Geologic map of the Chief Butte 7½' Quadrangle, southeastern Pinal County, Arizona

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INTRODUCTION

The study area is located ~50 km north of downtown Tucson, and is bounded by the Tortolita Mountains on the south, the Suizo Mountains on the west, and Black Mountain on the northeast. The map area covers the Chief Butte 7½' Quadrangle. The area was mapped during October 2001 through April 2002 as part of a multiyear mapping program directed at producing complete geologic map coverage for the Phoenix-Tucson metropolitan corridor. A 1:24,000 scale map is the primary product of this study. This map consists almost entirely of new mapping but locally incorporates past mapping by Banks et al., (1977). The text describes rock units and other geologic features. This map version (v. 1.1, completed in February, 2004) includes a cross-section and some geochronologic information that were not included on the original version.

The geology of the map area, which was previously mapped by Banks et al., (1977) at 1:62,500 scale, is dominated by several sets of map units, as follows: (1) Variably mylonitic granitic and gneissic bedrock on the western side of the map area form the Suizo Mountains and some low relief areas to the northeast of the Suizo Mountains. These rocks are part of the footwall of the Suizo-Cloudburst detachment fault, a low-angle normal fault that is probably correlative with the Guild Wash fault to the south (Banks et al., 1977, 1980; Dickinson, 1991, 1992; Richard et al., 2002, Ferguson et al., 2002). (2) Early Proterozoic Pinal Schist and intruding Early Proterozoic granodiorite that form a pediment in the southwestern part of the map area and that are structurally above and displaced by the Suizo-Cloudburst detachment fault. Also within this set of map units, but inferred to be in the footwall of the detachment fault, are granitic rocks and schist that are exposed in the northeastern corner of the map area at the foot of Black Mountain (Krieger, 1974; Skotnicki, 1999; Orr et al., 2002). (3) Oligo-Miocene mafic volcanic rocks and dominantly volcanic-lithic conglomerate that locally rest depositionally on the Early Proterozoic schist and granodiorite. These rocks are tilted to the east or northeast with stratal dips decreasing up stratigraphic section. Beds are locally very steep to vertical near the base of the section and generally moderately dipping toward the top (see also Ferguson, et al., 2002). This unit has been correlated with the Cloudburst Formation of Heindl (1963) and Creasey (1965) by Dickinson and Shafiqullah (1989) and Dickinson (1991). (4) Conglomerate generally dipping 5° to 25° to the east or northeast that contains dominantly granitic rock debris. This unit has been correlated with the San Manuel Formation of Heindl (1963) by Dickinson and Shafiqullah (1989) and Dickinson (1991). (5) A large rock-avalanche deposit of granite derived from Black Mountain forms hills along the east side of the map area. These rocks were interpreted by Banks et al., (1977) as bedrock but are interpreted here as forming a discrete slide mass in the Tertiary stratal sequence. (6) Late Cenozoic alluvial deposits.

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. Includes a demolished Titan nuclear-weapon missile-silo complex south of upper Coronado Wash.

Qy_c — Modern river channel deposits (<~1 ka)
Active channel deposits composed of well-sorted sand and gravel to poorly-sorted sand, gravel and cobbles in the steeper channels. Channels are generally incised less than 1 m below adjacent terraces and bars, but locally incision may be as much as 2 m. Channel morphologies generally consist of a single-thread high flow channel or multi-threaded low flow channels with gravel bars. Channels are extremely flood prone and are subject to deep, high velocity in moderate to large flow events, and severe lateral bank erosion.

Qy_2 — Late Holocene alluvium (<~2 ka)
Channels, low terraces, and small alluvial fans composed of gravel, sand, and silt with cobbles, and boulders recently deposited by modern drainages. Includes Qy_c where not mapped separately. Near mountain fronts, channel sediment is generally sand and gravel, but may include cobbles and boulders; terraces typically are mantled with sand and finer sediment. On piedmont areas, young deposits consist predominantly of sand and silt, with some gravels and cobbles in channels. Channels generally are incised less than 1 m below adjacent terraces and fans, but locally incision may be as much as 2 m. Channel morphologies generally consist of a single-thread high flow channel or multi-threaded low flow channels with gravel bars adjacent to low flow channels. Downstream branching distributary channel patterns - small, discontinuous, well-defined channels alternating with broad expansion reaches where channels are very small and poorly defined - are typically on the western piedmont. Local relief varies from fairly smooth channel bottoms to the undulating bar-and-swale topography that is characteristic of coarser deposits. Channels are flood prone and may be subject to deep, high velocity flows in moderate to large flow events. Potential lateral bank erosion is severe. Flood flows may significantly change channel morphology and flow paths. Terraces are planar, often with small channels incised less than 1 m. 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. Soil development associated with Qy_2 deposits is minimal. Vegetation along Qy_2 channels includes mesquite and acaccias, along with several shrub species.

Qy_1 — Holocene alluvium (~2 to 10 ka)
Low terraces found at scattered locations along incised drainages and broad alluvial fans on the northwestern edge of map area. Qy_1 terraces are slightly higher and less subject to inundation than adjacent Qy_2 terraces. Surfaces are generally planar but fans may be incised up to 2 m. Qy_1 terraces are 1 to 2 m above adjacent active channels. Surfaces typically are sandy but locally have unvarnished, open, fine gravel lags. Soil development is minimal with weak subangular blocky structure and no to weak (stage 1) carbonate accumulation (see Machette, 1985, for description of stages of calcium carbonate accumulation in soils). Yellow brown (10YR) soil color is similar to original fluvial deposits Qy_1 surfaces support creosote bush, cholla, grasses, prickly pear, mesquite and acaccias.

Qy — Holocene alluvium, undifferentiated (<~10 ka)
Includes Qy_c, Qy_2, and/or Qy_1 deposits. Used where not possible, at this scale, to map surfaces separately. Unit Qy consists of smaller incised drainages in the mountains and on the upper piedmonts.

Qly — Holocene to late Pleistocene alluvium (~2 to 130 ka)
Unit Qly is found in two locations within the map area. In the central portion of the map area, between Forman and Coronado washes, unit Qly is found in abandoned stream channels on unit Tb, approximately 6 m above active washes. These channel deposits are composed of poorly-sorted, sand and gravel of possible late Pleistocene to early Holocene age. In the southwest corner, Qly terraces are approximately 2 m above active channels. These surfaces are covered by a thin veneer of light brown, fine-grained Holocene alluvium and scattered fine gravel lag (Qy_1 and Qy_2), with reddened Pleistocene alluvium (Ql) exposed in wash cut banks. Vegetation on Qly terraces includes triangle leaf bursage, creosote bush, cholla, prickly pear, barrel cacti, and palo verde trees.

Ql — Late Pleistocene alluvium (~10 to 130 ka)
Broadly rounded and moderately dissected terraces. Surfaces are 1 to 2 m above active channels with relict bar and swale morphology preserved. Deposits consist of gravel, cobbles, and finer-grained sediments. Ql surfaces commonly have loose, open lags of gravel and cobbles; surface clasts may exhibit weak rock varnish. Ql soils are brown to strong brown (7.5YR), weakly to moderately developed, small to moderate subangular blocky structure and stage I-II calcium carbonate accumulation. Vegetation includes triangle leaf bursage, creosote bush, cholla, prickly pear, barrel cacti, yuccas, mesquite and palo verde trees.

Qm — Middle Pleistocene alluvium (~130 to 750 ka)

Qm_p — Middle Pleistocene alluvium over pediments (~130 to 750 ka)
Moderately dissected relict alluvial fans drained by well-developed, moderately to deeply incised tributary channel networks. Channels are incised 1-4 meters with channel dissection increasing towards the mountains. Well-preserved, planar Qm surfaces are smooth with moderately to strongly varnished, loose to moderately packed gravel and cobble pavements. More eroded, rounded Qm surfaces are characterized by scattered cobble lags and broad ridge-like topography. Qm alluvium derived from granitic rocks tend to have smooth gravel surfaces with little to no varnish on surface clasts, and lesser amounts of carbonate accumulation through the soil profile. Qm surfaces have a distinctive dark red color on color aerial photos, reflecting reddening of the surface soil and surface clasts. Soils typically contain reddened (7.5-5YR), clay argillic horizons, with obvious clay skins and subangular to angular blocky structure. Underlying soil carbonate development is typically stage II-III, with abundant carbonate through at least 1 m of the soil profile; indurated petrocalcic horizons are rare. Unit Qm_p consists of thin, discontinuous pockets of Qm alluvium over bedrock pediments. Outcrops of bedrock are common in these areas. Qm surfaces generally support yucca, mesquite, acacia, palo verde, creosote, cholla, prickly pear, and occasionally saguaro or ocotillo.

Qmo — Middle to Early Pleistocene alluvium (~500 ka to 1 Ma)
Moderately to deeply dissected relict alluvial fans. Qmo forms broadly rounded ridges that are higher than adjacent Qm surfaces but not as high or eroded as Qo surfaces. Tributary drainage networks are incised 3 to 6 m, increasing towards the mountains. Qmo soils are very well developed with a distinct dark red (5-2.5 YR), heavy clay argillic horizon and subangular blocky to prismatic structure. Carbonate accumulations are 2-4 m thick and range from stage III -V; up to stage VI in areas between the Florence Highway and Suizo Mountains. Qmo surfaces support sparse vegetation including palo verde, mesquite, ocotillo, cholla, prickly pear cacti, and saguaro.

Qo — Early Pleistocene alluvium (~750 ka to 2 Ma)

Qo_p — Early Pleistocene alluvium over pediments (~750 ka to 2 Ma)
Deeply dissected relict alluvial fans remnants in the southern map area. Qo surfaces are highly eroded, rounded ridges with up to 10 m of active channel incision. Qo deposits consist of cobbles, boulders, and sand and finer clasts with soil development similar to Qmo soils. Qo surfaces vary from red where the argillic horizon is preserved, to light colored where carbonate-rich fragments derived from the underlying petrocalcic horizon litter the surface. Qo surfaces record the highest levels of aggradation in the area surround the Tortolita Mountains, and are probably correlative with other high, remnant surfaces found at various locations throughout southern Arizona (Menges and McFadden, 1981; Pearthree and Calvo, 1987; Skotnicki, 2000). Unit Qo_p is a thin veneer of well-preserved Qo alluvium over bedrock pediment. Outcrops of bedrock are common in these areas. Qo surfaces support sparse vegetation including palo verde, mesquite, triangle leaf bursage, creosote, ocotillo, cholla, prickly pear, and saguaro.

Qro — Regolith and early Pleistocene alluvium (~130 ka to 2 Ma)
This unit forms a mantel over the granite-clast sedimentary breccis (Txg) and other nearby units, and is derived from them. It is composed of grussy sand and finer-grained materials and is ess than 1 m thick. Qro deposits vary in thickness from less than 1 m up to 2 m. The older alluvium is dark red where the argillic horizon is preserved, and light colored where carbonate-rich fragments derived from the underlying petrocalcic horizon litter the surface. Vegetation includes triangle leaf bursage, creosote, ocotillo, prickly pear, cholla, and palo verde.

Qr — Regolith alluvium (Holocene and Pleistocene)

Qr/Tb — Regolith alluvium derived from basalt (Holocene and Pleistocene)

Qr/Tc — Regolith alluvium derived from conglomerate (Holocene and Pleistocene)
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 (< 1m) with scattered outcrops of underlying rock.

Qc — Talus and colluvium (Holocene and Pleistocene)
Qc consists of gravity-transported, unconsolidated talus and colluvium on steep hillslopes where it is sufficiently thick to obscure underlying bedrock. Deposits consist of angular to subangular boulders to fine sediments, composed mainly of adjacent bedrock lithologies. Vegetation is generally not found on these deposits due to the frequent movement of material.

Quaternary to late Tertiary map units

QTs — Early Pleistocene to Pliocene alluvium, undivided (~1 to 5 Ma)
Unit QTs is a basin fill deposit consisting of very old, deeply dissected and highly eroded alluvial fan deposits derived from nearby mountains. QTs surfaces are alternating eroded ridges and deep valleys, with deeply incised tributary channel networks. Pockets of red, well developed soil mantle some of the hillslopes. QTs is composed of poorly sorted angular to subangular gravel and cobbles. Deposits are moderately indurated with carbonate sporadically exposed at the surface. The unit correlates with map unit Tcy of Skotnicki (2000).

QTc — Early Pleistocene to Miocene alluvium (~1 to 5 Ma)
Moderately consolidated, clast-supported boulder alluvial deposits found in the northeastern map area. Clasts resemble bedrock at Black Mountain, are coarser near Black Mountain and are inferred to have been derived from it. Rocks of this unit could be regolith derived from underlying Tertiary boulder fanglomerate of map unit Tcg, reworked underlying fanglomerate, or Quaternary deposits carried in streams from bedrock source areas.

Tertiary map units

Txg — Rock avalanche breccia derived from granite (middle Tertiary)
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, especially east of Hit Tank, 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, this unit is not brecciated and apparently forms a megablock within the breccia. Locally, rocks of this unit were derived from banded gneiss. Almost all exposures form a large, discontinuous sheet that appears to be stratigraphically above map unit Tcg, but 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, where bedrock is lithologically very similar (Orr et al., 2002).

Txgm — Rock avalanche breccia derived from mylonitic granite (middle Tertiary)
Breccia and rubble derived from mylonite derived from coarse-grained, equigranular to K-feldspar-porphyritic granite containing up to 10% biotite. In some exposures, especially east of Hit Tank, rocks of this unit are so weakly brecciated that mylonitic shear zones within granite can be mapped for tens of meters with little internal disruption or dismemberment. Mylonitic shear zones have well developed S-C fabrics similar to local bedrock of Black Mountain (Orr et al., 2002). All exposures associated with breccia of map unit Txg.

Txlg — Rock avalanche breccia derived from leucogranite (middle Tertiary)
All exposures associated with breccia of map unit Txg.

Txd — Rock avalanche breccia derived from diabase (middle Tertiary)
All exposures associated with breccia of map unit Txg.

Txp — Rock avalanche breccia derived from Pinal Schist (middle Tertiary)
Almost all exposures are associated with a large, discontinuous sheet of map unit Txg that appears to be stratigraphically above map unit Tcg, but locally includes exposures that are associated with map units Tb and Tc.

Txq — Rock avalanche breccia derived from quartzite (middle Tertiary)
All exposures associated with basalt and conglomerate of map units Tb and Tc.

Txc — Rock avalanche breccia derived from carbonate rocks (middle Tertiary)
All exposures associated with basalt and conglomerate of map units Tb and Tc.

Tty — Younger tuff (middle Tertiary)
This tuff unit is the younger of two Tertiary tuffs exposed in the map area. Only one tiny exposure is shown on the map, which is in upper Coronado Wash. At this exposure the tuff is 10 cm thick, horizontal, and contains 2-3%, 1 mm biotite, and 1 mm sanidine. Sample 3-26-02-1, from this location, yielded a sanidine 40Ar/39Ar radiometric date of 19.68 ± 0.3 Ma (Peters et al., 2003). Other exposures were seen in the area but only this one is shown on the map.

Tcg — Conglomerate, dominantly granitic clasts (middle Tertiary)
Poorly sorted, poorly to moderately bedded, sandy conglomerate with dominantly granitic debris. Outcrops commonly have a rounded form similar to the possibly correlative San Manuel Formation farther east (Dickinson, 1991), and are tan to light brown, unlike typically medium to dark brown to reddish brown conglomerate of underlying map unit Tc. Pinal Schist clasts are locally abundant in southeasternmost exposures. Contact with underlying conglomerate of map unit Tc is gradational near Parker Wash. Rocks of this unit were correlated with the San Manuel Formation of Heindl (1963) by Dickinson and Shafiqullah (1989) and Dickinson (1991).

Tbt — Basalt of Three Buttes (middle Tertiary)
Basalt flows and dikes in the Three Buttes area. Basalt contains <1%, conspicuous, dark, glassy clinopyroxene crystals up to 3 cm diameter and untwinned feldspar crystals to 15 mm diameter. Exposures of most outcrops do not reveal the extrusive vs. intrusive nature of the basalt, and the map unit includes both dikes and flows. Average results of three chemical analysis, one by Jennison (1976) and two done as part of this mapping study, are as follows: 47.9% SiO_2, 16.96% Al_2O_3, 10.36% Fe as Fe_2O_3, 8.58% CaO, 7.08% MgO, 3.52% Na_2O, 1.79% K_2O, 1.75% TiO_2, 0.17% MnO. Detailed petrographic descriptions are provided by Banks et al. (1977).

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, date listed under "Durham - Suizo area"; sample originally collected by Jennison, 1976). Jennison's (1976) abstract states that the sample came from two miles north of Three Buttes in the Coronado Wash area, and that it came from an area where "a basalt layer that Barter (1962) called a sill" is "concordant with Pantano-like beds." Basalt of Three Buttes in this area consists of lava flows and probable dikes or sills. No other location information was identified regarding the sample location.

Recognition of lava flows and stratigraphic relationships indicate substantial relief before deposition of underlying conglomerate of map unit Tcg (San Manuel Formation [Dickinson, 1991]). At one location (NW¼, NW¼, sec. 19, T. 9 S., R. 13 E.; JES GPS station 116), Basalt of Three Buttes is represented by vesicular lava flows and flow breccias, the flows are concordant to bedding in host conglomerate, and clasts of the basalt are present in the upper conglomerate of map unit Tcg. This location is approximately 500 m stratigraphically above the contact where conglomerate of map unit Tcg rests on conglomerate of underlying map unit Tc. (Strata are concealed between these locations and could be repeated by unmapped faults, in which case the stratigraphic separation is less.) Farther north, on the north side of Coronado Wash, Basalt of Three Buttes is in contact with the older conglomerate of map unit Tc (Cloudburst Formation [Dickinson, 1991]). At this locality, and along strike to the north, the Basalt of Three Buttes is represented by lava flows, with vesicles and flow breccia. It thus appears that the Basalt of Three Buttes formed lava flows that, in the Three Buttes area, flowed over and intruded conglomerate of map unit Tcg, and farther north flowed over the underlying conglomerate of map unit Tc. This implies that much relief existed after most middle-Tertiary volcanism (underway locally at 26.7 ± 0.5 Ma; Banks et al., 1978) and related conglomerate deposition, that deposition of post-volcanic conglomerate (unit Tcg) had partially filled in topographic lows when the Basalt of Three Buttes was deposited at 21 Ma and, that deposition of conglomerate of map unit Tc was still underway at this time.

A sample of dark, glassy clinopyroxene from this basalt yielded a 143Nd/144Nd ratio of 0.5124, a 147Sm/144Nd ratio of 0.15984, and an eNd(0) of -4.39 (Clark Isachsen, University of Arizona, written communication, 2002). The negative eNd value indicates that this rock unit was not derived from uncontaminated asthenosphere, but was either derived from lithospheric mantle (probably by subduction-related magmatic processes) or, less likely, was an asthenosphere-derived magma with an eNd greater than about +2 that was contaminated by lithospheric material (e.g., Livaccari and Perry, 1993). In contrast, identical appearing dark, glassy clinopyroxene (crystals also up to 3 cm diameter), from an ~10 Ma basalt dike in the Roskruge Mountains west of Tucson, yielded an eNd(0) of 7.02 (Richard et al., 2000). This high positive ratio indicates an origin as uncontaminated, asthenosphere derived magma, or as an uncontaminated xenocryst in a possibly contaminated magma. A major decrease in eNd between 20 and 10 Ma as documented by these two samples, as well as a regional increase in 87Sr/86Sr in igneous rocks erupted in Arizona at this time, is consistent with an inferred transition from subduction-related magmatism to post-subduction extension and derivation of basalts from asthenosphere (Spencer and Reynolds, 1989; Leighty, 1998).

Tc — Conglomerate, dominantly volcanic clasts (middle Tertiary)
Poorly to moderately well sorted conglomerate with typically subangular clasts of mafic volcanic rocks and less abundant granitic rocks. Mafic volcanic rocks are abundant at lower stratigraphic levels, whereas granitic rock types and, locally, Pinal Schist, commonly comprise a significant minority of clasts at higher stratigraphic levels. Sub-rounded quartzite cobbles are locally present. Unit locally includes poorly sorted, coarse sandstone and sandy pebble conglomerate. Medium to dark brown to reddish brown colors are dominant, whereas overlying, granite-dominant conglomerate of map unit Tcg is typically light brown, tan and gray. Locally occurring massive conglomerates are interpreted as mudflows. Bedded deposits are interpreted to be alluvial fan deposits. Most clasts are 1 to 20 cm diameter, locally are as large as 2 m. In some areas mixing of volcanic and granitic clasts has not been effective so that segregation is apparent over a few meters across section, suggesting that conglomerate sources were very near and that channel migration in an alluvial fan environment changed clast source areas. Rocks of this unit were correlated with the Cloudburst Formation of Heindl (1963) and Creasey (1965) by Dickinson and Shafiqullah (1989) and Dickinson (1991).

Ttl — Volcanic-lithic tuff (middle Tertiary)
Tuff is approximately 10 m thick, with 1-2% 1 mm quartz, 2-3% 1-2 mm oxidized biotite, several percent feldspar, and 5-10%, 1-10 mm mafic to intermediate volcanic-lithic fragments.

Tt — Tuff (middle Tertiary)
Tuff is pale whitish tan to buff, slightly porous, and moderately to strongly consolidated. This tuff is thought to be correlative with a tuff interbedded with the Cloudburst Formation to the east that has been dated at 26.33 ± 0.1 Ma, and with a tuff to the southwest in the northern Tortolita Mountains dated at 26.39 ± 0.07 Ma (Orr et al., 2002; Ferguson et al., 2002; Spell et al., 2003).

Tb — Basalt (middle Tertiary)
A composite unit of amalgamated mafic lava flows and flow breccias. Clinopyroxene(?) crystals up to 2 mm diameter are sparse but characteristic of most exposures. Vesicles are characteristic of many exposures. Relict olivine altered to iddingsite is visible in some outcrops, as are acicular plagioclase microlites. In the Chief Butte area, lava flows are characterized by phenocryst assemblages of 2-15% pyroxene, + olivine, and subordinate plagioclase (ranging in size from 0.3 mm to 4 mm). The unit is differentiated from andesite lava of map unit Ta by the subordinate abundance and size of the plagioclase phenocrysts relative to the ferromagnesian phenocrysts. The matrix of the lavas is typically microcrystalline, but locally aphanitic, and ranges from vesicular to massive. Individual flow units are 2 to 20 m thick. In some areas flow tops are defined by reddish scoriaceous zones that are commonly infiltrated with red volcaniclastic sandstone, and in many areas, thin intervals of volcaniclastic sandstone occur between the flows.

Td — Dacite (middle Tertiary)
Dacite lava flows and flow breccias. Exposures north of Chief Butte contain <1%, 2-3 mm quartz and <1%, 1 mm biotite, and 2-5%, 1-4 mm feldspar which is largely or entirely plagioclase but could include some sanidine.

Tdi — Dacite intrusions (middle Tertiary)
Contains minor biotite. A sample of a similar and probably correlative dacite from the adjacent Tortolita Mountains 7½' Quadrangle yielded an K-Ar biotite age of 26.7 ± 0.5 Ma (Banks et al., 1978).

Ta — Andesite (middle Tertiary)
Andesite lava flows and flow breccias in which ferromagnesian minerals are subordinate in size and abundance to plagioclase.

Tb0 — Basal basalt unit (middle Tertiary)
Massive, sparsely vesicular and rarely autobrecciated basalt lava flows, with crystalline matrix.

Tmd — Mafic dike (middle Tertiary)
Mafic dike associated with detachment fault near lower Coronado Wash.

Tmi — Mafic intrusion (middle Tertiary)
Mafic intrusions at Lopez Wells (upper Coronado Wash). Holocrystalline, fine- to very fine-grained, medium gray diorite(?). Suspected to be intrusive because of its homogeneity and lack of any evidence of extrusion such a vesicles or flow breccia.

Tertiary to Proterozoic map units

cbx — Chloritic breccia (middle Tertiary with Tertiary to Early Proterozoic protoliths)
Generally occurs as strongly fractured to highly brecciated, medium to dark greenish gray, chloritically altered granitoid or schist. Fractures commonly host hematite staining, locally with chrysocolla. In areas of strong development of brecciation and alteration it was not possible to determine protolith composition. Brecciation was caused by crushing in the footwall of the Suizo-Cloudburst detachment fault (e.g., Dickinson, 1991), and alteration was caused by movement of hot water along this fault (e.g., Rehrig and Reynolds, 1980; Reynolds and Lister, 1987).

TYgp — Granitoid protocataclasite (middle Tertiary with middle Proterozoic(?) protolith)
Very strongly shattered coarse-grained granitoid. Protolith is probably biotite granite of map unit Yg. All biotite altered to chlorite, and plagioclase is greenish and saussuritized. Rock appears granulated, almost like a very coarse-grained arkose, 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.

TYgm — Muscovite leucogranite of Black Mountain (Tertiary to Middle Proterozoic)
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 (Spell et al., 2003).

Proterozoic map units

Yd — Diabase (Middle Proterozoic)

Yg — Biotite granite (Middle Proterozoic)
Coarse-grained, equigranular to K-feldspar-porphyritic granite containing up to 10% biotite.

Xgd — Granodiorite (Early Proterozoic)
Fine grained, equigranular, plagioclase + quartz + biotite granodiorite(?) with 5-8%, 1-2 mm, generally oxidized biotite, 1-3 mm, dark gray quartz, and 1-4 mm, white plagioclase. At one location southwest of Chief Butte (E492356, N3609435; JES GPS 218), in a major wash tributary to Parker Wash, granodiorite of this unit intrudes Pinal Schist, and both are foliated by a deformation that does not affect nearby Middle Proterozoic porphyritic granite of map unit Yg. The granodiorite is therefore interpreted to be early Proterozoic and to have been deformed in the early Proterozoic. A sample of this unit yielded a biotite K-Ar date of 1,438 ± 10 Ma (Banks et al., 1978).

Xp — Pinal Schist (Early Proterozoic)
Pale gray to medium gray to silvery gray, fine-grained schist, psammite, and phyllite, in hanging wall of detachment fault, exposed in washes and on pediment in southwestern corner of map area. Locally contains 1-2 mm diameter dark spots, siliceous laminations, and sandy lenses. Fabric is very variable. Generally, the unit is sufficiently metamorphosed that pelitic rocks have significant phyllosilicate development and cleavage parallel to preferred orientation of phyllosilicates. Phyllosilicates, locally visible in hand sample without the aid of a hand lens, impart a silvery sheen to the rock. Quartz veins and stringers are locally abundant, especially in pelitic rocks.

Xp? — Pinal Schist? (Early Proterozoic)
Areas where designation as Pinal Schist is based on aerial photograph interpretation and extrapolation from nearby areas where schist was positively identified. Designation as Pinal Schist remains somewhat uncertain.

Xpq — Pinal Schist, quartzite (Early Proterozoic)

Leucogranite complex of the Suizo Mountains

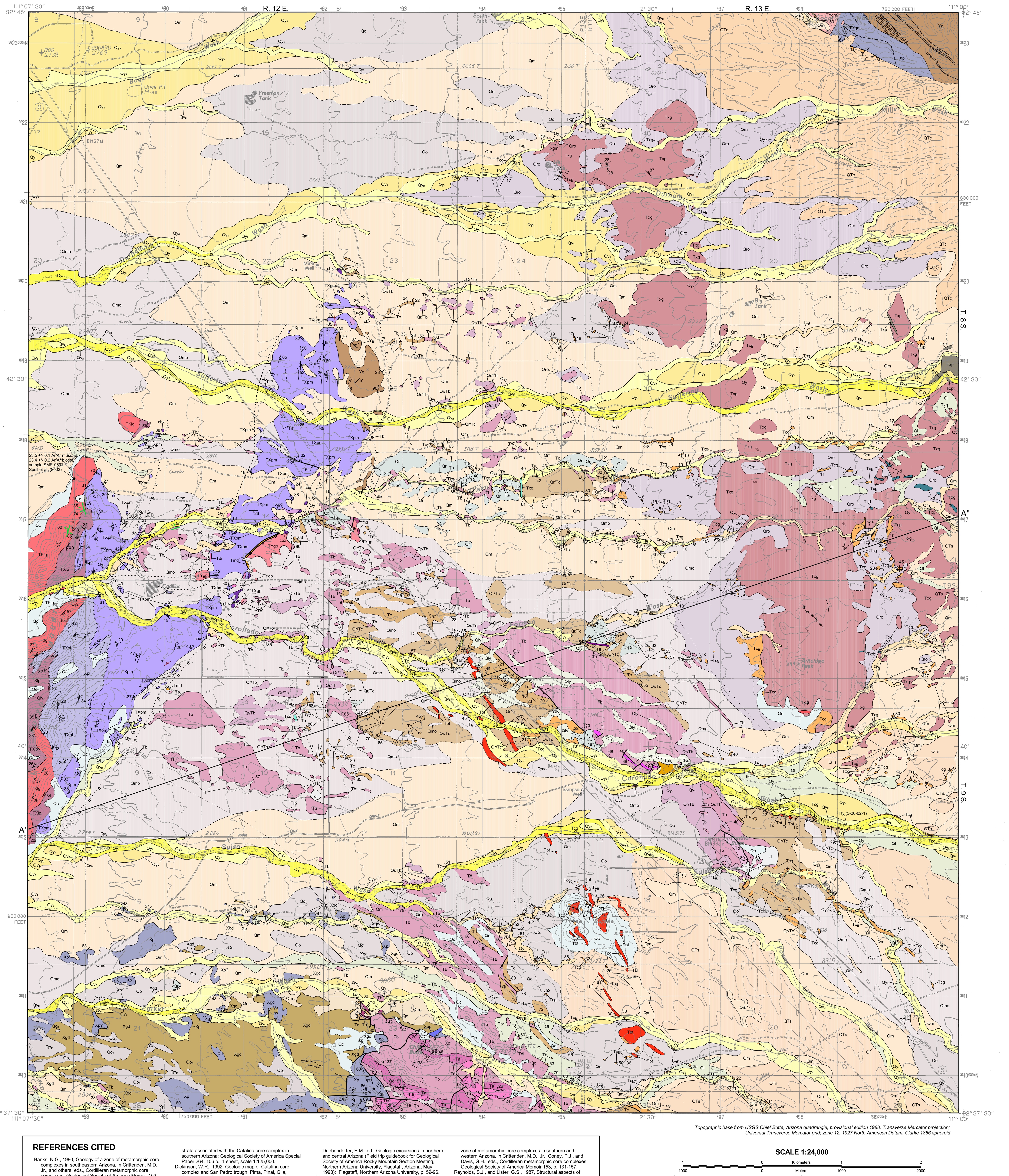
TKlg — Leucogranite of the Suizo Mountains (Late Cretaceous or Tertiary)
Leucocratic muscovite-biotite granite, consists of about 20% quartz that is 1-3 millimeter in diameter, weakly to moderately sericitized plagioclase, and generally less than about 7% muscovite + biotite. Locally contains 2-3%, 0.1 to 3 mm garnet, and up to 7% muscovite. Biotite typically forms <2% of rock unit. The unit consists of pegmatite and pegmatitic quartz veins in some areas. Rock is generally resistant and forms ridge tops in Suizo Mountains.

TXlp — Mixed unit, leucogranite predominant over Pinal Schist (Early Proterozoic and Late Cretaceous or Tertiary)
Heterogeneous pegmatitic muscovite leucogranite with screens of muscovite-biotite schist, and schist with concordant veinlets and sheets of leucogranite. This unit mapped where leucogranite is the predominant phase present, and schist forms 10% to 50% of rock volume. Garnet is only locally present in the schist phase. Leucogranite dikes locally cross-cut laminated differentiated foliation in schist, which is interpreted to represent the Proterozoic fabric in the schist.

TXpl — Mixed unit, Pinal Schist predominant over leucogranite (Early Proterozoic and Late Cretaceous or Tertiary)
Identical to map unit TXlp, but schist is predominant, and leucogranite forms 10% to 50% of rock.

TXpm — Pinal Schist with mylonitic overprint (Middle Proterozoic and Cretaceous or Tertiary)
Pinal Schist with strongly planar fabric. Lenses of leucocratic granite concordant to foliation are apparently the transposed remnants of muscovite granite and pegmatite dikes. Floating isoclinal fold hinges in millimeter- to centimeter-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 intrusions. The stretching lineation in granitic rocks and quartz veins is typically parallel to intersection lineation formed between older laminated differentiated foliation and mylonitic foliation, which is the most prominent lineation in most outcrops. This parallelism is inferred to be due to a pre-mylonitic orientation of the laminated differentiated foliation that was steep and east-northeast striking, so that strike was fortuitously subparallel to later mylonitic shearing and stretching. Mylonitic foliation is almost certainly the result of middle Tertiary extensional tectonism as is typical of metamorphic core complexes (e.g., Rehrig and Reynolds, 1980; Davis, 1980).

TXgd — Granodiorite in Pinal Schist (Proterozoic or middle Tertiary)
Small intrusions of medium- to fine-grained biotite granodiorite in Pinal Schist. Rock is dark greenish gray with chloritized mafic minerals, and typically has moderately to strongly developed mylonitic fabric. Contains 5-10%, 2-3 millimeter white feldspar porphyroclasts that give the rock a speckled look. In a few places seems to grade into microdiorite dike rock that commonly intrudes chloritic breccia along detachment fault (map unit Tmd), suggesting that this may be a coarser-grained equivalent of rocks of map unit Tmd.



Topographic base from USGS Chief Butte, Arizona quadrangle, provisional edition 1988. Transverse Mercator projection. Universal Transverse Mercator grid; zone 12; 1927 North American Datum; Clarke 1866 spheroid

SCALE 1:24,000

Kilometers: 1 0 1 2
Meters: 1000 0 1000 2000
Miles: 1 0 1
Feet: 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL 40 FEET

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GEOLOGIC MAP SYMBOLS

Bedding symbols
- Bedding
- Vertical bedding
- Horizontal bedding
- Overturned bedding
- Bedding with stratigraphic facing direction known
- Indistinct bedding
- Vertical indistinct bedding
- Variable bedding
- Apparent dip of bedding
- Horizontal apparent dip of bedding

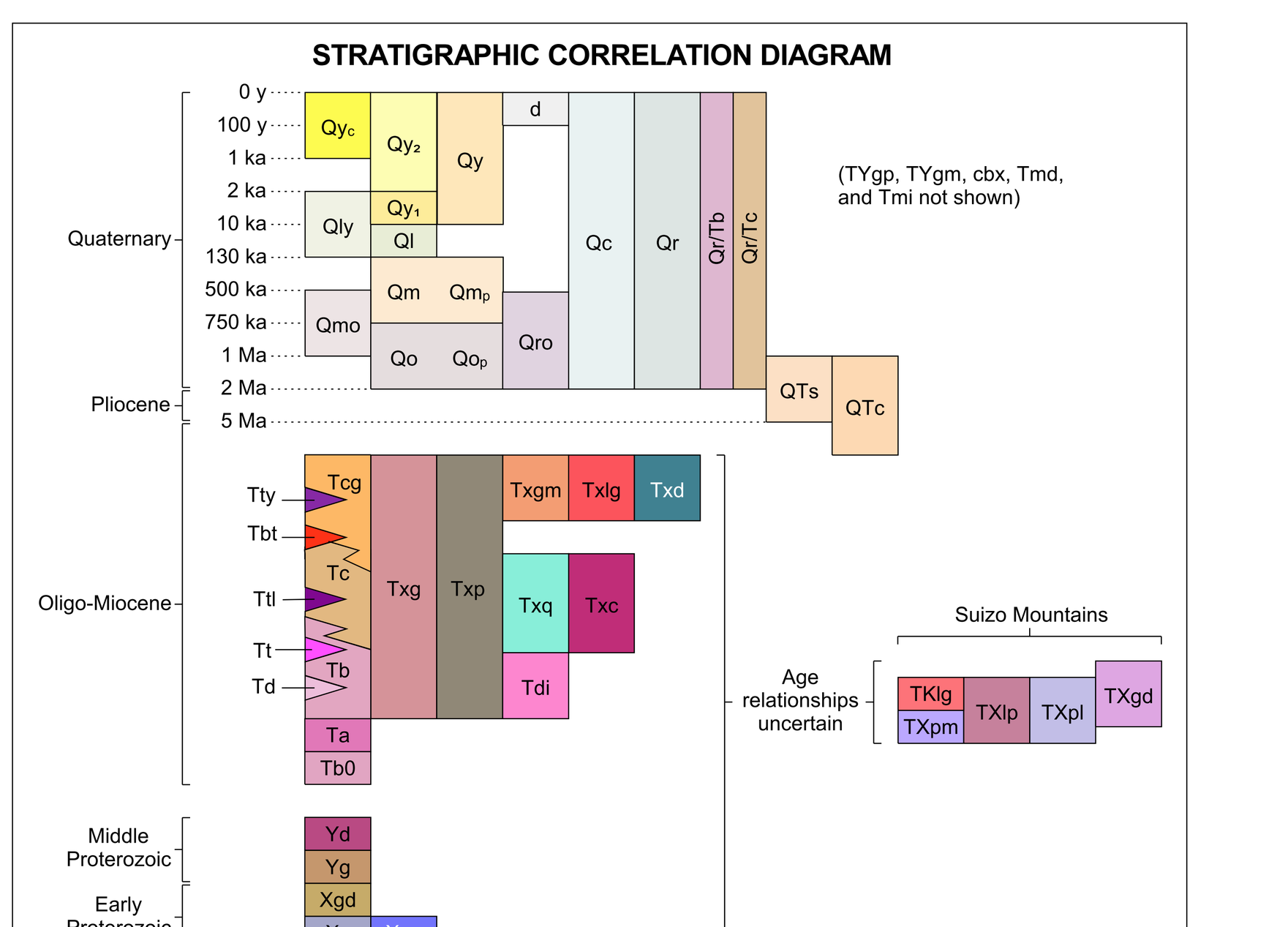
Lineation symbols
- Cleavage/foliation intersection lineation
- Mylonitic stretching lineation with sense of shear not determined
- Mylonitic stretching lineation with down-dip sense of shear
- Mylonitic stretching lineation with up-dip sense of shear

Foliation and cleavage symbols
- Eutaxitic foliation
- Schistosity
- Vertical schistosity
- Inclined close disjunct cleavage
- Crenulation surface
- Slaty cleavage
- Unspecified tectonic foliation
- Laminated differentiated foliation
- Weak shape fabric (incipient mylonitic foliation)
- Moderately developed mylonitic foliation
- Mylonitic foliation
- Ultramylonitic foliation
- Mylonitic gneissic foliation
- Gneissic foliation

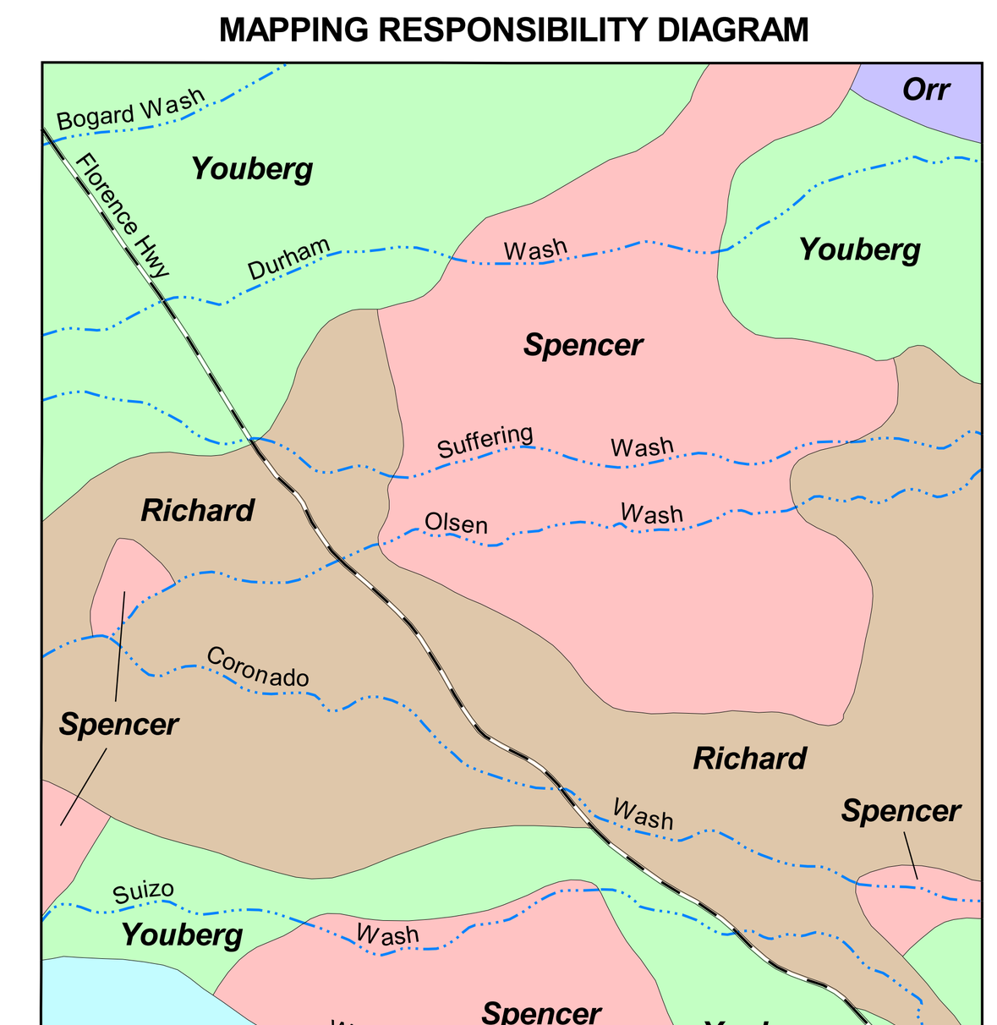
Other symbols
- Minor fault, showing dip
- Minor dike, showing dip

Contact, fault, and dike symbols
- Depositional or intrusive contact — *Dashed where approximately located, dotted where concealed, queried where location uncertain.*
- Gradational contact
- Cutbank exposures, showing height of cutbank (meters)
- Cartographic contact — *Used to close map unit polygons where true contact location is unknown.*
- Fault, showing dip — *Dashed where approximately located, dotted where concealed, queried where location uncertain.*
- Detachment fault — *Dashed where approximately located, dotted where concealed, tics indicate hanging wall.*
- Mylonitic shear zone
- Marker bed
- Felsic dike
- Mafic dike

STRATIGRAPHIC CORRELATION DIAGRAM



MAPPING RESPONSIBILITY DIAGRAM



Additional surficial mapping by Youberg throughout map area.