains a plug of crystal-poor rhyolite intrudes the upper basaltic trachyandesite (unit Tbu) and is associated with thin- and medium-bedded, non-welded, lithic rhyolitic tuff.

**Ttu** – **Upper trachyandesite and breccia of Sawtooth Mountains (Miocene)**
The lower part of this unit is a massive to thick-bedded breccia that contains clasts of trachyte and dacite plus minor amounts of basalt and rare pre-Tertiary rocks. The clasts are angular to subrounded and their composition reflects local provenance: near its southern limit, the breccia is essentially monomictic, consisting of >95% clasts of dacite derived from map unit Tdw, and near its northeastern limit the clasts are over 70% trachyte derived from map unit Ttl. Rare, discontinuous, volcaniclastic sandstone beds are also present.

The breccia is overlain by crystal-poor to aphyric trachyandesite containing between 2% and <<0.5% small phenocrysts (<0.5 mm) of clinopyroxene and olivine in a dark-gray glassy groundmass containing felted plagioclase microlites. The unit occurs as multiple amalgamated flows separated by reddish scoria and rare volcaniclastic sandstone.

**Tbu** – **Upper basaltic trachyandesite of Sawtooth Mountains (Miocene)**
Vesicular mafic lava flows containing 2-5% phenocrysts (0.2-1 mm) of pyroxene and olivine.

**Tdw** – **Dacite of Wildcat Peak (Miocene)**
Crystal-rich (>25%), fine-grained, hornblende-biotite-plagioclase dacite. Plagioclase (20%) occurs as strongly zoned (An30-An80), euhedral, blocky phenocrysts (0.3-0.7 mm). Biotite (<5%, 0.3-0.7 mm) and hornblende (<3%, 0.1-0.3 mm) phenocrysts are also present. The unit forms a large intrusive mass at the south end of the Sawtooth Mountains and occurs as smaller dikes, plugs and hypabyssal bodies that intrude crystal-rich trachyte of unit Ttl.

**Ts** – **Conglomerate (Miocene)**
Medium- to thick-bedded conglomerate containing rounded pebble- to boulder-sized clasts of local volcanic rocks (chiefly crystal-rich trachyte of unit Ttl) and variable amounts of Paleozoic or Mesoproterozoic quartzite, Mesoproterozoic granitoid, and Laramide porphyry. In the northern Sawtooth Mountains this unit interfingers with and grades eastward into monomict volcanic and epiclastic breccia of unit Ttl and, to a lesser degree, unit Tbu (Ferguson et al., 1999a). To the west, the conglomerate grades into an essentially non-volcaniclastic lithofacies containing clasts of quartzite, limestone, granitoid, and porphyry. Light-brown to reddish-brown conglomerate adjacent to Silver Reef Valley (Blacet et al., 1978) is considered correlative and is included in this unit.

**Ttl – Trachyte of Sawtooth Mountains (Miocene)**
Includes trachyte lava flows and associated volcaniclastic rocks that were subdivided into several units by Ferguson et al. (1999a). The stratigraphically lowest unit, exposed only in a canyon at the north end of the Sawtooth Mountains, contains up to 10% phenocrysts of plagioclase and biotite in a purple-gray groundmass. Plagioclase phenocrysts are sparse and <2 mm. The content of biotite ranges up to 10%, and it ranges from <2 mm to >15 mm in size. The biotite-rich lavas are overlain by an interval of medium- to thin-bedded non-welded tuff.

These rocks are overlain by crystal-rich trachyte, which dominates the lower part of unit Ttl and consists of lava domes, lava flows, and flow breccia containing 20-40% phenocrysts of plagioclase, hornblende, biotite, and clinopyroxene. Plagioclase (20-30%) occurs as strongly zoned, rounded, blocky crystals, commonly in glomeroporphyritic masses up to 2 cm. Individual plagioclase crystals range between 0.3 and 10 mm, averaging 2-5 mm. Euhedral hornblende (1-7%) ranges from 1 to 10 mm and averages 1-4 mm. Biotite (1-5%) is generally <2 mm. Clinopyroxene phenocrysts (<2%) are 0.5-2 mm. Sanidine phenocrysts (up to 10%, subhedral, 1-2 mm) are locally present in plugs of this unit. The lava flows are intercalated with abundant tuff and tuff breccia, and lesser amounts of volcaniclastic sedimentary rocks including monomictic conglomerate that grades westward into polymictic conglomerate of unit Ts.

The upper part of unit Ttl is a sequence of purple to black, amalgamated, crystal-poor lava flows containing 2-5% needle-shaped mafic phenocrysts and sparse plagioclase phenocrysts <1mm long. A few flows and plugs contain up to 15% phenocrysts. Sparse yet conspicuous feldspar xenocrysts up to 2 cm are also characteristic of the upper lavas. Black vitric zones are common at the bases of flow units, and these weather light greenish-gray with pitted surfaces.

**Tbl – Lower basaltic trachyandesite of Sawtooth Mountains (Miocene)**
This unit includes basaltic trachyandesite lava flows that were subdivided into several map units by Ferguson et al. (1999a). In southern exposures, the lower part of unit Tbl consists of crystal-rich trachyandesite lava with 20-40% phenocrysts of plagioclase, biotite, clinopyroxene and orthopyroxene. Plagioclase (20%, 1-4 mm) is weakly zoned (An40) and inclusion-rich. Biotite (2-7%) is 1-2 mm and commonly occurs in clumps with opaque minerals. Clinopyroxene (1-5%) is 1-2 mm and occurs as discrete phenocrysts and in glomeroporphyritic clots along with opaque minerals. Orthopyroxene (1-2%) occurs as brownish, inclusion-rich, rounded crystals typically surrounded by clinopyroxene, and also in glomeroporphyritic clots. The crystal-rich lavas are overlain by vesicular basaltic trachyandesite lava flows containing 5-10% phenocrysts (1-3 mm) of rusty clinopyroxene and olivine.

Other rocks of similar bulk composition but with variations in phenocryst assemblages occupy a similar stratigraphic position in the east-central and northern Sawtooth Mountains and are included in unit Tbl. At one area in the east-central part of the range, Ferguson et al. (1999a) subdivided these into three units. A lower vesicular basaltic trachyandesite contains 5-10% phenocrysts of olivine (0.5-3 mm) and clinopyroxene (0.5-1.5 mm) in subequal proportions, in a matrix of felted plagioclase microlites. This is overlain by moderately crystal-rich basaltic trachyandesite lava characterized by 5-10% phenocrysts of biotite up to 2 mm and conspicuous quartz (as much as 2%). Quartz forms rounded, embayed phenocrysts 0.5-1 mm in size. Biotite and quartz phenocrysts decrease in both size and abundance northward, coupled with an increase in size and abundance of strongly zoned plagioclase (up to 2 mm, 5-10%) and presence of clinopyroxene (<1 mm, < 2%). The quartz-phyric lava is overlain by vesicular basaltic andesite lava containing 5-10% phenocrysts of olivine (0.5-1 mm) and clinopyroxene (0.5-1.5 mm), which is the only subunit present in northernmost exposures of unit Tbl.

### *Samaniego Hills*

**Tts – Trachyte of Sasco (Miocene)**
The youngest succession of lava flows exposed in the Samaniego Hills, formerly called the Sasco Andesite and variations thereof (Eastwood, 1970), and consisting of several subunits that were described by Eastwood (1970) and later mapped by Ferguson et al. (1999b). Lava flows display widely variable textures including streaky flow-banded, massive, and pervasively brecciated. The lower part of the sequence consists of light-gray trachyte containing less than 1% phenocrysts of rounded subhedral plagioclase, lath-shaped hypersthene up to 2 mm long, and rare rounded quartz in a vitreous matrix. Both the hypersthene and quartz are commonly rimmed by augite. The middle and upper parts of the unit are typically crystal-poor (3-7%), but crystal-rich (25%) variations are locally present. The phenocryst assemblage is dominated by euhedral to subhedral (rounded) plagioclase (0.5-2 mm, An28-35) and biotite (<3 mm), with lesser amounts of rounded and embayed quartz (0.5-2 mm), subhedral sanidine (0.5-1 mm), augite, and rare hornblende. Euhedral magnetite grains 0.05-0.1 mm are ubiquitous. Microlites in the trachytic groundmass are predominantly plagioclase and pyroxene with variable amounts of biotite. The groundmass is typically vitreous and light gray to black. Alteration locally makes the rock appear dark red. Chemical analyses show all rocks of this unit to be trachyte (Eastwood, 1970).

**Tcu – Conglomerate, volcaniclastic (Miocene)**
Coarse-grained volcaniclastic sedimentary rocks, locally including some probable volcanic breccia. Overlies the basalt of Cerro Prieto.

**Tbcp – Basalt of Cerro Prieto (Miocene)**
Gray basalt containing up to 10% clinopyroxene (pigeonite) and olivine (0.5 mm) phenocrysts suspended in a highly crystalline matrix characterized by interlocking plagioclase crystals up to 3 mm long (An54-62). The matrix texture is reminiscent of diabase, and non-vesicular, massive portions of the flows strikingly resemble this type of rock. The basalt occurs as amalgamated lava flows with little or no sedimentary interbeds. Chemical analyses show this rock to be a true basalt (Eastwood, 1970).

**Tcl – Conglomerate and sandstone (Miocene)**
Medium- to thick-bedded sandstone, pebbly sandstone, and conglomerate containing clasts of basalt or pyroxene trachyandesite (70%), and dacite and granite (30%). The sand-sized fraction is typically arkosic. Underlies basalt of Cerro Prieto.

**Tta – Pyroxene trachyandesite (Miocene)**
Trachyandesite containing up to 10% phenocrysts of euhedral hypersthene (0.2-2 mm) ± olivine (up to 2 mm), and rare plagioclase (<1 mm). The unit occurs as amalgamated lava flows displaying widely variable textures and colors of matrix. The matrix ranges from glassy to finely crystalline and phenocryst content varies down to a few percent. The average of two analyses show this rock to be a trachyandesite (Eastwood, 1970).

## *Picacho Peak*

**Ta3 – Crystal-poor andesite (late Oligocene or early Miocene)**
Crystal-poor pyroxene-porphyritic lavas of probable trachyte, basaltic andesite, or andesite composition. The unit is characterized by sparse 1-mm pyroxene phenocrysts that typically have been replaced by brown iron-oxide(?) minerals, with finer-grained plagioclase phenocrysts also sparsely present. Locally this unit contains vesicles or amygdules, fresh pyroxene, or abundant plagioclase microlites. These lavas form a thick succession of amalgamated flows at the top of the volcanic sequence at Picacho Peak. Volcaniclastic and pyroclastic units are present between many of the flows, including thin-bedded tuff, massive tuff breccia, medium-grained volcaniclastic sandstone, and cobble-boulder conglomerate (Richard et al., 1999). The conglomerates locally contain some granitoid clasts.

A small klippe of andesite in the hanging wall of the Picacho Mountains detachment fault in the southeastern Picacho Mountains was included in this map unit (Richard et al., 1999). A sample from that rock contained 11.1% K20 and only 0.4% Na20, which indicates severe potassium metasomatism (Brooks, 1986). Lava flows with similar phenocryst mineralogy to that of typical rocks of Ta3 are present at the base of the Picacho Peak volcanic succession where they are mapped as older andesite (Ta1). The contact between unit Ta3 and the underlying biotite dacite (unit Td) is sharp and commonly marked by thin intervals of clastic rocks.

**Td – Dacite (late Oligocene or early Miocene)**
Crystal-rich biotite- and/or hornblende-phyric dacite. Plagioclase is commonly altered to chalky white, and mafic phenocrysts are commonly replaced by brown iron-oxide(?) minerals. The unit consists of amalgamated massive lava flows and flow breccia that thin from northwest to southeast into lava breccia, tuff breccia, and coarse-grained volcaniclastic sedimentary rocks in the vicinity of Picacho Peak. Volcaniclastic rocks, which were mapped separately by Richard et al. (1999), also underlie the dacite lava flows in the northwest, and pinch out to the southeast. They include a heterogeneous assemblage of massive to crudely bedded volcanic-lithic sandstone, conglomerate, and tuff. Clasts are mostly dacite, but also include a variety of andesitic lavas and light-gray pumiceous clasts. Crystal-rich andesite lava flows like those in underlying unit Ta2 are intercalated in the basal part of unit Td.

**Ta2 – Crystal-rich andesite (late Oligocene or early Miocene)**
A complex sequence of crystal-poor to crystal-rich lava flows of probable andesitic composition in amalgamated sequences and intercalated with thin volcaniclastic and pyroclastic units. The flows are characterized by dark-gray weathered surfaces, abundant 1-2 mm plagioclase phenocrysts, and pyroxene phenocrysts in widely varying amounts. In general, the flows become more crystal-rich upward. The unit includes small irregular intrusions of crystal-poor andesite that strongly resembles andesite of unit Ta3, and some of them were mapped separately by Richard et al. (1999). The contact with underlying andesite breccia of unit Ta1 appears to be a buttress unconformity at the northwest end of the outcrop belt, but at the southeast end the two units appear concordant.

**Ta1 – Andesite and andesite breccia (late Oligocene or early Miocene)**
This is a composite andesite unit that was subdivided into several units by Richard et al. (1999). The basal part consists of lava flows of probable trachyte, basaltic andesite, or andesite

composition and characterized by pyroxene-porphyritic texture and finer-grained, sparse plagioclase phenocrysts. These rocks are nearly identical to lava flows of unit Ta3, at the top of the Picacho Peak volcanic succession, but they are generally slightly more crystal-rich and are intercalated with nonvolcaniclastic conglomerate (Wymola conglomerate of Briscoe, 1967). Medium- to thick-bedded, pebble to boulder conglomerate and pebbly sandstone are weathered purple-gray and form rounded outcrops. Clasts include Proterozoic(?) phyllite and mica schist, coarse-grained pink biotite granitoid, fine-grained diorite, and quartzite. Rare clast types include Tertiary(?) andesite, Proterozoic(?) gneiss, Mesozoic(?) lithic arkose, and Proterozoic(?) conglomerate. The clasts are subrounded to subangular and are highly nonspherical. Imbricated phyllite clasts suggest transport toward the WSW. Some thick, matrix-supported beds in conglomerate may represent debris flows.

The upper part of unit Ta1 is a heterogeneous succession of crystal-poor to moderately crystal-rich andesitic lava breccia, tuff breccia and probable epiclastic breccia with several intercalated andesite lava flows. Some thin flows are plagioclase-phyric and crystal-poor. At least two lava flows are crystal-rich, containing about 50% plagioclase in 2-3 mm long laths that are aligned in a distinctive trachytic texture, as well as sparse pyroxene phenocrysts. These crystal-rich flows are at the base and the top of the andesite breccia pile. The most common clasts in the breccia at the northwest end of the outcrop belt are andesite containing ~5% equant white plagioclase phenocrysts. At the southeast end of the belt, the breccia contains angular boulders of andesite or dacite with hornblende phenocrysts up to 1 cm long. Neither of these clast types match any of the exposed lava flows in the Picacho Peak volcanic sequence.

### ***Tortolita Mountains***

**Tct – Conglomerate, sandstone, and tuff (Miocene)**
Thin- to thick-bedded pebbly sandstone, sandy pebble-cobble conglomerate, and sandstone, typically in tabular sets. Clasts are rounded to sub-angular and dominated by schist and granite with up to 20% mafic volcanic clasts. The unit includes a layer up to 5 m thick of white, phenocryst-poor, nonwelded tuff containing sparse lithic lapilli of granite and schist. The tuff yielded a 40Ar/39Ar sanidine age of 17.69 ± 0.17 Ma (Peters et al., 2003).

A small inselberg of arkosic sandstone in the basin east of Desert Peak has been included in this unit although correlation is uncertain. The sandstone is dark red, thin- to medium-bedded in tabular planar-laminated sets, and is medium-grained with trains of sub-rounded basalt pebbles.

**Tbtb – Basalt of Three Buttes (Oligocene–Miocene)**
Basalt flows and dikes in the Three Buttes area, north of the Tortolita Mountains. Basalt contains <1% conspicuous, dark, glassy clinopyroxene phenocrysts up to 3 cm and untwinned feldspar phenocrysts up to 15 mm.

Stratigraphic relationships between this distinctive basalt and underlying conglomerate units indicate that substantial topographic relief existed before deposition of conglomerate unit Tcg (Spencer et al., 2002). At one location, intercalated basalt lava flows are concordant to bedding in the conglomerate, and conglomerate contains clasts of the basalt. This location is approximately 500 m stratigraphically above the contact where conglomerate of unit Tcg rests on conglomerate of underlying map unit Tc, but on the north side of Coronado Wash, vesicular basalt lava flows and flow breccia are in contact with the older conglomerate of unit Tc.

A sample of the basalt of Three Buttes yielded a K-Ar whole-rock date of 21.06 ± 0.45 Ma (Damon et al., 1996). Spencer et al. (2002) reported isotopic data from a sample of clinopyroxene from the basalt, including an εNd value of -4.39. They interpreted this negative εNd value as indicating that the basalt was most likely derived from lithospheric mantle, probably by subduction-related magmatic processes.

**Tcg – Conglomerate, dominantly granitic clasts (Oligocene–Miocene)**
Poorly sorted, massive to thick-bedded, sandy conglomerate with dominantly granitic debris including pebbles, cobbles, and boulders of coarse-grained, K-feldspar porphyritic granite. The unit contains up to 10% mafic volcanic clasts, and clasts of Pinal Schist are locally abundant in southeasternmost exposures. Outcrops commonly have a rounded form and are tan to light brown, unlike typically medium- to dark-brown to reddish-brown polymictic conglomerate of underlying map unit Tc, although the contact with unit Tc is locally gradational. Rocks of unit Tcg were correlated with the San Manuel Formation of Heindl (1963) by Dickinson and Shafiqullah (1989) and Dickinson (1991). A sample from a 10-cm-thick tuff layer in this conglomerate exposed in upper Coronado Wash yielded a 40Ar/39Ar sanidine date of 19.68 ± 0.3 Ma (Peters et al., 2003).

**Tc – Conglomerate, polymictic (Oligocene–Miocene)**
Conglomerate and pebbly sandstone containing subangular to rounded pebbles, cobbles, and rare boulders of schist, granite, and mafic to intermediate volcanic rocks. Mafic volcanic clasts are abundant at lower stratigraphic levels, whereas granitic rocks and Pinal Schist commonly constitute a significant minority of clasts at higher levels. Subrounded quartzite cobbles are locally present. The conglomerate is medium to dark brown to reddish brown, thin- to thick-bedded, poorly to moderately sorted, and generally clast-supported. The unit locally includes poorly sorted coarse-grained sandstone and sandy pebble conglomerate. Bedded intervals are interpreted as alluvial fan deposits, and local massive conglomerates are interpreted as mudflows (Spencer et al., 2002). Rocks of this unit were correlated with the Cloudburst Formation of Heindl (1963) and Creasey (1965) by Dickinson and Shafiqullah (1989) and Dickinson (1991).

Near Forman Wash the unit contains a volcanic-lithic tuff approximately 10 m thick, with 1-2% 1mm quartz, 2-3% 1-2mm oxidized biotite, several percent feldspar, and 5-10% 1-10mm mafic to intermediate volcanic-lithic fragments (Spencer et al., 2002).

**Tx – Rock avalanche breccia (Oligocene–Miocene)**
Breccia and rubble derived from coarse-grained, equigranular to K-feldspar-porphyritic granite containing up to 10% biotite. Quartz veins are typically shattered and recemented with reddish brown hematitic silica. In some exposures, rocks of this unit are so weakly brecciated that mylonitic shear zones and shattered quartz veins within granite can be mapped for tens of meters with little dismemberment. In the Antelope Peak area near the southern limit of unit Tx on this map, the granite is not brecciated and apparently forms a megablock within the breccia. Locally, rocks of this unit were derived from banded gneiss. Spencer et al. (2002) also mapped subunits of breccia derived from mylonitic granite, leucogranite, diabase, and Pinal Schist. Almost all exposures form a large, discontinuous sheet that appears to be stratigraphically above map unit Tcg, but that locally includes exposures that are associated with map units Tc and Tb. This unit is inferred to have been derived from the Black Mountain area to the northeast (east of this map area), where bedrock is lithologically very similar (Orr et al., 2002; Krieger, 1974).

**Tbd – Basaltic andesite, andesite, and dacite (Oligocene–Miocene)**
A succession more than 1 km thick of basalt to trachyte lava flows with sparse volcaniclastic sandstone, conglomerate, and silicic ash-flow tuff, that overlies crystalline basement in the northern foothills of the Tortolita Mountains (Ferguson et al., 2002; Spencer et al., 2002). In general, the lava flows are less than 50 m thick and intervening sedimentary strata, where present, are thin and discontinuous. Flow breaks in amalgamated sequences are defined by zones of reddish autobreccia typically infiltrated with red volcaniclastic sandstone.

Ferguson et al. (2002) mapped four different lava types to which they assigned field names based on phenocryst mineralogy. An aphyric basalt unit occurs at the base of the succession, locally overlying conglomerate <20 m thick containing clasts of schist derived from the local Paleoproterozoic basement. Porphyritic mafic lavas like those of unit Tb contain 2-15% phenocrysts of pyroxene and olivine and range from basalt to basaltic trachyandesite in composition. Intermediate (andesitic) lavas contain plagioclase with subordinate pyroxene and olivine phenocrysts and range from trachyandesite to trachyte in composition. Silicic (dacitic) lavas contain plagioclase and biotite phenocrysts and range from trachyte to rhyolite in chemical composition. In the Owl Head Buttes, dacitic lavas contain 5-10% plagioclase phenocrysts along with biotite and form two massive to autobrecciated flows that grade northward into monomict dacite-clast breccia and conglomerate. Dacitic lavas exposed north of Chief Butte contain <1% quartz (2-3 mm), <1% biotite (1 mm), and 2-5% feldspar phenocrysts (1-4 mm). Dacitic lava flows on inselbergs southwest of Durham Hills contain 20-25% plagioclase phenocrysts and are strongly potassium metasomatized (Richard et al., 2002). Except for the aphyric basalt, which is only at the base of the volcanic section, lava flows of all types occur at multiple stratigraphic levels in the succession.

A moderately welded rhyolitic ash-flow tuff up to 15 m thick is intercalated with mafic lava flows in the upper part of the succession at Chief Butte and in the lower part of the section at Owl Head Buttes (Ferguson et al., 2002). The tuff contains ~10% phenocrysts of plagioclase, sanidine, biotite, and quartz and up to 10% mafic to intermediate volcanic lapilli in a peach-colored matrix. This tuff yielded a 40Ar/39Ar sanidine age of 26.39 ± 0.07 Ma (Peters et al., 2003). Hypabyssal intrusions identical to the andesitic and dacitic rocks have also been mapped in this volcanic sequence (Ferguson et al., 2002; Spencer et al., 2002). A K-Ar biotite date of 26.7 ± 0.5 Ma was obtained from a dacitic intrusion (Banks et al., 1978).

**Tb – Basaltic andesite (Oligocene–Miocene)**
Amalgamated mafic lava flows characterized by phenocryst assemblages of 2-15% pyroxene, olivine (partly altered to iddingsite), and subordinate plagioclase. Pyroxene and olivine range from 0.3 to 4 mm and plagioclase phenocrysts are typically less than 1.5 mm. The groundmass is typically microcrystalline, but locally aphanitic, and ranges from vesicular to massive. Individual flow units are 2 to 20 m thick. The flow tops are defined by reddish scoriaceous zones that are commonly infiltrated with red volcaniclastic sandstone, and thin intervals of volcaniclastic sandstone occur between many of the flows. Compositionally, the lavas range from true basalt to trachybasalt and basaltic trachyandesite. A sample of this unit from the Owl Head Buttes area yielded a whole rock K-Ar date of 21.0 ± 0.5 Ma (Jennison, 1976).

North of the Tortolita Mountains near Coronado Wash, a thin tuff unit is intercalated with the basaltic lava flows. The tuff is pale tan, slightly porous, and moderately to well-consolidated.

Spencer et al. (2002) inferred the tuff as being correlative with tuff that is interbedded with the Cloudburst Formation east of the map area, which has been dated at 26.33 ± 0.1 Ma, and with a tuff within map unit Tbd to the southwest in the northern Tortolita Mountains dated at 26.39 ± 0.07 Ma (40Ar/39Ar sanidine dates; Orr et al., 2004; Ferguson et al., 2002; Peters et al., 2003).

### *Inselbergs*

**Tcb – Breccia and conglomerate (Oligocene–Miocene)**
Interbedded matrix-supported breccia, clast-supported conglomerate, and minor reddish brown, medium- to coarse-grained sandstone. The unit is exposed at Burgess Peak (on the northwest side of the city of Casa Grande) and in the Sacaton porphyry copper deposit. These poorly sorted deposits contain angular to subrounded clasts up to 50 cm of quartz-porphyritic medium-grained granitoid (map unit Kgq), medium-grained equigranular granitoid with minor hornblende (map unit Kgs), and less abundant granite porphyry and fine-grained biotite schist, in a red sandy matrix. Clast sizes range from sand to boulders. The deposits are thin- to medium-bedded with interbeds and thin lenses of red, fine-grained, silty sandstone a few cm thick. Some beds are normally or reversely graded.

**Tmv – Mafic volcanic rocks, undivided (Oligocene–Miocene)**
Fine-grained mafic volcanic rocks exposed in isolated inselbergs northwest of Chuichu and the Silver Reef Mountains (Klawon et al., 1998). An isolated hill near the center of the southern edge of the map area was included in this unit based on similar appearance on imagery to nearby hills to the south that were mapped as basalt and andesite by Sawyer (1996).

## Late Paleogene – Neogene tectonites derived from older protoliths

**Tz – Mylonitic rocks (late Oligocene and older protoliths, Oligocene to early Miocene overprint)**
Heterogeneous mylonitic rocks, derived from granodiorite and diorite of the Durham Hills (units Tgd and Tdi), Pinal Schist (Xp), and possibly other units. Characterized by well-developed mylonitic fabric that obscures the exact nature of the protolith. Rock is typically drab gray-green, very fine-grained, quartz-feldspar-chlorite mylonite. Transposed quartz veins are common. This unit includes strongly fractured and hematite-stained mylonite that was mapped as a separate unit by Richard et al. (2002), affected by chloritic and hematitic alteration with local fracture-filling secondary copper minerals. Some rocks have been so transposed by shearing that they have been converted to a thinly layered gneiss, with layers 2-10 mm thick.

**TYp – Granitoid protocataclasite (Mesoproterozoic(?) protolith, Oligocene–Miocene overprint)**
Very strongly shattered coarse-grained granitoid. Protolith is probably biotite granite of map unit Yg. All biotite has been altered to chlorite, and plagioclase is greenish and saussuritized. Rock appears granulated, but aplite dikes and quartz veins are locally preserved. Cataclasis is associated with the Suizo-Cloudburst detachment fault (e.g., Dickinson, 1991), and occurred in the hanging wall of the fault and directly adjacent to it (Spencer et al., 2002).

**TXz** – **Pinal Schist with mylonitic overprint (Paleoproterozoic protolith, Oligocene–Miocene overprint)**
Pinal Schist (unit Xp) with strongly planar fabric. Lenses of leucocratic granitoid concordant to foliation are apparently the transposed remnants of muscovite granite and pegmatite dikes. Rootless isoclinal fold hinges in mm- to cm-scale differentiated foliation are commonly visible. Mylonitic stretching lineation is poorly developed in mica-rich rock, but is easily seen in transposed quartz veins and granitoid dikes. The stretching lineation is typically parallel to prominent intersection lineation formed between older laminated differentiated foliation and mylonitic foliation. The map unit includes chloritic breccia in the immediate footwall of the Suizo-Cloudburst detachment fault, which was mapped as a separate unit by Spencer et al. (2002) and Richard et al. (2002).

## Late Paleogene – Neogene intrusive rocks

### *Picacho Mountains*

**Tm** – **Mafic intrusive rocks (Oligocene or Miocene)**
Mostly dark gray, very fine-grained diorite or diabase. The rock consists of aphanitic to very fine-grained aggregate of plagioclase and hornblende or pyroxene (variably altered to chlorite-epidote), and contains sparse feldspar and quartz crystals up to 3 mm in diameter. Texture varies from nearly massive to mylonitic, and the following structural relationships described by Richard et al. (1999) support an interpretation that this unit was emplaced at upper-crustal levels during mylonitization associated with detachment faulting.

A sill of this diorite intrudes granitoid rocks in the footwall of the Picacho Mountains detachment fault. Below the sill, mylonitic hornblende-K-feldspar granitoid of map unit TXg is progressively more brecciated and silicified structurally upward toward the intrusive contact with the sill. Granite of unit Yg above the sill is crushed and propylitically altered but is not mylonitic. The sill itself locally exhibits mylonitic fabric near its base, and near its upper contact with the overlying granite it is brecciated, chloritic, contains fragments of fine-grained mylonite, and is broken by pervasive hematite-filled fractures. Small dikes extend upward from the sill into overlying granite and locally extend to the level of the detachment fault at the structural top of the granite. The lack of mylonitic fabric in the granite (Yg) above the sill, the presence of incipient microbreccia along the contact of the sill with the underlying granitoid (TXg), and the presence of mylonitic fabric in the lower part of the diorite sill are consistent with synkinematic emplacement of the sill along another, structurally lower, detachment fault between mylonitic unit TXg and overlying unit Yg. Rehrig (1986) interpreted the base of the sill as the lower of two detachments, with the upper detachment as shown on this map.

**Ti** – **Fine-grained monzogranite (late Oligocene or Miocene)**
Small stocks of fine-grained monzogranite intruding unit Tgh in the northern Picacho Mountains (Johnson, 1981a). The stocks are predominantly monzogranite, whereas associated dikes range from monzogranite to monzonite to alkali feldspar syenite. The rocks generally contain 5-10% mafic minerals, primarily hornblende and biotite, and are holocrystalline, fine grained, and equigranular (Johnson, 1981b).

**Tgh – Hornblende granitoid of Picacho Reservoir (late Oligocene)**
Medium- to coarse-grained equigranular granite, quartz monzonite, quartz monzodiorite, and granodiorite. Consists of 12-25% quartz, 20-35% orthoclase, 35-50% plagioclase, and 10-20% mafic minerals (Johnson, 1981b). Hornblende is the predominant mafic mineral, forming euhedral crystals up to 1 cm long. Dark colored, medium- to fine-grained, hornblende-rich enclaves, typically about 10 cm diameter, are common. Intrudes Picacho Mountains Granite. Johnson (1981b) reported a K-Ar biotite date of 24.6 ± 0 .5 Ma from the hornblende granitoid unit. The rock has also yielded a U-Pb zircon age of 25.1 Ma (Spencer et al., 2022).

**Tib – Barnett Well Granite and felsic dikes (late Oligocene – Miocene)**
Barnett Well Granite (Tgb) intruded by abundant sub-parallel felsic dikes. Some dikes display an internal foliation parallel to dike margins, but the granite is non-foliated or very weakly foliated (Richard et al., 1999).

**Tgb – Barnett Well Granite (late Oligocene)**
Fine- to medium-grained, equigranular biotite granite or granodiorite, named for exposures near Barnett Well in the southern Picacho Mountains (Richard et al., 1999). The rock consists of 20-40% quartz, 60-80% feldspar, and 2-5% biotite. Plagioclase appears to be the predominant feldspar. Grain size is typically 1-2 mm, with sparse subhedral feldspar crystals 2-3 mm in diameter. The Barnett Well Granite is typically non-foliated and it intrudes across the vague compositional layering in Picacho Mountains Granite (Tpm) and across well-developed mylonitic foliation in hornblende-K-feldspar granitoid of unit TXg. However, the rock displays mylonitic foliation near contacts with some other units, especially with the amphibolite and diorite of unit TXm. A U-Pb zircon age of 25.4 Ma has been reported from the Barnett Well Granite (Spencer et al., 2022).

### *Tortolita Mountains and Durham Hills*

**Tgt – Tortolita Granite (late Oligocene)**
Medium-grained equigranular granite composed of 35% K-feldspar, 30% quartz, 20% plagioclase, 5-12% biotite and opaque minerals. The granite occurs as a swarm of dikes that intrude the pluton of Wild Burro Canyon in the southeast corner of the map area, emanating from a pluton south of the map area (Ferguson et al., 2002). The dikes exhibit strong mylonitic fabrics. A K/Ar biotite cooling age of 22.7 ± 0.7 Ma (Creasy et al., 1977), a 40Ar/39Ar biotite cooling age of 23.69 ± 0.15 Ma (Spell et al., 2003), and a U-Pb (TIMS) zircon crystallization age of 24.2 ± 1.3 Ma (Spencer et al., 2015) have been obtained from this unit. The unit was previously referred to as the quartz monzonite of Tortolita Mountains by Banks (1980) and the Tortolita quartz monzonite by Keith et al. (1980).

**Tgw – Pluton of Wild Burro Canyon (late Oligocene)**
Called the quartz monzonite of Wild Burro Canyon by Banks (1980) and considered by Keith et al. (1980) as correlating with the Catalina quartz monzonite in the Santa Catalina Mountains, this is a steeply southeast-dipping tabular pluton composed of three distinct phases that were mapped separately by Ferguson et al. (2002). The main phase is medium- to coarse-grained, K-feldspar porphyritic quartz monzonite with 15-30% biotite and hornblende. The mafic phase consists of lenticular to irregular bodies of fine- to medium-grained biotite-hornblende quartz monzodiorite

to diorite, variably containing 30-60% mafic minerals, distributed along the southeast margin of the pluton. And the western phase forms a sheet of medium- to coarse-grained equigranular granite with <10% biotite along the northwest margin of the pluton. The main and mafic phases show mutually intrusive contact relationships and mingling textures. The western phase is generally the youngest phase but is locally intruded by mafic phase.

The mafic phase is characteristically heterogeneous, with mafic-rich, fine- to medium-grained diorite to monzodiorite mingled with less mafic-rich, medium-grained monzodiorite to quartz monzodiorite, locally with streaks of quartz monzonite that are sparsely K-feldspar porphyritic. The main phase contains up to 10% mafic enclaves oriented parallel to a pervasive foliation, and these are most abundant near bodies of the mafic phase. The foliation is a weak shape fabric to moderate protomylonitic foliation that dips steeply southeast, parallel to metasedimentary screens located in the northwestern part of the pluton.

A K-Ar biotite date of 28.0 ± 0.9 Ma (Mauger et al., 1968), a 40Ar/39Ar biotite cooling age of 22.36 ± 0.15 Ma (Spell et al., 2003), and a U-Pb (LA-ICPMS) zircon crystallization age of 24.4 ± 0.3 Ma (Spencer et al., 2015) have been obtained from the main phase of the pluton.

**Tgd – Porphyritic granodiorite of Durham Hills (late Oligocene)**
Distinctive porphyritic rock, contains pinkish white K-feldspar phenocrysts (1-2 cm) in highly variable abundance up to approximately 40%, in a dark biotite-rich groundmass. The rock commonly weathers to form large rounded boulders littering the surface. A sample from this unit yielded a U-Pb (TIMS) zircon age of 25.7 ± 0.1 Ma (Spencer et al., 2015).

**Tdi – Diorite to granodiorite of Durham Hills (late Oligocene)**
Ranges from medium-grained (3-5 mm), equigranular hornblende diorite to fine-grained biotite-hornblende granodiorite, mostly medium-gray color. K-feldspar phenocrysts 0.5-1 cm are present locally, and sphene is a common accessory mineral. Irregular intrusive contacts between phases within the unit. A dike of porphyritic granodiorite (unit Tgd) containing stoped blocks of diorite-granodiorite was observed intruding this unit in the southern Durham Hills, demonstrating that at least locally the porphyritic granodiorite is younger (Richard et al., 2002). Strain is highly variable, the rock ranging from mylonite to non-foliated.

## Late Cretaceous – Paleogene intrusive rocks (and crystalline complexes that include older country rocks)

### *Picacho Mountains*

**Tpm – Picacho Mountains Granite (Paleocene)**
Texturally and compositionally variable granitoid complex, named for exposures in the west-central Picacho Mountains (Richard et al., 1999). Rocks range in composition from medium-grained, biotite±muscovite granite or granodiorite to faintly heterogeneous layered granitoids to heterogeneous gneiss with local layers of augen gneiss and muscovite granite. The predominant phase is medium-grained biotite to muscovite-biotite granite, locally slightly K-feldspar porphyritic, characterized by seriate texture, tawny color, vague compositional banding, and moderate to strong foliation. In northwestern exposures it is more equigranular, medium-grained, contains 2-5% biotite, and foliation is less apparent. In some areas, notably along the west side of

Newman Peak, the rock contains 2-5% muscovite flakes 1-4 mm across as well as 1-4% biotite. Along the ridge north of Newman Peak the granite contains >10% variably foliated, locally garnet-bearing pegmatite dikes and sills, and typically contains more muscovite than the main phase. West and southwest of Newman Peak the unit contains zones of distinctly gneissic and heterogeneous granitoid with ubiquitous and obvious compositional banding and lithologic variability. Heterogeneous gneissic varieties at low elevations include dark-gray, coarse-grained, porphyritic biotite granitoid and gray, fine-grained, equigranular granodiorite in addition to the main-phase granite. Richard et al. (1999) mapped muscovite-rich, pegmatite-rich, and gneissic phases separately from the main phase. A K-Ar biotite date of 23.57 ± 0.5 Ma was derived from massive granite in the northwest part of the unit (Johnson, 1981a, b; Damon et aI., 1996), representing either post-intrusive cooling of a mid-Tertiary pluton or cooling related to tectonic denudation of an older buried pluton. A U-Pb (TIMS) zircon age of 59.3 ± 1 Ma has been obtained from the granite (Spencer et al., 2003, 2015).

TKn – **Newman Peak Leucogranite (Late Cretaceous – Eocene)**
Medium-grained, equigranular muscovite granite, locally containing garnet, exposed at the summit of Newman Peak in the southern Picacho Mountains. Pegmatite is common, especially near contacts with structurally underlying rocks and with screens of Pinal Schist (Xp) that are common near the structural base of the unit. Numerous sills of muscovite leucogranite and pegmatite occur in the upper part of unit TXg where it is present beneath the Newman Peak leucogranite, and the base of the Newman Peak unit is mapped where overlying rock is more than 50% muscovite granite (Richard et al., 1999). Mylonitic fabrics are well developed in screens of Pinal Schist but are absent to weak in the granite and pegmatite. In general, the upper part of the unit is homogeneous muscovite granite.

TKct – **Clemans Tank Diorite (Late Cretaceous or Paleogene)**
Diorite and minor associated granite in the northern Picacho Mountains, collectively called Clemans Tank Diorite (Richard et al., 1999). The diorite and granite are both medium- to coarse-grained and are texturally similar (Johnson, 1981b). The diorite contains over 30 percent mafic minerals. The granite also has a high mafic mineral content (about 20 percent). A K-Ar date of 67.0 ± 1.4 Ma was reported from the granite by Johnson (1981b) and was recalculated as 65.08 ± 1.4 Ma by Damon et al. (1996).

TKin – **North Star granite and monzonite (Late Cretaceous or Paleogene)**
The North Star granite and the North Star monzonite are small stocks mapped in the vicinity of the North Star mine in the northern Picacho Mountains (Johnson, 1981a, 1981b). The granite is coarse-grained and equigranular and is composed of about 35% quartz, 35-45% K-feldspar, 15-25% plagioclase, and 4-8% mafic minerals. The monzonite is fine- to medium-grained and is typically porphyritic with medium-grained phenocrysts of plagioclase in a fine-grained phaneritic groundmass of orthoclase, quartz, and mafic minerals. It contains 40-50% plagioclase and up to 20% mafic minerals.

## *Tortolita Mountains*

**Tgf – Derrio Canyon granite (Paleogene)**
Medium-grained leucogranite containing small amounts of muscovite, garnet, and biotite in varying ratios. Pegmatite containing muscovite, garnet, and rare biotite forms dikes and pods in the leucogranite and in adjacent country rocks. The dikes typically consist of a pegmatite core and margins of fine- to medium-grained leucogranite. The Derrio Canyon granite forms a broadly arched sheet-like pluton in the northwestern Tortolita Mountains, from which dikes of the granite and pegmatite extend into country rocks of the pluton of Chirreon Wash (unit Kgc) and the Pinal Schist (unit Xp). Dike swarms were mapped as composite units by Ferguson et al. (2002), which are here designated Tf-Kc, Kc-Tf, and Tf-Xp.

The Derrio Canyon granite generally exhibits a protomylonitic foliation and WSW-trending elongation lineation, with asymmetric fabrics in the pluton consistently indicating top-to-WSW sense of shear (Ferguson et al., 2002). Spell et al. (2003) obtained a 40Ar/39Ar muscovite cooling age of 25.29 ± 0.15 Ma from the granite near the head of Fresnal Canyon. The unit has been called the quartz monzonite of Samaniego Ridge (Banks et al., 1977), the pluton of Cottonwood Canyon (Banks, 1980), the Derrio Canyon granite (Keith et al., 1980), and the granite of Fresnal Canyon (Ferguson et al., 2002), and it is related to the Wilderness suite of peraluminous granites in the Santa Catalina Mountains (Keith et al., 1980; Dickinson, 1991). U-Pb zircon (LA-ICPMS) ages from the Wilderness suite are latest Paleocene to middle Eocene, ranging from 58 to 45 Ma (Fornash et al., 2013). Zircons from one Wilderness intrusion show complex zoning with magmatic domains as young as 40 Ma and metamorphic rims as young as 34 Ma (Davis et al., 2019).

**Tf-Kc – Derrio Canyon granite with abundant screens of the pluton of Chirreon Wash (Paleogene and Late Cretaceous)**
A composite unit consisting of pluton of Chirreon Wash (unit Kgc) intruded by abundant dikes of Derrio Canyon granite (Tgf) that constitute more than 35% of the unit.

**Tf-Xp – Derrio Canyon granite with abundant screens of Pinal Schist (Paleogene and Paleoproterozoic)**
A composite unit consisting of Pinal Schist (unit Xp) intruded by abundant dikes of Derrio Canyon granite (unit Tgf).

**Kgc – Pluton of Chirreon Wash (Late Cretaceous)**
Medium-grained, equigranular quartz monzonite, monzogranite, and granodiorite in the northern Tortolita Mountains. These rocks contain 15-30% ferromagnesian minerals, comprised of subequal amounts of biotite and hornblende, minor clinopyroxene, and minor opaque minerals. In the southeastern part of the pluton there are a few small zones with K-feldspar-porphyritic texture, and relatively mafic and leucocratic phases are present in the eastern part (Ferguson et al., 2002). A weak foliation with a consistent moderate northwesterly dip is ubiquitous. The unit was named the pluton of Chirreon Wash by Banks (1980) and has also been referred to as the Chirreon Wash granodiorite (Keith et al., 1980) and the Granite of Derrio Canyon (Skotnicki, 2000). A U-Pb (TIMS) zircon crystallization age of 69.5 ± 0.5 Ma was obtained from the central

part of the Tortolita Mountains (Spencer et al., 2003). A K-Ar biotite cooling age of 25.1 ± 0.9 Ma was obtained from this unit on the eastern piedmont (Banks et al., 1978).

Kc-Tf – **Pluton of Chirreon Wash and abundant dikes of the Derrio Canyon granite (Late Cretaceous and Paleogene)**
A composite unit consisting of the pluton of Chirreon Wash (unit Kgc) intruded by 5-35% dikes of Derrio Canyon granite (Tgf).

### *Suizo Mountains*

TKlg – **Leucogranite of the Suizo Mountains (Late Cretaceous or Paleogene)**
Leucocratic biotite-muscovite granite containing about 20% quartz 1-3 mm in diameter, weakly to moderately sericitized plagioclase, and generally <7% combined muscovite and biotite. Locally contains 2-3% garnet (0.1-3 mm) and up to 7% muscovite, while biotite typically forms <2% of the rock. In some areas the unit consists of pegmatite and pegmatitic quartz veins. Rock is generally resistant and forms ridge tops in the Suizo Mountains.

TKl-Xp – **Leucogranite complex of the Suizo Mountains (Paleoproterozoic and Late Cretaceous or Paleogene)**
Heterogeneous pegmatitic muscovite leucogranite with screens of muscovite-biotite Pinal Schist (unit Xp), and Pinal Schist with concordant veinlets and sheets of leucogranite. Garnet is locally present in the schist. Leucogranite dikes locally cross-cut laminated differentiated foliation in schist, which is interpreted as Proterozoic fabric. As designated by Spencer et al. (2002), the leucogranite complex of the Suizo Mountains comprises the crystalline rocks of the Suizo Mountains and adjacent lowlands that have been exhumed in the footwall of the Suizo-Cloudburst detachment fault, including map units that are combined here as unit TKl-Xp, but also leucogranite of unit TKlg and mylonitic Pinal Schist (unit TXz). The name is used in a restricted sense here.

### *Ninetysix Hills*

TKgm – **Muscovite-biotite granite of the Ninetysix Hills (Late Cretaceous or Paleogene)**
Granite containing light gray anhedral to subhedral phenocrysts of feldspar up to ~8 mm, dark clear-gray quartz, and 5-10% mica (biotite:muscovite typically ~4:1). Micas occur both as thin sheets and as subhedral books 2-5 mm wide. The granite is cut by pegmatitic and leucogranite dikes, particularly near contacts with older rocks. In at least one location the rock contains traces of dark-red subhedral garnet 5-10 mm across. The rock is generally nonfoliated except on the southeast side of the pluton where augen-shaped feldspars, elongate quartz, and aligned micas define a protomylonitic fabric. Fresh surfaces of this granite are light gray and weathered surfaces are light tan to orange. The contact with the Tea Cup granodiorite is very poorly exposed, but since dikes cutting Kgt do not cut this granite, TKgm is inferred as being younger (Skotnicki, 1999).

Kgt – **Tea Cup Granodiorite (Late Cretaceous)**
Medium- to coarse-grained leucogranite to leucogranodiorite containing abundant conspicuous, gray, anhedral quartz phenocrysts 0.5-1.5 cm wide, surrounded by light pinkish-gray subhedral

K-feldspar, subordinate white plagioclase (euhedral to subhedral), 2-5% biotite, and locally minor muscovite (Skotnicki, 1999, and the present study). Including groundmass quartz, the overall quartz content is 30-35%. Biotite is relatively fresh but locally altered to hematite, and forms anhedral to subhedral crystals and thin books commonly 3-4 mm across but locally as large as 1 cm. The rock crumbles into low relief, light-gray, gruss-covered hills and pediment. Sample BJJ-6675 was collected from Box O Wash near the Florence-Kelvin Highway during the present compilation project in 2022 and analyzed at the Arizona LaserChron Center, University of Arizona, in 2023. The analyses yield a preliminary U-Pb (LA-ICPMS) zircon age of 69.1 ± 0.9 Ma. North of this map area, the Tea Cup granodiorite is extensively exposed in the Mount Grayback area (Cornwall and Krieger, 1975). U-Pb (LA-ICPMS) zircon ages have been obtained from hornblende-biotite granodiorite (73.8 ± 0.8 Ma and 70.53 ± 0.73 Ma) in upper levels of the composite pluton and from biotite-muscovite granite (72.7 ± 1.1 Ma and 71.1 ± 1.9 Ma) exposed at deeper levels near Mount Grayback (Seedorff et al., 2019; Nickerson, 2012).

**Kgo – Box O Granodiorite and related intrusions (Late Cretaceous)**
Skotnicki (1999; map unit TYg) described this unit as medium-grained to locally coarse-grained and containing subhedral phenocrysts of light-gray feldspar, abundant clear-gray quartz, biotite, minor hornblende, and locally abundant sphene (titanite). The rock locally contains tabular mafic inclusions ~5-20 cm long and K-feldspar megacrysts up to 3 cm long, aligned parallel to a weak to strong foliation. In some exposures a slightly more felsic variety of granite is in sharp contact with a more mafic variety. Skotnicki noted that there are textural differences between northern and southern exposures of this unit and that they may be two different plutons. Spencer et al. (2003) obtained a U-Pb (TIMS) zircon age of 75.8 ± 2.3 Ma from a foliated granitoid of this unit in the southeast, which they described as a compositionally heterogeneous suite of tonalitic to quartz dioritic granitoids, some of which are variably mylonitic. Sample BJJ-6673 was collected from a northern exposure at Box O Ranch during the present compilation project in 2022 and analyzed at the Arizona LaserChron Center, University of Arizona, in 2023. The analyses yield a preliminary U-Pb (LA-ICPMS) zircon age of 75.2 ± 1.0 Ma. At Box O Ranch and on the west side of unit Kgt this unit is medium-grained hornblende-biotite granodiorite containing 15% mafic minerals, including up to 1% titanite. The rock locally grades into a leucocratic phase with 5% biotite, which resembles unit Kgt. Yeend et al. (1977) used the name ‘granodiorite of the Box O Ranch’ for this unit along Box O Wash.

### *Sacaton Mountains*

**TKs – Sacaton porphyry and breccia (Late Cretaceous or Paleogene)**
Quartz-biotite-feldspar porphyry and associated intrusive breccia, exposed in the Sacaton porphyry copper mine. Phenocrysts in the porphyry are 75% euhedral plagioclase 2-4 mm long, 10-15% euhedral biotite books 2 mm across, 10% or more clear subhedral quartz 2-3 mm, and 1-3% subhedral orthoclase 2-3 mm in a fine-grained groundmass of intergrown feldspar and quartz (Cummings, 1982; Skotnicki and Ferguson, 1996). Feldspar in the matrix is altered. Hornblende is present locally. These rocks occur as irregular masses, dike-like bodies, and breccias that in some places contain a mix of porphyry and granite clasts.

**Kgq – Sacaton Peak Granite, quartz-porphyritic phase (Late Cretaceous)**
Equigranular, medium-grained, slightly quartz-porphyritic granite to quartz monzonite exposed in the eastern Sacaton Mountains. Quartz phenocrysts are clear to milky gray and are typically rounded. The quartz-porphyritic phase is slightly coarser-grained than unit Kgs, and the contact between them is subtle but sharp. Compositional banding, defined by cm-scale bands of leucocratic and melanocratic granite containing 5-10% and 20-50% biotite respectively, is well-developed locally. The bands are not internally foliated. This unit forms the central core zone of the Sacaton Peak Granite pluton as mapped by Balla (1972), named for Sacaton Peak which is <300 m north of the edge of this map area. Balla (1972) reported a K-Ar biotite date of 62.9 ± 1.4 Ma (recalculated in Reynolds et al., 1986) from north of Sacaton Peak.

**Kgk – Sacaton Peak Granite, K-feldspar porphyritic phase (Late Cretaceous)**
Porphyritic granite to quartz monzonite characterized by relatively abundant euhedral poikilitic phenocrysts of orthoclase up to 4 cm long. The rock is medium to coarse grained and is sparsely porphyritic to seriate. Grades northward into the quartz-porphyritic phase (map unit Kgq), the contact being indistinct.

**Kgs – Sacaton Peak Granite, equigranular phase (Late Cretaceous)**
Medium-grained, equigranular quartz monzonite to granite containing clear-gray quartz, gray subhedral feldspars, biotite, and locally hornblende. K-feldspar is locally poikilitic. Near the contact with the mafic phase of the Sacaton Peak Granite (unit Kgm) the rock contains 1-2% hornblende phenocrysts 4-8 mm long and euhedral to subhedral sphene, and locally displays flow banding defined by subtle alignment of biotite and feldspar. This unit was originally named the Three Peaks Monzonite by Balla (1972). Skotnicki and Ferguson (1996) considered it to be closely related to the Sacaton Peak Granite of Balla (corresponding to units Kgq and Kgk here) and renamed it as a phase of that pluton. A K-Ar biotite date of 71.4 ± 1.4 Ma from this unit was reported by Balla (1972; recalculated in Reynolds et al., 1986).

**Kgm – Sacaton Peak Granite, mafic phase (Late Cretaceous)**
Biotite-rich, medium- to fine-grained, equigranular granitoid ranging in composition from quartz monzonite to quartz monzodiorite and diorite. The rock contains about 5% quartz, 60% light gray feldspars, and 15-25% biotite, with variable amounts of hornblende generally less abundant than biotite. Biotite occurs in felty clumps. Hornblende forms phenocrysts that locally are up to 1 cm long. Subhedral to euhedral sphene is commonly present. Intrusive contacts with Proterozoic units Yga and Yg are sharp, and xenoliths of those rocks occur in Kgm near the contact. The contact between this unit and unit Kgs is difficult to discern in outcrop, but from a distance it appears as a subtle color difference between the darker Kgm and the lighter Kgs. Unit Kgm is the outer zone of the Three Peaks Monzonite of Balla (1972). Skotnicki and Ferguson (1996) reassigned it to the Sacaton Peak Granite because they considered it to be genetically related to that pluton as defined by Balla.

**Ksp – Signal Peak Granite (Late Cretaceous)**
Equigranular biotite granite and quartz monzonite with sparse hornblende phenocrysts, exposed at the southeastern end of the Sacaton Mountains at Signal Peak. The rock is mineralogically very similar to the Sacaton Peak Granite (map unit Kgs) but is distinguished from it because it is foliated and locally lineated. Rare magmatic layering is crosscut by tectonic foliation. Skotnicki

and Ferguson (1999) reported S-C tectonite fabric and associated down-dip lineations in the southern part of the unit indicating top-to-the-north (mostly reverse) sense of shear. The contact with the Sacaton Peak Granite to the north (unit Kgq) is very sharp. A U-Pb (TIMS) zircon age of 73.8 ± 1.6 Ma has been reported from the Signal Peak Granite (Skotnicki and Ferguson, 1999; Spencer et al., 2015).

***Other areas***

TKgc – **Granodiorite dikes (Late Cretaceous – Paleogene)**
Fine- to medium-grained, equigranular, locally miarolitic granodiorite dikes of probable Late Cretaceous or Paleogene age. The dikes cut Pinal Schist and associated migmatitic gneiss (unit Xp).

TKqd – **Quartz diorite (Late Cretaceous – Paleogene)**
Light- to medium-gray, medium- to coarse-grained, biotite quartz diorite to quartz monzonite porphyry in the Slate Mountains.

## Paleogene or older intrusive rocks and crystalline complexes

TYlg – **Muscovite leucogranite of Black Mountain (age unknown, Proterozoic–Paleogene)**
Leucogranite with several percent muscovite and sparse to abundant garnet up to 1 cm diameter. K-feldspar crystals are locally up to 20 cm. Muscovite from a dike of this unit yielded an 40Ar/39Ar plateau date of 40.6 ± 0.3 Ma (Spell et al., 2003).

TXdp – **Granodiorite of Desert Peak (age unknown, Proterozoic–Paleogene)**
A granitoid and gneiss complex exposed at Desert Peak, in the middle of the map area. Granodiorite in the central and eastern part of this 2-km-long inselberg is texturally variable, ranging from fine-grained to coarse-grained porphyritic with 1-cm white feldspar phenocrysts. The most common phase contains plagioclase up to 7 mm, 25-30% anhedral quartz, 10% biotite in 1-mm flakes, and 2-3% hornblende in prisms 1-2 mm long. The rock has been recrystallized and has granoblastic texture. Granodiorite on the eastern flank of Desert Peak has intruded fine-grained, medium gray, psammitic semi-schist that contains 5-7% biotite. Aplite dikes intrude all of these rocks and are the predominant rock exposed on the west flank of Desert Peak where the country rock is poorly exposed fine-grained granitoid. Youberg et al. (2002) subdivided the complex into several map units.

TXg – **Hornblende-K-feldspar granitoid and gneiss (age unknown, Proterozoic–Paleogene)**
Heterogeneous unit consisting of a variety of foliated granitoid rocks and banded gneiss near the southeast end of the Picacho Mountains. In the two southeasternmost exposures this unit is represented predominantly by foliated to gneissic granitoid, complexly interfoliated with older gneiss. The typical granitoid rock is porphyritic quartz monzonite, characterized by 10-20% K-feldspar phenocrysts 1-3 cm across in a fine-grained (1-3 mm) groundmass of about 60% plagioclase, 20-30% quartz, 5-7% biotite, and 2-5% hornblende in 3-8 mm long prisms. In the northwestern exposures at Newman Peak and on a ridge south of there, the unit is composed of heterogeneous banded gneiss that includes granitic rocks interlayered with screens of Pinal

Schist (unit Xp) and, in the structurally higher parts of the unit, deformed sills of Newman Peak granite (unit TKn). Correlation of some components of this heterogeneous map unit between the southeastern and northwestern exposures (which were mapped as two different units by Richard et al., 1999) is possible but is not implied.

**TXm – Amphibolite and diorite (age unknown, Proterozoic–Paleogene)**
Dark colored, texturally variable gabbro to granodiorite, microdiorite, and mafic gneiss in the southeastern Picacho Mountains. Includes fine-grained diorite of unit Tm, mylonitic and K-feldspar-porphyroclastic hornblende quartz monzonite or granodiorite of unit TXg, banded white and dark gray mylonite possibly derived from gneiss protolith, and medium-grained diorite or gabbro cut by aplite-pegmatite dikes.

## Mesoproterozoic, Paleozoic, and Mesozoic strata

**J₸v – Volcanic and sedimentary rocks, undivided (Triassic–Jurassic)**
Conglomerate, arkose, and volcanic flows in the southern part of the Slate Mountains.

**P**P**n – Naco Group (Pennsylvanian–Permian)**
Light- to dark-gray, micritic to finely crystalline limestone with brownish- to purplish-gray silty interbeds.

**Me – Escabrosa Limestone (Mississippian)**
Dark-gray, thick-bedded to massive, cliff-forming, fossiliferous limestone containing abundant discontinuous siliceous bands.

**MDc – Martin Formation and Escabrosa Limestone, undivided (Devonian–Mississippian)**
Map units Dm and Me undivided at this scale; mapped separately at 1:24,000 scale by Blacet et al. (1978).

**Dm – Martin Formation (Devonian)**
Dark-gray to light-brown, finely crystalline, ledge-forming dolostone interbedded with siltstone and crossbedded quartzite.

**Ꞓba – Bolsa Quartzite and Abrigo Formation, undivided (Cambrian)**
The Bolsa Quartzite consists of gray to reddish-brown, fine- to coarse-grained, arkosic, ledge-forming, locally crossbedded sandstone grading laterally into quartzite. It is overlain by the Abrigo Formation, consisting of light-gray to dark-brown, fine-grained, crossbedded, ledge-forming quartzite interbedded with ripple-marked, thin-bedded, platy-weathering mudstone. The two formations were mapped separately at 1:24,000 scale by Blacet et al. (1978), but are undivided at this scale.

**Ym – Mescal Limestone (Mesoproterozoic)**
Medium- to dark-gray, finely crystalline, blocky-weathering limestone and dolostone. Locally contains nodules and thin layers of reddish and brownish chert. The base of the formation

consists of reddish-brown to yellowish-brown argillite overlain by interbedded quartzite and carbonate.

Ymd – **Mescal Limestone intruded by diabase (Mesoproterozoic)**
Unit Ym intruded by sills and dikes of diabase (unit Yd). These two units were mapped separately at 1:24,000 scale by Blacet et al. (1978), but are undivided at this scale.

Yds – **Dripping Spring Quartzite (Mesoproterozoic)**
Reddish-brown-weathered, laminated and cross-laminated quartzite locally containing arkosic and conglomeratic beds; interbedded with reddish-brown, ferruginous siliceous argillite in upper part of the unit.

Ydd – **Dripping Spring Quartzite intruded by diabase (Mesoproterozoic)**
Unit Yds intruded by sills and dikes of diabase (unit Yd). These two units were mapped separately at 1:24,000 scale by Blacet et al. (1978), but are undivided at this scale.

Yp – **Pioneer Shale (Mesoproterozoic)**
Grayish-red to reddish-brown, fissile, tuffaceous mudstone with yellowish-gray to light-brown bleached spots 1-5 mm in diameter. Interbedded with brownish arkosic sandstone.

## Mesoproterozoic – Paleozoic metamorphic rocks

Pzm – **Metasedimentary rocks (Paleozoic)**
Quartzite, calcsilicate schist, rusty sericitic schist, and light-gray marble. These rocks are complexly interfingered with one another and are preserved as screens that are interfoliated with the pluton of Wild Burro Canyon in the Tortolita Mountains. Rare primary sedimentary structures (such as tabular-planar crossbedding) are preserved locally, but compositional layering nearly everywhere is interpreted as transposed bedding. Ferguson et al. (2002) mapped some of the rock types separately where feasible. They also mapped zones containing lenses and pods of fine- to medium-grained amphibolite schist (mostly south of this map area), which they interpreted as deformed and metamorphosed diabase dikes of probable Mesoproterozoic age interfoliated with metasedimentary rocks of Mesoproterozoic and Paleozoic ages.

PzYq – **Quartzite and marble (Mesoproterozoic or Cambrian?)**
Unit PzYq occurs as a roof pendant in the Sacaton Peak Granite (map units Kgs and Kgm). Bergquist and Blacet (1979a) described the rocks as iron-stained, locally crossbedded orthoquartzite, minor amounts of dark maroon shale and siltstone, and cherty limestone locally altered to marble and skarn. They considered the siliciclastic and carbonate components as possible correlatives of the Cambrian Bolsa Quartzite and Devonian Martin Formation, respectively. They did not mention possible correlation of some or all of the carbonate with Cambrian Abrigo Formation, an alternative that is offered here. Skotnicki and Ferguson (1996) described this unit as highly shattered, medium-bedded, light-gray quartzite with bedding (where visible) defined by dark-colored laminae, and they considered the rocks possibly correlative with Mesoproterozoic Dripping Spring Quartzite or Cambrian Bolsa Quartzite. Immediately north of the Casa Grande map boundary, their map shows outcrops described as poorly exposed, white to

light-gray, massive, fine-grained metasedimentary rock containing porphyroblasts of corundum? (based on a description by Balla, 1972) and exhibiting a relict cm-scale granular or filled-vugs texture (possibly a fenestral fabric). They interpreted this rock as calcsilicate derived from contact metamorphism of one of the lower Paleozoic or Mesoproterozoic formations.

## Proterozoic crystalline rocks

**Yd – Diabase (Mesoproterozoic)**
Fine-grained diabase dikes and sills.

**Yga – 'Sacaton Granite' (Mesoproterozoic)**
Medium- to fine-grained, equigranular syenite to alkali feldspar granite. It is locally slightly K-feldspar porphyritic and contains 2-10% biotite and/or muscovite, which is locally altered to hematite and gives the rock a light orange tint. Exposures are light gray to light rusty orange and have angular, cobble-sized debris. Locally contains small enclaves of coarse-grained granite (map unit Yg). The rock forms irregular intrusive bodies, everywhere in contact with unit Yg, and is likely a younger phase of the latter. The rock generally forms resistant buttes. This unit was named the 'Sacaton Granite' by Balla (1972); that name was not used by Skotnicki and Ferguson (1996), but it is revived here.

**Yg – Oracle Granite (Mesoproterozoic)**
Medium- to coarse-grained megacrystic granite composed of light-gray subhedral plagioclase, light-gray to pink K-feldspar, clear to milky gray quartz, and up to 15% biotite. K-feldspar megacrysts up to 5 cm long are characteristic and locally abundant. K-feldspar in the groundmass is subhedral and commonly 1 to 1.5 cm across. Biotite is anhedral to subhedral and occurs in loose, felty masses and small books. Near intrusive contacts with the Pinal Schist there are zones in which the granite contains both biotite and muscovite. There also locally are zones with abundant tourmaline-bearing pegmatite. A flow foliation defined by crude alignment of biotite clots and feldspar crystals is displayed in some places (Skotnicki and Ferguson, 1996), but tectonic foliation is limited to narrow shear zones several cm to meters wide (Skotnicki, 1999). The rock typically weathers into low-relief, rounded, boulder-covered hills and crumbly pediment. The Oracle Granite (Peterson, 1938) is equivalent to the Ruin Granite (Ransome, 1903), and that name is commonly used north and northeast of this map area (e.g., Krieger, 1974). U-Pb zircon ages from the Oracle Granite are in the range 1440 ± 20 Ma (Fornash et al., 2013).

**Ygm – Oracle Granite, medium-grained equigranular phase (Mesoproterozoic)**
Medium-grained granite composed of light-gray to pink feldspar, gray quartz, and up to 15% anhedral to subhedral biotite. Biotite is locally partially altered to hematite. Quartz is weakly stained by hematite, giving the rock a light orange color. Coarse-grained and fine-grained zones are present and, although the rock is typically equigranular, it locally has phenocrysts up to 1 cm across of subhedral quartz and/or K-feldspar. In the northeast corner of the map area Skotnicki (1999) observed a biotite-rich variety and a muscovite-rich variety of this unit, with uncertain relationships between them. In the same area this unit complexly intrudes the coarse-grained porphyritic phase of the Oracle Granite (unit Yg).

**Xgd – Granodiorite (Paleoproterozoic)**
Fine grained, equigranular granodiorite composed of white plagioclase (1-4 mm), dark-gray quartz, and 5-8% biotite (1-2 mm, generally oxidized). At one location reported by Spencer et al. (2002), granodiorite of this unit intrudes Pinal Schist (unit Xp), and both are deformed by a foliation that does not affect nearby Mesoproterozoic porphyritic granite of unit Yg. The granodiorite was therefore assigned a Paleoproterozoic age and inferred as having been deformed in the Paleoproterozoic. A sample of this unit yielded a biotite K-Ar date of 1,438 ± 10 Ma (Banks et al., 1978).

**Xp – Pinal Schist (Paleoproterozoic)**
Regionally metamorphosed sedimentary rocks, predominantly schist, psammite, and phyllite. Metamorphism ranges from lower greenschist to amphibolite facies. The unit crops out in Proterozoic basement exposures and is preserved as pendants among younger plutons. At the lowest metamorphic grade, north of the Tortolita Mountains in the southeastern part of the map area, the Pinal Schist is represented by slate and phyllite derived from laminated to thin-bedded siltstone, mudstone, and thin- to medium-bedded sandstone. These rocks locally display primary sedimentary structures such as ripple crosslamination, graded bedding, and flute molds (Ferguson et al., 2002). Pelitic rocks exhibit cleavage parallel to preferred orientation of phyllosilicate minerals. At slightly higher metamorphic grade the rocks are light- to medium-gray to silvery gray phyllite, psammite, and fine-grained schist (Spencer et al., 2002). Quartz veins and stringers are locally abundant, especially in pelitic rocks. In the Ninetysix Hills and near intrusive contacts with Proterozoic granites the texture and mineralogy of the Pinal Schist are indicative of upper greenschist or lower amphibolite facies. Schist in the Ninetysix Hills is composed of coarse-grained muscovite and quartz, with less abundant biotite (mostly altered to chlorite), feldspar, and traces of tourmaline and garnet (Skotnicki, 1999). Segregated layers of quartz and mica are generally parallel to shistosity, but are transected by it where the layers are locally folded. Metamorphic grade is highest in the core of the Tortolita Mountains near the southeast corner of the map, where Pinal Schist deep in the footwall of the Carpas Wash shear zone and Guild Wash detachment fault ranges from coarse-grained schist to thinly layered quartzofeldspathic sillimanite gneiss (Ferguson et al., 2002).

In the western part of the map area, Pinal Schist in the Slate Mountains is quartz-muscovite schist, locally containing abundant quartz veins and stringers (Blacet et al., 1978). Bedding is preserved, in keeping with relatively low metamorphic grade and degree of deformation. In contrast, Pinal Schist in the Casa Grande Mountains is quartz-biotite-muscovite schist and migmatitic quartz-plagioclase-biotite gneiss, locally cut by small quartz-feldspar-muscovite veins and numerous pegmatoid alaskite dikes. In the northwest part of the range the schist and gneiss contain up to 25% hornblende, and schist in the southeast contains up to 5% subhedral to euhedral garnets 2-7 mm in diameter (Bergquist and Blacet, 1978).

**YXg – Pinal Schist intruded by Oracle Granite (Paleoproterozoic and Mesoproterozoic)**
Pinal Schist (map unit Xg) intruded by K-feldspar-porphyritic granite of unit Yg.

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