Geologic Map of the Redington 7½' Quadrangle, Cochise, Graham, and Pima Counties, Arizona

by

Joseph P. Cook and Jon E. Spencer

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INTRODUCTION

The Redington 7 ½' Quadrangle includes part of the northern San Pedro River and flanking valley fill, as well as two areas of bedrock on the east side of the valley (Figure 1). Production of this new geologic map continues the Arizona Geological Survey mapping program in the San Pedro River valley, and complements geologic mapping to the south of this quadrangle. 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 06HQAG0051. Mapping was compiled digitally using ESRI ArcGIS software.

Geologic setting

The map area is located within the San Pedro River valley in the Basin and Range Province of southeastern Arizona. Oligocene to early Miocene, compositionally diverse volcanism in the Galiuro Mountains to the east of the map area occurred during the initiation of a period of severe tectonic extension that uncovered the Catalina-Rincon metamorphic core complex to the southwest (Dickinson and Shafiqullah, 1989; Dickinson, 1991). The San Pedro Valley was created in its basic form by this period of extensional faulting, which largely ended in the early to middle Miocene. Relative to this period of severe faulting, minor faulting affected the valley during late Miocene to Quaternary time, probably with declining activity over this time period.

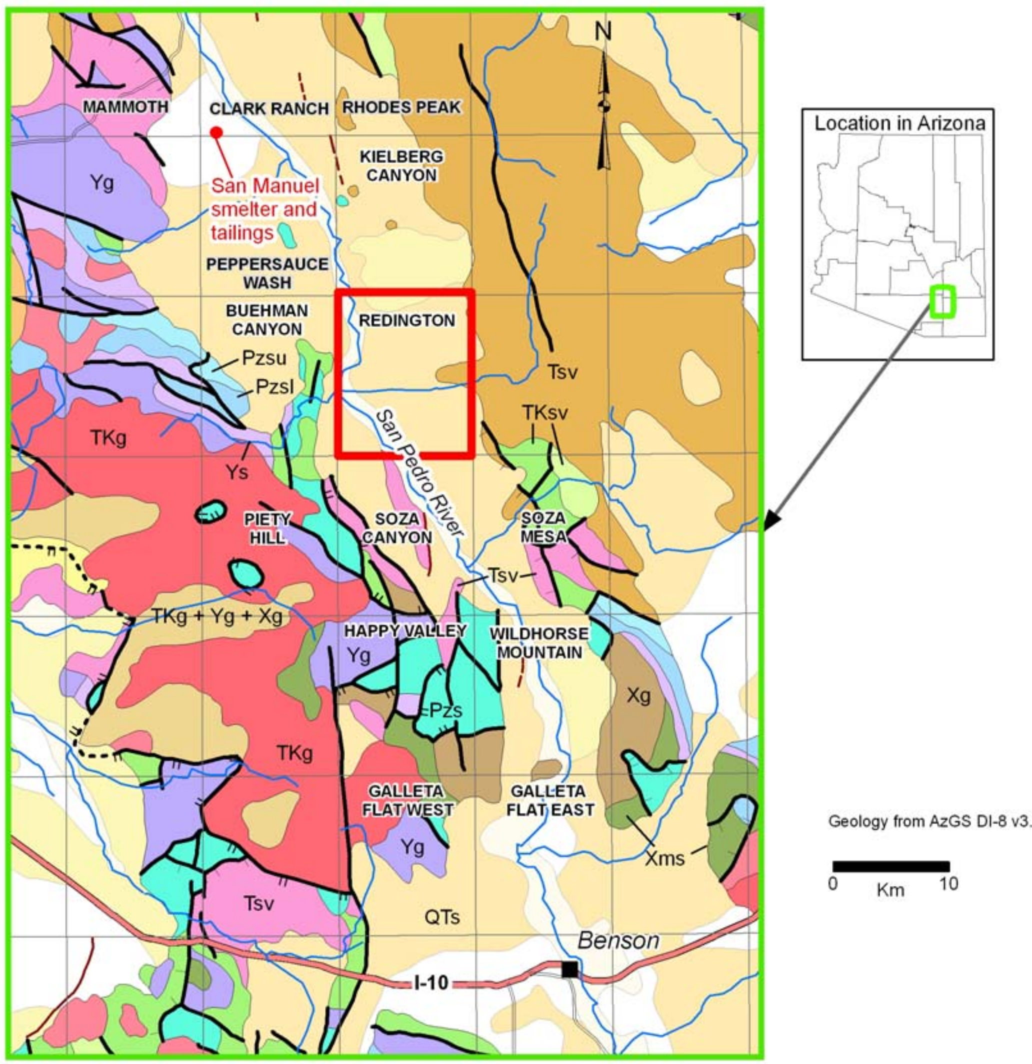
Laramide (latest Cretaceous to earliest Tertiary), steeply southwest dipping to locally overturned volcanic and sedimentary rocks are exposed over part of Redfield Canyon. These are overlain by gently dipping Oligocene to early Miocene Galiuro Volcanics. Tilting of the Laramide strata is thought to be Laramide, not middle Tertiary, because Galiuro Volcanics participated in the middle Tertiary extensional faulting in those areas where faulting occurred, and the Galiuro Volcanics that overlie the Laramide strata are only slightly tilted (Dickinson, 1991).

Most of the Redington Quadrangle is underlain by late Cenozoic, valley-filling clastic sedimentary strata of the Quiburis Formation (Dickinson, 1998, 2003). These consist mostly of coarse sand to conglomeratic debris in alluvial fans that flank the valley and an axial valley facies including both fine-grained fluvial and lacustrine sedimentary units. Integration of the San Pedro drainage system with the Gila River terminated lacustrine sedimentation and began a period of incision that continues to the present (Dickinson, 2003). Geomorphic modification of the valley during incision has produced a complex Quaternary landscape with many Quaternary units reflecting different periods of Quaternary aggradation and incision.

Mapping Methods

Surficial deposits that cover most of the quadrangle were mapped using stereo pairs of 1:24,000-scale black and white aerial photos taken in 1984, georeferenced digital color orthophotos taken in 2005 and 2006, and topographic information from the U.S. Geological Survey 7 ½' quadrangle map. Mapping was verified by field observations during the fall of 2006 and spring of 2007, and unit boundaries were spot-checked in the field. Map data was compiled digitally using the ArcMap program and the final linework for the map was generated from the digital data. The bedrock outcrops on the eastern and western sides of the quadrangle were mapped and structural measurements obtained in the fall of 2006 and spring of 2007.

Characteristics evident on aerial photographs and on the ground were used to differentiate and map various alluvial surfaces. The color of alluvial surfaces depicted on aerial photographs is primarily controlled by soil or deposit color, vegetation type and density, and locally by rock varnish on surface gravel clasts. Significant soil development begins on an alluvial surface after it becomes isolated from active flooding and depositional processes (Gile et al., 1981, Birkeland, 1999). Two typical soil horizons in Pleistocene alluvial sediments of southeastern Arizona are reddish brown argillic horizons and white calcic horizons. On well-preserved surfaces, increases in soil clay content and reddening are excellent indicators of increasing soil age (Pearthree and Calvo, 1987). Soil carbonate content also increases with soil age, especially in lower altitude portions of the map area or where soil parent material is rich in carbonate. As a result, on color aerial photographs older alluvial surfaces characteristically appear redder or whiter (on more eroded surfaces) than younger surfaces. Differences in the drainage patterns between surfaces provide clues to surface age and potential flood hazards. Young alluvial surfaces that are subject to flooding commonly display distributary (branching downstream) or braided channel patterns; young surfaces may have very little developed drainage if unconfined shallow flooding predominates. Dendritic tributary drainage patterns and increasingly deep dissection are characteristic of older surfaces, although dissection varies substantially across the piedmont based on proximity to the incised San Pedro River. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereo-paired aerial photographs and topographic maps. Young flood-prone surfaces appear nearly flat on aerial photographs and are characteristically situated less than 1 m above channel bottoms. Active channels are typically entrenched 2 to 15 m or more below older surfaces.



QTs - Quaternary and upper Tertiary sedimentary units
Tsv - Oligo-Miocene sedimentary and volcanic rocks
TKg - Early Tertiary and late Cretaceous (Laramide) granitic rocks
TKsv - Early Tertiary and Cretaceous sedimentary and volcanic rocks
Pzsu - Upper Paleozoic sedimentary rocks
Pzsl - Lower Paleozoic sedimentary rocks
Pzs - Paleozoic sedimentary rocks, undivided
Ys - Mesoproterozoic sedimentary rocks of the Apache Group and diabase
Yg - Mesoproterozoic granitic rocks
Xg - Paleoproterozoic granitic rocks
Xms - Paleoproterozoic metasedimentary rocks

Figure 1. Geologic map of the lower San Pedro River valley area, southeastern Arizona, showing 7.5' quadrangles and DGM map area.

MAP UNITS

SURFICIAL MAP UNITS

Other units

Plowed areas - Historically or actively plowed fields, irrigated pastures, and other lightly disturbed ground.

d **Disturbed ground** – Heavily disturbed ground due to agriculture, extensive excavation, or construction of earth dams.

Qc **Quaternary hillslope talus and colluvium –** Unconsolidated to weakly consolidated, very poorly sorted angular rock debris deposited at the base of bedrock slopes.

San Pedro River alluvium

Quaternary San Pedro River sediments derived from both adjacent and upstream piedmont and basin fill alluvium are transported north through the mapped area towards the San Pedro's confluence with the Gila River. Pleistocene age river deposits are located outside the modern floodplain and stand much higher than the present-day channel. Prior to about 1900, the San Pedro was a low energy, unentrenched, narrow channel and cienega drainage system (Hereford, 1993). Late Holocene river valley and floodplain deposits were much more widespread than the modern incised meandering system. Modern and historical San Pedro deposits are confined to the entrenched meandering swath occupying the lowest elevations in the mapped area.

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 5 meters or more below adjacent early historical floodplain deposits depending on location, geomorphic relationship, and local channel conditions. Although much of the San Pedro River was a perennial stream historically, some modern sections are dry or marshy at the surface throughout much of the year. These deposits are the first to become submerged during flow events and can be subject to deep, high velocity flow and lateral bank erosion.

Qy_4r **Flood channel and low terrace 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 5 meters or more below adjacent early historical floodplain deposits depending on location, geomorphic relationship, and local channel conditions. Although much of the San Pedro River was a perennial stream historically, some modern sections are dry or marshy at the surface throughout 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.

Qy_3r **Historical river terrace deposits -** Terrace deposits that occupy elevations from 1 to 2 meters above Qycr or Qy_4r 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 Qy_3r surfaces is possible during lower flow events.

Qy_2r **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). Qy_2r deposits are associated with broadly planar surfaces that locally retain the shape of historical river meanders. Qy_2r surfaces are up to 7 meters above modern Qycr deposits and are the most extensive river terraces in the valley. Qy_2r sediments were deposited when the San Pedro River 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 Qy_2r 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. Qy_2r deposits are subject to catastrophic bank failure due to undercutting and lateral erosion during flow events. Distal piedmont fan deposits (Qy_2 ,Qyaf, and Qys) onlap onto Qy_2r deposits although an interfingering relationship likely exits in the subsurface.

Qy_1r **Late to early Holocene river 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, Qy_1r 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. Qy_1r surfaces stand up to 7 meters above the active channel in highly incised locales and typically are located less than 1.5 m higher than adjacent Qy_2r surfaces. These terraces are typically covered with fine-grained floodplain deposits, but relict gravel bars and lenses are common.

Qi_3r **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 nearby mountains from which modern piedmont material is derived. Qi_3r terrace surfaces are planar, often surrounded by distal piedmont alluvium, and are generally lightly vegetated by small weeds and grasses. Commonly, Qi_3r 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.

Qi_2r **Middle to late Pleistocene river terrace deposits** - Terrace deposits are similar to Qi_3r 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 Qi_2r surfaces. Vegetation is sparse, consisting of small shrubs and grasses. Soil development is generally weak on Qi_2r surfaces, but soil development is more evident in finer grained sections. Qi_2r 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.

Qi_1r **Early to middle Pleistocene river terrace deposits –** Deposits are associated with high-standing, well-rounded river gravel terraces. Where Qi_1r deposits are extensive, remnant planar caps are preserved near the center of the surface. Qi_1r 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 Qi_1r deposits, but clay accumulation is variable, probably due to poor surface preservation. Sparse small shrubs, weeds, and cacti are present on these surfaces.

Piedmont alluvium and surficial deposits

Holocene to late Pliocene piedmont deposits derived from the Santa Catalina and Rincon Mountains west and the Galiuro Mountains to the east of the mapped area grade toward the San Pedro River which runs from south to north through the Redington quadrangle. Piedmont alluvium was deposited by repeated episodes of alluvial channel migration, incision, and aggradation. These processes have resulted in a series of nested terraces, some of which are partially sourced from older alluvium. Due to multiple source lithologies, similar age surfaces on different sides of the San Pedro River may exhibit different pedogenic and geomorphic characteristics. In many places throughout the mapped area these deposits are incised into and deposited directly upon latest Tertiary Quiburis basin fill sediments. Due to historical downcutting of the San Pedro River, relief between active piedmont channels and perched terraces can exceed 20 meters.

Qyc **Modern stream channel deposits -** Qyc deposits are composed of unconsolidated, very poorly sorted sandy to cobbly ephemeral 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.

Qy_3 **Latest Holocene alluvium –** Recently active piedmont alluvium located primarily along active drainages including floodplain, low-lying terrace, and ephemeral tributary channels. Qy_3 deposits are composed of unconsolidated to very weakly consolidated sandy to pebbly deposits and exhibit greater vegetation than Qyc deposits. These deposits generally exhibit bar and swale microtopography and are susceptible to inundation during moderate to extreme flow conditions when channel flow exceeds capacity. Soil development is generally absent or incipient on Qy_3 deposits which exhibit pale buff to light brown (10 YR) surface coloration.

Qyaf **Late Holocene alluvium, active fan deposits –** Qyaf deposits consist of active alluvial fan deposits in the San Pedro valley. These deposits have distributary drainage patterns and are extremely prone to flooding and channel migration. Sediments are unconsolidated and consist of very poorly sorted sand to cobbles. Vegetation includes small mesquite trees, shrubby acacia, prickly pear, and medium creosote.

Qy_2 **Late Holocene alluvium –** Qy_2 deposits consist of piedmont terrace deposits located primarily along the flanks of incised drainages, broad low-relief distal fan deposits onlapping onto Holocene river alluvium, and infrequently 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, Qy_2 deposits are planar with remnant bar and swale microtopography. Distal fan Qy_2 deposits are broad and sandy with numerous small braided channel systems. Rarely active Qy_2 tributary drainages are generally of limited extent, relatively steep, and more densely vegetated than Qy_3 tributary drainages. Soil development on Qy_2 deposits is minor, characterized by incipient stage I calcium carbonate accumulation in the form of small filaments and medium brown (10 YR) surface coloration. Vegetation on Qy_2 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. Planar Qy_2 terraces are typically elevated from 30 cm to 1.5 m above active channels.

Qy_1 **Older Holocene alluvium -** Qy_1 deposits consist of broad, low-relief, undulating fan deposits, exhibit shallow widespread braided drainage patterns, and 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 Qy_1 deposits typically does not exceed 1.5 meters. Numerous shallow braided channels drain widespread portions of Qy_1 surfaces. Qy_1 deposits exhibit incipient calcium carbonate accumulation (stage I) and soil development characterized by medium brown (10-7.5 YR) coloration where unincised. Deposition of Qy_1 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 Qy_1 deposits overly redder, grusy, clay-rich Qi_2 or Qi_3 deposits.

Qys **Holocene alluvium derived from distal Quiburis basin fill alluvium** – Qys deposits are unconsolidated, very fine to fine grained alluvium located in close proximity to Tq and Tqe deposits. These sediments are lighter in color and finer than alluvium derived from further upfan. In general, Qys deposits are loamy silts to fine sands with moderate amounts of gypsum fragments derived from Tqe deposits. Vegetation on Qys deposits consists of small shrubs, grasses, creosote, and acacia.

Qi_3 **Late Pleistocene alluvial fan and terrace deposits -** Qi_3 deposits are characterized as widespread planar reddish fan terraces mantled by angular to sub-angular pebbles to cobbles. These deposits exhibit moderate calcium carbonate accumulation (stage I-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, carbonate, and metamorphic clasts on the west side of the river vs. predominantly Galiuro volcanic clasts to the east). Qi3 deposits exhibit medium (1-2 m tall) mesquite, cholla, prickly pear, creosote, acacia, and numerous small grasses and shrubs. Qi3 deposits stand up to 3 meters higher in the landscape than adjacent Qy1 and Qyc deposits depending on local incision and position within the piedmont.

Qi_2 **Middle to late Pleistocene alluvial fan and terrace deposits –** Qi2 surfaces consist of broad planar fan terraces capping Quiburis basin fill deposits, inset into older, more well-rounded alluvial deposits, or lining significant piedmont drainages. These deposits generally exhibit reddish (7.5-5 YR 5/4) soils and moderate calcium carbonate accumulation (stage I-II+). Qi2 deposits are overall planar but can exhibit mild to moderate rounding near incised channels or inset terraces. Vegetation on Qi2 surfaces consists of 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 30 meters above active piedmont channels.

Qi_2a **Middle to late Pleistocene alluvial fan and terrace deposits (younger member)** – Qi_2a deposits strongly resemble Qi_2 deposits but are inset into these deposits along major drainages. Surface coloration, vegetation, and soil development are all very similar to those found on Qi_2 deposits.

Qi_2b **Middle to late Pleistocene alluvial fan and terrace deposits (youngest member)** – Qi_2b deposits strongly resemble Qi_2 and Qi_2a deposits but are inset into both along major drainages. Surface coloration, vegetation, and soil development are all very similar to those found on Qi_2 and Qi_2a deposits.

Qi_1 **Early to middle Pleistocene alluvial fan and terrace deposits –** Qi_1 deposits are characterized by high-standing, moderately to well-rounded alluvial deposits exhibiting strong (stage II-III) calcium carbonate accumulation and, where preserved, dark reddish (5–2.5 YR 4/6) soils. Like Qi_2 deposits, Qi_1 deposits may cap underlying Quiburis basin fill deposits. Where widespread (greater than 30 meters across), Qi_1 deposits retain a remnant, indurated planar cap with moderately to well rounded edges. Narrow (less than 30 meters across) Qi_1 terraces and caps are generally well-rounded and do not exhibit a planar remnant. Qi_1 terraces are commonly mantled by coarse pebbles to boulders and exhibit vegetation consisting of medium to large mesquite, acacia, saguaro, prickly pear, cholla, barrel cactus, and grasses.

Qo **Early Pleistocene alluvium** – Deposits associated with very high relict alluvial surfaces. A remnant planar cap may be present on extensive surfaces. 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 yucca, prickly pear, mesquite, and isolated creosote. The creosote population becomes significantly denser on the eroded flanks of Qo surfaces, possibly due to greater proximity to buried clays and carbonate. Remnant argillic horizons exhibit clay faces, blocky ped structures, and are deep red in color. Exposures of the calcium carbonate horizon exhibit stage III-IV accumulation. 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.

QTa **Late Pliocene to early Pleistocene fan gravel -** Coarse gravelly deposits that erosionally overlie Quiburis basin-fill sediments and form the upper parts of high, very rounded ridges. QTa deposits are composed of very poorly sorted angular to sub angular sand, pebbles, cobbles, and boulders arranged in alternating fine to coarse beds common in alluvial fan deposits. 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. Locally these deposits are capped by very old, very high relict Qo alluvial fan deposits, but are generally not capped and are deeply incised.

Tertiary Basin Fill alluvium (Quiburis)

Tqc **Late Miocene to Pliocene Quiburis basin fill deposits, alluvial fan facies –** Gravelly alluvial-fan and braidplain facies. Gray to buff-colored deposits vary from massive, sand-rich beds that predominate in the lower piedmonts to imbricated pebble-cobble-small boulder beds higher on the valley margins. In some areas, Tqc deposits grade into alternating thin unconsolidated beds of gypsum, silt, and very fine sand with occasional pebble stringers (Tqa deposits) along the valley axis. Tqc sediments are encountered throughout the mapped area and are generally well-exposed in deeply incised piedmont channel walls. In these exposures, Tqc deposits are often observed as capped by relict QTa, Qo, or younger (Qi_1 to Qi_3) deposits.

Tqs **Late Miocene to Pliocene Quiburis deposits, fan toe and axial valley facies** - Sandy fan-toe, lake-margin, and delta-front sandflat facies (massive to laminated sandstone with minor shale or mudstone interbeds and local thin pebble stringers) intermediate in both grain size and depositional environment between laterally equivalent alluvial-fan/braidplain (Tqc) and finer grained (Tqe) facies.

Tqe **Pliocene Quiburis basin fill deposits, low energy fluvial deposits –** Tqe deposits are located along the axis of the San Pedro Valley and represent a period of sedimentation in a closed basin prior to the initiation of the San Pedro River (Dickinson, 2003). Tqe deposits are composed of alternating thin unconsolidated beds of gypsum, silt, and very fine sand with occasional pebble stringers. The environment of deposition for these deposits was most likely a low energy axial fluvial system with either overbank stillwater or levee zones which allowed standing water to accumulate. The presence of pebbly beds or stringers indicates these deposits are not indicative of a lacustrine environment. Repeated episodes of sedimentation and evaporation of ponded water have resulted in stacked deposits observable within walls of incised drainages near the valley axis. The fine grained character of Tqe deposits becomes gradually coarser upfan. Tqe deposits are light to medium brown in color and are easily erodible unless protected by an indurated capping unit. Uncapped Tqe deposits are commonly observed to form intricately-dissected mounds similar in appearance to those found in badlands landscapes. The flanks of these mounds are often littered with gypsum crystals.

BEDROCK MAP UNITS

Tr **Rhyolite lava (Oligo-Miocene)** – Flow-banded silicic lava containing 2-3%, <2 mm quartz, 1-3%, <3 mm plagioclase, and ~1-2%, <2 mm sanidine. Unit weathers pale tan to pale gray. Flow foliation is defined by color variations and by variations in resistance to weathering over a scale of 1-100 cm. Locally present stretched vugs parallel flow banding. In northeastern exposures, flow banding is highly variable in orientation over distance of hundreds of meters. Variations are inferred to represent convolutions of flow banding during emplacement of a very thick extrusion or, less likely, emplacement of a vent plug or shallow intrusion.

Tf **Felsite lava (Oligo-Miocene)** – Variably brecciated, aphyric lava flows that contain <1%, <1 mm quartz, and <1%, <1 mm sanidine. This unit is characterized by convolute layering defined by variable devitrification and/or silicification.

Tbp **Bedded pyroclastic rocks (Oligo-Miocene)** – Bedded pyroclastic rocks that contain 1-2%, <1 mm quartz, <1%, <1 mm biotite(?), <1%, <1 mm sanidine, and abundant, 1-10 cm, angular, volcanic-rock fragments. Bedding is crudely defined by variations in volcanic-lithic fragment abundance and size. Unit does not contain visible pumice fragments. Volcanic-lithic fragments are varicolored, not flattened. Bedding is apparent on 1-10 m thick bed scale. The lower part of this unit is more obviously bedded whereas the upper part is more massive. The upper part of the unit is somewhat darker and more resistant to weathering than that lower part. Examination of a single thin section revealed numerous devitrified volcanic rock fragments, sparse, <1 mm quartz, and little else.

Tb **Basalt (Oligo-Miocene)** – Basalt in Redfield Canyon. A 2-m-thick tuff at the base of the basalt (station JES-07-660) contains ~40%, <2 mm plagioclase, ~5-8%, <2 mm biotite, and ~5-8%, <1 mm hornblende. The biotite and hornblende appear in thin section to be quite unaltered.

Tap **Andesite porphyry lava flows (Oligo-Miocene)** – Medium to dark gray to dark brown, generally massive lava flows with conspicuous, 10-50%, 3-30 mm, tabular, plagioclase phenocrysts ("Turkey-track porphyry" of Cooper, 1961). A sample of this unit, from upper Youtcy Canyon in the Soza Canyon 7 ½' Quadrangle to the south, yielded a K-Ar date of 26.9 ± 2.5 Ma from plagioclase (Shafiqullah et al., 1978).

Tvg **Galiuro volcanics, undivided (Oligo-Miocene)**

TKs **Sandstone and conglomerate (late Cretaceous to early Tertiary)** – Moderately lithified, moderately sorted sandstone and silty sandstone in beds 10-100 cm thick, with subordinate conglomerate. Subrounded conglomerate clasts include Paleozoic carbonate, Glance(?) conglomerate, quartzite, and sparse feldspar porphyry and mafic volcanic rocks.

TKt **Rhyolite tuff (late Cretaceous to early Tertiary)** – Quartz-biotite tuff with flattened pumice fragments and, for a Laramide tuff, surprisingly fresh biotite. Examination of a single thin section, stained for potassium, reveals ~2-4%, <1 mm sanidine, ~25-35%, <2 mm plagioclase, 5-10%, <2 mm quartz, and ~2%, <1 mm biotite that is somewhat reddish brown from oxidation (sample 4-3-07-7 from station JES-07-661). Sanidine is tentatively recognized in thin section because it (1) takes on a stain for potassium, (2) is not twinned like "tartan" twinning of microcline, and (3) does not have microperthitic textures characteristic of orthoclase (criteria from Deer et al., 1966, p. 310).

KJb **Bisbee Group, undivided (Cretaceous to Jurassic) –** Siltstone, sandstone, and conglomerate of the Bisbee Group, undivided.

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