GEOLOGIC MAP OF THE ORO VALLEY 7½' QUADRANGLE AND THE PUSCH PEAK AREA, NORTHEASTERN PIMA COUNTY, ARIZONA

by: Jon E. Spencer and Philip A. Pearthree

Arizona Geological Survey Digital Geologic Map 21, version 2.0

March, 2004

Citation for this map:
Spencer, J.E., and Pearthree, P.A., 2004, Geologic map of the Oro Valley 7½' Quadrangle and the Pusch Peak area, northeastern Pima County, Arizona: Arizona Geological Survey Digital Geologic Map 21, version 2.0 (DGM-21,v. 2.0), scale 1:24,000.

Research supported by the Arizona Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award #01HQAG0098. The views and conclusions contained in this map are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

INTRODUCTION

The Oro Valley 7½' quadrangle covers an area, located approximately 25 km north of downtown Tucson, that extends over much of Oro Valley and includes parts of the adjacent Tortolita Mountains and Santa Catalina Mountains. The area was mapped during November 2001 through April 2002 as part of a multiyear mapping program directed at producing a complete geologic map coverage for the Phoenix-Tucson metropolitan corridor. Previous geologic maps of the area by Banks (1976) and Dickinson (1994), and maps of adjacent areas by Banks et al. (1977), Skotnicki (2000), and Force (2002) were used to focus mapping on areas of interest, but all of the mapping shown on Plate 1 is new and was produced by the authors. The accompanying legend describes rock units and other geologic features. This map version (2.0) includes new mapping by J. Spencer south of Pusch Peak in the Tucson North 1:100,000 quadrangle, a new cross-section, the locations of 3 rock samples that yielded radiometric age determinations, and a revised age assignment for the Biotite granite of Alamo Canyon (now known to be 70 Ma).

The Santa Catalina and Tortolita Mountains are part of the Catalina metamorphic core complex, an area where low- to moderate-angle normal faulting has accommodated uplift and exhumation of rocks that formerly resided in the middle crust, at depths of perhaps 5 to 15 km. The mylonitic fabrics on the south side of Pusch Ridge and locally exposed in the southeastern Tortolita Mountains are the product of deep-seated shearing during this uplift and exhumation process (e.g., Davis, 1980; Davis and Lister, 1988; Spencer and Reynolds, 1989; Dickinson, 1991; Force, 1997). Most of the rocks exposed, however, are not mylonitic and were apparently not deeply enough buried to be at temperatures sufficient for mylonitization (e.g., Banks, 1980). Approximately 5 km of displacement on the steeply west-dipping Pirate normal fault uplifted the steep west side of the Santa Catalina Mountains and down-dropped the bedrock beneath what is now Oro Valley (Budden, 1975; Dickinson, 1994).

ACKNOWLEDGEMENTS

Jon Spencer thanks Steve Richard, Charles Ferguson, and Bill Dickinson for discussions that were helpful in understanding the geology of the map area. Tim R. Orr was the cartographer for version 1.0; Erin M. Moore was the cartographer for version 2.0.

QUATERNARY GEOLOGY

Quaternary deposits cover most of the Oro Valley 7½' quadrangle, between the Tortolita Mountains in the west and the Santa Catalina Mountains in the east. These alluvial deposits were deposited primarily by larger streams that head in the mountains; smaller streams that head on the piedmont have eroded into older deposits and have reworked some of them. The lower margin of the piedmonts are defined by their intersection with stream terraces or channels of Cañada del Oro Wash, Sutherland Wash, and Big Wash, large drainages that head outside of the map area. Areas west and north of Cañada del Oro and Big washes are called the Tortolita piedmont in this report; areas east and south of Cañada del Oro and Sutherland washes are called the Catalina piedmont. Approximate age estimates for the various units are given in parentheses after the unit name. Abbreviations are ka, thousands of years before present, and Ma, millions of years before present.

GEOLOGIC MAP UNITS

Quaternary and late Tertiary map units

d — Disturbed ground (<100 years)

Areas where human activity has obscured the geologic nature of underlying material.

Qyc — Modern channel deposits (<100 years)

Unit Qyc consists of deposits in active channels of the larger tributary drainages and the major washes. Channel deposits are mapped where they are extensive enough to represent at 1:24,000 scale. They were outlined using the 1997 digital orthophotos for the Oro Valley quadrangle. Deposits are composed of primarily of sand, pebbles, and cobbles; small to medium boulders are abundant in channels of larger tributaries of the Catalina piedmont. Channels are incised as much as several meters below adjacent Holocene terraces (units Qyt and Qy). Channels consist of single, relatively large channels and smaller branching channels in areas of channel expansions. Local relief within channels varies from minimal to more than 1 meter between low-flow channels and adjacent gravel bars. Vegetation generally consists of small bushes and grasses, although the channel banks are typically lined with trees including mesquite, acacia, and palo verde. Areas mapped as Qyc are flood prone unless engineering structures have been built to divert flow away from them.

Qy — Holocene alluvium of tributary washes (<~10 ka)

Unit Qy consists of young deposits in small channels, low terraces, and alluvial fans. Deposits vary widely in particle size. Qy deposits on the Catalina piedmont are typically quite coarse, locally including medium to large boulders, cobbles, pebbles, sand, and minor silt and clay. Qy deposits on the Tortolita piedmont are finer, consisting mainly of cobbles, pebbles, sand, silt and minor clay. Channels generally are incised less than 2 m below adjacent terraces and fans, but locally incision may be somewhat greater. Channel morphologies generally consist of a single-thread channel or multi-threaded channels with gravel bars adjacent to low flow channels. Fairly extensive distributary channel systems where channels branch and decrease in size downstream existed on the lower margin of the Tortolita piedmont. Many of these systems have been profoundly altered by channelization associated with development. Local relief on Qy deposits varies from fairly smooth channel bottoms to the undulating bar-and-swale topography that is characteristic of coarser deposits. Terrace surfaces typically have planar surfaces, but small channels are also common on terraces. Soil development associated with Qy deposits is weak. Soil clay accumulation is minimal, and calcic horizon development is typically stage I to II (see Machette [1985] for description of stages of calcium carbonate accumulation in soils). Terrace and fan surfaces are brown, and on aerial photos they generally appear darker than surrounding areas, whereas sandy to gravelly channels appear light-colored on aerial photos. Vegetation density is variable. Channels typically have sparse, small vegetation. The densest vegetation in the map area is found along channel margins and on Qy terraces along channels. Vegetation includes mesquite, palo verde, and acacia trees; smaller bushes and grass may also be quite dense. Many areas mapped as Qy are flood prone, including channels and overbank areas. Much of the area mapped as Qy on the Catalina piedmont has been subject to debris flow activity in the past 10,000 years.

Qyt — Holocene alluvium of major washes (<~10 ka)

Unit Qyt consists of deposits of terraces found along Cañada del Oro, Sutherland, and Big washes. Qyt surfaces are slightly higher and more vegetated than adjacent Qyc surfaces and generally are not subject to flood inundation. Surfaces are generally planar; local relief may be up to 1 m where gravel bars are present, but typically is much less. Qyt surfaces typically are about 2 m above adjacent active channels, but may be higher. Qyt deposits typically are composed of sand, silt, and fine gravel, but locally contain lenses or layers of coarser gravel. Qyt surfaces generally are fine-grained and lightly vegetated, but appear somewhat darker on aerial photos than Qyc surfaces. Qyt terrace surfaces support creosote and other small bushes, with some mesquite and palo verde trees along drainages. Qyt soils typically are weakly developed, with some soil structure but little clay and stage I to II calcium carbonate accumulation.

Qc — Holocene and Pleistocene hillslope colluvium

Unit Qc consists of locally-derived colluvial and talus deposits on moderately steep hillslopes in the Santa Catalina Mountains. Colluvium is mapped only where sufficiently thick and extensive as to obscure underlying bedrock. Deposits are very poorly sorted, ranging from clay to cobbles and large boulders derived from rockfalls. Clasts typically are subangular to angular because they have not been transported very far. Bedding is weak and dips are steep, reflecting the steep depositional environment. Deposits are a few meters thick or less; thickest deposits are found at the bases of hillslopes. Some stable hillslopes are covered primarily with Pleistocene deposits, which are typically reddened and enriched in clay. Most colluvial hillslopes are covered with Holocene deposits, which have minimal soil development.

Qly — Undivided late Pleistocene to Holocene alluvium (<~130 ka)

Ql — Late Pleistocene alluvium (~10 to 130 ka)

Unit Ql consists of deposits associated with moderately dissected terraces and small relict alluvial fans found on the upper, middle and lower piedmont. Moderately well developed, slightly to moderately incised tributary drainage networks are typical on Ql surfaces. Active channels typically are incised less than 5 meters below Ql surfaces. Ql fans and terraces are lower in elevation than adjacent Qm and oldersurfaces, but elevation differences are minimal in some places. Ql deposits generally consist of pebbles, cobbles, and finer-grained sediment, but are much coarser on the Catalina piedmont. Ql surfaces commonly have loose, open lags of pebbles and cobbles; surface clasts exhibit weak rock varnish. Ql surfaces appear orange on color aerial photos, reflecting slight reddening of surface clasts and the surface soil horizon. Ql soils are moderately developed, with orange to reddish brown clay loam to light clay argillic horizons (McFadden, 1978) and stage II calcium carbonate accumulation. Vegetation includes grasses, small shrubs, mesquite, and palo verde. Ql surfaces generally are not flood prone.

Qm — Middle Pleistocene alluvium (~130 to 500 ka)

Unit Qm consists of moderately to highly dissected relict alluvial fans and terraces with strong soil development found throughout the map area. Qm surfaces are drained by well-developed, moderately to deeply incised tributary channel networks; channels are typically several meters up to 10 m below adjacent Qm surfaces. Qm deposits typically consist of sand, pebbles and cobbles, but on the Catalina piedmont are quite bouldery. Qm surfaces are characterized by scattered cobble to boulder lags with moderate to strong varnish. Well-preserved, planar Qm surfaces are smooth with scattered pebble and cobble lags; surface color is reddish brown rock varnish on surface clasts is typically orange or dark brown. More eroded, rounded Qm deposits are less clay-rich and have some carbonate litter on the surface. Well-preserved Qm surfaces have a distinctive bright red color on color aerial photos, reflecting reddening of the surface soil and surface clasts. Soils typically contain reddened, clay argillic horizons (McFadden, 1978), with obvious clay skins and subangular to angular blocky structure. Underlying soil carbonate development is typically stage II to III, with abundant carbonate through at least 1 m of the soil profile, but indurated petrocalcic horizons were not observed. Qm surfaces generally support grasses, bursage, cholla, and small shrubs.

Qmo — Middle to early Pleistocene alluvium (~500 ka to 1 Ma)

Unit Qmo consists of deposits associated moderately to deeply dissected relict alluvial fans with variable soil development. Qmo surfaces are drained by well-developed, deeply incised tributary channel networks. Surfaces are typically well rounded, and few planar remnants of the original deposition surfaces exist. Qmo surfaces are typically 5 to 20 meters above adjacent active channels. Qmo deposits are not well-exposed, but probably consist of primarily of pebbles, cobbles, sand and fines. Where Qmo surfaces are fairly well preserved, they are smooth with pebble and cobble lags; rock varnish on surface clasts is typically orange to red. Soil carbonate development is variable, but locally is quite strong. Where surfaces are well preserved, soils typically contain deep reddish brown, clay argillic horizons, with obvious clay skins and subangular blocky structure (McFadden, 1978). More eroded Qmo surfaces are characterized by loose cobble lags with moderate to strong varnish, ridge-and-valley topography, and carbonate litter on the side slopes. On aerial photos, ridge crests on Qmo surfaces typically are reddish brown, reflecting reddening of the surface soil and surface clasts, and eroded slopes are gray to white. Qmo surfaces generally support bursage, ocotillo, and creosote.

Qo — Early Pleistocene alluvium (~1 to 2 Ma)

Unit Qo consists of deposits associated with very old, high, alluvial fan remnants capping high ridges. Qo deposits and fan surface remnants are found only in a few places in the map area. Qo surfaces are as much as 100 m above adjacent active channels. Qo deposits consist of boulders, cobbles, and sand and finer clasts. Surfaces are dark reddish brown in color. Where surfaces are planar and well-preserved, reddish brown, clay argillic horizons are typical. Qo surfaces are dominated by grass, small shrubs, and ocotillo. Qo surfaces record the highest levels of aggradation in the Cañada del Oro valley, and are correlative with the Cordones surface farther north in the valley and other high, remnant early Pleistocene to latest Pleistocene alluvial surfaces found at various locations throughout southern Arizona (Menges and McFadden, 1981).

QTs — Miocene to Pliocene alluvium mantled by Quaternary slope deposits (Quaternary to late Tertiary)

Unit QTs consists of hillslope deposits formed on fine- to moderately-coarse, highly eroded alluvial fan deposits. QTs surfaces typically are alternating eroded ridges and valleys with ridgecrests typically 5 to 20 meters above adjacent active channels. QTs deposits are also exposed beneath overlying Quaternary deposits. The thickness of QTs deposits is not known. QTs surfaces are drained by deeply incised tributary channel networks. Even the highest surfaces atop QTs ridges are rounded, and original highest capping fan surfaces are not preserved. QTs deposits are dominated by sand and gravel ranging from pebbles to cobbles. Deposits are moderately indurated and are moderately resistant to erosion because of the clast size and carbonate cementation. Soils typically are dominated by carbonate. accumulation, which is typically cemented on ridgecrests, but areas of clay-rich soils are found locally on ridge flanks. Carbonate litter is common on ridgecrests and hillslopes. On aerial photos, QTs surfaces are generally gray to white, but include some dark reddish brown areas where clay is more abundant. QTs surfaces support creosote, mesquite, palo verde, ocotillo, and cholla.

Exposures in stream cutbanks reveal that conglomerate clasts are 1-10 cm diameter, locally to 30 cm, and include abundant sand in matrix (east edge of SE ¼, NE ¼, sec. 13, T. 11 S., R. 13 E.). Unit is crudely to moderately well bedded, with beds typically 5-30 cm thick. Beds are generally planar over 1-3 m lengths, lenticular at larger dimensions. Mostly beds are poorly channelized and many appear planar. All or nearly all clasts are locally derived granite (Granite of Tortolita Mountains).

QTc — Coarse Miocene to Pliocene alluvium mantled by Quaternary slope deposits (Quaternary to late Tertiary)

Unit QTc consists of hillslope deposits formed on very coarse, old, deeply dissected and highly eroded alluvial fan deposits. QTc surfaces are alternating eroded ridges and deep valleys, with ridgecrests typically ranging from 30 to 100 meters above adjacent active channels. The thickness of QTc deposits is not known. QTc surfaces are drained by deeply incised tributary channel networks. Even the highest surfaces atop QTc ridges are rounded, and original highest capping fan surfaces are not preserved. On aerial photos, QTc surfaces are orange to gray. QTc surfaces support creosote, mesquite, palo verde, ocotillo, and cholla.

Unit QTc consists of massive boulder conglomerate at the foot of the Santa Catalina Mountains. Clasts are typically 10-200 cm, locally to 10 m (some ~20 m clast was observed in Alamo Canyon; some exceptionally large boulders are identified on the map). Clasts are derived from same rock types as are present in nearby bedrock in the Santa Catalina Mountains, and include abundant, highly resistant leucogranite and pegmatite boulders. Deposits also include cobbles, pebbles, and sand, especially in matrix, but matrix is exposed only in stream cutbanks. Deposits are quite resistant to erosion because of the large clast sizes. Carbonate litter is common on ridgecrests and hillslopes.

QTcx — Coarse Miocene to Pliocene alluvium (Quaternary to late Tertiary)

Unit QTcx is mapped in areas where basin deposits of map unit QTc are exposed in wash cutbanks. Exposures reveal gray, grussy, stratified fluvial deposits interbedded with cobbly to bouldery, massive debris-flow deposits. Deposits are weakly to moderately indurated.

Bedrock map units in the Santa Catalina Mountains

Tertiary map units

Tf — Fault rocks (late Tertiary)

Fault breccia with abundant hematite-stained fractures and hematite-silica material filling open spaces between breccia fragments. Hematite is earthy and brownish red. Fault breccia is located along the Pirate fault. In some exposures, the fault surface is a planar, polished surface on hematite-silica microbreccia, locally with black manganese oxide coating. Breccia below microbreccia surface is up to 70% hematite silica microbreccia/hydrothermal silica with as little as 30% of rock consisting of 2-20 mm granitic rock fragments. Brecciation decreases in intensity away from contact into granitic footwall rocks. Fault rocks of this map unit extend over, typically, 1 to 10 m away from fault trace and grade into moderately to slightly brecciated or strongly fractured granitic footwall rocks.

Tx — Breccia (late Tertiary)

Well cemented breccia with no preferred orientation of angular fragments, almost all of which are less than 20 cm diameter. Earthy hematite locally coats fractures but does not discolor the rock as it does with fault rocks of map unit Tf. Breccia is cemented and is moderately resistant to weathering, forming some bold outcrops. Weathers tan with much pale green lichen. Sparse planar fractures and crude variations in color and resistance to weathering define indistinct fabric that dips steeply to northwest, parallel to regional dip of Pirate fault which is buried under younger deposits at some unknown but probably small (<100 m) distance to the northwest. Fractures and crude layering that impart a fabric to this rock unit are only weakly and sparsely developed. Most of rock is remarkable massive and directionless, and strongly resembles rock-avalanche breccia in which all clasts are reduced to less than a threshold size.

This rock unit is interpreted as a co-seismic implosion breccia in which the granite and perhaps coarse hanging-wall conglomerate catastrophically disaggregated, or exploded, into a dilational void within the Pirate fault. This could have occurred repeatedly during earthquakes that produced dilational voids along the fault. It is not obvious that the area that contains these breccias is a dilational zone along the Pirate fault, but since movement is entirely or almost entirely dip slip, irregularities along the fault that would produce a dilational jog would not likely be visible. A major change in the strike of the fault occurs just to the north of the zone containing the breccia such that the southern sections strikes northwest but the northern section strikes north. The intersection of two planar fault segments with these strikes would be a steeply plunging line. If displacement of the hanging-wall was more northerly than the plunge of this line, dilation would result along the fault surface immediately to the south for the case of a southward-propagating seismic dislocation (a dilational bend, e.g., Sibson, 1989). Finally, the lack of hydrothermal hematite-silica in this breccia or adjacent to it could be the result of downward percolation of groundwater beneath the head of an alluvial fan emanating from the Romero and Montrose canyons area. This could have depressed isotherms. Farther south where hematite-silica breccia is common (map unit Tf), perhaps hot water ascended along the active fault rather than descended.

Tsu — Clastic sedimentary rocks, undivided (Tertiary)

Concealed strata displaced by the Catalina detachment fault and correlative with the Swan-Craycroft gravels of Dickenson (1999) and the underlying Pantano Formation. Shown in cross-section only.

Tgc — Catalina granite (middle Tertiary)

Fine- to medium-grained, hornblende-biotite granite. Mafic minerals are generally unaltered. Varies from equigranular to porphyritic, with K-feldspar up to 2 cm long. Contains very few pegmatite or aplite dikes and is only slightly fractured. Weathering has produced an extensive pediment surface developed on homogeneous granite with few fractures, dikes, or veins.

The Catalina granite is exposed over a large area northeast of the map area. It generally consists of porphyritic biotite ± hornblende granite. Pink orthoclase phenocrysts are as long as 4 cm (Suemnicht, 1977) to perhaps 7 cm (Budden, 1975). Xenoliths are locally abundant (Budden, 1975). Texture is hypidiomorphic granular and plagioclase composition is An 26-32 (Suemnicht, 1977). Three K-Ar dates considered reliable by Reynolds et al. (1986) range from 24.0 Ma to 25.6 Ma (Damon et al., 1963; Creasey et al., 1977), while rock Rb-Sr isotopic analyses indicate an age of ~26 Ma (Keith et al., 1980), and Shakel et al. (1977) report "nearly concordant 27 ± 2 m.y. old zircons" but give no uranium-lead analytical data or location information.

Many different names have been used for this granitoid intrusion, but the most common has been Catalina granite (Bromfield, 1950; McCullough, 1963; Shakel et al., 1972, 1977; Budden, 1975; Suemnicht, 1977; Reynolds et al., 1986). Creasey et al. (1977) referred to this intrusion, and much of the rest of the granitoids and gneissic granitoids in the Santa Catalina Mountains, as "quartz monzonite of Samaniego Ridge." However, 11 of 13 modal mineral determinations indicate that the unit is a granite according to IUGS classification (Streckeisen, 1973). Because of conflicting name usage and because a type area has not been designated, the term "Catalina granite" is here considered informal.

Tgl — Heterogeneous, pegmatitic, muscovite leucogranite (early Tertiary)

Fine-to medium-grained, equigranular muscovite leucogranite with fine-grained leucogranite dikes and, especially in the Romero and Montrose canyon areas, abundant pegmatite dikes that lack mica but contain abundant K-feldspar up to 15 cm long. Leucogranite generally contains 0 to 2% of each of the following, 1-3 mm muscovite, 1-2 mm biotite, and <1 mm garnet. Rocks of this unit are part of the Wilderness Suite granites of Keith et al. (1980) and Force (1997) that is generally thought to be Eocene. Muscovite from a leucogranite sill yielded an 40Ar/39Ar isochron date of 24.96 ± 0.13 Ma. Biotite from a pegmatite yielded an 40Ar/39Ar isochron date of 23.41 ± 0.15 Ma. Both dates are interpreted as cooling dates related to tectonic exhumation, and are younger than the inferred Eocene age of the leucogranites and pegmatites (both dates from Spell et al., 2003).

Contact between leucogranite and biotite granite of Alamo Canyon is gradational over hundreds of meters. Percentage of pegmatite and leucogranite dikes and sills increases toward area mapped as heterogeneous pegmatitic muscovite leucogranite. Contact marks approximate transition from roughly equal amounts of each rock type, (mapped as biotite granite of Alamo Canyon) to 90-100% heterogeneous leucogranite.

Tglx — Fractured, heterogeneous, pegmatitic, muscovite leucogranite (early Tertiary)

Areas where heterogeneous, pegmatitic, muscovite leucogranite is significantly fractured, with sparse earthy hematite on some fracture surfaces. Fracturing is associated with the late Cenozoic Pirate fault.

Tgp — Muscovite leucogranite of Pusch Peak (early Tertiary)

Muscovitic, medium-grained, slightly porphyritic granite. This granite has a pale orangish tan, iron-stained character, and is more easily weathered, in contrast to white, resistant, heterogeneous, pegmatitic, muscovite leucogranite that makes up a cliff-forming sill below Pusch Peak and that contains less muscovite and is finer grained. Muscovite forms estimated 3-5% of rock in crystals as large as 10 mm, but mostly <5 mm. In weakly mylonitic rocks, muscovite is preferentially aligned with mylonitic fabric.

Kga — Biotite granite of Alamo Canyon (Tertiary or 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. Foliation attitudes measured here are generally on lithologic layering. Much weakly gneissic biotite granite is too irregularly layered to get meaningful attitudes. Elongation of dark, biotite-rich aggregates defines vague lineation fabric (L fabric). Granite is not consistently foliated and in many areas is an L-tectonite where only lineation could be measured.

The Biotite granite of Alamo Canyon yielded a U-Pb zircon date of 71 ± 1 Ma. This granite is similar to the nearby Pluton of Chirreon Wash in the Tortolita Mountains (Banks et al., 1977; Ferguson et al., 2002) , which yielded a U-Pb zircon date of 69.5 ± 0.5 Ma (both dates from Spencer et al., 2003). These two granite rock units are tentatively correlated.

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 (map unit Tgl), are dominated by K-feldspar and contain 0 to 1%, 2 to 20 mm biotite, no muscovite and, commonly, little or no quartz. Lithologic layering in granite is somewhat wavy and non-planar in detail, especially adjacent to some pegmatite and aplite dikes where distortion of layering in host biotite granite apparently accompanied emplacement of dikes. Some dikes follow foliation and lithologic layering in host granite, some are irregular, variably concordant stringers, and some are simply discordant and truncating. Preferred interpretation is that foliation and gneissic layering developed during dike emplacement and associated high temperature deformation and recrystallization, and that some dike emplacement occurred late during or after the period of deformation and development of lithologic layering.

Contact between biotite granite and heterogeneous pegmatitic muscovite leucogranite (map unit Tgl) appears from a distance on the north face of Bighorn Mountain to be gradational over approximately 50 m of structural thickness. Farther southwest this contact zone is marked by a sheet of Pinal Schist that is intruded by pegmatites. Farther northeast, the contact between leucogranite and biotite granite of Alamo Canyon is gradational over hundreds of meters, with numerous dikes of leucogranite and screens of biotite granite.

Foliation and lineation in biotite granite are interpreted as high temperature fabric elements with sufficient recrystallization during deformation that grain-size reduction, characteristic of mylonitic fabrics, is generally not visible. This fabric is therefore considered to be crystalloblastic and to have developed at higher temperature than is characteristic of mylonitization. Some lineations, however, seems to be weakly mylonitic. In the Alamo Canyon area, foliation in biotite granite is associated with weak lithologic layering and does not seem to be at all mylonitic, however lineation developed on foliation surface in some areas, especially near Pusch Peak, does seem to be weakly mylonitic.

The foliation and compositional layering in the biotite granite of Alamo Canyon define a doubly plunging antiform with an axis that trends approximately N 65° E (Pashley, 1963). This feature has been interpreted as a fold (e.g., Pashley, 1963). However, mapping during this study did not locate any axial planar fabric to such a fold, and found that much of the rock that made up the antiform was a high-temperature L-tectonite with lineation trend and plunge parallel to the axis of the antiform. It is suspected that the antiformal form of compositional layering in the biotite granite and intruding pegmatites and aplites is a feature that formed during L and L-S fabric development and vein and dike emplacement. The features that define the antiform may have never been planar and thus the antiform may not be a fold.

Kgax — Fractured Biotite granite of Alamo Canyon (middle Tertiary)

Areas where Biotite granite of Alamo Canyon is significantly fractured, with sparse earthy hematite on some fracture surfaces. Fracturing is associated with the late Cenozoic Pirate fault.

Proterozoic map units

Yg — Porphyritic granite (Middle Proterozoic)

Dark, coarse-grained, K-feldspar-porphyritic (up to 4 cm) granite containing up to 10% biotite. Probably correlative with Oracle Granite of Peterson (1938).

Xp — Pinal Schist (Early Proterozoic)

Pale-gray to medium-gray micaceous schist and psammitic schist, commonly intruded by numerous leucogranite dikes and quartz veinlets.

Bedrock map units in the Tortolita Mountains

Tertiary or Cretaceous map units

Ttm — Granite of Tortolita Mountains (middle Tertiary)

Medium- to fine-grained, equigranular granite with 3-5%, 1-3 mm biotite. This unit locally forms dikes in porphyritic biotite granite of map unit TKgp. Unit is equivalent to Quartz monzonite of the Tortolita Mountains of Banks et al. (1977).

Td — Dikes associated with Granite of Tortolita Mountains (middle Tertiary)

Fine-grained leucogranite dikes containing ~1-2% biotite.

Tgd — Granodiorite (middle Tertiary)

Fine-grained, dark, equigranular, biotite-hornblende granodiorite or granite. Contains up to 20% mafic minerals. In northern exposures along edge of the quadrangle, rocks of this unit contain 5-10% biotite and 5-10% hornblende. This unit is probably correlative with the mafic phase of the pluton of Wild Burro Canyon (Banks, 1980; map unit Tgm of Skotnicki [2000]; C.A. Ferguson, oral communication, 2002). It is not clear that the scattered exposures of this map unit are really all co-magmatic or the same age.

TKgp — Porphyritic biotite granite (Cretaceous to Tertiary)

Heterogeneous, coarse-grained, porphyritic, biotite granite with 1-2 cm K-feldspar phenocrysts. This unit is probably correlative with the porphyritic phase of the pluton of Wild Burro Canyon (Banks, 1980; map unit Tgc of Skotnicki [2000]; C.A. Ferguson, oral communication, 2002), but it also resembles Middle Proterozoic Oracle Granite (Peterson, 1938). Southernmost exposures (sec. 24 and 25, T.11 S, R 13 E) locally have weak mylonitic fabric and very sparse, strongly developed mylonitic shear zones with a very high degree of grain size reduction such that shearing processes appear to be almost entirely brittle with little recrystallization during shearing or plastic deformation of quartz. Foliation measurements are shown on map as protomylonite. No chlorite and/or epidote fracture coatings or hematite fracture coating were seen in southernmost exposures, which suggests that a buried detachment fault is not located to the south near bedrock exposures and does not project over these outcrops closer than perhaps 50 to 100 m.

Paleozoic map unit

₽m — Metasedimentary rocks (Paleozoic protolith, Mesozoic to Tertiary metamorphism)

Includes several rock types, including the following: (1) Fine-grained to locally medium-grained (crystals up to 3 mm) biotite+chlorite+quartz+feldspar rock. Protolith is inferred to be sandstone or silty sandstone, in some areas calcareous. (2) Tan carbonate. (3) Gray, fine grained metaquartzite. Contact with adjacent granitoids is locally mineralized with at least one prospect pit and minor green or blue copper stain in rubble. (4) Thin bedded quartzite with thin layers of recess-forming carbonate, both in layers 2-20 mm thick.

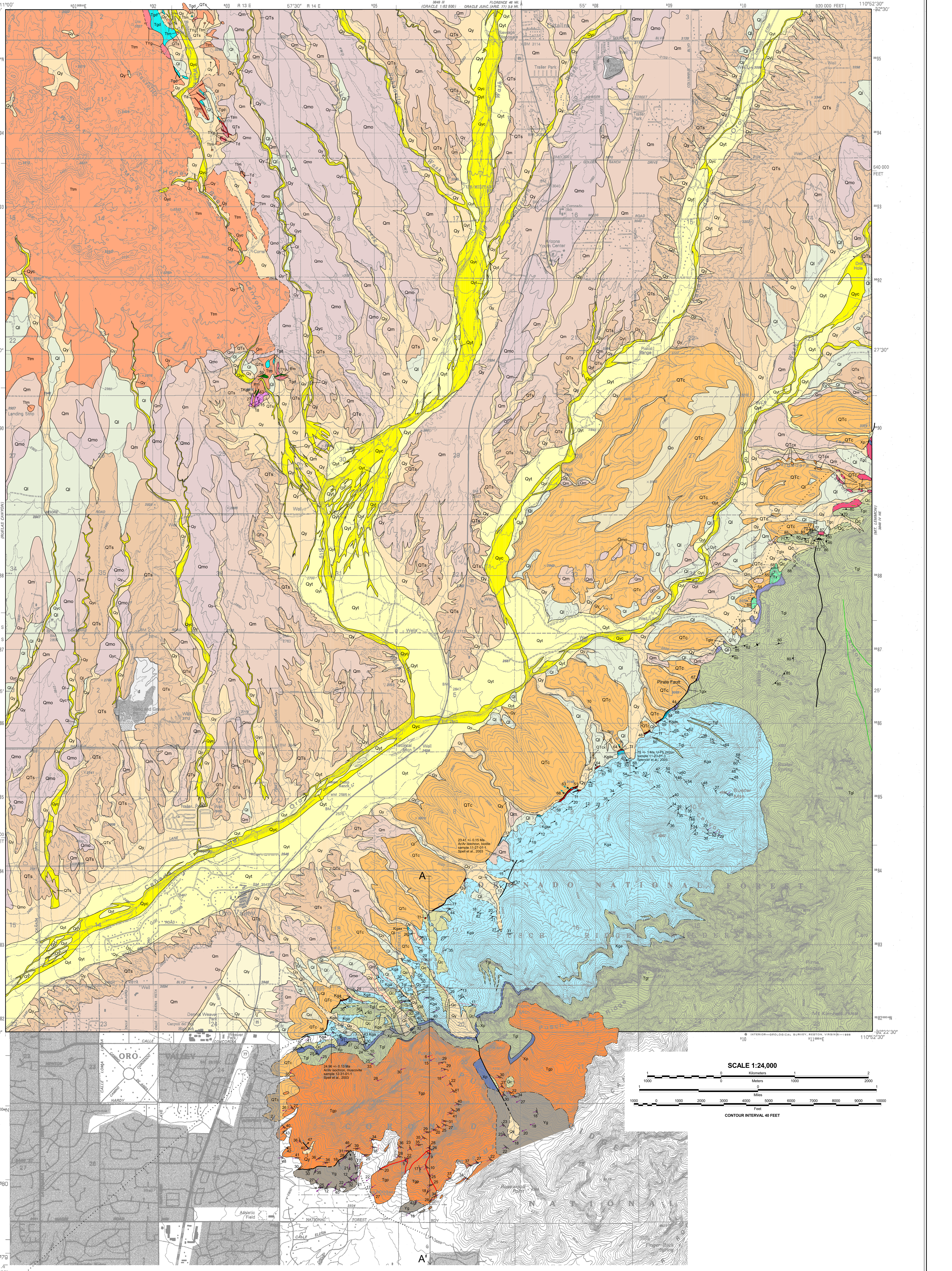
Tertiary to Proterozoic map unit

TYg — Porphyritic granite (Tertiary to Middle Proterozoic)

Dark, coarse-grained, K-feldspar-porphyritic (up to 4 cm) granite containing up to 10% biotite. Probably correlative with Oracle Granite of Peterson (1938) or with the coarse grained phase of the pluton of Wild Burro Canyon (Quartz Monzonite of Wild Burro Canyon of Banks [1980]).

REFERENCES CITED

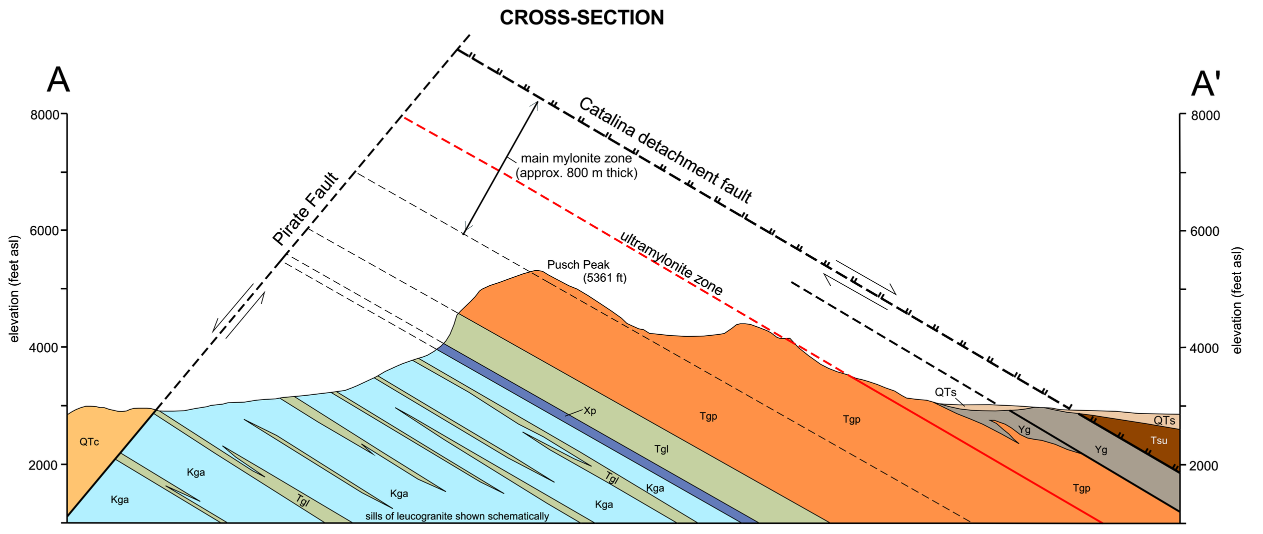
Banks, N.G., 1976, Reconnaissance geologic map of the Mount Lemmon quadrangle, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-747, scale 1:62,500.
Banks, N.G., 1980, Geology of a zone of metamorphic core complexes in southeastern Arizona, in Crittenden, M.D., Jr., Coney, P.J., and Davis, G.H., eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153, p. 177-215.
Banks, N.G., Dockter, R.D., Briskey, J.A., Davis, G.H., Keith, S.B., Budden, R.T., Kiven, C.W., and Anderson, Philip, 1977, Reconnaissance geologic map of the Tortolita Mountains quadrangle, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-864, scale 1:62,500.
Bromfield, C.S., 1950, Geology of the Maudina mine area, northern Santa Catalina Mountains, Pinal County, Arizona: Tucson, University of Arizona, M.S. thesis.
Budden, R.T., 1975, The Tortolita-Santa Catalina Mountain complex: Tucson, University of Arizona, M.S. thesis.
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, p. 705-717.
Damon, P.E., Erickson, R.C., and Livingston, D.E., 1963, K-Ar dating of Basin and Range uplift, Catalina Mountains, Arizona: National Academy of Sciences-National Research Council Publication 1075, Nuclear Science Series, report 38.
Davis, G.A., and Lister, G.S., 1988, Detachment faulting in continental extension; Perspectives from the southwestern U.S. Cordillera: Geological Society of America Special Paper 218.
Davis, G.H., 1980, Structural characteristics of metamorphic core complexes, southern Arizona, in Crittenden, M.D., Jr., Coney, P.J., and Davis, G.H., eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153.
Dickinson, W.R., 1991, Tectonic setting of faulted Tertiary strata associated with the Catalina core complex in southern Arizona: Geological Society of America Special Paper 264.
Dickinson, W.R., 1994, Trace of main displacement surface (bedrock/basin fill contact) of Pirate fault zone, west flank of Santa Catalina Mountains, Pima and Pinal Counties, Arizona: Arizona Geological Survey Contributed Map CM-94-G, scale 1:24,000.
Dickinson, W.R., 1999, Geologic framework of the Catalina foothills, outskirts of Tucson (Pima County), Arizona: Arizona Geological Survey Contributed Map CM-99-B.
Ferguson, C.A., Johnson, B.J., Skotnicki, S.J., Maher, D.J., Spencer, J.E., Gilbert, W.G., Richard, S.M., and Youberg, A., 2002, Geologic map of the Tortolita Mountains, Pinal and Pima Counties, Arizona: Arizona Geological Survey Digital Geologic Map 26.
Force, E.R., 1997, Geology and mineral resources of the Santa Catalina Mountains, southeastern Arizona: Tucson, Arizona, Center for Mineral Resources, Monographs in Mineral Resource Science, n. 1.
Force, E.R., 2002, Structural reconnaissance of lower-plate rocks along the Catalina-Rincon range front, Pima County, Arizona: Arizona Geological Survey Contributed Map CM-02-A.
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., and others, eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153.
Machette, M.N., 1985, Calcic soils of the southwestern United States, in Weide, D.L., ed., Soils and Quaternary Geology of the Southwestern United States: Geological Society of America Special Paper 203.
McCullough, E.J., Jr., 1963, A structural study of the Pusch Ridge-Romero Canyon area, Santa Catalina Mountains, Arizona: Tucson, University of Arizona, Ph.D. dissertation.
McFadden, L.D., 1978, Soils of the Cañada del Oro Valley, southern Arizona: Tucson, University of Arizona, M.S. thesis.
Menges, C.M., and McFadden, L.D., 1981, Evidence for a latest Miocene to Pliocene transition from Basin-Range tectonic to post-tectonic landscape evolution in southeastern Arizona: Arizona Geological Society Digest 13.
Pashley, E.F., Jr., 1963, A reinterpretation of the anticlinal structure exposed in the northwest face of Pusch Ridge, Santa Catalina Mountains, Arizona: Arizona Geological Society Digest 6.
Peterson, N.P., 1938, Geology and ore deposits of the Mammoth mining camp area, Pinal County, Arizona: Arizona Bureau of Mines Bulletin.
Reynolds, S.J., Florence, F.P., Welty, J.W., Roddy, M.S., Currier, D.A., Anderson, A.V., and Keith, S.B., 1986, Compilation of radiometric age determinations in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 197.
Shakel, D.W., Livingston, D.E., and Pushkar, P.D., 1972, Geochronology of crystalline rocks in the Santa Catalina Mountains, near Tucson, Arizona: A progress report: Geological Society of America Abstracts with Programs.
Shakel, D.W., Silver, L.T., and Damon, P.E., 1977, Observations on the history of the gneissic core complex, Santa Catalina Mtns., southern Arizona: Geological Society of America Abstracts with Programs.
Sibson, R.H., 1989, Earthquake faulting as a structural process: Journal of Structural Geology.
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 00-04, scale 1:24,000.
Spell, T., Zanetti, K., 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.
Spencer, J.E., Isachsen, C.E., Ferguson, C.A., Richard, S.M., Skotnicki, S.J., Wooden, J., and Riggs, N.R., 2003, U-Pb isotope geochronologic data from 23 igneous rock units in central and southeastern Arizona: Arizona Geological Survey Open-File Report 03-08.
Spencer, J.E., and Reynolds, S.J., 1989, Middle Tertiary tectonics of Arizona and the Southwest, in Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Arizona Geological Society Digest, v. 17.
Streckeisen, A.L., 1973, Plutonic rocks: Classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes.
Suemnicht, G.A., 1977, The geology of the Cañada del Oro headwaters, Santa Catalina Mountains, Arizona: Tucson, University of Arizona, M.S. thesis.



SCALE 1:24,000

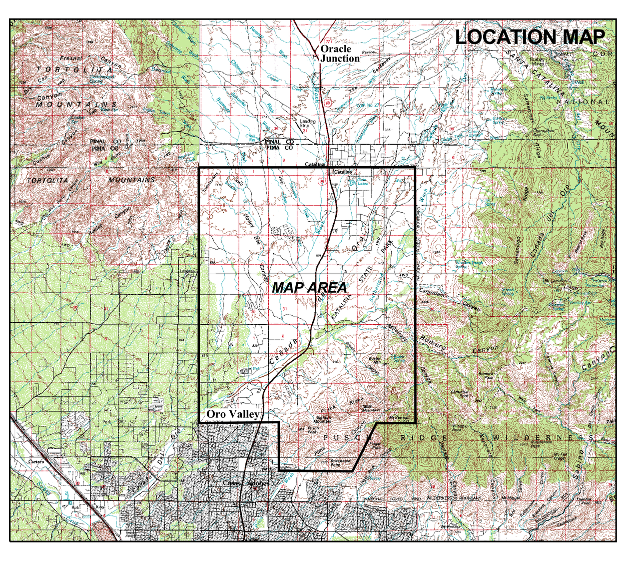
CONTOUR INTERVAL 40 FEET

CROSS-SECTION

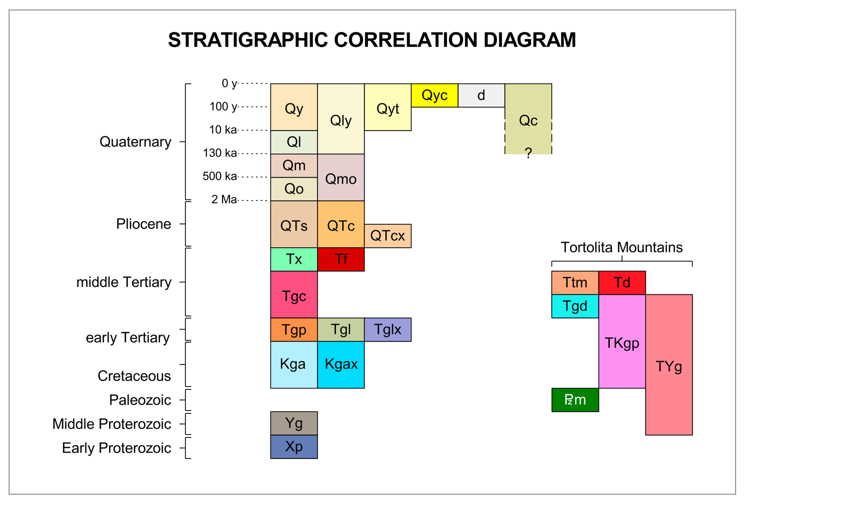


NO VERTICAL EXAGGERATION (1:1)

LOCATION MAP



STRATIGRAPHIC CORRELATION DIAGRAM



GEOLOGIC MAP SYMBOLS

Depositional or intrusive contact — Dashed where approximately located, queried where guessed or very uncertain.

Contact determined by aerial photograph interpretation

Gradational contact

Fault, showing dip, and striation trend — Dashed where approximately located.

Ultra-mylonite shear zone

Debris-flow levee

Quartz vein

Mafic dike

Bedding

Apparent dip of bedding

Primary lithologic layering in igneous rocks — Primarily defined by compositionally distinct layers in pegmatitic granite. Variations in crystal size and relative content of quartz, K-feldspar, and plagioclase are primary defining feature. These rocks are generally undeformed.

Gneissic layering — Layering in Pinal Schist with parallel alignment of mica.

High temperature foliation with lineation — Mineralogic preferred orientation and lithologic layering produced at sufficiently high temperatures that recrystallization obscured or prevented significant grain-size reduction associated with shearing and flattening. Fabric defined by elongation of mafic mineral aggregates, weak lithologic segregation of light and dark minerals into layers, and development of preferred orientation of biotite. Identified primarily in granite of Alamo Canyon where stretching to produce an L fabric was commonly dominant.

High temperature lineation without foliation — Lineation that was produced by constrictional strain at sufficiently high temperatures that recrystallization obscured or prevented significant grain-size reduction. Fabric defined by elongation of mafic aggregates and weak lithologic segregation of light and dark minerals into elongate forms. Identified primarily in granite of Alamo Canyon where stretching to produce an L fabric was commonly dominant.

Mylonitic foliation with lineation

Mylonitic lineation without foliation

Weak mylonitic foliation (protomylonite) with lineation — Mylonitic foliation that is restricted to discrete shear zones that form a small fraction of the rock.

Set of joints, and crude layering in breccia — These are possibly relict fault surfaces or large parallel fractures, small faults, or brittle shear zones associated with the Pirate fault.

Joint — Sparse joints but some may be large.

Joint that could be footwall surface of Pirate fault

Boulder — Seven to twenty meters in diameter.

Geochronology location