STRUCTURAL-GEOLeGIC MAP RELATIONSHIPS IN THE SALCITO RANCH AREA, RINCON MOUNTAINS, SOUTHERN ARIZONA

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Introduction

Formerly known as the Martinez Ranch area (e.g., see Davis, 1975; Davis and others, 2004), the Salcito Ranch area is located at the southeastern-most corner of the Rincon Mountains (Figure 1) and contains a magnificent display of the structural characteristics of the Catalina-Rincon metamorphic core complex and superposed Basin and Range faulting. We carried out large-scale mapping of the geology of a part of this area in the mid-1990s. This mapping, which was initiated as a class project, expanded to become part of a larger study of geologic structures associated with extensional tectonics in a region centered on the Catalina and Rincon Mountains. Observations and conclusions based on this larger work were published in the Geological Society of America (GSA) Bulletin (Davis and others, 2004). The GSA Bulletin journal article contains a simplified, generalized version of the more detailed geological map of the Salcito Ranch area. Furthermore, practical page limits for the article prevented an elaboration on certain descriptive details that may be of interest. Thus we take this opportunity to release this more comprehensive accounting of our findings as an Arizona Geological Survey Contributed Report, with the expectation that the map (Plate 1) and this text will be useful to others.

Broad Tectonic Relationships

Cenozoic extension in the southern part of the Basin and Range province in the western Cordillera is the product of two major deformations, distinguishable both in
Figure 1. Top: Index map and showing location of Salcito Ranch study area. Bottom: Photograph showing profile of Rincon Mountains that parallels Catalina detachment fault. View looking from southeast to northwest. Salcito Ranch study area is located in lower left where the valley floor meets the lower flank of the range. Martinez Ranch normal fault expressed in steep mountain-flank topography on right side of photo.
timing and style. In the late Oligocene-middle Miocene, between about 25 and 18 Ma (Crittenden and others, 1980; Davis, 1980, 1981; Dickinson, 1991; Force, 1997; Davis and others, 2004; Damon and Shafiquallah, 2006), the crust was extended by deformation accommodated by regional brittle-ductile shear zones, now expressed in the form of metamorphic core complexes and detachment faults. Then, in middle Miocene-Pliocene time, between ~15 and 5 Ma, the crust was extended by deformation accommodated by normal faults that cross cut and exposed deep levels of the core complex. Rock fabrics and structural trends indicate that local core-complex extension was NE-SW oriented, in contrast to later E-W Basin and Range extension.

The geology and regional tectonic significance of the Catalina-Rincon metamorphic core complex has received significant attention in the literature. This work focuses on late Oligocene-early Miocene shearing and detachment faulting circa 25 to 20 Ma along the Catalina brittle/ductile shear zone at the southeast corner of the Rincon Mountains. The inferred depth level for the most deformed (sheared) rock in the Salcito Ranch area is ~10 km (Davis and others, 2004). Though exposures of Basin and Range faults are rare within southern Arizona, the Salcito Ranch area contains one of these (the Martinez Ranch fault), which truncates the core-complex fabrics (Drewes, 1974, 1977).

**Basic Map Relationships**

We mapped the Salcito Ranch area at a scale of 1:6000 (see Plate 1, Figure 2). It contains a superb display of metamorphic core complex fabrics and structures. Mylonites, ultramylonites, and microbrecciated mylonites are very well exposed, and they are derived from a granitic protolith. Furthermore, not only is the gently dipping
Catalina detachment fault well exposed, it is accompanied by a similarly oriented “subdetachment” fault lying a few tens of meters beneath it, and within the mylonities (see Plate 1, Figure 2). A subdetachment fault (named the Javalina fault) was discovered and mapped by Davis (1987) in Saguaro National Park (East) along the western margin of the Rincon Mountains. Its actual physical (topographic) expression is nil, and yet its trace can be placed consistently within several meters because of the profound contrasts in rock and fabric above and below. In contrast, the physical expression of the subdetachment fault within the Salcito Ranch area is magnificent.

Another attraction of the Salcito Ranch area is the presence of well exposed, though thinned, upper plate stratigraphy with units ranging from Precambrian to Miocene in age (see Plate 1, Figure 2). Furthermore, along the eastern margin of the area the Martinez Ranch fault, of Basin and Range origin, truncates the upper-plate stratigraphy, core-complex mylonites, detachment fault, subdetachment fault, and crystalline protolith. The Martinez Fault defines the steep eastern margin of the Rincon Mountains (see Plate 1, Figure 2) (Drewes, 1974, 1977).
Figure 2. Geologic map of the Salcido Ranch locality emphasizing faults and fault rocks related to the Catalina detachment fault. Key to fault-rock units (also see Table 1): c, cataclasite; cohesive microbreccia, and breccia derived from mylonite; cl, cataclasite beneath sub-detachment; g, gouge; m, mylonite; protomylonite and ultramylonite. Protolith of fault rocks is considered to be Eocene Wilderness Suite Granite (quartz monzonite). Rock unit abbreviations: Yr = Pinal Schist and Johnny Lyon Granite; Ca = Cambrian Bolsa Quartzite; Ca = Cambrian Abrigo Formation; Dm = Devonian Martin Formation; Ph = Pennsylvanian Palominos Limestone; PP = Pennsylvanian C. Cambrian Bossa Whipple Mountain Quartzite (quartz monzonite); R = Pennsylvanian-Permian Earp Formation. Fault-rock units are derived from mylonite associated with the Catalina detachment fault. Map based on field mapping by the authors and compilation of previous mapping by Drewes 1974, 1977; Liming, 1974.
Catalina Detachment Fault

The Catalina detachment fault is readily traced, east-west, though the southern part of the map area where it dips 10° to 20° southward. It separates non-mylonitic and non-cataclasitic upper plate rocks from underlying cataclastic and mylonitic rocks (see Plate 1, Figure 2). The location of the detachment fault is easy to spot, for it separates non-mylonitic, non-cataclastic upper plate rocks from an underlying ledge of brown or gray cataclasite and ultracataclasite. In places the trace of the fault has clear expression as a smooth surface. At a number of locations directly above the Catalina detachment fault, gouge zones as thick as 10 m are developed at the expense of upper plate rocks. One of these zones of gouge, formed in Precambrian granite, contains abundant, faceted, fist-size nodules of granite that survived milling. These are enveloped in a talc-like gouge.

Upper Plate Rocks

Upper plate rocks above the detachment fault were mapped by Liming (1974) and Drewes (1977), and both Liming (1974) and Davis (1975) carried out detailed structural analysis of folds. Although we spent some time mapping and measuring structural features within the upper plate (see Plate 1), this was not a focus of study. The upper plate of the Catalina detachment fault consists of slices of recognizable Precambrian, Paleozoic, and Oligocene-Miocene units, most of which are internally deformed in one way or another (Figure 3). Most of the slices eventually lose continuity along strike, reflecting younger-on-older truncations by faulting (see Plate 1). The overall dip of the upper plate rocks is gently to moderately northward, i.e., back-tilted toward the Catalina detachment fault.
Figure 3. Strata and fault rocks of the Salcito Ranch map area.

**Protolith of Sheared Rocks**

In Catalina Fault Zone

- **Catalina Detachment Fault**
  - Precambrian Granodiorite
  - Cretaceous Cretaceous
  - Coconino Sandstone
  - Mohave Limestone
  - Devonian Galesville Formation

- **Fault detachment Fault**
  - Quaternary Alluvium
  - Oligocene-Miocene Panamint Formation
  - Eocene Wilcox Limestone Suite Granite

- **Sub-detachment Fault**
  - Cretaceous, thickness: 0 - 110 m

- **Quartz Monzonite. White to light gray. Grain size variable.**
Directly above the Catalina detachment fault in the southeastern part of the area are Precambrian rocks, including Pinal Schist and Johnny Lyon Granodiorite, both Proterozoic in age (see Plate 1). Tectonic slices containing each of these formations are no greater than 15 m thick. Above the tectonic slices of Precambrian rocks are slices of Paleozoic formations, all in the correct stratigraphic order but each diminished in thickness compared to measured thicknesses in nearby ranges outside of the Catalina-Rincon metamorphic core complex (see Figure 3). The sequence of Paleozoic formations, from older to younger, includes Bolsa Quartzite (middle Cambrian), Abrigo Formation (upper and middle Cambrian), Martin Formation (Upper Devonian), Escabrosa Limestone (Mississippian), Horquilla Limestone (upper and middle Pennsylvanian), and Earp Formation (Lower Permian and upper Pennsylvanian). The contrast between the normal section versus the tectonically thinned section reveals a reduction in thickness to 10 to 50 percent of original.

Thinning of the upper plate has been accomplished by down-to-the-southwest shearing and faulting. As reported by Davis (1975, 1981, 1987) and Liming (1974), the Horquilla Formation is replete with overturned fold structures which verge south to southwest and which can be interpreted via separation arc methodology as a response to top to the southwest movement. Axial surfaces for these folds are inclined to the north and northeast. Some faults which are in part responsible for thinning of the section are quite mappable within the upper plate of the Catalina detachment fault.

Oligocene-Miocene sandstones and conglomerates of the Pantano Formation
also are part of the upper plate of the Catalina detachment fault, and these rocks rest in fault contact upon upper Paleozoic sedimentary rocks, in most cases the Pennsylvanian-Permian Earp Formation (see Plate 1; Figure 2). These rocks structurally comprise a tilt panel that strikes east-west and dips north. Deposition of the Oligocene-Miocene sequence is thought to have accompanied detachment faulting.

Lower Plate – Cataclastic Rocks

Below the Catalina detachment surface are highly indurated cataclastic rocks that comprise the brittle part of the Catalina brittle-ductile shear zone. Thickness of the zone where mylonites are cataclastically overprinted is ~330 m. The top of the zone of cataclastic rocks was simple to map, because it is demarcated by the Catalina detachment fault (see Plate 1; Figure 2). The immediate footwall physical expression of the Catalina fault is a 1 to 2-m thick highly resistant ledge of cataclasite and ultracataclasite that commonly has a conspicuous physiographic expression. Downward at different levels through the zone of cataclastic deformation is a gently dipping fault surface that we have called the ‘subdetachment fault’ (see Plate 1; Figure 2). Over much of the east-west length of the map area, the subdetachment fault is straightforward to trace; in fact locally its surface is so smooth and wide that it looks like a road surface (Figure 4). But there are subregions within the map area where the subdetachment fault is more difficult to trace, especially toward the east.
Above the subdetachment fault the cataclastic rocks tend to be relatively coarse grained, and it is possible to recognize in hand samples and outcrops the protolith in the form of mylonite and ultramylonite overprinted by the cataclasis. Directly beneath the subdetachment fault, over a distance of several meters, the rock is reduced to very fine-grained cataclasite and ultracataclasite, in a manner resembling the fault rock directly beneath the Catalina detachment surface.
Significant variations in thickness of the cataclastic unit are seen beneath the subdetachment fault, and it requires very careful mapping to accurately pin the exact location of the base of the zone of cataclastic deformation. The base is marked by a sharp transition, usually over a distance of less than several meters, from cataclastic deformation to mylonitic deformation, similar to what Davis (1987) recognized in Saguaro National Park - East. Yet, from place to place below the mapped base of the cataclastic unit it is possible to see thin zones of cataclastic deformation that are traceable for many tens of meters. The overall geometry of the base of the zone of cataclasis, as viewed in map pattern, is systematically corrugated (Spencer, 1999; Plate 1, Figure 2). The pattern is best seen in down-plunge view, i.e., southwestward in the direction of tectonic transport. In this view the lower contact resembles a fault-mullioned surface.

![Down-plunge view of mapped structural relationships in the Salcito Ranch locality showing mullioned nature of Catalina detachment and subdetachment faults.](image)

**Figure 5.** Down-plunge view of mapped structural relationships in the Salcito Ranch locality showing mullioned nature of Catalina detachment and subdetachment faults.
Structural relationships within the zone of cataclasis include the presence of discrete fault surfaces whose linked geometries resemble extensional duplexes bounding horses. In this context, the subdetachment fault may well represent a "flat" that further down-dip is connected with the main Catalina detachment fault by a ramp.

**Mylonites**

Beneath the zone of cataclasis are beautiful mylonites, and some ultramylonites. Gently dipping, the mylonitic fabric imparts a ledgy characteristic to the landscape *(Figure 6)*. Protolith is of two varieties: a coarse porphyritic quartz monzonite that may represent a part of the Precambrian Oracle/Ruin suite; and a much more voluminous, finer grained, muscovite granite, that may represent a part of the Laramide Wilderness Granite suite *(Keith and others, 1980)*. Streaky mineral lineation pervades all of the mylonites and ultramylonites, and it plunges very gently S50°W. The ubiquitous sense of shear indicator in the muscovite granite mylonite is fish-flash *(Davis and Reynolds, 1996, p. 523)*, and everywhere (with one special exception yet to be discussed) reveals a top-to-the-southwest sense of shear. In mylonite derived from Precambrian Oracle/Ruin suite, the top-to-the-southwest shear sense is again apparent, disclosed through S-C fabrics.

The transformation of granite protolith to mylonite and ultramylonite, and to cataclasite and ultracataclasite, is beautifully recorded in microstructures in thin section. We have described this transition in Davis and others *(1998)*. To the north of the map area, we would expect that the mylonite gives way downward to nonmylonitic granitic protolith. In fact, even within the map area we see small pockets of nonmylonitic protolith where the original granites escaped complete mylonitization. We imagine in
the transition between (totally) mylonitic rocks above and (totally) unsheared protolith below that individual shear zones are anastomosing or inosculating and that these zones locally envelope “lenses” of protolith that were bypassed during the shearing.

![Image of Salcito Ranch map area with geological features](image)

**Figure 6.** View of Salcito Ranch map area looking from north of Breccia Mountain east-southeast toward small hill capped by Pennsylvanian Horquilla Limestone. Gouge zone of main Catalina detachment fault and Cambrian Abrigo Formation seen as lighter colored swath at base of hill. Foreground comprised of mylonite and protomylonite in footwall of detachment fault. Ridge in middle distance is cataclasite resting on subdetachment fault.

**Martinez Ranch Fault**

Along the eastern margin of the map area the upper plate rocks, the Catalina detachment fault, the cataclastic rocks, and the mylonitic rocks are truncated and offset by the Martinez Ranch fault. The Martinez Ranch fault, like the Pirate fault, is a Basin and Range fault with several kilometers of down-to-the-east normal displacement.
(Drewes, 1974, 1977). The Martinez Ranch fault demarcates the eastern margin of the Rincon Mountains, striking N-S and dipping 70ºE.

Dickinson (1998) mapped the full extent of the Martinez Ranch fault at the 1:24,000 scale along a 30 km stretch from the I-10 freeway to the eastern edge of Mica Mountain. The Martinez Ranch fault strikes essentially north-south, and dips eastward.

In the study area, where the Martinez Ranch fault cuts and displaces the Catalina detachment fault, it dips 55º east. At a much higher structural level, Dickinson (1998) notes that it dips more steeply, at ~70º east. The locale where this is observed is along Interstate 10, where Neogene gravels are down faulted against Lower Cretaceous Bisbee Group rocks. Offset along the Martinez Ranch fault in the study area is estimated to be ~ 2 km (Dickinson, 1998).

Separating the Rincon Mountains and the Little Rincon Mountains is a half graben of basin fill, bordered on the west by the Martinez Ranch fault (Dickinson, 1998).

The map trace can be tightly pinned in the southeastern corner of our map area (see Plate 1), where upper plate sandstones and limestones (transformed to quartzite and marble) are in sharp contact with cataclasite or mylonite to the west. Both the quartzite and marble strike parallel to the trace of the Martinez Ranch fault, and dip very steeply eastward. The resistant nature of the quartzite calls attention to the location of the fault, for the quartzite forms a tall strike wall, locally highly brecciated, right along the contact.

Our mapping reveals that mylonitic foliation and several structural geologic contacts are broadly dragged into the Martinez Ranch fault (Plate 1, Figure 2). Note the change in dip of the subdetachment from its characteristic southwest trend to
southeast and east-southeast in proximity to the Martinez Ranch fault. Mylonite in the immediate footwall is locally strongly folded to a steep easterly dip. It is along this zone that fish-flash sense-of-shear indicators are high-angle reverse, east block up. Unfolding the folded mylonites restores the pre-Martinez Ranch fault top-to-the-southwest sense of shear. Also along this zone are marble and quartzite mylonites overprinted by tectonic breccia related to movement on the Martinez Ranch Fault.

**General Interpretation**

Consistent with the broader geologic relationships in the Rincon Mountain region, the Catalina brittle-ductile shear zone accommodated at least 15 km of top-to-the-southwest displacement. The extensional deformation expressed in this shearing raised deep granites and mylonites upward to structural locations adjacent to Miocene basin fill, which is a stratigraphic separation of at least 8 km. Then, relative to hanging wall sedimentary rocks, the mylonites and granites and cataclasites were raised another 2 to 3 km (or more) by the Basin and Range Martinez fault event (Davis and others, 2004). Deformation mechanisms range from ductile to semi-brittle to brittle, reflecting the progressive deformation by shearing in environments that ranged from high to low temperature/pressure over the course of tectonic denudation. Deepest level shear is represented by mylonites and ultramylonites. Shallowest levels of faulting and shearing are represented by upper plate gouge zones. Intermediate levels of faulting and brittle shearing are represented by cataclasites whose fabrics overprint mylonitic and ultramylonitic fabrics. We interpret discrete fault surfaces within the zones of cataclasis to represent some of the youngest faults; they survived because they were not
themselves overprinted by yet younger faulting and brecciation. The best such example
is the subdetachment fault.

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