

GEOLOGIC FIELD GUIDES TO THE SOUTHEASTERN PICACHO MOUNTAINS AND PICACHO PEAK, PINAL COUNTY, ARIZONA

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Picacho Peak (Photograph by Phil Pearthree)

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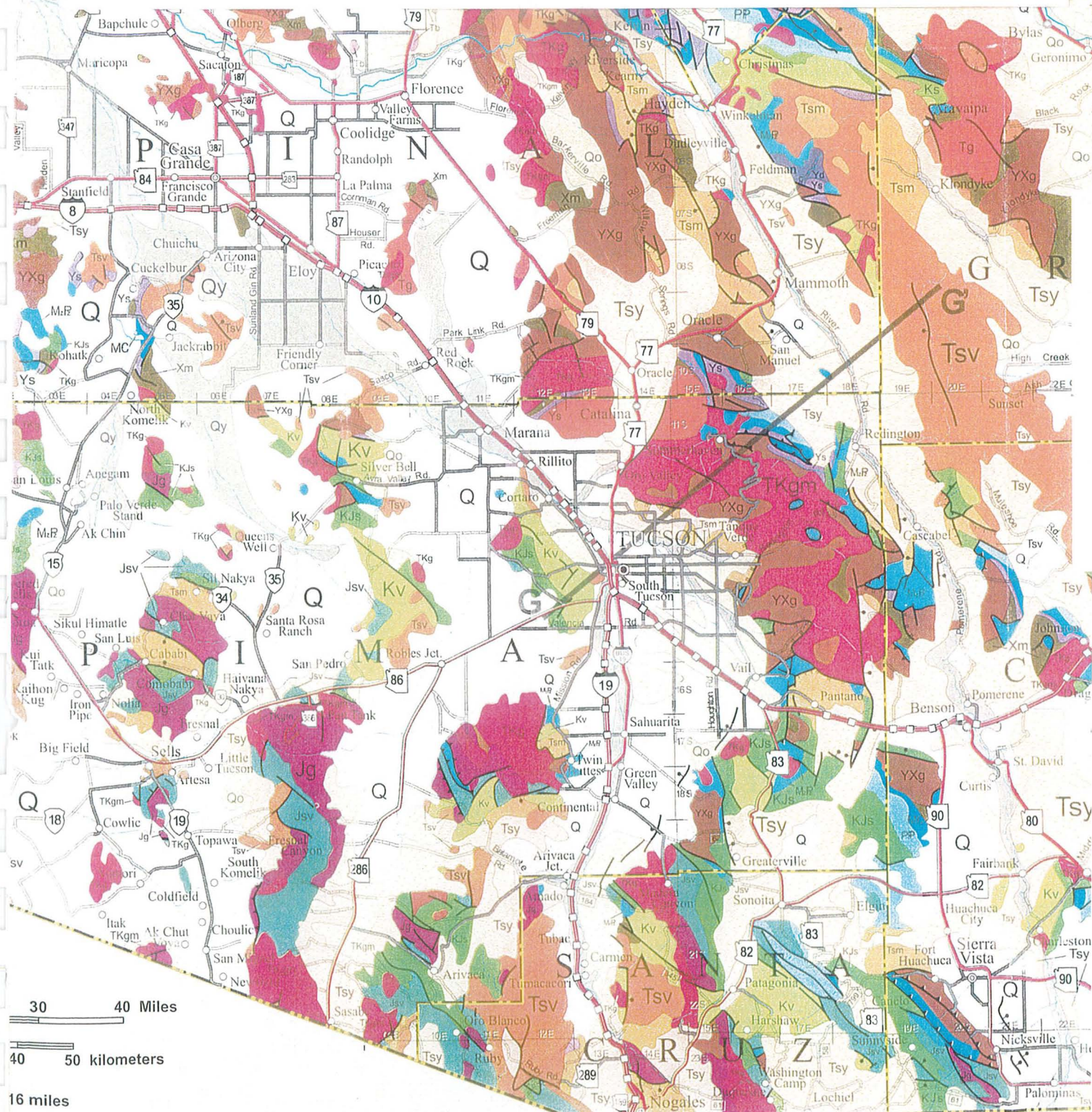
2001 University of Arizona GeoDaze field guide

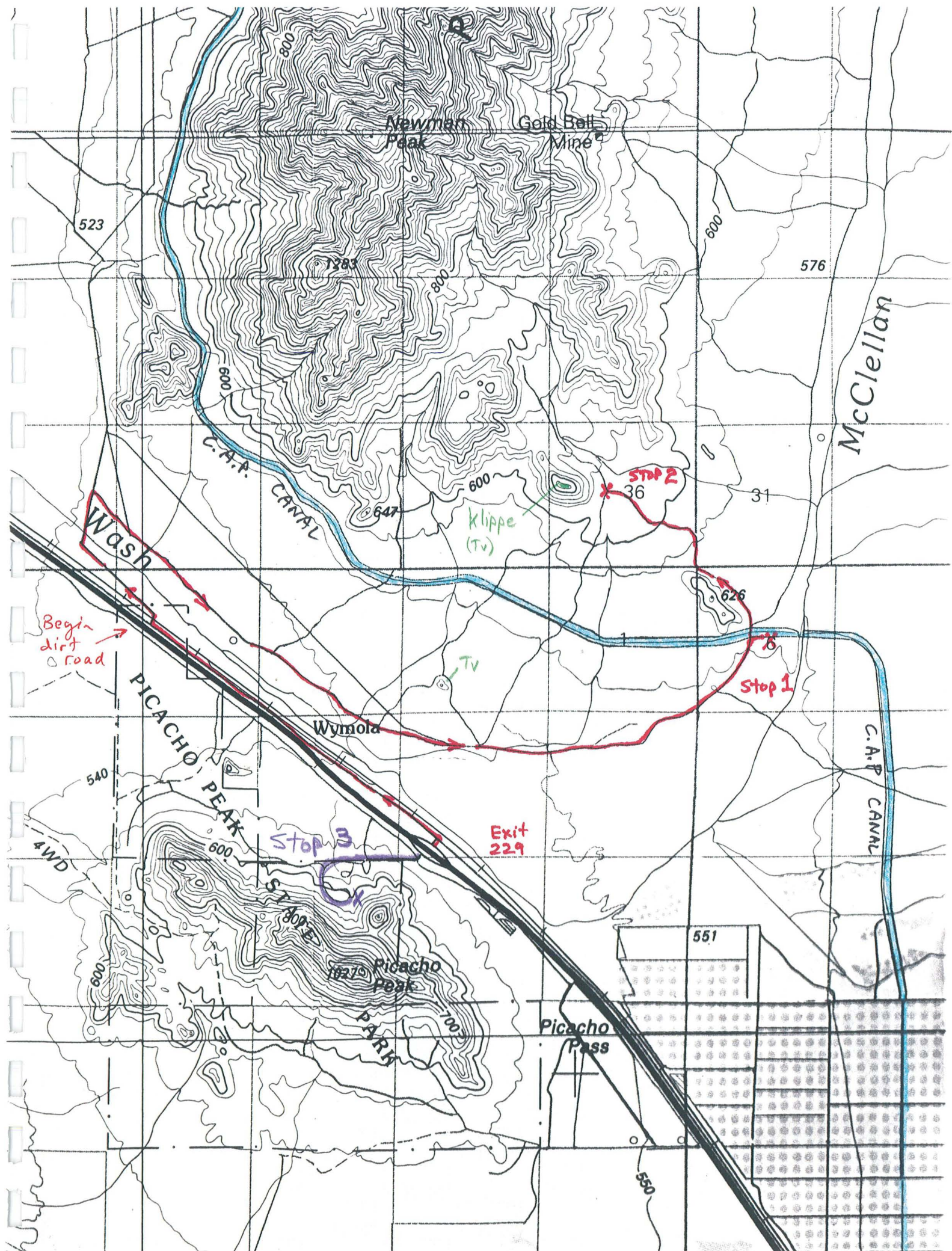
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Geologic field guide to the southeastern Picacho Mountains, Pinal County, Arizona

by

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INTRODUCTION

The Picacho Mountains are a north-south trending mountain range in southeastern Arizona that is completely surrounded by Quaternary alluvium. Picacho Peak, located south of the south end of the range, is also surrounded by Quaternary alluvium. Picacho Peak and the Picacho Mountains are separated by a gap of shallowly buried bedrock through which pass Interstate 10 and the Central Arizona Project canal. Although closely related geologically, these two mountainous areas consist of completely different rock types. The Picacho Mountains consist largely of a compositionally diverse suite of Laramide to middle Tertiary biotite granite, muscovite granite, and heterogeneous to gneissic granite (Yeend, 1976; Johnson, 1981a, b; Rehrig, 1986; Richard et al., 1999). At the southern end of the range, most of the crystalline rocks have been affected by middle Tertiary mylonitic deformation. Mylonitization is inferred to have accompanied normal faulting and ascent of the bedrock from mid-crustal depths to near the Earth's surface. Ascent occurred in the footwall of a moderate to low-angle normal fault commonly known as a "detachment fault". The crystalline rocks of the Picacho Mountains are part of the footwall of a south- to southwest-dipping detachment fault that is exposed only at the base of a small klippe of volcanic rock on a hill top in the southeastern Picacho Mountains. Picacho Peak, which consists almost entirely of northeast dipping basaltic and andesite volcanic rocks, is part of the hanging wall of the detachment fault (Briscoe, 1967; Yeend, 1976; Richard et al., 1999).

Metamorphic core complexes

The association of a mylonitic footwall, a large-displacement, moderately to gently dipping normal fault, and tilted hanging-wall rocks, is characteristic of "metamorphic core complexes" (e.g., Rehrig and Reynolds, 1980; Davis and Lister, 1988; Wernicke, 1992). The basic interpretation of these complexes is that large displacement on the normal fault associated with each complex caused uplift and exhumation of footwall crystalline rocks, and that these rocks ascended from mid-crustal depths where temperatures were initially sufficient for mylonitization along the down-dip projection of the normal fault. Rocks above the normal fault were extended and tilting. Rocks from much different levels in the crust were juxtaposed by this faulting. Mylonitic fabrics are inferred to have been produced where the normal fault originally extended down dip into a ductile (or plastic) shear zone. Identification of these features in the Picacho Mountains led to classification of the range as a metamorphic core complex (Davis, 1980; Banks, 1980; Rehrig and Reynolds, 1980).

High-angle normal faulting and earth fissures

The steep west side of the Picacho Mountains is thought to reflect late Cenozoic high-angle normal faulting that uplifted the range and produced the adjacent Picacho basin. The Picacho basin, west of the Picacho Mountains, was penetrated by an Exxon drill hole that passed through 3 km of sediments, including about 2 km of anhydrite, before reaching crystalline bedrock (Peirce, 1976). Vertical displacement on the inferred buried normal fault west of the Picacho Mountains is estimated at 3-4 km. The inferred fault is everywhere buried, but the subsurface interface between bedrock and basin filling sediments is so steep that earth fissures have been very effectively localized to a belt adjacent to the range. Earth fissures are produced by compaction of aquifer materials as groundwater is withdrawn, the water table drops many tens of meters and the buoyancy force associated with subaqueous submersion is removed. Short-distance lateral variations in subsidence cause earth fissures to form to accommodate differential subsidence. Differential subsidence may be associated with buried fault scarps because only the basin side of the buried scarp will undergo significant subsidence (Holzer, 1978; Holzer et al., 1979; Slaff et al., 1989; Slaff, 1991, 1993). Repeated fracturing and offset of I-10 ~4.2 miles northwest of the Picacho Mountains exit has led to repeated highway repairs and a vertical offset that is apparent to aware motorists.

Purpose of field trip

A lithologically diverse suite of variably deformed crystalline rocks is well exposed and accessible in the southeastern Picacho Mountains. These rocks were located in the middle crust, probably at 10 to 15 km depth, and were subjected to repeated intrusions of magma and high-temperature plastic deformation before mid-Tertiary mylonitic deformation marked the beginning of cooling, exhumation, and subaerial exposure. Metamorphic core complexes are created by geologically rapid delivery of mid-crustal rocks to the Earth's surface in an extensional tectonic environment. Viewing the lithologies and structures in these rocks is a major goal of this field trip.

In addition, the Picacho detachment fault and overlying volcanic rocks are exposed on a hill top in the southeastern Picacho Mountains. Hydrothermal alteration has affected the rocks below the detachment fault, and possibly records the arrival of near-surface, oxidizing fluids late in the history of footwall exhumation. Dark, mafic volcanic rocks that form the hanging wall are probably correlative with similar rocks visible to the south at Picacho Peak and at a small hill between the Picacho Mountains and Picacho Peak. These rocks were strongly affected by hydrothermal alteration during the time of detachment faulting and core complex uplift (Brooks, 1986; Kerrich and Rehrig, 1987). Viewing the detachment fault and contrasts in alteration and deformation history across the detachment fault are also goals of this field trip.

FIELD GUIDE

Directions to Stop 1

mileage	Leave Tucson and proceed northwest on Interstate 10. After crossing Ina road on northwest fringe of Tucson, travel ~28.4 miles to exit freeway at Picacho Peak (exit 229). Begin mileage at stop sign at end of freeway offramp.
0.0	Turn right at stop sign. Turn left at next stop sign so that you are then heading northwest on frontage road parallel to I-10.
2.4	Turn right onto dirt road, cross railroad tracks, and pass through gate (leave gate open or closed, as you found it, or closed if sign instructs you to do so). Road turns left to parallel railroad tracks to left and McClellan Wash to right. Road then bends right and crosses McClellan Wash.

- 3.6 After crossing McClellan Wash, turn right (southeast) on dirt road. This old dirt road gradually bends left (east) as it extends about 6 miles around the south end of the Picacho Mountains. Follow most-used track and beware of taking wrong track at several forks. This road is passable for high-clearance, two-wheel drive vehicles, but there are some ruts and sandy stretches. Use caution at the ruts and maintain your momentum through the sandy stretches to avoid getting stuck. At about 3.5 miles along the unimproved road you can turn off to the left for an optional stop at a low isolated hill composed of highly faulted and brecciated, sparsely porphyritic, dark lava that is probably correlative with the lava on Picacho Peak and that has been altered by potassium metasomatism (Brooks, 1986; Richard et al., 1999).
- 9.4 Immediately before bridge over CAP canal, turn right and park next to very small hill of bedrock that is next to the CAP canal. This is Stop 1.

Stop 1

Stop 1 is located at a very small hill on the south side of the CAP canal and just west of McClellan Wash. The hill represents a lithologically diverse suite of crystalline rocks and deformation fabrics that reflect magmatism and deformation in the middle crust and during later ascent and mylonitization in the footwall of the Picacho detachment fault. Four rock types are visible at the west end of the hill: (1) megacrystic granite in which large K-feldspar phenocrysts are now augen porphyroclasts (possibly derived from 1.4 Ga granite), (2) medium grained Picacho Mountain granite (dated at 59.3 ± 1 Ma by Clark Isachsen, U of A; 5 zircon crystals analyzed for U and Pb isotopes), (3) pegmatite, and (4) fine-grained aplitic granite. All of the rock types form layers in the gneiss that makes up most of the hill. This gneissic layering was apparently produced by magmatic intrusion and by high temperature deformation and recrystallization. Such quartzo-feldspathic gneisses are generally thought to be produced in the middle crust and to be characteristic of exposures of middle crustal rocks, and are sometimes referred to as "lit-par-lit injection gneiss" (lit-par-lit, pronounced *lee par lee*, means bed-by-bed in French).

This gneiss has been deformed to produce a mylonitic fabric with a well developed lineation. Grain-size reduction is a defining characteristic of mylonitization in quartzo-feldspathic rocks, and such lineated gneisses are typical of metamorphic core complexes. Mylonitic fabric is developed to different degrees, and has different characteristics, in the different rock types. The lineation produced by the mylonitization is striking, especially in the aplitic granite which, because of its high quartz content and fine grain size, appears to have absorbed a disproportionately large amount of the mylonitic strain. The highly strained aplitic granite in places looks like an L-tectonite in which lineation is better developed than foliation. The pegmatite veins, because of their abundant, large K-feldspar, are not strongly mylonitic. However, K-feldspars contain numerous small fractures that are perpendicular to mylonitic lineation and were probably produced by stretching during mylonitization.

Asymmetric K-feldspar porphyroclasts are especially visible in the megacrystic granite. Rock faces that are parallel to lineation and perpendicular to foliation reveal asymmetric porphyroclasts that suggest top-to-the-southwest shearing during mylonitization. This sense of shear is consistent with the overall asymmetry of mylonitization in the Picacho Mountains in which the largely granitic north end of the range is not mylonitized and appears to have resided at shallow crustal levels, whereas the southern end of the range was mylonitized and uplifted in the footwall of a southwest-dipping detachment fault. Furthermore, northeastward tilt directions in hanging wall rocks at Picacho Peak are suggestive of top-to-the-southwest displacement on the underlying detachment fault. This is also the same sense of shear as inferred for mylonitization and exhumation of the Tortolita, Santa Catalina, and Rincon Mountains to the southeast (e.g., Reynolds and Lister, 1990; Naruk and Bykerk-Kauffman, 1990; Dickinson, 1991).

Near the hill top are several small intrusions of hornblende-bearing mafic granitoid that are not significantly affected by mylonitization and were possibly intruded late during mylonitization or after

mylonitization. Also near hill top are numerous grinding holes left by Native Americans who were probably crushing mesquite beans.

Directions to Stop 2 (from stop 1)

mileage

- 0.0 Cross CAP canal on bridge.
- 0.1 Turn left toward Newman Peak (highest point in the Picacho Mountains).
- 0.7 Stay on most-used track, cross small wash, proceed to corner of fenced area, take right track parallel to fence (heading north; don't take left track which heads west).
- 1.7 Stop at wide area in road next to gate (don't go through gate).

Stop 2

The hill west of the parking spot consists of a layered sequence of intrusive rocks overlain at the very top by the Picacho detachment fault and a small klippe of Tertiary mafic volcanic rock. At this stop we will hike up the hill, observing rock types, deformation fabrics, alteration, and contact relationships along the way.

In the wash below the parking area observe the excellent exposures of mylonitic fabric that here overprint a hornblende-bearing, K-feldspar porphyritic granitoid of uncertain age (unit TXg of Richard et al., 1999). This rock contains small sheets of very fine grained, dark gray rock that could be intrusions of mafic lava that were emplaced late during mylonitization, or they could be ultramylonites with very highly comminuted grains. Proceed up hill to west and note that mylonitic fabric is variably developed in granitoid.

About half way up the hill you will reach a contact where the granitoid is intruded by a very fine grained to aphanitic mafic dike that is much less affected by mylonitization than the granitoid. The contact is obscure because of strong weathering and some interdigitation of contact. Study the contact over several meters or tens of meters to convince yourself that the contact is intrusive. Intrusion of the subhorizontal mafic dike is interpreted as syn-mylonitic, and the fine grain size of the dike is suggestive of shallow intrusive depth.

Proceed up hill to west until you reach a non-mylonitic granite that is intruded by the mafic dike. The non-mylonitic granite has been subjected to substantial brittle deformation and alteration and it is difficult to discern its original texture, but it contains enough fragments of K-feldspar that it is suspected to have been a porphyritic granite of early to middle Proterozoic age. The fact that this granite is not mylonitized, and that it is directly below the detachment fault farther up the hill, led to the interpretation that the granite was originally a fault sliver along the detachment fault that was displaced from crustal levels too high and cool for mylonitization and that it was originally juxtaposed with underlying crystalline rocks by brittle faulting (Richard et al., 1999). This was followed by abandonment of the lower slip surface, which was intruded by the mafic dike, and transfer of fault slip to the detachment fault above the granite sliver. Study the contact with the mafic dike to convince yourself that it is intrusive, and study the granite to convince yourself that it was not mylonitized.

Proceed up hill to reddish brown, mafic volcanic rocks that make up klippe above concealed detachment fault. Note that just above fault, on southeast side of klippe, is a sheet of light gray to tan hydrothermal carbonate ("travertine-barite" of Kerrich and Rehrig [1987]). Overlying mafic volcanic rocks are brecciated but it is uncertain if brecciation is related to fault movement or to volume change during alteration. These volcanic rocks were described by Kerrich and Rehrig (1987) as having "undergone intensive low-temperature oxidative alteration and massive potassium fixation, to the degree that the dominant secondary minerals are K-feldspar, calcite, hematite, and manganese oxides." Chemical analysis by Brooks (1986) determined that a sample of the altered mafic volcanic rock

contained 47% SiO₂, 11% K₂O, and 0.4% Na₂O. The K₂O/Na₂O ratio of 27.5 is unusual for magmatic compositions but typical for K-metasomatized volcanic rocks (Brooks, 1986). Chemical analysis by Shafiqullah et al. (1976) determined that a sample of the altered mafic volcanic rock contained 59% SiO₂, 13.3% K₂O, and 0.74% Na₂O (K₂O/Na₂O ratio of 18).

Proceed along south side of klippe to west side of klippe. Green, brecciated, silicified and chloritically altered granite forms a ledge that marks the top of the detachment-fault footwall. This "red-on-green" contact, with reddish brown volcanic rocks above the detachment fault, is characteristic of many detachment fault contacts in the Mojave-Sonora desert region and in some cases is highly visible in aerial photographs. At the west end of the klippe, at the ridge crest, brown siliceous microbreccia forms the top surface of the ledge that marks the top of the detachment-fault footwall. Such microbreccia is also characteristic of detachment fault footwalls (e.g., Davis et al., 1980).

Return to vehicles and return to I-10.

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INTRODUCTION

The Picacho Mountains and Picacho Peak represent the footwall and hanging wall, respectively, of a Miocene metamorphic core complex in south-central Arizona. The area is located along Interstate 10 northwest of Tucson, and represents the northwestern end of the greater Catalina metamorphic core complex that includes the Tortolita, Santa Catalina, and Rincon Mountains (e.g., Banks, 1980; Davis, 1980; Rehrig and Reynolds, 1980; Dickinson, 1991). The Miocene volcanic rocks of the hanging wall are very well exposed at Picacho Peak, southwest of I-10. The Proterozoic through Mid-Tertiary plutonic and metamorphic rocks of the footwall are exposed to the northeast in the higher and more extensive Picacho Mountains. The Picacho Peak area was mapped by Briscoe (1967), Yeend (1976), and Richard et al. (1999). Geochemical studies include those by Shafiqullah et al. (1976) and Brooks (1986). This field guide describes the volcanic rocks in the Picacho Peak area that can be viewed along the trail to the summit of Picacho Peak.

PICACHO PEAK

Access to the Picacho Peak area is along paved roads within Picacho Peak State Park. Take Interstate 10 to Exit 219 and proceed southwest about 1 mile to the Picacho Peak State Park headquarters. There is a \$5 fee per vehicle (up to 6 persons allowed), and \$10 fee per vehicle to camp at the campground (2001 fees).

The best trail for viewing the geology is the main Hunter Trail which climbs from the parking lot (elevation ~2000 ft.), over the crest of the main ridge at ~3000 ft., down the back side of the main ridge to ~2520 ft. elevation, and then up to the highest point in the park, Picacho Peak (elevation 3370 feet). The total vertical climb for the round trip hike is ~2300 ft.. The climb up the back side of the main ridge requires climbing over steep rock faces using handholds attached to the rock. The climb should not be attempted by those with a strong fear of heights.

The first section of the trail climbs through Quaternary coarse-grained alluvial fan and talus deposits. Eventually the trail climbs onto exposures of the main volcanic unit in the range, a sparsely pyroxene-porphyritic basaltic andesite lava with a matrix that varies from aphanitic to rich in microcrystalline plagioclase microlites. The unit consists of multiple lava flows interbedded with thin sequences (generally less than 5 meters thick) of medium- to thin-bedded, well-sorted, medium- to coarse-grained arkosic sandstone and granule sandstone. Shortly after climbing onto the first exposures of bedrock, the trail crosses one of these sandstone units. The lavas are generally dark purple, gray or reddish brown in color, and the sandstones are lighter gray or tan.

The trail continues up to the base of a cliff where it turns sharply to the east along the base of the cliff. At the base of the cliff several steeply southwest-dipping faults can be seen, but none of these juxtapose rocks of significantly different composition and all of the rocks consist of the sparsely porphyritic basaltic andesite lava. As the trail continues along the base of the cliff, note a major, gently southwest-dipping fault in front of you. The fault forms a prominent ledge near the base of the cliff just below the level of the trail. Just before the trail switches back to the west, climb down about 50 feet to examine the fault zone. The fault is poorly exposed, but a breccia zone at least 1 meter thick makes a prominent recess in the rock, and if you follow the ledge to the east, you will eventually find exposures of the fault. It strikes about 120° and dips about 30° to the southwest. In the footwall of this fault, in the gully, note a steeply northeast-dipping depositional contact between a coarse-grained, crystal-rich, plagioclase-porphyritic dacitic lava below and the sparsely pyroxene-porphyritic lava above. The upper contacts of the lava flows in this area are characterized by carapace autobreccia infiltrated with arkosic sandstone. You can trace this contact down the gully to another minor fault with about 5 meters of normal stratigraphic offset. At the bottom of the gully you can walk around the base of another minor cliff face and see the contact again, dipping about 60° to the northeast. This porphyritic dacite serves as an important stratigraphic marker in the range.

If you follow the trail over the crest of the range and then back up to the top of Picacho Peak, you will be in the upper, sparsely porphyritic lava for the rest of the hike. The trail on the southwest side of the range descends along a prominent ledge that marks the trace of another low-angle normal fault. As you climb down this steep section of the trail using the handrails and steps cut into the footwall of the fault note that the lava on either side of the fault is essentially identical in composition.

As this trail turns to the east and starts to climb up again notice that you can continue down another trail a few hundred feet to a sharp little knob overlooking the gully to the west in which you can see the continuation of the fault you just followed down from the crest. In the footwall of this fault, the older sequence of lavas is exposed. However, this terrain is very difficult to negotiate, with steep rocky gullies and dangerously loose talus. The rock sequence in the footwall consists, from top to bottom, of a heterolithic pyroclastic/epiclastic breccia, conglomerate, or diamictite that contains clasts of the dacitic lava, a medium-bedded sandstone, a plagioclase microporphyritic lava, and then at the base of the slope another dacitic lava with distinctive, large (2-4 mm) hornblende phenocrysts. From this knob you can descend using another trail all the way to the base of the mountain where you can see the upper end of a jeep trail. If you descend along this trail, you will eventually cross into the older sequence of dacitic lava-clast breccia, sandstone and older lavas. Near the base of the mountain, another poorly exposed, gently southwest dipping fault carries in its hanging wall the younger, peak-forming, sparsely porphyritic lava. This repetition of the stratigraphy by southwest-dipping normal faults continues farther to the southwest in the foothills you see across the piedmont.

The trail to the crest is interesting because of the wonderful view, and because, near the top, it crosses a large block of coarse-grained, equigranular granite suspended within the sparsely porphyritic lava. The granite block is interpreted as a slide block that was derived from a steep normal-fault escarpment related to the ancestral Picacho Mountains detachment fault during eruption and emplacement of the lava sequence. The lavas accumulated to a thickness of at least 5 km and possibly more in this area. Interbedded throughout this sequence are arkosic sandstones and conglomerates that contain locally abundant clasts of granite and metamorphic rocks that were probably derived from the footwall block of the Picacho Mountains detachment fault. Near the base of the section, the conglomerates are dominated by metamorphic rocks that resemble Pinal Schist, suggesting that these rocks were stripped first during the initiation of uplift of the Picacho Mountains.

Looking to the southwest several miles the low Samaniego Hills consists of a flat-lying to gently dipping sequence of Miocene lavas that are very similar in composition to the lavas at

Picacho Peak, and these lavas are interpreted to be part of the same volcanic field (Ferguson et al., 1999).

As you return along the trail and start your descent down the northeast side of the range, it is instructive to go back by a slightly different route. At the first switchback go back down to the same ledge and fault exposure that you visited on the your way up, and continue down from there off-trail to the prominent saddle between Picacho Peak and the smaller peak to the northeast. There is another trail at this saddle that will take you back to the same parking area. As you descend, notice the multiple, strike-parallel gullies which represent flow-boundaries between the fairly thin, amalgamated flows of the sparsely porphyritic lava unit. In some areas you can see thin sandstone units along these boundaries. Just before you reach the saddle notice that you have crossed another major, southwest-side-down normal fault which brings up the crystal-rich dacite unit again. The fault is not exposed, but from the saddle you can see where it continues to the northwest along the base of the range. The fault runs just on the up-slope side of a series of low knobs and hills that stick up through the alluvial fan and piedmont surface. The knobs are composed of the dacite lava.

The tilted volcanic rocks of Picacho Peak are affected by subtle but locally extreme alteration by potassium metasomatism. This type of alteration adds potassium and removes calcium and sodium. Some of the most extremely K-metasomatized rocks in Arizona are present in the Picacho Mountains and in a hill between the Picacho Mountains and Picacho Peak (Brooks, 1986). It has been proposed that the detachment fault that separated the volcanic rocks from the crystalline rocks served as a conduit for circulation of altering fluids, and that the heat of the uplifted crystalline rocks helped drive fluid circulation (Kerrick and Rehrig, 1987). This is consistent with the greater degree of K-metasomatism near the detachment fault (Brooks, 1986) but inconsistent with another study in Arizona (Roddy et al., 1988). K-metasomatism is not well understood but may be an important process in genesis of some copper and gold ore bodies (Hollocher et al., 1994). K-metasomatism may have liberated the metals that were then deposited in the many small deposits in the Picacho Peak area that have yielded 2400 lbs. of copper and 100 oz. of silver (Keith et al., 1983).

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