Geologic Map of the Boulder Mountain 7.5' Quadrangle, Maricopa and Gila Counties, Arizona

by

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INTRODUCTION

The Boulder Mountain quadrangle is centered on the northwest side of the southern Mazatzal Mountains. It includes the area from the ridge-line westward to State Route 87 and the area between the Ballentine trailhead on the south and the small hamlet of Sunflower on the north (see figure 1). The elevation ranges from 2200 feet along Sycamore Creek to over 6200 feet at Pine Mountain. The western parts of the region below about 4000 feet are within the Sonoran Desert and contain saguaro cactus, palo verde, and Sonoran desert vegetation. The highest, north-facing peaks of the Mazatzal Mountains--including Pine Mountain, Little Pine Flat, and Edwards Park--contain conifer and oak forests. But most of the area above 4000 feet is covered with an impenetrable blanket of dense chaparral vegetation. The thick brush combined with the precipitous boulders and deep crags make access to most of the eastern half of the quadrangle extremely difficult. The pipeline trail and the Ballentine Trail were deeply rutted and overgrown.

A dirt road follows the ridge line northward from Pine Mountain all the way to Edwards Park. However, the road is deeply rutted locally and probably impassable for all vehicles except ATV's. An old pick-up truck stuck in a ravine off the side of the road east of Boulder Mountain is a reminder of how unforgiving the road is. Several good dirt roads split off a main road from Sunflower and head up Ram Valley. The trails marked on the map, however, are mostly overgrown with brush.

PREVIOUS STUDIES

Wilson, Moore, and Pierce (1957) published reconnaissance geology of the area in a geologic map of Maricopa County, and later in the geologic map of Arizona (Wilson, Moore, and Cooper, 1969). Anderson and others (1986), and more recently Pearthree and others (1995), made investigations along the Sugarloaf Fault to the southwest of the study area in the Adams Mesa and Mine Mountain quadrangles. Skotnicki (1992) completed a study of the Tertiary rocks in the western half of the map area as part of an M.S. thesis. Conway (1995) mapped the region around Sunflower in a geologic study along Kitty Joe Canyon between Sunflower and Slate Creek to the north. Field work for this project was carried out during the same field season as mapping to the west in the Maverick Mountain quadrangle (Skotnicki and Leighty, 1998).

GEOLOGIC SETTING

Plutonic rocks

Four plutons are exposed in the study area: (1) a coarse-grained quartz monzonite on the south (map unit Xg) is separated from (2) a coarse-grained rapakivi granite on the north (map unit Xgr) by (3) a screen of intrusive rhyolite/granophyre. These three plutons comprise most of the plutonic rocks in the study area. Intruding the quartz monzonite (and non-foliated coarse-grained granite to the west in the Maverick Mountain quadrangle) is (4) a non-foliated medium- to fine-grained granite (map unit Ygm).

The intrusive rhyolite/granophyre (map unit Xf) is the oldest pluton and forms a screen on its western side between the two other plutons (see figures 2 and 3). West of Cypress Peak, Xf contains enclaves of quartzite that Xf clearly intrudes. The contacts between Xf and the other plutons are sharp, though mostly covered by thin colluvium. Near Mud Springs the quartz monzonite is finer-grained near the contact with Xf and is weakly to nonfoliated, whereas Xf is foliated right up to the contact. Locally, along the contact between Xf and Xgr, thin centimeter-wide veins of Xgr intrude Xf. The intrusive rhyolite is both mineralogically and texturally very similar to the rock mapped as metarhyolite to the west in the Maverick Mountain quadrangle. The hypabyssal rock may be the source for the lavas to the west.

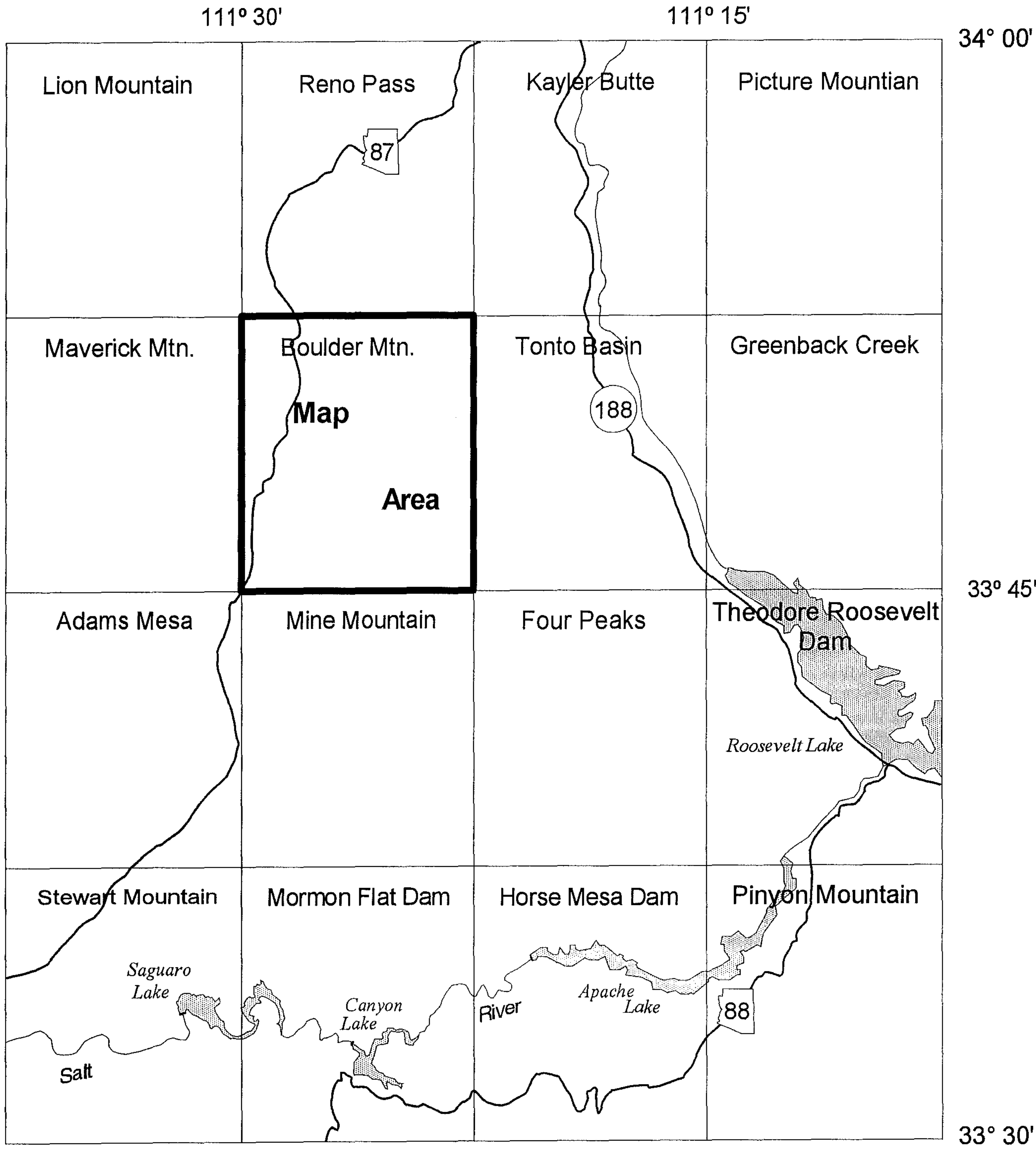

Figure 1. Location of U.S.G.S. topographic maps and study area.

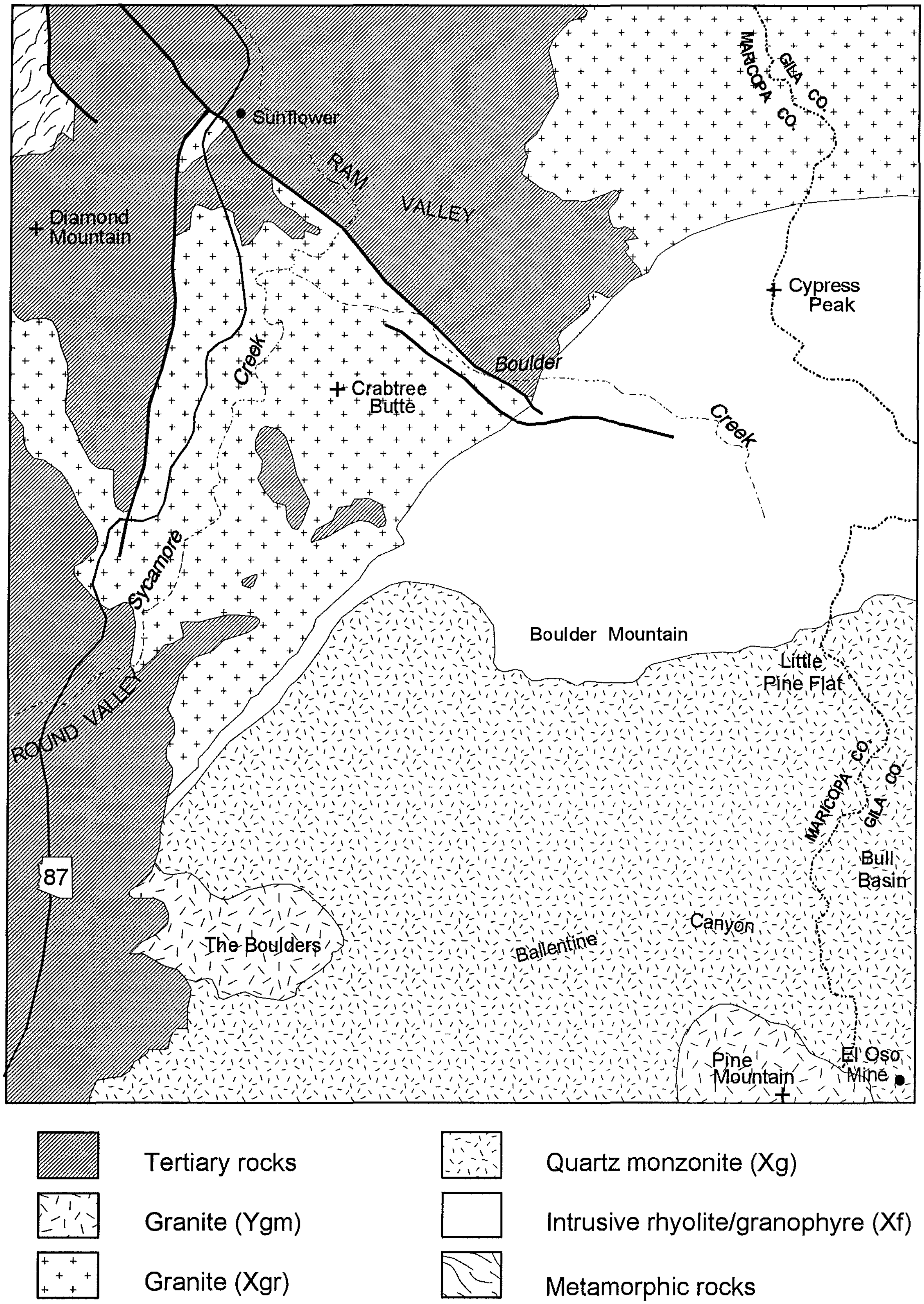

Figure 2. Index map showing general geology and geographic place names in the Boulder Mountain quadrangle.

The quartz monzonite intrusion is very homogeneous. Except near Mud Springs, east of Round Valley, where it is finer-grained, everywhere else the rock was examined it is coarse-grained and contains abundant, square, light grey K-feldspar phenocrysts 1 to 1.5 cm wide. The northern and western parts of the pluton exhibit only a very weak to unmeasurable foliation. Instead, foliation is confined to narrow zones centimeters wide.

The granite to the north (map unit Xgr), dated by Silver (1965) at 1640 ± 15 Ma, is locally nonfoliated most of the way along the highway. It was probably these nonfoliated exposures that led Silver (1965) to interpret this granite as a post-tectonic pluton. In fact, the granite is locally very strongly foliated. The southern-most part of the pluton south-southeast of Black Mesa exhibits both pervasive foliation and foliation confined to narrow zones centimeters to meters wide. North of Round Valley the granite contains a pervasive northeast-striking foliation. Less than 0.5 miles upstream from the head of Round Valley, narrow zones several meters wide have been deformed into mylonite, where the quartz phenocrysts have been smeared and elongated along with the feldspars and micas. Because of time constraints we were unable to examine the area around Crabtree Butte. From a distance the rock in the vicinity of the butte has a slightly darker hue than the surrounding granite and exhibits a more pronounced jointing. This suggests it may exhibit a stronger degree of deformation than the rounded boulders along the highway. Foliation in this unit is also seen in Reno Pass, in the Reno Pass quadrangle to the north.

The youngest plutonic rock in the area is a medium- to fine-grained granite (map unit Ygm). This unit forms two relatively small intrusions in the southern part of the quadrangle at The Boulders and at Pine Mountain. This is the same rock that intrudes coarse-grained granite to the west in the Maverick Mountain quadrangle. In fact, this unit is composed of several separate, but mineralogically identical, bodies that form an arc of small plutons intruding all older granitic rocks from Bartlett Lake to Apache Lake. In the study area at The Boulders, Ygm even intrudes the nonfoliated quartz-feldspar porphyry dikes cutting across the quartz monzonite. Contacts with older rocks are very sharp.

Tertiary rocks

The base of the Tertiary section is defined by a tan-colored pre-volcanic conglomerate. South of Ram Valley the unit is dominated by thin- to medium-bedded grussy sandstones and contains very minor pebbles of metarhyolite and rare quartzite. In Ram Valley the unit still contains mostly granite grus but contains up to about 5% cobbles of grey to tan quartzite, dark purple quartz-rich metaconglomerate, intrusive rhyolite (map unit Xf), tan argillite, and granite, mostly as thin, coarse lenses. The unit is thickest in the south where it is more than 500 feet thick and in Ram Valley where it is at least 300 feet thick. The conglomerate thins towards Diamond Mountain where it appears to have been lapping onto a paleo-topographic high. The paleo-topographic high may have been created purely by differential erosion or possibly by faulting and relative uplift. Northwest of Round Valley (in the Maverick Mountain quadrangle) conglomerate appears to have deposited up against a steep buttress unconformity in granite created by east-side-down normal faulting. The buried fault there project northward and may have controlled local topography. There is evidence farther south in the Adams Mesa quadrangle (Skotnicki and Leighty, 1997a) that the same conglomerate filled a fault-bounded basin created by faulting along the east-dipping Sugarloaf Fault.

Although the original thickness of the conglomerate in the eastern part of the map area is unknown, it is probable that there was much topographic relief in the study area, particularly in the resistant metamorphic rocks. It is not known what the local drainage patterns were during the Miocene. A more detailed study of sedimentary features in the conglomerate might help determine the direction of transport, but we did not have the time to do that in this study. It is possible that the conglomerate was being deposited by streams flowing to the southwest. The fault-bounded basin to the south along the Sugarloaf Fault probably accepted sediment from the east. The basin at Sunflower formed during volcanism and also probably aquired at least some of its sediment from the east. It is also possible that the conglomerate was being deposited by north- and northeast-flowing streams. Such a drainage pattern may have developed during the Eocene, inherited from the time of deposition of the 'rim gravels'. The conglomerate at Edwards Park (map unit Tcr), although of uncertain association to the basal conglomerate (map unit Tc), contains clasts derived from the east, southeast, and south, but not from the north. Just south of the Slate Creek divide, in the Reno Pass quadrangle to the north, the basal conglomerate is composed of mostly granitic material, even though the nearest exposure of granite is several miles to the south. This suggests that here, locally at least, transport was to the north. More work needs to be done before any firm conclusions can be reached.

The conglomerate forms remnants that dip westward off the west slope of the Mazatzal Mountains. From a distance the slope of this depositional, paleo-erosion surface or is now deeply dissected. On the ridge line near Edwards Park (mostly within the Tonto Basin quadrangle), there are remnants of conglomerate containing clasts identical to those within the conglomerate at Ram Valley. The deposits on the ridge-line are mantled by a lag gravel and show no good exposures. They form relatively flat, nearly horizontal constructional surfaces at two distinct elevations that closely resemble river or stream terraces. The fact that they contain the same clasts as those within the conglomerate in Ram Valley suggests the deposits at Edwards Park may be remnants of the basal conglomerate, in which case they would probably be middle (?) Miocene in age. However, the flat constructional surfaces at two distinct levels suggest that if they are remnants of Tc they have since been modified. This suggests the deposits may be Late Tertiary (Pliocene?) in age.

The existence of flat, unfaulted(?) stream-terrace deposits on the ridge-line of the Mazatzal Mountains (if that is in fact what they are) is remarkable and suggests that the development of the Tonto Basin may have occurred more recently than middle Miocene. Melchiorre (1992) found similar fluvial cobble deposits perched on top of the Sierra Ancha Mountains south of Phoenix. The gravels on top of the Mazatzal Mountains contain clasts of quartzite, metaconglomerate, argillite, intrusive rhyolite/granophyre, and granite--no slates, phyllites nor metarhyolites--rocks which are abundant to the north. The source for the clasts within the gravels are exposed only to the east and southeast. If these gravels are really nearly flat-lying then they are either (1) remnants of the basal conglomerate (map unit Tc) sitting on a bedrock block that has undergone minimal rotation during Tertiary block-faulting, or (2) they are younger than Tc and their deposition post-dates tilting of the conglomerate and basalt on the west side of the quadrangle. Even though the event that tilted the basal conglomerate and basalt may have occurred much later than their deposition, at the moment the best constraint on the age of the flat-lying gravels is they are younger than about 15 Ma (see next paragraph for dates).

Overlying the basal conglomerate (map unit Tc) is a sequence of olivine-pyroxene basalts. Tilted mafic flows probably correlative to these basalts have been dated near Bartlett Dam at 14.78 ± 0.40 Ma (K/Ar/w.r., Shafiqullah, 1980), and north of Stewart Mountain at 15.43 ± 0.34 Ma (K/Ar/w.r., Shafiqullah, 1980). Wrucke and Conway (1987) dated similar rocks to the north in the Lion Mountain quadrangle and farther north with ages between 16.1 ± 0.15 Ma and 8.3 ± 2.9 Ma, and correlated them with the widespread Hickey Formation.

South of Round Valley basalt is interbedded with the basal conglomerate (map unit Tc). Elsewhere the flows are interbedded with thin grussy conglomerates a few meters thick, as well as basalt autobreccia and bedded fine-grained scoria. As with the conglomerate, the basalt flows thin near Diamond Mountain where they meet a paleo-topographic high. At Sunflower the upper part of the basalt sequence contains a thick volcaniclastic conglomerate about 150 feet thick. This conglomerate contains poorly sorted, subangular to subrounded basalt clasts in a tan, sandy matrix, and is overlain by basalt containing fresh dark green pyroxene phenocrysts. The entire sequence is cut by a major normal fault slicing northwest through Sunflower. This upper conglomerate is in the same stratigraphic position as the conglomerate to the south along Mesquite Wash in the Mine Mountain quadrangle (Skotnicki and Leighty, 1997b). Both conglomerates contain basaltic material and are overlain by basalt flows containing fresh green pyroxene phenocrysts. The Tertiary sequence to the south along Mesquite Wash filled a basin created by faulting along the Sugarloaf Fault. The conglomerate near Sunflower is not exposed on the opposite side of the fault at Diamond Mountain and thus may also have been deposited in a similar basin created by faulting along the Sunflower Fault.

Quaternary deposits

At least four levels of stream terraces are exposed along Sycamore Creek. They are best exposed along Round Valley where the oldest terrace (Qor) crops out about 90 feet above the modern creek bed. Most of the terrace remnants along the creek contain subrounded to rounded pebbles to small boulders of various metamorphic and plutonic clasts derived from both within and north of the study area. At Round Valley some of the terrace remnants, including the younger flood-plain deposits (map unit Qycr1) contain large rounded boulders of granite (map unit Xgr) up to 2 meters across. The immense size of these boulders in Round Valley may have something to do with the fact that this is where the narrow gorge of Sycamore Creek opens into a wide, flat-floored channel.

The number of major terrace levels (four) suggests a correlation with the terrace levels defined by Pewe (1978) along the lower Salt and Verde Rivers. Although we used this correlation for terrace remnants along Sycamore Creek in the Adams Mesa quadrangle, we were cautious about making the same correlation in the Boulder Mountain quadrangle. This is because it is far from clear if the terrace levels really do correlate. Near Stewart Mountain Dam to the south, old terrace remnants probably equivalent to the Sawik terrace are 200 to 300 feet above the modern drainage. Along Sycamore Creek near Round Valley, however, the oldest terrace remnants are only about 120 feet above the modern drainage. Since Pewe showed that the longitudinal profiles of the Salt and Verde River terraces diverge upstream, one would expect to see the same terraces along Sycamore Creek at elevations higher than 200 to 300 feet above the creek (not taking into account any tectonic activity during the Quaternary). Since they are much lower, the terrace remnants in the study area are either younger than mapped, or the area experienced less relative uplift than surrounding areas where terrace levels are higher.

STRUCTURE

The Sugarloaf Fault, to the south and east of the map area, is a major north- to northwest-striking east-dipping normal fault that formed a basin into which the conglomerates and basalts were deposited. This fault and several smaller, parallel faults immediately to the west in the Maverick Mountain quadrangle have tilted the Tertiary section in the southwest corner of the map about 10°-20° to the west.

Another major north-striking fault is well-exposed in the road-cut immediately south of Black Mesa. This normal fault dips to the west and has down-dropped the Tertiary section in the opposite sense. Together these two faults form a graben, through which State Route 87 now climbs from the southwest corner of the map to Black Mesa.

The Sunflower Fault (adopted after Conway, 1995) is another major east-dipping normal fault. It strikes to the northwest through the town of Sunflower, dips steeply to the northeast, and has down-dropped the Tertiary section on the northeast. The Tertiary rocks dip 5°-10° to the southwest, but are warped in the opposite direction locally adjacent to the fault by drag-folding. If the base of the basalt flows near Sunflower is equivalent to the base of the basalt flows at Diamond Mountain then offset along the Sunflower Fault is about 580 meters. About 2 miles southeast of Sunflower, along Boulder Creek, the fault is really two separate faults. One is well exposed on aerial photos and cuts through the granite and intrusive rhyolite/granophyre up on the slope on the south side of Boulder Creek. On the ground this branch is characterized by a local change in slope and dense vegetation. The second branch is mostly obscured and projects beneath the alluvium of Boulder Creek, where it displaces conglomerate and basalt on the northeast from plutonic rocks on the southwest. This branch is not well exposed and can only be seen in two places along the creek where conglomerate and basalt butt up against granite (exposures are poor). It is not known if the two branches converge to the east. The Sunflower Fault projects eastward along the south side of Boulder Creek at least as far as where the creek enters a narrow gorge. About at the same place the fault appears to die out in intrusive rhyolite/granophyre.

About 1 mile south of Crabtree Butte two small high-angle faults within the granite strike northeast and dip to the southeast. These faults are defined by a 1-2 meter-thick zone of crushed granite stained by hematite. The orientation of these faults is parallel to two small faults within granite about three miles directly west, southeast of Black Mesa. The faults to the west also are high-angle, southeast-dipping faults defined by a zone of crushed granite 1-2 meters thick stained by hematite. They are parallel to several other larger northeast-striking faults to the west in the Maverick Mountain quadrangle which formed prior to development of the northwest-striking faults.

MINERALIZATION

Just north of where Boulder Creek crosses the Sunflower Fault the granite is cut by narrow 5 meter-wide shear zones filled with dark grey-green chlorite schist. At least one pit has been dug into one of them. No mineralization was seen. Less than 200 meters southwest of this area, on the south side of the fault, a near-vertical fracture zone in the granite is permeated by white vein quartz. The quartz forms a resistant dike 2-4 meters thick. The quartz infiltrates the bordering granite in thin, anastamosing veinlets. Hematite is very abundant on secondary fracture surfaces in the quartz. At least three adits have been dug north of the vein but not into it. They appear to have been dug along north-striking fractures/shear zones filled with dark green chlorite schist and crushed granite with much hematite alteration. No slicks are visible. Some fractures are filled with thin quartz veins. One zone has an attitude of about 150°, 85°W.

At the El Oso Mine in the southeast corner of the map a deep adit has been dug into quartz monzonite (map unit Xg). The adit appears to follow several closely spaced fractures with attitudes of about N10°E, 75°E. A discontinuous white quartz vein 0-30 cm thick, with an attitude of N60°E, 30°E, cuts obliquely across the adit. Pyrite occurs as fine-grained (less than 2 mm) disseminated clumps in the quartz vein and throughout the granite. The El Oso Mine produced Tungsten in the form of both wolframite and scheelite. According to the Department of Mineral Resources Mine Owner's Report dated April 29, 1942, the tungsten minerals were found associated with quartz veins. Very fine-grained, dark grey disseminated crystals are all that are visible today but wolframite crystals the size of a fist were reported. Other minerals found during mining were large crystals of feldspar, quartz, mica, tourmaline, and fluorite. We did not have the time to examine the Jolene Mine, about 2 km north of the El Oso Mine, but the same report describes the Jolene Group of claims as being within a roof pendant (of unspecified composition) within the surrounding granite. The report describes two sets of (conjugate) veins. In the north, east-west veins have attitudes of N75°W, dip north, and in the south, north-south veins have attitudes of

N24°E, and dip west. According to the Department of Mineral Resources Field Engineers Report dated March 21, 1956 the Mine was last worked in September, 1955.

About 1 km northwest of Sunflower a quarry and a few small pits have been dug into the Sunflower Fault where it down-drops basalt on the northeast against conglomerate (map unit Tc) on the southwest. The fault is filled with a zone 0-10 meters thick locally of light grey, coarse-grained, radiating calcite crystals. The crystals radiate outward from a central clast and also form crudely laminated deposits encrusting fault breccia. Locally, the laminae have a pervasive attitude of N60°W, 60°N.

About 2 miles northeast of Sunflower, just outside the map area in the Reno Pass quadrangle, is a small grouping of adits dug into granite (map unit Xgr). The adits follow narrow, near-vertical, northwest-trending zones 1-3 meters wide containing dark biotite/chlorite schist. Exposures of the schist are mostly mined out, but the zones may have striked northwest. Locally, the feldspars in the surrounding granite appear to be altered to sericite(?), but no mineralization was seen in the schist. These narrow, northwest-striking schist zones are similar to those observed at Stewart Mountain, in the Stewart Mountain quadrangle (Skotnicki and Leighty, 1997c), and in the Buckhorn quadrangle (Skotnicki and Ferguson, 1996).

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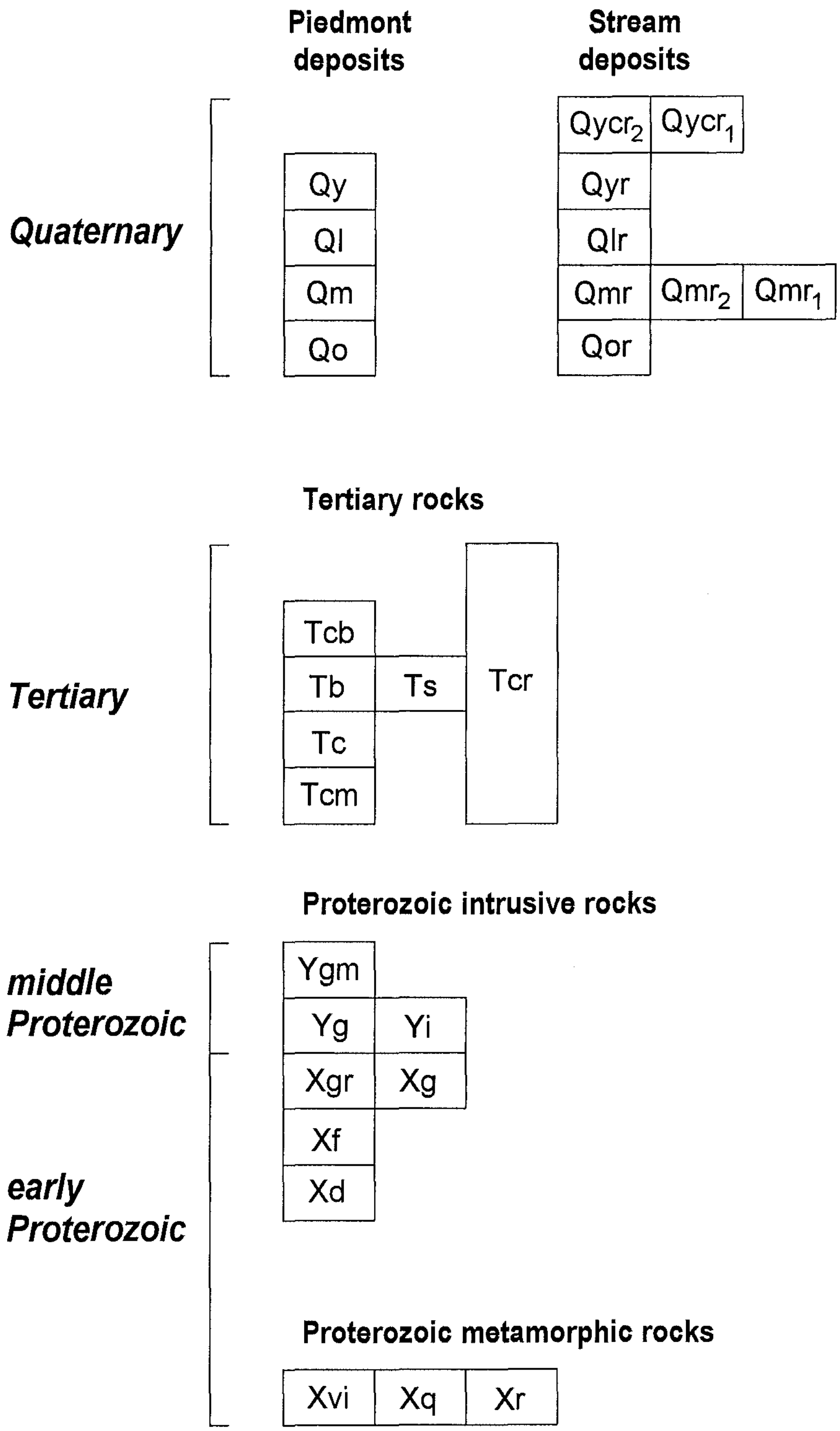

Figure 3. Correlation diagram for the Boulder Mountain quadrangle.

UNIT DESCRIPTIONS
FOR THE BOULDER MOUNTAIN QUADRANGLE
AZGS OFR-98-15

Quaternary

Piedmont Deposits

Qt **Talus (<750 ka).** Unconsolidated scree deposits covering steep slopes, especially beneath large mesas and cliffs.

Qtb **Talus dominated by basalt clasts (<750 ka).**

Qc **Colluvium (<750 ka).** Unconsolidated to moderately consolidated colluvial deposits on hillslopes. These steeply-sloping deposits are typically coarse, containing subangular to angular clasts, are very poorly sorted, and weakly bedded. The unit is well-developed on poorly consolidated conglomerate (map unit Tc).

Qct **Colluvium and talus, undifferentiated (<750 ka).**

Qy **Holocene alluvium (<10 ka).** Unconsolidated sand to small boulders reaching several tens of centimeters in diameter upstream but smaller and fewer downstream. Qy soils are characterized by stratified, poorly to moderately sorted sands, gravels and cobbles frequently mantled by sandy loam sediment. On the surface the main channel commonly diverges into braided channels. Locally exhibits bar and swale topography, the bars being typically more vegetated. Soil development is relatively weak with only slight texturally or structurally modified B horizons and slight calcification (Stage I). Some of the older Qy soils may contain weakly developed argillic horizons. Because surface soils have little clay or calcium carbonate, Qy deposits have relatively high permeability and porosity. Throughout the study area these deposits are dissected as much as 3 meters where a narrow inner gully has dissected the broader fan-like deposits.

Ql **Late Pleistocene alluvium (10 to 250 ka).** Moderately sorted, clast-supported sandstones and conglomerates containing subangular to subrounded locally derived clasts in a grussy and sandy tan to brown matrix. Ql surfaces are moderately incised by stream channels but still contain constructional, relatively flat, interfluvial surfaces. Ql soils typically have moderately clay-rich, tan to red-brown argillic horizons. They contain some pedogenic clay and some calcium carbonate, resulting in moderate infiltration rates. Thus, these surfaces favor plants that draw moisture from near the surface. Ql soils typically have stage II calcium carbonate development.

Qm **Middle Pleistocene alluvium (250 to 750 ka).** Moderately to poorly sorted, clast-supported sandstones and conglomerates containing subangular subangular to subrounded pebbles to boulders of locally derived rocks. Argillic horizons are weak to strong. The deposits are locally strongly indurated by calcium carbonate. Clasts are slightly to moderately varnished. The unit is deeply dissected and ravines reveal relatively thin deposits, from 2 to 5 meters thick. Argillic horizons are strongly developed where original depositional surfaces are well-preserved, but are much weaker or nonexistent on ridge slopes.

Qo **Early Pleistocene alluvium (750 ka to 2 Ma).** These poorly sorted deposits contain subangular to subrounded gravel- to boulder-size clasts of basalt (map unit Tb), granite (map unit Xgr), and intrusive rhyolite (map unit Xf). Clasts exhibit weak to moderate varnish. Argillic horizon is moderately to strongly developed. Prickly pear and hedgehog(?) cactus grow in abundance on these surfaces. This unit is exposed only on the north side of Round Valley where it forms a large flat terrace.

Stream Deposits along Sycamore Creek

$Qycr_2$ **Active channel deposits.** Unconsolidated, moderately to poorly sorted, clast-supported sand, cobbles, and small boulders. Deposits along Sycamore Creek alternate between rounded cobbles and grussy sand. Because the channel is relatively active there is little or no vegetation.

$Qycr_1$ **Modern flood plain deposits (0 to 100 yrs).** This surface is inundated during floods. It consists of moderately sorted, unconsolidated to poorly consolidated sand, cobbles, and small boulders in recently active channels separated from the main active channel. The unit also contains sandy and silty overbank deposits.

Qyr **Holocene stream terrace deposits (0 to 10 ka).** Equivalent to the Lehi Terrace of Pewe (1978). Consists mostly of unconsolidated, well-rounded pebble- to cobble-size river gravels surrounded by a sand and minor silt matrix. Also includes overbank sediments (finely laminated clays, silts, and fine sands). Soil development is weak, primarily consisting of slight organic accumulation at the surface and some bioturbation. This unit is used for terraces along Sycamore Creek that are about 10 to 20 feet above the modern channel and do not show evidence of recent flooding. Most have upper surfaces covered by thick groves of mesquite. Surfaces with obvious alluvial fan morphology are grouped in unit Qy.

Qlr **Late Pleistocene stream terrace deposits (10 to 250 ka).** Equivalent to the Blue Point terrace of Pewe (1978). Well-rounded, pebble- to cobble-size stream gravels surrounded by a sand and minor silt matrix. Soil development includes moderate clay and calcium carbonate accumulation.

Qmr **Middle Pleistocene stream terrace deposits (250 to 750 ka).** Equivalent to the Mesa terrace of Pewe (1978). Contains well-rounded pebble- to small boulder-size (~40 cm) stream gravels in a gravely matrix of granite grus. Well-developed argillic horizons where terrace surface is well-preserved. Exposures on the north side of Round Valley form large, flat terrace remnants about 40 to 50 feet above the modern drainage. Locally this surface is covered with finer, younger material, which was not mapped separately.

Qmr_2 Younger member of middle Pleistocene stream terrace deposits (250 to 750 ka).

Qmr_1 Older member of middle Pleistocene stream terrace deposits (250 to 750 ka).

Qor **Early Pleistocene stream terrace deposits (750 ka to 2 Ma).** Equivalent to the Sawik terrace of Pewe (1978). Contains well-rounded pebble- to small boulder-size (~30 cm) stream gravels, in a gravely matrix of granite grus. Exposed only on the north side of Round Valley where it forms a flat terrace remnant about 120 feet above the modern drainage.

Tertiary Units

Tcr **Conglomerate near Edwards Park (middle or Late Tertiary).** Contains subangular to well-rounded pebble- to cobble-size clasts of quartzite, metaconglomerate, argillite, intrusive rhyolite/granophyre, and granite, all in a sand and gravel matrix of granitic grus. These deposits form two separate, relatively horizontal terrace levels on the ridge-line at Edwards Park (mostly in the Tonto Basin quadrangle). The deposits are mostly covered by a lag gravel and no exposures showing bedding were seen.

Tcb **Basaltic conglomerate (middle to late Tertiary).** These poorly sorted to moderately sorted deposits contain subangular to subrounded clasts of basalt altered to shades of red, brown, and grey, all in a light brown sandy to silty matrix. Locally, the basalt clasts contain abundant carbonate, and to a lesser extent, so does the matrix. Clasts range from sand to boulders. The unit is locally thinly bedded near the base (exposed in the north in Sycamore Creek), but is mostly thickly bedded. Moderately to strongly consolidated. These rocks are exposed immediately west of sunflower where they are interbedded with basalt near the top of the volcanic sequence.

Ts **Sandstone and conglomerate (middle to late Tertiary).** These thin fluvial sandstones and conglomerates are interbedded with basalt (map unit Tb) are typically 1-3 meters thick, but locally much thicker. Lower in the section, these beds are composed dominantly of arkosic sandstone and conglomeratic sandstones, whereas higher in the section they contain mostly basaltic sandstone. Some beds are rich in scoria, probably derived from nearby basaltic vents. It is possible that the felsic tuffs to the north grade southward into one or more of these sedimentary strata.

Tb **Basalt (middle to late Tertiary).** This unit consists of basaltic lavas exhibiting various textures and phenocryst assemblages. Aphyric to porphyritic. Where porphyritic, distinctive dark red-brown subhedral olivine phenocrysts (3-10%) less than 3 mm wide are mostly altered to red opaques (probably iddingsite), and dark green to green-black pyroxene in a fine-grained to microcrystalline groundmass. These lavas are generally massive to slightly vesicular, with less than 1% rounded vesicles less than 5 mm in diameter. This unit includes minor interbedded scoria and basaltic sandstones. Thick, cliff-forming flows suggest they may be more andesitic in composition. In the Black Mesa area, massive, dark blue-grey flows with no discernible phenocrysts cap the mesas. These rocks are very dense and difficult to break. These flows locally contain uncommon, small olivine-pyroxene inclusions (xenoliths) up to about 5 cm across. These massive basalts commonly exhibit a pitted weathered surface with grey spots, also observed elsewhere in the region (Skotnicki, 1992).

Tc **Conglomerate (middle Tertiary).** Tan to slightly red-colored, interbedded sandstone and conglomerate. The unit is clast-supported, and inversely to normally graded (where grading exists). Exposures are very poor and the unit is almost everywhere covered by an obscuring lag gravel. In the south the deposits consists almost entirely of granitic clasts and grus, with only very minor, gravel-size metarhyolite and quartzite clasts. In the north, in Ram Valley, the deposits are also dominated by tan-colored granitic grus, but also contain larger cobbles of grey to tan quartzite, dark purple quartz-pebble metaconglomerate, and granite cobbles. Some granite clasts resemble quartz monzonite (map unit Xg) exposed to the south. The larger clasts range in size from a few centimeters to half a meter or more, and are commonly poorly sorted and subangular to rounded. Stratification is best seen from a distance. Exposures are poorly to moderately consolidated. In the south, the top 2 meters below the basalt are commonly a dark rusty red color. The deposits commonly erode into smooth slopes. In the southwest corner of the study area the surface is mantled by a lag of large boulders 2 or more meters wide, even though the underlying deposits are mostly finer-grained grussy sandstones and conglomerates. Rare exposures south of Pine Creek that some large boulders are within the deposits and are surrounded by the finer-grained matrix.

Tcm **Conglomerate with greenstone clasts (middle Tertiary).** This conglomerate contains almost exclusively dark green clasts containing subhedral dark green pyroxene phenocrysts up to 1 cm long and minor plagioclase up to 4 mm in a dark green aphanitic matrix. These clasts were derived from the north and northeast from the greenstone rocks at Mount Ord. Other, minor clasts include nonwelded tuff, purple quartzite, and purple gritty metaconglomerate. Where exposed well in the north-south drainage north of Ram Valley the deposits are poorly sorted, non-bedded, and contain subangular to subrounded clasts. The light tan conglomerate composed mostly of granitic clasts (map unit Tc) overlies this unit north of Ram Valley.

<u>Proterozoic Intrusive Rocks</u>

Ygm **Medium- to fine-grained granite (middle Proterozoic).** Contains anhedral to subhedral phenocrysts of clear quartz, fresh biotite, light grey K-feldspar, and plagioclase. This granite is mostly equigranular, but contains large, outsized phenocrysts of K-feldspar and quartz commonly al large as 2 cm long. The larger quartz and K-feldspar crystals are mostly subhedral but locally rounded and the K-feldspar is locally zoned. The quartz in this unit is almost everywhere stained light rusty orange (except at the top of Granite Mountain). This gives the rock a rusty orange shade which is generally slightly darker than that of the coarse-grained granite (map unit Yg) and is useful for distinguishing the two units. This unit generally weathers into small angular blocks, rather than spheroidal boulders. Some surfaces exhibit weak varnish.

Yi **Quartz-feldspar porphyry dikes (middle Proterozoic).** These dikes contain subhedral cloudy- to clear-grey quartz and light grey K-feldspar from 2-8 mm wide in a light grey aphanitic matrix. Contains rare biotite locally. Feldspar is commonly sericitized and weathers chalky white. Forms resistant ridges. All dikes observed near The Boulders strike to the northwest. Intrudes quartz monzonite (map unit Xg) and is intruded by the medium-grained granite (map unit Ygm).

Yg **Coarse-grained granite (middle Proterozoic).** Nonfoliated, coarse-grained granite containing large, abundant, pink, subhedral to euhedral K-feldspar phenocrysts up to 5 cm long, in a matrix of subhedral plagioclase, quartz, and biotite. Plagioclase is light grey and commonly sericitized. Biotite (about 2-10%) of rock) occurs as anhedral to subhedral books 4-5 mm wide. Quartz is clear-grey. This rock is less resistant than the older granite to the northeast (map unit Xgr) and weathers into smooth slopes and grus. This unit is only exposed along the highway about 0.5 miles north of Round Valley. This is probably the same granite that is exposed in the northern McDowell Mountains and at Carefree.

Xgr **Granite (early Proterozoic).** This coarse-grained granite is slightly porphyritic with ovoid to subhedral phenocrysts of light grey K-feldspar (microcline), in a matrix of light grey subhedral plagioclase, biotite, and quartz. Biotite occurs a dark clumps mostly altered to chlorite. Quartz is a distinctive milky blue and translucent. The 1-2 cm K-feldspar phenocrysts are typically surrounded by a rim of light grey plagioclase (rapakivi texture). Locally, K-feldspar crystals are completely altered to plagioclase, while other K-feldspar crystals within the same sample exhibit only a very thin rim or are completely unaltered and grey. The rapakivi texture is most obvious on a weathered surface. Locally, along the highway, fine pyrite (chalcopyrite?) crystals occur as disseminated grains within the rock and within small quartz veins. The unit is weakly foliated northwest of the highway, but southeast of the highway it is locally strongly foliated. Silver (1965) reported a U-Pb age from zircon of 1640 ± 15 Ma. This unit is locally cut by fine-grained granite (aplite) dikes which are commonly bordered by dark green, fine-grained micro-diorite dikes. The relationship between the two different dikes is not clear. Locally, the granite contains dark grey inclusions up to several tens of centimeters across containing the same crystals as the granite but finer-grained and with a larger percentage of biotite.

Xg **Quartz monzonite (early Proterozoic).** Foliated, coarse-grained, K-feldspar porphyritic quartz monzonite. Contains anhedral to subhedral, light grey to locally pink, square equant K-feldspar phenocrysts, which are nowhere larger than 1.5-2 cm across. Light grey plagioclase and clear-grey quartz are 2-8 mm wide. Biotite occurs as felty clumps and is locally altered to chlorite. This unit forms most of the mass of the southwestern Mazatzal Mountains south of Boulder Mountain. Foliation is weak in the north and west parts of the quadrangle and strongest in the southeast. The rock forms light grey rounded boulders. The quartz monzonite is strongly foliated and lineated (mylonite) for about 10 meters next to the contact with Xf at its narrowest part, about 1 mile southeast of Round Valley. Also at this location Xg is cut by non-foliated coarse-grained feldspar veins 2-4 cm thick.

Xf **Intrusive rhyolite/granophyre (early Proterozoic).** This rock contains anhedral to subhedral 1-5 mm phenocrysts (about 5% of rock) of light grey feldspar, dark green to black biotite, and minor clear-grey quartz, all in a light tan, microcrystalline, granular matrix of feldspar and quartz. Biotite is mostly altered to chlorite. Plagioclase is partly altered to sericite. In one thin section containing K-feldspar and plagioclase phenocrysts, the opaque minerals are rimmed by a high relief mineral with birefringence similar to titanite/sphene. In another thin section microcline phenocrysts are more abundant than plagioclase and the opaques are not rimmed. Zircon is common in all rocks. The unit exhibits a pervasive, but weak, foliation defined by alignment of biotite crystals. Locally, foliation is defined by alignment of dark green lenticular colorations in the rock. The colorations are a few millimeters to a centimeter thick across the small axis, and from 1-20 cm long (good exposures are along the trail east of Edwards Park). There is no apparent difference in mineralogy between the colorations and the host rock, though superficially, they resemble fiamme. The contact between Xgr and Xf is sharp. Grain size in both units remains constant up to the contact. The contact between Xg and Xf is also sharp. Grain size is constant as well, except near Mud Spring where Xg is finer-grained and only marginally porphyritic. To the east in the Tonto Basin quadrangle this rock is intruded by quartz-feldspar porphyry dikes (not mapped). Locally, the rock contains dark oval inclusions 1-40 cm wide composed of fine-grained biotite, and others of unknown original composition altered to epidote. Muscovite is locally common on fracture surfaces. It occurs as masses of intergrown anhedral to subhedral crystals up to 3 mm long. Less common on fracture surfaces are rectangular hematite crystals up to 3-4 mm long.

Xd **Diorite (early Proterozoic).** This dark green intrusive rock contains anhedral to subhedral phenocrysts of light grey plagioclase from 2-8 mm long, abundant biotite up to 5 mm wide in clumps partially altered to chlorite and hematite, and less abundant hornblende and minor quartz. The rock is exposed 1 mile southwest of Cypress Peak where. Good polished exposures in the creek bed are very difficult to access but clearly show that the intrusive rhyolite/granophyre (map unit Xf) intruded the diorite--lenticular pods of Xd several centimeters long are surrounded by Xf. Rounded boulders or diorite in the upper reaches of Boulder Creek near Crabtree Spring suggest that there are more exposures of diorite hidden beneath the brush on the north side of Boulder Mountain.

Proterozoic Metamorphic Rocks

Xvi **Intermediate composition metavolcanic rocks (early Proterozoic).** Dark green-grey meta-andesite flows are typically massive and very fine-grained, with feldspar phenocrysts less than 1 mm across. Medium green-grey meta-dacite flows are more crystal-rich, and contain creamy white feldspar phenocrysts. Relative to the meta-andesite, the meta-dacite generally contains more abundant K-feldspar, is coarser-grained, and epidote alteration is more pervasive. These rocks likely represent an assemblage of hypabyssal intrusions to extrusive flows.

Xq **Quartzite (early Proterozoic).** Blue-grey to tan, fine- to coarse-grained quartzite. Typically fine-grained (grains less than 1 mm) and laminated with thin ilmenite/magnetite layers. Locally recrystallized. Grains are well-sorted and subrounded to rounded. Contains minor metamorphic muscovite. Locally the unit contains light grey, radiating mica crystals (pyrophyllite?), black tourmaline, rectangular hematite crystals up to about 3 mm wide, and rare red garnet a few millimeters across. Locally the unit contains stretched-pebble conglomerate. The pebbles are between 1 and 4 cm long, are felsic (probably vein quartz or quartzite, and possibly rare felsic volcanic rock), and are elongated in northeast-southwest direction. Bedding, where visible, is approximately parallel to foliation, though foliation is not expressed well in the more competent units. Cross-bedding is abundant. There is an excellent exposure of cross-bedded quartzite containing thin conglomeratic beds at the Xf/Xgr contact west of Cypress Peak on the north side of the Boulder Creek Trail. Contacts with Xf are sharp. The quartzite is intruded by the intrusive rhyolite/granophyre body (map unit Xf) and, consequently, is exposed as lens-like enclaves within the western side of Xf. Bedding attitudes within the quartzite suggest that the bedding may have been overturned and folded prior to intrusion of Xf. This unit is very similar to enclaves of blue-grey quartzite intruded by granite in the Adams Mesa quadrangle (Skotnicki and Leighty, 1997a).

Xr **Metarhyolite (early Proterozoic).** This rock is exposed in one small outcrop northeast of Ram Valley, covered by the contact between Tcm and Xgr. The rock contains porphyroblasts of anhedral light green muscovite, in a white siliceous matrix. Locally, foliation is mylonitic. Small nearly recumbent folds are visible locally.