DETAILED GEOLOGIC MAP OF THE UPPER APACHE WASH AREA, CENTRAL SOUTHERN PLOMOSA MOUNTAINS WEST-CENTRAL ARIZONA

by

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Rock Units

Qs **Undivided alluvial sediments (Quaternary)**--Undivided alluvial sediments; includes unindurated to poorly indurated sand, silt, and gravel. Generally includes alluvium in active channels, old alluvium underlying adjacent terraces (Qoa), and some colluvium (Qtc).

Qtc **Talus and colluvium (Quaternary)**--includes talus with little or no matrix and colluvium mantling hill slopes.

Qoa **Old alluvium (Quaternary)**--generally slightly indurated conglomerate and sandstone. Conglomerates typically are poorly sorted cobble to boulder conglomerate, massive to poorly bedded, with low-angle cross beds and channels preserved. Sandstone occurs as thin, discontinuous lenses.

QTs **Boulder and cobble conglomerate (Quaternary or Tertiary)**--Moderately indurated sandstone and conglomerate, generally buff color; underlies highest geomorphic surfaces preserved. Generally coarser grained and more indurated than Quaternary units.

Tb **Basalt or basaltic andesite (Miocene)**--mostly lava flows, but probably includes some intrusive basalt in section below the felsite unit in the eastern part of the map area. Rock is light to dark grey on fresh surfaces, with a very fine-grained groundmass, and 1-5% crystals of olivine (variably altered to iddingsite), pyroxene and plagioclase, typically 1 mm or less in diameter. Where flows are clearly delineated by basal breccia and scoria zones, they are 2-10 m thick. In the eastern part of the map area the crystal content in the flows varies up section from aphyric to ol ± pyx to ol = pyx (with 2 mm pyx crystals) to ol + pyx + plag. The capping flows on Black Mesa contain fresh olivine, pyroxene and acicular plagioclase crystals. The relative freshness of these capping flows is interpreted to reflect the minimal amount of time these rocks have spent below the water table and is not considered a reliable criteria for identification. The top of Black Mesa is blanketed with pedogenic carbonate of unknown thickness.

Tbs **Basaltic pyroclastic rocks (Miocene)**--red to brown basaltic lapilli to block tuff consisting of scoria, generally poorly indurated and massive. Clasts range from <1 cm to about 1 m in diameter.

Tbi **Intrusive basalt or basaltic andesite (Miocene)**--lithologically identical to unit Tb, but occurs in irregular dikes. Small body that intrudes unit Jqp in the SE part of the map area has a 10-20 cm pyrometamorphic rind of melted and recrystallized Jqp.

Tf **Felsite lava (Miocene)**--light pink grey flow banded felsite containing 2-4% 1mm crystals of plagioclase, biotite, and trace amounts of green pyroxene and hornblende. A 2-3 m thick black vitrophyre is present at the base of the unit, overlying 2-15 m of block tuff and tuffaceous sediments (unit Tft). A single flow is present in the central

eastern part of the map area, approximately 40 m thick; this flow thins rapidly to the N and NW. Probably equivalent to the rhyolite unit of Sherrod and others [1990] (unit Tr) in the adjacent Vicksburg Quadrangle; Sherrod and others [1990] report a biotite K-Ar date of 19.8 ± .4 Ma (biotite) from this unit, and correlate it with the 'older hornblende-biotite andesite' of Miller [1970], which has yielded K-Ar dates of 19.6±.6 and 20.7 ±.6 Ma (hornblende and biotite respectively) [Miller and McKee, 1971; recalculated to new decay constants].

Tft **Tuff and tuffaceous sediments (Miocene)**-- lithic-pumice block tuff and tuff underlying the felsite flow. Interpreted as a pyroclastic apron related to the flow. Lithic fragments in tuffs include basalt scoria and minor black obsidian. Unit probably correlates with unit Tts_2.

Tfi **Intrusive felsite (Miocene)**--lithologically identical to felsite lava, but contacts are vertical and cross-cutting, with 10-20 cm of vitrophyre locally present along contact.

Tts_2 **Lapilli tuff (Miocene)**-- lithic lapilli tuff and tuffaceous sediments, characterized by red-brown basalt scoria lapilli. Contains 1 mm crystals of biotite and plagioclase.

Tt **Welded tuff (Miocene)**--brown weathering dacite(?) tuff containing 5-7% 1 mm crystals of hornblende and plagioclase, with sparse biotite, and trace amounts of quartz and pyroxene. At base is a dark brown porcelaneous densely welded zone. Fiamme are black and glassy in densely welded zone, and light brown (lighter than matrix) in overlying welded tuff; they are generally small (3-5 cm long, ~1 cm thick). Lithic fragments compose about 5% of rock, and consist of dark to light grey and red-brown felsite. Unit probably includes two cooling units, one above and one below the poorly welded tuff unit (Ttu). Lower cooling unit is exposed on the south side of the hill capped by Tf a the eastern edge of the map area; this unit contains sparse blocks of flow-banded felsite (like Tf) and felsite breccia up to about 2 m in diameter; several internal cooling breaks are present in this unit.

Ttu **Poorly welded tuff (Miocene)**--white, non-resistant massive tuff, with crystal assemblage identical to Tt. Poorly welded equivalent of that tuff. Some rocks mapped as Tts are probable equivalent to this unit.

Tts **Tuff and tuffaceous sediments (Miocene)**--buff to white thin to medium bedded massive tuff and laminated reworked tuff. Crystal and lithic content somewhat variable, this unit is a catch all for the thin tuffaceous units commonly present at the base of the basalt sections. Well developed bedding is interpreted to be due to deposition on pre-existing slopes. Irregular and generally anomalously steeply dipping atitudes measured in this unit where it is deposited on pre-Tertiary rocks reflect pre-existing topography. This is particularly well demonstrated where the massive, very gently dipping Ttu unit grades into well bedded Tts with dips of 20°-30° along the buttress unconformity at the eastern edge of the map area.

Ttb **Block tuff (Miocene)**--poorly exposed block tuff containing blocks of pre-Tertiary rocks up to about 1 m in diameter. Probably more widespread than is shown, but impossible to map separately from the conglomerate unit (Tc) due to poor exposures on slopes of Black Mesa. Bedding commonly visible due to internal cooling breaks and crude bedding defined by clast size variations.

Tc **Conglomerate (Miocene)**--Massive cobble to boulder conglomerate. Clasts include all pre-Tertiary units, but clast composition is variable from place to place. Conglomerates in vicinity of the junction of Apache and Italian Washes is nearly monolithologic, derived from Xsm and Yg in the north, grading south to more heterolithic conglomerates southward. The unit is this area includes some sedimentary

breccia (Tsb). Conglomerate on the slopes of Black Mesa contains abundant clasts of strongly foliated Jurassic volcanic rocks (quartz porphyry), along with Paleozoic sedimentary rocks. Major clast types are indicated in parenthesis. Includes coarse alluvial deposits and debris flows. Much of this unit along Apache and Italian washes was mapped as bedrock by Miller [1970], but recognized by Davis [1985] to be a Tertiary deposit.

Tsb **Sedimentary breccia (Miocene)**-- Monolithologic conglomerate and breccia with abundant mudstone to fine-grained sandstone or conglomeratic sandstone matrix. Matrix or clast supported. Blocks are up to about 3 m in diameter. Unit is interbedded with and grades into conglomerate (unit Tc). Lithology of clasts is indicated in parenthesis. Interpreted to include talus, coarse alluvium and debris flow deposits.

Tbr **Monolithologic breccia (Miocene or Oligocene)**--bodies of rock derived from a single parent rock unit, which consist of relatively coherent blocks up to 10 m in longest dimension enclosed in a matrix of breccia with comminuted rock matrix. Contact with coherent (but typically shattered) rock is mapped where preexisting internal structure in the parent rock (e.g. bedding, cleavage) becomes strongly rotated and distrupted between blocks. Also occurs interbedded with conglomerate (unit Tc). Monolithologic breccia grades into intact rock in the Paleozoic section NW of Black Mesa. The breccias in this area preserve the large-scale stratigraphy of the parent Paleozoic section, implying mixing on a scale of less than about 20 m. This unit is distinguished from the sedimentary breccia (unit Tsb) by the lack of epiclastic matrix. This unit is interpreted rock avalanche deposits.

JKd **Diorite intrusions (Jurassic or Cretaceous)**--fine to very fine-grained equigranular diorite or gabbro, consisting of altered hornblende and plagioclase. Hornblende typically altered to chlorite and actinolite(?); plagioclase commonly sericitized. Occurs as thick sills within JKc, and rarely in Jv. Two major sills appear to intrude JKc. In the southwestern corner of the map area the upper sill is boudinaged in sheared JKc below the fault superposing Kfg on JKc.

Apache Wash formation (Cretaceous)

Conglomerate, sandstone and mudstone in the central Plomosa Mountains probably correlates with the McCoy Mountains Formation [Harding and Coney, 1985; Richard and others, 1987; Stone, 1990], but is lithologically distinct due to the abundance of Paleozoic clasts in conglomerates in the section. These sediments will be referred to here as the Apache Wash formation. Although a progression from conglomerate to sandstone to mostly siltstone and fine-grained sandstone is present in the central outcrop belt of the Apache Wash formation south of the map area (see Miller, 1970), mapping along the north edge of this unit suggests complex facies changes are present adjacent to a probable fault that was one boundary of the depocenter. Unrecognized internal faults may also seriously disrupt the apparently simple stratigraphic sequence. Several facies of the Apache Wash formation have been differentiated and mapped in this study and are described below. However, no stratigraphic sequence is implied. Further work will elucidate the relationships between these units.

Kfg Fine-grained clastic rocks--very thin bedded, locally laminated, mudstone, siltstone and very fine-grained sandstone. Thin cobble conglomerate beds are present. Generally medium to dark grey weathering, with phyllitic sheen; locally greenish grey or brown weathering. Distinguished by very thin bedding and fine grain size. Forms wide outcrop area E of Apache Wash, but variable, typically gentle to moderate dips and the presence a open upright folds suggest that the stratigraphic thickness is much less that the width of outcrop would indicate. Appears to be interbedded with megablock conglomerate at the southeast edge of its outcrop in the map area. Contact

with megablock conglomerate just east of Apache Wash is abrupt fining upward gradation over about 10 m. This unit is also interbedded with sandstone and conglomerate in the area SW of Dos Picachos.

Ks Sandstone--massive to medium bedded sandstone. Fine to coarse grained lithofeldspathic sandstone and conglomeratic sandstone, generally medium grey to greenish grey. Characterized by monotonous, relatively homogeneous sandstone, in which bedding orientation is commonly difficult to see.

Ksc Sandstone and conglomerate--thin to medium bedded interbedded sandstone, conglomeratic sandstone and conglomerate. Siltstone or mudstone partings are common. Sandstone is lithologically similar to that in the sandstone unit (Ks). This unit is typically well bedded, and is lithologically more variable.

Kc Conglomerate--Massive cobble to boulder conglomerate. Clasts include Jurassic volcanic rocks (Jv), lower Paleozoic formations, and Proterozoic granitoid (unit Yg). Bedding is absent.

Kbr Breccia--monolithologic breccia consisting of angular clasts of Coconino Quartzite in a matrix of comminuted quartzite. Unit is well indurated. Present at the base of the Apache Wash Formation NE of Dripping Spring.

Kmb Megablock conglomerate and breccia--blocks of Paleozoic and Proterozoic rock up to about 50 m in long dimension enclosed in a matrix of lithofeldspathic to arkosic sandstone and conglomerate. Two types have been observed: 1) Yg/Cb and quartzite cobble conglomerate type present in a zone below the Poorman thrust in the eastern part of the map area. This type consists of 1-50 m long blocks which appear to be internally coherent (locally depositional contacts between Cb and Yg are preserved) thin sheets with a sandstone and conglomeratic sandstone matrix (like Ks). Depositional contacts between sandstone matrix are locally preserved, indicating that the mixing of the blocks in the sandstone is primary. The matrix is an arkosic grit apparently consisting largely of disaggregated Yg. In outcrops east of Apache Wash the blocks become mostly Redwall and Martin Formation westward towards the wash. The unit apparently grades into sandstone (Ks) or sandstone and conglomerate (Ksc) to the east both in the Poorman Mine area and in the southeastern part of the map. The contact with Crystal Hill formation (JKc) in the southeastern part of the map is interpreted to be depositional; an interval of bleached JKc, and local angular clast conglomerated derived from JKc is present along the contact. This contact may also be a fault. Whatever its nature, it pre-dates the formation of cleavage in rocks adjacent to the contact.

2) The second megablock conglomerate type is present in a thin interval between the chaos unit (JKch) and conglomerate SW of the Apache Chief mine. This unit contains much less matrix, and consists of large blocks or sheets of Dm, Mr and Cb separated by thin lenses of calcareous lithic sandstone. Thin limestone beds with algal structures are rarely present in these sandstones.

JKch (Pzl; DMu) **Chaos (Jurassic or Cretaceous)**--complexly mixed lenses and blocks of Cb, Dm, Mr, Jv and rarely Pk. Contacts are faults, no matrix is present. Blocks are 5 to several hundred meters long. The unit was not mapped in sufficient detail to establish the geometry of the individual blocks, but a large and several small masses of Jurassic volcanics (Jv) and a swarm of smaller blocks of Cb have been mapped. Association with the megablock conglomerate and the presence of conglomerate apparently in depositional contact on the west side of the unit north of Dripping Springs suggest a sedimentary origin as a large rock avalanche deposit. Complex intermixing of Jurassic volcanic rocks (interpreted to be welded tuff) within the unit suggests the

possibility that the unit is related to a caldera collapse event associated with Jv. Alternatively the chaos may have developed as a series of rock avalanche deposits or by mixing in a fault zone.

JKc **Crystal Hill formation (Jurassic or Cretaceous)**-- interbedded quartzite cobble conglomerate, quartzite, calcareous quartz arenite, and fine to very-fine grained purple sandstone. Thin to thick bedded. Equivalent to continental red bed deposits of Miller [1970]. Informal name proposed here for lithologically distinct quartz-rich sedimentary rocks previously included as the basal units of the McCoy Mountains Formation [Harding and Coney, 1985; Stone, 1990]. In the Plomosa Mountains area these sediments are overlain in angular unconformity by conglomerates of the McCoy Mountains Formation in the Livingston Hills and Apache Wash formation in the southeastern part of this map area.

JKcc **basal conglomerate of the Crystal Hill formation (Jurassic or Cretaceous)** locally differentiated, otherwise indicated as a marker bed along the basal contact of the unit. Angular to sub-rounded clasts of Jurassic volcanic rocks and sediments derived from Jurassic volcanic rocks, Proterozoic volcanic rocks (like unit Xh), Scadden Mountain quartz monzonite(?), bull quartz and subrounded to rounded vitreous quartzite clasts. Massive; cleavage obscures sedimentary structures. Matrix is lithic sandstone; conglomerate is clast supported.

Jrv **Rhyolite to rhyodacite volcanic rocks (Jurassic)**--very light grey quartz-feldspar phyric welded tuff and hypabyssal intrusions. Generally massive and featureless, but sparse fiamme and lithic fragments are visible on properly weathered surfaces. Unit is crystal rich within the map area, with 15-20% crystals of quartz in 1-4 mm eyes, and feldspar (mostly plagioclase?) in 2-3 mm subhedral to euhedral crystals. Lithologically identical to volcanic rocks dated at 155-160 Ma in the southern Little Harquahala Mountains [Reynolds and others, 1987].

Jqp **Monzogranite porphyry (Jurassic)**--Massive, very light grey monzogranite intrusion with 5-20% 1-4 cm potassium feldspar phenocrysts, 5-15% 3-7 mm rounded quartz phenocrysts, and 20-40% 1-3 mm blocky plagioclase phenocrysts in a very-fine grained groundmass. Equivalent to quartz monzonite porphyry of Miller [1970], but that unit included at least two other rock types mapped separately here.

Jl **Latite(?) flow (Jurassic)**--Massive dark purple gray lava with local fragmental texture. 2-3% crystals of plagioclase are present.

Jv **Vampire Conglomerate (Jurassic)** --Massive purple-gray cobble to boulder conglomerate. Consists of angular to sub-round clasts of Proterozoic volcanic rocks, Scadden Mountain quartz monzonite, and brown crystalline carbonate, and rounded vitreous quartzite clasts. Strong cleavage obscures sedimentary structures. Matrix is lithic sandstone to grit. Correlated with the Vampire Formation of the Buckskin Mountains -[Reynolds and others, 1987] by Lerch [1990].

Pc **Coconino Quartzite (Permian)**--very thinly bedded white vitreous quartzite; high angle eolian cross beds are visible in good outcrops.

Ps **Supai Formation (Pennsylvanian and Permian)**--calcareous quartz arenite, interbedded with sandy limestone, vitreous quartzite and purple siltstone; medium to thick bedded.

DMu **Martin and Redwall formations undivided**

Mr **Redwall Limestone (Mississippian)**--Massive limestone with lenticular stratiform chert nodules. On the west slope of Black Mesa concentric structure within these

nodules is preserved. At the top the the section a paleo-karst zone is preserved, with carbonate cemented breccias and irregular (cavern-filling?) pods of purple mudstone.

Dm **Martin Formation (Devonian)**--medium bedded dark grey, brown and tan dolomite. Basal part of unit is sandy and dark brown weathering.

Ca **Abrigo Formation (Cambrian)**--thin to very thin bedded quartzite and mudstone. Coarsening upward cycles from mudstone to very thin-bedded fine grained feldspathic sandstone are present in the central part of the unit. Best preserved section on west slope of Black Mesa is cut by numerous faults, making reliable thickness estimates difficult, but unit appears thicker that Abrigo Formation in the Little Harquahala Mountains.

Cb **Bolsa Quartzite (Cambrian)**--thin to medium bedded feldspathic and arkosic quartzite. Grades from arkosic grit at basal contact with Yg to thin-bedded fine grained feldspathic sandstone at top. Contact with Abrigo Formation is placed at first mudstone bed thicker than 10 cm.

JYsf **Sore Fingers monzogranite(?) (Jurassic or Proterozoic)**--porphyritic monzogranite; consists of 40-50% plagioclase in 3-5 mm subhedral blocky grains, 20-30% K-feldspar in 1-3 cm blocky, equant phenocrysts, 15-20% quartz in 2-4 mm grains interstitial to the plagioclase, 5-7% biotite in very fine grained recrystallized clots. Strongly resembles Sore Fingers monzogranite of the Little Harquahala Mountains [Spencer and others, 1985]. May actually be a phase of the Proterozoic monzogranite (Yg); strong hematite-sericite alteration makes recognition of the rocks difficult. Generally finer grained than Yg, with a more porphyritic look.

JYd **Diorite (Jurassic or Proterozoic)**--texturally variable diorite, ranges from very fine to medium-fine grained. Dark greenish grey rock consists of altered hornblende and plagioclase. Occurs as sill (now vertical) intruding Yg just below nonconformity with Bolsa Quartzite. Just south of map area may intrude Bolsa Quartzite.

JYg **Granite (Jurassic or Proterozoic)**--medium grained, equigranular granite, consisting of 40-50% pink K-feldspar in 3-6 mm anhedral to subhedral grains, 20-25% 2-3 mm subhedral blocky plagioclase, 25-30% quartz in 1-3 mm anhedral grains, and 2-4% biotite in variably chloritized and recrystallized 1-2 mm flakes. Typically has bleached look with white sericitized or argillized plagioclase. Unaltered boulders of this granite are present in the conglomerate between Italian and Apache Washes north of the Apache Chief Mine.

JXg **Poorman granitoid (Jurassic or Proterozoic)**--medium grained equigranular monzogranite, consisting of 40-50% subhedral to euhedral plagioclase with rare 1 cm euhedral plagioclase phenocrysts, 30-35% K-feldspar in 2-5 mm subhedral to anhedral grains, 15-20% 1-2 mm anhedral quartz, and 3-5% biotite generally recrystallized to very fined grained clots, but rarely preserved as 3 mm flakes. Ubiquitously sericitized and hematite stained (see notes on alteration and mineralization)

Yg **Monzogranite (Proterozoic)**--coarse grained, slightly porphyritic monzogranite. Consists of 30-35% quartz in 1-5 mm anhedral grains, 30-35% plagioclase in 1-4 mm blocky subhedral grains, 15-25% K-feldspar in anhedral 2-8 mm grains and in elongate blocky, zoned phenocrysts 2-3 cm in diameter, and 3-5% biotite in 1-3 mm very fine-grained recrystallized clots. Equivalent to coarse grained quartz monzonite of Miller [1970]. Lithologically identical to Socorro Granite

Xsm **Scadden Mountain quartz monzonite (Proterozoic)**--medium grained equigranular monzogranite to granodiorite; consists of 25-35% anhedral quartz, 40-50% subhedral plagioclase, 10-20% subhedral K-feldspar, and 3-5% 1-2 mm

recrystallized biotite clots. Miller [1970] reports a uranium-lead age of 1730-1750 Ma attributed to L. T. Silver.

Xh **Hornfels (Proterozoic)**--dark reddish grey, greenish grey and grey aphanitic hornfels; locally contains 1-2 mm quartz phenocrysts and a laminar foliation, strongly resembling the Proterozoic volcanic rocks associated with the Scadden Mountain quartz monzonite (northern outcrop of pCv unit, Miller [1970]). Other rocks included in this unit are aphyric, aphanitic and homogeneous, and include dikes of unknown (pre-Tertiary) age as well as Proterozoic metavolcanic rocks.

—^^— **old mafic dike**--altered very fine grained, equigranular basaltic dikes. May be related to JYd or JKd. Consist of chloritized amphibole(?) and plagioclase.

ooooo **conglomerate marker bed**

sandstone marker bed

Alteration and Mineralization

Mines and prospects in the map area are located primarily in two settings: 1) in quartz veins cutting all pre-Tertiary rock units and 2) along mineralized faults. Numerous quartz ± calcite veins are found throughout the map area; these are typically steeply dipping and trend 090°-150°. Mineralized quartz veins typically contain specular hematite, red iron oxides replacing pyrite or less commonly chalcopyrite, and sparse malachite and chrysocolla. Sphalerite(?) is rarely present. Sericitic bleached selvages occur along the margins of the quartz veins. Mineralized faults typically contain gouge zones with sericitic alteration in and adjacent to the fault. Earthy hematite and sparse malachite and chrysocolla are present along these fault zones.

In addition, rocks adjacent to the Jurassic monzogranite porphyry west of Black Mesa are pervasively weakly to strongly sericitized and hematite stained, but there are presently no mines in this alteration zone. Similar alteration affects the Proterozoic monzogranite exposed on the pediment NNE of Chalk Tank but Jqp is not exposed in this area. This alteration may be related to the Poorman thrust, intrusion of Jqp, or to fluid flow in the vicinity of the breakaway zone related to Miocene extension.

Description of mines and prospects visited.

1. 30-40 foot deep trench, 70-80 feet long in shattered Redwall-Martin undivided carbonates. Can't see structure of vein; trench trends NE. Judging from mine waste, mineralized zone was shattered with rest of block, probably associated with movement on east-trending fault that juxtaposes Tc and Xsm. In waste heap see quartz veins with abundant malachite + chrysocolla; strongly sericitized Xsm, and some bull quartz with massive, very fine-grained chlorite. Minor specular hematite is present in quartz.
2. Quartz-hematite-malachite vein. Highly fractured. Oriented 003/77°W. Black, red and orange FeO_x ($\pm MnO_x$) in veins; open space with drusy quartz crystals also present. Adjacent latite (Jl) is sericitized.

3. Mineralized fault zone. Series of adits into fault zone. Dos Picachos thrust is brittlely overprinted and mineralized on the N side of Dos Picachos. In the largest adit, a quartz vein in footwall is shattered and cut by the latest phase of movement (associated with mineralization); it consists of quartz with calcite, hematite and minor malachite. Open space in the vein contains drusy quartz. Limonite after pyrite is present. Large calcite rhombs are locally enclosed in quartz. Other adits penetrate strongly sericitized and sheared (both cleaved and gougy) rocks in the fault zone, with abundant hematite staining and sparse malachite and chrysocolla.

4. Series of shafts and prospects in quartz veins. Veins are subconcordant with cleavage in Kfg near contact with JKc. Veins consist of quartz with large calcite rhombs. Black FeO_X, MnO_X, and minor malachite are present in younger crush zones in veins. Open space contains drusy quartz, limonite after pyrite and minor barite(?). Some veins have comb structure in quartz. Veins have sericitic alteration selvages. Typical vein orientation 030/40°NW.

5. Thin quartz veins in lower Paleozoic carbonate trend 160/90. These consist of quartz, with calcite, chrysocolla and malachite.

6. Apache Chief mine. Series of north-trending (150-180), east-dipping (40-80°) shear zones with associated quartz veins. Veins are quartz with spotty limonite after pyrite and chalcopyrite(?) stockwork. Open spaces in veins contain drusy quartz and malachite. Some veins cut fault between conglomerate (Kc) and Crystal Hill formation (JKc). Also gougy shears that cut the quartz veins and contain abundant earthy hematite. Waste heaps around major shaft and tunnel (at south end of the series of shafts) suggest at least 100 feet of underground workings.

7. Poorman mine. Main shaft is in Mesozoic sandstone (Ks) (under thin alluvial cover), waste suggest it bottoms in Bolsa Quartzite (Cb). Quartz-siderite vein material is abundant in waste heap. These veins contain open space with drusy quartz, locally with very fine-grained barite(?) on quartz. The drusy quartz is sometimes brecciated and recemented with more quartz. Other prospects are in sheared, sericitized Ks along fault placing Ks on Cb; thin quartz-hematite veins are abundant. Other prospects explore veins in Cb, oriented 080/90, that consist of quartz with brown carbonate (siderite?) and FeO_X after pyrite or chalcopyrite; sparse chrysocolla is present along their margins. Ks and overlying JXg have pervasive, moderate sericite-hematite alteration; Cb shows much less evidence of alteration.

8. quartz vein. Black, flinty quartz with calcite, chlorite and epidote(?) and tourmaline(?) at contact between Jurassic monzogranite porphyry (Jqp) and Proterozoic monzogranite (Yg). A small prospect in the vein exposes vein material containing specular hematite. Vein looks like it is mostly intensely silicified wall rock. In the prospect, a gouge zone 10-20 cm thick. bounds the vein on one side, oriented 170/60°E. Some drusy quartz in open space and earthy FeO_X are present in the gouge zone.

9. Scattered limonite after pyrite cubes are scattered in bleached, sericitic JKc near the contact with the megablock conglomerate (Kmb). This may be a paleo-weathered zone.

10. Massive silica-tourmaline replacement vein along contact between Jqp and JYsf. JYsf near contact has moderately to strongly silicified, sericitized with hematite staining and spotty aphanitic tourmaline. Sparse radiating clusters of fine-grained tourmaline are present. Alteration is less intense as move away from contact, but all rocks within about 100 m of east contact of Jqp are sericitized and hematite stained.

11. Tunnels in brecciated fault zone between Redwall and Martin formations. Waste heap contains massive and comb-structured silica-FeO_X vein material, as well as spongy quartz-limonite (after pyrite) stockwork. Sparse malachite and chrysocolla fill open space in

refractured silica-FeO_x veins. Brecciated quartz vein material with silica-FeO_x cement also present. In shaft on SE side of canyon mineralized breccia zones in carbonate are irregular and lenticular, along both high and low-angle zones. Adjacent carbonate rocks show little evidence of alteration.

12. hematite-tourmaline(?)-calcite vein. Massive fine-grained specular hematite; cryptocrystalline brown calcite, and cryptocrystalline black tourmaline. To north vein grades into calcite with specular hematite replacing siliceous stringers. May be a metasomatized pendant of Paleozoic carbonate along contact between Jqp and Yg.

13. series of prospects along mineralized fault zone. Hematitic gouge along fault, sericitic alteration in hanging wall and footwall. Fault oriented 032/38 SE here. Minor faults oriented 090/46 N cut the main fault. In one pit a quartz vein oriented 125/90 cuts Kc in the footwall and is truncated at the fault. Vein consists of quartz with brown calcite, and minor very fine-grained cuprite or sphalerite. Trace of chrysocolla disseminated in footwall Kc; wads of earthy hematite are present along subsidiary shears in the conglomerate.

14. Quartz vein. Quartz with limonite after pyrite vein in hematite-sericite altered JKc, about 40 cm thick. Vein is oriented 134/74 NE. Specular hematite replaces drusy quartz in open space in vein. Earthy hematite is present in clots enclosed in quartz. Minor black FeO_x stockwork after pyrite or chalcopyrite is present in quartz. Quartz vein is continuous to NW for about 200 feet and is truncated at a minor NE-trending fault.

15. Belle of Arizona Mine. ENE trending steep quartz vein with a series of shafts dug along it. Vein .5 to 1 m thick, consists of bull quartz shot through with specular hematite veinlets. Vein is highly fractures. Occasionally see specular hematite filling open space around drusy quartz in open space. Intense sericitization and silicification of Xsm adjacent to vein; sparse fine grained disseminated sphalerite(?) in wall rocks. Xsm in area is pervasively weakly sericitized. Northwest-trending quartz (± calcite) veins around the mine are barren.

16. Shaft in fault between Redwall and Supai Formations, oriented 134/64 NE. Massive dense silica-hematite in irregular clots along fault zone. Also earthy hematite along fractures. A few lenses of sericitized Bolsa quartzite are present in the fault zone, otherwise alteration outside of fault zone is minimal.

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Detailed study of this area was prompted by the M. S. Thesis of G. Davis [1985], which indicated that the complexity of faulting in the area might in part be due to the presence of significant, unrecognized Tertiary faults. Conversations and field trips with J. E. Spencer, S. J. Reynolds, D. R. Sherrod, R. M. Tosdal, P. Stone, and G. B. Haxel have helped shape my ideas about the regional geology of southwestern Arizona. A review by J. E. Spencer improved the map and accompanying manuscript.

References

Davis, G., 1985, Geology of the southern Plomosa Mountains [M. S. thesis]: Phoenix, Arizona, Arizona State University, 159 p.

Harding, L. E., and Coney, P. J., 1985, The geology of the McCoy Mountains formation, southeastern California and southwestern Arizona: Geological Society of America Bulletin, v. 96, p. 755-769.

Lerch, M. F., 1990, Geologic mapping and isotopic studies in the Quartzsite region, west-central Arizona: Implications for Proterozoic and Mesozoic tectonics [M. S. thesis]: Tucson, Arizona, University of Arizona, 104 p.

Miller, F. K., 1970, Geologic map of the Quartzsite Quadrangle, Yuma County, Arizona: U. S. Geological Survey GQ-841, scale 1:62500.

Miller, F. K., and McKee, E. H., 1971, Thrust and strike-slip faulting in the Plomosa Mountains southwestern Arizona: Geological Society of America Bulletin, v. 82, p. 717-722.

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

Richard, S. M., Reynolds, S. J., and Spencer, J. E., 1987, Mesozoic stratigraphy of the Little Harquahala and Harquahala Mountains, west-central Arizona, *in* Dickinson, W. R., and Klute, M. A., editors, Mesozoic geology of southern Arizona and adjacent areas, Arizona Geological Society Digest, V. 18, p. 101-120.

Sherrod, D. R., Koch, R. D., and Grubensky, M. J., 1990, Geologic Map of the Vicksburg quadrangle, La Paz County, Arizona: U. S. Geological Survey GQ-1684, scale 1:62500.

Spencer, J. E., Richard, S. M., and Reynolds, S. J., 1985, Geologic map of the Little Harquahala Mountains: Arizona Bureau of Geology and Mineral Technology Open-file report 85-9, Tucson, Arizona, scale 1:24000.

Stone, P., 1990, Preliminary Geologic map of the Blythe 30′ by 60′ quadrangle, California and Arizona: U. S. Geological Survey Open-file Report 90-497, Denver, Colorado, scale 1:100000.

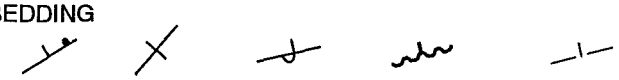
SYMBOLS

FOLIATION; strike and dip

Broken and wavy lines may be used to indicate approximate measurments or curviplanar foliation in conjunction with any symbol

Primary foliation

BEDDING



upright vertical overturned irregular approximate

dots on strike line indicate facing direction based on primatry features

FLOW FOLIATION

flow banding in lavas or hypabyssal intrusions, eutaxitic foliation in welded tuffs; igneous flow foliation in plutons

Tectonic foliations

Differentiated foliations

TRANSPOSED BEDDDING

COMPOSITIONAL BANDING

LAMINATED DIFFERENTIATED FOLIATION

Shape foliation

SCHISTOSITY, CONTINUOUS CLEAVAGE

Disjunct foliation

JOINTS

SPACED (WEAK DISJUCT) CLEAVAGE

CLOSE DISJUNCT CLEAVAGE (fracture cleavage)

Mylonite series

In plutonic rocks

WEAK SHAPE FABRIC (generally L>S)

WELL DEVELOPED S-TECTONITE

PROTOMYLONITE (significant grainsize reduction)

MYLONITE (with lineation indicated)

In gneissic rocks

PROTOMYLONITE; protolith fabric recognizable

MYLONITE; protolith fabric transposed

Superimposed Fabrics symbols as above, double dip tics indicate that fabric is superimposed

GRADATIONAL CRENULATION

SCHISTOSITY

CLEAVAGE PARALLEL TO BEDDING

LINEAR FEATURES; trend and plunge

MINOR FOLD HINGE, showing plunge direction

upright, symmetrical anticline

upright, symmetrical syncline

cascade fold

asymmetrical anticline, showing vergence

LINEATIONS

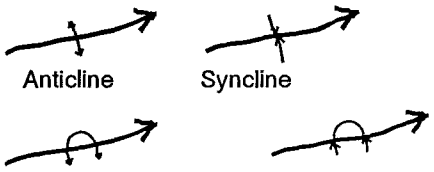
Mineral lineation in L-tectonites

APPARENT DIP

Trace of bedding on cliffs or steep slopes

MAJOR FOLDS

HINGE PLANE TRACE, AND PLUNGE DIRECTION OF FOLD



Anticline Syncline

Overturned anticline overturned syncline

CONTACTS

Solid lines indicate precise location, dashed lines approximate location, dashed with queries very approximate, and dotted inferred beneath younger blanketing or intrusive units.

intrusive or depositional contact; dots indicate well exposed depositional contact

FAULTS

HIGH ANGLE (ball on down-thrown side, arrow indicates dip, box arrow indicates orientation of slickenside striations)

LOW ANGLE (barbs on hanging wall)

thrust

low-angle, nature uncertain

low-angle normal fault

MISCELLANEOUS

Tie line joining regions underlain by same map unit

Patterns

karst zone at top of Redwall Limestone

shattered rock