GEOLOGIC MAP OF THE HAPPY VALLEY 7 ½' QUADRANGLE, COCHISE AND PIMA COUNTIES, ARIZONA

Arizona Geological Survey Digital Geologic Map DGM-89, version 1.1

Scale 1:24,000

By

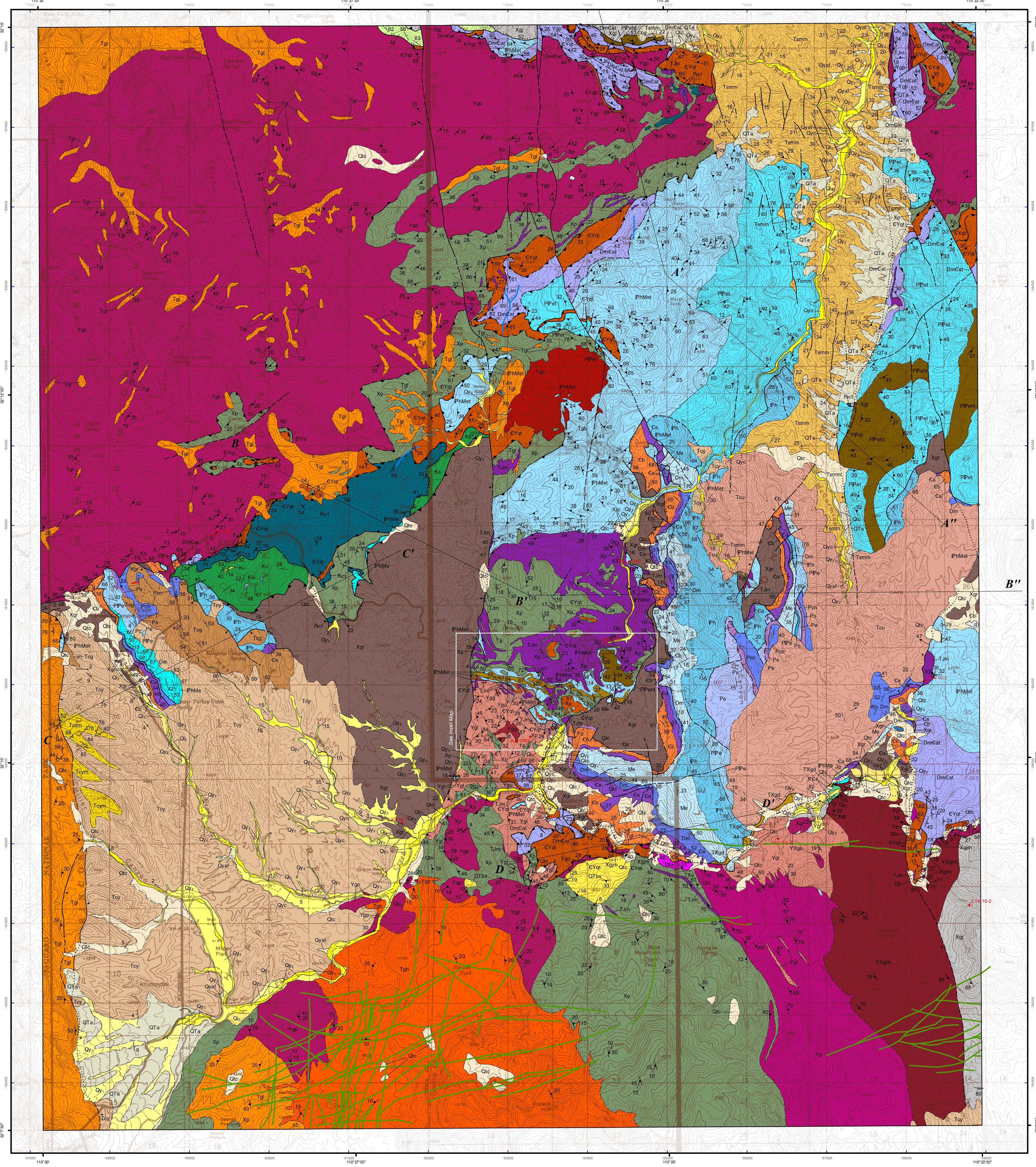
Spencer, J.E., Lingrey, S.H., Johnson, B.J., Cook, J.P., and Richard, S.M.

October 2011

Citation for this map:

Spencer, J.E., Lingrey, S.H., Johnson, B.J., Cook, J.P., and Richard, S.M., 2011, Geologic map of the Happy Valley 7 ½' Quadrangle, Cochise and Pima Counties, Arizona: Arizona Geological Survey Digital Geologic Map DGM-89, version 1.1, scale 1:24,000.

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G09AC00199. 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.



Topographic base from USGS 1:24,000 Quadrangle Series.
Seamless basemap generated using iGage All Topo Pro software.

Cartography by Mitchell F. Levine and Janel C. Day

SCALE 1:24 000

1 MILE / 7000 FEET / 1 KILOMETER

CONTOUR INTERVAL 40 FEET

10.8° APPROXIMATE MEAN DECLINATION, 2011

Projection Information:
North American Datum of 1983.
1000-meter Universal Transverse Mercator grid tics, zone 12, shown in blue.

Map Unit Description

Other units

d — **Disturbed ground** - Heavily disturbed ground due to human activity, including agricultural activities, excavation, and construction of earth dams.

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

QTbx — **Landslide breccia** - **Landslide breccia** and rubble derived from megacrystic biotite granite. Angular clasts are up to 5m diameter.

Piedmont alluvium and surficial deposits

Qyc — **Modern stream channel deposits** - Unconsolidated, poorly to moderately sorted sandy to cobbly deposits in active stream channels. 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 intermittent 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. 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.

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 4/4). This color varies with position in the piedmont due to differences in parent material. Qi_3 deposits exhibit medium (1-2 m tall) mesquite, cholla, prickly pear, creosote, acacia, and numerous small grasses and shrubs. Qi_3 deposits stand up to 3 meters higher in the landscape than adjacent Qy_1 and Qyc deposits depending on local incision and position within the piedmont.

Qi_2 — **Middle to late Pleistocene alluvial fan and terrace deposits** - Qi_2 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+). Qi_2 deposits are overall planar but can exhibit mild to moderate rounding near incised channels or inset terraces. Vegetation on Qi_2 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 Qi_2 surface as well as any deposits it may overly. Qi_2 terraces deposited onto basin fill deposits may stand as much as 30 meters above active piedmont channels.

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 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.

QTa — **Late Pliocene to early Pleistocene fan gravel** - Coarse gravelly deposits that erosionally overlie 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. Exposures of QTa deposits are generally poor, but may locally be up to 10 meters thick and are commonly the highest standing deposits in the proximal piedmont. These deposits are very well rounded, deeply incised, and exhibit a redder color than underlying basin-fill deposits.

Tertiary sedimentary units

Tcym — **Megablock conglomerate (Pliocene)** - Poorly consolidated boulder to megablock conglomerate that is exposed largely as lag of boulders on hilltops and ridge crests adjacent to the Martinez Ranch fault at the west edge of the Happy Valley 7.5' Quadrangle. Boulders up to 3m consist largely of banded gneiss, foliated leucogranite, and heterogeneous pegmatitic leucogranite. Near the Martinez Ranch fault, the nature of outcrop (bedrock vs. megablock conglomerate) is difficult to determine because blocks are large and surrounded by soil and vegetation. Random vs. aligned nature of foliation and gneissic layering were used to determine bedrock vs. conglomerate nature of outcrop. Blocks appear to be as large as 20 m. Location of contact between bedrock and megablock conglomerate is not well determined.

Tcy — **Fanglomerate (Pliocene)** - Poorly lithified, poorly sorted, weakly stratified conglomerate, pale gray to pale tan. Most clasts are subangular, <50cm diameter (locally to 5 m), and consist of variably foliated granitoids that are mostly pegmatitic and leucocratic with sparse to abundant clasts of Paleozoic and Mesozoic sedimentary units and other granitoids. This conglomerate unit, unlike map unit Tcg, was deposited following exhumation of the footwall of the San Pedro detachment fault, and could have been deposited in a topographic and geologic setting much like the modern setting. Upward coarsening into overlying megablock map unit Tcgm is inferred to reflect deposition during movement on the Martinez Ranch fault.

Tsmm — **Conglomerate, San Manuel Formation, metamorphiclastic Paige Canyon facies (upper Miocene to Pliocene)** - Weakly to moderately consolidated, moderately to poorly sorted, allvial-fan deposits, Clasts are derived primarily from metamorphic tectonites like those that form nearby bedrock in the Little Rincon Mountains (Dickinson, 1991).

Tcg — **Conglomerate (Oligocene to Miocene)** - Pale-gray to tan to medium-brown conglomerate and sparse, poorly sorted sandstone and pebbly sandstone with generally subangular to subrounded clasts. Conglomerate is crudely bedded to massive, locally well bedded where sandy. Bedding is generally defined by variations in clast size, with sandy layers locally defining bedding. Poorly sorted nature of conglomerate generally precludes identification of bedforms. Clasts generally range from 1 to 50cm, and rarely exceed 1m. Clast composition is highly variable and commonly reflects nearby or underlying bedrock. Abundant subrounded clasts of speckled equigranular granite in Happy Valley are inferred to have been derived from nearby granite that forms upper plate of San Pedro detachment fault. Mylonitic and pegmatitic leucogranite that form the footwall of the San Pedro detachment fault in the Happy Valley area are not represented in clast compositions, presumably because, at the time of conglomerate deposition, the footwall of the detachment fault in the Rincon Mountains had not been tectonically exhumed.

Tcu — **Conglomerate, undivided (Oligocene to Miocene)** - Undivided conglomerate and related clastic sedimentary rocks equivalent to Fanglomerate (map unit Tcy), conglomerate of the San Manuel Formation (map unit Tsmm), and older conglomerate (map unit Tcg). In some areas, rocks of this unit are steeply tilted where well exposed in canyon bottoms, but are elsewhere mantled by younger units or by disaggregated and weathered conglomerate. These units are undivided because of the difficulty in correlation without visible bedding.

Mesozoic sedimentary units

Kv — **Basalt in Bisbee Group sandstone (Cretaceous)** - An approximately 3-m-thick, locally vesicular lava flow. No flow breccia was seen, and it is not entirely certain this is not a shallow, slightly vesiculated, hypabyssal intrusion.

Ks — **Calcareous siltstone and sandstone of the Bisbee Group (Cretaceous)** - Calcareous siltstone and sandstone and rare conglomerate. Typically consists of tan, medium brown, reddish brown, or reddish tan, plane-bedded, calcareous siltstone and fine to very fine-grained, calcareous sandstone. Sands are quartz rich but contain feldspar and lithic grains that are visible in hand lens (quartz-rich QFL sands). Magnetite is visible in some sands. Grains vary from sub-rounded to sub-angular. Primary porosity appears to be present locally. Unit is laminated to thin-bedded to medium-bedded (<20 cm). Unit includes rare pale gray silty limestone and sparse conglomerate beds containing sub-rounded, 1-10 cm clasts of carbonate and siliciclastics.

Ksl — **Silty limestone of the Bisbee Group (Cretaceous)** - Silty limestone within sandstone and siltstone of the Bisbee Group.

Jg — **Glance Conglomerate of the Bisbee Group (Upper Jurassic)** - Lithified conglomerate containing subrounded carbonate and siliceous clasts, 1-10 cm diameter, in a calcareous matrix.

Paleozoic to Mesoproterozoic sedimentary units

KЄs — **Fine-grained clastic rocks (Cretaceous to Cambrian)** - Fine-grained clastic rocks, thin- to very thin-bedded, medium-gray color, very low metamorphic grade with weak cleavage. Poorly exposed, mostly float with sparse outcrop visible through colluvium. Lithology is compatible with various parts of the Bisbee group, the Abrigo Formation, or Mesozoic clastic rocks below the thrust fault at Lookout Mountain (83 km to the north-northeast). Low carbonate content is suggestive of Mesozoic strata. Eastern end of outcrop area is exposure of quartzite that strongly resembles Bolsa Quartzite, but could be quartzose sandstone of the Turney Ranch Formation of the Bisbee Group.

Pcn — **Concha Limestone (Permian)** - Massive, medium-gray carbonate, with abundant cherty to siliceous blobs and irregular stringers that generally do not define bedding. Locally includes striated shells ~3 cm across.

Ps — **Sherrer Formation (Permian)** - Fine- to very fine-grain, pale-gray quartzite.

Pe — **Epitaph Formation (Permian)** - Dark-gray, moderately thick-bedded, slightly cherty dolostone. Includes a lower unit (commonly faulted out) of dolomitic marl and some intercalated limestone.

Pc — **Colina Limestone (Permian)** - Medium to dark gray, thick-bedded, slightly cherty limestone. Some beds contain small white blebs of dolomite.

Paleozoic to Mesoproterozoic sedimentary units continued

PPe — **Earp Formation (Permian to Pennsylvanian)** - Medium-gray limestone, 1-4 m thick resistant beds, separated by 1-10 m wide zones of calcareous siltstone, pale-red to yellowish-tan, slope forming and commonly covered by rubble. Limestone is generally medium- to thick-bedded, dark- to medium-gray, locally with irregular silica stringers and masses. The Earp Formation grades upward from thick limestone beds and thick siltstone units to thin limestone beds and thick siltstone units. Most of the upper Earp is very fine-grained, medium-red, quartzose sandstone, reddish- to pale-gray calcareous siltstone, and medium to thick bedded carbonate. Upper Earp sands include 1-3 cm thick climbing ripple cross beds and 3-12 cm thick sets of low-angle cross beds.

IPh — **Horquilla Limestone (Pennsylvanian)** - Medium- to pale-gray to tannish-gray to olive-brown carbonate, medium- to thick-bedded (beds 5-300 cm), with parting on bedding planes. Tannish-gray carbonate appears slightly silty in hand lens view. Limestone is commonly cherty, and locally silty, with thin beds and lamination of pale-red and reddish-tan silty carbonate. Carbonate locally contains solitary coral. Forms ledges with intervening covered slopes.

IPhMe — **Horquilla Limestone (Pennsylvanian) and Escabrosa Limestone (Mississippian), undivided** - Medium- to thick-bedded to massive, medium-gray to locally dark-gray limestone, commonly with chert and siliceous stringers. Bedding is generally defined by variable resistance to weathering and sparse stringers of silica. Limestone is recrystallized; some pale gray limestone consists of 1-3 mm calcite crystals. Elsewhere recrystallization is cryptic and carbonate is inferred to be less pure. Locally includes terra rosa breccia zones that are not clearly laterally continuous. Locally this unit includes laminated to thin bedded silty limestone to siltstone.

Me — **Escabrosa Limestone (Mississippian)** - Thick-bedded to massive, light- to medium-gray, variably cherty carbonate with local dissolution breccia. The unit is predominantly limestone, although brown-gray to tan dolostone is abundant in the lower part and near the top of the formation, and patchy dolomitization is common locally. Large chert lenses and layers are characteristic, as is the thick-bedded (rarely medium-bedded), cliff-forming nature of outcrops. Remains of rugose corals are present locally.

Dm — **Martin Formation (Devonian)** - Light-brown to tan, silty to sandy, thin- to medium-bedded dolostone and limestone; fine- to medium-grained, calcareous, quartzose sandstone; calcareous siltstone; and locally thick beds of massive gray limestone. Sand grains are fine- to medium-grained, well rounded, and almost all quartz. In general, the lower Martin Formation consists of thin-bedded to laminated, very fine-grained, quartzose sandstone and medium-gray to light-brownish-gray bioclastic limestone. The limestone is commonly mottled as if bioturbated, and limestone locally grades abruptly along strike to tan- or orange-brown-weathered dolostone. Overlying middle Martin Formation (~30-50 m thick) consists of thin- to medium- bedded (10-100 cm), very-fine- to medium-grained quartzose sandstone, siltstone, calcareous siltstone, and silty tan carbonate. Upper Martin Formation is similar, with very fine-grained quartzose sandstone forming the top of the formation. Sandstone and sandy carbonate units are locally cross-bedded (including herringbone cross-bedding), and some contain glauconite.

Єa — **Abrigo Formation (Cambrian)** - Tan to light-brown to gray limestone and dolostone, thinly interbedded with fine-grained, light-brown, shaley, commonly calcareous quartz sandstone and yellow to olive-green shale containing flakes of white mica. Glauconitic siltstone and sandstone are present in some intervals, notably near the base of the formation. Cross-bedding and cross-lamination are locally common. Some carbonate and calcareous sandstone units are medium-bedded. Intraclast conglomerate beds up to 15 cm thick, containing flat pebbles of laminated quartzose sandstone in limestone matrix, are conspicuous in some intervals, especially in the middle of the section.

The base of the Abrigo Formation is placed at the first upward appearance of calcareous strata. South of Eagle Peak this transition is marked by a ~1m thick, medium-red, fine-grained calcareous sandstone. North of Eagle Peak, the lower Abrigo includes beds of dark-purple-weathered, hematite-stained, glauconitic siltstone. The contact with overlying Martin Formation is an unconformity that is commonly cryptic, occurring in an apparent transition upward from dominantly sandstone and calcareous sandstone to dominantly sandy and silty carbonate. North and south of Eagle Peak, the top of the Abrigo Formation is marked by a 1-2 m thick bed of medium-grained quartz sandstone with cross-bedding accentuated by recessive laminations. Where stratigraphic context is uncertain, Abrigo Formation can be distinguished from sandstone of the Bisbee Group by the relative lack of magnetite and very high quartz content in the Abrigo Formation.

Єb — **Bolsa Quartzite (Cambrian)** - Generally medium- to fine-grained, thin- to thick-bedded, locally cross-bedded, quartz-rich sandstone. As estimated in the field, the composition ranges from quartz arenite to subarkosic or sublithic arenite, with minor arkose in the lower part of the section. Most beds are medium-grained and moderately sorted, with subrounded to subangular grains. Fine-grained intervals appear more mature, moderately to possibly well-sorted, with subrounded grains. Some beds contain dispersed coarse-sand and granule-sized grains of quartz and subordinate jasper and are poorly sorted. Planar lamination is common throughout the unit; low-angle and trough cross-bedding are common in some intervals. Amalgamated, tabular, medium bedsets weather to form slabs and blocky ledges. Color ranges from white to tan to dark brown. Black, magnetite(?)-rich laminations are present locally, especially at lower stratigraphic levels. Near the western edge of the Happy Valley, the top 3-4 m of the Bolsa Quartzite is somewhat massive, resistant to erosion, and pale-gray to pale whitish-tan. The top of the unit is placed at the base of the lowest overlying calcareous sandstone or siltstone bed.

Yp — **Pioneer Shale (Mesoproterozoic)** - Thin-bedded to laminated (less commonly medium-bedded) shale, mudstone, and subordinate siltstone. Colors are highly variable, including red, purple, black, and white. Includes an outcrop of metamorphosed Pioneer Shale northwest of Wildhorse Mountain near the east edge of the map area.

Tertiary to Proterozoic intrusive units

Tgh — **Granodiorite of Happy Valley (upper Oligocene)** - Medium-grained, equigranular biotite granodiorite (Drewes, 1974). Local border phase consists of fine grain, two-mica granite (all phenocrysts <2mm, with ~4-6%, <2mm biotite, 0-2%, <2mm muscovite, and locally, <<1% garnet, <3mm). Border phase may include locally abundant dikes with highly variable muscovite content. Two samples of this rock unit yielded K-Ar biotite dates of 26.9 +/- 0.9 Ma and 28.0 +/- 1.1 Ma (Marvin et al., 1973).

Tgb — **Barney Ranch quartz monzonite (upper Oligocene to Eocene)** - Leucocratic biotite quartz monzonite of Lingrey (1982) forms an ~1km^2 stock in the central part of the map area, east of Barney Ranch. Biotite content is ~5%; garnet and muscovite were not observed by Lingrey (1982); texture is medium grained, hypidiomorphic-granular with sparse feldspar phenocrysts.

Tgl — **Heterogeneous pegmatitic leucogranite (Eocene)** - Heterogeneous pegmatitic leucogranite with locally abundant screens of host biotite granite forming layered gneiss. Leucogranite commonly contains muscovite and, locally, garnet. Eocene age is based on correlation to lithologically similar Eocene leucogranites in the Santa Catalina Mountains.

TJm — **Hornblende meladiorite (early Tertiary, Cretaceous, or Jurassic)** - Meladiorite forms an intrusion, exposed in a 4-km^2 area between Driscoll Mountain and Bear Creek, and several peripheral dikes and small intrusions. The rock is composed of hornblende, fine-grained plagioclase, and locally biotite. Hornblende typically is fine- to medium-grained and forms aggregates 5-10 mm long, although crystals up to 1 x 12 cm are locally present in dikes. The mafic-mineral content is typically 60% or more, and some dikes range to hornblendite in composition (with >90% hornblende). Thin sections from Paige Creek east of Driscoll Mountain contain 45-60% hornblende, 0-10% biotite, 30-40% plagioclase, 3-5% opaque minerals (ilmenite?), and trace apatite.

Near contacts with metasedimentary tectonites, including marble and Pinal schist, meladiorite typically is well-foliated and commonly grades toward the contact to fine-grained plagioclase-hornblende-biotite schist. In one locality along Paige Creek east of Driscoll Mountain, meladiorite with chilled intrusive margins is exposed in intrusive contact with Pinal schist and interfoliated fine-grained granitoid tectonites. Near the eastern edge of the Happy Valley 7.5' Quadrangle, meladiorite intrudes Paleozoic carbonate tectonites and so are younger than Paleozoic. Tectonite deformation has affected rocks of this unit before middle Tertiary tectonic exhumation and cooling. The meladiorite therefore was likely emplaced during middle Jurassic arc-related magmatism (~180-160 Ma), during late Jurassic basaltic magmatism related to extension in the Bisbee trough (160-150 Ma), or during regional Laramide magmatism (~75-55 Ma).

TXgd — **Equigranular hornblende-biotite granodiorite (Tertiary to Proterozoic)** - Equigranular hornblende-biotite granodiorite, medium grained, with ~3-5%, <2mm biotite, and 5-8%, <3mm hornblende. This unit forms a sheet-like, subhorizontal fault sliver along the San Pedro detachment fault south of Eagle Peak.

TXa — **Aplite (Tertiary to Protorozoic)** - Aplite intruding Pinal Schist south of Eagle Peak.

Yd — **Sierra Ancha Diabase (Mesoproterozoic)** - Very dark-gray to dark-greenish-gray to black, fine-grained diabase, generally with 0.5-3 mm long acicular plagioclase in a dark groundmass in which pyroxene has been altered to iron oxides.

Xgr — **Granodiorite of Rincon Valley (Paleoproterozoic)** - In Happy Valley this unit is a coarse-grained granitoid with conspicuous gray quartz up to 10 mm, white plagioclase up to 8 mm, pink K-feldspar up to 15 mm, and <5% oxidized biotite. Quartz superficially appears to represent <20% of rock unit. Alteration is everywhere sufficient that all rocks readily disintigrate when hit with a rock hammer. A sample of this unit was dated at 1658 +/- 22 Ma (one-sigma; U-Pb isotopic analysis by M. Pecha and G. Gehrels, University of Arizona; sample 3-23-10-1 collected by J. Spencer). In Redrock Canyon this unit is a medium- to coarse-grained, megacrystic biotite granite with pale-pink K-feldspar up to 3 cm diameter, and 4-7% biotite in <5mm clots. In both areas this unit was mapped by Drewes (1974) as the Granodiorite of Rincon Valley.

Oracle granite suite (Mesoproterozoic)

Ygp — **Porphyritic biotite granite to granodiorite (Mesoproterozoic)** - Commonly foliated granite with K-feldspar augen up to 4 cm long and up to ~15% mafic minerals which consist mostly of fine biotite. Deformation and recrystallization obscure orignal grain size, which was probably medium- to coarse-grained. Foliation is variably developed and is interpreted to be recrystallized mylonitic fabric, but original mylonitic character is obscure. Northwest of Happy Valley this unit is extensively intruded by dikes and sills of heterogeneous pegmatitic granite and locally appears as the melanosome in banded gneiss. A sample of this unit was dated at 1449 +/- 11 Ma (one-sigma; U-Pb isotopic analysis by M. Pecha and G. Gehrels, University of Arizona; sample 2-5-10-3 collected by J. Spencer). This unit resembles Oracle Granite in the southern Santa Catalina Mountains where it similarly forms screens between sills and dikes of heterogeneous pegmatitic leucogranite.

Yg — **Equigranular biotite granite to granodiorite (Mesoproterozoic)** - Fine- to medium-grained biotite granite with up to ~15% mafic minerals which consist mostly of fine biotite. Sparse white feldspar are up to 10 mm diameter. Foliation is variably developed and is interpreted to be recrystallized mylonitic fabric, but original mylonitic character is obscure. This unit is considered to be an equigranular facies of "Porphyritic biotite granite to granodiorite" of map unit Ygp, and was mapped as Continental Granodiorite by Drewes (1974). It is differentiated from phophyritic variety because it does not contain large K-feldspar megacrysts like most of that unit, but rather is weakly porphyritic to equigranular. This unit is exposed near the southeastern corner of the map area.

Ygg — **Biotite granodiorite and melatonalite (Mesoproterozoic)** - Fine- to medium-grained, recrystallized granodiorite, containing 10-25% fine-grained biotite in 5-10-mm aggregates that define a prominent foliation. Pillow-like inclusions of fine-grained hornblende-augite-biotite melatonalite contain ~30% biotite and grade to finer-grained quartz diorite, diorite, or gabbro lacking biotite. The biotite-free phase appears to have been chilled against the granodiorite, whereas the biotite-rich phase displays sharp to gradational (commingled) contacts with granodiorite, indicating that the granodiorite was not completely crystallized when the more mafic melt was emplaced. The biotite-rich melatonalite phase may be a hybrid formed by mixing of the biotite-free phase and the granodiorite.

The granodiorite locally contains K-feldspar megacrysts up to 35 mm long, and may correlate with unit Ygp. In thin section, it can be seen that aggregates of fine-grained quartz and feldspar have replaced crystals with medium-grained outlines. Relics of medium-grained K-feldspar (orthoclase) display Carlsbad twinning.

A thin section of the biotite-rich melatonalite contains approximately 30% biotite, 15-20% clinopyroxene (augite), 1-2% amphibole (hornblende?), 25-30% plagioclase, 20-25% quartz, and trace apatite. Quartz is polycrystalline and formed in part as replacement of plagioclase. Some of the biotite has replaced embayed pyroxene and amphibole.

This unit apparently forms enclaves or screens in muscovite leucogranite of map unit Ygl, but intrusive relationships have been obscured by foliation of both units.

Oracle granite suite (Mesoproterozoic) continued

Ygl — **Muscovite leucogranite (Mesoproterozoic)** - Fine- to medium-grained leucogranite containing 2-10% very-fine-grained muscovite. Heterogeneously foliated and recrystallized, with non-foliated zones locally ranging in texture to coarse-grained or medium-grained porphyritic. K-feldspar in such zones is commonly in the 5-10 mm size range, rarely up to 25 x 5 mm. Muscovite is very fine-grained even where feldspar is coarse-grained. The rock locally contains traces to a few percent biotite, also very fine-grained. In eastern exposures along Redrock Creek this unit contains as much as 10% biotite.

In thin section, a specimen of this unit from near Paige Creek is leucomonzogranite containing 25-30% K-feldspar, 35-40% plagioclase, ~30% quartz, and 5% muscovite. The rock is fine-grained with medium-grained K-feldspar (orthoclase) phenocrysts up to 5 mm, some of which display Carlsbad twinning.

Two samples of this unit were dated at 1440 +/- 13 Ma and 1441+/- 18 Ma (one-sigma; U-Pb isotopic analysis by M. Pecha and G. Gehrels, University of Arizona; sample 3-11-10-4 collected by J. Spencer, sample BJJ-2800 collected by B. Johnson),

Ygu — **Undivided granitoid tectonites (Mesoproterozoic)** - Generally fine-grained, recrystallized, foliated, leucocratic granitic rocks containing up to 7% very-fine-grained biotite (locally altered to chlorite) and 0-10% very-fine-grained muscovite. Contacts between biotite-bearing and muscovite-bearing phases range from abrupt to gradational, but intrusive relationships, if any, are obscured by foliation. The contact between this unit and muscovite leucogranite unit Ygl is apparently gradational; muscovite leucogranite components of this unit are indistinguishable from map unit Ygl. The biotite-bearing components bear a mineralogical resemblance to granodiorite of unit Ygg, but correlation is only speculative. Recrystallized mylonitic to ultramylonitic foliation is common near contacts with non-granitic rocks. Near contacts with meladiorite of unit TJm, recrystallized mylonite derived from granitoid and meladiorite is locally interfoliated on few-mm to 20-cm scale. Screens of Pinal schist are also locally interfoliated with the granitoid rocks.

Johnny Lyon granodiorite and related units

Xgj — **Johnny Lyon granodiorite (Paleoproterozoic)** - Johnny Lyon granodiorite, consisting of medium- to coarse-grained biotite granite and granodiorite with up to 20% K-feldspar megacrysts that are up to 5 cm long, white to pale-pinkish to pale-gray, and generally blocky or tabular. Prominent gray quartz is up to 10 mm, but mostly 2-8 mm. Fresh biotite is preserved locally, but mafic minerals are typically altered; felted aggregates typically form 4-7% of the rock. The rock is generally not foliated. A sample of this unitwas dated at 1651 +/- 17 Ma (one-sigma; U-Pb isotopic analysis by M. Pecha and G. Gehrels, University of Arizona; sample 3-16-10-2 collected by J. Spencer).

Xgjm — **Mylonitic Johnny Lyon granodiorite (Paleoproterozoic protolith, Laramide mylonitization)** - Mylonitic granodiorite above the Wildhorse Mountain thrust fault. Asymmetric petrofabrics (S-C shear-sense indicators) indicate top-northeast shearing during mylonitization.

YXgjm — **Mixed border phase of Johnny Lyon granodiorite (Mesoproterozoic to Paleoproterozoic)** - The southeast corner of the Happy Valley Quadrangle is the western margin of the Johnny Lyon granodiorite. Gradational contacts with adjacent equigranular biotite granite of map unit Yg and muscovite leucogranite of map unit Ygl indicate that the margin of the Paleoproterozoic Johnny Lyon granodiorite underwent melting and mixing when intruded by these two Mesoproterozoic granites. Variation in the fraction of K-feldspar megacrysts characterizes the margin of the porphyritic main phase, and K-feldspar megacrysts may locally form xenocrysts in adjacent phases. The mixed border phases map unit includes five phases, as follows: (1) The porphyritic to megacrystic main phase of the Johnny Lyon Granodiorite (Xgj), (2) intruding equigranular biotite granite to granodiorite (Yg), (3) intruding muscovite leucogranite (Ygl), (4) biotite granite(?) and granodiorite(?) (YXgb), and (5) a two-mica phase that appears to represent compositions intermediate between the biotite granodiorite(?) phase (YXgb) and the muscovite leucogranite phase (Ygl).

YXgb — **Equigranular biotite granite and/or granodiorite (Mesoproterozoic to Paleoproterozoic)** - Equigranular, fine-grained biotite granite to granodiorite, with <1mm, somewhat fresh biotite, commonly intruded by leucogranite dikes. Mafic minerals are difficult to distinguish with hand lens, but biotite, hornblende(?), and magnetite form 20-70% of rock. Oxidative hydrothermal alteration has affected adjacent granitoids near Redrock Creek.

Paleoproterozoic metamorphic units

Xp — **Pinal Schist (Paleoproterozoic)** - Fine-grained quartz-feldspar-muscovite schist, commonly with fine magnetite, and fine-grained quartzite. Includes slightly to moderately micaceous quartzose metasandstone and schist intruded by locally abundant pegmatites, leucogranite dikes or sills, and quartz veins.

In the Driscoll Mountain area, metasandstone units range from a few cm to 20 m thick. They consist mainly of resistant, fine-grained, quartzofeldspathic psammite and semipelitic schist, along with some micaceous quartzite and pelitic schist. These rocks are composed of quartz, feldspar, and muscovite in various proportions. Some intervals contain chlorite or biotite (in part replaced by chlorite) as well. The resistant rocks of this assemblage typically form layers a few cm thick, with thin partings of pelitic quartz-muscovite schist. Thick intervals of psammite and semipelite contain interlayers of pelitic schist (or locally phyllite) several cm thick.

The psammite-semipelite units form ledges that are interfoliated with thick units of less-resistant, fine- to medium-grained, pelitic to semipelitic quartz-muscovite and quartz-feldspar-muscovite schist.

Leucogranite dikes and stringers locally are interfoliated with the metasedimentary rocks of the Pinal schist. They grade to fine-grained muscovite-quartz-feldspar or biotite-quartz-feldspar schist, becoming difficult to distinguish from semipelite and psammite with increased metamorphic differentiation and transposition.

Metasedimentary tectonites (Paleozoic to Paleoproterozoic protoliths)

PPet — **Tectonite derived from Earp Formation (Permian to Pennsylvanian protolith)** - Foliated calc-silicate marble, calc-pelitic schist, and variably calcareous, quartzose meta-sandstone. Interlayered calcite and dolomite marble tectonite are less common. The unit includes a distinctive, stretched-pebble conglomerate with whitish and dark bluish recrystallized chert clasts in a sandy, calcareous matrix (Lingrey, 1982). The conglomerate is probably correlative with the "Jelly Bean conglomerate" member of the Earp Formation (Armin, 1987).

PPeht — **Tectonite derived from Earp Formation and Horquilla Limestone, undivided (Permian to Pennsylvanian protolith)** - Interlayered marble, calc-silicate marble, calc-pelite, and quartzose metasandstone. Interpreted by Lingrey (1982) to represent tectonically interlayered rock units derived from Earp Formation and Horquilla Limestone.

Near Paige Creek east of Driscoll Mountain, this unit is a heterogeneous assemblage of siliceous and calcareous rocks, including marble with thin siliceous layers, siliceous hornfels with thin recessive marble layers, thin layers of epidote calc-silicate, fine-grained quartzite and quartzofeldspathic psammite, semipelitic feldspar-muscovite-quartz schist, and minor pelitic quartz-muscovite schist.

IPhMet — **Marble tectonite derived from Horquilla Limestone and Escabrosa Limestone, undivided (Pennsylvanian to Mississippian protolith)** - Calcite marble, slightly siliceous calcite marble, and zones up to tens of centimeters thick of calcite marble containing silt or very fine sand. Colors are variable and include whitish-tan, pale-gray, grayish-white, and pale-red. Thin transposed siliceous layers are sparse to moderately abundant and are typically light orange-pink. Rarely, siliceous units are up to 5 m thick and are characterized by resistant layers of very fine-grained quartzite or metasiltstone hornfels and recessive layers of marble tectonite.

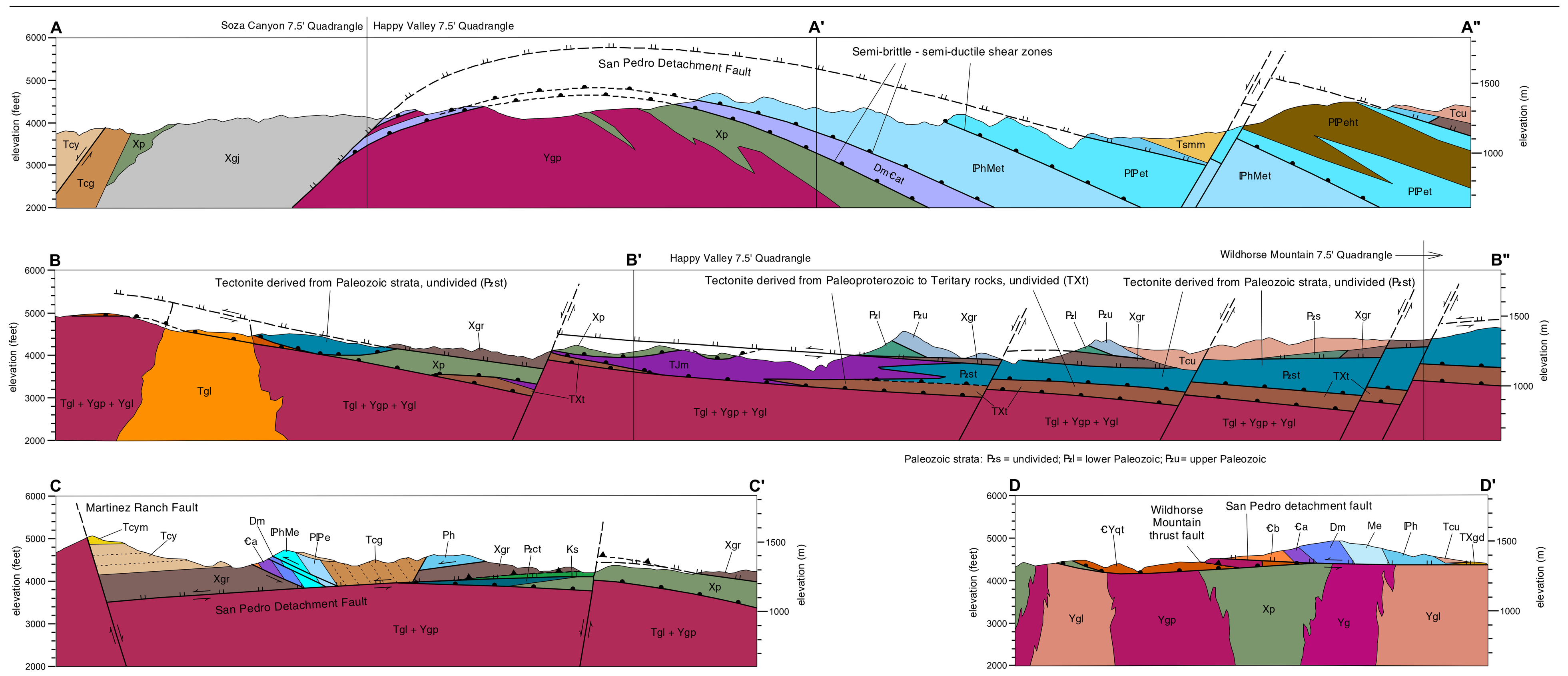
DmЄat — **Tectonite derived from Martin Formation and Abrigo Formation, undivided (Devonian and Cambrian protoliths)** - Strongly foliated, silicate-banded marble and less common quartzite, nearly pure calcitic to dolomitic marble, pale to dark green calc-silicate marble, and calc-pelitic schist. Silicate-banded marble is brown to tan and contains numerous thin (<1cm), resistant, green to pink siliceous layers rich in fine- to very fine-grained quartz sand grains.

Pzct — **Tectonite derived from calcareous strata (Paleozoic protolith)** - Calcite marble tectonite derived probably from Escabrosa Limestone and Horquilla Limestone is the dominant unit. Less common are (1) quartzite, (2) micaceous schist, (3) carbonate tectonite that contains layers in which fine to medium quartz sand grains have retained their equant shape within highly strained calcite marble, (4) green calc-silicate with siliceous and calcareous layers alternating on a scale of 3 to 30 mm. The carbonate tectonite contains inclusions of heterogeneous pegmatitic myscovite leucogranite that could be tectonically incorporated or intruded.

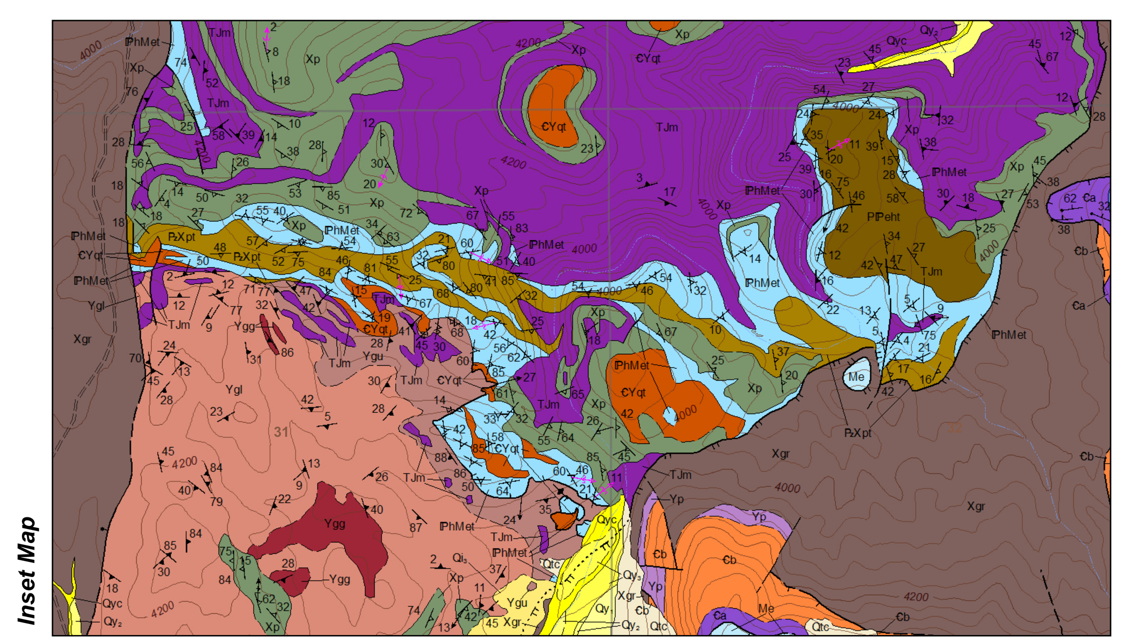
ЄYqt — **Tectonite derived from Bolsa Quartzite and Dripping Spring Quartzite, undivided (Cambrian and Mesoproterozoic protoliths)** - White, light- to medium-gray, or pale reddish-gray quartzite, commonly with transposed thin beds and laminations. The unit locally contains conglomerate beds and pelitic schist. Several conglomerate beds, 0.5 to 3 m thick, contain quartzite clasts that are flattened parallel to compositional layering and that rarely exceed 15 cm in longest direction. Locally includes fine-grained micaceous quartzite, some of which could have been derived from the Mesoproterozoic Pioneer Shale of the Apache Group. Where this quartzite is derived from Dripping Spring Quartzite, it locally contains lenses and stringers derived from Mesoproterozoic Sierra Ancha diabase. South of Driscoll Mountain, fine-grained quartzite interfoliated with marble tectonites may have been derived from Permian Scherrer Formation.

PzXpt — **Heterogeneous schist, micaceous quartzite, marble, calcsilicate (Paleozoic and Proterozoic protoliths)** - A heterogeneous assemblage of fine-grained quartzofeldspathic psammite, semipelitic schist, siliceous hornfels (some with recessive carbonate laminations), marble with siliceous laminations, and pelitic quartz-muscovite schist. Thin layers of epidote calc-silicate and discontinuous units of dark-gray, fine-grained, quartz-biotite-feldspar schist are also present. Some quartzofeldspathic layers interfoliated with the schist and psammite appear to have been derived from a leucogranitic protolith. The semipelite and psammite contain quartz, feldspar, and muscovite, plus locally chlorite or biotite. Abundant chlorite and epidote veinlets locally give the rock a green color. This unit is interpreted as having been derived from Pinal schist interfoliated with tectonites of calcareous Paleozoic protoliths (e.g., Escabrosa, Horquilla, and Earp formations).

Cross-Section Diagrams



Inset Map



Topographic base derived from USGS NED 1/3 arc-second (~10 meter resolution), NHD, GNIS, Arizona State Lands Department

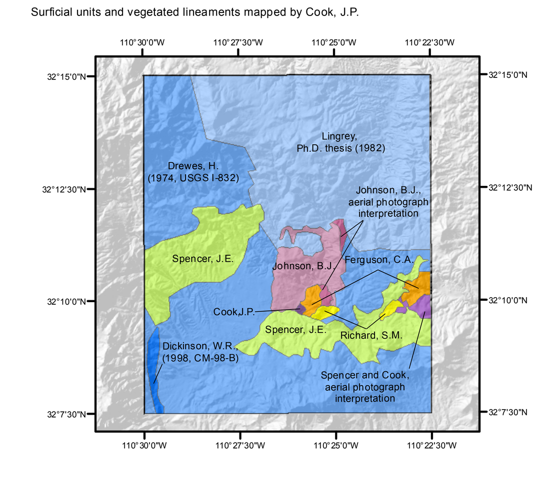
SCALE 1:10 000

520 METERS / 1000 FEET

Projection Information:
UTM Zone 12
North American Datum of 1983.

Bedrock Mapping Responsibility Diagram

Surficial units and vegetated lineaments mapped by Cook, J.P.



Line Symbol Descriptions

All geologic contacts are solid where accurately located, dashed where approximately located and dotted where concealed beneath surficial units.

- hypothetical contact
- lithologic contact
- fault, displacement unspecified
- normal fault, ball and bar on hanging wall
- brittle-ductile shear zone, half-circles on hanging wall
- thrust fault, teeth on hanging wall
- detachment fault, double tics on hanging wall
- low-angle normal fault, tics on hanging wall
- landslide scar, tics on hanging wall
- air photo lineament representing vegetation concentration inferred to be due to crushed rock along fractures
- mafic dike
- felsic dike

Introduction

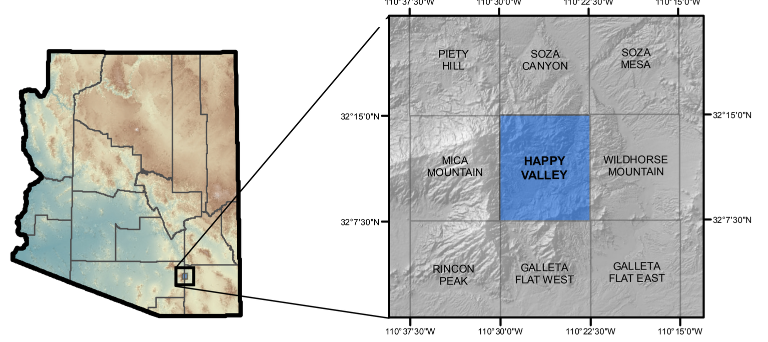
The Happy Valley 7 ½' Quadrangle extends over the eastern Rincon Mountains in southeastern Arizona, located about 50 km east of downtown Tucson. Production of this new geologic map continues the Arizona Geological Survey mapping program of the San Pedro River valley. This mapping was done under the joint 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 contract award G09AZ00199. Mapping was compiled digitally using ESRI ArcGIS software.

This map incorporates both old and new mapping. Previous maps used in map compilation are those by Drewes (1974), Lingrey (1982), and Dickinson (1998). New mapping was directed at structurally complex areas where it was considered likely that substantial improvements could be made to the accuracy of geologic mapping. Mapping in some areas utilized aerial photography. Maps of directly adjacent areas include those by Thorman and Drewes (1981), Smith (1989), Skotnicki and Siddoway (2001), Youberg et al. (2006), and Spencer et al. (2008a, b). Overviews of the Cenozoic structural and stratigraphic development of the area are provided by Davis (1980) and Dickinson (1991).

See accompanying text for additional information regarding structural geology and geochemistry.

Location Map

Mapped area shown in blue



Citations

Armin, R.A., 1987, Sedimentology and tectonic significance of Wolfcampian (lower Permian) conglomerates in the Pedregosa Basin: Southeastern Arizona, southwestern New Mexico, and Northern Mexico: Geological Society of America Bulletin, v. 99, no. 1, p. 42-65.

Davis, G.H., 1980, Structural characteristics of metamorphic core complexes, southern Arizona, in Crittenden, M.D., Jr., Coney, P.J., and Davis, G.H., eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153, p. 35-77.

Dickinson, W.R., 1991, Tectonic setting of faulted Tertiary strata associated with the Catalina core complex in southern Arizona: Geological Society of America, Special Paper 264, 106 p.

Dickinson, W.R., 1998, Geologic relations of Martinez Ranch fault and Happy Valley Neogene Basin, east flank of Rincon Mountains, Pinal County, Arizona: Arizona Geological Survey Contributed Map CM-98-B, scale 1:24,000, with 16 p. text.

Drewes, H., 1974, Geologic map and sections of the Happy Valley Quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-832, scale 1:48,000.

Lingrey, S. H., 1982, Structural geology and tectonic evolution of the northeastern Rincon Mountains, Cochise and Pima Counties, Arizona: Tucson, University of Arizona, unpublished Ph.D. thesis, 202 p.

Marvin, R.F., Stern, T.W., Creasey, S.C., and Mehnert, M.H., 1973, Radiometric ages of igneous rocks from Pima, Santa Cruz, and Cochise Counties, southeastern Arizona: U.S. Geological Survey Bulletin 1379, 27 p.

Skotnicki, S.J., and Siddoway, C.H., 2001, Geologic map of the Galleta Flat West 7 ½' Quadrangle, Pima and Cochise Counties, Arizona: Arizona Geological Survey Digital Geologic Map 8, layout scale 1:24,000, with 18 p. text.

Smith, C., 1989, Geologic map of the Little Rincon Mountains: Arizona Geological Survey Contributed Map CM-89-C, scale 1:10,000.

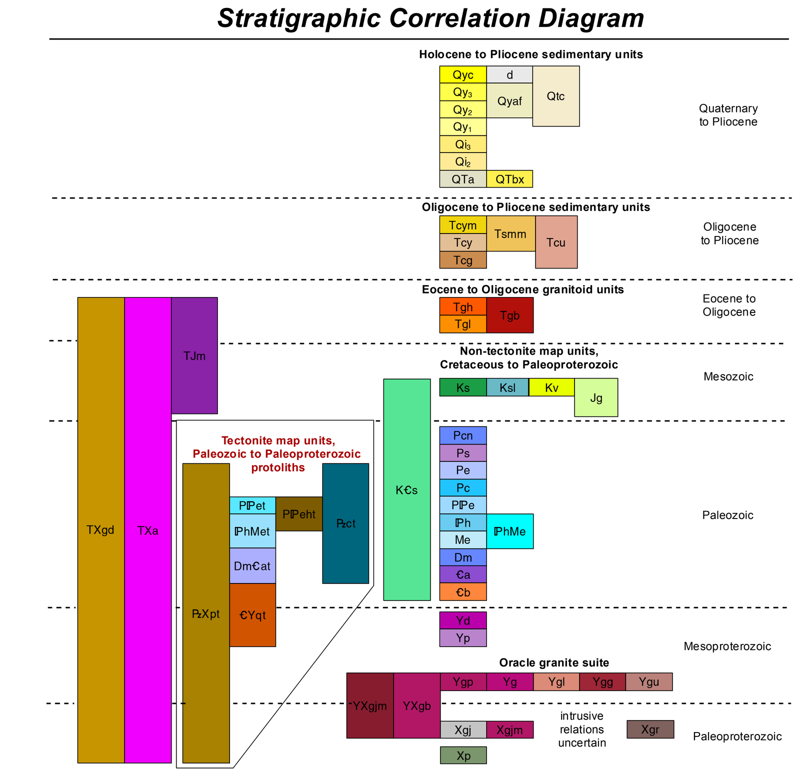
Spencer, J.E., Cook, J.P., Lingrey, S.H., Richard, S.M., Ferguson, C.A., and Guynn, J.H., 2008a, Geologic map of the Wildhorse Mountain 7 ½' Quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map DGM-62, scale 1:24,000.

Spencer, J.E., Richard, S.M., Cook, J.P., Dickinson, W.R., Lingrey, S.H., and Guynn, J.H., 2008b, Geologic map of the Soza Canyon 7 ½' Quadrangle, Cochise and Pima Counties, Arizona: Arizona Geological Survey Digital Geologic Map DGM-61, scale 1:24,000.

Thorman, C. H., and Drewes, Harald, 1981, Geology of the Rincon wilderness study area, Pima County, Arizona, in Mineral Resources of the Rincon wilderness study area, Pima County, Arizona: U.S. Geological Survey Bulletin 1500, p. 5-37.

Youberg, A., Spencer, J.E., and Richard, S.M., 2006, Geologic map of the Galleta Flat East 7 ½' Quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map 56, layout scale 1:24,000, with 7 p. text.

Stratigraphic Correlation Diagram



Structural Symbol Descriptions

- bedding
- bedding,strike and dip approximately measured
- bedding,where top direction is known
- bedding, apparent dip, showing trend and plunge
- lineation defined by axes of rootless folds
- lineation defined by elongate mineral aggregates and/or mineral shape
- mylonitic lineation not measured in foliation
- axis of minor folds
- dip of fault
- slickenside lineation or groove on fault surface
- joint
- magmatic flow foliation
- parallel lithologic layering and preferred mineral orientation, showing trend and plunge of lineation where measured
- lithologic or gneissic layering, showing trend and plunge of lineation where measured
- transposed bedding, showing trend and plunge of lineation where measured
- transposed bedding, vertical
- mylonitic foliation, showing trend and plunge of lineation where measured; where present, arrowhead indicates sense-of-shear (displacement direction of structurally higher rocks)
- recrystallized mylonitic foliation, showing trend and plunge of lineation where measured
- generic foliation, showing trend and plunge of lineation where measured
- generic foliation, vertical
- disjunct cleavage
- sample location and number for geochemistry or geochronology analysis