Geologic map of the Esperanza Mill 7½' Quadrangle, Pima County, Arizona

by

Jon E. Spencer, Charles A. Ferguson, Stephen M. Richard, and Ann Youberg

Arizona Geological Survey DGM-33 v.2

September 2019

Scale 1:24,000 (1 sheet)

Arizona Geological Survey
416 W. Congress St., #100, Tucson, Arizona 85701

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number #02HQAG0016. The views and conclusions contained in this document 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.

Geologic map of the Esperanza Mill 7½' Quadrangle, Pima County, Arizona

by:

Jon E. Spencer, Charles A. Ferguson, Stephen M. Richard, and Ann Youberg

INTRODUCTION

The Esperanza Mill 7 ½' Quadrangle is located approximately 40 km south-southwest of downtown Tucson, and is on the southeast flank of the Sierrita Mountains. The quadrangle encompasses the eastern edge of the Esperanza ore body, which is now mined from within a single large open pit that encompasses both the Sierrita and Esperanza ore bodies. It also encompasses bedrock hills on the southeastern flank of the Sierrita Mountains, extensive piedmont alluvial deposits, Santa Cruz River deposits, and extensive mine tailings from the Sierrita-Esperanza mine. Bedrock in the area was mapped during December 2002 to May 2003. Quaternary deposits, mapped earlier by Pearthree and Youberg (2000), were the target of mapping in specific areas that were considered to be incompletely understood. In addition, all of the Quaternary deposits were evaluated and in part reinterpreted based on aerial photograph interpretation. All of this mapping was done as part of a multiyear mapping program directed at producing complete geologic map coverage for the Phoenix-Tucson metropolitan corridor. This map is one of four 1:24,000 scale geologic maps that cover most of the Sierrita Mountains and that were produced for this study. This mapping was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992. Mapping was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP Program Contract #02HQAG0016.

The bedrock geology of the map area is dominated by the Cretaceous Demetrie Volcanics and Oligo-Miocene andesite and dacite, both which were previously mapped by Cooper (1973) at a scale of 1:48,000. The Cretaceous Demetrie Volcanics and stratigraphically underlying Cretaceous conglomerate and Jurassic rhyolite are intruded by the earliest Tertiary Ruby Star granodiorite in the northwestern part of the map area. At the northwestern corner of the map area, these Mesozoic rock units are buried by the mine dump adjacent to the Sierrita-Esperanza porphyry copper ore body (Lynch, 1968; Aiken, and West, 1978; West and Aiken, 1982; Preece and Beane, 1982). The Demetrie Volcanics and overlying Oligo-Miocene andesite and dacite are overlain by extensive Quaternary piedmont alluvial deposits that extend eastward to the Santa Cruz River. This map includes updated mapping and interpretations based on the earlier mapping of Quaternary deposits by Pearthree and Youberg (2000).

Acknowledgments. We especially thank Dan Aiken of Phelps-Dodge Sierrita Inc. for his efforts in obtaining permission for the authors to enter Phelps-Dodge property. He and Greg Baugh are gratefully acknowledged for providing access to mine maps, other information regarding the geology of the Sierrita mine area, and many interesting and informative discussions. We also thank Mat Turner of Caterpillar Inc. for granting permission to map on Caterpillar property.

QUATERNARY AND LATEST TERTIARY MAP UNITS

Map Units Related to Human Activity

d **Disturbed ground (<100 years)** — Areas that have been so profoundly disturbed by human activity as to completely obscure the preexisting natural surface.

dl **Mine dump and leach pads (<100 years)** — Areas where mining operations have buried geologic features with generally coarse rock debris.

t **Mine tailings (<100 years)** — Areas where mining operations have buried geologic features with fine-grained rock debris that was depleted of sulfide minerals in the Sierrita and Esperanza mills.

Piedmont Alluvium

Quaternary and late Tertiary deposits cover the most of the eastern piedmont of the Sierrita Mountains. This alluvium was deposited primarily by larger streams that head in the mountains; smaller streams that head on the piedmont have eroded and reworked some of these deposits. Deposits range in age from modern to Pliocene. The lower margin of the piedmont is defined by the intersection of piedmont alluvial fans and terraces with stream terraces of the Santa Cruz River. 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.

Qy_c – Modern stream channel deposits (< ~1 ka). Active channel deposits composed of moderately-sorted sand and pebbles with some cobbles in the lower piedmont areas to very poorly-sorted sand, pebbles, and cobbles with some boulders in the upper piedmont areas. Channels are generally incised less than 1 m below adjacent Holocene terraces and alluvial 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. 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). Young deposits in low terraces, alluvial fans, and small channels that are part of the modern drainage system. Includes Qy_c where not mapped separately. In upper piedmont areas, channel sediment is generally poorly to very poorly sorted sand and pebbles, but may include cobbles and boulders; terrace and fan surfaces typically are mantled with sand and finer sediment. On lower piedmont areas, young deposits consist predominantly of moderately sorted sand and silt, with some pebbles 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. 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. 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. Flood flows may significantly change channel morphology and flow paths. Downstream-branching distributary channel patterns - small, discontinuous, well-defined channels alternating with broad expansion reaches where channels are very small and poorly defined - are associated with the few young alluvial fans in the area. Local relief varies from fairly smooth channel bottoms to undulating bar-and-swale topography that is characteristic of coarser deposits. Terraces have planar surfaces, but small channels are common. Soil development associated with Qy_2 deposits is weak.

Qy_1 - Holocene alluvium (~2 to 10 ka). Older Holocene terrace deposits found at scattered locations along incised drainages throughout the Sierrita piedmont. Qy_1 surfaces are higher and less subject to inundation than adjacent Qy_2 surfaces, and are generally planar. Local surface relief may be up to 1 m where gravel bars are present, but typically is much less. Qy_1 surfaces are 1 to 2 m above adjacent active channels. Surfaces typically are sandy but locally have unvarnished open fine gravel lags. Qy_1

soils typically are weakly developed, with some soil structure but little clay and stage I to II calcium 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 – undifferentiated Holocene alluvium (<10 ka). Includes Qy_c, Qy_2, and Qy_1 deposits. On the upper piedmonts, unit Qy consists of smaller incised drainages where, at this scale, it was not possible to map surfaces separately. At the lower margin of the piedmont, unit Qy consists of young alluvial fans deposited by piedmont tributary streams interbedded with Santa Cruz River floodplain deposits (unit Qyr).

Qly - Holocene to Late Pleistocene alluvium (~2 to 130 ka). Terraces and broadly rounded alluvial fan surfaces approximately 1 m above active channels. Qly surfaces are primarily covered by a thin veneer of Holocene fine-grained alluvium (Qy) over reddened Pleistocene alluvium (Ql) or eroded, gray to white, basin-fill deposits (QTs). The older units (Ql and QTs) are exposed in patches on low ridges and in cut banks of washes. The Holocene surfaces usually are light brown in color and soils have weak subangular blocky structure with no to minor carbonate accumulation.

Ql - Late Pleistocene alluvium (~10 to 130 ka). Deposits associated with slightly to moderately dissected relict alluvial fans and terraces. Extensive slightly to moderately incised tributary drainage networks are typical on Ql surfaces. Active channels are incised up to about 2 m below Ql surfaces, with incision typically increasing toward the mountain front. Ql fans and terraces are commonly lower in elevation than adjacent Qm and older surfaces, but the lower margins of Ql deposits lap out onto more dissected Qm surfaces in some places. Ql deposits consist of pebbles, cobbles, and finer-grained sediment. Ql surfaces commonly have loose, open lags of pebbles and cobbles and are moderately reddened; surface clasts exhibit weak rock varnish. Ql soils are moderately developed, with orange to reddish brown clay loam to light clay argillic horizons and stage II calcium carbonate accumulation.

Qm - Middle Pleistocene alluvium (~130 to 750 ka). Deposits associated with 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 below adjacent Qm surfaces. 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 surfaces are characterized by scattered cobble lags with moderate to strong varnish and broad ridge-like topography. Soils typically contain reddened, clay argillic horizons, with obvious clay skins and subangular to angular blocky structure. Underlying soil carbonate development is typically stage III, with abundant carbonate through at least 1 m of the soil profile; indurated petrocalcic horizons are rare.

Qmo - Middle to Early Pleistocene alluvium (~500 ka to 1 Ma). Deposits associated with deeply dissected relict alluvial fans. Qmo surfaces form broadly rounded ridges that are higher than adjacent Qm surfaces but not as high or eroded as adjacent Qo surfaces or the highest QTs deposits. Tributary drainage networks are incised 3 to 6 m, increasing towards the mountains. Eroded QTs deposits are occasionally exposed along some ridgeslopes. Where well preserved, Qmo soils are strongly developed with a distinct dark red (5-2.5 YR), heavy clay argillic horizon and subangular blocky to prismatic structure. Carbonate accumulations are 1-2 m thick and range from stage III - V.

Qo – Early Pleistocene alluvium (~1 to 2 Ma). Deposits associated with very old, high, deeply dissected alluvial fan remnants with moderately well preserved fan surfaces and strong soil development. Qo deposits and fan surface remnants are scattered across the southern Sierrita piedmont, but are best preserved near the mountain front. Qo surfaces range from fairly smooth to broadly rounded. Qo deposits vary from cobbles and boulders to sand, silt and pebbles. Stage III to IV calcic horizons are typical, but not always present. Where surfaces are planar and well-preserved, red, heavy clay argillic horizons are typical, but may include pockets of moderately developed, reddish brown (7.5YR), sandy loam with scattered gravel lag. Qo surfaces record the highest levels of aggradation in the Santa Cruz Valley, and are probably correlative with other high, remnant surfaces found at various locations throughout southern Arizona (Menges and McFadden, 1981; Youberg and Helmick, 2001).

QTs - Early Pleistocene to Pliocene alluvium (~1 to 5 Ma). Deeply dissected and highly eroded alluvial fan deposits. QTs surfaces are alternating broadly rounded ridges and deep valleys, with ridgecrests typically 10 to 30 meters above adjacent active channels. The thickness of QTs deposits is not known. QTs surfaces are drained by deeply incised tributary channel networks. QTs deposits include very coarse boulder and cobble hillslope deposits, moderately-indurated pebble to cobble conglomerates, sandy to bouldery alluvial fan deposits, and buried paleosols. QTs deposits are coarser towards the mountains and finer grained near the Santa Cruz River. Soils on ridgecrests are dominated by carbonate accumulation, which is typically stage V (cemented petrocalcic horizons with laminar cap). Carbonate litter is common on ridgecrests and hillslopes. Small pockets of preserved Qo and Qmo may be found along QTs ridges.

Axial Stream Deposits

Sediment deposited by the Santa Cruz River covers a north-south-trending strip through the central part of the map area. Surfaces consist of channels and young stream terraces that compose the geologic floodplain. Deposits are a mix of gravel and sand and finer material; they exhibit mixed lithologies and a higher degree of clast rounding, reflecting the large drainage area of this watershed. Much of the area covered by river deposits has been altered by intense agricultural and urban development, so there is greater uncertainty regarding the locations of unit contacts than in piedmont areas.

Qyc_r - Modern river channel deposits (< 100 years). River channel deposits of the Santa Cruz River, composed primarily of sand and pebbles. Along the Santa Cruz River, modern channels are typically entrenched several meters below adjacent young terraces. The current entrenched channel configuration began to evolve with the development of arroyos in the late 1800's, and continued to evolve through this century (Betancourt, 1990; Wood and others, 1999). Channels are extremely flood prone and are subject to deep, high velocity in moderate to large flow events. Banks along some portions of the Santa Cruz River have been protected with soil cement, but other reaches are unprotected and are subject to several lateral erosion during floods.

Qy_r - Holocene floodplain and terrace deposits (<10 ka). Floodplains and low terraces flanking the main channel system along the Santa Cruz River. Most Qy_r areas along the Santa Cruz River are part of the active floodplain and may be inundated in large floods. Terrace surfaces are flat and uneroded, except immediately adjacent to channels. Qy_r deposits consist of weakly to unconsolidated sand, silt, and clay with some lenses of coarser material. These deposits are interbedded with piedmont Qy deposits. Soils are weakly developed, with some carbonate filaments and fine masses and weak soil structure in near surface horizons. Locally, Qy_r surfaces may experience sheetflooding during large floods in areas where the main channel is not deeply entrenched, and as a result of flooding on local tributaries that debouch onto Qy_r surfaces. Unprotected channel banks formed in Qy_r deposits are very susceptible to lateral erosion.

Hillslope Deposits

Qtc – Holocene and Pleistocene hillslope colluvium and talus (<10 ka). Unit Qtc consists of locally-derived deposits on moderately steep hillslopes in the Sierrita Mountains. Colluvium is very extensive in the mountains, but is mapped only where sufficiently thick and extensive as to obscure underlying bedrock. Deposits are very poorly sorted, ranging from clay to cobbles and boulders. Clasts typically are subangular to angular because they have not been transported very far. Bedding is weak and dips are quite 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. Other more active hillslopes are covered with Holocene deposits, which have minimal soil development.

Qr(Ta) and Qr(Tdh) – Holocene and Pleistocene regolith deposits over Tertiary bedrock units Ta and Tdh (<10 ka). Qr deposits form in situ and vary from disaggregated, angular bedrock clasts to well-developed, reddened, clay-rich residuum, which grades into bedrock and retains original bedrock texture in the C horizon.

TERTIARY MAP UNITS

Tdh **Hornblende dacite of Tinaja Peak (Tertiary)** — Massive and flow banded, generally devitrified hornblende dacite lava flows and/or shallow intrusions. Variations in resistance to weathering define 2-20 cm thick layers that are inferred to reflect igneous flow foliation and variations in degree of devitrification. This banding is irregular on scale of several to several tens of meters. Rock contains approximately 2-5%, 0.5-3 mm hornblende that is locally up to 8 mm, and ≤1%, <1 mm biotite.

Tdx **Lower dacite of Tinaja Peak (Tertiary)** — Dacitic lava containing approximately 20%, 1-3.5 mm subhedral to euhedral, rounded, strongly zoned plagioclase, 3-5%, 0.5-3.0 mm hornblende, and traces of 2 mm subhedral to euhedral clinopyroxene, <1 mm biotite, and <0.3 mm opaque phenocrysts. Matrix is typically gray to orange-brown and crystalline. A well-developed vitric autobreccia occurs at the base, but the carapace autobreccia is mostly absent. Exposed only on the east side of Tinaja Peak.

Tcx **Conglomerate and volcanic breccia (Tertiary)** — Coarse-grained clast to matrix-supported, generally massive conglomerate with a light-colored pumiceous, sandy volcaniclastic matrix. Typically contains 5-40% clasts of the lower dacite of Escondido Wash (map unit Tdf), 30-90% clasts of the lower dacite of Tinaja Peak (map unit Tdx), and 10-30% clasts of Mesozoic volcanic rocks. Exposed only on the east side of Tinaja Peak. The unit mostly underlies the lower dacite of Tinaja Peak, but appears to overlap the lava along its eastern margin.

Tdf **Dacite of Escondido Wash (Tertiary)** — Dacitic lava containing 20-30%, 0.3-2.0 mm, euhedral, zoned plagioclase, and 5-7%, 0.2-2mm subhedral to euhedral clinopyroxene. Exposed only in one small area south of Tinaja Peak. Matrix is typically vitric and very dark, and the lava is massive, displaying only rare zones of autobreccia.

Tdfl **Andesite of Escondido Wash (Tertiary)** — Andesite lava containing 20-30%, 0.3-2.0 mm, euhedral, zoned plagioclase, and 5-7%, 0.2-2 mm subhedral to euhedral clinopyroxene, plus sparse yet conspicuous large phenocrysts (xenocrysts?) of plagioclase (<6 mm) and olivine (2-5 mm). Matrix is typically microcrystalline and crumbly. One chemical analysis of this unit indicates that it is an andesite.

Ta **Andesite of Tinaja Hills (Tertiary)** — Crystal-poor mafic lava flows of probable andesite to basaltic traychyandesite composition preserved in amalgamated flows with massive flow interiors and abundant flow-breccia. Reddish weathering scoriaceous zones locally mark flow contacts. Rarely contains volcanic-lithic sandstone beds up to 3 m thick between flow breccias. Generally contains 0.5-2%, <1 mm plagioclase phenocrysts. Locally contains up to 5% small plagioclase phenocrysts. Microcrystalline matrix is commonly strongly devitrified, with a blotchy, micro-amygdaloidal texture

Tvs **Volcanic-lithic sandstone and conglomerate (Tertiary)** — Clastic sedimentary rocks beneath mafic lava flows of map unit Ta. Locally consists of lapilli(?) sandstone and pebbly volcanic lithic sandstone. Thickness 1-10 m.

Tsb **Sierrita breccia (Tertiary)** — This igneous breccia unit is exposed in the Sierrita open-pit copper mine. Examination by Jensen (1998) indicates that this unit consists of 5% to 60% mafic xenoliths in a porphyritic matrix. This unit is younger than the Ruby Star granodiorite.

Tgd **Ruby Star granodiorite (Tertiary)** — Medium grained, generally equigranular, biotite granodiorite with 3-8% biotite typically 1-4 mm diameter but locally up to 6 mm. Biotite has fresh, reflective faces in some areas, unlike nearby Proterozoic granite in the Twin Buttes 7.5' Quadrangle. Modal mineral analysis by Jensen (1998) determined that this rock unit is in the granodiorite field of the IUGS classification scheme (Streckeisen, 1973), but is very close to the granite field.

Tgx **Ruby Star granodiorite, porphyritic phase (Tertiary)** — Medium grained, porphyritic biotite granodiorite exposed in the Sierrita open-pit copper mine. Known locally as the Esperanza quartz monzonite porphyry. A sample of this rock unit yielded a U-Pb zircon date of 64.3 ± 0.4 Ma (Herrmann, 2001).

TKf **Felsite intrusion (Tertiary)** — White felsite, crystal poor, with sparse 0.5-1 mm quartz crystals, and abundant sericite after feldspar(?); a few lenses of medium-grained granitoid are present.

TKmd **Mafic dike (Tertiary or Cretaceous)** — Very dark gray to black, finely crystalline to aphanitic mafic dike rock with chilled margins.

CRETACEOUS AND JURASSIC MAP UNITS

Ka **Andesite intrusion (late Cretaceous)** — Massive intrusive andesite, contains ~40% crystals, including 1 mm euhedral plagioclase (~25%), 15-20% mafic crystals (hornblende?) altered to chlorite, in medium to dark gray aphanitic groundmass. Host tuff appears slightly hornfelsed at irregular, interdigitated contact.

Kd **Demetrie Volcanics, andesite (late Cretaceous)** — Massive andesitic volcanic rocks and possible hypabyssal equivalents. Generally consists of medium to dark gray rock with 5-40% 1-4 mm gray to chalky white plagioclase(?) and 2-15%, <2 mm biotite(?). Flattened inclusions, represented by 1-10 cm long, 0.5-5 cm thick pits formed after lithic fragments(?), define fabric that could be related to horizontal flow and vertical flattening. Faint flow(?) banding, defined by differences in resistance to weathering, could be flow banding. Crude layering in autoclastic breccia also defines planar fabric element that could be related to lava flow over the Earth's surface. South of Esperanza Well this unit appears locally as fine-grained quartz(?)-feldspar-biotite porphyry with quartz-epidote alteration.

In thin section this rock contains 0-12%, 0.2-2.0 mm, brown biotite(?) that is typically rimmed with opaque minerals (probably iron oxides). Opaques, 0.1-0.5 mm, make up as much of 15% of rock. Birdseye maple extinction is strongest indicator that this mineral is biotite. Another clear mineral could be biotite that has lost its iron due to alteration. One crystal contained a brown core, clear zone around the brown center, and opaque rim. Possibly, the clear zone represents biotite that has been depleted in iron, and this iron is now in the opaque rim. Extinction is parallel to long axis of biotite(?) crystals and parallel cleavage. It is estimated that, unaltered, this rock unit would contain about 10% brown biotite and 5% opaques. Altered, 0.3-3.0 mm feldspar, makes up 35-60% of the rock. Albite twinning is common in some samples, rare in others.

This unit rests on tuff (map unit Kdlr), which in turn rests on conglomerate (map unit Kcg) that is intruded by the 64.3 ± 0.4 Ma Ruby Star granite. The Ruby Star granodiorite was intruded at sufficient depth (probably several kilometers) that it did not develop hypabyssal textures. We therefore infer that the Demetrie Volcanics are older than the Ruby Star granodiorite, and so are probably older than Tertiary (the Cretaceous-Tertiary boundary is dated at 65.5 Ma). The conglomerate and sandstone that underlie the Demetrie Volcanics are considered to be Cretaceous in age and broadly correlative with the Bisbee Group and/or Fort Crittenden Formation (Dickinson et al., 1989). We therefore consider the Demetrie volcanic to be late Cretaceous in age.

Kda **Demetrie Volcanics, andesite, altered (late Cretaceous)** — Andesitic lava flows and volcanogenic breccias that were subjected to oxidizing alteration that converted biotite and other mafics to iron oxides and produced pervasive orangish-brown iron-oxide staining that is visible in outcrop and concentrated on fracture surfaces.

Kdlr **Demetrie Volcanics, lower rhyolitic tuff (late Cretaceous)** — Lithic tuff exposed between the Sierrita-Esperanza mine dump and Demetrie Wash (Cooper, 1971, 1973). Tuff is light gray to tan with flattened aphyric volcanic-lithic fragments, 3-100 mm, forming up to 70% of rock. Content of volcanic lithic fragments varies over tens of meters in some areas. Also includes <1%, <1 mm feldspar and up to 4%, <4 mm quartz phenocrysts. In roadcuts along Caterpillar Road the tuff locally contains sparse 2-10 mm dark pink to red K-feldspar xenocrysts, sparse iron-oxide stained fractures with discoloration over 1-2 cm from fractures, and sparse clots of iron oxide that look a little like oxidized sulfides, but no boxwork seen. Examination of two thin sections from near the center of the tuff reveals that this rock contains 1-3%, 0.1-1.0 mm, subangular to subrounded quartz, 2-4% 0.5-2.0 mm altered feldspar, and 1-2 % altered mafic minerals that are too altered to identify. Examination of two thin sections from near the base of this unit reveal 5-15% feldspar fragments, subrounded to subangular, with abundant volcanic lithic fragments.

Kvcg **Volcanic-lithic conglomerate (Cretaceous)** — Volcanic-lithic pebble-cobble conglomerate with sparse quartz grains. Clasts in conglomerate include gray porphyry with 30-40%, 2-4 mm blocky white feldspar phenocrysts. Epidote lenses and stringers are notably less common than in adjacent feldspathic lithic sandstone. Contact with more quartz-rich sandstone is abrupt. Outcrop is poor, mostly boulder-cobble colluvium on surface.

Kcg **Conglomerate (Cretaceous)** — Massive to poorly sorted sandy conglomerate, conglomeratic sandstone, and sandstone. Sand contains roughly 40% quartz, 3-5% mafics, most of which is probably magnetite that locally forms laminations. Clasts are locally up to 50 cm diameter, are subrounded to subangular, and include medium grained granite with 5% mafics, fine grained leucogranite with <2% mafics, fine grained quartzite, banded aphyric rhyolite, and coarse grained granite with approximately 10% mafics (primarily biotite). All exposures are located near lower Demetrie Wash.

Kss **Sandstone (Cretaceous)** — Fine- to coarse-grained, moderately to poorly sorted sandstone that varies from containing subequal amounts of quartz, feldspar, and lithic fragment to quartz-rich sandstone with up to perhaps 80% quartz.

KJmv **Mafic to intermediate metavolcanic rocks (Cretaceous to Jurassic)** — This unit consists of mafic volcanic/hypabyssal rock and autobreccia, dark gray to blackish gray, massive, with 20% 1-2 mm plagioclase and 3-4% 1 mm dark (magnetite and clinopyroxene(?)). Mafic volcanic/hypabyssal rocks are either intruded into associated autoclastic breccia or are gradational with it. Most likely both are part of intrusive/extrusive complex.

Jr **Rhyolite (Jurassic)** — Rhyolite of inferred Jurassic age is exposed in the Sierrita-Esperanza mine area where this unit consists of generally pale gray, massive rhyolite with faint and vaguely defined aphyric silicic lithic fragments visible on weathered surfaces. In thin section this rock appeared as completely recrystallized, with 0.1-1.0 mm quartz and feldspar(?) crystals with 1-2%, 0.5-2.0 mm relict plagioclase and 2-3%, 1-3 mm relict K-feldspar. Abundant opaque minerals <<1mm were seen in some hand samples but were not seen in thin section. In some areas unit has granular texture and contains fresh pink K-feldspar up to 5 mm diameter, making up ~5% of rock, that could be product of potassic alteration. Some quartz grains approximately 1 mm diameter are enclosed by secondary K-feldspar. A Jurassic age in inferred because of the association of the rhyolite with quartz arenite that is thought to be regionally correlative with Jurassic eolian quartz arenite (e.g., Bilodeau and Keith, 1986; Busby-Spera, 1988; Tosdal et al., 1989).

Jq **Quartzite (Jurassic)** — Fine grained quartzite.

(KJu) **Quartzite and volcanic rocks, undivided (Cretaceous to Jurassic)** — Rocks mapped by Lynch (1967) but now covered by the Sierrita mine dump. Map units Kcg and KJmv, exposed to the east, project beneath the mine dump. Lynch (1967) mapped conglomerate of map unit Kcg as part of the lower tuff in the Demetrie Volcanics (map unit Kdlr), apparently interpreting it as pyroclastic. It is therefore uncertain which units are actually present beneath the mine dump in this area.

REFERENCES CITED

Aiken, D.M., and West, R.J., 1978, Some geologic aspects of the Sierrita-Esperanza copper-molybdenum deposit, Pima County, Arizona, *in* Jenney, J.P., and Hauck, H.R., eds., Proceedings of the Porphyry Copper Symposium, Tucson, Ariz., March 18-20, 1976: Arizona Geological Society Digest, v. 11, p. 117-128.

Betancourt, J.L., 1990, Tucson's Santa Cruz River and the arroyo legacy: Tucson, University of Arizona, unpublished Ph.D. dissertation, 239 p.

Bilodeau, W.L., and Keith, S.B., 1986, Lower Jurassic Navajo-Aztec-equivalent sandstones in southern Arizona and their paleogeographic significance: American Association of Petroleum Geologists Bulletin, v. 70, p. 690-701.

Busby-Spera, C.J., 1988, Speculative tectonic model for the early Mesozoic arc of the southwest Cordilleran United States: Geology, v. 16, pl 1121-1125.

Cooper, J.R., 1971, Mesozoic stratigraphy of the Sierrita Mountains, Pima County, Arizona: U.S. Geological Survey Professional Paper 658-D, 42 p.

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

Dickinson, W.R., Fiorillo, A.R., Hall, D.L., Monreal, R., Potochnik, A.R., and Swift, P.N., 1989, Cretaceous strata of southern Arizona, *in* Jenny, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Arizona Geological Society Digest 17, p. 397-434.

Herrmann, M.A., 2001, Episodic magmatism and hydrothermal activity, Pima Mining District, Arizona: Tucson, University of Arizona, M.S. thesis, 44 p.

Jensen, P.W., 1998, A structural and geochemical study of the Sierrita porphyry copper system, Pima County, Arizona: Tucson, University of Arizona, M.S. thesis, 136 p.

Lynch, D.W., 1967, Geology of the Esperanza mine and vicinity, Pima County, Arizona: Tucson, University of Arizona, M.S. thesis, 70 p., with map, scale 1:6,000 (map dated 1963).

Lynch, D.W., 1968, The geology of the Esperanza mine, in Titley, S.R., ed., Southern Arizona Guidebook III: Arizona Geological Society, p. 125-136.

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, p. 1-21.

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, p. 151-160.

Pearthree, P.A., and Calvo, S.S., 1987, The Santa Rita fault zone: Evidence for large magnitude earthquakes with very long recurrence intervals, Basin and Range province of southeastern Arizona: Bulletin of the Seismological Society of America, v. 77, p. 97-116.

Pearthree, P.A., and Youberg, Ann, 2000, Surficial geologic map and geologic hazards of the Green Valley – Sahuarita area, Pima County, Arizona**:** Arizona Geological Survey Open-File Report 00-13, 21 p., two maps, scale 1:24,000.

Preece, R.K., III, and Beane, R.E., 1982, Contrasting evolutions of hydrothermal alteration in quartz monzonite and quartz diorite wallrocks at the Sierrita porphyry copper deposit, Arizona: Economic Geology, v. 77, no. 7, p. 1621-1641.

Streckeisen, A.L., 1973, Plutonic rocks: Classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, n. 10, p. 26-30.

Tosdal, R.M., Haxel, G.B., and Wright, J.E., 1989, Jurassic geology of the Sonoran Desert region, southern Arizona, southeastern California, and northernmost Sonora: Construction of a continental-margin magmatic arc, *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Arizona Geological Society Digest, v. 17., p. 397-434.

West, R.J., and Aiken, D.M., 1982, Geology of the Sierrita-Esperanza deposit, Pima mining district, Pima County, Arizona, *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits, southwestern North America: Tucson, University of Arizona Press, p. 433-465.

Wood, M.L., House, P.K., and Pearthree, P.A., 1999, Historical geomorphology and hydrology of the Santa Cruz River: Arizona Geological Survey Open-File Report 99-13, 98 p., with map, scale 1:100,000.

Youberg, A., and Helmick, W.R., compilers, 2001, Surficial geology and geologic hazards of the Amado-Tubac area, Santa Cruz and Pima Counties, Arizona: Arizona Geological Survey Digital Geologic Map 13, scale 1:24,000.