Geologic Map of the Lookout Mountain 7½' Quadrangle, Pinal County, Arizona

by

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**INTRODUCTION**

The Lookout Mountain 7½' Quadrangle includes part of the San Pedro River lowlands, flanking valley fill, and bedrock on the west side of the valley that forms the eastern Black Hills and southeastern-most Tortilla Mountains (Fig. 1). Production of this new geologic map continues the Arizona Geological Survey mapping program of the San Pedro River valley. This mapping was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992, and was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP Program Contract award number 07HQAG0110. Mapping was compiled digitally using ESRI ArcGIS software.

The Lookout Mountain 7½' Quadrangle was mapped previously by Krieger (1968). More recent studies focused on the middle to late Cenozoic strata and structure (Dickinson, 1987, 1991, 1993, 1998; Dickinson and Shafiqullah, 1989). Studies of upper Cenozoic sedimentary strata in the Quadrangle include those by Dickinson (2003). New mapping done for this study was directed primarily at Quaternary deposits and surfaces, but includes older strata and rocks in some areas. Bedrock north of Putnam Wash and adjacent to the San Pedro River lowlands was re-mapped in order to evaluate the structure and extent of a thrust fault mapped previously by Krieger (1968). Although shown as a discontinuous structure by Krieger (1968), we mapped the fault as continuous through the outcrop area, and interpreted the underlying Mesozoic sandstone and conglomerate as everywhere in depositional contact with underlying Escabrosa Limestone.

**Geologic Setting**

The map area is located within the San Pedro River valley, in the Basin and Range Province of southeastern Arizona. Most of the Lookout Mountain Quadrangle is underlain by late Cenozoic sedimentary facies of the Quiburis Formation and an overlying coarse, gravel-rich fanglomeratic deposit (Dickinson, 1998 and 2003). The Quiburis Formation is characterized by coarse, alluvial-fan deposits that grade into fine-grained lacustrine deposits towards the center of the valley. The fine-grained, more easily eroded lacustrine deposits of the Quiburis dominate the Quiburis lithology exposed in the Lookout Mountain Quadrangle and have been the target of several gypsum-mining operations in the area. A complex Quaternary landscapes and associated Quaternary units evolved in response to incision and aggradation. The coarse-grained carbonate-rich fanglomeratic unit that overlies the Quiburis represents a back-filling event that followed the deposition of the Quiburis Formation. The integration of the San Pedro drainage system with the Gila River resulted in the cessation of basin-fill sedimentation and the onset of incision of the Quiburis and overlying sediments, and geomorphic surfaces (Dickinson, 2003).

Paleo-San Pedro River deposits with interfingered deposits from tributary channels can be seen along the San Pedro River corridor, especially on the eastern flank, along Highway 79. Rounded, imbricated river-cobble deposits are interbedded with fine-grained overbank deposits. These deposits may overlay fine-grained deposits of the Quiburis Formation, and are locally cut and filled with deposits
from tributary channels. Several paleo-river terraces associated with Aravaipa Creek can be seen along the river margins and are several meters to tens of meters above the present base-level of the creek.

**Geologic Hazards**

Geologic hazards identified during this study are associated with flooding along the San Pedro River, flooding along Aravaipa River, flooding along other tributaries such as Zapata Wash, and expansive soils related to the fine-grained lacustrine deposits of the Quiburis Formation. Slope instability may occur in soft, more easily erodible sediments, and the alternating wet and dry seasons may increase the shrink and swell factor of fine-grained mud deposits.

**REFERENCES CITED**


Figure 1. Geologic map of the lower San Pedro River valley area, southeastern Arizona, showing STATEMAP 2008 map areas.

Key:
- Tsv - Oligo-Miocene sedimentary and volcanic rocks
- Tg - Oligo-Miocene granitic rocks
- TKg - Early Tertiary and late Cretaceous (Laramide) granitic rocks
- TKev - Early Tertiary and Cretaceous sedimentary and volcanic rocks
- Pzs - Paleozoic sedimentary rocks
- Yg - Mesoproterozoic granitic rocks
- Xms - Paleoproterozoic metasedimentary rocks
MAP UNITS

SURFICIAL MAP UNITS

d  Disturbed ground (upper Holocene) – Disturbed ground due to mining activity, agriculture, extensive excavation, or construction of earth dams.

Qc  Colluvium (Quaternary) – Unconsolidated to weakly consolidated, very poorly sorted angular rock debris deposited at the base of bedrock slopes. Includes talus in areas of very steep slopes.

Qs  Terrace gravels and alluvial deposits, undivided (Quaternary)

QTa  Alluvial deposits (Quaternary to upper Tertiary) – Late Pliocene to early Pleistocene fanglomerate - Loosely consolidated, poorly sorted, angular to sub-angular, tan to tan-gray, angular sand, pebbles, cobbles, and boulders arranged in alternating fine to coarse beds common in alluvial fan deposits that erosionally overlying the Quiburis Formation and are found high in the landscape. These deposits have been dissected and eroded and are mostly exposed as rounded ridges. High standing rounded ridges are composed of carbonate-cemented fanglomerate cap which armors the underlying, less indurated basin-fill sediment. The flanks of QTa ridges are also armored against erosion due to the mantle of coarse clast cover derived from weathered sections of the cap. Exposures of QTa deposits are generally poor, but they may locally be at least 30-40 meters thick and are commonly the highest standing deposits in the proximal piedmont.

San Pedro River Alluvium

Qycr  Active river channel deposits - Deposits are dominantly unconsolidated, very poorly sorted sandy to cobbly beds exhibiting bar and swale microtopography but can range from fine silty beds to coarse gravelly bars in meandering reaches based on position within the channel. Clasts are typically well-rounded but may be angular to sub angular. Qycr deposits are typically unvegetated to lightly vegetated and exhibit no soil development. Qycr deposits are entrenched from 30 cm to 10 meters or more below adjacent early historical floodplain deposits depending on location, geomorphic relationship, and local channel conditions. Although much of the San Pedro was a perennial stream historically, some sections are dry or marshy at the surface during much of the year. These deposits are the first to become submerged during moderate to extreme flow events and can be subject to deep, high velocity flow and lateral bank erosion.

Qy4r  Flood channel and low terrace deposits - Deposits are found adjacent to active channels that form lightly vegetated in-channel bars, small planar fluvial terraces within 30 cm of river elevation, and recent erosional meanders outside the presently active channel. Terrace deposits are inset into older river alluvium and usually narrow, rarely more than 100 meters across. Qy4r deposits are composed of poorly sorted unconsolidated sediments ranging from fine silts to gravel bars depending on location in the channel at the time of deposition. Pebbles and cobbles are well-rounded to sub-rounded. These surfaces are commonly inundated under moderate to extreme flow events and can be subject to deep, high velocity flow and lateral bank erosion. These deposits do not exhibit soil development but may exhibit a light vegetation cover of small trees and bushes and grasses due to their relatively frequent inundation.

Qy3r  Historical river terrace deposits - Terrace deposits that occupy elevations from 1 to 2 meters above Qy4r deposits and are inset below the pre-incision historical floodplain. These surfaces are
generally planar but exhibit bar and swale microtopography. Although no soil development is present, dense grasses and small mesquite trees abound. Sediments composing these deposits are poorly sorted silt, sand, pebbles and cobbles. Pebbles and cobbles are well-rounded to sub-angular. Trough crossbedding, ripple marks, and stacked channel deposits viewable in cross-section indicate deposition in a low to moderate energy braided stream environment. These deposits are prone to flooding during extreme flow events, and undercutting and rapid erosion of Qy3r surfaces is possible during lower flow events.

**Qy2r Latest Holocene to historical river deposits** - Deposits associated with the floodplain that existed prior to the early historical entrenchment of the San Pedro River (Hereford, 1993; Huckleberry, 1996; Wood, 1997). Qy2r deposits are associated with broadly planar surfaces that locally retain the shape of historical river meanders. Qy2r surfaces are up to 7 meters above modern Qycr deposits and are the most extensive river terraces in the valley. Qy2r sediments were deposited when the San Pedro was a widespread, shallowly-flowing river system and are dominated by fine grained floodplain deposits. Dense mesquite bosque and tall grass is typically present on these surfaces except where historic plowing or grazing has taken place. These surfaces appear predominantly fine grained at the surface due in part to the input of organic matter and windblown dust deposition but are composed of interfingering coarse sandy to pebbly braided channel and fine sand to silty river floodplain deposits. Where Qy2r deposits are moderately to deeply incised they not subject to inundation by river floods, but they may be flood-prone in areas with less channel incision. Qy2r deposits are subject to catastrophic bank failure due to undercutting and lateral erosion during flow events. Distal piedmont fan deposits (Qy2 and Qy2f) onlap onto Qy2r deposits although an interfingering relationship likely exits in the subsurface.

**Qy1r Late to Early Holocene San Pedro terrace deposits** - Deposits associated with slightly higher terraces that represent either higher elements of the early historical floodplain or remnants of older Holocene aggradation periods. These fine-grained terrace deposits commonly have been disturbed by plowing or cattle grazing. When undisturbed, Qy1r deposits are densely vegetated by mature mesquite trees (mesquite bosque) and tall grasses. Soil development is moderate and surface color ranges from 10 to 7.5 YR 4/4. Due to the dense vegetation input of organic matter at the surface is high and often results in a thin (< 10 cm) organic soil horizon. A light dusting (incipient stage I) calcium carbonate accumulation is evident on the undersides of some buried clasts. Qy1r surfaces are up to 7 meters above the active channel in highly incised locales and typically are less than 1.5 m higher than adjacent Qy2r surfaces.

**Qi3r Late Pleistocene river terrace deposits** - Terrace deposits are up to 10 to 25 m higher than and up to 500 m outside the margins of the modern San Pedro channel. These deposits consist of well rounded pebbles to cobbles exhibiting stage I+ calcium carbonate accumulation with cross-bedded coarse sandy interbeds. Clast composition is varied and includes rock types not found in the mountains from which modern piedmont material is derived from. Qi3r terrace surfaces are planar, often surrounded by distal piedmont alluvium, and are generally lightly vegetated except for small weeds and grasses. Commonly, Qi3r deposits are inset into adjacent piedmont alluvial deposits but can also be inset into older river gravel terraces. Soil development is weak, possibly due to the porous nature of these deposits.

**Qi2r Middle Pleistocene river terrace deposits** - Terrace deposits are similar to Qi3r deposits but occupying higher positions in the landscape. Terrace surfaces are slightly to moderately rounded. Clast composition is diverse. Well-rounded pebbles to cobbles with stage I-II calcium carbonate accumulation armor Qi2r surfaces. Vegetation is sparse, consisting of small shrubs and grasses. Soil development is generally weak on Qi2r surfaces, but soil development is more evident in
finer grained sections. Qi2r surfaces are typically found as high-standing isolated mounds surrounded by distal fan alluvium or as small terraces inset into older fan or basin fill alluvium.

**Qi1r**  Early to middle Pleistocene river gravel terraces  - Deposits are associated with high-standing, well-rounded river gravel terraces. Where Qi1r deposits are extensive, remnant planar caps are preserved near the center of the surface. Qi1r deposits are composed of very well rounded to well rounded pebbles and cobbles from diverse lithologies. Cross-bedded sands with pebbly stringers are interbedded throughout. Near-surface cobbly beds exhibit stage II+ calcium carbonate accumulation. Moderately to strongly calcium carbonate coated clasts or cemented aggregates of clasts mantle the flanks of Qi1r deposits, but clay accumulation is variable, probably due to poor surface preservation. Sparse small shrubs, weeds, and cacti are present on these surfaces.

**Piedmont Deposits**

**Qyc**  Active tributary channel alluvium  - Unconsolidated, very poorly sorted sandy to cobbly piedmont channel sediments. Channels may exhibit bar and swale microtopography with bars composed of coarser sediments. Qyc deposits are typically unvegetated and exhibit no soil development although small shrubs and grasses can be found on slightly elevated bars. Qyc deposits commonly become submerged during moderate to extreme flow conditions and can be subject to deep, high velocity flow and lateral bank erosion. Channels are generally incised 1 to 2 m below adjacent Holocene alluvium and may be incised into adjacent Pleistocene alluvium by 10 m or more.

**Qy3**  Latest Holocene alluvium  - Recently active piedmont alluvium located primarily along active tributary drainages including floodplain, low-lying terrace, and overflow channels. Qy3 deposits are composed of unconsolidated to very weakly consolidated silty to cobbly deposits and exhibit greater vegetation than Qyc deposits. These deposits generally exhibit bar and swale meso-scale topography and are susceptible to inundation during moderate to extreme flow conditions when channel flow exceeds capacity. Soil development is generally absent or incipient on Qy3 deposits which exhibit pale buff to light brown (10 YR) surface coloration.

**Qy2**  Late Holocene alluvium  - Piedmont terrace deposits located primarily along the flanks of incised drainages and ephemeral floodplains, broad low-relief distal fan deposits onlapping onto Holocene river alluvium, and active tributary drainage deposits. These deposits consist of predominantly fine grained unconsolidated to weakly consolidated sediments although isolated sub-rounded to sub-angular cobbles and boulders may be present at the surface in small quantities. Where inset into older alluvium, Qy2 deposits are planar with remnant bar and swale meso-scale topography. Distal fan Qy2 deposits are broad and sandy with numerous small braided channel systems. Rarely active Qy2 tributary drainages are generally of limited extent, relatively steep, and more densely vegetated than Qy3 tributary drainages. Soil development on Qy2 deposits is weak, characterized by incipient stage I calcium carbonate accumulation in the form of small filaments and medium brown (10 YR) surface coloration. Vegetation on Qy2 surfaces ranges from numerous small mesquite trees and grasses in distal fan environments to medium creosote, acacia, and cholla in tributaries and inset terraces. These surfaces are subject to inundation during moderate to extreme flow conditions when channel flow exceeds capacity or due to channel migration on low-relief portions of broad distal fan deposits. Qy2 terraces are typically elevated from 30 cm to 1.5 m above active channels.
**Qy2f Late Holocene alluvial fan** - Qy2f deposits consist of active alluvial fan deposits in the San Pedro valley. These deposits have distributary drainage patterns and are prone to flooding and channel migration. Sediments are unconsolidated and consist of poorly sorted silt to cobbles. Vegetation includes small mesquite trees, shrubby acacia, prickly pear, and creosote.

**Qy1 Early to late Holocene alluvium** - Deposits consist of broad, low-relief, undulating fan deposits that sit higher in the landscape than younger Holocene alluvium. Portions of these deposits are mantled by coarse to very coarse angular quartz sand and exhibit diverse vegetation patterns dominated by cholla, prickly pear, small (1-1.5 m tall) mesquite, and numerous small shrubs and grasses. Overall relief between broad fan crests and incised drainages on gently rolling Qy1 deposits typically does not exceed 1.5 meters. Numerous shallow braided channels drain widespread portions of Qy1 surfaces. Qy1 deposits exhibit incipient calcium carbonate accumulation (stage I) and soil development characterized by medium brown (10-7.5 YR) coloration where un-incised. Deposition of Qy1 sediments in a braided channel aggrading alluvial fan environment has, in places, resulted in shallow burial of adjacent piedmont deposits. This relationship is visible along incised channels where thin Qy1 deposits overly redder, grusy, clay-rich Qi2 or Qi3 deposits.

**Qi3 Late Pleistocene alluvium** - Qi3 deposits widespread planar reddish fan terraces mantled by angular to sub-angular pebbles to boulders. These deposits exhibit moderate calcium carbonate accumulation (stage I to II) and soil development with reddish shallow subsurface coloration (7.5 YR 4/4). This color varies with position in the piedmont due to differences in parent material (mixed granitic, metamorphic and volcanic clasts west of San Pedro and volcanic clasts to the east). Qi3 deposits have saguaro, palo verde, mesquite, cholla, prickly pear, creosote, acacia, and numerous small grasses and shrubs. Qi3 deposits stand up to 3 to 4 meters higher in the landscape than adjacent Qy1 and Qyc deposits depending on local incision and position within the piedmont.

**Qi2 Middle to late Pleistocene alluvium** - Qi2 deposits form broad planar fan and terrace surfaces that cap Quiburis basin fill deposits. These deposits are inset below older or lining the margins of piedmont drainages. These deposits generally exhibit reddish (7.5-5 YR 5/4) soils and moderate calcium carbonate accumulation (stage I to II+). Varnish and pavement development is moderate to poorly exhibited. Qi2 deposits are overall planar but can exhibit mild to moderate rounding near incised channels or inset terraces. Vegetation on Qi2 surfaces consists of saguaro, palo verde, medium mesquite, prickly pear, cholla, barrel cactus, and numerous small shrubs and short grasses. Where incised, these deposits often exhibit a cap up to 1 meter thick of moderately calcium carbonate cemented clasts. This cap preserves underlying, less-indurated portions of the Qi2 surface as well as any deposits it may overly. Qi2 terraces deposited onto basin fill deposits may stand as much as 20 meters above active piedmont channels.

**Qi1 Early to middle Pleistocene alluvium** - Qi1 deposits are characterized by high-standing, moderately to well-rounded alluvial deposits exhibiting strong (stage II to III) calcium carbonate accumulation and, where preserved, dark reddish (5-2.5 YR 4/6) soils. Like Qi2 deposits, Qi1 deposits may cap underlying Quiburis basin fill deposits. Where widespread (greater than 30 meters across), Qi1 deposits retain a remnant, indurated planar cap with moderately to well rounded edges. Narrow (less than 30 meters across) Qi1 terraces and caps are generally well-rounded and do not exhibit a planar remnant. Qi1 terraces are commonly mantled by coarse pebbles to boulders, sub-angular to sub-rounded and exhibit vegetation consisting of medium to large mesquite, acacia, saguaro, palo verde, prickly pear, cholla, barrel cactus, and grasses. In places cholla dominate and are densely packed. Varnish and clay-coatings are weak to moderate and common on overturned clasts and desert pavement is poorly to moderately exhibited.
Qo  Early Pleistocene fan gravel - Deposits associated with very high relict alluvial surfaces. A remnant planar cap may be present on extensive surfaces such as ancestral planar alluvial fans. Where preserved, soils on Qo surfaces exhibit clay rich argillic and well developed calcic horizons. Dark red soils (2.5 YR 4/6) are sparsely covered by mild to moderately varnished pebbles to small cobbles. Near surface soil is loamy and overlies much coarser clasts visible on the eroded flanks of Qo surfaces. Vegetation consists of tall saguaro, palo verde, prickly pear, mesquite, and isolated creosote. Remnant argillic horizons exhibit clay faces, blocky ped structures, and are deep red in color. Exposures of the calcium carbonate horizon exhibit stage III to IV accumulation. Qo deposits average 5 meters to as much as 15 meters thick. Aggregate chunks of eroded portions of the carbonate horizon commonly litter the flanks of Qo and underlying deposits. Qo surfaces generally occupy the highest position in the landscape, capping Quiburis basin fill deposits. Thin relict ridge-capping reaches of Qo deposits are commonly encountered where the underlying basin fill deposits are highly eroded and incised. Underlying basin fill deposits stand much higher in the landscape relative to comparable, uncapped deposits.

Qiu  Pleistocene alluvial terrace deposits, undivided

Basin Fill Deposits

Tqc  Late Miocene to Pliocene Quiburis deposits, conglomeratic facies - sandy conglomerate, conglomeratic sandstone, some sandstone, rare mudrock. Generally very light gray and moderately to strongly indurated. Outcrops of Tqc weather moderately to well rounded. Sand is poorly sorted, angular, medium grained to granule sand, with abundant disaggregated granite particles of quartz or feldspar. Clasts in conglomerate typically include significant percentage of Oracle granite, also Cloudburst volcanics, and sparse Apache group clasts. Percentages of granite and volcanics vary as much as 50% depending on location and proximity to source terrain. Bedding generally massive yet distinguishable by grain size variations, locally by parting between beds. Tqc overlies the playa facies in sharp contact, most noticeably near cliffs, along the west and east basin margins, interpreted to be a progradational event. Tqc deposits are characterized by completely indurated (stage III-IV) sections of Quiburis basin fill sediments. Portions of these deposits are clast supported while others are completely calcium carbonate matrix supported.

Tqp  Late Miocene to Pliocene Quiburis deposits, playa facies - Playa facies include bedded and laminated mudstone, siltstone, and gypsum. Interstitial gypsum in fine-grained clastic deposits are more common and characteristic of this distal fan-facies. Occasional beds of diatomite up to 0.75m thick and 10 to 30cm beds of green-brown mudstone are interbedded. Volcanic ash beds have been documented in this facies and are locally reworked into clastic beds. Tqp weathers commonly into slopes, although where gypsum predominates cliff exposures appear to be more common. Tqp gradationally overlies the lacustrine facies east of the San Pedro River, interpreted to be a progradational event.

Tql  Late Miocene to Pliocene Quiburis deposits, lacustrine facies - Laminated lacustrine facies includes interbedded mudstone, limestone, gypsum, and diatomite beds of varying thickness, with sparse and thin intercalations of laminated lacustrine sandstone. Diatomite beds range from 20cm to 1.5m thick. Where diatomite beds interbedded with siltstone dominate this facies exhibits a characteristic white outcrop color, although silt and mud commonly coat outcrop surfaces. Diatomite beds are resistant to weathering and commonly form cliff-slope-cliff topography. Relatively softer beds are composed of a mix of mudstone, siltstone, and limestone. Rare beds of
soft, unconsolidated volcanic ash are preserved best underlying resistant beds of gypsiferous siltstone and diatomite. Insects commonly burrow in the volcanic ash layers. Laminated lacustrine facies includes interbedded mudstone, limestone, gypsum, and diatomite beds of varying thickness, with sparse and thin intercalations of laminated lacustrine siltstone and rare sandstone. The axial center of the San Pedro basin was centered in the area east of the San Pedro River, in the Lookout Mountain Quadrangle, resulting in a thick sequence of lacustrine deposits, much of which flank bedrock to the east.

**Tqr** Late Pliocene (?) Quiburis deposits, fluvial facies - Fluvial facies includes moderately to well-indurated sandstone and conglomerate beds with river bedding structures. Fine-grained deposits are not found in this facies. River bedding structures include channel lag boulders in trough cross-beds overlain by climbing sets of tabular cross-beds (up to 1m thick). These deposits are scoured into Tqc and Tqp deposits and weather as a cliff-forming unit typically. In some localities a relict stage III+ to IV calcrete is present; no clay accumulation was observed within this facies. Characteristic euhedral calcite and quartz form cement commonly molded around cobbles. The type locality for this facies is at the mouth of Tar Wash in the Mammoth Quadrangle. This facies can be laterally followed from the mouth of Tar Wash down the west flank of the San Pedro River. Paleo-flow directions are down-gradient to the northwest, sub-parallel to the San Pedro River. Paleo-gradients were not measured. This facies is interpreted to be lateral-bank fluvial deposits that mark the initial formation of the San Pedro River.

**BEDROCK MAP UNITS**

**Oligocene to lower Miocene volcanic units**

**Trx** Rhyolite intrusion and intrusive breccia (Oligocene to lower Miocene) – At the south edge of the map area, this unit consists of crystal-poor, massive to flow-banded rhyolite and clast-supported brecciated rhyolite.

**Tvl** Latite lava flows (Oligocene to lower Miocene) – Aphanitic and locally vitric, flow-banded lava flows and autobreccia. Locally includes andesitic to basaltic lava flows (Krieger, 1968).

**Ta** Andesite (Oligocene to lower Miocene) – Three small, widely separated exposures of dark-gray andesite (from Krieger, 1968).

**Laramide to Middle Tertiary intrusive unit**

**TKr** Rhyolite dike (Upper Cretaceous to Oligo-Miocene) – Rhyolitic dike with phenocrysts of quartz (<3 mm), plagioclase, sanidine, and biotite (Krieger, 1968).

**Mesozoic sedimentary unit**

**Mzs** Clastic sedimentary rocks (Mesozoic) – Sandstone and siltstone with basal conglomerate and chert-fragment breccia. The basal part of this unit consists of a 5-10-m-thick, chert-clast breccia to angular-clast conglomerate. Clasts are 1-10 cm diameter, angular, and composed of fine-grained quartzose rocks (chert). Some clasts contain fossil debris, some with radial, coral-like form as if derived from underlying Paleozoic carbonates. Just above basal contact, chert-clast
breccia forms 50- to 200-cm-thick beds, interbedded with similar-thickness sandstone that is pale gray, tan, or reddish tan. Above basal breccia and conglomerate, rocks of this unit consist of plane-beded, reddish brown, medium-grained sandstone. Upper part of unit consists of friable, very fine-grained quartzose sandstone to siltstone.

This unit was mapped by Krieger as thrust over underlying Escabrosa Limestone (Krieger, 1968). However, this thrust contact is interpreted as depositional based on new mapping (Spencer and Richard, this report), with a basal chert-clast breccia derived from weathering of underlying Escabrosa Limestone and possibly other Paleozoic carbonate units.

Paleozoic sedimentary units

**Me** Escabrosa Limestone (Mississippian) – Resistant, massive to thick bedded limestone, generally gray or yellowish to greenish gray. Fossil crinoids, coral, and brachiopods are common (Krieger, 1968). Stratigraphically highest preserved levels consist of fine grained calcareous sandstone and sandy tan to brown carbonate. Sandy carbonates are interpreted as correlative with the overlying Horquilla Limestone, but were not mapped separately because of their very small outcrop area.

**Dm** Martin Formation (Devonian) – Slope forming, interbedded carbonate and siltstone. Described by Krieger (1968) as consisting of basal 3-5 m of thin-bedded, grayish red limestone, overlain by a middle unit of olive to reddish brown shale with locally interbedded, 10-100 cm limestone beds, and capped by ~12 m of interbedded, olive to reddish brown “shale” and brown to gray limestone.

**ºa** Abrigo Formation (Cambrian) – Divided into three units by Krieger (1968), but field mapping by Spencer and Richard (this report) resulted in correlation of the middle and lower units with the Cambrian Bolsa Quartzite, which was not identified by Krieger in the Lookout Mountain Quadrangle. The Abrigo Formation consists of thin- to thick-bedded, cross bedded, dolomitic sandstone with local dolomite, siltstone, sandstone, and intraformational conglomerate (upper unit of Krieger, 1968). Dark chocolate-brown calcareous sandstone is characteristic of this unit in easternmost exposures.

**ºb** Bolsa Quartzite (Cambrian) – Fine- to locally medium-grained sandstone, plane bedded to cross bedded. Sandstone varies from chocolate brown to orangish tan to white. Sandstone is coarse to granule within basal several meters. Pebby beds with quartzite pebbles up to 3 cm are present locally near the base. Locally abundant, cylindrical trace fossils (burrows?), <1 cm diameter, visible on both on bedding planes and on surfaces perpendicular to bedding planes, indicate that this unit is not Proterozoic. Lack of carbonate and coarseness indicate correlation with Bolsa Quartzite rather than Abrigo Formation.

Mesoproterozoic Apache Group and diabase

**Yd** Diabase (Mesoproterozoic) – Dark greenish gray to olive gray, medium grained diabase forming sills and dikes in all Proterozoic rock units. Krieger (1968) described the diabase as ophitic and consisting of 3-5 mm plagioclase, pyroxene (some poikilitic crystals as large as 1 cm), magnetite, ilmenite, and sparse olivine. This unit is correlated with the Sierra Ancha diabase (Wrucke, 1989).

**Yt** Troy Quartzite (Mesoproterozoic) – The Troy Quartzite was divided by Krieger (1968) into two units, as follows: (1) an upper unit (up to 200 m thick) of white to very light gray, thin- to thick-bedded feldspathic to quartzose sandstone and granule to small-pebble conglomerate, and (2) a
lower unit (up to 120 m thick) of mostly thin-bedded, medium gray to pale red sandstone and granule to small pebble conglomerate.

Ym  **Mescal Limestone (Mesoproterozoic)** – Thick to thin bedded, brown to gray dolomite and silty to cherty dolomite, less abundant laminated limestone, and brown dolomitic sandstone locally at base (Krieger, 1968). Asbestos veins are locally present near intrusive contact with diabase. This unit appeared in easternmost exposures as silty to cherty, medium to light brown dolostone, with laminations locally in dolostone. These laminations likely would have been obliterated by bioturbation if this unit were Phanerozoic.

Yds  **Dripping Spring Quartzite (Mesoproterozoic)** – This unit consists of gray, brown, red, and yellow, feldspathic, arkosic, and quartzose sandstone and less abundant siltstone. Sands are typically fine to medium grained and appear feldspathic with red K-feldspar grains. Sandstone is locally cross bedded. Bed thickness decreases upsection, from very thick bedded (locally to 4 m) near the base to thin to medium bedded (<25 cm) at higher stratigraphic levels (Krieger, 1968).

Ydsb  **Barnes Conglomerate Member, Dripping Spring Quartzite (Mesoproterozoic)** – Up to 4 m of pebble and cobble conglomerate, with well rounded clasts up to 12 cm diameter of quartzite, vein quartz, and red jasper, in a matrix of red to gray arkosic sandstone (Krieger, 1968).

Yp  **Pioneer Formation (Mesoproterozoic)** – Dark red to purple siltstone and fine-grained to very fine-grained sandstone, and light reddish orange fine- to medium-grained to locally coarse-grained, cross-bedded sandstone. Grain size generally decreases up section (Krieger, 1968).

**Mesoproterozoic granitoid units**

Yo  **Oracle Granite (Mesoproterozoic)** – Porphyritic, medium- to coarse-grained biotite granite (“quartz monzonite” of Krieger [1968]). Microcline phenocrysts are as large as 2 x 4 cm and somewhat poikilitic, with included mafic minerals imparting a speckled appearance. K-feldspar is commonly pink to reddish, and mafic minerals are generally abundant (7-12%). [Speckled, poikilitic, reddish to pink K-feldspar megacrysts and abundant mafics dominated by aggregates of fine biotite are characteristic of Oracle Granite that are commonly used as criteria for tentative correlation]. Granite in the Samaniego Hills (Ferguson et al., 1999), located 70 km to the southwest and probably correlative with the Oracle Granite, yielded a U-Pb data of 1434.5 ± 3.4 Ma (Spencer et al., 2003).

Yoa  **Oracle Granite, alaskitic (Mesoproterozoic)** – Equigranular, medium to coarse-grained, dark orange to pale red alaskite that is gradational with the Oracle Granite (Krieger, 1968). Local porphyry, aplite, and potassic granite were included with this map unit by Krieger (1968). This unit is possibly correlative with fine grained, two-mica granite in the Black Mountain area to the west (Orr et al., 2002) that yielded a U-Pb data of 1433.5 ± 2 Ma (Spencer et al., 2003).

Yoap  **Oracle Granite, aplite (Mesoproterozoic)** – White to pale orange to light brownish gray, fine-grained leucogranite dikes, locally pegmatitic or muscovitic (Krieger, 1968). This aplite granite is likely correlative with aplite and pegmatitic granite that intrude Oracle Granite in the Oracle area to the south but do not intrude Mesoproterozoic diabase (Force, 1997), and in both areas are inferred to be related to the Oracle Granite.

Yogd  **Oracle Granite, granodioritic (Mesoproterozoic)** – Medium-grained, gray granite or granodiorite containing biotite and hornblende (Krieger, 1968).
You Oracle Granite, undivided (Mesoproterozoic)

Paleoproterozoic metamorphic rocks

Xp Pinal Schist (Paleoproterozoic) – Faintly laminated, very fine grained, medium to dark gray sandstone to siltstone. Described by Krieger (1968) as fine-grained, slaty to foliated, quartz-sericite-magnetite schist, but is here considered insufficiently recrystallized to be classified as schist.

REFERENCES CITED