DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Preliminary geologic map of the Monkeys Head quadrangle, Mohave and La Paz Counties, Arizona

by

David R. Sherrod[1]

Open-File Report 88-597

[1]Menlo Park, Calif.

INTRODUCTION

The Monkeys Head 7.5-minute quadrangle is located at the confluence of the Colorado and Bill Williams Rivers in westernmost Arizona. This area is in the Basin and Range Province, which is characterized by mountain ranges and intervening alluviated valleys (fig. 1). The Colorado Plateau lies 150 km to the east, separated from the Basin and Range in Arizona by the Transition Zone.

The mountains in the northern and central parts of the Monkeys Head quadrangle are northwest-trending, southwestwardly tilted blocks of Proterozoic metaplutonic rocks and Tertiary volcanic and sedimentary strata. The tilt is indicated by the steep to gentle southwest dip of Tertiary strata and underlying Tertiary-Proterozoic nonconformity. The tilted rocks are buried in the southern part of the quadrangle by nearly flat-lying upper Miocene lava flows that fringe the Buckskin Mountains. The entire quadrangle lies in the upper plate of a regional detachment fault system exposed in the Whipple, Buckskin, and Rawhide Mountains (Davis and others, 1980; Dickey and others, 1980; Shackelford, 1980).

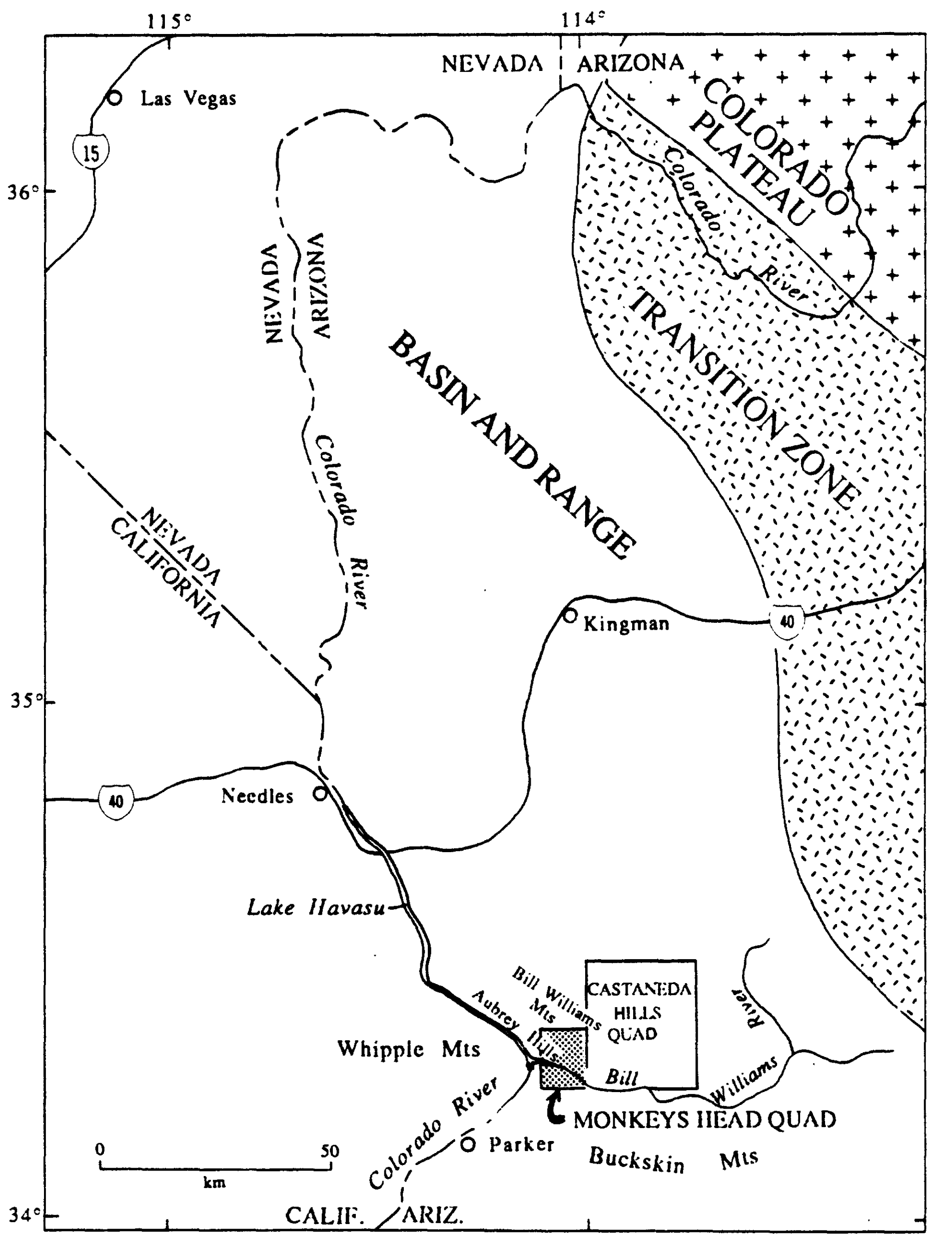

Figure 1. Map showing location of Monkeys Head quadrangle and some geographic features named in text.

STRATIGRAPHY

Proterozoic rocks

The oldest rocks in the quadrangle are Proterozoic metaplutonic rocks, which form the cores of the Bill Williams Mountains and Aubrey Hills. In the Bill Williams Mountains, the preponderant rock is weakly to moderately foliated granodiorite gneiss. The granodiorite is intruded by leucogranite gneiss on the east flank of the range (northeast corner of the map). Steeply dipping Proterozoic diabase sheets cut all these rocks.

On the west flank of the Bill Williams Mountains, a gradational zone of highly foliated, weakly to moderately lineated gneiss separates the granodiorite from a unit of granite and quartz monzonite along a northwest-trending zone about 300-600 m wide. There are too few data to define the main trend of foliation in the zone; lineations plunge chiefly to the south. The unit of granite and quartz monzonite flanking the gradational zone on the southwest form a large mass of coarsely porphyritic granite gneiss and related(?) slightly porphyritic quartz monzonite gneiss. Tertiary sedimentary and volcanic rocks nonconformably overlie the granite and quartz monzonite along the west flank of the Bill Williams Mountains.

The granodiorite unit (Pgd) as mapped in the Aubrey Hills consists of a complexly layered sequence of granodiorite gneiss and quartz monzodiorite gneiss, which is moderately foliated and lineated. Leucogranite gneiss (unit Plg) forms small pods and masses in the Aubrey Hills. Northwest-striking Tertiary sedimentary rocks nonconformably overlie the granodiorite on the west flank of the Aubrey Hills.

Tertiary rocks deposited prior to tilting

Sedimentary and volcanic rocks of Fox Wash

In most of the map area, lower Tertiary(?) and lower Miocene sedimentary and volcanic rocks form the oldest strata overlying the Proterozoic rocks. These strata, named informally the sedimentary and volcanic rocks of Fox Wash, include arkosic sandstone and grits; gypsiferous sandstone and siltstone; volcaniclastic mudflow deposits and tuff; pebble, cobble, and boulder conglomerate; and basalt lava flows and coarse breccia. Hydrothermally altered limestone of uncertain age forms a thin bed that nonconformably overlies unit Pg for about 1 km in the northwest corner of the quadrangle. Towards the south, the Fox Wash sequence interfingers with coarse breccia and megabreccia (unit Tx). The sedimentary and volcanic rocks of Fox Wash are early Miocene or older in age because they are conformably overlain by 18-19 Ma Peach Springs Tuff (unit Tp). Beds within the Fox Wash sequence appear concordant, dip steeply, and were deposited prior to mid-Tertiary tilting that deformed the mountain blocks in the map area.

The oldest Fox Wash strata are dark reddish brown and reddish orange arkose (base of unit Tfs). The lowest beds, totaling 5-40 m thick, are pebbly arkosic grits formed of grus from adjacent Proterozoic crystalline rocks; the crystalline rocks are commonly deeply weathered for several tens of meters beneath the contact. This profound weathering horizon probably corresponds to a regional period of weathering and erosion that occurred in Eocene and Oligocene time (for example, Eberly and Stanley, 1978; Shafiqullah and others, 1980). Inasmuch as the oldest beds are undated, they are assigned to the lower Tertiary(?) (pre-Miocene). Overlying the reddish brown arkose are white gypsiferous sandstone, light-gray to light-brownish-gray arkosic sandstone, pebbly sandstone, and coarse conglomerate, also in unit Tfs.

Volcaniclastic beds in the Fox Wash sequence comprise grayish-red tuff and lapilli tuff. These beds were deposited mostly as mudflows; airfall tuff is minor. Stratigraphically, the volcaniclastic strata begin abruptly, most commonly within 40 m above the base of the Tertiary section. The sudden influx of volcaniclastic debris probably corresponds to flare-up of nearby volcanic centers. According to Nielsen (1986), volcanic rocks to the north of the map area have K-Ar ages as old as 22-20 Ma (the few older dates are suspect). Therefore the Fox Wash sequence above the basal arkosic grits is probably no older than about 22 Ma.

The upper part of the Fox Wash sequence consists of interfingering basalt and basaltic andesite lava flows (units Tfb and Tfbp) and conglomerate (unit Tfc). The basalt and basaltic andesite are thickest and most continuous in the northwestern part of the quadrangle. Coarse volcaniclastic breccia exposed in the northwest corner of the map may represent a near-vent facies of the basalt and basaltic andesite.

Locally, the lowest lava flow is a basalt or basaltic andesite porphyry (unit Tfbp) that contains coarse tabular plagioclase phenocrysts as much as 2 cm long. This flow is probably analogous to "andesite porphyry", "jackstraw porphyry", or "turkey-track andesite" described by other authors working in the region. Northwest of the map area the porphyry has a K-Ar whole-rock age of 19.8±0.5 Ma (Nielsen, 1986).

Conglomerate and sandstone (unit Tfc) form the largest volume of the Fox Wash sequence and indicate the presence of a large river system during early Miocene time. Pebbles and cobbles in the conglomerate are nearly all well-rounded metaplutonic clasts. Pebble imbrication indicates a source to the northwest, which is compatible with the clast composition. The clasts clearly were not derived from the Colorado Plateau to the northeast because the deposits lack clasts from Paleozoic or Mesozoic sedimentary rocks that are exposed on the Plateau. Conglomerate and sandstone are present in equal proportions.

Tertiary megabreccia and breccia

Very thickly bedded breccia and blocks of shattered bedrock are interbedded with the sedimentary and volcanic rocks of Fox Wash. The unit of megabreccia and breccia is well exposed in the central part of the map area. It thins to the northwest and apparently was never deposited in the northwest corner of the map area. It is buried by younger rocks to the southeast but is exposed in the southeast corner.

The unit was probably emplaced as a series of small to large gravity-slide blocks and debris-avalanche deposits. Grain size decreases as the unit thins, and the unit is conformably interbedded with unbrecciated strata. The megabreccia and enclosing units have been equally deformed by regional tilting. Similar conclusions about the origin and structural history of stratigraphically equivalent megabreccia were reached by Spencer and others (1986) and Suneson (1980), working to the south and east, respectively.

The following description of some well-exposed granite-clast megabreccia (Txgr, a subunit of Tx) from the Fox Wash area summarizes the character of many parts of the megabreccia. Granite-clast megabreccia and breccia comprise monolithologic beds 8-10 m thick. Locally, clasts are tightly fitted together to form coherent, shattered blocks as much as 10 m across. In granite-clast megabreccia, aplite veins can be traced from clast to clast with little or no disruption of their trend. These large blocks are bounded by highly disrupted granite breccia that contains clasts to 80 cm in a matrix of reddish gray to reddish brown very fine-grained rock paste. Grains recognizable in the paste are 1-2 mm-sized biotite, quartz, and feldspar from the granite.

The megabreccia and breccia are rarely well-exposed. Instead, they commonly weather to angular and subangular blocks that litter the hillsides. Cavernous weathering is common where the unit forms prominent outcrops.

Peach Springs Tuff

The Peach Springs Tuff of Young and Brennan (1974) is a regionally widespread densely to slightly welded ash-flow sheet of early Miocene age. The tuff lacks a known source but variations in thickness suggest it was erupted somewhere in the Colorado River area near the southern tip of Nevada, perhaps at least 50 km north of the map area (Young and Brennan, 1974; Glazner and others, 1986). The Peach Springs Tuff, which conformably overlies the sedimentary and volcanic rocks of Fox Wash in the map area, is the youngest unit erupted prior to the episode of middle and early(?) Miocene tilting and deformation.

Tertiary rocks deposited during tilting

Older fanglomerate

Sedimentary breccia and sandstone, informally named "older fanglomerate", form a map unit critical to understanding the tectonic events affecting rocks of the Monkeys Head quadrangle during latest early Miocene or middle Miocene time. The breccia and sandstone, which may be as thick as 1 km, conformably overlie Peach Springs Tuff wherever the upper Peach Springs contact is preserved, but commonly they lie unconformably on older Miocene rocks. Older fanglomerate has dips that range from 70° to 0°. The dip diminishes upwards across a stratigraphic interval of less than 130 m. Thus, the older fanglomerate records the structural events that tilted the lower Tertiary(?) and Miocene sedimentary and volcanic rocks, as well as post-tilting sedimentation.

The unit of older fanglomerate comprises very poorly bedded, medium- to thick-bedded coarse sedimentary breccia, sandstone, pebbly sandstone, and grit that formed as alluvial fan deposits. In the northwestern part of the quadrangle, the upper part of the unit includes relatively fine-grained sandstone, pebbly sandstone, and minor siltstone characteristic of a distal fan or playa environment. Rock color varies with composition: beds rich in volcanic clasts are pale brownish gray, whereas arkosic granite-clast beds are reddish brown. Clasts are generally angular to subangular, in contrast to the commonly rounded or subrounded clasts found in the underlying conglomerate unit (Tfc) of the sedimentary and volcanic rocks of Fox Wash. Locally, however, the older fanglomerate contains rounded clasts that have been reworked from the conglomerate in the underlying Fox Wash sequence.

Tertiary rocks deposited after tilting

Volcanic and volcaniclastic rocks of Bill Williams Mountains

A series of lava flows, domes, and pyroclastic and epiclastic volcanic strata were deposited above variably deformed older strata during middle and late Miocene time. The volcanic rocks are bimodal in composition, comprising almost entirely rhyolite (71-76 percent SiO_2) and basalt and basaltic andesite (45-55 percent SiO2) (analyses from Suneson and Lucchitta, 1983, on equivalent units exposed to the east in the Castaneda Hills quadrangle). The volcanic rocks of the Bill Williams Mountains were erupted between about 13.7 and 6.8 Ma (Suneson and Lucchitta, 1979, 1983).

Volcaniclastic rocks are interbedded with lava in the southern Bill Williams Mountains. They are mapped separately from the lava and divided by gross composition into either mafic (Twmv) or silicic (Twsv) tuff and tuffaceous sandstone. A wedge of arkosic sandstone and breccia too small to show separately is interbedded with the volcaniclastic rocks in one locale. The minor arkosic interbed suggests that the volcanic field had sufficient relief to divert encroaching alluvial fans.

Younger fanglomerate

Younger fanglomerate (unit Tyf) is lithologically similar to older fanglomerate (unit Tof) and is only locally important. It is distinguished in the south-central part of the map area where it overlies older fanglomerate with angular discordance of 20-25°. The younger fanglomerate is probably equivalent to the upper, nearly flat-lying parts of older fanglomerate exposed in the northwestern and southern parts of the map.

Basalt, basaltic andesite, and andesite of The Mesa

The basalt, basaltic andesite, and andesite of The Mesa, a thick sequence of flat-lying lava flows exposed south of the Bill Williams River, were erupted contemporaneously with volcanic and volcaniclastic rocks of the Bill Williams Mountains. Mafic volcaniclastic rocks are minor and are shown as a separate unit (Tmv); no silicic rocks were seen. The basalt, basaltic andesite and andesite of The Mesa were only briefly examined for this map. They are correlated with the volcanic and volcaniclastic rocks of the Bill Williams Mountains and are assigned an age of middle and late Miocene on that basis.

STRUCTURE

The prominent structural features of the quadrangle are northwest-trending faults that have tilted pre-middle Miocene rocks; bedded units commonly dip 50-80°. The main episode of tilting, which began less than 18 Ma, was finished by about 13.7 Ma, prior to the earliest eruptions of volcanic and volcaniclastic rocks of the Bill Williams Mountains (e.g., units Twb, Twr).

A second structural feature is a northwest-trending zone of faults that parallels the Bill Williams River. This fault zone has cumulative strike separation of perhaps 1 km; dip separation is locally as much as 200 m. Several small broad anticlines in middle and (or) upper Miocene fanglomerate along this zone may be related to shear along the Bill Williams River fault zone.

Faults

Northwest- and north-northwest-trending faults are the main structures developed in the quadrangle. Northeast-trending faults are minor and have mostly small displacements. Fault dips generally range from 50-90° (85 percent of exposed fault planes). Slickensided surfaces indicate chiefly dip-slip displacement.

The northwest trend of faults is roughly parallel to the strike of lower Tertiary(?) and lower to middle Miocene strata, and to the trend of the Bill Williams Mountains and Aubrey Hills. The major faults responsible for the regional tilting are now presumably low-dipping, northwest-striking surfaces. However, it remains equivocal whether these particular faults curve upwards and crop out or whether they are cut by younger, more steeply dipping faults.

Generally, northnorthwest-trending steep to vertical faults are among the youngest faults in the area. These faults deform the upper Miocene volcanic sequences of the Bill Williams and Buckskin Mountains.

Bill Williams River fault zone

The Bill Williams River fault zone (named here) comprises northwest-trending faults along the Bill Williams River and Aubrey Hills. In the Aubrey Hills, faults that deform Proterozoic rocks are difficult to trace because there are few marker units. Southwest of the Aubrey Hills, many of the fault traces align with the Bill Williams River valley, and presumably lie buried in the alluvium there. The fault zone is defined on the basis of (1) right-lateral separation of units in the Aubrey Hills, (2) a zone of moderately to intensely shattered Tertiary and pre-Tertiary rocks in the Aubrey Hills, and (3) dip separation of as much as 200 m (down to the northeast) along faults in the southeast corner of the quadrangle and in the Buckskin Mountains (this map; Spencer and others, 1986).

(1) **Right-lateral separation.** A northeast-trending mass of Proterozoic leucogranite about one km long intrudes Proterozoic granodiorite along steep contacts near State Highway 95 northeast of Lake Havasu. Several northwest-trending faults displace the contact of the leucogranite in a right-lateral sense. The maximum strike-separation along any one fault is about 100 m, and cumulative strike-separation shown by all faults cutting the leucogranite is about 200 m. One km northwest of the leucogranite, the Tertiary-preTertiary nonconformity is displaced about 0.5 km in a right-lateral sense, but the evidence for strike-slip here is less compelling; the apparent right-lateral separation could result from normal fault displacement of a steeply dipping contact.

(2) **Zone of shattered rocks in Aubrey Hills.** A zone of closely spaced fractures (10-100 m spacing) has shattered pre-Tertiary and Tertiary rocks along Arizona Highway 95 in the Aubrey Hills northeast of Lake Havasu. This shattering is not characteristic of rocks at the Tertiary-preTertiary nonconformity elsewhere in the quadrangle and is presumably an expression of the Bill Williams River fault zone. The fracture planes and slickensides show no preferred orientation, and there is insufficient evidence to define the strike- or dip-slip character of the fault zone.

(3) **Dip separation in southeast corner of quadrangle.** Lava flows in two temporally equivalent units (Tb and Twb) overlie older fanglomerate along the Bill Wil-

liams River in the southeast corner of the quadrangle. The contact between lava and fanglomerate is displaced as much as 200 m (down to northeast) along a northwest-trending fault. This fault continues southsoutheast for as much as 12 km (mapping of Spencer and others, 1986).

In summary, the Bill Williams River fault zone extends at least 25 km along the Bill Williams River and through the Buckskin Mountains. It has chiefly dip separation of as much as 200 m in the Buckskin Mountains (this map; Spencer and others,1986) but apparently splays into several lesser faults with cumulative right-lateral separation of perhaps 1 km along the Bill Williams River near Lake Havasu. Offset along the zone in the southeastern part of the map is younger than the middle and (or) upper Miocene basalt, basaltic andesite, and andesite of The Mesa (unit Tb). Offset in the northern part is only known to be younger than middle Miocene. Quaternary and latest Pliocene(?) older alluvium and old river sediment (units QTa and QTrs) are probably undeformed by faults in the zone but the generally unconsolidated nature of these deposits might not preserve escarpments or other mappable evidence of faults.

Folds

Several small, broad anticlines, a syncline, and a monocline locally deform the sedimentary rocks of the Fox Wash sequence (units Tfs and Tfc) and older fanglomerate (unit Tof). These folds trend mainly north-northwest to west-northwest and are less than 1 km in length. Northeast-trending folds occur in the older fanglomerate exposed in Giers Wash in the southwest corner of the map.

Several of the folds probably result from pinching or drag in areas where faults converge. This is certainly the case in the Havasu Springs area on the southwest shore of Lake Havasu (southwest end of section B-B'), where arkosic sandstone of the Fox Wash sequence has been squeezed and dragged(?) along a faulted block of Proterozoic granodiorite gneiss.

The most extensive fold is exposed in older fanglomerate north of The Mesa and south of the Bill Williams River. This anticline may represent contraction related to right-lateral displacement along the Bill Williams River fault zone.

Dikes

Tertiary dikes, mostly mafic in composition, follow three trends. Many dikes trend northwest or northeast. A third orientation is marked by north- and north-northwest-trending dikes. In many cases, these more-northerly trending dikes are known to be the youngest dikes in the area because they cut up through and feed the middle and upper Miocene volcanic rocks in the Bill Williams and Buckskin Mountains (e.g., units Twb and Tb). By analogy, faults that trend north-northwest and cut these volcanic rocks are perhaps some of the youngest faults in the area. The north- and northnorthwest-trending faults and dikes are consistent with a broadly east-west-oriented least compressive stress (σ_3) at least during late Miocene time, and perhaps continuing since then.

ACKNOWLEDGMENTS

This work is part of a mineral survey of the U.S. Bureau of Land Management's Mohave Wash Wilderness Study Area. I wish to acknowledge K.A. Howard and J.G. Evans for their considered reviews of this map.

COMBINED MAP AND TEXT REFERENCES

Carr, W.J., Dickey, D.D., and Quinlivan, W.D., 1980, Geologic map of the Vidal NW, Vidal Junction, and parts of the Savahia Peak SW and Savahia Peak quadrangles, San Bernardino County, California: U.S. Geological Survey Miscellaneous Investigations Map I-1126, scale 1:24,000.

Davis, G.A., Anderson, J.L., Frost, E.G., 1980, Mylonitization and detachment faulting in the Whipple-Buckskin-Rawhide Mountains terrane, southeastern California 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. 79-129.

Dickey, D.D., Carr, W.J., and Bull, W.B., 1980, Geologic map of the Parker NW, Parker, and parts of the Whipple Mountains SW and Whipple Wash quadrangles, California and Arizona: U.S. Geological Survey Miscellaneous Investigations Map I-1124, scale 1:24,000.

Eberly, L.D., and Stanley, T.B., Jr., 1978, Cenozoic stratigraphy and geologic history of southwestern Arizona: Geological Society of America Bulletin, v. 89, p. 921-940.

Glazner, A.F., Nielsen, J.E., Howard, K.A., and Miller, D.M., 1986, Correlation of the Peach Springs Tuff, a large-volume Miocene ignimbrite sheet in California and Arizona: Geology, v. 14, p. 840-843.

Light, T.D., Pike, J.E., Howard, K.A., McDonnell, J.R., Jr., Simpson, R.W., Raines, G.L., Knox, R.D., Wilshire, H.G., and Pernokas, M.A., 1983, Mineral resource potential map of the Crossman Peak Wilderness Study Area (5-7B), Mohave County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1602-A, scale 1:48,000.

Nielsen, J.E., 1986, Miocene stratigraphy of the Mohave Mountains, Arizona, and correlation with adjacent ranges, *in* Nielsen, J.E., and Glazner, A.F., leaders, Cenozoic stratigraphy, structure, and mineralization in the Mojave Desert: Geological Society of America Guidebook and Volume, Field trip number 5, 82nd Annual Meeting of the Cordilleran Section of the Geological Society of America, Los Angeles, California, p. 15-24.

Reynolds, S.J., Spencer, J.E., and DeWitt, Ed, 1987, Stratigraphy and U-Th-Pb geochronology of Triassic and Jurassic rocks in west-central Arizona, *in* Dickinson, W.R., and Klute, M.A., eds., Mesozoic rocks of southern Arizona and adjacent areas: Arizona Geological Society Digest, v. 18, p. 65-80.

Shackelford, T.J., 1980, Tertiary tectonic denudation of a Mesozoic-early Tertiary(?) gneiss complex, Rawhide Mountains, western Arizona: Geology, v. 8, p. 190-194.

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: Arizona Geological Society Digest, v. 12, p. 201-260.

Spencer, J.E., Reynolds, S.J., and Lehman, N.E., 1986, Geologic map of the Planet-Mineral Hill area, northwestern Buckskin Mountains, west-central Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 86-9, scale 1:24,000.

Suneson, N.H., 1980, The origin of bimodal volcanism, west-central Arizona: Santa Barbara, University of California, Ph.D. dissertation, 293 p.

Suneson, Neil, and Lucchitta, Ivo, 1979, K-Ar ages of Cenozoic volcanic rocks, west-central Arizona: Isochron/West, no. 24, p. 25-29.

—— 1983, Origin of bimodal volcanism, southern Basin and Range province, west-central Arizona: Geological Society of America Bulletin, v. 94, p. 1005-1019.

Young, R.A., and Brennan, W.J., 1974, Peach Springs Tuff: Its bearing on structural evolution of the Colorado Plateau and development of Cenozoic drainage in Mohave County, Arizona: Geological Society of America Bulletin, v. 85, p. 83-90.