GEOLOGIC MAP OF THE WESTERN HARCUVAR MOUNTAINS, LA PAZ COUNTY, WEST-CENTRAL ARIZONA

by

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INTRODUCTION

The western Harcuvar Mountains are a fairly rugged, fairly inaccessible range located north and northwest of Salome in west-central Arizona. The area was mapped in a detailed reconnaissance manner on a 1:24,000-scale topographic base, with the initial intention of releasing the mapping on the Salome 1:100,000 quadrangle. As we proceeded with the mapping, however, we made some exciting new, and unexpected, discoveries. As a result, we decided to compile and release the mapping at 1:24,000, even though we have not covered the entire map area at a level of detail commensurate with that scale. The mapping represents approximately 30 person-days spent in the field between 1984 and 1991. In this report, we present the results of our mapping and reconnaissance structural studies. Some of the foliation attitudes in the northeastern part of the map area were measured by Robert Scott. Some aspects of the geology of the area have been discussed elsewhere (Bancroft, 1911; Tovote, 1918; Keith, 1978; Rehrig and Reynolds, 1980; Coney and Reynolds, 1980; Reynolds, 1980, 1982; Reynolds and others, 1986, 1988, 1989, 1991; Spencer and Reynolds, 1989; Spencer and Welty, 1989; Drewes and others, 1990; Reynolds and Lister, 1990).

The geology of the western Harcuvar Mountains is dominated by crystalline rocks, including high-grade Proterozoic gneiss and schist, strongly deformed and metamorphosed metaplutonic rocks of Jurassic and/or Proterozoic age, and geometrically complex intrusions of variably deformed Cretaceous Tank Pass Granite. Less abundant rock types include Paleozoic or Mesozoic quartzite and marble, Middle Tertiary mafic dikes and intrusions, and hydrothermal veins.

The structural-metamorphic history of the area is very complex, and most rock units have experienced multiple episodes of metamorphism and deformation. The area contains a number of previously unrecognized ductile and brittle-ductile shear zones with various geometries, ages, and kinematic histories. In the western part of the area, near Cottonwood Pass, is a synmetamorphic ductile shear zone, the Cottonwood Pass thrust, which places compositionally diverse metamorphic rocks over a deformed granodioritic pluton. In the eastern part of the area, southwest of the Critic Mine, is a southwest-dipping mylonite zone, the Critic shear zone, which places porphyritic granite over banded gneiss and other metamorphic rocks. Both thrust zones are cross cut by the Late Cretaceous Tank Pass Granite and an associated, variably developed synplutonic fabric. The granite, its synplutonic fabric, and its wall rocks are crosscut by younger, high- and low-angle, brittle-ductile shear zones of middle Tertiary age.

MAP UNITS

Qs **SURFICIAL DEPOSITS** (QUATERNARY) -- Undifferentiated alluvium, colluvium, and rare eolian deposits.

Tm **MAFIC INTRUSION** (MIDDLE TERTIARY) -- Mostly medium- to fine-grained diorite and gabbro in small dikelike intrusions; related to Middle Tertiary mafic (microdiorite) dikes.

Kt **TANK PASS GRANITE** (CRETACEOUS) -- Undeformed to strongly foliated granite, consisting of the following three phases:

- medium-grained, generally equigranular granite with 3 to 5 percent biotite. This is the main phase of the pluton and is exposed near Tank Pass. It is locally porphyritic, with less than 5% K-feldspar phenocrysts that are 1 to 2.5 cm long. This phase is distinctive, even where strongly deformed, because it contains biotite books that are 0.5 to 1 mm in diameter, 0.25 mm thick, and widely disseminated in the rock. This phase contains abundant aplite and pegmatite dikes that locally contain garnet and locally includes a granodioritic border phase, especially where the pluton contains abundant inclusions of metamorphic rocks. Visible sphene up to 1 mm long, several percent quartz eyes 1 to 3 mm in diameter, and plagioclase phenocrysts are also locally present.

- medium-grained, biotite-muscovite granite; commonly associated with pegmatite and aplite. This phase of the pluton is most common in the central and eastern part of the map area. It is nearly white on fresh surfaces, but commonly weathers tan to orangish-brown tint. It contains approximately 1 to 3 % biotite and 1 to 2 % muscovite with a slightly greenish tint. Muscovite and biotite range from very thin platelets to discrete books 0.5 to 3 mm thick. This phase also contains less than 1 % reddish garnet on the south flank of the range southwest of Cottonwood Pass.

- fine- to coarse-grained leucocratic granite, pegmatite, and layered aplite-pegmatite. This phase rarely makes up large areas, but is most common as strongly foliated sills in high-grade gneiss in the northeastern half of map area, such as near Cunningham Pass. It commonly contains some reddish garnet and locally contains quartz eyes 2 to 4 mm in diameter.

Contacts between the three different phases of the pluton vary from gradational to locally sharp, and more than one pulse of magma is probably represented within the mapped pluton. All three phases of the pluton are at least locally foliated. Foliation is defined by oriented biotite, lithologic banding produced by variations in grain size and composition, and spaced fractures parallel to foliation. Lineation defined by elongated biotite streaks is present where the rock is strongly foliated. Foliation and lineation are both progressively better developed toward the east, where the rock has a gneissic aspect. Quartz eyes are locally conspicuous in deformed exposures.

MzPzq **QUARTZITE** (MESOZOIC TO PALEOZOIC)--Fine-grained quartzite.

TrPcs **CALC-SILICATE ROCKS** (TRIASSIC TO PENNSYLVANIAN)--Fine-grained calc-silicate rocks. Protolith was probably Triassic Buckskin Formation or Pennsylvanian-Permian Supai Group.

Pzc **CARBONATE ROCKS** (PALEOZOIC)--Tan dolomite marble with sparse, dark-brown siliceous stringers. This rock unit is pervasive replaced with secondary iron oxides. Replacement postdates tectonism.

JXa **APLITE** (JURASSIC TO PROTEROZOIC X)--Fine-grained, leucocratic granitoids commonly containing muscovite and locally containing garnet and pegmatite dikes. Quartz veins and pervasive orange iron-oxide staining characterize this unit in the extreme northwestern part of the map area.

JXgd **GRANITOID ROCKS** (JURASSIC TO PROTEROZOIC X) -- Variably deformed and metamorphosed granodiorite, tonalite, granite, and quartz diorite. Less deformed outcrops are generally equigranular to slightly porphyritic hornblende-bearing granodiorite or tonalite containing 5 to 10 % mafic minerals, including both biotite and hornblende. Epidote is very common. Where strongly deformed and metamorphosed, the rock unit is a medium- to dark-gray, well foliated, feldspar-quartz-biotite-amphibole schist. Unit commonly has a gneissic aspect due to the presence of feldspar segregations 1 mm to 5 cm thick. Exposures of deformed granitoids are generally homogeneous over large outcrops. Where porphyritic, the granodiorite contains plagioclase feldspar and quartz phenocrysts 0.5 to 2 cm long. The most porphyritic varieties are also the coarsest. Map unit locally contains areas of porphyritic granite with 10% K-feldspar phenocrysts 1 to 3 cm long and abundant biotite and epidote. Less common rock types include fine-grained, equigranular granodiorite, rare amphibolite, quartz diorite, quartz diorite gneiss, and miscellaneous gneiss and schist. The granodiorite is very muscovite rich, schistose, and mylonitic directly beneath the Cottonwood Pass thrust. Original granodiorite protolith is probably Proterozoic or Jurassic, but the structural fabric, including most of the gneissic aspect, is probably Cretaceous. In extreme northwest part of the map area, this unit is a medium-grained, foliated biotite granite to granodiorite that resembles rock unit YXg + Ja of Reynolds and others (1991) in the adjacent northeastern Granite Wash Mountains.

JXpg **PORPHYRITIC GRANITE** (PROTEROZOIC X) -- variably deformed and metamorphosed, coarse-grained porphyritic granite with 5 to 25 percent K-feldspar phenocrysts 1 to 3 cm diameter. In extreme northwestern part of map area this unit consists of foliated and lineated, porphyritic, medium-grained biotite granite. Where strongly deformed, such as along a thrust north of Cottonwood Pass and another thrust southwest of the Critic Mine, the granite is converted into a muscovite schist with scattered remnant large K-feldspar augen with an orangish- to yellowish-gray weathered color due to iron staining and conversion of all biotite to either muscovite or light-gray fine-grained aggregates. The porphyritic granite is very similar to the 1.4-Ga Harquahala Granite of the Harquahala Mountains.

Xm **METAMORPHIC ROCKS** (PROTEROZOIC X) -- compositionally diverse metamorphic and deformed plutonic rocks with a complex metamorphic-deformational history. Common rock types include: (1) compositionally banded gneiss, consisting of interlayered mica schist, amphibolite, granitic gneiss, and quartzofeldspathic layers, in part probably representing metamorphic segregations and lit-par-lit intrusion; (2) black to dark greenish gray amphibolite, with or without feldspathic segregations; (3) fine- to medium-grained, quartz-feldspar-biotite-muscovite and quartz-feldspar-actinolite schists; schist locally has a probable metasedimentary protolith and contains thin (up to 0.5 m thick) banded-quartzite layers and quartz-feldspar segregations up to 1 cm thick that impart a gneissic texture; (4) granitic gneiss and various metaplutonic rocks, including aplite, pegmatite, and foliated leucogranite with 1 to 5 % muscovite; (5) foliated granite and light-gray foliated granodiorite-granite with 5 % scattered biotite and rare phenocrysts of feldspar and an early northeast-striking, steep fabric defined by compositional layering parallel to layering in adjacent compositionally banded gneiss; (6) foliated granodiorite and quartz diorite that are generally distinctive from, but locally similar to, the structurally underlying JXgd unit; and (7) fine-grained siliceous gneiss, schist, and laminated tan-buff quartzite.

STRUCTURAL GEOLOGY

The structural geology of the western Harcuvar Mountains is exceptionally complex, even for us, who have mapped some really bad, complex mountain ranges. The rocks have experienced the unfortunate combination of Proterozoic amphibolite-facies metamorphism and deformation, multiple episodes of Cretaceous metamorphism, deformation (including ductile thrusting), and migmatization before, during, and after intrusion of Tank Pass Granite, and mylonitization and brittle-ductile shear zones related to regional middle Tertiary extension. In view of these complexities and our yet-incomplete understanding of the overprinting and timing relations of different fabrics, our discussion is organized geographically, outlining the main features of several key areas from west to east.

The extreme northwestern part of the Harcuvar Mountains contains complexly slivered and probably highly attenuated thrust slivers that represent the eastward continuation of a belt of faulted and attenuated rocks in the Cobralla area of the northeastern Granite Wash Mountains (Reynolds and others, 1991). A complex structural succession is exposed on two small ridges that project northward along the north flank of the range. Pervasive nonmylonitic foliation is parallel to lithologic contacts in these sequences. Lineation in rocks adjacent to lithologic contacts is northwest trending and is very well developed in aplitic granitoids (map unit Ja) directly adjacent to their contact with structurally underlying strongly foliated and lineated granitoids (map unit JXgd), including a porphyritic granodiorite.

To the south, 2 km east of Tank Pass, pendants within Tank Pass Granite contain a ductile shear zone that places metamorphic rocks over unit JXgd. A strongly developed mylonitic fabric with a northeast-southwest-trending lineation is present along the shear zone. The metamorphic rocks contain numerous southwest-vergent flexural flow folds with their axial planes inclined to the northeast. The ductile shear zone is discordantly intruded by the Tank Pass Granite and the granite contains inclusions of previously foliated granodiorite. The shear zone, with its NE-SW lineation, is distinct from the Cottonwood Pass thrust, although the two shear zones juxtapose the same rock units. Instead, the shear zone may be related to the southwest-vergent Hercules thrust of the Granite Wash Mountains to the west. Undeformed Tank Pass Granite contains numerous aplite dikes that strike between 295° and 325° and mostly dip steeply.

The area around Cottonwood Pass to the east is dominated by the Cottonwood Pass thrust, which typically places heterogeneous metamorphic rocks (schist, gneiss, amphibolite, and meta-intrusions) over lighter-colored, more slope-forming porphyritic granodiorite. The metamorphic rocks also contain porphyritic granodiorite, so the total amount of displacement on the Cottonwood Pass thrust need not be great. A well-developed mylonitic foliation with a north-south-trending lineation is characteristic of the thrust, whereas a nonmylonitic foliation with a northwest-trending (290° to 330°, averaging 310°) lineation is pervasive in rocks away from the thrust. A top-to-the-south sense of shear for the thrust-related fabric is revealed by S-C fabrics, mica fish flash, asymmetrical foliation fish, and small shear-zone geometries. Locally along the thrust is a cream to light-gray, fine- to medium-grained quartzite with visible quartz grains and less than 1 % muscovite. Some bedding is visible, but rock is very mylonitic. The quartzite is associated with carbonate-rich soil, but is not either of the two main Paleozoic quartzites of the region; instead, it is probably Mesozoic based on the presence of gypsiferous soil with the quartzite. The thrust is locally warped by a SE-plunging fold.

The origin of the northwest-trending lineation and its timing with respect to the thrust are not known. In places, the northwest-trending lineation is an intersection lineation formed where an older northwest-striking, NE-dipping compositional layering is cut by a new flat fabric; this might imply that the flat thrust-related fabric postdates this earlier steep fabric. The N-S-trending, thrust-related streaky lineation, however, appears to be overprinted by a northwest-trending mineral lineation in one exposure of foliated granodiorite. North of Cottonwood Pass, rocks contain two NW-trending lineations: an older 340°-350°-trending intersection lineation that is clearly overprinted by a 320°-trending mineral-growth lineation. A northwest-trending lineation is also present in Tank Pass Granite, where it is a mineral lineation defined by aligned streaks of biotite. Elongated deformed inclusions in foliated Tank Pass Granite trend between 270° and 315°, parallel to lineation in the host granite.

North of Cottonwood Pass, a ductile shear zone (thrust?) structurally above the Cottonwood Pass thrust places deformed porphyritic granite over the metamorphic rocks that form the hangingwall of the Cottonwood Pass thrust. This ductile shear zone has a well-developed north-south-trending lineation and clear top-to-the-south sense of shear indicators, including S-C fabrics and asymmetric feldspars. An older, northwest-striking compositional layering is locally preserved in the granite above the shear zone. The shear-zone-related fabric and foliation with the northwest-trending lineation are both folded to the northeast, locally becoming overturned, near a major brittle high-angle reverse(?) fault of probable Tertiary age that defines the southwestern flank of Harcuvar Peak.

Further north, along the north edge of the range west of Harcuvar Peak, a flat, thrust-related(?) cleavage-foliation cuts preexisting compositional layering that strikes northwest and dips northeast. The older fabric is extensively isoclinally folded and transposed. Adjacent Tank Pass Granite is also foliated but intrudes across axial planes of some folds. In other areas, Tank Pass Granite is folded by northeast-vergent folds and has an axial planar cleavage.

South of Cottonwood Pass, a 290°-trending lineation and southeast-vergent S-C fabrics are present in mylonitic granodiorite within unit Xm. In a nearby area, the Proterozoic metamorphic rocks also contain a gently dipping mylonitic foliation containing a strongly developed 045°-trending stretching lineation. The northeast-trending lineation is parallel to SE-vergent interfolial folds with flexural-flow to passive-flow geometries. Adjacent Tank Pass Granite is weakly foliated with the NW-trending lineation and clearly postdates the mylonitic fabric in one exposure. However, a similar nearby mylonitic shear zone cuts the granite and its older foliation, has top-to-the-northeast sense of shear based on S-C fabrics and mica fish flash, and is probably middle Tertiary.

In the northeastern part of the map area, between the Bonanza Mine and Cunningham Pass, the Tank Pass Granite possesses a very banded, high-grade foliation that we interpret to have formed during intrusion of the granite (Rehrig and Reynolds, 1980; Reynolds, 1982; Reynolds and others, 1988). This fabric is commonly defined by pegmatitic or layered-aplite segregations that probably formed while the granite was still partially molten. The fabric does not appear to be a solid-state fabric that was superimposed on the granite after it was totally solid.

In this same area, ductile shear zones and metamorphic fabrics both predate and postdate Tank Pass Granite. Two kilometers southwest of the Critic mine, a short segment of a moderately west-dipping Critic shear zone places mylonitic porphyritic granite over greenish, platy mylonites derived from hornblende-bearing intermediate composition metaplutonic rocks, including fine-grained granodiorite, medium-grained granodiorite-granite, and compositionally banded gneiss. The shear zone is intruded by the Tank Pass Granite, although the granite contains its typical foliation and northwest-trending lineation. The rock types in and geometry of pendants in the Tank Pass Granite suggest that porphyritic granite was successively overlain by epidote-bearing tonalite and amphibolite gneiss to the southwest.

The Critic shear zone is also truncated and/or overprinted upward by a more gently dipping Tertiary mylonitic shear zone. The younger zone contains a northeast-trending lineation and has a probable top-to-the northeast sense of shear based on the way it deflects fabric in the older, underlying shear zone. Several similar Tertiary brittle-ductile shear zones with 045° to 065° lineations/striations are present in this part of the range. These zones are associated with greenish, brittle-ductile fault rocks and top-to-the-northeast shear based on shear-zone geometries, S-C fabrics, and asymmetric foliation fish. One zone is associated with chloritic alteration, carbonate alterations, and cataclasis, and a mafic dike that is clearly deformed by the shear zone. These shear zones truncate map units.

In many parts of the range, the metamorphic rocks have an older compositional layering that strikes northeast and is vertical. The intersection of this older and the younger fabric locally forms an intersection lineation. In the area of the Bonanza Mine, the older fabric is transposed by yet another high-grade gneissic fabric that dips 55° S. This younger fabric may be related to the high-grade fabric that developed in the Tank Pass Granite during its emplacement.

With our present understanding about the structural overprinting relations, we recognize six apparently distinct deformational episodes in the area, some of which are probably correlative with events recognized in adjacent mountain ranges (Reynolds and others, 1986, 1988, and 1989). These episodes include a Proterozoic metamorphic-deformational event, which formed the earliest compositional banding in the metamorphic rocks, and five Mesozoic-Cenozoic events, referred to as D1 to D5, from oldest to youngest.

- D1, the oldest event, formed gently dipping foliation and a northwest-trending lineation in the westernmost parts of the range. This fabric affects Paleozoic-Mesozoic strata, is crosscut by undeformed Tank Pass Granite, and is similar to fabric related to southeast-vergent (D1) thrusting in the Cobralla area of the Granite Wash Mountains.
- D2 is represented by northeast-trending lineation and mylonitic fabric along a ductile shear zone in pendants within Tank Pass Granite between Tank Pass and Cottonwood Pass. This fabric is crosscut by the granite and is similar to D2 fabric associated with the southwest-vergent Hercules thrust system in the Granite Wash Mountains.
- D3 includes mylonitic foliation and N-S-trending lineation developed along the south-vergent Cottonwood Pass thrust. This fabric is older than Tank Pass Granite and may be related to south-vergent structures such as the Harquahala thrust in the Harquahala Mountains and to east-west-trending D3 folds and brittle-ductile shear zones in the Granite Wash Mountains.
- D4 is the most widespread event, and formed the northwest-trending lineation in the Tank Pass Granite and its wall rocks. It is probably the same age as the granite, and may be related to a late, southwest-dipping D4 cleavage in adjacent mountain ranges.
- D5 consists of mylonitic fabric and brittle-ductile shear zones with northeast-trending lineation and a general northeast sense of shear. This fabric crosscuts Tank Pass Granite and the fabrics described above, and some brittle-ductile shear zones crosscut middle Tertiary microdiorite dikes. Subsequent to this fabric, northwest-striking high-angle faults, probably with northeast-side-up reverse or oblique offset, formed west of Harcuvar Peak and in the Cunningham Pass area.

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MAP SYMBOLS

CONTACTS

INTRUSIVE CONTACT -- May locally include faulted or sheared contacts that have been annealed or recrystallized during metamorphism so that the original nature of the contact is uncertain. Dashed where approximately located.

INTRA-UNIT CONTACT

HIGH-ANGLE FAULT -- Arrow represents dip. Line with diamond shows trend of striations. Dashed where approximately located, dotted where concealed.

THRUST FAULT -- Teeth on hanging wall block. Arrow represents dip. Dashed where approximately located, dotted where concealed.

BRITTLE-DUCTILE FAULT -- Shear zone with both brittle and ductile deformation features. Arrow represents dip. Dashed where approximately located, dotted where concealed. Teeth and hatchures on hanging wall block.

ORIENTATION OF GNEISSIC LAYERING AND MYLONITIC FOLIATION AND LINEATION -- Arrow on lineation symbol indicates sense of shear (direction of relative movement of structurally higher rocks).

COMPOSITIONAL LAYERING OR HIGH-TEMPERATURE CRYSTALLOBLASTIC FOLIATION

VERTICAL COMPOSITIONAL LAYERING OR HIGH-TEMPERATURE CRYSTALLOBLASTIC FOLIATION

HORIZONTAL COMPOSITIONAL LAYERING OR HIGH-TEMPERATURE CRYSTALLOBLASTIC FOLIATION

MYLONITIC FOLIATION

JOINT

DIKES AND VEINS

QUARTZ VEIN

MAFIC DIKE -- Equivalent to map unit Tm.

INTERMEDIATE DIKE

FELSIC DIKE