GEOL OGY AND MINERAL RESOURCES
OF THE BOUSE HILLS, LA PAZ
COUNTY, WEST-CENTRAL ARIZONA

by

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Arizona Geological Survey
Open-File Report 90-9

December, 1990

Arizona Geological Survey
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This study was done as part of COGEOMAP,
a cooperative geologic mapping project between the
U.S. Geological Survey and the Arizona Geological Survey

[21 page text and one plate]

This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards
INTRODUCTION

The Bouse Hills are located in west-central Arizona (Fig. 1) and are within the Basin and Range physiographic province of the Southwest. The Bouse Hills consist of four rock assemblages (Fig. 2), as follows: (1) Proterozoic crystalline rocks, (2) moderately to steeply tilted Oligocene (?) to lower Miocene volcanic and sedimentary rocks, (3) a Miocene pluton and related dikes, and (4) flat-lying to gently tilted Miocene volcanic and minor sedimentary rocks. Assemblages (1) and (2) were tilted by early Miocene rotational normal faulting that was widespread in the Basin and Range province (Spencer and Reynolds, 1989). In the Bouse Hills, tilting was probably related to movement on the Plomosa detachment fault which projects beneath the Bouse Hills from the west (Scarborough and Meader, 1989). Manganese and barite mineral deposits are mineralogically distinct, and fluid-inclusion data indicate that they were derived from aqueous fluids with different salinities. These deposits are confined to the Miocene volcanic and sedimentary rocks.

This report includes a geologic map of the Bouse Hills at a scale of 1:24,000 (Plate 1), descriptions of rock units (Appendix 1), and a stratigraphic correlation diagram (Fig. 3). Also included are descriptions of mineral deposits (Appendix 2) and a geologic map of some small hills northwest of the Bouse Hills (Fig. 4).

ROCK TYPES, AGES, AND FIELD RELATIONS

Proterozoic crystalline rocks in the Bouse Hills are lithologically diverse; they consist primarily of the following: (1) unfoliated to weakly foliated granite or granodiorite, (2) metasedimentary rocks with steep, east-northeast striking lithologic layering and foliation, and (3) porphyritic biotite granite and leucocratic muscovite granite. The steep, east-northeast striking crystalloblastic foliation and compositional layering are characteristic of early Proterozoic rocks in Arizona and suggest that such rocks in the Bouse Hills are of similar age; however, some of the granitoids, however, are not foliated and are probably younger.

The Proterozoic crystalline rocks are intruded by a biotite granodiorite (?) that forms the eastern Bouse Hills. Numerous dikes intrude older crystalline rocks near the contact with the pluton. Some of these dikes are fine-grained granitoids that resemble the pluton whereas others have an aphanitic groundmass with phenocrysts of biotite, feldspar, and quartz. Dikes with an aphanitic groundmass commonly have chilled margins suggesting shallow levels of emplacement. Biotite from three widely spaced samples, two from the pluton and one from a dike adjacent to the pluton, yielded K-Ar dates of approximately 20 Ma (R. Miller, written commun., 1990) which is interpreted as the age of the pluton.

Crystalline rocks in the western Bouse Hills are depositionally overlain by a sequence of volcanic and sedimentary rocks that are now tilted moderately to steeply to the southwest. This sequence includes basal sandstone and conglomerate, volcanic flows and tuffs, sedimentary breccias that are products of catastrophic debris avalanches (e.g., Shreve, 1968; Krieger, 1977), and limestone. These rocks record the beginning of volcanism and the development of fault scarps and sedimentary basins at about 24 to 22 Ma (K-Ar dates from R. Miller, written commun., 1986).

The tilted sequence and underlying crystalline rocks are unconformably overlain by flat-lying to gently dipping, felsic, ash-flow tuffs and related flows and pyroclastic rocks. A K-Ar date indicates that these volcanic rocks are 20.5 Ma (Eberly and Stanley, 1978), which is about the same age as the nearby granitoid pluton in the eastern Bouse Hills. It is possible that the felsic volcanic rocks are eruptive equivalents of the eastern Bouse Hills pluton and that the two rock types were derived from the same magma. Mafic volcanic flows (possibly entirely basalt) overlie the felsic volcanic rocks and are only slightly younger (19.5 Ma; J. Spencer, unpub. K-Ar data).
MINERAL DEPOSITS

Mineral deposits in the Bouse Hills can be divided into three groups: (1) amorphous fracture- and open-space-filling manganese oxides, commonly with coarse brown calcite, hosted by fractured or brecciated Miocene volcanic rocks, (2) barite veins with minor fluorite hosted by Miocene volcanic and sedimentary rocks, and (3) brittle shear zones within crystalline rocks that contain chrysocolla and hematite. Individual deposits are located on figures 4, 5, and 6 and are described in Appendix 2.

Approximately a million pounds of manganese were mined from the Bouse Hills during a brief period (1952-1954; Keith and others, 1983), and most of this manganese came from the Black Bird mine in the western Bouse Hills. All of the manganese deposits in the Bouse Hills except the Black Bird deposit are hosted by sheared and locally brecciated rocks that are known or suspected to be along fault zones. A shear zone passes through the Black Bird mine and was clearly a major controlling factor in manganese mineralization, but most of the manganese ore was deposited within a sedimentary (talus?) breccia of basalt clasts that locally contains sandstone lenses. Manganese mineralization occurred in association with aqueous fluid movement along generally northwest-trending shear zones in the Bouse Hills, but was much more significant at the Black Bird deposit than elsewhere because a large volume of highly permeable and porous rock was present adjacent to the shear zone. Calcite is commonly associated with the manganese deposits. Slickenside striations on manganiferous rocks indicate that some fault movement occurred after mineralization.

Approximately 2500 tons of barite were mined from the Bouse Hills in 1948, and were derived largely from the Black Mountain #1 mine (Stewart and Pfister, 1960). Most of the barite deposits are veins up to 2 m thick. The Black Mountain #2 barite deposit is hosted in Tertiary sedimentary breccia formed by a catastrophic debris avalanche and consists largely of irregular open-space fillings. Minor fluorite is commonly associated with barite.

Deposits of fracture- and open-space-filling chrysocolla + hematite ± malachite ± quartz are present along two brittle shear zones within crystalline rocks in the central Bouse Hills. These small deposits resemble some of the detachment-fault-related deposits in the nearby Buckskin Mountains (Spencer and Welty, 1989).

Reconnaissance study of fluid inclusions from manganese deposits and barite veins reveals the different compositions of the aqueous fluids that were responsible for mineralization (Figs. 7, 8; J. Duncan, unpub. data, 1990). All but one of the 26 fluid inclusions (mostly primary) studied in calcite, from four samples of manganese deposits, contained 1-10 wt. % equiv. NaCl. In contrast, fluid inclusions (uncertain primary or secondary) in fluorite from two samples of barite veins contained 14-21 wt. % equiv. NaCl. Fluid-inclusions (uncertain primary or secondary) in barite varied from 1 to 22 wt. % equiv. NaCl. The high salinity of fluids in some inclusions in barite and in all of the inclusions in fluorite is typical of fluid inclusions from similar deposits in the nearby Northern Plomosa mineral district (Duncan, 1990) and suggests that the barite veins of the northwestern Bouse Hills are a distal part of the Northern Plomosa mineral district. The low- to moderate-salinity fluid inclusions in barite are probably secondary and do not reflect the composition of the mineralizing fluids. In contrast, the manganese deposits appear to have been derived from low- to moderate-salinity fluids that were distinctly different from fluids responsible for the barite-fluorite mineralization.

The three types of mineral deposit in the Bouse Hills are mineralogically distinct and are not obviously related to each other. Fluid-inclusion data reveal differences in fluids responsible for barite and manganese mineralization. The barite veins and manganese deposits are hosted in Miocene volcanic rocks and are therefore Tertiary in age, although the manganese deposits are hosted by some of the youngest recognized volcanic rocks and may be several million years younger than the barite deposits. The structural and mineralogic similarity of the shear-zone hosted chrysocolla-hematite deposits to deposits related to detachment faults in the nearby Plomosa and Buckskin Mountains suggests that these
deposits were derived from basin brines (Wilkins and others, 1986; Spencer and Welty, 1989; Duncan, 1990).

Reported production of Cu, Au, and Ag from the Bouse Hills mineral district, consisting of approximately 13,000 lbs. of copper and 100 oz. of gold and silver (Keith and others, 1983), is in error. U.S. Bureau of Mines data indicate that the production reported by Keith and others for the Bouse Hills was actually from the Buckskin and possibly Rawhide mountains (Appendix 2). The barite veins in the northwestern Bouse Hills should be included with the northern Plomosa mineral district of Keith and others (1983) and the rest of the Bouse mineral district should be reclassified as a manganese district.

ACCESS

Construction of the Central Arizona Project canal across the Bouse Hills has affected access to the central part of the eastern Bouse Hills, which must be reached by foot from the northern or southern edge of the Hills, or by a few foot bridges designed to allow animals to cross the canal. The dirt road that extends around the periphery of the eastern Bouse Hills crosses the canal at a bridge on the north side of Hills, and at Cunningham Wash where the canal is underground south of the Hills. To reach the Cunningham Wash crossing turn east off of State Highway 72 at McVay Road approximately 13 miles southeast of Bouse and follow the dirt road north. The western Bouse Hills are accessible by several old roads.
APPENDIX 1: DESCRIPTION OF MAP UNITS SHOWN ON PLATE 1

Sedimentary and Volcanic Rocks

Qs SURFICIAL DEPOSITS (QUATERNARY) -- Unconsolidated to poorly consolidated sandstone, conglomeratic sandstone, and fanglomerate. Includes sand dune deposits along the north flank of the Bouse Hills.

QPc CALICHE-CEMENTED TALUS BRECCIA (PLIOCENE OR QUATERNARY)

Tm MAFIC VOLCANIC ROCKS (MIocene) -- Resistant, dark-gray, dark-brown-weathering (desert varnished), aphanitic basaltic andesite to basalt with local scattered, barely visible plagioclase phenocrysts. Sparse secondary iddingsite(?) is probably an alteration product of olivine. Unit varies from massive to vesicular. Includes scoriaceous breccia that consists of vesicular and nonvesicular, brownish-gray basaltic andesite(?) in a scoriaceous, red matrix. A sample of this unit yielded a K-Ar whole-rock date of 19.5±0.3 Ma (sample 2-10-85-1; J. Spencer, unpublished data).

Tslt SILTSTONE AND SANDSTONE (MIocene) -- Light-gray siltstone that is locally calcareous, gypsiferous, or sandy. Red jasperoid is locally associated with siltstone. Siltstone just west of Black Bird mine contains white, poorly resistant, airfall tuff bed.

Tct CONGLOMERATE AND TALUS BRECCIA (MIocene) -- Includes the following: (1) red, conglomeratic sandstone, with variably rounded cobbles composed primarily of biotite granite with less abundant silicic volcanics, that forms northeast wall of Black Bird mine pit, and (2) angular fragments of basalt, interpreted as talus, that hosts manganese mineralization at the Black Bird mine and contains local sandstone lenses. This unit is only recognized at the Black Bird mine.

Thb HORNBLENDE-BIOTITE TUFF (MIocene) -- White friable tuff with medium to fine-grained quartz, feldspar, biotite, and acicular hornblende. Variably rounded, 2- to 40-mm-diameter, volcanic lithic fragments are locally present in lower part of unit. Unit locally includes poorly sorted, coarse-grained, tuffaceous sandstone with 5% to 10% quartz grains. A sample of this unit yielded a K-Ar biotite date of 21.5±0.5 Ma and a K-Ar hornblende date of 18.4±0.5 Ma (sample 12-6-84-3; R. Miller, written commun., 1990).

Thbw WELDED HORNBLENDE-BIOTITE TUFF (MIocene) -- This unit is probably a welded equivalent of hornblende-biotite tuff (map unit Thb). Marked lateral variations in texture, color, and degree of welding within these two map units suggest proximity to eruptive center.

Tuf UPPER FELSIC VOLCANIC UNIT (MIocene) -- This unit consists of a complex assemblage of felsic tuffs, flows, and volcanic breccia. Most tuff and breccias contain abundant gray volcanic lithic fragments. The unit is generally gently dipping and sandstone is locally present at its base. A sample of this unit yielded a K-Ar biotite date of 20.5±1.1 Ma (sample 90ES; Eberly and Stanley, 1978; date corrected for new decay and abundance constants by Reynolds and others, 1986). Typical rock types include the following:

1. Crystal-rich, lithic tuff that is pinkish to tan weathering with large blocks (as large as 50 cm in diameter) of pinkish-gray to medium-gray rhyodacite with 3 to 5 percent biotite. Tuff is associated with feldspar porphyries, both biotite-bearing and biotite-poor, and with gray lithic tuff.

2. Mottled maroon and gray volcanic breccia with gray volcanic lithics and light-colored, void-forming pumice clots. Rock contains 5 percent phenocrysts, including 0.5 to 1 percent biotite. Underlain by a greenish slope-forming lithic tuff.

3. Slope-forming, purplish-gray weathering, light-colored tuff with 20 to 50 percent light-colored
tuffaceous volcanic lithics. Matrix is moderately crystal poor with 1 to 3 percent feldspar and quartz phenocrysts. Tuff is associated with reddish- to pinkish-orange weathering, light-colored tuff with 15 percent light-colored volcanic lithics and 5 to 10 percent feldspar and quartz phenocrysts.

(4) Purplish lithic tuff with 25 percent light-colored volcanic lithics that are crystal rich, including abundant quartz. Unit is associated with maroon and purplish-gray rhyolite with 10 to 15 percent crystals of feldspar and quartz.

(5) Flow-banded rhyolite(?) with 5 to 10 percent feldspar phenocrysts and a mottled maroon, purple, and pink tint. Alternatively, some flows are light-gray and pinkish-gray, and brownish-gray weathering. Some outcrops are dominated by breccia. It is associated with pinkish-maroon lithic tuffs with several percent phenocrysts (including 0.5 percent biotite), abundant maroonish-gray volcanic fragments, and some light-colored pumiceous fragments that weather out leaving voids.

(6) Pinkish- or purplish-gray lithic tuff with a lower, poorly welded zone. Tuff contains light-gray volcanic lithics and is crystal poor with less than 1 percent very fine-grained phenocrysts. Brown weathering with angular pumice clots that weather out forming vugs several cm in diameter. Very slight flattening of pumice into horizontal plane. This tuff is overlain by orangish-pinkish-red-weathering, crystal poor, nonwelded, lithic tuff with 25 percent gray volcanic lithics.

(7) Pink to tan-weathering, aphanitic, nonporphyritic, nonflow-banded rhyolite associated with slope-forming, pink to greenish-buff tuffs, some of which are very lithic, and with reddish lithic tuff.

(8) Gray, crystal-bearing rhyolite with 10 to 20 percent gray volcanic lithics in a medium to light gray, locally flow-banded matrix. Unit contains feldspar crystals and 1 to 2 percent biotite.

(9) Massive and cluffy, pinkish-gray and locally flow-banded rhyodacite flow breccia with 10 percent crystals that are 0.5 to 1.5 mm long.

(10) Pinkish- to purplish-gray flow-banded rhyolite with 10 percent crystals, including 2 percent biotite. Unit is locally associated with flow breccia and tuff with similar phenocrysts.

(11) Massive breccia derived from feldspar porphyry, maroon and aphanitic intermediate volcanic flow rock, and gray lithic tuff, all of which were probably derived largely from the medial felsic volcanics. Breccia rests on several different units of the upper felsic volcanics and probably represents landslide deposits formed during normal faulting and associated tilting.

(12) Rhyodacite(?), rhyodacite(?) flow breccia, and associated pyroclastic rocks that underlie brecciated feldspar porphyry and unconformably overlie the upper basaltic andesite. The main rock type is a greenish-gray, flow-banded flow with 5 to 10 percent phenocrysts of mostly feldspar with minor biotite. It contains light-colored spots that are spherulites formed by devitrification of a vitrophyre. The pyroclastic rocks underlie the flow breccia and are reddish, vuggy, and probably more mafic in composition.

(13) Light- tan to light-gray ash-flow tuff that weathers dark brown to black and contains quartz, plagioclase, sparse, 1- to 2-mm-diameter biotite and, locally, hornblende(?).

(14) Tan, grayish tan, red, or reddish purple, variably brecciated flows and/or tuffs that contain fine-grained quartz, feldspar, biotite, and hornblende.

(15) Pale-green tuff breccia. Volcanic-lithic and non-lithic tuffs are also locally present within this unit.
unit locally contains interbedded sandstone. Unit is similar to, and possibly interbedded with, map unit Tm. This unit is suspected to be slightly more silicic than rocks of map unit Tm based on outcrop appearance and, locally, mineralogy.

Locally interbedded with rocks of this map unit are several light-colored tuffs, including a pinkish-weathering, light-colored crystal tuff with 10 to 20 percent crystals, mostly of quartz with lesser feldspar and 1 percent biotite. The tuff contains light-colored volcanic lithics, most of which have a similar phenocryst assemblage to the matrix, but have differing proportions of phenocryst phases.

A breccia bed is interbedded with the basal part of this map unit and consists mostly of clasts of coarse-grained granite with 1- to 2-cm-long K-feldspar phenocrysts and less abundant clasts of carbonate rocks, quartz veins, and metamorphic calc-silicate rocks. The breccia is associated with a lithic tuff that contains light-colored pumiceous-tuffaceous clots as large as 7 cm in diameter.

Tis SEDIMENTARY ROCKS ASSOCIATED WITH INTERMEDIATE TO MAFIC VOLCANIC ROCKS OF MAP UNIT Ti (MIOCENE) -- Poorly sorted clastic rocks that locally contain large angular blocks of underlying intermediate to mafic volcanic rocks and stratigraphically lower units. Rocks of this unit are associated with some slope-forming, pinkish, orange, and cream-colored lithic tuffs of map unit Ti. The unit is locally scoriaceous, and some outcrops have soft, gypsiferous soil, chalcedonic quartz, and replacements of gray carbonate, quartz, and jasper.

Unit also locally contains interbedded medium- to light-gray or brownish-gray bedded limestone with orangish, limonitic siliceous layers. Some of the tuffaceous outcrops are similar to rocks of the upper felsic volcanics (map unit Tut) but locally have dips of 40 degrees and appear as a strike belt within the intermediate to mafic volcanic rocks (map unit Tm).

Tmf MEDIAL FELSIC VOLCANIC UNIT (MIOCENE) -- This map unit consists of a distinctive sequence of felsic flows, tuffs, and sedimentary breccias. The five main rock types within this sequence, from top to bottom, are as follows:

1. Chaotic, poly lithologic sedimentary breccia: Shattered blocks of brown carbonate, mylonitic and lineated Proterozoic granite, metamorphosed and lineated calc-silicate rocks, vein quartz, granite megabreccia, and breccia, conglomerate, and sandstone derived from granite. It is generally overlain by intermediate to mafic volcanic rocks (map unit Ti), but locally is overlain by a thin biotite-bearing, pink volcanic-lithic tuff.

2. Biotite-bearing feldspar porphyry: Reddish-brown-weathering, pinkish, biotite-bearing rhyolite that contains 20 percent crystals, mostly sanidine and quartz, but including 3 percent biotite crystals up to 2 mm in diameter.

3. Pink lithic tuff: Maroonish-gray, brown-weathering tuff with 25 percent crystals of feldspar and quartz, and 15 to 20 percent medium-gray volcanic lithics with feldspar and biotite phenocrysts similar to those in the host tuff.

4. Crystal-poor latite: Purplish-gray latite(? ) with 1 percent reddish-brown spots, some of which are replacements of stubby laths.

5. Gray lithic tuff: Pinkish-gray- to light-gray-weathering rhyolitic breccia with 10 to 25 percent medium-gray and light-tan- and cream-colored volcanic lithics in a medium- to light-gray matrix. Tuff also contains lighter colored fragments of tuff and locally weathers to tan-colored, pitted rock. It contains 2 to 3 percent cream-colored feldspars up to 1.5 mm long. This unit is associated with an overlying massive and cliffy, pinkish-gray, locally flow-banded rhyodacite flow breccia with 10 percent crystals 0.5 to 1.5 mm long.

Tfp FELDSPAR PORPHYRY (MIOCENE) -- Massive, blocky, commonly brecciated, mottled purplish, maroonish-gray, or medium-gray dacitic(?) flow with 5 to 10 percent brownish-gray laths of feldspar.

Tta TUFF AND ANDESITE (MIOCENE) -- Moderately welded crystal-lithic tuff. Tuff is brownish tan, light gray, pinkish gray, or pink weathering with 35 percent crystals, mostly of quartz, but with minor
sandine and one percent biotite. It contains abundant lithic fragments of similar, but not identical composition (most are less crystal rich). One abundant clast type occurs as subangular pebble- to cobble-sized fragments of medium-gray rhyolite with several percent quartz and feldspar phenocrysts and 1 to 2 percent fresh biotite. Lithics are angular, vary from light tanish-cream colored to medium gray, and most are 1 to 8 cm in diameter. The upper contact is locally marked by volcanic breccia. This unit also includes:

1. pinkish-gray rhyolite tuff(?) with several percent crystals and 10 to 15 percent clasts of medium-gray volcanic rocks and lighter colored tuff. Unit locally weathers to tan-colored, pitted rock and is overlain by resistant purplish-gray dacite with several percent crystals.

2. Fine-grained, aphanitic, reddish-brown to brown andesite(?) that weathers reddish brown to purplish-brown and contains abundant Liesegang bands and breccia zones. Most flows contain 1 to 2 percent plagioclase laths that are light greenish gray and 1 to 2 mm long. Also locally contains rounded blebs 1 to 2 mm in diameter of quartz(?).

3. Tan to buff (with pinkish tint), nonwelded tuff at the base of the aphanitic andesite contains 30 percent gray volcanic lithics and abundant pumice clasts. Tuff forms slopes with light colored soil and contains large pieces of aphanitic brownish-gray volcanic rocks and pink, lithic rhyolite with less than 1 percent biotite and feldspar phenocrysts.

The base of the unit overlies mafic volcanics (map unit Tab) and includes beds of pinkish-brown to tan sandstone, grit, and conglomerate composed of volcanic clasts and some granitic clasts. The clastic rocks are locally very tuffaceous and are associated with gray lithic-poor and crystal-poor tuff.

Tab  ANDESITE TO BASALT (Miocene) -- Vesicular to amygdaloidal mafic rocks, probably consisting of andesite, basaltic andesite, and basalt. Unit is locally brown with tan motting and contains 1 percent reddish, altered crystals that are possibly iddingsite after olivine. The mafic flows are widely altered and commonly contain several percent brown to black calcite in amygdules that weather out, leaving vesicles. Rock is locally strongly replaced by brown to tan calcite. This unit contains local interbeds of brown to reddish-brown sandstone with reddish siltstone and tan-brown calcareous sandstone, some of which contain sticklike or reed like plant fossils. This unit also includes a crystal-lithic tuff stratigraphically adjacent to the sandstone. The tuff is pinkish-gray, maroonish-gray, or tan and contains 15 to 20 percent gray, volcanic-lithic fragments and several percent phenocrysts of feldspar, biotite, and hornblende. The tuff yielded a K-Ar biotite date of 22.5±0.7 Ma (sample 851-11-2; R. Miller, written commun., 1986).

Tlc  LITHIC AND CRYSTAL TUFF (Late oligocene to early Miocene) -- This map unit represents two lithic tuffs. The upper tuff is tan- and cream-colored lithic tuff, at least 14 m thick, with numerous angular fragments of tuff and pumice that weather out leaving voids. The upper tuff also contains scattered reddish and purplish volcanic lithics up to 4 cm in diameter. The underlying crystal-lithic tuff is nonresistant, reddish- to maroonish-salmon gray, and contains 5 to 10 percent crystals, including 1 to 2 percent biotite. Purple and pink lithics make up 5 to 15 percent of the rock.

Tx  BRECCIA (Late oligocene to early Miocene) -- Breccia with fragments of limestone, quartzite, and volcanic rocks. Limestone clasts are locally more than 20 m long and are brownish gray or pinkish gray with multicolored, especially pink and red, chert. The breccia locally contains a nonresistant, reddish gray, maroonish gray, or salmon-gray tuff with 5 to 10 percent crystals, including 1 to 2 percent biotite, and 5 to 15 percent purple and pink volcanic-lithic fragments.

A volcanic-lithic sandstone and conglomerate is locally present at the base and contains locally well rounded pebbles of pinkish or purplish gray, gray, or vitreous white quartzite, calcisilicate rocks, and volcanic rocks. It also contains clasts of stretched-pebble conglomerate similar to conglomerates exposed in the Granite Wash Mountains (Reynolds and others, 1989).

Tt  TUFFS (Late oligocene to early Miocene) -- This map unit represents three or four tuffs,
which are, from top to bottom, as follows:

(1) Lithic tuffs: Includes two lithic tuffs as follows: (A) An upper, dark-tan, brown, or cream-colored, locally orangish-tan-weathering tuff with abundant purple volcanic lithics. This tuff also contains numerous angular fragments of tuff and pumice that weather out leaving pits in exposed surfaces. Some enclosed volcanic fragments are purplish and red and are as large as 4 cm in diameter. Scattered feldspar phenocrysts are greenish and highly altered. (B) A lower lithic tuff that contains 1 to 3 percent biotite, abundant volcanic lithics, quartz, brownish, altered plagioclase(?), and diffuse color bands, possibly reflecting K-metasomatism. A sample of this tuff yielded a biotite K-Ar date of 24.0±0.7 Ma (sample 851-11-1; R. Miller, written commun., 1986).

(2) Altered, potassic (?) tuffs: Reddish-brown K-metasomatized (?) ash-flow tuffs with 1 percent fresh biotite, 2 percent feldspar phenocrysts, 1 to 2 percent lithic fragments, and locally well-defined eutaxitic structure. Tuff is brownish red, weathers same, and is 5 m thick.

(3) Crystal tuff: Purplish-, maroonish- or pinkish-gray, crystal-bearing tuff with about 5 percent altered plagioclase crystals that are 1 to 3 mm in diameter. Tuff contains 1 to 2 percent lithic fragments and less than 0.5 percent biotite, and weathers to pinkish or purplish gray with tan patches. Some outcrops are composed of greenish tuff derived from pinkish- to tannish-brown tuff with 10 percent quartz phenocrysts. Tuff is rarely over 2 m thick.

Tl LACUSTRINE ROCKS (LATE OLIGOCENE TO EARLY MIOCENE) -- Medium- to thin-beded, gray to brownish-gray limestone with chert. The limestone is associated with thinly bedded, fine- to medium-grained sandstone and reddish siltstone.

Tba BASAL ARKOSE (LATE OLIGOCENE TO EARLY MIOCENE) -- Nonresistant, slope-forming arkosic sandstone, conglomeratic sandstone, and conglomerate that is reddish brown to greenish gray, poorly sorted with poorly defined bedding in conglomerate, and contains local beds of resistant brown or green sandstone. Sequence locally contains thin-beded tuffaceous siltstone, cherty and siliceous rocks, and tuffs.

TvU VOLCANIC AND SEDIMENTARY ROCKS, UNDIVIDED (LATE OLIGOCENE TO EARLY MIOCENE)

Intrusive and Metamorphic Rocks

Tdm MAFIC DIKES (MIOCENE) -- Dark-gray, mafic dikes containing fine-grained plagioclase, quartz, and hornblende.

Tds SILICIC DIKES (MIOCENE) -- White to whitish-gray to gray, commonly tan-weathering, silicic dikes with sparse, fine-grained feldspar, biotite, and locally, hornblende(?). These dikes are abundant near contact with a Miocene granitoid pluton (map unit Tg) and are possibly derived from the same magma. A sample of one of these dikes yielded a K-Ar biotite date of 19.7±0.5 Ma (sample 12-14-88-4; R. Miller, written commun., 1990).

Tg GRANITOID ROCKS (MIOCENE) -- Fine- to medium-grained, equigranular, biotite ± hornblende granitoid rocks. No pegmatites were seen in this unit and no evidence of hydrothermal alteration or mineralization at the margins of this unit was recognized except possibly rare and thin epidote- and hematite-filled fractures. Map-scale compositional layering characterizes this unit in the northeastern Bouse Hills and is visible on air photographs. Light layers are typical granite or granodiorite with little or no hornblende. Dark layers contain much hornblende and little quartz. A weak, steeply dipping crystalloblastic foliation in the northeastern Bouse Hills is defined by biotite orientation. Crystalloblastic foliation is parallel to compositional layering, which is locally visible in outcrop, and suggests that both
are primary features related to magma emplacement and are unrelated to postmagmatic deformation.

Locally in the southern part of the eastern Bouse Hills this unit is composed of fine-grained biotite granite or granodiorite that is moderately resistant to weathering and forms resistant ridges. Along the crest of one such ridge (NW1/4 sec. 19, T. 7 N., R. 15 W., and adjacent unsurveyed area to northwest) epidote-filled fractures strike parallel to ridge and dip 15 to 30 degrees to the west. Well-denuded epidote-coated surfaces locally form flat ridge-crest areas, up to five meters across and tens of meters long, with numerous subvertical fractures that trend approximately due N and are spaced at 1 to 10 cm. Local steep epidote-filled veins are up to 2 cm thick. Gently dipping epidote-filled fractures are the dominant control of ridge-crest morphology.

Samples of this unit have yielded K-Ar biotite dates of $20.0 \pm 0.6 \text{ Ma}$, $20.2 \pm 0.5 \text{ Ma}$, (samples 12-12-88-5 and 12-14-88-3, respectively; R. Miller, written commun., 1990) and $16.5 \pm 0.5 \text{ Ma}$ (sample UAKA 73-127; Shafiqullah and others, 1980). A 20 Ma age for the pluton is supported by two of these three dates and by a 19.7 Ma K-Ar biotite date on a silicic dike (map unit Tds) that is probably genetically related to the pluton.

Tdi INTERMEDIATE DIKES (TERTIARY) -- Intermediate composition dikes in the northwestern Granite Wash Mountains that are medium gray and contain biotite and hornblende.

TXg GRANITOID ROCKS (TERTIARY TO PROTEROZOIC)-- Fine- to coarse-grained, equigranular to porphyritic, medium- to light-gray, biotite granite or granodiorite with local fine-grained, leucocratic phases. Porphyritic varieties contain 1- to 2-cm-diameter, stubby potassium-feldspar phenocrysts. Plagioclase is variably sericitized.

TXgd GRANODIORITE TO DIORITE (TERTIARY TO PROTEROZOIC) -- Fine-grained mafic plutonic rocks that contain hornblende, locally biotite, and locally numerous pegmatites.

TXc CRYSTALLINE ROCKS (TERTIARY TO PROTEROZOIC) -- Includes granitoid rocks of map unit TXg and their foliated equivalents. Eastern exposures of this unit near the Tertiary pluton (map unit Tg) consist largely of Tertiary siliceous dikes. Unit also locally includes medium-grained, leucocratic, muscovite granite and quartzofeldspathic gneiss. Weak, northeast-striking, steeply dipping crystalloblastic foliation is present in granitoid rocks in some areas and may contain parallel quartz veins up to 10 cm thick. Local shear zones contain semi-mylonitic, semi-crystalloblastic foliation and, where superimposed on compositionally variable granitoids, have converted the protoliths to gneiss. Granitoid rocks of this map unit also contain local inclusions (many meters diameter) of quartzose and dark, compositionally layered metasedimentary rocks. In southeastern exposures of this map unit distinctive porphyritic granite consists of plagioclase, 10 to 50 percent K-feldspar phenocrysts up to 2 cm long, 20 to 40 percent quartz, and 2 to 10 percent biotite that is commonly altered or associated with epidote.

XYg GRANITOID ROCKS OF THE NORTHWESTERN GRANITE WASH MOUNTAINS (PROTEROZOIC X or Y) -- Medium-grained, slightly porphyritic, dark-brown weathering granitoid rocks. Augen are up to 1.5 cm diameter. Unit is probably granite or granodiorite. Moderate to strong foliation is dominantly crystalloblastic. Weak mylonitic foliation is parallel to crystalloblastic foliation. Local 1- to 10-cm-thick alaskitic layers and variably developed but locally strong spaced cleavage are parallel to foliation.

Xs SCHIST (PROTEROZOIC) -- Black-weathering, variably micaceous, locally and variably calcareous and quartzose schist. Steep, east- to northeast-striking foliation is defined by schistosity and by compositional layering as revealed by variations in color and resistance to weathering. Interpreted as metamorphosed siltstone, calcareous siltstone, and quartzose sandstone.
APPENDIX 2: DESCRIPTION OF MINERAL DEPOSITS
(DEPOSIT LOCATIONS SHOWN ON FIGURES 4, 5, AND 6)

(1) Black Bird mine. This is the largest manganese mine in the Bouse Hills and was the source of most past manganese production. The mine is a long, narrow, northwest-trending pit. The northeast wall of the pit is a vertical contact between contrasting rock types that appears in some places to be a fault and in other places to be a depositional contact. Rocks to the southwest of the contact consist of a talus-breccia of basalt with local sandstone lenses that is overlain by interbedded sandstone, siltstone, gypsiferous siltstone, and basalt. Rocks to the northeast of the contact consist of red conglomeratic sandstone that contains subangular to well-rounded clasts of silicic volcanic rocks and biotite granite. The contact appears to be a shear zone in the northwestern part of the mine where it juxtaposes basalt against basalt.

The talus-breccia derived from basalt is the primary host rock for manganese mineralization at this mine. Manganese oxides with sparse calcite fill open spaces within breccia. Hematite staining is common, especially on fracture surfaces. Basalt at the northeast edge of the mine contains veins of white and brown calcite and manganese oxides (see also Farnham and Stewart, 1958).

(2) Fracture- and open-space-filling manganese oxides in variably fractured and brecciated basalt. Amorphous manganese-oxide fillings are up to 10 cm thick. Late white calcite fills vugs and fractures. Very sparse, late drusy quartz coats some open spaces. Northwestern of two pits contains patchy limonite staining.

(3) Minor drusy quartz.

(4) Prospect pit with no apparent mineralization.

(5) Fracture- and open-space-filling manganese oxides in variably fractured and brecciated basalt. Manganese oxide veinlets up to 20 cm thick contain late brown calcite and drusy quartz.

(6) Bentonite mine (Keith, 1978; location from MILS)

(7) Black Hills group. Variably fractured and brecciated Tertiary volcanic rocks host manganese oxides in fractures and as open-space fillings, up to 20 cm thick, with minor white and dark-gray calcite. Most fractures trend northwest. We did not see any evidence of copper or precious-metal mineralization at this deposit.

This is Black Hills group of Farnham and Stewart (1958) as located by the MILS subset of the U.S. Bureau of Mines Mineral Availability System (Babitzke and others, 1982). U.S. Bureau of Mines production data (compiled in about 1980) indicate that approximately 11,000 lbs. of copper and a few dozen ounces of gold and silver were derived from a Black Hills mine in the Bouse Hills in the 1930s. However, USBM microfilm records on the Production and Development of Metal Mines in 1939 (Roll #19, Index 10.19) indicate that the Black Hills mine, from which base and precious metal production is recorded in the 1980s USBM compilation, is 25 miles from Parker and is on the Bill Williams River. Thus it appears that the recorded copper, gold and silver production from the Black Hills mine that was attributed to the Bouse mineral district by Keith and others (1983) is from a mine that is not in the Bouse Hills.

(8) Highly fractured Tertiary volcanic rocks host manganese oxides in fractures and as open-space fillings with coarse brown calcite and sparse fine-grained milky quartz. May be part of Laurella claims of Farnham and Stewart (1958).

(9) Highly fractured Tertiary volcanic rocks host manganese oxides in fractures and as open-space fillings with moderately abundant medium to coarse brown calcite. Most fractures are steep and trend N30°W. May be part of Laurella claims of Farnham and Stewart (1958).

(10) North- to northwest-trending, approximately vertical brittle shear zone with fracture-filling calcite and manganese oxides. Fault zone is typically 0.5 m thick. Locally abundant brown calcite crystals are up to 4 cm diameter. May be part of Laurella claims of Farnham and Stewart (1958).
(11) Manganiferous, hematite-stained fault breccia in footwall of fault trending N35°W, dipping 55°SW, in Tertiary volcanic rocks. Lack of manganese deposits in the hanging-wall block suggests that final faulting occurred after mineralization. This may be the Linda K mine described by Farnham and Stewart (1958). The Little Jessie mine (Cu, Ag), located by the MILS subset of the USBM Minerals Availability System (Babitzke and others, 1982) at this mine, is probably at a different location, perhaps in the Plomosa Mountains. The Good Bet prospect, an iron replacement deposit hosted in Paleozoic carbonate described by Harrer (1964), is located approximately at this mine by the USGS Mineral Resource Data System (Peterson, 1984). This location must be greatly in error, however, because there are no Paleozoic rocks in the area and, to our knowledge, there are no iron replacement deposits in the Bouse Hills.

(12) Brown and white calcite and manganese oxides fill fractures and open spaces in Tertiary volcanic rocks.

(13) Dobbins claims of Jones and Ransome (1920) as located by the USGS Mineral Resource Data System (Peterson, 1984). Shear zone oriented N70°E 50°NW contains fracture-filling manganese oxides and sparse calcite (see also Jones and Ransome, 1920).

(14) Brittle shear zone oriented N10°E 80°W hosts open-space and fracture-filling manganese oxides in Tertiary volcanic rocks.

(15) Crushed granitoid and Tertiary mafic dike rocks in 1- to 2-meter-thick shear zone oriented N35°W 40°NE contains pervasive chrysocolla and malachite in 5- to 10-cm-thick zone that is surrounded by hematite. Decline in shear zone, approximately 30 meters deep, exposes planar, hematite-stained slip surface.

(16) Brittle shear zone oriented N40°W 40°NE in dark, fine-grained crystalline rocks contains fracture- and open-space-filling quartz, earthy hematite, micaceous specular hematite, chrysocolla, and malachite(?).

(17) White Christmas mine of Stewart and Pfister (1960); identified as Barber Gene mine on Utting USGS 15’ quadrangle map (1962). Mine is located on a barite vein, approximately 50 meters long, up to 1 meter thick, and oriented N65°W 60°NW, that consists of coarse (1 to 3 cm diameter) bladed barite with minor pale green to clear fluorite and brown calcite. Locally, vein material is fine grained and banded.

(18) Happy Day #1 mine of Stewart and Pfister (1960). Mine is located on a barite vein, 30 cm thick and 20 m long.

(19) Black Mountain #1 mine (Stewart and Pfister, 1960). Two N60°W-trending, near-vertical zones of veins of coarse barite with minor fluorite in Tertiary volcanic rocks. Deposits consist mostly of anastomosing veinlets 5 to 50 cm thick that locally converge into single veins up to 2 meters thick. Most historic barite production from the Bouse Hills probably came from shafts in these veins (see also Stewart and Pfister, 1960). We saw no evidence of copper or precious metal mineralization at any mineral deposits in the area of the Black Mountain #1 or #2 mines.

U.S. Bureau of Mines production data compiled around 1980 indicate that approximately 1600 lbs. of copper and a few dozen ounces of gold and silver were mined at the Black Mountain mine. However, USBM microfilm records on the Production and Development of Metal Mines in 1937 (Roll #17, Index 10.7) indicate that the Black Mountain mine, from which base and precious metal production was recorded in the 1980s compilation, is 5 miles southeast of Parker and is therefore in the Buckskin Mountains. Thus it appears that the recorded copper, gold and silver production from the Black Mountain mine that was attributed to the Bouse mineral district by Keith and others (1983) is from a mine that is not in the Bouse Hills.

(20) Black Mountain #2 mine (Stewart and Pfister, 1960). Coarse white barite, with minor fluorite, forming veins and irregular open-space and fracture fillings in Tertiary debris-avalanche deposit derived from cherty marble tectonite, calc-silicate tectonite, and quartzite (Paleozoic and Mesozoic?).
REFERENCES CITED


Figure 1. Map showing location of Bouse Hills, which are in La Paz County in west-central Arizona.
Crystalline rocks, undivided (Tertiary to Proterozoic)
Flat-lying to gently dipping volcanic rocks
Tilted volcanic and sedimentary rocks
Granitoid pluton

Crystalline rocks, undivided (Tertiary to Proterozoic)

Fault
Bedding attitude
Foliation attitude

Figure 2. Simplified geologic map of the Bouse Hills.
CORRELATION OF MAP UNITS
Sedimentary and volcanic rocks

Quaternary

Unconformity

Tertiary

Intrusive and metamorphic rocks

Bouse Hills

Granite Wash Mts.

Figure 3. Correlation diagram for map units of the Bouse Hills.
Figure 4. Geologic map of small isolated hills northwest of the Bouse Hills. Numbered localities correspond to barite deposits described in Appendix 2.

QPs  Surficial deposits (Pliocene to Quaternary)
Ts  Sandstone (Tertiary)
Tv  Volcanic rocks (Tertiary)
Txl  Sedimentary breccia derived from Paleozoic limestone
Txq  Sedimentary breccia derived from Paleozoic or Mesozoic quartzite
Figure 5. Locations of mineral deposits in the Douse Hills that are described in Appendix 2.
Figure 6. Locations of mineral deposits in the Bouse Hills that are described in Appendix 2.
Figure 7. Histogram of equivalent weight-percent NaCl in fluid inclusions in brown calcite from manganese deposits and barite and fluorite from massive barite veins (fluid-inclusion analyses done by J. Duncan).
Figure 8. Homogenization temperature versus equivalent weight percent NaCl for fluid inclusions from brown calcite in manganese deposits and barite and fluorite from massive barite veins (fluid-inclusion analyses done by J. Duncan).