

**Geologic map of the Picacho Mountains
and Picacho Peak, Pinal County,
Southern Arizona**

by

**Stephen M. Richard, Jon E. Spencer, Charles A.
Ferguson, and P. A. Pearthree**

Arizona Geological Survey Open-File Report 99-18

September, 1999

Scale 1:24,000 (2 sheets), with 43 pages text

*Jointly funded by the Arizona Geological Survey
and the U.S. Geological Survey under
STATEMAP Program Contracts #98HQAG2064.*

Arizona Geological Survey
416 W. Congress St., #100, Tucson, Arizona 85701

This report is preliminary and
has not been edited or reviewed
for conformity with Arizona Geo-
logical Survey standards

TABLE OF CONTENTS

INTRODUCTION.....	3
GEOLOGY OF VOLCANIC ROCKS OF PICACHO PEAK.....	4
STRATIGRAPHY.....	4
REGIONAL CORRELATIONS AND TECTONIC SIGNIFICANCE OF FACIES ASSOCIATIONS	6
STRUCTURE OF THE PICACHO PEAK AREA	7
POTASSIUM METASOMATISM.....	8
GEOCHRONOLOGY OF VOLCANIC ROCKS	8
GEOLOGY OF CRYSTALLINE ROCKS OF THE PICACHO MOUNTAINS.....	9
FABRIC IN GNEISSIC GRANITOIDS OF THE PICACHO MOUNTAINS	9
GEOCHRONOLOGY OF CRYSTALLINE ROCKS	10
NOMENCLATURE FOR CRYSTALLINE ROCKS	12
OTHER NOMENCLATURE USED FOR ROCKS IN THE PICACHO MOUNTAINS OUTSIDE THE MAP AREA	13
PICACHO DETACHMENT FAULT.....	14
DETACHMENT FAULTING AND ALTERATION	15
MINERAL DEPOSITS.....	16
PICACHO PEAK AREA.....	17
PICACHO MOUNTAINS	18
DESCRIPTION OF ROCK UNITS.....	20
REFERENCES.....	33
FIGURES.....	35
TABLES.....	42

INTRODUCTION

The Picacho Mountains are north-south trending mountain range that is completely surrounded by Quaternary alluvium, and consists of Tertiary and older granitic and gneissic rocks (Figure 1). Picacho Peak, located south of the south end of the range, is also surrounded by alluvium, and consists of Tertiary andesitic volcanic rocks. Picacho Peak and the Picacho Mountains are separated by a gap of shallowly buried bedrock through which pass Interstate 10, the Southern Pacific Railroad, and the Central Arizona Project canal. The Picacho Mountains consists of a compositionally diverse suite of Tertiary, Cretaceous or Proterozoic granitoids, heterogeneous to gneissic granite, muscovite granite, schist, and gneiss, much of which has been affected by middle Tertiary mylonitic deformation and probably by late Cretaceous syn-plutonic deformation [Rehrig, 1986]. Mylonitization is inferred to have accompanied normal faulting and ascent of the bedrock from mid-crustal depths in the footwall of a moderate to low-angle normal fault commonly known as a "detachment fault". Older gneissic fabrics may record Laramide mid-crustal deformation, or relict Proterozoic fabric. The crystalline rocks of the Picacho Mountains are part of the footwall of a south- to southwest-dipping detachment fault that is exposed in only one small area in the southern 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.

The association of a mylonitic footwall, a large displacement normal fault, and a tilted hanging wall, are typical of features referred to as "metamorphic core complexes" [e.g. Rehrig and Reynolds, 1980]. The basic interpretation of these complexes is that large displacement across the normal fault (detachment fault) resulted in uplift and exhumation of mid-crustal rocks and tilting of rocks overlying the detachment fault. Rocks from much different levels in the crust are 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 and classification of the range as a metamorphic core complex [Davis, 1980; Banks, 1980; Rehrig and Reynolds, 1980; Rehrig, 1982] is supported by this study.

The southern Picacho Mountains had been mapped previously by Yeend [1976] and the northern Picacho Mountains by Johnson [1981a, b], but the area mapped by Yeend was mapped in considerably less detail. Picacho Peak had been mapped by Briscoe [1967]. The southern Picacho Mountains and Picacho Peak were both mapped in detail for this study, largely because we expected to be able to make significant improvements in the detail of mapping. In addition, unlike earlier investigators, we now have the benefit of understanding the basic processes of metamorphic core complex genesis [Wernicke, 1981; Spencer, 1984;

outcrop of granite within a small, probably Laramide, diorite body (Clemans Tank Diorite, see below) that intrudes Ruin(?) granite.

Correct location: 32° 51.95' N., 111° 20.12' W. Picacho Reservoir SE 7 ½' quadrangle.

Shafiqullah et al. [1980] report an additional date (UAKA 73-64, biotite, 24.35 ±0.73 Ma) from a “small pluton and associated northerly trending dikes [that] intrude the Precambrian basement”. This sample was not plotted by Johnson [1981a, b]. Using the latitude and longitude given by Shafiqullah, the sample locality for this date was plotted on Johnson’s map and falls in Quaternary alluvium directly adjacent to a dirt road and to an elongate, north-trending outcrop belt of Johnson’s map unit “Fine grained intermediate igneous rocks” of map unit “F”. This sample is #660 of Reynolds et al. [1986].

Another date reported by Reynolds et al. [1986] (#1159, biotite, 64.7 ±2.3 Ma), attributed to “Rehrig, W.A., written communication, 1986” and included by Reynolds et al. [1986] with the Picacho Mountains dates, plots in Quaternary alluvium adjacent to a small bedrock hill that is an outlier of the 96 Hills east of Arizona State Highway 79. This sample and date should not be included with the Picacho Mountains.

The four K-Ar dates reported from the Picacho Mountains indicate that granitic rocks are of both Laramide and middle Tertiary age. The 23.57 ±0.5 Ma biotite K-Ar date from the gneissic granitoids in the central Picacho Mountains is from a map unit that is variably affected by mylonitic deformation of middle Tertiary age, and so it is uncertain if this date reflects the age of the rock or cooling during tectonic exhumation that occurred millions of years after emplacement of the gneissic granitoids. This date is the only one of the four from the Picacho Mountains that is from the map area of this report.

Nomenclature for Crystalline Rocks

The names Picacho Mountains Granite, Newman Peak Leucogranite, Barnett Well Granite, and Picacho Reservoir Hornblende Granitoid are proposed here as formal names for the major granitoid units that form the bulk of the southern and central Picacho Mountains. Names are also proposed for two small igneous bodies in the northern part of the range. The distribution of the named units and the location of type localities are shown on Figure 6. The names Picacho Mountains Granite and Newman Peak granite have both been applied to the same rock sample in existing literature on the Picacho Mountains (see above). A variety of conflicting names have been applied to specific rock samples collected for age dates [Shafiqullah et al., 1980; Reynolds, 1986; Damon et al., 1996], in the context of geologic mapping by Johnson [1981a, b] in the northern Picacho Mountains, and reconnaissance mapping by Yeend [1976] in the southern Picacho Mountains. Completion of 1:24,000-scale geologic mapping in the southern Picacho Mountains provides a basis for proposing formal rock unit nomenclature for the granitic rocks in the range.

Reynolds, 1985; Davis and Lister, 1988], and this understanding provides a framework for understanding the geologic evolution of the study area.

The steep west side of the Picacho Mountains is thought to reflect late Cenozoic high-angle normal fault movement that uplifted the range and produced the adjacent basin. The inferred fault is everywhere buried, but coincides with steep segments of the subsurface interface between bedrock and basin filling sediments [Holzer, 1978; Pankratz et al., 1978]. The earth fissures apparently have been very effectively localized in a belt adjacent to the range above this steeply dipping fault(?) contact. Earth fissures are produced by compaction of aquifer materials as groundwater is withdrawn 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 subsidence [Holzer, 1978; Holzer et al., 1979; Slaff et al., 1989; Slaff, 1991, 1993]. Fissures may also be associated with zones of rapid facies change from coarse alluvial fan material near the mountain ranges to fine-grained basin fill with higher porosity along the Santa Cruz River floodplain. This mapping project was undertaken in part to determine if any unrecognized normal faults were exposed within bedrock and projected under flanking basin strata. If so, these buried faults would be possible sites for differential subsidence and earth fissure development associated with groundwater withdrawal. Numerous faults were identified in the Picacho Peak area. The only potentially significant fault recognized in the Picacho Mountains is in the southwestern part of the range, separating the main range from outlier hill 2405 in sec. 28, T. 8 S., R. 9 E.

Gneissic rocks exposed in the southwestern part of the Picacho Mountains are the structurally deepest rocks exposed in the range. These are interpreted to have been uplifted from mid-crustal depths both by the Picacho detachment fault and by the now buried, presumably steep normal fault that bounds the west side of the Picacho Mountains.

GEOLOGY OF VOLCANIC ROCKS OF PICACHO PEAK

Stratigraphy

The stratigraphy of the volcanic rocks at Picacho Peak is dominated by mafic to intermediate composition lavas interbedded with a wide variety of clastic rocks ranging from nonvolcaniclastic conglomerate and pebbly sandstone to massive volcanoclastic diamictite (massive, matrix-rich, angular-clast conglomerate), and a wide variety of pyroclastic rocks and lava breccias. Volcanic rocks in extensive alteration zones are strongly fractured and iron-stained, and have been invaded by quartz, carbonate, and sulfate mineral veins.

Mafic minerals are commonly altered to epidote and chlorite or clay. The alteration makes it difficult to differentiate the rocks into meaningful units, and the high density of normal faults results in a complex jumble of juxtaposed units in many areas. The alteration also tends to homogenize the appearance of the rocks so that volcanoclastic and pyroclastic units appear similar to adjacent lavas. It is likely that some of the apparent heterogeneity of phenocryst assemblages that has been attributed to the lavas in the Picacho Mountains [Shafiqullah et al., 1976] resulted from misidentification of lithic and detrital grains in interbedded clastic rocks as phenocrysts in lava units.

A prominent crystal-rich dacitic lava (Td, Tdx) occurs near the middle of the sequence and serves as the most distinct marker interval. The dacite has a coarse-grained, crystal-rich texture with phenocrysts of plagioclase, biotite and hornblende. Briscoe [1967] recognized the dacite as a medial marker, and described the overlying and underlying mafic lavas as being essentially indistinguishable, so that it was impossible or at least very difficult to identify which sequence was present in isolated exposures where the dacite lava is not present. We found this to be an accurate assessment, and agree that Briscoe's [1967] use of only one map unit to represent the older and younger andesite was appropriate. In areas where there are good upper and lower depositional contacts with the dacite, lavas with nearly identical phenocryst assemblages can be found above and below. There are however, certain types that are more abundant either above and below, and we used these to make a distinction between the older and younger rocks, and as a basis for our stratigraphic framework (Figure 2). The principal characteristic we use for the distinction of the stratigraphic units is phenocryst assemblage, and these observations are summarized in Figure 3.

The younger lavas (Tau) are characterized by crystal-poor, pyroxene porphyritic texture. Plagioclase phenocrysts are rare to absent. Phenocryst content in the younger andesite lava unit is usually less than 7-10%. The younger andesite lavas form thick sequences of amalgamated flows, separated in some places by thin beds of granule or pebbly volcanoclastic sandstone or, rarely, conglomerate. Picacho Peak and most of the hills to the northeast of the range crest are composed of the upper, crystal-poor andesite (Tau).

The lavas that underlie the dacite sequence consist of a fairly distinctive plagioclase-porphyritic andesitic lava unit (Tap) that is characterized by the dominance of plagioclase crystals in the phenocryst population. This unit consists of both crystal-poor and crystal-rich lavas. In the more crystal-poor varieties pyroxene phenocrysts are very small and are rare to nonexistent. In the crystal-rich varieties, pyroxene is always less abundant and finer-grained than the plagioclase (which means that in some rocks it can be relatively abundant and coarse-grained). The plagioclase-porphyritic andesite (Tap) unit is generally more crystal-rich and coarser-grained up-section, and some of the uppermost lavas closely resemble the dacite lava map unit (Td). This is an important point, because the dacite lavas pinch out to the southeast near Picacho Peak [Briscoe, 1967] and because of the pervasive alteration it is not always possible to identify which unit di-

rectly underlies the upper andesite (Tau), either the dacite (Td or Tdx) which contain abundant alkali mafic minerals or crystal-rich varieties of the older andesite (Tap) which contain abundant pyroxene phenocrysts.

The plagioclase-porphyrific andesites (Tap) overlie a sequence of volcanic rock dominated by massive lava breccia (Tax) associated with coarse-grained, plagioclase and pyroxene phenocryst lavas with well-developed trachytic texture (Tat). Lavas with well-developed trachytic texture, however, are not restricted to this interval (Figure 2). The breccia unit thickens dramatically to the northwest, and it is interpreted to be a debris apron associated with a nearby andesitic volcano, possibly located just to the north of the range.

The base of the volcanic sequence is not preserved, but the oldest exposed volcanic unit (Tao) consists of crystal-poor, pyroxene-porphyrific andesite interbedded with at least two intervals of non-volcanic lithic conglomerate. These were named the Wymola Conglomerate by Briscoe [1967] and the individual sequences are up to 120 meters thick. The clasts in the conglomerates are rounded to subrounded, but highly non-spherical. They consist mostly of phyllite and psammite, with less than 20% granitoid, and less than 5% volcanic clasts. Lavas of the older andesite (Tao) are nearly identical petrographically to the upper andesites (Tau) with pyroxene phenocrysts dominating over plagioclase, and their identification depends primarily on stratigraphic position and association with the non-volcanic lithic conglomerate.

Regional correlations and tectonic significance of facies associations

Although the alteration and K-metasomatism (see below) [Brooks, 1986] has severely changed the chemical composition of most of the volcanic rocks in the Picacho Mountains, their petrographic similarity to rocks in the nearby Samaniego Hills [Eastwood, 1970, Ferguson et al., 1999a] and Sawtooth Mountains [Ferguson et al., 1999b] and a similarity in general stratigraphic sequence (crystal-poor mafic-intermediate lavas bracketing a sequence of crystal-rich dacitic to trachytic lavas) strongly suggests that the three ranges represent a single, tectonically dismembered volcanic field. The greatest thickness of volcanic rocks is preserved in the Picacho Mountains (between 1.5 and 2 km) probably because this area was the most active in terms of tectonic subsidence. Crystalline basement is exposed directly underlying the volcanic rocks in the Samaniego Hills [Eastwood, 1970, Ferguson et al., 1999a], and is inferred to directly underlie the volcanic rocks in the Sawtooth Mountains [Ferguson et al., 1999b], but no top of the sequence is preserved in any of the ranges. The minimum thickness of volcanic rocks in the Samaniego Hills and Sawtooth Mountains is on the order of 600 and 500 meters, respectively.

A hypothetical, reconstructed Sawtooth-Samaniego-Picacho volcanic field (Figure 4) portrays a northeast-thickening sequence of volcanic rocks. The volcanic rocks are interpreted to have overlapped a steeply southwest-dipping range-front fault to the northeast, which may represent the precursor to the Picacho Mountains detachment fault (named modified from Rehrig [1986] and Brooks [1986] to avoid confusion

with low-angle normal faults in the vicinity of Picacho Peak in southeastern California). The presence of coarse-grained granitoid-clast conglomerate, and one large slide block of granitoid in the Picacho Peak volcanic sequence is the main evidence for such a structure.

We indicate a basal unconformity with Proterozoic crystalline basement on our cross-sections (Plate 2) and stratigraphic columns (Figure 2) merely to constrain a minimum thickness for the volcanic pile in the Picacho Mountains at about 2 km. Non-volcaniclastic conglomerate is present over 300 m stratigraphically above the oldest preserved lava, and granitic cobbles and boulders are present in trace amounts in thin sedimentary units throughout the volcanic sequence in the central part of the map area. Some of the upper andesites are interbedded with conglomerates with up to 30% granite boulders, and there is one 200 m-long, coherent block of granite intercalated with lavas at the top of Picacho Peak which represents one of the youngest stratigraphic levels in the entire mountain range. The granite boulders and conglomerate containing large granite clasts are mostly confined to the central part of the Picacho Peak area. This distribution suggests the interpretation that the current location of Picacho Peak corresponds with a topographically low area at the time of volcanism, possibly between stratovolcanoes to the northwest and southeast. This would explain the accumulation of granitic clasts from outside the volcanic field only in this part of the strike belt.

Proterozoic basement must have been exposed somewhere near the Picacho Mountains portion of the volcanic field, and the presence of blocks or rafts of granite up to 200 m long at the top of the volcanic sequence suggests that a major fault separated the area of volcanic accumulation from exposed crystalline basement. It seems logical to place this fault along the current structural boundary of the range which is now marked by a broad valley underlain by a major, gently southwest dipping detachment fault. This relationship is depicted in Figure 4.

Structure of the Picacho Peak area

A myriad of gently to steeply southwest-dipping normal faults dismember the volcanic rocks of the Picacho Peak area. Although fault strike varies considerably along the length of the range, slickenline orientation is consistently NE-SW (with similar azimuths to the pervasive, linear ductile fabrics in the crystalline rocks of the northern part of the range). Briscoe [1967] recognized some of these faults and the overall structural configuration of the range, but the faults shown on his cross-section (most are steeper than about 45°) do not dip gently enough to have accommodated 40° to 70° of tilting of the volcanic strata.

Three structural cross-sections transecting the Picacho Peak area were prepared (sections A-A', B-B' and C-C'), but only section B-B' includes enough structural data (in the form of dips of faults) to show any detail. At least two generations of faults are present; an older gently southwest-dipping set, and a younger

moderately to steeply dipping set. The offset of older faults is depicted somewhat diagrammatically on the cross-section, but is based on real relationships observed near the crest of the range.

Beyond the limits of the crest of the range, the structural geometry depicted on cross-section B-B' is conjectural. In particular, the major offset along the fault to the southwest of Picacho Peak depends largely on our correlation of the medial dacite lava unit (Td) from the crest of the range to a similar unit in the western foothills.

Potassium Metasomatism

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 depletes sodium, calcium, and magnesium. Table 2 summarizes chemical analyses of volcanic rocks from Shafiqullah et al. [1976], Brooks [1986], and Kerrich et al. [1989]. The predominant mineralogical effect of the metasomatism is replacement of plagioclase by very fine-grained adularia [Brooks, 1986]. The $K_2O:Na_2O$ ratio is a good indicator of the degree of metasomatism. The most extremely K-metasomatized rocks are from the andesite klippe on Hill 2437 in the southeastern Picacho Mountains ($K_2O:Na_2O$ 18-28). Rocks at the isolated inselberg north of the interstate (PP2 and UAKA 75-29) and at the hill adjacent to the Picacho Peak campground (PP-3, S3, S4) are all strongly K-metasomatized ($K_2O:Na_2O$ 12-23). Rocks from the top of Picacho Peak are moderately metasomatized ($K_2O:Na_2O$ 4-6). The degree of metasomatism decreases down section from the top of Picacho Peak to the southeast (samples PP-5, -6, and -7, and UAKA-27, -28 and -85). Correlation of the degree of metasomatism with stratigraphic position is at least as good as correlation with distance from the detachment fault. The detachment fault is interpreted to dip gently to the southwest (section B-B'), but depth to the fault is very poorly constrained. Sample locations progressively farther to the southwest may lie progressively higher above the detachment fault, but the actual distance from the fault is not constrained. The data available are consistent with interpretation that the metasomatism is spatially associated with the detachment fault, but the evidence is not compelling.

Geochronology of Volcanic Rocks

Six K-Ar isotopic age determinations have been reported from volcanic rocks in the map area, along with one zircon fission-track date and one $^{40}Ar/^{39}Ar$ plateau age (Table 1, Figure 5). Six of these dates, spanning the entire exposed section, cluster between 22.1 and 22.6 Ma, and all of these overlap within error. The fission track date and one K-Ar whole rock date are from an isolated hill between the Picacho Mountains and Picacho Peak (SW¼ sec. 2, T. 9 S. R. 9 E.), and these dates are younger than other dates from the area. The $^{40}Ar/^{39}Ar$ plateau age [Brooks and Snee, 1996] from the same sample as the zircon fission-track date is 22.3 ± 0.1 Ma, concordant with the other K-Ar dates. Brooks and Snee [1996] interpreted their pla-

teau age to indicate the time of cessation of hydrothermal circulation that caused potassium metasomatism. The fact that many of the other dates from Picacho Peak (three whole-rock K-Ar and one hornblende K-Ar date) are concordant with the $^{40}\text{Ar}/^{39}\text{Ar}$ plateau age indicates that all of these dates only provide a younger age limit for the time of eruption of the volcanic rocks that form Picacho Peak at about 22.3 Ma. If the hydrothermal circulation and K-metasomatism accompanied detachment faulting (as seems likely), these dates suggest that detachment faulting was underway at this time [Brooks and Snee, 1996].

GEOLOGY OF CRYSTALLINE ROCKS OF THE PICACHO MOUNTAINS

Fabric in gneissic granitoids of the Picacho Mountains

The texturally variable granitic rocks that form most of the southern Picacho Mountains contain a variety of foliation-forming features that mostly appear to be related to deformation in a magmatic state. These include strongly flattened enclaves and vague to obvious compositional banding defined by darker layers slightly enriched in biotite. The compositional banding is curvilinear. Aplite and pegmatite dikes are common in the gneissic granitoid and these cut the compositional banding.

Small bodies of coarse-grained biotite granite form lenses that are concordant with the compositional banding. Thin, fine-grained biotite-rich bands were observed to cut and offset the boundaries of these lenses at a low angle to the compositional banding; these may represent high-temperature shear zones. Similar schlieren-like shear zones cut and are cut by aplite-pegmatite dikes.

Incipient mylonitic fabric is defined by alignment of flattened quartz grains and recrystallized(?) biotite aggregates. This fabric is referred to as weak protomylonite fabric. Coarse-grained granite inclusions in the Gold Bell mine area contain weak protomylonite fabric that is cut by non-foliated aplite dikes. The weak protomylonite fabric is sometimes observed to intersect vague compositional banding in this area at a low angle. In many cases, the orientation of neither fabric can be determined accurately enough to verify cross-cutting relationships, or even whether the fabrics are concordant or discordant. The mylonitic fabric is more strongly developed in scattered shear zones cutting the gneissic granitoid. These shear zones cut thin very fine-grained diorite lenses and aplite dikes in the granitoid.

In the southwestern part of the Picacho Mountains, mafic dikes (Tdm) are weakly cleaved. Weak schistosity in the dikes is defined by recrystallized biotite. The fabric in the dikes is slightly discordant to the weak protomylonite fabric in host Picacho Mountains Granite. Some cleaved dikes contain thin mylonitic quartz veins. Spatial association of these fabrics suggest that cleavage in dikes is cogenetic with the weak protomylonite fabric.

In most places, the felsite dikes (Tdf) cut the vague compositional banding and mylonitic fabrics. North of Newman Peak on the range crest, southwest-dipping mylonitic fabric is associated with some dikes, as if the dikes localized ductile strain, and in these areas this associated mylonitic fabric is discordant to regional, northeast-dipping mylonitic fabric, as if orientation of dike localized shear strain in a different direction than the regional strain (this relationship seen clearly about 1.5 mi. north of Newman Peak, just east of the center of the east edge of section 9, at the base of the mountain slope; unsurveyed section 10; T. 8 S., R. 9 E.).

Relationships between Picacho Mountains Granite (TKpm) and aphyric rhyolite dikes (Tdf) on the hill at the east edge of the range along the boundary between sections 24 and 25, T. 8 S., R. 9 E. indicate that the rhyolite was intruded during development of the mylonitic fabric in the granite. These relationships are similar to those described by Rehrig [1986] and Kerrich and Rehrig [1987] on the hill southwest of this location where the detachment fault is exposed (see section on detachment fault below), and they also concluded that rhyolite intrusion accompanied mylonitization. Rhyolite dikes can be observed intruding across mylonite zones at a high angle, but locally the dikes are cut by mylonite zones, and the rhyolite is parallel to the mylonite zone. It is difficult to determine the nature of deformation in rhyolite dikes that parallel mylonite zones because of their fine grain size. Some of the dikes have a lamination that resembles both foliation in ultramylonite and flow banding in rhyolite. Dark, intermediate composition, aphyric, very fine-grained dikes (Tdi?) on this hill are deformed by the mylonitic foliation and cut by the aphyric rhyolite dikes. These older dikes cut the vague compositional banding that is locally preserved in Picacho Mountains Granite.

Sharp intrusive contact with older units shows that the Barnett Well Granite (Tg) was emplaced near the end of ductile deformation. It intrudes across the vague compositional banding in Picacho Mountains Granite (TKpm), and intrudes across well developed mylonitic foliation in the hornblende-K-feldspar granitoid (TXg) unit at the eastern edge of the map area (east-center sec. 25, T. 8 S., R. 9 E.).

Geochronology of Crystalline Rocks

Johnson [1981a, b] reported three K-Ar dates, and Shafiqullah et al. [1980] reported one other date from rock samples in the northern half of the Picacho Mountains. The three dates in Johnson [1981a, b] are located on his map, but analytical data and latitude-longitude coordinates for sample locations are not reported. Damon et al. [1996] report analytical data for two of these three dates, and a muscovite date that may be equivalent to the other date mentioned by Johnson [1981a, b]. The latitude and longitude for sample locations in Damon et al. [1996] are partially inconsistent with the plotted locations on Johnson's maps. Some corrected information, including latitude and longitude as measured from Johnson's map follows below. The locations are shown on Figure 6.

(1) UAKA 76-17, biotite(?), 23.57 ± 0.5 Ma (plotted on Plate 1 of this report).

Sample number 1 from "Granite gneiss" of Johnson [1981a, b]; Picacho Mountains Granite of this report. Sample is called "Newman Peak granite" in Reynolds et al. [1986] (their #624). Damon et al. [1996] report a muscovite date of 24.09 ± 0.5 Ma from a very nearby latitude-longitude coordinate, in what they called "Picacho Mountains Granite", and attribute the sample to Johnson [1981a]; they report a field sample number of PM 303 for this rock. Johnson only shows one sample location in this area. The biotite reported by Reynolds et al. [1986] is based on a personal communication to Johnson from P. E. Damon in 1975, mentioned in Johnson [1981a] (page 19). The data reported in Damon et al. [1996] for a muscovite analysis may represent a separate analysis (in which case the analytical data for the biotite analysis were not in P.E. Damon's files when the 1996 report was compiled and are lost). Alternatively Johnson may have made an error in reporting that the date P.E. Damon told him about was from biotite. In this case, there is only one (probably muscovite) analysis and the difference in reported ages is due to different data reduction procedures (new decay constants?).

Correct location: $32^{\circ} 45.36' N.$, $111^{\circ} 25.37' W.$ Picacho Reservoir 7 ½' quadrangle.

(2) UAKA 76-18, biotite, 24.57 ± 0.54 Ma.

Picacho Reservoir Hornblende Granitoid of this report. Sample number 2 of Johnson [1981a, b], from "Hornblende monzogranite to quartz monzonite." Not reported by Reynolds et al. [1986]; analytical data reported in Damon et al. [1996]; they name the sample "Picacho Mountains quartz monzonite". We propose the name Picacho Reservoir Hornblende Granitoid for this unit (see below). May represent a cooling age in a Laramide granitoid or a near crystallization age if the granitoid is Tertiary. The lithology of the body is more consistent regionally with a Laramide age.

Correct location: $32^{\circ} 49.73' N.$, $111^{\circ} 22.19' W.$ Picacho Reservoir SE 7 ½' quadrangle.

(3) UAKA 76-19, biotite, 65.08 ± 1.4 Ma.

Sample number 3 of Johnson [1981a], named "Section 29 granite" by him and by Reynolds et al. [1986] (sample #1191), but named "Granite" by Johnson [1981b]. The sample is called "Picacho Mountains quartz monzonite" in Damon et al. [1996], where the analytical data for the date are published. Use of the same name for both UAKA 76-19 and 76-18, which were mapped as different units by Johnson [1981a], is clearly inconsistent. We propose the name Clemans Tank Diorite for this rock unit (see below). Location is outside of this map area in the northernmost Picacho Mountains. Sample location on Johnson's [1981a] map falls in small

Based on our mapping, the name **Picacho Mountains Granite** is restricted to massive to gneissic, biotite or muscovite-biotite granite that forms much of the southern Picacho Mountains below an elevation of 3600 feet. The type locality is exposures in a cut along the CAP canal in the west-central part of the Picacho Mountains (NW¼NE¼NE¼ sec. 9, T. 8 S., R. 9 E.). The Picacho Mountains Granite is interpreted to be older than the non-foliated Picacho Reservoir Hornblende Granitoid (see below; unit TKgh on this map; 'hornblende monzogranite to quartz monzonite' of Johnson [1981a]). The Picacho Reservoir Hornblende Granitoid bounds the Picacho Mountains Granite on the north, and the Barnett Well Granite (defined below) forms the southeastern boundary.

The name **Newman Peak Leucogranite** is applied to leucocratic muscovite granite and pegmatite that crops out along the crest of the Picacho Mountains. The type area is outcrops on Newman Peak. Subhorizontal sheet-like bodies of gneiss (TXgn) and Pinal Schist (Xp) separates the Newman Peak Leucogranite from the Picacho Mountains Granite in some areas.

The name **Barnett Well Granite** is applied to fine-grained biotite granite in the southeastern Picacho Mountains. Barnett Well is the closest named location to the granite outcrops, and is located along McClellan Wash just off the east edge of the map area. The type locality is along a major wash about 2 miles (3.2 km) WNW of Barnett Well on the Newman Peak 7.5' USGS Quadrangle. The location is the NE ¼ Sec 26 (unsurveyed), T. 8 S., R. 9 E., in the vicinity of UTM 3618100 N, 464300E.

We propose the name **Picacho Reservoir Hornblende Granitoid** for the lithologically variable granitic rocks that underlie the Picacho Mountains between the North Star Mine and outcrop of the Picacho Mountains Granite. This unit is the 'hornblende monzogranite to quartz monzonite' (unit 'H') of Johnson [1981a], who mapped its extent and described its lithology. Picacho Reservoir is located about 6 miles east of the outcrop of the granite, but the outcrop area occupies the central part of the boundary between the Picacho Reservoir and Picacho Reservoir SE 7 ½' quadrangles, and other suitable named geographic features are absent in the area. The type area is the south side of Hill 2212, in SW¼SW¼NE¼ sec. 12, T. 7 S., R. 9 E., on the Picacho Reservoir SE 7 ½' quadrangle. A sample (UAKA 76-18 [Damon et al., 1996], sample 2 [Johnson, 1981a, b]) from this area yielded a biotite K-Ar date of 25.1 ± 0.5 Ma [Damon et al., 1996].

Other nomenclature used for rocks in the Picacho Mountains outside the map area

The name **North Star Granite** was applied by Johnson [1981a] to outcrops of his unit 'M' in the vicinity of the North Star Mine (NW¼SE¼ sec. 8, T. 7 S. R. 10 E.). His mapping and description indicate that this is probably a valid usage for a small granitoid body between the Picacho Reservoir Hornblende Granitoid (TKgh of this report, 'H' of Johnson [1981a]) and Proterozoic rocks to the north. Usage of the name North Star granodiorite by Shafiqullah et al. [1980] for rocks about 2 miles south of the North Star Mine

(sample UAKA 73-64, assuming latitude-longitude coordinates for sample location are correct), mapped as 'fine-grained intermediate igneous rock' (unit 'F') or 'hornblende monzogranite' (unit 'H') by Johnson [1981a], is inconsistent with the definition of this unit by Johnson [1981a].

The name **Section 29 granite** was applied by Johnson [1981a] to a small (~1000 m²) outcrop of granite (his unit 'LG') in SW¼SE¼ sec. 29, T. 6 S., R. 10 E. This granite is associated with, and is apparently genetically related to a small diorite body that intrudes Proterozoic granitic rocks, and was interpreted to be Laramide in age [Johnson, 1981a]. Because section 29 is not a named geographic feature, it is not appropriate for use as a formal rock unit name and should be discontinued. We propose the name **Clemans Tank Diorite** for this body of diorite and minor associated granite located in the south part of sec. 29, T. 6 S., R. 10 E. at the northern end of the Picacho Mountains. Clemans Tank is located on the Cactus Forest, AZ 7 ½' quadrangle, in the northern part of sec. 29, about 0.5 mile north of the outcrop of the pluton. The type area for the Clemans Tank Diorite is Hill 1925, NW¼SW¼SE¼ sec. 29, T. 6 S., R. 10 E., on the Picacho Reservoir SE 7 ½' quadrangle. The unit includes rocks mapped as 'DI' and 'LG' by Johnson [1981a].

PICACHO DETACHMENT FAULT

Volcanic rocks of Picacho Peak and the crystalline rocks that form the main body of the Picacho Mountains are separated by a southwest-dipping low-angle normal fault named the Picacho Mountains detachment fault (named modified from Picacho Detachment fault of Rehrig [1986] and Brooks [1986] to avoid confusion with low-angle normal faults in the vicinity of Picacho Peak in southeastern California). This fault is exposed in only one place in the map area, at the top of hill 2437 near the center of section 36, T. 8 S., R. 9 E. (referred to below as 'Hill 2437'). This hill has been described in several papers [Rehrig, 1982, 1986; Kerrich and Rehrig, 1987].

A layered sequence of crystalline rocks below the detachment fault consists of the following, from the base of the hill up to the fault: (1) Rocks at the base of the hill, shown as mylonitic Oracle granite on the cross sections in Rehrig [1986] and Kerrich and Rehrig [1987], are here mapped as hornblende-K-feldspar granitoid (TXg). The abundance of hornblende and lack of large (3-4 cm) K-feldspar phenocrysts are inconsistent with correlation of this rock with Oracle granite. We did not observe felsic dikes intruding the hornblende-K-feldspar granitoid (TXg) on this hill as shown by Rehrig [1986] and Kerrich and Rehrig [1987], but similar relationships are exposed on the hill at the east edge of the range along the boundary between sections 24 and 25, T. 8 S., R. 9 E. (see description in section on fabric in gneissic granitoids, above). This granitoid is overprinted by a well-lineated mylonitic fabric and is progressively more strongly brecciated and silicified structurally upward toward an intrusive contact with a (2) structurally overlying,

subhorizontal sheet-like mafic hypabyssal sill (map unit Tm). This contact was interpreted as the lower of two detachment faults by Rehrig [1986] and Kerrich and Rehrig [1987]. We observed an incipient microbreccia ledge on the north side of the hill along this contact. Underlying rocks of map unit TXg are shattered and silicified as if affected by typical detachment-fault footwall brecciation and alteration before sill emplacement. Some mylonitization affected the mafic sill after it was intruded, mostly near its base, and the sill is inferred to be broadly syn-mylonitic and therefore early Miocene. The hypabyssal character of the mafic intrusive rock is consistent with synkinematic intrusion because host rocks had ascended to shallow crustal depths and temperatures by the time the mafic intrusion was emplaced, presumably as a consequence of Tertiary tectonic denudation. The other 90% of the contact at the base of the sill is commonly obscured by strong fracturing but appears to be intrusive. Screens and inclusions of underlying granitoid are present in the mafic sill on the ridge northwest of the hill top. The mafic sill intrudes (3) structurally overlying medium to coarse grained granite (map unit YXg) that is typically crushed and propylitically altered. Mylonitic foliation is lacking in this granite. It apparently represents a sliver of crystalline rock in the hanging wall of the major detachment [Rehrig, 1986; Kerrich and Rehrig, 1987] and is probably representative of the granitic rock that the volcanic rocks of Picacho Peak were deposited upon. This rock is similar in gross character to the granite that underlies volcanic rocks in the Samaniego Hills south of Picacho Peak [Ferguson et al., 1999a]. The crushed granite is structurally overlain by a subhorizontal fault (the upper detachment of Rehrig [1986]), and near this fault the granite is especially strongly affected by silicification, iron oxide staining, and chloritic alteration. Above the upper detachment fault is (4) a 2-3 m thick subhorizontal sliver of massive hydrothermal carbonate with minor barite (unit Thc). This carbonate grades up into (5) shattered aphyric andesite (unit Tau?), through calcite-cemented breccia, to calcite-veined andesite to massive, highly fractured andesite. Only a 3-5 m thickness of andesite is preserved at the hill top. This rock is highly potassium-metasomatized, and contains about 12% K₂O, with a K₂O:Na₂O ratio of 18-28 (Table 2, samples PP-1, S1, and K1-3).

Detachment faulting and alteration

A genetic relationship has been proposed between detachment faulting, K-metasomatism, and base-metal mineralization [Roddy et al, 1988; Hollocher et al., 1994]. This model suggests that the exhumation of relatively hot, mid-crustal rocks along large-displacement low-angle normal faults, in concert with coeval magmatic activity, produced elevated geothermal gradients to drive a large scale hydrothermal system. Sedimentary basins formed during the normal faulting accumulated thick sections of elastic rocks. Intense faulting in the hanging wall of the detachment fault provided abundant zones of permeability to channel fluid flow. Potassium metasomatism of hanging-wall volcanic and sedimentary rocks by basin brines led to enrichment of the fluids in manganese and base metals. The metal-enriched basin brines were then convec-

tively drawn into the detachment zone, where changes in temperature and chemical environment lead to mineral deposition. Metallic mineralization is consistently superimposed on K-metasomatized rock, indicating that the two events occurred in different environments [Hollocher et al. 1994]. K-metasomatism may have liberated the metals that were subsequently deposited in the many small deposits in the Picacho Peak area. These deposits have yielded 2400 lbs. of copper and 100 oz. of silver [Keith et al., 1983].

Kerrick and Rehrig [1987] reported oxygen isotopic data that constrain the fluid environment in rocks adjacent to the detachment fault. Oxygen isotopic fractionation inferred from samples of hornblende-K-feldspar granitoid (TXg) beneath the detachment fault zone indicate near-magmatic conditions ($\delta^{18}\text{O} \sim 8$ per mil), with calculated temperature of fluid-rock equilibration between 550 and 580°C. The whole-rock $\delta^{18}\text{O}$ values from this sample is typical of plutonic granitic rocks. These oxygen isotopic data indicate that mylonitic deformation in these rocks occurred at low water:rock ratios. Propylitically altered, shattered granite (unit YXg) between the lower and upper detachments is relatively enriched in ^{18}O (~ 12 per mil), and oxygen isotopic fractionations indicate that the temperature of fluids during alteration was 260-310°C. Hydrothermal quartz in veins is isotopically in compliance with quartz in the granite, indicating that both have equilibrated with a common aqueous reservoir. Hematite in hematite-calcite- MnO_x veinlets that cut the shattered granite is not in equilibrium with magnetite in the granite. This, along with the contrast in mineralogy and oxidation state of the veinlets, indicates they were deposited by a different fluid. K-metasomatized andesite at the top of the hill is characterized by extreme but variable ^{18}O enrichment (~ 15 per mil). From this data, Kerrich and Rehrig [1987] interpreted that two distinct hydrologic systems were operating in the vicinity of the detachment fault: 1) a high temperature rock-equilibrated reservoir related to the propylitic alteration in granite between the upper and lower detachment faults; and 2) a cooler, oxidizing reservoir related to K-metasomatism in the volcanic rocks above the upper detachment.

The superposition of rocks altered in different fluid environments suggests that displacement on the upper detachment fault transported the K-metasomatized andesites structurally downward onto the highly fractured, propylitically altered granitoid (unit YXg). Formation of late-stage calcite, hematite, and barite veins may have resulted from flooding by meteoric water as the hydrothermal system collapsed [Roddy et al., 1988]. The structural and geochemical data available are consistent with the model for the hydrothermal system adjacent to the detachment fault proposed by Roddy et al. [1988] and Hollocher et al. [1994].

MINERALIZATION

Base and precious metal production from the southern Picacho Mountains and Picacho Peak has been very small. Mineralization in both areas appears to be related to Tertiary magmatism and detachment fault-

ing. Aside from the weak vein mineralization associated with Tertiary igneous rocks, the mineral potential of the southern Picacho Mountains is considered quite low. The Picacho Mountains Granite was probably in the middle crust in Laramide time, too deep to have benefited from Laramide mineralizing events. Similar two-mica granites in the region are typically barren. Copper mineralization in the volcanic rocks of Picacho Peak indicates the presence of copper in the area, and the Picacho Mountains certainly lie in the heart of porphyry copper elephant country. Perhaps the best mineral potential in the area is the location of dismembered pieces of a porphyry system in shallow basin-margin setting, similar to the Florence, Sacaton, or Santa Cruz deposits. Granitic rocks are inferred to underlie Tertiary volcanic rocks in the hanging wall of the Picacho Mountains detachment fault, and these may host Laramide mineralization.

Locations discussed in the text are located on the geologic map plate and labeled with the "M#" label included in this list.

Picacho Peak area

- M1) Near the southwestern edge of the map area, near the hill named "Picacho," several small prospects and local areas of mineralization contain fracture-filling chrysocolla and less common iron oxide stain and possible secondary silica.
- M2) About 300 m southeast of Picacho Peak summit (SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 14, T. 9 S., R. 9 E.) a mine dump and adit contain crushed andesite with fracture-filling malachite(?), chrysocolla, and iron oxides. Prospect just northwest of this adit is caved but dump material is similar except some rocks have been entirely altered to iron oxides with fracture filling malachite(?) and chrysocolla and local calcite.
- M3) Barite vein, oriented N090E/76S. Thin discontinuous zones of barite cement breccia along a fracture zone.
- M4) Prospect pit on fault offsetting Tertiary volcanic strata. Trace copper oxides in silica and red hematite along a planar fault zone. Mineralized vein about 15 cm thick, oriented 150/54SW.
- M5) Vesicular plagioclase-pyroxene andesite (unit Tap) in this area is strongly altered. Pyroxene to brown clay(?), plagioclase to white clay(?), abundant secondary epidote and calcite. Epidote locally forms 20-30% of rock.
- M6) Prospect pit in sheared crystal rich andesite (Tap). Sheared zone/vein oriented 115/50SW, appears to be major normal fault placing Tau against Tap. Minor malachite along fractures.
- M7) Mines and prospects, NE $\frac{1}{4}$ sec. 16, T. 9 S., R. 9 E. Abundant copper oxide mineralization on northwest-trending, southwest-dipping brittle shears/fractures, in dacite unit (Td). Copper minerals include chrysocolla and malachite. Plagioclase in dacite adjacent to mineralized fractures is

chalky, and pyroxene is altered to drab green or dark brown clay(?); biotite is copper-colored. Little or no hydrothermal silica observed. Some brown calcite present in veins with copper minerals. One mine tunnel about 50' long, oriented N000E in highly fractured dacite with irregular bleached zones, highly variable shear orientation, and abundant iron staining on fractures. Two other planar zones of strong bleaching with minor copper mineralization were observed, oriented N008/30E and 286/50N.

- M8) A series of prospect pits in dacite (Td), near the contact with andesite intrusion (Tai). Red brown to orange iron staining and sparse green copper oxide mineralization on steep northwest-trending fractures. Minor fractures have widely varying orientation. Prospects aligned along N140E trend, parallel to contact with andesite intrusion but about 20 meters away from the contact.
- M9) On outlier hill north of Picacho Peak campground (NE¼ sec. 9, T. 9 S., R. 9 E.). Prospect pit on crest of hill, about 20 m wide, 10-15 m deep excavation forms natural bridge. Prospect is in zone of silica-barite-brown carbonate veins. Zone is 1-2 m wide, and consists of 5-10 1-2 cm thick veins and 1 or 2 10 cm thick veins with barite crystals and cryptocrystalline quartz fill. Veins oriented N105E/60S. Trace malachite present.
- M10) Prospect pit about 2 m deep, with copper oxide mineralization and orange iron oxide staining in highly fractured andesite fragmental rock. Quartz and copper mineralization fill vesicles and occur along fractures. Rock is shot through with irregular bleached zones with no apparent systematic orientation or controlling structure.

Picacho Mountains

Mineralization in the southeastern Picacho Mountains is associated with northwest-trending joints, mineralized shears, felsic dikes, and quartz veins. A northwest-trending, near vertical joint set overprints the northern part of the Barnett Well Granite unit (Tg), especially in a zone of silicification and iron staining at the northwest end of the ridge in NW¼ sec. 25, T. 8 S., R. 9 E. Felsic dikes appear to emanate from the Barnett Well Granite, also trending northwest. Fractures trending 120-140 typically have more silica fill and iron staining along them than other prominent fracture sets.

- M11) Prospect east of Gold Bell mine (NE¼NE¼NW, sec. 24, T. 8 S., R. 9 E.). Prospect east of Gold Bell mine contains milky quartz vein with spots of green copper minerals and brown iron minerals that could be relict sulfides (no clear pseudomorphs). Northwest-striking shear zones in and near the prospect have hematite coating on lineated fracture surface. The mineralized fractures dip moderately NE to steeply SW. Also present in one prospect is crushed quartz with cemented by silica+hematite; drusy quartz fills open space in the shattered quartz. Some fragments of the

hematite + quartz breccia are cut by striated fault surfaces. Granite country rock is weakly silicified near the fractures, and biotite is slightly chloritized. See very little bleaching of rock typical of supergene acid leaching by sulfide oxidation. Chrysocolla occurs as stringers within quartz.

Hematite mostly coats fractures.

- M12) Gold Bell Mine (NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 24, T. 8 S., R. 9 E.). Shaft about 30 m (100 feet) deep, estimate dump volume to be about 5000 cubic meters. Most of the rock on the dump is non-altered biotite granite with very weak foliation. The shaft is on strike with several steeply dipping, northwest-trending quartz veins on the hill to the north. Shattered milky quartz along these veins contains red-brown hematite and sparse green secondary copper mineralization. The mineralized zone consists of a series of en echelon quartz veins that trend slightly more northerly than the mineralized zone. This pattern suggests vein formation by dilation along a northwest-trending zone of right shear.
- M13) Vein oriented 000/65 (right hand rule), consists of quartz, and shattered quartz with silica-hematite cement. Trace of copper oxide mineralization (chrysocolla, malachite?) on fractures and between clasts in breccia. Strike length of about 10 m exposed in prospect pit.
- M14) About 1 mile west-southwest of Newman Peak, a shaft and some workings are developed on quartz veins up to 2 m thick that are variably fractured and contain abundant chrysocolla(?), yellowish goethite(?), and black iron+manganese oxides. Vein quartz is locally affected by mylonitic fabric.
- M15) In basin SE of Newman Peak (5900' on bearing 130 from peak). Mine tunnel about 30 m long (100 feet) in Barnett Well Granite (Tg) near contact with Picacho Mountains Granite (TKpm). Steeply dipping northwest-trending fractures at portal have abundant red brown to black hematite. Estimated dump volume is about 2000 cubic meters. Rock on dump is all Barnett Well Granite with hematite on fractures. Biotite in the rock between the fractures is still fresh, and plagioclase also appears fresh. Rare hematite boxwork after pyrite(?) in thickest hematite fracture fillings. See no secondary copper mineralization. Sparse silica is present in joint filling.
- M16) About 500 feet NE of location M15. NNE-trending fault offsets intrusive contact of Barnett Well Granite (Tg) into Picacho Mountains Granite. Strong silica-hematite alteration with sparse chrysocolla(?) within 1 m of the fault between the granites. Fault zone is silicified.

Acknowledgements. This study was done as part of STATEMAP (a component of the National Geologic Mapping Act), and was part of a mapping program jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP Program Contract #98HQAG2064. Surficial geologic mapping was done by J. J. Field and G. Jackson, and was compiled on this map from previously released reports [Field and Pearthree, 1993; Jackson, 1990]. We thank Pete Corrao for assistance with map labeling and layout, and Larry Fellows for consistent support of geologic mapping.

DESCRIPTION OF ROCK UNITS

- Qs **Surficial deposits** (Holocene and Late Pleistocene) -- Undifferentiated sand, gravel, silt and clay.
- Qyd **Debris-flow deposits** (Holocene) -- Non-indurated, matrix poor to matrix rich, very coarse boulder gravel deposited by historical debris flows. Terminal lobes are heaps of boulders with no matrix. Levee and channel deposits are sandy gravel to boulder gravel. No desert varnish on clasts, and no soil developed on surfaces. Surface morphology reflects depositional events, which occurred sometime in the 1980's.
- Qtc **Talus and colluvium** (Holocene and Pleistocene) -- Non-consolidated talus and colluvium on hill slopes; mostly boulders and coarse gravel with very little soil development.
- Qy **Low terrace and alluvial fan deposits** (Holocene) -- Undifferentiated deposits equivalent to Qya and Qma
- Qy_{2f} **Fine-grained basin-fill deposits** (late Holocene) -- Non-indurated sediment consisting of sand and gravel in well defined channels on piedmont slope. In basin floor areas becomes finer grained and consists of fine to coarse sand, silt and some clay. Includes deposits mapped as Y2 by Jackson [1990] and Y2r by Field and Pearthree [1993].
- Qy_{2r} **Alluvium in major active channels and floodplains** (late Holocene) -- Non-indurated to weakly indurated silt to coarse sand with lenses of rounded gravel. Very little soil developed on surfaces. Outcrop areas may be subject to flooding. Includes outcrops mapped as Y2r and Y2rt by Field and Pearthree [1993] and one area mapped as Y1 by Jackson [1990].
- Qy₂ **Alluvium in active floodplains and fans** (late Holocene) -- Weakly indurated to non-indurated sand to boulder gravel, grading to sand and silt away from mountains. May experience flooding. Soil is not developed (Entisols). Surfaces typically not dissected, and preserve depositional morphology.
- Qy_{1f} **Fine-grained basin fill deposits** (late Holocene to middle Holocene) -- Fine-grained, non-indurated to poorly indurated deposits, with slight soil development (Camborthids), stage I carbonate morphology, and little or no desert varnish or pavement development. Surface on deposits is up to 4 m above active stream channels. Includes most deposits mapped as Y1 by Jackson [1990].
- Qy₁ **Alluvium on undissected terraces and alluvial fans** (middle Holocene to early Holocene) -- Weakly to moderately indurated sand and gravel. Generally finer grained than late Holocene

alluvium (Qya). Soil is weakly to moderately developed (Camborthids). Incipient desert varnish developed on surface clasts. Little or no desert pavement developed. Stream channels are incised less than 1 m.

- Qlyf **Fine-grained deposits** (Holocene and Late Pleistocene) -- Weakly indurated, fine-grained (<2 mm), well stratified sand and well rounded gravel. Soils typically contain argillic horizons (haplargid soils) and/or moderately developed (stage II) calcic horizons (calciorthid soils). Deposited by ancestral Santa Cruz River or other axial streams. Strongly alkaline in some areas. Includes deposits mapped as M2 by Jackson [1990].
- Ql **Alluvium on slightly dissected fans** (Late Pleistocene) -- Weakly indurated sand and gravel deposits, generally non-consolidated. Clasts range from sand to cobbles, and are significantly larger than in younger alluvial fan deposits. Soil is well developed with argillic and/or stage II+ calcic horizons. Desert pavement discontinuous and moderately developed. Desert varnish moderately developed. Surfaces are incised up to 2 m by active drainages. Includes deposits mapped as Mf2 by Jackson [1990] and M2 by Field and Pearthree [1993].
- Qlr **Fluvial deposits** (Late Pleistocene) -- Deposits of well stratified sand and well rounded gravel. Forms level surface 0.5 to 3 m above Qyr surfaces. Silty sand covers the surface in most places, but granule to pebble desert pavement is locally present. Soils are Haplargids, with stage II to III calcic horizons. Generally not prone to flooding.
- Qm **Alluvium on relict, moderately dissected fans** (Middle Pleistocene) -- Weakly indurated sand and gravel deposits, generally non-consolidated. Clasts range from sand to cobbles, and are significantly larger than in Holocene alluvial fan deposits. Deposits are poorly sorted, with angular to subangular clasts. Deposits resemble unit Qma2. Soils have petrocalcic horizons, and an argillic horizon may be present. Surface clasts have well developed desert varnish. Desert pavement is well developed, but discontinuous. Stream channels are incised up to 3 m. Includes deposits mapped as Mf1 by Jackson [1990] and M1 by Field and Pearthree [1993].
- Qmf **Fine-grained basin fill** (Middle Pleistocene) -- Fine-grained deposits (<2mm), soils commonly have petrocalcic (stage III-IV) horizons and silica-cemented duripans; argillic horizons may or may not be preserved. Virtually all outcrop of this surface is under cultivation, obliterating any altitudinal difference between this and other basin terrace surfaces.
- Qo **Alluvium on old, dissected fans** (Early Pleistocene) -- Moderately indurated sand and gravel to sandy conglomerate. Soil mostly removed by erosion, and petrocalcic horizon crops out at sur-

face. Pieces of caliche broken from the petrocalcic horizon outcrops litter the surface locally. Desert pavement well developed, but discontinuous. Stream channels incised up to 8 m.

- The **Hydrothermal carbonate** (Miocene or Oligocene) -- Lens of carbonate along detachment fault in southeastern Picacho Mountains. Rock is tan weathering, white on fresh surfaces, variably and locally highly brecciated. Some of this carbonate is clearly a vein complex that encloses lenses of overlying Tertiary andesite. In other areas the carbonate has fine layering defined by variations in silica(?) content, color, and resistance to weathering; this layered carbonate is suggestive of a sedimentary protolith. Calcite spar and manganiferous calcite are notably absent. Carbonate permeates fault zone between altered Tertiary volcanic rocks and crushed, chloritized granite (YXg).
- Tvs **Volcanic lithic sandstones** and bedded pyroclastic rocks (Miocene or Oligocene) -- A wide variety of bedded clastic rocks are included in this unit, from thin-bedded, fine-grained tuff to coarse-grained, massive tuff breccia and medium-grained volcanoclastic sandstone and cobble-boulder conglomerate. The conglomerates locally contain some granitoid clasts. The unit is interbedded principally with lava flows of the crystal poor andesite unit (Tau).
- Tau **Crystal-poor andesite** (Early Miocene or Late Oligocene) -- Crystal-poor, pyroxene-porphyritic lavas of probable trachyte, basaltic andesite, or andesitic composition characterized by pyroxene-porphyritic texture and finer grained sparse plagioclase phenocrysts. Brown iron oxide(?) minerals typically replace sparse 1-mm pyroxene phenocrysts. Locally this unit contains vesicles or amygdules, fresh pyroxene, or abundant plagioclase microlites. These lavas occur at the top of the volcanic sequence in a very thick succession of amalgamated flows or flows with thin intervening volcanoclastic or pyroclastic intervals (Tvs). Flows with similar phenocryst mineralogy are present at the base of the section in the southeast where they are mapped as older andesite (Tao).

An isolated hill between Picacho Peak and the Picacho Mountains is probably composed of this unit, but extreme alteration has obscured phenocrysts and it is uncertain if this unit actually is part of the crystal-rich andesite (map unit Tac). A sample from this hill analyzed by Brooks (1986) contained 11.0% K₂O and only 0.8% Na₂O (K₂O/Na₂O = 13.7), which indicates severe potassium metasomatism.

The small klippe of andesite in the southeastern Picacho Mountains, possibly also composed of this map unit, is the most severely K-metasomatized, with 11.1% K₂O and only 0.4% Na₂O (K₂O/Na₂O = 27.7; Brooks, 1986; see also Kerrich and Rehrig [1987]). The contact on the bitite dacite unit (Td) is sharp and commonly marked by thin sequences of clastic rocks.

- Tai **Intrusive andesite** (Early Miocene or Late Oligocene) -- Very-fine grained crystal-poor intrusive andesite that strongly resembles crystal-poor andesite (Tau). Forms small, irregular intrusions in dacite (Td) and crystal-rich andesite (Tap).
- Td **Biotite dacite** (Early Miocene or Late Oligocene) -- Crystal-rich, biotite and/or hornblende phyric dacitic lava. The unit consists of amalgamated massive flows and flow breccia that thin from NW to SE into a sequence of lava breccia, tuff breccia, and coarse-grained volcanoclastic sedimentary rocks in the vicinity of Picacho Peak (unit Tdx). Plagioclase commonly altered to chalky white, and mafic phenocrysts commonly replaced by brown iron oxide(?) minerals. Underlain by and grades laterally into dacitic volcanoclastic rocks (unit Tdx).
- Tdx **Dacitic volcanoclastic rocks** (Early Miocene or Late Oligocene) -- A heterogeneous assemblage of volcanic-lithic sandstone and conglomerate and tuff. Clasts are mostly dacite resembling unit Td, but also include a variety of andesitic lavas. Generally massive to very crudely bedded. Very light gray pumiceous clasts with irregular boundaries are characteristic of this unit. Underlies the dacite lava map unit (Td) in the northwest, and pinches out to the southeast beyond the eastern limit of the dacite map unit. One or two crystal-rich andesite lava flows are interbedded in the basal part of the unit. The lower contact is placed where crystal-rich lava flows become predominant.
- Tap **Crystal-rich andesite** (Early Miocene or Late Oligocene) -- A complex sequence of crystal-poor to crystal-rich lava flows of probable andesitic composition interbedded with thin volcanoclastic and pyroclastic units or in amalgamated sequences. In general, the flows become more crystal-rich and coarser grained upwards. The flows are characterized by abundant 1-2 mm diameter plagioclase phenocrysts in varying amounts. Pyroxene phenocrysts are present in widely varying amounts and are not diagnostic for identifying this unit. In contrast to the crystal-poor andesite (Tau), which weathers brown and commonly contains pyroxene, the crystal-rich andesite weathers dark gray and rarely contains pyroxene. Contact with plagioclase-porphyrific andesite breccia (unit Tax) at the northwestern end of the outcrop belt appears to be a buttress unconformity, but at the southeast end of the outcrop belt the two units appear concordant.
- Tax **Plagioclase-porphyrific andesite breccia** (Early Miocene or Late Oligocene) -- A heterogeneous succession of crystal-poor to moderately crystal-rich andesitic lava breccia, tuff breccia and probable epiclastic breccia interbedded locally with thin, crystal-poor, plagioclase-phyric lava flows. The most common clasts in the breccia at the northwestern end of the outcrop belt are andesite containing ~5% equant, white plagioclase phenocrysts in a very fine-grained ground-

mass. At the southeast end of the outcrop belt, this breccia unit contains angular boulders of andesite or dacite with hornblende phenocrysts up to 1 cm long. Neither of these clast types match any of the exposed lava flows in the Picacho Peak volcanic sequence. The breccia includes several interbedded andesitic lava flows. At least two of these have a distinctive, coarse-grained, trachytic texture defined by aligned plagioclase lathes, and sparse pyroxene phenocrysts, and are shown separately as unit Tat.

Tat **Crystal-rich trachytic texture andesite** (Early Miocene or Late Oligocene) -- Gray, plagioclase- and pyroxene-phyric andesite lava with a distinctive trachytic texture defined by aligned plagioclase lathes. Rock consists of about 50% plagioclase in 2-3 mm long lathes. This rock forms at least two lava flows; one at the base, and the other at the top of the andesite breccia unit (Tax).

Tao **Older andesite** (Early Miocene or Late Oligocene) -- Mafic lavas of probable trachyte, basaltic andesite, or andesitic composition characterized by pyroxene-porphyritic texture and finer grained, sparse plagioclase phenocrysts. These lavas are nearly identical to a sequence of flows which occur at the top of the volcanic sequence (Tau), but the older andesite is generally slightly more crystal-rich, and it is interbedded with nonvolcaniclastic conglomerate (Tc).

Tc **Arkosic sandstone and conglomerate** (Early Miocene or Late Oligocene) -- Medium- to thick-bedded, pebble- to boulder conglomerate and pebbly sandstone that weathers to a purple gray color and forms rounded outcrops. Clasts include Proterozoic(?) phyllite and mica schist, coarse-grained homogranular pink biotite granitoid, very fine-grained homogranular diorite, and Dripping Spring(?) quartzite. Rare clast types include Tertiary(?) andesite, Proterozoic(?) quartz-feldspar-mica gneiss, Mesozoic(?) lithic arkose, and Barnes(?) conglomerate. The clasts are subrounded to subangular, and highly nonspherical. Granite clasts up to 30 cm diameter and quartzite clasts up to 1 m were observed. Imbricated phyllite clasts suggest transport towards the WSW. Some thick, matrix-supported beds in conglomerate may represent debris flows. The unit consists of at least two separate sequences interbedded with the older andesite unit (Tao) at the base of the Picacho Peak volcanic succession in the extreme SE corner of the map area. This unit was called Wymola conglomerate by Briscoe [1967]. Conglomerate is entrained in base of overlying andesite lava flow, indicating that it was not consolidated when the andesite was erupted. The base of the conglomerate is not exposed.

Tdf **Felsic dikes** (Miocene to Oligocene) -- Aphyric to crystal poor, light-colored dikes and irregular pods. Mostly cream to light-gray colored. Porphyritic dikes contain up to several percent biotite

up to 1 mm diameter, and 5-20% quartz, plagioclase and K-feldspar crystals about 1 mm in diameter. Groundmass is aphanitic. Locally these grade into very fine-grained holocrystalline granite dikes. These dikes intrude the Picacho Mountains Granite (TKpm) and the Barnett Well Granite (Tg). Felsic dikes are abundant in the vicinity of the contact between the Barnett Well Granite and Picacho Mountains Granite. Older, medium gray, aphyric, very fine-grained dikes are common along the edge of the range east of Newman Peak. These are cut by felsic dikes, and predate formation of the mylonitic fabric. Generally the older gray dikes are too thin to map. They may be related to intermediate-composition dikes in the northern part of the map area (Tdi), or to the mafic dikes (unit Tdm). On the ridge in NE¼ sec. 9, T. 8 S., R. 9 E. mafic and felsic dikes are both common, and form a stockwork in Picacho Mountains Granite. Felsic dikes intrude mafic dikes in this area. The dike swarm becomes more regular and NW-striking to the east along this ridge.

- Tdg **Granophyre dikes** (Miocene or Late Oligocene) -- Fine-grained, holocrystalline biotite granite or granodiorite dikes.
- Tm **Intrusive mafic rocks** (Miocene or Oligocene) -- Mostly dark gray, very fine-grained diorite. Rock consists of aphanitic to very fine-grained aggregate of plagioclase and hornblende or pyroxene (variably altered to chlorite-epidote), and contains sparse feldspar and quartz crystals up to 3 mm in diameter. Rock varies from mylonitic to nearly massive. Some very dense, very fine-grained parts have a conchoidal fracture. The diorite appears to be comagmatic with the Barnett Well Granite (Tg). Near upward bounding contact of this body with the overlying non-mylonitic granite or andesite klippe, this unit is brecciated, chloritic, pervasively broken by hematite stained fractures, and contains fragments of fine-grained mylonite in a crushed and indurated but not obviously silicified matrix. Irregular dikes of this intrusion extend upward from main body shown on map into overlying granite and locally extend upward to the detachment fault at the structural top of the granite. This rock intrudes brecciated and silicified quartz monzonite of map unit TXg at the base of the sill.
- TXm **Amphibolite and diorite** (Miocene, Early Tertiary, Cretaceous or Early Proterozoic) -- Dark colored, texturally variable gabbro to granodiorite, microdiorite, and mafic gneiss. Dark color and variability distinguish this unit from hornblende-K-feldspar granitoid (TXg). On hill 2575 (NW¼ sec. 25, T. 8 S., R. 9 E.), the unit consists of mixed fine-grained diorite (Tm), mylonitic hornblende-K-feldspar quartz monzonite or granodiorite (TXg), aphanitic medium gray dike rock (Tdi?), and possibly some mylonitic amphibole-plagioclase gneiss (TXgn). Mylonitic rocks with possible gneiss protolith are banded white and dark gray mylonite; the white com-

ponent of this tectonite in some places looks like rhyolite dike rock (Tdf?), and in other places like pegmatite/aplite (TKp) that has undergone massive tectonic reduction in grain size. Equigranular medium-grained hornblende-biotite diorite or medium-grained gabbro, cut by aplite/pegmatite dikes is preserved in rare low-strain zones in this area.

On the southeasternmost hills in the Picacho Mountains are two small exposures of weakly to moderately porphyritic, dark hornblende granodiorite included in this unit. Rocks of this unit are locally mylonitic. Biotite is probably present, but it is difficult to distinguish because it is fine-grained and chloritized. In its southeasternmost exposure, rocks of this unit are weakly layered and foliated, contain a moderate amount of sphene, intrude gneiss of map unit TXgn, and are probably intruded by variably gneissic granitoids of map unit TKpm.

- Tgm **Barnett Well Granite and felsic dikes** (Miocene or Late Oligocene) -- Mixed unit consisting of Barnett Well Granite (Tg) intruded by abundant, sub-parallel felsic dikes. Some felsic dikes contain an internal foliation parallel to dike margins, but the granite is non- or very weakly foliated.
- TKpr **Picacho Mountains Granite and dikes** (Miocene or Early Oligocene) -- Mixed unit consisting of 40-50% dikes that form a boxwork intruding Picacho Mountains Granite; in the northern Picacho Mountains, dikes are intermediate to mafic (Tdm and Tdi); in southeastern Picacho Mountains near the Barnett Well Granite, dikes are aphyric rhyolite (Tdf).
- Tdi **Intermediate-composition dikes** (Miocene or Late Oligocene) -- Very fine-grained, homogranular, biotite granodiorite to diorite dikes that consist of 10-20% anhedral 1 mm-diameter quartz, 4-10% 0.5-1mm diameter biotite flakes, and 80% subhedral to anhedral 1 mm diameter feldspar (mostly plagioclase?). Scattered biotite flakes give the rock a 'salt and pepper' look on close inspection; rock is light gray from a distance. Rock is non-foliated, and weathers to form rounded boulders. There appears to be a compositional continuum between the intermediate and mafic (Tdm) dikes in the northern part of the map area; dikes with a color index <50 are classified as intermediate composition dikes. Inclusions of mafic dike rock were observed enclosed in intermediate dike rock, indicating that the intermediate dikes are younger. Dikes labeled 'F' on Johnson's [1981a] map are interpreted to be this unit. Johnson reports that dikes mapped as 'F' range in composition from monzogranite to alkali feldspar syenite, generally contain 5-10% hornblende and biotite, and are cut by 'non-porphyritic andesite' dikes here correlated with Tdm. The cross cutting relationship reported by Johnson [1981a] contrasts with the observation of Tdm inclusions in Tdi made by the author. There may be more than one generation of Tdi dikes, or Tdm and Tdi are coeval. The second alternative seems more likely.

Tdm **Mafic dikes** (Miocene or Oligocene) -- This unit includes generally dark gray-green to black, very fine-grained, aphyric or slightly porphyritic dikes. The mafic dikes commonly have a weak cleavage. Because the dikes are non-resistant and crop out poorly, they are probably more abundant than shown on the map. Dikes exposed in CAP canal cuts (NW $\frac{1}{4}$ sec. 9, T. 8 S., R. 9 E.) are dark greenish black, and contain 1-5 mm black hornblende(?) crystals with greenish pyroxene(?) cores. Dikes on hill 2405 in the southwestern part of the Picacho Mountains are slightly schistose, have mullions along their contacts, and irregular map traces, suggesting deformation after intrusion. Dikes west of Newman Peak are very fine-grained, and consist of amphibole + biotite + plagioclase with sparse 3-5 mm long amphibole crystals. Dikes labeled 'A' on Johnson's [1981a] map are interpreted to be this unit. In the area labeled 'many dikes' near the northern edge of the map area, the mafic dikes appear to form a boxwork of mostly northwest-trending dikes connected by NNW-trending segments. Mafic and intermediate dikes are both present in this area, but are not differentiated on the map.

Tg **Barnett Well Granite** (Miocene or Late Oligocene) -- Medium- to fine-grained, equigranular biotite granite or granodiorite. This is a new named unit, defined here for its type locality along a major wash about 2 miles (3.2 km) WNW of Barnett Well on the Newman Peak 7.5' USGS Quadrangle. The location is the NE $\frac{1}{4}$ sec. 26 (unsurveyed), T. 8 S., R. 9 E., in the vicinity of UTM 3618100 N, 464300E. The Barnett Well Granite is typically non-foliated and massive and weathers to rounded boulders. The rock consists of about 20-40% quartz, 60-80% feldspar, and 2-5 % biotite. The K-feldspar/plagioclase ratio could not be estimated in the field, but plagioclase appears to be predominant. Grain size is typically 1-2 mm, with sparse subhedral feldspar crystals 2-3 mm in diameter scattered through the rock. Local weak protomylonite foliation is defined by oriented biotite and aligned, slightly flattened quartz grains. A few thin mylonite zones cut the granite. Gneissic layering is rarely apparent where the granite is intruded by sparse, subhorizontal, parallel sheets of aplitic granite. The contact between Barnett Well Granite and Picacho Mountains Granite is sharp, but difficult to locate in detail because of the similarity of the two rocks.

At upper contact where variably gneissic granitoids (map unit TKgn) overlie the granite in the bottom of a small canyon south of peak 4209 (center of unsurveyed section 27, T. 8 S., R. 9 E.), the granite is massive to locally weakly foliated except at a 1 m thick contact zone where both(?) rock units are strongly mylonitically deformed and lineated (lineation plunges 5° and trends 243°). This contact is generally concordant to layering in overlying gneissic granitoids.

At top of hill 2701 northwest of klippe in the southern Picacho Mountains, this unit is leucocratic possibly because all biotite had been destroyed by hydrothermal alteration beneath the detachment fault, and seems unusually quartz rich. Pink stain and brown splotches are suggestive of oxidized sulfides. Mylonitic fabric is locally developed in this altered rock. At lower elevations on east side of hill 2701 granite appears less altered, is medium to fine grained, with biotite. Also, on west edge of hill top, fine-grained mafic intrusion (map unit Tm) invades the granite along a complex, interdigitated contact that is suggestive of magma mixing or of softening and stoping of plastic felsic host rocks.

Mylonitic foliation in Barnett Well Granite intensifies near contacts on the southwest side of the body, and the rock is strongly mylonitic in some places, especially along the contact with the amphibolite and diorite (TXm)

TKgh Picacho Reservoir Hornblende Granitoid (Miocene, Late Oligocene, Early Tertiary or Late Cretaceous) -- Medium- to coarse-grained homogranular granite, quartz monzonite, quartz monzodiorite, and granodiorite. Consists of 12-24% quartz, 24-34% orthoclase, 35-50% plagioclase, and 10-23% mafic minerals. Hornblende is the predominant mafic mineral, forming euhedral crystals up to 1 cm long. Dark colored, medium- to fine-grained, hornblende-rich enclaves, usually about 10 cm diameter, are common. The rock is non-foliated. Intrudes Picacho Mountains Granite near the northern edge of the map area (description from Johnson [1981a]).

TKnp Newman Peak Leucogranite (Eocene to Late Cretaceous) -- The type locality for the Newman Peak Granite is the outcrop area at the summit of Newman Peak, where medium-grained, equigranular, homogeneous, muscovite granite, locally with garnet is exposed. Pegmatites are common in the granite, especially near contacts with structurally underlying rocks. Iron stained blotches on fractures are common and probably represent oxidized sulfide minerals. In general, pegmatite veins and screens of Pinal Schist are most common at base of muscovite granite exposures around Newman Peak, and homogeneous muscovite granite is typical near the summit. Mylonitic fabrics are absent to weak in muscovite granite and pegmatitic granite, but are well developed in screens of Pinal Schist that are common near the structural base of the muscovite granite. Newman Peak Granite is distinguished from Picacho Mountains Granite by lighter color, greater abundance of muscovite, presence of garnet, and greater abundance of pegmatite.

Picacho Mountains Granite (Eocene to Cretaceous)

Texturally and compositionally variable granitoid complex, named here for the type location in the cut along the CAP canal in NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 9, T. 8 S., R. 9 E., in the west central part of the Picacho Mountains. A reference location is the ridge west of the Gold Bell Mine at

the NW corner of sec. 24, T. 8 S., R. 9 E. Rocks in the complex range in composition from medium-grained, biotite±muscovite granite or granodiorite to faintly heterogeneous layered granitoids to heterogeneous gneiss with local layers of augen gneiss and muscovite granite. This unit is distinguished from the Barnett Well Granite (Tg) in the southwestern part of the range by its generally coarser grained character, wider variation in grain size in hand samples, and the absence of ubiquitous gneissic foliation in the Barnett Well Granite (Tg).

Southeast of Newman Peak the Picacho Mountains Granite contains sparse screens of porphyritic to megacrystic granite in which phenocrysts up to 3 cm in diameter are deformed into augen. The porphyritic granite typically contains 7-12% biotite.

Near base of the Picacho Mountains northwest of Newman Peak, mylonitic fabric is absent and the Picacho Mountains Granite unit consists mostly of medium- to fine-grained leucocratic granite with a seriate texture (grain size varies continuously from fine to coarse grain). Local, sparse, K-feldspar crystals could be xenocrysts. Lithologic layering is weak to absent and defined mainly by variations in biotite content and by intruding muscovite granite and pegmatitic granite sills. Some muscovite granite and pegmatitic granite forms dikes discordant to weak gneissic fabric. Discordant pegmatites in this area seem to dip preferentially to northeast. Mylonitic fabric is weak and only locally present; it is most apparent where sides of quartz veins are striated (sometimes referred to as "hot slickensides"). Sparse, sheet-like bodies of banded gneiss could be large, highly flattened xenoliths. In this area mylonitic fabric is better developed structurally upward toward the range crest, whereas gneissic layering is less developed and pegmatitic granite layers are less abundant toward the range crest. Near the northwesternmost part of the map area, rocks of this unit consist of largely massive (non-layered and non-foliated), pale white, medium-grained, equigranular granite which contains 2 to 5% biotite in clots up to 1 cm across and very rare garnet. A K-Ar date (biotite) of 23.57 ± 0.5 Ma was derived from this massive granite (Johnson, 1981a, b; Damon et al., 1996; sample location plotted on Plate 1). This unit is the granite labeled 'G' on Johnson's [1981a] map. This date may be either a cooling age related to tectonic denudation, or represent post-intrusive cooling in a Tertiary pluton.

TKp aplite and pegmatite-

TKpm Main biotite-muscovite phase -- Moderately to strongly foliated, biotite-bearing, medium-grained granite, locally slightly K-spar porphyritic. Towards the upper part of this pluton, and to the west, two micas are commonly present and the granite is invaded by less than 10% variably foliated, pegmatite or aplite dikes and sills. Characterized by seriate (heterogranular) texture,

tawny color, and vague compositional banding. Rock in the northern part of map area is generally more homgranular and foliation is less apparent.

TKm Muscovite-rich phase -- Locally mapped phase in western Picacho Mountains. Typical rock contains 2-5% muscovite in 1-4 mm diameter flakes, 1-4% biotite in 1-3 mm flakes, 60-80% feldspar (K-feldspar > plagioclase?) in subhedral 4-6 mm diameter grains, and 20-40% quartz in slightly flattened 2-4 mm diameter grains. Grain size ranges from fine- to medium-grained within individual hand samples. Mica content is variable. Contacts between the muscovite-rich and main phases are gradational over 10-20 m. Fabric in the muscovite granite west of Newman Peak is weaker than in adjacent main phase lower on the mountain. On the ridge southeast of the Picacho Pumping Plant (east from NE¼ sec. 9, T. 8 S., R. 9 E.) muscovite-biotite ratios vary erratically over 10's of m from 10:1 to 1:4, making delineation of muscovite vs. main phase impossible. Muscovite becomes less abundant eastward along the ridge, and the contact on the map indicates where the muscovite-rich phase becomes uncommon.

TKpp Pegmatite-rich phase -- Similar to the main phase except that this unit contains >10% variably foliated, coarse-grained, locally garnet-bearing pegmatite dikes and sills, and typically contains noticeably more muscovite than main phase.

TKpg Gneissic phase (Eocene to Cretaceous) -- Distinctly gneissic and heterogeneous granitoid. Similar in character to main phase, but vague compositional banding becomes ubiquitous and obvious, and lithologic variability is greater. Very heterogeneous and gneissic varieties are common at low elevations. At the base of the steep bedrock exposures southwest of Newman Peak and west of peak 4209 (1 mile south-southwest of Newman Peak), the unit is a well banded gneiss that grades up-slope to cliff-forming, less gneissic and more granitic rock that is in turn overlain by the Pinal Schist (map unit Xp), muscovite granite (map unit TKgm), and related gneissic rocks (map unit TXgn) that make up the slope-forming Newman Peak summit complex. The contact between the banded gneiss and overlying granitic gneiss is locally shown on the map but was not mapped consistently because of its gradational nature and because of difficult access to the steep slopes and cliffs where the gradational contact is exposed. Banded felsic gneiss is cut by intruding dark, hornblende-bearing granitoid (possibly related to unit TXg). Some layers of granitic rock in the gneiss contain 2 to 3 cm diameter, K-feldspar porphyroclasts. Weak mylonitic fabric is developed locally on surfaces between gneiss layers with contrasting compositions.

Gneissic phase at the base of the range west of Newman Peak the unit consists of: 1) about 10% fine- to very fine-grained gray, homgranular granodiorite in sheets that are slightly dis-

cordant to the vague compositional banding; 2) 30-50% dark gray coarse-grained, porphyritic, biotite granitoid and 3) 40-60% main phase Picacho Mountains Granite.

TXgn Gneiss (Middle Tertiary, Cretaceous, or Early Proterozoic) -- Heterogeneous, banded gneiss. (1) At a hill in the extreme southeastern part of the Picacho Mountains this rock unit is intruded by weakly layered hornblende granodiorite (map unit TXm). (2) On flat-topped hill 2701, northwest of the klippe of Tertiary volcanic rocks in the southern Picacho Mountains, gneiss of this unit includes a few percent of Pinal Schist within layered gneissic rocks that are, at least in part, granitic in origin. (3) On top of a ridge south of Newman Peak rocks of this unit overlie gneissic Picacho Mountains Granite (TKpm) with a gradational contact between the two. Contact is placed below areas where Pinal Schist (map unit Xp) is present so that all Pinal Schist is included within the gneiss unit (TXgn). Also in this area, the gneiss contains numerous sills of Newman Peak granite (TKnp) that are increasingly abundant structurally upward. Upper contact is placed where overlying rock is more than 50% muscovite granite. Screens of fine-grained biotite granite with 10-25 mm rounded K-feldspar phenocrysts (not porphyroclasts) are present in the gneiss in this area. This unit is inferred to represent Pinal Schist intruded by one or more granitic rocks, deformed into gneiss, intruded by Newman Peak granite, and further deformed during either a single progressive event or several discrete events.

TXg **Hornblende-K-feldspar granitoid and gneiss** (Eocene, Cretaceous or Early Proterozoic) -- Foliated to gneissic granitoid at southern end of Picacho Mountains characterized by the presence of hornblende and 1-3 cm diameter K-feldspar porphyroblasts/phenocrysts. Contacts with gneiss unit (TXgn) and Picacho Mountains Granite are interleaved. This unit represents rock that is predominantly foliated granite older than the Picacho Mountains Granite. Distinction of older (Proterozoic) gneiss components from granitic components is difficult in these rocks. This unit is considered pre-Oligocene because Picacho Mountains Granite intrudes it, and major gneissic foliation-forming event is interpreted to be Early Tertiary or older.

The typical rock is medium- to coarse-grained, porphyritic biotite quartz monzonite characterized by 10-20% K-feldspar porphyroclasts up to 2 cm in diameter in a groundmass of about 60% anhedral to subhedral plagioclase 1-3 mm in diameter, 20-30% quartz, 5-7% biotite, and 2-5% hornblende in 3-8 mm long prisms. Classification as quartz monzonite is based on field estimation of mineral content. Rocks of this unit are exposed low on the hill slopes below the klippe in the southeastern Picacho Mountains. Rocks in the western part of the outcrop area become gneissic, and appear to have a distinctly stronger, probably older, gneissic foliation than that seen in the Picacho Mountains Granite; the contact between the two units was not observed

in the field in this area. The contact with Picacho Mountains Granite in the eastern outcrops is gradational, but obscured by strong deformation. The Barnett Well Granite (Tg) intrudes, and truncates foliation in, the quartz monzonite.

YXg Granite (Middle Proterozoic or Early Proterozoic) -- Equigranular to weakly porphyritic, medium- to coarse-grained, non-mylonitic granite that is directly beneath the andesite klippe in the southeastern Picacho Mountains.

Also includes a large, elongate block of granite in the crystal-poor andesite unit (Tau) near the summit of Picacho Peak. This block consists of porphyritic biotite granite with 2 cm-diameter K-feldspar phenocrysts, which contain included biotite similar to that in other 1.4 Ga granites in southeastern Arizona. In some parts of the block, grain-scale disaggregation and secondary interstitial iron-oxides and silica(?) indicate severe alteration, but biotite in the granite block is fairly fresh. These observations suggest potassium metasomatism of the granite (Brooks, 1986; Kerrich and Rehrig, 1987). The granite block forms a single tabular outcrop located 50 to 100 m west of the Picacho Peak summit, and is mostly a solid mass of rock that is not brecciated. The tabular mass may be truncated at its southeastern end by a fault, although this was not determined definitively because the contact is exposed on an inaccessible cliff face on the south side of the Picacho Peak summit. The block is interpreted as an allochthonous block of crystalline basement intercalated within or between lava flows of the Tau unit. The mechanism of transport may have been gravity sliding from an escarpment into a basin filling with lava, lateral transport within or on a lava flow, or upward transport from within a volcanic vent; the distance of transport is unknown. The rock is grossly similar to granite in clasts of the conglomerate at the base of the Picacho Peak volcanic sequence (unit Tc), to the granite beneath the andesite klippe in the southern Picacho Mountains, and to granite that underlies Tertiary volcanic rocks in the Samaniego Hills south of the map area [Ferguson et al., 1999a]. Intruded by mafic sill rock (map unit TXm), and by crystal-poor andesite unit (Tau)

Xp Pinal Schist (Early Proterozoic) -- Fine-grained, quartz + feldspar + biotite + muscovite schist and psammite, containing variable amounts of pegmatite and granite correlated with Newman Peak Granite (TKnp) along the crest of the Picacho Mountains. Also occurs as pendants in the contact zone between the Picacho Mountains Granite (TKpm) and hornblende granitoid (TKgh). Mapped in outcrops that clearly have sedimentary protolith with <20% granitic component.

REFERENCES

- Banks, N.G., 1980, Geology of a zone of metamorphic core complexes in southeastern Arizona, *in* Crittenden, M.D., Jr., and others, eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153, p. 177-215.
- Briscoe, 1967, General geology of the Picacho Peak area: Tucson, University of Arizona, M.S. thesis, 52 p.
- Brooks, W.E., 1986, Distribution of anomalously high K₂O volcanic rocks in Arizona: Metasomatism at the Picacho Peak detachment fault: *Geology*, v. 14, no. 4, p. 339-342.
- Brooks, W. E., and Snee, L. W., 1996, Timing and effect of detachment-related potassium metasomatism on ⁴⁰Ar/³⁹Ar ages from the Windous Butte Formation, Grant Range, Nevada: Washington, D.C., U. S. Geological Survey Bulletin 2154, 25 pages.
- Damon, P.E., Shafiqullah, M., Harris, R.C., and Spencer, J.E., 1996, Compilation of unpublished K-Ar dates from the University of Arizona Laboratory of Isotope Geochemistry, 1971-1991: Arizona Geological Survey Open-File Report 96-18, 56 p.
- 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.
- Davis, G.A., and G.S. Lister, 1988, Detachment faulting in continental extension; Perspectives from the southwestern U.S. Cordillera, *in* Clark, S.P., Jr., Burchfiel, B.C., and Suppe, J., eds., Processes in continental lithosphere deformation: Geological Society of America Special Paper 218, p. 133-160.
- Eastwood, R. L., 1970, A geochemical-petrological study of mid-Tertiary volcanism in parts of Pima and Pinal Counties, Arizona [Ph.D. Dissertation]: Tucson, University of Arizona, 212 p.
- Ferguson, C. A., Gilbert, W. G., Orr, T. R., Spencer, J. E., Richard, S. M., and Pearthree, P. A., 1999a, Geologic map of the Samaniego Hills, Pinal and Pima Counties, southern Arizona: Arizona Geological Survey Open-File Report 99-17, 15 pages, 1 sheet, scale 1:24000.
- Ferguson, C. A., Gilbert, W. G., Klawon, J. E., and Pearthree, P. A., 1999b, Geologic map of the Sawtooth Mountains and the north end of the West Silver Bell Mountains, Pinal and Pima Counties, southern Arizona: Arizona Geological Survey Open-File Report 99-16, 27 pages, 1 sheet, scale 1:24,000.
- Field, J. J. and Pearthree, P. A., 1993, Surficial Geologic Maps of the Northern Avra Valley-Desert Peak area, Pinal and Pima Counties, southern Arizona: Tucson, Arizona Geological Survey Open-File Report 93-13, 7 sheets, 11 pages 1:24000.
- Hollocher, K., Spencer, J.E., and Ruiz, J., 1994, Composition changes in an ash-flow cooling unit during K-metasomatism, west-central Arizona: *Economic Geology*, v. 89, p. 877-888.
- Holzer, T.L., 1978, Surface faulting in Arizona induced by ground-water withdrawal coincident with a geologic fault, *in* Geological Survey research 1978: U.S. Geological Survey Professional Paper 1100, p. 291.
- Holzer, T.L., Davis, S.N., and Lofgren, B.E., 1979, Faulting caused by ground-water extraction in south-central Arizona: *Journal of Geophysical Research*, v. 84, no. B2, p. 603-612.
- Jackson, G., 1990, Surficial geologic maps of the Picacho Basin [Picacho Reservoir, Newman Peak, Casa Grande Mtns., Eloy North, and Eloy South 7.5 min]: Arizona Geological Survey Open-File Report 90-02, 9 p., 5 sheets, scale 1:24,000.
- Johnson, G.S., 1981a, The geology and geochronology of the northern Picacho Mountains, Pinal County, Arizona: Tucson, University of Arizona, M.S. thesis, 65 p., 3 sheets, scales 1:24,000 and 1:6,000.
- Johnson, G.S., 1981b, Geologic maps and sample location map of the northern Picacho Mountains, Pinal County, Arizona: Arizona Bureau of Geology and Mineral Technology Miscellaneous Map MM-81-A, 3 sheets, scales 1:24,000 and 1:6,000.
- Keith, Stanley B., Gest, D.E., DeWitt, Ed, Woode Toll, Netta, and Everson, B.A., 1983, Metallic mineral districts and production in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 194, 58 p., 1 sheet, scale 1:1,000,000.
- Kerrich, R., and Rehrig, W.A., 1987, Fluid motion associated with Tertiary mylonitization and detachment faulting: ¹⁸O/¹⁶O evidence from the Picacho metamorphic core complex, Arizona: *Geology*, v. 15, no. 1, p. 58-62.

- Kerrick, R., Rehrig, W. A., and McLarty, E., 1989, Volcanic rocks in the suprastructure of metamorphic core complexes, southwest Arizona: Geochemical and isotopic evidence for primary magma types and secondary hydrothermal regimes, *in* Spencer, J. E., and Reynolds, S. J., eds., *Geology and Mineral Resources of the Buckskin and Rawhide Mountains, West-Central Arizona*: Tucson, Arizona Geological Survey Bull 198, p. 203-214.
- Pankratz, L. W., Ackermann, H. D., and Jachens, R. C., 1978, Results and interpretation of geophysical studies near the Picacho Fault, south-central Arizona, U. S. Geological Survey Open-File Report 78-1106, 17 pages.
- Rehrig, W. A., 1982, Metamorphic Core complexes of the southwestern United States-an updated analysis, *in* Frost, E. G., and Martin, D. L., editors, *Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada (Anderson-Hamilton Volume)*: San Diego, CA, Cordilleran Publishers, p. 551-560.
- Rehrig, W.A., 1986, Processes of regional Tertiary extension in the western Cordillera: Insights from the metamorphic core complexes, *in* Mayer, L., ed., *Extensional Tectonics of the southwestern United States: A perspective on processes and kinematics*: Geological Society of America Special Paper 208, p. 97-122.
- Rehrig, W.A., and Reynolds, S.J., 1980, Geologic and geochronologic reconnaissance of a northwest-trending zone of metamorphic core complexes in southern and western 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. 131-157.
- Reynolds, S.J., 1985, *Geology of the South Mountains, central Arizona*: Arizona Bureau of Geology and Mineral Technology Bulletin 195, 61 p., 1 sheet, scale 1:24,000.
- Reynolds, S.J., Florence, F. P., Welty, J. W., Roddy, M. S., Currier, D. A., Anderson, A. V., and Keith, S. B., 1986, *Compilation of radiometric age determinations in Arizona*: Tucson, Arizona Bureau of Geology and Mineral Technology Bulletin 197, 258 p.
- Roddy, M.S., Reynolds, S.J., Smith, B.M., and Ruiz, Joaquin, 1988, K-metasomatism and detachment-related mineralization, Harcuvar Mountains, Arizona: *Geological Society of America Bulletin*, v. 100, p. 1627-1639.
- Shafiqullah, M., Lynch, D.J., Damon, P.E., and Peirce, H.W., 1976, *Geology, geochronology and geochemistry of the Picacho Peak area, Pinal County, Arizona*: Arizona Geological Society Digest, v. 10, p. 305-324.
- Shafiqullah, M., Damon, P. E., Lynch, D. J., Reynolds, S. J., Rehrig, W. A., and Raymond, R. H., 1980, K-Ar geochronology and geologic history of southwestern Arizona and adjacent areas, *in* Jenney, J. P., and Stone, C., eds, *Studies in Western Arizona*: Tucson, Arizona Geological Society Digest 12, p. 201-260.
- Slaff, S., 1991, Earth-fissure activity near Brady and Picacho pumping plants, Tucson Aqueduct, Central Arizona Project, Pinal County, Arizona - A report to the U.S. Bureau of Reclamation: Arizona Geological Survey Open-File Report 91-01, 48 p., 2 sheets, scale 1:24,000.
- Slaff, S., 1993, Earth fissures and related subsidence features adjacent to the Tucson Aqueduct, Central Arizona Project, Pinal and Pima Counties, Arizona: Arizona Geological Survey Open-File Report 93-11, 18 p., 6 sheets, scale 1:24,000.
- Slaff, S., Jackson, G.W., and Pearthree, P.A., 1989, Development of earth fissures in Picacho basin, Pinal County, Arizona from 1959 to 1989 [Newman Peak, Picacho Reservoir, Casa Grande Mtns., Eloy South, Eloy North, and Valley Farms 7.5 min]: Arizona Geological Survey Open-File Report 89-10, 38 p., 6 sheets, scale 1:24,000.
- Spencer, J.E., 1984, Role of tectonic denudation in warping and uplift of low-angle normal faults: *Geology*, v. 12, p. 95-98.
- Wernicke, Brian, 1981, Low-angle normal faults in the Basin and Range Province: Nappe tectonics in an extending orogen: *Nature*, v. 291, p. 645-648.
- Yeend, W., 1976, Reconnaissance geologic map of the Picacho Mountains, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-778, 1 sheet, scale 1:62,500.

LIST OF PLATES (IN POCKET)

Plate 1. Geologic Map of the Picacho Mountains and Picacho Peak, Pinal County, Southern Arizona

Plate 2. Cross sections of the Picacho Mountains and Picacho Peak, Pinal County, Southern Arizona.

LIST OF FIGURES

Figure 1. Location map for study area.

Figure 2. Stratigraphic framework and correlation diagram for supracrustal rocks of the southern Picacho Mountains.

Figure 3. Idealized variations of principal phenocrysts phases in volcanic units of the southern Picacho Mountains. The variations of three principal phenocryst phases define the various stratigraphic units, but it should be stressed that these variations are merely general tendencies, and the actual variations would be far more complex. The relative abundance of phenocrysts depicted in this diagram is based on field observation only.

Figure 4. Hypothetical structural cross-section of the composite Sawtooth Mountains - Samaniego Hills - Picacho Mountains volcanic field and its relationship to a major northeastern basin-bounding normal fault which probably evolved into the Picacho Mountains detachment.

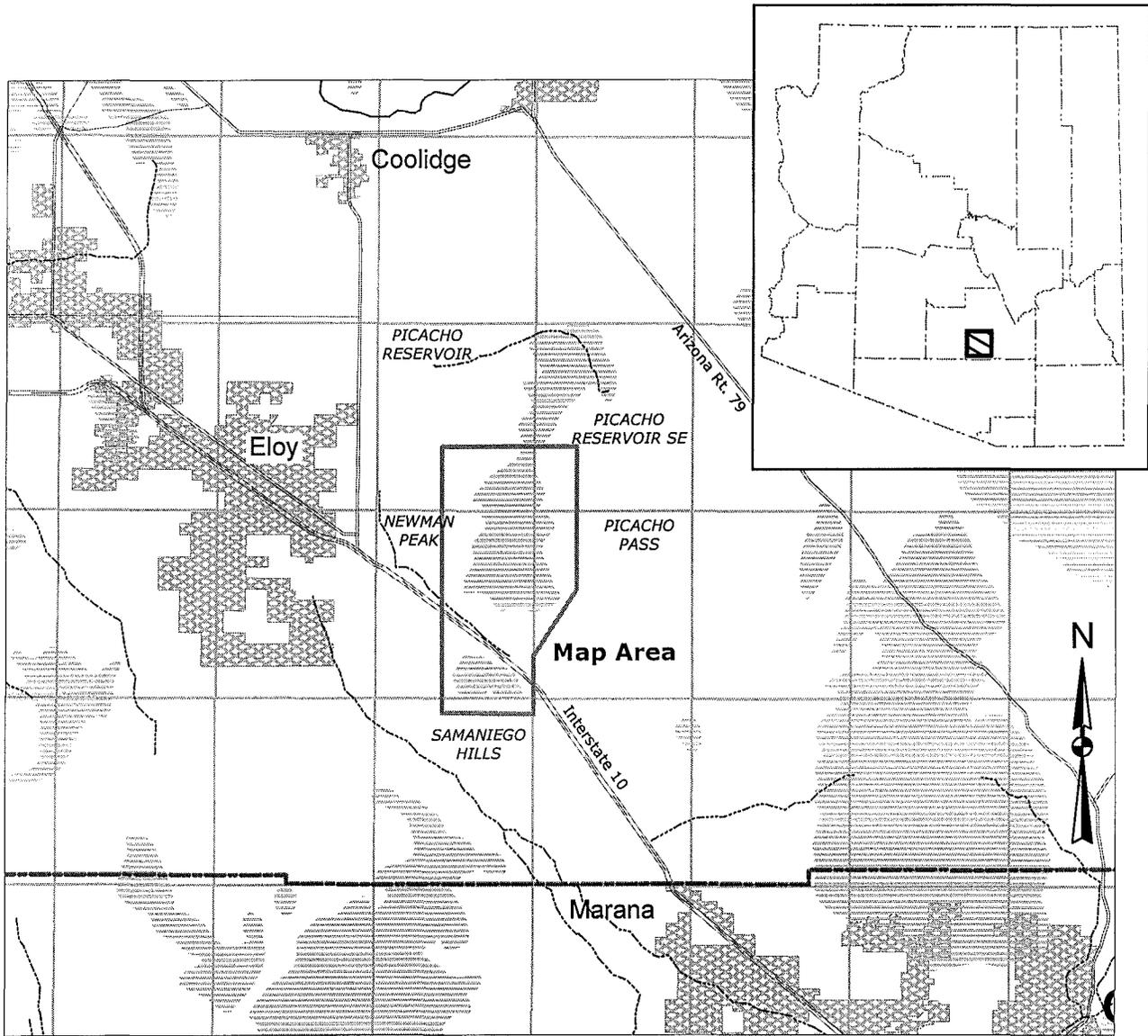
Figure 5. Map showing location of dated volcanic rocks and samples collected for chemical analyses.

Figure 6. Generalized geologic map of the Picacho Mountains, based on mapping presented in this report and mapping by Johnson [1981a]. Type areas proposed for named units and corrected locations for K-Ar dates in Picacho Mountains are shown.

LIST OF TABLES

Table 1. Summary of isotopic age dates from the Picacho Mountains and Picacho Peak.

Table 2. Chemical analyses for volcanic rocks from the Picacho Peak area. Compiled from Shafiqullah et al. [1976] (UAKA and S- sample numbers), Brooks [1986] (PP sample numbers), and Kerrich et al. [1989] (K- sample numbers). Shafiqullah et al. [1976] samples consistently have higher silica contents than other studies; the reason for this is unknown.



2 0 2 4 6 8 10 Kilometers


Figure 1. Location of map area.

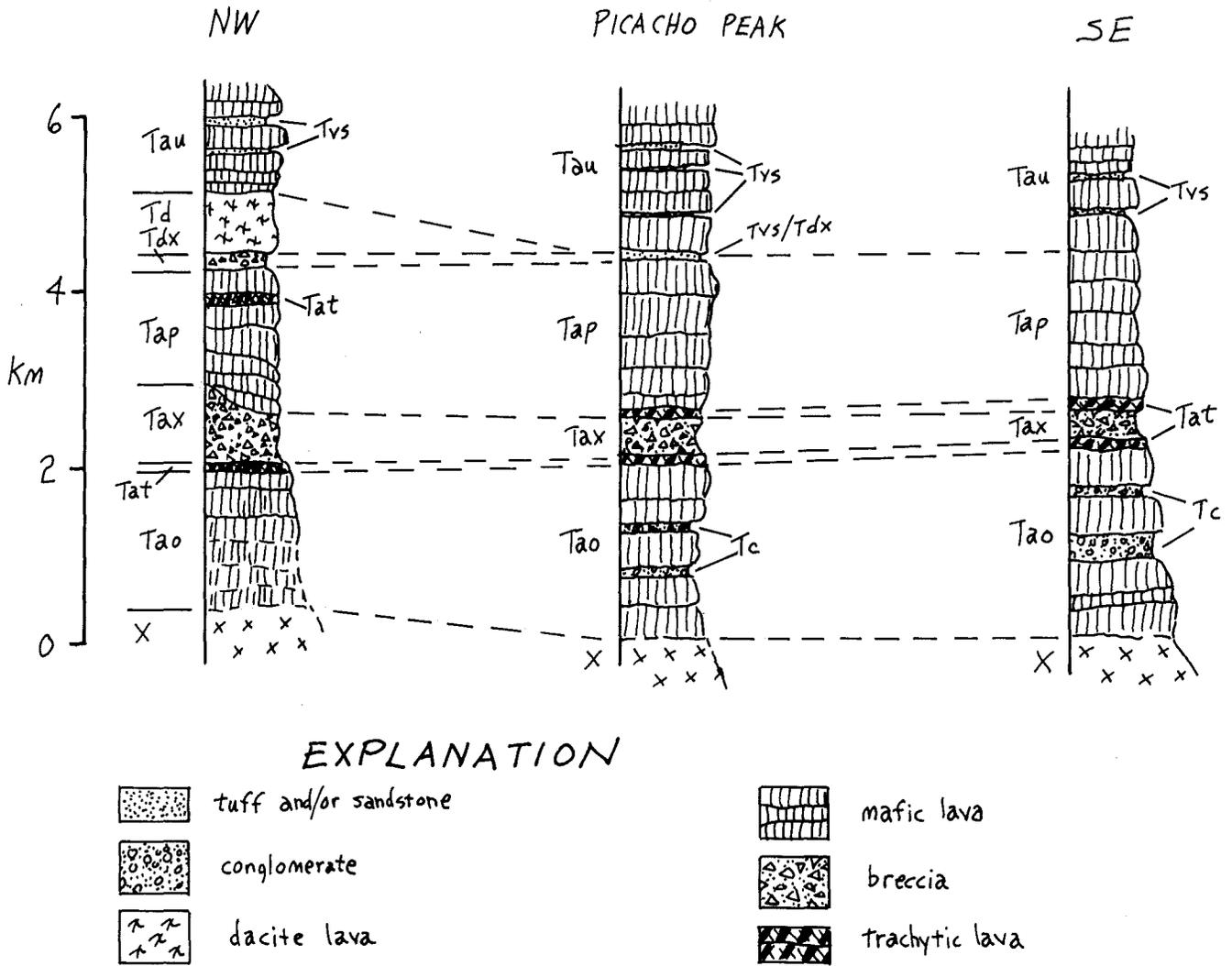


Figure 2. Stratigraphic framework and correlation diagram for supracrustal rocks of the southern Picacho Mountains.

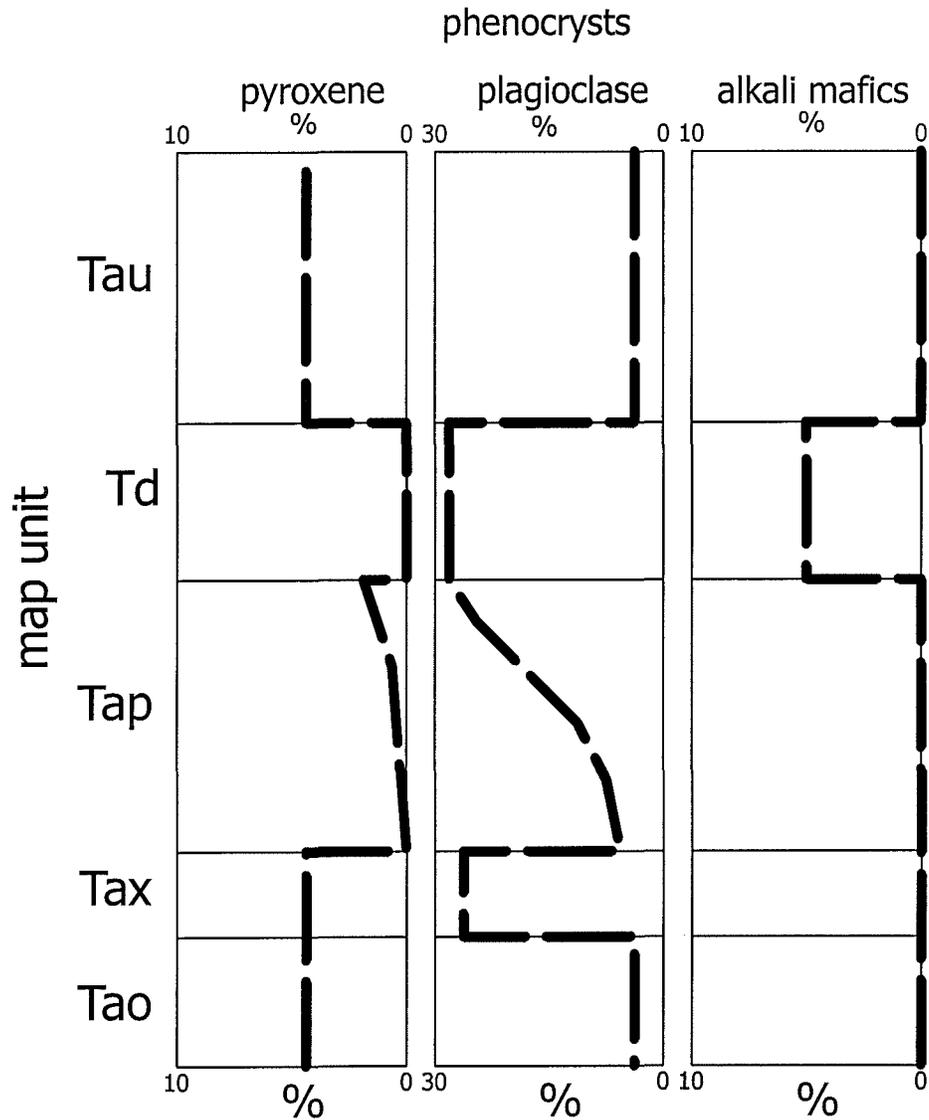


Figure 3. Idealized variations of principal phenocrysts phases in volcanic units of the southern Picacho Mountains. The variations of three principal phenocryst phases define the various stratigraphic units, but it should be stressed that these variations are merely general tendencies, and the actual variations would be far more complex. The relative abundance of phenocrysts depicted in this diagram is based on field observation only.

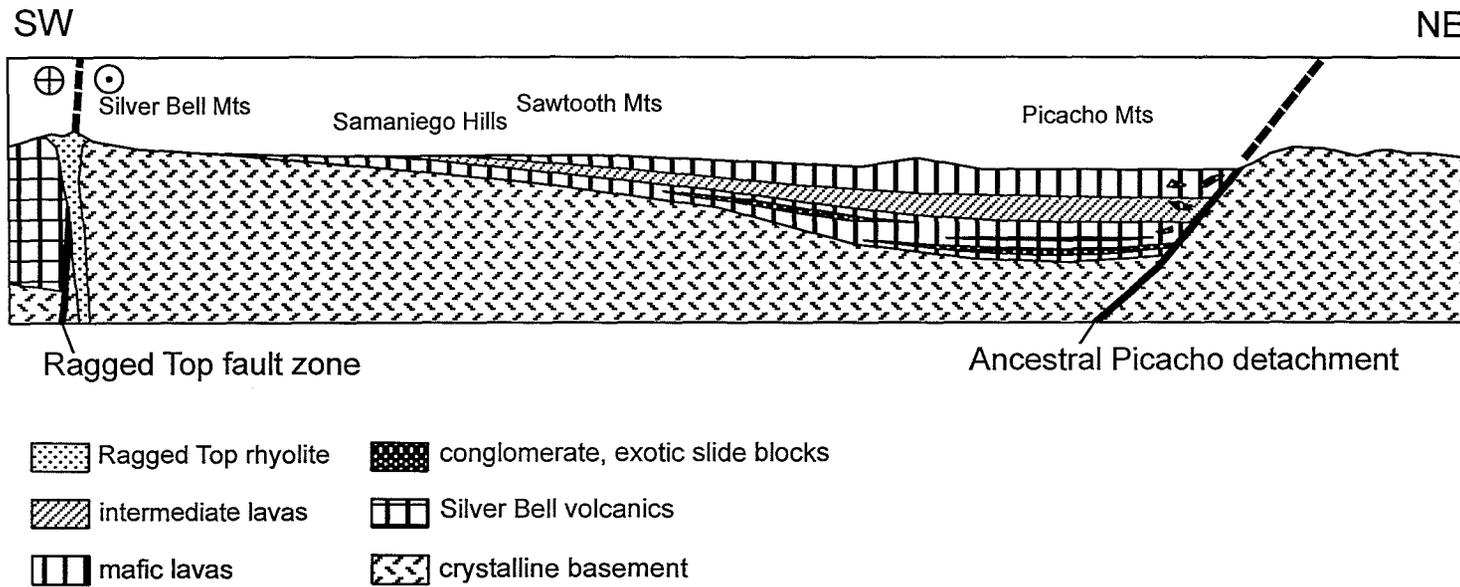
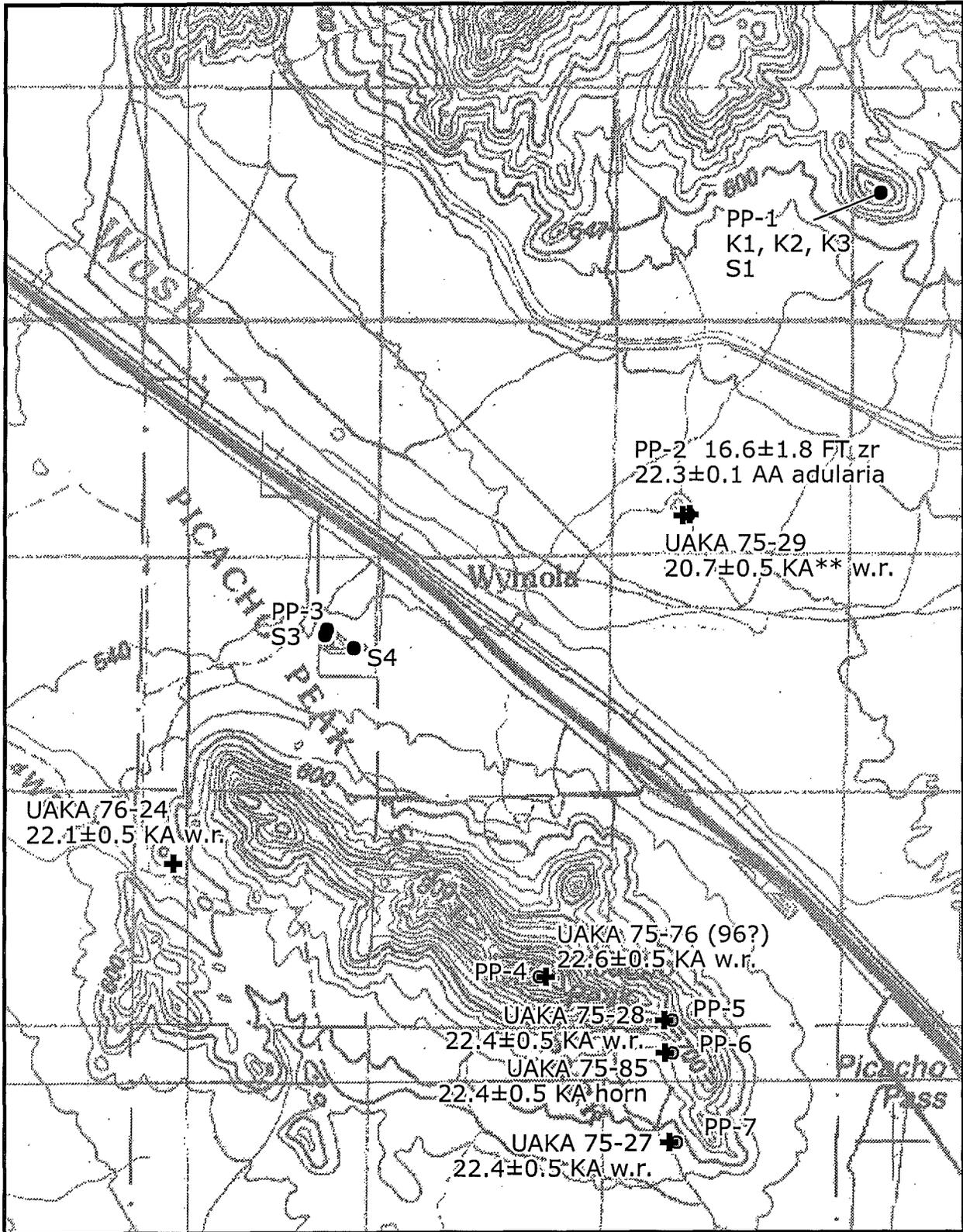


Figure 4. Hypothetical structural cross-section of the composite Sawtooth Mts - Samaniego Hills - Picacho Mts volcanic field and its relationship to a major northeastern basin-bounding normal fault which probably evolved into the Picacho Mountains detachment.



Age dates for Tertiary Volcanic rocks, Picacho Peak area



Figure 5

Sample ID	Unit	sample description	latitude longitude	Date (Ma)	Mat.	% K	%rad Ar	References
UAKA-75-27	Volcanic rocks of Picacho Peak (Tao)	K20:Na20=1.0*	32° 37.58' 111° 23.5'	22.4 ± 0.5	w.r.	2.8	84	Shafiqullah and others, 1976
UAKA-75-85	Volcanic rocks of Picacho Peak (Tax?)	K20:Na20=~1.3 *	32° 37.83' 111° 23.5'	22.4 ± 0.5	horn	0.8	58	Shafiqullah and others, 1976
UAKA-75-28	Volcanic rocks of Picacho Peak (Tap?)	K20:Na20=~2.4 *	32° 37.93' 111° 23.52'	22.4 ± 0.5	w.r.	3	94	Shafiqullah and others, 1976
UAKA-75-76	Volcanic rocks of Picacho Peak (Tau)	K20:Na20=~4.8*	32° 38.12' 111° 26'	22.6 ± 0.5	w.r.	6.7	94	Shafiqullah and others, 1976
UAKA 76-24	Volcanic rocks of Picacho Peak (Td)	Latite dike exposed in a wash west of the saddle between the main massif and the low western hills	32° 38.53' 111° 25.61'	22.1 ± 0.5	w.r.	5.41	93.1	Damon et al., 1996
UAKA-75-29	Volcanic rocks of Picacho Peak (Tau?)	K20:Na20=~12.9 *	32° 39.83' 111° 23.43'	20.7 ± 0.5	w.r.	9.6	56	Shafiqullah and others, 1976
PM 303 (UAKA 76-17)	Picacho Mountains Granite	gneissic granite	32° 45.36' 111° 25.37'	24.1 ± 0.5	musc	8.685	86	Johnson, 1981
PM 303 (UAKA 76-17)	Picacho Mountains Granite	gneissic granite; analytical data not reported in literature; may be same analysis as musc date reported above (see discussion in text)	32° 45.36' 111° 25.37'	23.6 ± 0.5	biot	0		Johnson, 1981
UAKA-73-64	probably unit 'F'--Fine grained intermediate igneous rocks of Johnson, 1981; Tdi? of this report		32° 48.1' 111° 21.3'	24.4 ± 0.7	biot	6.1	46	Shafiqullah and others, 1980
PM 304 (UAKA 76-18)	Picacho Reservoir Hornblende Granitoid	Quartz Monzonite, non-foliated	32° 49.73' 111° 22.19'	25.1 ± 0.5	biot	7.424	86.3	Johnson, 1981
PM 305 (UAKA 76-19)	Clemans Tank Diorite	Quartz monzonite; locally mineralized, abundant epidote veins	32° 51.57' 111° 20.1'	66.5 ± 1.4	biot	7.752	88.9	Johnson, 1981

Table 1. Summary of potassium-argon isotopic age dates from the Picacho Mountains and Picacho Peak.

Rock unit	Tau											Tpa		Tpa, Tat, or Tax		Tao			
location	S. Picacho Mtns.					Isolated Inselberg		Hill at campground			Picacho Peak summit		ridge SE of Peak		middle of slope		interbedded w/ cong.		
Sample#	PP-1	K1	K2	K3	S1	PP2	UAKA 75-29	PP-3	S3	S4	PP-4	UAKA 75-76 (96?)	PP-5	UAKA 75-28	PP-6	UAKA 75-85	PP-7	UAKA 75-27	
component																			
SiO ₂	47.0	47.7	47.2	48.9	59.1	56.6	60.9	50.8	59.7	56.4	50.4	67.2	51.6	56.1	46.1	61.8	49.2	60.4	
Al ₂ O ₃	13.4	14.1	13.7	13.4	17.1	14.5	16.7	14.9	16.5	16.4	13.5	16.3	14.8	17.9	15.1	16.4	16.8	16.7	
Fe(total)O ₃	5.9	6.6	5.9	6.2	7.0	7.3	7.6	6.8	7.5	7.5	6.5	3.9	6.7	7.1	6.0	5.6	7.5	5.9	
MgO	0.2	0.4	0.3	0.7	0.1	0.6	0.2	0.3	0.4	0.3	4.1	1.7	2.4	3.0	4.2	3.6	6.1	3.0	
CaO	11.6	9.7	11.0	9.9	0.8	3.5	0.4	7.1	2.0	2.6	7.6	1.0	6.6	6.5	9.6	2.8	4.8	1.4	
Na ₂ O	0.4	0.5	0.5	0.5	0.7	0.8	1.0	0.5	1.0	0.5	1.2	2.1	2.1	3.3	3.0	4.4	3.9	3.7	
K ₂ O	11.1	11.1	11.3	10.9	13.3	11.0	11.8	11.3	12.4	12.5	6.9	8.1	7.3	4.0	4.9	4.0	3.8	3.9	
TiO ₂	0.9	0.9	0.8	0.8	1.1	1.1	1.2	1.1	1.0	1.2	0.8	1.1	0.8	0.9	0.8	0.8	1.0	1.0	
P ₂ O ₅	0.6	0.7	0.6	1.0		0.9		0.8			0.6		0.6		0.4		0.5		
MnO	0.2	0.1	0.1	0.1	0.1	0.3	0.1	0.3	0.2	0.2	0.4	0.1	0.2	0.1	0.2	0.1	0.2	0.1	
LOI	8.6	7.9	8.8	7.5	0.7	2.5	0.8	5.4	1.4	2.3	7.7	2.5	6.0	3.6	9.1	1.8	5.5	2.8	
total	99.9	99.6	100.2	99.9	100.1	99.1	100.8	99.3	102.0	99.8	99.7	104.0	99.1	102.4	99.4	101.1	99.3	98.8	
K ₂ O:Na ₂ O	27.8	24.7	24.6	21.0	18.0	13.8	11.9	22.6	12.9	23.1	5.8	3.8	3.5	1.2	1.6	0.9	1.0	1.0	
Trace elements (ppm)																			
Rb	381	442	401	379		379		345			205		235		124		101		
Sr	196	314	262	247		149		142			209		439		510		733		
Y	26	35	29	30		22		25			28		16		27		9		
Zr	357	533	455	429		323		347			320		271		247		186		
Nb	14	29	28	25		27		12			16		13		11		0		
Ba	1485	1727	1457	1026		2144		2469			2122		2350		1881		1707		

Table 2. Chemical analyses for volcanic rocks from the Picacho Peak area. Compiled from Shafiqullah et al. [1976] (UAKA and S- sample numbers), Brooks [1986] (PP sample numbers), and Kerrich et al. [1989] (K- sample numbers). Shafiqullah et al. [1976] samples consistently have higher silica contents than other studies; the reason for this is unknown.

