Geologic Diversity of Arizona and Its Margins: Excursions to Choice Areas

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Field-Trip Guide to Parts of the Harquahala, Granite Wash, Whipple, and Buckskin Mountains, West-Central Arizona and Southeastern California

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INTRODUCTION

This three-day field-trip guide is intended to provide the reader with a guide to areas of the Harquahala, Granite Wash, Whipple, and Buckskin Mountains that are illustrative of regional geologic relationships and styles of mineralization. All field-trip stops are accessible by 2-wheel-drive vehicle with high clearance. Some of the field-trip stops are at patented or unpatented mining claims, and it is advisable to obtain permission to enter these areas.

The first day will be focused on the geology of Mesozoic thrust faults in the Harquahala, Little Harquahala, and Granite Wash Mountains. These ranges contain the most extensive exposures of stacked Mesozoic thrust faults known in Arizona (Spencer and others, 1985a; Laubach, 1986; Reynolds and others, 1986; Richard and others, in press). With minor exceptions, the thrusts are southwest, south, and southeast directed. The structurally lowest Hercules thrust, which is exposed in the western Harquahala, Little Harquahala, and Granite Wash Mountains, places Precambrian and Jurassic crystalline rocks over moderately to steeply dipping, southeast-facing sections of Paleozoic and Mesozoic sedimentary and volcanic rocks. All of the field-trip stops on the first day are at outcrops along the Hercules thrust or related subsidiary thrusts. Mineralization along the Hercules thrust zone is either pre- to synthrusting (Calcite mine) or is younger and was localized along the thrust zone (Yuma mine).

The second day will be focused on the Whipple Mountains detachment fault and structures and lithologies in the upper and lower plates. Upper-plate rocks consist of tilted Tertiary clastic and volcanic rocks that rest depositionally on primarily 1.4 to 1.7 Ga crystalline rocks. The lower plate consists of a variety of variably mylonitized crystalline rocks including granitic sills of Upper Cretaceous and middle Tertiary age. Brecciation and chloritic alteration have overprinted lower-plate rocks near the detachment fault (Davis and others, 1980, 1982; Wright and others, 1986).

The third day will be focused on the geology and mineralization of the Buckskin-Rawhide detachment fault in the Buckskin Mountains. The Buckskin-Rawhide detachment fault is thought to be correlative with the Whipple detachment fault in California and with the Bullard detachment fault at the east end of the Harcuvar and Harquahala Mountains. Top-to-the-northeast displacement on this regional detachment fault has uncovered one of the largest Tertiary mylonite complexes in the North American Cordillera (Davis and others, 1980; Rehrig and Reynolds, 1980; Reynolds and Spencer, 1985; Spencer and Reynolds, 1986a). Mineralization along and near the detachment fault is better developed and more extensive than in any other Cordilleran metamorphic core complex (Wilkins and Heidrick, 1982; Spencer and Welty, 1985, 1986; Wilkins and others, 1986). Field-trip stops will be at areas of mineralization along and below the detachment fault, at exceptional exposures of the fault, and at areas in the upper and lower plates where characteristic structures and lithologies are well exposed.

DAY 1: HARQUAHALA AND GRANITE WASH MOUNTAINS
(by S. J. Reynolds, J. E. Spencer, S. E. Laubach, and S. M. Richard)

Directions and Comments En Route to Stop A1

The trip starts at the Phoenix Civic Center. Proceed west on Van Buren Street, turn north (right) on 27th Avenue, and turn west (left) onto I-10 toward Los Angeles. The small mountain range on the south flank of Phoenix is the South Mountains, a geologically simple metamorphic core complex. The eastern half of the range consists of a middle Tertiary pluton and the western half is composed of Proterozoic gneiss. Both rock types are cut by a middle Tertiary mylonite zone formed by top-to-the-northeast ductile shear along a normal-displacement detachment zone that dips gently to the northeast and projects beneath tilted middle Tertiary sedimentary and volcanic rocks east of Phoenix (Reynolds, 1985; Reynolds and Lister, 1987). The breakaway of the detachment system is probably represented by the east margin of the Sierra Estrella, the large, rugged mountain range to the southwest of the South Mountains. The Sierra Estrella contain Proterozoic metamorphic and granitic rocks that lack Tertiary mylonitic fabric (Spencer and others, 1985b).

Northwest of Phoenix are the White Tank Mountains, another metamorphic core complex with mylonitic fabrics predominantly formed by top-to-the-northeast ductile shear along a northeast-dipping

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detachment zone. The mylonitic fabrics have been overprinted on a basement of Proterozoic crystalline rocks, a peraluminous early Tertiary(?) granite, and middle Tertiary dikes.

West of the Hassayampa River and north of I-10 are the Big Horn and Belmont Mountains. The light-colored Belmont Mountains are underlain by a middle Tertiary fluorite-bearing granite, whereas the Big Horn Mountains to the west are composed of lower Miocene volcanic and sedimentary rocks that overlie Proterozoic crystalline rocks and Cretaceous granodiorite (Capps and others, 1985). The entire assemblage of rocks is cut by low- to high-angle normal faults that bound a series of north-northwest-trending tilted fault blocks.

Near Tonopah, I-10 passes north of the low-relief Palo Verde Hills (near Palo Verde Nuclear Generating Station) and more rugged Saddle Mountain, both of which are composed of middle Tertiary volcanic rocks. The larger range further south, the Gila Bend Mountains, is composed of Proterozoic crystalline rocks and Late Cretaceous(?) and middle Tertiary sedimentary and volcanic rocks.

Exit I-10 at mile post (MP) 69, proceed north (right) on maintained dirt road for 4 mi, and turn northwest (left) on the graded Salome-Buckeye Road. The topographically high Harquahala Mountains to the north are composed of Proterozoic, Paleozoic, and Mesozoic rocks that are metamorphosed and cut by major thrust faults (Figure 1). The top of the range consists of Proterozoic crystalline rocks that overlie Proterozoic granitoid rocks and tectonized Paleozoic and Mesozoic metasedimentary rocks along the south-vergent Harquahala thrust (Reynolds and others, 1986). The Paleozoic rocks, which contain large southeast-facing folds, extend along the ridge southwest of the high peak. These rocks have been intruded by a large Late Cretaceous granite and numerous pegmatitic and middle Tertiary dioritic dikes. Rocks in the Harquahala Mountains occur in the lower plate of the Bullard detachment fault, a regional low-angle normal fault with approximately 40 to 50 km of top-to-the-northeast displacement (Reynolds and Spencer, 1985). Rocks directly beneath the fault locally contain a Tertiary mylonitic fabric formed during top-to-the-northeast ductile shear along the detachment zone. The fault dips southeast under tilted fault blocks of Tertiary volcanic rocks in the Big Horn Mountains. Major topographic notches in the Harquahala Mountains were formed by preferential erosion along northwest-trending, high-angle faults that offset the Bullard detachment fault.

South of I-10 are the topographically impressive Eagle Tail Mountains, which are composed of southwest-dipping middle Tertiary volcanic rocks, middle Tertiary hypabyssal intrusions, and foliated granitic rocks.

The Salome-Buckeye Road passes between the Harquahala and Little Harquahala Mountains. Paleozoic rocks in the Little Harquahala Mountains form a northeast-trending, southeast-facing strike belt that projects to the northeast into similar rocks in the Harquahala Mountains. The Paleozoic rocks are successively overlain to the southeast by lower(?) Mesozoic sedimentary rocks, Jurassic(?) volcanic rocks, and Jurassic and/or Cretaceous clastic rocks of the McCoy Mountains Formation (Richard, 1982; Spencer and others, 1985a; Reynolds and others, 1986). To the north, the Paleozoic section is in depositional contact with Proterozoic granite. The entire southeast-facing Proterozoic to Mesozoic section is truncated at depth by two gently dipping thrust faults, the structurally higher Centennial thrust and the lower Hercules thrust. Beneath the Hercules thrust is a section of McCoy Mountains Formation that is stratigraphically distinct from the section deposited on the Paleozoic rocks.

Two miles south of where the road crosses Centennial Wash, turn right (east) on the dirt road and park slightly in front of a small incised wash that is crossed by the road.

Stop A1: 'S' Mountain Window

At this stop we will proceed up the southern branch of this small wash to examine an excellent exposure of the Hercules thrust, which places mylonitic alaskite and quartz dioritic rocks over quartzite and stretched-pebble conglomerate of the basal part of the McCoy Mountains Formation. The quartzite rests depositionally on deformed and metamorphosed Jurassic volcanic, volcaniclastic, and hypabyssal rocks. Mylonitic lineation and stretched pebbles along the thrust trend north-south.

Directions and Comments En Route to Stop A2

En route to stop A2 we can see the Harquahala Mountains and the Harcuvar Mountains to the northeast. Each range is a northeast-trending culmination (antiform) of the Harcuvar metamorphic core complex (Rehrig and Reynolds, 1980) and is composed of metamorphic, mylonitic, and igneous rocks present beneath the Bullard detachment fault. The Harcuvar Mountains are composed of metamorphic and granitic rocks with a gently dipping, Tertiary mylonitic fabric that defines the broad northeast-trending Harcuvar Mountains antiform (which parallels and controls the overall topography of the range).

Return to the Salome-Buckeye Road, turn right toward Salome, and turn left onto U.S. Highway 60 in downtown Salome. Proceed west for approximately 2 blocks and turn right on Center Street, which is marked by a sign to the local VFW post. Begin cumulative mileage, which is listed within parentheses in following directions. Continue on the paved road as it turns to the left (0.3 mi) near a sign for "La Paz County Transfer Site." Continue straight where the pavement ends (0.8 mi). The western Harcuvar Mountains to the north contain dark-colored pendants of foliated crystalline rocks intruded by light-colored Late Cretaceous Tank Pass Granite. Turn left on the less-traveled dirt road where the main road turns north (right) and becomes Winchester Avenue (2.6 mi). Continue on the left forks of the road (2.7 mi and 3.3 mi) near a small knob of Late Cretaceous Granite Wash Granodiorite. At 4.1 mi the road crosses a stream along which we can view exposures of high-grade Proterozoic metamorphic rocks in the upper plate of the Hercules thrust. Continue on the main road to the right (4.5 mi) and park along the side of the road (4.6 mi).

Stop A2: Hercules Thrust Zone

At this stop we will traverse through the Hercules thrust zone, which regionally dips gently to the northeast but has been folded at this locality into a northwest-trending, near-vertical attitude. Lineation in the thrust zone plunges down the dip of the foliation. Starting several hundred meters north of the parking spot, we will walk southwest, down structural section, sequentially through the following structurally juxtaposed lithologies: (1) Proterozoic crystalline rocks that are most mylonitic down-section to the southwest; (2) mylonitic rocks along the Hercules thrust zone; (3) Mesozoic quartzofeldspathic schists situated directly beneath the thrust and derived from felsic volcanic rocks, intermediate-composition hypabyssal rocks, and sedimentary rocks,

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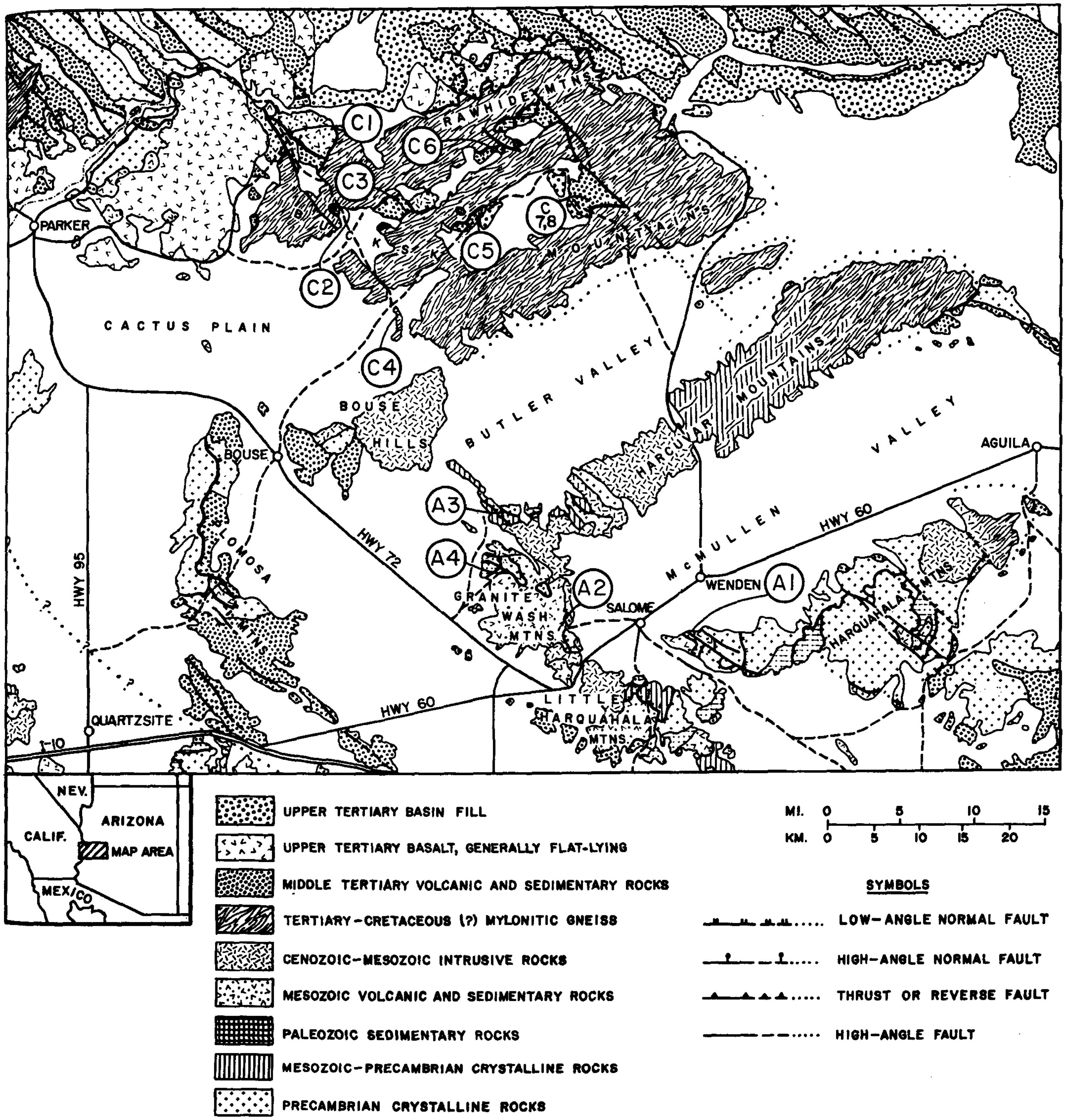

Figure 1. Simplified geologic map of west-central Arizona showing roads and locations of field-trip stops on days 1 and 3.

including ferruginous quartzite; and (4) locally calcareous metasedimentary rocks. The ferruginous quartzite and schists extend along strike into the Calcite mine area, where they are strongly pyritic and have been heavily prospected. These rocks are locally associated with andalusite-rich schists, which probably represent metamorphosed argillic-alteration zones within the volcanic sequence. The Calcite mine area is interpreted as an occurrence of metamorphosed Mesozoic volcanogenic mineralization and alteration.

Directions and Comments En Route to Stop A3

Retrace your steps and return to Salome via the same route, making sure that you go straight and not left where the less-traveled Calcite mine road

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0.24), but also by the aluminous nature of hornblende in a quartz diorite (exposed elsewhere) dated by Wright and others (1986) at 783±3 Ma. Barometric estimates for mylonitization (16±4 km) and postkinematic Tertiary plutons (4-8 km) indicated successively shallower crustal depths demonstrating dramatic decompression of the complex (Anderson, 1985; Anderson, 1987a; Anderson and others, 1987).

Return to the vehicles and return to Parker.

DAY 3: BUCKSKIN MOUNTAINS
(by J. E. Spencer, S. J. Reynolds, and S. Marshak)

Directions and Comments En Route to Stop C1

Drive northeast from downtown Parker on Arizona Highway 95 toward Lake Havasu City, as was done yesterday. The Central Arizona Project pump station is visible to the right at 17.8 mi from Parker. This station serves as the intake for water for the CAP system. The levy visible in Lake Havasu to the left is intended to prevent sediment from the Bill Williams River from clogging the intake. The northeast-dipping Havasu Springs normal fault, which places Miocene sandstone against Proterozoic crystalline rocks, is exposed in the large cuts on both sides of the pump station.

At 18.4 mi from Parker (0.6 mi from the CAP pump station), turn right on the dirt road. If you cross the Bill Williams River you have gone too far. Drive 7 mi up the Bill Williams River and note the tilted Tertiary sandstone and fanglomerate beneath flat-lying 10 Ma mesa-forming basalt. The tilted sedimentary rocks are the youngest tilted rocks in the Tertiary section and become less steeply tilted to horizontal up-section. Turn right up Mineral Wash. The sign "COUNTY MAINTENANCE ENDS" marks the turnoff. Drive 2 mi up the wash through tilted Mesozoic and Tertiary rocks (Spencer and others, 1986), then turn right to go to Mineral Hill mine.

Stop C1: Mineral Hill Mine

Park at the flat area above the white "sulfuric acid" tanks. You are at the Mineral Hill mine, which is one of the largest mines in the Buckskin Mountains. From where the vehicles are parked, we will walk west and northwest, beginning a 0.5- to 1.0-mi-long, clockwise loop through the mine workings and adjacent areas. We will observe styles of mineralization, the detachment fault, carbonate replacements, and the Mineral Wash fault that displaces the orebody and underlying detachment fault. Please note that the Mineral Hill mine is a patented claim; permission to enter should be obtained from the owner.

Host rocks for mineralization are variably calcareous lower Mesozoic quartzites and sandy phyllites that form the lowest stratigraphic member of the Triassic(?) Buckskin formation. This lowest member is overlain in ascending order by the phyllite member, quartzite member, and upper sedimentary member. These four members compose the informally named Buckskin formation. The Buckskin formation is overlain with low-angle angular unconformity by the informally named Vampire formation, a light-colored quartzite with a local conglomeratic base, which is overlain by the massive quartz porphyry of the informally named Planet volcanics. This tripartite stratigraphic sequence was first recognized by Norm Lehman during detailed mapping for AMAX Inc. The Buckskin formation is tentatively correlated with the Triassic Moenkopi Formation, the Vampire formation is tentatively correlated with the Lower Jurassic Aztec-Navajo Sandstone, and the Planet volcanics are almost certainly correlative with Jurassic quartz porphyries that are widespread in southern Arizona. Middle Tertiary sandstone, conglomerate, megabreccia, and volcanic rocks overlie the Mesozoic section. All of these rocks are tilted and unconformably overlain by flat-lying, upper Miocene mesa-forming basalt (Spencer and others, 1986).

Mesozoic and Tertiary rocks are cut by numerous normal faults and are tilted to moderate or steep attitudes. The normal faults are truncated by, or flatten with depth and merge into, the basal Buckskin-Rawhide detachment fault (see cross section of Mineral Hill-Planet area in Wilkins and Heidrick, 1982).

The Mineral Hill mine is located in rocks that are within about 50 m of the Buckskin-Rawhide detachment fault, which is exposed at several locations in the mine area. Hydrothermal circulation within brecciated rocks along and above the detachment fault caused the mineralization. The high-angle, northeast-side-down, Mineral Wash fault offsets the detachment fault and the Mineral Hill orebody and passes approximately through the flat area where the vehicles are parked. The location of the offset continuation of the orebody is unknown.

Mineralization at the Mineral Hill mine is typical of upper-plate, detachment-fault-related deposits in the Whipple-Buckskin-Rawhide Mountains area (Wilkins and Heidrick, 1982; Spencer and Welty, 1986). Hematite and specular hematite form pervasive fracture fillings, disseminations, and replacements throughout the mine area, and mineralized rocks are typically dark red or black in color as a consequence. Sparse fracture-filling specular hematite is characteristic of the margins of the mineralized area. Chrysocolla and malachite fill thin fractures in the hematite-mineralized rocks. Quartz and calcite are locally present on fracture surfaces. Minor hematite and chrysocolla are present in lower-plate, chloritically altered mylonitic gneisses (Spencer and Welty, 1985).

Massive brown carbonate overlies the basal detachment fault at the northern edge of the mine workings. Carbonate lenses and sheets such as this one are locally present throughout the Buckskin-Rawhide Mountains, especially in areas of mineralization, and are interpreted as replacements of upper-plate rocks along the detachment fault (Wicklein, 1979; Spencer and others, 1986).

Directions and Comments En Route to Stop C2

Leaving Mineral Hill mine, drive approximately 1/2 mi up Mineral Wash. Mineral Wash fault is clearly visible on the right side of the wash, where it places Tertiary breccia of Planet volcanics to the southwest over postdetachment basin-fill fanglomerate to the northeast. The fault dips to the southwest and thus has apparent reverse offset. The fault dip is highly variable, and the fault has horizontal striations on slickenside surfaces.

Continue driving up Mineral Wash. Follow the road to the left as it leaves Mineral Wash approximately 1 mi from the Mineral Hill mine and drive another 5 mi to the pass over the northernmost of three foliation arches that form the lower plate of the central and eastern Buckskin Mountains. To the south of the pass is Squaw Peak, a klippe composed primarily of Paleozoic carbonates. Drive another 1.3 mi and turn left onto the straight road that becomes an old landing strip. Drive 3/10 mi and turn right to go by four white claim posts.

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Stop C2: BCC Mines

Stop and walk east or southeast to the open cuts and mine dump. This is an excellent example of lower-plate mineralization consisting of specular hematite-chlorite-quartz with local chrysocolla along fractures and shear zones in lower-plate gneiss. Specular hematite here is unusually coarse grained and hard. This is part of the Squaw Peak subdistrict of the Swansea mineral district (Keith and others, 1983; Spencer and Welty, 1985).

Directions and Comments En Route to Stop C3

Return to the vehicles, drive back to the main road, and turn left at the stop sign. Drive 1.4 mi to the stop sign at the four-way intersection. Turn left and drive approximately 5.5 mi to a pass. Stop at the pass and walk up the ridge to the left (north).

Stop C3: Swansea Overlook

Lower-plate crystalline rocks are well exposed in road cuts near the pass. Walk up the ridge on the north side of the pass to the detachment fault and upper-plate carbonates. The carbonates probably were originally Paleozoic carbonates but have been so modified by Tertiary hydrothermal activity that their protolith is uncertain. Walk further up the carbonate ridge if you want a better view. From here, looking east and northeast, you can see upper-plate rocks in the Swansea synform, and the Clara Peak klippe on the Clara arch, which forms the south flank of the Swansea synform. Beyond the Bill Williams River, which crosses the Swansea synform approximately 10 mi to the east-northeast, are the Rawhide Mountains. Dark upper-plate Paleozoic, Mesozoic, and Cenozoic rocks in detachment-fault contact with light-gray, lower-plate mylonitic crystalline rocks are clearly visible in the Rawhide Mountains (Shackelford, 1980). Approximately 12 mi to the east-northeast, the northwest-trending, northeast-side-up Lincoln Ranch reverse fault offsets the detachment fault and forms an abrupt termination of exposures of upper-plate rocks in the Swansea synform.

One-and-a-half miles to the east along the south side of the Swansea synform is the Swansea mine. A 1-mi-long sliver of dominantly Paleozoic carbonates is bounded by the detachment fault to the southeast and upper-plate crystalline rocks to the northwest. The carbonate sliver dips northeast beneath the crystalline rocks (see cross section in Wilkins and Heidrick, 1982). Mineralization at surface exposures consists of massive specular hematite replacing carbonates, with fracture-filling chrysocolla. Nineteenth-century underground mining was focused on chalcopyrite veins up to 1-2 m thick within specular hematite (J. Challinor, pers. comm., 1984).

Directions and Comments En Route to Stop C4

Drive 5.5 mi back to the four-way intersection and turn left at the intersection. Drive 5.8 mi over the Clara arch to the intersection with the Bouse-Lincoln Ranch Road. Turn left, then immediately turn right onto the powerline road. Drive approximately 1/2 mi and park near the base of the hill to the south.

Stop C4: Starting Point Knob

Walk up the ridge to the south through tectonized lower-plate metasedimentary rocks and locally interleaved crystalline rocks. The southwest end of the Ives Peak arch, the southern of three lower-plate arches that form much of the Buckskin and Rawhide Mountains, is clearly visible to the east. Tectonized metasedimentary rocks form a southwest-dipping carapace over the southwest end of the arch and are underlain by crystalline rocks. The metasedimentary rocks contain at least six map units (Marshak and Vander Muelen, 1987), which were probably derived from lower Mesozoic and possibly Paleozoic sedimentary protoliths. The contact between the metasedimentary cover sequence and underlying basement crystalline rocks is everywhere parallel to mylonitic foliation and local lithologic layer in cover rocks, but is discordant to more steeply dipping, premylonitization, crystalloblastic foliation in basement rocks. Mylonitic shear zones in basement rocks overprint and transpose older foliation and gneissic layering. Slip-line calculations based on tight inclined to recumbent folds in cover rocks indicate top-to-the-northeast shear parallel to the direction of mylonitic lineation (Marshak and Vander Muelen, 1987).

Directions and Comments En Route to Stop C5

Return to the vehicles, turn around, drive back (1/2 mi) to Bouse-Lincoln Ranch Road, and turn right. Drive 8.5 to 9 mi northeast along the axis of the Lincoln Ranch synform to the second of two adjacent roads joining the main road from the left. Turn left on the second road and drive up the canyon for several hundred yards to an area that is suitable for parking and for turning around and that is next to a mine.

Stop C5: Clara Mineral District

The detachment fault in the Clara mineral district places Miocene sandstone and conglomerate above mylonitic crystalline rocks. Most of the mineralization in the Clara district is represented by fracture-filling chrysocolla and iron oxides in microbreccia below and adjacent to the detachment fault. The mine at the area where the vehicles should be parked contains typical detachment-related mineralization. Note that mineralization ends abruptly upward at the detachment surface, indicating that mineralization at this mine ended before faulting ended.

Directions and Comments En Route to Stop C6

Drive back to the main road, turn left, and continue down the Lincoln Ranch synform. After 2 to 2.5 mi, the main road will fork. Take the left fork to Johnson Ranch, not the right fork, to Lincoln Ranch. At 2.5 to 3 mi past the fork, the road will merge with a gasline road as the road you are on turns left. Continue north-northwest for 3.5 mi along the gasline road until you are at the Bill Williams River crossing. Do not cross the river! Go left up the wash that enters the river at the crossing. Approximately 1/4 mi up the wash is a wide concave-eastward bend. Stop here.

Stop C6: Upper-Plate Normal Fault

Along the outside bend in the wash is a gently dipping normal fault that places steeply tilted, massive to very poorly bedded, Miocene conglomerate on top of gently tilted Miocene sandstone. The conglomerate unit is the stratigraphically highest tilted Tertiary unit in the central Buckskin Mountains and depositionally overlies the sandstone unit. The major difference in bedding attitudes above and below this gently northeast-dipping normal fault is interpreted as a product of rotation of the upper unit above a listric normal fault. Mylonitic clasts derived from completely denuded lower-plate rocks

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during detachment faulting are present in the conglomerate unit.

Directions and Comments En Route to Stop C7

Drive the vehicles 1/3 mi up the wash and note the detachment fault descending into the wash from the left side. If we have time, we will stop here and examine the fault and upper-plate, mylonite-clast-bearing conglomerate.

Continue up the wash for perhaps 100 to 200 yd and turn left on the road that ascends out of the wash and returns to the gasline road. Turn right on the gasline road and drive 3 to 3.5 mi to the fork in the road. Take the left fork, which will keep you on the gasline road. Drive another mile until you reach the point where the gasline road crosses the Lincoln Ranch Road. Turn left onto the Lincoln Ranch Road and drive 2 mi until you approach the gate to Lincoln Ranch. At approximately 150 yd before the gate to Lincoln Ranch, note the mileage, turn right onto an old road, and follow the road around the base of the cliffs of upper Tertiary basin fill. The road eventually leads to the south, up and out of the Lincoln Ranch area. After you have driven 3.6 mi from the intersection with the Lincoln Ranch Road, you will be at the top of a hill in light-colored, older Quaternary alluvium. Turn left on the old road and drive down the ridge crest to the flat area.

Stop C7: "A-Bomb Canyon"

Stop at the flat cleared area that looks like an old drill pad. Walk approximately 50-100 yd farther down the road and look for the burro trail descending into the canyon to the east. Follow the trail down to the wash. A detachment fault is beautifully exposed in the canyon bottom. Chloritic breccia and microbreccia below the fault contain "floating" clasts of protolith mylonitic granitic and gneissic rocks. The fault contact is sharp, with shattered granite forming the upper plate. A broken lens of dark-brown carbonate is exposed at the base of the upper-plate granite.

Walk down the canyon through shattered, upper-plate granite to a high-angle normal fault in the upper plate that places red Miocene sandstone down against the shattered granite. Note the high-angle discordance between the bedding and fault plane.

Return to the exposure of the detachment fault and, if there is time, walk up the canyon. Various upper-plate rock types, consisting primarily of mid-Tertiary volcanic and sedimentary rocks, are crushed, brecciated, and cut by a reverse fault. Upper-plate conglomerate and sandstone locally contain manganese oxides that occur at the same stratigraphic level throughout the Lincoln Ranch basin (Spencer and Reynolds, 1986b). The deposits are stratabound sedimentary deposits similar to those in the Artillery Mountains to the east (Lasky and Webber, 1949).

Directions and Comments En Route to Stop C8

Return to the vehicles, drive back to the gasline road, and turn left. At about 1 mi from the intersection with the gasline road, you will see a klippe of mid-Tertiary volcanic and sedimentary rocks that forms a dark-brown hill to the left. Drive another 1/4 mi past the klippe to a point where the road crosses a wash. Turn left down the wash, drive for approximately 1/2 mi, and ascend to the right on a road leading out of the wash. Drive another 1/4 mi and stop at the manganese mine.

Stop C8: Manganese Mine

A sandstone and conglomerate unit forms a small fault block bounded below by the detachment fault and bounded above by several intersecting upper-plate faults. Manganese mineralization occurs within this stratigraphic unit elsewhere in the Lincoln Ranch basin, but not in other units. Mineralization is interpreted to be sedimentary, as are deposits to the northeast in the Artillery Mountains (Lasky and Webber, 1949). At this locality, aqueous fluids are interpreted to have mobilized the manganese slightly after sedimentary deposition, resulting in manganese coatings along some well-exposed fault surfaces. Manganese mineralization ends abruptly downward at the detachment fault, indicating that detachment faulting ended after mineralization.

Directions and Comments En Route to Phoenix

Return to the gasline road (3/4 mi), turn left, and proceed over Ives Peak arch to Butler Valley. The Little Buckskin Mountains form the small range to the east in Butler Valley. The Harcuvar Mountains form the large range-flanking Butler Valley to the south. These two ranges are composed of lower-plate, variably mylonitic crystalline rocks, and each represents an east-northeast-trending foliation arch like the three in the Buckskin and Rawhide Mountains (Rehrig and Reynolds, 1980). Approximately 15 mi from the last stop, the gasline road will intersect a paved road. Turn right, drive over Cunningham Pass, and turn left when you reach the town of Wenden. The highway continues up McMullen Valley, which is interpreted to be a synform in the Bullard detachment fault between the antiformal crests of the Harquahala Mountains to the south and Harcuvar Mountains to the north.

At MP 74, the bench slightly below and to the north of Harquahala Peak, the highest point in the Harquahala Mountains, contains the Harquahala thrust, a major thrust that here places Proterozoic crystalline rocks over a deformed Proterozoic porphyritic granite and slices of Paleozoic metasedimentary rocks (Reynolds and others, 1986). Lower-plate granite and thrust-zone mylonites are cut by numerous light-colored pegmatites and northwest- to west-trending dioritic dikes that readily weather to form small topographic notches.

The small dark-colored hills along the southeastern flank of the Harcuvar Mountains are Tertiary volcanic and sedimentary rocks in the upper plate of the Bullard detachment fault, which dips southeast off the flanks of the range. Bullard Peak, the low, dark peak at the base of the range, is composed of moderately dipping to vertical Miocene andesite flows that strike east-west, directly into the underlying detachment fault. Aguila Ridge, the long ridge north of Aguila, is composed of southwest-dipping, upper-plate middle Tertiary volcanic and sedimentary rocks that depositionally overlie Proterozoic crystalline rocks (Reynolds and Spencer, 1985).

Eagle Eye Peak, the dark reddish-brown peak on the northeast end of the Harquahala Mountains (south of Aguila), is composed of southwest-dipping, middle Tertiary volcanic and sedimentary rocks that are underlain by the northeast-dipping Bullard detachment fault. South of Eagle Eye Peak are the Big Horn Mountains.

Closer to Wickenburg, the highway passes north of the Vulture Mountains. This range contains a series of tilted fault blocks of moderately northeast-dipping middle Tertiary volcanic and sedimentary rocks, underlying Proterozoic crystalline rocks, and Late Cretaceous granodiorite (Rehrig and others, 1980). A

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low-angle normal fault that places tilted volcanics over Proterozoic crystalline rocks is exposed at MP 102.1. Gently dipping 13.5-m.y.-old basalt that unconformably overlies the tilted Vulture volcanics is present near MP 103.

From Wickenburg proceed to Phoenix via U.S. Highway 60 to either (1) the Carefree Highway past Lake Pleasant and south on I-17, or (2) Litchfield Park Road south past Luke Air Force Base and east on I-10. Do not take U.S. Highway 60 all the way to Phoenix; it is a very slow route because of numerous six-way stop lights.

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