Compilation Geologic Map of the Galleta Flat West 7.5′ Quadrangle, Pima and Cochise Counties, Arizona

by

Steven J. Skotnicki and Christine H. Siddoway

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416 W. Congress, Suite #100, Tucson, Arizona 85701

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INTRODUCTION

The Galleta Flat West quadrangle includes the northern part of the divide between the Tucson basin to the west and the San Pedro Basin to the east, and the southern part of the Little Rincon Mountains. The region is dominated by Proterozoic and mid-Tertiary granitic rocks bordered by Late Tertiary basin-fill deposits that fill the low divide between the Whetstone Mountains to the south and the Rincon and Little Rincon Mountains to the north. Interstate 10 slices across this low area a few miles south of the quadrangle. Fieldwork was carried out between November, 2000 and April, 2001. This study was done during the same field season as mapping to the south in the Mescal 7.5' quadrangle (Skotnicki, 2001).

Shallow-water platform carbonates were deposited during the Paleozoic on an extensive erosion surface beveled into Proterozoic granitic and metamorphic rocks. Erosion and faulting during the Late Jurassic led to infilling of the Bisbee Basin by the Upper Jurassic to middle Cretaceous Bisbee Group. The resulting succession of Paleozoic and Mesozoic strata in the Whetstone Mountains to the south is one of the thickest sequences preserved anywhere in the state. These rocks were deformed during compression and thrust faulting during the Laramide orogeny at the end of the Cretaceous. The folded Paleozoic rocks are exposed in the Little Rincon Mountains. Identification of the Laramide features was made difficult by overprinting of younger deformation fabrics formed during plutonism and extensional. The region owes its present geography to younger (Miocene) block-faulting that occurred during Basin-and-Range extension. Late Tertiary (Late Miocene to Pliocene) sediments partially filled the low areas, and these deposits have been modified by repeated cycles of dissection and deposition during the Quaternary.

PREVIOUS STUDIES

Creasey (1967) made a geologic map of the Benson 15' quadrangle, which includes the Mescal 7.5' quadrangle immediately to the south. He measured detailed stratigraphic sections in the Paleozoic and Mesozoic sedimentary rocks and also recognized the folded nature of the Mesozoic and Paleozoic strata in the area. Drewes (1974) mapped the Happy Valley 15' quadrangle, which includes the Galleta Flat West 7.5' quadrangle. Smith (1989) made a detailed study of the igneous and metamorphic fabrics in the little Rincon Mountains. Gehrels and Smith (1991) reported U-Pb ages that helped constrain the age of thrusting, crustal extension, and peraluminous plutonism in the Little Rincon Mountains. Richard and Harris (1995) mapped the geology and geophysics of the Cienega Basin. Dickinson (1998) made a detailed study of the Martinez Ranch Fault from Happy Valley in the north southward past Interstate 10 in the Mescal 7.5' quadrangle. Davis and others (in press) examined the rocks along the Catalina detachment fault at the southeastern end of the Rincon Mountains.

PROTEROZOIC ROCKS

The oldest rock in the study area is the Pinal Schist. Smith (1989, p. 9) described the unit as follows: "The…Pinal Schist is characterized by alternating, thinly laminated, dark gray to black aphanitic siliceous bands and quartzofeldspathic aplitic layers. A shallow-dipping to horizontal foliation orientation predominates. The axes of isoclinal, overturned or recumbent penetrative folds generally parallel the foliation." The Pinal

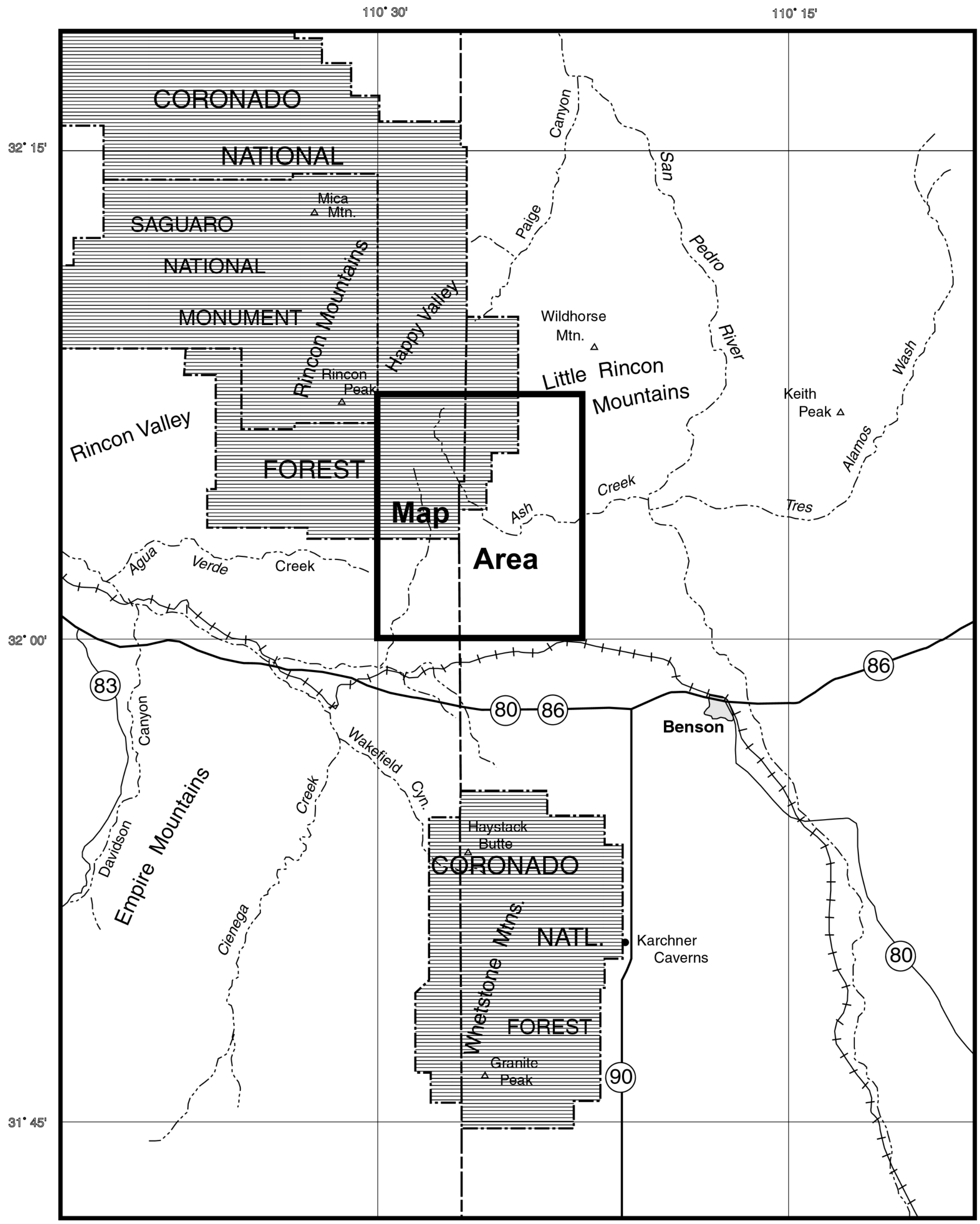

Figure 1. Index map showing location of the Galleta Flat West 7.5' quadrangle.

Schist is exposed in two separate exposures in the Little Rincon Mountains, where they form dark, resistant outcrops.

A coarse-grained, K-feldspar megacrystic granite intrudes the Pinal Schist. It contains large tan to pink K-feldspar phenocrysts commonly between 1-4 cm long, and locally up to 8 cm long, light gray plagioclase, clear gray quartz, and abundant biotite. In most areas examined the granite is moderately to strongly sheared and biotite forms a prominent lineation. Where intensely sheared biotite and quartz+feldspar form alternating dark and light gneissic layering. Silver (1978) reported an age of 1.42 Ga for this unit farther north. Drewes (1974) called this rock the Continental Granodiorite because of its similarity to that unit in the Santa Rita Mountains. It is mineralogically similar to the Ruin-Oracle suite of ~1.4 Ga granite plutons exposed throughout the state.

PALEOZOIC METAMORPHIC ROCKS

Smith (1989a, b) mapped in detail the outcrops of metamorphosed sedimentary rocks in the Little Rincon Mountains. She identified a sequence of rocks of (from bottom to top) (1) quartz cobble conglomerate, (2) siliceous marble and calc-silicate rock, (3) massive marble, and (4) quartzite and marble. She interpreted units 1 through 4, respectively as (1) Bolsa Quartzite, (2) Abrigo Formation, lower unit, (3) Abrigo Formation, middle unit, and (4) Abrigo Formation, upper unit. Although the sequence is more than 300 meters thick all of the contacts are sheared and some reduction of the section may have occurred.

BISBEE GROUP

Outcrops in the southwest corner of the map are composed of strongly lithified sandstone and conglomerate that are correlated with the Glance Conglomerate that forms the lowest member of the Bisbee Group (Creasey, 1967). The thinly bedded sandstone is commonly arkosic and planar laminated. The conglomerate beds are more massive and thicker—up to several meters thick—and contain clasts of locally derived sandstone, limestone, chert, and locally abundant crystal-rich biotite-rich dacite. The outcrops are locally cut by thin quartz veins and the green tint in some outcrops is due to disseminated epidote. The sandstone beds are thin compared to the conglomerates, but are more resistant.

Dip directions are variable and appear to define at least one small northwest-trending syncline. Because laminations in the sandstone beds are so nearly planar, unequivocal up-directions from cross-bedding are few and far between.

South of the map area these conglomerates grade abruptly laterally into sandstones and shales of the Lower Cretaceous Bisbee Group. Hence, the conglomerates are interpreted to be equivalent to the Glance Conglomerate observed elsewhere at the base of the Bisbee Group. Hayes (1970) observed that sandstones in the Bisbee Group become increasingly arkosic westward. These observations led Hayes (1970) and others to conclude that the Early Cretaceous seaway shallowed westward, and that the Bisbee Group strata in the Whetstone and Empire Mountains represent deltaic and fluvial deposits. The location of the edge of the Bisbee Basin is not clear but the abrupt gradation from shales and sandstones to conglomerate may indicate that it was nearby.

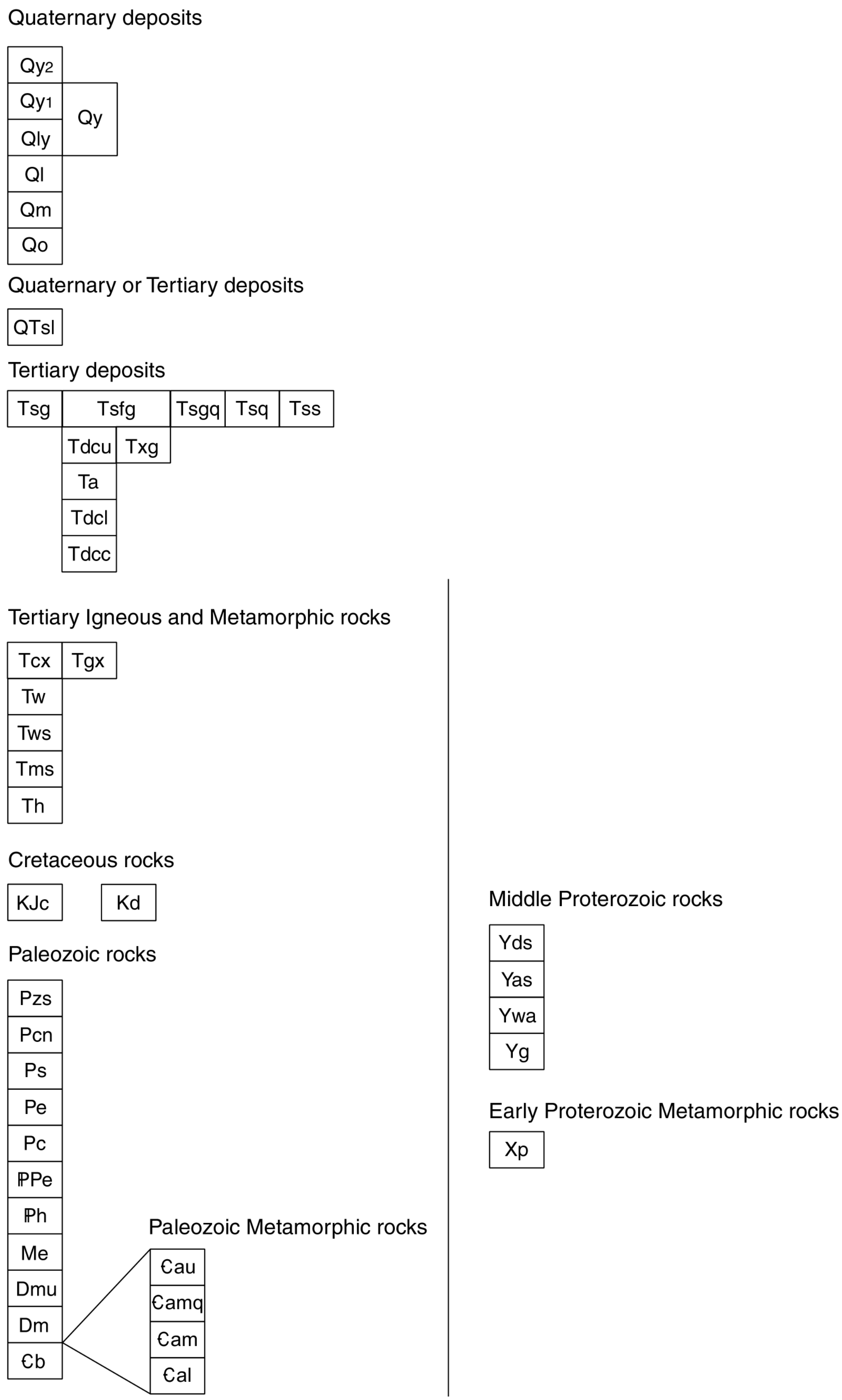

Figure 2. Correlation diagram for the Galleta Flat West 7.5' quadrangle.

TERTIARY INTRUSIVE ROCKS

Smith (1989) mapped one large mid-Tertiary granitic pluton in the Little Rincon Mountains—the Wrong Mountain Quartz Monzonite (map unit Tw; named by Drewes, 1974). This pluton truncates mylonitic fabrics in the Little Rincon Shear Zone (defined by Smith, 1989). Gehrels and Smith (1991) reported a U-Pb lower-intercept age on zircon from this granite of 24 ± 12 Ma and a monazite age of about 30 ± 6 Ma. This medium- to coarse-grained granite is peraluminous and contains 3% garnet, 5% biotite, and 15% muscovite (Gehrels and Smith, 1991). Drewes (1974) originally subdivided the eastern area of this pluton into the Granodiorite of Happy Valley (map unit Th), which he described as a moderately coarse-grained massive granodiorite. The contact between the two units is everywhere dashed and it is not clear if the two granites are distinct or if they represent phases of one pluton. He reported two biotite K-Ar dates "from two stocks" of 27.3 ± 1.1 Ma and 26.3 ± 0.9 Ma. These biotite 'ages' are cooling ages and are likely younger than the crystallization age of the pluton. Smith (1989) correlated the Wrong Mountain Quartz Monzonite with the Wilderness granite based on mineralogical and textural similarities. Keith and others (1980) reported a Rb-Sr whole rock age of about 47 Ma for the Wilderness Granite. Smith (1989) pointed out that Rb-Sr analyses of two samples from what is probably the Wrong Mountain Quartz Monzonite in the Rincon Mountains also fall on this isochron.

Smith (1989) mapped several separate quartz diorite intrusions in the map area. The rocks are medium- to coarse-grained, locally plagioclase porphyritic, and moderately foliated. Plagioclase phenocrysts are commonly 2-5 mm across and rarely up to 2 cm across. The dark matrix of quartz and biotite are in marked contrast to the lighter plagioclase phenocrysts. From a distance this rock commonly appears both darker and lighter than the coarse-grained granite (map unit Yg) it intrudes. The quartz diorite has not been dated in this area. Smith (1989) tentatively correlated these intrusions to the Late Cretaceous Leatherwood Suite (Keith and others, 1980).

The reader should keep in mind that mapping of the granite bodies is not always straight forward. The granites are commonly strongly foliated and mylonitized, which tends to mask the original texture of the rocks. Leucocratic sills and pegmatites intrude preferentially parallel to the mylonitic foliation. As a result, some outcrops are layered on the meter scale and are composed of about ½ of an older pluton and ½ of intruding sills from the younger pluton. In these situations giving the outcrop a map label is somewhat arbitrary. It is not clear how heterogeneous the exposures are in the steep, brush-covered Rincon Mountains.

TERTIARY DEPOSITS

Middle Tertiary Deposits

Middle Tertiary deposits are exposed only in the southwest corner of the map area. Here, from bottom to top, the sequence is composed of older conglomerates containing dominantly clasts of Paleozoic carbonate (map unit Tdcc) and clasts of quartzite and schist (map unit Tdcl), overlain by porphyritic andesite, in turn overlain by a younger conglomerate containing mixed limestone and granite clasts (map unit Tdcu). An ash-flow tuff interbedded with the sequence to the south in Anderson Canyon has an $^{40}Ar/^{39}Ar$ age of 26.5 ± 0.08 Ma (W.C. McIntosh, written communication to J. Spencer, 1997). The conglomerates are red-colored and contain a matrix of red to tan sand and silt. The age and presence of volcanic rock within this sequence of red conglomerates suggests this sequence is the Pantano Formation. The deposits on the east side of the Martinez Ranch Fault dip moderately to steeply to the east-northeast. Dips in the uppermost conglomerate appear to form a fanning dip sequence in the southeast ¼ corner of section 23, T. 16 S., R. 18 E., where dips range from 67° to 2°. The mixed lithology of upper conglomerate clasts appears to grade upward and eastward into younger basin-fill deposits (map unit Tsfg) which are dominated by Tertiary granitic clasts.

The steep eastward dips of the Pantano Formation suggest relatively low-angle, west-dipping faults in the subsurface east of the Martinez Ranch Fault, although no evidence of these faults exists at the surface. It is possible that the eastward dips are a consequence of drag folding during displacement along the Martinez Ranch Fault. Outcrops of conglomerate on the west side of the Martinez Ranch Fault are continuous with limestone-rich conglomerates mapped immediately to the west in the southern Rincon Mountains (Spencer et al., 2001). If the limestone-rich conglomerates of the Pantano Formation on both sides of the Martinez Ranch Fault are equivalent, it suggests that displacement on the Martinez Ranch Fault is not great.

Late Tertiary Deposits

At least four separate Late Tertiary deposits were identified on the basis of clast compositions. The deposits occupying the south-central part of the map and in the extreme southwest corner of the map (map unit Tsg) are dominated by clasts of weakly to strongly foliated Tertiary and Proterozoic granites derived from the north and minor clasts of Pinal Schist, quartzite, and rare limestone. The deposits in the south portions of the map (map unit Tsgq) are dominated by clasts of limestone and quartzite (Bolsa Quartzite), locally abundant sandstone (Bisbee Group), and minor light gray felsite, biotite dacite and chert. Deposits in the southeast part of the study area (map unit Tsq) are dominated by clasts of limestone, quartzite (Bolsa Quartzite), sandstones (Bisbee Group), rhyolite, andesite, biotite-quartz-sanidine welded tuff, and chert.

The contacts between the different units are difficult to locate precisely due to subsequent soil formation and slope wash. Where exposures are relatively good, the contacts appear to be at least locally gradational. These deposits likely represent separate Late Tertiary alluvial fans that interfingerred and coalesced down-slope. Their clast compositions were controlled by their source-rocks. Near their distal ends, these deposits become finer-grained and grade laterally into fine-grained sandstone and siltstone (map unit Tss) that is equivalent to the St. David Formation (Smith,

QUATERNARY GEOMORPHOLOGY

The Late Tertiary sedimentary deposits have been deeply incised by erosion during the Quaternary. East-southeast of Ashrama Ranch in T. 16 S., R. 18 E., section 12, two separate drainages line up in an east-northeast direction. The clast composition of the Late Tertiary deposits does not appear to change in this area, and there does not appear to be any lithologic control on the orientation of the drainages. The linear alignment suggests some type of structural control but there is no visible evidence for this.

In the southwest part of the map area Cumaro Wash has changed its source since the middle Pleistocene. Middle (to Late?) Pleistocene alluvial deposits west of White

Cross Cemetery indicate that the drainage originally flowed west-northwestward through the narrow, flat valley immediately south of the limestone hills, into Agua Verde Creek. The low hills underlain by carbonate-clast conglomerate (map unit Tdcc) south of the cemetery were subsequently breached, possibly as a result of headward erosion by Cumaro Wash. The drainage in Cumaro Canyon was pirated and flow was diverted to the south through the gap in the hills. Deposits south of the gap are dominated by Holocene alluvial fan deposits.

STRUCTURE

Laramide Thrusting

The Paleozoic metasedimentary rocks rest on Pinal Schist and have been overridden by the Little Rincon Thrust Fault, which thrust coarse-grained granite up on top of the sequence. A 'syntectonic' leucocratic sill within the shear zone yields a U-Pb concordia-intercept age of 66 ± 10 Ma for zircon and a concordant age of 51 ± 2 Ma for fractions composed of monazite and xenotime (Gehrels and Smith, 1991). Thus, thrusting was probably associated with the Laramide orogeny. The shear zone was subsequently intruded and truncated by a peraluminous granite pluton—the Wrong Mountain Quartz Monzonite—which has a U-Pb monazite age of 30 ± 6 Ma (Gehrels and Smith, 1991).

Mid-Tertiary detachment faults

The mid-Tertiary, low-angle detachment fault on the south side of the Catalina-Rincon metamorphic core complex is broken into two parts by the north-striking Martinez Ranch fault. Following the conventions of Lingrey (1982) and Dickinson (1998), each section has been assigned a different name. The western section, called the Catalina detachment fault, is well exposed on the south side of the Rincon Mountains where it separates Proterozoic and Tertiary intrusive rocks in the footwall from the predominantly sedimentary rocks in the hanging wall. The inferred continuation of the Catalina detachment fault on the east side of the Martinez Ranch fault is called the San Pedro detachment fault, but is nowhere exposed in the study area.

The exposures of the Catalina detachment fault in section 22, T. 16 S., R. 18 E., near the southwest corner of the map, are on private property and access was not granted during this study. Instead, the current map incorporates unpublished mapping by Davis and others (in press) and Drewes (1974). Drewes (1974) shows several stacked thrust sheets of Paleozoic carbonate formations cut by the south-dipping Catalina detachment fault. The structurally lowermost fault displaces what Drewes interpreted to be Pinal Schist. Davis and others (in press) reinterpreted this outcrop as breccia and cataclasite derived from the underlying granitic rocks. Davis and others mapped a band of breccia and cataclasite between the main Catalina detachment fault and the 'sub-detachment fault'. Drewes (1974) mapped the contact between the Martin Formation and the overlying Horquilla Limestone as a thrust fault. Davis and others (in press) drew a very similar contact but drew it as a depositional contact.

Drewes (1974) identified what he interpreted to be isolated outcrops of non-foliated Rincon Valley Granodiorite surrounded by basin-fill deposits in section 21, T. 16 S., R. 19 E. in the southeast part of the map area. The Rincon Valley Granodiorite is present only in the hanging wall of the San Pedro detachment fault exposed to the north in Happy Valley. Because of this he placed the San Pedro detachment fault north of the isolated outcrop in section 21. Dickinson (1987, 1991) identified this isolated outcrop as Johnny Lyon Granodiorite and placed the detachment fault north of it for similar reasons. In this study the detachment fault was placed in the same position, but for a different reason. The two isolated outcrops are not Rincon Valley Granodiorite. They are monolithic megabreccia composed of gravel- to boulder-size clasts of coarse-grained granite (map unit Yg) and very minor medium-grained granite. The individual clasts are foliated but the strike of the foliations show random orientations with respect to one another. These outcrops probably represent debris-flow or avalanche deposits shed onto the hanging wall of the San Pedro detachment fault. This is the only exposure of its kind in the study area, but similar monolithic megabreccias are more abundant to the west in the Rincon Peak South quadrangle (Drewes, 1977; Richard and Harris, 1996; Spencer et al., 2001) where they truncate more steeply tilted conglomerates and mudstones of the Pantano Formation. Dickinson (1998) described similar megabreccias to the north in Happy Valley.

Martinez Ranch Fault

As Dickinson (1998) pointed out, the steep eastern escarpment of the Rincon Mountains owes its impressive relief to down-dropping along the eastern side of the Martinez Ranch Fault. Projecting the base of the supracrustal rocks in Happy Valley to the top of Rincon Peak provides a minimum estimate of about 1500 meters of displacement along that section of the fault. In the study area the feature shows up as an obvious lineament in aerial photographs.

In the northwest part of the quadrangle the fault is not easy to follow on the ground. Heavily vegetated Quaternary sedimentary deposits of low relief are composed of large boulders of granite derived from nearby exposures. The Quaternary deposits appear very similar to bedrock outcrops, and these deposits appear to overlap the Martinez Ranch Fault without displacement. As a result, identifying the fault trace on the ground is very difficult in this region. The same problem exists in section 2, T. 16 S., R. 18 E., where Tertiary basin-fill deposits rest in apparent depositional contact on granite. The contact here lines up along strike with the fault, suggesting it is also a fault contact. However, the low-angle of the contact with respect to the high-angle nature of the Martinez Ranch Fault everywhere else suggests it is a depositional contact. Farther south the fault contact is sharp and easily identifiable where it down-drops basin-fill sediments on the east against granite on the west.

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UNIT DESCRIPTIONS
FOR THE GALLET FLAT WEST 7.5' QUADRANGLE
AZGS DGM-08

Quaternary Surficial Deposits

Qy_2 **Younger Holocene alluvium (< 100 yr).** Unconsolidated sand and gravel in active stream channels. Deposits consist of stratified, poorly to moderate sorted sands, gravels, pebbles, cobbles, and boulders. These deposits are highly porous and permeable. Soils are generally absent.

Qy_1 **Older Holocene (< 10 ka).** Unconsolidated sand to small boulders reaching several tens of centimeters in diameter upstream but smaller and fewer downstream. Qy_1 soils are characterized by stratified, poorly to moderately sorted sands, gravels and cobbles frequently mantled by sandy loam sediment. On the surface the main channel commonly diverges into braided channels. Locally exhibits bar and swale topography, the bars being typically more vegetated. Soil development is relatively weak with only slight texturally or structurally modified B-horizons and slight calcification (Stage I). Some of the older Qy_1 soils may contain weakly developed argillic horizons. Because surface soils have little clay or calcium carbonate, Qy_1 deposits have relatively high permeability and porosity.

Qy **Holocene alluvium, undivided (<10 ka).**

Ql **Late Pleistocene alluvium (~10 to 250 ka).** Moderately sorted, clast-supported sandstones and conglomerates containing subangular to subrounded locally derived clasts in a grussy and sandy tan to brown matrix. Ql surfaces are moderately incised by stream channels but still contain constructional, relatively flat, interfluvial surfaces. Ql soils typically have moderately clay-rich, tan to red-brown argillic horizons. They contain some pedogenic clay and some calcium carbonate, resulting in moderate infiltration rates. Thus, these surfaces favor plants that draw moisture from near the surface. Ql soils typically have Stage II calcium carbonate development.

Qm **Middle Pleistocene alluvium (~250 to 750 ka).** Moderately to poorly sorted, clast-supported sandstones and conglomerates

Qo **Early Pleistocene alluvium (750 ka to ~1.2 Ma).** These relatively flat surfaces at the southern edge of the quadrangle are covered with pebbles and cobbles of the same lithologies as the underlying Tertiary deposits. The matrix contains variable amounts of red-brown silty clay and/or carbonate. No good cross-sections were seen in the field. Clasts typically are slightly to moderately varnished. The high surfaces in the northeast part of the map area were mapped using aerial photographs and were not examined in the field.

Quaternary or Late Tertiary Deposits

QTsl **Landslide deposits (Quaternary or Late Tertiary).** Very coarse, blocky detritus. Age assignment uncertain. (Description and mapping from Drewes, 1974).

Late Tertiary Sedimentary Deposits

The Tertiary basin-fill units were mapped separately on the basis of clast-composition. Each has a distinct clast assemblage derived from different source areas, although the contacts between them are locally gradational. Gradational contacts suggest all four units were deposited penecontemporaneously. Dickinson (1998) included all of these units within what he called the "Gravels of Mescal Divide."

Tss **Siltstone, central valley facies (Late Tertiary).** This unit is composed mostly of fine-grained siltstone and silty sandstone with trains of pebbles and cobbles spaced widely apart. The unit is moderately consolidated and crumbles relatively easily. Exposed surface is mostly mantled by coarser-grained detritus from younger Holocene fan remnants. Where exposed, outcrops are light to medium tan and medium- to thick-bedded. Becomes coarser-grained westward where the unit grades into interbedded sandstone and conglomerate. These deposits are probably correlative to the St. David Formation (see Smith, 1994).

Tsfg **Basin-fill deposits, granite-clast dominated (late Tertiary).** These light tan interbedded sandstones and conglomerates are dominated by subangular to subrounded, pebble- to cobble-size clasts of foliated medium-grained granites (probably map units Tw, Th, and Tws) surrounded by a tan sandy matrix. Other clast lithologies are rare. Exposures near bedrock contain boulders of local rocks. Good exposures are rare. Deposits are mostly mantled by a thin layer of regolith and darker soil. The exposed surface farther down-slope is characteristically composed of fine-grained gravel, sand and silt. Becomes finer-grained eastward where it grades into map unit Tss.

Tsq **Basin-fill deposits, quartzite- and limestone-clast dominated (late Tertiary).** This interbedded sandstone and conglomerate unit crops out in the southeastern corner of the quadrangle. It contains subrounded to subangular pebbles to cobbles (up to ~20 cm) of gray limestone, light gray to purple, medium- to coarse-grained clean quartzites (Bolsa Quartzite), grayish green arkosic sandstone and conglomerate (Bisbee Group), light gray to tan rhyolite, medium gray andesite, minor biotite-rich, quartz-sanidine welded tuff, and gray chert, all in a silty to sandy matrix. The most abundant clasts are quartzite, then limestone. The matrix locally contains abundant sand and granules of granite (map unit Tw), but larger granite clasts are rare.

Tsgq **Basin-fill deposits, granite- and quartzite-clast dominated (late Tertiary).** This conglomerate contains angular to subrounded clasts of medium- to coarse-grained granite, light gray fine- to medium-grained quartzite, limestone, and minor chert and vein quartz. This unit crops out in the southern part of the study area east of exposures of Bisbee Group (map unit Kb). Deposits nearest the underlying bedrock are dominated by granite that contains biotite in small books up to 3 mm across. Feldspars in the granite are commonly light green. Most clasts in this unit are pebble- to cobble-size but locally boulders are up to 1 meter across. Eastward, granite clasts are much less common and deposits are dominated by quartzite clasts. The matrix, where exposed, is moderately to strongly cemented by carbonate.

Tsg **Basin-fill deposits, granite- and metamorphic-clast dominated (late Tertiary).** This interbedded sandstone and conglomerate unit crops out only in the southwestern corner of the quadrangle. These deposits contain subangular to subrounded pebbles to cobbles of medium- and coarse-grained strongly foliated granites, less abundant light blue-gray quartz-muscovite schist, muscovite schist with dark spots (of biotite?), vein quartz, dark and light gray quartzite, and rare limestone. Locally the unit contains abundant boulders of coarse-grained granite up to 1 meter across. This unit is equivalent to what Spencer and others (2001) termed the "Agua Verde facies" of the Pantano Formation.

Tertiary Sedimentary and Volcanic Rocks *(Davidson Canyon facies of the Pantano Formation)*

Tdcu **Upper conglomerate (middle tertiary).** This unit contains clasts of limestone and light gray medium- to coarse-grained quartzite. Clasts are angular to subrounded and range in size from granules to cobbles 25 cm agross. Matrix is red sand and moderately to strongly cemented by locally silica and/or carbonate. Minor schist in matrix. Where exposed in the stream cut, the unit is medium-bedded. This conglomerate is probably the lower part of the younger, more extensive, Late Tertiary basin-fill deposits (map unit Tsgq) but was mapped separately where this unit is tilted. The unit rests on the porphyritic andesite (map unit Ta).

Txg **Granite breccia (middle Tertiary).** These small hills in T. 16 S., R. 19 E., are composed of clasts of foliated coarse-grained granite (of map unit Yg) and minor clasts of medium-grained granite, ranging in size from gravel-size to large subangular boulders. At first glance the exposures resemble bedrock, but the foliation direction is random. These deposits may represent avalanche deposits or poorly exposed debris flows.

Ta **Porphyritic andesite (middle Tertiary).** These dark gray lava flows contain large, subhedral to euhedral, glassy, gray plagioclase phenocrysts 1-3 cm wide, small altered mafic minerals 1-4 mm across, and yellowish green spots, all in a gray, aphanitic matrix. Plagioclase crystals are most visible on weathered surfaces where they commonly appear either lighter or darker than the matrix. Phenocrysts comprise 50% or more of the rock. The rock is permeated by irregularly shaped, dark maroon vein-like features composed of silica and abundant fine-grained hematite(?). Many appear to fill cracks and others may be alteration features. Some are laminated. White fibrous chert and euhedral quartz locally fill vugs 1-7 cm across. This volcanic unit forms low, very dark-colored hills in the southwest corner of the map area.

Tdcl **Lower conglomerate (middle tertiary).** Two small exposures in the southeast corner of the map area (T. 16 S., R. 18 W., sections 26 and 35). These sedimentary deposits below the andesite are composed of variable amounts of pebble- to cobble-conglomerate, light pinkish tan arkosic sandstone, and fine-grained purple to pink siltstone. The coarser beds contain subangular to subrounded pebbles to cobbles of light gray to purple quartzite, vein quartz, bluish gray quartz-muscovite schist, coarse-grained muscovite granite, red arkosic quartzite, limestone, meta(?)rhyolite, and pink, gray, and purple cherts. The finer-grained deposits are typically thin- to medium-bedded and crumble easily. Most exposures below the steeper volcanic deposits are covered with colluvium and are visible only in gullies. May be equivalent to the red conglomerate exposed to the south in the Mescal 7.5' quadrangle (map unit TKcr).

Tdcc **Carbonate-clast conglomerate (middle tertiary).** Rare fresh outcrops reveal interbedded sandstone and conglomerate. These deposits are composed almost entirely of angular to subrounded pebbles to cobbles of limestone (mostly blue-gray micritic to fossiliferous) and minor chert and quartzite, some as well-rounded pebbles. The matrix is dark red sand and silt. Cement is minor carbonate but mostly siliceous. This unit is moderately to steeply tilted, unconformably overlies Paleozoic carbonate formations, and is overlain by the porphyritic andesite (map unit Ta).

Tertiary Igneous and Metamorphic Rocks

Tcx **Cataclastite (middle Tertiary).** Cohesive microbreccia and breccia derived from mylonite. (Description from Davis et al., in press, where they labeled this unit "c" in figure 12.)

Tgx **Crushed rock (middle Tertiary).** (Description from Davis et al., in press, where they labeled this unit "g" in figure 12.)

Tw **Wrong Mountain Quartz Monzonite (early to middle Tertiary). W**eakly deformed, medium-grained, peraluminous granite. The relatively homogeneous rocks east of the Martinez Ranch Fault contain biotite, muscovite, and garnet (Smith, 1989). Smith (1989) describes two intermixed phases: an earlier, medium-grained, reddish-weathering, biotite- and muscovite-bearing phase and a younger, more leucocratic, white to grayish-pink-weathering, garnet-muscovite granite. The younger phase, including pegmatite and aplite dikes, cuts consistently across the primary igneous fabric of the older phase (description from Smith, 1989). Named by Drewes (1977). Gehrels and Smith (1991) reported a mid-Oligocene U-Pb age of ~30 Ma for a sample of this rock east of Happy Valley, north of the study area. It is uncertain if the ~30 ± 6 Ma granite dated by Smith is the same intrusion with the same age as the "Wrong Mountain Quartz Monzonite" of Drewes (1977) that appears to comprise most of the Rincon Mountains.

Th **Granodiorite of Happy Valley (Oligocene?).** Named by Drewes (1974). Moderately coarse-grained massive biotite granodiorite. Locally contains faint flow-aligned crystals. K-Ar ages on biotites from two stocks of 27.3 ±1.1 Ma and 26.3 ± 0.9 Ma. (Description from Drewes, 1974). It is not clear if this pluton is distinct from map unit Tw or whether or not the two represent phases of one another.

Tws **Muscovite-garnet granite sills (Tertiary).** Light gray, medium-grained, strongly foliated sills of leucocratic granite.

Tms **Quartz-muscovite schist (Tertiary).** Contains large quartz "eyes" within a micaceous matrix. Interpreted to be derived from the coarse-grained granite (map unit Yg of this study), (description from Smith, 1989).

Cretaceous Sedimentary Rocks

KJc **Conglomerate (Lower Cretaceous).** This unit contains mostly coarse conglomerate with minor thin- to medium-bedded layers of sandstone and maroon siltstone. Most clasts in exposures in the east side of section 35, T. 16 S., R. 18 E. are subrounded to rounded, pebbles to cobbles of limestone with very minor chert, all in a sandy to silty matrix cemented by carbonate. Abundant orange cherts may have originated from Pennsylvanian carbonate strata. These deposits are strongly indurated and are mostly covered with a lag. Exposures are both matrix- and clast-supported and change character abruptly over a distance of a few meters. Locally contains minor well-rounded quartz pebbles. There are no granitic clasts. Lower contacts of some conglomeratic beds show scour channels. Exposures in the western side of the same section contain very abundant subangular to subrounded pebbles to cobbles of pink to purple dacite. The dacite contains abundant subhedral, light gray plagioclase, biotite, and possible amphibole. Exposures here contain interbedded sandstone beds similar to those in the Bisbee Group (map unit Kb). Some resistant sandstone layers contain spots of hematite that may have been pyrite. Both of these subunits appear to grade abruptly into map unit Kb and may be equivalent to the Upper Jurassic to Lower Cretaceous Glance conglomerate.

Cretaceous Intrusive Rocks

Kd **Quartz diorite (Late Cretaceous?).** These separate intrusions are medium- to coarse-grained, locally plagioclase porphyritic, and moderately foliated. Plagioclase phenocrysts are commonly 2-5 mm across and rarely up to 2 cm across. The dark matrix of quartz and biotite are in marked contrast to the lighter plagioclase phenocrysts. From a distance this rock commonly appears both darker and lighter than the coarse-grained granite (map unit Yg) it intrudes. The quartz diorite has not been dated in this area. Smith (1989) tentatively correlated these intrusions to the Late Cretaceous Leatherwood Suite (Keith and others, 1980; Force, 1997).

Paleozoic Rocks

₽s **Paleozoic rocks, undivided.**

Pcn **Concha Limestone (Lower Permian).** Medium-gray, fine-grained, medium- to thick-bedded cherty limestone. Some beds contain large productid brachiopods. (description from Drewes, 1974)

Ps **Scherrer Formation (Lower Permian).** Very light brownish gray, fine-grained quartzite and sandstone, and some light gray dolomite. (description from Drewes, 1974)

Pe **Epitaph Dolomite (Lower Permian).** Dark gray, moderately thick-bedded, slightly cherty dolomite. Includes a lower unit, commonly obscured by faulting, of dolomite marlstone and some intercalated limestone. (description from Drewes, 1974)

Pc **Colina Limestone (Lower Permian).** Medium-dark gray, moderately thick-bedded, slightly cherty limestone. Some beds contain small white blebs of dolomite. (description from Drewes, 1974)

PIPe **Earp Formation? (Lower Permian and Upper Pennsylvanian).** Interbedded limestone and sandstone. Thin- to medium-bedded. Blue-gray limestone beds are thin- to medium-bedded. Tan sandstone beds are well-sorted and contain no carbonate in the matrix. Locally, fissile purple shale is abundant and forms slopes near the bottom of the formation. The lower contact was drawn at the base of the shale bed above which sandstone became more abundant. From a distance this formation is distinguished from the underlying Horquilla Limestone by the redder color of the former.

IPh **Horquilla Limestone (Upper and Middle Pennsylvanian).** This unit is composed of medium- to thick-bedded light gray limestone interbedded with minor lavender shale beds. The limestone is locally slightly lighter gray than the underlying Escabrosa and contains locally abundant light rusty orange to pink cherts. The cherts are irregularly shaped and sheet-like, and rarely nodular. Fossil fragments are not obvious except in some beds composed of silicified shell fragments.

Me **Escabrosa Limestone (Mississippian).** This light blue-gray, thick-bedded limestone contains very minor light gray chert nodules up to 15 cm across. The rock is composed of very abundant fragments of crinoid stems and brachiopods, all replaced by calcite spar. In the northeast corner of section 12, T. 18 S., R. 18 E., to the south the base is defined by a very continuous, irregularly shaped, black chert ribbon. The ½ meter of the formation below this ribbon is composed of abundant calcite spar and shows some solution brecciation. The lower cliff-forming part locally contains peloid-like features faintly visible with a hand-lens. Near the center of the formation is a very distinctive, nonbedded horizon containing abundant chert nodules. The chert nodules are irregularly shaped, some forming lenses, from a few centimeters to over 1 meter across. The chert is light to dark gray, but mostly dark and vitreous. The limestone surrounding the chert nodules is pink. Overlying this horizon are more beds of light blue-gray limestone. The limestone bed immediately overlying the chert bed characteristically contains large solitary horn corals up to 10 cm long replaced by light tan chert. This is a useful marker bed where the distinctive chert horizon is missing.

Dm **Martin Formation (Devonian).** (This description is from the Mescal 7.5 quadrangle to the south). The outcrop capping the hill in the west-central part of section 7, T. 18 S., R. 19 E., shows a massive portion of the Martin Formation. Here the rock is massive dolomitic limestone. Bedding is indistinct. The rock contains localized solution collapse breccias with dolomite clasts surrounded by slightly lighter pink carbonate and some terra rosa. Vugs are lined with red calcite spar or are partially to completely filled with white calcite spar. Some crinoid stems are visible. Besides this hill, the other exposures are composed of a series of step-like ledges of thin- to thick-bedded blue-gray limestone interbedded with pinkish, sandy carbonate. The rock contains worm burrows and rare crinoids but it is not obviously fossiliferous. Light gray chert is rare and the unit is mostly chertfree. Limestones in the upper part are interbedded with light tan, thinly bedded, fine-grained sandstone containing no carbonate in the matrix.

Ꞓau **Upper map unit (Cambrian).** Siliceous sequence of hornblende quartzite, topped by a coarsely crystalline marble marker bed. Rusty brown on all surfaces. (Description from Smith, 1989). Smith (1989) correlated this unit with the upper part of the Abrigo Formation.

Ꞓamq **Prominent reddish brown quartzite bed of middle map unit Ꞓam (Cambrian).**

Ꞓam **Middle map unit (Cambrian).** Massive, coarsely recrystallized white to gray marble. Contains a prominent reddish brown quartzite marker bed. (Description from Smith, 1989). Smith (1989) correlated this unit with the middle part of the Abrigo Formation.

Ꞓal **Lower map unit (Cambrian).** Siliceous marble and calc-silicate rock. Red, green, and white to gray banding on weathered surfaces. Contains partings of thin green and rust-brown shales. (Description from Smith, 1989). Smith (1989) correlated this unit with the middle part of the Abrigo Formation.

Ꞓb **Bolsa Quartzite (Middle Cambrian).** This resistant unit is exposed in a tiny exposure on the east side of the Martinez Ranch Fault in section 23, T. 16 S., R. 18 E. Here the quartzite is intensely brecciated. Light gray, fine-grained quartzite clasts are separated from one another by a red matrix of crushed quartz and fine-grained red hematite. The breccia is strongly cemented and the outcrop forms a resistant knob and arch.

Middle Proterozoic Sedimentary Rocks

Yds **Dripping Spring Quartzite? (Middle Proterozoic).** Quartzite and amphibolite schist.

Middle Proterozoic Intrusive Rocks

Yas **Amphibolite schist (Middle Proterozoic).** Irregular outcrops of medium-grained, greenish-black schist. Interpreted to be derived from Proterozoic diabase intrusions. (Description from Smith, 1989).

Ywa **Aplite (Middle Proterozoic).** Small bodies, only some of which are mapped [only one on this map]. (Description from Drewes, 1974).

Yg **Coarse-grained granite (Middle Proterozoic).** This coarse-grained megacrystic granite contains large subhedral to euhedral, pink K-feldspar phenocrysts commonly up to 3 cm long and locally as long as 8 cm (Smith, 1989). Plagioclase is either difficult to distinguish or is serricitized and appears light gray. Biotite occurs as anhedral books and is mostly altered to hematite and/or chlorite. May contain minor muscovite locally. The rock exhibits a widespread penetrative foliation, and is locally gneissic. Where gneissic, stretched and elongated quartz and fractured feldspar crystals form banded mineral segregations with dark biotite. Outcrops of the more strongly foliated rocks are dark gray and from a distance resemble Pinal Schist (map unit Xp). Immediately north of the study area in Happy Valley the granite has a U-Pb zircon age of ~1.42 Ga (Silver, 1978). Drewes (1974, 1980) and Smith (1989) correlated this rock with the Continental Granodiorite.

Early Proterozoic Metamorphic Rocks

Xp **Pinal Schist (early Proterozoic).** Quartz-muscovite±biotite schist. Thin compositional banding is common and locally defines small, nearly isoclinal folds. This unit forms resistant dark-colored hills shedding angular, cobble-sized platy fragments.